Water Resources Atlas of Newfoundland

Water Resources Division
Department of Environment and Lands
Government of Newfoundland and Labrador

Water Resources Atlas of Newfoundland

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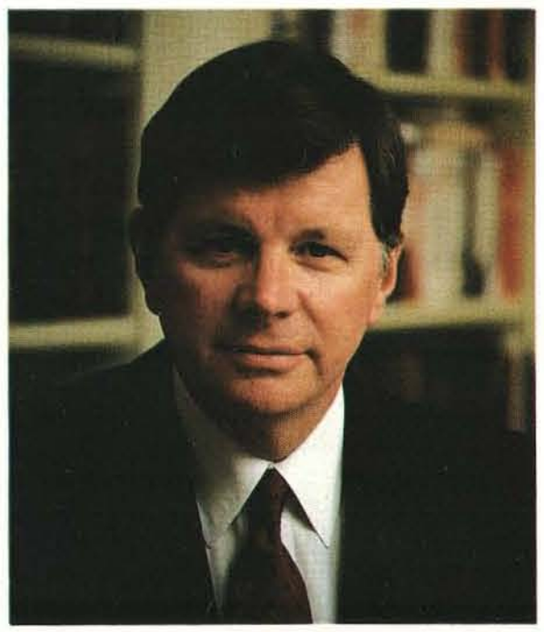

The Honourable Clyde K. Wells,
Premier of Newfoundland

Water has a unique place among our natural resources. The first Europeans who settled here over 1,000 years ago and the aboriginal people who they found living here relied on water as a means of travel and as a source of much of their food. Today, water provides the means of producing power to meet much of our energy needs and sustains our primary natural resources such as fish and forest. Water is, of course, essential for life.

Historically, because of the abundance of water in Newfoundland and Labrador, we have used it with little restraint. But the growth of population, urbanization, industrialization, and technology have begun to impose demands that strain the capacity and quality of some of our natural water systems. Newfoundlanders recognise that the responsibility for protecting the quality of our water resources and managing the competing demands imposed on them belongs to everyone. It is ever more important to develop a society in which citizens have the knowledge, skills, and values necessary for informed and responsible actions.

As part of this information and education process, the Water Resources Division of the Department of Environment and Lands has produced the Water Resources Atlas of Newfoundland. It presents for the first time, comprehensive and compatible maps of our province's geology, climate, hydrology, groundwater, water quality, and water uses. It is my hope that the Atlas will serve as a general source of information on our water resources for scientists and citizens alike, and that it will prove to be a valuable tool in the management and protection of this very precious part of our heritage.

Statement by the Minister of Environment and Lands

Much of Newfoundland's economic development and material well-being is derived from the use of renewable and non-renewable resources. Among the renewable resources the water resources of the province play a vital role in providing for our basic sustenance and health needs, maintaining the viability of our other primary resources such as fish and forest, meeting our energy needs, and offering recreational benefits. Over the past few years the heavy reliance of our economy and way of living on these resources has brought about an acute awareness of our environmental responsibilities. The Government of Newfoundland and Labrador, through the Department of Environment and Lands, discharges these responsibilities by defining policy objectives and administering legislation which affect how water is used and developed. The mandate of the Department, as enacted in The Department of Environment and Lands Act, 1989, includes "supervision, control, and direction of all matters relating to ... the protection and enhancement of the natural environment, including, ... water, air and soil quality". In addition, the Department has overall management responsibility " ... for the conservation, development, control, improvement, and proper utilization of the water resources of the province".

The Honourable Patricia A. Cowan,
Minister of Environment and Lands

Patricia A. Cowan

The Water Resources Management Division has the responsibility to carry out the water-related mandate of the Department. This responsibility includes " ... assembling the fullest possible information on the quantity, quality, character, location and use or possible use of those bodies of water ... ". Intensified research into complex hydrological processes and water resources systems is a prerequisite for translating policy objectives into results and enforcing legislation and regulations. The information collected is essential to sound decision-making on environmental matters and can also alert us to emerging problems, thus making possible successful implementation of preventive policies. Furthermore, Newfoundlanders are demanding access to better information about their environment. They seek authoritative and easy-to-use indicators to assess current and changing conditions of their resources, and prefer solutions to water problems which are suitable for their own unique needs, goals, values, and culture, and for their political, economic, and social systems.

As part of its legislative mandate and public information responsibilities, the Water Resources Division has published this Water Resources Atlas of Newfoundland. The Atlas is the result of several years of intensive data collection and analysis. It presents, for the first time, comprehensive, valuable, and easily understood information on our geology, climate, hydrology, groundwater, water quality and water uses. I express the hope that the Atlas will prove to be a valuable contribution to the appreciation of our water resources. Such an appreciation will ensure the rational utilization of our water resources and thus satisfy our needs and the needs of generations to come.

Acknowledgements

The production of the Water Resources Atlas of Newfoundland would not have been possible without the dedicated efforts of many individuals. Thanks are extended to several students in the Advanced Cartographic Design class in the Department of Geography at Memorial University of Newfoundland who designed the maps for the Atlas under the supervision of Clifford H. Wood, Associate Professor of Geography and Director of the Cartographic Laboratory. Photographs were graciously provided by various individuals and agencies, and their contributions are recognised. The help of Mrs. A. Hodder in proofreading the text of the Atlas is appreciated. Thanks are also due to Mr. David Jeans, Assistant Deputy Minister of the Department of Environment and Lands for his encouragement and support. The following individuals deserve special mention for their significant contribution to the success of the project:

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Water Resources Atlas of Newfoundland

1 – Newfoundland – An Overview

Newfoundland, the easternmost province of Canada, consists of the Island of Newfoundland, situated in the Gulf of St. Lawrence, and Labrador on the northeastern Canadian mainland.

The area of the Island is 111,390 square kilometres and that of Labrador is 294,330 square kilometres. The distance from the southern to the northern limits of the province is nearly 1500 kilometres. In most areas the terrain is hilly and rugged; mountain ranges are found on the west coast of the Island and in northern Labrador. Lakes and ponds are common features of the landscape. Vegetation in the province varies from tundra in northern Labrador to mixed deciduous and coniferous forests in the southwest to barrens on the Avalon Peninsula. Peatlands are concentrated along the coastal lowlands and on the interior high plateaus.

The province experiences a variety of climates: northern Labrador is arctic, while the interior of Labrador is continental with cold dry winters and warm summer days. The Island, close to the confluence of the warm Gulf Stream waters and cold ex-Arctic waters of the Labrador Current, has mild winters and cool summers.

The province has approximately 580,000 residents, sixty percent of whom live in urban centres and the other forty percent in hundreds of small fishing communities scattered along the coast. Much of the province's economic development and material well-being is derived from renewable and non-renewable resources such as fish, forest, water, and minerals. About ten percent of the workforce is involved with fisheries. Forests support a paper and lumber industry worth nearly a half-billion dollars annually. Mining of gold, copper, lead, zinc, and iron, in particular, contributes significantly to the province's gross domestic product. The extensive network of lakes and rivers in the province has allowed the development of several major hydroelectric projects. The vast bulk of the electricity is produced at Churchill Falls in Labrador. Potential hydro sites throughout the province are being investigated for their economic feasibility. The lakes and rivers also provide an almost unlimited opportunity for a wide variety of water-related activities ranging from camping, fishing, boating, and cottaging to white-water rafting.

The water resources of the province, in addition to maintaining the viability of industries such as fisheries, forestry, hydropower, and tourism, are vital in providing for basic sustenance and health needs. Approximately seventy-one percent of the total population is serviced by surface water supply systems, while the remaining twenty-nine percent, living in smaller communities, relies upon groundwater wells. Many water supply areas, over two hundred so far, have been designated as protected areas to preserve their water quality.

Extreme regional fluctuations in the amount of water in circulation can result in droughts and floods. In Canada, the impacts of droughts are most noticeable in the Prairies; the Atlantic provinces and British Columbia, on the other hand, occasionally experience severe floods. While the extremes in water quantity fluctuations can cause severe hardships, the natural daily and seasonal variability in water quantity also has a profound influence on almost every aspect of our lives. Hydroelectric power generation, transportation, fisheries, wildlife, recreation, waste disposal, mineral extraction, irrigation, manufacturing, and municipal uses are all affected to some degree by the variability in water quantity.

Water quality is defined by its chemical, physical, and biological content. Many factors affect water quality. Geology may give water quality a regional character. Industrial, farming, mining, and forestry activities can significantly affect the quality of water in rivers, lakes, and in the ground. There is no single measure that constitutes good water quality; water for drinking, recreation, industrial, and agricultural uses have different water quality guidelines. Nevertheless, poor water quality seriously affects ecological diversity and water supplies.

As pressures on the resource such as demand and pollution increase, the traditional view of water as infinitely renewable and consistently pristine is gradually changing into a realisation that water is a scarce and sensitive resource.

A knowledge of the current state of the province's water resources is essential for appreciating and addressing related environmental concerns. The Water Resources Atlas of Newfoundland was a special project of the Water Resources Division of the Department of Environment and Lands, and was produced to serve two purposes: a general educational document on the water resources of the province and a source of preliminary information for those involved in the planning, design, and management of water resources systems.

The maps in this Atlas are presented in a sequence which describes the various aspects of water resources: geology, climate, hydrology, water quality, groundwater and beneficial uses. Each map was based on the latest available data for Newfoundland and Labrador during the production period (1988-1991). Most of the data were compiled from databases maintained by various agencies such as Water Survey of Canada and Atmospheric Environment Service, from joint federal-provincial monitoring programs such as the Canada-Newfoundland Water Quality Agreement and from numerous reports produced by the Water Resources Division and engineering consultants.

Although the maps themselves are the primary means of presenting information, each map is accompanied by a supporting text which describes the parameters depicted, interprets the map, and provides details on the type and quality of data used. Some of the texts may also present additional information which could not be shown on the maps.

Location Map

NEWFOUNDLAND AND LABRADOR

PHYSIOGRAPHY AND GEOLOGY

Introduction

Physiography is a description of surface features such as mountains, valleys, rivers, and lakes. These features have a significant influence on the climate, vegetation, land use, hydrology, and water resources of a region. Geology, on the other hand, is a description of the underlying types of soils and rocks in terms of their origins and changes over time and space. Geology has a considerable bearing on the location and yield of groundwater resources.

The two shaded relief maps on the next page show the major physiographic features of the province. The Island portion of the province consists basically of a tilted plateau, which is higher in the west than the east. The highland areas in the west, which include the Long Range Mountains, range from 200 to 600 metres in elevation, with some peaks rising to nearly 800 metres. The central region of the Island has an elevation which usually ranges from 200 to 300 metres. The eastern part of the Island, including the Avalon Peninsula, is generally at a lower elevation with undulating topography where only isolated peaks reach an elevation of 300 metres.

The drainage pattern of the Island was originally developed by the erosion of valleys along the lines of weaknesses produced by tectonic folding and faulting. This pattern was then extensively modified by the glaciation of the Island which over-deepened some valleys and interrupted the drainage network on the plateau by the deposition of drift material. As a result of the modification of the drainage pattern the plateau is now covered with lakes and swamps over extensive areas.

In Labrador the highest elevations, in excess of 1500 metres, occur in the Torngat Mountains along the north Labrador Sea coast. Significant highlands can also be found in the Mealy Mountains, south of Lake Melville, where elevations approach 1500 metres. The plateau in the interior of Labrador is generally between 300 and 650 metres, with occasional hills rising to 900 metres.

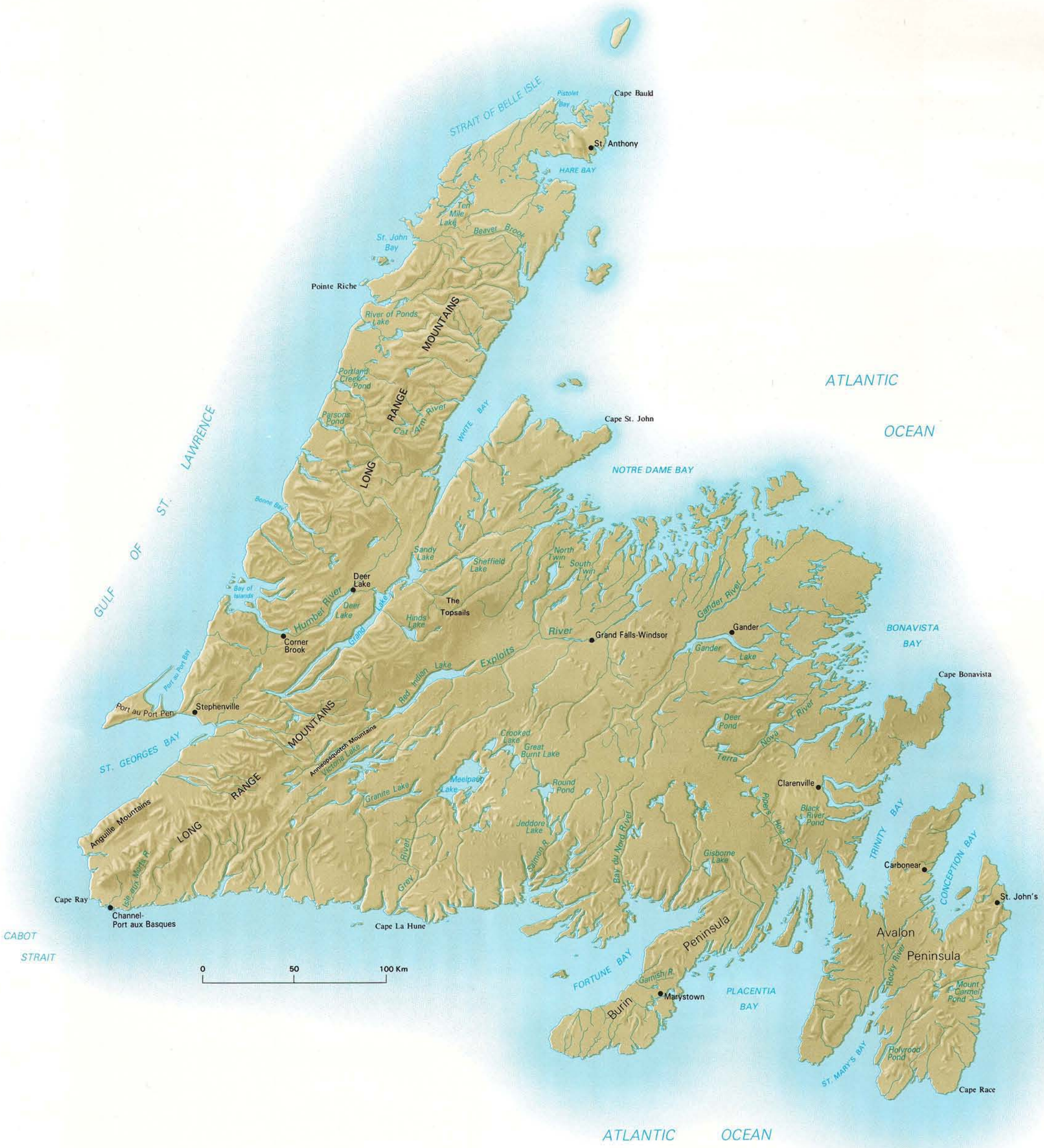
In general, drainage in Labrador has not yet reached a mature stage because of the post-glacial and relatively recent uplift of the land surface relative to the sea. The uplift has given rise to rivers with deeply-incised gorges; Churchill River is a good example. In the central interior of Labrador glacial activity has interfered with the drainage leaving a large concentration of lakes and swamps in the region. The sea coast of Labrador, particularly in the north, is rugged with many long and deep fjords.

Lewis Hills (Elevation : 815 metres) on the West Coast of the Island of Newfoundland

Surface features conceal a fascinating geological history of the province recorded in the rocks below. The Island represents the northeastern extremity of the Appalachian mountain system in North America, while Labrador is the easternmost part of the Canadian Shield which contains some of the oldest known rocks on earth. The Bedrock Geology and Surficial Geology maps present detailed information on the geology of the province.

2 – Major Physiographic Features

Island of Newfoundland



Labrador


Cape Chidley
Cape Labrador
Cape Kakkivak
Saglek Fiord
TORNGAT
MOUNTAINS
Nachvak Bay
North Head
Cape Uivak
Nachvak Fiord
Kaumajet Mountains
Cape Mugford
Cape Kiglapait
Kingurutik Lake
Fraser River
Nain
Voisey Bay
Mistastin Lake
Davis Inlet
Labrador Sea
ATLANTIC
OCEAN
Hopedale
Ugjoktok River
Attikamagen Lake
Cape Makkovik
Makkovik
Postville
Cape Harrison
False Cape
Hare Lake
Kanairiktok River
Snegamook Lake
Naskaupi River
Smallwood Reservoir
Nipishish Lake
GROSWATER BAY
Rigolet
Double Mer Inlet
Hamilton Inlet
Grand Lake
LAKE MELVILLE
North West River
Sheshatshui
Goose Bay
Happy Valley
Goose Bay
Churchill Falls
Gabbro Lake
Churchill River
Goose River
MEALY MOUNTAINS
Cartwright
Table Bay
Sandwich Bay
Eagle River
Labrador City
Wabush
Wabush Lake
Lac Joseph
Attikonak Lake
Little Mecatina River
Minipi Lake
Minipi River
Alexis River
Port Hope Simpson
Mary's Harbour
St. Lewis River
STRAIT OF BELLE ISLE
L'Anse-au-Loup
Forteau
0
50
100 Km

3 – Bedrock Geology

The rocks beneath our feet contain more than 95 percent of the fresh, unfrozen water available to us. Groundwater is the largest source of water for rivers and lakes, and resides in the ground much longer than in surface water bodies. Consequently, it is subject to the hydraulic and chemical properties of bedrock and overlying unconsolidated formations. These factors determine its quantity and quality.

Rocks in insular Newfoundland are normally grouped into four zones, reflecting different geological histories between the Proterozoic III and the Ordovician (about 700 to 440 million years ago). The zones are shown on the map, together with separate groups for cover rocks which are younger than Ordovician and overlap zone boundaries, and intrusive rocks, many of which also cross zone boundaries. The zonal division is of limited application to water resources because it does not emphasize differences in the physical properties of rocks. It is useful, therefore, to superimpose a primary grouping by age, which reflects, in a general way, the amount of tectonic deformation and metamorphism that the rocks have undergone.

Proterozoic I and II of the Humber Zone

These are the oldest rocks in insular Newfoundland (over 1 billion years) and are part of the Grenville Province of the Canadian Shield, which also outcrops in southern Labrador and parts of Quebec and Ontario. They were formed by metamorphism at extreme temperatures and pressures deep in the Earth's crust, and are hard and resistant to weathering. These rocks generally have low primary porosity, which is the porosity of the rock matrix. This limits groundwater flow to micro fractures and along intergranular boundaries. Where there has been later faulting, however, fractures may produce high secondary permeability. Rocks in this category are usually composed of minerals with low solubility, so the contained groundwater is soft and has a low capacity for neutralizing acids.

Proterozoic III to Silurian

Avalon Zone. Two distinct sequences are distinguished in this zone, the first deposited entirely in the Proterozoic III between about 760 and 570 million years ago and the second deposited mainly in the Cambrian and Ordovician between 570 and 480 million years ago. The first sequence is further divided on the map into volcanic and sedimentary rocks. The sedimentary rocks of both sequences, from the Proterozoic III to the Ordovician, consist mainly of well consolidated slates, shales, and sandstones.

Gander Zone. This zone consists of a monotonous Cambrian and Ordovician sequence of interbedded sandstone and slate which has been metamorphosed to quartzite, schist, and migmatite in many places.

Dunnage Zone and Silurian Cover Rocks. There are two divisions of the Dunnage as shown on the map. The Cambrian to Ordovician ophiolites division consists of lava and volcanic ash, gabbro, ultramafic rock and small amounts of granite, and represents ancient oceanic crust on which many of the other rocks in the zone were deposited. The Cambrian to Silurian sedimentary and volcanic division consists mainly of lava and ash northwest of Red Indian Lake, and slate and sandstone to the southeast. The latter part, however, also contains volcanic rocks, as well as thick units of conglomerate.

Humber Zone. Proterozoic III to Ordovician rocks deposited unconformably on the Grenvillian basement (Proterozoic I and II) are divided into four groups. At the base are well consolidated, erosion-resistant sandstones with lesser amounts of shale, limestone and lava. They are overlain by extensive units of limestone and dolostone, which were overthrust in the Ordovician by huge displaced slabs of sandstone, shale, limestone, and minor volcanic rocks, as well as by pieces of oceanic crust from the Dunnage Zone. Sedimentary rocks on the Baie Verte Peninsula are still located where they were deposited, but have been metamorphosed to schists, whereas equivalent sandstones and shales farther west have escaped metamorphism.

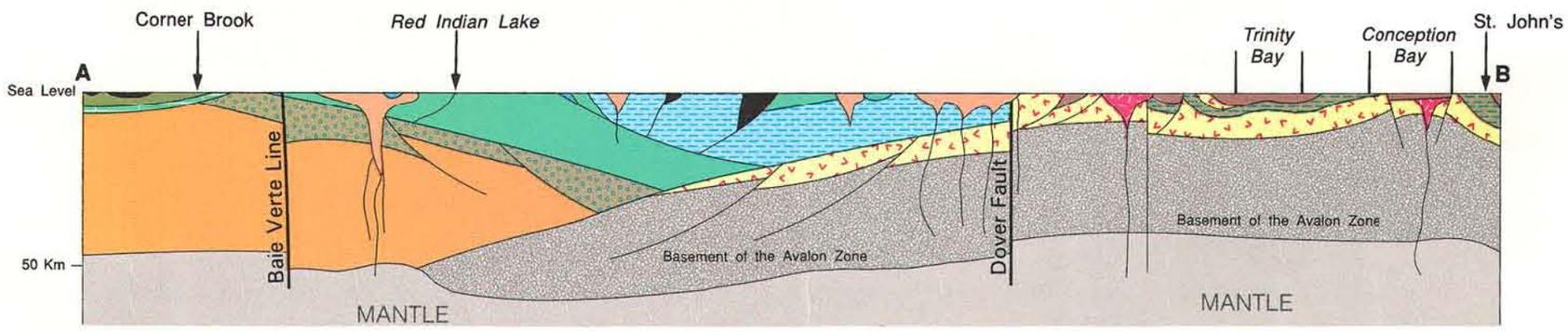
The permeability of these rocks depends on the degree of cementation of individual grains and the extent of fracturing. Generally slates, shales, and volcanic rocks have low primary porosity since they are normally fine grained and compact, but fractures may have created secondary porosity. Sandstone is often permeable, but in Newfoundland the voids between the sand grains are usually well cemented, reducing the permeability significantly. Limestone and dolostone in the Humber Zone are relatively soluble and cause problems with hard groundwater, but sandstones and shales are composed mainly of low solubility minerals and contain soft groundwater. Petroleum and natural gas in some of the carbonate formations of the Humber Zone have associated hydrogen sulphide, which gives groundwater an offensive odour that is difficult to correct.

Devonian to Carboniferous Cover Rocks

These rocks are between 390 and 290 million years old. They were deposited after the main Appalachian mountain building episodes and are less deformed and consolidated than older rocks. As a result, they are more easily eroded and tend to form low-lying areas with gentle relief. They consist mainly of sandstone and shale, but also contain limestone, salt, gypsum, and coal. Because they are less consolidated, they have higher primary porosity and are more permeable. Limestone, gypsum, and salt consist of soluble minerals and tend to dissolve along flow paths, causing greater flow capacity but increased mineral content. In some areas, limestone makes the groundwater hard, and in others gypsum or salt makes it undrinkable.

Intrusive Rocks

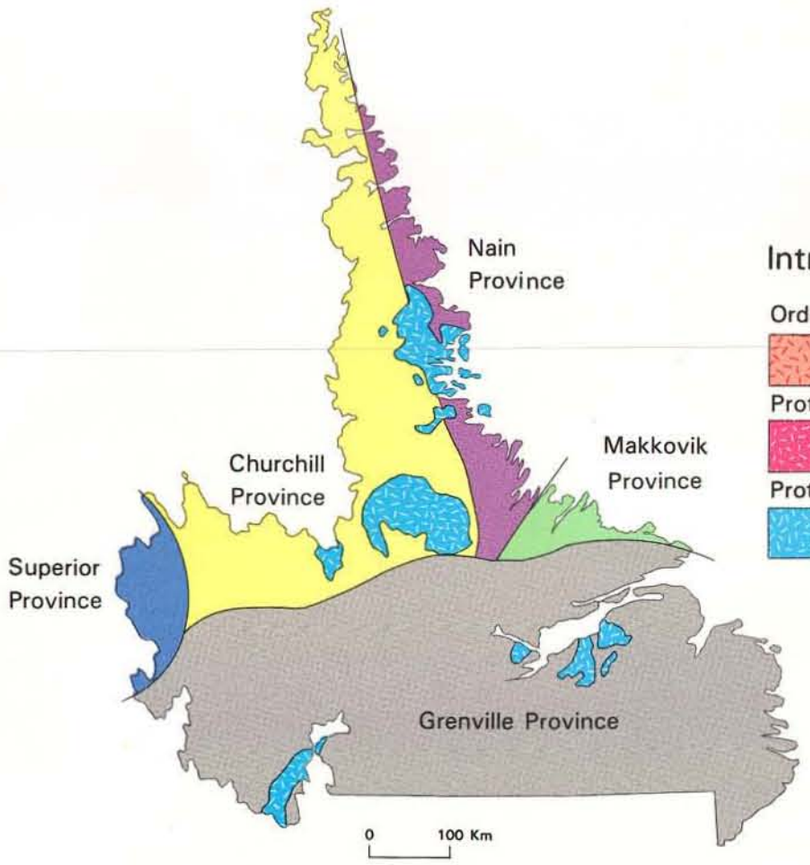
Most of the igneous intrusions in insular Newfoundland are granite, but there are also large gabbro, diorite, and anorthosite plutons. They vary in age from Proterozoic II to Carboniferous and have accompanied the formation of volcanic and metamorphic rocks in all four of the geologic zones. Intrusive rocks of all ages are similar to the Proterozoic I and II units of the Humber Zone in their effect on the flow and chemical quality of groundwater. They contain substantial amounts of water in micro fractures, but with the exception of fracture zones, have limited ability to transmit this water.



Bedrock Characteristics along Section A-B of Bedrock Geology Map; Refer to Map for Identification of Rock Type.

BEDROCK GEOLOGY

Newfoundland and Labrador



Intrusive Rocks

Ordovician to Carboniferous
Granitic and gabbroic

Proterozoic II to Cambrian
Granitic and gabbroic

Proterozoic II
Anorthosite

Appalachian Orogen

COVER ROCKS

Devonian to Carboniferous
Subaerial, lacustrine, fluvial and deltaic clastic sedimentary rocks; minor limestone

Silurian
Shallow marine and subaerial clastic sedimentary rocks; volcanic and volcaniclastic rocks

AVALON ZONE

Proterozoic III to Ordovician
Subaerial and marine clastic sedimentary rocks; minor limestone

Proterozoic III
Marine and deltaic clastic sedimentary rocks

Mafic and felsic volcanic and volcaniclastic rocks

GANDER ZONE

Cambrian to Ordovician
Clastic metasedimentary rocks and migmatitic equivalents

DUNNAGE ZONE

Cambrian to Silurian
Marine clastic sedimentary rocks; island-arc volcanic and volcaniclastic rocks

Cambrian to Ordovician
Ophiolitic mafic-ultramafic rocks; pillow lava and related intrusions

HUMBER ZONE

Proterozoic III to Ordovician
Autochthonous and parautochthonous clastic and metasedimentary rocks

Platformal limestone and dolostone; includes clastic sedimentary rocks

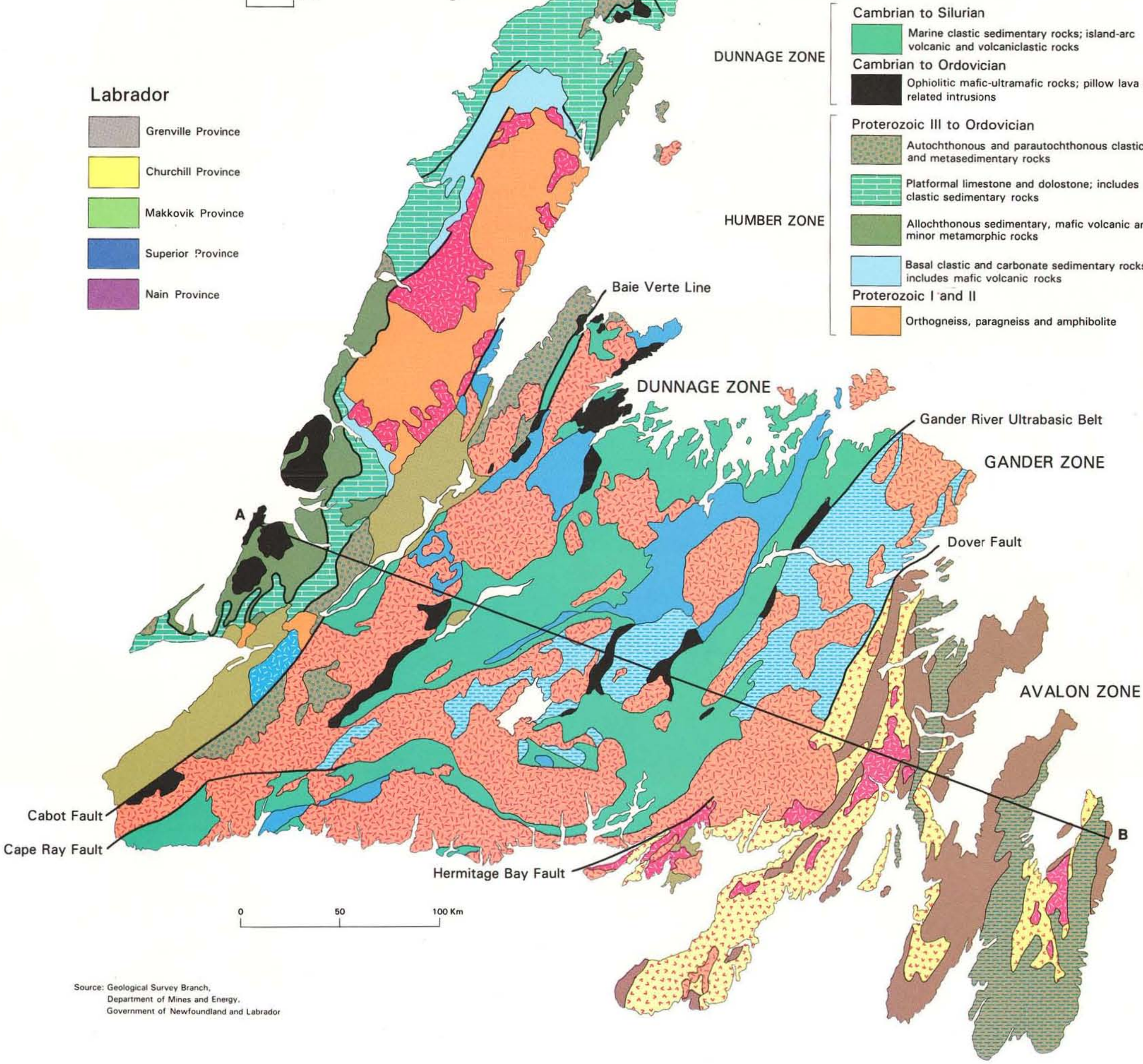
Allochthonous sedimentary, mafic volcanic and minor metamorphic rocks

Basal clastic and carbonate sedimentary rocks; includes mafic volcanic rocks

Proterozoic I and II
Orthogneiss, paragneiss and amphibolite

Labrador

Grenville Province
Churchill Province
Makkovik Province
Superior Province
Nain Province



Source: Geological Survey Branch,
Department of Mines and Energy,
Government of Newfoundland and Labrador

4 – Surficial Geology

Surficial geology refers to the description of materials lying on top of bedrock; these materials range in size from fine silt to boulders. A discussion of surficial geology is necessary for an understanding of the occurrence and movement of groundwater. In Newfoundland unconsolidated sediments were deposited during the Quaternary period and covered a wide area. Analyses of offshore sediment samples indicate that this period was marked by extensive glaciation, with up to eleven glacial periods occurring over the last two million years. The surficial geology of present-day Newfoundland is dominated by the effects of the last glaciation, the Wisconsian, which occurred between 25,000 and 10,000 years ago. On the Avalon Peninsula ice persisted into the Holocene until at least 8000 years ago.

The most common depositional product of the retreating glacial ice was till, a poorly sorted sediment containing a mixture of grain sizes from clays to boulders. It was deposited directly from ice by passive melt-out or by a lodgement process. During the melting of glacial ice sheets large volumes of water were released. The meltwater deposited glacial-fluvial sand and gravel in a number of ways: either below the glacial ice (eskers), at the margins of the ice (kames), or in front of the ice (outwash plains and deltas). The most prominent examples of glacial deposits are large boulders called erratics which can be seen in certain areas of the province. An example of an erratic is shown in Figure 4.1.

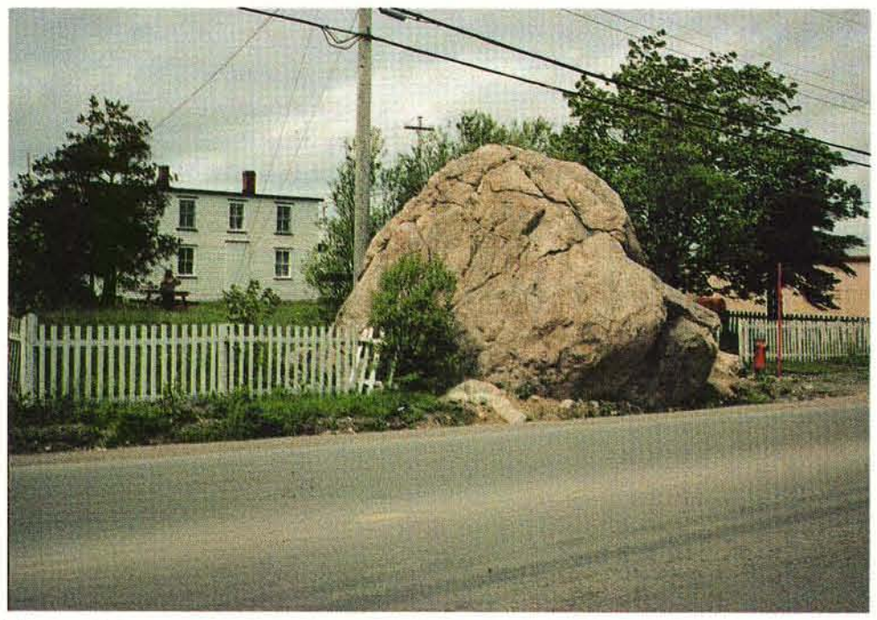


Figure 4.1 Large Erratic in Conception Bay South

Well sorted, coarse grained sediment deposits allow percolation and movement of water through the spaces between the grains. These deposits allow rapid infiltration of precipitation and consequently rarely support significant surface runoff. On the other hand, they allow the storage of relatively large quantities of water in the intergranular spaces. Thus, deposits of sand and gravel can form important aquifers and potential water sources. Tills in some areas of the province have poor porosity and permeability due to the presence of silt and clay. These fine particles occupy the spaces between the grains and restrict the flow of water. Such tills are thus poor aquifers. In many areas of Newfoundland, however, silt and clay constitute less than 10% of tills and therefore allow considerable water storage and movement. Deposits consisting mostly of silt and clay are impermeable and do not form aquifers.

The weight of glacial ice over the province resulted in the land surface being depressed. This caused a relative rise in sea level, which varied from over 130 m above present sea level in Labrador and the Northern Peninsula to near zero on the Avalon Peninsula. Following melting of the ice, the land surface has been rebounding, resulting in a relative fall in sea level. This has caused the sediments originally deposited in a marine environment to be exposed well above present sea level. Such features include sand and gravel deposited in deltas and beaches, and sand, silt, and clay deposited in the near shore environment. Figure 4.2 shows fine glacial deposits in the Springdale area. Bogs and fens developed in poorly drained areas during the Holocene through accumulation of organic matter.

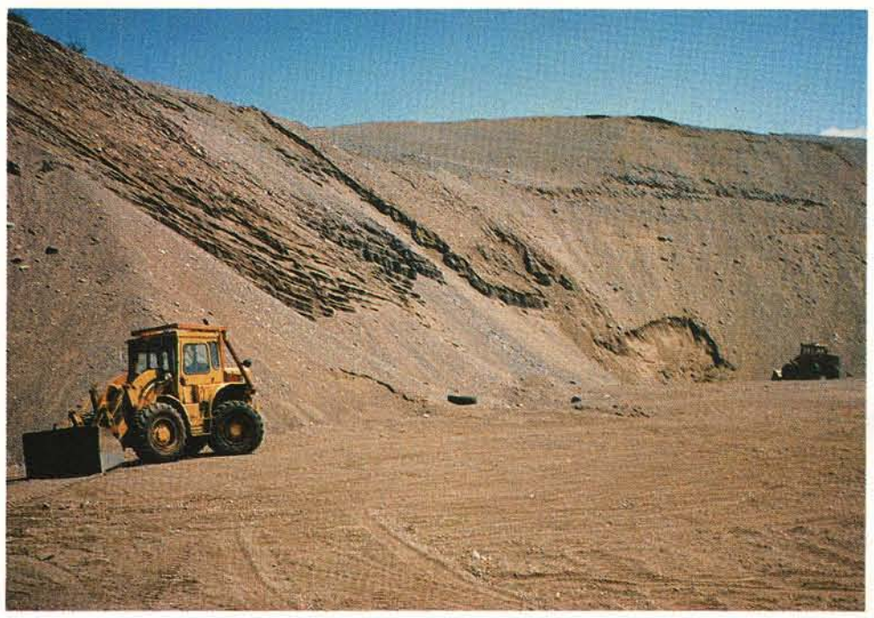


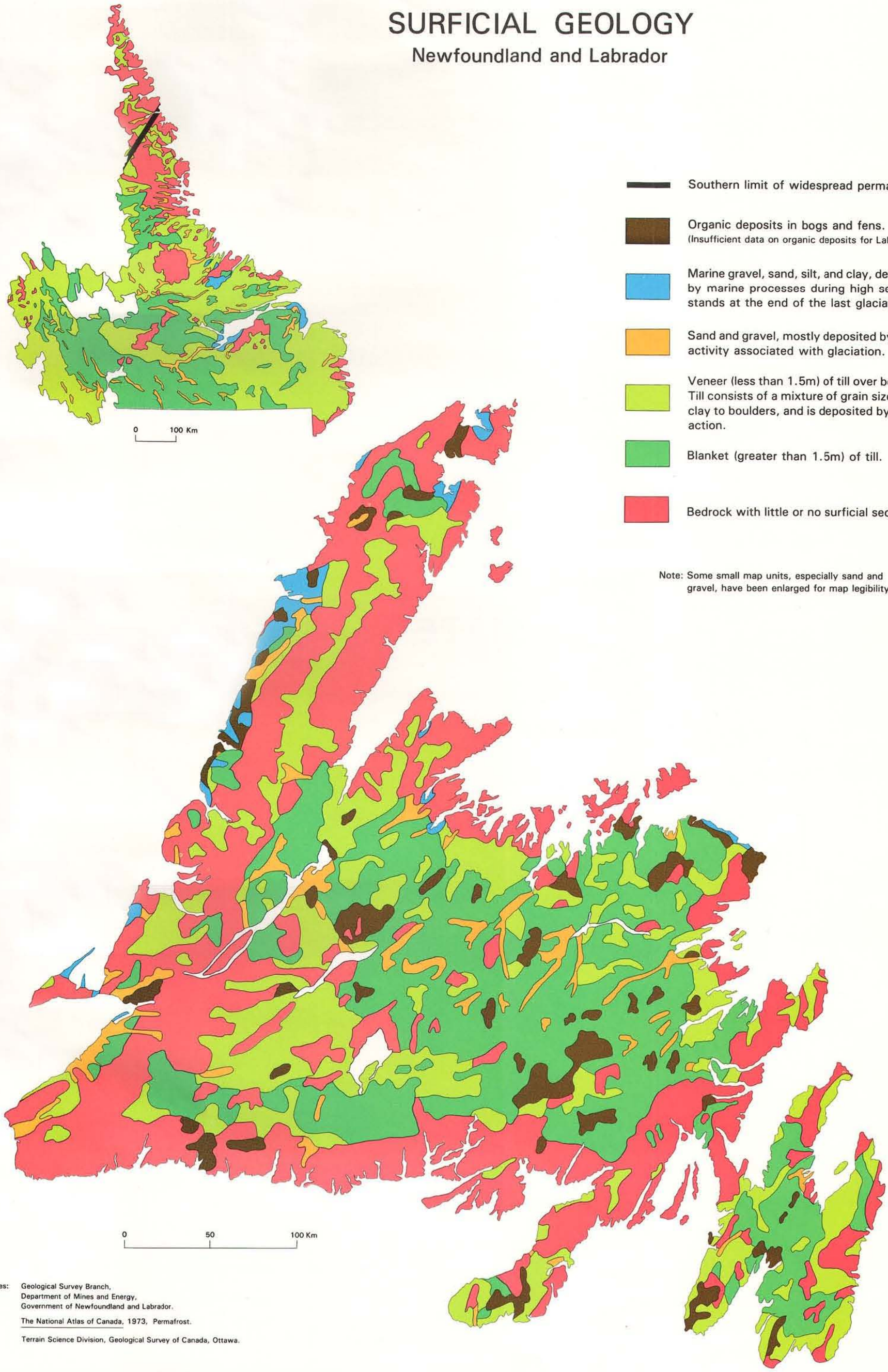
Figure 4.2 Fine Glacial Deposits in Springdale

Some areas of the province have only a thin veneer of surficial sediment overlying bedrock along with sparse vegetation. Poor infiltration of rainwater into the ground results in significant surface runoff and flows in rivers draining these areas tend to rise and fall rapidly with precipitation events.

Permafrost occurs mainly in Northern Labrador as shown on the map. It is present wherever the ground temperature remains at or below 0°C for two or more years in a row. Permafrost results in poorly drained soils and the typical muskeg and marsh vegetation of tundra regions. Groundwater below a permafrost layer is not subject to recharge from the surface. It is usually saline or brackish indicating that the water is in poor circulation.

SURFICIAL GEOLOGY

Newfoundland and Labrador



Southern limit of widespread permafrost.

Organic deposits in bogs and fens.
(Insufficient data on organic deposits for Labrador).

Marine gravel, sand, silt, and clay, deposited by marine processes during high sea level stands at the end of the last glaciation.

Sand and gravel, mostly deposited by fluvial activity associated with glaciation.

Veneer (less than 1.5m) of till over bedrock. Till consists of a mixture of grain sizes from clay to boulders, and is deposited by glacial action.

Blanket (greater than 1.5m) of till.

Bedrock with little or no surficial sediment.

Note: Some small map units, especially sand and gravel, have been enlarged for map legibility.

Sources: Geological Survey Branch,
Department of Mines and Energy,
Government of Newfoundland and Labrador.

The National Atlas of Canada, 1973, Permafrost.

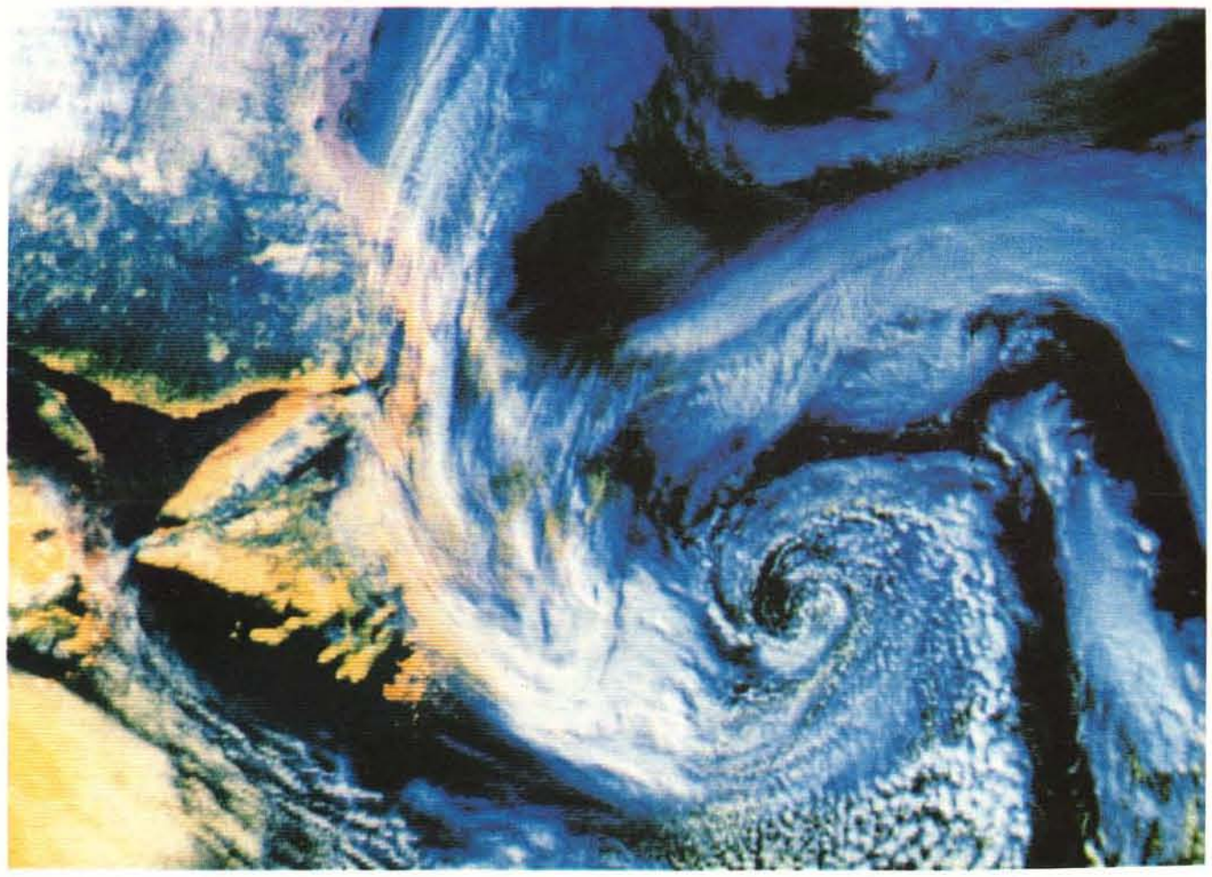
Terrain Science Division, Geological Survey of Canada, Ottawa.

CLIMATE

Introduction

Climate can be defined as the sum total of the meteorological elements that characterize the average and extreme atmospheric conditions over a long period of time at any one place or region of the earth's surface; it can be loosely defined as the "average weather". It is the primary determinant of the amount, distribution, and movement of water over time and space. The regional climates of the province are determined by the atmospheric circulation patterns in the Northern Hemisphere and the proximity of a cold ocean environment. The northern region of Labrador has an Arctic climate, while its interior has a continental climate with cold dry winters and warm summers. The Island, close to the confluence of the warm Gulf Stream waters and cold ex-Arctic waters of the Labrador Current, has mild winters and cool summers. At a local level the climate can be substantially modified by topographic features.

Several parameters such as temperature, precipitation (rain or snow), evaporation, wind speed and direction, etc., are used to characterize the climate of a region. Some or all of these parameters are measured at climatic stations across the province. The next six maps illustrate the location of the climatic stations and the regional and seasonal variations in temperature, rainfall, snowfall, and evapotranspiration in Newfoundland and Labrador.



Satellite Image of Clouds Associated with a Low Pressure System off the East Coast of Newfoundland.
(Image courtesy of Atmospheric Environment Service, Environment Canada)

5 – Weather and Climate Networks

WEATHER NETWORKS:

Synoptic Stations:

Detailed weather observation programs are carried out at the synoptic stations in the province. Parameters measured include: cloud cover, visibility, pressure, temperature, dew point, relative humidity, precipitation, sunshine, and wind velocity. Solar radiation, evaporation and soil temperature are measured at select locations. In addition, the occurrences of thunder, hail, and freezing rain are recorded, as well as a description of sky conditions. Observations are usually made hourly. At a few sites, observations are made every six hours. Synoptic stations are operated by the Atmospheric Environment Service of Environment Canada, other federal government departments (e.g. Ministry of Transport, Department of National Defence), or by private firms under contract.

There are 27 stations in the synoptic network, nine of which are automatic. Most of the stations in the network are located in coastal areas. The range of elements recorded at the automatic stations is not as complete as that of the manned stations. The advantage of automatic stations, however, is that they can be set up in remote areas of the province. The synoptic network provides data for the preparation of weather forecasts on a real time basis. Historical weather records at St. John's date back to 1871. The weather station at St. John's Airport is shown in Figure 5.1.

Upper Air Stations:

Twice daily, at 0000 and 1200 Universal Time, observations of upper air conditions are made at three locations in Newfoundland: Stephenville, St. John's and Goose Bay. A radiosonde (an airborne device that radios meteorological data to the ground) is sent up into the atmosphere via a weather balloon. Parameters measured are: altitude, temperature, humidity, and wind velocity for a number of pressure levels ranging from surface level to an altitude of about 30 kilometres. These stations are operated by the Atmospheric Environment Service and the Department of National Defence. The data obtained from this network are used for forecasting and research. Records for these stations date back to 1942 at Stephenville, 1947 at Goose Bay, and 1971 at St. John's. Data are also available for Argentia from 1945 to 1970.

CLIMATE NETWORKS:

Atmospheric Environment Service (AES) Network:

The network consists of approximately 86 stations and is operated by cooperative government agencies or by private individuals under contract. Observations are normally taken twice daily. Parameters measured include: maximum and minimum temperatures, rainfall, and depth of snow on the ground. In addition, the occurrences of thunder, hail, and freezing rain are recorded, as well as a brief description of sky conditions. A small number of stations are also equipped to record wind velocity, evaporation, radiation, soil temperatures, rainfall intensity, and sunshine. Records date back to the early 1870's.

Newfoundland Department of Environment and Lands Network:

The federal government's requirement for climate stations in the province was basically met in 1986. Due to a need for stations to support provincial programs, the federal and provincial governments signed an agreement in September 1986 regarding climate stations and programs in the province. A number of stations were established during and after 1986 under the cost sharing agreement. Compared to the stations in the AES network, many of the 35 stations in the provincial network have only short periods of record. The parameters measured and the frequency of observations are, however, the same for federal and provincial climate stations.

DATA PROCESSING AND AVAILABILITY:

All climate and weather data are processed at the Atmospheric Environment Service office in Bedford, Nova Scotia. Subsequently, the data are sent to the Canadian Climate Centre in Downsview, Ontario, where they are checked once again before being placed in the National Climatological Archive. Data from this archive are available in paper, microfilm, and computer based formats. In addition, a number of data periodicals and statistical publications is prepared by the Atmospheric Environment Service. Data are also available for approximately 95 discontinued stations which are not shown on the map. Further information on climate services can be obtained from:

Atmospheric Environment Service
Scientific Services Division
P.O. Box 9490, Station B
St. John's, NF
A1A 2Y4
Telephone (709) 772 4695

Atmospheric Environment Service
Scientific Services Division
Climate Services
5th Floor, Bedford Tower
1496 Bedford Highway
Bedford, NS
B4A 1E5
Telephone (902) 426 9226

Figure 5.1 Weather Station at St. John's Airport
(a) Anemometer (Wind speed and direction)
(b) Snow Depth Sensor
(c) Stevenson Screen (Thermometers)
(d) Tipping Bucket Rainguage

WEATHER AND CLIMATE NETWORKS

Newfoundland and Labrador

Nain A.
Hopedale
Makkovik A.
Cartwright
Wabush Lake A.
Churchill Falls A.
Goose Bay A.
Mary's Harbour
0 100 Km
St. Anthony A.
St. Anthony
Ferolle Point
Englee
Daniel's Harbour
La Scie
Twillingate
Comfort Cove
Deer Lake A.
Badger
Gander Int'l A.
Bonavista
Stephenville A.
Port Aux Basques
Burgeo
0 50 100 Km
Sagona Island
Argentia
St. John's A.
St. Lawrence
Cape Race

Weather Networks

- Synoptic Station
- Upper Air Station

Climate Networks

- Atmospheric Environment Service Network
- Newfoundland Department of Environment and Lands

Sources: Environment Canada Atmospheric Environment Service.
Newfoundland Department of Environment and Lands.

6 – Temperature

Air temperature may be considered to be the most important of all climatological parameters. It determines the types of vegetation possible and, therefore, the forms of wildlife which can exist. Its effects on humans range from determining physical comfort and psychological mood to influencing socio-economic activities such as fishing, construction, transportation, and recreation. It determines the various forms of precipitation, and the rates of snowmelt and evapotranspiration.

Air temperature is measured by self-registering maximum and minimum temperature thermometers. The thermometers are set in a white, wooden, louvered box, which is about 1.5 metres above ground level. The box is designed not to be directly affected by sunlight. Typically, morning and evening observations are made. The maximum daily temperature is the highest temperature recorded by the maximum temperature thermometer during a 24-hour period following the morning observation. The minimum daily temperature is the lowest temperature recorded by the minimum temperature thermometer during a 24-hour period following the evening observation. The mean daily temperature is defined as the average of the maximum and minimum daily temperatures. Figure 6.1 shows a maximum temperature thermometer (top) and a minimum temperature thermometer (bottom). The front door of the louvered box is normally closed.

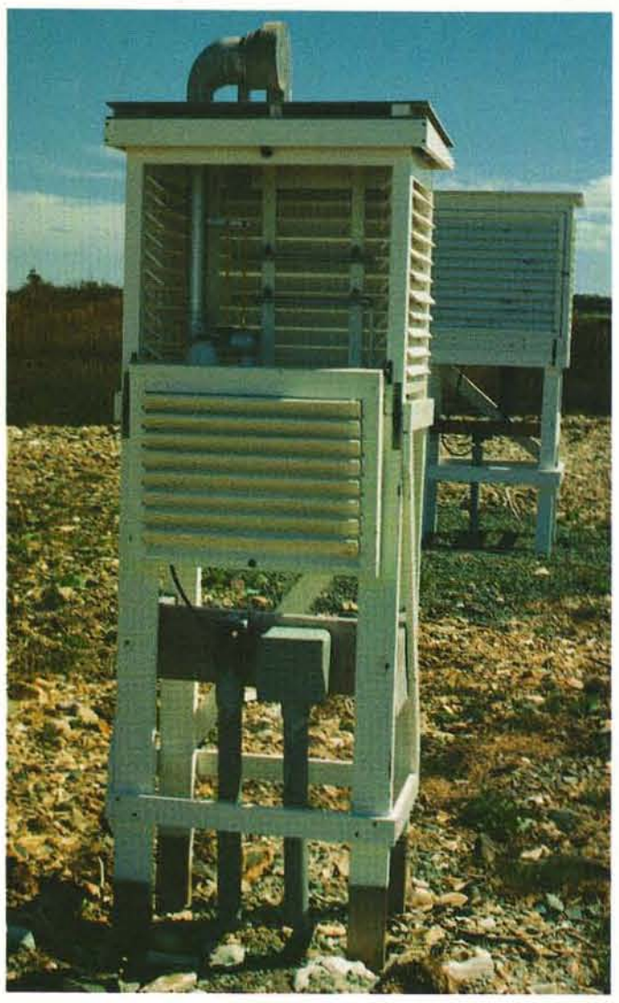


Figure 6.1 Maximum and Minimum Temperature Thermometers

The map on the opposite page shows the variations in mean monthly, seasonal, and annual air temperatures in the province. It is based on temperatures recorded at 62 climatological stations.

Air temperature in the province is primarily influenced by latitude, distance from the ocean, and prevailing winds. Many climatological stations are located in coastal areas and may not give accurate representations of temperature regimes further inland.

On the Island the mean annual air temperature varies from 5°C on the Avalon and Burin Peninsulas to 1°C on the Northern Peninsula. In Labrador the mean temperature varies from 1°C in the southeast to -2°C in the north and -3°C in the west. The warmest month is usually July or August and the coldest is usually January or February.

During summer the south coast of the Island is slightly cooler than central Newfoundland due to the predominant on-shore winds. The Northern Peninsula is significantly cooler than the interior of Newfoundland because of its higher latitude. In Labrador summer mean temperatures are highest in the central region and lowest in the northern coastal zone.

In the fall the south and southwest coasts of Newfoundland are warmer than most of central and northern Newfoundland due to the thermal inertia of the ocean and on-shore winds. In Labrador the fall mean temperatures vary from a few degrees below zero in the west to a few degrees above zero in the east.

Winter temperatures in central and western Labrador are largely influenced by the cold arctic air mass. Near the coast temperatures are higher due to the moderating effect of the Labrador Sea. The arctic air mass also depresses temperatures over the western region of the Island. On the Avalon and Burin Peninsulas temperatures are relatively higher due to frequent warm air masses which originate along the United States eastern seaboard.

In the spring isotherms in Labrador begin to shift from a north-south orientation to an east-west orientation. The coldest areas are in the north and west while the highest mean temperatures are in the southeast. On the Island relatively higher temperatures are recorded in southern areas because of the absence of offshore sea ice.

The highest and lowest temperatures recorded on the Island to date are: +36.7°C near Bishop's Falls, and -45.0°C near Badger. In Labrador the maximum and minimum temperatures were recorded at North West River, +41.7°C and at Esker, -51.2°C. The highest and lowest temperatures recorded in Canada to date are: +45.0°C at Yellow Grass, Saskatchewan and -63.0°C at Snag, Yukon Territory.

Figure 6.2 shows the mean annual temperatures for 14 cities across Canada. The maximum and minimum monthly mean temperatures are also shown. The major influences on air temperature in Canada are latitude and distance from large water bodies.

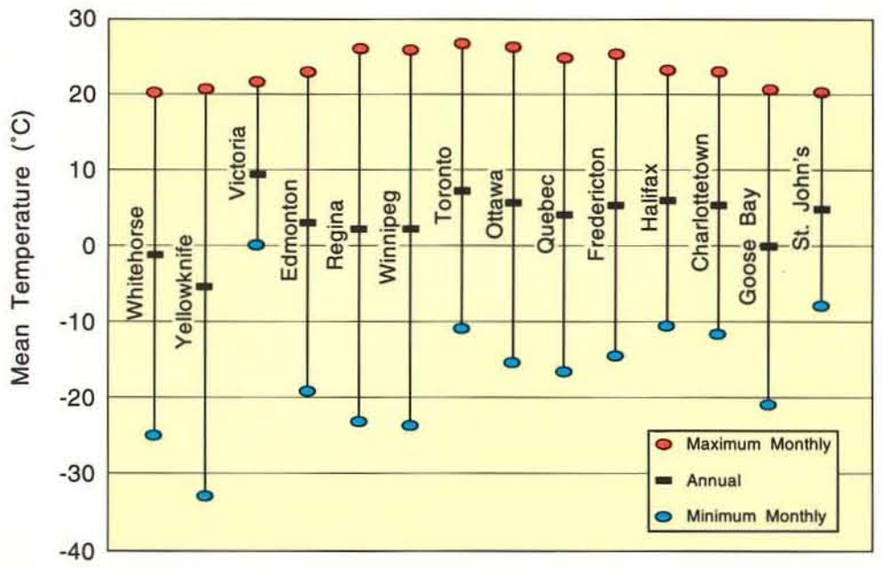


Figure 6.2 Mean Temperatures for Canadian Cities

TEMPERATURE

Newfoundland and Labrador

Churchill Falls

Goose Bay

Battle Harbour

Wabush Lake

St. Anthony

0 100 km

Daniel's Harbour

Comfort Cove

Deer Lake

Gander

Stephenville

St. John's

Port Aux Basques

Burgeo

St. Alban's

St. Lawrence

0 50 100 km

Mean Yearly Temperature (°C)

5.0 — 7.9	1.0 — 1.9
4.0 — 4.9	0.0 — 0.9
3.0 — 3.9	-1.0 — -0.1
2.0 — 2.9	-4.0 — -1.1

Contour Interval = 0.5°C

Monthly Temperature

Station Name

Degrees Celsius

Maximum
Mean
Minimum

Station Location

Spring
March-May

Summer
June-August

Mean Seasonal Temperature (°C)

14.0 — 19.9
12.0 — 13.9
6.0 — 11.9
2.0 — 5.9
0.0 — 1.9
-4.0 — -0.1
-6.0 — -4.1
-8.0 — -6.1
-12.0 — -8.1
-20.0 — -12.1

Fall
September-November

Winter
December-February

Source: Atmospheric Environment Service (AES)
Data up to and including 1986

7 – Mean Annual Precipitation

Precipitation is one of the primary components of the hydrologic cycle. Its usual forms are rain and snow, and variations of these such as drizzle and sleet. Hail, although relatively infrequent and light in Newfoundland, is another form of precipitation. Precipitation is derived from atmospheric water and thus its form and quantity are influenced by other climatic variables such as wind, temperature, and atmospheric pressure.

Evaporation from ocean surfaces is the principal source of atmospheric moisture. Dynamic or adiabatic cooling of the rising moist air causes condensation of water vapour into cloud droplets. Precipitation starts when the cloud droplets have grown to a sufficient size. Vertical transport of moist air masses is a requirement for precipitation.

Precipitation may be classified according to the conditions that generate vertical air motion. The three major categories in this respect are convective, orographic and cyclonic. Convective precipitation is brought about by the heating of air at ground level. This warm and light air absorbs water vapour and begins to rise. At high altitudes cooling takes place causing condensation and precipitation. Convective precipitation may be in the form of light showers or thunderstorms. Orographic precipitation results from mechanical lifting of moist horizontal air currents over natural barriers such as mountain ranges. Cyclonic precipitation is associated with the movement of air masses from high pressure regions to low pressure regions.

Most of the province's precipitation is of the cyclonic type. Low pressure systems typically approach the Island from the St. Lawrence River valley and the eastern seaboard of the United States. An orographic effect is present along the west and south coasts of the Island.

The amount of rain, drizzle, freezing rain, freezing drizzle or hail is measured in standard rain gauges. The rim of the gauge is placed 400 millimetres (mm) above the surface of the ground and has a circular orifice 113 mm in diameter. The rain is funnelled into a clear plastic graduated cylinder, which serves as the measuring device. The depth of the water in the cylinder is read to the nearest 0.2 mm. Figure 7.1 shows a standard rain gauge.

Figure 7.1 A Standard Rain Gauge

Snowfall amount is quantified by measuring depths of freshly fallen snow at a number of representative points with a standard snow ruler and recording the average to the nearest 0.2 centimetre (cm). The water equivalent of the snowfall is obtained by dividing the average snowfall depth by 10; thus, 1 cm of snow is assumed to be equivalent to 1 mm of water.

At most stations precipitation measurements are made twice daily, in the morning and late in the afternoon. At some stations only one observation is taken daily, while at synoptic stations observations are taken four times daily.

The map on the opposite page illustrates the distribution of mean annual precipitation in the province. The accompanying graphs show the distributions of the mean monthly precipitation as well as the amounts occurring as rain and snow at several climate stations.

The data for the map were obtained from records at 76 climate stations located in the province. For each station daily precipitation amounts for each year from 1951 to 1980 were added and these annual precipitation amounts were averaged over the 30-year period to give the mean annual precipitation. The mean monthly precipitation values were similarly calculated for each month of a year. In the cases where stations did not have a complete record of 30 years of data, the precipitation records were extended using statistical techniques.

A computer program was used to generate the isohyets (lines of equal precipitation depth) from the point data at the climate stations. The inadequacy of the climate network, both in terms of density and geographical distribution, on the Island and in Labrador may have introduced some errors in the estimates of precipitation amounts shown on the map.

The mean annual precipitation on the Island ranges from 779 mm in Fogo to 1644 mm in St. Albans. Relatively higher precipitation occurs over the Avalon Peninsula, along the south coast, and over the highlands of the Long Range Mountains. Precipitation is generally greatest during the autumn and early winter months and lowest in the spring or early summer months. Average annual snowfall varies from 92 cm in St. Shotts to 523 cm in Woody Point, with the higher snowfall amounts occurring over the western mountains and along the east coast.

The mean annual precipitation in Labrador varies from 740 mm in the north at Nain to 963 mm in Churchill Falls. Precipitation is fairly evenly distributed throughout the year with slightly higher values occurring during the summer and early autumn. Snowfall is relatively heavy with annual amounts ranging from 396 cm to 481 cm.

Figure 7.2 shows the spatial variation of mean annual precipitation amounts in selected regions of Canada as published in the Hydrological Atlas of Canada.

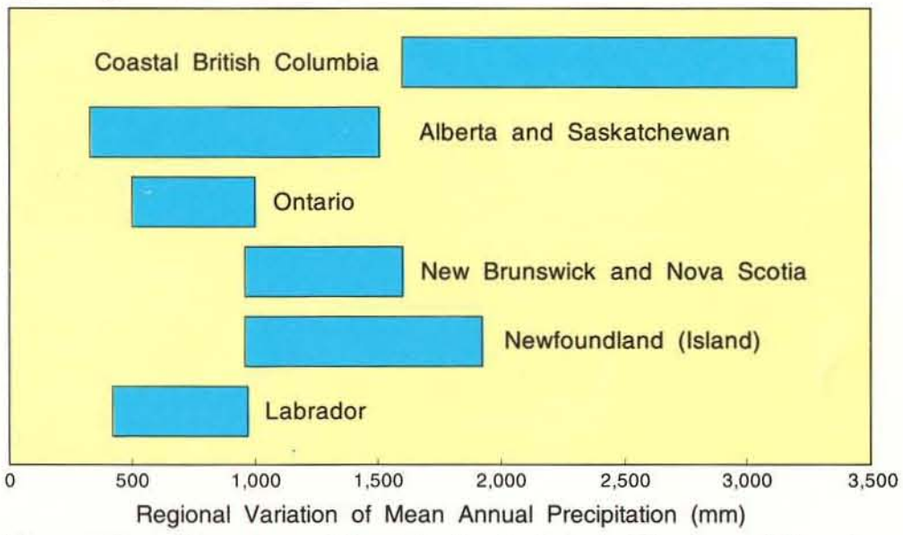


Figure 7.2 Mean Annual Precipitation in Selected Regions of Canada

MEAN ANNUAL PRECIPITATION

Newfoundland and Labrador

Churchill Falls

Goose Bay

Battle Harbour

Wabush Lake

St. Anthony

Daniel's Harbour

Comfort Cove

Deer Lake

Gander

Stephenville

St. John's

Port Aux Basques

Burgeo

St. Alban's

St. Lawrence

0 100 Km

0 50 100 Km

Monthly Preciptation by Station

Mean Annual Preciptation

millimetres

- 700 — 900
- 900 — 1100
- 1100 — 1300
- 1300 — 1500
- 1500 — 1700

Contour interval = 50mm

Source: Atmospheric Environment Service (AES)
Data up to and including 1986

8 – Rainfall Intensity for Selected Frequencies and Durations

Mean annual precipitation is a measure of the total amount of precipitation expected during a typical year. For the engineering design of hydraulic structures such as bridges, dams, spillways, canals, etc., however, it is necessary to analyze individual rainfall events. The required carrying capacities of the hydraulic structures are estimated from the extreme amounts of rainfall recorded over minutes or hours.

Most analyses of extreme rainfall events involve the determination of the following parameters: duration of the rainfall event in minutes or hours, volume of rainfall over the duration of the storm expressed as a total volume or an equivalent depth, and the frequency of occurrence of rainfall events with specified duration and volume.

Rainfall is also described in terms of its intensity. Intensity is calculated by dividing the equivalent depth of rainfall by its duration. A given volume or depth of rainfall may occur from many different combinations of intensities and durations. For example, 30 millimetres (mm) of rainfall may result from a 1-hour storm having an intensity of 30 mm per hour or from a 15-hour storm having an intensity of 2 mm per hour. In the design of hydraulic structures the former storm is considered to be a more severe and critical storm. Although the volume or depth of rainfall is the same for both storms, in the first storm this amount of rainfall must be handled by the hydraulic structures in a shorter period of time.

The intensity of rainfall during a storm can be extremely variable in time and space. Rainfall intensity is usually highest at the centre of the storm and decreases away from the storm's centre. The intensity at any given point in the storm also changes with time. Thus, as a storm moves over a climate station, the rainfall intensity recorded will show considerable variation with time.

Rainfall intensity is measured with a recording rain gauge such as a tipping-bucket rain gauge. The tipping-bucket is a small container mounted on the cylindrical gauge; every time it fills up, it tips over and empties. The gauge works by having a clock-driven drum carrying a chart on which a pen records a series of blips made each time the tipping-bucket spills its content. The higher the intensity of rainfall, the shorter is the time between successive tips of the bucket. Figure 8.1 shows a tipping-bucket rain gauge and a recorder. The recorder is usually located in a sheltered place.

Figure 8.1 Tipping-bucket Rain Gauge (left) and Recorder (right)

The strip charts recording the rainfall data are analyzed with a digitizer to obtain the maximum rainfall amounts for selected durations of rainfall events. The durations are generally 5, 10, 15, 30, and 60 minute periods as well as 2, 6, 12, and 24 hour periods. The analysis is repeated for every year of rainfall record. The series of annual data for each duration is then processed using statistical methods to obtain the frequencies of rainfall events.

Very often, the frequency of a rainfall event is expressed as a return period. The return period is the average number of years, over a long time, between rainfall events with the same duration equalling or exceeding a given intensity. The return period is also the reciprocal of the probability of a rainfall intensity being equalled or exceeded in any year. The relationship between rainfall intensity, duration, and frequency (return period) is usually expressed graphically as a set of Intensity-Duration-Frequency (IDF) curves. It is considered necessary to have at least 10 years of data before reliable IDF curves can be generated. One set of such curves for the St. John's Airport area is shown in Figure 8.2.

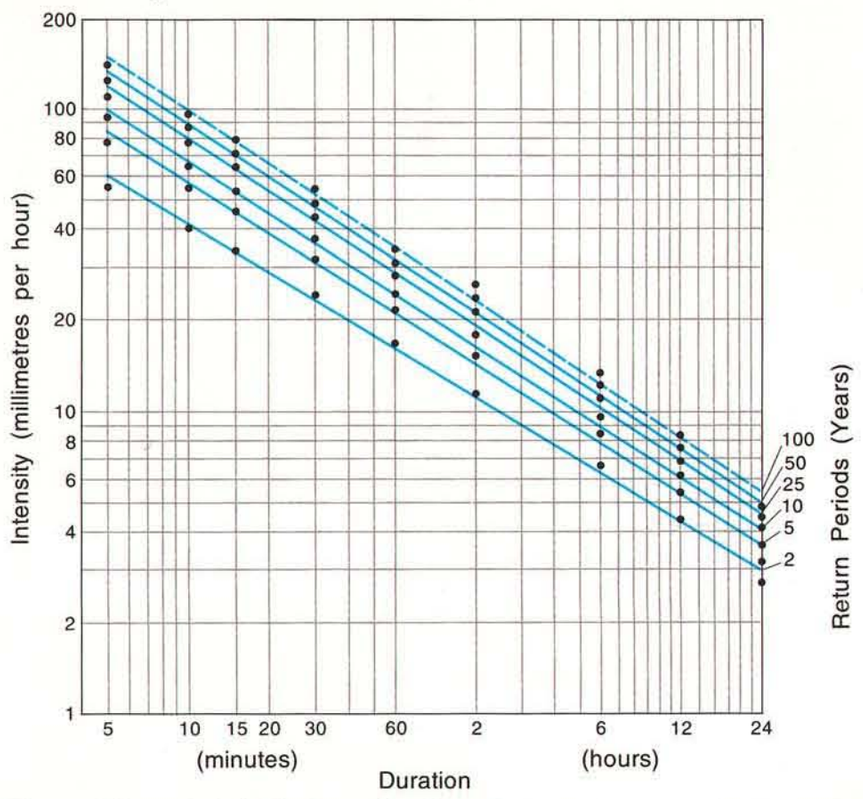


Figure 8.2 Rainfall Intensity-Duration-Frequency Curves (St. John's)

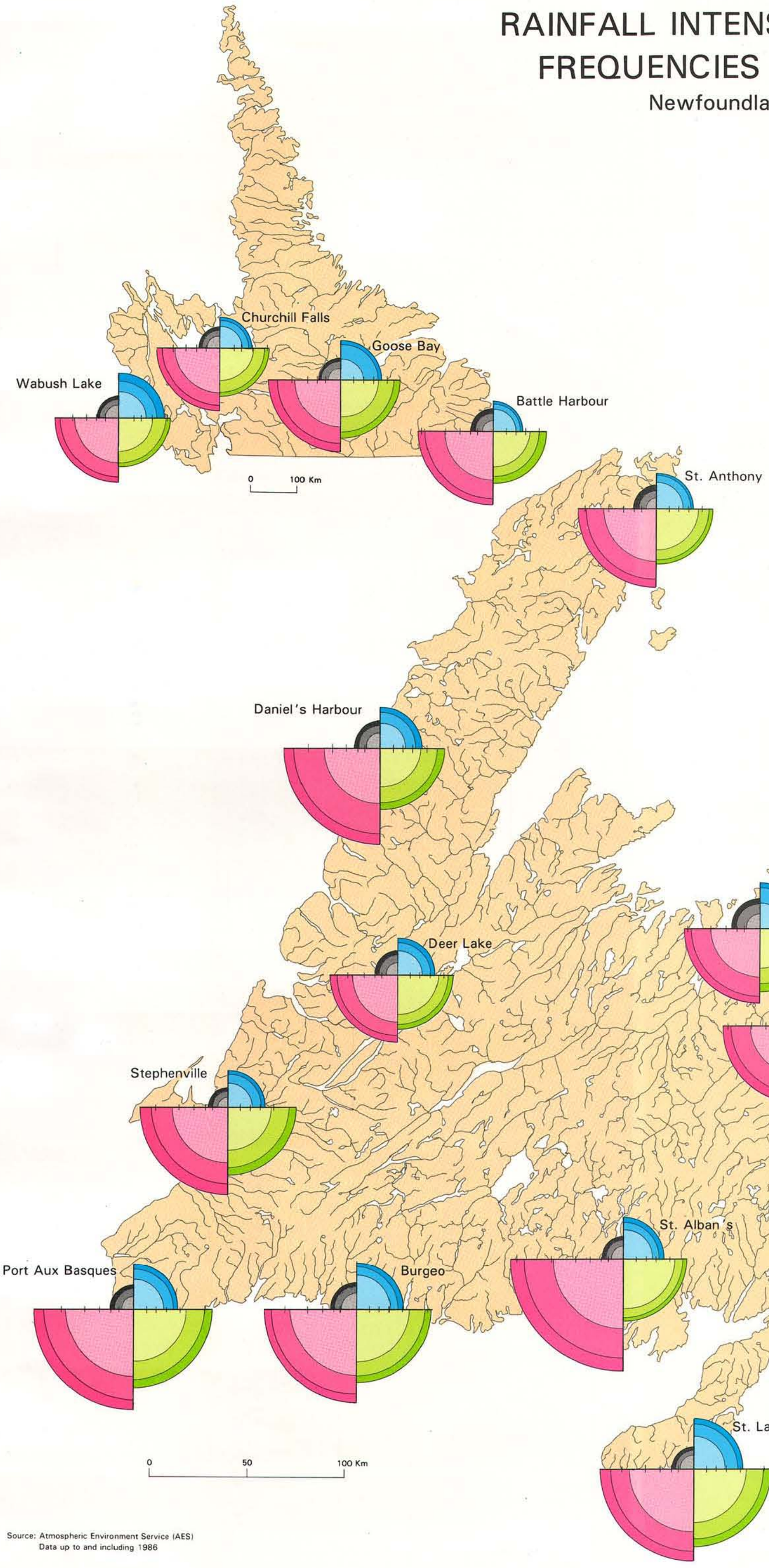
As shown in Figure 8.2, in the St. John's area, 6-hour duration rainfall events have intensities equalling or exceeding 8 mm per hour every 5 years on the average.

Fifteen stations in the province equipped with recording rain gauges and for which IDF curves were available are represented on the rainfall intensity map on the opposite page. The pie-charts give the 2, 25, and 100-year rainfall depths of events with 5-minute and 1, 6, and 24-hour durations (the intensity is calculated as the ratio of depth in millimetres to duration in hours).

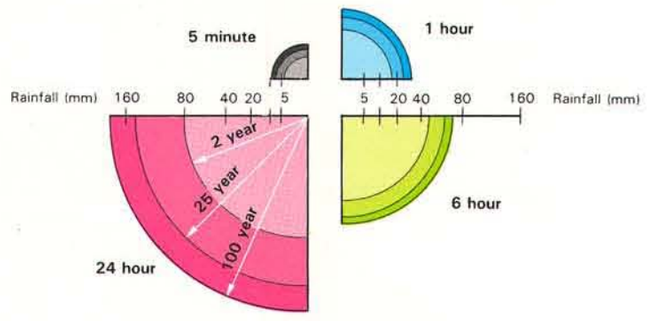
The map indicates that the rainfall events are relatively more severe along the southwest, south, and east coasts of the Island. The climatic conditions of Newfoundland are such that the worst storms generally track into the Island from the southwest. As they progress inland they lose some of their energy and the intensity decreases. Labrador is less likely to be affected by intense storms.

RAINFALL INTENSITY FOR SELECTED FREQUENCIES AND DURATIONS

Newfoundland and Labrador



Duration and Intensity by Station



Source: Atmospheric Environment Service (AES)
Data up to and including 1986

9 – Snowfall

Snowfall accounts for a significant percentage of annual precipitation amounts in virtually all regions of the province, and has a considerable influence on the regional characteristics of river flows. The occurrence of floods in the springtime due to snowmelt is a major concern in certain communities. In our daily lives, especially during the winter, the amount of snowfall determines resources which have to be allocated to the snow-clearing of roads, parking lots, and airport runways. Heavy snowfall can seriously reduce visibility and disrupt travel plans. On the other hand, heavy snowfall can be beneficial to skiers.

Snowfall is generally associated with freezing temperatures. The meteorological conditions producing snowfall are the same as those generating other forms of precipitation such as rainfall. Orographic features such as mountain ranges tend to increase the total amount of snowfall depending on the moisture-bearing characteristics of the air masses.

Snow measurements are usually obtained with rain gauges fitted with heating systems or with snow stakes. A snow stake is a calibrated wooden post which is inserted into the snowpack to determine its depth. Direct measurement of snow depth at a single station is of limited value because drifting and blowing snow can make the measured depth highly unrepresentative of the snowfall in the area. Furthermore, the density of fresh snow is significantly different from packed snow, hence, the amount of snow depends upon the state of the accumulated snow. To circumvent these measurement problems snow surveys of depth and water equivalent are carried out at various points along a snow course. The water equivalent is the depth of water that would weigh the same amount as the sampled snow. As snowfall is a form of precipitation, climatological records commonly report snowfall depth as measured at the time of fall, and the water equivalent of the snow is included in precipitation totals.

The snowfall records for the period 1951-1980 at fifteen stations in the province were used to derive information on the mean annual snowfall, average number of days in a year with snowfall, mean monthly snow depth, and maximum 24-hour recorded snowfall. These characteristics are shown on the map opposite. The lack of data from stations located at high altitudes, where snowfall is generally higher, and the low density of climatic stations limit the accuracy of the information presented.

Snow occurs in measurable quantities on the ground from November to May in most regions of insular Newfoundland; in Labrador the period is from October to early July. In the eastern region of Newfoundland the average number of days with measurable snowfall is approximately thirty and is significantly less than the one hundred and ten days for the interior region of Labrador. The early occurrence and longer period of snow in Labrador are indicative of its relatively colder climate.

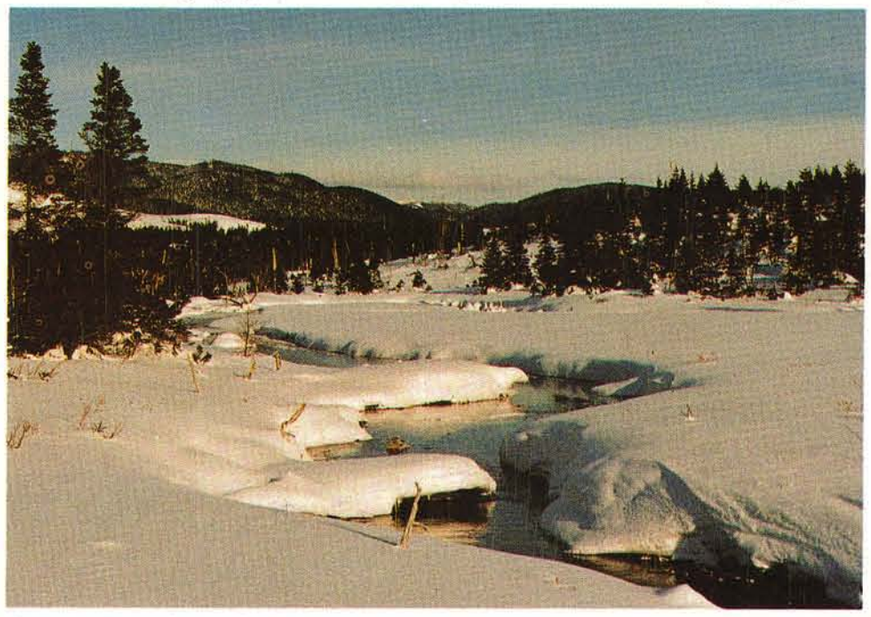
The mean annual snowfall in the province varies from approximately 150 centimetres (cm) in the southeast region of the Island to nearly 475 cm in the interior of Labrador. The orographic effect of the Long Range Mountains on snowfall amounts in the western region of the Island is evident from the map. The high mean annual snowfall around Gander is believed to be due to local factors.

The data for mean monthly snow depth show that, for most regions of the Island, the maximum values occur between February and April. In Labrador the maximum values occur between March and May, thus spring snowmelt occurs about a month later in Labrador than on the Island. The mean monthly snow depth varies from nearly 30 cm on the east coast of the Island to over 100 cm in Labrador. The sequence of snowfall accumulation and subsequent melt generally governs the pattern of mean monthly snow depth. In the maritime climate of Newfoundland it is not uncommon for several freeze-thaw cycles to occur during the winter season. In Labrador, in contrast, the climate is relatively colder and mid-winter snowmelt events are less common; therefore, more snow is likely to accumulate on the ground.

Regions with high annual snowfall generally also have high values for maximum mean monthly snow depth, although interesting exceptions do occur. For example, Gander has a much higher mean annual snowfall than Port aux Basques, but the values for maximum mean monthly snow depth are similar.

The data on the maximum 24-hour snowfall give an indication of the intensity of winter snow storms. Coastal regions seem to experience relatively higher storm intensities than the interior regions.

The estimation of the contribution of snow to river flows and the forecasting of floods resulting from combined large-scale rainstorms and snowmelt are highly dependent upon an adequate knowledge of the extent and characteristics of the snow cover within a watershed. Such information cannot be easily obtained from ground surveys when the watersheds are large and rugged. Recent advances in remote sensing have enabled hydrologists to use data collected by satellites equipped with appropriate sensors to map the areal extent of seasonal snow cover over large areas with good accuracy. The acquisition and analysis of satellite imagery promises to be very valuable in snow hydrology.



Snow-covered Landscape

SNOWFALL

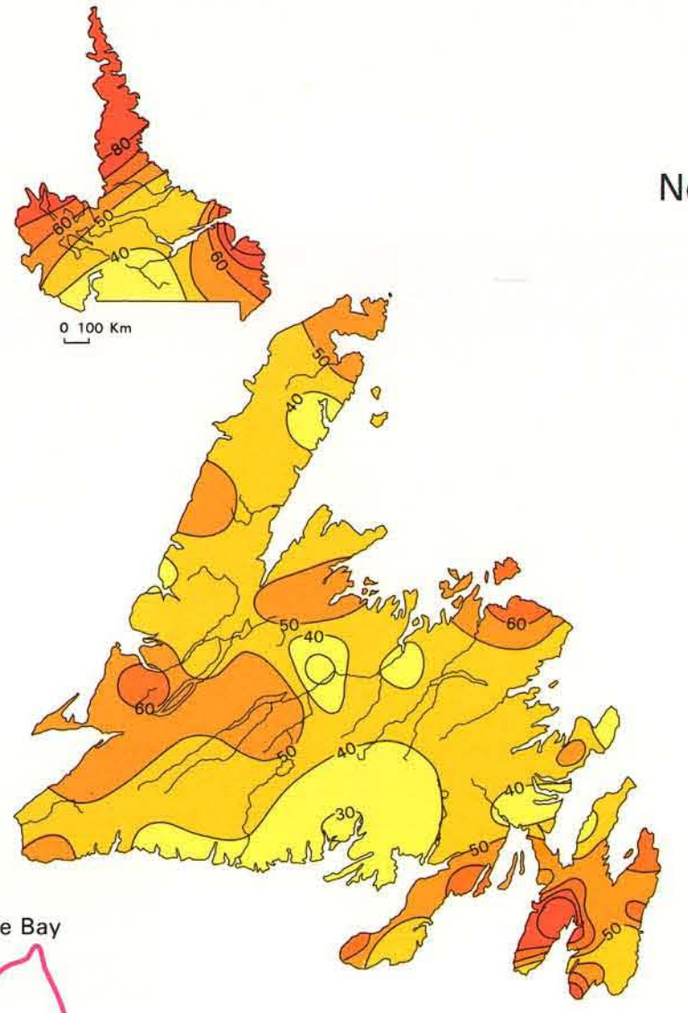
Newfoundland and Labrador

Maximum 24 Hour Snowfall
in centimeters

30 – 40
40 – 50
50 – 60
60 – 70
70 – 90

contour interval = 10 cm

0 100 km

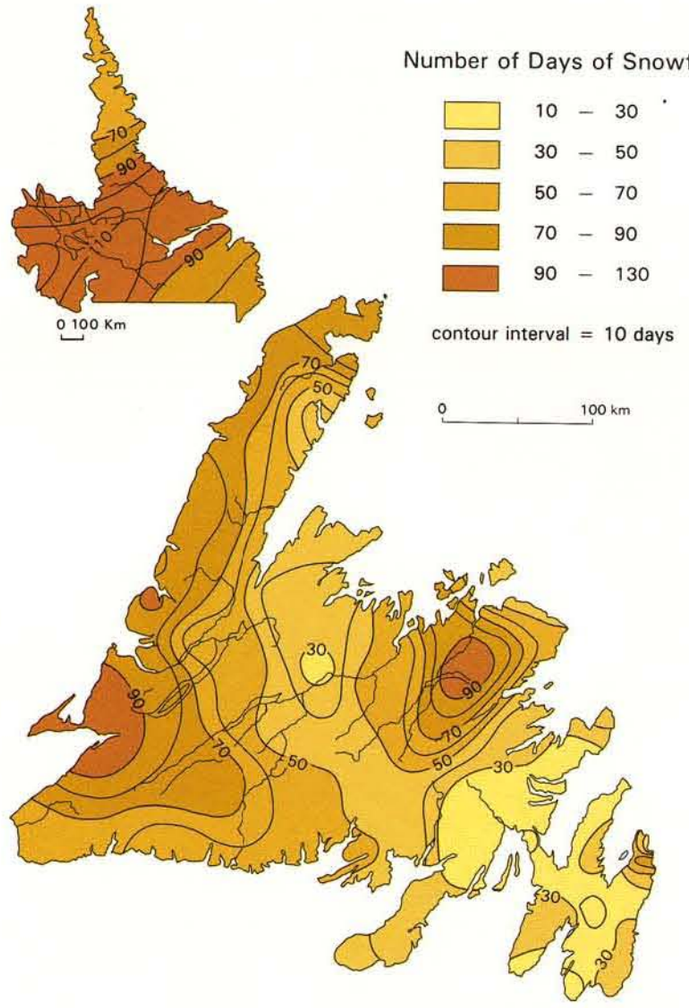


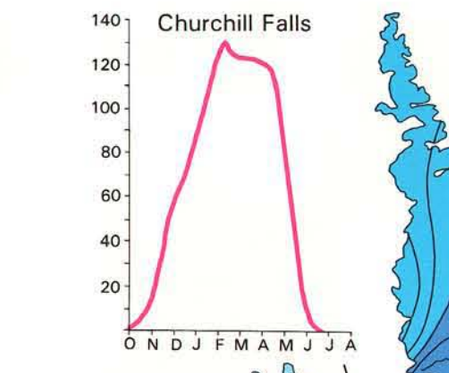
Number of Days of Snowfall

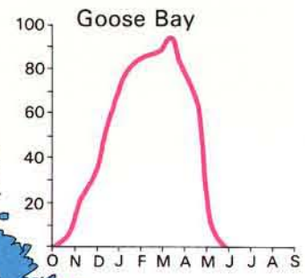
10 – 30
30 – 50
50 – 70
70 – 90
90 – 130

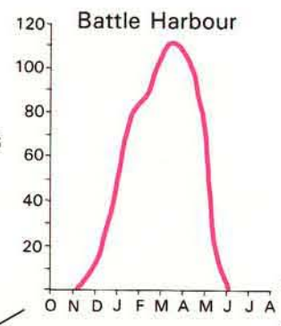
contour interval = 10 days

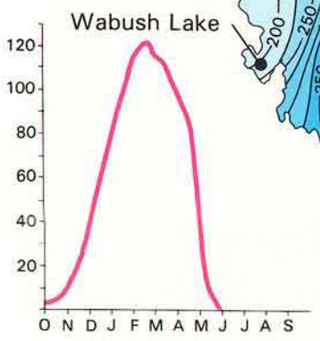
0 100 km

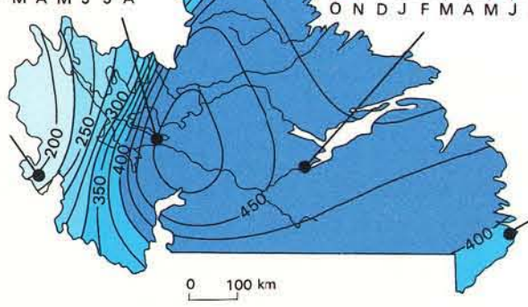


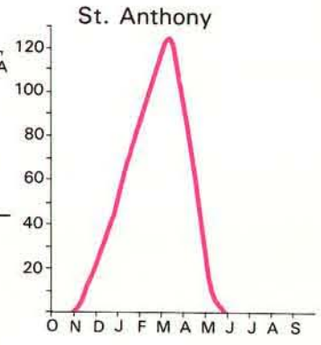


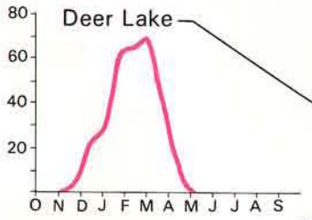


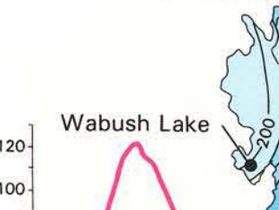


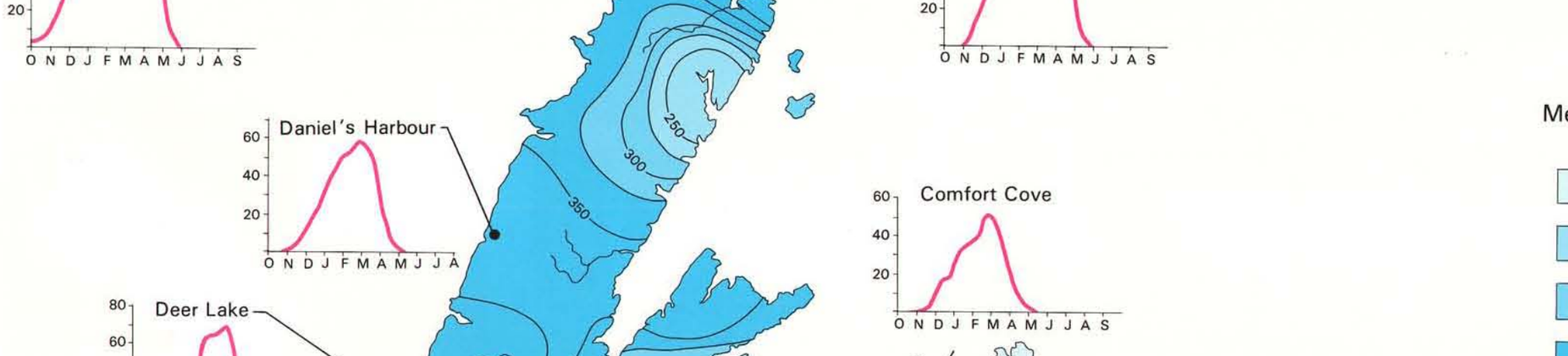










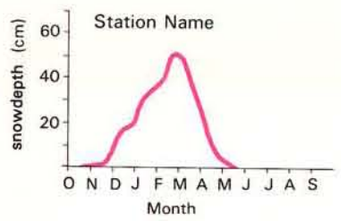


Mean Annual Snowfall
in centimeters

125 – 225
225 – 275
275 – 325
325 – 400
400 – 500

Contour interval = 25 cm

Mean Monthly Snowdepth



Source: Atmospheric Environment Service (AES)
Data up to and including 1986

10 – Potential Evapotranspiration

Evaporation is the process which transforms water from the land and water masses of the earth into atmospheric water vapour by solar radiation. Transpiration is the process by which soil moisture and groundwater absorbed by roots of plants are released to the atmosphere as water vapour through the pores in leaves. In vegetated areas evaporation and transpiration take place simultaneously; the two processes are usually considered together and referred to as evapotranspiration.

The meteorological factors which affect the rate of evapotranspiration are solar radiation, wind speed, relative humidity, and temperature. Other factors include the type and extent of vegetation and the availability of water. The maximum amount of water which can evaporate and be transpired will be limited by the amount of water available. The availability of water, however, is difficult to quantify over time and space. For estimation purposes it is usually assumed that there is an abundant supply of water, and the estimated values are then called potential evapotranspiration as opposed to actual evapotranspiration.

Direct measurements of evaporation are made with the Class A evaporation pan which is 25 centimetres deep, 120 centimetres in diameter, and partly filled with water. Figure 10.1 shows an example of the Class A evaporation pan. Changes in water levels, as well as air and water temperatures, total wind run, and precipitation, are noted on a daily basis. The relative difficulty in measuring small changes in water levels in the pan introduces some errors in the determination of evaporation. The observed data from the evaporation pans can be used, after adjustment, to estimate evaporation from large water bodies such as lakes. In Newfoundland evaporation is measured at three locations, namely, St. John's, Gander and Goose Bay. The measurements are only taken for three or four months of the year because of overnight freezing of water during the winter months. Figure 10.2 shows the spatial variation of estimated mean annual lake evaporation across Canada as published in the Hydrological Atlas of Canada.

Figure 10.1 Class A Evaporation Pan

The highest value for mean annual lake evaporation, about 900 mm, occurs in southern Alberta and Saskatchewan. Such a high evaporation rate has necessitated the use of irrigation to sustain agriculture. The lowest value for mean annual lake evaporation, about 100 mm, occurs in the Arctic region of Canada because of the relatively lesser amounts of solar radiation and longer period of below freezing temperatures. The spatial variation of mean annual lake evaporation is a function of the latitudinal range within each region.

A number of methods can be used to estimate evapotranspiration. These include the water budget method, the energy budget method, and several empirical formulae. The water and energy budget methods require several meteorological data of adequate accuracy as inputs. These data are often not available. Among the empirical methods, the Thornthwaite's formula is one of the simplest. The formula uses the mean monthly temperatures and latitude of the climatic station to give an estimate of mean annual potential evapotranspiration. Based on Thornthwaite's formula and the temperature and location data available at 56 climatic stations in the province, isolines of mean annual potential evapotranspiration were generated for the province. These isolines are shown on the map on the opposite page.

The mean annual potential evapotranspiration in the province ranges from a low of about 350 millimetres (mm) in northern Labrador to a high of about 550 mm in central Newfoundland. This pattern is a result of the increasing latitude and decreasing mean temperature from the central region of insular Newfoundland to the northern region of Labrador.

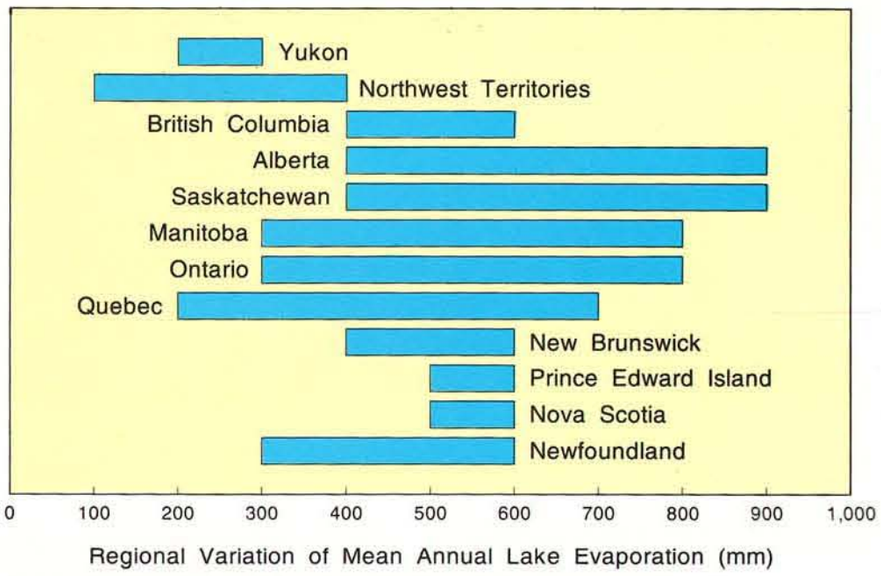
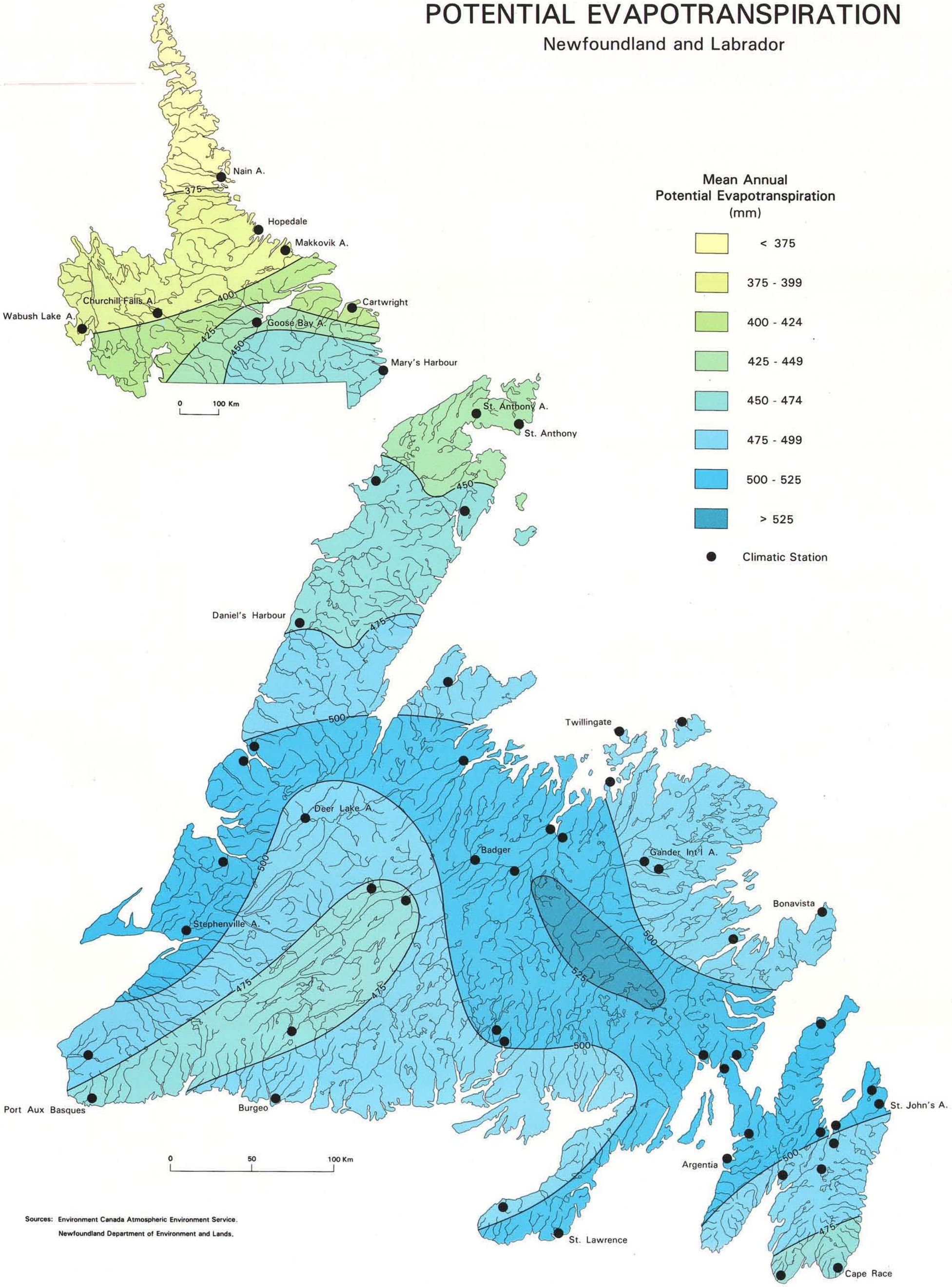


Figure 10.2 Mean Annual Lake Evaporation Across Canada

POTENTIAL EVAPOTRANSPIRATION

Newfoundland and Labrador



Mean Annual
Potential Evapotranspiration
(mm)

- < 375
- 375 - 399
- 400 - 424
- 425 - 449
- 450 - 474
- 475 - 499
- 500 - 525
- > 525
- Climatic Station

Sources: Environment Canada Atmospheric Environment Service.
Newfoundland Department of Environment and Lands.

HYDROLOGY

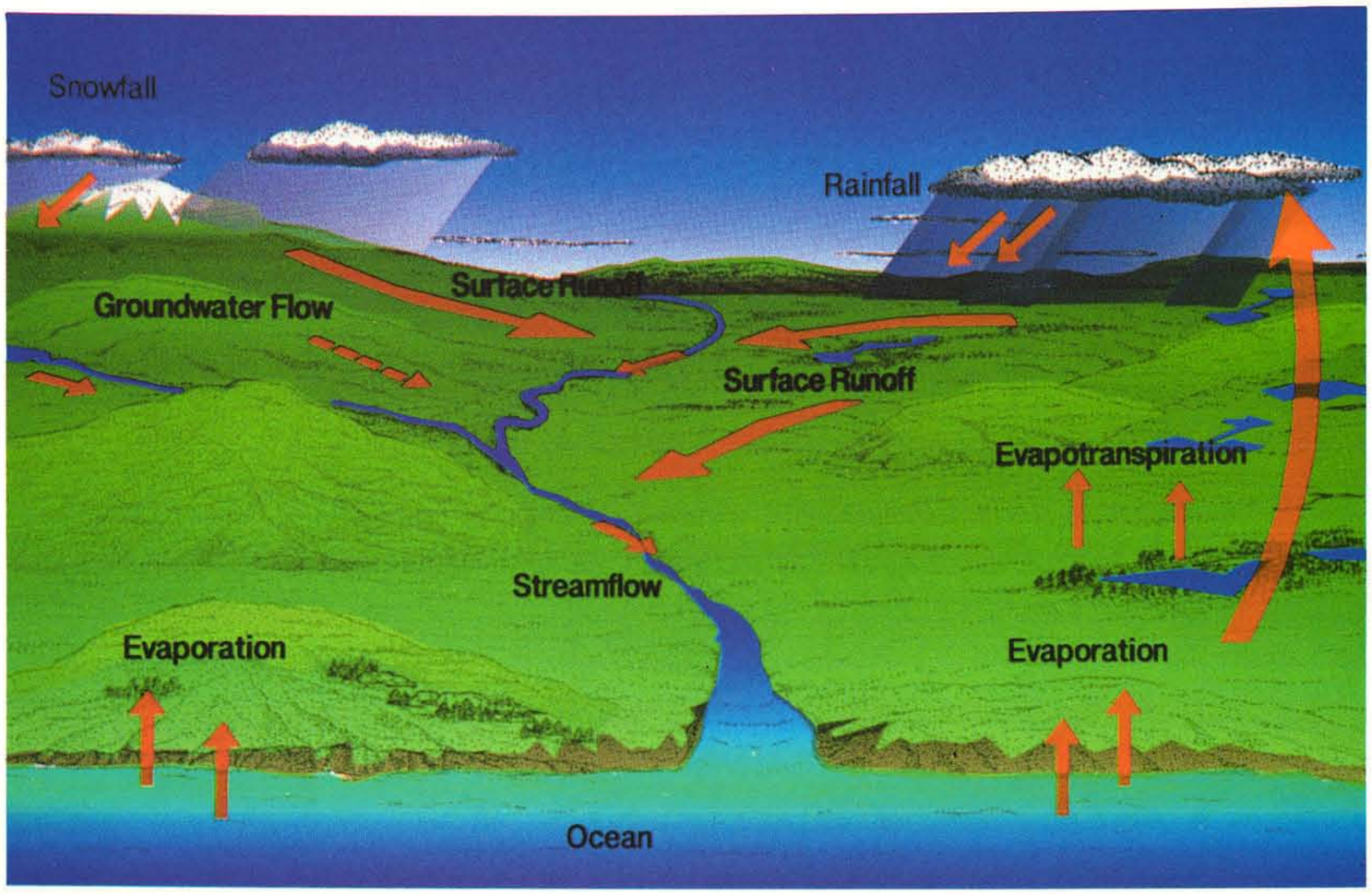
Introduction

Hydrology is the applied science concerned with the occurrence, distribution, and circulation of the waters of the earth.

Less than three percent of the earth's water resources is fresh, and most of that is inaccessible, locked in polar ice caps and deep underground. Little more than one-hundredth of one percent of the earth's water is in lakes, rivers, the soil, and the atmosphere.

Most of the earth's accessible freshwater is stored in large lakes; the rest circulates dynamically: it evaporates from the earth's surface and is transpired from plants, it falls as rain or snow, it percolates into the ground, it travels through rivers and lakes, and eventually returns to the ocean. This continuous recycling process, which is so vital to life on earth, is called the hydrological cycle. The figure below illustrates the various components of the cycle. Though simple in concept, the many alternative routes within the cycle make the science of hydrology very complex.

This section of the Atlas describes Newfoundland's freshwater resources in terms of their natural quantity and regional distribution patterns. The overview of such a complex subject provides only enough detail to establish a general picture.



The Hydrological Cycle

11 – Drainage Basins and River Gauge Locations

Rivers are the natural drainage channels for surface runoff and the topography of the river basins determines the natural drainage boundaries. A drainage basin, often also called a watershed or catchment, is defined as the area which has a common outlet for the runoff. The boundaries of the basin are delineated along the heights of land surrounding the watershed, and separating it from adjacent watersheds.

The map on the opposite page shows the drainage boundaries of rivers with drainage areas greater than 50 km^2 on the Island and greater than 500 km^2 in Labrador. These basins have been assigned numbers which are associated with the river names listed in the drainage basin key. The rivers in the list have been grouped according to the general direction of drainage and the colours used for the map.

Rivers on the Island drain primarily either northeast or south to the Atlantic Ocean, and west to the Gulf of St. Lawrence. Rivers in Labrador drain primarily east to the Labrador Sea, and south to the Gulf of St. Lawrence. The western provincial boundary between Newfoundland and Quebec runs along the drainage division between rivers flowing east through Labrador and those flowing west and north through Quebec.

The management and allocation of water resources require an accurate assessment of the quantities of water available in various drainage basins. Water Survey of Canada, in co-operation with the province, operates a network of standard river gauge stations which continuously record water levels. The costs of constructing, operating, and maintaining these stations are shared between the province and the federal government under the Canada-Newfoundland Hydrometric Surveys Agreement signed in April 1975. The total annual cost of the program exceeds $500,000. The purpose of the Agreement is to secure coordinated and standardised basic streamflow data to facilitate water resource planning and management. The map shows the locations of various types of gauging stations on rivers in the province.

At standard gauging stations the recorded water levels or "stage" measurements are converted to streamflows by means of a stage-discharge curve, which is established by measuring the river flows for a number of water levels, and is unique for each station. Some of the gauging stations are equipped with a Data Collection Platform (DCP) which not only records the water levels, but also transmits the data via satellite to provide near-to-real-time information to federal and provincial authorities and other agencies for assessing flood risks and optimising hydro power generation. Figure 11.1 shows a DCP station on the Exploits River.

Figure 11.1 A Gauging Station with a Data Collection Platform. Note the antenna for data transmission via satellite.

DRAINAGE BASIN KEY

Avalon Peninsula
Atlantic Ocean Drainage

1 Piccos Brook
2 Island Pond Brook
3 Northeast Pond River
4 Broad Cove River
5 Rennies River
6 Waterford River
7 Raymond Brook
8 Manuels River
9 Bay Bulls River
10 Perrys Brook
11 Mobile River
12 Tors Cove River
13 La Manche River
14 Horse Chops River
15 Cape Broyle River
16 Black River
17 Seal Cove Brook
18 Chance Cove Brook
19 Biscay Bay River
20 Northwest Brook
21 St. Shotts River
22 Peter's River
23 Crossing Place River
24 Little Harbour River
25 Salmonier River
26 Harricott River
27 North Arm River
28 Mahers River
29 Seal Cove River
30 Maloneys River
31 Avondale River
32 Colliers River
33 Goulds Brook
34 North River
35 Shearstown Brook
36 South River
37 Mosquito Brook
38 Island Pond Brook
39 Spout Cove Brook
40 Broad Cove Brook
41 Western Bay Brook
42 Northern Bay Brook
43 Gull Island Brook
44 Big Brook
45 Unnamed River
46 New Perlican River
47 Heart's Delight Brook
48 Pitchers Pond Brook
49 Gull Pond Brook
50 Unnamed River
51 Unnamed River
52 Rocky River
53 Colinet River
54 North Harbour River
55 Little Salmonier River
56 Big Barachois River
57 Little Barachois River
58 Red Head River
59 Branch River
60 Unnamed River
61 Unnamed River
62 Little Barachois Brook
63 Southeast River
64 Northeast River
65 Unnamed River
66 Trout Brook

South Coast
Gulf of St. Lawrence Drainage

67 Come By Chance River
68 North Harbour River
69 Black River
70 Pipers Hole River
71 Sandy Harbour River
72 Paradise River
73 Unnamed River
74 Bay De L'eau River
75 Rattle Brook
76 Unnamed River
77 Devil Brook
78 Garnish River
79 Grand Beach Brook
80 Tides Brook
81 Big Salmonier Brook
82 St. Lawrence River
83 Unnamed River
84 Little Barasway Brook
85 Salmonier River
86 Piercey Brook
87 Southwest Brook
88 Long Harbour River
89 Bay Du Nord River
90 Rencontre Brook
91 Salmon River
92 Unnamed River
93 Little River
94 Conne River
95 Upper Salmon River
96 Lower Salmon River
97 D'espoir Brook
98 Bottom Brook
99 Dollard Brook
100 Morgan Brook
101 Lower Grey River
102 Unnamed River
103 Unnamed River
104 Lower White Bear River
105 Bay de Loup Brook
106 Kings Harbour Brook
107 Grandy Brook
108 Unnamed River
109 Cinq Cerf Brook
110 La Poile River
111 Garia Brook
112 Grandys Brook
113 Isle aux Morts River

West Coast
Gulf of St. Lawrence Drainage

114 Little Codroy River
115 Codroy River
116 Highlands River
117 Crabbes River
118 Barachois Brook
119 Fischells Brook
120 Flat Bay Brook
121 Little Barachois Brook
122 Southwest Brook
123 Harrys River
124 Blanche Brook
125 Fox Island River
126 Serpentine River
127 Corner Brook
128 Humber River
129 Hughes Brook
130 Rattler Brook
131 Old Mans Brook
132 Goose Arm Brook
133 Lower Crabb Brook
134 Trout River
135 Lomond River
136 Southeast Brook
137 Deer Brook
138 Bottom Creek
139 Bakers Brook
140 Western Brook
141 Parsons Pond River
142 Portland Creek
143 River of Ponds
144 Torrent River
145 East River
146 Castors River
147 Ste. Genevieve River
148 West River
149 Green Island Brook
150 Big Brook
151 Unnamed River
152 Unnamed River
153 Bartletts River

Northeast Coast
Atlantic Ocean Drainage

154 Rocky Cove Brook
155 West Brook
156 Salmon River
157 Southwest Brook
158 Northeast Brook
159 Beaver Brook
160 Northwest Brook
161 Cloud River
162 Unnamed River
163 Unnamed River
164 Soufflets River
165 Unnamed River
166 Great Harbour Deep River
167 Little Harbour Deep River
168 Cat Arm River
169 Unnamed River
170 Main River
171 Doucers Brook
172 Hampden River
173 Big Chouse Brook
174 Indian Brook
175 Rattling Brook
176 Wild Cove Brook
177 Middle Arm Brook
178 West Brook
179 South West Brook
180 Pacquet Brook
181 Barneys Brook
182 Tommy's Arm River
183 Shoal Arm Brook
184 Seal Bay Brook
185 West Arm Brook
186 New Bay River
187 Northern Arm Brook
188 Peters River
189 Exploits River
190 Rattling Brook
191 Unnamed River
192 Unnamed River
193 Indian Arm Brook
194 Ten Mile Lake
195 Gander River
196 Ragged Harbour River
197 Deadman's Brook
198 Pound Cove Brook
199 Unnamed River
200 Indian Bay Brook
201 Traverse Brook
202 Middle Brook
203 Gambo Pond
204 Northwest Brook
205 Terra Nova River
206 Wings Brook
207 Southwest Brook
208 Northwest River
209 Southwest River
210 Shoal Harbour River
211 Georges Brook
212 Southwest Brook
213 Southern Bay River
214 Salmon Cove River
215 Unnamed River
216 Unnamed River
217 Unnamed River
218 Hickmans Harbour River
219 Northwest Brook
220 Unnamed River

Southern Labrador
Gulf of St. Lawrence Drainage

221 St. Paul River
222 St. Augustin River
223 Little Mecatina River
224 Natashquan River

Labrador
Labrador Sea Drainage

225 Churchill River
226 Kenamu River
227 Kenemich River
228 Eagle River
229 Alexis River
230 Hawke River
231 Sand Hill River
232 North River
233 Goose River
234 Beaver River
235 Naskaupi River
236 Unnamed River
237 Unnamed River
238 Big River
239 Kanairiktok River
240 Ugjoktok River
241 Notakwanon River
242 Kogaluk River
243 Anaktalik River
244 Fraser River
245 Kingurutik River
246 North River
247 Siugak River
248 Unnamed River
249 Unnamed River
250 Unnamed River
251 Unnamed River
252 Nakvak Brook

The number of gauging stations operating as of 1990 was 84 on the Island and 13 in Labrador. The number of gauging stations equipped with a Data Collection Platform was 23 on the Island and 6 in Labrador. The size distribution of the gauged drainage basins, including those basins where the stations are no longer operating but have previously recorded flows, is shown in Table 11.1.

Table 11.1 Size Distribution of Gauged Drainage Basins

Drainage Area (km^2)	Number of Gauged Basins	
	Island	Labrador
1 – 25	17	0
25 – 50	8	1
50 – 100	16	0
100 – 200	14	0
200 – 500	17	0
500 – 1000	14	0
1000 – 10,000	18	15
10,000 – 100,000	0	11

DRAINAGE BASINS AND RIVER GAUGE LOCATIONS

Newfoundland and Labrador

Station Type

- Data Collection Platform
- Standard River Gauge
- Flow Monitoring Dam
- Discontinued Station (any type)

Drainage Basin Boundary

River Network

0 100 Km

0 50 100 Km

0 25 Km

Source: Inland Waters Directorate
Water Resources Branch
Water Survey of Canada, 1987

12 – Major Lakes, Ponds, and Reservoirs

From a hydrological point of view, lakes, ponds, and reservoirs can be defined as inland water bodies which function as temporary storage areas for runoff. While lakes and ponds are of natural origin, reservoirs have been "created" either by the damming of a section of a river or by controlling the outflows from existing natural lakes.

Lakes and ponds in the province range in size from small peat-bog ponds of a few hundred square metres to lakes having surface areas in the hundreds of square kilometres. It is estimated that lakes and ponds occupy between 10% and 20% of the land area of the province; the uncertainty in the estimate is due to the potentially enormous area occupied by the vast number of peat-bog ponds. The map on the opposite page shows eighty-seven water bodies on the Island with surface areas greater than ten square kilometres and seventeen in Labrador which exceed one hundred square kilometres in surface area.

The largest water body in the province is the Smallwood Reservoir on the Churchill River in Labrador. It has a surface area of 3640 square kilometres. On the Island the largest water body is Grand Lake with a surface area of 354 square kilometres. The size distribution of water bodies in the province is shown in Figure 12.1.

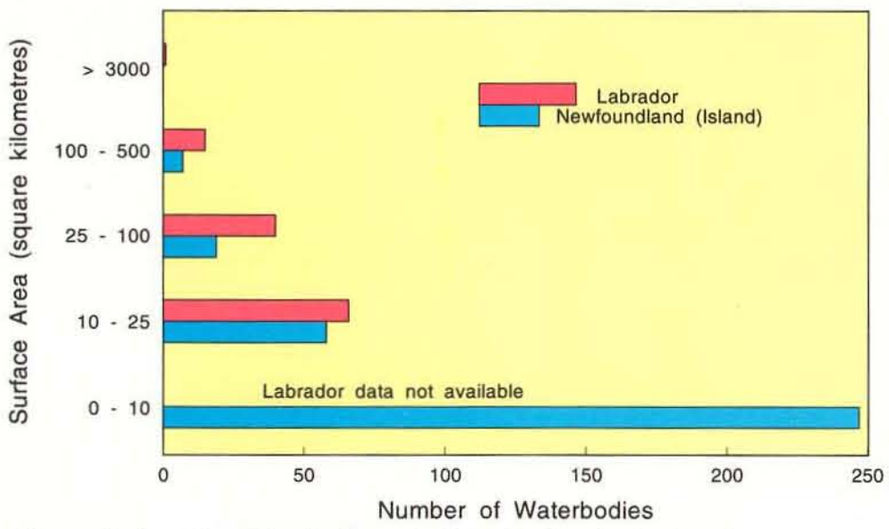


Figure 12.1 Size Distribution of Water Bodies in the Province

Lakes and ponds are common features of Newfoundland's landscape. Several processes have been postulated for their origin. The three major ones are tectonic, glacial, and organic processes. Minor lake formation processes include solution of limestone deposits and lowering of the sea level. Differential erosion of structural bedrock features is generally cited as being responsible for the geologically controlled lakes. These lakes tend to include the relatively larger ones. It is thought that the lakes of tectonic origin were subsequently deepened by glacial erosion. Grand Lake and Sandy Lake are examples of such lakes. Lakes of glacial origin tend to be middle-sized. Damming, rather than erosion, however, is thought to be the primary process that initially formed the lakes. In places, many of these lakes lie in strings in the direction of ice flow. The profile of the glacial lakes tends to be regular, typically ovoid, with the longer axis in the direction of the ice movement. An example of a lake of glacial origin is Gander Lake. Peat-bog ponds are generally classified as of organic origin. These ponds are commonly only a few hundred square metres in area and are rarely more than three metres deep. They are thought to have originated in irregular surfaces left by the retreat of glaciers.

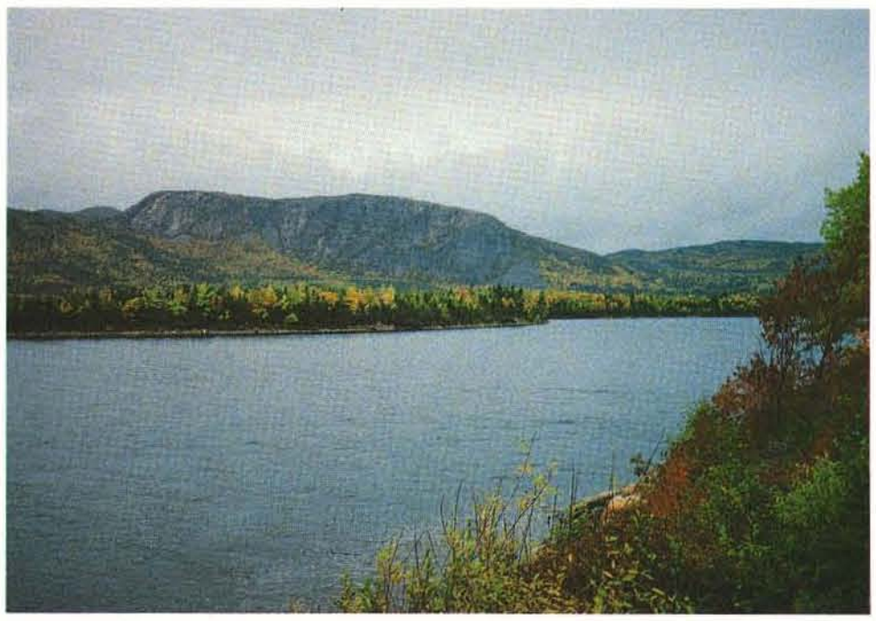
There has not been extensive bathymetric surveys of lakes and ponds in Newfoundland. The scant information available suggests that the small peat-bog ponds are generally less than three metres deep, while lakes of glacial origin are much deeper; the maximum depth of Gander Lake, for example, is estimated to be over 240 metres.

As systems which maintain ecological diversity and stability, lakes and ponds are important components of the natural environment. They are the natural habitat for a variety of aquatic life and are food sources for several land-based animals. In addition, lakes and ponds, because of their intrinsic aesthetic value, play a significant role in the social and economic welfare of the public. They are a common feature in many of the parks in the province where they are used extensively for such recreational activities as fishing and boating. The shores of lakes have traditionally been prime locations for cottages.

Lakes and ponds are integral components of river systems and, as such, influence the hydrology of watersheds. The storage capacities of lakes and ponds attenuate flood flows and the water stored is released gradually over a longer period of time. Thus, lakes and ponds sustain river flow during low precipitation periods. Also, since lakes and ponds have relatively large areas of open water, the evaporation losses from them are relatively higher. These losses are important considerations in analyzing the water balance in a watershed.

Reservoirs are generally lakes or ponds with their outlet flows controlled by man-made structures. Sometimes, new lakes are "created" by the damming of a section of a major river system. The depth and surface areas of these reservoirs are determined by the size and operation of the control structures. The water stored in the reservoirs may be used for water supply, hydro power generation, flood control, or recreational activities. Grand Lake and the Smallwood Reservoir are examples of water bodies with controlled outlets. The flows from them are used to generate hydro power. The map on the opposite page shows the locations of several reservoirs in the province.

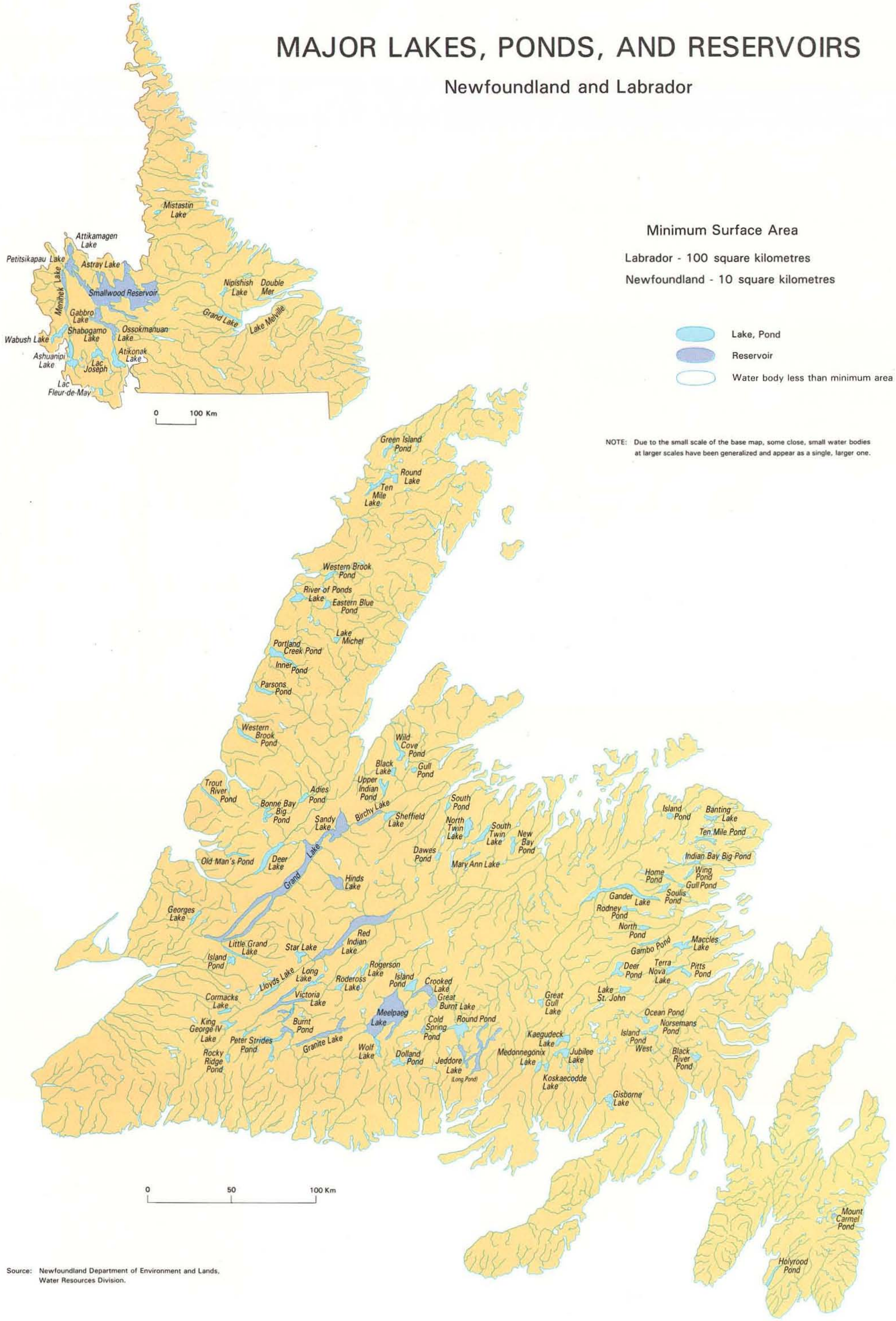
The considerable economic and recreational uses of lakes and ponds are putting a tremendous pressure on the ecological and physical health of these systems. With the privilege of enjoying their benefits comes the responsibility of protecting them.



Lakes and Ponds: To be Enjoyed and Protected

MAJOR LAKES, PONDS, AND RESERVOIRS

Newfoundland and Labrador



Minimum Surface Area

Labrador - 100 square kilometres

Newfoundland - 10 square kilometres

Lake, Pond

Reservoir

Water body less than minimum area

NOTE: Due to the small scale of the base map, some close, small water bodies at larger scales have been generalized and appear as a single, larger one.

Source: Newfoundland Department of Environment and Lands, Water Resources Division.

13 – Mean Annual Runoff

Runoff is that portion of precipitation which flows into rivers, lakes, and oceans by surface drainage and through the ground. The remaining portion of the precipitation either is returned to the atmosphere through evapotranspiration or percolates into deep aquifers.

The total volume of river flow from a watershed during a year expressed as an average depth of water in millimetres (mm) over the drainage area of the watershed is called the annual runoff. Annual runoff amounts from rivers vary from year to year depending upon the amount of precipitation and other factors such as temperature and type of vegetation cover. The mean annual runoff is the sum of all the recorded annual runoff amounts divided by the number of years in the period of record.

Mean annual runoff is an important parameter in the design of water supply systems, hydro power generating plants, and other water resources engineering projects. It is also used in the management of fisheries resources.

The map of mean annual runoff on the opposite page shows isolines of mean annual runoff amounts for the province. These isolines were developed on the basis of calculated mean annual runoff amounts at 56 gauging stations on the Island and 14 gauging stations in Labrador. Because of the limited number and non-uniform spatial distribution of the gauging stations, the mean annual runoff amounts at most points on the isolines were approximated from the known values at the nearest gauging stations.

The map shows that there are significant differences in mean annual runoff between various regions of the province. In Labrador the mean annual runoff ranges from 600 mm to 700 mm. On the Island three distinct regions of mean annual runoff can be delineated: (1) the eastern and southwestern areas where the mean annual runoff ranges from 1300 mm to 2100 mm, (2) the central region where the mean annual runoff ranges from 700 mm to 900 mm, and (3) the Humber Valley and Northern Peninsula region where the mean annual runoff ranges from 900 mm to 1400 mm.

The differences between regional mean annual runoff amounts are indicative of the variations in mean annual precipitation across the province. A comparison between the mean annual runoff map and the mean annual precipitation map (Map 7) shows that both variables exhibit the same spatial pattern. The eastern and southwestern regions of the Island receive the highest amount of precipitation and also have the highest mean annual runoff amounts.

A comparison of the mean annual runoff and mean annual precipitation maps also indicates that the fraction of precipitation that appears as runoff is approximately 0.8. In some regions mean annual precipitation appears to be less than mean annual runoff; this is clearly not possible. The explanation for the anomaly is that the mean annual precipitation map was based on precipitation data obtained mostly from gauges located, for ease of access by observers, near communities at lower elevations along the coast. Since precipitation generally increases with elevation, the precipitation data at these climatic stations may underestimate precipitation over large areas with a range of elevations.

If mean annual runoff is converted into mean annual runoff volume, on the Island about 105 billion cubic metres (bcm) of water are discharged annually into the sea; in Labrador the annual discharge is about 190 bcm. Figure 13.1 shows the regional mean annual runoff volumes. The regions were delineated on the basis of topography and major direction of flow, and they nearly correspond with the regions shown on the drainage basin map (Map 11).

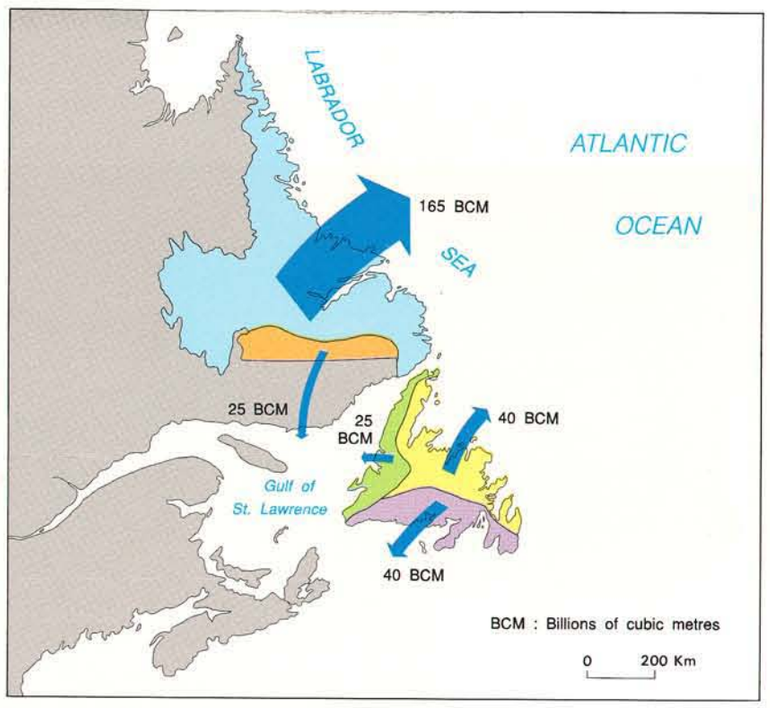


Figure 13.1 Regional Mean Annual Runoff Volumes

In Newfoundland the mean annual runoff ranges from 600 mm to 2100 mm. Figure 13.2 shows the spatial variation of mean annual runoff in various regions across Canada as published in the Hydrological Atlas of Canada. British Columbia has the largest variation: 100 mm to 3200 mm, while in the Northwest Territories the range is only from 25 mm to 100 mm. In certain areas in Alberta and Saskatchewan the mean annual runoff is less than 10 mm. The wide variation in mean annual runoff across the country is a reflection of the regional differences in precipitation, topography, and latitude.

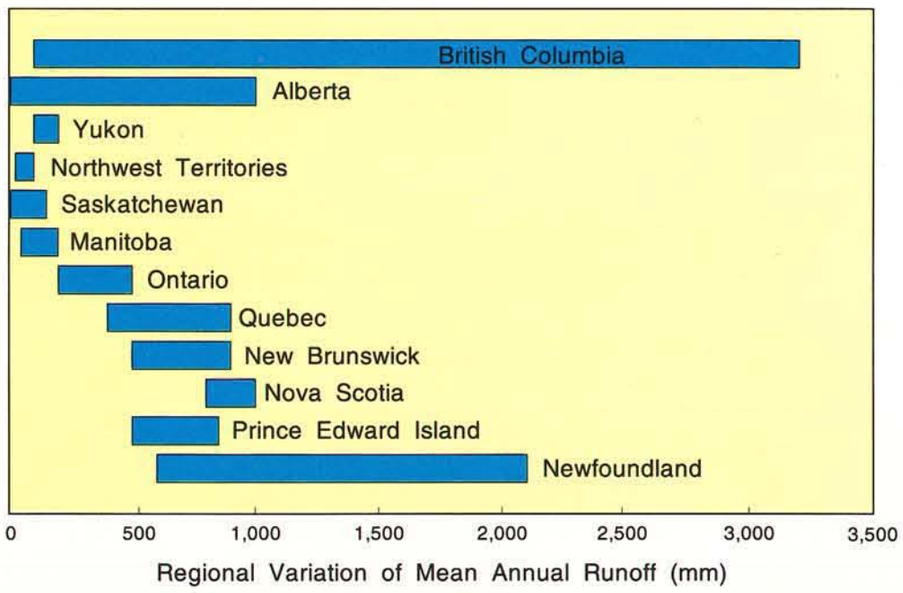
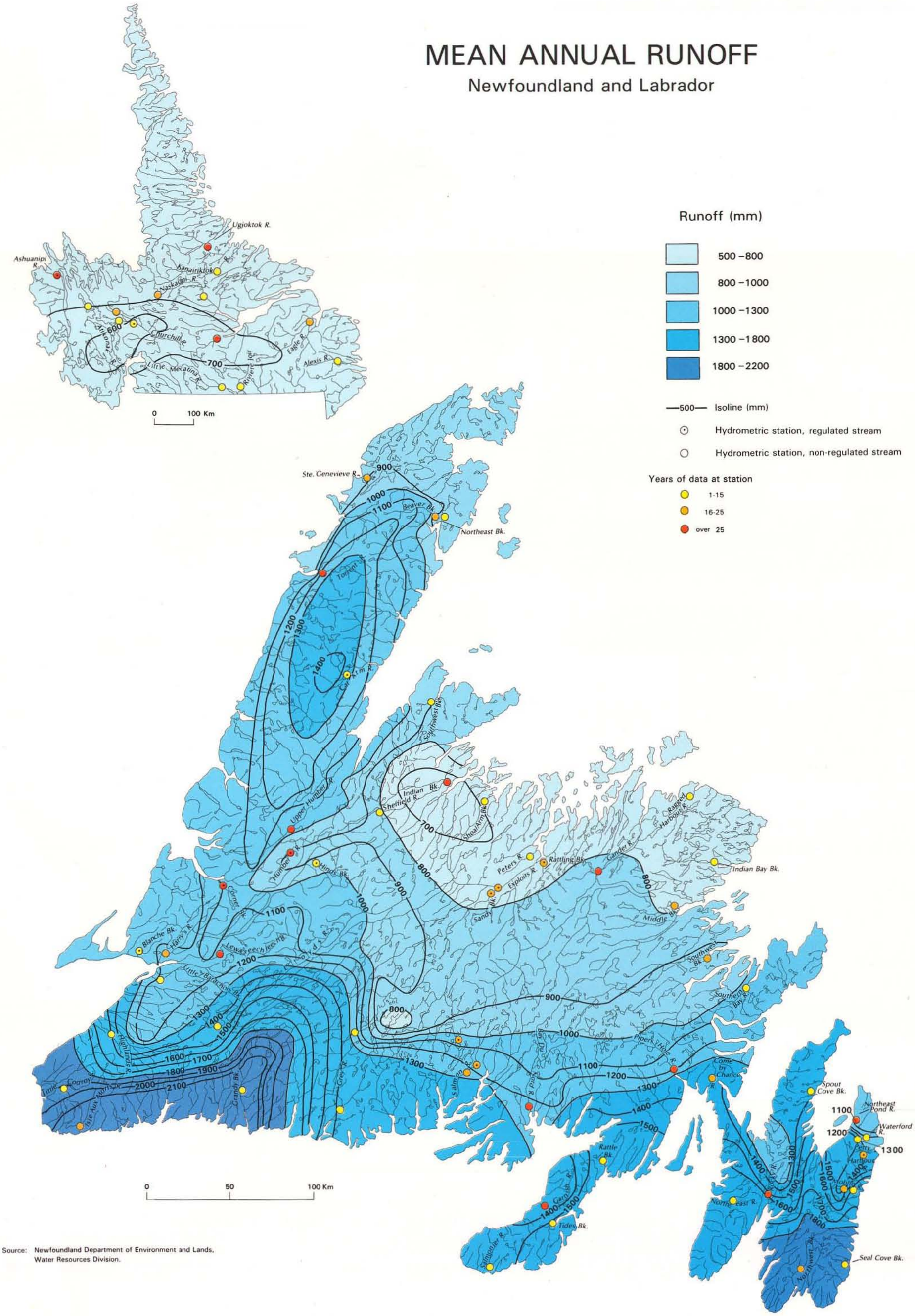


Figure 13.2 Mean Annual Runoff Across Canada

MEAN ANNUAL RUNOFF

Newfoundland and Labrador



Source: Newfoundland Department of Environment and Lands, Water Resources Division.

14 – Annual River Flow

The total annual discharge of the rivers of the world is estimated at 35,000 billion cubic metres, representing about one-third of the annual precipitation. The Amazon River in South America has the world's largest annual discharge, which is estimated to be about 6,000 billion cubic metres or approximately one-sixth of the world's total discharge. Canada's largest river, the St. Lawrence, annually discharges an average of about 319 billion cubic metres of water at Nicolet; the second largest river, the Mackenzie, annually discharges an average of about 312 billion cubic metres of water into the Arctic Ocean.

The annual river flow map on the opposite page shows the annual river flows from some of the larger gauged watersheds on the Island and in Labrador. The width of the arrow on each river represents the estimated mean annual flow at any point along the river. These arrows were developed on the basis of measured discharges at gauged sections; at ungauged sections the widths of the arrows were estimated by pro-rating measured flows with drainage areas.

The annual river flow from the Exploits River, which has the largest watershed on the Island, is estimated at about 8.5 billion cubic metres at the gauging station. In Labrador the largest basin is the Churchill River basin, and the mean annual river flow at the gauging station is estimated at 55 billion cubic metres.

Figure 14.1 illustrates the estimated mean annual river flows from the largest gauged basins in Newfoundland and the maritime provinces. Clearly, drainage area, in addition to mean annual precipitation, is a major factor in determining the magnitude of annual river flow.

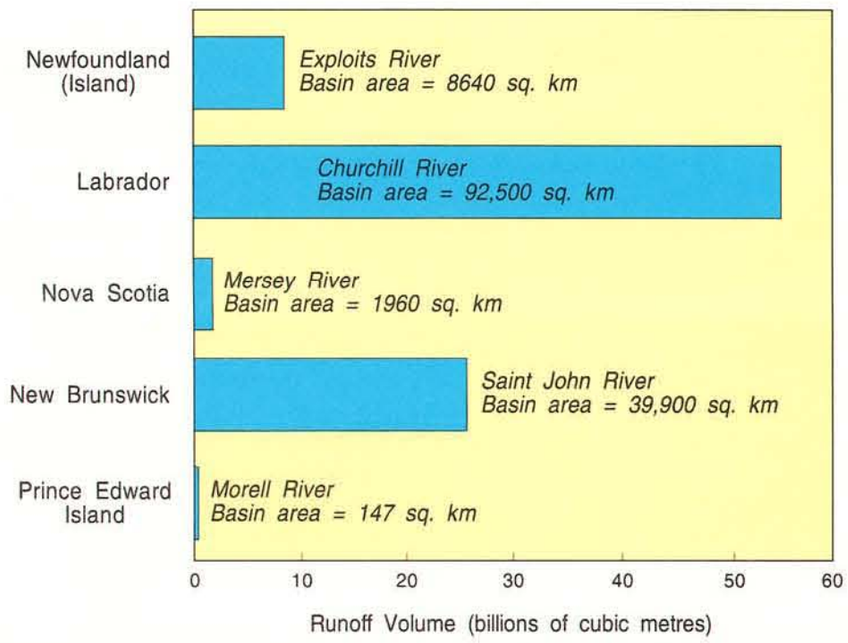


Figure 14.1 Mean Annual River Flows from the Largest Gauged Basins in Newfoundland and the Maritime Provinces

In Newfoundland, for watersheds greater than 1000 square kilometres, the logarithm of mean annual river flow volume is almost linearly related to the logarithm of the drainage area of the river. Figure 14.2 shows a plot of mean annual runoff volume for several watersheds of varying sizes on the Island and in Labrador. Basins in Labrador have lower mean annual runoff volumes than basins of similar areas on the Island; this is a reflection of the relatively lower mean annual precipitation in Labrador (see Map 7).

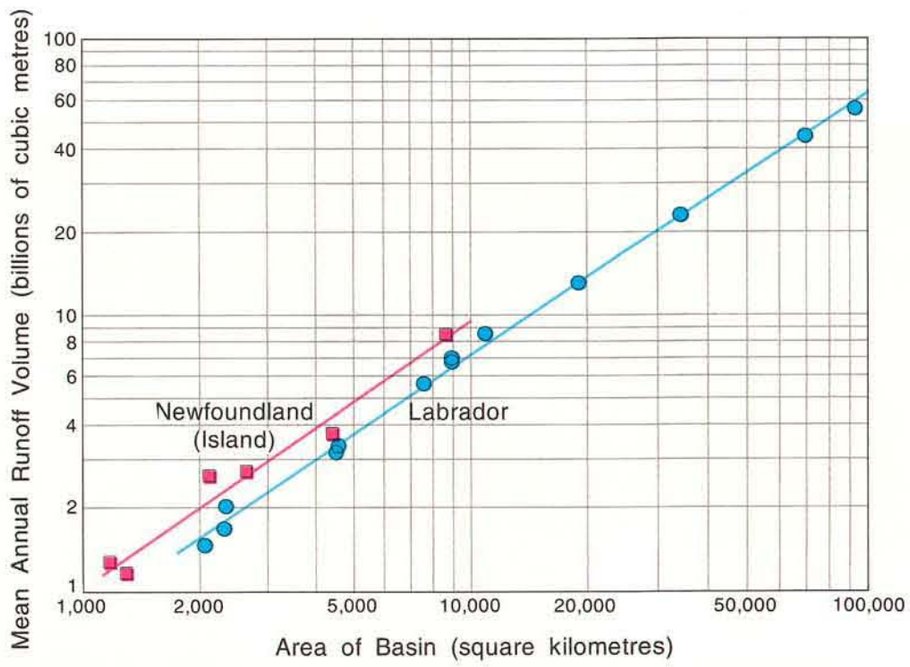
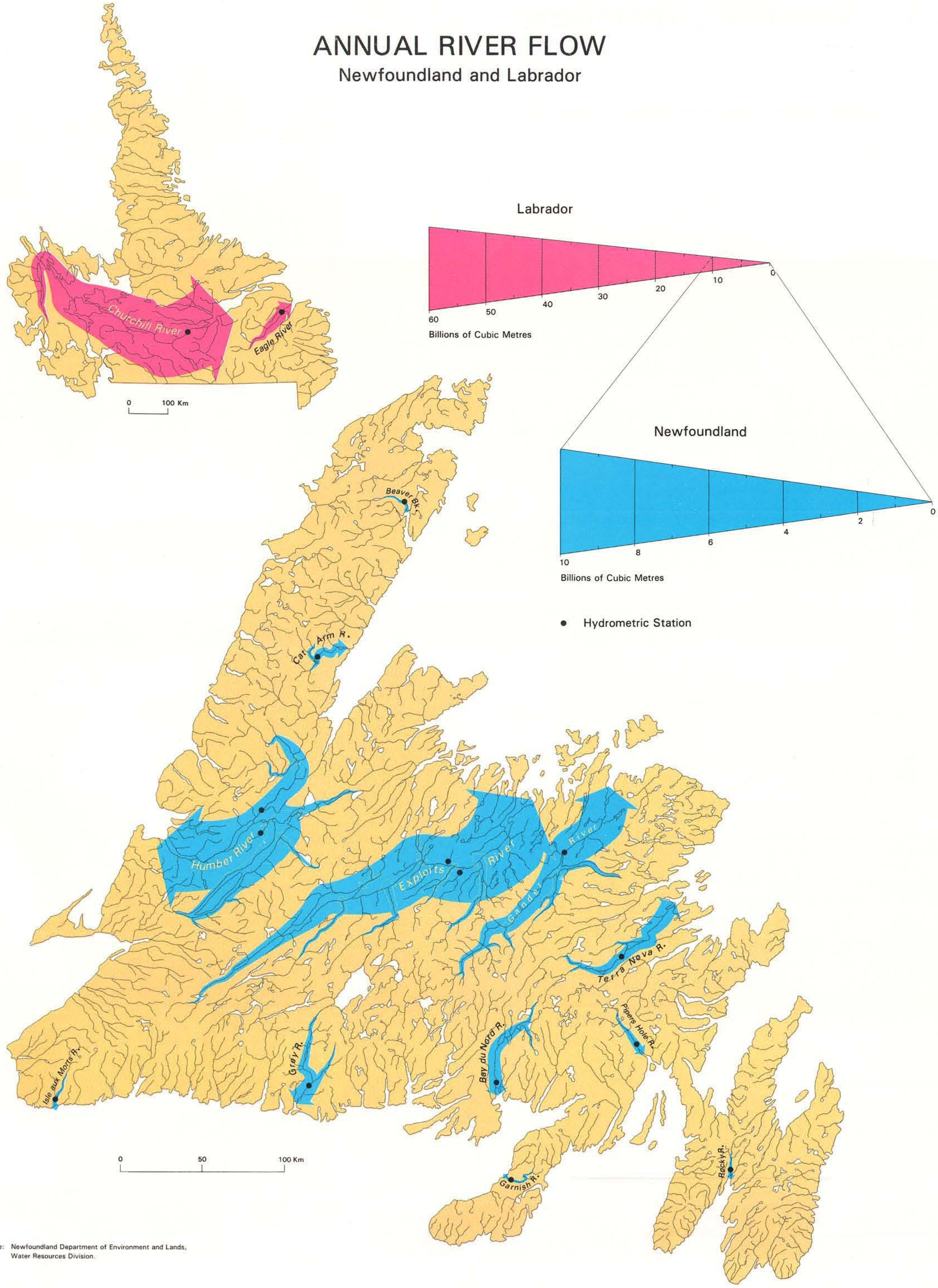


Figure 14.2 Relationship between Mean Annual River Flow and Area of Basin on the Island and in Labrador

ANNUAL RIVER FLOW

Newfoundland and Labrador



Source: Newfoundland Department of Environment and Lands,
Water Resources Division.

15 – Monthly Streamflow

Maps 13 and 14, respectively, show the mean annual runoff across the province and the annual flows for some of the larger rivers. Another important aspect of river flow is its variation within an average year. The monthly streamflow map on the opposite page shows the mean monthly flows for selected unregulated rivers in the province.

The monthly mean flow is defined as the arithmetic mean of all the daily flows during a particular month. The mean monthly flow for any specific month is defined as the arithmetic mean of all the monthly mean flows of that month over the period of record.

Thirty gauging stations on the Island and five stations in Labrador were selected for depicting the patterns of mean monthly flows across the province. On the graphs shown on the map, the mean monthly flows have been expressed in cubic metres per second. The colours represent different ranges of the mean monthly flows. It is evident that watersheds of relatively larger drainage areas generally have higher mean monthly flows.

The monthly streamflow graphs indicate that all the rivers have variable flows during an average year. A typical graph shows a period of high flows during spring preceded and followed by periods of low flows. Most of the high flows in the spring are the result of melting of snow accumulated during the winter months. A second period of high flows, due to rainstorms, occurs from October to December. This is most apparent on the eastern region of the Island. Winter low flows are caused by below freezing temperatures resulting in very little precipitation available for runoff, while depletion of soil moisture reserves in the ground by evapotranspiration is the major cause of summer low flows.

In the eastern and southern regions of the Island, the high spring flows start in March. Streams in these regions also exhibit a high runoff period during January and February. This is primarily due to the milder winter temperatures which can induce combined rainfall and winter snowmelt events. With an increase in the latitude of the rivers, the starting date of the spring high flows is delayed: on the Northern Peninsula and in Labrador snowmelt starts in April and May, respectively. The spring runoff takes about two months to reach its peak across the Island and Labrador.

The rivers in the province usually exhibit two periods of low flows: one during the winter months and the other during the summer months. In the eastern region of the Island, the summer low flows are more severe than the winter low flows and occur between July and September. In the central region of the Island, the winter and summer low flows appear to be equally severe. In contrast, in Labrador, the winter low flows, which occur between January and March, are more severe than the summer low flows.

Information presented on the map and the bar graphs indicates that the timing and duration of the high and low flows in the province depend on the latitudes of the rivers and hence on the regional climate. Figure 15.1 illustrates the effect of latitude on the monthly distribution of an average year's flow. The increased severity of winter low flows and the forward shift in the timing of the high flow period with an increase in latitude are quite noticeable.

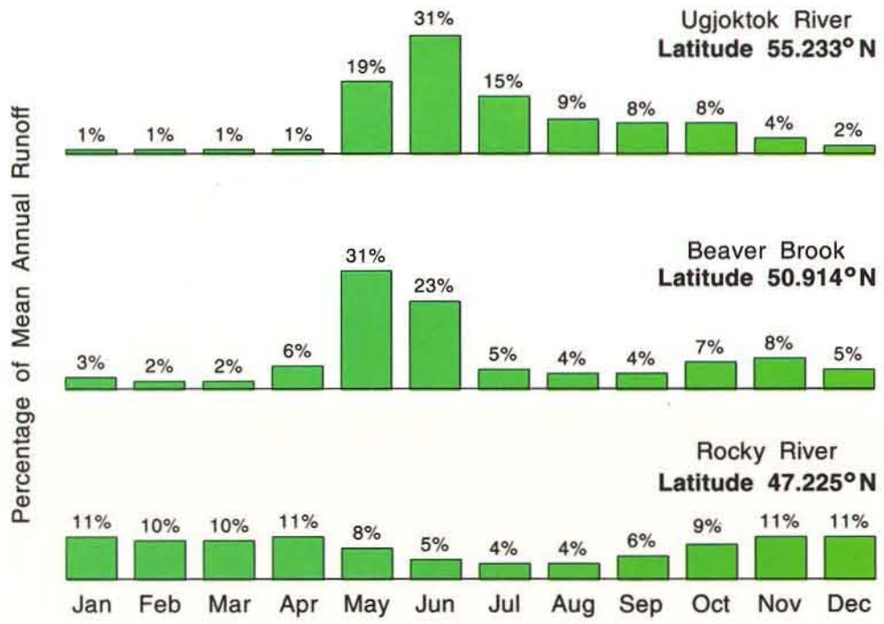


Figure 15.1 Effect of Latitude on Monthly Distribution of Annual Runoff

A knowledge of monthly streamflows is important for projects where a firm supply of water is required. Examples of such projects are municipal water supplies, hydro power generation and mining operations. As already discussed, however, monthly streamflows from natural rivers tend to be highly variable and, if they are not regulated, cannot be depended upon for a steady supply throughout the year. Figure 15.2 shows the effect of regulation on the variation of monthly streamflows. The rivers selected for illustration are the unregulated Gander River and the regulated Exploits River. The flow in the Exploits River is regulated for hydro power generation. Figure 15.2 shows that mean monthly flows on a regulated river are closer to the mean annual flow than on an unregulated river.

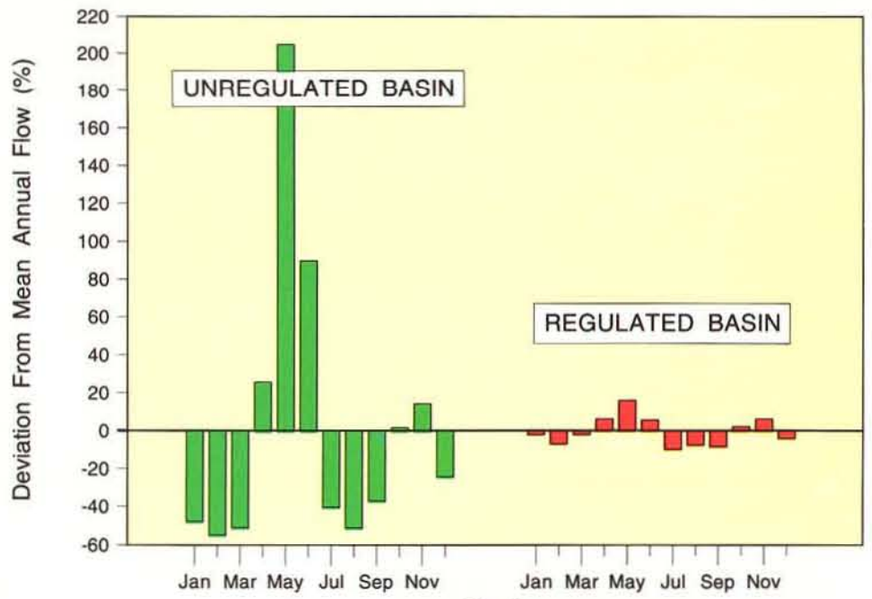


Figure 15.2 Effect of Regulation on Monthly Streamflows

MONTHLY STREAMFLOW

Newfoundland and Labrador

Monthly Flow Rate By Station

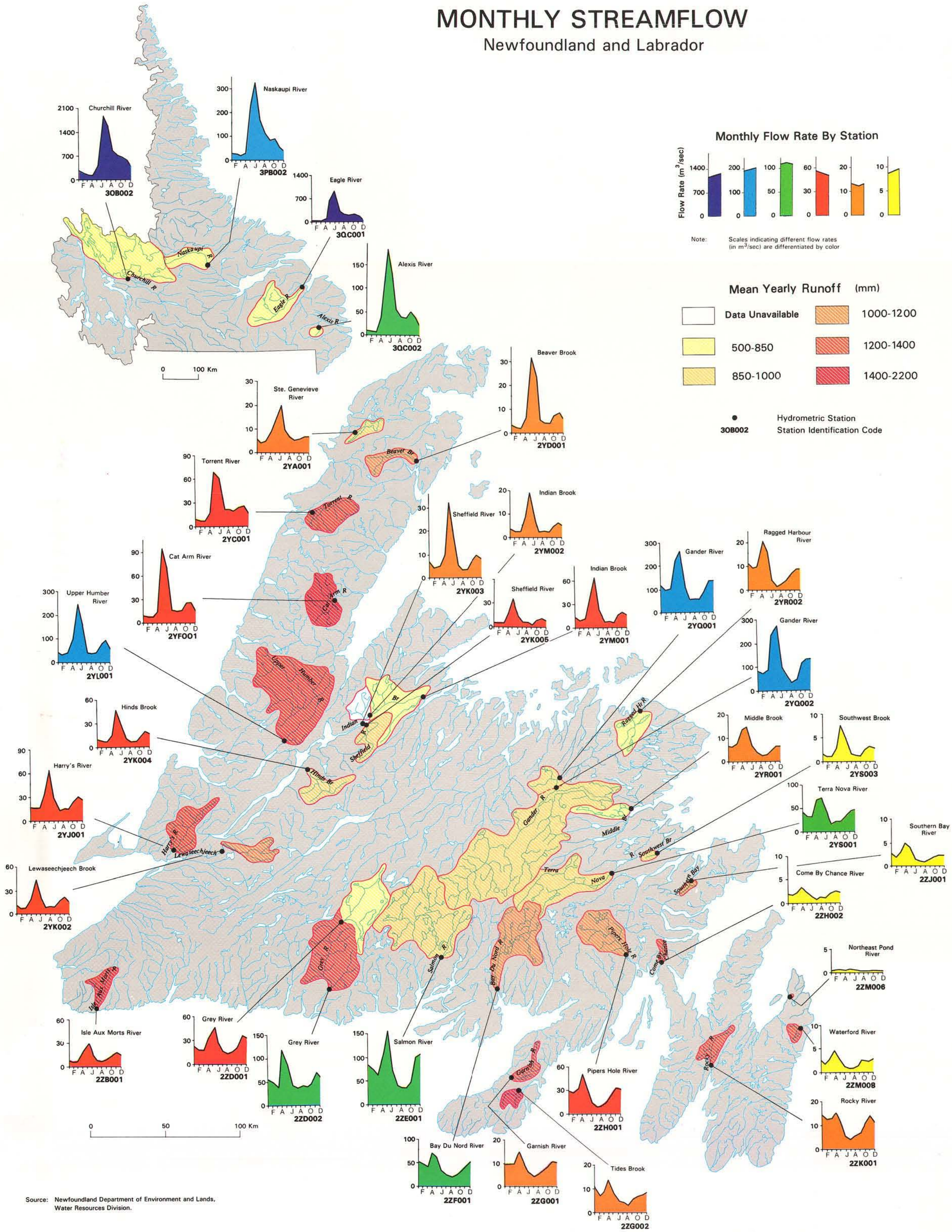
Note: Scales indicating different flow rates (in m^3/sec) are differentiated by color

Mean Yearly Runoff (mm)

- Data Unavailable
- 500-850
- 850-1000
- 1000-1200
- 1200-1400
- 1400-2200

● Hydrometric Station

3OB002 Station Identification Code



Source: Newfoundland Department of Environment and Lands, Water Resources Division.

16 – Minimum Streamflow

All rivers in Newfoundland and Labrador have annual periods of low flows. Some of the rivers occasionally even run dry. Information on the timing and severity of the low flow periods is important for several water resources engineering and management applications, such as: estimating available water supply for municipal and industrial uses, determining the wastewater dilution potential of a receiving stream, predicting the impact of stream diversions on the minimum flow requirements for spawning and migrating fish, and, generally, for environmental impact assessment studies.

Certain terms need to be defined for understanding the information on low flows provided on the minimum streamflow map shown on the opposite page. The lowest daily flow recorded during a year is called the 1-day annual minimum flow. Similarly, the 1-day monthly minimum flow is the lowest daily flow recorded during a month. Very often, one is interested in the lowest flow averaged over a period longer than 1 day. In this instance, the lowest flow averaged over a period of N consecutive days during a year is called the N-day annual minimum flow.

The N-day annual minimum flow varies from year to year and cannot be forecasted. One can only estimate the frequency of its occurrence based on a statistical analysis of several years of streamflow data. Hydrologists express the frequency and magnitude of the N-day annual minimum flow in terms of a "return period". The return period is the average time interval in years, over a long period of time, between occurrences of low flows either equalling or being less than a given magnitude. A return period of X years does not imply a regularity of occurrences.

Figure 16.1 shows that the recorded 1-day annual minimum flows on the Rocky River at its gauging station varied considerably from year to year during the period 1950 to 1989. A frequency analysis of the data gives the 1-day annual minimum flow with return period of 2 years as 1.06 m^3/s; the 20-year 1-day annual minimum flow is 0.33 m^3/s. These values are illustrated in Figure 16.1. According to the definition of the "return period", one would expect the average time interval between occurrences of the 20-year 1-day minimum flow to be 20 years, or alternatively, one would expect it to occur, on the average, about twice during the 40-year period of 1950-1989. Figure 16.1 shows there were four such occurrences recorded; deviations of recorded occurrences from statistical predictions should be expected when the period of recorded flows is relatively small. Recorded minimum flows were equal to or less than the 2-year low flow about every two years.

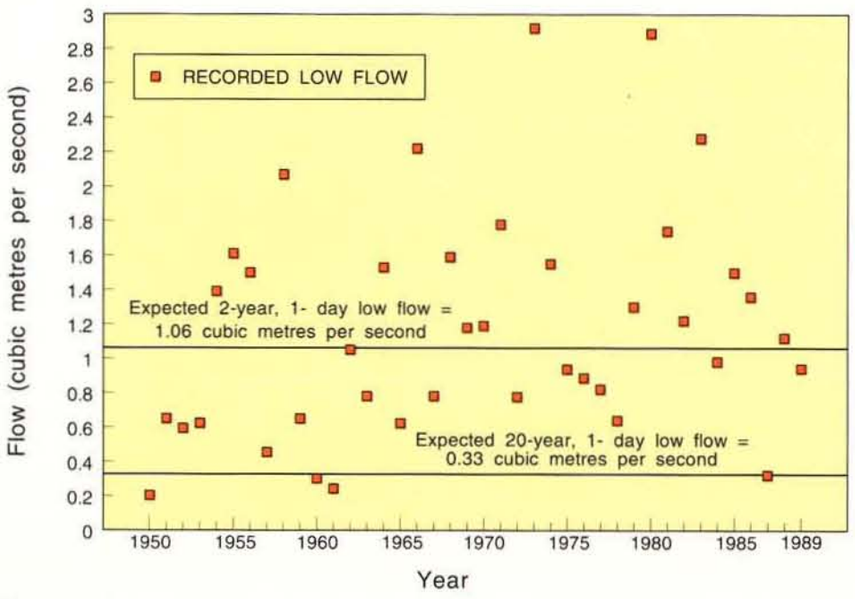


Figure 16.1 Recorded and Expected 1-Day Minimum Flows on Rocky River

The selection of the duration and return period of a minimum flow for design purposes is based on the particular application. For example, the 10-year 7-day minimum flow is usually one parameter in the evaluation and design of water supply systems.

The minimum streamflow map shows the magnitudes of the 1-day, 7-day, 15-day and 30-day minimum flows of return periods of 2, 5, 20, 50 and 100 years. Similar information is not provided for Labrador and some stations on the Island because of insufficient data for a reliable statistical analysis. Larger watersheds usually have larger minimum flows; therefore, for ease of comparison between watersheds of different sizes the flows were divided by the area of the watershed, and have been expressed in litres per second per square kilometre, $l/s/km^2$. The map also shows the minimum daily flows, averaged over the period of record, for every month of the year. It is, of course, extremely unlikely that these minimum flows would all occur in a single year.

As shown on the map, on the Island, the 2-year 1-day minimum flow varies between 2 $l/s/km^2$ and 8 $l/s/km^2$. There is no distinct trend in the magnitude of the minimum flows across the Island. The bar charts on minimum daily flows indicate that there are two periods of minimum flows on the Island: winter and summer months. In the eastern region of the Island, the summer minimum flows tend to be lower than the winter minimum flows. In the central region and in the Northern Peninsula, the winter and summer low flows tend to be equally severe. In Labrador, the winter low flows are significantly more severe than the summer low flows.

The monthly frequency of occurrence, shown in Figure 16.2, of recorded 1-day annual minimum flows over the periods of records of the rivers shown on the map indicate that there is a shift from summer minimum flows to winter minimum flows with an increase in latitude.

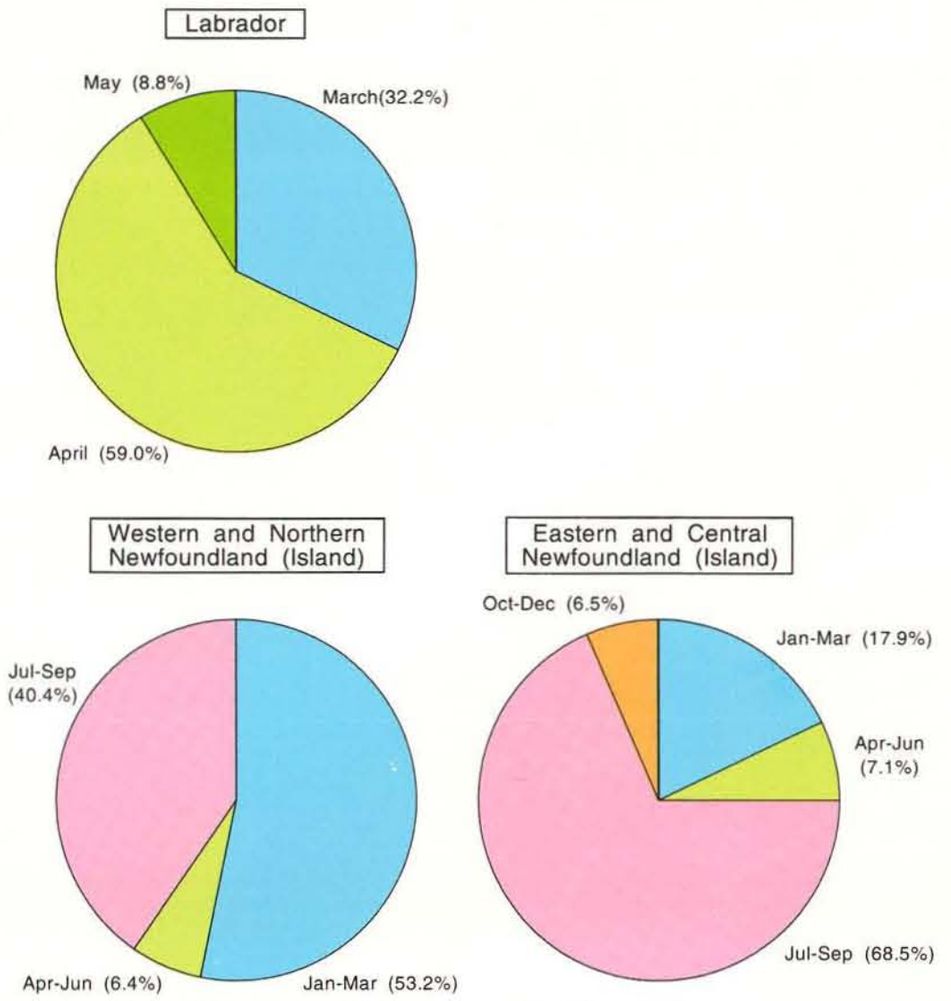
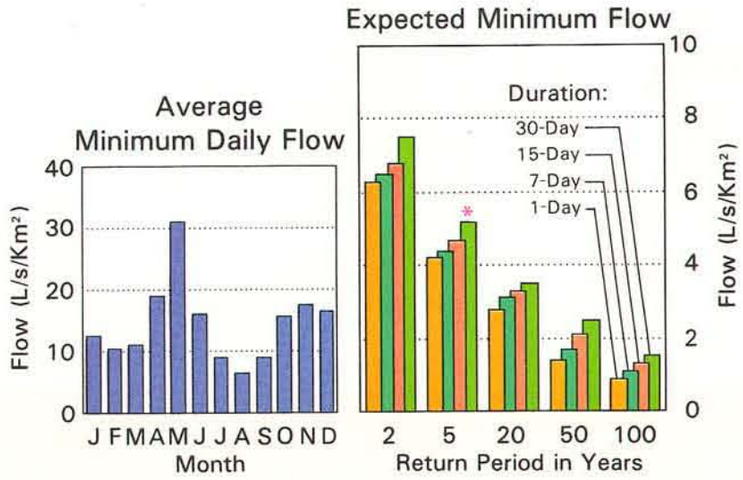


Figure 16.2 Frequency of 1-Day Annual Minimum Flows

MINIMUM STREAMFLOW

Newfoundland and Labrador

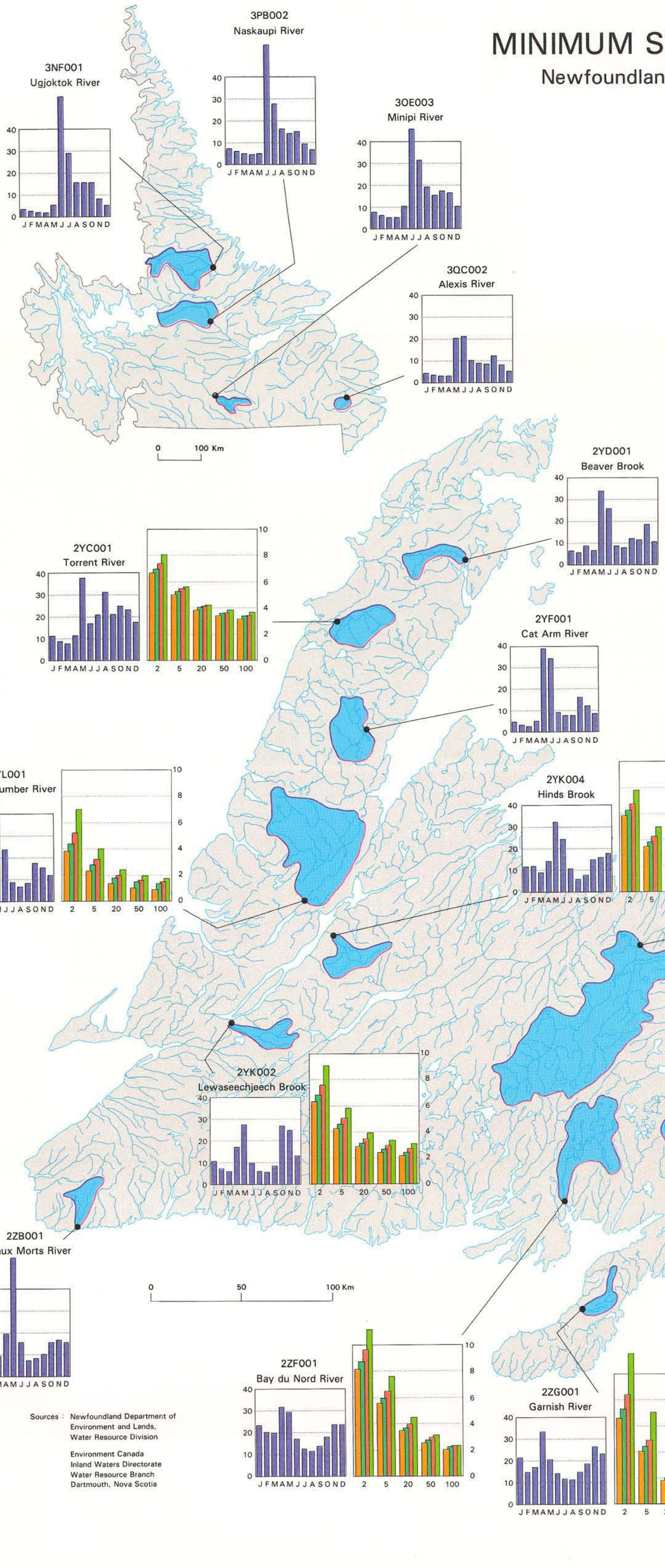


INTERPRETATION OF THE EXPECTED MINIMUM FLOW DIAGRAM:
Using the 5-year return period, 30-day minimum flow bar indicated with an asterisk.

* — On the average, the mean flow over a 30-day duration will be equal to or less than 5.2 litres per second per square kilometre of drainage area (L/s/Km²) at least once within a 5-year period.

● Hydrometric Station

2ZB001 Station Identification Code



Sources : Newfoundland Department of Environment and Lands, Water Resource Division

Environment Canada
Inland Waters Directorate
Water Resource Branch
Dartmouth, Nova Scotia

17 – Maximum Streamflow

All rivers in the province have annual periods of high flows. These high flows can be caused by heavy rainfall, melting of snow accumulations, or both simultaneously. Moderate to relatively high flows are generally beneficial for water supply, hydro power generation, fish habitat management, and other uses. Extremely high flows, on the other hand, can cause considerable damage to bridges, dams, roads, houses, and other structures across or alongside rivers. Loss of life may also occur.

In the hydrologic literature, the maximum instantaneous river flow recorded during a year is called an annual flood flow. Estimates of these flood flows are required as inputs in flood risk mapping (see Map 19) and studies for flood control. In addition, estimates of flood flows are required for the adequate design of hydraulic structures such as dams, levees, bridges, culverts, etc. The magnitudes of the annual flood flows vary from year to year and cannot be forecasted. One can only estimate the frequency of occurrences of these flood flows. The estimate is based on a statistical analysis of several years of recorded annual flood flows. For design purposes, hydrologists express the frequency of flood flows in terms of a "return period". The return period is the average time interval in years, over a long period of time, between occurrences of flood flows which equal or exceed a given magnitude. A return period of, say, X years does not imply a regularity of occurrences, rather, it is an average time interval between occurrences.

Figure 17.1 shows that the recorded flood flows on the Isle aux Morts River varied considerably from year to year between 1962 and 1988. A frequency analysis of these flood flows gives the flood flow with a 2-year return period, also called the 2-year flood flow, as 357 m^3/s, the 20-year flood flow as 648 m^3/s and the 100-year flood flow as 798 m^3/s. These values are shown in Figure 17.1. According to the definition of "return period", one would expect the average time interval between two successive occurrences of a 20-year flood flow to be about 20 years, or alternatively, one would expect the 20-year flood flow to be equalled or exceeded, on the average, at least once over the 27-year period between 1962 and 1988. Figure 17.1 shows that the 20-year flood flow was exceeded once, in 1985, during the period of record. The figure also shows that no 100-year flood flow has been recorded yet. It is certain that this flood flow will occur sometime in the future, but the year of its occurrence cannot be predicted.

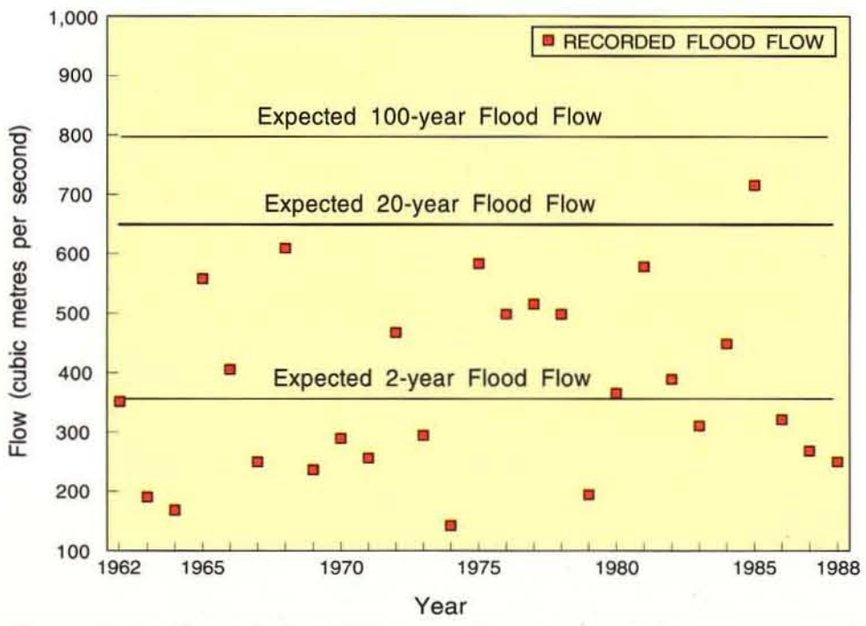


Figure 17.1 Recorded and Expected Flood Flows on the Isle aux Morts River

The return periods of flood flows selected for design of water control or hydraulic structures depend on the type of structure and the risk to property and life if the structure fails due to flooding. For example, it is usually recommended that culverts be designed for the 25-year flood flow, whereas, for major dams, where failure could be catastrophic, the design flood flow may be the 150-year flood flow or even one of a higher return period.

The maximum streamflow map on the opposite page shows the magnitudes of the 2-year, 10-year, 20-year, 50-year and 100-year flood flows expected on watersheds on the Island and Labrador. These values were obtained from a frequency analysis of recorded annual flood flows. Larger watersheds usually have larger flood flows; therefore, for ease of comparison between watersheds of different sizes, the flood flows were divided by the area of the watershed, and have been expressed in cubic metres per second per square kilometre, $m^3/s/km^2$. The map also shows the average of maximum daily flows recorded, over the period of record, for every month of the year. It is, of course, extremely unlikely that these monthly maximum flows would all occur in a single year.

The bar charts for expected maximum streamflow indicate that, on the Island, flood flows are higher on the eastern and southwestern regions than in the central and Northern Peninsula regions. The flood flows, on a per unit area basis, are lowest in Labrador. The flood flows are higher in the lower latitudes of the province because of the greater amounts of precipitation in these regions.

The bar charts for average maximum daily flow indicate that in Labrador most of the high flows occur between April and July and are caused by snowmelt. The same observation can be made for the Northern Peninsula and central region of the Island. Flood flows between October and December, due to rainstorms, are also possible. In the eastern and southwestern regions of the Island, flood flows are possible in almost any month of the year. Flood flows in these regions during the period January to March are often due to combined snowmelt and rainfall. Figure 17.2 shows the monthly frequency of recorded flood flows for the rivers shown on the map in the eastern and south-western regions of the Island and in Labrador.

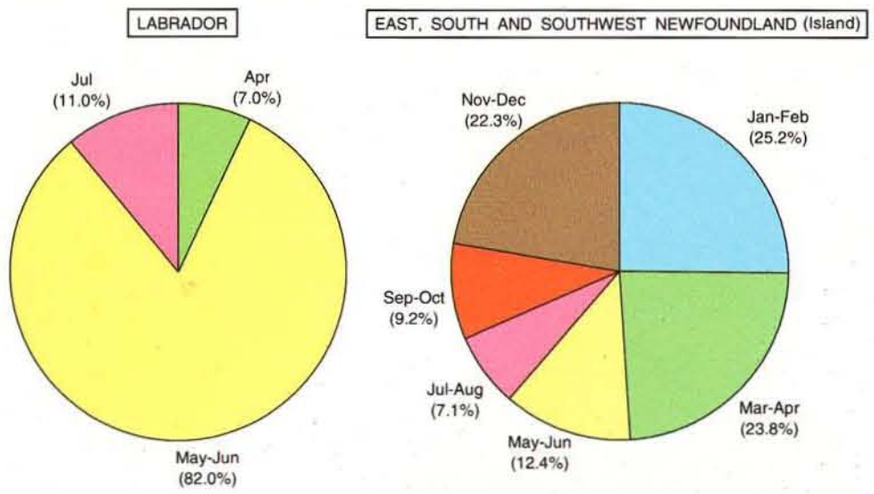
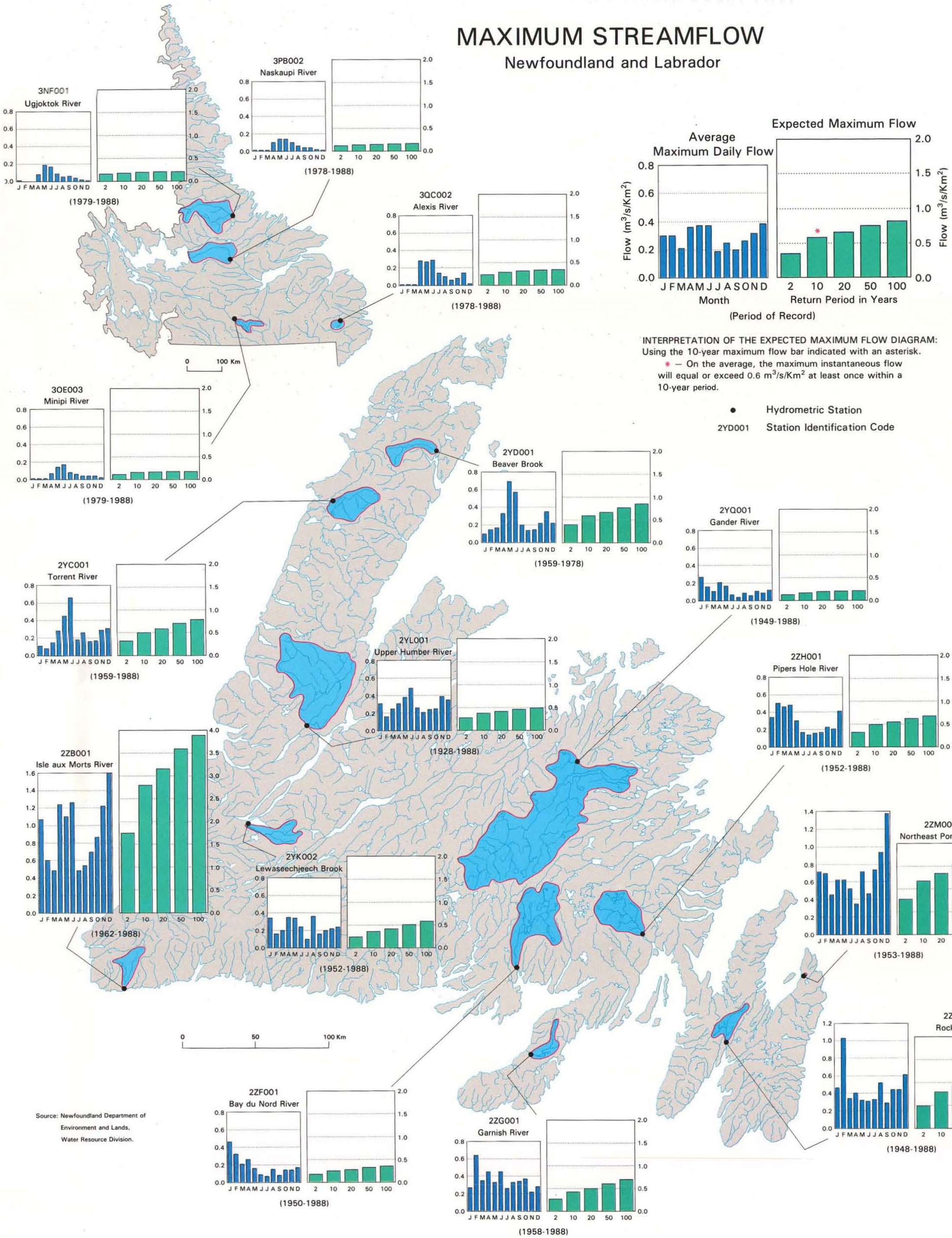


Figure 17.2 Frequency of Annual Flood Flows

MAXIMUM STREAMFLOW

Newfoundland and Labrador



INTERPRETATION OF THE EXPECTED MAXIMUM FLOW DIAGRAM:
Using the 10-year maximum flow bar indicated with an asterisk.

* – On the average, the maximum instantaneous flow will equal or exceed 0.6 $m^3/s/Km^2$ at least once within a 10-year period.

● Hydrometric Station

2YD001 Station Identification Code

Source: Newfoundland Department of Environment and Lands, Water Resource Division.

18 – Ice Conditions

Most rivers and lakes in the province are covered with ice during the winter season. Break-up of the ice covers usually occurs in spring. The timing of these freeze-up and break-up events affects a variety of water uses including water supplies, transportation, and recreational uses. Break-up, in particular, can cause ice jams which are the most important cause of flooding in many regions of the province. These floods often have serious economic consequences.

In rivers the formation of an ice cover is determined primarily by weather conditions; other factors include the size and shape of the river channel, river slope, and runoff volume. An ice cover will start to form in a river or lake after the air temperature drops below freezing. The type of ice cover formed depends on the velocity of the water in the channel. These types are illustrated in Figure 18.1.

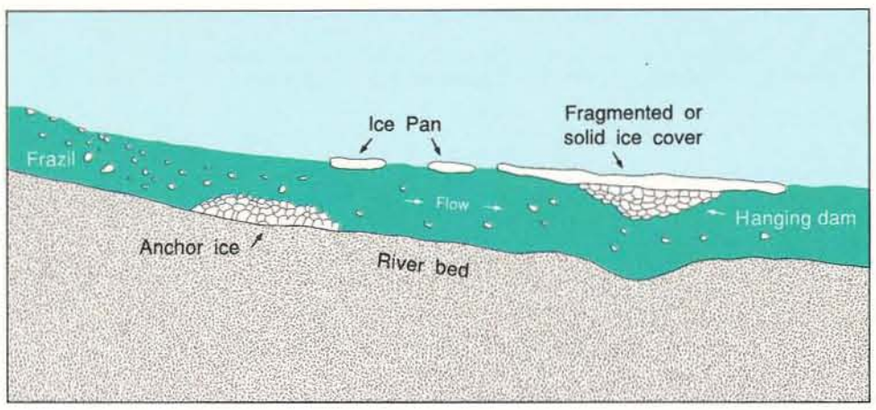


Figure 18.1 Types of Ice Cover

In the low velocity reaches of a river ice cover formation usually starts along the banks. This process produces a thin, continuous strip of ice, called border ice, which progresses towards the centre of the channel. In areas where the velocities of the flow are less than 0.6 metres per second (m/s) and the temperature is below freezing a thermal ice cover will form as takes place on a lake or pond.

In rivers where the flow velocities are greater than 0.6 m/s surface turbulence may prevent the formation of an ice sheet. In this case, the water becomes supercooled and tiny ice particles called frazil ice are formed. These ice particles cling together and form clusters, or ice pans, which move downstream with the current and come to rest at a channel constriction or at a low velocity reach of the river. With cold temperatures the ice pans will freeze together and form a continuous ice cover which will progress upstream. Figure 18.2 shows a reach of the Exploits River with border ice and ice pans.

Figure 18.2 Border Ice and Ice Pans on the Exploits River

A hanging dam is formed when frazil ice is transported under an ice cover where it adheres and accumulates. A hanging dam can cause extensive blockage of the flow which results in higher upstream water levels and potential flooding. Figure 18.3 shows a reach of the Exploits River where partial blockage of flow by ice has occurred.

Figure 18.3 Blockage of Flow by Ice on the Exploits River

In wide, shallow rivers with turbulent reaches frazil ice particles may form, cling to the river bed, and accumulate to form anchor ice. As with the hanging dam, anchor ice can cause a significant blockage of flow which can result in local flooding.

Break-up normally occurs in the spring when the ice cover is weakened by warm temperatures. A mid-winter break-up can also occur on rivers in the eastern and southern parts of the Island. If the snow pack melts slowly the ice cover will deteriorate gradually without serious flooding. Rapid snowmelt and mild temperatures, however, particularly when accompanied by rain, cause the break-up to occur quickly. In this case, broken pieces of ice may be swept downstream until a constriction is reached, form an ice jam, and create the potential for a serious flood.

Automatic streamflow recorders installed on many rivers in Newfoundland and Labrador maintain continuous records of discharge. It is possible to determine from the discharge data the times of first freeze-up and last break-up of the ice cover on these rivers. The map on ice conditions on the opposite page shows the average dates of first freeze-up, and last ice break-up of the ice cover, along with the average number of days between first and last ice cover.

First freeze-up over much of the Island occurs between mid-November and early December. Break-up occurs during late April or early May, except on the Avalon Peninsula where break-up tends to occur earlier in April. The average number of days from first to last ice cover progresses from less than 100 on the Avalon Peninsula and south coast to more than 130 days on the Northern Peninsula. There is a lack of adequate data for the central interior region of the Island.

First freeze-up in Labrador occurs much earlier than on the Island, ranging from mid-October to early November. Spring break-up is delayed until late May or even early June at some stations. The average number of days from freeze-up to break-up increases from less than 170 in the south to more than 180 further north.

ICE CONDITIONS

Newfoundland and Labrador

Contour Interval = 10 days

Contour Interval = 15 days

Mean Annual Days Between
First Ice and Last Ice

100

Ice Extremes by station

January
Earliest Freeze-up
Latest Breakup
July

Hydrometric Station

5-9	Years of Data
10-14	
15-20	
20+	

Ugjoktok R.
Kanairiktok R.
Naskaupi R.
Eagle R.
Alexis R.
Minipi R.
Little Mecatina R.
Riviere Joir
Ste. Genevieve R.
Torrent R.
Upper Humber R.
Sheffield R.
Harry's R.
Middle Bk.
South West Bk.
Terra Nova R.
Isle aux Morts R.
Bay du Nord R.
Come-by-Chance R.
Piper's Hole R.
North East Pond R.
Garnish R.
Rocky R.
North West Bk.

180 170 160 160 170 170 130 115 100 100 115 115 100 85 85 70 100 100 55

0 100 Km

0 50 100 Km

Source: Newfoundland Department of Environment and Lands,
Water Resources Division.

19 – Flood Risk Zones

Newfoundland has had its share of serious floods in the past. In fact, Newfoundland led Canada in the number of flood events reported in the period 1983-1987. Flooding in Newfoundland, as in many other places, causes damage to personal property, disrupts the lives of individuals and communities, and can be a threat to life itself. The continuing developments in floodprone areas increase these risks.

Floods in Newfoundland can be the result of many factors, often acting in combination as illustrated in Figure 19.1, 19.2, and 19.3.

Figure 19.1 Heavy rain and snowmelt flooding in Bishop's Falls in 1983 resulted in severe damage.

Figure 19.2 High tides combined with onshore winds and storm surge caused extensive flooding in Placentia. Cox's Cove and Stephenville Crossing also experience this type of flooding.

Figure 19.3 Ice jams and high river flows can cause flooding in communities along rivers, such as Badger. Other communities prone to this type of flooding include Rushoon, Glovertown, and Black Duck Siding.

In order to reduce flood damage, the governments of Canada and Newfoundland signed a cost-shared agreement in 1981 under the national Flood Damage Reduction Program. The objective of the program is to reduce flood damage to properties located in floodplains along the shores of lakes, rivers, and the sea, and by discouraging further development of flood prone lands. The preferred approach adopted for reducing potential flood damage is to identify the probable extent of flooding and to discourage development in these flood risk zones. If a development does proceed, however, the structures should be floodproofed.

The objective of the program is accomplished, in part, by the flood risk mapping program. Flood risk maps are produced to inform both the general public and professionals of the risks involved in the development of flood prone areas. Two types of maps are produced: a Flood Information Map designed to be easily understood by the general public and a detailed Flood Risk Map suitable for use by engineers, planners, or others involved with developments proposed in floodplain areas.

For selected flood prone areas in Newfoundland, new base maps at 1:2500 scale, with contour intervals of 0.5 m, were prepared. Hydrotechnical studies involving hydrologic, hydraulic, oceanographic, and ice analyses provided the water surface profiles for the 1:20 and 1:100 year recurrence interval floods. These values were applied to the detailed topographic maps to delineate the areal extent of the flood risk zones.

The flood risk maps delineate the flood risk areas using a two zone approach. The "designated floodway" (1:20 year flood zone) is the area subject to the most frequent flooding. The "designated floodway fringe" (1:100 year flood zone) constitutes the remainder of the flood risk area. No building or structure should be erected in the "designated floodway" since extensive damage may result from deeper and more swiftly flowing waters. It is often acceptable, however, to use land in this area for agricultural or recreational purposes. Development is acceptable in the floodway fringe provided that the structure is floodproofed.

Flood risk maps have been produced for sixteen communities in the province. Some of these are shown on the accompanying map. Municipal authorities are encouraged to incorporate the flood risk zones into their development regulations. Also, federal and provincial agencies and Crown corporations will not fund developments within the 1:20 year flood zone. Further information on the Flood Damage Reduction Program may be obtained from:

Flood Damage Reduction Program
c/o Water Resources Division
Department of Environment and Lands
P.O Box 8700
St. John's, Newfoundland
A1B 4J6

Flood Damage Reduction Program
c/o Inland Waters Directorate
Environment Canada
4th Floor, Queen Square
45 Alderney Drive
Dartmouth, Nova Scotia
B2Y 2N6

FLOOD RISK ZONES

Newfoundland and Labrador

Normal Water Surface

1:20 Year Flood Zone

1:100 Year Flood Zone

Road

0 100 Km

Parson's Pond

4120 m

Steady Brook

5850 m

6845 m

Deer Lake

5930 m

Pasadena

5470 m

2590 m

Rushy Pond

5690 m

Black Duck Siding

3075 m

Waterford River Basin

4960 m

6450 m

Stephenville Crossing

5750 m

Badger

1430 m

Stephenville

6845 m

Rushoon

1425 m

Placentia

2130 m

0 50 100 Km

Source: Newfoundland Department of Environment and Lands,
Water Resources Division.

SURFACE WATER QUALITY

Introduction

Pure water is not found in nature. As it makes its way through the various phases of the hydrological cycle water accumulates various substances in suspension, solution, and colloidal dispersion. Droplets of water in the atmosphere incorporate dissolved gases and dust particles. Falling as precipitation, water may trap or dissolve other substances. Upon reaching the surface and on its journey over and through the ground it picks up silt, bacteria, decaying matter, and various minerals which occur in soils and rocks. In addition to the natural processes that cause water quality to vary over time and space, human activity can have an impact through urbanization, industrialization, deforestation, sewage disposal, mining, and recreational activities.

Even in its natural state water usually contains measurable amounts (parts per million) of dissolved gases and major ions, as well as traces (parts per billion or trillion) of other substances such as organic compounds. Water quality can also be characterized by physical properties such as acidity (pH), colour, and conductivity. Different users of water may be concerned with different aspects of water quality depending upon the nature of the beneficial water use.

A description of some of the significant water quality parameters is presented in the next five maps. The data presented in these maps were obtained under the Canada - Newfoundland Water Quality Monitoring Agreement signed in 1986. The Agreement provides for the regular monitoring of an index network of about 56 stations on the Island and Labrador, as well as an annual recurrent study concentrating on some aspects of water quality in selected watersheds. Water quality monitoring consists of the regular collection of water, sediment, and biological samples at carefully selected sites for analysis of a variety of physical, chemical, and biological parameters.

Collecting Water Samples from a River

20 – Water Colour and Turbidity

The map on the opposite page shows the average level of colour and turbidity in water sampled at various locations in the province. These two parameters largely determine the appearance of a sample of water, that is, clear or coloured, and transparent or cloudy.

Water colour is affected by dissolved substances in water, often these are naturally occurring organic materials. Bogs and swamps produce large amounts of dissolved organic materials such as tannins, lignins, and humic acids, which can give water a tea-like colour. Calcium carbonate from regions with limestone bedrock may give water a greenish colour, while ferric hydroxide (iron) may impart a reddish colour. The degree of colouring will depend on the concentrations of these and other substances.

Turbidity is a measure of how cloudy a water sample appears, or how well it transmits light. Turbidity results from suspended solids and materials such as clay and silt or microorganisms in the water. It may also be caused by naturally occurring silt and sediment runoff from watersheds. These substances tend to scatter light and make the water sample appear cloudy. They are kept in suspension by turbulent flow, or by random movement (Brownian motion) of the water molecules. Turbidity is often highest during spring runoff.

Colour is measured in Relative Units which represent a standard scale against which a sample is compared. Turbidity is expressed in Jackson Turbidity Units (JTU), a standard scale against which samples are compared. The values shown on the map are the averages over a number of years of record for each station.

Water colour is categorised by the colour of the dot at each sample station location. The colours of the dots fall in four categories covering a range from 5 to 100 colour units. The least coloured waters tend to occur on the west coast and Northern Peninsula, and the upper Avalon Peninsula. More heavily coloured waters occur in central and northeastern areas, and on the Burin and southern Avalon Peninsulas. Labrador has lightly coloured waters with one exception (Eagle River) to the east. Water colour is highly influenced by land cover in a basin. Bog or swampy drainage will contribute high levels of colour to surface runoff, while less organic soils or exposed bedrock in a basin will contribute little to water colour. Central Newfoundland and the southern Avalon and Burin Peninsulas contain large bog areas which contribute strongly to the observed patterns. Figure 20.1 shows the number of stations reporting various levels of water colour.

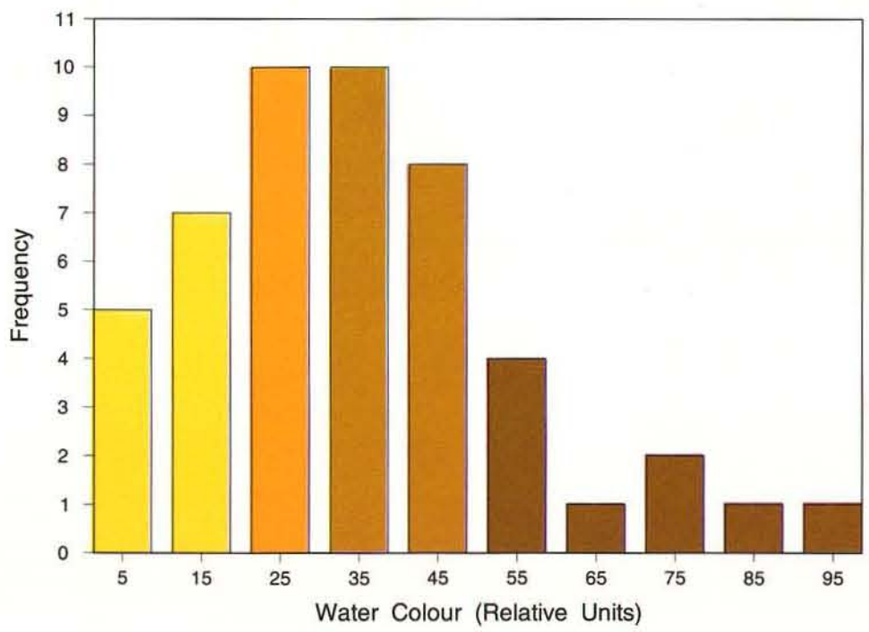


Figure 20.1 Frequency of Occurrence of Various Levels of Water Colour in Newfoundland

Turbidity of waters in the province ranges from zero to two JTU, with the exception of one station on the Churchill River which consistently shows high turbidity of around 6 JTU. This site may be overly influenced by local upstream conditions such as soil erosion, channel degradation, etc. Water samples at the other stations in Labrador also have generally higher turbidity than at the stations on the Island.

Patterns of turbidity on the Island tend to follow those found for colour, with low colour waters showing low turbidity, and higher values of colour coinciding with higher values of turbidity. There are, however, interesting exceptions to this. The four stations in the St. John's area on the northeast Avalon Peninsula (inset map) showed low colour coinciding with high turbidity values. The drainage basins above these sites have been extensively urbanized, with large areas developed for housing, business, roads, etc. Urbanized areas are often subject to soil disturbance from development activities, runoff of dirt and debris from roadways, and higher variability of runoff due to reduced water holding capacity in an urban drainage system. These factors may all contribute to increases in sediment input and siltation in a river, leading to higher turbidity values. The stations on the southern Avalon and Burin Peninsulas showed high colour from bog drainage, but low turbidity values, indicating low levels of sediment and suspended solids.

Concern about water colour in drinking water is essentially an aesthetic one. Treated drinking water should not have much apparent colour. Turbidity in drinking water should be reduced as much as possible prior to treatment since the suspended organic materials which contribute to turbidity have the potential to form trihalomethanes (possibly toxic compounds) when subjected to chlorination. Excess colour and turbidity are also of concern to industrial water users. For example, excess colour can affect the quality of paper products, while excess turbidity can cause corrosion and deposition control problems for industrial users.

WATER COLOUR AND TURBIDITY

Newfoundland and Labrador

Colour — Relative Units

- 5.0-19.9
- 20.0-34.9
- 35.0-49.9
- 50.0-99.9

Turbidity — Jackson Turbidity Units

- 0.10-0.29
- 0.30-0.39
- 0.40-0.59
- 0.60-1.90
- 6.30

0 100 Km

0 25 Km

0 50 100 Km

Sources: Water Quality Data; Newfoundland, 1965-1985.

Canada — Newfoundland Water Quality Monitoring Agreement.

21 – Concentrations of Sodium, Chloride, and Sulphate Ions

A very large number of elements and compounds may be present in dissolved form in varying concentrations in natural waters of lakes and rivers. Chemical compounds are made up of combinations of elements united by electrical attractions between the constituent elements. When a compound dissolves in water, it separates or dissociates into electrically charged ions. Ions may be divided into two groups, depending on whether the ion carries a positive or negative electrical charge. Those ions with negative charges are termed anions, and include chloride, sulphate, carbonate and bicarbonate, hydroxide, and others (such as fluoride, bromide, iodide, and nutrients such as nitrite and phosphate) which may be present in trace concentrations. Ions with positive charges are termed cations, and include calcium, magnesium, sodium, potassium, and others which may be present in smaller concentrations.

The map on the opposite page presents data for two major anions, chloride and sulphate, as well as for a major cation, sodium at stations where water samples are collected regularly for analysis. The bar graph for each station shows the concentration for each ion measured in milligrams per litre (mg/l) or parts per million. The scale for the bar graphs is logarithmic, meaning that the vertical extent of the 1-10 mg/l range is the same as the vertical extent of the 10-100 mg/l range. In this way, widely diverse values between 1 and 200 mg/l can be conveniently displayed on the same scale.

Two of the elements represented on the map, sodium and chloride, when combined chemically make the very familiar compound sodium chloride, or common table salt. These elements are major ionic constituents of natural waters. The third ion, sulphate, is a component of acid precipitation produced by human activities such as the burning of fossil fuels. Sulphate combined with hydrogen ions forms sulphuric acid, which dissociates to release the hydrogen ions in water thus increasing acidity. Elevated sulphate concentrations may indicate the effects of acid precipitation, although there are also natural sources.

Natural sources of chlorides include sedimentary rocks, natural salt deposits, and contributions from ocean spray which may be carried some distance inland. The latter source is obviously of particular importance in marine areas such as Newfoundland and the Maritimes. Other sources resulting from human activities may include domestic and industrial contamination, soil or bedrock disturbances from construction activities, and the application of road salt in urban areas. High chloride concentration in coastal areas is sometimes the result of direct contamination of surface or groundwater by ocean water, which contains about 19,000 mg/l of chloride. Such contamination can be a problem for water wells in coastal areas.

The Canadian and U.S. standard for chloride in drinking water supplies is 250 mg/l. Natural water may contain from a few mg/l to a few hundred. Drinking water standards are based mostly on considerations of taste rather than health implications since food sources contribute a much higher proportion of total chloride intake. Average daily intake of chloride for Canadian adults is about 6000 mg, of which only about 20 mg is likely to come from drinking water. Other considerations include the corrosive potential for pipes and equipment. Fresh waters used for cooling should have less than 600 mg/l of chloride. Steel manufacturing requires less than 150 mg/l of chloride for process water, while the pulp and paper and petroleum industries generally require less than 200 mg/l of chloride for most uses. Chloride concentration guidelines for the food and beverage industries range from 20 to 250 mg/l for different uses. Agricultural use of water for irrigation may be limited by chloride concentration. Sensitive crops should not be irrigated with water of more than 100 mg/l of chloride, while tolerant crops may be irrigated with water of up to 700 mg/l of chloride. Removal of chloride from water sources is difficult, and requires expensive treatment methods such as reverse osmosis, ion exchange, or distillation.

Sources of sulphate include rock weathering, as well as human sources such as industrial release or burning of fossil fuels high in sulphur. The Canadian drinking water guideline for sulphate is 500 mg/l, while the U.S. guideline is 250 mg/l, although drinking water sources frequently exceed this level. Potential health effects include gastrointestinal irritation, particularly in children, at levels greater than 600 mg/l. Objectionable taste is also a consideration. Daily adult sulphate intake is about 500 mg, of which approximately 100 mg comes from drinking water. Sulphate is not usually a concern for agricultural water use. For industrial use cooling water should have less than 680 mg/l of sulphate, and process water should have less than 200 mg/l of sulphate for steel manufacturing. The food and beverage industry may require less than 20 mg/l of sulphate for sugar manufacturing, although 100-250 mg/l is acceptable for other uses. Removal of sulphate from water sources requires expensive procedures similar to those for chloride.

Sodium is considered to be a major ionic constituent for most waters. Rocks and soils, sewage input and industrial waste are common sources of sodium in water. Sodium in concentrations normally found in natural waters is not considered to have any health implications, and there are no drinking water guideline limits. If sodium is present at high levels relative to calcium and magnesium, there may be implications for irrigation use from effects on soil structure. Sodium concentration is not normally a consideration for industrial water users.

The map shows that the highest sodium and chloride concentrations tend to occur at stations on the east and west coasts, those closest to potential marine sources. Interior sites showed much lower levels of sodium and chloride. In particular, the highest sodium and chloride concentrations were found in the urbanized watersheds of the St. John's region on the eastern Avalon Peninsula, reflecting the contributions from a variety of runoff sources in an urban environment. The trend for sulphate is similar, but less pronounced, with slightly higher values in coastal areas and slightly lower values inland.

Figure 21.1 shows the monthly variations of sodium, chloride, and sulphate ions in Rennies River at Carrell Drive in St. John's. The noticeable annual peaks in levels of sodium and chloride during the period January to March are due to road salt from urban runoff.

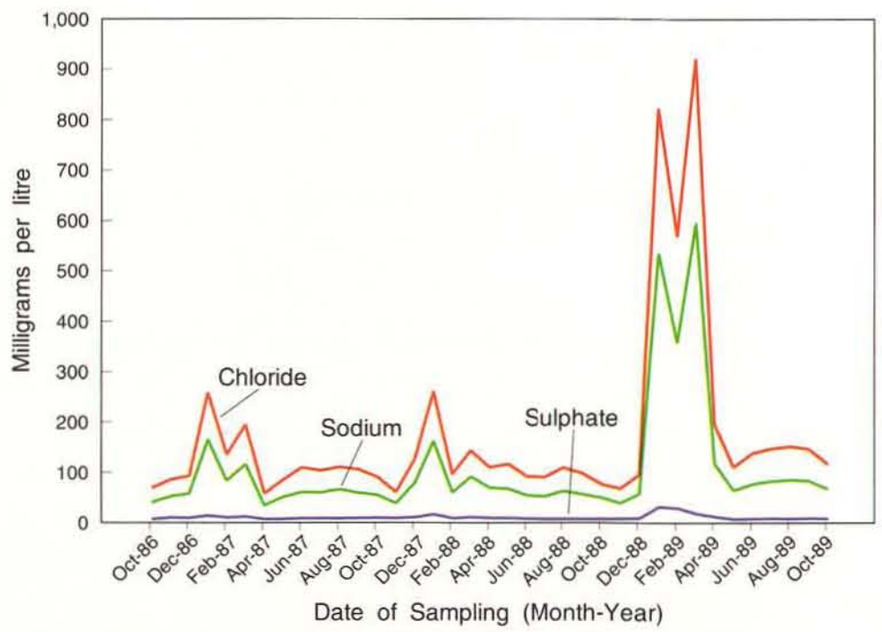
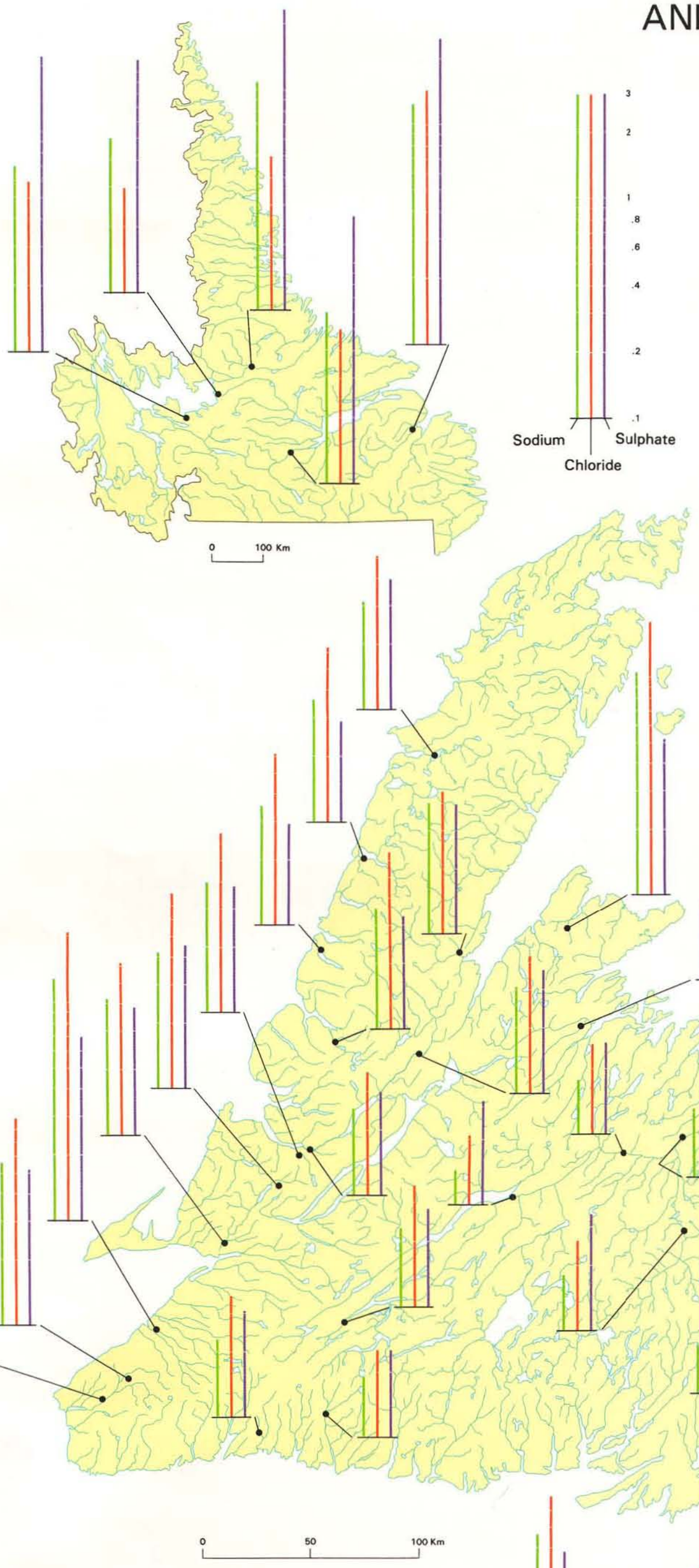


Figure 21.1 Concentrations of Sodium, Chloride, and Sulphate Ions in Rennies River

CONCENTRATIONS OF SODIUM, CHLORIDE, AND SULPHATE IONS IN SELECTED DRAINAGE BASINS

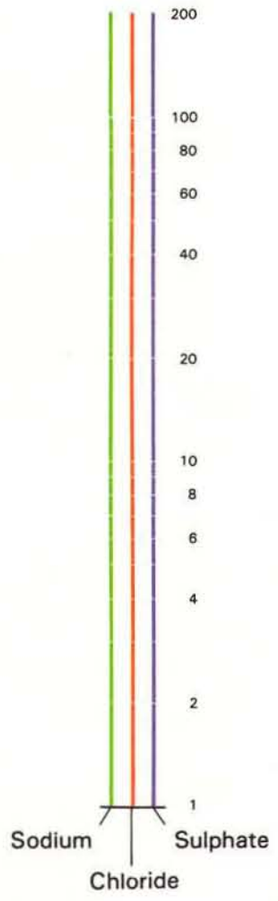
Newfoundland and Labrador

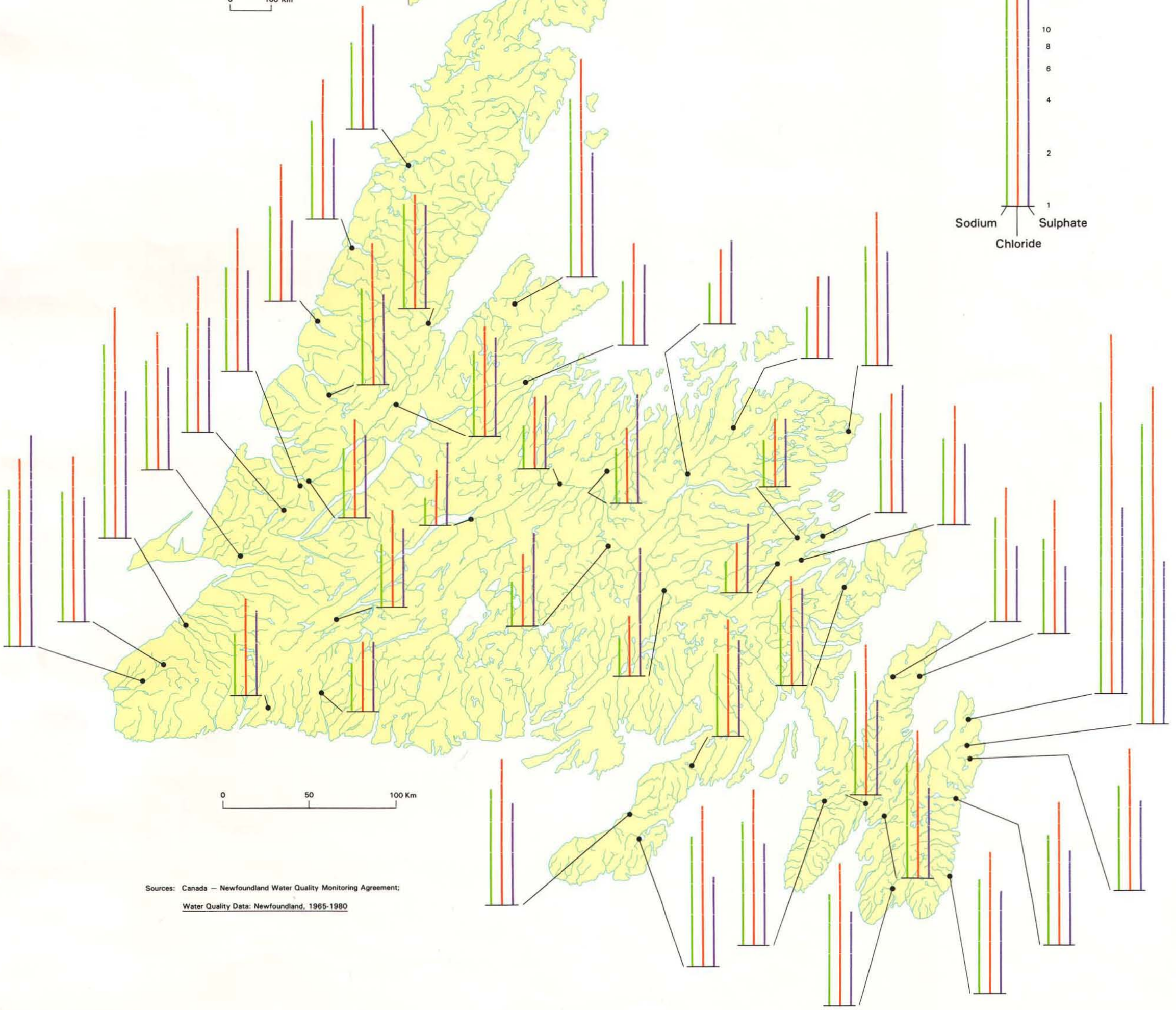


• Water Sampling Station

Logarithmic Scales

Concentration in Milligrams Per Litre (Mg/L)





Sources: Canada — Newfoundland Water Quality Monitoring Agreement;

Water Quality Data: Newfoundland, 1965-1980

22 – Concentrations of Calcium, Magnesium, and Potassium Ions

Calcium, magnesium, and potassium are all major ionic constituents of natural waters. The values shown on the map on the opposite page are the average concentration of each parameter calculated over the number of years of record at each site. Concentrations in milligrams per litre (mg/l) are presented as bar graphs with a logarithmic scale, meaning that the vertical extent of the 0.1-1.0 mg/l range is the same as the vertical extent of the 1.0-10 mg/l range. In this way, widely diverse values between 0.1 and 20 mg/l can be conveniently displayed on the same scale.

Calcium and magnesium are similar cations in many respects, and both are derived from many types of rocks and soils. Calcium may be dissolved from limestone (calcite), dolomite and gypsum, while magnesium is dissolved from dolomite, magnesite, mica, and other rock types. The concentrations of calcium in water are generally higher than those of magnesium, reflecting calcium's greater abundance in the earth's crust. The concentration of calcium in water is typically less than 15 mg/l, although this may increase to 30-100 mg/l in areas with carbonate rocks. Concentrations of magnesium may exceed those of calcium in marine areas. This, however, does not occur in the waters of the province. Calcium and magnesium together largely determine the hardness of water. Deposits of calcium and magnesium may form scales following evaporation of water containing them. Calcium and magnesium are both essential nutrients in the human diet, and are considered desirable in appropriate quantities for most beneficial uses of water.

Calcium in drinking water is not considered to have any health implications, and there are no guideline limits for it. A recommended guideline limit of 1000 mg/l of calcium for livestock watering is included in the Canadian Water Quality Guidelines. High concentrations may contribute to phosphorus deficiency. Calcium levels can be important for industrial water uses, primarily because of calcium's contribution to water hardness, and subsequent tendency to form scales in pipes and equipment. Recommended guidelines include: <200 mg/l for cooling water, <20 mg/l for pulp and paper industry use, <75 mg/l for petroleum industry use, and <100 mg/l for the brewing and food processing industries.

The U.S. Public Health Service recommends a limit of 50 mg/l for magnesium in drinking water due to the potential for gastrointestinal upset; the Canadian drinking water guidelines, however, do not set an upper limit for magnesium. Magnesium is not considered to be a problem for agricultural or most industrial uses of water. Guideline limits recommended in Canada are 12 mg/l for the pulp and paper industry, 25 mg/l for the petroleum industry, and 30 mg/l for the brewing industry.

Potassium is another metal normally considered as a major ion in water. Potassium is similar in many respects to sodium, although it is normally less easily dissolved from rocks and therefore found at lower concentrations than sodium, normally less than 10 mg/l. Potassium is an essential nutrient for both plants and animals. There are no drinking water guidelines for potassium, nor are there any guidelines for limits on potassium for agricultural or industrial uses of water.

The map shows that the highest concentrations of calcium concentrations occur on the west coast of the Island, reflecting the presence of carbonate rocks. The concentration of magnesium also tends to be highest on the west coast, and at some sites on the Avalon Peninsula.

The temporal variation of the ionic constituents in surface water samples is not reflected in the average data presented on the map. Analysis of non-averaged data show that the concentrations of the ionic constituents tend to follow a yearly cycle. This pattern occurs because river discharge varies over the course of a year according to climatic and precipitation cycles. The relative contribution of surface water runoff and groundwater seepage to streams and rivers changes with time of the year, and in turn affects water chemistry. While the contribution of groundwater to river discharge tends to be relatively stable over the course of a year, that of surface runoff can be quite variable. Groundwater often has higher concentrations of ions than surface water from longer-term contact with rocks and soils, so that ionic concentration of river water is often inversely related to discharge. At relatively higher discharges, the greater contribution of more dilute surface water lowers concentrations of the ions. This inverse temporal relationship, however, is complex and generally more pronounced in arid regions than in the more humid climate of Newfoundland. The concentration of ionic constituents also varies along a river, with concentrations tending to increase from headwaters to the river mouth. Figure 22.1 shows the temporal variations of calcium, potassium, and magnesium in Rennies River at Carrell Drive in St. John's. Peaks in levels of calcium each winter are due to road salt in urban runoff.

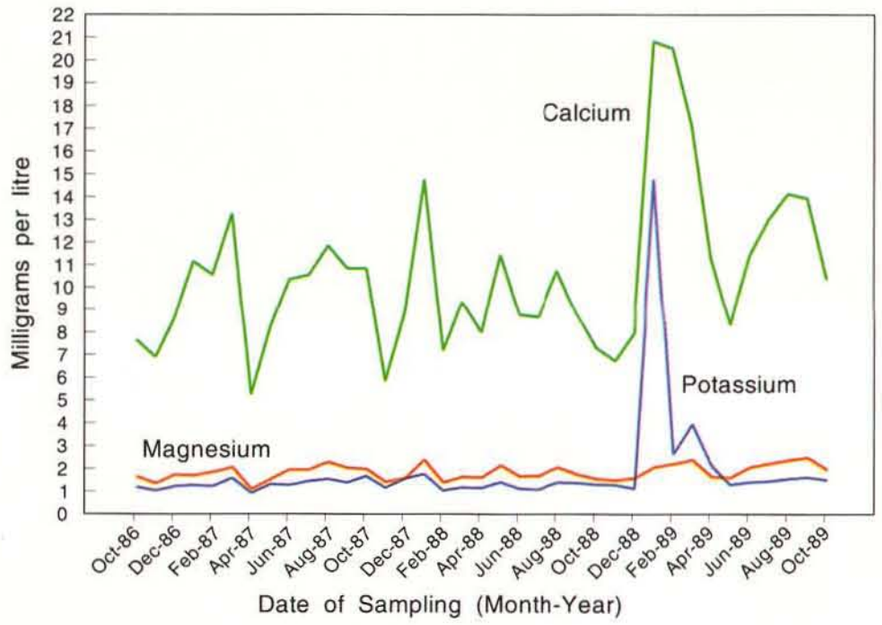
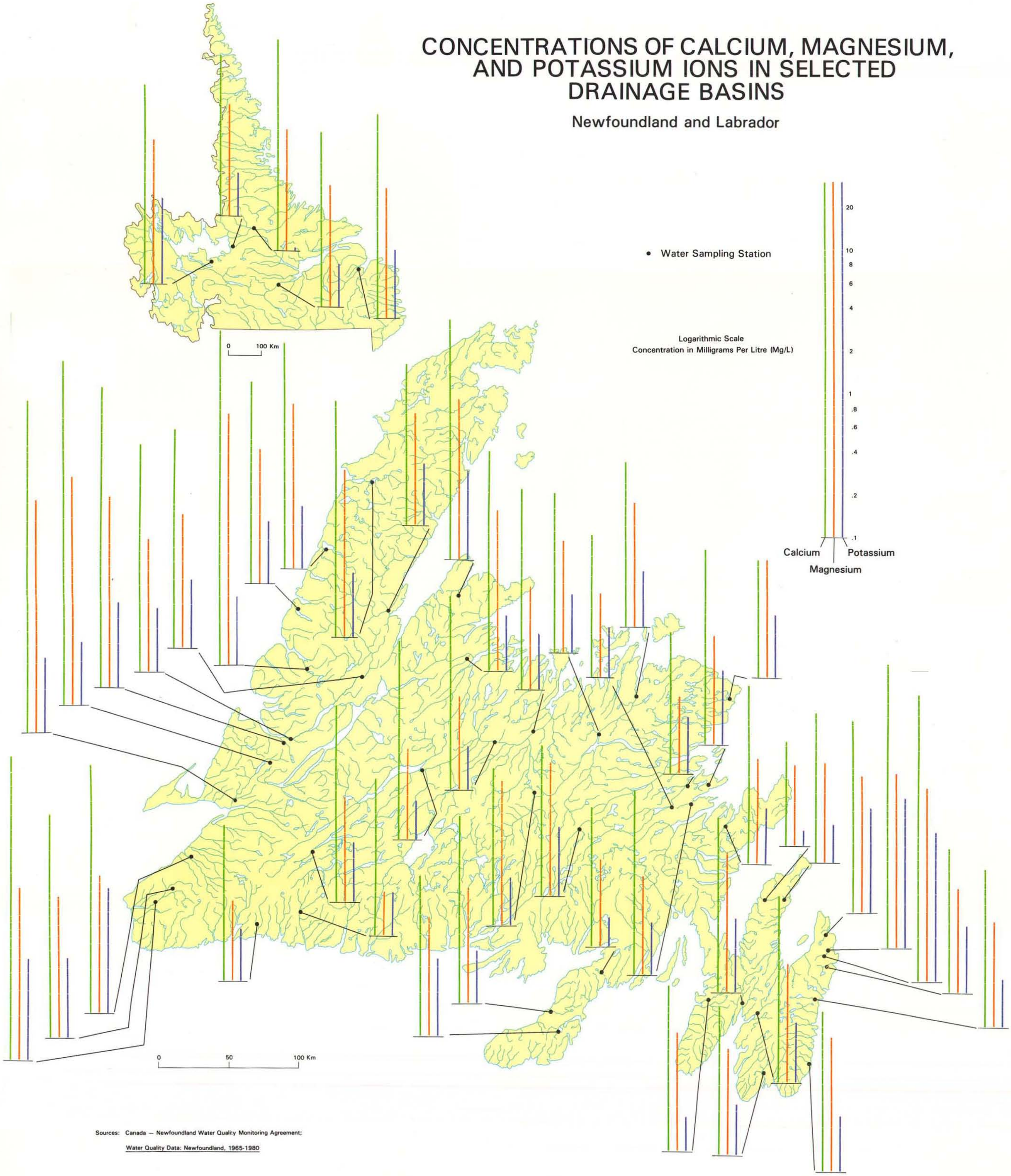


Figure 22.1 Concentrations of Calcium, Magnesium and Potassium Ions in Rennies River

CONCENTRATIONS OF CALCIUM, MAGNESIUM, AND POTASSIUM IONS IN SELECTED DRAINAGE BASINS

Newfoundland and Labrador



Sources: Canada — Newfoundland Water Quality Monitoring Agreement;

Water Quality Data: Newfoundland, 1965-1980

23 – Surface Water: pH and Total Alkalinity

One aspect of water quality which recently has been of particular concern is acidity resulting from increased acid loads contributed to lakes and rivers by human activities. The acidity of water is measured on the pH scale, which provides an indication of the concentration of hydrogen ions (H^+). The higher the hydrogen ion concentration, the more acidic the water will be. The pH scale ranges from 0 (most acidic) to 14 (most alkaline). A value of 7 is neutral (neither acidic nor alkaline), and the scale is logarithmic, meaning that a change of 1 pH unit reflects a 10-fold change in the acidity. Thus, for example, a pH of 4 is ten times as acidic as a pH of 5, and a pH of 12 is ten times as alkaline as a pH of 11. Distilled water has a pH of 7, while natural uncontaminated rain has a pH of 5.6.

THE pH SCALE

```
0  1  2  3  4  5  6  7  8  9  10 11 12 13 14
ACIDIC                NEUTRAL          ALKALINE
   |     |     |     |                 |     |
   |     |     |     |                 |     Lime
   |     |     |     |                 Ammonia
   |     |     |     Distilled Water
   |     |     "Pure" Rain (5.6)
   |     Vinegar
Battery Acid
```

The extra acidity in pure rain comes from carbonic acid produced when atmospheric carbon dioxide dissolves in the rainwater. When rain becomes contaminated by nitric and sulphuric acids from human activities the pH level can fall below 5 or even 4, which is between 10 and 100 times as acidic as pure rainwater. Sulphuric acid comes mostly from the burning of fossil fuels (coal and oil) in power plants, and from industrial sources such as non-ferrous metal smelting. The largest source of nitric acid is motor vehicle emissions. When sulphur dioxide and oxides of nitrogen are released into the atmosphere they are further oxidized by ozone and oxygen under exposure to sunlight, and then combine with moisture to form sulphuric and nitric acids. Such pollutants may be transported by moving weather systems hundreds or thousands of miles from their sources, and enter terrestrial and aquatic ecosystems through precipitation (wet deposition) or direct deposit of gases and particulates (dry deposition).

Rain in Newfoundland is most acidic along the south coast and southwestern region of the Island, which is the area of the province closest to major sources in the northeastern U.S., and central and eastern Canada. This area is also in the path of weather systems moving northeast and bringing rainfall with an average pH level of 4.5 (about 12 times as acidic as clean rain). The pH level of rainfall increases (less acidic) toward the northeast, for example averaging 4.8 around Bonavista Bay. Labrador also has less acidic rain; the average pH level of rain is 4.8 at Goose Bay (about 6 times as acidic as clean rain) and the pH level increases (less acidic) further north. It is estimated that, of the acidic pollutants deposited in Newfoundland from outside sources, approximately 60% originates from Canadian sources and 40% from the United States.

One of the most obvious effects of acid precipitation is the reduction of the pH of surface waters. The ability of water to neutralise excess acid is termed the buffering capacity and depends on the dissolved materials in the water, particularly carbonate and bicarbonate. Alkalinity is a measure of the acid-neutralizing capacity of water. The relative amount of acid-neutralizing ions in surface waters depends largely on the rock types in the drainage basin, increasing with higher proportions of carbonate rocks such as limestone, and decreasing with higher proportions of insoluble rocks such as granite.

Parameters which exert a significant influence on acidity and alkalinity include nutrients (phosphate, carbonate, ammonia, silicate, and sulphide), metals (iron, manganese, magnesium), organic acids (amino, fulvic, and humic), gases (carbon dioxide, hydrogen sulphide), and particulates (aluminum, iron and manganese oxides and hydroxides, clay minerals, organic particulates). Alkalinity is primarily controlled by carbonates, and is usually expressed in terms of calcium carbonate ($CaCO_3$) equivalents (mg/l).

The range of pH reported for natural waters in Canada is generally between 3 and 10, while average pH for waters in Newfoundland and Labrador is between 5.3 and 8.0. Alkalinity for Canadian waters ranges from below detection limit (0.5 mg/l) to 750 mg/l. The range for Newfoundland is from 2 mg/l to 60 mg/l.

The Canadian guidelines for drinking water specify a range of pH between 6.5 and 8.5 in order to avoid corrosion and encrustation problems, and to avoid the formation of trihalomethanes when raw water is subjected to chlorination treatment. Adjustment of pH is feasible during water treatment processes. Waters for contact recreational use should fall in the range 5.0 to 9.0 to avoid any possibility of eye irritation. Water for industrial cooling uses should be in the range of 5-10, while the iron and steel industries require water between 5.0 and 9.0. The pulp and paper industry guidelines for pH are from 6 to 8 for corrosive considerations, while the food and beverage industries have varying requirements in the range from 6.5 to 8.5.

The map on the opposite page presents median data for surface water pH and average alkalinity, calculated over the number of years of record at each sampling station. The map shows that the pH of surface water is greatest on the west coast of the Island, in the Stephenville-Gros Morne region. This reflects the predominantly carboniferous bedrock characteristics of this area. Alkalinity patterns parallel those of pH, with highest values on the west coast, and lower values on the south coast, Burin and Avalon Peninsulas. These waters will be much more susceptible to acidification. Figure 23.1 shows monthly variations in pH and total alkalinity in Rennies River at Carrell Drive in St. John's. Reductions in alkalinity every spring may reflect the pulse of acidic runoff from snowmelt; the acids are neutralised by carbonates present in the water, thus lowering the alkalinity.

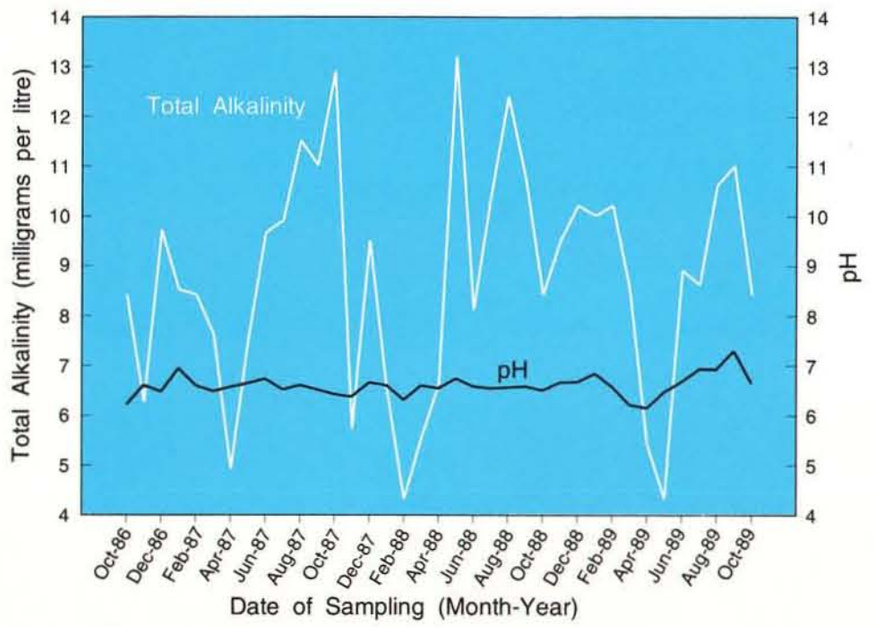
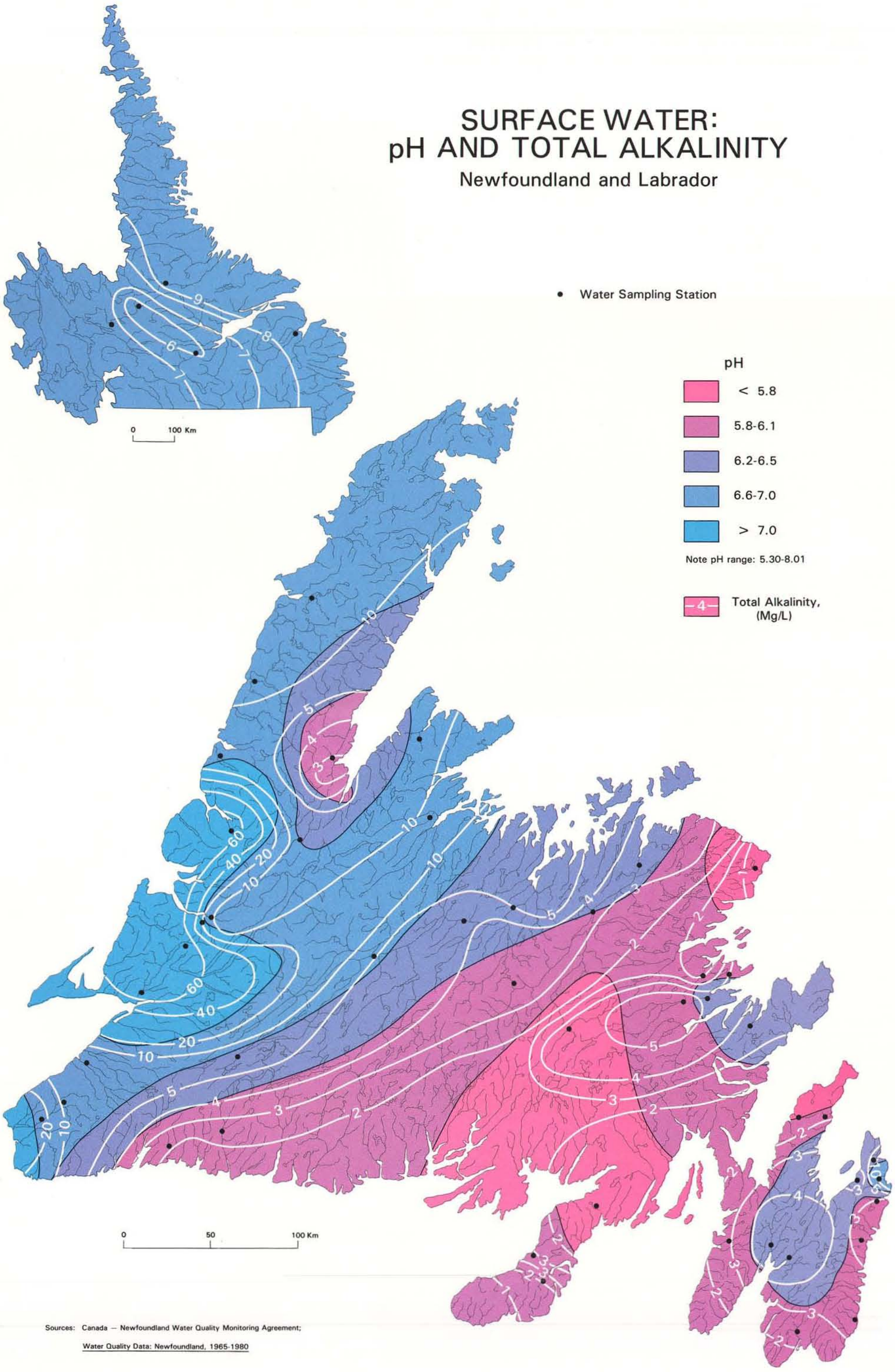


Figure 23.1 Monthly Variation in pH and Total Alkalinity in Rennies River

SURFACE WATER:
pH AND TOTAL ALKALINITY

Newfoundland and Labrador



Sources: Canada — Newfoundland Water Quality Monitoring Agreement;

Water Quality Data: Newfoundland, 1965-1980

24 – Sensitivity to Acid Rain

The ability of water to resist changes in pH, and in particular to resist acidification, is measured by its alkalinity. Alkalinity in most waters is determined by a number of dissolved substances, primarily calcium carbonate. Alkalinity is usually expressed in terms of calcium carbonate equivalents, either in milligrams per litre (mg/l) or in microequivalents per litre (µeq/l). Sensitivity of water to acidification caused by acid precipitation can thus be measured by alkalinity. The map on the opposite page shows the sensitivity of water in the province to acid rain in microequivalents of alkalinity. Water with an alkalinity below 60 µeq/l is generally regarded as extremely sensitive to acid precipitation, meaning that the water has little capacity to buffer any additional acid. Water with an alkalinity from 60-100 µeq/l is considered highly sensitive, while water with 100-400 µeq/l of alkalinity is progressively less sensitive to acidification. Water with an alkalinity greater than 400 µeq/l is not likely to suffer any reduction in pH from acid precipitation and should be able to completely buffer any added acid.

The sensitivity of an area to acid precipitation may also be judged on the basis of the underlying rocks. The geology of an area will strongly influence the buffering capacity of surface waters, since it is the substances dissolved from rocks in a drainage basin which provide the buffering capacity. Carboniferous rocks, such as limestone, can provide strong buffering capacity, while many other rocks such as granite are quite insoluble and provide little buffering capacity. The small inset map accompanying the main map shows sensitivity to acid precipitation based upon the nature of the underlying geology.

The major acidic constituent of acid rain is sulphur dioxide, or sulphate ion. It has generally been accepted that moderately sensitive aquatic ecosystems can tolerate a wet sulphate deposition rate of no more than 20 kilograms per hectare per year (kg/ha/yr). This is equivalent to rainfall with an average pH between 4.4 and 4.5. Extremely sensitive areas may tolerate only 15 kg/ha/yr of wet sulphate deposition before suffering significant effects. Areas of the south coast, central region, and Burin and Avalon peninsulas on the Island receive more than 15 kg/ha/yr, so extremely sensitive areas in these regions may suffer some acidification effects. The west coast, northeast coast, the Northern Peninsula, and most of Labrador receive less than 15 kg/ha/yr sulphate, and so sensitive areas in these regions will be less likely to show any acidification effects. Sulphate reduction efforts in Canada and the United States attempt to achieve levels of sulphur dioxide emissions which should protect sensitive target ecosystems. A maximum "target loading" level of 20 kg/ha/yr has been selected as a preliminary goal for such reduction programs, in order to maintain the pH of surface water above 5.3 for all but the most sensitive areas.

Acid deposition causes multiple stresses in aquatic communities. There are three general stages of lake acidification:

1. The first stage is characterised by decreased alkalinity, but the bicarbonate buffering system is maintained and pH levels stay above 5.5-6.0.

2. The bicarbonate buffer system is lost during longer periods of stress, and severe pH fluctuations occur.

3. The final stage is characterised by chronically depressed pH levels (below 4.7), and an elevation in toxic metal concentrations, especially aluminum.

The most noticeable effects of acidification have been documented for fish populations. Symptoms of acid stress in fish include physical deformities, reproductive inhibition, decreased growth, and subsequent depletion of fish stocks. Trout are highly susceptible to acid rain, with brook trout disappearing when the pH goes below 5.1. Restocking is unsuccessful due to effects on embryonic development. Atlantic salmon have declined in Nova Scotia recently in rivers with pH values below 5.0, and have disappeared in rivers with pH values below 4.7. It is estimated that one third of Nova Scotia's Atlantic salmon production has been lost through acidification. Shifts in species composition of fish communities with changes in pH have been documented for lakes both in North America and Europe. Tolerant fish species such as yellow perch become abundant in acidified lakes. Undoubtedly, these changes in fish stocks result in lake-wide alterations in predation patterns which subsequently affect plankton community structure.

Likewise, acidification directly affects much of the foodweb which supports fish production. The small, mostly unicellular plant species in aquatic communities, known as phytoplankton, provide the primary production for the community. Tiny animal species, known as zooplankton, live off the phytoplankton, and in some cases prey on each other. Zooplankton communities in acidified lakes become less complex with fewer species coexisting as acidity increases. Some groups, such as daphniids, are intolerant of increasing acidity and disappear at a pH of approximately 5.0. Indirect effects of acidification on zooplankton include changes in the thermal regime, changes in food abundance or quality, increased metal concentrations, and shifts in predation and competition patterns. Phytoplankton communities also exhibit decreased diversity with acidification. As primary production decreases, water transparency increases. Certain phytoplankton groups such as green algae and some diatoms tend to dominate in acidic lakes, while blue-green algae increase at higher pH. Generally, there is a decrease in overall lake productivity with acidification, and some acid-tolerant bottom plants such as sphagnum may increase. This further degrades available habitat for the remaining fish. Insect species which are important food resources for fish may also decline.

Acid deposition has effects on resources other than aquatic systems, although these have been more difficult to document. Forest decline and dieback has been attributed to both direct effects of acid rain, as well as indirect effects caused by increased susceptibility to insects and disease in trees. Quebec, for example, is experiencing widespread dieback of its extensive sugar maple forests, with circumstantial evidence pointing to air pollution including acid rain. The pollutants which cause acid rain also affect visibility through production of haze and smog. These pollutants affect materials in buildings, and there is increasing concern for potential effects on human health.

The map on the opposite page presents surface water data from the Canada-Newfoundland Water Quality Agreement and other sampling programs. It is clear that the most sensitive areas, as determined by surface water alkalinity, occur on the south coast, parts of the central and north-east coastal areas, and on the Burin and Avalon Peninsulas. The west coast and northern peninsula are well buffered, and hence much less sensitive. The limited data available for Labrador indicates that this region is moderately sensitive, although its location is sufficiently remote from major sources of sulphates. The area of most concern is along the south coast of the Island, where rivers and lakes of extreme sensitivity coincide with areas where the precipitation is likely to be acidic (below 4.5), and sulphate deposition greater than 15 kg/ha/yr.

The trend in sensitivity as represented by surface water alkalinity is generally confirmed by patterns of sensitivity based on geology. Areas of low sensitivity resulting from carboniferous rocks appear on the west coast of the Island, while areas of higher sensitivity are found on the south coast and north-east central regions.

SENSITIVITY TO ACID RAIN

Newfoundland and Labrador

Sensitivity Based on
Total Alkalinity

- Extreme
- High
- Moderate
- Low
- Nil

−20− Total Alkalinity
(Microequivalents per litre)

0 100 Km

Sensitivity Based on
Bedrock Geology

- High
- High to Moderate
- Moderate
- Low to Moderate
- Low
- No Data

0 100 Km

0 50 100 Km

Sources: Canada — Newfoundland Water Quality Monitoring Agreement;
Department of Fisheries and Oceans, Newfoundland Region;
Water Quality Data; Newfoundland, 1965-1980.

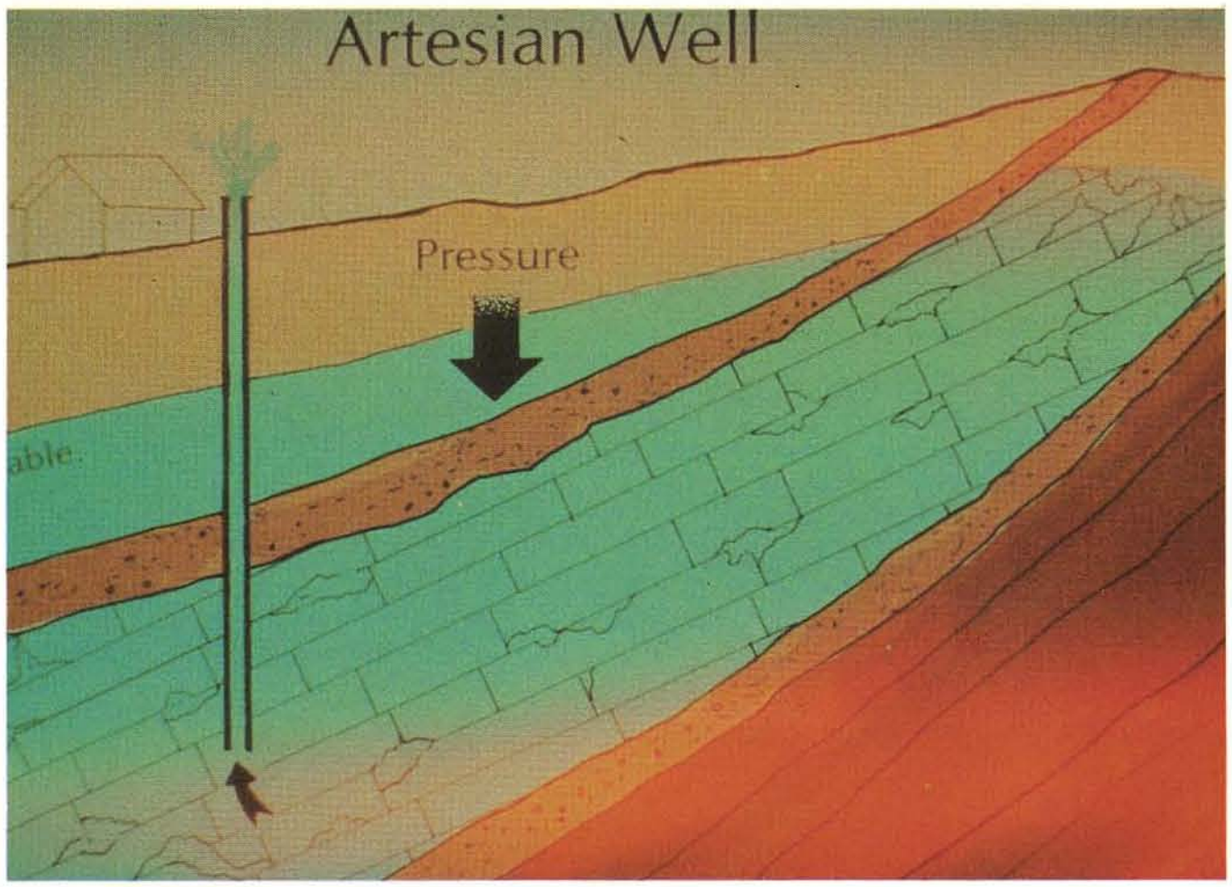
GROUNDWATER

Introduction

Below the surface of the earth lies a huge reservoir of water many times larger than the amount of water on the surface and in the atmosphere. Groundwater comes from precipitation which filters down into the soil until it reaches the water table. If the water moves through a geological formation at measurable speeds, and can be withdrawn at significant rates, this zone is called an aquifer.

Groundwater is important for two reasons. First, like surface water bodies, it feeds streams and rivers, sometimes sustaining flows during periods of low precipitation. Second, it can be intercepted by wells, thus supplying water to thousands of users in many communities.

The following two maps describe the distribution of water wells in Newfoundland and Labrador and the expected yield from various regions of the province.



Schematic of an Artesian Well

25 – Distribution of Water Wells, 1950 - 1988

The province has numerous ponds, lakes, and rivers that provide the major source of water for the population. About 29% of the population living in the smaller communities, however, relies on groundwater as a source of water. The main use of groundwater is for domestic purposes.

Most communities in the province are situated where bedrock is exposed or just below the surface, thus making the construction of community water and sewer systems very expensive. This, in addition to the "spread out" nature of houses in most communities, makes the use of water wells more economical. The groundwater obtained is generally of good quality, further increasing the advantage of water wells.

Groundwater is obtained from both dug and drilled wells. Dug wells are usually between 2 and 5 metres (m) deep, depending on the depth at which bedrock was encountered during construction. No data exists on the number of dug wells in the province. The dug wells draw upon water from the water-filled spaces between the grains of the overburden material. The porosity and permeability of overburden material, and hence the water yield, can be quite high where large grain sizes are encountered. In many locations the yield from sands, gravels, and glacial till overburden is much higher than the yield from wells drilled in bedrock. These high yield wells are found in the Codroy Valley, Bay St. George, and Deer Lake areas where the groundwater yield may vary from 20 to 140 litres per minute (l/min).

Approximately 750 wells are drilled every year in the province. More than 90% of these wells are drilled in bedrock and have an average depth of 60 metres. Fracture flow in the bedrock is the primary source of water into drilled wells. The yield of a drilled well is generally not as high as from an overburden or dug well due to the low porosity and permeability of bedrock compared with overburden material; most drilled wells yield between 3 and 10 l/min.

Figure 25.1 shows that the depths of most wells in the province are in the 30 to 45 m range. Figure 25.2 shows that the yield of wells in Newfoundland is usually less that 8 l/min. This is due to the fact that the majority of wells are located into low-yield bedrock aquifers.

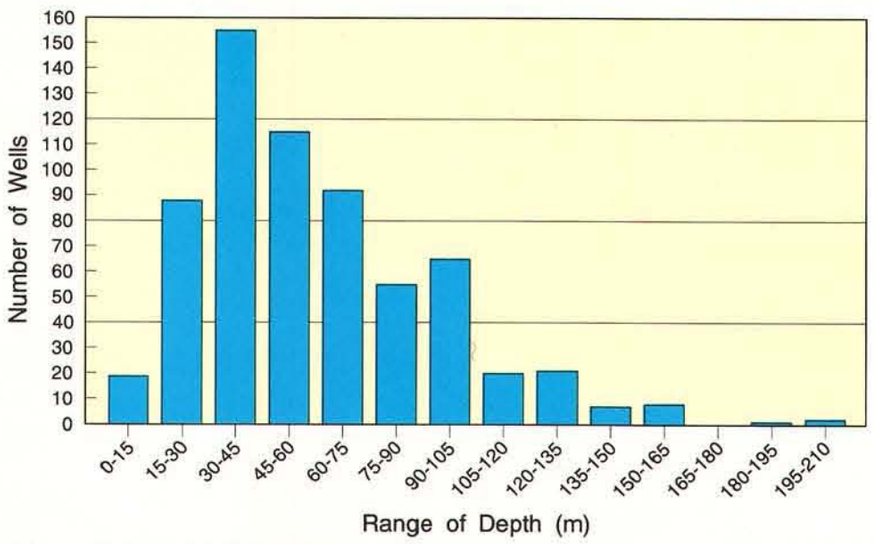


Figure 25.1 Well Depth Histogram

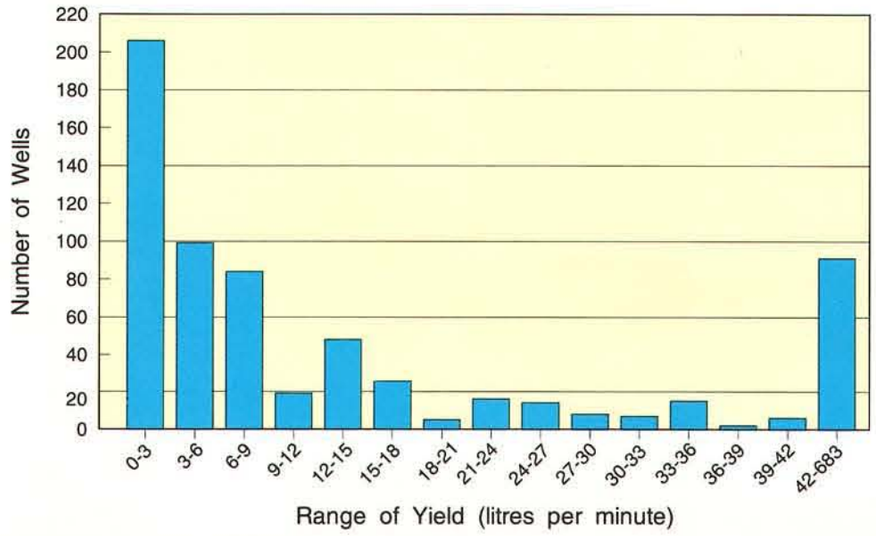


Figure 25.2 Well Yield Histogram

The map on distribution of water wells on the opposite page shows that the majority of drilled wells is located along the coasts of the province. The Avalon Peninsula has a high proportion of drilled wells because of higher population densities. Other areas where hig numbers of drilled wells exist are Notre Dame Bay, the Bonavista and Burin Peninsulas, and the Bay St. George area. Factors that influence the distribution of water wells are unfavourable site conditions for surface water supplies, inadequate surface water supply through existing services, and size and development patterns of communities.

Problems with the use of water wells include salt water intrusion of coastal aquifers, road salt contamination of wells in close proximity to a public road where salt is applied for ice control purposes, oil spills from leaking underground storage tanks, and septic tank contamination of wells situated close to the distribution fields.

The process of contamination of coastal wells due to salt water intrusion is shown schematically in Figure 25.3. During pumping, water is drawn to the well from every direction of the surrounding aquifer. If a salt water/fresh water interface exists within the radius of influence of the pumping well, this interface will be drawn toward the well. The higher the pumping rate, the closer the interface approaches the well. Pumping the well at very high rates can draw this interface into the well opening and contaminate the water being withdrawn. Owners of wells in salt water intrusion areas must keep the pumping rate of their well to a minimum to avoid this problem.

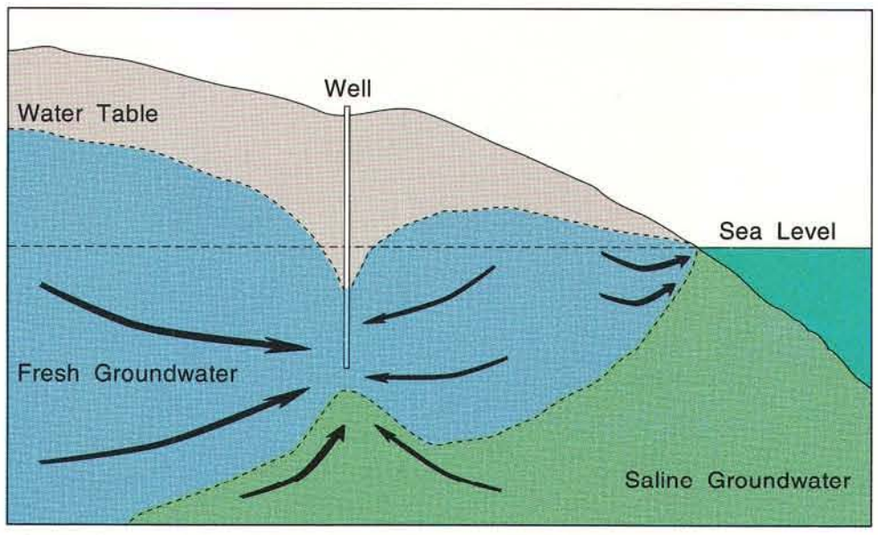


Figure 25.3 Salt Water Contamination of a Well

DISTRIBUTION OF WATER WELLS, 1950-1988

Newfoundland and Labrador

Number of Wells

- 1 - 10
- 11 - 20
- 21 - 40
- 41 - 70
- 71 - 110
- 111 - 200
- 548
- 1 038

Labrador City

0 100 Km

Sandy Cove
Flowers Cove
St. Anthony
Roddickton
Brent's Cove
Harbour Round
Change Islands
Fogo
Joe Batt's Arm
Brighton
Cottles Island
Leading Tickles
Pilley's Island
Summerford
Boyd's Cove
Fredericton
Point Leamington
Birchy Bay
Campbellton
Lewisporte
Cormack
Deer Lake
Norris Arm
Trinity
Gander
Grand Falls
Corner Brook
St. George's
Robinsons
Jeffrey's
Terra Nova
Plate Cove
Port Rexton
Bonavista
Elliston
Musgravetown
Bloomfield
Lethbridge
Clarenville
Bay de Verde
Port aux Basques
Burgeo
English Harbour West
Marystown
Green's Harbour
New Harbour
Dildo
Norman's Cove
Salmonier

0 50 100 Km

Gull Island
Western Bay
Salmon Cove
Victoria
Harbour Grace
Pouch Cove
Bauline
Flatrock
Torbay
Portugal Cove
Bell Island
St. John's
Spaniard's Bay
Bay Roberts
Port de Grave
Bareneed
Cupids
Clarke's Beach
Brigus
Colliers
Upper Gullies
Goulds
Harbour Main
Goal Cove
Conception Bay South
Avondale
Holyrood
Whitbourne
Bay Bulls
Tors Cove
Cape Broyle

0 25 Km

Source: Newfoundland Department of Environment and Lands,
Water Resources Division.

26 – Groundwater Yield from Bedrock

The information on groundwater yield from various regions of the province, shown on the map on the opposite page, was summarized from a series of eight reports prepared by consulting firms on contracts with the Department of Environment and Lands. Figure 26.1 shows the areas of the Island to which the reports pertain. These reports were based on data contained in well drilling records prepared by local well drillers, and hydrogeological investigations that may have been done in the development of municipal water supply systems. The bulk of the information was derived from well drilling records.

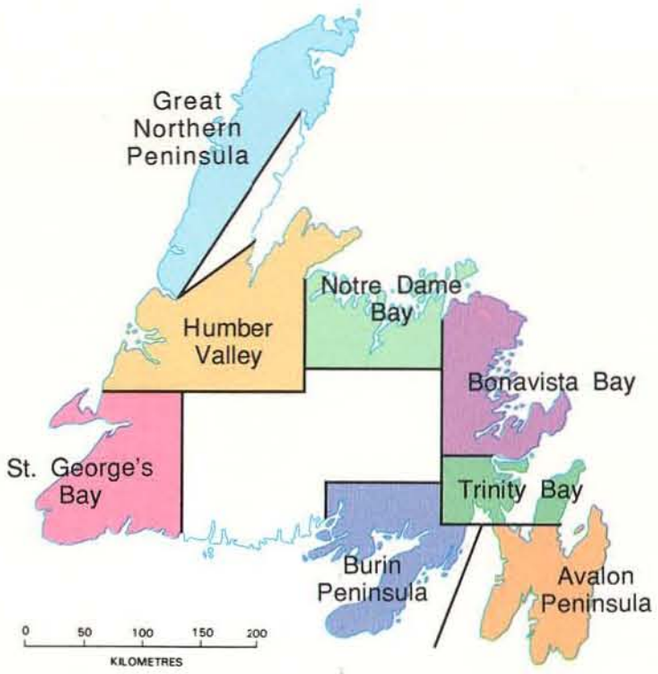


Figure 26.1 Areas Covered by Hydrogeological Reports

Since the first hydrogeological report was completed in 1979 the number of well records received from well drillers has increased every year. Before 1983 well records were submitted voluntarily by well drilling companies. After the passage of the Well Drilling Act in 1983 the number of records submitted rose dramatically.

The bedrock hydrostratigraphic maps prepared for each area covered by the hydrogeological reports were combined to form a hydrostratigraphic picture of the whole Island. As shown in Figure 26.1, some interior areas of the Island and all of Labrador were not covered by the mapping due to a lack of groundwater related information. In the preparation of the map on groundwater yield these areas were mapped using the average yield results derived for the bedrock formations of the areas that were covered.

Groundwater is an integral part of the hydrologic cycle. It has been estimated that on a world wide basis, groundwater makes up about 98% of all liquid fresh water. This may seem inconsistent with the appearance of bedrock as a solid-looking material. Bedrock, however, contains a matrix of major, small, and hairline microfractures. The volume of these open spaces in the apparently solid rock, expressed as a percentage of the total rock volume, is called porosity, and determines the volume available for storage of water. In any geologic material zones which are able to yield usable quantities of groundwater are called aquifers. This ability depends not only on the porosity, but perhaps more importantly, on the permeability of the rock. Permeability is a measure of the ability of the material to transmit water.

The groundwater yield map shows that aquifers exist beneath most land areas of Newfoundland. It has not been possible, with the data available, to map out individual aquifers in the bedrock. Such distinct zones exist, no doubt, but much more data on porosity and permeability would be required to identify them. The approach which has been utilized in the production of this map was to group geologic formations according to their yield characteristics as reported from the available well records. Using this single criterion various rock types having similar yield characteristics were included together in the same grouping. Three categories of yield, namely, low yield with a mean value of 12 litres per minute and suitable for domestic purposes, moderate yield with a mean value of 27 litres per minute and suitable for small communities, and high yield with a mean value of 58 litres per minute and suitable for larger municipal and industrial supplies, were chosen for illustration on this map.

In many rocks such as granite and shale primary openings are very small. Groundwater flow through such voids may take years. In addition to the primary openings there are four other major conduits in bedrock through which groundwater moves. These are depicted in Figure 26.2. These major void spaces are formed after the rock has formed, and are called secondary openings. Although movement in these flow paths may be relatively unimpeded it is usually very tortuous. Solution channels, in contrast to fractures, are only common in soluble rocks such as limestone. Developing a dependable well in bedrock with large primary openings is usually quite easy. Such formations, however, are not common in Newfoundland. Developing a dependable well in bedrock which has low primary porosity depends on intercepting one or more of the secondary openings; the attempt may not always be successful.

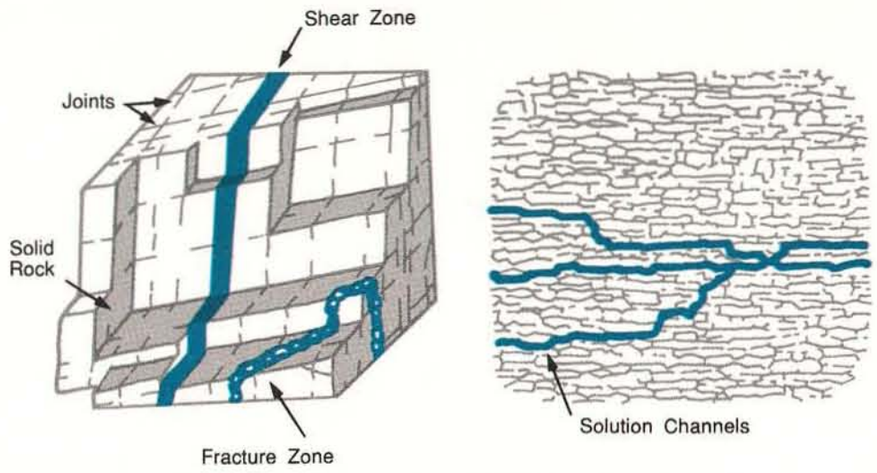
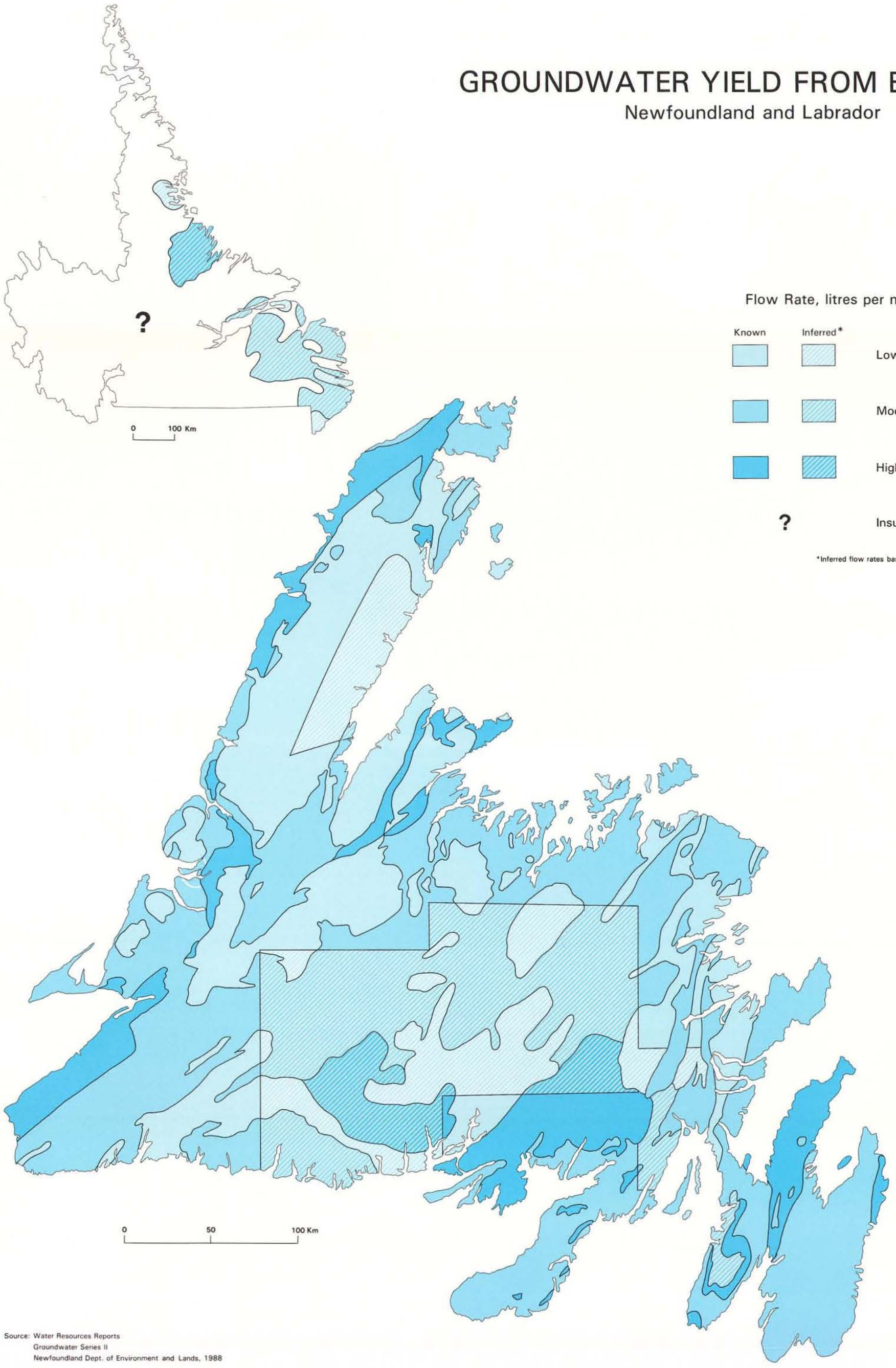


Figure 26.2 Major Groundwater Conduits in Bedrock

GROUNDWATER YIELD FROM BEDROCK

Newfoundland and Labrador



Flow Rate, litres per minute (Lpm)

Known	Inferred*	
		Low Yield mean – 12 Lpm range 1 – 136 Lpm
		Moderate Yield mean – 27 Lpm range 1 – 454 Lpm
		High Yield mean – 58 Lpm range 1 – 545 Lpm

? Insufficient Data

*Inferred flow rates based on geology.

Source: Water Resources Reports
Groundwater Series II
Newfoundland Dept. of Environment and Lands, 1988

WATER USE

Introduction

The accessibility and frequent replenishment of water stored in lakes, reservoirs, and streams make surface water the most important source of supply for our municipal and industrial needs. In addition, the mountainous topography of some regions of the province, combined with the relatively high amounts of precipitation, has meant that Newfoundland derives a significant amount of its energy needs from water. Last, but not least, rivers and lakes provide outlets for recreational activities such as boating, swimming, fishing, and also enhance the aesthetic quality of campgrounds, picnic sites, and hiking trails.

The final section of the Atlas presents maps which describe some of the more significant uses of water in the province. Since many of these uses require the flow of water to be controlled by means of dams, the first map in this section describes the distribution and purpose of some of the major dams in the province.

Rivers and lakes in Newfoundland have tremendous recreational potential.

27 – Distribution of Dams

Early man settled near lakes and rivers where there was a suitable supply of drinking water. Later dams were constructed to impound or divert water to maintain a constant water supply for domestic and irrigation purposes. Dams, no doubt, have played a very important role in the development of civilization by allowing relatively large numbers of people to live in close proximity. Ruins in Egypt, the Middle East, India, and China indicate that dams have been in use for at least the past 5000 years.

Dams are constructed for a variety of purposes. Some of the more common uses of dams include water impoundment or diversion for the following: municipal and domestic water supply, irrigation and livestock water, hydroelectric developments, streamflow regulation including high and low flows, industrial uses, and recreational uses.

Dams are diverse structures which may be classified based on size: small and large; function: storage, diversion, and detention; hydraulic design: overflow and nonoverflow; construction material: earth, rock, and concrete; structural design: gravity, arch, etc. The selection of a particular type of dam is largely governed by the purpose, local conditions, and the cost of construction.

In Newfoundland the primary uses of dams are for water impoundment and diversion for hydroelectric development, for water detention to permit log driving in the forestry sector, and for water impoundment for a municipal supply. The map on the opposite page shows the distribution of 470 dams in the province. About 190 dams are used for hydroelectric development. About 200 are used in the forestry industry. Most of the dams in the "Other" class are used for municipal water supplies.

Because Newfoundland has a natural abundance of water its electrical energy requirements are met almost exclusively through hydropower. There are about 45 dams constructed at large-scale hydroelectric development sites and about 145 dams on small-scale hydroelectric development sites. For the province, large-scale can be defined as having a capacity exceeding 40 megawatts. Figure 27.1 shows an example of a large hydro dam in the province. Because of local topography, the large-scale developments are located in western and southern Newfoundland. The largest, Churchill Falls, is located in western Labrador. Most of the small-scale hydroelectric developments are located on the Avalon Peninsula. Figure 27.2 shows an example of a small hydro dam.

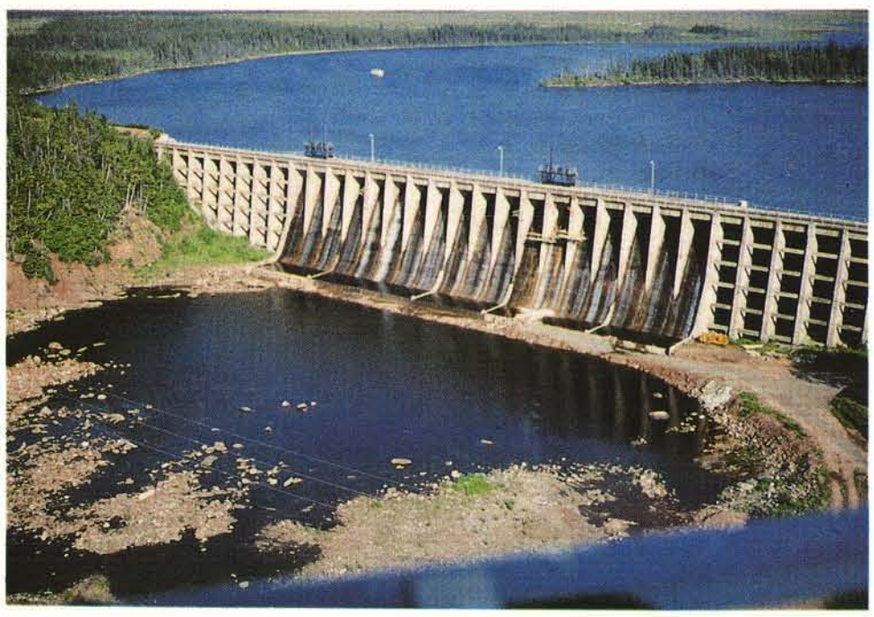


Figure 27.1 Large Hydro Dam on Deer Lake

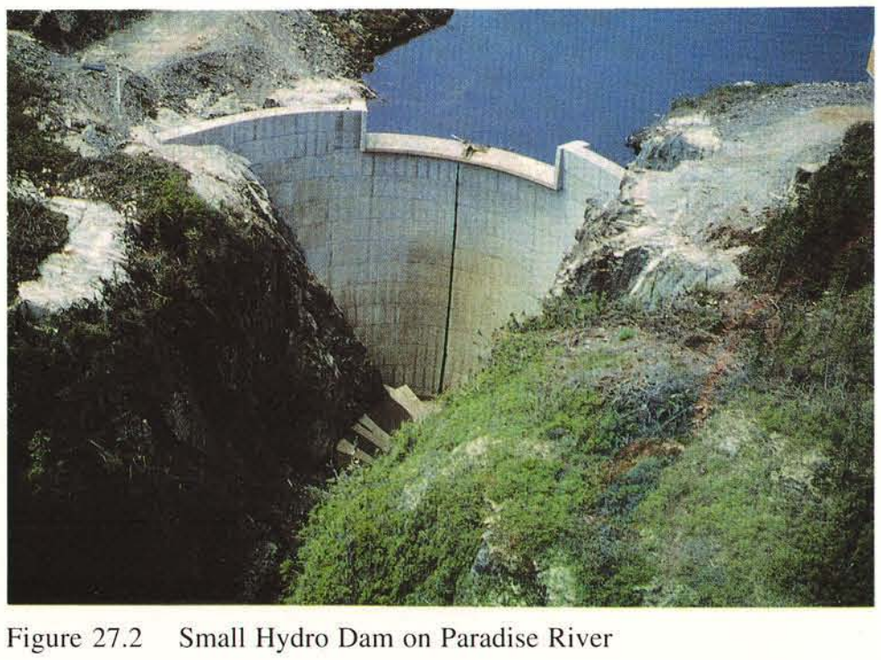


Figure 27.2 Small Hydro Dam on Paradise River

In the forestry sector rivers are sometimes used as an economical transportation system for logs. Rapids are encountered along some sections which result in log jams because of the low depths of flow. Small dams are sometimes constructed to raise and maintain the water level in these areas to allow the floatation of logs downstream. In order to permit the passage of logs these dams are usually designed for flow over their top. Most of these dams are located in central and western Newfoundland near the two major pulp and paper mills in Grand Falls and Corner Brook.

In Newfoundland municipal water supply is usually taken from a nearby pond, lake, or river. In some instances the water supply is inadequate to meet community needs for drinking, bathing, fire fighting, etc. In situations of inadequate water supply a small dam is constructed across a river channel, or at the outlet of a pond or lake, to provide additional storage for municipal uses. These dams are numerous and are located near the communities that they serve. Figure 27.3 shows an example of a municipal dam.

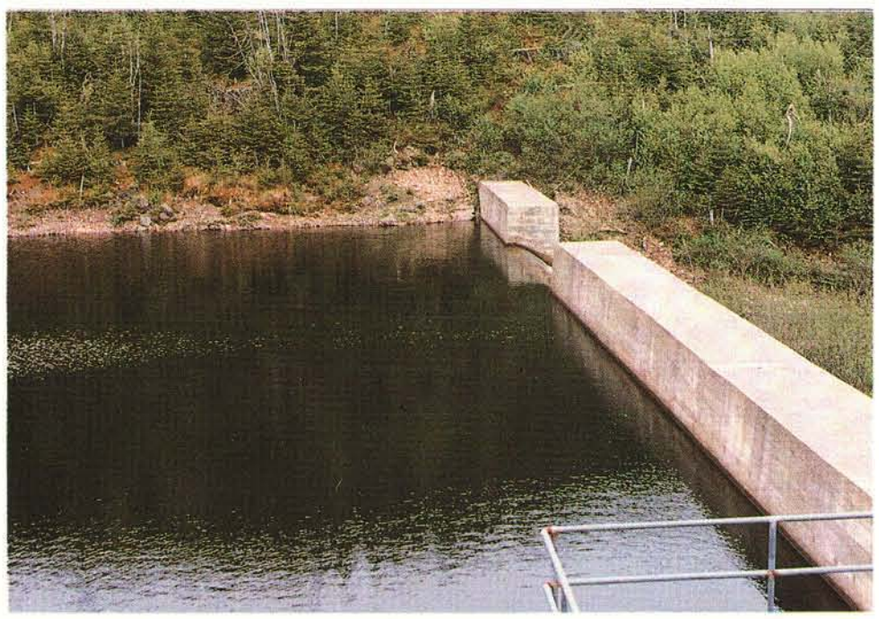
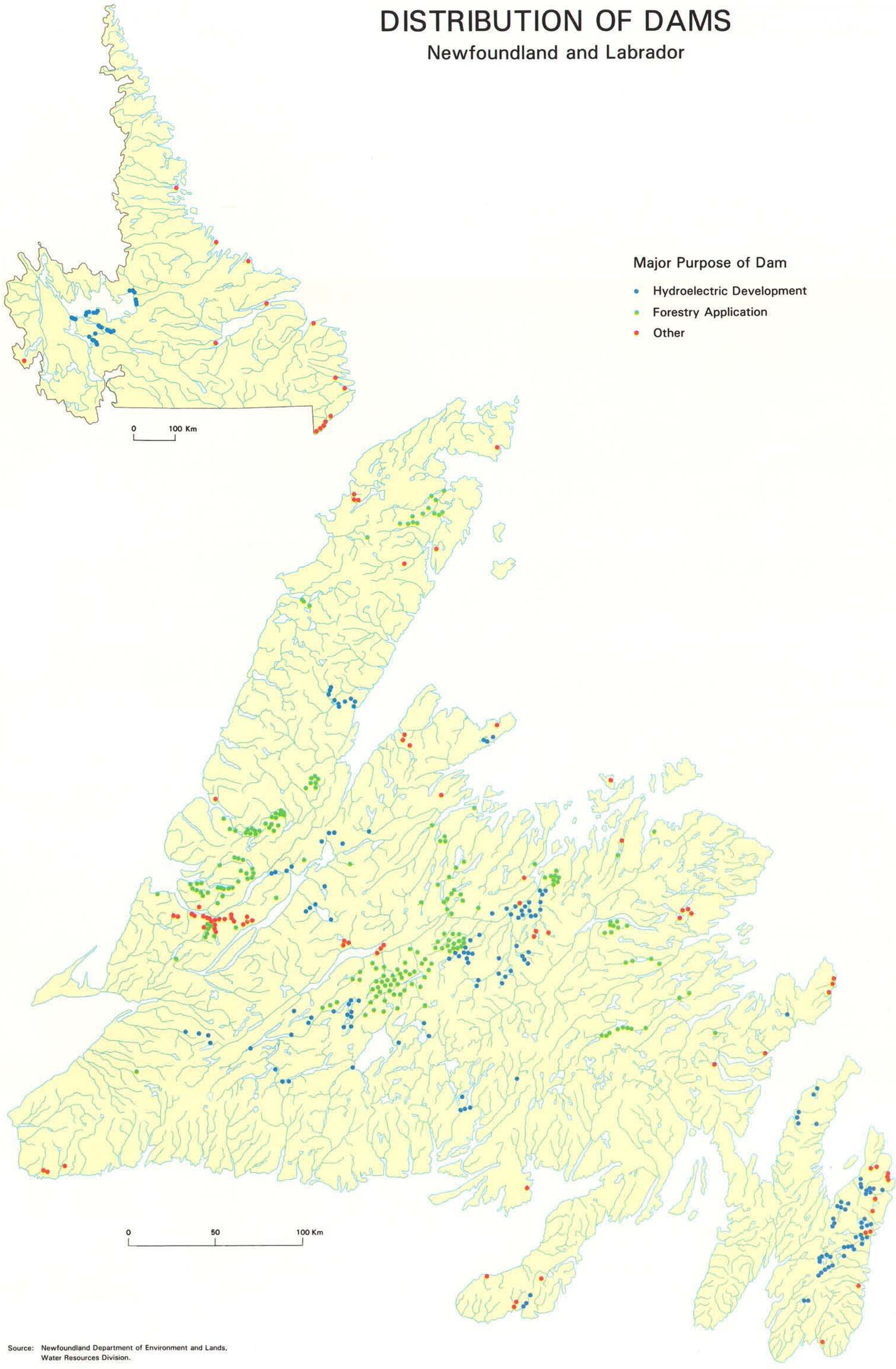


Figure 27.3 Municipal Dam for Arnolds Cove's Water Supply

DISTRIBUTION OF DAMS

Newfoundland and Labrador



Source: Newfoundland Department of Environment and Lands, Water Resources Division.

28 – Municipal Water Supplies

According to the 1986 census, the total population of the province is 568,349. Of this total, 539,608 live on the Island and the remaining 28,741 in Labrador. The distribution of communities for selected population sizes is shown in Figure 28.1. Geographic distribution of the population indicates that 90% of the population is concentrated along the coasts.

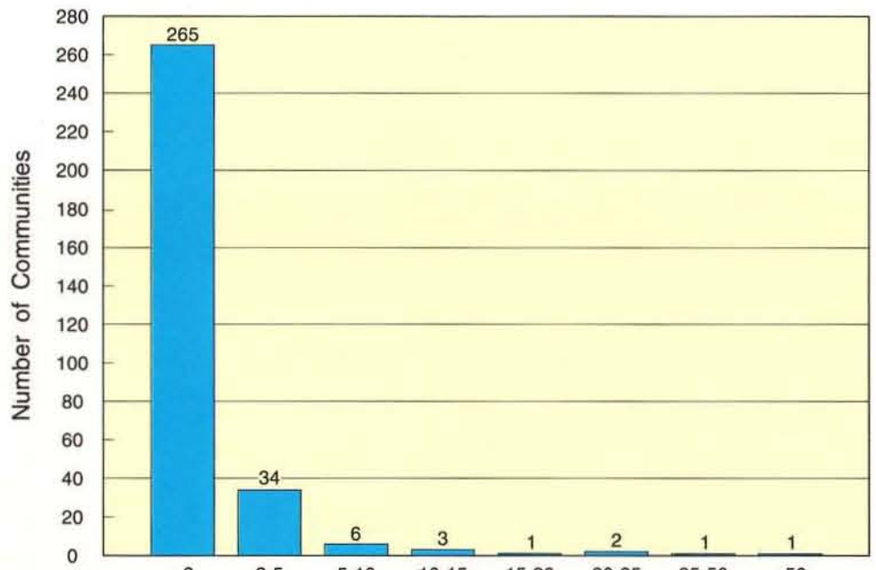


Figure 28.1 Distribution of Community Sizes on the Island of Newfoundland

Approximately 85% of the total population is serviced by municipal water supply systems, while the remaining 15%, living in smaller communities, generally relies upon groundwater wells. Municipal water supply services for the other Atlantic provinces are reported to be 90% for New Brunswick, 95% for Nova Scotia and 81% for Prince Edward Island.

Surface water constitutes the primary source of water for domestic and municipal uses as well as for other purposes. The surface water supply systems generally receive water either from natural lakes or ponds or directly from streams and rivers. Because of unfavourable hydrogeologic conditions, and consequent low well yield, the use of groundwater is generally limited to individual homes, though in some cases wells provide water for small communities. There are 332 municipal water supply systems in the province, of which 294 use surface water sources and 38 use groundwater. Design capacities of surface water supply systems range from 44 m^3/day to 65,461 m^3/day, while capacities of groundwater based systems range from 21 m^3/day to 2272 m^3/day. A breakdown of the number of systems for each design capacity range is shown in Figure 28.2. In most of the systems chlorination is the commonly used treatment.

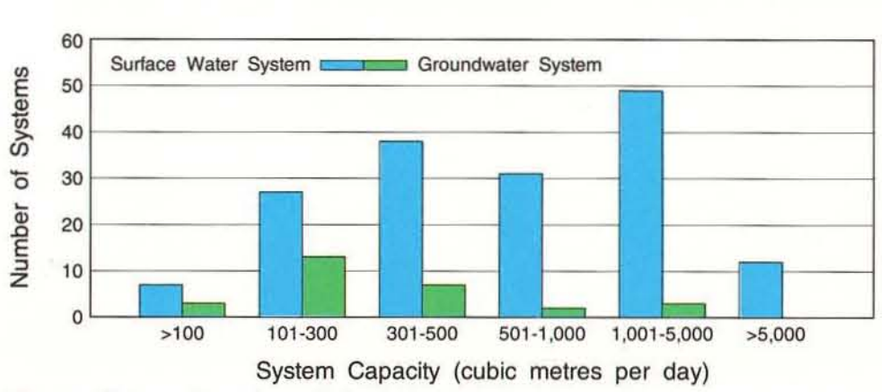


Figure 28.2 Capacity of Municipal Water Supply Systems

Municipal water supplies are used to meet domestic (residential, commercial, and institutional) and, in a few cases, industrial water needs. In Newfoundland fish plants are the major industrial demand sector; some of these plants have their own water supply systems while others meet their demand through municipal water supplies. The per capita municipal water use in the province ranges from 410 litres/day in rural communities to 820 litres/day in urban centres. Average municipal water demand for other Atlantic provinces is reported to be 528 litres/capita/day for Prince Edward Island, 705 for Nova Scotia, and 1433 for New Brunswick.

Water supply sources are adequate to meet the present and future water demands of the province. There are some areas where supply-demand ratio is less than one and water supply is critical during low flow periods. Water shortage problems can be overcome, in most cases, by some structural modifications to upgrade the storage facilities.

Water quality of surface and groundwater is generally good. Levels of colour, turbidity, iron, and manganese in a few sources of water supply are sometimes higher than desirable. In areas such as the Northern Peninsula water tends to be harder because of underlying limestone formation units, while in other areas it tends to be soft with low pH, as discussed in the text accompanying the Bedrock Geology map (Map 3).

Municipal water users in Newfoundland pay for their water consumption on a flat rate basis fixed by individual municipalities. According to a recent survey, water charges are in the range of $84 to $212 per year with a typical value being $140, which is comparable to the Environment Canada Survey (1989) figure of $129 per year. This annual charge does not take into account the capital cost of the facility and the economic value of water.

The map on the opposite page shows the communities served by municipal water supplies along with protected water supply areas. Section 26 of *The Department of Environment and Lands Act* authorizes the Department to designate public water supply areas as protected areas where resource development activities having potential to impair water quality are not permitted. One hundred ninety seven water supply areas in the province have so far been designated as protected water supply areas. Figure 28.3 shows the source of water supply for one of the protected water supply area.

Figure 28.3 Water Supply Source of a Protected Area

MUNICIPAL WATER SUPPLIES

Newfoundland and Labrador

Groundwater Supplies

- Municipality (over 500 people)
- Protected groundwater zone

Surface Water Supplies

- Municipality (over 1000 people)
- Municipality with protected watershed
- Major protected watershed

Nain
Wabush
Labrador City
North West River
Happy Valley-Goose Bay
Cartwright
Forteau
0 100 Km
Flower's Cove
St. Anthony
Goose Cove East
Plum Point
Roddickton
Englee
Port au Choix
Bellburns
Parson's Pond
Cow Head
St. Pauls
Rocky Harbour
Norris Point
Glenburnie
Sop's Arm
Pollards Point
Hampden
The Beaches
Baie Verte
La Scie
Shoe Cove
Silverdale
Beaumont-Lushes Bight
Pilley's Island
King's Point
Miles Cove
Springdale
Robert's Arm
Triton-Jim's Cove-Card's Harbour
Cottrell's Cove
Twillingate
Purcell's Harbour
Herring Neck
Tizzard's Harbour
Newville
Chanceport
Summerford
Fairbank
Port Albert
Stoneville
Musgrave Harbour
Deadman's Bay
Lumsden
Newtown
Wesleyville
Valleyfield-Pool's Island
Greenspond
Comfort Cove-Newstead
Carmanville
Main Point-Davidsville
Gander Bay South
Birchy Bay
Loon Bay
Campbellton
Embree
Point Leamington
Phillips Head
Lewisporte
Northern Arm
Botwood
Norris Arm
Indian Bay
Centreville-Wareham
Trinity
Glenwood
Gander
Benton
Hare Bay
Dover
Bishop's Falls
Grand Falls
Windsor
Badger
Buchans
Buchans Junction
Gambo-Dark Cove-Middle Brook
Glovertown
Happy Adventure
Sandy Cove
Eastport
Keels
Bonavista
Elliston
Catalina-Port Union-Melrose
Plate Cove East
Port Blandford
Milton
Burgoynes Cove
Shoal Harbour
Lower Lance Cove
Clarenville
Hickman's Harbour
Southport
Lead Cove-Sibleys Cove
Old Perlican
Bay de Verde
New Perlican
Heart's Content
Heart's Desire
Heart's Delight
Whiteway
Arnold's Cove
Grand Le Pierre
Bellevue
Thornlea
Broad Cove-Dildo
Chapel Arm
Whitbourne
Jerseyside
Dunville
Placentia
St Catherines-Mt. Carmel-Mitchell's Brook
St. Bride's
Gaskiers-Point La Haye
Fermeuse
Renews
St. Vincent's-St. Stephen's-Peter's River
Cappahayden
Trepassey
Bay L'Argent
Belleoram
Harbour Breton
Gaultois
Hermitage-Sandyville
Grey River
Francois
Ramea
Burgeo
Channel-Port aux Basques
Isle aux Morts
Margaree
Rose Blanche
La Poile
St. Jacques-Coomb's Cove
Parkers Cove
Rushoon
Garnish
Marystown
Burin
Grand Bank
Fortune
Lawn
Little St. Lawrence
St. Lawrence
0 50 100 Km
Lourdes
Piccadilly Head
Berry Head
Stephenville
Stephenville Crossing
St. George's
Cape St. George
Felix Cove-Aguathuna
Port au Port West
Milltown-Head of Bay d'Espoir
St. Alban's
Morrisville
Conne River
Hant's Harbour
Winterton
0 25 Km
Salmon Cove
Victoria
Freshwater
Carbonear
Harbour Grace
Pouch Cove
Bauline
Flat Rock
Portugal Cove
Torbay
Wabana
Outer Cove-Middle Cove-Logy Bay
Spaniard's Bay-Bay Roberts
Windsor Lake
St. Phillips
St. Thomas
St. John's
South River
Cupids
Brigus
Donovans
Petty Harbour/Long Pond
Reservoirs St. John's Water Supply
Colliers
Conception Harbour
Chapel Cove-Harbour Main-Lakeview
Avondale
Holyrood
Bay Bulls Big Pond
Bay Bulls
Witless Bay
Cape Broyle
Aquaforte
Ferryland

Source: Newfoundland Department of Environment and Lands, Water Resources Division.

29 – Hydroelectric Developments

Newfoundland has tremendous hydroelectric power generation potential because of the rugged landform, abundant and evenly distributed precipitation, and consequently large flows. Hydroelectric power plants utilize the energy of flowing water combined with a difference in water level elevations. Hydroelectric power was first generated on a large scale early in the century by the two pulp and paper companies at Grand Falls on the Exploits River and Deer Lake on the Humber River. The generation and distribution of power for domestic and other purposes was done by various smaller companies which were amalgamated in 1966 into one company known as Newfoundland Light and Power Company Ltd.

The Newfoundland and Labrador Hydro Act, 1975, makes the Crown Corporation, Newfoundland and Labrador Hydro, responsible for the generation, distribution, and sale of all hydropower in the province subject to the existing rights of a few companies. Newfoundland and Labrador Hydro is the parent company of the hydro group of companies, comprising of Newfoundland and Labrador Hydro, Churchill Falls (Labrador) Corporation Ltd., Lower Churchill Development Corporation Ltd., Gull Island Power Company Ltd., and Twin Falls Power Corporation Ltd.

As shown on the map on the opposite page, a significant number of drainage basins on the Island contributes water for generation of hydroelectric power. The Bay d'Espoir development, operated by Newfoundland and Labrador Hydro, is by far the largest (604 MW) followed by the Deer Lake plant (124.7 MW). In contrast to the Island, hydroelectric power development in Labrador started in the mid-1950's. The Churchill Falls hydroelectric power generating station, the largest underground power facility in the western world, has a gross capacity of 5428 MW. The power generated at this station is exported to Quebec under the terms of the agreement between Newfoundland and Hydro Quebec.

There are 39 hydropower plants in the province (see Appendix) with a gross power generating capacity of 6853 MW. The gross or installed capacity describes the size of a power plant in terms of its potential to produce electricity. Eight hydroelectric plants with a total capacity of 899 MW are being operated by Newfoundland and Labrador Hydro. The Newfoundland Light and Power Company is responsible for 22 plants on the Island with a total capacity of 84 MW. Three plants owned by the Abitibi-Price (Nfld.) Pulp and Paper Ltd. have an installed capacity of 63.5 MW. Two plants operated by the Deer Lake Power Company have a capacity of 134 MW. The Twin Falls Power plant was mothballed after the completion of the Churchill Falls plant, while the Iron Ore Company has been operating the Menihek plant which has an installed capacity of 18.7 MW since 1954. The first small-scale hydroelectric plant with a capacity of 150 KW, located in Labrador, is operated by Mary's Harbour Hydro of Clarenville. Figure 29.1 shows the installed generating capacity of hydroelectric plants operated by various agencies in the province.

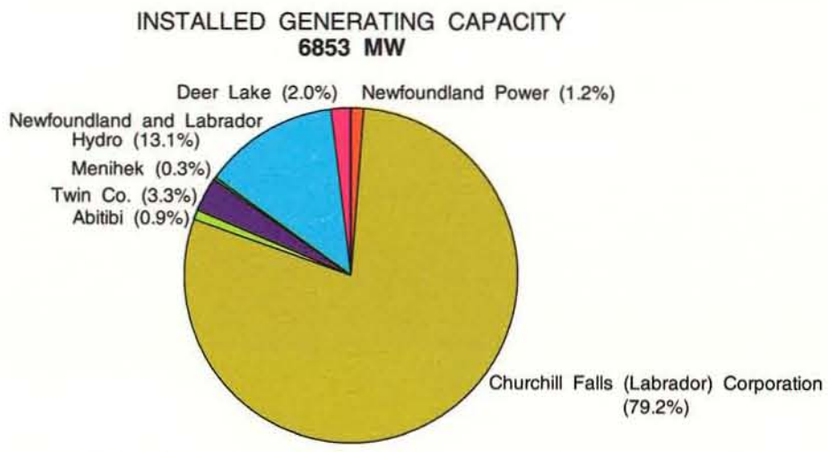


Figure 29.1 Installed Generating Capacity of Hydropower Plants

The average annual water use by the various power companies is shown in Figure 29.2.

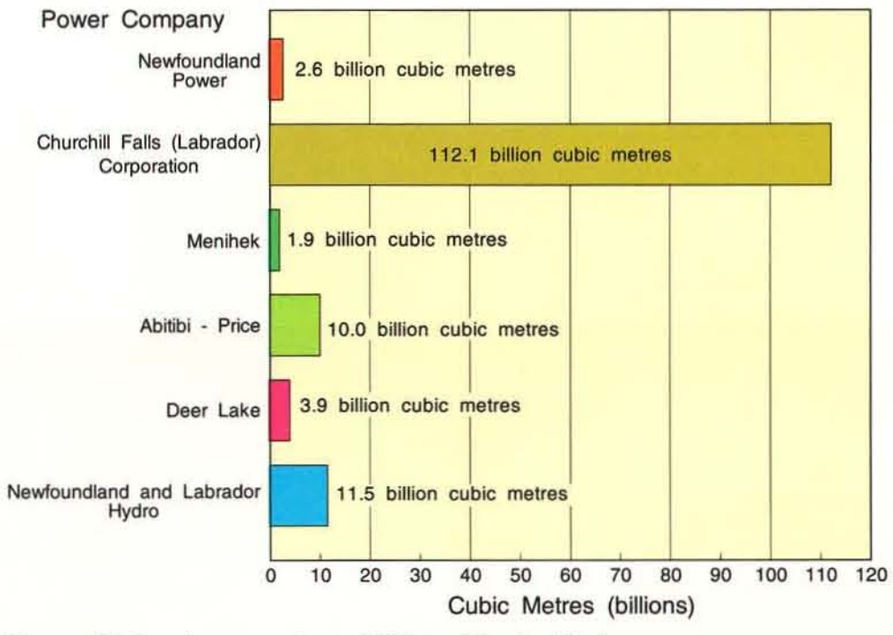


Figure 29.2 Average Annual Water Use by Hydropower Companies

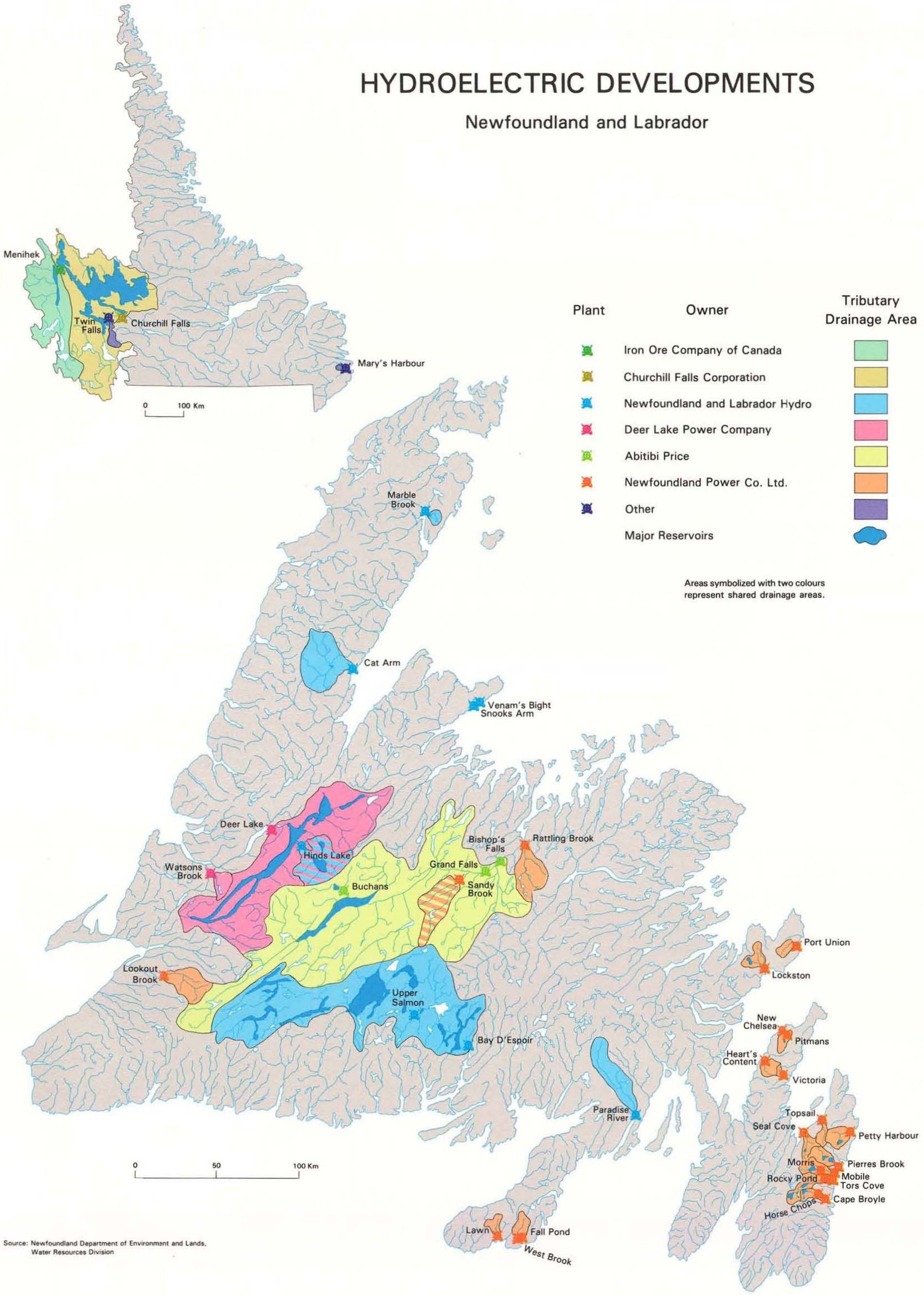
Newfoundland and Labrador Hydro also operates 36 thermal (diesel/gas/wood chip) plants which serve nearly 30,000 customers living in rural and isolated communities. The most significant thermal plants are Holyrood (diesel/gas) and Roddickton (wood chip) which accounted for 34% of the gross Island interconnected energy supply by Newfoundland and Labrador Hydro in 1990.

Although the economically feasible hydroelectric potential of the Island is almost exhausted, a few large scale possibilities still remain which may be developed sometime in the future. Numerous small scale hydroelectric schemes (1 MW to 20 MW capacity) have been identified which may be developed by private developers since Newfoundland and Labrador Hydro has relinquished its franchise rights for hydro projects of 10 MW capacity or less. There is a tremendous potential to develop hydroelectric power in Labrador. Future development of large hydroelectric projects in Labrador will depend upon the province's ability to economically develop and export the energy through Quebec.

The value of the large block of developed hydroelectric potential of the Island needs to be given prominence as it has contributed very significantly to the development of the industrial base of the province. Due to the inherent difference between hydro and thermal technology and the renewable nature of water resources, the operating and maintenance costs of hydropower tend to be virtually inflation proof and relatively lower than the costs of thermal power. Utility experience, over recent years, has shown that variable operating and maintenance costs of hydro plants are about 30% of the thermal plants, while the fixed operating and maintenance costs of thermal plants, on a $/KW basis, are typically twice that of hydro operations.

HYDROELECTRIC DEVELOPMENTS

Newfoundland and Labrador



Plant	Owner	Tributary Drainage Area
	Iron Ore Company of Canada	
	Churchill Falls Corporation	
	Newfoundland and Labrador Hydro	
	Deer Lake Power Company	
	Abitibi Price	
	Newfoundland Power Co. Ltd.	
	Other	
	Major Reservoirs	

Areas symbolized with two colours represent shared drainage areas.

Source: Newfoundland Department of Environment and Lands, Water Resources Division

30 – Industrial Water Use by Source

Surface water constitutes the main source of water supply for industrial purposes in the province. The use of groundwater is generally limited to areas where yields are high. The largest withdrawal demand for water on the Island is for the pulp and paper industry; in Labrador, it is for the mining industry. The total fresh water intake for industrial uses amounts to about 350 million cubic metres/year. Amongst other small industrial users, fish processing plants are the main users of water. Average annual water use, including both fresh and salt water, by major industries in the province is shown in Figure 30.1.

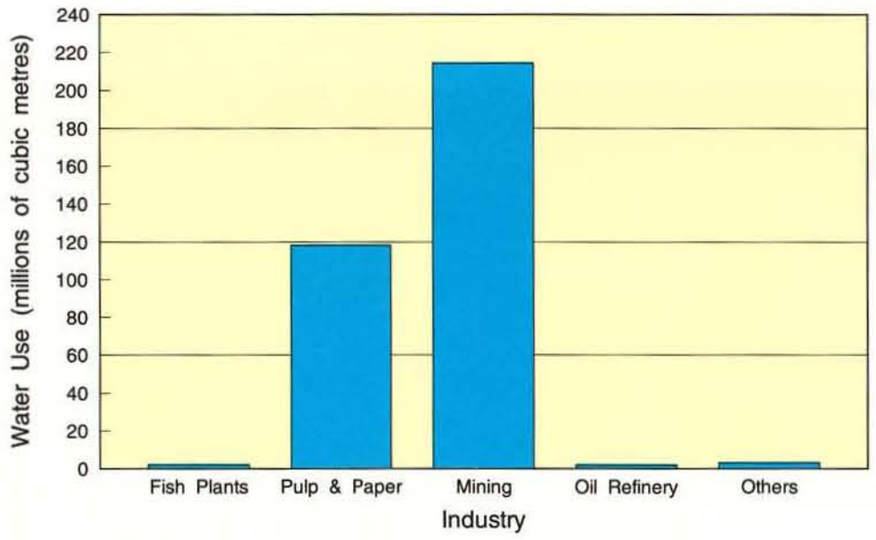


Figure 30.1 Average Annual Water Use by Major Industries

FISH PROCESSING INDUSTRY

Fishing in the abundant water surrounding the coast of Newfoundland dates back to the 16th century. Despite diversification of the province's resource based economy with the development of the forestry and mining industries, the fishery has retained its predominance due to multi-species resource base. Its annual contribution to the province's Gross Domestic Product is approximately 5% and employs more than 20% of the province's workforce.

The fish processing sector is comprised of 219 plants, with 104 engaged in the production of frozen products. Both fresh and sea water are used for various purposes and the water demand varies widely depending on the type of product and in-plant technology. The average water use by a fish processing plant, during its peak production, is estimated to be 10,000 m^3/year for various processes. Figure 30.2 shows the percentage of water usage from different sources by fish plants in the province.

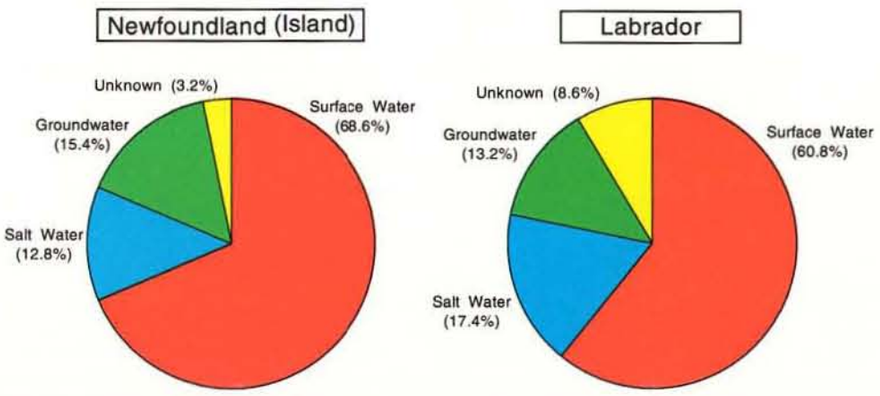


Figure 30.2 Source of Water Used by Fish Plants in the Province

OIL REFINERY

The refinery at Come By Chance is the only oil refinery in the province. It has a daily production capacity of 105,000 barrels/day. Water usage in refineries varies with the process used, type of cooling, recycling, and quality of water. On average, the refinery at Come By Chance uses 4864 m^3/day. The water is extracted from Inksters Pond. The wastewaters with a temperature of about 21°C to 24°C are lagooned before disposal.

MINING INDUSTRY AND MINERAL PRODUCTION

Newfoundland produces about 37.5% of Canada's iron ore, 3.5% of its copper, 9.5% of its lead, and 8.5% of its zinc. Despite the fact that mining is the major primary resource of the province, no smelting and refining activity takes place, and concentrates of copper, lead, zinc, and iron are shipped to smelters outside the province.

The water usage per tonne of output is dependent upon the type of mining operation and the extent of recycling. The average annual water use by the mining industry is about 215 million cubic metres. Iron Ore Company of Canada uses about 91% of the total water used by this sector followed by Wabush Mines using about 8.1% while the remaining 0.9% is being used by smaller mining activities.

PULP AND PAPER INDUSTRY

The pulp and paper industry accounts for approximately 75% of the economic activity of the province's forest sector. Approximately 1.77 million hectares (63%) of the productive forest area on the Island is controlled by two companies having three pulp and paper mills located in Corner Brook, Grand Falls, and Stephenville. The Corner Brook mill is owned by Kruger Inc., while the other two are owned by Abitibi-Price Inc. These mills have a total production capacity of 754,000 tonnes and provide employment for about 1% of the workforce.

The water requirements of these mills vary appreciably with the process used. Processes such as de-barking frequently use untreated water whereas paper making and bleaching require water of good quality. Average annual water consumption values are as follows:

Name of Company	Source of Water	Debarking (m^3/s)	Processing (m^3/s)	Avg. Annual Water Use (m^3)
Kruger Inc.	Corner Brook River	0.15**	1.1	36,500,000
Abitibi-Price	Exploits River	2.6**	1.4	73,000,000
Abitibi-Price	Mine Pond	0.18**	0.3	8,500,000

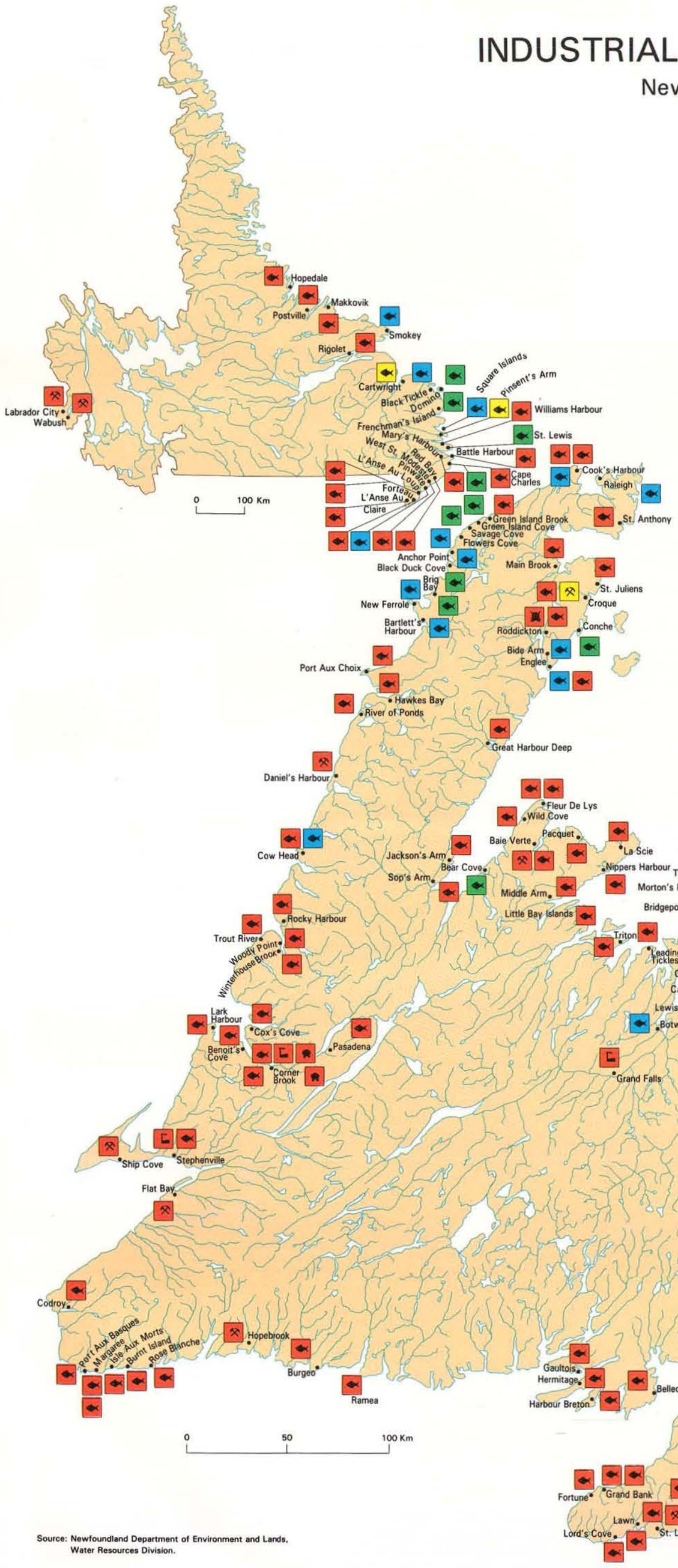
**Used only 8 to 10 hours/day

ENERGY PRODUCTION - THERMAL GENERATING STATIONS

It is estimated that about 95% of the water usage in a thermal plant is for cooling. There are two major thermal plants in the province - one at Holyrood with a generating capacity of 2,140 million kwh and another at Roddickton with an annual capacity of 32 million kwh. Average annual salt water use by the Holyrood plant is 274 million cubic metres, while the Roddickton plant uses 8 million cubic metres.

INDUSTRIAL WATER USE BY SOURCE

Newfoundland and Labrador



User

- Pulp and Paper Mill
- Industrial Plant
- Refinery
- Fishplant
- Mine
- Thermal Generating Station

Source

- Surface Water
- Salt Water
- Ground Water
- Unknown

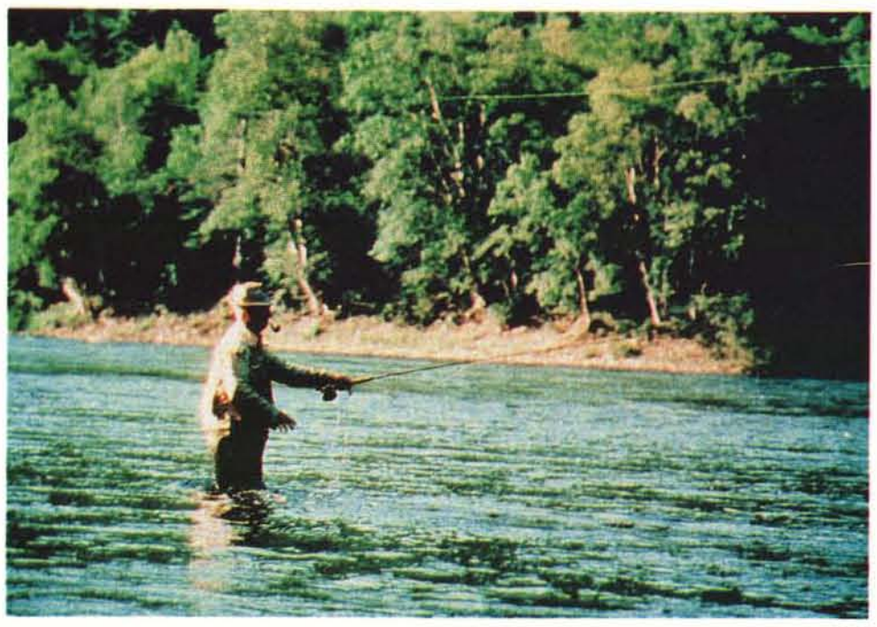
Source: Newfoundland Department of Environment and Lands, Water Resources Division.

31 – Water Recreational Areas

Newfoundland is blessed with an abundance of both fresh and salt water oriented recreational areas. It has a land area of 405,720 square kilometres (km²) of which 34,032 km² or 8.4% is covered with water. The total length of the province's coastline is approximately 17,540 km. With a population of about 580,000, an average of less than two persons per square kilometre, Newfoundland is a relatively uncrowded place for water oriented recreationists. There is an abundance of clean water in the many lakes, ponds, and rivers throughout the province. Hundreds of small islands dot the scenic coastline, and a number of bird species and other wildlife can be found on the high coastal cliffs. From April to June one is certain to be treated to a spectacle of huge icebergs drifting past on their way to melt in the warmer waters of the Gulf Stream.

There are two national parks and 76 provincial parks in the province as shown on the map on the opposite page. The provincial parks have 2317 campsites and 1347 picnic sites for use. Practically all parks have either ponds, rivers, or beaches within their boundaries. The main recreational activities are canoeing, boating, swimming, and fishing. July and August are the best months for swimming. The cold waters of the Labrador Current flowing from the north can make swimming at the seaside beaches an invigorating experience.

Salmon fishing by both resident and non resident anglers is permitted on 174 scheduled salmon rivers in the province. These rivers, which are frequented by the Atlantic salmon for spawning, are regulated or scheduled for the protection and conservation of the salmon run, while at the same time increasing the economic benefit of this resource. Unlike some salmon species on the west coast of Canada, all Atlantic salmon do not die after spawning, but can return to the sea and spawn again in subsequent years. Their sea habitat areas include the Labrador Sea, northern parts of the Grand Banks, and the ocean near Greenland. On the scheduled rivers regulations concerning fishing seasons, licensing, type of fishing gear used, bag limit, and season dates are enforced by the Department of Fisheries and Oceans. Only salmon called grilse, that have spent one winter at sea, may be taken on the Island. Both grilse and larger multi-sea-winter salmon may be taken in Labrador. Salmon must be caught by fishing rod and artificial fly.



Salmon Fishing

Power boating along the coast provides easy access to beaches and coves not accessible by land. Fuel and provisions, along with public wharves for berthing, are available in most coastal communities. Advance planning of trips is recommended to make sure supplies are available when needed. Scuba diving is becoming popular because of Newfoundland's clear waters, abundant fish, and many shipwrecks.

The province offers many rivers and lakes for the recreational canoeing and kayaking enthusiasts to explore. For those who enjoy flatwater paddling, ponds and gullies exist with short portages between them. Canoeing and kayaking are available on a number of rivers on the Island and in Labrador; high river flows occurring after spring snowmelt in April, May, and June provide the optimum conditions. Due to the remoteness of many rivers, especially in Labrador, fly in trips are necessary. Parties must be well equipped to deal with changing weather conditions and the lack of services. The relatively new water sport of sea kayaking is ideal in the numerous bays and inlets along the coastline.

Water Rafting

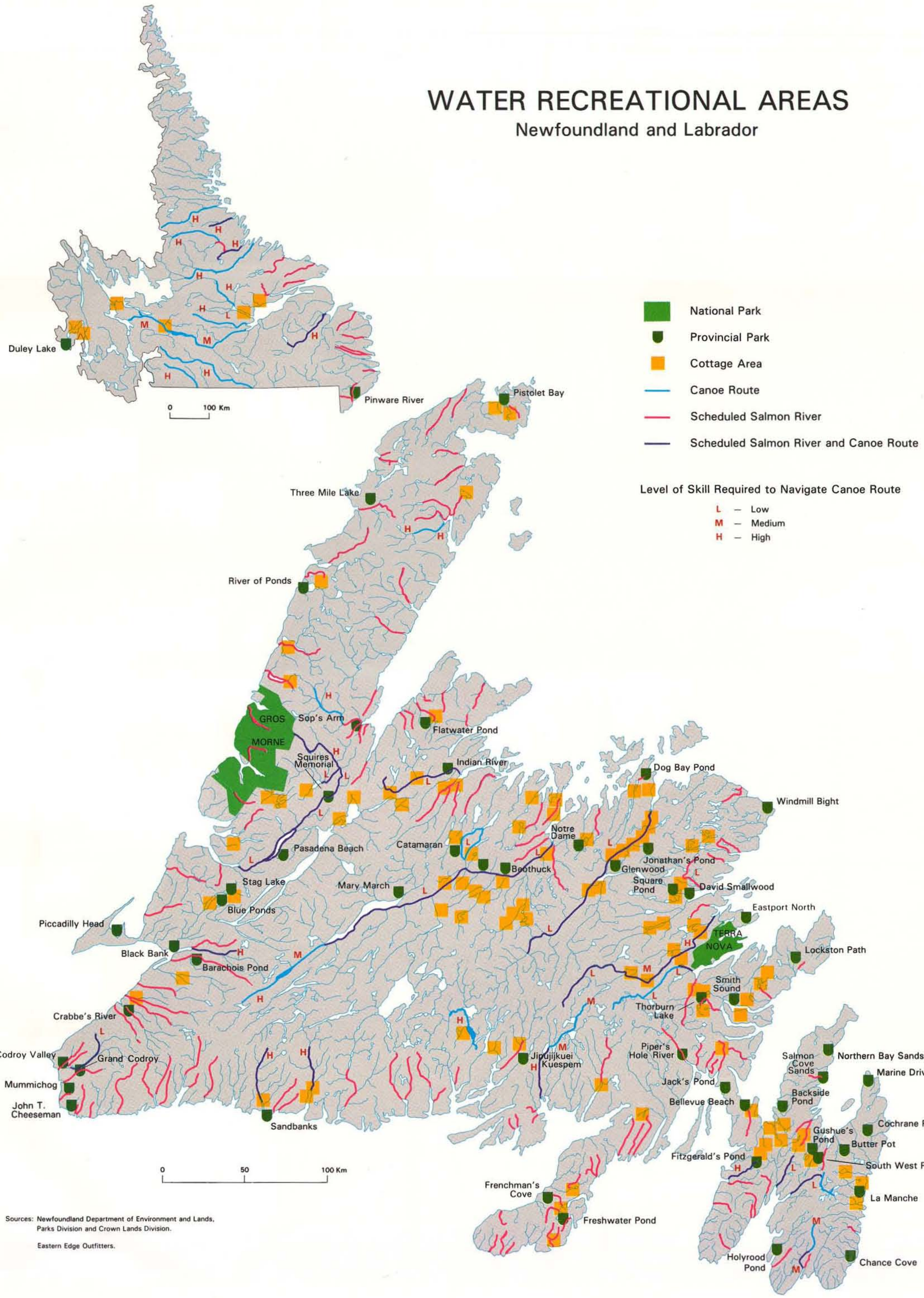
The level of skill rating shown on the map for canoeing on rivers relates to the challenge a canoeist may expect to find on a particular river. On a difficult river, a canoeist will encounter numerous rocks, ledges, and class III and IV rapids requiring a high skill level of manoeuvering. Portages over difficult terrain may also be encountered.

Many residents have cottage lots adjoining water bodies. Crown land for cottage lots is normally available through two processes: identification and selection of a suitable site by an individual, or by public draw of preplanned cottage subdivisions in high demand areas. Prospective cottage lot owners must submit a Crown lands application for their sites and comply with all provincial regulations.

Cottage Lots

WATER RECREATIONAL AREAS

Newfoundland and Labrador



Sources: Newfoundland Department of Environment and Lands, Parks Division and Crown Lands Division.

Eastern Edge Outfitters.

Conclusion

The current state of the water resources of the province has been described in the Water Resources Atlas of Newfoundland by means of maps and texts. The data presented have great intrinsic value because of the information they provide on the water resources. They also have economic value as they form the basic requirements for planning, designing, and operating water resources projects.

The collection, analysis, and presentation of data on geology, climate, hydrology, water quality, groundwater, and water uses are, however, just one aspect in the protection of our water resources. Other components include assessment of the potential impacts of water-related projects on water quantity and quality, determining water rights, and defining water management policy. Water rights are concerned with the rights of individuals or organisations to divert and use water or to use it in place. Water policy is the development of guidelines, strategies, and programs within the framework of, and consistent with, economic and social policies, with a view to increasing the welfare of the whole population. These aspects are difficult to illustrate on maps, but, together with data collection and analysis, are essential for an efficient and equitable management of the water resources of the province.

The dramatic increase in magnitude and scope of human intervention in natural water systems during the last quarter century has made the task of managing our water resources very complex. Water management is already hampered by incomplete understanding of the water resource systems in their present state and their vulnerability to cumulative impacts. In the future a range of environmental changes is expected to result from continued urbanization, agricultural and industrial pollution, and from progressively larger schemes of water development. Changes in global and regional climates will affect river hydrology and watershed geomorphology. The impacts of these changes on our water resources are very difficult to predict. Collection and analysis of water resources data, together with the other aspects of water resources management, will become even more critical. And the dissemination of the information on the changing attributes of the water environment will continue to be an important part of water resources management.

Appendix

HYDROELECTRIC PLANTS								
NO.	PLANT NAME	OWNER	YEAR COMPLETED	NORMAL HEAD (M)	INSTALLED CAPACITY (mw)	AVERAGE ANNUAL WATER USE (m^3)X10^6	SOURCE OF WATER SUPPLY Main	Diverted
ISLAND OF NEWFOUNDLAND								
1	Petty Hr.	NF Light & Power	1908	58	5.25	162	Redmans Brook	
2	Victoria	NF Light & Power	1914	65	0.45	25	Rocky Pond	
3	Grand Falls	Abitibi Price	1909	33.2	44.5	4271	Exploits River	
4	Bishop's Falls	Abitibi Price	1909	10.6	17.2	5713	Exploits River	
5	Port Union	NF Light & Power	1918	21	0.51	44	Whirl Pond	
6	Hearts Content	NF Light & Power	1917	46	2.65	94	Hearts Content Bk	
7	Seal Cove	NF Light & Power	1924	58	3.18	93	Seal Cove River	
8	Deer Lake	Deer Lake Power	1925	75	124.65	3805	Humber River	Indian River
9	Buchans (ARASCO)	Abitibi Price	1927	49.6	1.8	27	Buchans Brook	
10	Lawn	NF Light & Power	1930	20	0.63	48	Lawn	
11	Pierres Brook	NF Light & Power	1931	86	4.0	157	Pierres Brook	Witless Bay Diversion
12	Topsail	NF Light & Power	1932	86	2.34	74	Island Pond	Manuels Pond
13	Fall Pond	NF Light & Power	1939	15	0.35	39	Waterfall Brook	
14	Tors Cove	NF Light & Power	1942	56	6.75	282	Tors Cove	
15	West Brook	NF Light & Power	1942	43	0.76	27	St. Lawrence	
16	Rocky Pond	NF Light & Power	1943	35	3.10	245	Tors Cove Pond	
17	Lookout Brook	NF Light & Power	1958	155	5.55	89	Lookout Brook	
18	Mobile	NF Light & Power	1951	120	11.97	167	Mobile Big Pond	
19	Cape Broyle	NF Light & Power	1952	57	6.4	349	Cape Broyle Pond	Crossing Place River/Cape Broyle/ North West River Diversion
20	Horse Chops	NF Light & Power	1957	89	7.60	276	Horse Chops Pond	Crossing Place River/Cape Broyle/ North West River Diversion
21	Lockston	NF Light & Power	1955	82	3.0	38	Lockston	
22	New Chelsea	NF Light & Power	1957	84	3.73	75	New Chelsea Brook	
23	Snooks Arm	NF & Lab Hydro	1957	83	0.56	23	East Pond	
24	Venam's Bight	NF & Lab Hydro	1957	79	0.36	17	Long Pond	
25	Watsons Brook	Deer Lake Power	1958	170	9.2	97	Corner Brook	
26	Rattling Brook	NF Light & Power	1958	100	11.50	266	Rattling Brook	
27	Pitmans Pond	NF Light & Power	1959	20	0.61	50	New Chelsea	
28	Sandy Brook	NF Light & Power	1963	33	5.70	256	Sandy Brook	West Stony Brook
29	Bay D'Espoir	NF & Lab Hydro	1967	176	604	5531	Salmon River	Grey River/White Bear River/ Victoria River/Lloyds River
30	Hinds Lake	NF & Lab Hydro	1980	217	75.00	491	Hinds Brook	
31	Upper Salmon	NF & Lab Hydro	1982	50	84.0	4196	Salmon River	
32	Morris	NF Light & Power	1983	29	1.14	109	Mobile Big Pond	
33	Cat Arm	NF & Lab Hydro	1985	380	127	800	Cat Arm River	
34	Paradise River	NF & Lab Hydro	1989	44	8.0		Paradise River	
35	Marble Brook	NF & Lab Hydro	1980	47	0.4		Marble Brook	
LABRADOR								
36	Churchill Falls	Churchill Falls Corp.	1971	312	5428	112181	Upper Churchill	
37	Twin Falls	Twin Falls Corp.	Mothballed		225.0		Unknown stream	
38	Menihek	IOCC	1954	12	18.7	1883	Ashuanipi River	
39	White Rock Falls	Mary's Hr. Hydro (private)	1987	7.3	0.135	30	St. Mary's River	
MAJOR THERMAL PLANTS								
40	Roddickton	NF & Lab Hydro	1981		5	8 (cooling)	Shoal Cove Pond	
41	Holyrood	NF & Lab Hydro	1989		500	274 (cooling)	Sea	

Glossary

ALKALINE: Water which contains a sufficient amount of alkali substances to raise the pH value above 7.0.
ANCHOR ICE: Frazil ice that has collected on rocks on the stream bed.
ANNUAL FLOOD: The highest peak discharge in a water year.
AQUIFER: A body of earth material capable of transmitting water through its pores at a rate sufficient for water supply purposes.
BASE FLOW: That portion of the stream discharge which is derived from groundwater outflow or other sources outside the net rainfall which created the surface runoff.
BENEFICIAL USE OF WATER: The use of water for some purpose from which benefits are derived. Such use includes domestic, irrigation, hydroelectric power, industrial, etc.
CLIMATE: The sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time at any one place or region of the earth's surface.
CONVECTIVE PRECIPITATION: Precipitation resulting from vertical movement of moisture-laden air, which upon rising cools and precipitates its moisture.
CYCLONIC PRECIPITATION: Precipitation resulting from the lifting of air converging into a low-pressure area or cyclone.
DAILY TEMPERATURE RANGE: The difference between the highest and lowest temperatures recorded on a particular day.
DENSITY OF SNOW: The ratio, expressed as a percentage, of the volume which a given quantity of snow would occupy if it were reduced to water, to the volume of the snow.
DEPTH OF RUNOFF: The total runoff from a drainage basin, divided by the area. For convenience in comparing runoff with precipitation, the term is usually expressed in millimetres of depth during a given period of time over the drainage area.
DIRECT FLOOD DAMAGE: The damage done to property, structures, goods, etc., by a flood as measured by the cost of replacement and repairs.
DIRECT RUNOFF: The runoff entering stream channels promptly after rainfall or snowmelt.
DISCHARGE CURVE: A curve that expresses the relation between the discharge of a stream at a given location and the stage of the water surface at or near that location.
DOMESTIC USE OF WATER: The use of water primarily for household purposes, the watering of livestock, the irrigation of gardens, lawns, shrubbery, etc., surrounding a house or domicile.
DRAINAGE AREA: The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.
DRAINAGE BASIN: A drainage system which consists of a surface stream together with all tributary surface streams.
DRAINAGE DIVIDE: The boundary line, along a topographic ridge or along a subsurface formation, separating two adjacent drainage basins.
EVAPORATION: The process by which water is changed from the liquid state into the vapour state.
EVAPORATION PAN: A pan used to hold water during observations for the determination of the quantity of evaporation at a given location.
EVAPOTRANSPIRATION: The volume of water evaporated and transpired from soil and plant surfaces per unit land area.
FLOOD: (1) An overflow or inundation that comes from a river or other body of water and causes or threatens damage. (2) Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. (3) A relatively high flow as measured by either gauge height or discharge quantity.
FLOOD ZONE: The land bordering a stream which is subject to floods of about equal frequency.
GAUGING STATION: A particular site on a stream, canal, lake, or reservoir where systematic observations of gauge height or discharge are obtained.
GROUNDWATER: Water in the ground that is in the zone of saturation, from which wells, springs, and groundwater runoff are supplied.
GROUNDWATER DIVIDE: A line on a water table on either side of which the water table slopes downward. It is analogous to a drainage divide between two drainage basins on a land surface.
HYDROLOGIC CYCLE: The complete cycle of phenomena through which water passes, commencing as atmospheric water vapour, passing into liquid and solid form as precipitation, thence along or into the ground surface, and finally again returning to the form of atmospheric water vapour by means of evaporation and transpiration.
HYDROLOGY: The applied science concerned with the waters of the earth -- their occurrences, distribution, and circulation through the unending hydrologic cycle of: precipitation, consequent runoff, infiltration, and storage; eventual evaporation; and reprecipitation. It is concerned with the physical and chemical reaction of water with the rest of the earth, and its relation to the life of the earth.
INDUSTRIAL CONSUMPTION: The quantity of water consumed in a municipality or district for mechanical, trade, and manufacturing purposes, in a given period, generally one day.
MEAN ANNUAL PRECIPITATION: The average over a period of years of the annual amounts of precipitation.
MEAN ANNUAL TEMPERATURE: Is the average of the monthly means for the year.
MUNICIPAL USE OF WATER: The various uses to which water is put in developed urban areas, including domestic use, industrial use, street sprinkling, fire protection, etc.
OROGRAPHIC PRECIPITATION: Precipitation which is caused by hills or mountain ranges deflecting the moisture-laden air masses upward, causing them to cool and precipitate their moisture.
POTENTIAL EVAPOTRANSPIRATION: Water loss that will occur if at no time there is a deficiency of water in the soil for use of vegetation.
PRECIPITATION: As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. Precipitation includes rainfall, snow, hail, and sleet, and is therefore a more general term than rainfall.
QUALITY OF WATER: The physical, chemical, and biological characteristics of water relating to its suitability for a given use.
RAIN GAUGE: A device for catching and measuring the depth of rainfall.
RAINFALL: The quantity of water that falls as rain only. Not synonymous with precipitation.
RAINFALL-INTENSITY CURVE: A curve which expresses the relation of rates of rainfall and their duration. Each curve is generally for a period of years during which time the intensities shown will not, on the average, be exceeded more than once.
REGULATION: The artificial manipulation of the flow of a stream.
RESERVOIR: A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.
RETURN PERIOD: In statistical analysis of hydrologic data, where the interval between observations is a year, a return period of 100 years, for example, means that, on the average in the long run, nor more often than once in 100 years is an event of this magnitude, or greater, expected to occur.
RIVER BASIN: A term used to designate the area drained by a river and its tributaries.
RIVER STAGE: Is the elevation of the water surface at a specified station above some arbitrary zero datum.
RUNOFF: That part of the precipitation that appears in surface streams, drains or sewers.
SNOW: Precipitation in the form of branched hexagonal crystals or stars, often mixed with simple ice crystals, which fall more or less continuously from a solid cloud sheet. These crystals may fall either separately or in coherent clusters forming snowflakes.
SNOWFALL: The amount of snow, hail, sleet, or other precipitation occurring in solid form which reaches the earth's surface. It may be expressed in millimetres depth as it falls, or in terms of millimetres depth of the equivalent amount of water.
STAGE: The height of a water surface above an established datum plane.
STAGE-DISCHARGE CURVE: (Rating curve) A graph showing the relation between the gauge height, usually plotted as ordinate, and the amount of water flowing in a channel, expressed as volume per unit of time, plotted as abscissa.
STORM: A disturbance of the ordinary average conditions of the atmosphere which, unless specifically qualified, may include any or all meteorological disturbances, such as wind, rain, snow, hail, or thunder.
STREAM: A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel as distinct from a canal.
STREAMFLOW: The discharge that occurs in a natural channel.
SURFACE RUNOFF: That part of the runoff which travels over the soil surface to the nearest stream channel.
SURFACE WATER: Water on the surface of the earth.
TRANSPIRATION: The process by which water vapour escapes from the living plant, principally the leaves, and enters the atmosphere.
WATER ANALYSIS: The determination of the physical, chemical, and biological characteristics of water. Such analyses involve usually four different kinds of examinations, bacterial, chemical, microscopic, and physical.
WATER EQUIVALENT OF SNOW: Amount of water that would be obtained if the snow should be completely melted.
WATER LEVEL: Water-surface elevation or stage.
WATER QUALITY: A term used to describe the chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose. The same water may be of good quality for one purpose or use, and bad for another, depending upon its characteristics and the requirements for the particular use.
WATER TABLE: The upper surface of a zone of saturation, where the body of ground water is not confined by an overlying impermeable formation. Where an overlying confining formation exists, the aquifer in question has no water table.
WATERSHED: The area contained within a divide above a specified point on a stream.
WEATHER: One phase of the succession of phenomena whose complete cycle, recurring with greater or less uniformity every year, constitutes the climate or any locality.

GEOLOGY

PROTEROZOIC I: 2500 - 1600 million years ago.
PROTEROZOIC II: 1600 - 900 million years ago.
PROTEROZOIC III: 900 - 550 million years ago.
CAMBRIAN: 570 - 505 million years ago.
ORDOVICIAN: 505- 438 million years ago.

GLACIAL-LACUSTRINE SEDIMENTS: Silt and clay deposits formed in the quiet waters of lakes that received meltwater from glaciers.
GLACIAL OUTWASH: Well-sorted sand, or sand and gravel, deposited by the meltwater from a glacier.
GLACIAL TILL: A glacial deposit composed of mostly unsorted sand, silt, clay, and boulders and laid down directly by the melting ice.
PORE SPACE: The volume between mineral grains in a porus medium.
POROSITY: The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.
POROSITY, EFFECTIVE: The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.
POROSITY, PRIMARY: The porosity that represents the original pore openings when a rock or sediment is formed.
POROSITY, SECONDARY: The porosity that has been caused by fractures or weathering in a rock or sediment after it has been formed.
ROCK, IGNEOUS: A rock formed by the cooling and crystallization of a molten rock mass called magma.
ROCK, METAMORPHIC: A rock formed by the application of heat and pressure to preexisting rocks.
ROCK, PLUTONIC: An igneous rock formed when magma cools and crystallizes within the earth.
ROCK, SEDIMENTARY: A rock formed from sediments through a process known as diagenesis or formed by chemical precipitation in water.
ROCK, VOLCANIC: An igneous rock formed when molten rock called lava cools on the earth's surface.

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