HYDROLOGY

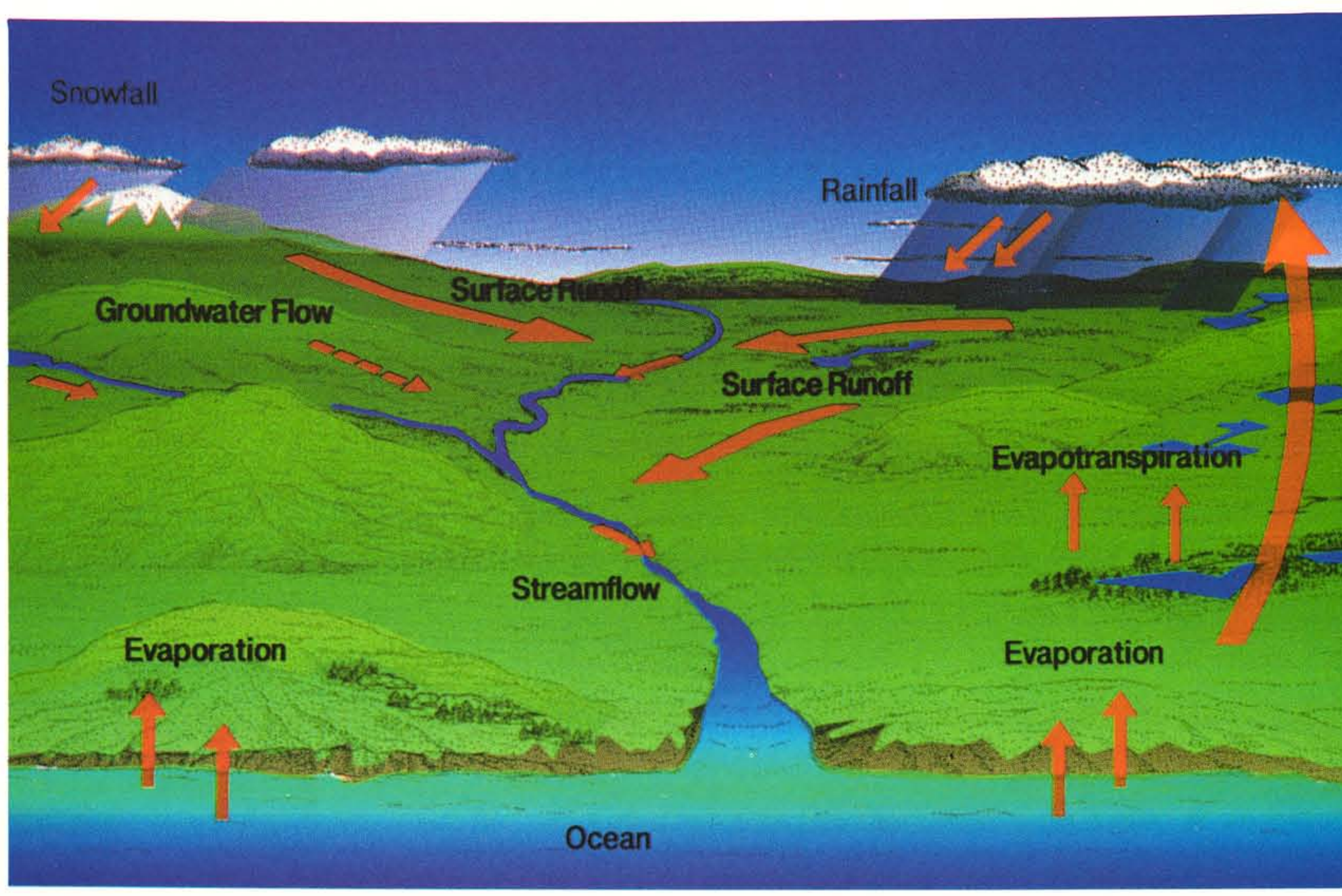
Introduction

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

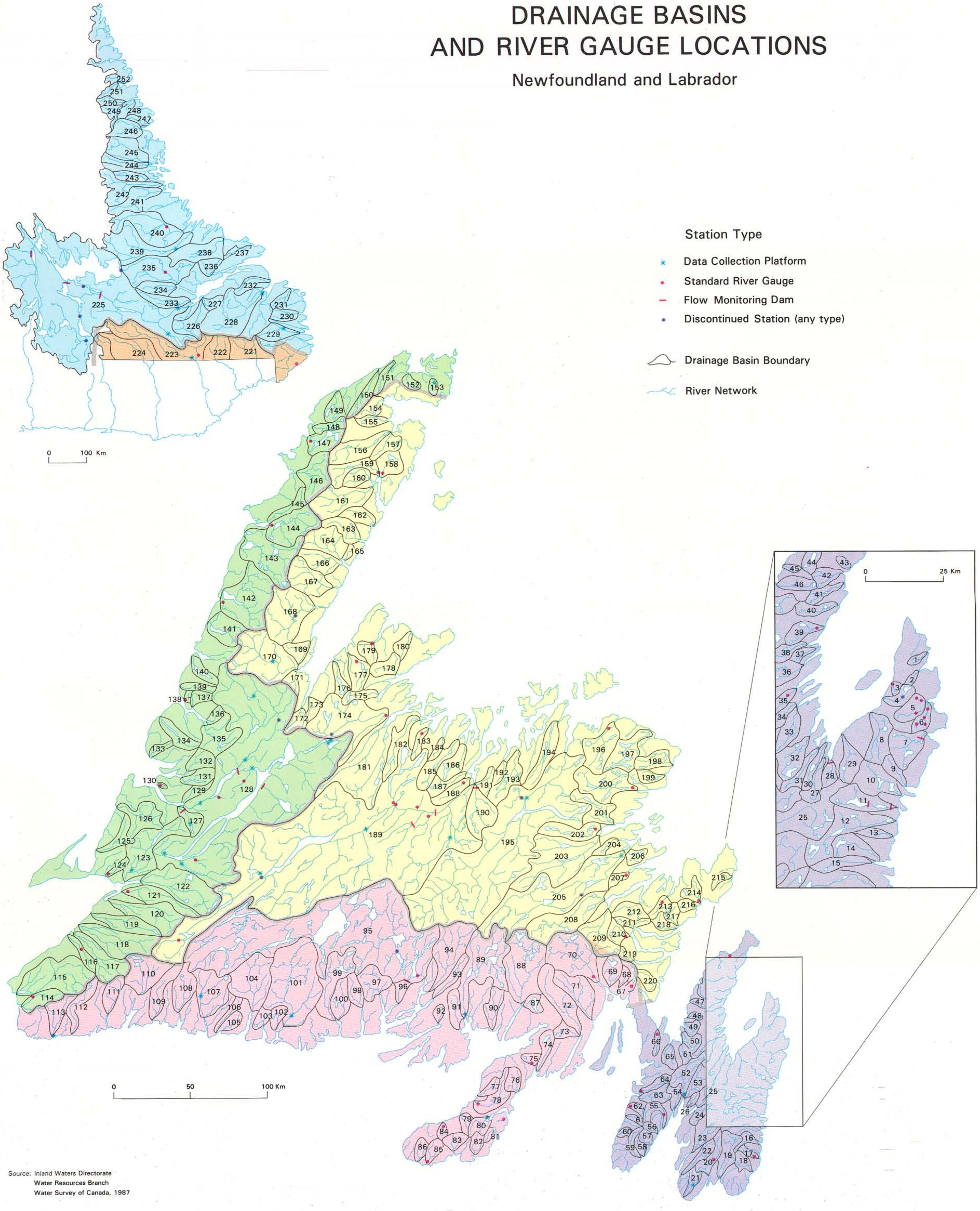
The number of gauging stations operating as of 1990 was 84 on the Island and 13 in Labrador. The number of gauging stations equipped with a Data Collection Platform was 23 on the Island and 6 in Labrador. The size distribution of the gauged drainage basins, including those basins where the stations are 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



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.

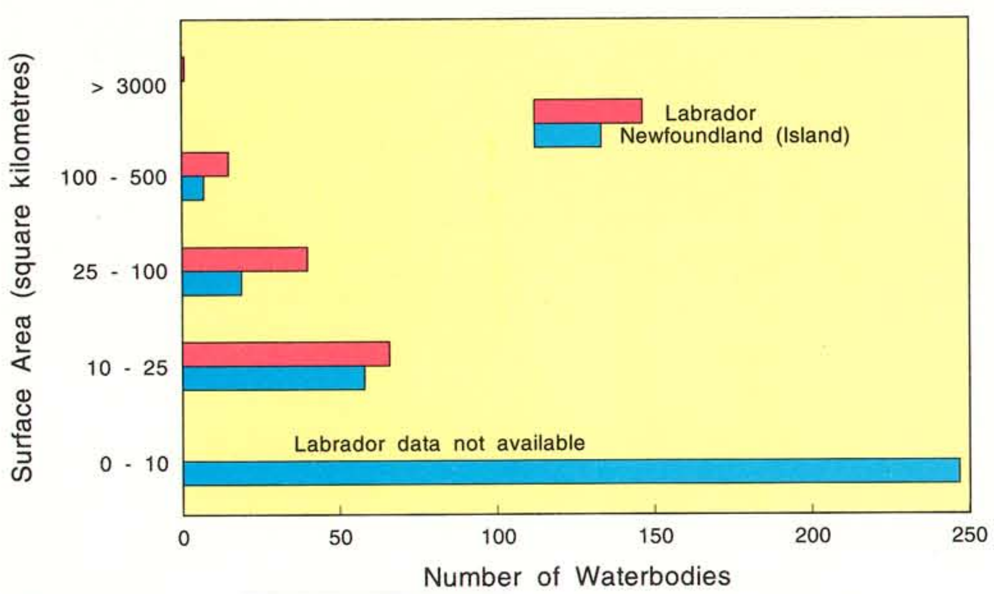


Figure 12.1 Size Distribution of Water Bodies in the Province

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.

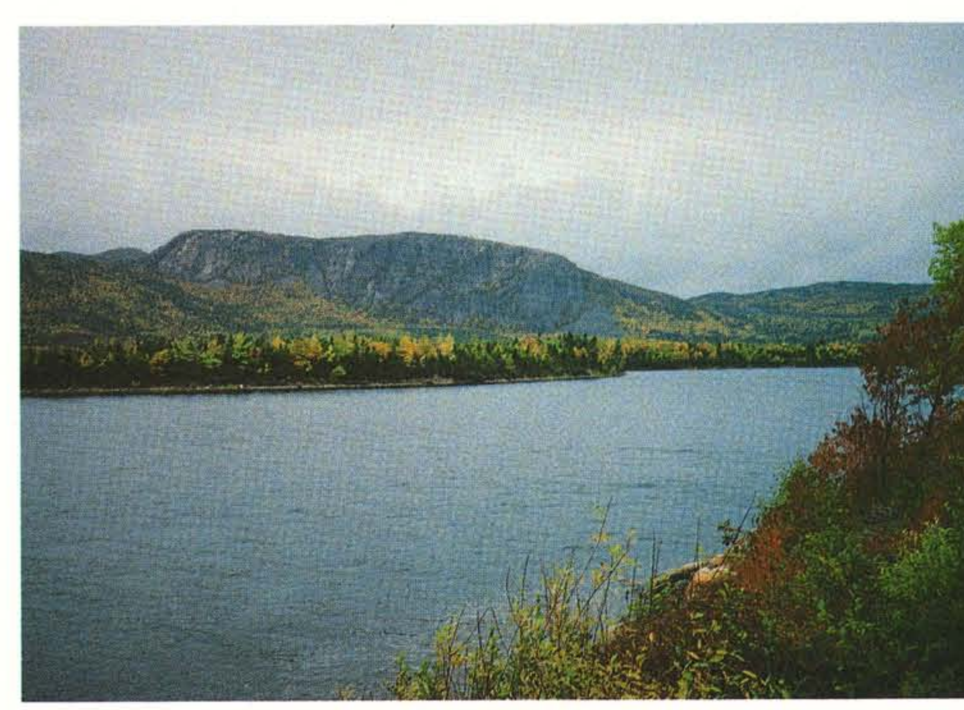
There has not been extensive bathymetric surveys of lakes and ponds in Newfoundland. The scant information available suggests that the small peat-bog ponds are generally less than three metres deep, while lakes of glacial origin are much deeper; the maximum depth of Gander Lake, for example, is estimated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

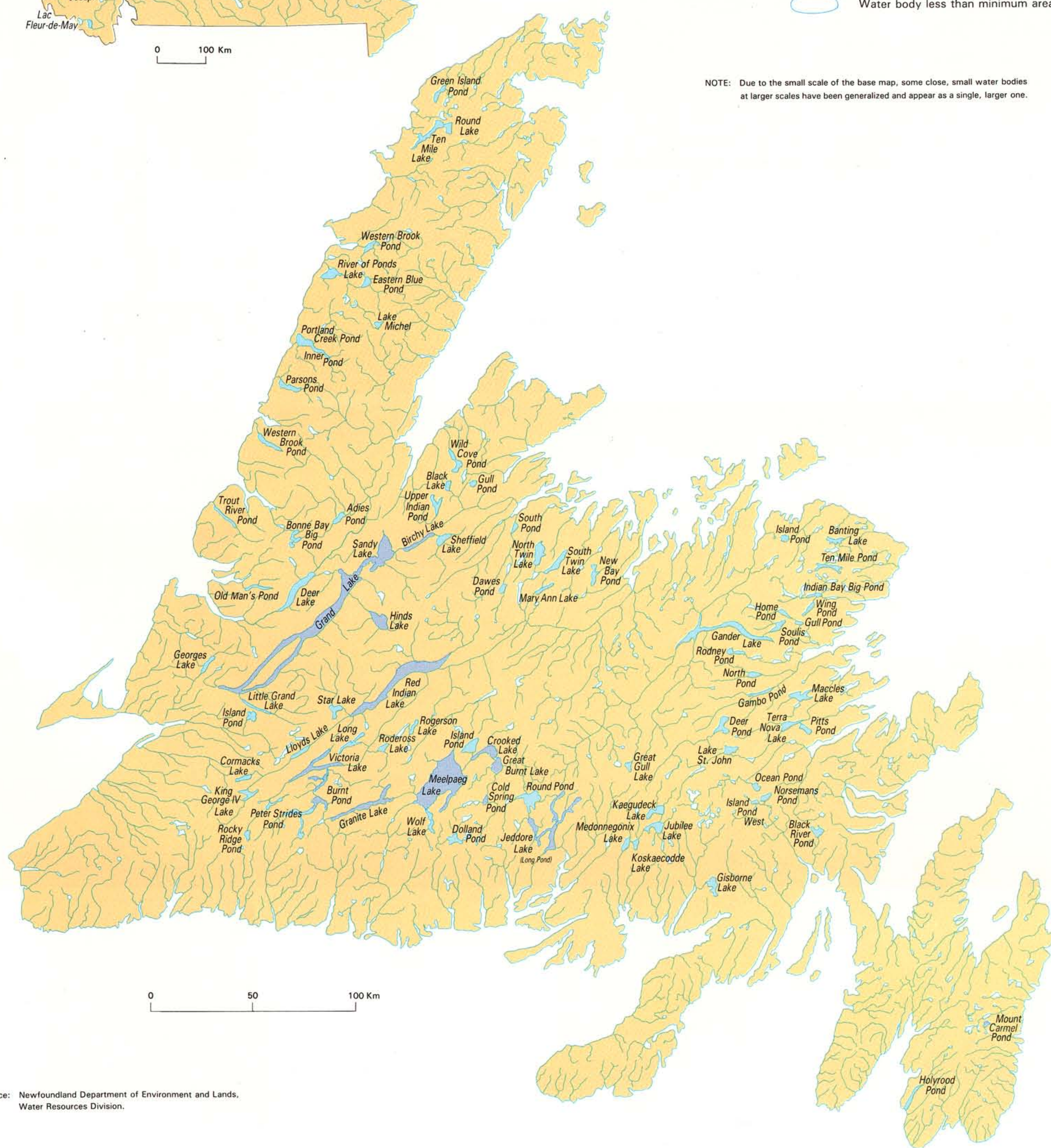
Newfoundland - 10 square kilometres

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).

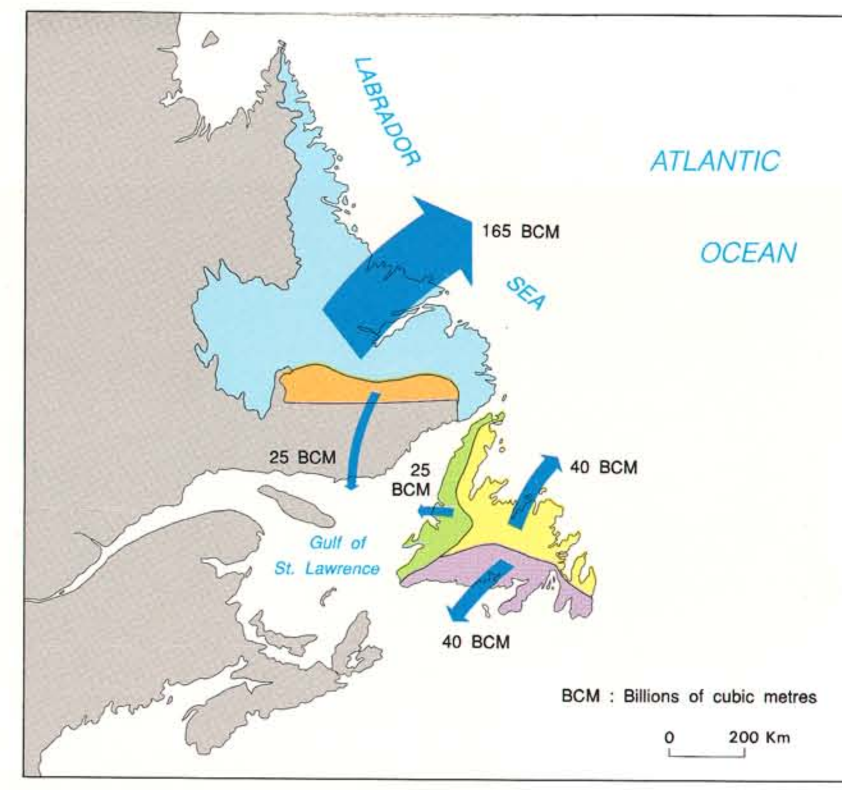


Figure 13.1 Regional Mean Annual Runoff Volumes

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.

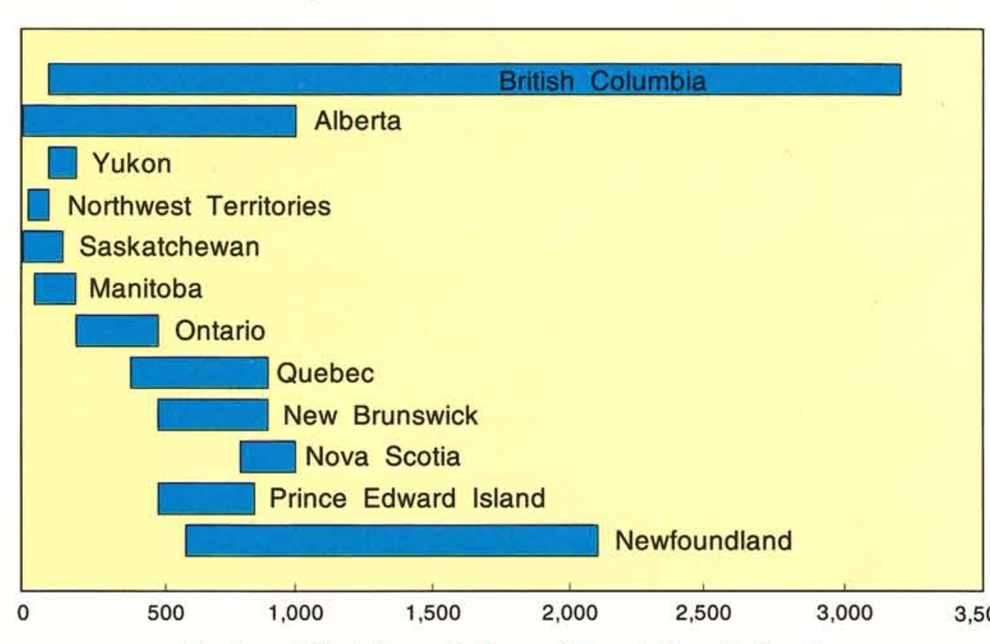
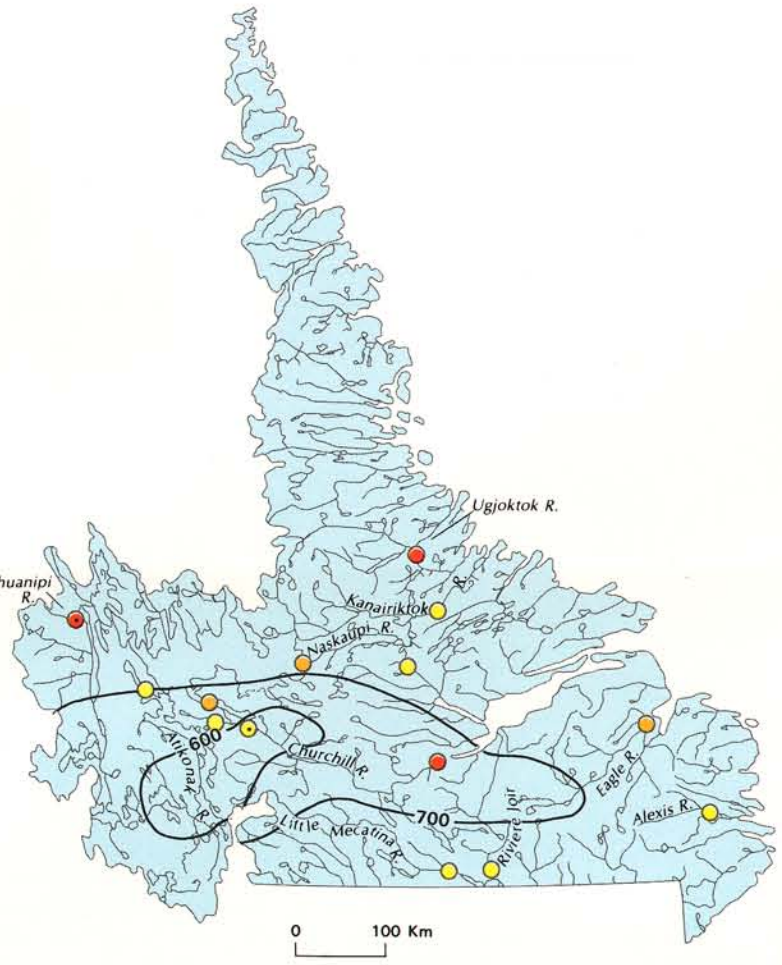
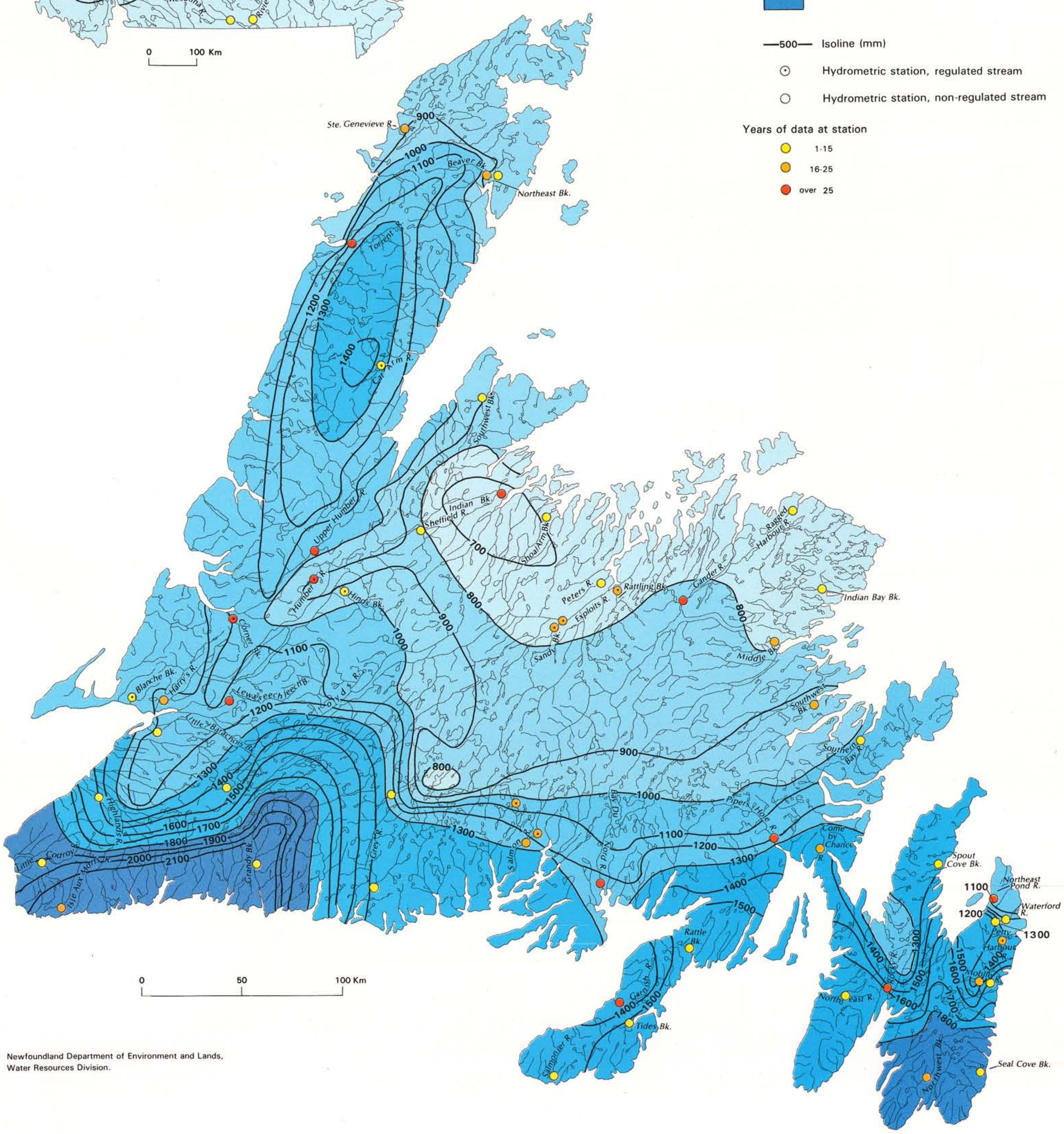


Figure 13.2 Mean Annual Runoff Across Canada

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.

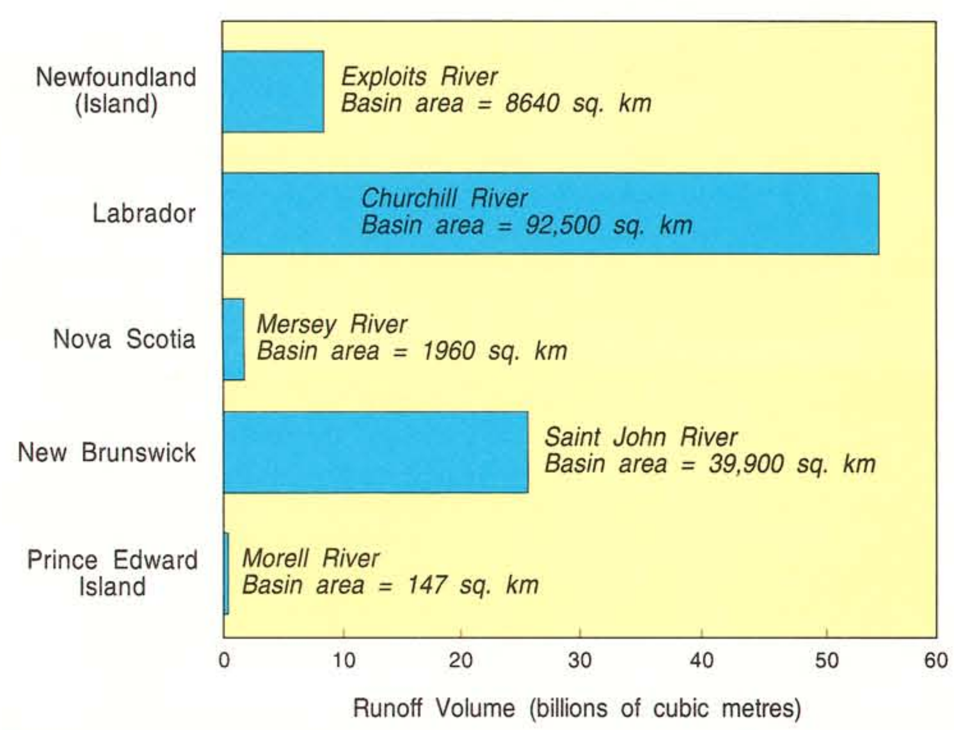


Figure 14.1 Mean Annual River Flows from the Largest Gauged Basins in Newfoundland and the Maritime Provinces

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).

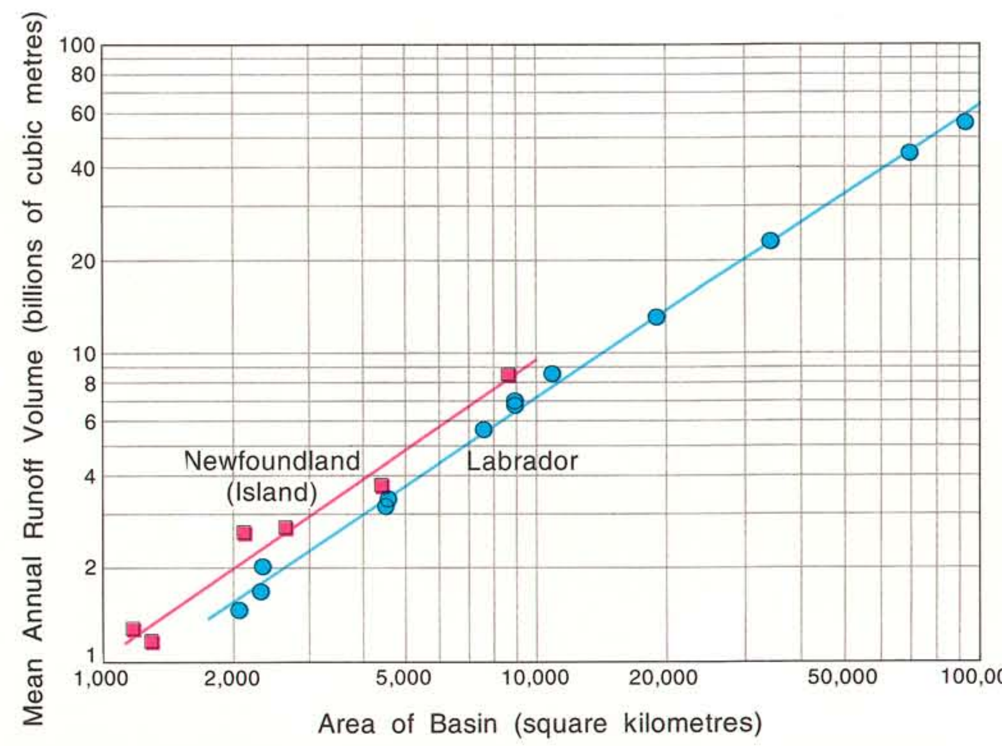
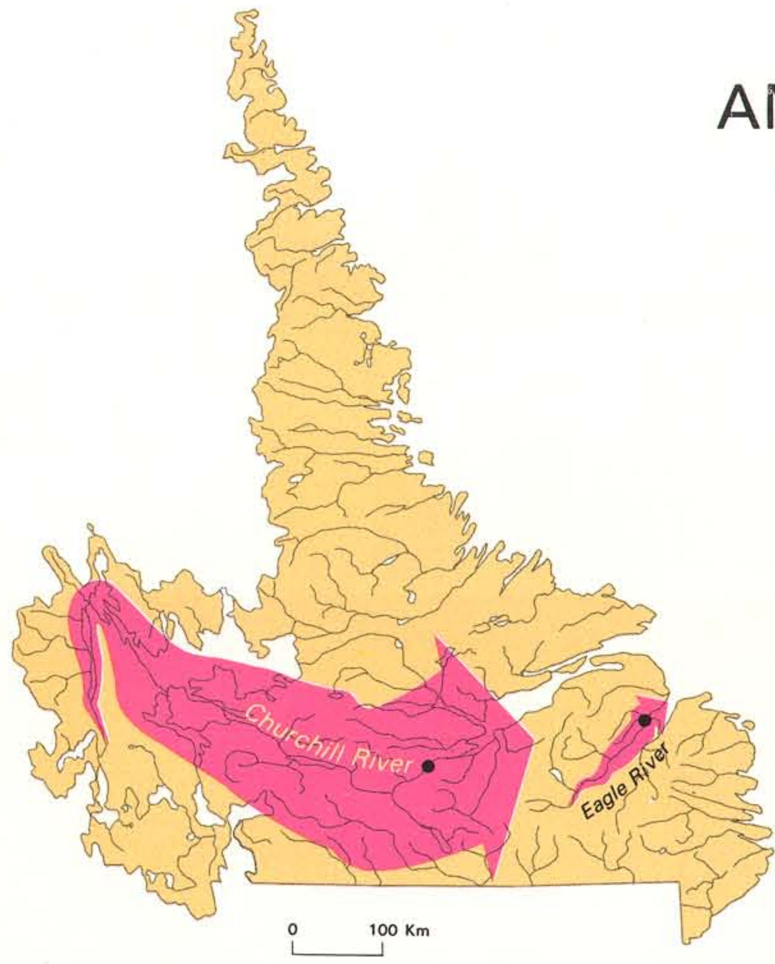
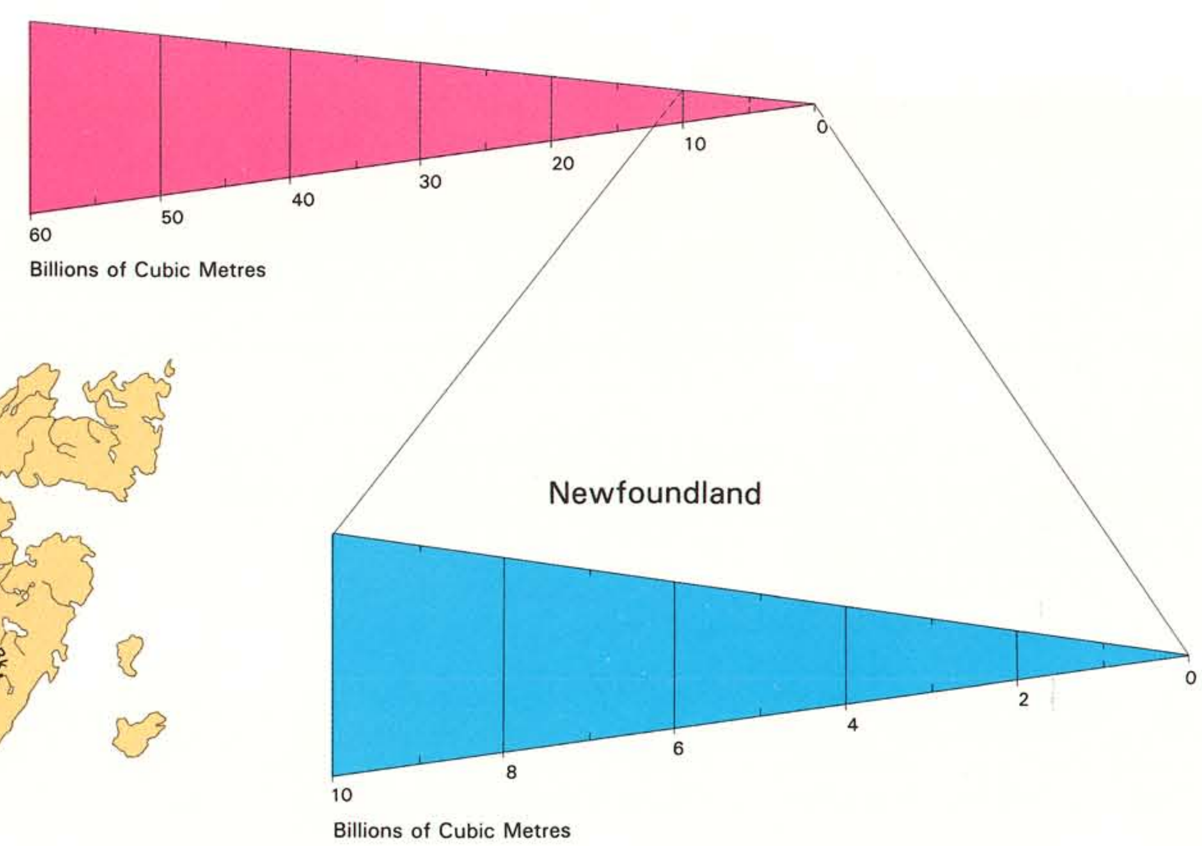


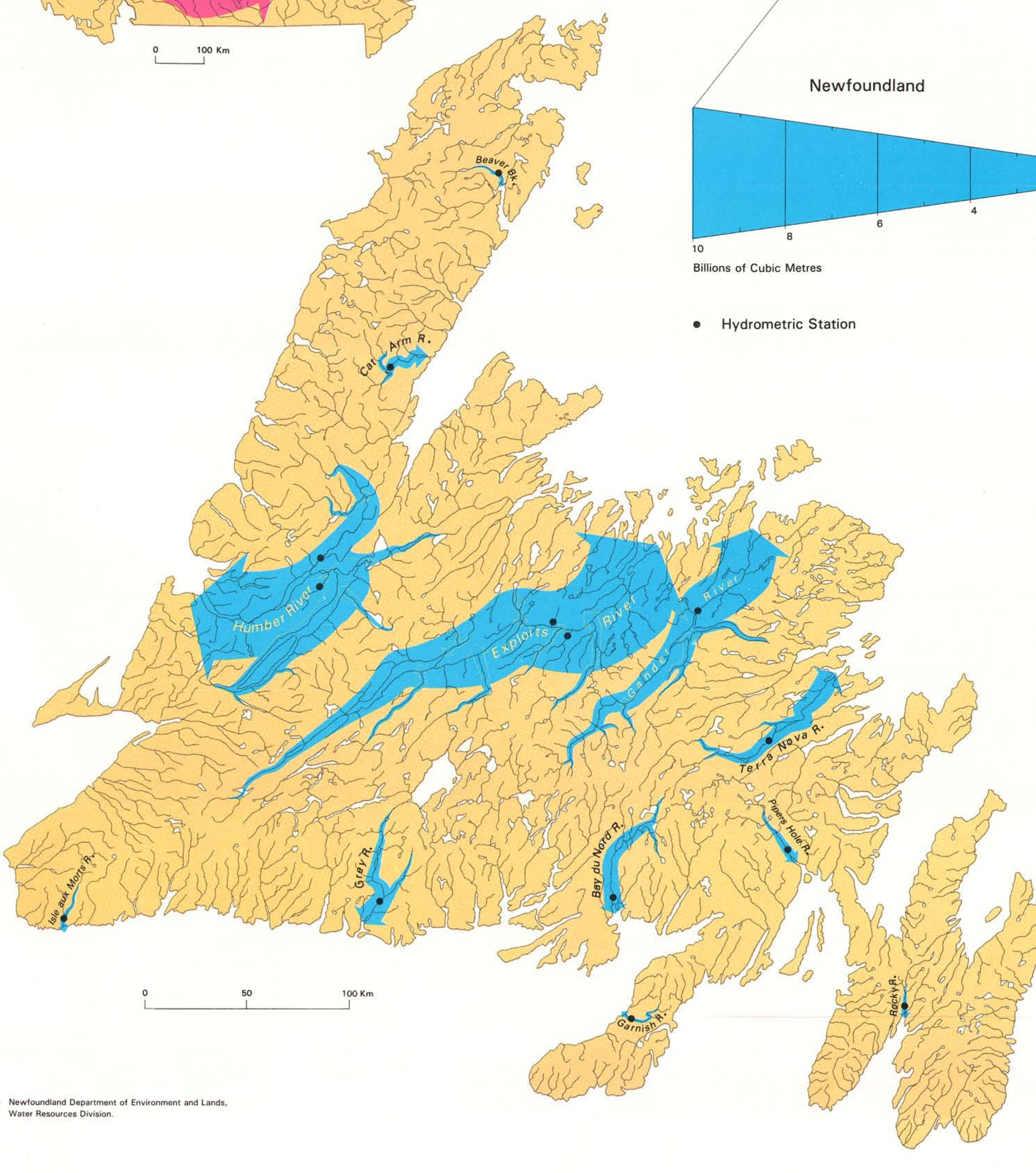
Figure 14.2 Relationship between Mean Annual River Flow and Area of Basin on the Island and in Labrador

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.

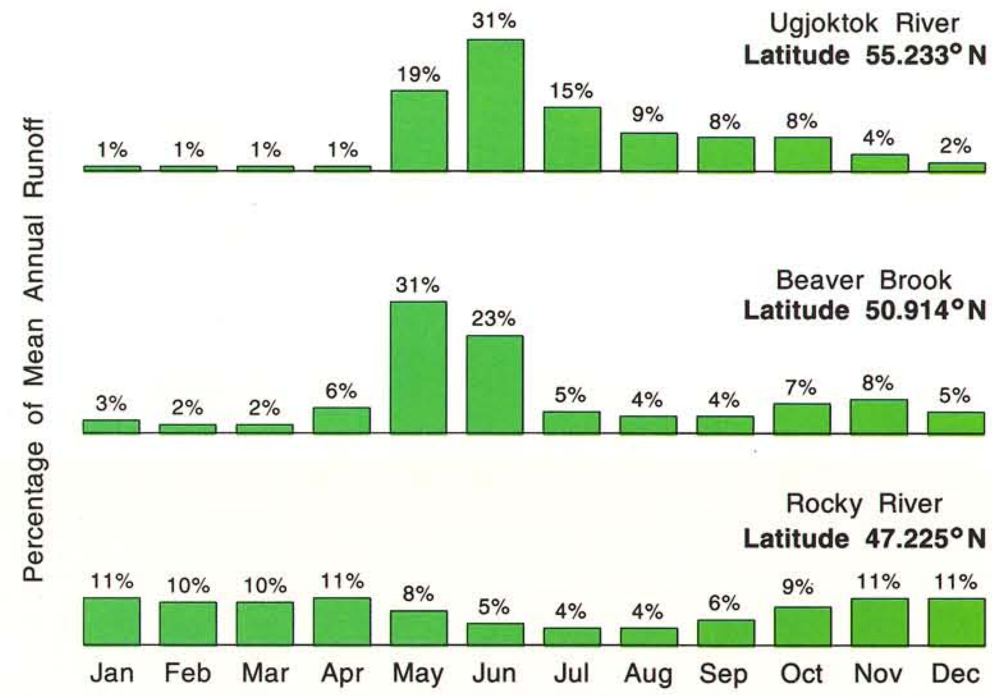


Figure 15.1 Effect of Latitude on Monthly Distribution of Annual Runoff

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.

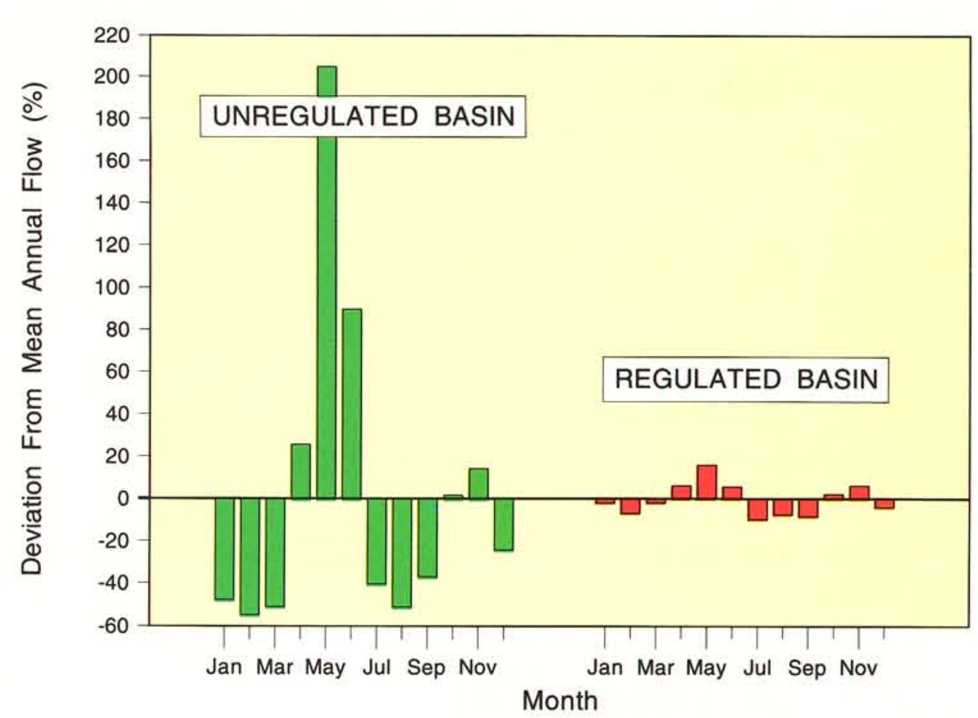
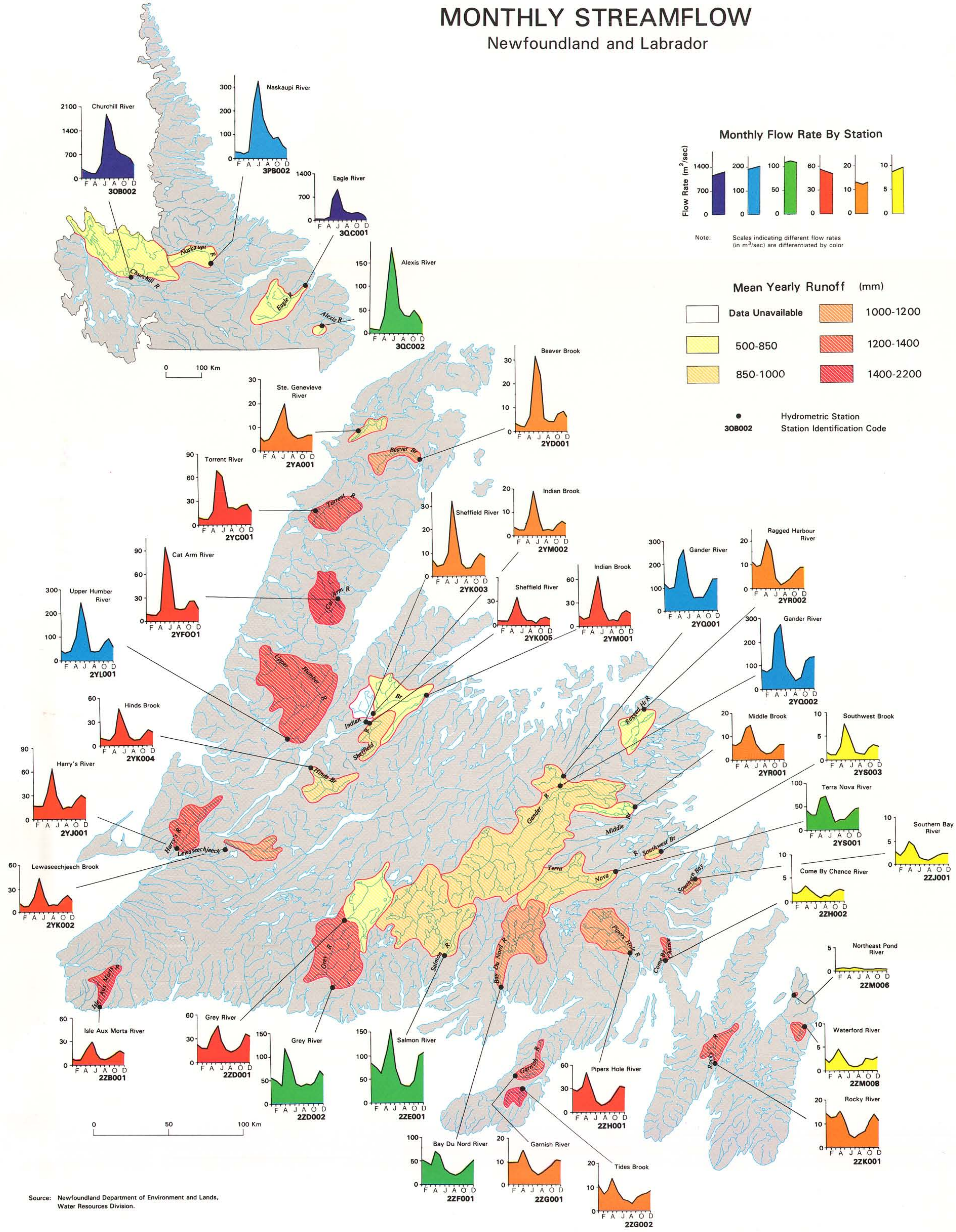


Figure 15.2 Effect of Regulation on Monthly Streamflows

MONTHLY STREAMFLOW

Newfoundland and Labrador



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.

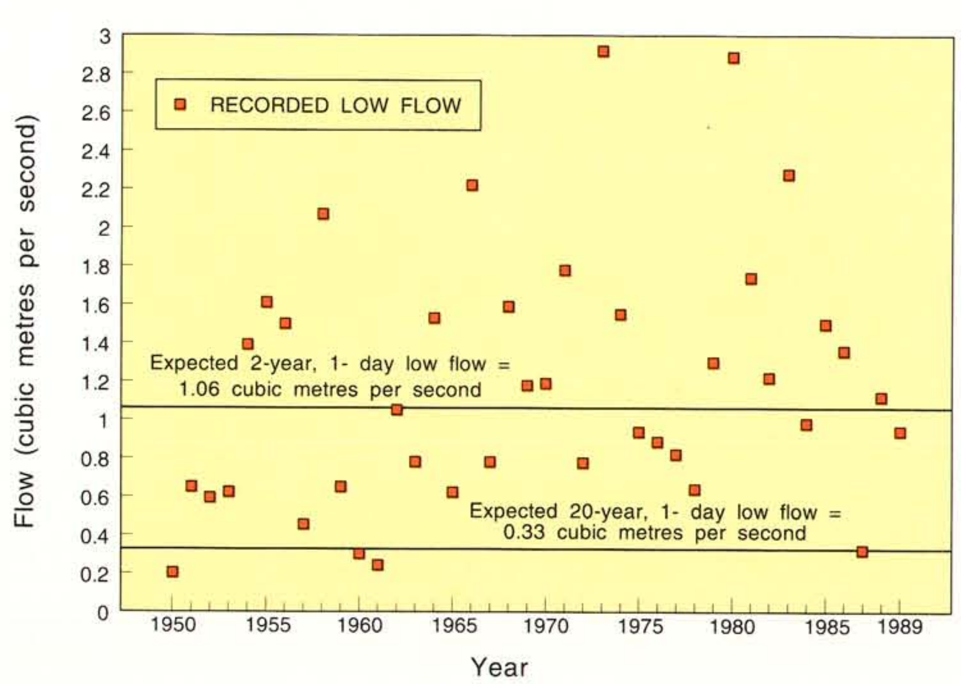


Figure 16.1 Recorded and Expected 1-Day Minimum Flows on Rocky River

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.

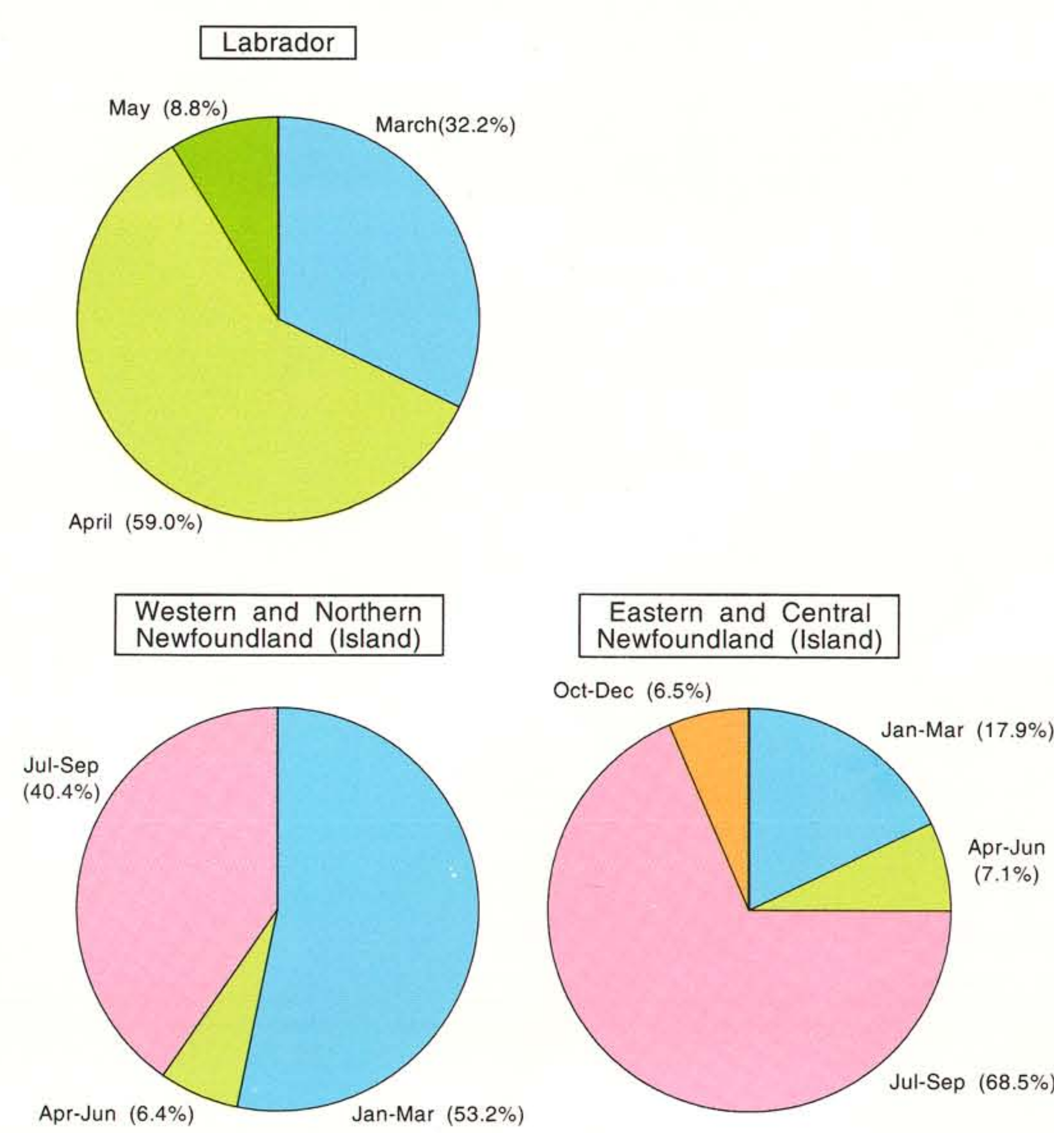
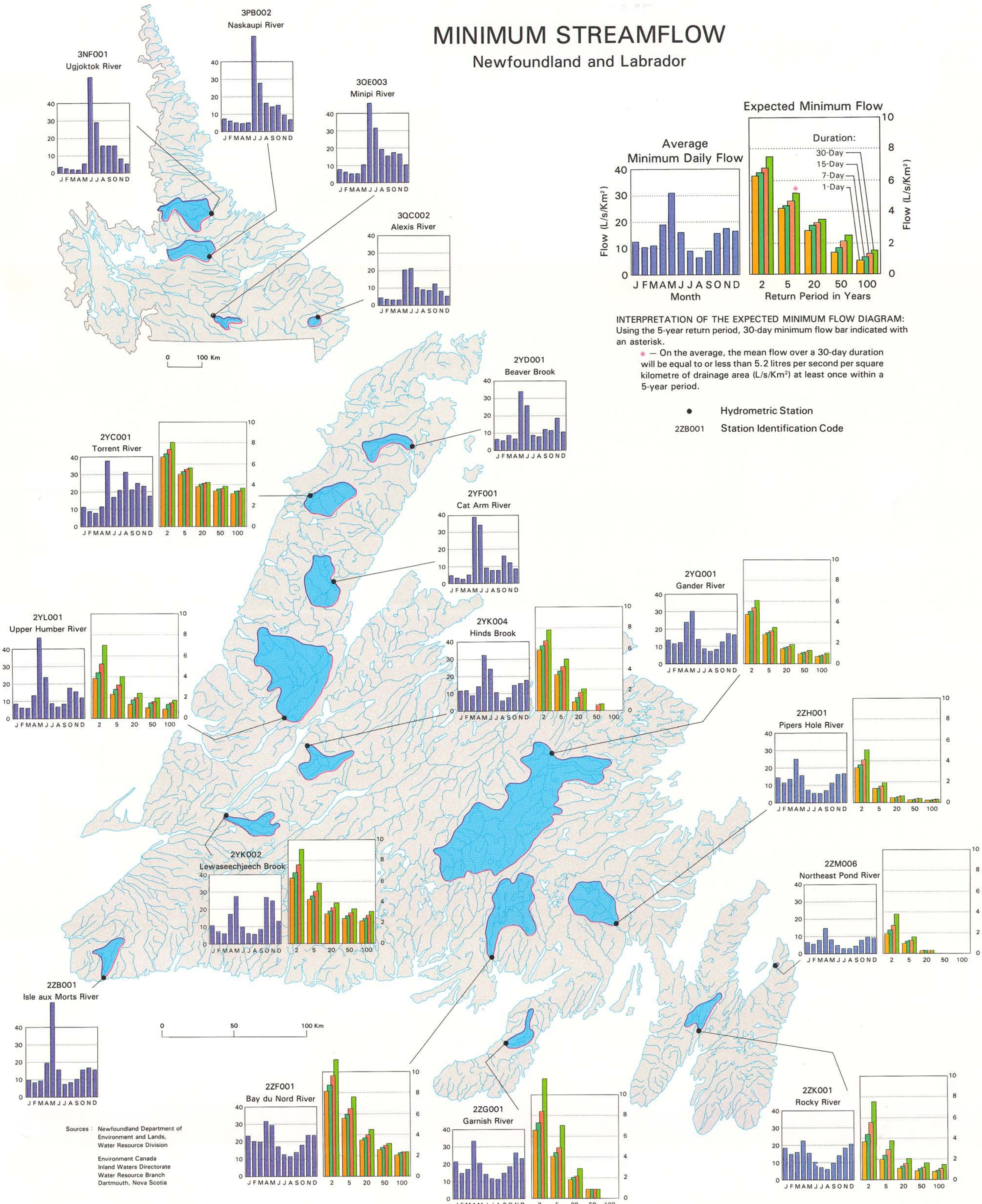


Figure 16.2 Frequency of 1-Day Annual Minimum Flows

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.

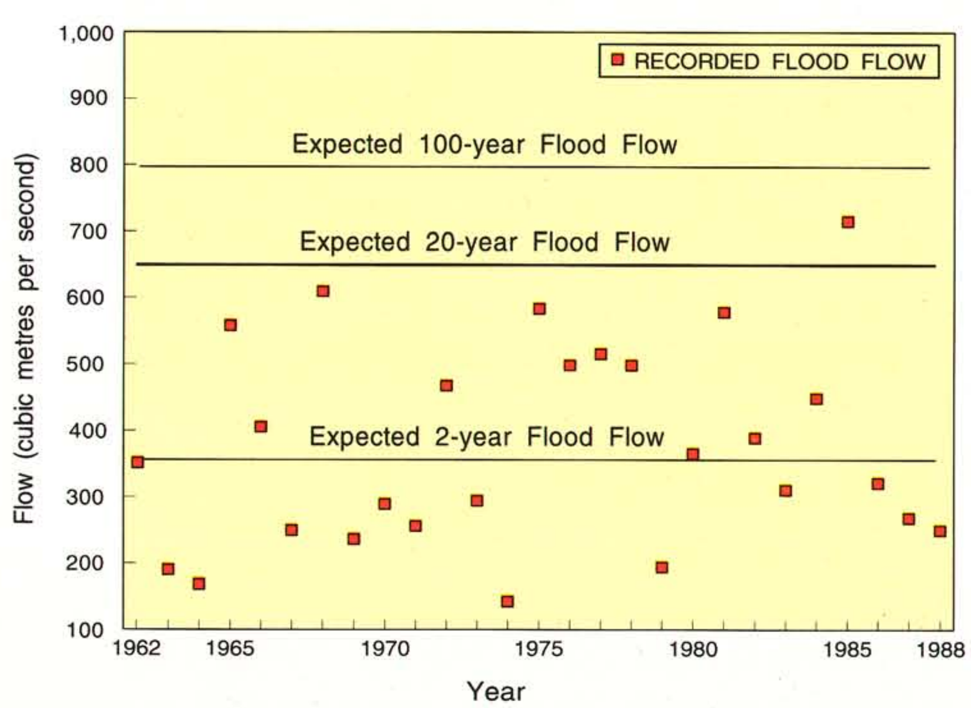


Figure 17.1 Recorded and Expected Flood Flows on the Isle aux Morts River

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.

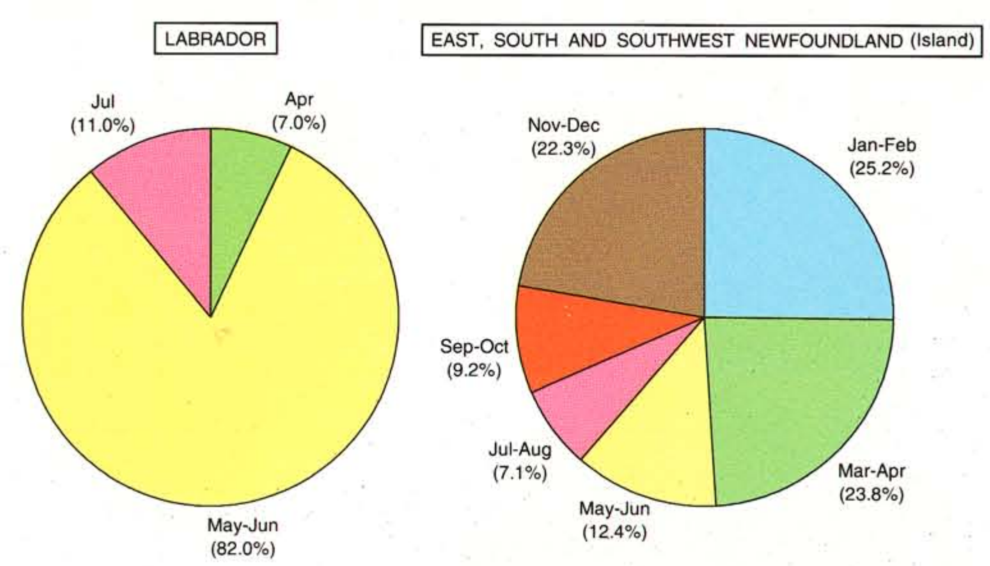
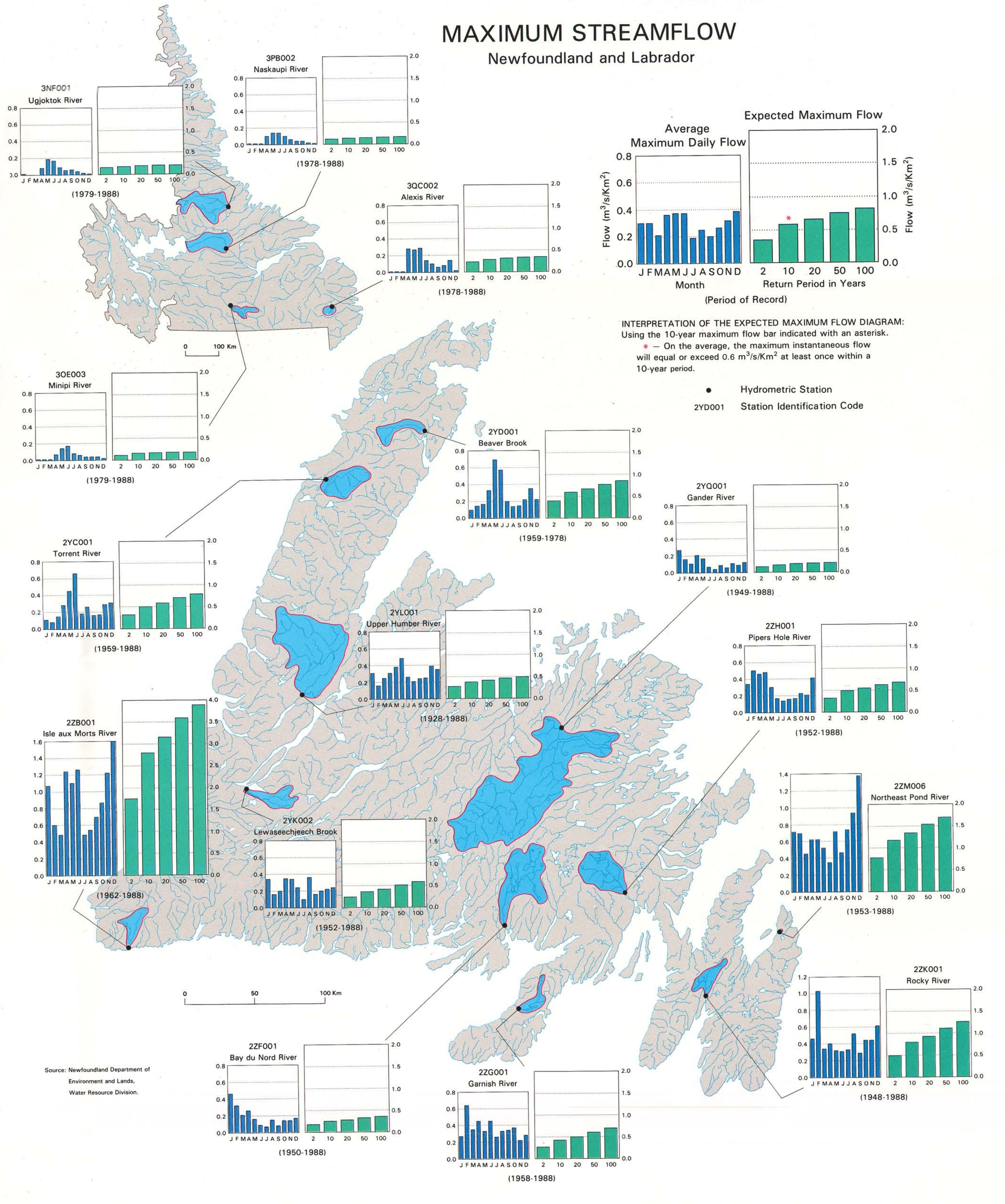


Figure 17.2 Frequency of Annual Flood Flows

MAXIMUM STREAMFLOW

Newfoundland and Labrador



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.

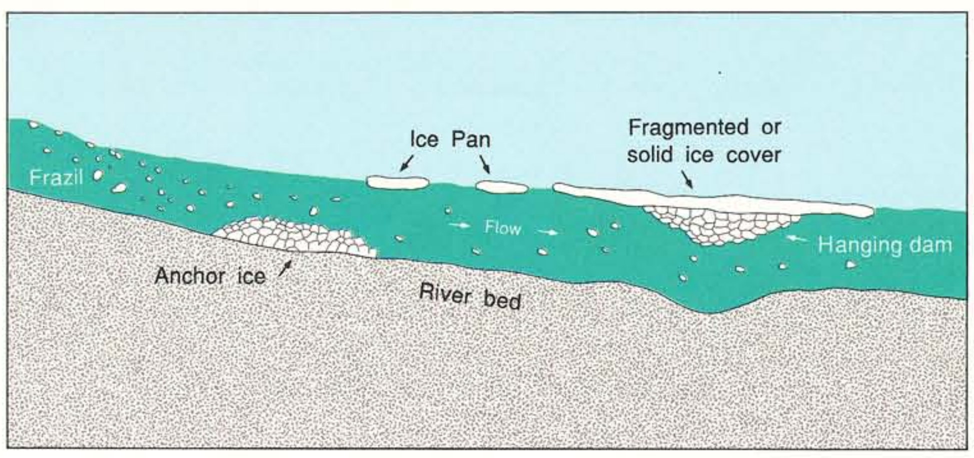


Figure 18.1 Types of Ice Cover

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.

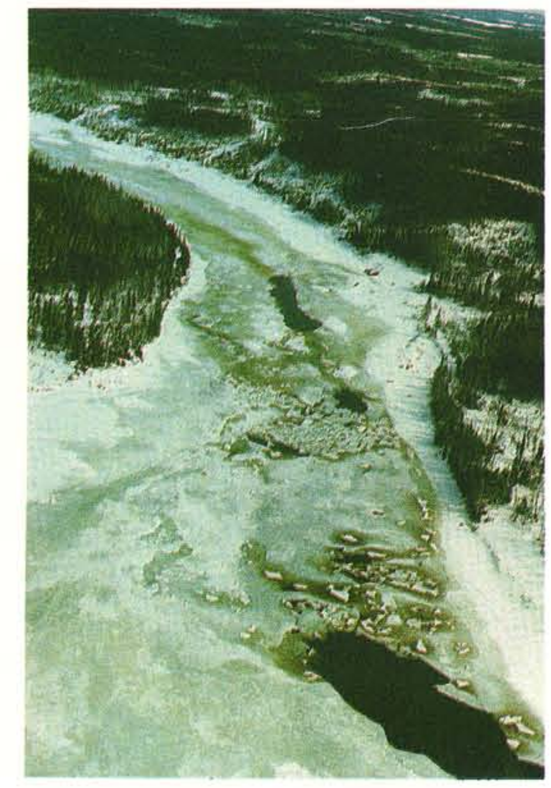


Figure 18.3 Blockage of Flow by Ice on the Exploits River

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.

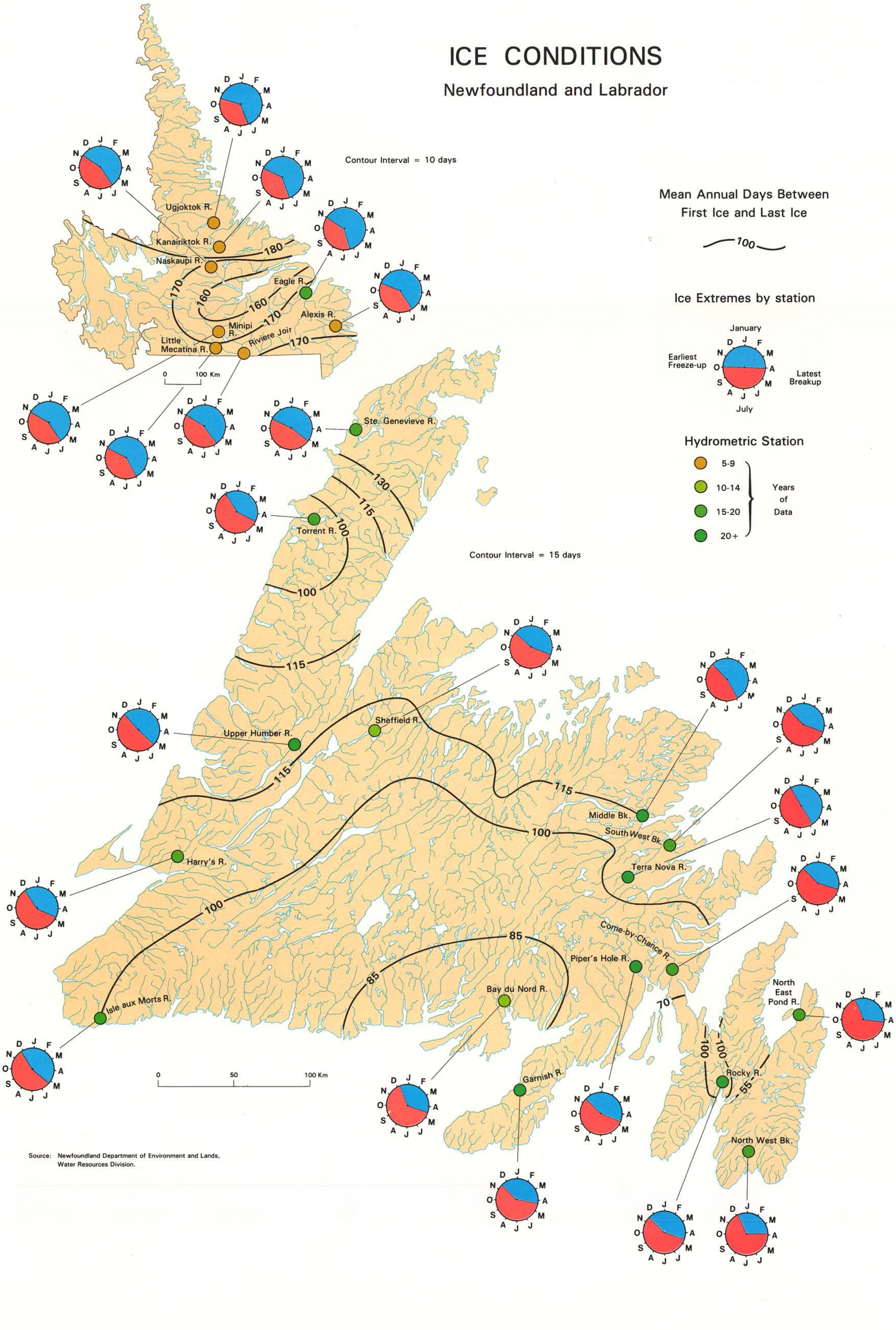
Automatic streamflow recorders installed on many rivers in Newfoundland and Labrador maintain continuous records of discharge. It is possible to determine from the discharge data the times of first freeze-up and last break-up of the ice cover on these rivers. The map on ice conditions on the opposite 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



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.

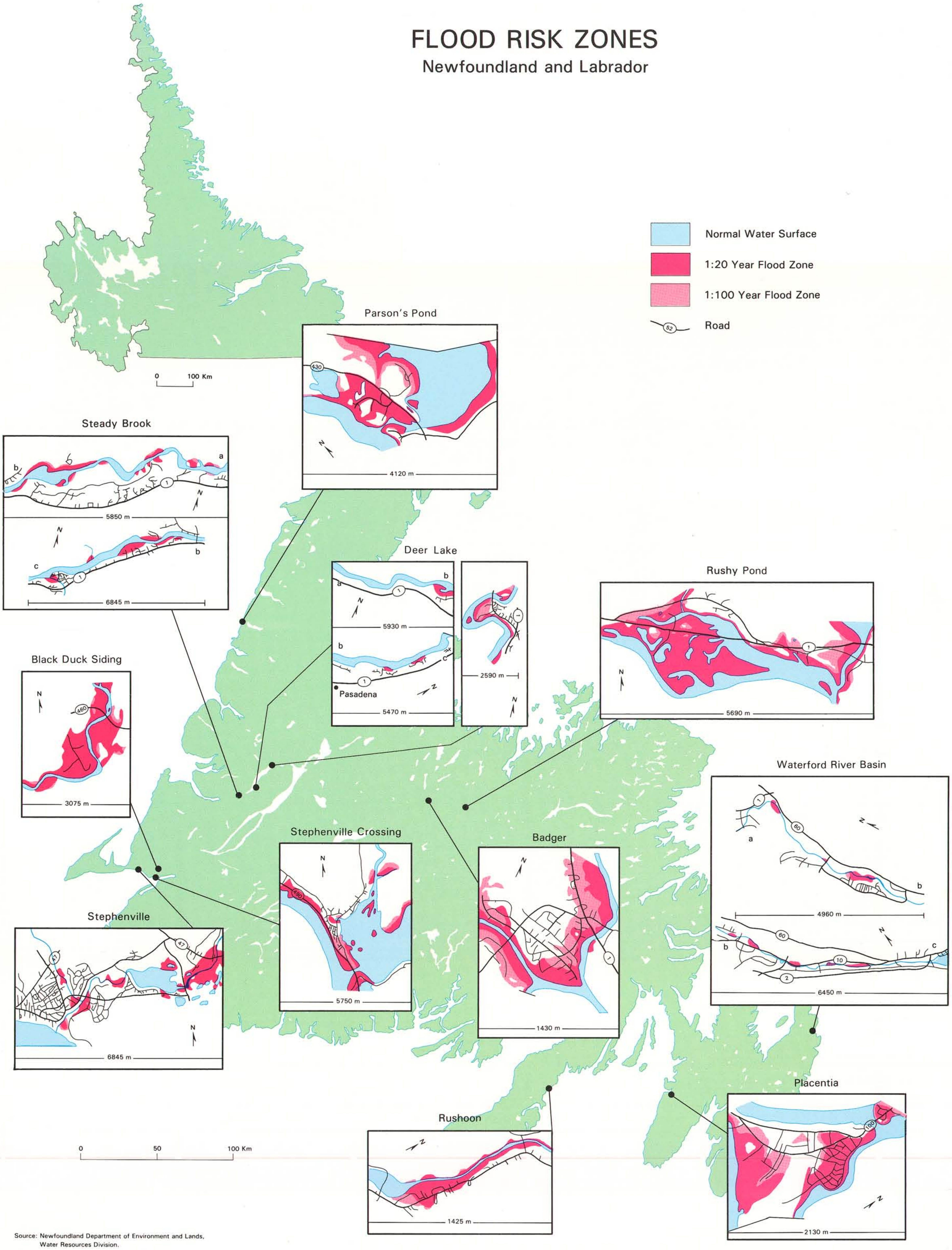
The flood risk maps delineate the flood risk areas using a two zone approach. The "designated floodway" (1:20 year flood zone) is the area subject to the most frequent flooding. The "designated floodway fringe" (1:100 year flood zone) constitutes the remainder of the flood risk area. No building or structure 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



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