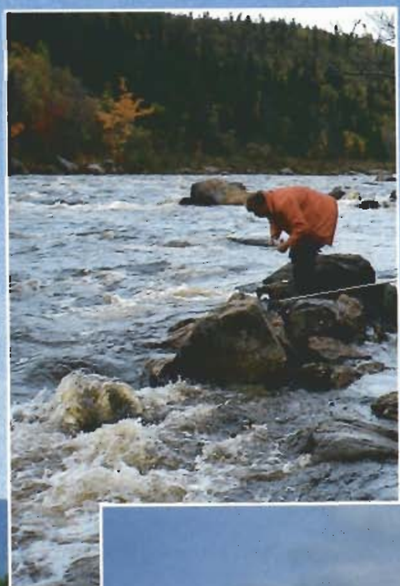
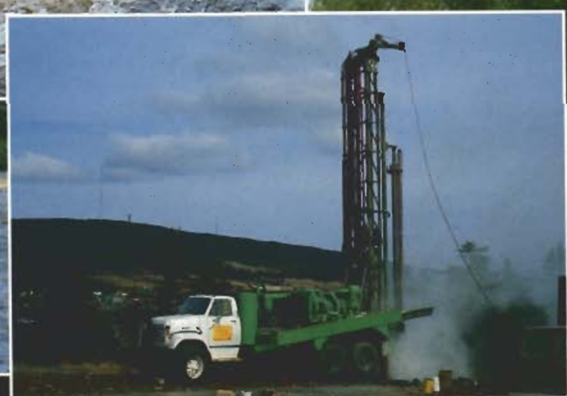
Regional Water Resources Study of the Notre Dame Bay Area and Central Newfoundland Region





GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES DIVISION

REGIONAL WATER RESOURCES STUDY

OF THE

NOTRE DAME BAY AREA AND

CENTRAL NEWFOUNDLAND REGION

Prepared for

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

Prepared by

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EXECUTIVE SUMMARY

The Regional Water Resources Study of the Central/Notre Dame Bay Region is the fifth in a series of water resources assessment studies for the Province of Newfoundland. To the extent appropriate, the format of the previous studies has been followed to provide comparability and continuity.

The purpose of the study is to assist the Water Resources Division in its planning, management, and regulatory mandates by collecting and synthesizing the information about water resources in this region.

The region generally extends from the Baie Verte Peninsula (Burlington Peninsula) south to Buchans, and eastward to the Gander River. It includes the offshore islands in Notre Dame Bay, including Fogo Island.

The region's economy is natural resource-based, depending mostly on pulp and paper and fish processing. Abundant fresh water has supported both these industries. Because of past mismanagement of both the forestry and fish resources, the economy is stagnating and the region is gradually depopulating. This reduces pressure on the supporting water resources.

Availability

The region receives about 1019 mm/year of precipitation on the average, of which about 858 mm runs off. Variation in mean annual runoff is not extreme, so that an abundant and reliable supply of fresh water is usually available.

Groundwater availability varies with geology, but is usually sufficient for provision of water to individual buildings and smaller communities. Of the 105 communities in the regional inventory, 20% derive a large portion of their water supplies from wells. The percentage of communities relying on groundwater as their water sources, both shallow dug and deep drilled wells, is slightly more than the 10% reported by Environment Canada (1988) and represents an important portion of the total groundwater supply for the study region. With the exception of Badger, no significant supplies of groundwater are extracted from surficial deposits, and most wells are in bedrock. However, surface water supplies are preferred, over groundwater supplies, since they generally provide larger yields.

Availability - Recommendations

- Runoff gauges (one permanent and one temporary) should be established on New World Island and Fogo Island to provide better information about water availability in the offshore region.

Quality

Surface water quality is generally good, but exceptions occur. The lower Exploits River is heavily polluted by the Abitibi-Price pulp and paper mill at Grand Falls/Windsor, and by municipal discharges. Heavy metal effluents from the former ASARCO mine at Buchans are polluting downstream waters. Most communities discharge their wastewater untreated, usually to the marine environment. The quality of the Grand Falls/Windsor/Bishop's Falls municipal supply is not good. Groundwater quality is generally good with occasional problems of pH and colour outside the ranges specified in Canadian Water Quality Guidelines. The only metals listed that frequently exceed Guideline concentrations are iron and manganese; however, arsenic and mercury are frequently not tested for and should be added to future sampling protocols.

Quality - Recommendations

- The lower Exploits River should be cleaned up.

- The extent and effects of pollution from the ASARCO operations should be studied to determine if remediation is warranted.

- Basin management boards should be established to protect the quality of the Exploits and Gander basins.

- The quality of the Exploits Regional Water Supply, which services Grand Falls/Windsor and Bishop's Falls, should be improved.

- The NDOEL Exploits River water quality survey should be extended downstream through the estuary.

- An assessment study of Gander Lake nonpoint-source pollution proposed by the Town of Gander should be done.

- Mercury and arsenic should be added to future groundwater sampling protocols.

Instream Uses

The main instream uses are hydropower, fishery enhancement (Atlantic salmon), recreational and commercial fishing, water-based recreation, withdrawal uses, and municipal and industrial wastewater pollution assimilation. The estimated gross value of all these activities in the region is $52.74 million/year. Of this, $29.0 million/year is estimated to accrue without charge to Abitibi-Price by virtue of its 99-year lease on the water resources of the Exploits River, which expires on June 15, 2004.

Instream Uses - Recommendations

Numerous recommendations are made in Sections 6 and 10, including:

- a rationalization of the use of the Exploits River, preferably in conjunction with the proposed Green Wood hydroelectric project,

- a re-evaluation of the value of the fishery enhancement program,

- further study to assess the potential value of the recreational fishery, particularly in light of opportunity costs for hydropower and pollution assimilation.

Water Supply

Most communities have a sufficient supply of water, but many have unsuitable collection and distribution systems. Water quality is generally good, with the exceptions of some groundwater supplies. In general, acceptable quality can be attained by proper treatment of surface supplies, or switching from groundwater to surface water supplies.

Supplies to some fish plants are inadequate, but the plants seldom meter their water nor take appropriate engineering measures to rectify them.

The supply problems reported by most communities are a result of inadequate funding. Most communities rely on the Province to support water supply systems, rather than undertaking it as a municipal responsibility.

Our screening model has identified a few communities with supply problems. We have tried to assess the problems and suggest appropriate engineering measures to rectify them.

Water Supply - Recommendations

- Attention should be given to those communities identified by the screening model as having supply problems.
- Water use by fish plants should be metered and studied.
- More intensive water availability assessments should be made of New World/Twillingate and Fogo Islands, where readily-available inexpensive supplies are limited.
- Gradual depopulation and a static economic base will, in general, not result in greater pressures on the water resources for water supply in the medium term.

Exploits River

The Exploits River has several conflicting beneficial uses, a proposed hydroelectric development, and a lease which expires in 13 years. The government should develop a plan which will optimize the basin's various beneficial uses and provide a more reasonable return to the Province for the water resources allocated.

Gander River and Gander Lake

The overall quality of the Gander River basin appears to be good, and development of a recreational salmon fishery may offer some economic potential. The Town of Gander has a concern about nonpoint-source induced long-term water quality degradation; and this should be addressed in a separate, more directed investigation.

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SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 Study Objectives

This is one of a series of regional water resources studies being conducted by the Water Resources Division of the Department of Environment and Lands. The Water Resources Division is responsible for the management and study of the freshwater resources of the Province. The purpose of this study is to provide both new and updated information to assist the Division to carry out its mandate.

To a large extent, this series of studies follows in the wake of the exhaustive survey performed in the 1960s by MacLaren/Shawinigan (1968) for the Atlantic Development Board, which has never been exceeded in scope and breadth.

In the Province of Newfoundland, and in the Central/Notre Dame Bay region, control of water resources rests with several agencies in addition to NDOEL; including Newfoundland and Labrador Hydro, DFO, and private firms such as Newfoundland Power and Abitibi-Price. Thus the Water Resources Division does not exercise complete control over the resource, but it is the only agency without a specialized interest and which can attempt to derive the best return from multipurpose use of the resource.

Specific study objectives include:

1. assess the availability of freshwater resources,

2. survey consumptive and nonconsumptive uses of water, including a detailed survey of municipal systems,

3. assess water quality,

4. estimate the value of the water resources in an economic sense; the general approach is to estimate gross benefits per year for each beneficial use; and

5. make observations and recommendations regarding freshwater resources.

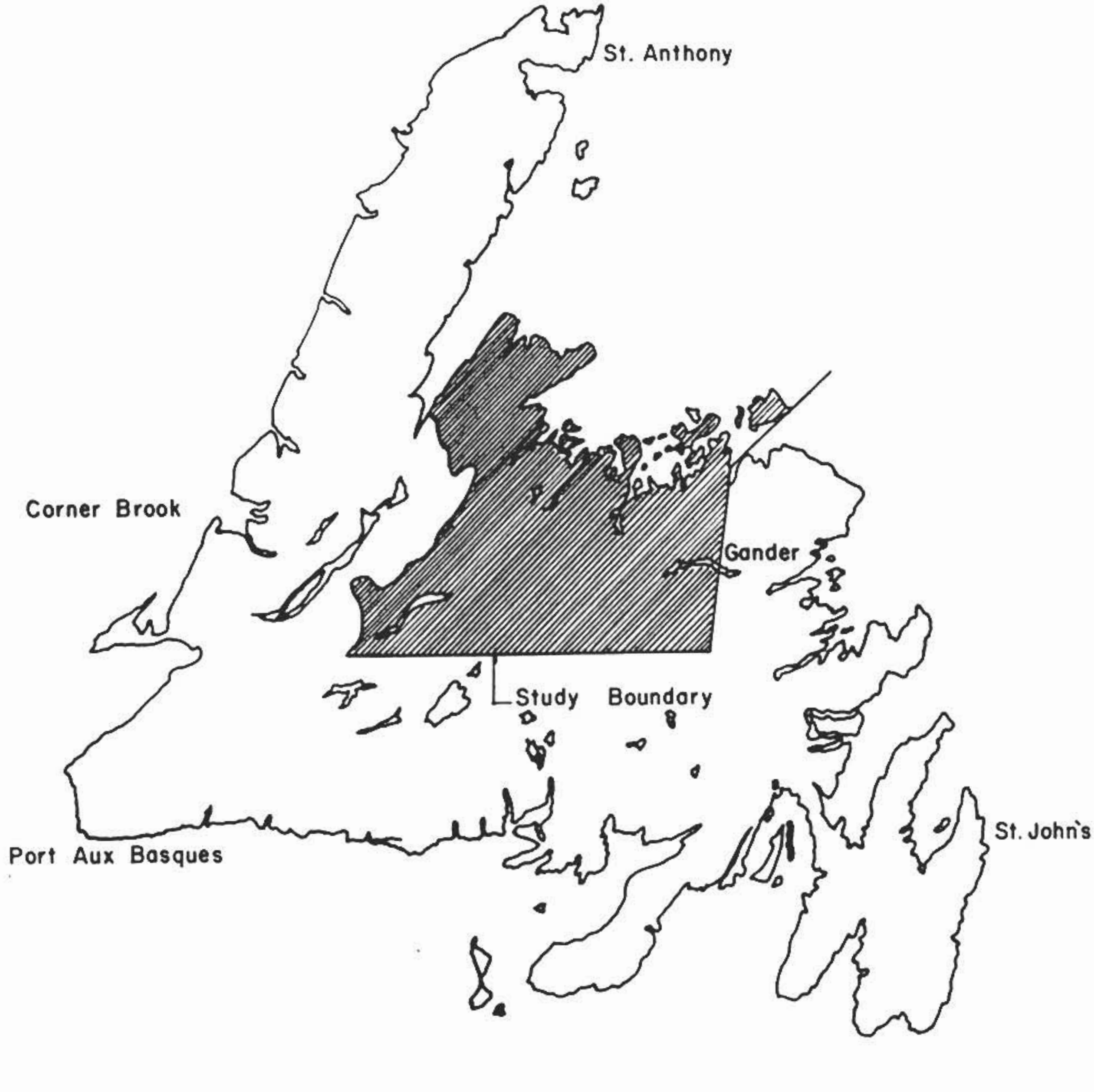
We wish to note that the level of effort and detail corresponds to that of a survey. Original field investigations were performed for the municipal survey; otherwise available information provided by various agencies was used. Thus the level of analysis is not sufficient for detailed engineering design.

1.2 Study Area Location

The location of the study area is illustrated on Figure 1-1. A detailed cultural map is presented as Figure 1-2. The southern limit (about latitude 48° 50' N), as shown on Figure 1 of the Terms of Reference, excludes the Upper Exploits River basin, although this area is described where appropriate in the text.

Several offshore islands not originally included in the Terms of Reference (Fogo Island, Change Islands, Long Island, Pilley's Island, and Triton Island) were subsequently also incorporated into the study area with the Department's approval.

A substantial portion of the Gander River basin is also excluded. Because of this, we decided to concentrate on the Exploits River basin which has several important projects requiring the Division's attention.



DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

LOCATION OF STUDY AREA

FIG. 1–1

1.3 Sources of Data

Information was graciously provided by many agencies, communities, and private companies. These include:

- Government of Newfoundland and Labrador

  Department of Environment and Lands
  - Water Resources Division
  - Parks Division
  - Environmental Assessment Division
  - Civil/Sanitary Engineering Division

  Department of Municipal & Provincial Affairs
  Economic Recovery Commission
  Department of Mines and Energy
  Newfoundland and Labrador Hydro

- Government of Canada

  DFO
  Environment Canada
  - EPS
  - AES
  - WSC

- Abitibi-Price Inc.

- Newfoundland Light & Power Co. Limited

- Communities

  - Baie Verte
  - Springdale
  - Buchans
  - Grand Falls/Windsor
  - Bishop's Falls
  - Lewisporte
  - Botwood

1.4 Brief Description of Study Area

The Central region has, for the Island of Newfoundland, a relatively continental climate. It is generally flat and well-forested, with two large rivers. The economy is resource-based, with forestry/pulp and paper being the largest single industry.

Mining was formerly of importance, but all the mines in the region are currently abandoned or inactive.

Notre Dame Bay is festooned with islands and thus offers a sheltered saltwater fishery ideal for inshore fishermen. The numerous small fishing communities along the coastline on the offshore islands attest to a long fishery tradition. Accordingly, the primary coastal economic base is fishing and fish processing. As fresh water for these communities and industries is supplied by smaller drainage basins, water supply and quality is a more constraining factor in many of the Notre Dame Bay-area communities.

Most of the water resources of the Exploits River Basin were allocated to the predecessor of Abitibi-Price Inc. in a 99-year cost-free lease which expires in 2004. In light of the imminent expiration of the lease, some opportunity exists for the Province to better allocate and manage the Exploits River water resources in the future.

Unfortunately, past overharvesting has led to current and anticipated shortfalls of both pulpwood and fish. This mis-management of natural resources is resulting in a pessimistic outlook for economic growth in the study area until the shortages can be rectified. It is thus unlikely that the water resources will be much impacted by new urban or commercial growth in the near to medium term.

The region has a limited tourist industry. There is some potential for growth and improvement on the basis of the Exploits River salmon enhancement program and proposed reduction of industrial pollution at Grand Falls/Windsor. A flourishing recreational salmon industry exists in the lower Gander River. There are 11 provincial parks in the region where popularity is beginning to increase following a downturn in the mid 1980s.

In summary, by supporting the pulp mill and fishery, the water resources of the Central/Notre Dame Bay region have been essential to the development of its resource-based economy.

1.5 References - Section 1.0

Atlantic Development Board, "Water Resources Study of the Province of Newfoundland and Labrador", prepared by The Shawinigan Engineering Company and James F. MacLaren Ltd., Rpt. 3591-1-68, September 1968, 8 Vols.

SECTION 2.0

SURFACE WATER

2.0 SURFACE WATER

2.1 Scope

The existing streamgauge data are reviewed and analyzed in this section to provide a general basis for understanding the freshwater resources of the region.

In particular, the analyses provide estimates of the mean annual runoff (MAR), describe typical variation in mean monthly flows through the annual cycle, provide representative flow duration curves, provide frequency estimates of low flow recurrence, and, finally, provide a regional estimate of the storage required to obtain selected water demands for smaller basins.

It is noted that the level of analysis is appropriate for screening and reconnaissance, but not for design.

Meteorological phenomena such as precipitation, evaporation, and a general water balance are reviewed in Section 3.

2.2 Mean Annual Runoff (MAR)

2.2.1 Scope

The mean annual runoff is the average annual discharge from a drainage basin, usually expressed as a depth in mm per year, or as unit discharge normalized by basin area -- $m^3/s\text{-}km^2$. (Note that $m^3/s\text{-}km^2$ is an improper metric unit; the proper unit should be m/s. This unit produces an unwieldy small number, though.) Since the $m^3/s\text{-}km^2$ is a unit more useful to water engineers, it will be employed in preference to mm/year. The conversion is:

$$\frac{m^3}{km^2.s} * 31{,}557{,}600 \; \frac{s}{yr} * \frac{1\ km^2}{1000\ m^2}{}_2 * \frac{1000\ mm}{1\ m} \dashrightarrow \frac{mm}{yr} \qquad (2\text{-}1)$$

so

$$1 \; \frac{m^3}{km^2.s} = 31{,}558 \; \frac{mm}{yr} \qquad (2\text{-}2)$$

Values in mm/year can be compared with meteorological data to assess the correspondence, and losses due to evaporation.

Streamgauge data used in the analyses were obtained from Water Survey of Canada (WSC) records; precipitation data in Section 3 were obtained from the Atmospheric Environment Service (AES).

The analysis for streamgauge MAR proceeded as follows:

(a) describe available data
(b) determine stationarity
(c) derive consistent records for as many gauges as possible by correlation and proration
(d) calculate MAR for gauges
(e) relate MAR to physiographic variables to the extent possible
(f) prepare a map showing isolines of MAR.

2.2.2 Available Data - WSC Gauges

There are 23 WSC streamgauge stations in the study area, of which five are no longer in operation. Some information on these stations is given in Table 2-1. WSC station 02YK001, Humber River at Grand Lake outlet, has also been included in the summaries and analysis since it has a longer term record (1925-1988) than any gauge in the study area, and provides some further opportunity to examine geographic variability of unit runoff.

Table 2-1

WSC Streamflow Gauging Stations

STATION NAME	STATION NUMBER	LOCATION	DRAINAGE AREA km2	PERIOD OF RECORD	NUM. ON FIG 2-1	REGULATED	VARIABLE LETTER
Exploits River @ Grand Falls	02YO001	48 55 50 N 55 40 07 W	8,390	'44-'88	21	yes	B
Exploits River below Noel Pauls Brook	02YO011	48 50 27 N 55 16 33 W	6,300	'85-'88	22	yes	-
Exploits River below Stony Brook	02YO005	48 55 27 N 55 39 29 W	8,640	'69-'88	20	yes	C
Gander River @ Big Chute	02YQ001	49 00 55 N 54 51 13 W	4,400	'49-'88	17	no	D
Gander River @ Outlet of Gander Lake	02YQ002	48 56 00 N 54 52 00 W	4,100	'23-'39	15	no	-
Gander River below Weirs Brook	02YQ003	49 10 00 N 54 51 13 W	5,010	'23-'30	18	no	-
Great Rattling Brook above Tote River Confluence	02YO008	48 49 38 N 55 31 50 W	823	'84-'88	12	no	E
Humber River @ Grand Lake Outlet	02YK001	49 09 43 N 57 25 28 W	5,020	'25-'88		yes	A
Indian Brook @ Indian Falls	02YM001	49 30 43 N 56 06 45 W	974	'54-'88	3	yes	F
Indian Brook Diversion to Birchy Lake	02YM002	49 22 18 N 56 37 14 W	N/A	'63-'78	4	no	-
Junction Brook near Badger	02YO010	48 58 23 N 56 01 21 W	61.6	'85-'88	9	no	-
Leech Brook near Grand Falls	02YO007	48 56 42 N 55 49 42 W	88.3	'84-'88	10	no	G
Middle Arm Brook below Flatwater Pond	02YG002	49 48 22 N 56 20 33 W	224	'87-'88	2	no	-
Northwest Gander River near Gander Lake	02YQ004	48 46 07 N 55 04 52 W	2,150	'83-'88	14	no	H
Peters River near Botwood	02YO006	49 06 21 N 55 24 38 W	177	'81-'88	13	no	I

Table 2-1 (cont'd)

STATION NAME	STATION NUMBER	LOCATION	DRAINAGE AREA km2	PERIOD OF RECORD	NUM. ON FIG 2-1	REGULATED	VARIABLE LETTER
Rattling Brook @ Rattling Brook Powerhouse	02YO003	49 03 12 N 55 17 12 W	378	'62-'88	24	yes	J
Rattling Brook near Norris Arm	02YO002	49 04 00 N 55 18 00 W	358	'56-'58	23	yes	-
Salmon River near Glenwood	02YQ005	49 00 41 N 54 55 03 W	80.8	'87-'88	19	no	-
Sandy Brook @ Sandy Brook Powerhouse	02YO004	48 53 18 N 55 49 14 W	508	'64-'88	11	yes	-
Sheffield Brook near Trans Canada Highway	02YK005	49 20 11 N 56 39 56 W	391	'72-'88	5	no	K
Sheffield River @ Sheffield Lake	02YK003	49 20 10 N 56 37 57 W	362	'55-'66	6	no	L
Shoal Arm Brook near Badger Bay	02YP001	49 22 18 N 55 48 44 W	63.8	'82-'88	7	no	M
Shoal West Brook near Baie Verte	02YM003	49 53 37 N 56 13 22 W	93.2	'80-'88	1	no	N
Unknown River @ Lewisporte	02YO009	49 14 02 N 55 03 58 W	15.5	'85-'88	16	no	-

NOTES:

"Number on Fig." refers to Figure 2-1

"Variable letter(s)" are identifiers used in statistical analyses.

The locations of the WSC gauges are shown on Figure 2-1.

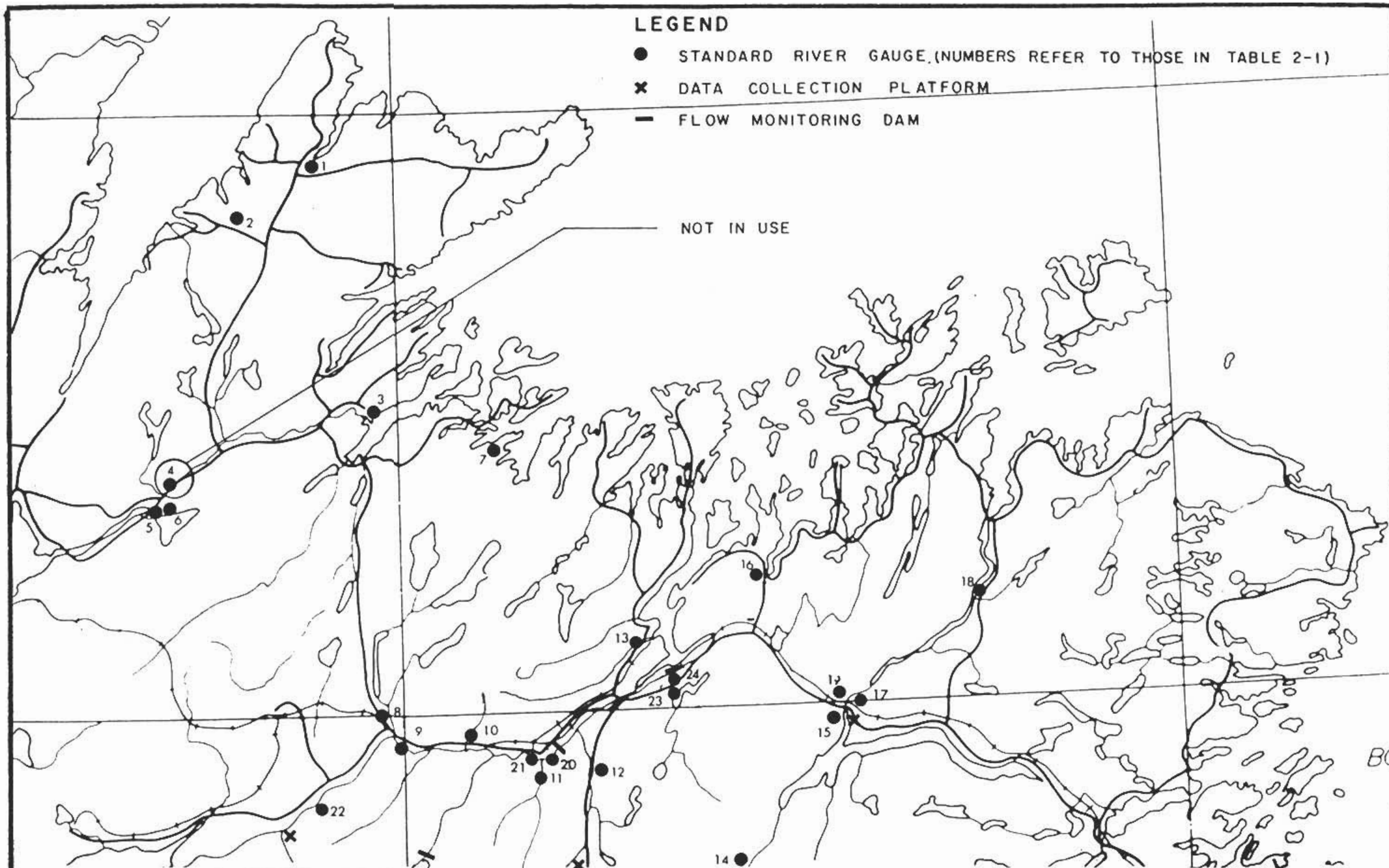
The periods of record of the WSC gauges are shown in Table 2-2. [Note that, as mentioned, 02YK001 has a longer record than shown on this figure.] There are six stations with record lengths of at least 20 years, and four more with 10 years or more of continuous records. The rest are short-term stations. (Two old discontinued stations on the Gander River - 02YQ002 and 02YQ003 - which were operational in the 1920s and 1930s were not used because the quality of the data was likely not up to modern standards.)

2.2.3 Stationarity of Data

Before most statistics can be performed on (time) series, it should be checked that the data are independent and stationary. Technically, a series is said to be stationary when its expected value does not vary with time and the autocorrelation function depends only upon the differences and not upon the absolute time scale (Julian, 1967). This condition could be relaxed in this study to a requirement that only the first and second moments be stationary. In fact, study constraints preclude an investigation of only the first moment.

Climate and associated hydrologic characteristics are nonstationary in the long term (in the order of 5,000 years) due to the glacial cycle, but the short length of available gauge records cannot discern these cycles.

The mean annual flows for the gauges listed in Table 2-2 are presented in Table 2-3. The 1926-1943 portion of the record of the Humber River has been omitted.



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WATER QUANTITY MEASURING STATIONS IN STUDY AREA

FIG. 2-1

Table 2-2 LENGTHS OF WSC STATION RECORDS

YEAR	GAUGE STATION																					
	02YO 001	02YO 011	02YO 005	02YQ 001	02YO 008	02YK 001	02YM 001	02YM 002	02YO 007	02YO 010	02YG 002	02YQ 004	02YO 006	02YO 003	02YO 002	02YQ 005	02YO 004	02YK 005	02YK 003	02YP 001	02YM 003	02YO 009
1944	x					x																
1945	x					x																
1946	x					x																
1947	x					x																
1948	x					x																
1949	x			*		x																
1950	x			x		x																
1951	x			x		x																
1952	x			x		x																
1953	x			x		x																
1954	x			x		x	*															
1955	x			x		x	x												*			
1956	x			x		x	x								*				x			
1957	x			x		x	x								x				x			
1958	x			x		x	x								*				x			
1959	x			x		x	x												x			
1960	x			x		x	x												x			
1961	x			x		x	x												x			
1962	x			x		x	x							*					x			
1963	x			x		x	x	*						x					x			
1964	x			x		x	x	x						x			*		x			
1965	x			x		x	x	x						x			x		x			
1966	x			x		x	x	x						x			x		*			
1967	x			x		x	x	x						x			x					
1968	x			x		x	x	x						x			x					
1969	x		x	x		x	x	x						x			x					
1970	x		x	x		x	x	x						x			x					
1971	x		x	x		x	x	x						x			x					
1972	x		x	x		x	x	x						x			x	*				
1973	x		x	x		x	x	x						x			x	x				
1974	x		x	x		x	x	x						x			x	x				
1975	x		x	x		x	x	x						x			x	x				
1976	x		x	x		x	x	x						x			x	x				
1977	x		x	x		x	x	x						x			x	x				
1978	x		x	x		x	x	x						x			x	x				
1979	x		*	x		x	x							x			x	x				
1980	x		*	x		x	x							x			x	x			x	
1981	x		x	x		x	x						x	x			x	x			x	
1982	x		x	x		x	x						x	x			x	x		x	x	
1983	x		x	x		x	x					x	x	x			x	x		x	x	
1984	x		x	x	x	x	x		x			x	x	x			x	x		x	x	
1985	x	x	x	x	x	x	x		x	x		x	x	x			x	x		x	x	x
1986	x	x	x	x	x	x	x		x	x		x	x	x			x			x	x	x
1987	x	*	x	x	x	x	x		x	x	x	x	x	x		x	x			x	x	x
1988	x	*	x	x	x	x	x		x	x	x	x	x	x		x	*			x	x	*

x- full data

*- incomplete data

from 1925 on, outside study area

Table 2-3 MEAN ANNUAL FLOWS(1) AT WSC STATIONS

YEAR	GAUGE STATIONS																					
	02YK 001	02YO 001	02YO 011	02YO 005	02YQ 001	02YO 008	02YM 001	02YM 002	02YO 010	02YO 007	02YG 002	02YQ 004	02YO 006	02YO 003	02YO 002	02YQ 005	02YO 004	02YK 005	02YK 003	02YP 001	02YM 003	02YO 009
1944	139	241																				
1945	171	240																				
1946	140	177																				
1947	127	188																				
1948	102	174																				
1949	137	226																				
1950	135	183			78.7																	
1951	122	189			114																	
1952	143	241			123																	
1953	136	193			112																	
1954	133	250			132																	
1955	139	195			117		24.7															
1956	141	231			124		23.4												10.2			
1957	131	199			111		25.1												10.1			
1958	130	226			102		20.8								10.7				9.35			
1959	129	168			91.5		16.7												7.31			
1960	128	173			95.4		20.7												8.79			
1961	114	154			71.4		21.8												9.16			
1962	144	247			158		25.5												12.9			
1963	168	275			142		22.5							13.2					11.7			
1964	142	233			129		19.4	5.13						11.4					9.55			
1965	145	227			121		20.1	4.84						12.9			15.3		10.8			
1966	150	179			106		17	4.64						9.52			10.8					
1967	97.9	197			110		15.6	4.27						8.65			11.4					
1968	131	246			132		16.5	5.33						10.7			13.7					
1969	161	253		303	134		23.2	6.68						10.8			14.3					
1970	152	221		287	142		17.2	4.5						11.2			15.3					
1971	148	200		273	119		19	5.79						9.43			12.9					
1972	141	212		270	121		17.5	5.68						9.96			12.6					
1973	164	197		269	139		19.5	7.14						10.7			13.5	11.4				
1974	148	228		253	116		18.3	5.66						8.52			10.4	10.2				
1975	113	165		205	104		17.1	5.85						7.86			10.9	10.4				
1976	156	209		241	129		18	6.37						9.41			12.3	11				
1977	163	241		312	128		23.1	8.43						9.32			13.7	14.3				
1978	161	189		228	93.3		15.4	4.71						8.61			9.67	8.5				
1979	122	184			120		21							11.3			11.3	10.9				
1980	147	210			142		22.8							11			14.5	13.2			3.94	
1981	171	254		316	146		23.1						5.19	10.1			13.8	12.5			3.38	
1982	166	234		299	105		19.4						4.18	9.3			12.7	11.6		2.03	2.67	
1983	174	249		336	131		18.5					68.9	5.42	9.48			18.3	11.1		2.19	2.4	
1984	161	233		308	155	26.4	18.3			2.53		77.7	5.14	11.6			16.7	10.1		1.82	2.54	
1985	123	166		214	82.1	16.1	13.6		1.14	1.55		39.9	2.9	7.3			10.1	7.77		1.35	1.6	0.19
1986	121	177		231	105	19.3	15.4		1.24	1.93		52.3	3.68	8.41			12.7	9.34		1.59	1.71	0.23
1987	114	159	141	218	98.3	20.8	16.6		1.23	1.9	5.42	51.3	3.49	7.89		2.26	11	9.69		1.48	2.3	0.24
1988	128	214	193	291	118	21.7	20.8		1.64	2.52	7.95	53.7	5.23	10.7		2.64		12.7		2.36	3.11	
mean	140.	210	167	270	118	20.9	19.6	5.67	1.31	2.09	6.69	57.3	4.4	9.97	10.7	2.45	13	10.9	9.99	1.83	2.63	0.22
DA km^2	5020	8390	6300	8640	4400	823	974		61.6	88.3	224	2150	177	378	385	80.8	508	391	362	63.8	93.2	15.5

(1) Flows are in m^3/s

For comparison the area-normalized MARs for the common period 1950-1988 for the three long-term gauges are presented as Figure 2-2. Note the large correlation between these records.

Humber River

Since, ideally, at least pi radians of a cycle should be sampled to reliably discern it, the longest record should be used to detect nonstationarity. Since long-term trends are probably driven by processes whose spatial extent is much larger than the study area, and since the nearby Humber River has, by far, the longest (63 years) record; the appropriate point of departure for the analysis is to review the Humber record. The results can then be related to the overlapping period with the longest gauge records in the study region (Exploits River at Grand Falls and Gander River at Big Chute).

Trend

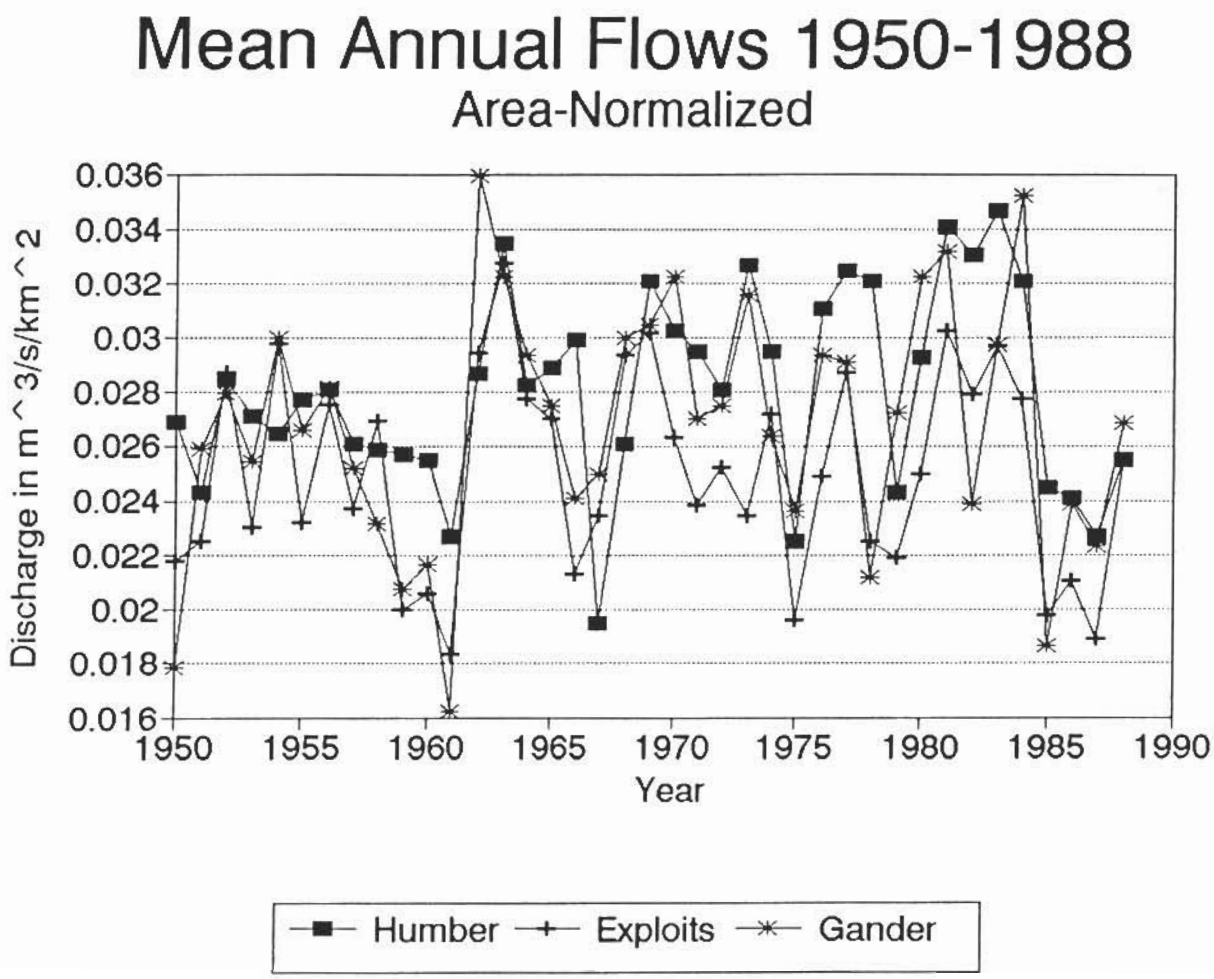
General temporal trend was tested by using linear regression, which is a simplified, yet effective, approach to the problem. The entire series of Humber River average annual flows 1926-1988 (n = 63) was regressed in order to determine the extent of first-order trend (ie. long period periodicity). The least-squares best-fit of a linear equation of the form f(x) = a + bx is:

$$_H\langle Q\rangle_{63\ yr} = 331.346 - 0.09643\ (\text{year}) \qquad (2\text{-}3)$$

where:
$n = 63$
$r^2 = 0.00858$
$r = 0.093$
H = Humber
$_{63\ yr}$ = period of record

so:
$a = 331.346$
$b = -0.09643$

FIG. 2-2



Mean Annual Flows 1950-1988
Area-Normalized
Discharge in m ^ 3/s/km ^ 2
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
1950
1955
1960
1965
1970
1975
1980
1985
1990
Year
Humber
Exploits
Gander

Since the overlap with the Exploits River records is only for the period 1944-1988, a linear regression analysis was also performed for this partial series. The best-fit equation is:

$$_{H}\langle Q\rangle_{45\ yr} = -395.44 + 0.2725\ (year) \qquad (2\text{-}4)$$

where:
$n = 45$
$r^2 = 0.037$
$r = 0.192$
H = Humber
$_{63\ yr}$ = period of record

The series of average annual flows and best-fit linear trend lines for both cases above are depicted on Figure 2-3. Note that, over the entire period of record, the MAR has been declining; however, over the period of coincidence with the Exploits River gauge (1944-1988), it has been increasing.

Are these trends significant? Since the 95% confidence interval for the regression coefficient "b" in the linear model $f(x) = a + bx$ in equation (2-3) is:

$$-0.357 < b = -0.09643 < 0.1644 \qquad (2\text{-}5)$$

the hypothesis that it is different from zero must be rejected and the series considered stationary.

Similarly, the 95% confidence interval of the coefficient 0.2725 in equation (2-4) is:

$$-0.14 < b = .2725 < 0.69 \qquad (2\text{-}6)$$

which also cannot be considered significantly different from zero.

In summary, it is assumed that the first moment of the series of annual coverage flows for the Humber River is stationary.

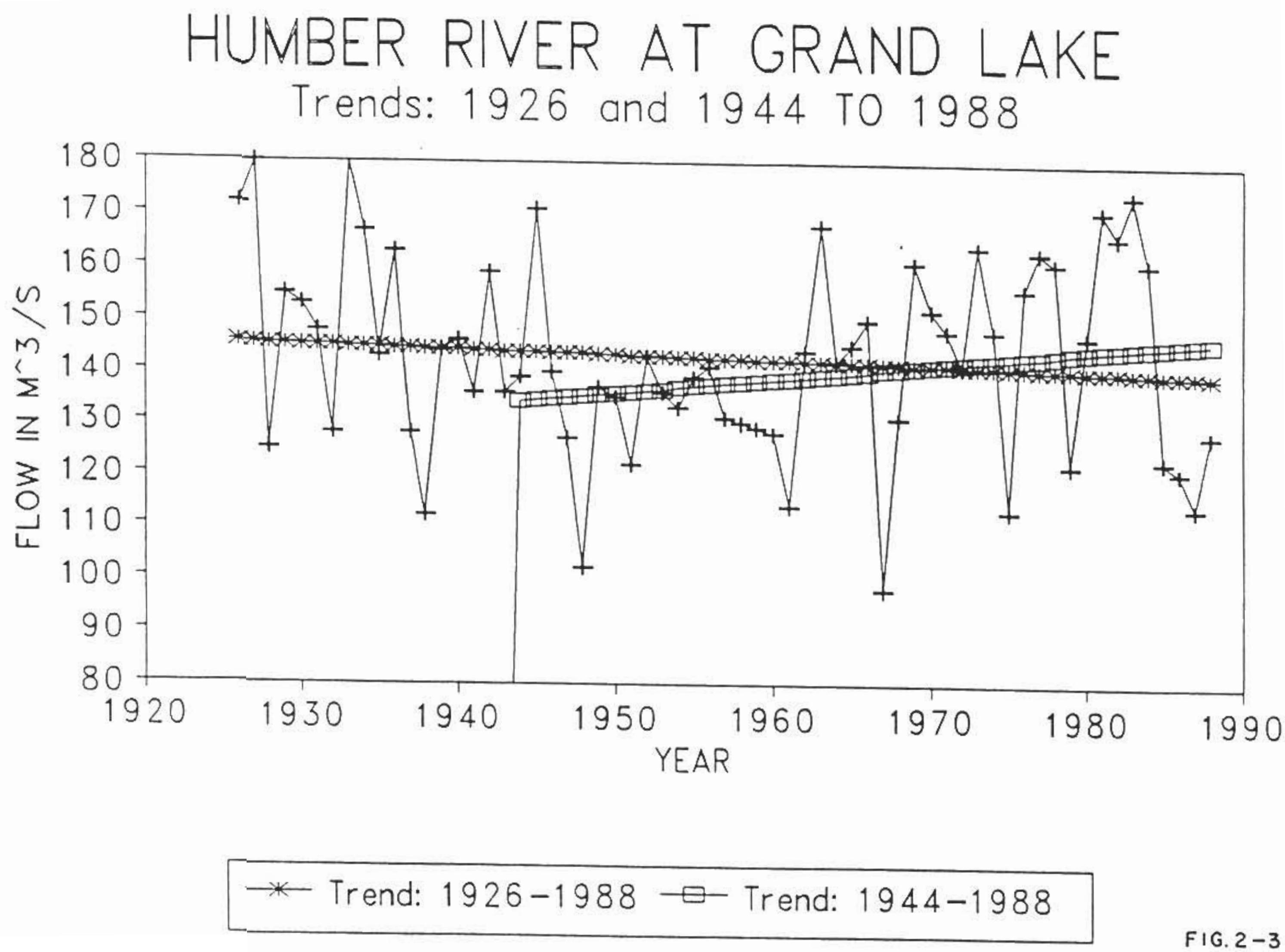

HUMBER RIVER AT GRAND LAKE
Trends: 1926 and 1944 TO 1988
FLOW IN M^3/S
180
170
160
150
140
130
120
110
100
90
80
1920
1930
1940
1950
1960
1970
1980
1990
YEAR
Trend: 1926-1988
Trend: 1944-1988

FIG. 2-3

Also, the hypothesis that the mean flow of the 1926-1988 series (142.6 m^3/s) is significantly different from the mean flow of the 1944-1988 series (140.9 m^3/s) cannot be accepted at a 95% confidence level.

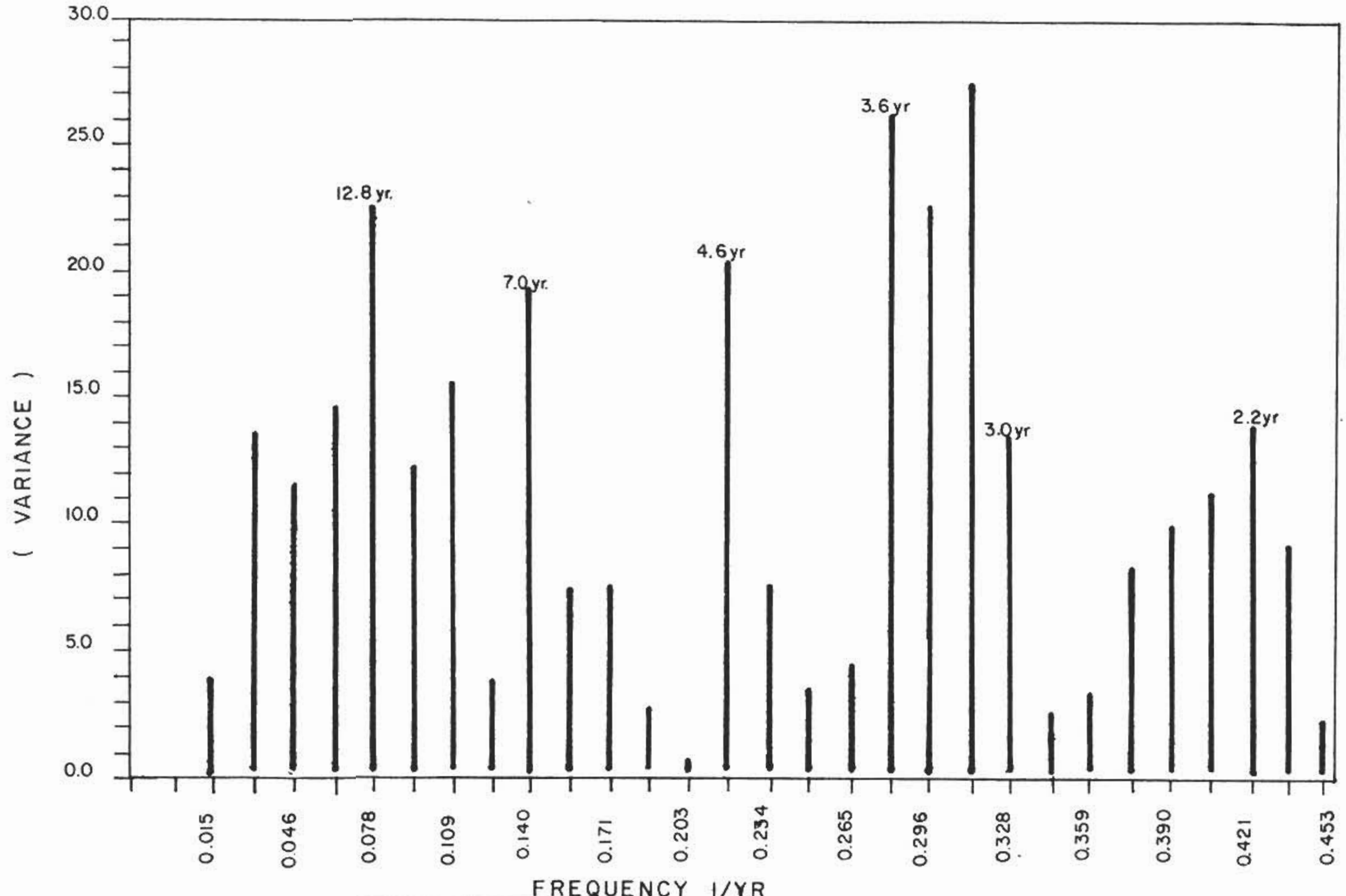
The sample variance of the 1944-1988 series (749.2 m^6/s^2) is 2.1 times that of the longer 1926-1988 series; however, an F-test does not permit rejection of the hypothesis that they are the same.

In summary, although the partial series from 1944-1988 appears to have different characteristics from the longer 1926-1988 series of which it is a part, it cannot be statistically concluded that this is the case. The apparent differences, however, do hint at the existence of long-term periodicities which cannot be resolved.

Periodicities

Other shorter-term variations within the 1926-1988 data set depicted on Figure 2-3 may be due to periodicities in the data. To analyze this, the series was subjected to both autocorrelation and Fourier analyses.

For the Fourier analysis, the mean was subtracted from the series, but no filtering or detrending was done. The frequency plot is given as Figure 2-4. Distinct peaks in variance occur at periods of 12.8 years, 7 years, 4.6 years, 3 to 3.6 years, and 2.2 years. (Recall the Nyquist frequency is 2.0 years.) The power in the 3-year range is very evident. [While mathematically real, the physical meaning of the 3-year cycle is more problematic. Its broadness may indicate aliaising of longer-period cycles just above the Nyquist period; or it may indeed be a real phenomenon. Further



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HUMBER RIVER
FOURIER PLOT OF AVERAGE ANNUAL
FLOWS. 1926 – 1988

FIG. 2-4

analysis on this should be done on other long-term records in the Province, and with appropriate filters.]

The 3-year, 4.6-year, and 7-year cycles are almost in phase with one another, while the 12.8-year cycle is about 2 radians out of phase with them. Note on Figure 2-3 that the 1950s appear to be a sum of out-of-phase signals, while the 1930s and 1970s do not.

The autocorrelation data for the Humber River 1926-1988 series are presented in Table 2-4 and depicted on Figure 2-5. The larger correlations are starred in Table 2-4. Seven- and 12.8-year cycles are quite evident in these data. Note that the autocorrelations for the 20-year lag (r = 0.072) and 30-year lag (r = -0.044) used by Acres (1990, Figure 2.2) are not particularly large. For illustrative purposes it appears better to use 7-year (r = 0.180), 22-year (r = -.263), and 47-year (r = -0.263) running averages. This has been done and the results are shown on Figure 2-6. The running averages all agree closely and indicate a highly variable wet period from 1925 to about 1940, followed by a more stable drier period from 1940 to 1961, followed by another variable wetter period which, it is inferred, may be ending.

<u>Summary</u>

In summary, for the Humber River, which has the longest series of average annual flows in the Province, the MAR series is statistically stationary with regard to the mean, and the variance of the partial series of years 1944-1988 is not statistically different from that of the whole record. The period 1944-1988 contained both a dry stable period and two wetter more volatile periods, so its mean (140.2 m^3/s) is close to the series mean (142.6 m^3/s) (delta% = -1.68%).

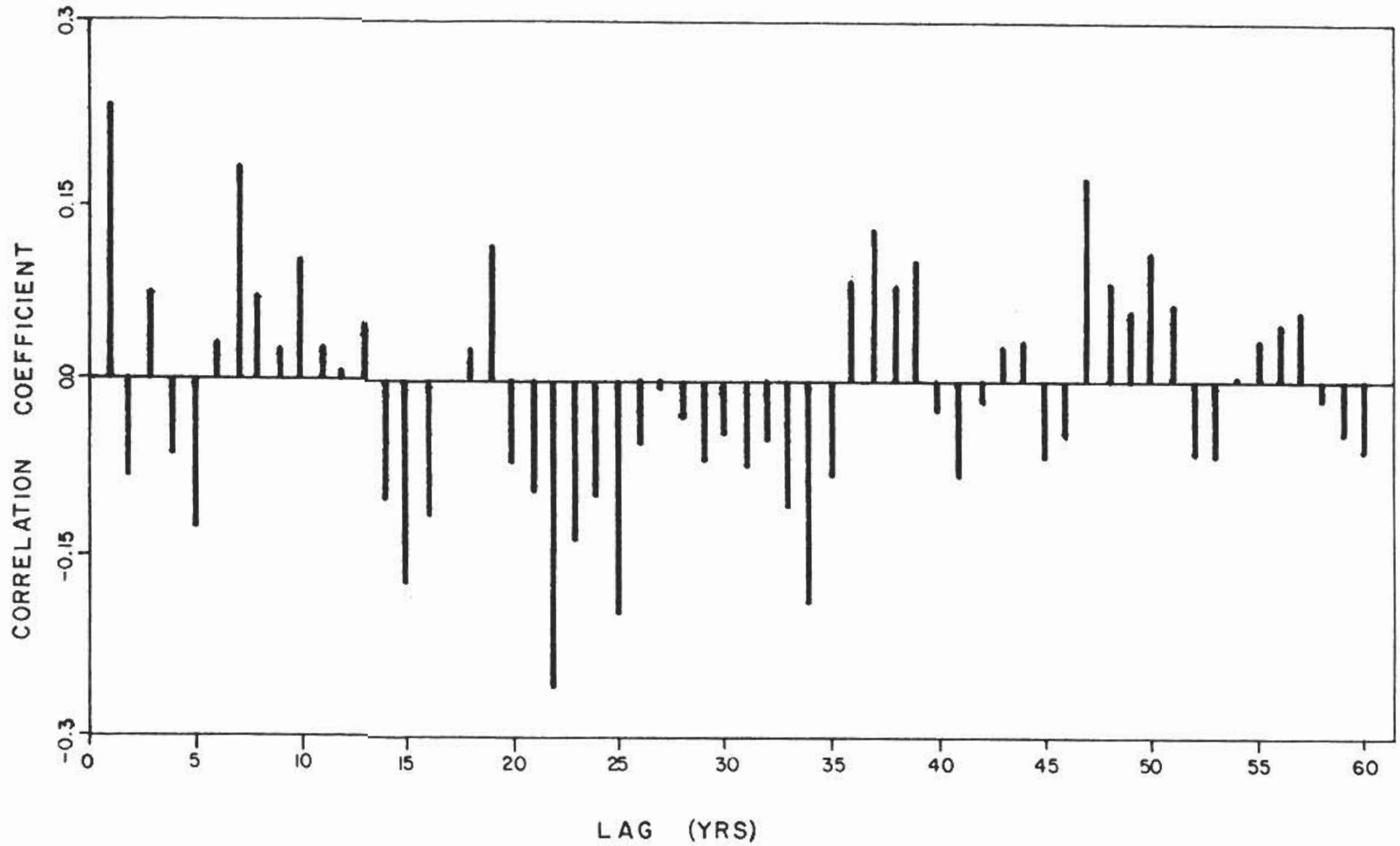
Table 2-4

AUTOCORRELATION COEFFICIENTS OF HUMBER RIVER MAR DATA - 1926-1988

LAG	CORR	SE	LAG	CORR	SE
1	.252	.126*	31	-.057	.170
2	-.084	.134	32	-.049	.170
3	.073	.135	33	-.110	.170
4	-.065	.135	34	-.198	.171*
5	-.128	.136	35	-.086	.176
6	.044	.138	36	.094	.176
7	.180	.138*	37	.131	.177
8	.075	.142	38	.082	.177
9	.034	.142	39	.109	.179
10	.106	.142	40	-.003	.180
11	.030	.144	41	-.082	.180
12	-.096	.144	42	-.015	.180
13	.050	.144	43	.029	.180
14	-.096	.144	44	.034	.180
15	-.173	.145*	45	-.068	.181
16	-.120	.148	46	-.049	.181
17	.029	.146	47	.175	.181*
18	.063	.152	48	.088	.184
19	.116	.152	49	.059	.184
20	.072	.154	50	.111	.185
21	.072	.154	51	.067	.186
22	-.098	.158	52	-.062	.186
23	-.137	.162	53	-.065	.186
24	-.097	.164	54	.055	.187
25	-.200	.165*	55	.041	.187
26	-.055	.169	56	.050	.187
27	-.001	.169	57	.058	.187
28	-.032	.169	58	-.014	.188
29	.069	.169	59	-.047	.188
30	-.044	.169	60	-.064	.188

(cont'd)

Number of Cases = 63
Mean of Series = 142.617
Standard Deviation of Series = 18.930



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CENTRAL NEWFOUNDLAND REGION

HUMBER RIVER
AUTOCORRELATION OF AVERAGE
ANNUAL FLOWS. 1926-1988

FIG. 2-5

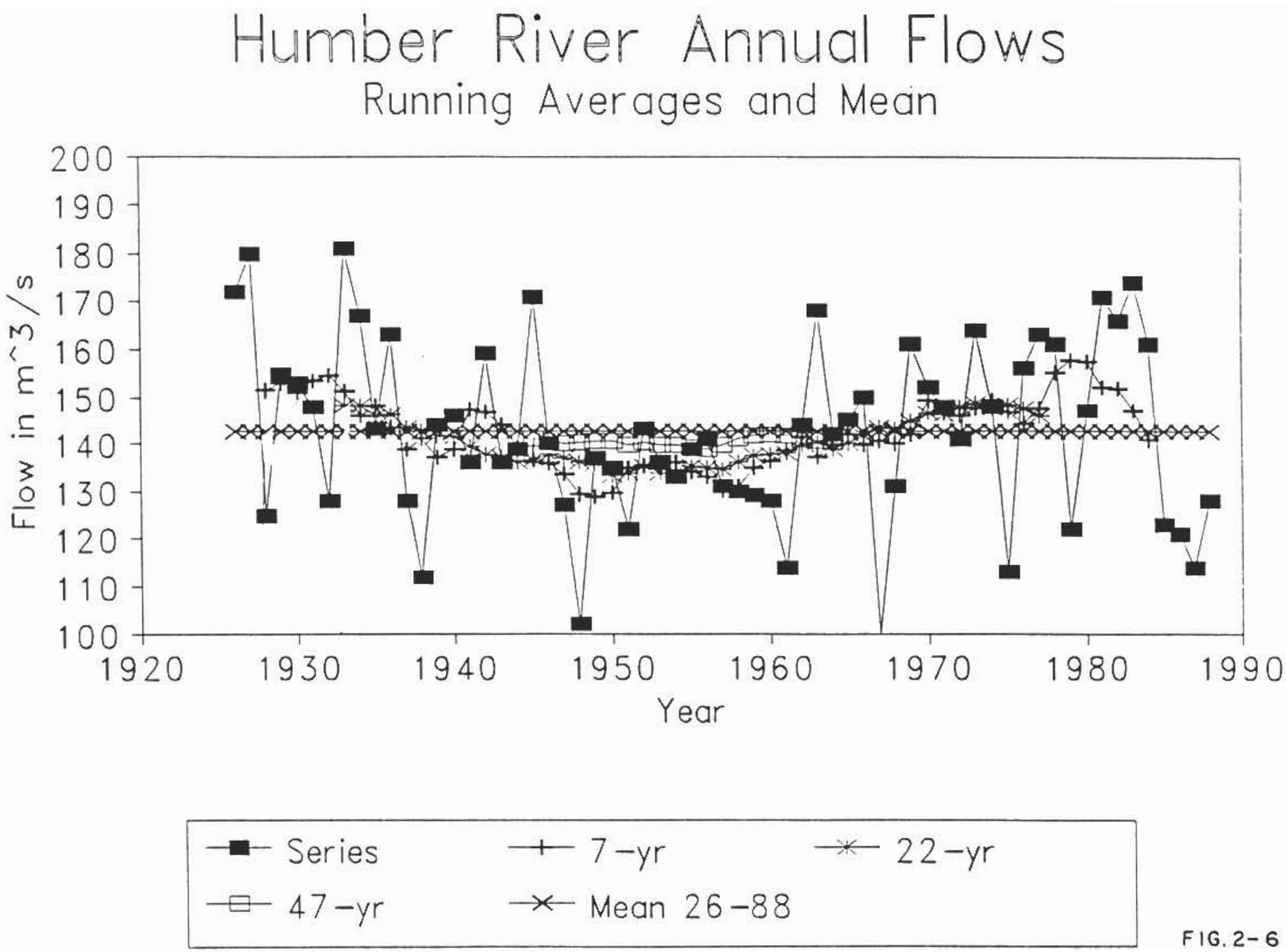

Humber River Annual Flows
Running Averages and Mean
Flow in m^3/s
200
190
180
170
160
150
140
130
120
110
100
1920
1930
1940
1950
1960
1970
1980
1990
Year
Series
7-yr
22-yr
47-yr
Mean 26-88

FIG. 2-6

[Note: further analysis of these longer-term trends may permit better operation of Grand Lake reservoir and the Deer Lake G.S.]

Exploits and Gander Rivers

As shown in Table 2-3, the gauges with the longest records in the study area are the Exploits River at Grand Falls (02YO001) (1944-1988) and the Gander River at Big Chute (02YQ001) (1950-1988).

Series of area-normalized mean annual flows for the Humber and Exploits Rivers are compared on Figure 2-7. The correspondence is close (r = 0.642). The basin yield is 11.6% greater for the Humber (0.02792 vs. 0.02502 $m^3/s\text{-}km^2$), which probably reflects the wetter conditions on the west coast.

A comparison of 7-year running averages and linear regressions for both the Humber and Exploits River gauges is presented on Figure 2-8. The regression equation for the Exploits River gauge is:

$$_E\langle Q\rangle_{45\ yr} = 278 * -0.0345\ (\text{year}) \qquad (2\text{-}6)$$

where the subscript E refers to the Exploits River and 45 yr refers to the period of record. Figure 2-8 clearly shows this series is stationary, and it can be inferred by correspondence to the Humber River that a longer record would be as well.

Area-normalized discharges for the Humber and Gander Rivers are shown on Figure 2-9 for the coincident period 1950-1988. There is, again, a close correlation of mean annual flows (r = 0.559), with the unregulated Gander River flows being slightly more variable (c.v. = 16.8%) than those of the regulated Humber River (c.v. = 13.4%).

FIG.2-7

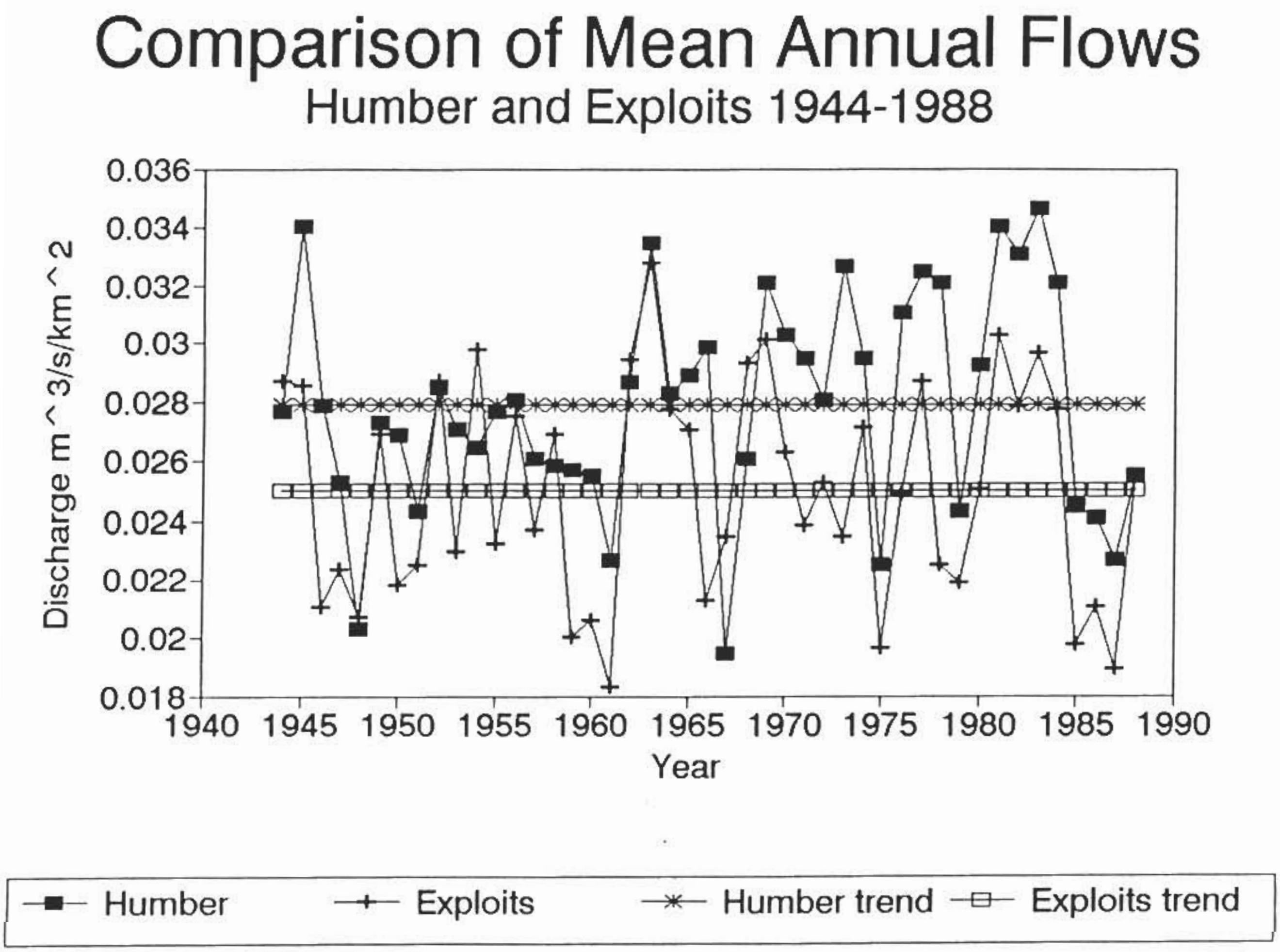
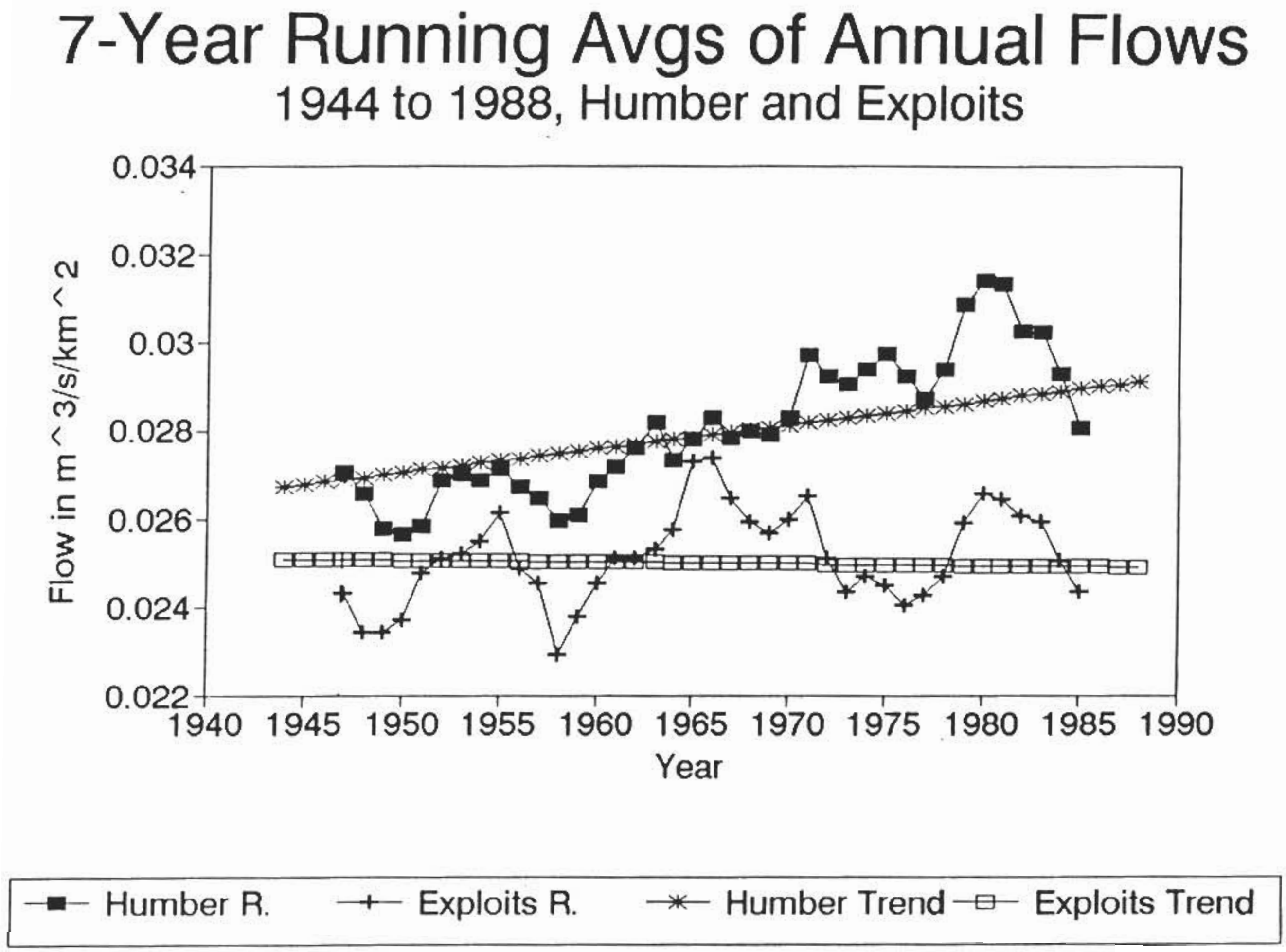
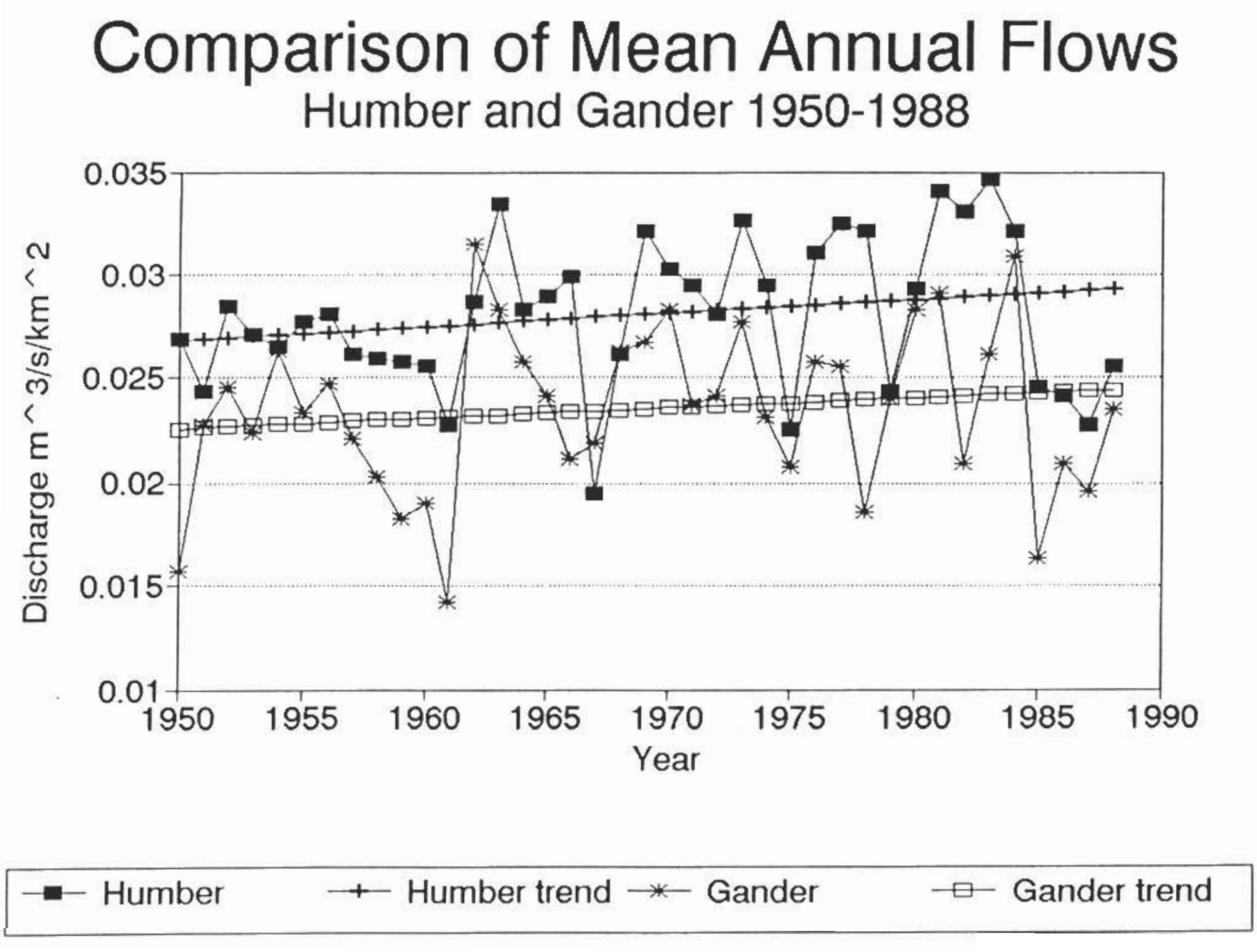

Comparison of Mean Annual Flows
Humber and Exploits 1944-1988
Discharge m ^ 3/s/km ^ 2
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Year
Humber
Exploits
Humber trend
Exploits trend

FIG. 2-8



7-Year Running Avgs of Annual Flows
1944 to 1988, Humber and Exploits
Flow in m ^ 3/s/km ^ 2
0.034
0.032
0.03
0.028
0.026
0.024
0.022
1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Year
Humber R.
Exploits R.
Humber Trend
Exploits Trend

FIG. 2-9



Comparison of Mean Annual Flows
Humber and Gander 1950-1988
Discharge m ^ 3/s/km ^ 2
0.035
0.03
0.025
0.02
0.015
0.01
1950
1955
1960
1965
1970
1975
1980
1985
1990
Year
Humber
Humber trend
Gander
Gander trend

The area-normalized MARs for the same period of record (1950-1988) are 0.0281 $m^3/s\text{-}km^2$ for the Humber River, 0.0251 for the Exploits River, and 0.0268 $m^3/s\text{-}km^2$ for the Gander River. Thus, the MAR for the Exploits river is 12.0% less than that for the Humber River; but the MAR for the Gander River is only 4.8% less than that for the Humber River.

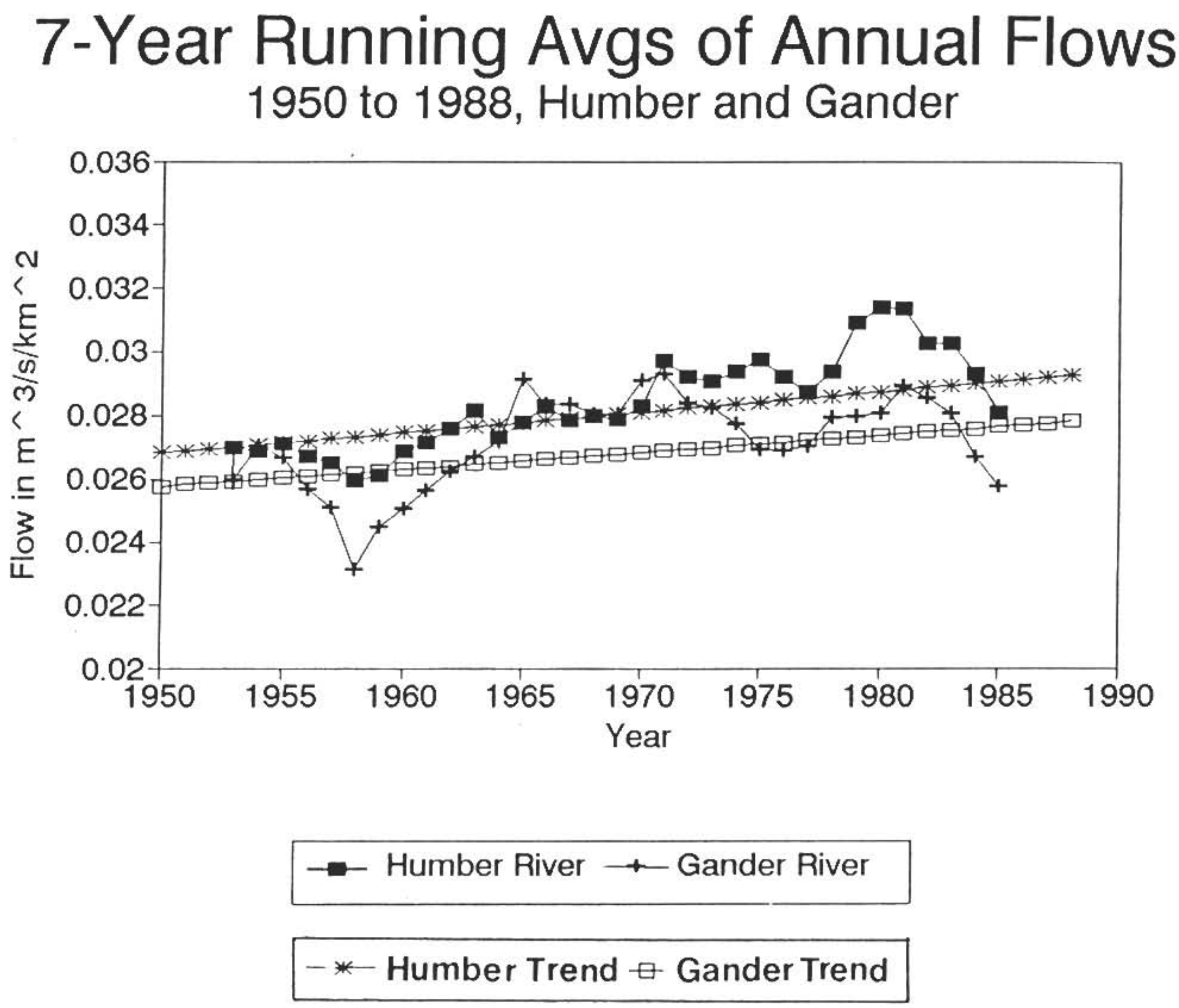
Seven-year running averages of the 1950-1988 coincident series of the Humber and Gander Rivers, as well as the linear regressions, are shown on Figure 2-10. Since the slope of the regression line is less for the Gander River than for the Humber River, it must be concluded that it cannot be accepted as significantly different than zero at 95%. The Gander River record is thus also considered stationary.

2.2.4 Extension of Records

To predict MAR for gauges with short records, a standard record length of 28 years was chosen since it would include near-integer multiples of the 12.8-, 7-, 4.6-, and 3-year cycles (Figure 2-4). The selected period is 1961-1988.

Since there is little evidence of any effect of regulation on annual flows in any of the rivers in the study area (including the Exploits River), records for all gauges except Indian Brook Diversion (02YM002) and those which had record lengths of less than 5 years were used. The Indian Brook at Indian Falls gauge had an apparently nonstationary record due to the diversion, but it was retained as a prediction gauge because of the length of record. The Humber River series was excluded as it lay outside the study area.

FIG. 2-10



7-Year Running Avgs of Annual Flows
1950 to 1988, Humber and Gander
Flow in m ^ 3/s/km ^ 2
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
1950
1955
1960
1965
1970
1975
1980
1985
1990
Year
Humber River
Gander River
Humber Trend
Gander Trend

The prediction gauges were those with records of 28 years or more:

02YO001	Exploits River at Grand Falls	B
02YQ001	Gander River at Big Chute	D
02YO003	Rattling Brook	J
02YM001	Indian Brook	F

The Rattling Brook gauge had only 26 years of record. This was first extended to 28 years and the 28-year record was then used as a prediction gauge.

All data were normalized by division by drainage areas. The data set is presented in Table 2-5.

As a first step, a correlation matrix was calculated. This matrix is presented in Table 2-6. A frequency table showing the number of data points used in the calculations is given in Table 2-7. In Tables 2-6 and 2-7 the letters refer to the gauge stations as indicated in Tables 2-1 and 2-5. This procedure simplified the statistical programming.

The equations for the linear extension relation were developed by stepwise multiple regression using the formula:

$$Y = \text{constant} + a_i x_i + a_2 x_2 + \ldots a_n x_n \qquad (2\text{-}8)$$

where Y is the estimate for the station to be extended, x_i are the prediction gauges in order of decreasing correlation (5% in and out criterion), and a_i are the best-fit coefficients. The results are given in Table 2-8.

Table 2-5 AREA - NORMALIZED FLOWS FOR WSC GAUGES USED FOR ANALYSIS OF FLOWS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	N
YEAR	02YK 001	02YO 001	02YO 005	02YQ 001	02YO 008	02YM 001	02YO 007	02YQ 004	02YO 006	02YO 003	02YK 005	02YK 003	02YP 001	02YM 003	02YM 003
1950	0.0269	0.0218		0.0179											
1951	0.0243	0.0225		0.0259											
1952	0.0285	0.0287		0.0280											
1953	0.0271	0.0230		0.0255											
1954	0.0265	0.0298		0.0300											
1955	0.0277	0.0232		0.0266											
1956	0.0281	0.0275		0.0282		0.0240						0.0282			
1957	0.0261	0.0237		0.0252		0.0258						0.0279			
1958	0.0259	0.0269		0.0232		0.0214						0.0258			
1959	0.0257	0.0200		0.0208		0.0171						0.0202			
1960	0.0255	0.0206		0.0217		0.0213						0.0243			
1961	0.0227	0.0184		0.0162		0.0224						0.0253			
1962	0.0287	0.0294		0.0359		0.0262						0.0356			
1963	0.0335	0.0328		0.0323		0.0231				0.0349		0.0323			
1964	0.0283	0.0278		0.0293		0.0199				0.0302		0.0264			
1965	0.0289	0.0271		0.0275		0.0206				0.0341		0.0298			
1966	0.0299	0.0213		0.0241		0.0175				0.0252					
1967	0.0195	0.0235		0.0250		0.0160				0.0229					
1968	0.0261	0.0293		0.0300		0.0169				0.0283					
1969	0.0321	0.0302	0.0351	0.0305		0.0238				0.0286					
1970	0.0303	0.0263	0.0332	0.0323		0.0177				0.0296					
1971	0.0295	0.0238	0.0316	0.0270		0.0195				0.0249					
1972	0.0281	0.0253	0.0313	0.0275		0.0180				0.0263					
1973	0.0327	0.0235	0.0311	0.0316		0.0200				0.0283	0.0292				
1974	0.0295	0.0272	0.0293	0.0264		0.0188				0.0225	0.0261				
1975	0.0225	0.0197	0.0237	0.0236		0.0176				0.0208	0.0266				
1976	0.0311	0.0249	0.0279	0.0293		0.0185				0.0249	0.0281				
1977	0.0325	0.0287	0.0361	0.0291		0.0237				0.0247	0.0366				
1978	0.0321	0.0225	0.0264	0.0212		0.0158				0.0228	0.0217				
1979	0.0243	0.0219		0.0273		0.0216				0.0299	0.0279				
1980	0.0293	0.0250		0.0323		0.0234				0.0291	0.0338			0.0423	0.0423
1981	0.0341	0.0303	0.0366	0.0332		0.0237			0.0293	0.0267	0.0320			0.0363	0.0363
1982	0.0331	0.0279	0.0346	0.0239		0.0199			0.0236	0.0246	0.0297		0.0318	0.0286	0.0286
1983	0.0347	0.0297	0.0389	0.0298		0.0190		0.0320	0.0306	0.0251	0.0284		0.0343	0.0258	0.0258
1984	0.0321	0.0278	0.0356	0.0352	0.0321	0.0188	0.0287	0.0361	0.0290	0.0307	0.0258		0.0285	0.0273	0.0273
1985	0.0245	0.0198	0.0248	0.0187	0.0196	0.0140	0.0176	0.0186	0.0164	0.0193	0.0199		0.0212	0.0172	0.0172
1986	0.0241	0.0211	0.0267	0.0239	0.0235	0.0158	0.0219	0.0243	0.0208	0.0222	0.0239		0.0249	0.0183	0.0183
1987	0.0227	0.0190	0.0252	0.0223	0.0253	0.0170	0.0215	0.0239	0.0197	0.0209	0.0248		0.0232	0.0247	0.0247
1988	0.0255	0.0255	0.0337	0.0268	0.0264	0.0214	0.0285	0.0250	0.0295	0.0283	0.0325		0.0370	0.0334	0.0334
mean	0.0281	0.0251	0.0312	0.0268	0.0253	0.0200	0.0236	0.0267	0.0249	0.0264	0.0279	0.0276	0.0287	0.0282	0.0065
DA-k	5020.0	8390.0	8640.0	4400.0	823.0	974.0	88.3	2150.0	177.0	378.0	391.0	362.0	63.8	93.2	93.2

Values in m^3/s/km^2

Table 2-6

CORRELATION MATRIX OF MAFs

YEAR	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	1.000													
B	0.642	1.000												
C	0.754	0.915	1.000											
D	0.556	0.757	0.733	1.000										
E	0.788	0.818	0.849	0.963	1.000									
F	0.314	0.463	0.732	0.447	0.699	1.000								
G	0.661	0.914	0.956	0.881	0.876	0.917	1.000							
H	0.845	0.837	0.833	0.975	0.966	0.569	0.789	1.000						
I	0.705	0.877	0.927	0.871	0.839	0.804	0.995	0.804	1.000					
J	0.387	0.625	0.726	0.732	0.884	0.600	0.970	0.798	0.876	1.000				
K	0.381	0.619	0.701	0.629	0.853	0.938	0.845	0.433	0.803	0.559	1.000			
L	0.658	0.770	-	0.837	-	0.764	-	-	-	0.963	-	1.000		
M	0.575	0.818	0.851	0.537	0.516	0.920	0.863	0.500	0.879	0.708	0.942	-	1.000	
N	0.424	0.548	0.709	0.677	0.672	0.965	0.874	0.480	0.769	0.749	0.935	-	0.839	1.000

PEARSON CORRELATION MATRIX

Letters identify WSC gauges - see Tables 2-1 and 2-4
(Pearson)

Table 2-7

FREQUENCY TABLE OF MAFs USED IN CORRELATION ANALYSIS

FREQUENCY TABLE

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	39													
B	39	39												
C	18	18	18											
D	39	39	18	39										
E	5	5	5	5	5									
F	31	31	18	31	5	31								
G	5	5	5	5	5	5	5							
H	6	6	6	6	5	6	5	6						
I	8	8	8	8	5	8	5	6	8					
J	26	26	26	26	5	26	5	6	8	26				
K	16	16	16	16	5	16	5	6	8	16	16			
L	10	10	10	10	0	8	0	0	0	3	0	10		
M	7	7	7	7	5	7	5	6	7	7	7	0	7	
N	9	9	9	9	5	9	5	6	8	9	9	0	7	9

Table 2-8

RESULTS OF MULTIPLE REGRESSION ANALYSES

WSC STATION	VARIABLE LETTER	MODEL	RESULT	COEFFICIENTS	r^2
02YO001	C	C = R+B+D+F+J	C = R+B+J	C = -0.001+0.961B+0.317J	0.849
02YO008	E	E = R+B+D+J	E = R+D	E = 0.007+0.702D	0.904
02YO007	G	G = R+B+D+J	G = R+J+B	G = 0.006+2.081J-1.473B	0.975
02YQ004	H	H = R+B+D+J	H = R+D+J	H = 0.004+1.576D-0.761J	0.997
02YO006	I	I = R+B+D+J	I = R+B+J	I = -0.008+0.603B+0.715J	0.828
02YO003	J	J = R+A+B+D+F	J = R+D	J = 0.006+0.720D	0.517
02YK005	K	K = R+B+D+F+J K = R+B+D+J	K = R+F K = R+D	K = 0.001+1.412F K = 0.012+0.591D	0.871 0.352
02YK003	L	L = R+B+D+F+A	L = R+D+F	L = -0.001+0.4580+0.778F	0.822
02YP001	M	M = R+B+D+F+J+K	M = R+B+K	M = -0.009+0.443B+1.029K	0.916
02YM003	N	N = R+B+D+F+J	N = R+B+F	N = -0.011+0.409B+1.634F	0.829

R = constant

The missing flow values from 1961 to 1988 in Table 2-5 were then calculated with the appropriate equations in Table 2-8. The series of estimated long-term area-normalized MARs are presented in Table 2-9. At the bottom of this table the measured means for the period of record are calculated, then the means for the 28-year index period of 1961-1988. The ratios of these two are then calculated. These ratios are close to one another (their average is 102.6%), with the largest deviations (up to 10%) occurring for the shorter records, as expected. A plot of estimated MARs for the index period vs. measured MARs for the periods of record is given on Figure 2-11. The fit is reasonably good (r = 0.77).

These statistics are then converted into units of mm/year below in Table 2-9.

Equivalent non-area-normalized values (i.e. m^3/s at the gauge are presented in Table 2-10 for convenience.

A regional average may be taken as the mean of all gauges for the standard period 1961-1988. This is 858 mm/year, or 0.027 $m^3/s\text{-}km^2$.

Often the unit basin yield is semilogarithmically related to drainage basin area. As shown on Figure 2-12, this does not appear to be the case for the study area. (A full log-log regression has an exponent of zero, implying a constant value of unit basin yield.)

2.2.5 Relationship of MAR to Physiographic Parameters

A stepwise multiple regression was performed to ascertain the effects of selected physiographic variables upon MAR.

Table 2-9 ESTIMATED LONG TERM MEAN ANNUAL RUNOFF IN m^3/S-km^2

		A	B	C	D	E	F	G	H	I	J	K	L	M	N
		02YK	02YO	02YO	02YQ	02YO	02YM	02YO	02YQ	02YO	02YO	02YK	02YK	02YP	02YM
	YEAR	001	001	005	001	008	001	007	004	006	003	005	003	001	003
1	1950	0.027	0.022	0.026	0.018	0.020		0.013	0.018	0.019	0.019				
2	1951	0.024	0.023	0.028	0.026	0.025		0.024	0.026	0.023	0.025				
3	1952	0.028	0.029	0.035	0.028	0.027		0.018	0.028	0.028	0.026				
4	1953	0.027	0.023	0.029	0.025	0.025		0.023	0.026	0.023	0.024				
5	1954	0.026	0.030	0.036	0.030	0.028		0.020	0.030	0.030	0.028				
6	1955	0.028	0.023	0.029	0.027	0.026	0.025	0.024	0.027	0.024	0.025	0.037	0.031	0.039	0.040
7	1956	0.028	0.028	0.034	0.028	0.027	0.024	0.020	0.028	0.027	0.026	0.035	0.028	0.039	0.040
8	1957	0.026	0.024	0.029	0.025	0.025	0.026	0.021	0.025	0.024	0.024	0.037	0.028	0.040	0.041
9	1958	0.026	0.027	0.032	0.023	0.023	0.021	0.014	0.023	0.024	0.023	0.031	0.026	0.035	0.035
10	1959	0.026	0.020	0.025	0.021	0.022	0.017	0.020	0.021	0.019	0.021	0.025	0.020	0.026	0.025
11	1960	0.025	0.021	0.026	0.022	0.022	0.021	0.021	0.022	0.020	0.022	0.031	0.024	0.032	0.032
*12	1961	0.023	0.018	0.022	0.016	0.018	0.022	0.016	0.016	0.016	0.018	0.033	0.025	0.033	0.033
13	1962	0.029	0.029	0.037	0.036	0.032	0.026	0.029	0.036	0.033	0.032	0.038	0.036	0.043	0.044
14	1963	0.033	0.033	0.042	0.032	0.030	0.023	0.030	0.028	0.037	0.035	0.034	0.032	0.040	0.040
15	1964	0.028	0.028	0.035	0.029	0.028	0.020	0.028	0.027	0.030	0.030	0.029	0.026	0.033	0.033
16	1965	0.029	0.027	0.036	0.028	0.026	0.021	0.037	0.021	0.033	0.034	0.030	0.030	0.034	0.034
17	1966	0.030	0.021	0.028	0.024	0.024	0.017	0.027	0.023	0.023	0.025	0.026	0.024	0.027	0.026
18	1967	0.020	0.023	0.029	0.025	0.025	0.016	0.019	0.026	0.023	0.023	0.024	0.023	0.026	0.025
19	1968	0.026	0.029	0.036	0.030	0.028	0.017	0.022	0.030	0.030	0.028	0.025	0.026	0.030	0.029
20	1969	0.032	0.030	0.035	0.030	0.028	0.024	0.021	0.030	0.031	0.029	0.035	0.031	0.040	0.040
21	1970	0.030	0.026	0.033	0.032	0.030	0.018	0.029	0.032	0.029	0.030	0.026	0.028	0.029	0.029
22	1971	0.029	0.024	0.032	0.027	0.026	0.020	0.023	0.028	0.024	0.025	0.029	0.027	0.031	0.031
23	1972	0.028	0.025	0.031	0.028	0.026	0.018	0.024	0.027	0.026	0.026	0.026	0.026	0.029	0.029
24	1973	0.033	0.023	0.031	0.032	0.029	0.020	0.030	0.032	0.026	0.028	0.029	0.029	0.031	0.031
25	1974	0.029	0.027	0.029	0.026	0.026	0.019	0.013	0.028	0.025	0.023	0.026	0.026	0.030	0.031
26	1975	0.023	0.020	0.024	0.024	0.024	0.018	0.020	0.025	0.019	0.021	0.027	0.023	0.027	0.026
27	1976	0.031	0.025	0.028	0.029	0.028	0.018	0.021	0.031	0.025	0.025	0.028	0.027	0.031	0.029
28	1977	0.032	0.029	0.036	0.029	0.027	0.024	0.015	0.031	0.027	0.025	0.037	0.031	0.041	0.040
29	1978	0.032	0.023	0.026	0.021	0.022	0.016	0.020	0.020	0.022	0.023	0.022	0.021	0.023	0.024
30	1979	0.024	0.022	0.030	0.027	0.026	0.022	0.036	0.024	0.027	0.030	0.028	0.028	0.029	0.033
31	1980	0.029	0.025	0.032	0.032	0.030	0.023	0.030	0.033	0.028	0.029	0.034	0.032	0.037	0.042
32	1981	0.034	0.030	0.037	0.033	0.030	0.024	0.017	0.036	0.029	0.027	0.032	0.033	0.037	0.036
33	1982	0.033	0.028	0.035	0.024	0.024	0.020	0.016	0.023	0.024	0.025	0.030	0.025	0.032	0.029
34	1983	0.035	0.030	0.039	0.030	0.028	0.019	0.014	0.032	0.031	0.025	0.028	0.027	0.034	0.026
35	1984	0.032	0.028	0.036	0.035	0.032	0.019	0.029	0.036	0.029	0.031	0.026	0.030	0.029	0.027
36	1985	0.025	0.020	0.025	0.019	0.020	0.014	0.018	0.019	0.016	0.019	0.020	0.018	0.021	0.017
37	1986	0.024	0.021	0.027	0.024	0.023	0.016	0.022	0.024	0.021	0.022	0.024	0.022	0.025	0.018
38	1987	0.023	0.019	0.025	0.022	0.025	0.017	0.022	0.024	0.020	0.021	0.025	0.022	0.023	0.025
39	1988	0.025	0.026	0.034	0.027	0.026	0.021	0.029	0.025	0.030	0.028	0.032	0.028	0.037	0.033
mean-p.o.r.		0.028	0.025	0.031	0.027	0.025	0.020	0.024	0.027	0.025	0.026	0.029	0.027	0.029	0.028
mean 1961-1988		0.029	0.025	0.032	0.028	0.026	0.020	0.023	0.027	0.026	0.026	0.028	0.028	0.032	0.031
ratio of means		102%	101%	102%	103%	104%	98%	99%	103%	105%	103%	95%	103%	110%	109%
DA-km^2		5020	8390	8640	4400	823	974	88	2150	177	378	391	362	64	93
mean of all 1961-1988				0.027	m^3/s-km^2										
In Units of mm/yr															
mean-p.o.r.		885	791	984	846	800	636	746	841	785	807	925	848	906	890
mean 1961-1988		904	800	1001	870	835	620	739	867	823	832	881	871	996	969
ratio of means		102%	101%	102%	103%	104%	98%	99%	103%	105%	103%	95%	103%	110%	109%

FIG. 2-11

Estimated vs. Measured Average MARs

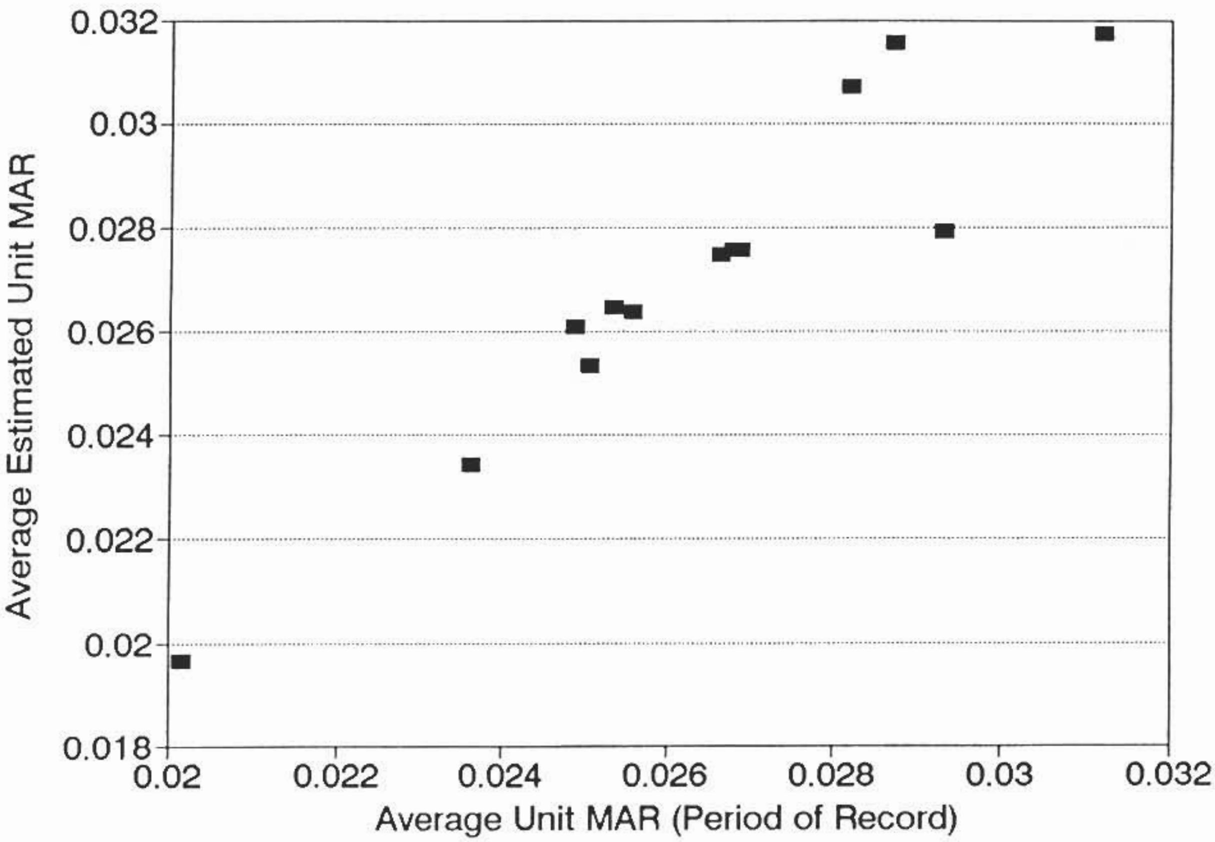
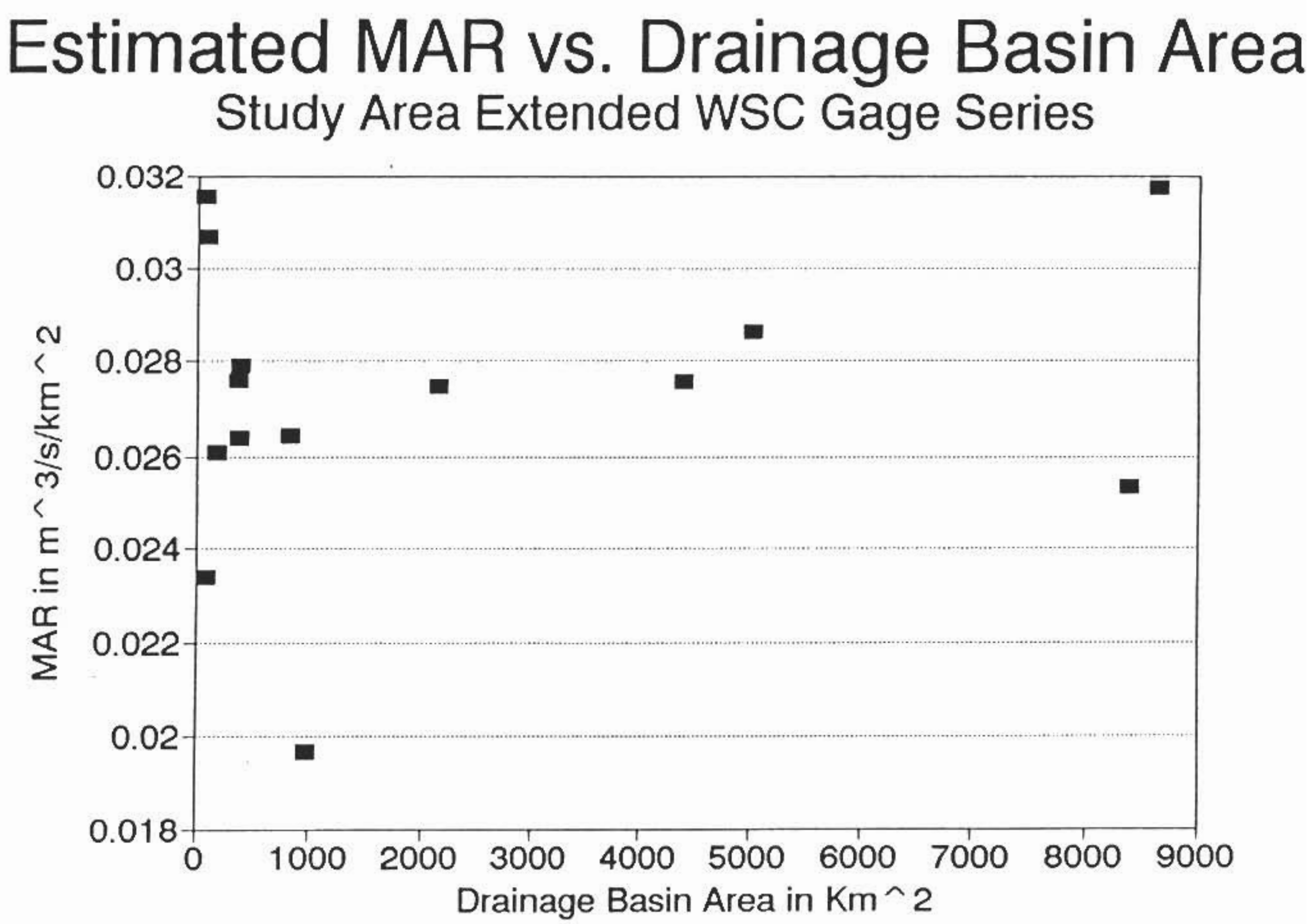


Table 2-10 ESTIMATED LONG TERM MEAN ANNUAL RUNOFF IN m^3/s

		A	B	C	D	E	F	G	H	I	J	K	L	M	N
		02YK	02YO	02YO	02YQ	02YO	02YM	02YO	02YQ	02YO	02YO	02YK	02YK	02YP	02YM
	YEAR	001	001	005	001	008	001	007	004	006	003	005	003	001	003
1	1950	135.0	183.0	224.3	78.7	16.1		1.2	38.3	3.3	7.1				
2	1951	122.0	189.0	246.1	114.0	20.7		2.1	56.1	4.1	9.3				
3	1952	143.0	241.0	301.6	123.0	21.9		1.6	60.6	5.0	9.9				
4	1953	136.0	193.0	249.1	112.0	20.5		2.0	55.0	4.1	9.2				
5	1954	133.0	250.0	314.6	132.0	23.1		1.7	65.1	5.3	10.4				
6	1955	139.0	195.0	253.4	117.0	21.1	24.7	2.1	57.6	4.2	9.5	14.4	11.2	2.5	3.7
7	1956	141.0	231.0	292.2	124.0	22.0	23.4	1.8	61.1	4.8	9.9	13.7	10.2	2.5	3.7
8	1957	131.0	199.0	254.6	111.0	20.3	25.1	1.9	54.5	4.2	9.1	14.6	10.1	2.6	3.8
9	1958	130.0	226.0	277.4	102.0	19.2	20.8	1.2	50.0	4.3	8.6	12.2	9.4	2.2	3.3
10	1959	129.0	168.0	215.2	91.5	17.8	16.7	1.8	44.7	3.4	7.9	9.9	7.3	1.6	2.3
11	1960	128.0	173.0	221.9	95.4	18.3	20.7	1.8	46.7	3.5	8.2	12.1	8.8	2.0	3.0
*12	1961	114.0	154.0	192.3	71.4	15.1	21.8	1.4	34.7	2.8	6.7	12.7	9.2	2.1	3.1
13	1962	144.0	247.0	323.2	158.0	26.5	25.5	2.6	78.2	5.8	12.0	14.8	12.9	2.8	4.1
14	1963	168.0	275.0	359.4	142.0	24.4	22.5	2.7	60.8	6.5	13.2	13.1	11.7	2.6	3.7
15	1964	142.0	233.0	304.7	129.0	22.7	19.4	2.5	58.6	5.4	11.4	11.4	9.6	2.1	3.1
16	1965	145.0	227.0	309.7	121.0	21.6	20.1	3.3	45.9	5.8	12.9	11.8	10.8	2.2	3.1
17	1966	150.0	179.0	237.6	106.0	19.7	17.0	2.4	49.0	4.0	9.5	10.0	8.5	1.7	2.4
18	1967	97.9	197.0	249.2	110.0	20.2	15.6	1.7	55.9	4.0	8.7	9.2	8.3	1.6	2.3
19	1968	131.0	246.0	312.5	132.0	23.1	16.5	1.9	63.9	5.3	10.7	9.7	9.4	1.9	2.7
20	1969	161.0	253.0	303.0	134.0	23.4	23.2	1.9	65.0	5.4	10.8	13.5	11.4	2.6	3.8
21	1970	152.0	221.0	287.0	142.0	24.4	17.2	2.5	69.5	5.1	11.2	10.1	10.0	1.9	2.7
22	1971	148.0	200.0	273.0	119.0	21.4	19.0	2.0	59.4	4.3	9.4	11.2	9.6	2.0	2.9
23	1972	141.0	212.0	270.0	121.0	21.6	17.5	2.1	58.7	4.6	10.0	10.3	9.3	1.9	2.7
24	1973	164.0	197.0	269.0	139.0	24.0	19.5	2.7	69.3	4.7	10.7	11.4	10.5	2.0	2.9
25	1974	148.0	228.0	253.0	116.0	21.0	18.3	1.1	61.1	4.3	8.5	10.2	9.3	1.9	2.9
26	1975	113.0	165.0	205.0	104.0	19.4	17.1	1.8	54.7	3.3	7.9	10.4	8.5	1.7	2.4
27	1976	156.0	209.0	241.0	129.0	22.7	18.0	1.9	67.2	4.4	9.4	11.0	9.7	2.0	2.7
28	1977	163.0	241.0	312.0	128.0	22.6	23.1	1.3	66.8	4.8	9.3	14.3	11.1	2.6	3.7
29	1978	161.0	189.0	228.0	93.3	18.0	15.4	1.8	43.2	3.9	8.6	8.5	7.6	1.5	2.2
30	1979	122.0	184.0	255.5	120.0	21.5	21.0	3.2	52.1	4.7	11.3	10.9	10.2	1.9	3.1
31	1980	147.0	210.0	279.1	142.0	24.4	22.8	2.6	70.3	4.9	11.0	13.2	11.6	2.3	3.9
32	1981	171.0	254.0	316.0	146.0	24.9	23.1	1.5	77.3	5.2	10.1	12.5	11.8	2.4	3.4
33	1982	166.0	234.0	299.0	105.0	19.5	19.4	1.4	49.2	4.2	9.3	11.6	9.2	2.0	2.7
34	1983	174.0	249.0	336.0	131.0	23.0	18.5	1.3	68.9	5.4	9.5	11.1	9.9	2.2	2.4
35	1984	161.0	233.0	308.0	155.0	26.4	18.3	2.5	77.7	5.1	11.6	10.1	10.8	1.8	2.5
36	1985	123.0	166.0	214.0	82.1	16.1	13.6	1.6	39.9	2.9	7.3	7.8	6.7	1.4	1.6
37	1986	121.0	177.0	231.0	105.0	19.3	15.4	1.9	52.3	3.7	8.4	9.3	8.0	1.6	1.7
38	1987	114.0	159.0	218.0	98.3	20.8	16.6	1.9	51.3	3.5	7.9	9.7	8.1	1.5	2.3
39	1988	128.0	214.0	291.0	118.0	21.7	20.8	2.5	53.7	5.2	10.7	12.7	10.1	2.4	3.1
mean-p.o.r.		140.8	210.3	269.4	117.9	20.9	19.6	2.1	57.3	4.4	9.7	10.0	8.5	1.8	2.6
mean 1961-198		143.8	212.6	274.2	121.3	21.8	19.2	2.1	59.1	4.6	10.0	10.9	10.0	2.0	2.9
ratio of means		102%	101%	102%	103%	104%	98%	99%	103%	105%	103%	109%	118%	110%	109%
DA-km^2		5020	8390	8640	4400	823	974	88	2150	177	378	391	362	64	93

FIG. 2-12


Estimated MAR vs. Drainage Basin Area
Study Area Extended WSC Gage Series
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
MAR in m ^ 3/s/km ^ 2
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Drainage Basin Area in Km ^ 2

The mean 1961-1988 values of MAR in mm/year were taken from Table 2-9. Other measured variables were:

(1) latitude (degrees)
(2) longitude (degrees)
(3) distance from sea in a SW direction (km)
(4) distance to sea due west (km), and
(5) elevation (feet) of the centroids of the basins.

The data used are presented in Table 2-11. Note that there is not a large variation in elevation.

A map showing the basins used and their centroids is given on Figure 2-13.

A correlation matrix is presented as Table 2-12. Note that no strong correlations exist. The largest is MAR vs. elevation (r = 0.238). The slight positive correlation with latitude and longitude indicates an increase in MAR to the NW, as does the inverse relation between MAR vs. distance to the west coast (r = -0.0261). However, as noted, none of these relationships is significant.

The stepwise linear regression was based on the model:

$$\text{MAR} = \text{constant} + \text{elev} + \text{lat} + \text{long} + \text{SW} + \text{west} \quad (2\text{-}9)$$

At a 15% enter, remove criterion, only elevation was significant. The result is:

$$\text{MAR (mm)} = 787.6 + 0.103 \text{ elev (ft)}, \ r = 0.238 \quad (2\text{-}10)$$

This is termed Model 1. If all variables are forced to enter, the coefficients are:

Table 2-11 TABLE OF VALUES USED IN PHYSIOGRAPHIC REGRESSION ANALYSIS

						Basin Centroid				
						Location		Distance (km)		
		Station	Fig	Station	MAR	Lat.	Long.	From		Elev.
No	Station Name	Code	No.	Letter	(mm)	Deg	Deg	SW	West	Feet
1	Exploits R. @ GF	02YO 001	21	B	800	48.78	56.62	105	142	550
2	Exploits R. b. S.B.	02YO 005	20	C	1001	48.78	56.62	105	142	550
3	Gander R. at Big Chute	02YQ 001	17	D	870	48.62	55.22	111	262	550
4	Gt.Rattling Brook	02YO 008	12	E	835	48.70	55.63	80	215	600
5	Indian Bk @ Indian Falls	02YM 001	3	F	620	49.47	56.38	43	123	300
6	Leech Brook	02YO 007	10	G	739	48.98	55.80	62	191	500
7	NW Gander River	02YQ 004	14	H	867	48.52	55.57	148	221	1000
8	Peters River	02YO 006	13	I	823	49.05	55.62	43	203	450
9	Rattling Bk @ GS	02YO 003	24	J	832	48.92	55.25	49	231	900
10	Sheffield Brook	02YK 005	5	K	881	49.27	56.58	58	120	1000
11	Sheffield River	02YK 003	6	L	871	49.27	56.58	58	120	1000
12	Shoal Arm Brook	02YP 001	7	M	996	49.30	55.80	15	185	500
13	South West Brook	02YM 003	1	N	969	49.85	56.23	31	114	500

NOTE:
GAUGE NUMBERS REFER TO TABLE 2-1

DRAINAGE BASINS USED FOR PHYSIOGRAPHIC REGRESSION ANALYSIS

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FIG. 2-13

Table 2-12

CORRELATION MATRIX OF PHYSIOGRAPHIC VARIABLES

PEARSON CORRELATION MATRIX

	MAR	LAT	LONG	SW	WEST	ELEV
MAR	1.000					
LAT	0.037	1.000				
LONG	0.049	0.422	1.000			
SW	0.010	-0.812	-0.085	1.000		
WEST	-0.026	-0.694	-0.939	0.340	1.000	
ELEV	0.238	-0.223	0.066	0.296	0.037	1.000

Constant	-69466.625
Latitude	595.565
Longitude	700.640
SW	0.979
West	9.723
Elevation	0.184

[r = 0.490] (2-11)

This is termed Model 2.

Finally, at a 5% enter, remove criterion, only the constant is returned, i.e.:

MAR = 854 mm (2-12)

This is termed Model 3.

The results of the three models are calculated in Table 2-13 and depicted on Figure 2-14.

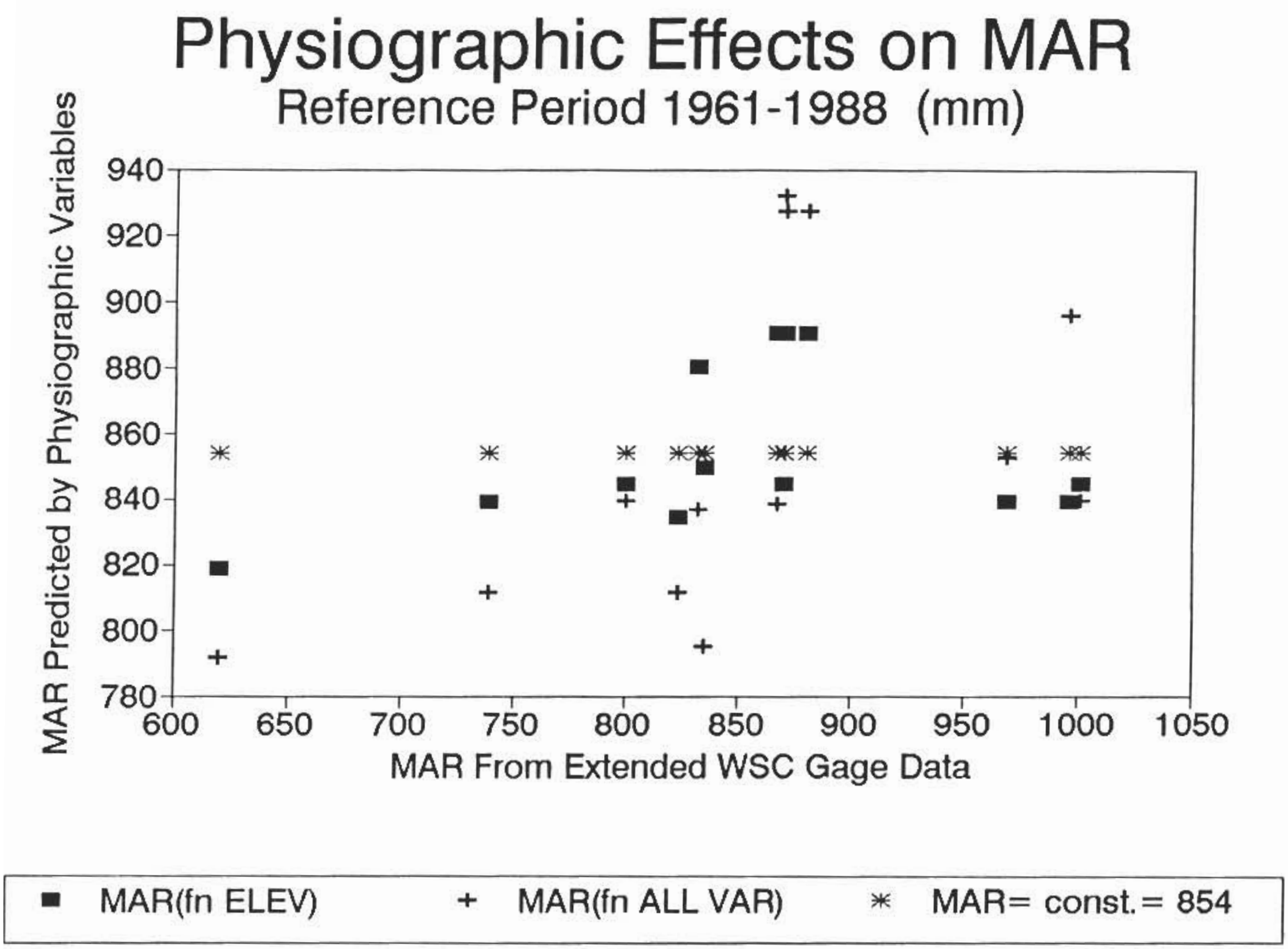
As anticipated by the low correlations, none of the models is particularly good. We plotted the distributions of MAR for all three cases in Table 2-13 and could not discern any pattern more meaningful than that of a constant value of 854 mm/year. The Sheffield Lake area is likely slightly wetter due to its higher elevation and more westerly location, and the Baie Verte peninsula is also likely wetter. However, the gage records are not sufficiently long to permit these distinctions to be clearly made.

[If the procedure of adopting a standard length of record (28 years; see Table 2-9) is continued, then a regional value of 858 mm/year is calculated instead of the 854 mm/year estimate based on actual records. While it differs by only 0.5%, it is preferred if the record extension methodology is accepted.]

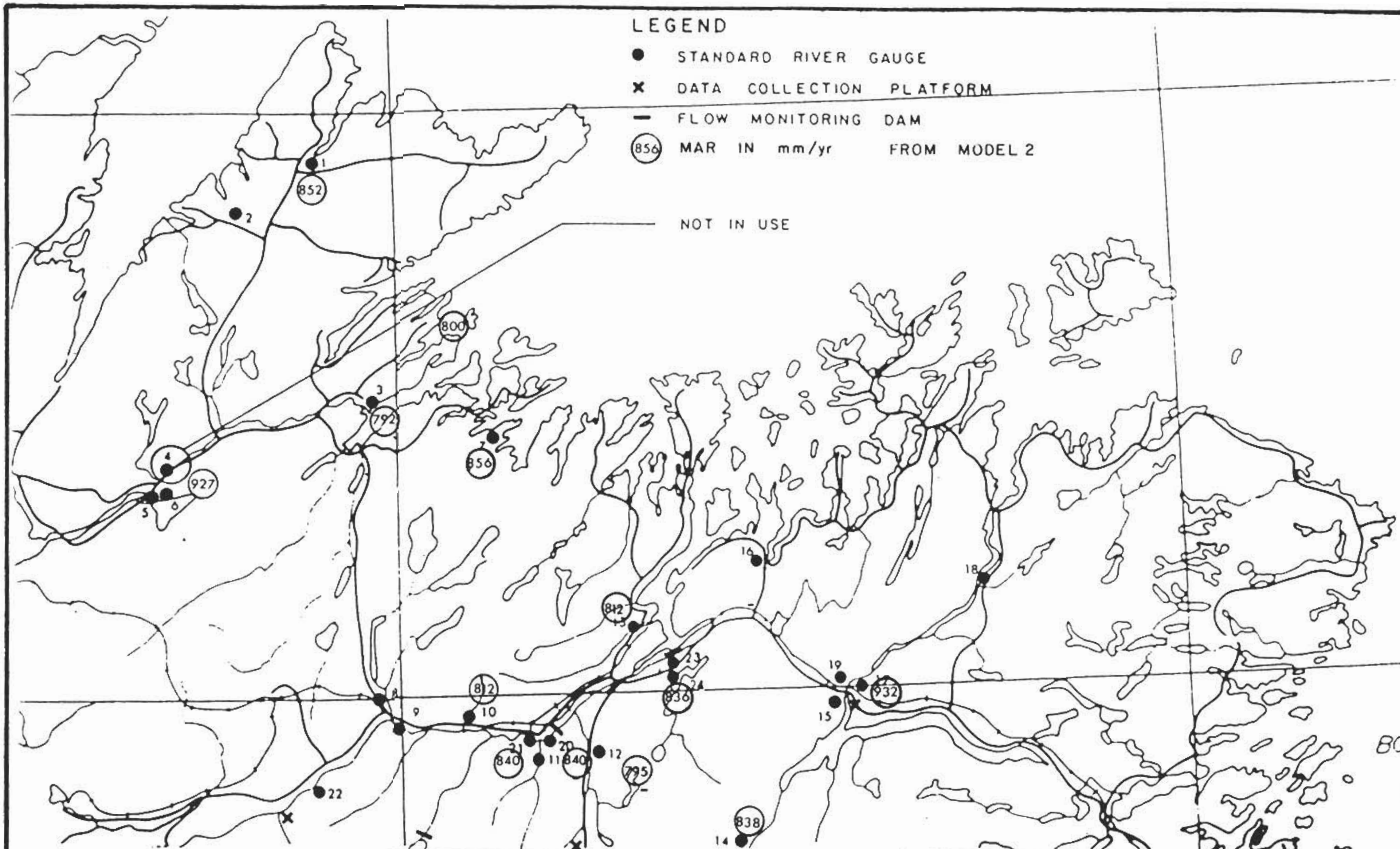
Table 2-13 EXTENDED MAR VALUES AND THOSE PREDICTED BY PHYSIOGRAPHIC VARIABLES

No	Station Name	Station Code	Figure Number	Station Letter	MAR (mm)	Model 1	Model 2	Model 3
1	Exploits R. @ GF	02YO 001	21	B	800	844	840	854
2	Exploits R. b. S.B.	02YO 005	20	C	1001	844	840	854
3	Gander R. at Big Chute	02YQ 001	17	D	870	844	932	854
4	Gt.Rattling Brook	02YO 008	12	E	835	849	795	854
5	Indian Bk @ Indian Falls	02YM 001	3	F	620	819	792	854
6	Leech Brook	02YO 007	10	G	739	839	812	854
7	NW Gander River	02YQ 004	14	H	867	891	838	854
8	Peters River	02YO 006	13	I	823	834	812	854
9	Rattling Bk @ GS	02YO 003	24	J	832	880	836	854
10	Sheffield Brook	02YK 005	5	K	881	891	927	854
11	Sheffield River	02YK 003	6	L	871	891	927	854
12	Shoal Arm Brook	02YP 001	7	M	996	839	896	854
13	South West Brook	02YM 003	1	N	969	839	852	854
				MEANS -	854.153	854	854	854

FIG. 2-14



Physiographic Effects on MAR
Reference Period 1961-1988 (mm)
MAR Predicted by Physiographic Variables
940
920
900
880
860
840
820
800
780
600
650
700
750
800
850
900
950
1000
1050
MAR From Extended WSC Gage Data
MAR(fn ELEV)
MAR(fn ALL VAR)
MAR= const.= 854



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PREDICTED MAR FROM MODEL 2 IN STUDY AREA

FIG.2-15

The most "reasonable" distribution of data results from Model 2, which is presented as Figure 2-15. Only data points are given and no distribution is inferred because none could be discerned. The distribution shown on Figure 2-15 is not considered better than a constant value of 858 mm/year for the region.

2.3 Monthly Flow Variations

Five longer-term gauges were selected to illustrate variations of flow within a year on an average monthly basis.

The average monthly flows were taken from the Historical Streamflow Summary (WSC, 1988). For comparison these were normalized by division by the mean flow of the gauge for the period of record.

The results are presented in Table 2-14 and Figure 2-16 on a water-year basis.

A single annual cycle is dominant. Cycles of the larger and more regulated basins have smaller amplitudes, as expected; but a bimodal drought can be discerned. Average peak vernal flows are about twice the value of the long-term mean flow. There are two annual drought periods -- one in mid-winter and one in late summer. The latter is more severe with average monthly minimum flows being typically one-half the long-term average discharge.

2.4 Low Flow Analysis

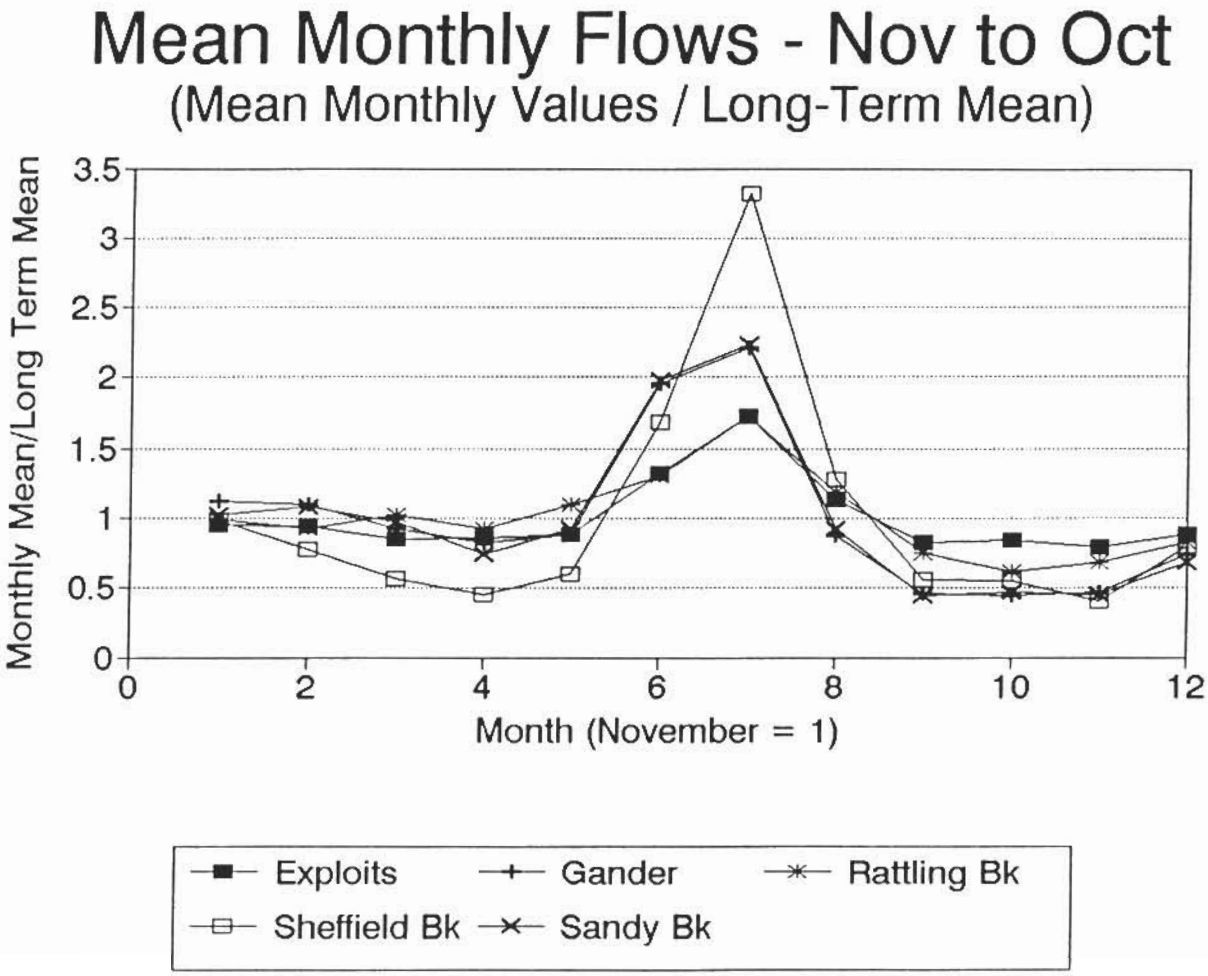
2.4.1 Introduction

Low flows affect such beneficial uses as water supply, water quality, and fisheries. A discussion appears in the Northern Peninsula/Humber Valley water resources study (Acres, 1990).

Table 2-14 ESTIMATION OF MEAN MONTHLY FLOWS
(Mean Monthly Flows Normalized by Mean Long Term Discharge)

	Exploits River @ Grand Falls	Gander River @ Big Chute	Rattling Brook @ G.S.	Sheffield Brook Nr TCH	Sandy Brook @ G.S.
November	0.95	1.12	0.98	0.98	1.02
December	0.94	1.10	0.92	0.77	1.08
January	0.85	0.92	1.02	0.57	0.97
February	0.86	0.82	0.92	0.46	0.74
March	0.88	0.88	1.10	0.60	0.92
April	1.31	1.96	1.30	1.69	1.98
May	1.72	2.21	1.73	3.33	2.24
June	1.12	0.87	1.18	1.28	0.92
July	0.82	0.46	0.75	0.56	0.44
August	0.84	0.44	0.63	0.55	0.48
September	0.79	0.47	0.69	0.40	0.45
October	0.88	0.74	0.82	0.80	0.68
Mean	1.00	1.00	1.00	1.00	1.00
Length of Record (yrs)	45	39	26	16	23

FIG. 2-16



Mean Monthly Flows - Nov to Oct
(Mean Monthly Values / Long-Term Mean)
Monthly Mean/Long Term Mean
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
Month (November = 1)
Exploits
Gander
Rattling Bk
Sheffield Bk
Sandy Bk

Two approaches are available for most low-flow analyses -- flow duration and frequency. Their relative utilities are also discussed in the Acres report (1990). In summary, duration curves are often used for hydropower studies and frequency methods for other beneficial uses.

The consultant acknowledges the assistance of Dr. Beersing of the Water Resources Division in the preparation of this section. The Division is currently preparing a major study on low-flow characteristics on the Island (Beersing, NDOEL Water Resources Division, January 1991)[1]. To avoid duplication of effort, the material in this section incorporates some of that from the draft of the NDOEL study relevant to the study area.

2.4.2 Flow Duration Curves

Flow duration curves, in units of litres/s-km^2, are presented as Figures 2-17 to 2-20 for the following rivers in the study area:

Peter's River near Botwood	WSC 02YO006
South West Brook near Baie Verte	WSC 02YM003
Shoal Arm Brook near Badger Bay	WSC 02YP001

While outside the study area, a flow duration curve for Lloyd's River below King George IV Lake is included since it also lies in the Exploits River basin. With the exception of Lloyd's River (which has a more constant discharge), the area-normalized flow duration curves for these small unregulated basins are all very similar. They can thus be considered representative of the region. These curves were produced with the LOFLOW program,

----

[1] Water Resources Division, NDOEL, "Characteristics and Estimation of Minimum Stream Flows for the Island of Newfoundland", January 1991, draft, not yet released.

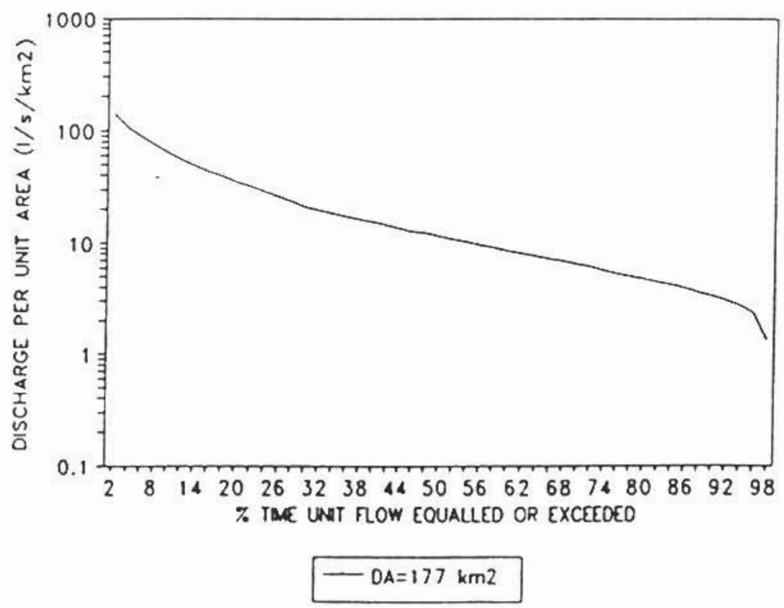


Figure 2-17 Daily Flow Duration Curve at Gauging Station 02YO006.

PETER'S RIVER NEAR BOTWOOD

SOURCE: N.D.O.E.L (1991)

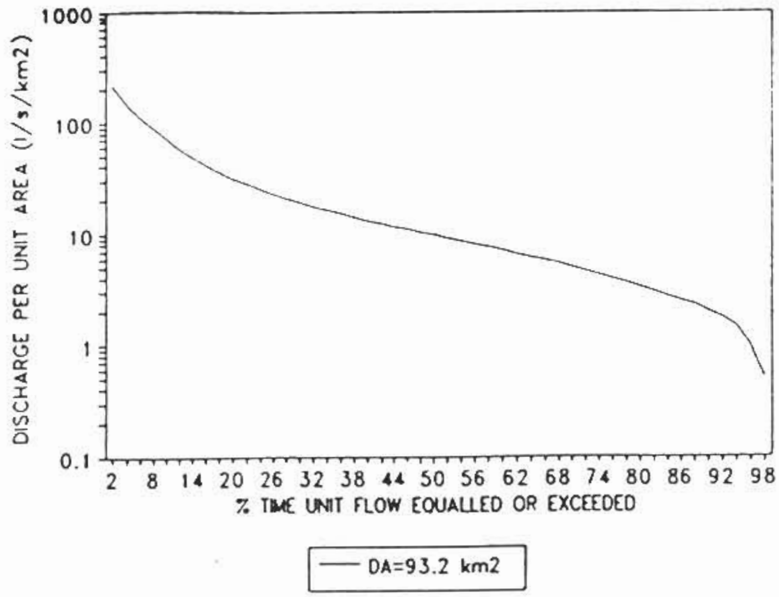


Figure 2–18 Daily Flow Duration Curve at Gauging Station 02YM003.

SOUTH WEST BROOK NEAR BAIE VERTE

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FIG. 2–18

SOURCE: N.D.O.E.L (1991)

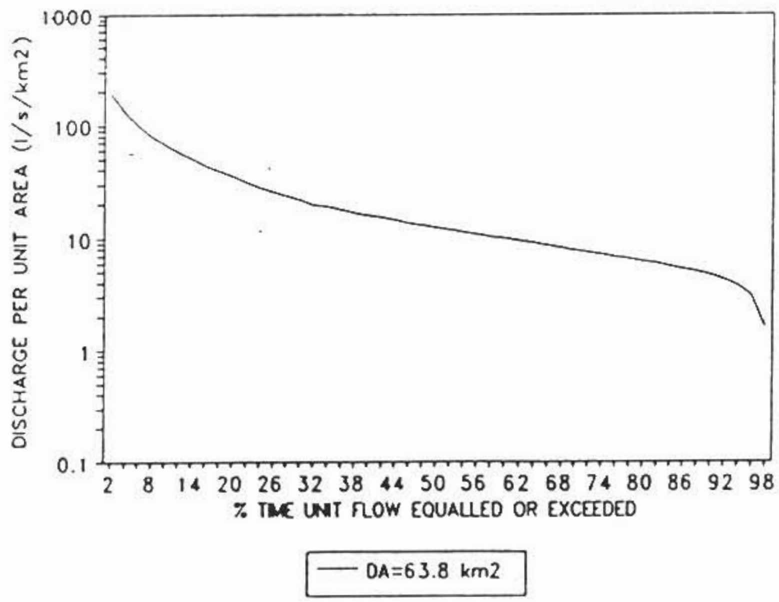

Figure 2-19 Daily Flow Duration Curve at Gauging Station 02YP001.
SHOAL ARM BROOK NEAR BADGER BAY

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FIG. 2-19

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

SOURCE: N.D.O.E.L. (1991)

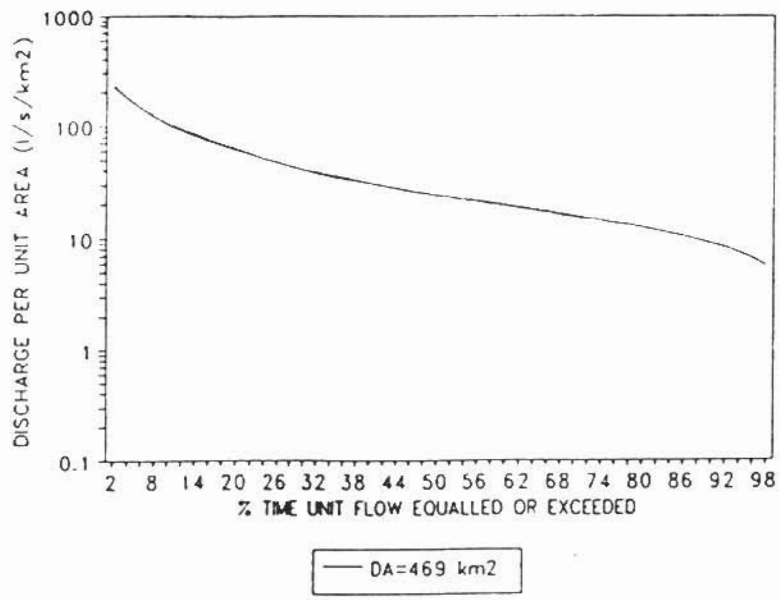

Figure 2-20 Daily Flow Duration Curve at Gauging Station 02YN002.

LLOYD'S RIVER BELOW KING GEORGE IV LAKE
(IN EXPLOITS RIVER BASIN ABOVE THE STUDY AREA)

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FIG.2-20

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

SOURCE: N.D.O.E.L (1991)

developed by the Water Resources Branch, Inland Waters Directorate of Environment Canada.

2.4.3 Frequency Method

The frequency-based methodology follows that developed by NDOEL (NDOEL, 1991).

The stations and physiographic parameters used in the analysis for the region are given in Table 2-15.

Note that the drainage areas used in the analysis ranged from 37 km^2 to 554 km^2, that the percentage of barren area is less than 3.3% and that the percentage of forested area is greater than 68.1% in all cases. (Thus, this sample may not be representative of, or applicable to, such cases as small basins on more barren offshore islands, such as Fogo Island.)

Please note that precipitation is not included in the data set in Table 2-15, nor as one of the predictive equations in the regression equations because:

(1) precipitation data are scarce at high elevations and there can be significant differences in precipitation amounts between even closely-related stations,

(2) it is a difficult parameter to estimate at sites with no precipitation data, and

(3) the error in estimating precipitation can be as large as the range of precipitation for this region (800 mm to 1100 mm).

It should also be explicitly noted that the accuracy of the low-flow estimates is dependent upon the accuracy of the low-flow measurements themselves. While the latter depends upon many

Table 2-15 LOW FLOW ANALYSIS - STATIONS AND PHYSIOGRAPHIC DATA

STATION NUMBER	DA (km2)	FOREST (%)	BARREN (%)	LAKES & SWAMPS (%)	LENGTH OF MAIN STREAM (km)	ELEVATION DIFFERENCE (m)	RECORD LENGTH (yrs)
02YS003	36.7	83.6	0.5	15.9	11.2	143	68-89, 22
02YP001	63.8	87.0	0.0	12.8	20.0	113	82-89, 8
02ZJ001	67.4	81.5	3.3	15.0	16.0	128	76-89, 14
02YM003	93.2	90.0	0.0	10.0	18.6	107	80-89, 10
02YO006	117.0	82.5	1.8	16.3	42.7	190	81-89, 9
02YD002	200.0	82.7	0.1	17.2	38.3	270	80-89, 10
02YR001	267.0	74.8	0.8	24.4	49.3	177	59-89, 31
02YR002	399.0	68.1	0.0	32.0	42.0	95	78-89, 12
02YR003	554.0	69.0	0.0	31.0	52.4	136	81-89, 9

parameters, including the absolute magnitude of the flows, a rule-of-thumb worst-case of typical data quality is ±50%.

As noted in the discussion accompanying Figure 2-16, there is a bimodal distribution of annual low flows. Typically the summer case is more severe, so the frequency analysis was based on these extrema.

The frequency estimates were made using the Gumbel Type III probability distribution function, i.e.:

$$p(x) = a(x-e)^{a-1}(b-e)^{-a}\exp[-\{(x-e)/(b-e)\}^{a}] \qquad (2\text{-}13)$$

where e is the lower bound or displacement parameter, often referred to as epsilon

b is the characteristic drought or a location parameter, often referred to as beta

and a is the scale parameter, often referred to as alpha.

The density function is integrable and results in

$$P(x) = 1 - \exp[-\{(x-e)/(b-e)\}^{a}] \qquad (2\text{-}14)$$

which gives the probability of non-exceedance of x. Alternately, the value of x for a given probability of non-exceedance is given by

$$x = e + (b-e)[-\ln\{1-P(x)\}]^{1/a} \qquad (2\text{-}15)$$ [1]

---

1 Some of the above text is from NDOEL (1991).

On this basis, frequency estimates for selected return periods for the stations listed in Table 2-14 are given in Table 2-16.

These results are then generalized by regression using the variables listed in Table 2-15. The procedure involves a similarity principle since the shapes of the functional plots are similar, but the origins and slopes vary. The procedure is:

(1) estimate the beta parameter for a 30-day low flow from an equation relating to the drainage area; (the other parameters in Table 2-14 follow from the stepwise regression);

(2) estimate 30-day low flows for selected recurrence intervals using the beta value from (1) above; and

(3) relate the low-flow estimates for other low-flow durations and recurrence intervals to those for the 30-day case.

The results are presented in Table 2-17.

2.5 Storage-Yield Analysis

A storage-yield analysis was performed using a methodology similar to that described in previous studies (eg. Acres, 1990), for consistency.

The primary application of the result is estimation of adequacy of supply to communities, so smaller unregulated basins were used in the analysis. From the results of the several basins analyzed, a regional curve was devised.

The procedure essentially involved selection of a dimensionless withdrawal rate, which is the ratio of the desired withdrawal rate divided by the mean annual flow over the

Table 2-16 FREQUENCY ESTIMATES OF ESTIVAL LOW FLOWS (m3/s)

STATION NUMBER	DA (km2)		1-DAY 2-YR	1-DAY 10-YR	1-DAY 20-YR		7-DAY 2-YR	7-DAY 10-YR	7-DAY 20-YR
02YS003	36.7		0.080	0.030	0.024		0.104	0.038	0.029
02YP001	63.8		0.181	0.041	0.000		0.201	0.050	0.006
02ZJ001	67.4		0.077	0.009	0.004		0.094	0.013	0.008
02YM003	93.2		0.053	0.002	0.000		0.063	0.004	0.000
02YO006	117.0		0.350	0.180	0.138		0.402	0.212	0.166
02YD002	200.0		0.385	0.029	0.005		0.453	0.054	0.024
02YR001	267.0		0.866	0.272	0.184		0.935	0.296	0.205
02YR002	399.0		0.368	0.040	0.021		0.417	0.054	0.031
02YR003	554.0		2.408	0.624	0.098		2.641	0.727	0.120
STATION NUMBER	DA (km2)		15-DAY 2-YR	15-DAY 10-YR	15-DAY 20-YR		30-DAY 2-YR	30-DAY 10-YR	30-DAY 20-YR
02YS003	36.7		0.126	0.050	0.043		0.175	0.074	0.063
02YP001	63.8		0.230	0.090	0.016		0.305	0.078	0.000
02ZJ001	67.4		0.113	0.096	0.010		0.129	0.020	0.015
02YM003	93.2		0.087	0.135	0.003		0.156	0.010	0.001
02YO006	117.0		0.479	0.267	0.190		0.683	0.338	0.230
02YD002	200.0		0.514	0.303	0.058		0.717	0.113	0.052
02YR001	267.0		0.990	0.412	0.222		1.128	0.343	0.242
02YR002	399.0		0.464	0.632	0.040		0.550	0.077	0.046
02YR003	554.0		2.833	0.895	0.146		3.088	1.062	0.348

Table 2-17

LOW-FLOW REGRESSION EQUATIONS FOR STUDY AREA

Equation			R^2	S.E.E.
BETA@30	=	$5.0466*DA^{0.966}$	0.83	0.184
Q2@30	=	0.844*BETA@30	0.99	0.101
Q5@30	=	0.566*Q2@30	0.97	0.102
Q10@30	=	0.588*Q5@30	0.99	0.032
Q20@30	=	0.393*Q10@30	0.77	0.062
Q50@30	=	0.602*Q20@30	0.88	0.022
BETA@15	=	$0.4046*BETA@30^{1.099}$	0.99	0.047
Q2@15	=	0.841*BETA@15	0.99	0.081
Q5@15	=	0.543*Q2@15	0.98	0.070
Q10@15	=	0.542*Q5@15	0.98	0.034
Q20@15	=	0.287*Q5@15	0.24	0.073
Q50@15	=	0.695*Q20@15	0.99	0.004
BETA@7	=	$0.2280*BETA@30^{1.166}$	0.98	0.075
Q2@7		= 0.834*BETA@7	0.99	0.072
Q5@7		= 0.526*Q2@7	0.98	0.063
Q10@7	=	0.529*Q5@7	0.98	0.033
Q20@7	=	0.280*Q10@7	0.21	0.070
Q50@7	=	0.694*Q20@7	0.99	0.004
BETA@1	=	$0.1449*BETA30^{1.214}$	0.98	0.077
Q2@1		= 0.826*BETA@1	0.99	0.064
Q5@1		= 0.509*Q2@1	0.98	0.057
Q10@1	=	0.518*Q5@1	0.98	0.031
Q20@1	=	0.275*Q10@1	0.19	0.065
Q50@1	=	0.670*Q20@1	0.99	0.004

NOTES:

BETA@N	-	Beta parameter of Gumbel Type III PDF for N-day low flow series (litres/second)
QT@N	-	T-year Low Flow Regression Estimate of duration N days, (litres/second)
R^2	-	Correlation coefficient
S.E.E.	-	Standard error of estimate in $\log_{10}$ (Dependent variable) for BETA's and (Dependent Variable) otherwise
DA	-	Drainage Area (km^2)

Source: (NDOEL, 1991)

period of record (i.e. Q/<Q>). The range of Q/<Q> considered was from 0.1 to 1.0. The withdrawal discharge was subtracted in turn from daily discharges over the entire period. The cumulative deficits, if any, were totalled until refill occurred. The maximum volume deficiency over the entire period of record was then identified. This was divided by the mean flow volume Q_v (= mean flow over period of record * 365.25 days/year) to provide a storage ratio $S/<Q_v>$. The duration of the flow deficiency, and hence the magnitude of S/<Qv> is a random variable. The computed value will depend upon the length of the record and the time of the record. An examination of the gauges used (Table 2-18) shows that all except Sheffield Brook had 5 to 10 years of record, and that these records were contemporaneous; so consistent records were used in the calculations. Thus, the failure criterion of S/<Qv> is approximately one in ten years. A verbal description of the normalized parameter S/<Qv> is that this represents the storage required to provide a normalized firm yield of magnitude Q/Qavg over the greatest flow deficiency in the period of record. Conversely, if the S/<Qv> to Q/Qavg function is inverted, a verbal description is that Q/Qavg is the largest (normalized) firm yield that can be expected (on the basis of a period of record of 5 to 10 years) from a (normalized) storage capacity of S/<Qv>. This firm yield can be compared with demand.

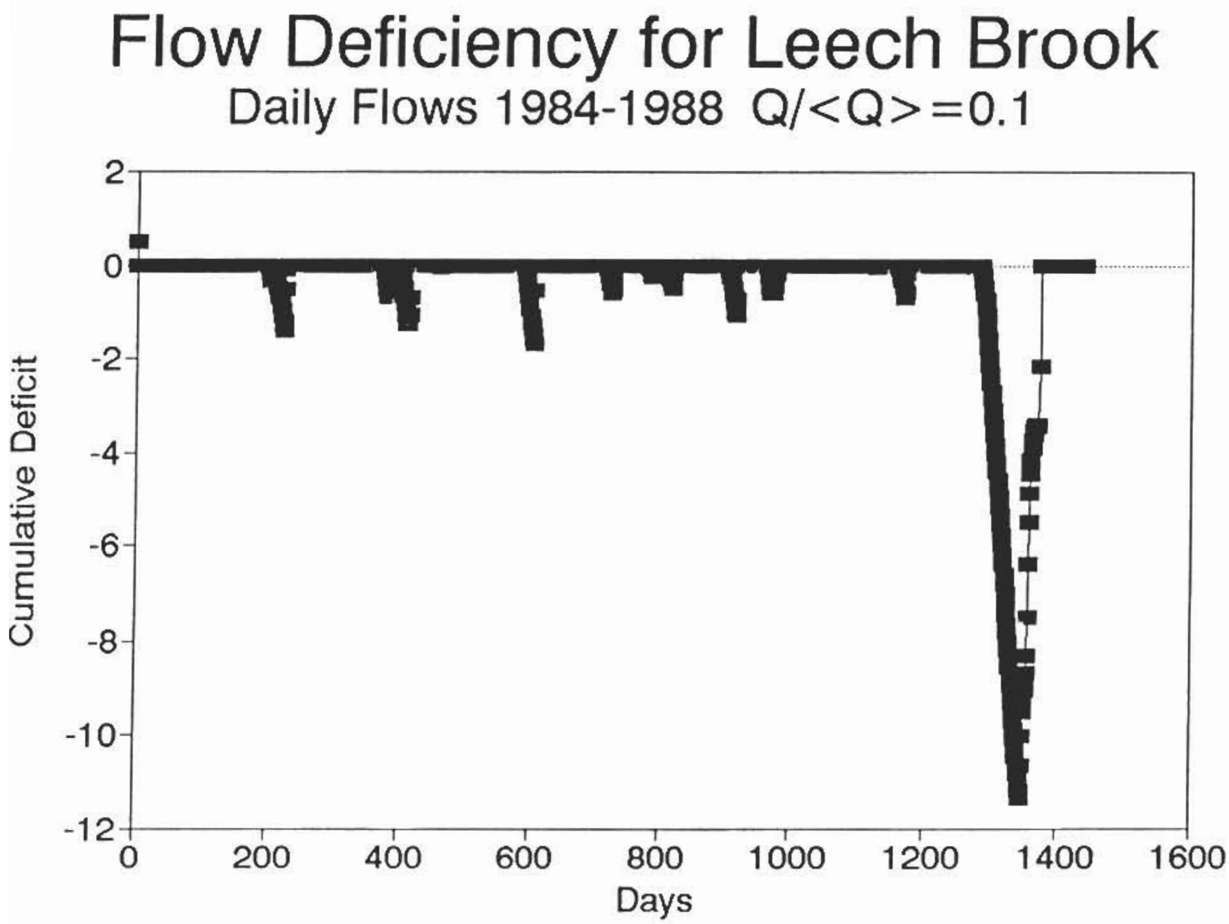
Note that, on the figures, S/<Q> has been used instead of $S/<Q_v>$ because of the inability to create subscripts. $S/<Q_v>$ is intended.

Examples are given for the cases of Leech Brook (Figure 2-21) and Peters River (Figure 2-22). The storage requirements are often driven by a single extreme drought episode for which the refill process is very rapid. Leech Brook is a good example. Peter's River has more frequent large deficiencies in volume.

Table 2-18 STORAGE - YIELD CURVE FOR STUDY AREA

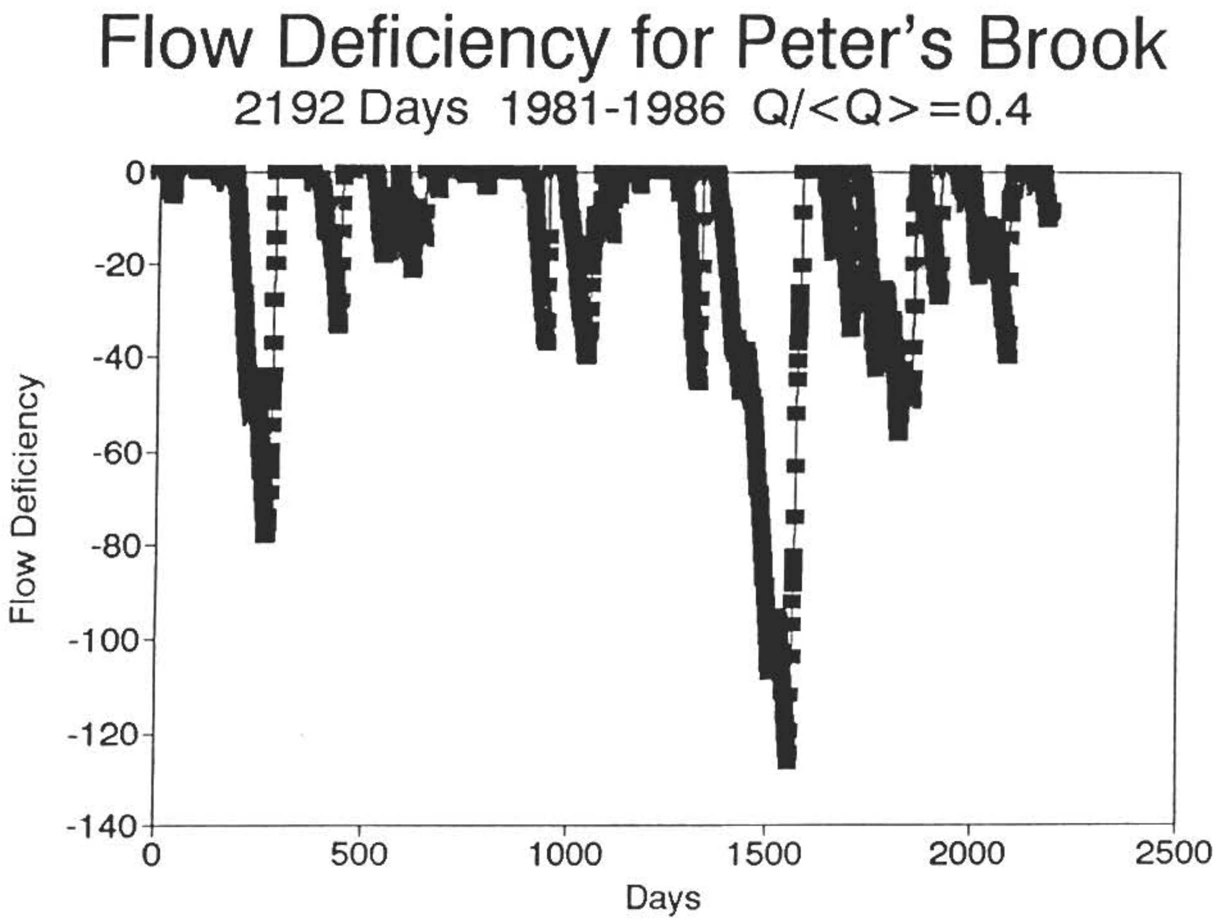
	Storage Required S/<Qv>									
Yield	YM003	YP001	YQ005	YO006	YO010	YO007	YO008	YQ004	YK005	Design
Q/<Q>	SWBk	ShoalArm	Salmon	Peters	Junction Bk	Leech	GtRattling	NWGander	Sheffield	
Q7/10	0.002	0.000	0.020	0.000	0.069	0.003	0.034	0.002	0.000	
0.1	0.017	0.010	0.015	0.001	0.016	0.015	0.015	0.014	0.002	0.016
0.2	0.042	0.028	0.037	0.010	0.044	0.035	0.038	0.037	0.017	0.044
0.3	0.095	0.051	0.071	0.027	0.078	0.065	0.068	0.071	0.041	0.078
0.4	0.171	0.096	0.113	0.079	0.113	0.102	0.103	0.107	0.069	0.113
0.5	0.248	0.174	0.156	0.132	0.148	0.139	0.139	0.145	0.115	0.148
0.6	0.326	0.255	0.201	0.186	0.185	0.177	0.178	0.188	0.165	0.185
0.7	0.505	0.336	0.263	0.249	0.254	0.220	0.221	0.232	0.218	0.254
0.8	0.781	0.419	0.341	0.406	0.331	0.301	0.265	0.286	0.278	0.331
0.9	1.060	0.695	0.420	0.585	0.409	0.464	0.339	0.383	0.379	0.585
1	1.404	1.065	0.498	0.793	0.516	0.723	0.416	0.725	0.568	0.793

FIG. 2—21



Flow Deficiency for Leech Brook
Daily Flows 1984-1988 Q/<Q>=0.1
Cumulative Deficit
2
0
-2
-4
-6
-8
-10
-12
0
200
400
600
800
1000
1200
1400
1600
Days

FIG. 2-22


Flow Deficiency for Peter's Brook
2192 Days 1981-1986 Q/<Q>=0.4
Flow Deficiency
0
-20
-40
-60
-80
-100
-120
-140
0
500
1000
1500
2000
2500
Days

The results are shown in Table 2-18. For convenience they are depicted on Figures 2-23 through 2-26. The full range of yields Q/<Q> from 0.1 to 1.0 is shown on Figures 2-23 and 2-24, while more detail is given for the range Q/<Q> from 0.1 to 0.5 on Figures 2-25 and 2-26. Note that the lines diverge more significantly in the range $0.7 \leq (Q/<Q>) \leq 1.0$, while a general regional relation is clear in the range $0.1 \leq (Q/<Q>) \leq 0.7$ (especially on Figure 2-24).

After close qualitative inspection of Figures 2-23 through 2-26, a suggested regional curve is provided on Figure 2-27 and the last column of Table 2-18. It is comprised of the values for Junction Brook (02YO010) for Q/<Q> from 0.1 to 0.7, and of Peter's River (02YO006) for $0.7 < (Q/<Q>) \leq 1.0$.

For demand/supply calculations it will be convenient to have an equation for the storage/yield curve. As shown on Figure 2-28, a good fit ($r^2 = 0.926$) is given by:

$$S/<Q_v> = 0.0180080 \exp (3.908714[Q/<Q>]) \qquad (2\text{-}16)$$

This equation is based on a regression of the range $(0.1 \leq (Q/<Q>) \leq 0.7)$. This range provides a better fit for the more important lower end of the scale.

It is recommended that Figure 2-27 be used for single applications to find required storage to obtain a preliminary design yield for the abscissa range shown. While less accurate, Figure 2-28 should be appropriate for multiple applications which require a numerical approximation of the abscissa range shown.

FIG. 2-23

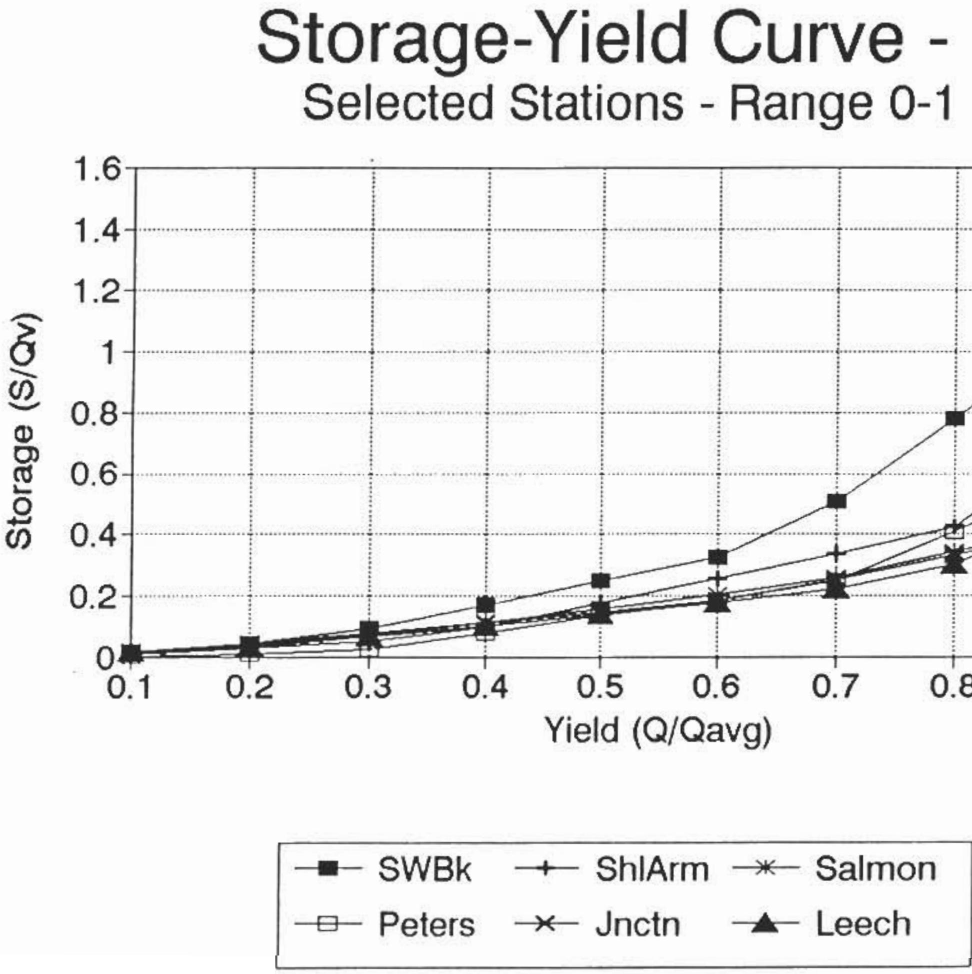
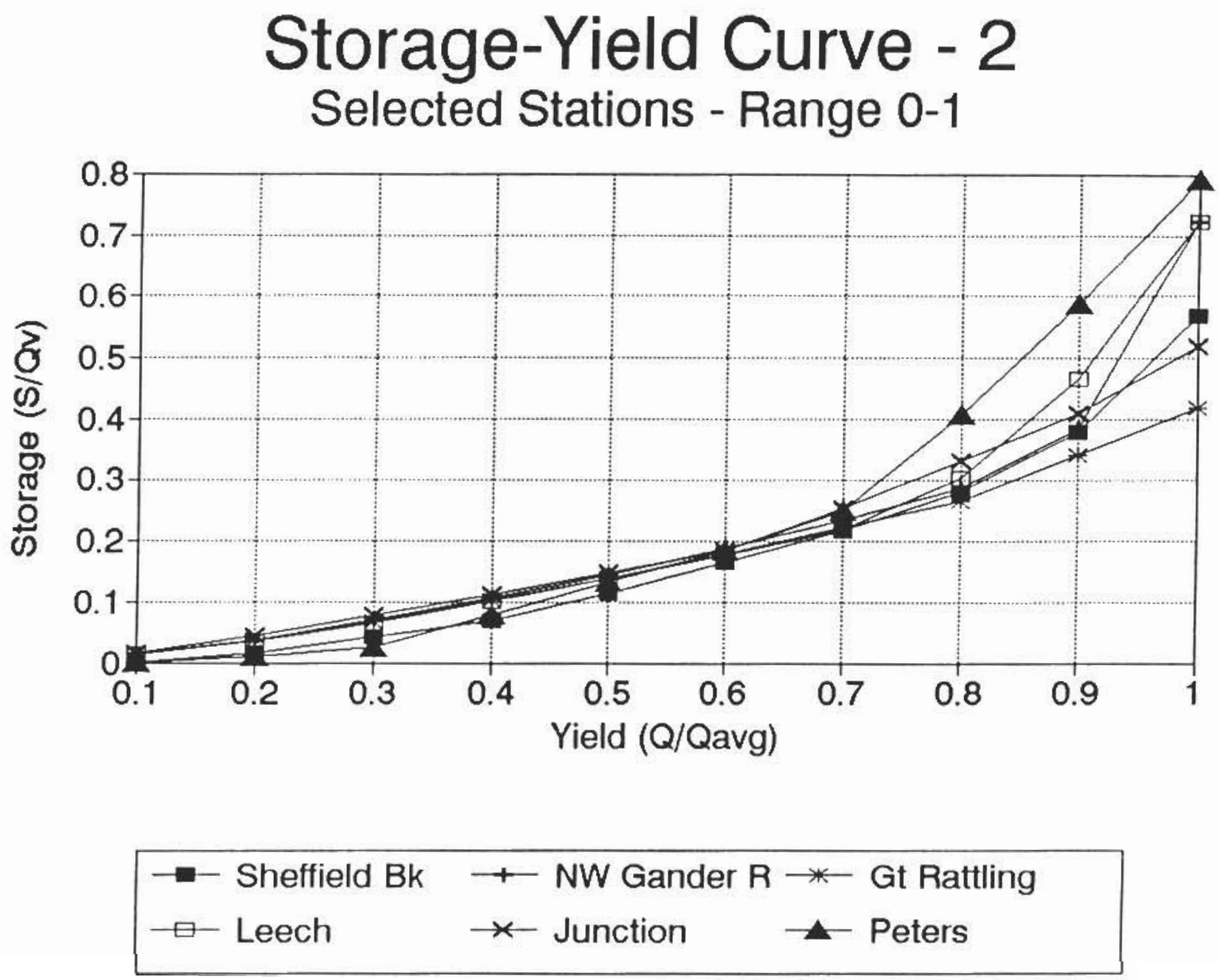
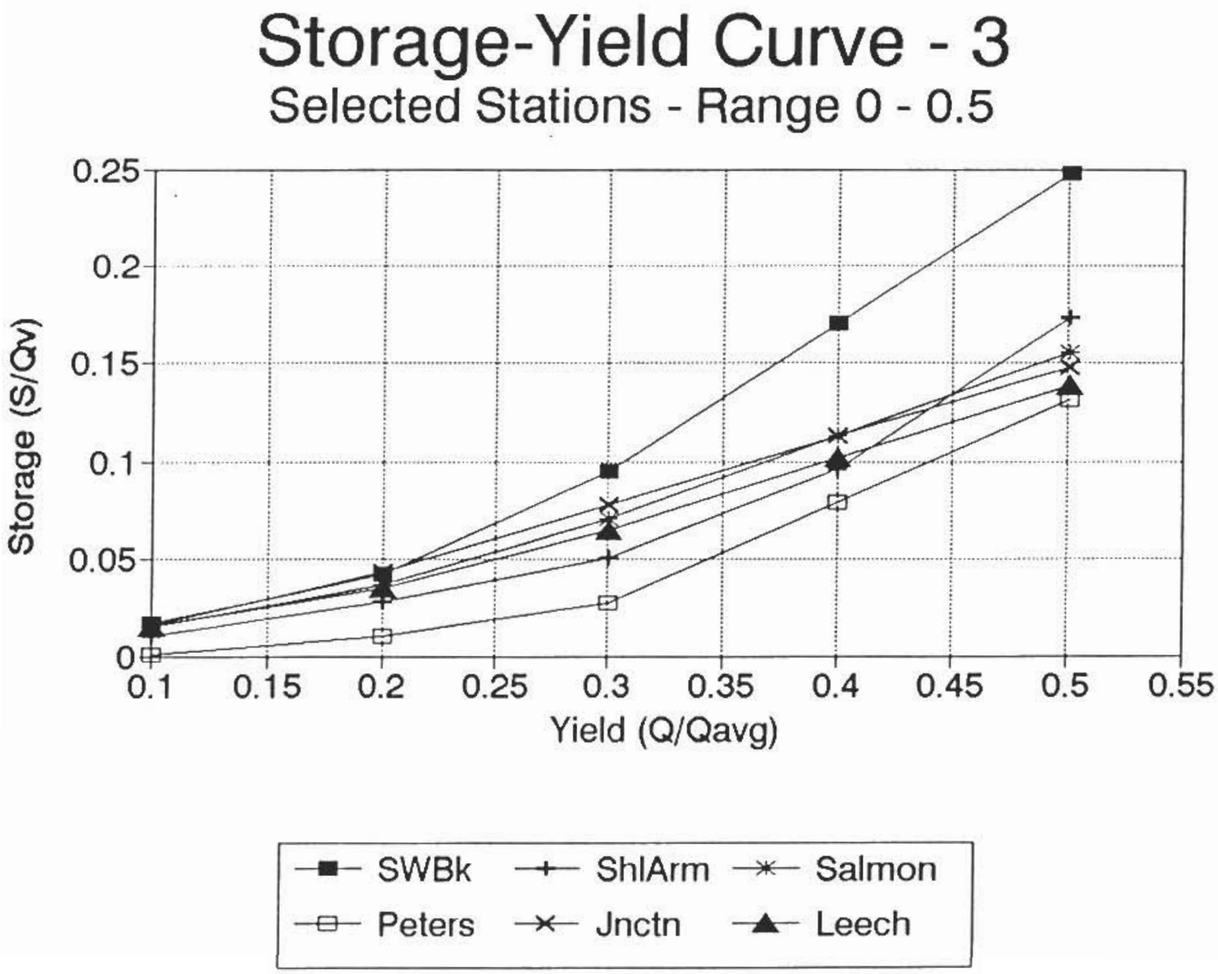

Storage-Yield Curve - 1
Selected Stations - Range 0-1
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Storage (S/Qv)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Yield (Q/Qavg)
SWBk
ShlArm
Salmon
Peters
Jnctn
Leech

FIG. 2-24



Storage-Yield Curve - 2
Selected Stations - Range 0-1
Storage (S/Qv)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Yield (Q/Qavg)
Sheffield Bk
NW Gander R
Gt Rattling
Leech
Junction
Peters

FIG. 2-25



Storage-Yield Curve - 3
Selected Stations - Range 0 - 0.5
0.25
0.2
0.15
0.1
0.05
0
Storage (S/Qv)
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
Yield (Q/Qavg)
SWBk
ShlArm
Salmon
Peters
Jnctn
Leech

FIG. 2-26

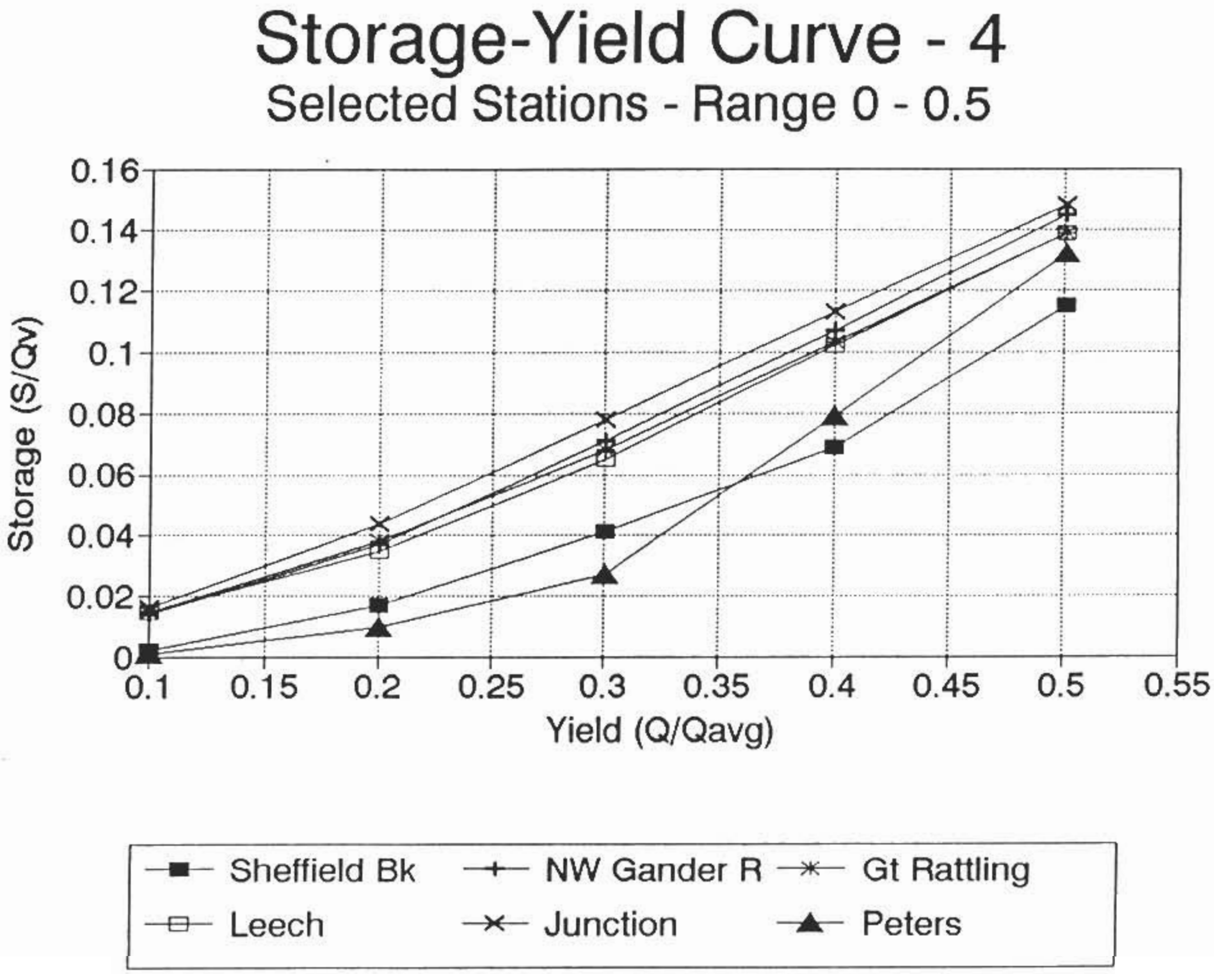

Storage-Yield Curve - 4
Selected Stations - Range 0 - 0.5
Storage (S/Qv)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
Yield (Q/Qavg)
Sheffield Bk
NW Gander R
Gt Rattling
Leech
Junction
Peters

FIG. 2-27

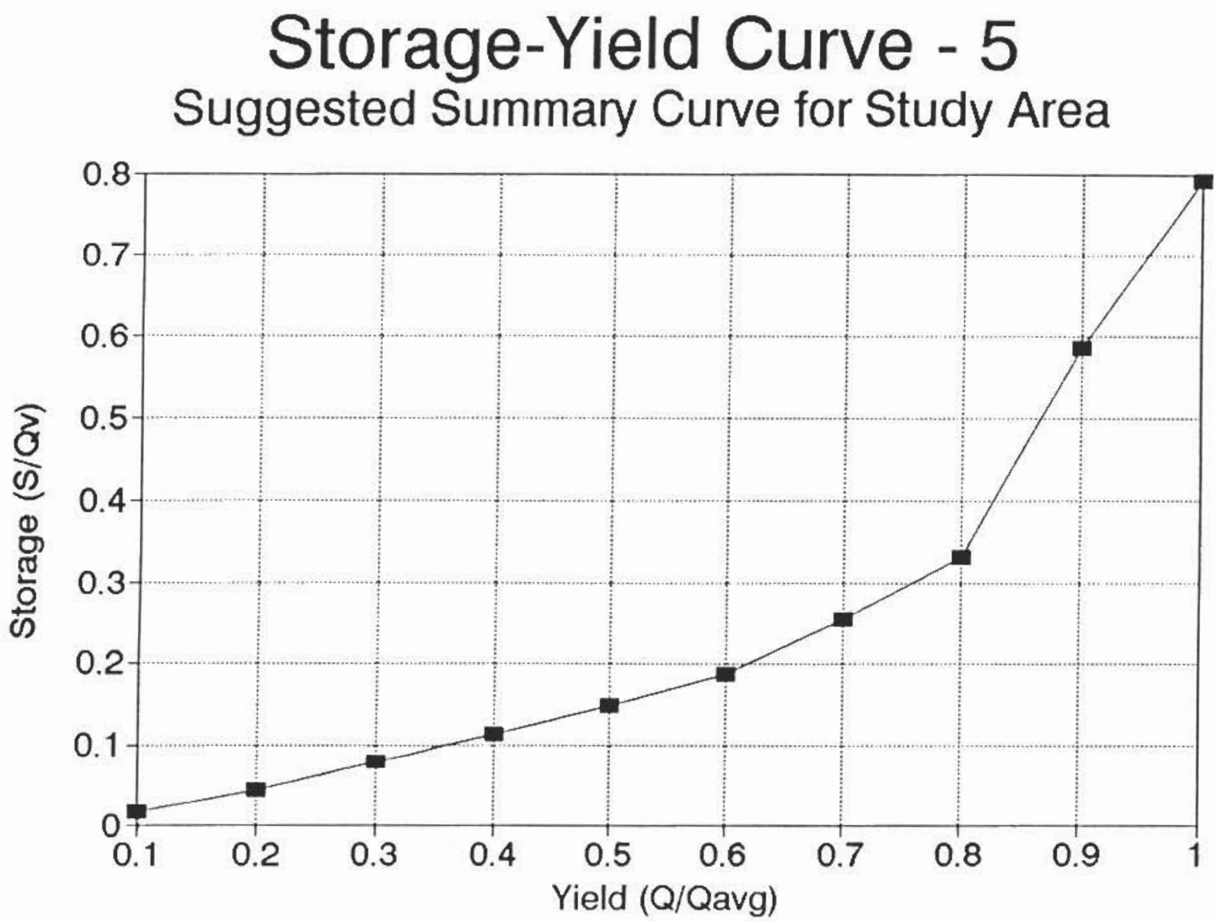
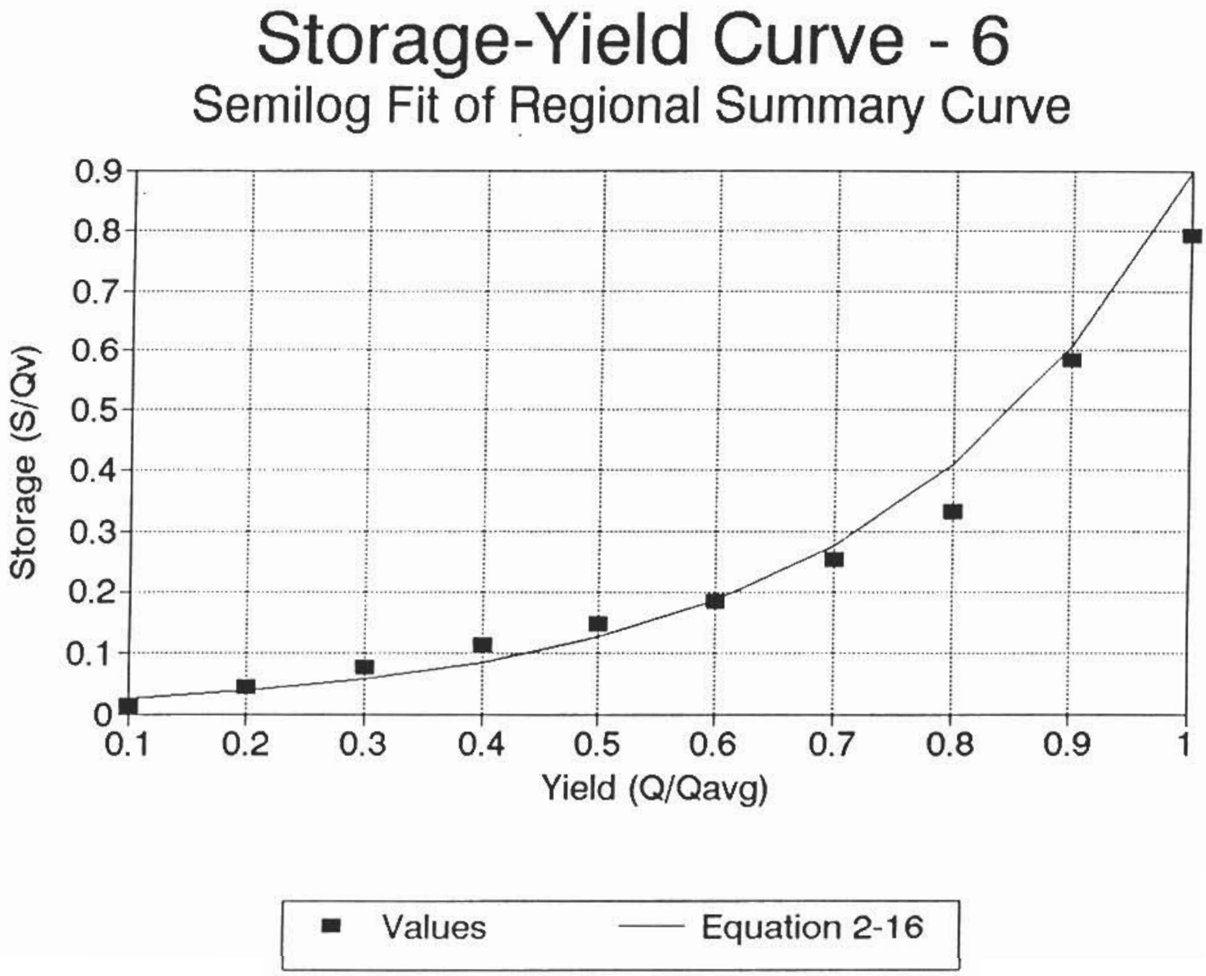

Storage-Yield Curve - 5
Suggested Summary Curve for Study Area
Storage (S/Qv)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Yield (Q/Qavg)

FIG. 2-28


Storage-Yield Curve - 6
Semilog Fit of Regional Summary Curve
Storage (S/Qv)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Yield (Q/Qavg)
Values
Equation 2-16

Note that the function on Figure 2-27 is almost linear in the range $0.1 \leq Q/Qavg \leq 0.4$, so that a linear fit would be preferable in this range. As shown on Figure 2-29, the best fit (r = .997) is obtained with a computed intercept. This is:

$$S/(Qv) = -0.0185 + 0.325\ (Q/Qavg) \qquad (2\text{-}17)$$

for the range $0.1 \leq Q/Qavg \leq 0.4$. Note on Figure 2-29 that equation (2-17) requires negative storage for the region $0 \leq Q/Qavg \leq 0.055$ (approximately) due to extrapolation error. In the event that the very small firm yield of Q/Qavg should fall in this range, a linear relation of the form:

$$S/Qv = 0 + 0.16\ Q/Qavg \qquad (2\text{-}18)$$

is suggested. This is shown by the dotted line on Figure 2-29. It is unlikely that this range would often be of practical interest.

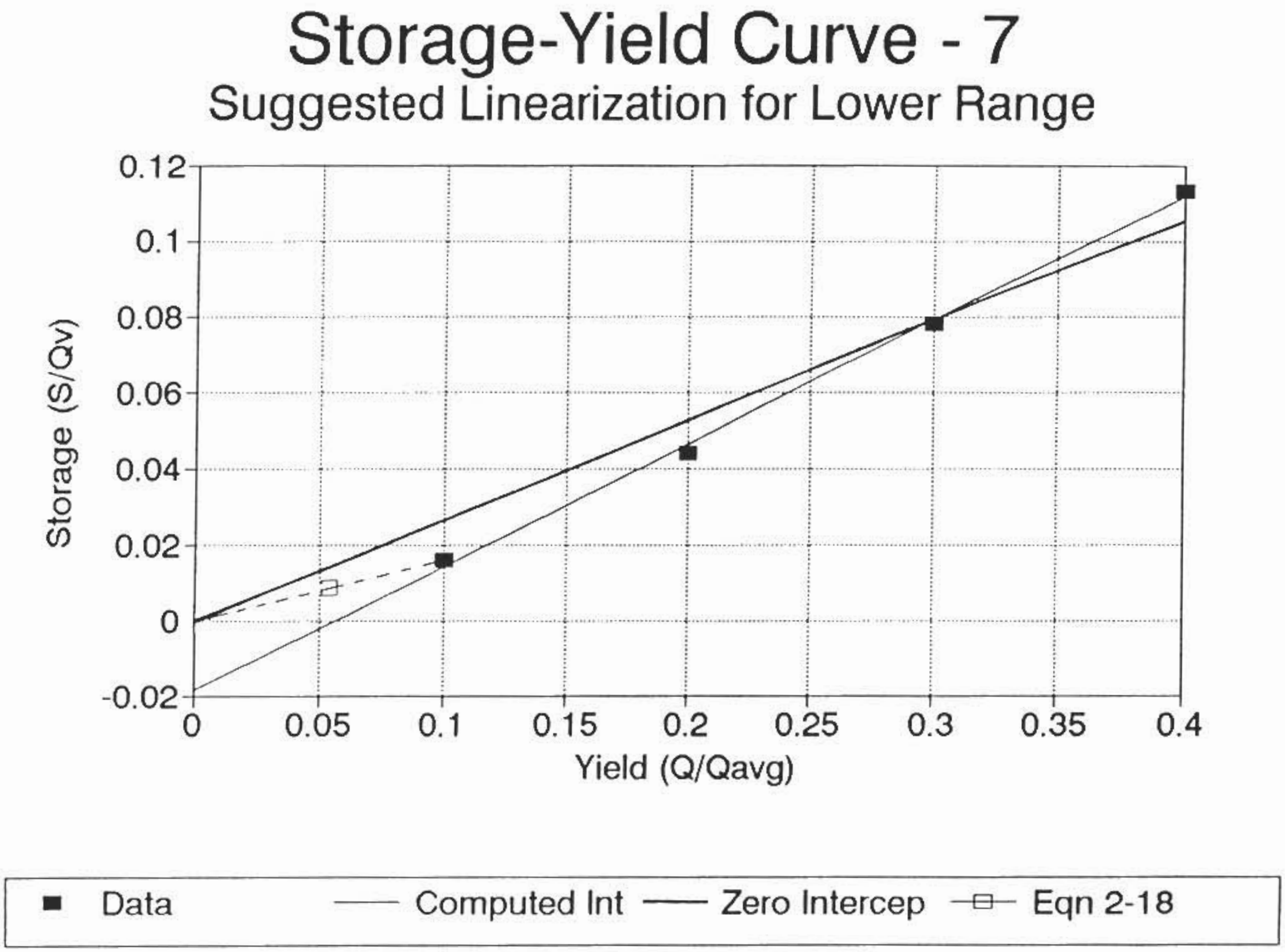
The relation given in equation (2-17) is inverted (actually x is regressed on y) on Figure 2-30 (which is also presented later as Figure 8-1). This linearized relation (equation 8-1) is used for the municipal supply screening model.

2.6 Surface Water Availability

Since no consistent variation in MAR could be found in the study region, it was concluded that a constant value of MAR of 858 mm/year could be adopted. Surface water availability can thus be readily calculated using unit discharge [equation (2-2)]:

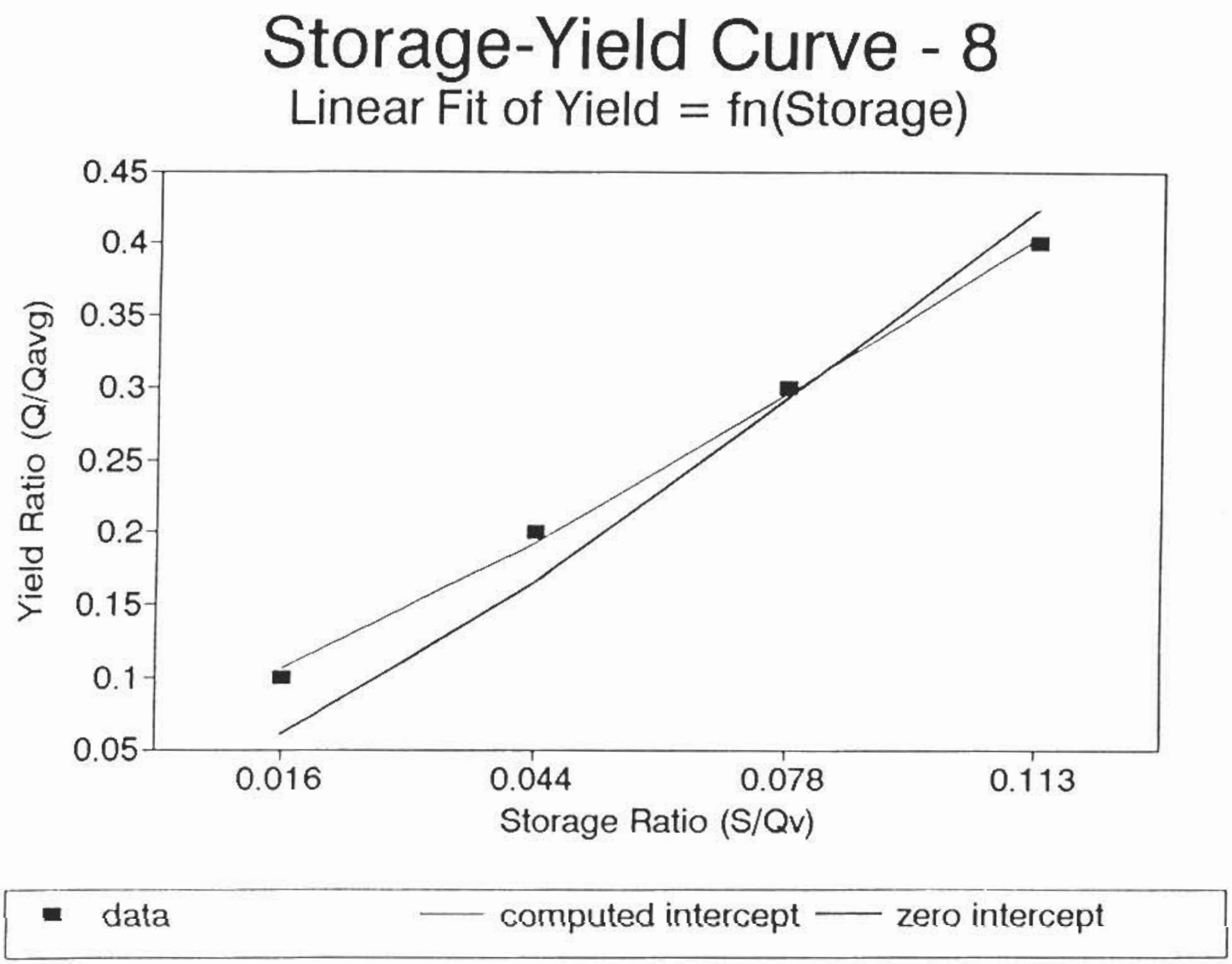
$$858\ \frac{mm}{yr} * \frac{1}{31{,}558}\ \frac{yr}{mm} \cdot \frac{m^3}{km^3\text{-}s} = 0.02719\ \frac{m^3}{km^2\text{-}s} \qquad (2\text{-}19)$$

FIG. 2-29



Storage-Yield Curve - 7
Suggested Linearization for Lower Range
Storage (S/Qv)
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Yield (Q/Qavg)
Data
Computed Int
Zero Intercep
Eqn 2-18

FIG. 2-30



Storage-Yield Curve - 8
Linear Fit of Yield = fn(Storage)
Yield Ratio (Q/Qavg)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.016
0.044
0.078
0.113
Storage Ratio (S/Qv)
data
computed intercept
zero intercept

The calculation is:

$$MAR = \langle Q \rangle_{year} = \text{Drainage Area } (km^2) * 0.02719 \ \frac{m^3}{km^2\text{-}s} \quad (2\text{-}20)$$

A list of MARs for the water supply basins of the communities in the study area is given in Table 2-19.

Table 2-19

Estimates of Surface Water Supply Availabilities

Community	Drainage Area (ha)	Mean Annual Runoff (m^3/s)	Mean Annual Flow Vol. (m^3/year)
Appleton	416000	113.065	3.57E+09
Baie Verte	8500	2.310	7.29E+07
Bayview	65	0.018	5.58E+05
Beachside	55	0.015	4.72E+05
Birchy Bay	3620	0.984	3.10E+07
Botwood	17700	4.811	1.52E+08
Brent's Cove	95	0.026	8.15E+05
Brighton	58	0.016	4.97E+05
Buchans	50800	13.807	4.36E+08
Burlington East Side	12225	3.323	1.05E+08
Burlington West Side	940	0.255	8.06E+06
Campbellton	28300	7.692	2.43E+08
Chanceport	62	0.017	5.32E+05
Comfort Cove/Newstead	220	0.060	1.89E+06
Cottrell's Cove/Moore's Cove	72	0.020	6.18E+05
Crow Head	62	0.017	5.32E+05
Embree	445	0.121	3.82E+06
Fairbanks	52	0.014	4.46E+05
Fleur De Lys	16.7	0.005	1.43E+05
Fleur De Lys	29.3	0.008	2.51E+05
Fleur De Lys	69	0.019	5.92E+05
Fogo	165.5	0.045	1.42E+06
Glenwood	416000	113.065	3.57E+09
Grand Fls/Windsor/Bishop's Fls	6025	1.638	5.17E+07
Herring Neck	19	0.005	1.63E+05
Hillgrade	120	0.033	1.03E+06
Indian Cove	12	0.003	1.03E+05
Jackson's Cove	210	0.057	1.80E+06
Joe Batts Arm	604	0.164	5.18E+06
King's Island/Smith's Harbour	950	0.258	8.15E+06
King's Point	1860	0.506	1.60E+07
La Scie	690	0.188	5.92E+06
Leading Tickles	118	0.032	1.01E+06
Lewisporte	2640	0.718	2.26E+07
Little Bay	10	0.003	8.58E+04
Loon Bay	7400	2.011	6.35E+07
Lushes Bight/Beaumont	55	0.015	4.72E+05
Merritt's Harbour	30	0.008	2.57E+05
Middle Arm	1585	0.431	1.36E+07
Miles Cove	90	0.024	7.72E+05
Millertown	88	0.024	7.55E+05
Ming's Bight/South Brook	225	0.061	1.93E+06
Newville	44	0.012	3.77E+05
Nippers Harbour	240	0.065	2.06E+06

Table 2-19 (Continued)

Estimates of Surface Water Supply Availabilities

Community	Drainage Area (ha)	Mean Annual Runoff (m^3/s)	Mean Annual Flow Vol. (m^3/year)
Norris Arm	315	0.086	2.70E+06
Northern Arm	185	0.050	1.59E+06
Pacquet	1920	0.522	1.65E+07
Phillip's Head	15	0.004	1.29E+05
Pilley's Island	112	0.030	9.61E+05
Pleasantview	83	0.023	7.12E+05
Point of Bay	5200	1.413	4.46E+07
Point Leamington	4020	1.093	3.45E+07
Port Albert	58	0.016	4.97E+05
Port Anson	25	0.007	2.14E+05
Purbeck's Cove	205	0.056	1.76E+06
Purcell's Harbour	300	0.082	2.57E+06
Rattling Brook	260	0.071	2.23E+06
Robert's Arm	120	0.033	1.03E+06
Rooms	990	0.269	8.49E+06
Seal Cove (Western Bay)	450	0.122	3.86E+06
Shoe Cove	470	0.128	4.03E+06
South Brook	58000	15.764	4.97E+08
Springdale (Sullivan's Pond)	386	0.105	3.31E+06
Springdale (Huxter's Pond)	106	0.029	9.09E+05
Stoneville	38000	10.328	3.26E+08
Summerford	215	0.058	1.84E+06
The Beaches	196	0.053	1.68E+06
Tilt Cove	30	0.008	2.57E+05
Tilting	1952	0.531	1.67E+07
Tizzard's Harbour	136	0.037	1.17E+06
Triton	430	0.117	3.69E+06
Twillingate	263	0.071	2.26E+06
Twillingate	200	0.054	1.72E+06
Valley Pond	28	0.008	2.40E+05
Westport	375	0.102	3.22E+06
Wild Cove	2550	0.693	2.19E+07
Woodstock	235	0.064	2.02E+06
Total	4010041.5	1089.889	3.44E+10

2.7 References - Section 2.0

Acres International Ltd., St. John's, "Final Report, Regional Water Resources Study of the Northern Peninsula and Humber Valley", prepared for NDOEL, Government of Newfoundland and Labrador, June 1990.

Environment Canada, Inland Waters Directorate, Water Resources Branch, Water Survey of Canada,a Historical Streamflow Summary Atlantic Provinces, to 1988, Ottawa, 1989.

Julian, Paul R., "Variance Spectrum Analysis", Water Resources Research, Volume 3, Number 3, 1967, pp. 831-845.

Water Resources Division, NDOEL, "Characteristics and Estimation of Minimum Stream Flows for the Island of Newfoundland", January 1991, draft, not yet released.

SECTION 3.0

METEOROLOGY

3.0 METEOROLOGY

3.1 Available Data

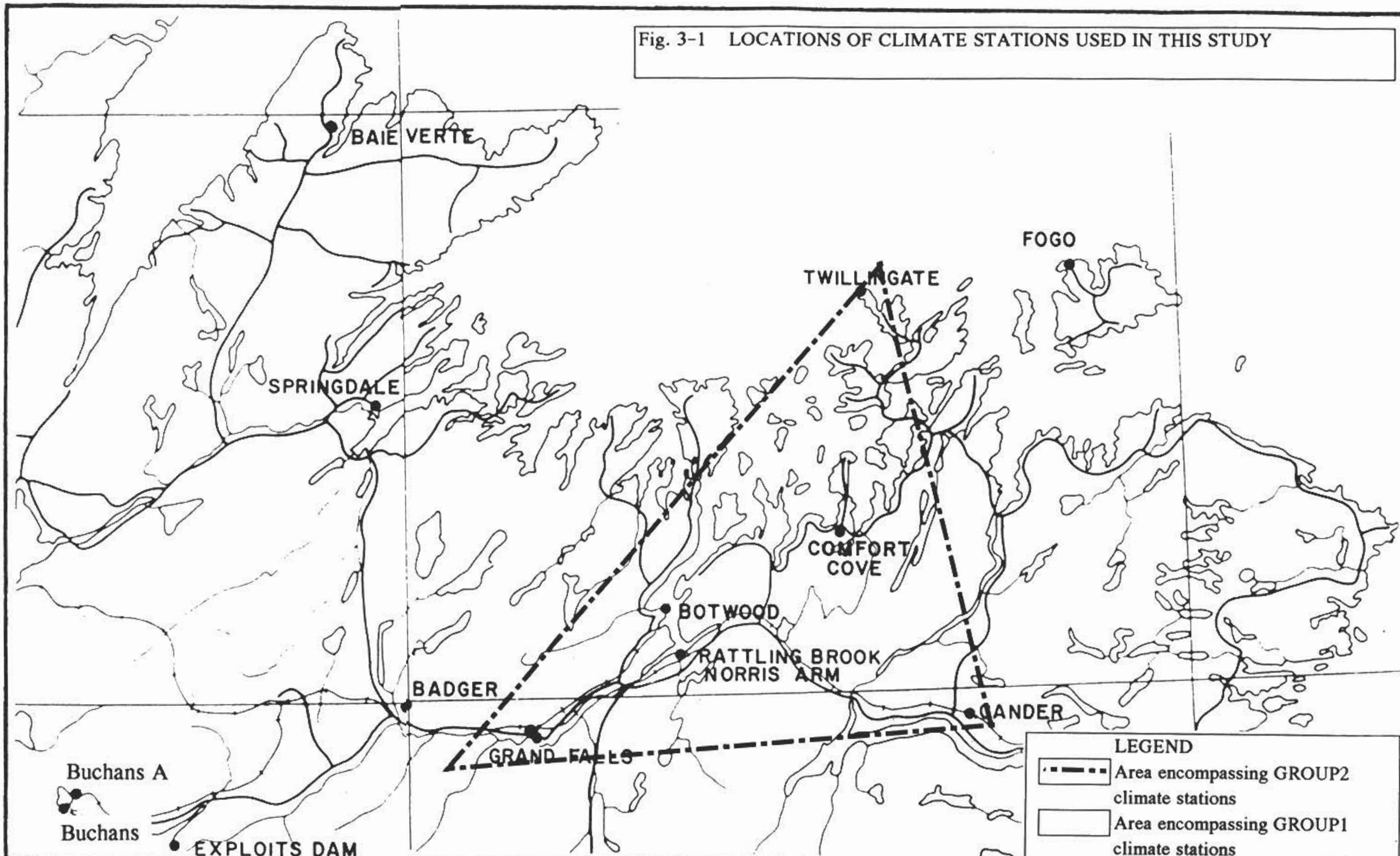
The climate stations from which climate data were studied are shown on Figure 3-1. These stations were selected on the basis of the availability of long term records. Data were extracted and collated from Environment Canada records for the periods 1951-1980 and 1981-1989 (Environment Canada 1951-1980 and 1981-1989). Not all climate records are continuous between these periods. Table 3-1 is a synopsis of the data used and the averages calculated for MAP and mean annual snowfall (MAS) in the study area. The table includes information about length of record and periods for which data are available. Thornthwaite evapotranspiration estimates, which are available from AES for some climate stations, are presented in Table 3-2.

3.2 Mean Annual Precipitation

Mean annual precipitation (MAP) was calculated with a simple average for all climate stations in the study region with periods of record greater than ten years during the two periods of record 1951-1980 and 1980-1989.

The average MAP of the entire study region is calculated to be 1019 mm with a standard deviation of 107.4 mm. MAP ranges from 774.9 mm at Fogo to 1130.1 mm at Gander International Airport. Figure 3-2 shows the calculated MAPs and mean annual snowfalls over the periods of record at each selected climate station.

Fig. 3-1 LOCATIONS OF CLIMATE STATIONS USED IN THIS STUDY



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LOCATIONS OF CLIMATE STATIONS
IN STUDY AREA

FIG. 3-1

Table 3-1 SYNOPSIS OF METEROLOGICAL DATA FROM SELECTED CLIMATE STATIONS IN THE STUDY REGION

Climate Station	GROUP	'PHYSIOGRAPHIC' DATA abbrev.	ELEV (m)	NE (km)	W (km)	TOTAL PRECIPITATION Years of Record 51-80 (yrs)	81-89 (yrs)	MAP (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAP (mm)	TOTAL SNOWFALL Years of Record 51-80 (yrs)	81-89 (yrs)	MAS (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAS (mm)
Badger	1	*BDG	101	92	182	9		943.5		943.5	9		163.2		163.2
Baie Verte	1	*BV	110	20	110	19	8	1064.7	1107.9	1077.5	19	9	369.7	375.9	371.7
Botwood	2	BOT	15	98	240	19	9	984.7	953.3	974.6	19	9	305.2	226.9	280.0
Buchans	1	*BUC	280	126	126	14	9	1071.5	1143	1099.5	14	9	256.4	336.8	287.9
Buchans A	1	*BUA	276	122	125	20		990.8		990.8	20		355.9		355.9
Comfort Cove	2	CC	99	70	248	14		1142.1		1142.1	14		407.0		407.0
Exploits Dam	1	*EXP	154	110	150	23	9	1099.0	1059.3	1087.8	23	9	321.9	277.3	309.4
Fogo	1	*FOG	15	0	265	8	8	779.1	770.7	774.9	8	8	169.6	242.5	206.1
Gander Int'l A	2	GAA	151	73	285	44		1130.1		1130.1	44		405.2		405.2
Grand Falls	2	GF	60	120	211	34	9	991.2	1071.3	1008.0	34	9	280.0	316.6	287.7
Rattling Brook	2	RB	9	101	233	22	9	1124.0	1112.1	1120.5	22	9	344.4	326.3	339.1
Springdale	1	*SPR	23	30	147	25		967.1		967.1	25		244.2		244.2
Twillingate	2	TWI	5	0	230	16		941.9		941.9	16		282.5		282.5
									Averages	1019.9					303.1
									Std. Devs	107.4					75.5

GROUP 1 Climate Station	GROUP	'PHYSIOGRAPHIC' DATA abbrev.	ELEV (m)	NE (km)	W (km)	TOTAL PRECIPITATION Years of Record 51-80 (yrs)	81-89 (yrs)	MAP (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAP (mm)	TOTAL SNOWFALL ears of Record 51-80 (yrs)	81-89 (yrs)	MAS (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAS (mm)
Badger	1	*BDG	101	92	182	9		943.5		943.5	9		163.2		163.2
Baie Verte	1	*BV	110	20	110	19	8	1064.7	1107.9	1077.5	19	9	369.7	375.9	371.7
Buchans	1	*BUC	280	126	126	14	9	1071.5	1143	1099.5	14	9	256.4	336.8	287.9
Buchans A	1	*BUA	276	122	125	20		990.8		990.8	20		355.9		355.9
Exploits Dam	1	*EXP	154	110	150	23	9	1099.0	1059.3	1087.8	23	9	321.9	277.3	309.4
Fogo	1	*FOG	15	0	265	8	8	779.1	770.7	774.9	8	8	169.6	242.5	206.1
Springdale	1	*SPR	23	30	147	25		967.1		967.1	25		244.2		244.2
									Averages	991.6					276.9
									Std. Devs	120.8					81.3

GROUP 2 Climate Station	GROUP	'PHYSIOGRAPHIC' DATA abbrev.	ELEV (m)	NE (km)	W (km)	TOTAL PRECIPITATION Years of Record 51-80 (yrs)	81-89 (yrs)	MAP (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAP (mm)	TOTAL SNOWFALL ears of Record 51-80 (yrs)	81-89 (yrs)	MAS (mm) 51-80 (mm)	81-89 (mm)	OVERALL AVERAGE MAS (mm)
Botwood	2	BOT	15	98	240	19	9	984.7	953.3	974.6	19	9	305.2	226.9	280.0
Comfort Cove	2	CC	99	70	248	14		1142.1		1142.1	14		407.0		407.0
Gander Int'l A	2	GAA	151	73	285	44		1130.1		1130.1	44		405.2		405.2
Grand Falls	2	GF	60	120	211	34	9	991.2	1071.3	1008.0	34	9	280.0	316.6	287.7
Rattling Brook	2	RB	9	101	233	22	9	1124.0	1112.1	1120.5	22	9	344.4	326.3	339.1
Twillingate	2	TWI	5	0	230	16		941.9		941.9	16		282.5		282.5
									Averages	1052.9					333.6
									Std. Devs	94.0					64.1

Table 3-2 CLIMATE STATIONS IN THE STUDY REGION WITH AVAILABLE THORNTHWAITE DATA AND A SYNOPSIS OF THE THORNTHWAITE DATA

	Years of Record	Elevation (m)	Assumed Holding Cap (mm)	Mean Annual Temp (°C)	Potential evapotrans (mm)	MAP (mm)	Storage (mm)	Actual Evapotrans (mm)	Moisture deficit (mm)	Moisture Surplus (mm)	Surplus Runoff (mm)	Snowmelt Runoff (mm)	MAR (mm)
Buchans A	20–24	276	100	2.8	497	976	479	472	25	311	311	194	504
Exploits Dam	10–14	153	100	3.3	493	1133	640	491	1	396	396	246	642
Gander Int'l A	30	146	100	4.3	531	1078	547	505	26	418	418	155	573
Grand Falls	20–24	60	100	4.6	567	981	414	532	36	310	310	140	450
Rattling Brk–	10–14	8	100	4.9	523	1167	643	502	21	478	478	187	664
Springdale	15–19	22	100	4.3	534	961	427	501	33	315	315	144	460
Twillingate	15–19	4	100	4.5	509	934	425	469	41	284	284	182	466
					Averages	1032.9		496.0					537.0
					Std. Dev.	97.5		22.7					94.7

Fig 3-2 AVERAGE TOTAL MEAN ANNUAL PRECIPITATION AND SNOWFALL AT SELECTED CLIMATE STATIONS IN THE NOTRE DAME BAY STUDY AREA

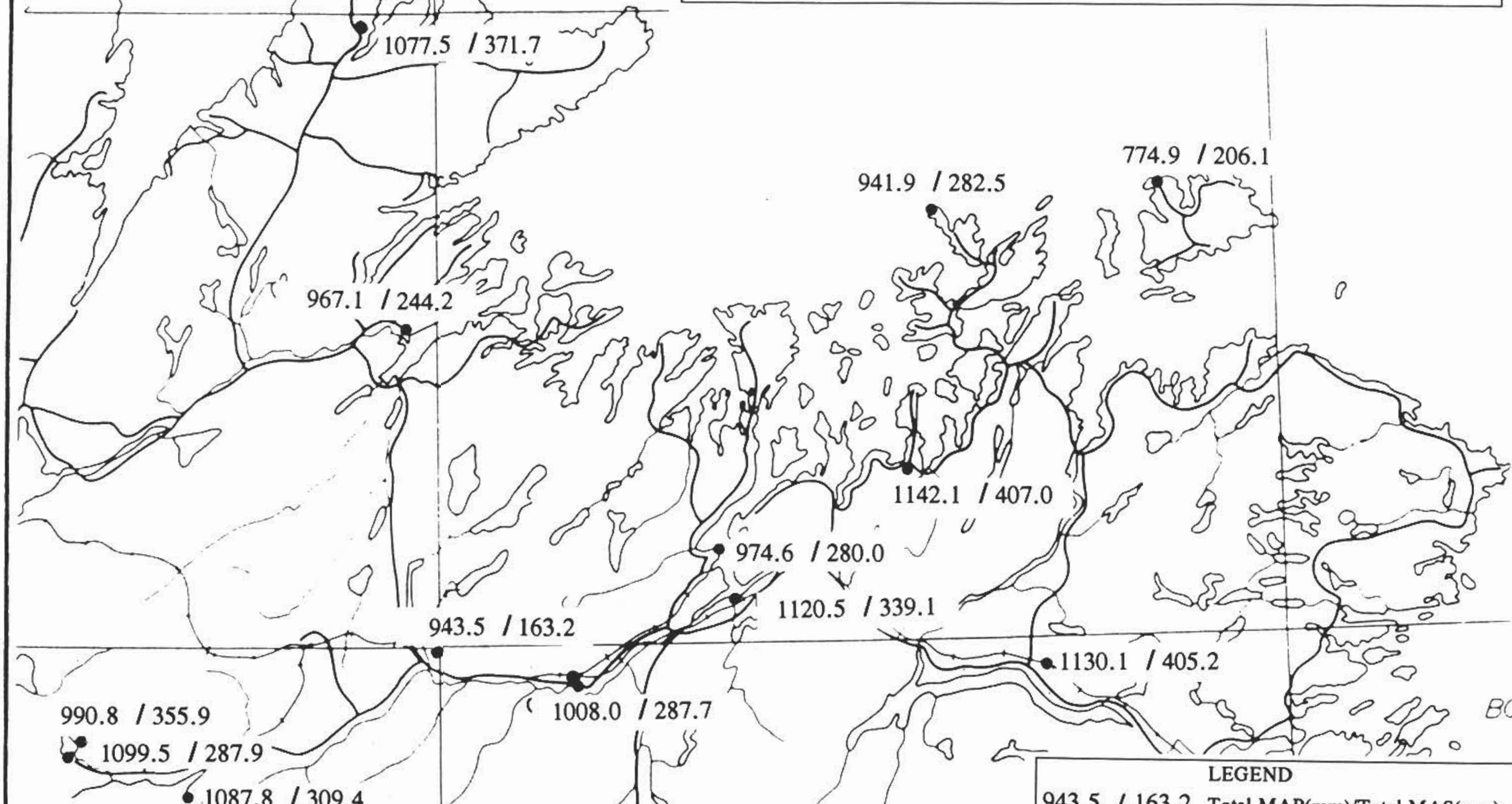

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FIG. 3-2

We attempted to correlate MAP with elevation, distance in a westerly direction from the coast, distance in a north-easterly direction from the coast, and elevation. The coast was approximated as the seaward edge of any coastal archipelago. Figure 3-3 shows graphs of both MAP and mean annual snowfall (MAS) plotted against these 'physiographic' parameters. There is no apparent correlation between total precipitation and either elevation, or distance in a north easterly direction. However, an inverse correlation exists between MAP and distance in a westerly direction (DWD) to the coast for certain areas in the Notre Dame Bay study region. This area in general lies north-west of a line projected between Twillingate and the midpoint between Badger and Grand Falls (see Figure 3-1), which approximately parallels the coastline of the Northern Peninsula. Thus, the relationship may reflect the effect of the rain shadow of the Long Range Mountains. Fogo is also included in this area even though it lies to the east of the projected line, as it seems to reflect the inferred relationship.

The selected climate stations where an inverse correlation exists between DWD and MAP have arbitrarily been designated Group 1. The Group 1 climate stations are Badger, Baie Verte, Buchans, Buchans A, Exploits Dam, Fogo and Springdale. A line of best fit for MAP vs. DWD is shown on Figure 3-3. It has a least squares regression equation of:

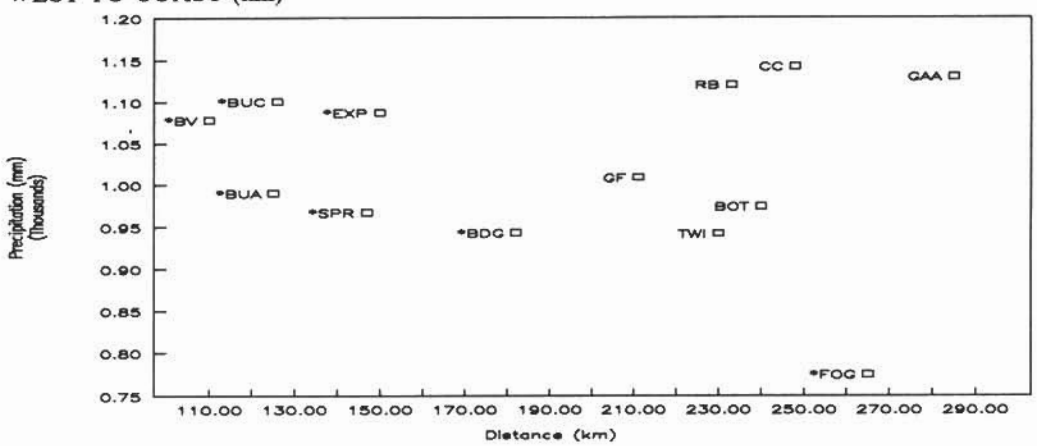
$$\text{Estimated MAP} = -1.9048 \times \text{DWD} + 1299.1 \qquad (3\text{-}1)$$

with a correlation coefficient of r = 0.90. Figure 3-4 shows the decrease in goodness of fit for mean annual snowfall compared to mean annual rainfall. The regression information for the precipitation data is included on Figure 3-4.

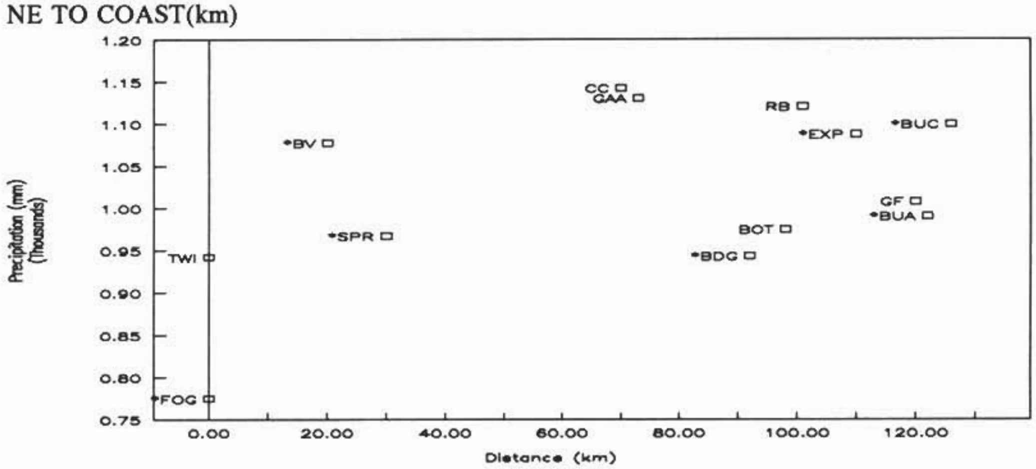
Fig. 3-3 FIGURE SHOWING PLOTS OF TOTAL MEAN ANNUAL PRECIPITATION AND TOTAL MEAN ANNUAL SNOWFALL AGAINST DISTANCE IN KM WEST TO THE COAST, NORTH EAST TO THE COAST, AND ELEVATION IN METRES.

TOTAL PRECIPITATION(mm)

WEST TO COAST (km)



NE TO COAST(km)



ELEVATION(m)

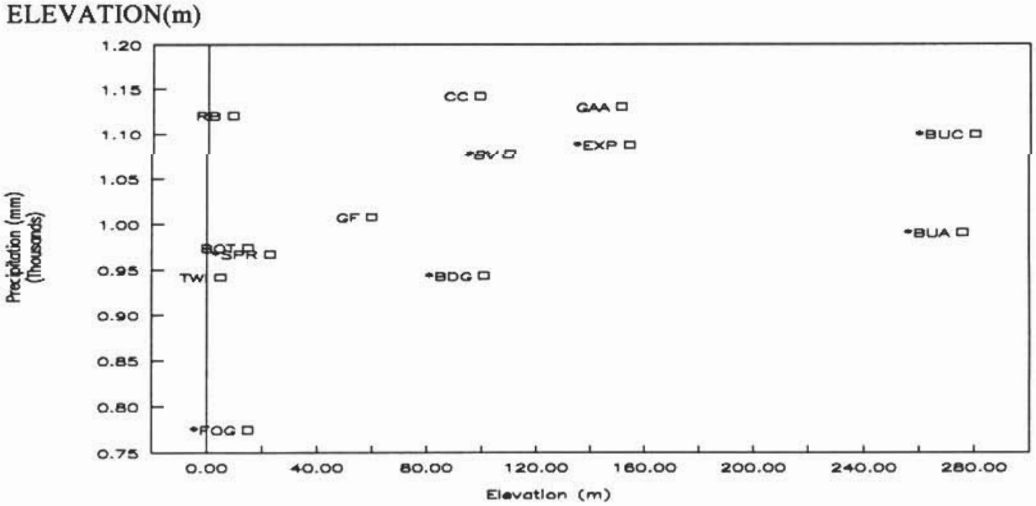
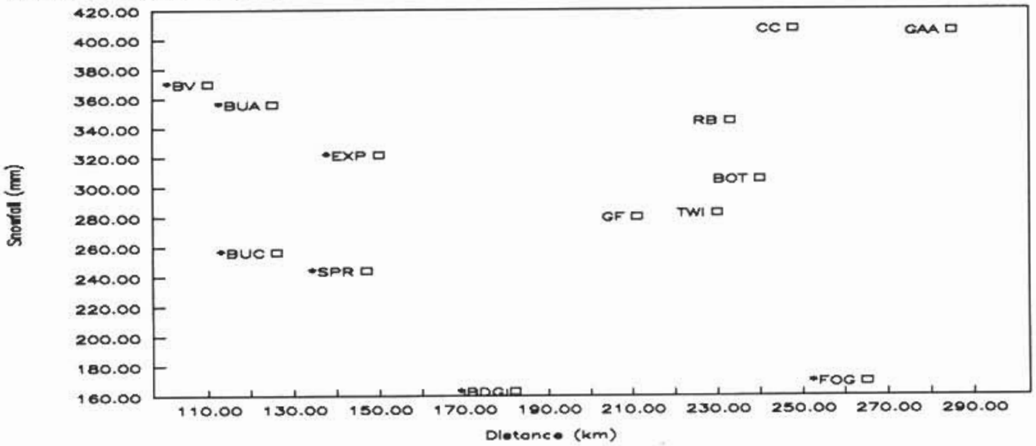


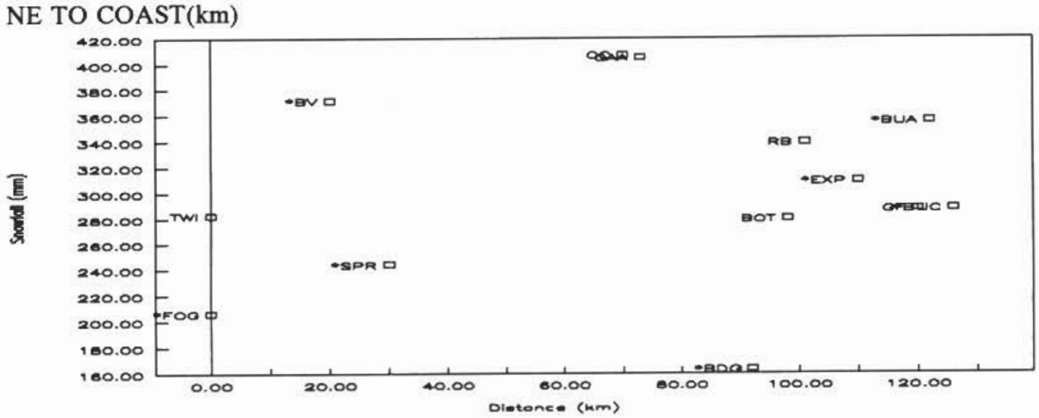
Fig. 3-3 (continued)

TOTAL SNOWFALL(mm)

WEST TO COAST (km)



NE TO COAST(km)



ELEVATION(m)

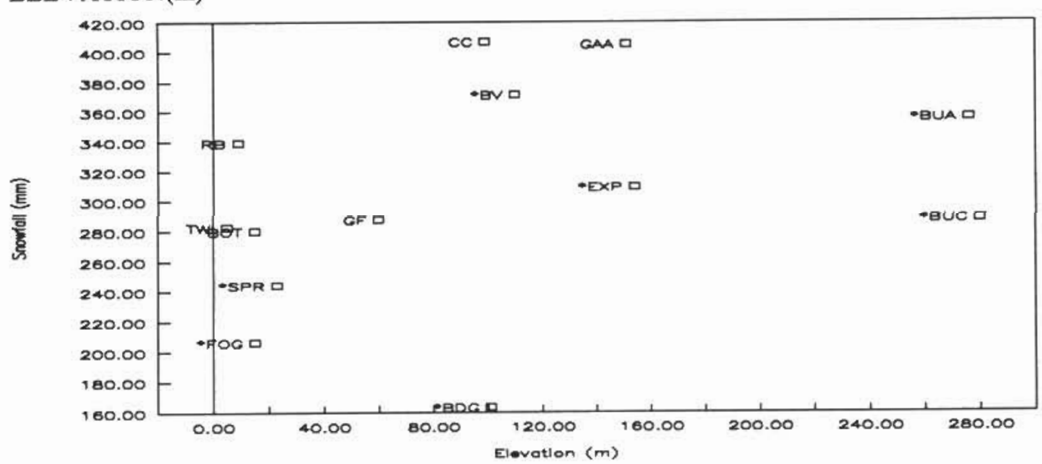
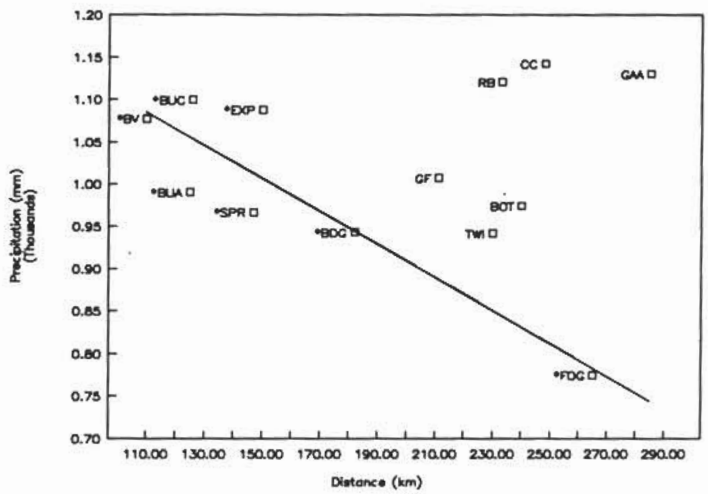


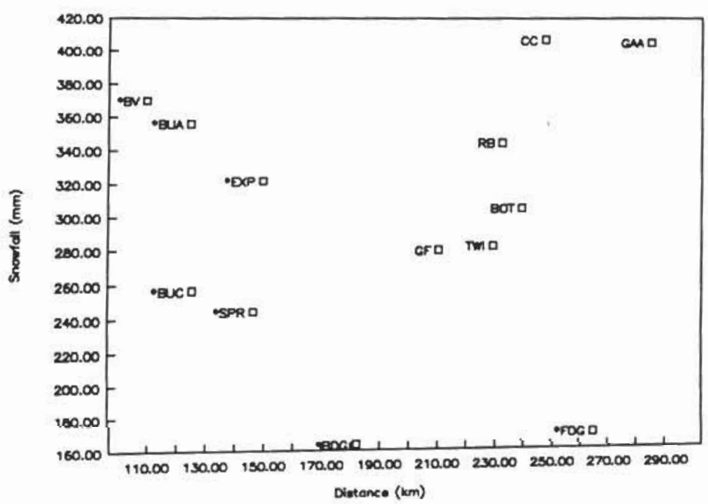
Fig. 3-4 FIGURE SHOWING CORRELATION BETWEEN TOTAL MEAN ANNUAL PRECIPITATION AND DISTANCE WEST IN KILOMETRES TO THE COAST FOR GROUP 1 CLIMATE STATIONS. NOTE LESSER CORRELATION FOR TOTAL MEAN ANNUAL SNOWFALL FOR THE SAME CLIMATE STATIONS.

TOTAL MEAN ANNUAL PRECIPITATION DATA



Regression Output:	
Constant	1299.107
Std Err of Y Est	54.86570
R Squared	0.807408
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	-1.94808
Std Err of Coef.	0.425496

TOTAL MEAN ANNUAL SNOWFALL DATA*



*Note lesser correlation of total mean annual snowfall and distance west to the coast, for the Group 1 climate stations, than between MAP and distance west to the coast.

The remaining climate stations denoted as Group 2 are Botwood, Comfort Cove, Gander International Airport, Grand Falls, Rattling Brook, and Twillingate. The Group 2 climate stations are, with the exception of Twillingate, inland. The MAP at the group 2 stations is relatively higher with an average of 1052.9 mm and a standard deviation of 94.0 mm. These stations do not have any significant correlation with 'physiographic' features. The area encompassing the Group 2 climate stations is shown on Figure 3-1. The difference in average MAP for the stations in Group 1 and Group 2 is statistically significant at the 90% confidence level, making the assumption that the standard deviations are not estimated.

3.3 Seasonal Distribution of Precipitation

Long term data, from the Environment Canada 1951-1980 and 1980-1989 records, were also used to calculate monthly mean precipitation. This was further disaggregated into monthly snowfall, rainfall and total precipitation for Baie Verte, Botwood, Buchans, Exploits Dam, Fogo, Grand Falls, and Rattling Brook. The results of these analyses are shown on Figure 3-5.

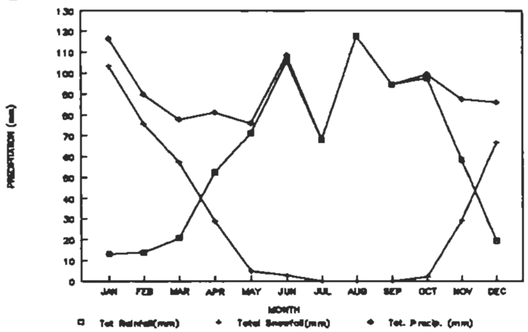
In general, the months of November to January have the greatest precipitation, usually falling as snow. The maximum precipitation of approximately 94 mm/month occurs in December; however, August is also frequently a wet month at all the selected climate stations.

3.4 Mean Annual Runoff

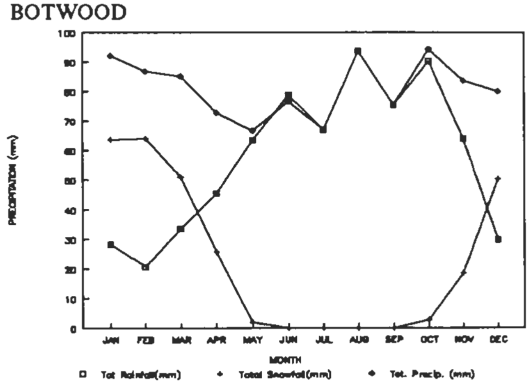
Estimates of mean annual runoff (MAR) were made, calculated as the difference between mean annual precipitation and actual mean annual evapotransipiration, for the AES stations listed in Table 3-2. This table also lists the Thornthwaite data used (1940-1971) to arrive at values of MAR at the climate stations.

Fig 3-5 MONTHLY RAINFALL, SNOWFALL AND TOTAL PRECIPITATION FOR CLIMATE STATIONS WITH LONG PERIOD OF RECORD IN THE NOTRE DAME BAY STUDY REGION

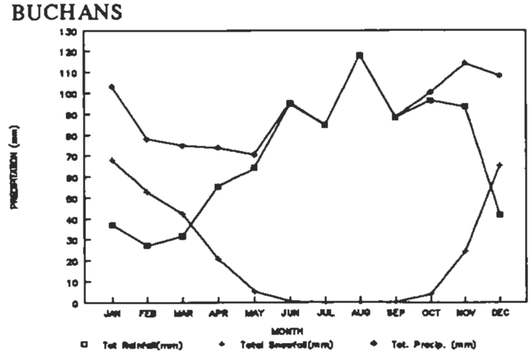
BAIE VERTE



BOTWOOD



BUCHANS



BAIE VERTE

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	25.1	14.0	26.9	33.0	69.8	83.7	68.8	101.6	94.4	89.1	73.7	28.7	708.8
Years of Record	26	26	25	27	24	27	30	30	32	29	29	29	
Total Snowfall													
Total Mean	84.1	73.6	59.6	35.7	8.1	0.8	0.0	0.0	0.0	4.1	29.7	73.9	369.7
Years of Record	26	26	25	27	24	27	30	30	32	29	29	29	
Total Precipitation													
Total Mean	108.3	85.3	81.3	68.7	71.3	88.0	68.8	101.6	94.4	100.3	104.4	102.6	1074.9
Years of Record	26	26	25	27	24	27	30	30	32	29	29	29	

BOTWOOD

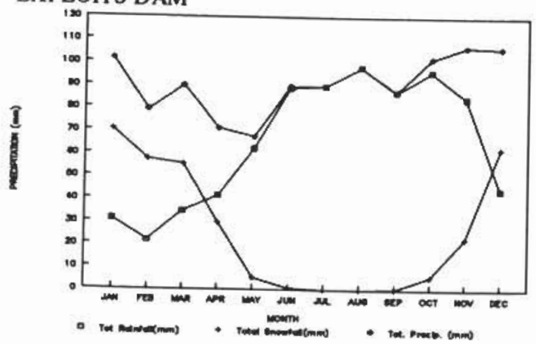
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	28.3	20.6	33.5	45.4	63.5	78.7	66.8	93.5	75.4	90.2	63.9	29.7	689.5
Years of Record	26	26	26	26	25	28	28	28	30	30	29	27	
Total Snowfall													
Total Mean	63.6	64.1	50.9	25.7	2.0	0.1	0.0	0.0	0.0	2.9	18.5	50.4	278.3
Years of Record	26	26	26	26	25	28	28	28	30	30	29	27	
Total Precipitation													
Total Mean	92.0	86.7	85.1	72.8	66.6	76.6	66.8	93.5	75.3	94.2	83.5	80.0	973.1
Years of Record	26	26	26	26	25	28	28	28	30	30	29	27	

BUCHANS

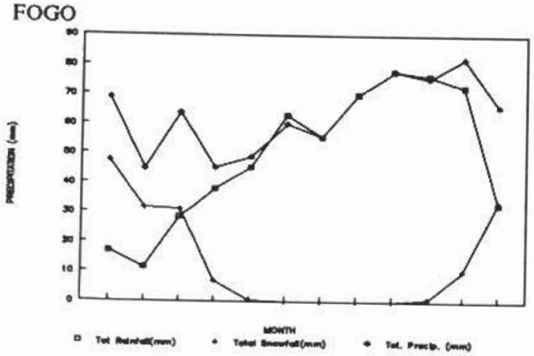
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	37.1	27.2	31.6	55.4	64.0	94.7	84.4	118.0	88.0	96.3	93.4	41.6	831.7
Years of Record	23	22	23	22	22	23	23	23	23	24	23	23	
Total Snowfall													
Total Mean	68.0	52.7	42.3	20.7	5.0	0.6	0.0	0.0	0.3	3.8	24.2	65.2	282.8
Years of Record	23	22	23	21	22	23	23	23	23	24	23	22	
Total Precipitation													
Total Mean	103.1	77.9	74.9	73.8	70.3	95.4	84.4	118.0	88.3	100.1	114.1	108.1	1108.5
Years of Record	23	22	23	21	22	23	23	23	23	24	23	22	

Fig. 3-5/cont

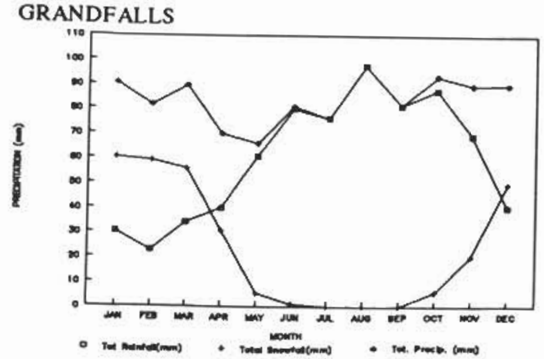
EXPLOITS DAM



FOGO



GRANDFALLS



EXPLOITS DAM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	31.0	21.8	34.6	41.5	62.2	88.8	89.6	97.9	86.9	96.0	84.4	44.1	778.8
Years of Record	33	31	33	33	32	33	33	32	33	32	33	34	
Total Snowfall													
Total Mean	70.5	57.4	55.3	29.6	5.3	0.9	0.0	0.0	0.1	5.6	22.6	62.3	309.6
Years of Record	33	31	33	33	32	33	33	32	33	32	33	34	
Total Precipitation													
Total Mean	101.5	79.2	89.9	71.1	67.5	89.6	89.6	97.9	87.1	101.8	106.9	106.3	1088.5
Years of Record	33	31	33	33	32	33	33	32	33	32	33	34	

FOGO

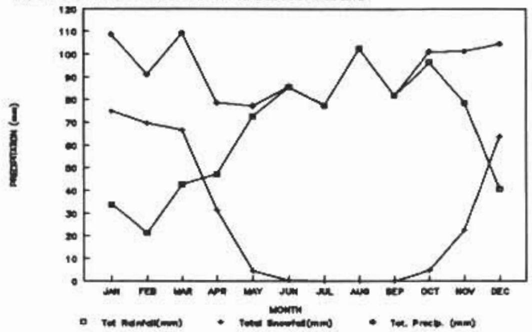
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	16.9	11.4	28.4	38.0	45.3	63.1	55.7	70.1	78.0	76.5	72.7	32.9	589.0
Years of Record	16	15	14	13	15	14	14	14	16	16	15	16	
Total Snowfall													
Total Mean	47.5	31.5	31.0	7.0	0.4	0.0	0.0	0.0	0.0	0.7	10.3	33.5	162.0
Years of Record	15	14	14	13	15	16	15	14	16	16	17	14	
Total Precipitation													
Total Mean	68.9	44.8	63.8	45.1	48.9	60.2	55.7	70.1	78.1	75.6	82.3	66.2	759.5
Years of Record	15	14	14	13	14	14	14	14	16	16	15	14	

GRANDFALLS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	30.4	22.7	33.9	39.5	60.7	80.2	76.3	97.7	81.6	87.7	69.2	40.2	720.1
Years of Record	42	41	41	44	44	44	44	45	45	45	41	42	
Total Snowfall													
Total Mean	60.5	59.2	55.8	30.4	5.2	0.8	0.0	0.0	0.0	5.8	20.6	49.7	288.0
Years of Record	42	41	41	44	44	44	44	45	45	45	41	42	
Total Precipitation													
Total Mean	90.7	81.9	89.7	69.8	65.9	81.0	76.3	97.7	81.6	93.5	89.7	89.8	1007.7
Years of Record	42	41	41	44	44	44	44	45	45	45	41	42	

Fig. 3-5/cont

RATTLING BROOK NORRIS ARM



RATTLING BROOK- NORRIS ARM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Rainfall													
Total Mean	33.7	21.4	42.8	47.2	72.8	85.5	77.5	102.5	81.9	96.5	78.7	40.7	781.2
Years of Record	30	30	30	29	31	31	31	31	31	31	31	31	
Total Snowfall													
Total Mean	75.0	69.7	66.6	31.4	4.5	0.3	0.0	0.0	0.0	4.7	22.7	63.9	338.6
Years of Record	30	30	30	29	31	31	31	31	31	31	31	31	
Total Precipitation													
Total Mean	108.7	91.0	109.4	78.7	77.3	85.8	77.5	102.5	81.9	101.3	101.4	104.6	1120.0
Years of Record	30	30	30	29	31	31	31	31	31	31	31	31	

The average regional MAR of 537 mm/year is considerably less than the 858 mm/year calculated using data from gauging stations. The difference is attributed to baseflow.

No correlation was found between MAR and 'physiographic' features; however, as MAR is controlled by MAP it is likely that the inverse correlation ascribed to Group 1 climate stations also holds true for the runoff. It was not possible to 'regionalize' the MAR, as was done for MAP, due to the paucity of sites providing Thornthwaite data.

3.5 Water Balance

Evapotranspiration estimates for seven climate stations in the study area for the period 1941-1970, which used the Thornthwaite methodology, are presented in Table 3-2.

An unweighted average MAP for these stations is 1033 mm/year, an unweighted average actual evapotranspiration (AET) estimate is 496 mm/year. Thus an imputed residual value for mean annual runoff (MAR) is 537 mm/year (range 460-664 mm). The average ratio of MAR to MAP is 52% which agrees with values given for the Northern Peninsula, Humber Valley Study by Acres (1990).

Recall from Section 2 that the characteristic MAR of the study region, from an analysis of WSC gauges, was 858 mm/year. Thus, the actual evapotranspiration (AET) can also be estimated as 175 mm by subtracting the MAR from streamgauge measurements (858 mm) from the precipitation (1033 mm). Note that the "observed" AET (175 mm) is one third (496 mm) that predicted from the Thornthwaite method. Thus the use of climate data and the Thornthwaite model to enhance the ability to predict MAR in this region does not appear promising.

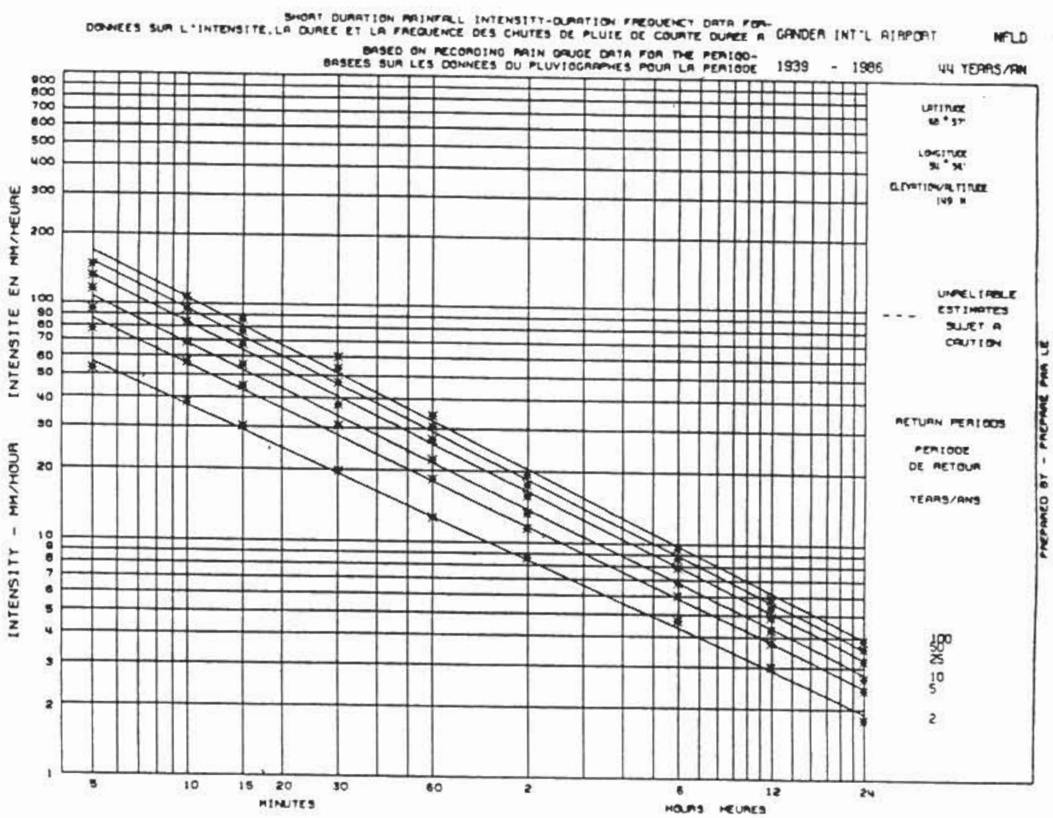
3.6 Storm Event Data

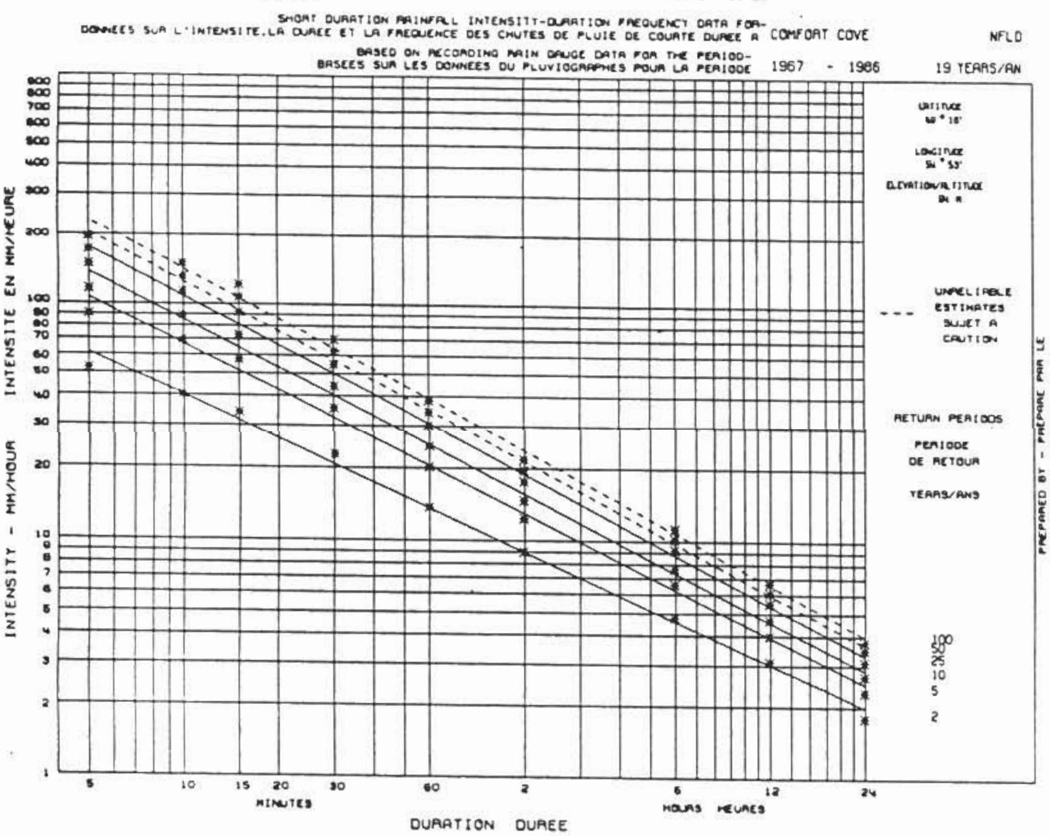
Data for storm intensity/duration were only available for two locations in the study area. Copies of the AES rainfall intensity/duration curves for Comfort Cove and Gander international Airport are provided on Figure 3-6.

3.7 Conclusions

A brief review of meteorological data for the Notre Dame Bay study region indicates there is an inverse correlation between distance to the coastline to the west and MAP for some of the region. The MAR calculated from meteorological data is considerably lower than the value calculated from gauging station information and may indicate a large component of baseflow for streams in the study region.

Fig 3-6 AVAILABLE AES RAINFALL INTENSITY CURVES FOR THE STUDY AREA





3.8 References - Section 3.0

Environment Canada, AES, 1951-1980 "Canadian Climate Normals, Temperature and Precipitation Atlantic Provinces" UDC:551.582 (715/9)

Environment Canada, 1981-1989 "Canadian Climate Normals Temperature and Precipitation" (supplied on magnetic media).

SECTION 4.0

WATER QUALITY

4.0 WATER QUALITY

The general health of a drainage basin can be characterized by studying the quality of its water, sediment, and biota.

4.1 Available Data

Large amounts of water quality data are available, mainly from NAQUADAT (National Water Quality Data Base). A variety of sites have been identified for the NAQUADAT data base. Water samples are taken and analyzed on a regular basis at these sites. Some sites are also identified for sampling and analysis of bottom sediments and biota (generally fish). Many of the toxic metals and some organic contaminants have a tendency to concentrate in bottom sediments, particularly clays. Both toxic chemicals and, to some extent, toxic heavy metals may also become concentrated through the food chain with higher members of the chain usually having the highest concentration of a contaminant (if present).

In addition to available NAQUADAT data, two water quality studies have been conducted which contain information relevant to the Notre Dame Bay study region:

a) "Exploits River Survey Report", 1987-1988

b) "Atlantic Region Federal-Provincial Toxic Chemical 1985-1988", Survey of Municipal Drinking Water Sources, Environment Canada (undated).

The Exploits River Survey was performed using existing NAQUADAT sites (and ones identified for the study); however, the toxic chemical survey required separate sampling and analyses.

The most recent unpublished data available, pertaining to groundwater quality in the Notre Dame Bay study region, were obtained from the Groundwater Section of the Newfoundland Water Resources Division. Water quality data published in the Water Resources Groundwater Series reports, identified in Section 5, were not used, as the quality of the analyses was generally poor with very high charge balance errors.

Sampling and analytical procedures will not be discussed here. Interested readers should refer to either Environment Canada et al. 1988 or "Analytical Methods Manual", Environment Canada, 1979.

4.2 Overall Water Quality

The surface and groundwater quality of the Notre Dame Bay region will be briefly reviewed using selected data from NAQUADAT sites and from analyses of well water samples. The NAQUADAT sites which have been established in the Notre Dame Bay region are shown in Table 4-1. Of the many NAQUADAT sampling sites listed, only nine sites were used, as many of the sites identified have only been sampled on one or two occasions. The sites reviewed are identified in Table 4-1.

4.3 Surface Water Quality

A synopsis of the ranges of water quality parameter values for both surface and groundwater in the study region is given in Table 4-2. For reference, Canadian Water Quality Guidelines (the CWQG) values are also shown for parameters in the categories of Drinking Water, Aquatic Life, Irrigation, and Livestock Watering. Note that many of the elements/parameters evaluated for NAQUADAT still do not have any guidelines for

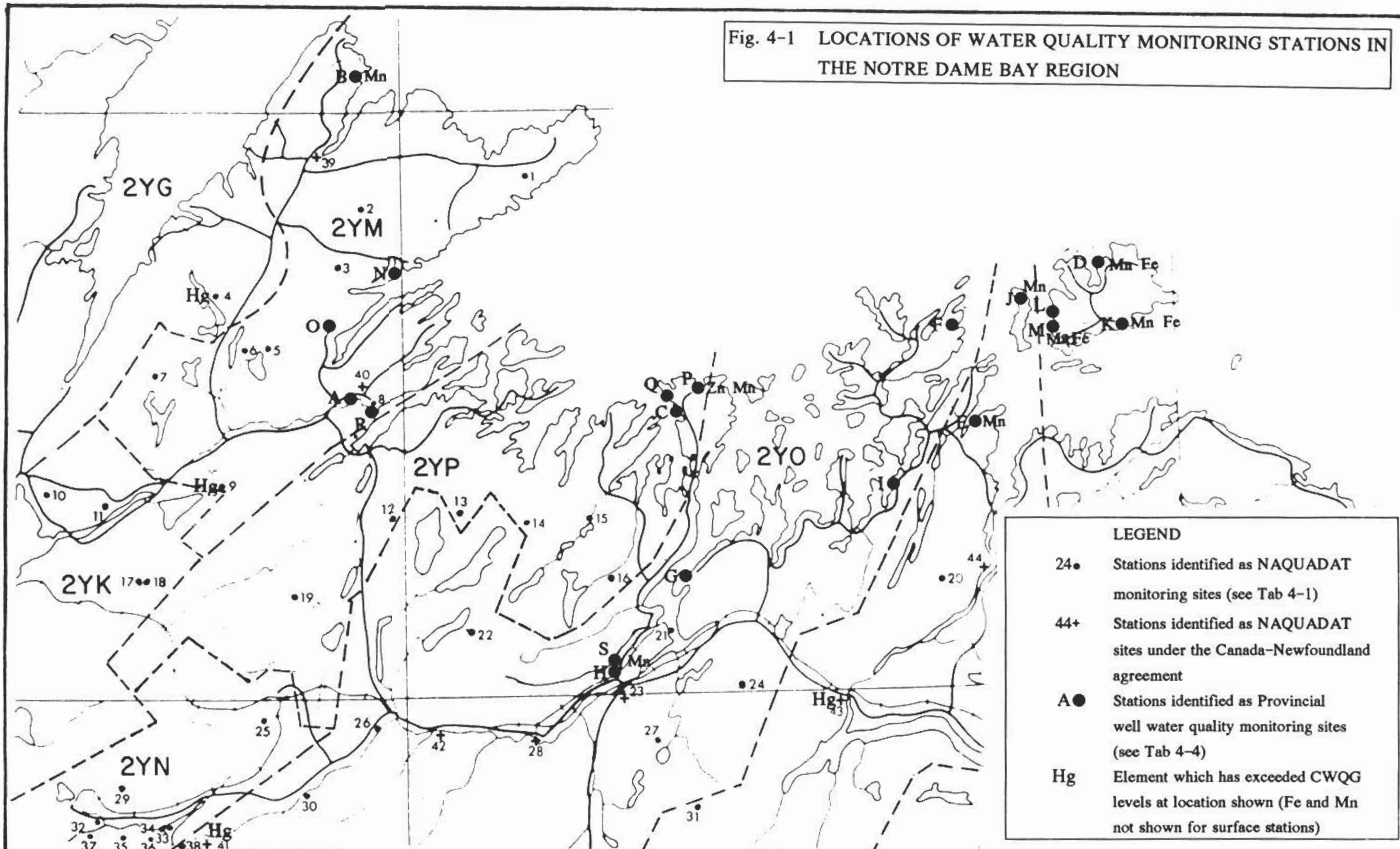
Table 4-1 NAQUADAT STATIONS IDENTIFIED ON FIGURE 4.1

Site No.	NAQUADAT loc	Site No.	NAQUADAT loc
1	01NF02YM0002	24	01NF02YO0004
2	01NF02YM0007	25	01NF02YO0010
3	01NF02YM0006	26	00NF02YO0015
4	01NF02YG0001	27	01NF02YO0007
5	01NFO2YM0008	28	00NF02YO0001
6	01NF02YM0005	29	01NF02YN0010
7	01NF02YM0003	30	00NF02YO0005
8	00NF02YM0001	31	01NF02YQOO12
9	01NF02YM0004	32	00NF02YN0005
10	01NF02YK0001	33	51NF02YN0024
11	01NF02YK0013	34	01NF02YN0023
12	01NF02YP0005	35	51NF02YN0021
13	01NF02YO0002	36	51NF02YN0022
14	01NF02YP0008	37	01NF02YN0020
15	01NF02YP0003	38	00NF02YO0014
16	01NF02YP0004	40	00NF02YM0001
17	01NF02YK0009	41	00NF02YO0019
18	01NF02YK0004	42	00NF02YO0020
19	01NF02YP0007	43°	00NF02YQ0004
20	01NF02YQ0001	43°	00NF02YQ0030
21	53NF02YO0002	44	00NF02YQ0005
22	01NF02YO0003	45	00NF02YR0001
23	00NF02YO0017		

° Two NAQUADAT sites at same location

Indicates information from site used in water quality study.

Fig. 4-1 LOCATIONS OF WATER QUALITY MONITORING STATIONS IN THE NOTRE DAME BAY REGION



DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA
CENTRAL NEWFOUNDLAND REGION

WATER QUALITY SAMPLING STATIONS IN STUDY AREA

FIG 4-1

Tab 4-2 OBSERVED RANGES OF WATER QUALITY PARAMETERS AT SELECTED WATER QUALITY STATIONS IN THE NOTRE DAME BAY REGION.

Water quality Parameter	RANGES OF VALUES observed at selected NAQUADAT locations From	To	observed at Provincial well quality stations From	To	CWQG Concentration Levels Drinking water	Aquatic Life	Irrigation	Livestock
Temp °C	0.000	- 23.700			15			
Oxygen	4.300	- 15.000						
Field pH	4.800	- 7.900	5.19 -	8.91	6.5-8.5			
Total Alk	0.000	- 18.700	0.3 -	275				
Conductivity µS	1.700	- 349	<55.4 -	804				
Turbidity NTU	0.080	- 4.800			5			
Colour TCU	0.000	- 200	0 -	140	15			
Sodium	0.000	- 52.800	1.98 -	120				
Calcium	0.000	- 11.700	3 -	88				1000
Magnesium	0.000	- 2.500	0.76 -	31				
Potassium	0.000	- 0.690	0.27 -	9.9				
Chloride	0.000	- 92.200	0 -	160	250		100-700	
Sulphate	0.000	- 9.800	1.9 -	44	500			1000
Flouride	0.000	- 0.000	0.00 -	0.46	1.5		1	2
DOC	0.000	- 20.300						
Phosphorous	0.000	- 0.030						
Nitrogen	0.100	- 0.640	0.004 -	1.2	10			100
Nitrate	0.000	- 0.230			10			
Silicate	0.000	- 7.200						
Aluminum	0.030	- 0.990				0.005-0.1	5	5
Barium	0.001	- 0.440			1			
Beryllium	0.000	- 0.060					0.1	0.1
Cadmium	0.000	- 0.001			0.005	0.002	0.01	0.02
Chromium	0.000	- 0.003			0.05	0.002	0.1	1
Cobalt	0.000	- 0.001					0.05	1
Copper	0.000	- 0.010			1	0.002	0.2	0.5
Iron	0.020	- 1.250	0 -	3.16	0.3	0.3	5	
Lead	0.000	- 0.090			0.05	0.001	0.2	0.1
Lithium	0.060	- 0.710					2.5	
Manganese	0.002	- 0.340	0 -	1.74	0.05		0.2	
Mercury	0.000	- 0.150			0.001	0.001		0.003
Molybdenum	0.000	- 0.001					0.01	0.5
Nickel	0.000	- 0.002				0.0025	0.2	1
Strontium	0.004	- 0.030						
Vanadium	0.000	- 0.002					0.1	0.1
Zinc	0.000	- 0.120	0 -	5.7	5	0.03	1	50

All concentrations are in mg/L

Other units as indicated

In instances where toxicity levels are affected by other factors (i.e. pH levels) the figure quoted is the lowest concentration in a range acceptable concentration levels in water. Research is ongoing in this area (see Inland Waters Directorate, 1990). A brief overview of surface water quality parameter values of interest is given below. Table 4-3 shows in more detail the ranges of parameter values at the NAQUADAT locations reviewed.

<u>Physical Parameters</u> Of the physical parameters recorded at NAQUADAT sites, colour frequently exceeded the 15 TCU (True Colour Unit) level recommended in the CWQG with levels in excess of 200 TCU. Turbidity was generally not a problem in the study region.

<u>Acidity</u> The surface waters of the study region are generally neutral to acidic with pH levels as low as 4.8, well outside the pH range of 6.5 to 8.5 recommended in the CWQG. As increased acidity is a factor in the mobility of metals such as aluminum, cadmium, uranium, and many of the other toxic heavy metals, low pH values are a cause for concern. Areas with low pH waters should be closely monitored for water quality.

<u>Anions</u> The waters of the Notre Dame Bay study region typically have very low anion concentrations. The levels of chloride, nitrate, phosphate, sulphate, and fluoride at the NAQUADAT study sites are well below the maximum acceptable concentration level (MACL) specified for drinking water in the *CWQG. Any elevated concentrations* that have been observed such as is in the Exploits River, are of anthropogenic origin.

<u>Cations</u> Most cation concentrations are below the MACL specified in the CWQG. However, concentrations of some of the cations which should be closely monitored are highlighted below.

<u>Aluminium</u> At low pH levels, aluminum is more mobile and more of a threat to aquatic life. The range of

concentrations recommended for survival of aquatic life is 0.005 to 0.1 mg/L, depending on pH (lower pH - lower recommended MACL). Some sites, usually with low pH, have reported levels of aluminium higher than are recommended for survival of aquatic life.

<u>Iron and Manganese</u> Guidelines for concentrations of iron and manganese in drinking water are specified for aesthetic reasons. Concentrations of both iron and manganese frequently exceed the MACL listed in the CWQG at the selected NAQUADAT sites and are highlighted in Table 4-3.

<u>Mercury</u> Mercury is a highly toxic heavy metal with an MACL of 0.001 mg/L. Of the nine NAQUADAT locations studied, five had reported mercury levels exceeding the MACL (though these were generally infrequent occurrences). However, due to the toxicity of mercury, sites that have reported high mercury levels should be closely monitored. Sites that reported mercury levels exceeding the CWQG are identified on Figure 4-1 and in Table 4-3.

<u>Lead</u> One NAQUADAT site has reported a lead level exceeding the MACL of 0.05 mg/L and is identified on Figure 4-1 and in Table 4-3.

Because of the paucity of long term water quality sampling sites, it is difficult to subdivide the Notre Dame Bay Region into water quality areas, or to make inferences about the relationship between water quality and geology or location.

Table 4-3 SYNOPSIS OF VALUES OF WATER QUALITY PARAMETERS AT SELECTED NAQUADAT WATER QUALITY STATIONS IN THE NOTRE DAME BAY REGION.

NAQUADAT Station		Temp	O	Ph°	Alk	Cond	Turb	Colour	Na	Ca	Mg	K	Cl	SO4	F	DOC	PO4	N(diss)
00NF02YG0001	#Analys:	43.000	42.000	42.000	27.000	43.000	43.000	43.00	43.000	43.000	43.000	43.000	43.000	43.000	1.000	43.000	36.000	41.000
Loc.4	Max:	21.500	14.800	7.000	5.300	43.750	1.300	120.00	4.380	2.100	0.850	0.440	8.250	3.700	0.000	13.700	0.010	0.330
Sample period	Min:	0.000	8.200	4.800	0.000	15.400	0.140	20.00	1.550	0.600	0.290	0.180	1.880	1.650	0.000	2.500	0.003	0.100
08/05/86	Avg:	7.214	12.088	5.967	2.178	26.073	0.377	60.47	2.602	1.287	0.562	0.276	3.981	2.697	0.000	7.328	0.007	0.169
09/01/89	Std(ub):	8.023	2.311	0.463	1.274	4.867	0.237	23.03	0.452	0.307	0.126	0.056	0.990	0.572	0.000	2.675	0.003	0.048
00NF02YM0001	#Analys:	16.000	0.000	20.000	23.000	24.000	24.000	24.00	24.000	24.000	24.000	24.000	24.000	24.000	21.000	24.000	22.000	0.000
Loc.8	Max:	22.000	ERR	7.400	18.700	68.000	4.700	70.00	5.800	6.300	1.860	0.690	9.300	3.400	0.000	8.700	0.010	ERR
Sample period	Min:	0.000	ERR	5.500	1.900	1.700	0.200	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ERR
10/27/86	Avg:	7.406	ERR	6.383	11.026	45.779	0.650	36.25	2.971	3.679	1.323	0.270	5.138	2.114	0.000	5.104	0.002	ERR
06/28/89	Std(ub):	8.444	ERR	0.680	4.045	13.187	0.909	20.13	1.039	1.382	0.435	0.144	1.881	0.616	0.000	2.026	0.002	ERR
00NF02YM0003	#Analys:	35.000	34.000	35.000	35.000	35.000	35.000	35.00	35.000	35.000	35.000	35.000	35.000	35.000	1.000	35.000	29.000	33.000
Loc.7	Max:	23.700	13.700	7.900	16.800	56.050	1.800	70.00	3.040	5.400	1.700	0.320	5.580	2.740	0.000	8.900	0.010	0.270
Sample period	Min:	0.100	8.200	6.500	4.800	26.850	0.140	10.00	1.800	1.900	0.960	0.160	2.520	1.510	0.000	2.900	0.002	0.110
08/11/86	Avg:	6.940	11.506	6.949	9.883	38.457	0.352	40.86	2.351	3.431	1.343	0.231	3.748	2.280	0.000	6.077	0.005	0.202
12/01/88	Std(ub):	7.837	1.699	0.292	3.033	7.184	0.310	14.83	0.294	0.865	0.198	0.036	0.735	0.299	0.000	1.519	0.003	0.039
00NF02YM0004	#Analys:	46.000	46.000	46.000	41.000	46.000	46.000	46.00	46.000	46.000	46.000	46.000	45.000	46.000	1.000	46.000	44.000	44.000
Loc.9	Max:	22.700	14.800	7.800	15.600	349.40	1.300	200.00	52.800	11.700	2.500	0.680	92.200	5.600	0.000	20.300	0.020	0.640
Sample period	Min:	0.100	4.300	5.700	1.100	27.450	0.100	5.00	3.000	1.800	0.600	0.190	4.660	1.440	0.000	4.600	0.010	0.110
08/11/86	Avg:	6.648	12.121	6.543	7.537	75.463	0.414	96.63	8.964	4.467	1.176	0.390	15.170	3.628	0.000	13.328	0.011	0.313
09/12/89	Std(ub):	7.394	2.453	0.475	3.954	52.279	0.278	37.48	7.853	1.845	0.398	0.113	14.048	0.815	0.000	3.472	0.003	0.123
00NF02YO0001	#Analys:	6.000	0.000	7.000	25.000	26.000	26.000	26.00	26.000	26.000	26.000	26.000	26.000	26.000	26.000	26.000	25.000	0.000
Loc.28	Max:	10.000	ERR	7.300	10.400	44.000	4.800	70.00	3.700	4.700	1.100	0.430	3.100	9.800	0.000	7.700	0.030	ERR
Sample period	Min:	0.500	ERR	6.150	3.400	18.000	0.500	10.00	0.600	2.100	0.370	0.000	0.800	1.250	0.000	2.200	0.002	ERR
09/10/87	Avg:	3.750	ERR	6.636	5.228	29.115	1.188	29.23	1.781	2.731	0.526	0.201	2.196	3.284	0.000	4.692	0.008	ERR
09/27/89	Std(ub):	5.160	ERR	0.482	1.445	5.352	0.942	12.53	0.582	0.493	0.133	0.068	0.429	1.758	0.000	1.129	0.006	ERR
00NF02YO0019	#Analys:	37.000	37.000	37.000	36.000	37.000	37.000	37.00	37.000	37.000	37.000	37.000	37.000	37.000	1.000	36.000	29.000	35.000
Loc.41	Max:	17.400	14.200	7.500	5.700	28.950	1.500	30.00	1.640	3.330	0.560	0.280	2.540	3.630	0.000	6.900	0.020	0.420
Sample period	Min:	0.100	9.400	6.400	3.500	21.500	0.120	0.00	1.390	2.300	0.390	0.140	1.880	2.110	0.000	3.200	0.002	0.130
08/11/86	Avg:	5.746	12.180	6.704	4.281	24.661	0.399	19.86	1.478	2.538	0.421	0.172	2.070	2.651	0.000	4.031	0.004	0.200
04/06/89	Std(ub):	5.811	1.479	0.206	0.574	1.544	0.377	5.91	0.057	0.206	0.032	0.021	0.127	0.278	0.000	0.670	0.004	0.046
00NF02YO0020	#Analys:	44.000	39.000	44.000	44.000	44.000	44.000	44.00	44.000	44.000	44.000	44.000	44.000	44.000	1.000	44.000	37.000	42.000
Loc.42	Max:	22.500	15.100	7.500	6.400	32.000	1.900	50.00	2.240	2.800	0.630	0.250	3.460	3.590	0.000	7.000	0.010	0.280
Sample period	Min:	0.100	4.300	6.300	2.500	20.350	0.130	0.00	1.180	1.350	0.270	0.130	1.710	1.550	0.000	1.800	0.002	0.130
08/11/86	Avg:	6.661	11.564	6.663	4.145	25.065	0.420	24.43	1.672	2.310	0.439	0.190	2.362	2.383	0.000	4.714	0.005	0.196
09/13/89	Std(ub):	7.254	2.173	0.251	0.841	2.324	0.332	12.20	0.227	0.330	0.056	0.025	0.410	0.383	0.000	1.174	0.003	0.036
00NF02YQ0004	#Analys:	27.000	27.000	27.000	27.000	27.000	27.000	27.00	27.000	27.000	27.000	27.000	27.000	27.000	1.000	27.000	24.000	25.000
Loc.43	Max:	19.700	13.660	6.800	3.700	24.750	1.500	60.00	2.220	1.790	0.650	0.330	3.270	2.510	0.000	7.400	0.020	0.270
Sample period	Min:	1.000	9.800	6.200	1.700	18.650	0.080	10.00	1.230	1.200	0.340	0.140	1.740	1.520	0.000	3.200	0.003	0.170
08/12/86	Avg:	6.063	12.218	6.420	2.556	22.024	0.409	41.30	1.818	1.362	0.606	0.266	2.567	1.902	0.000	5.837	0.006	0.233
06/12/89	Std(ub):	6.032	1.188	0.174	0.442	1.633	0.344	10.33	0.165	0.110	0.062	0.033	0.284	0.220	0.000	0.821	0.004	0.025
00NF02YQ0005	#Analys:	26.000	25.000	26.000	26.000	26.000	26.000	26.00	26.000	26.000	26.000	26.000	26.000	26.000	1.000	26.000	20.000	24.000
Loc.44	Max:	20.400	13.600	7.400	4.700	26.450	1.500	50.00	2.220	1.650	0.780	0.300	3.710	2.750	0.000	7.400	0.010	0.280
Sample period	Min:	0.100	8.400	6.200	2.000	19.850	0.090	20.00	1.800	1.200	0.640	0.240	2.420	1.580	0.000	4.800	0.003	0.150
08/13/86	Avg:	8.754	11.363	6.585	3.342	23.913	0.447	39.62	1.988	1.494	0.713	0.263	2.887	1.957	0.000	6.054	0.006	0.225
08/07/89	Std(ub):	7.921	1.895	0.316	0.606	1.624	0.446	7.33	0.110	0.098	0.045	0.015	0.298	0.293	0.000	0.504	0.003	0.044
TOTALS	Max:	23.700	15.100	7.900	18.700	349.40	4.800	200.00	52.800	11.700	2.500	0.690	92.200	9.800	0.000	20.300	0.030	0.640
	Min:	0.000	4.300	4.800	0.000	1.700	0.080	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100

#Analys: Number of available analyses
Max: Maximum value of available analyses
Min: Minimum value of available analyses
Avg: Average value of available analyses
Std(ub): Standard deviation (unbiased) of available analyses
Loc: Number of location shown on Fig 4-1
pH°: Field pH measurement
ERR: Insufficient or no data

Table 4-3 (continued)

N/NO2/ NO3	Si	Al	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Mo	Ni	Ra	Sr	Va	Zn
24.000	28.000	45.000	41.000	44.000	43.000	39.000	40.000	38.000	45.000	38.000	36.000	41.000	21.000	42.000	41.000	0.000	45.000	37.000	37.000
0.100	4.160	0.980	0.010	0.000	0.000	0.002	0.001	0.002	0.600	0.002	0.001	0.050	0.030	0.000	0.001	ERR	0.010	0.001	0.004
0.000	0.130	0.040	0.003	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.002	0.000	0.000	0.000	ERR	0.004	0.000	0.000
0.027	2.472	0.212	0.007	0.000	0.000	0.000	0.000	0.001	0.309	0.000	0.000	0.013	0.002	0.000	0.000	ERR	0.010	0.000	0.002
0.025	1.266	0.139	0.003	0.000	0.000	0.000	0.000	0.001	0.114	0.000	0.000	0.010	0.007	0.000	0.000	ERR	0.002	0.000	0.001
24.000	16.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.000	0.000	0.000	0.000
0.180	7.200	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.050	ERR	ERR	ERR
0.000	0.000	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.000	ERR	ERR	ERR
0.048	4.456	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.020	ERR	ERR	ERR
0.049	1.477	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.029	ERR	ERR	ERR
24.000	22.000	34.000	29.000	34.000	33.000	30.000	33.000	29.000	34.000	30.000	27.000	33.000	11.000	31.000	28.000	0.000	34.000	29.000	29.000
0.140	5.310	0.220	0.010	0.050	0.000	0.001	0.000	0.004	0.340	0.001	0.001	0.040	0.000	0.000	0.002	ERR	0.020	0.001	0.005
0.000	1.220	0.030	0.004	0.000	0.000	0.000	0.000	0.000	0.030	0.000	0.000	0.004	0.000	0.000	0.001	ERR	0.010	0.000	0.000
0.052	4.170	0.108	0.006	0.001	0.000	0.000	0.000	0.001	0.146	0.000	0.000	0.011	0.000	0.000	0.002	ERR	0.012	0.000	0.001
0.036	0.878	0.043	0.002	0.009	0.000	0.000	0.000	0.001	0.060	0.000	0.000	0.007	0.000	0.000	0.000	ERR	0.004	0.000	0.001
24.000	33.000	45.000	43.000	45.000	43.000	38.000	39.000	37.000	45.000	38.000	36.000	45.000	22.000	41.000	38.000	0.000	45.000	37.000	37.000
0.250	5.620	0.380	0.010	0.000	0.000	0.002	0.001	0.010	0.480	0.001	0.001	0.110	0.020	0.001	0.002	ERR	0.030	0.001	0.005
0.010	0.890	0.040	0.004	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.010	0.000	0.000	0.000	ERR	0.010	0.000	0.000
0.081	2.931	0.265	0.008	0.000	0.000	0.001	0.000	0.002	0.267	0.000	0.000	0.029	0.001	0.000	0.001	ERR	0.016	0.000	0.001
0.066	1.433	0.098	0.003	0.000	0.000	0.000	0.000	0.002	0.110	0.000	0.000	0.024	0.005	0.000	0.000	ERR	0.006	0.000	0.001
26.000	22.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.000	0.000	0.000	0.000
0.180	3.200	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.090	ERR	ERR	ERR
0.000	1.600	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.000	ERR	ERR	ERR
0.054	2.477	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.025	ERR	ERR	ERR
0.053	0.488	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.042	ERR	ERR	ERR
21.000	24.000	36.000	36.000	36.000	28.000	34.000	35.000	28.000	36.000	35.000	30.000	36.000	15.000	34.000	34.000	0.000	36.000	30.000	36.000
0.300	2.620	0.290	0.250	0.000	0.000	0.001	0.000	0.010	0.370	0.020	0.000	0.060	0.010	0.000	0.000	ERR	0.010	0.001	0.050
0.010	2.170	0.050	0.020	0.000	0.000	0.000	0.000	0.002	0.030	0.002	0.000	0.010	0.000	0.000	0.000	ERR	0.010	0.000	0.010
0.090	2.380	0.082	0.083	0.000	0.000	0.000	0.000	0.006	0.072	0.009	0.000	0.016	0.001	0.000	0.000	ERR	0.010	0.000	0.039
0.054	0.113	0.045	0.036	0.000	0.000	0.000	0.000	0.003	0.066	0.003	0.000	0.010	0.003	0.000	0.000	ERR	ERR	0.000	0.007
22.000	31.000	43.000	43.000	43.000	40.000	40.000	41.000	37.000	43.000	36.000	36.000	43.000	22.000	41.000	39.000	0.000	43.000	39.000	43.000
0.110	3.200	0.990	0.440	0.060	0.001	0.003	0.001	0.010	1.250	0.090	0.001	0.340	0.000	0.000	0.001	ERR	0.010	0.002	0.120
0.010	1.640	0.050	0.010	0.000	0.000	0.000	0.000	0.001	0.040	0.001	0.000	0.010	0.000	0.000	0.000	ERR	0.010	0.000	0.010
0.070	2.418	0.127	0.060	0.003	0.000	0.000	0.000	0.004	0.163	0.008	0.000	0.027	0.000	0.000	0.000	ERR	0.010	0.000	0.028
0.027	0.312	0.160	0.065	0.012	0.000	0.001	0.000	0.003	0.233	0.015	0.000	0.053	0.000	0.000	0.000	ERR	ERR	0.000	0.017
15.000	19.000	26.000	22.000	26.000	26.000	24.000	25.000	22.000	26.000	24.000	21.000	26.000	12.000	25.000	22.000	0.000	26.000	22.000	22.000
0.130	2.450	0.190	0.002	0.000	0.000	0.003	0.001	0.003	0.280	0.001	0.001	0.100	0.010	0.000	0.001	ERR	0.010	0.000	0.002
0.000	1.900	0.100	0.001	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.000	0.003	0.000	0.000	0.000	ERR	0.010	0.000	0.000
0.079	2.277	0.117	0.002	0.000	0.000	0.000	0.000	0.001	0.092	0.000	0.000	0.016	0.001	0.000	0.000	ERR	0.010	0.000	0.001
0.041	0.163	0.026	0.000	0.000	0.000	0.001	0.000	0.001	0.068	0.000	0.000	0.020	0.003	0.000	0.000	ERR	ERR	0.000	0.001
13.000	20.000	25.000	19.000	25.000	23.000	23.000	22.000	19.000	25.000	22.000	18.000	25.000	13.000	24.000	19.000	0.000	25.000	23.000	19.000
0.120	2.500	0.980	0.004	0.000	0.000	0.002	0.000	0.003	0.980	0.001	0.001	0.130	0.150	0.000	0.001	ERR	0.010	0.000	0.003
0.010	0.450	0.070	0.001	0.000	0.000	0.000	0.000	0.000	0.060	0.000	0.000	0.005	0.000	0.000	0.000	ERR	0.010	0.000	0.000
0.070	1.800	0.153	0.002	0.000	0.000	0.000	0.000	0.001	0.160	0.000	0.000	0.026	0.012	0.000	0.001	ERR	0.010	0.000	0.001
0.044	0.736	0.183	0.001	0.000	0.000	0.000	0.000	0.001	0.212	0.000	0.000	0.036	0.043	0.000	0.000	ERR	ERR	0.000	0.001
0.300	7.200	0.990	0.440	0.060	0.001	0.003	0.001	0.010	1.250	0.090	0.001	0.340	0.150	0.001	0.002	0.090	0.030	0.002	0.120
0.000	0.000	0.030	0.001	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.004	0.000	0.000

(shaded) water quality parameters which are outside CWQG ranges specified for drinking water

The Baie Verte Peninsula has two sites (Locations 4 and 9 on Figure 4-1) where high levels of mercury have been recorded; but a site lying between the two has reported no mercury contamination at all. The relationship between water quality, geology, and anthropogenic activity is worthy of further study.

4.4 Groundwater Quality

Analyses of water well samples were supplied by Newfoundland Department of Environment and Lands. The locations of sites used for sampling water wells are shown on Figure 4-1. The range of parameter values for groundwater samples is shown in Table 4-2. Table 4-4 details the water analyses used for this review. The parameters of interest are reviewed below. A review of problems reported with groundwater in the study region is also presented in Section 5.

Physical Parameters Colour is the only physical parameter for which the CWQG limit of 15 TCU colour is exceeded. Colour values of up to 140 TCU were recorded in the well records studied. The reason for the high colour is not known.

Acidity The groundwaters analyzed in the study area, as would be expected, are slightly more basic than the surface waters. A few locations have pH both above and below the range specified by the CWQG. For the same reasons mentioned for surface waters, sites reporting excessively low pH values should be closely monitored.

Anions Concentrations of fluoride, sulphate, chloride, and nitrate from groundwater samples generally exceed concentrations of anions in surface water. However, the concentrations of these anions do not exceed the levels specified in the CWQG.

Table 4-4 PARAMETER VALUES FOR WELLS USED FOR WATER QUALITY MONITORING NOTRE DAME BAY REGION (SEE FIGURE 4-1 FOR LOCATIONS)

Note: values shown are the most recent analyses available from NDOEL for single samples

Location Fig4-1	LOCATION				WATER QUALITY PARAMETERS														
	Well#	Map#	Northings	Eastings	Alkalinity mg/L	NO3+NO2 mg/L	pH	Cond µS	Ca mg/L	Mg mg/L	Mn mg/L	Fe mg/L	Zn mg/L	Cl mg/L	Na mg/L	K mg/L	F mg/L	NO3 mg/L	SO4 mg/L
A	10311	12H/8	5482300	560100	69.4	0.000	-	-	27.00	5.70	0.00	0.12	0.00	130.00	86.00	1.40	0.07	0.000	7.00
B	10633	12I/1	5544650	563100	82.4	0.560	-	-	27.00	3.30	0.09	0.24	0.03	11.00	11.00	1.70	0.01	0.000	5.60
C	11061	2E/6	5483550	623400	159.0	0.079	8.06	-	18.00	21.00	0.02	0.05	0.00	21.00	24.00	9.90	0.06	0.000	5.70
D	10560	2E/9	5510400	702500	0.3	0.520	5.19	241	3.94	4.50	0.38	0.49	0.13	64.00	24.00	2.00	0.14	-	8.00
E	12371	2E/7	5485500	679150	112.0	0.005	6.40	607	50.00	7.40	0.06	0.00	0.00	110.00	70.00	1.47	0.00	<0.001	9.50
F	11278	2E/10	5497600	674200	166.0	0.270	6.72	452	60.00	4.40	0.00	0.00	0.17	24.00	19.00	1.18	0.07	0.070	24.00
G	11186	2E/3	5451300	626100	153.2	1.200	-	-	69.00	8.90	0.00	0.26	0.06	160.00	110.00	1.60	0.04	-	11.00
H	10478	2E/3	5432100	613660	111.0	0.560	-	352	20.00	17.00	0.00	0.05	0.00	52.00	27.00	2.50	0.05	-	5.80
I	10822	2E/7	5467700	664350	109.7	0.003	-	-	24.00	9.30	0.00	0.21	0.15	23.00	3.20	3.20	0.07	-	3.70
J	10714	2E/9	5505125	686150	173.0	0.071	7.33	569	51.00	12.00	0.20	0.18	0.00	43.00	57.00	6.00	0.06	-	24.00
K	12177	2E/9	5505175	700700	114.0	<0.004	6.99	365	37.00	10.00	1.74	3.16	0.12	27.00	14.00	2.91	0.43	0.001	14.00
L	12454	2E/9	5500300	694350	24.8	0.084	6.53	184	13.00	3.23	0.03	0.24	0.15	28.00	15.00	1.00	0.00	<0.001	8.50
M	13226	2E/9	5494950	697050	107.0	0.087	6.66	803	88.00	17.00	1.71	3.00	3.75	160.00	48.00	6.70	0.09	0.006	15.00
N	11059	2E/12	5509950	57400	162.3	0.118	-	-	43.00	7.30	0.00	0.11	0.11	0.00	16.00	1.40	0.04	-	29.00
O	11800	12H/9	5597425	560525	21.8	0.068	6.58	55	6.70	0.76	0.00	0.04	0.01	2.00	1.98	0.27	0.15	0.001	1.90
P	13900	2E/11	5485050	628100	275.0	<0.004	7.12	773	58.00	11.00	0.51	0.26	5.70	55.00	79.00	2.29	0.21	0.001	40.00
Q	14793	2E/6	5484125	622800	269.0	<0.004	8.91	634	3.00	1.31	0.00	0.03	0.00	21.00	120.00	0.44	0.46	<0.001	44.00
R	14254	12H/8	5482650	559550	45.9	<0.004	6.36	187	20.00	4.60	0.00	0.03	0.00	19.00	7.00	0.36	0.07	<0.001	3.50
S	12172	2E/3	5432225	613650	217.0	0.007	7.48	538	50.00	31.00	0.20	0.18	0.01	52.00	10.00	3.97	0.08	<0.001	4.90
			Overall	Max	275.0	1.2	8.91	803	88	31	1.74	3.16	5.7	160	120	9.9	0.46	0.07	44
				Min	0.3	<0.004	5.19	<55	3	0.76	0	0	0	0	1.98	0.27	0.00	0	1.9

(shaded) indicates water quality parameter outside acceptable range specified in CWQG

Cations With the exception of manganese, iron, and zinc, all cations analyzed in groundwater samples were at concentrations below their MACL as specified in the CWQG. Iron and manganese frequently exceed the levels specified in the CWQG for aesthetic reasons. Zinc was reported as exceeding the CWQG levels for drinking water at one location (see Table 4-4).

As with the surface water quality data, the poor coverage of groundwater monitoring sites in the Notre Dame Bay Region makes it difficult to generalize about formations prone to water quality problems; however, manganese and iron contamination are problems endemic to the area. For example, all of the monitoring wells on Fogo report unacceptable levels of manganese and iron. Mercury and arsenic were not reported in the groundwater data provided. As these two elements are toxic at very low concentrations, it is suggested that they should be added to the list of elements tested at groundwater monitoring stations.

Despite the problems with mercury and iron contamination, the groundwater quality of the study region is characteristically good.

4.5 Exploits River Water Quality Synopsis

A water quality survey of the Exploits River was conducted during 1987-1988 as a joint project of the Water Resources Division of the Province of Newfoundland and the Inland Waters Directorate of Environment Canada (Roussel et al. 1990). A synopsis of that report follows.

The Exploits River drainage basin has an area of 11000 km^2 and a length of nearly 430 km. It is the largest drainage basin on the Island of Newfoundland and the dominant drainage basin of the Central Notre Dame Bay study region.

Low flow studies (fall 1987) revealed that effluent from Badger, Grand Falls/Windsor, Bishop's Falls, and mine tailings from an abandoned mine at Buchans, discharges into the Exploits River. The contaminants are diluted by the large flow of the Exploits River system. High concentrations of metals have been detected in bottom sediments at Red Indian Lake; however, the high concentrations of metals are isolated in the bottom sediments, and have not reached the pelagic organisms. Thus they are generally unavailable to the fish community. Analyses of the sediments of the lower Exploits River basin also revealed the presence of metals and PCBs, likely a result of anthropogenic activities.

The Exploits River study was based on chemical analyses of water quality, sediments, and fish. Water quality stations were placed both downstream of pollution inputs and in areas of minimal anthropogenic activity. Samples downstream of pollution inputs showed evidence of contamination. Analyses of water quality samples from Buchans revealed copper, lead, and zinc contamination with levels of some metals exceeding water quality guidelines for the protection of freshwater species. Aluminium, copper, iron, lead, and zinc levels exceeded water quality guidelines with copper and zinc at levels that could cause avoidance behaviour in salmonids.

High nutrient levels from sewer discharge were detected downstream from the Town of Buchans. Discharges from sanitary and storm sewers are also responsible for noticeable levels of particulate matter, nutrients, major ions, and some metals in the Exploits River in the Badger, Grand Falls/Windsor, and Bishop's Falls areas.

The effluent from the pulp mill at Grand Falls results in localized high levels of sulphate, turbidity, colour, dissolved organic carbon, total iron, and biological oxygen demand (BOD).

Aluminium occasionally exceeded levels recommended in the Canadian Water Quality Guidelines (the CWQG) when associated with low pH (lower than 6.5). Zinc concentrations were always at, or around, the MACL of 0.03 mg/L set for protection of freshwater life. Results for periods of high flow in the Exploits River (spring 1988) showed results characteristic of Newfoundland ambient surface waters except for the stretch of river downstream from the Abitibi-Price pulp mill where high concentrations of major ions, some nutrients, and some metals were detected. Turbidity was measured at 79 JTU.

Overall, the river water was characterized as being very dilute and homogeneous during periods of high flow.

Differences between high flow and low flow water quality were ascribed to the physical condition of the river during the sampling periods. This difference (dilute during periods of high flow and more concentrated during periods of low flow) is reflected by slightly increased conductivity during periods of low flow.

Bottom sediment analyses revealed low levels of toxic metals and organic matter below the Buchans mine. Sediment samples from water quality stations below Grand Falls and Bishop's Falls were high in particulate organic matter and nitrogen. Toxic metals, such as mercury, cadmium, lead, and zinc, were concentrated at these sites. Decaying wood chips and slimy organic matter were also observed. The latter originated from a sewer outfall.

Generally, PCBs were below detection limits for most of the Exploits River study, with the exception of Arochlor, which was detected at all sites except Buchans Brook. The Grand Falls water quality station showed PCB concentrations which probably originated from raw municipal sewage. The pesticide P.P methoxychlor, used for control of blackfly, was also detected at the water quality station below Grand Falls. It is not considered to be a threat.

As a result of a 900 litre PCB spill at Bishop's Falls, during January 1983, higher levels of PCBs were detected at the water quality station below Bishop's Falls than at Grand Falls.

Some temporal variability in concentration of contaminants in bottom sediments was noted. At Buchans Brook variations in concentrations of about two to three times for cadmium, copper, lead, and zinc were noted. Most variations in bottom sediment chemistry were attributed to spatial variability in sampling.

4.6 Gander River Water Quality Synopsis

Two NAQUADAT water quality stations are located in the Gander River, at the west and east ends of Gander Lake, respectively (locations 43 and 44 on Figure 4-1). Analyses from both NAQUADAT stations reveal that water quality in the Gander River Basin, at least to the most downstream NAQUADAT site, is relatively unaffected by anthropogenic activity. Concentrations of dissolved oxygen do not fall to some of the low values seen in the Exploits River, probably reflecting a lower BOD (biological oxygen demand) resulting from a lack of anthropogenic activities such as sewage disposal and logging activities, and/or a lower COD (chemical oxygen demand). In general, the Gander River Basin, at least where it has been studied, is in good health with little impact from anthropogenic activities.

4.7 Toxic Chemicals

Toxic substances of concern in water usually include heavy metals, organic parameters, and pesticides. Ingestion of these substances can have adverse effects upon people, animals, and aquatic life, although the dose/response relationships are not well-known for the very low concentrations typically encountered.

Municipal Supplies

Toxic chemical occurrences in municipal supplies were also tested during a Federal-Provincial survey of municipal drinking water sources (Environment Canada et al. 1988). Of the 40 sites sampled in Newfoundland, ten fall in the study region. Their locations are shown on Figure 4-2.

The toxic chemical study was conducted in a manner which ensured good quality control and rejection of any spurious results. Of the toxic organic constituents tested, the following were identified as causing concern within the Notre Dame Bay study region. It should be noted that problems, where they arose, were often reviewed only in a general manner and that the sites with problems were often not identified. Thus, some of the comments below are general for Newfoundland.

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs are carcinogenic and result from the incomplete combustion of inorganic matter, fossil fuels, or by natural burning.

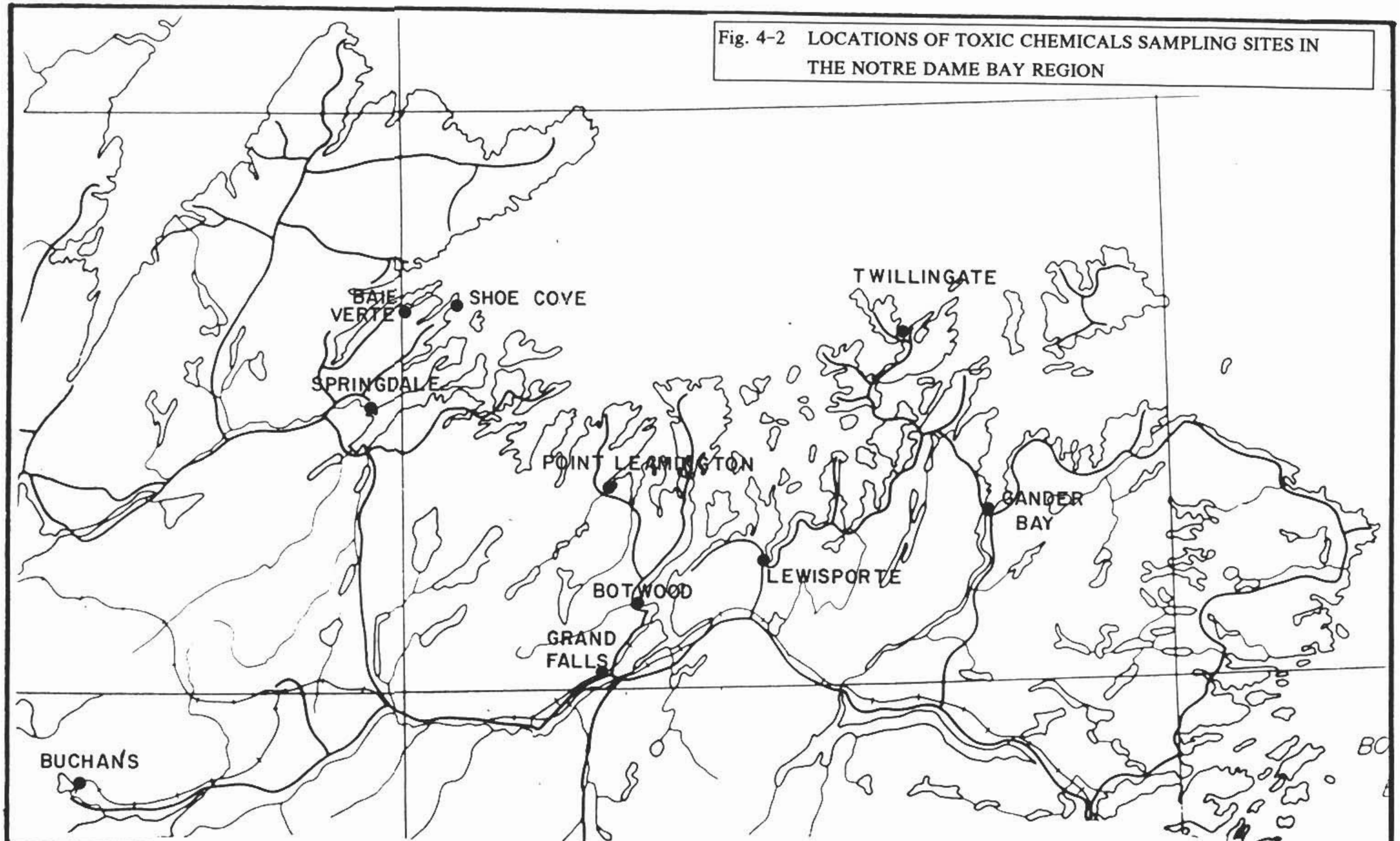
Six PAHs were quantified in the toxic chemical survey. Of the six, fluoranthene, a low molecular weight PAH, was reported at, or near, the detection limit of 0.001 ug/L for nearly all sites in Newfoundland. However, the Baie Verte water supply was observed to have detection limit observations of three other PAH compounds. These observations were noted as worthy of follow-up. It should be noted that the Baie Verte water supply system uses a creosoted crib dam which may result in the leaching of unacceptable toxic chemicals into the water supply system.

Volatile Organic Matter Data for Health and Welfare Canada, concerning VOMs, was also included in the Atlantic Region Toxic Chemical Study. VOMs include industrial/commercial thinners, degreasing agents, as well as some by-products of chlorination of water sources. VOMs are ubiquitous and were even detected in the blanks used as controls.

Trihalomethane (THM) A MACL of 350 ug/L for trihalomethane is set by Health and Welfare Canada. All values detected in the Newfoundland area were below the MACL. However, values as high as 180 mg/L were detected. It is unknown if any sites in the study area had these high THM values. It should be noted that THMs are believed to be produced by the chlorination of water containing organic matter.

Dichloroacetonitrile can also be formed during the chlorination of drinking water. Dichloroacetonitrile was detected at five sites in Newfoundland. No specifics of site location were detailed in the toxic chemicals report and it is not known whether these sites are in the study area. It should be noted that dichloroacetonitrile contains cyanide.

Fig. 4-2 LOCATIONS OF TOXIC CHEMICALS SAMPLING SITES IN THE NOTRE DAME BAY REGION



DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA
CENTRAL NEWFOUNDLAND REGION

FIG. 4-2

Pesticides and Herbicides

Pesticides are applied by the Department of Forestry and Agriculture to control spruce budworm and hemlock looper. Utility companies also apply herbicides on rights-of-way where appropriate. Some pesticides are also applied for agricultural and domestic purposes, although applications would be quite limited in scope and mass in the study area. Forestry applications would be of the greatest concern.

Fortunately, all pesticide application is strictly regulated by the Pesticides Control Branch of NDOEL, which ensures the dosages and masses applied are safe.

4.8 Acidification of Surface Waters

As noted by Acres (1990), there is some concern about the potential adverse effects of acid rain (defined as having a pH below 5.6) on the Island of Newfoundland. Acid rain is generated by combustion of fossil fuels, particularly coal. The major centre of production is the US Midwest, and the major zone of adverse impact has been upstate New York, New England, southern Quebec, and the Maritimes. DFO and AES conducted studies to assess acid rain and its effects in Newfoundland, in general the island has not been significantly impacted because of the distance from the source of emissions.

Acres (1990) noted that the first zone of impact would be the west coast of Newfoundland as it is closest to source of emissions. Fortunately, the west coast/Northern Peninsula region has carbonate rocks which will buffer the acid rain. In general the Central/ Notre Dame Bay study area does not, so it is more susceptible to acidification.

The pH data from the NAQUADAT database were analyzed to assess any trend of acidification in surface waters in the study area.

Exploits River Data

A review of the pH data in the NAQUADAT files, no long-term records exist for this basin. Of the two longest records, the one at Grand Falls is deleted because of proximity to the pulp mill. The other record, for Exploits River below Noel Paul's Brook [YO0005, YO0019], has a duration from May 30, 1968, to September 13, 1989 (7926 days), during which 59 samples were taken. Only lab samples are available over the entire period of record. The data are presented in Table 4-5. Note that the samples can be divided into two data sets, separated by about 20 years.

The data are plotted on Figures 4-3 (pH vs. time) and 4-4 (H^+ vs. time). The best fit regression of H^+ vs. time is

$$H^+ = 9.55\ E\text{-}7 - 8.310\ E\text{-}11 * \text{time} \qquad (4\text{-}1)$$

where time is days since 01/01/68. Note that H^+ is decreasing; hence pH is increasing.

The average pH over the period 30/05/68 to 11/03/69 was 6.0, while that for the period 11/08/86 to 13/09/89 was 6.47. Thus pH appears to have increased a half unit over the 20 years of record. This phenomenon, if real, cannot be explained; nevertheless it hints that acidification may not be a problem in the Upper Exploits River basin.

Finally, note that only one of the data points on Figure 4-3 lies below the "acid rain" criterion of pH = 5.6.

Table 4-5

EXPLOITS RIVER pH RECORD AT NOEL PAUL BROOK

D a t e	Days From 01/01/68	Lab pH	Equiv. H+
68/05/30	150	6.5	3.16E-07
68/10/02	275	6.2	6.31E-07
68/10/08	281	6.2	6.31E-07
68/10/15	288	6.4	3.98E-07
68/10/22	295	6.3	5.01E-07
68/10/29	302	6.5	3.16E-07
68/11/05	309	6.6	2.51E-07
68/11/19	323	6.5	3.16E-07
68/11/26	330	5.8	3.16E-07
68/12/10	344	6.2	1.58E-06
68/12/24	358	6.4	6.31E-07
68/12/31	365	6.5	3.98E-07
69/01/14	379	6.6	3.16E-07
69/02/11	407	5.6	2.51E-06
69/03/11	435	5.3	5.01E-06
81/05/06	4,874	6.5	3.16E-07
83/07/06	5,665	6.1	7.94E-07
11 Aug 86	6,797	6.69	2.04E-07
14 Oct 86	6,861	6.34	4.57E-07
14 Nov 86	6,892	6.38	4.17E-07
03 Dec 86	6,911	6.77	1.70E-07
08 Jan 87	6,947	6.57	2.69E-07
04 Feb 87	6,974	6.79	1.62E-07
04 Mar 87	7,002	6.69	2.04E-07
13 Apr 87	7,042	6.62	2.40E-07
17 May 87	7,066	6.63	2.34E-07
04 Jun 87	7,094	6.62	2.40E-07
04 Jun 87	7,094	6.60	2.51E-07
04 Jun 87	7,094	6.57	2.69E-07
07 Jul 87	7,127	6.61	2.45E-07
12 Aug 87	7,163	6.32	4.79E-07
12 Aug 87	7,163	6.90	1.26E-07
09 Sep 87	7,191	6.61	2.45E-07
08 Oct 87	7,220	6.36	4.37E-07
03 Nov 87	7,246	6.48	3.31E-07
03 Dec 87	7,276	6.39	4.07E-07
06 Jan 88	7,310	5.62	2.40E-06
03 Feb 88	7,338	6.57	2.69E-07
08 Mar 88	7,372	6.60	2.51E-07
06 Apr 88	7,401	6.52	3.02E-07
06 Apr 88	7,401	6.52	3.02E-07
06 Apr 88	7,401	6.55	2.82E-07

Table 4-5 (cont'd)

Exploits River pH Record at Noel Paul Brook

D a t e	Days From 01/01/68	Lab pH	Equiv. H+
03 May 88	7,428	6.64	2.29E-07
02 Jun 88	7,458	6.62	2.40E-07
06 Jul 88	7,492	6.62	2.40E-07
12 Aug 88	7,529	6.43	3.72E-07
07 Sep 88	7,555	6.49	3.24E-07
06 Oct 88	7,584	6.11	7.76E-07
02 Nov 88	7,611	6.12	7.59E-07
06 Dec 88	7,645	6.63	2.34E-07
18 Jan 89	7,688	6.77	1.70E-07
13 Feb 89	7,714	6.42	3.80E-07
14 Mar 89	7,743	6.59	2.57E-07
06 Apr 89	7,766	6.33	4.68E-07
04 May 89	7,794	6.76	1.74E-07
05 Jun 89	7,826	6.62	2.40E-07
17 Jul 89	7,868	7.24	5.75E-08
03 Aug 89	7,885	6.98	1.05E-07
13 Sep 89	7,926	6.85	1.41E-07

Gander River Data

Again, for the Gander River, there is only one long data set; that being for the Gander River in the Glenwood area (Stations YQ0001/0004/0030). The period of record is, again, 1968 to 1989. The data are given in Table 4-6, and depicted on Figure 4-5.

As with the Exploits river, there is a trend of increasing pH in the water, going from an average pH for the period 1968 to 1978 of 6.00 units, to 6.36 units for the period 1986 to 1989 . The best fit linear regression of H^+ ion concentration with time is

$$H^+ = 1.29 \text{ E-06} - 1.10 \text{ E-10} * \text{time} \qquad (4\text{-}2)$$

where time is in days since 09/05/68. The rate of increase in pH for the Gander River is thus less than that for the Exploits River.

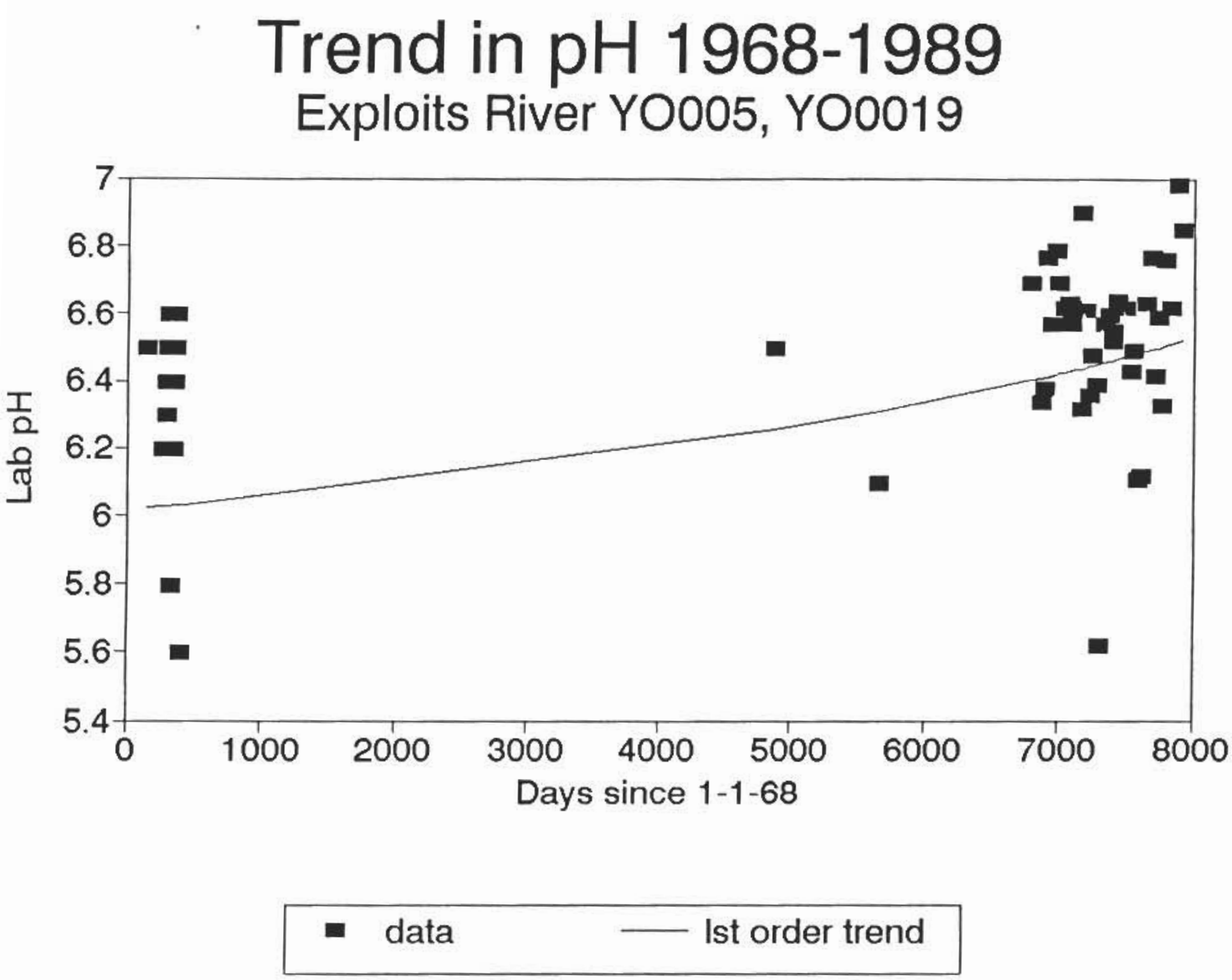
Summary

Irrespective of the trend of pH in rainwater, if any, the pH of the waters in the Exploits and Gander Rivers appears to have increased by about one-half unit in the last 20 years. The cause of this increase is not known, but there should be no immediate concern about acidification.

4.9 Conclusions

The surface and groundwater quality of the Central Notre Dame Bay study region is generally good. However, anthropogenic activity is having localized effects on surface water quality and continuance of water quality monitoring is essential. The major sources of water quality contamination are the pulp mill at Grand

FIG. 4-3



Trend in pH 1968-1989
Exploits River YO005, YO0019
Lab pH
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
0
1000
2000
3000
4000
5000
6000
7000
8000
Days since 1-1-68
data
lst order trend

FIG. 4-4

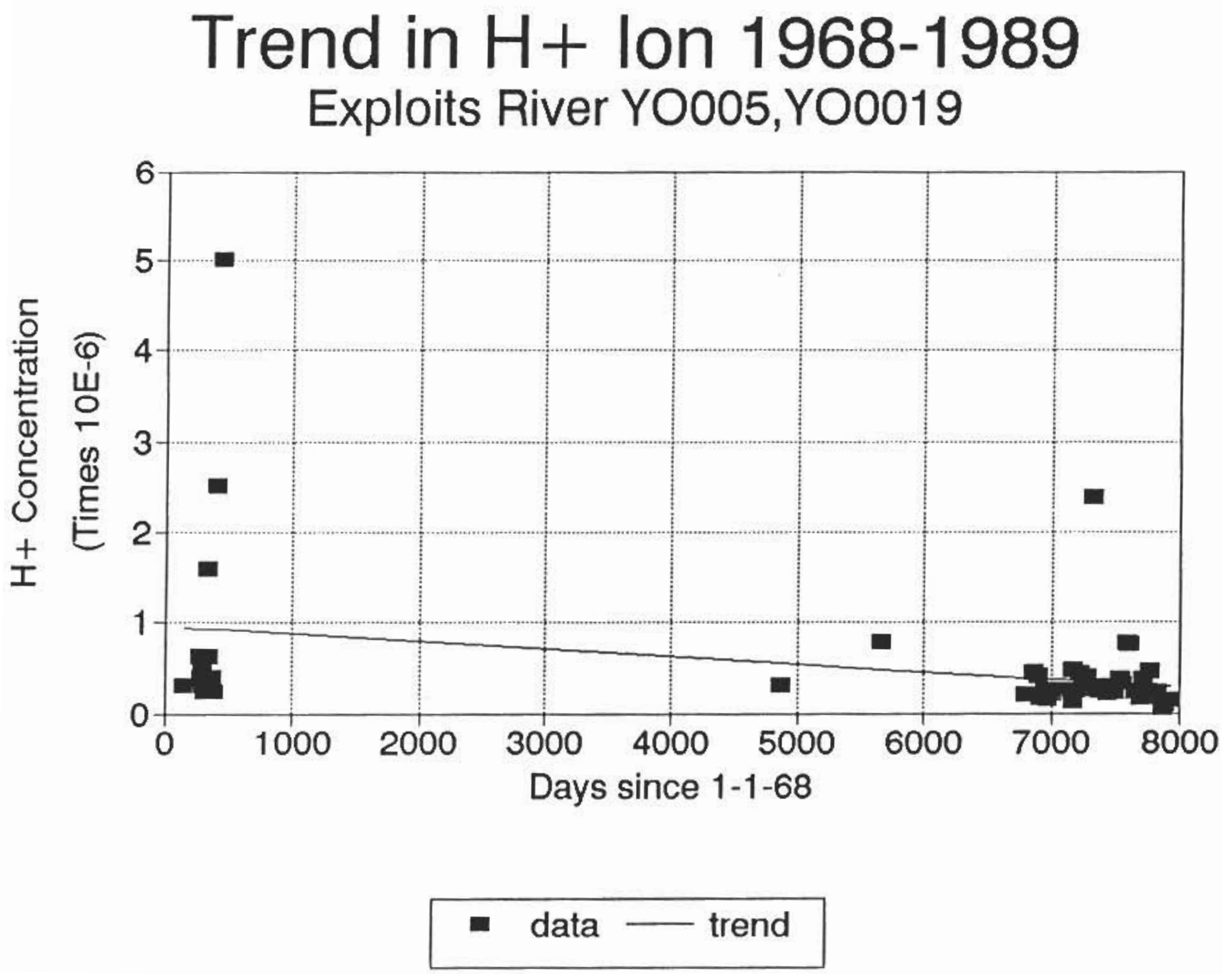

Trend in H+ Ion 1968-1989
Exploits River YO005,YO0019
H+ Concentration (Times 10E-6)
0
1
2
3
4
5
6
0
1000
2000
3000
4000
5000
6000
7000
8000
Days since 1-1-68
data
trend

Table 4-6

Gander River pH Record at Glenwood

Days Since 9-9-66	Lab pH Value	Equiv. H+ Conc.	Estimated H+ Conc.	Estimated pH
0	6.6	2.51E-07	1.29E-06	5.89
0	6.6	2.51E-07	1.29E-06	5.89
83	6.4	3.98E-07	1.28E-06	5.89
112	6.3	5.01E-07	1.28E-06	5.89
958	6.3	5.01E-07	1.19E-06	5.93
1050	6.3	5.01E-07	1.18E-06	5.93
1081	6.1	7.94E-07	1.17E-06	5.93
1121	8.4	3.98E-09	1.17E-06	5.93
1253	6.4	3.98E-07	1.15E-06	5.94
1290	6.2	6.31E-07	1.15E-06	5.94
1322	6.4	3.98E-07	1.15E-06	5.94
1351	6.1	7.94E-07	1.14E-06	5.94
1382	5.9	1.26E-06	1.14E-06	5.94
1413	6.1	7.94E-07	1.14E-06	5.94
1474	6	1.00E-06	1.13E-06	5.95
1506	5.9	1.26E-06	1.13E-06	5.95
1539	6.2	6.31E-07	1.12E-06	5.95
1571	6.5	3.16E-07	1.12E-06	5.95
1597	6	1.00E-06	1.12E-06	5.95
1629	6.3	5.01E-07	1.11E-06	5.95
1658	6.2	6.31E-07	1.11E-06	5.95
1697	6.3	5.01E-07	1.11E-06	5.96
1719	6.2	6.31E-07	1.10E-06	5.96
1750	6	1.00E-06	1.10E-06	5.96
1779	6	1.00E-06	1.10E-06	5.96
1839	6.1	7.94E-07	1.09E-06	5.96
1871	5.6	2.51E-06	1.09E-06	5.96
1903	6.1	7.94E-07	1.08E-06	5.97
1929	6	1.00E-06	1.08E-06	5.97
2002	6.2	6.31E-07	1.07E-06	5.97
2024	5.8	1.58E-06	1.07E-06	5.97
2054	5.7	2.00E-06	1.07E-06	5.97
2089	5.9	1.26E-06	1.06E-06	5.97
2114	5.9	1.26E-06	1.06E-06	5.97
2144	6.2	6.31E-07	1.06E-06	5.98
2178	6.4	3.98E-07	1.05E-06	5.98
2267	6.3	5.01E-07	1.04E-06	5.98
2296	5.7	2.00E-06	1.04E-06	5.98
2331	6	1.00E-06	1.04E-06	5.98
2388	4.7	2.00E-05	1.03E-06	5.99
2426	5.9	1.26E-06	1.03E-06	5.99
2461	6	1.00E-06	1.02E-06	5.99
2487	5.6	2.51E-06	1.02E-06	5.99
2518	6	1.00E-06	1.02E-06	5.99

Table 4-6 (Cont'd)

Gander River pH Record at Glenwood

Days Since 9-9-66	Lab pH Value	Equiv. H+ Conc.	Estimated H+ Conc.	Estimated pH
2572	7.2	6.31E-08	1.01E-06	6.00
2579	6.5	3.16E-07	1.01E-06	6.00
2635	5.7	2.00E-06	1.00E-06	6.00
2635	5.9	1.26E-06	1.00E-06	6.00
2694	5.8	1.58E-06	9.98E-07	6.00
2761	6.6	2.51E-07	9.90E-07	6.00
2795	5.9	1.26E-06	9.87E-07	6.01
2822	6	1.00E-06	9.84E-07	6.01
2854	6.1	7.94E-07	9.80E-07	6.01
2883	6.1	7.94E-07	9.77E-07	6.01
2914	6.2	6.31E-07	9.74E-07	6.01
2935	6.2	6.31E-07	9.72E-07	6.01
2975	6.2	6.31E-07	9.67E-07	6.01
3057	6.3	5.01E-07	9.58E-07	6.02
3091	6.5	3.16E-07	9.55E-07	6.02
3127	5.5	3.16E-06	9.51E-07	6.02
3181	6.5	3.16E-07	9.45E-07	6.02
3212	7	1.00E-07	9.42E-07	6.03
3241	5.5	3.16E-06	9.38E-07	6.03
3342	6.7	2.00E-07	9.27E-07	6.03
3362	6	1.00E-06	9.25E-07	6.03
3576	5.8	1.58E-06	9.02E-07	6.04
3602	6	1.00E-06	8.99E-07	6.05
3627	6.4	3.98E-07	8.97E-07	6.05
3670	7	1.00E-07	8.92E-07	6.05
3734	5.8	1.58E-06	8.85E-07	6.05
3792	7.2	6.31E-08	8.79E-07	6.06
3823	5.6	2.51E-06	8.75E-07	6.06
3911	6.5	3.16E-07	8.66E-07	6.06
3941	6.8	1.58E-07	8.62E-07	6.06
3975	7	1.00E-07	8.59E-07	6.07
4007	6.6	2.51E-07	8.55E-07	6.07
4015	6.5	3.16E-07	8.54E-07	6.07
4056	6.8	1.58E-07	8.50E-07	6.07
4090	6.5	3.16E-07	8.46E-07	6.07
4127	6.5	3.16E-07	8.42E-07	6.07
4158	6.5	3.16E-07	8.39E-07	6.08
4188	6.3	5.01E-07	8.36E-07	6.08
4214	6	1.00E-06	8.33E-07	6.08
4235	6.6	2.51E-07	8.31E-07	6.08
4252	6.5	3.16E-07	8.29E-07	6.08
4284	6.5	3.16E-07	8.25E-07	6.08
4309	6.2	6.31E-07	8.23E-07	6.08
4345	6.1	7.94E-07	8.19E-07	6.09

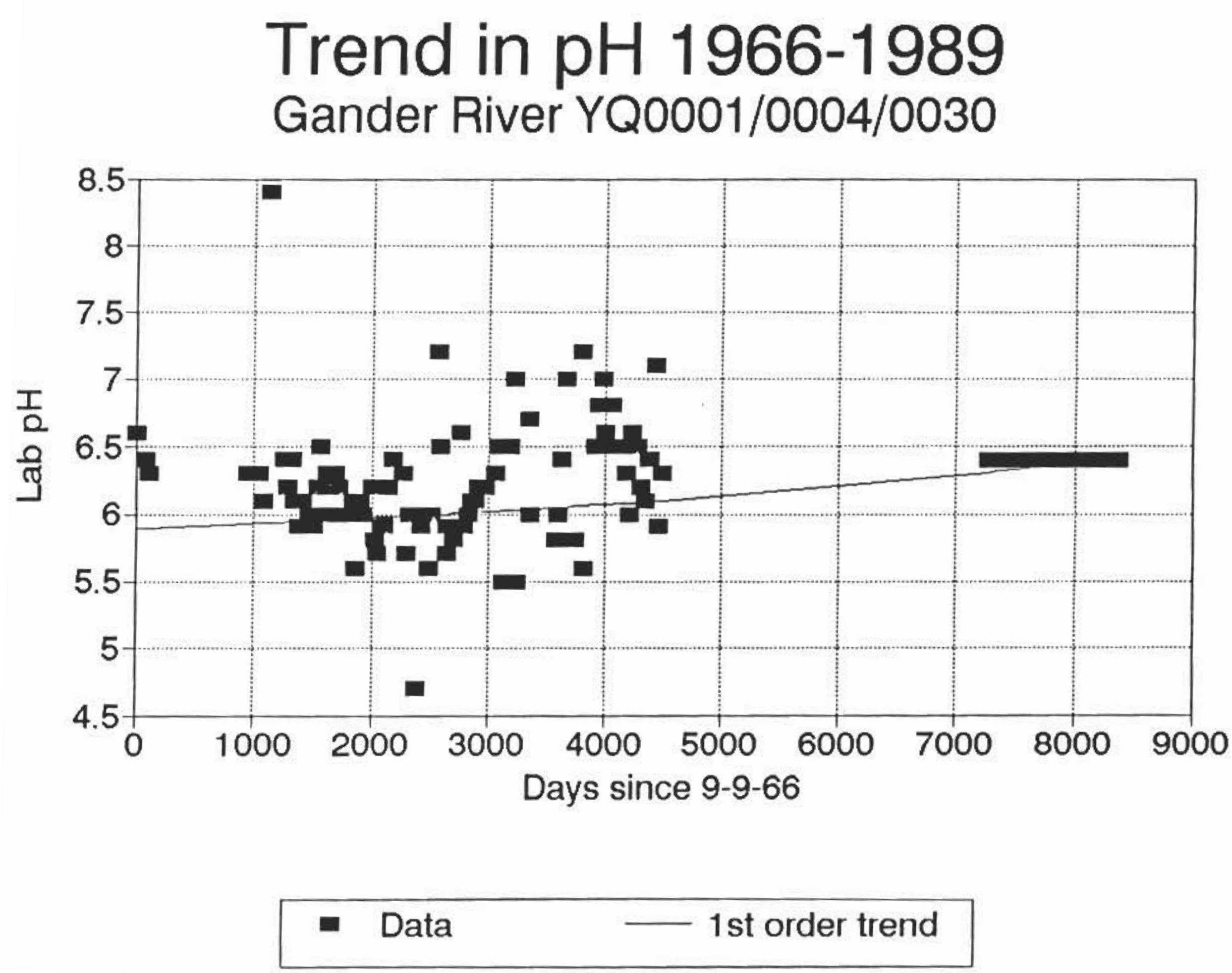
Table 4-6 (Cont'd)

Gander River pH Record at Glenwood

Days Since 9-9-66	Lab pH Value	Equiv. H+ Conc.	Estimated H+ Conc.	Estimated pH
4373	6.4	3.98E-07	8.16E-07	6.09
4389	6.4	3.98E-07	8.14E-07	6.09
4431	7.1	7.94E-08	8.09E-07	6.09
4463	5.9	1.26E-06	8.06E-07	6.09
4485	6.3	5.01E-07	8.03E-07	6.10
7277	6.39	4.07E-07	5.01E-07	6.30
7356	6.39	4.07E-07	4.92E-07	6.31
7404	6.39	4.07E-07	4.87E-07	6.31
7466	6.39	4.07E-07	4.80E-07	6.32
7523	6.39	4.07E-07	4.74E-07	6.32
7586	6.39	4.07E-07	4.67E-07	6.33
7649	6.39	4.07E-07	4.60E-07	6.34
7649	6.39	4.07E-07	4.60E-07	6.34
7711	6.39	4.07E-07	4.54E-07	6.34
7770	6.39	4.07E-07	4.47E-07	6.35
7832	6.39	4.07E-07	4.41E-07	6.36
7892	6.39	4.07E-07	4.34E-07	6.36
7951	6.39	4.07E-07	4.28E-07	6.37
8013	6.39	4.07E-07	4.21E-07	6.38
8074	6.39	4.07E-07	4.14E-07	6.38
8125	6.39	4.07E-07	4.09E-07	6.39
8196	6.39	4.07E-07	4.01E-07	6.40
8250	6.39	4.07E-07	3.95E-07	6.40
8312	6.39	4.07E-07	3.88E-07	6.41
8368	6.39	4.07E-07	3.82E-07	6.42

Estimated values from linear regression of H+ vs. time

FIG. 4-5



Trend in pH 1966-1989
Gander River YQ0001/0004/0030
Lab pH
8.5
8
7.5
7
6.5
6
5.5
5
4.5
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Days since 9-9-66
Data
1st order trend

Falls, the abandoned mine at Buchans, and numerous outfalls of untreated municipal sewage. No reports of adverse effects on water quality as a result of logging activities were found during the data search for water quality information; however, it is likely that any clear cut logging activity will increase the influx of sediments to streams and rivers and will have a detrimental effect on water quality and aquatic biota.

4.10 References - Section 4.0

Environment Canada, 1979, "Analytical Methods Manual", Inland Waters Directorate, Water Quality Branch, Ottawa.

Environment Canada, Conservation and Protection, Inland Waters Directorate, Water Quality Branch, "Atlantic Region Federal-Provincial Toxic Chemical Survey of Municipal Drinking Water Sources, 1985-1988, Interpretive Report", Moncton, N.B., 51 pp (in English).

Environment Canada in conjunction with the Atlantic Region Provinces (undated), "Atlantic Region Federal-Provincial Toxic Chemical Survey of Municipal Drinking Water Sources, 1985-1988."

Inland Waters Directorate, 1990, "Canadian Water Quality Guidelines."

Roussel, S., Arseneault, R. and Blouin, T., 1990, "Exploits River Survey Report 1987-1988", Canada-Newfoundland Water Quality Monitoring Agreement, published by Environment Canada.

SECTION 5.0

GROUNDWATER

5.0 GROUNDWATER

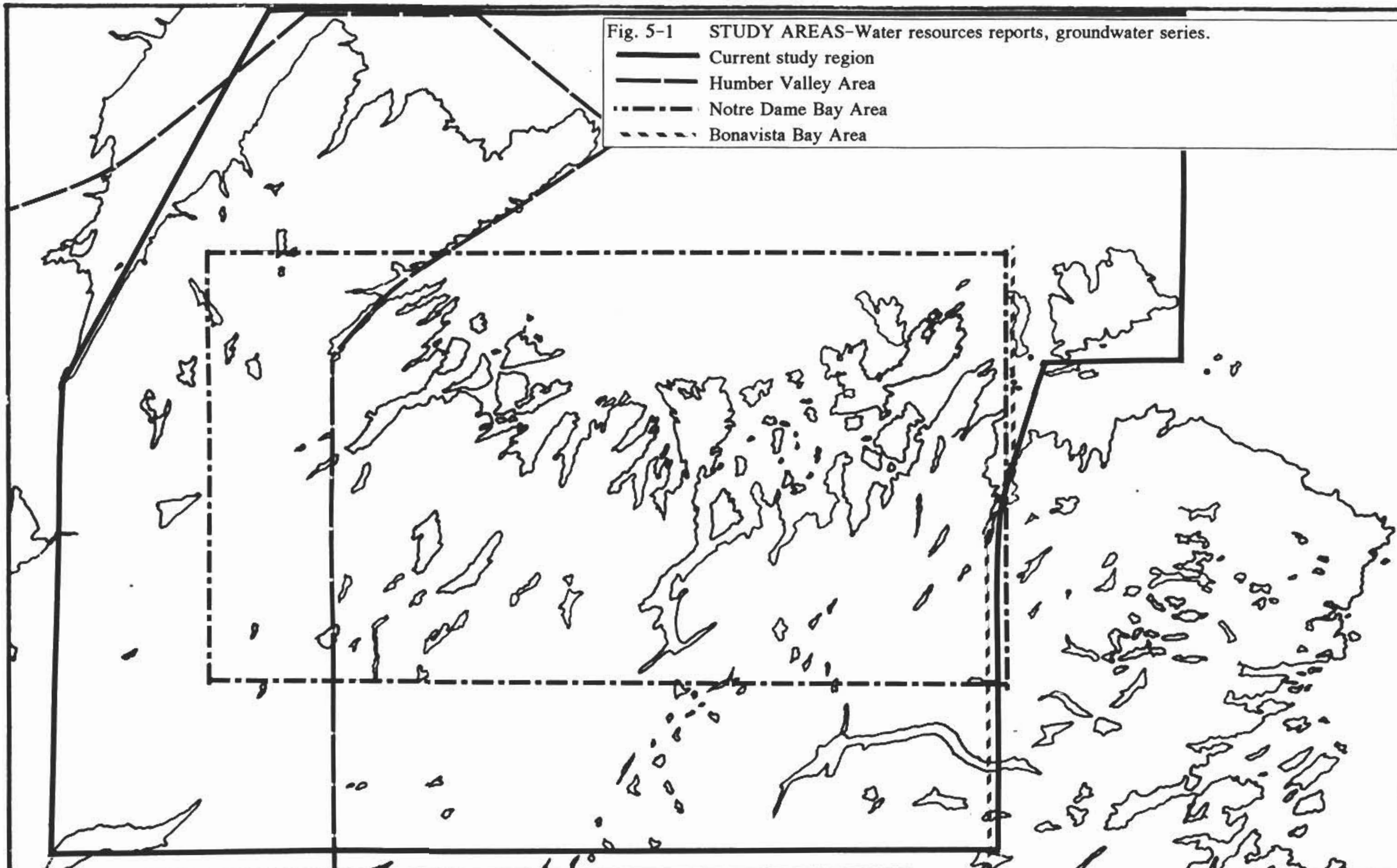
The hydrogeology of a large part of the study region has been reviewed in water resources reports 2-2, 2-3 and 2-5 of the provincial groundwater series. The areas studied in these reports are depicted on Figure 5-1. Report 2-2, "Hydrogeology of the Notre Dame Bay Area" (Hydrology Consultants Ltd, 1980) deals with an area entirely within the study region of this report. The study region also overlaps the eastern part of an area reviewed in Report 2-5 "Hydrogeology of the Humber Valley Area" (Golder Associates, 1983), and the western edge of a study area reviewed in "Hydrogeology of the Bonavista Bay Area" (Nolan, Davis and Associates 1981). This section is a synopsis of the above reports. The region immediately south of the Notre Dame Bay study area has not been studied in any of the provincial groundwater series reports; however, it is virtually unpopulated.

Field work was directed towards identifying supply problems, from both surface and groundwater sources; see Appendix A, "Inventory of Water Supply Systems."

5.1 Physiography

The major physiographic areas of the study region are shown in Figure 5-2. The physiography of the study region is controlled by the underlying geology, and thus the boundaries of most physiographic areas trend approximately NNE-SSW. In general, the elevation of the study region decreases from a high of the Topsails Plateau of the Newfoundland Highlands in the west, towards the east, across the central lowlands.

With the exception of its western edge, the study region is comprised of the Newfoundland Central Lowlands. West of the Bay of Exploits, the Central Lowlands are relatively rugged and ridged,



DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

FIG. 5-1

Fig. 5-2 PHYSIOGRAPHIC DIVISIONS OF THE NOTRE DAME BAY STUDY REGION AND ENVIRONS

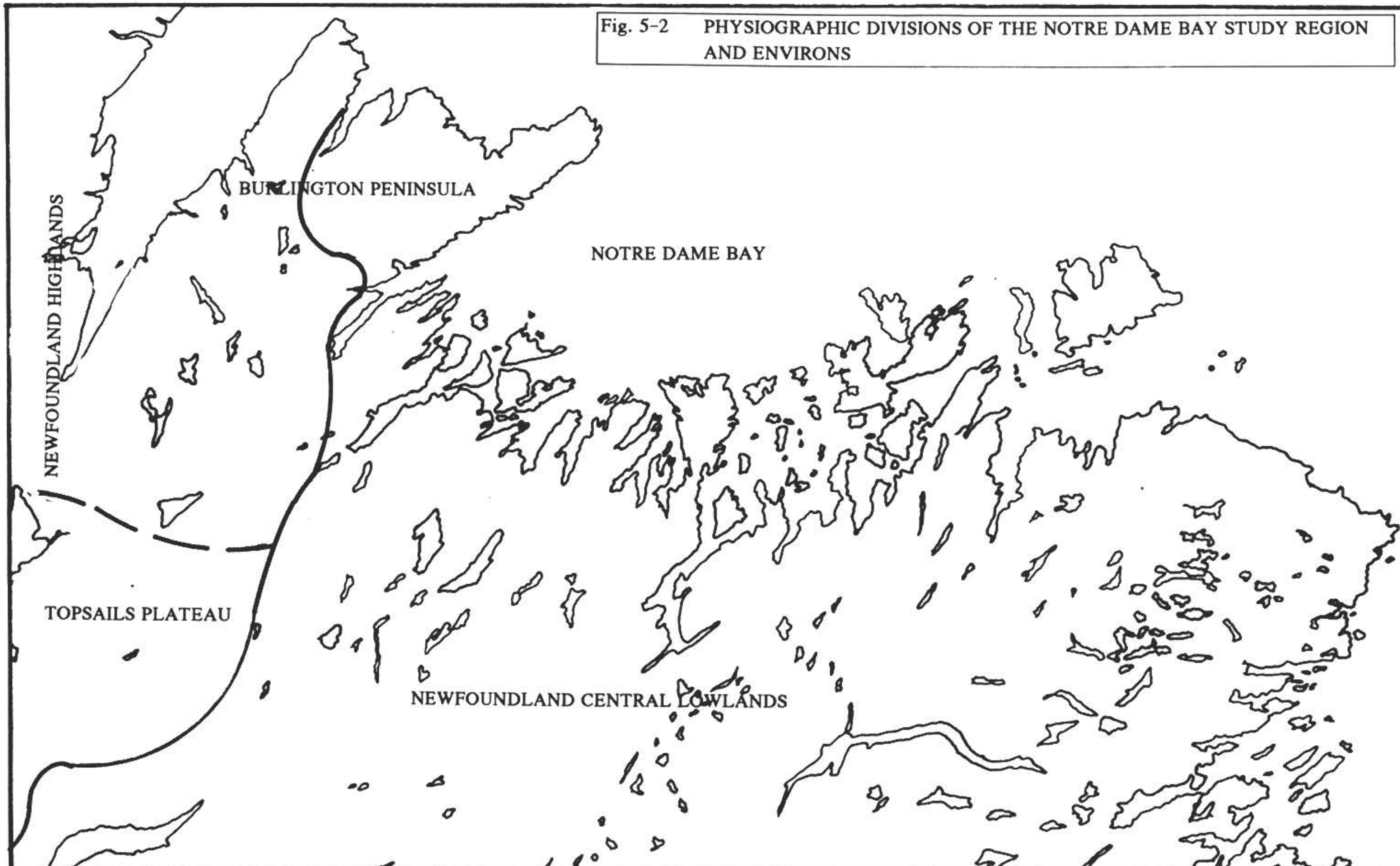


FIG. 5-2

DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

with elevations attaining approximately 300 m. The Newfoundland Central Lowlands become lower and flatter in the east of the study region. The lower lying area is often covered by glacial till of only low to moderate potential as aquifer material. Fluvioglacial sands, often overlain by till, have been identified but are generally sparse.

Along its entire western edge, the study region is bounded by the eastern extremity of the Newfoundland Highlands, with characteristic higher altitudes of 300 to 400 m. Inland, the Newfoundland Highlands are comprised of the sparsely vegetated rolling plateau of the Topsails Plateau, which is the divide between the Exploits River drainage system to the east and the Humber River/Grand Lake drainage system to the west. Moving NNE onto the Burlington (Baie Verte) Peninsula, the extension of the Newfoundland Highlands rises sharply from the Green Bay fault on the east side of the peninsula to a rugged plateau with a characteristic elevation of 300 m. The Newfoundland Highlands in the study region are generally covered with till and some peat. There are deposits of fluvioglacial sand and gravel deposits in some river valleys such as the Exploits River valley at Badger and Bishop's Falls (see Figure 5-4). These deposits are usually excellent aquifers.

5.2 Hydrogeologic Units

As the main intent of this section is to identify lithological units of hydrogeological interest; the geology of the study region is reviewed only in terms of its hydrogeological units. In general, areally large and thick fluvioglacial sand and gravel deposits offer the best potential for groundwater sources in the study region. However, these units are relatively scarce.

Fig. 5-3 SYNOPSIS OF THE HYDROGEOLOGIC UNITS OF THE NOTRE DAME BAY REGION AND ENVIRONS*

*see text for discussion of correlation of hydrogeologic units between study areas, and yields.

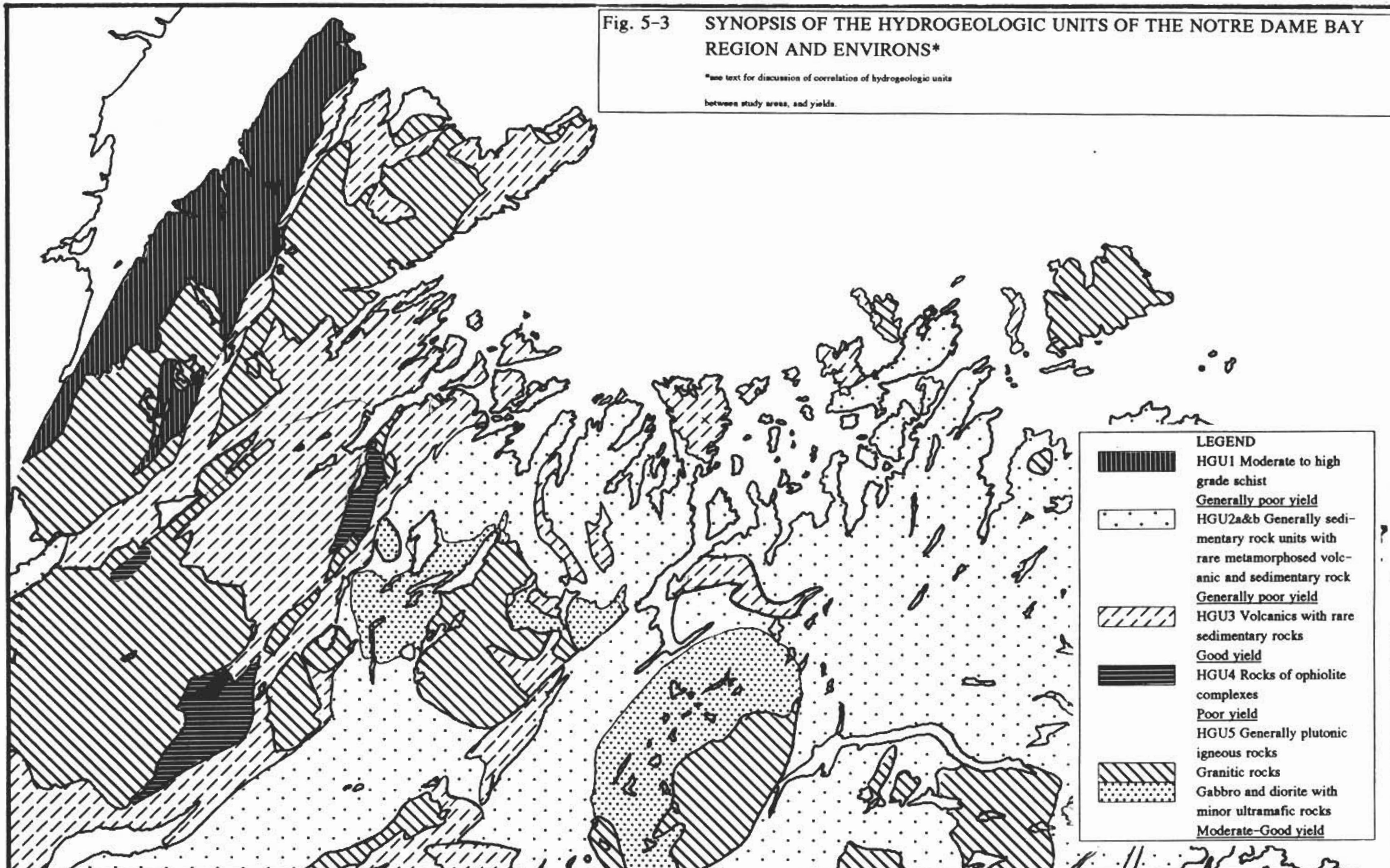
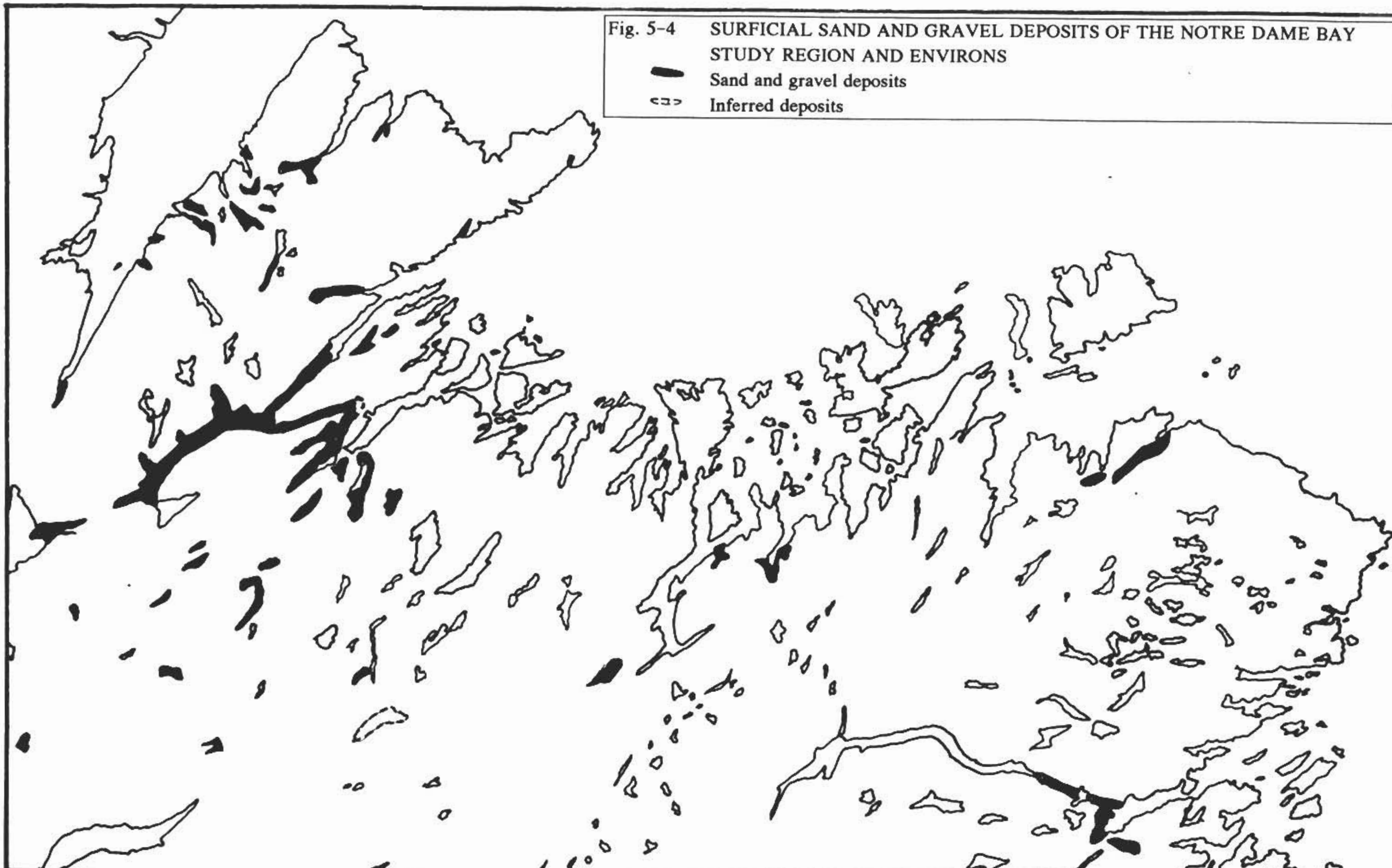


FIG. 5-3

DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.



DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

FIG. 5-4

The bedrock hydrogeologic units have been variously classified in the groundwater series reports 2-2, 2-3 and 2-5. Within an area, however, it is generally difficult to distinguish between bedrock hydrogeologic units on a basis of yields reported from wells tapping these units. It is noted by the authors of the groundwater series reports that the dominant porosity in the bedrock hydrogeologic units is secondary fracture porosity rather than primary intergranular/crystalline porosity. The pervasive fracturing generally results in well yields that are highly variable and, on the average, approximately the same for disparate lithologies within a given study area. Figure 5-3 depicts the bedrock hydrogeologic units, which are described below. This map was compiled from Colman-Sadd et al. (1990) (not from the groundwater series reports).

Known locations of surficial sand and gravel deposits are depicted in Figure 5-4. (These data have been recompiled from maps contained in the groundwater series reports, and from Kirby and Ricketts (1983a and b)). Till deposits have been omitted as they are ubiquitous.

5.2.1 Surficial Hydrogeologic Units

The surficial deposits in the study region can be divided into two broad categories:

1. HGU-S Fluvioglacial sand and gravel deposits.

The stratified sand and gravel units are believed to be surficial outwash, deltaic, fluvioglacial and kame deposits. Thicknesses up to 27 m have been recorded in the Exploits River basin. Sand and gravel deposits are generally best developed in river valleys.

Well yields from 3 to 340 L/min have been reported for the fluvioglacial sands and gravels of the study region. Wells in these deposits are usually not screened (Hydrology Consultants Ltd. 1980), resulting in well yields which are lower than would be expected if they were properly completed. The communities of Badger and Bishop's Falls use, or have used, well fields tapping fluvioglacial aquifers. The wells at Bishop's Falls are infiltration wells. One of the well field boundaries at Badger is the Exploits River; however, the well drawdown cones are not believed to extend far enough to intercept this boundary (Nolan, Davis, 1989). Problems, where they arose, were generally of water quality, not quantity, and are briefly discussed in Section 5.3.1. Many single domestic wells are completed in fluvioglacial sands, chiefly in the communities of Springdale, Norris Arm, Port Leamington, and Notre Dame Junction.

Because of their usually shallow position and their matrix chemistry the fluvioglacial aquifers are susceptible to contamination. Road salt and household sewage from septic tanks can pose dangers to these highly permeable surficial aquifers. Water extraction from two gravel infiltration wells at Bishop's Falls was stopped and a surface water supply used, when water quality from the wells deteriorated and the water became unpotable. Among other problems, extremely high concentrations of manganese were detected in the contaminated well water. The wells had operated for six months without problems before becoming contaminated (Personal communication, 1991, S. O'Rafferty, Proctor and Redfern Ltd.).

As noted by Nolan, Davis (1981), some of the high permeability glacial deposits, particularly kame deposits and eskers, stand above the local water table and thus are well-drained. These well-drained deposits are of no interest as aquifers. Of 24 wells drilled in the fluvioglacial sands and gravels in the Norris Arm and Point Leamington areas, 37% were reported dry by Hydrology Consultants Ltd. (1980).

2. HGU-T Low permeability glacial tills.

Many homes successfully use wells which produce from low permeability tills, which vary from silty sand to clayey silt and range in thickness from less than 4.5 m to 60 m. Wells dug, or drilled, in these deposits are usually made effective by enhancing the well storage capacity with either large dug pits or large bore wells. When present, lenses and layers of coarse-grained material improve well yields from these glacial tills.

Due to the methods of reporting well data for wells tapping the surficial deposits, it is not possible to precisely calculate average yields for them. However, yields from the tills are generally low and yields from the sands are generally high to extremely high.

5.2.2 Bedrock Hydrogeologic Units

It is noted in the groundwater series reports pertaining to the study region, that secondary fracture porosity is the most important component of effective porosity for most bedrock formations, regardless of origin. Sedimentary rocks have often been so deeply buried or metamorphosed that only vestiges of the original intergranular porosity remain.

There is a general decrease in reported well yields from the bedrock hydrogeologic units from the west to the east of the study region. The eastward decrease in well yields is probably attributable to the west to east decrease in the intensity of faulting, as shown on Figure 5-5 (from Colman-Sadd et al., 1990).

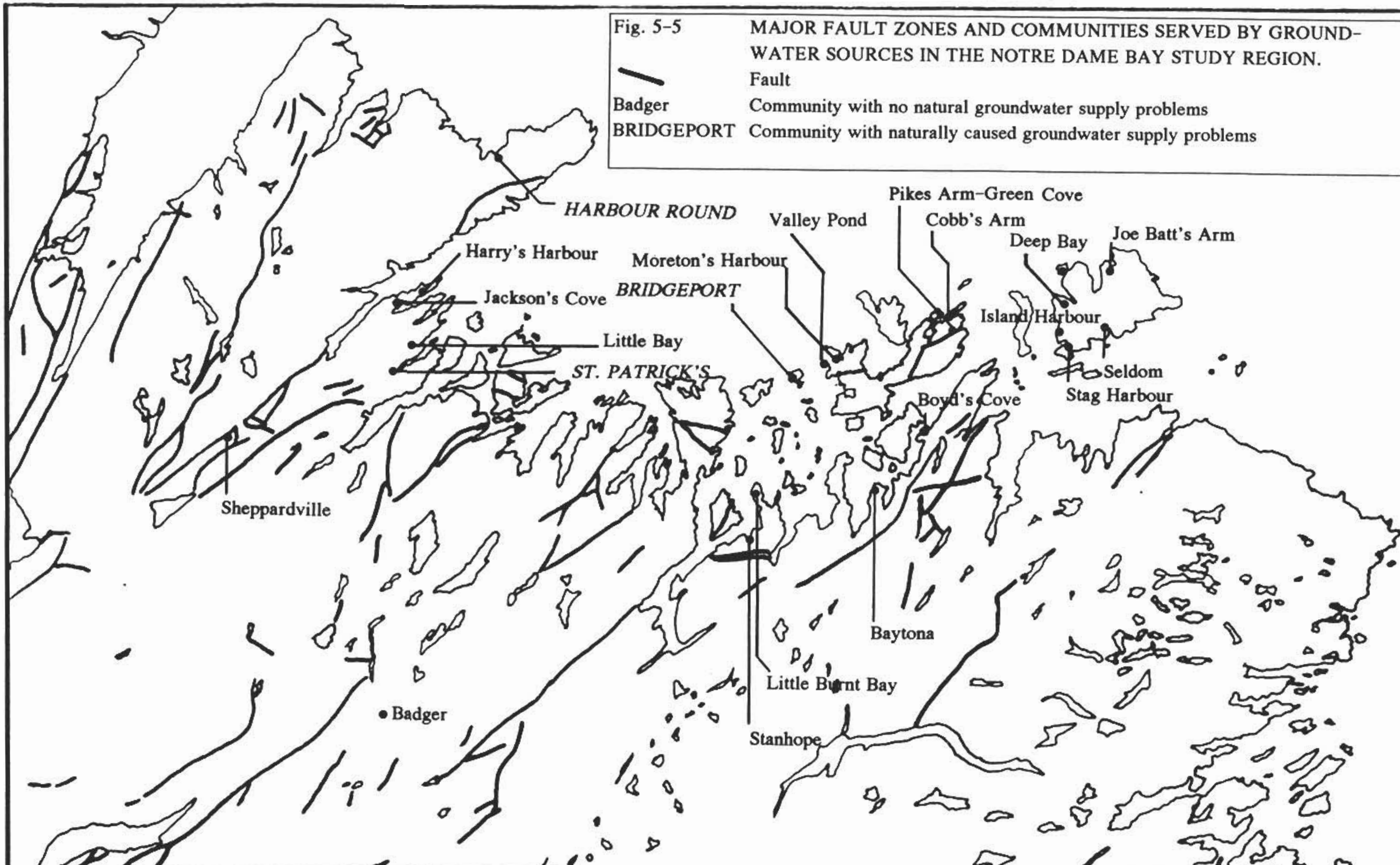


FIG. 5–5

DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA — CENTRAL NEWFOUNDLAND REGION.

Table 5-1 shows the average well yields for each of the three areas studied in the groundwater series reports 2-2, 2-3 and 2-5. These have been calculated using equation 5.1:

$$\bar{Y}=\frac{\sum_{i=1}^{n}\bar{W_i}\cdot w_i}{\sum_{i=1}^{n}w_i}$$

Where:

$\bar{Y}$	-	average well yield in L/min for an area
$\bar{W}$	-	the average well yield in L/min for a hydrogeologic unit in an area
w	-	the number of wells in a hydrogeologic unit of an area
n	-	the number of hydrogeologic units, with producing wells, in an area.

The average well yield for an area ($\bar{Y}$) is the average well yield for any of the columns in Table 5-2

A summary of the hydrogeologic units relevant to the study region, which have been identified in the groundwater series reports 2-2, 2-3 and 2-5, is presented in Table 5-2. We attempted to correlate the units between areas on the basis of the lithological descriptions given in these reports. The correlation of hydrogeologic units between areas conflicts with the usual method of describing hydrogeologic units solely on the basis of hydrogeologic characteristics (Walton 1970). Units not represented in the study region have been omitted from Table 5-2 and have not been used to calculate any well yield statistics.

Table 5-1

AREA AVERAGE WELL YIELDS
FOR THE THREE STUDY AREAS OF INTEREST

	Humber Valley	Notre Dame Bay	Bonavista Bay
Area average well yield	36.01 L/min	26.12 L/min	15.02 L/m
No. of wells surveyed	117	325	119

Bedrock Hydrogeologic Units

TABLE 5-2. HYDROGEOLOGIC UNITS AS OUTLINED IN THREE SEPARATE GROUNDWATER SERIES REPORTS. NOTATION FOLLOWS THAT USED IN THE REPORT SPECIFIED.

	Report 2-5: HUMBER VALLEY AREA				Report 2-2: NOTRE DAME BAY AREA				Report 2-3: BONAVISTA BAY AREA			
HGU-1	Unit 1 (Fleur de Lys Gp.)				Metamorphic Rock Units							
	Mod-High grade schist				NO DATA							
	Yield A/M:	10	6.8	L/min								
	# Wells:	10										
	Low yield:	0.3		L/min								
	Hi. yield:	54.6		L/min								
	Depth A/M:	40.5	40	m								
HGU-2a	Unit 2								HU-1			
	Shale and Phyllite								Meta volcanic and sedimentary rocks			
	Yield A/M:	36	22.7	L/min					Yield A/M:	5	-	L/min
	# Wells:	40							# Wells:	12		
	Low yield:	0		L/min					Low yield:	1.1		L/min
	Hi. yield:	145.5		L/min					Hi. yield:	22.7		L/min
	Depth A/M:	53	53	m					Depth A/M:	49.7	-	m
HGU-2b	Unit 4				RU-3				HU-2			
	Sedimentary units				Sedimentary rock unit				Meta sedimentary&sedimentary rocks			
	Yield A/M:	21.8	17.3	L/min	Yield A/M:	24.8	13.5	L/min	Yield A/M:	10.5	-	L/min
	# Wells:	23			# Wells:	165			# Wells:	69		
	Low yield:	0.5		L/min	Low yield:	-		L/min	Low yield:	0		L/min
	Hi. yield:	91		L/min	Hi. yield:	-		L/min	Hi. yield:	56.8		L/min
	Depth A/M:	34.5	34.5	m	Depth A/M:	43	-	m	Depth A/M:	48.4	-	m
HGU-3	Unit 5				RU-2				HU-3			
	Volcanics				Volcanics				Volcanics & rare sedimentary rocks			
	Yield A/M:	58.2	22.7	L/min	Yield A/M:	28.8	18	L/min	Yield A/M:	18.2	-	L/min
	# Wells:	36			# Wells:	135			# Wells:	69		
	Low yield:	1		L/min	Low yield:	-		L/min	Low yield:	0		L/min
	Hi. yield:	455		L/min	Hi. yield:	-		L/min	Hi. yield:	159.1		L/min
	Depth A/M:	53.5	46	m	Depth A/M:	45.7		m	Depth A/M:	44.5	-	m
HGU-4	Unit 6											
	Ophiolites											
	Yield A/M:	9.5	9.1	L/min								
	# Wells:	8										
	Low yield:	2.3		L/min								
	Hi. yield:	18		L/min								
	Depth A/M:	54	61	m								
HGU-5	Unit7				RU-1				HU-4			
	RU-1 of Notre Dame Bay				Plutonic Rock Unit				Plutonic igneous rocks			
	Area. NOT INCLUDED IN				Yield A/M:	20.3	9	L/min	Yield A/M:	26.4	-	L/min
	AREA AVERAGE.				# Wells:	25			# Wells:	38		
					Low yield:	-		L/min	Low yield:	6.8		L/min
					Hi. yield:	-		L/min	Hi. yield:	68.2		L/min
					Depth A/M:	42.1	-	m	Depth A/M:	60.4	-	m

A/M average/median
m=metres

wells refers to number used to derive yield figures
L/min=litres/minute

On the basis of the hydrogeologic units identified in the area groundwater surveys, five hydrogeologic units, HGU 1 through 5, are identified for the study region. The notation HGU is used to differentiate these regional units from hydrogeologic units defined in the area groundwater studies. A brief lithological description of each unit follows. For information on typical well yield in each area, please refer to Table 5-2.

HGU-1

HGU-1 is only identified in the Humber Valley and Notre Dame Bay areas. No wells have been reported drilled into this unit in the Notre Dame Bay area. HGU-1, which includes the Fleur de Lys group, is composed of metamorphic strata of schist to high grade quartzites. Shales and minor volcanic flows also occur in the Notre Dame Bay area. Well yields from 0.3 to 54.6 L/min are reported.

HGU-2a

HGU-2a consists of metamorphosed sedimentary (with some volcanic) rocks, generally of lower metamorphic grade than the rocks of HGU-1. HGU-2a is only differentiated in the Humber Valley and the Bonavista Bay areas. In the Humber Valley area, the unit consists of clastic sedimentary rocks including shale, phyllitic *shale, greywacke,* and sandstone with minor limestone and dolostone. In the eastern area, HGU-2 consists of metavolcanic and sedimentary rocks of the Love Cove, Adeyton and Harcourt Groups. Well yields vary from an average of 36 L/min in the west to 5.0 L/min in the east.

HGU-2b

HGU-2b, which is usually composed of sedimentary rocks, is represented in all areas of the region. In the west of the region, HGU-3 is composed of carboniferous strata of red bed sequences which may include mudstone, siltstone and indurated sandstone. In the central area, HGU-2b is comprised of mainly Ordovician to Silurian age sandstones, siltstones and conglomerates with minor volcanic flows. Some of the sedimentary units may be moderately metamorphosed. HGU-2b is represented in the eastern area as Pre-Cambrian and Ordovician sandstones, mudstone and chaotic melange. Average well yields decrease from 21.8 L/min in the west to 10.5 L/min in the east.

HGU-3

This unit has good aquifer potential. Though hydrogeologic units in some areas may have higher well yields, possibly due to the proximity of faults, HGU-3 has the highest aquifer potential of any of the five regional bedrock hydrogeologic units. It is composed of volcanic rocks with sedimentary formations (of minor importance) in the eastern area. Well yields vary from an average of 58.2 L/min in the west to 18.2 L/min in the east.

HGU-4

This unit is only represented on the Burlington Peninsula and consists of mafic and ultramafic intrusions of ophiolite complexes. Well yields from this unit are generally poor, averaging 9.1 L/min.

HGU-5

HGU-5 is only differentiated in the central and eastern areas of Notre Dame Bay and Bonavista Bay. The unit is chiefly granitic but includes diabase and diorite intrusions. In the west of the region, it underlies part of the Burlington Peninsula and most of the Topsails. This unit occurs sporadically throughout the region east of the Green Bay Fault. Average well yields from HGU-5 vary from 20.3 to 26.4 L/min.

5.3 Groundwater Use and Groundwater Problems

Groundwater use has been reviewed on the basis of the three existing groundwater studies and the fieldwork conducted for this regional study. It should be noted that this section of the report concentrates on community supply systems, but many homes are adequately supplied by dug and drilled wells. Though groundwater supply systems in the study area can provide water of sufficient quantity and quality for domestic use, they frequently do not have adequate yield to provide sufficient water for industry or fire services. Inadequate water supply for fire fighting services results in increased community insurance rates. Some community leaders believe that the cost of installing a surface supply may be offset by reduced insurance rates.

5.3.1 Community Survey

A list of the communities that have groundwater supply systems, including a brief summary of readily available information, is presented in Table 5-3. Groundwater supply problems reported by many communities are attributable to problems with the pumping and distribution systems rather than a hydrogeologic deficiency. In general these problems could be rectified by funds and/ or expertise.

TABLE 5-3. COMMUNITIES REPORTING GROUNDWATER SUPPLY FOR THE NOTRE DAME BAY REGION.

NOTRE DAME BAY AREA.

COMMUNITY	AQUIFER TYPE	REPORTED PROBLEMS	COMMENTS
Badger	Sand and Gravel	NO	100% serviced by well field.
Baytona	Plutonic	NO	~50% of home owners have private drilled wells
Boyd's Cove	Sedimentary	NO	100% serviced by private wells
Bridgeport	Volcanic	YES	15 private wells, surface source provides only seasonal supply
Cobb's Arm	Sedimentary	MECH	3 wells, pumps failed funding unavailable to replace
Harry's Harbour	Volcanic	NO	100% community serviced by three wells
Jackson's Cove	Volcanic	NO	95% of community serviced by two wells
Little Bay	Volcanic	NO	~75% serviced by one well. Remainder use dug wells
Little Burnt Bay	Sedimentary	NO	1 pumphouse, potable water by buckets
Moreton's Harbour	Volcanic	MECH	3 community wells never used as water supply. 6-7 private wells.
Pikes Arm-Green Cove	Sedimentary	NO	4 Govt. wells abandoned. 1 in use w/ hand pump. ~50% of homes have private drilled wells. ~50% dug wells.
St. Patrick's	Volcanic	YES	~65% of community serviced by community well, residents at higher altitudes have poor supply at peak periods. Remainder private wells
Sheppardville	Volcanic	NO	100% of community served by one well
Stanhope	Volcanic	NO	~80-90% serviced by one well
Valley Pond	Volcanic	MECH	4 community wells, 2 dry, 2 serve only four families

BONAVISTA BAY AREA

COMMUNITY	AQUIFER TYPE	REPORTED PROBLEMS	COMMENTS
Deep Bay	Plutonic	NO	2 Government wells went foul. 90% of homes have drilled wells
Island Harbour	Sedimentary	NO	2-3 Govt wells went dry 10 private wells in community
Joe Batt's Arm	Plutonic	NO	4 govt. wells w/ hand pumps supply drinking water for community.
Seldom	Plutonic	NO	Majority of families have drilled wells. 2 community wells exist for potable H_2O.
Stag Harbour	Plutonic	NO	2 Government drilled wells, one still used. ~75% of homes have private drilled wells
HUMBER VALLEY AREA			
Harbour Round	Volcanic	YES	~65% of wells have high Fe. Water cannot be used for drinking or washing clothes.

MECH indicates mechanical supply problem

Several hydrogeologic units act as aquifers to the listed communities; however only three appear to be reliable aquifers;

(1) sand and gravel units
(2) volcanic units
(3) plutonic units.

Aquifers of sedimentary rock are relatively scarce and where they are used the water supply is variable in quantity and quality. Any unit that is expected to act as an aquifer must also be located in a favourable hydrogeologic setting and be of sufficient size.

Of the 105 communities in the regional inventory, 20% (21) derive a large portion of their water supply from wells. Their locations are shown on Figure 5-5. This percentage of communities depending upon groundwater as their water source is the same as that reported by Meyboom (1968), for municipal and rural groundwater use in Canada, but more than the 10% quoted by Environment Canada (1988) for the province of Newfoundland. The figure for percentage use of groundwater in the Notre Dame Bay region was derived solely on the basis of the number of communities using groundwater supplies, compared with the total number of communities inventoried. It does not take into account figures for well yields, population or the many domestic wells.

Several problems have been reported by communities that are served by groundwater. The identified problems relate to both quantity and quality, and mechanical problems associated with groundwater supply systems (see Table 5-3). These two cases are distinguished in Figure 5-5. Some of the communities listed as having a groundwater supply problem may have found an alternative water source (often dug wells); nevertheless, the community system has failed. A synopsis of the communities listed in Table 5-3 as having water supply problems is presented below:

Bridgeport

A surface source of water provides only a seasonal water supply. Fifteen private wells, possibly supplemented by dug wells, provide a year-round water supply.

Cobb's Arm

Three drilled wells have fallen into disrepair as a result of the pumps failing.

Moreton's Harbour

Three community wells were drilled but have never been linked to a community system. There are 6-7 private wells in the community.

St.Patrick's

Sixty-five percent of the community is served by a community well. Houses at higher altitudes suffer from supply problems during peak periods.

Valley Pond

Four community wells have been drilled, two of which are dry. The remaining two wells supply only four families.

Harbour Round

Sixty-five percent of the wells in Harbour Round produce water with iron concentrations that render the water unfit either for drinking or washing clothes.

Badger, though not listed as having a groundwater supply problem, has had water quality problems in the past. Heavy iron flocs were noted when two new high flow wells were brought on stream in 1988. As a result of the iron contamination, the wells were subsequently abandoned (Nolan, Davis & Associates, 1989). In general, all other water quality parameters meet Canadian Water Quality Guidelines, except for manganese and sporadic occurrences of already-mentioned iron and sodium and zinc. A detailed description of the water supply system at Badger, and past problems, is given separately in Section 5.3.2 below.

5.3.2 Community Groundwater Supply at Badger

In 1988 Badger was chosen for study by the Newfoundland Department of Environment and Lands (NDOEL). The purposes of the study were to address supply difficulties, determine the hydrogeology of the well field, the resource capabilities, current and future demands, and to develop a long-term protection and management strategy.

The Town of Badger (population 1,150) has been supplied since 1967 by groundwater extracted from a well field located at the south end of the town. This well field consisted initially of nine screened wells within a relatively thin (5 to 6 m) sand and gravel deposit. The combined initial extraction rate was in the order of 850 to 900 litres per minute.

Prior to 1985 the system operated automatically and was essentially maintenance-free. However, during the following four years, water shortages and associated low operating pressures occurred on several occasions. Given a constant population, and therefore demand, it was assumed that the source of recharge to the aquifer had been adversely affected. Additional drilling was conducted in 1988 to identify an additional source of supply. In addition, a water meter was installed and a leak survey was performed throughout the distribution system.

Two new high-producing wells were subsequently drilled and brought on-line. Although initially the water was potable, the quality declined after one month of pumping due to heavy iron flocs. As a result, the wells were taken off-stream.

The leak survey indicated that leakage throughout the distribution system accounted for roughly half the Town's consumption. The depressed pumping levels were, therefore, more appropriately attributable to excessive pumping required to meet the combined domestic and leakage demand. A program to repair the distribution system has been undertaken.

5.4 Conclusions

With the exceptions of Badger and Shepardville, all of the communities that depend on groundwater supply are located on the coast. Not surprisingly, brackish well water is a common problem. Saltwater intrusion problems could possibly be alleviated if stricter controls were placed on drilling wells in coastal aquifers, and if basin studies were conducted to determine the safe yield of the coastal aquifers.

A disproportionate number of water supply problems also appears to occur in wells tapping sedimentary aquifers. This apparent correlation warrants further study.

Maintenance problems with community wells are quite common. Many of the communities identified in the three groundwater series reports as having private wells, and/or community wells, have subsequently installed surface supplies to provide water for the entire community.

5.5 References - Section 5.0

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SECTION 6.0

INSTREAM BENEFICIAL USES

6.0 INSTREAM BENEFICIAL USES

6.1 Introduction

The instream uses which are important in the study area are hydroelectric production; recreation and tourism; the freshwater fishery, which has a recreational and commercial component; and pollutant disposal.

Each of these uses is discussed in this section. Values for each use are estimated. Potential conflicts between them are also discussed.

6.2 Hydroelectric Power and Energy Production

6.2.1 Existing Hydro Plants

There are six hydro plants currently operating in Central:

Venam's Bight	(Newfoundland Hydro)
Snook's Arm	(Newfoundland Hydro)
Rattling Brook	(Newfoundland Light & Power)
Sandy Brook	(Newfoundland Light & Power)
Grand Falls	(Abitibi-Price)
Bishop's Falls	(Abitibi-Price)

A listing of information provided by plant owners about these hydroelectric plants is given in Tables 6-1 and 6-2. The plant locations and tributary basins are shown on Figure 6-1.

Figure 4-3 of the Atlantic Development Board study (1968) shows two plants which are no longer in operation -- the Buchans plant at Buchans (1758 KW), and the Star Lake plant above Red Indian Lake (26 075 KW).

Table 6-1

Hydro Plants in Study Area

Name	Source of Supply	Owner	Date in Service
Venam's Bight	Long Pond[1]	NF & Lab. Hydro	1957
Snook's Arm	East Pond[1]	NF & Lab. Hydro	1957
Rattling Brook	Rattling Brook	NF Light & Power	1963
Sandy Brook	Sandy Brook	NF Light & Power	1958
Grand Falls	Exploits River	Abitibi-Price	1909
Bishop's Falls	Exploits River	Abitibi-Price	1909/ 1953*

* 1909 - Bishop's Falls started up as a pulp plant
1953 - Bishop's Falls converted to a generating station

1 Streams are unnamed on 1:50,000 topo sheets

Table 6-2

CHARACTERISTICS OF EXISTING HYDROPOWER STATIONS

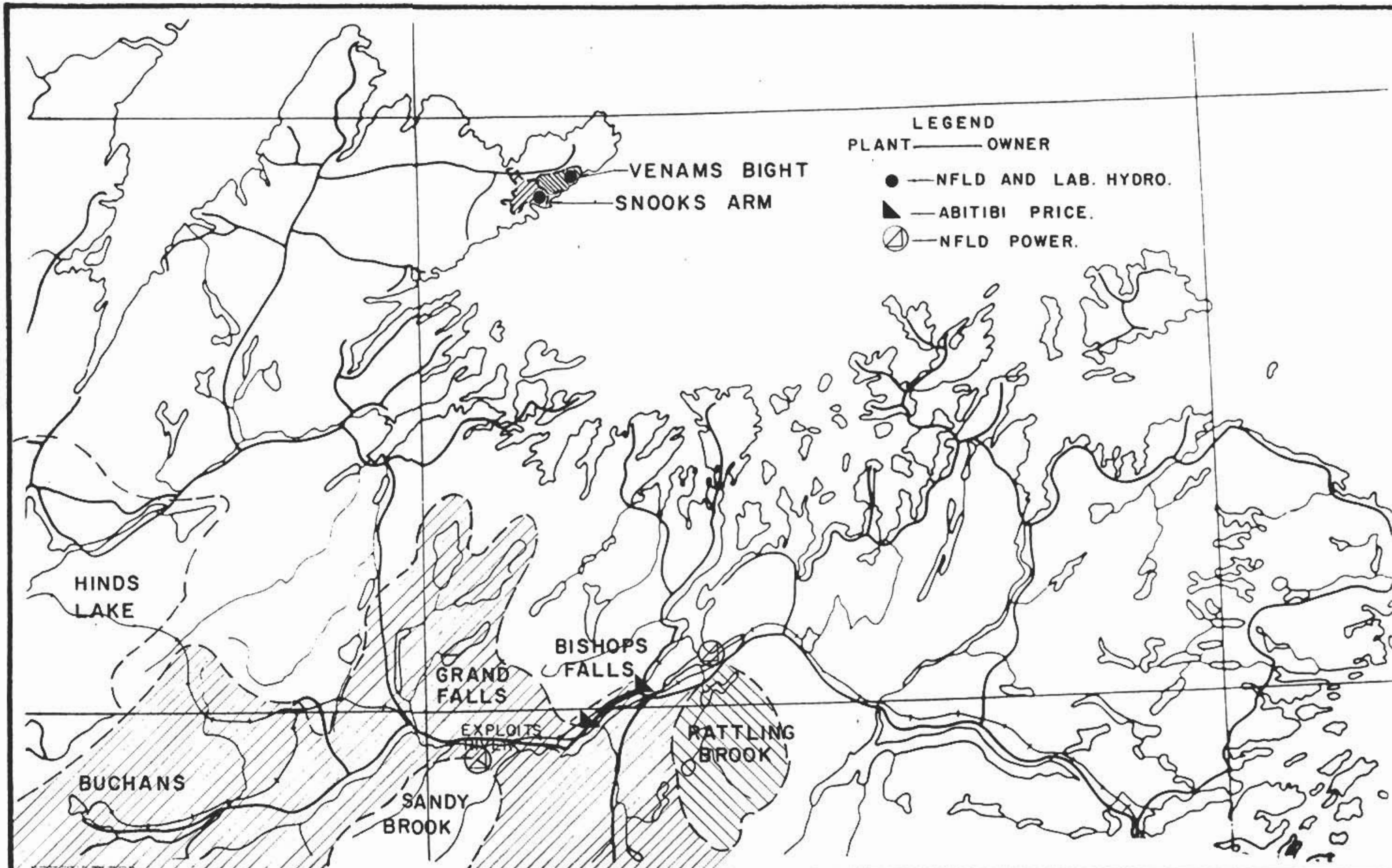
	Venam's Bight	Snooks Arm	Rattling Brook	Sandy Brook	Grand Falls	Bishop's Falls
Capacity (KW)	343	567	11,500	5,700	45,000	13,000
Average Annual Energy Production (GWh)	(5 firm) (7 ave.) (both plants combined)		71.7	25.9	315	90
Average Annual Production (barrels of oil equivalent)	(8,300 firm) (11,700 ave.)		119,500	43,170	525,000	150,000
Head (m)	82	82.9	93.6	33.5	39	10
Rated Flow (m^3/s)	0.52[1]	0.86[1]	15.1	21.5	213	213
Annual Average Spill (GWh)	not available	not available	7.0	7.7	not available	not available
Drainage Area (km^2)	18[2]	29[2]	379	506	8,363	10,103
Annual Water Charges ($)	none	none	6,340	0	0	0

----

1 estimated

2 measured from 1:50,000 topo map

SOURCES: Plant Owners; Statistics Canada



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HYDROELECTRIC DEVELOPMENTS IN STUDY AREA

FIG. 6-1

Other relevant information on existing plants is given below.

Rattling Brook Plant

A summary of Newfoundland Power's experience with maintenance and upgrading of its small hydro plants is given in an internal report by A.W. Greeley (1988), which includes a two-page review of the Rattling Brook plant. The plant was commissioned in 1958 to serve an area unconnected to the grid, so reliability was a factor. Two units rated at 6375 KW were installed on a single 2130 mm penstock, with one being intended as a backup. When the area was connected to the grid in 1966, the layout became inefficient. Runners were replaced in 1986-1987, which improved efficiency 3 to 4%; however, it was decided that replacement of the now-undersized penstock was not economic.

Rattling Brook and Sandy Brook

Newfoundland & Labrador Hydro (NLH) noted (pers. comm.) that its plants are old and few data about them are available; however, Hydro is planning to conduct discharage measurements this year. These plants originally served mining operations and were taken over by Hydro when the mines closed.

Abitibi-Price Inc.

Abitibi-Price has two hydro plants on the Exploits River to serve its pulp mill. Located at Grand Falls and Bishop's Falls (see Figure 6-1), these are, by far, the largest hydro plants in Central.

The plants are quite old, having been built in 1909 (Bishop's Falls was converted to a generating station in 1953).

The power is used by Abitibi-Price. The basis for the use is a 99-year lease which expires in 2004. Abitibi is not charged for the water used. Since the plants are now quite old, the energy is available to Abitibi at a very low cost, which presumably enhances the competitiveness of the Grand Falls operation. Conversely, there was no incentive to modernize or upgrade beyond the mill's demand, so the site was likely underdeveloped for some time as energy prices rose. Fortunately, the proposed Green Wood project would correct that situation.

6.2.2 New Developments

Newfoundland Power

In a letter of February 12, 1991, Newfoundland Power stated that it is not planning to develop any new hydro projects in the study region.

Newfoundland and Labrador Hydro

Newfoundland & Labrador Hydro (fax, 1991) said that its next preferred projects are in Baie d'Espoir and Labrador. No new projects in Central are being planned.

Abitibi-Price -- Green Wood Project

Abitibi-Price, which has rights to the Exploits River basin until 2004, has proposed a substantial upgrade to its Grand Falls hydroelectric site, which has been named the Green Wood project. As further details are provided in the environmental assessment registration (Abitibi-Price, 1990), only a brief review is given herein.

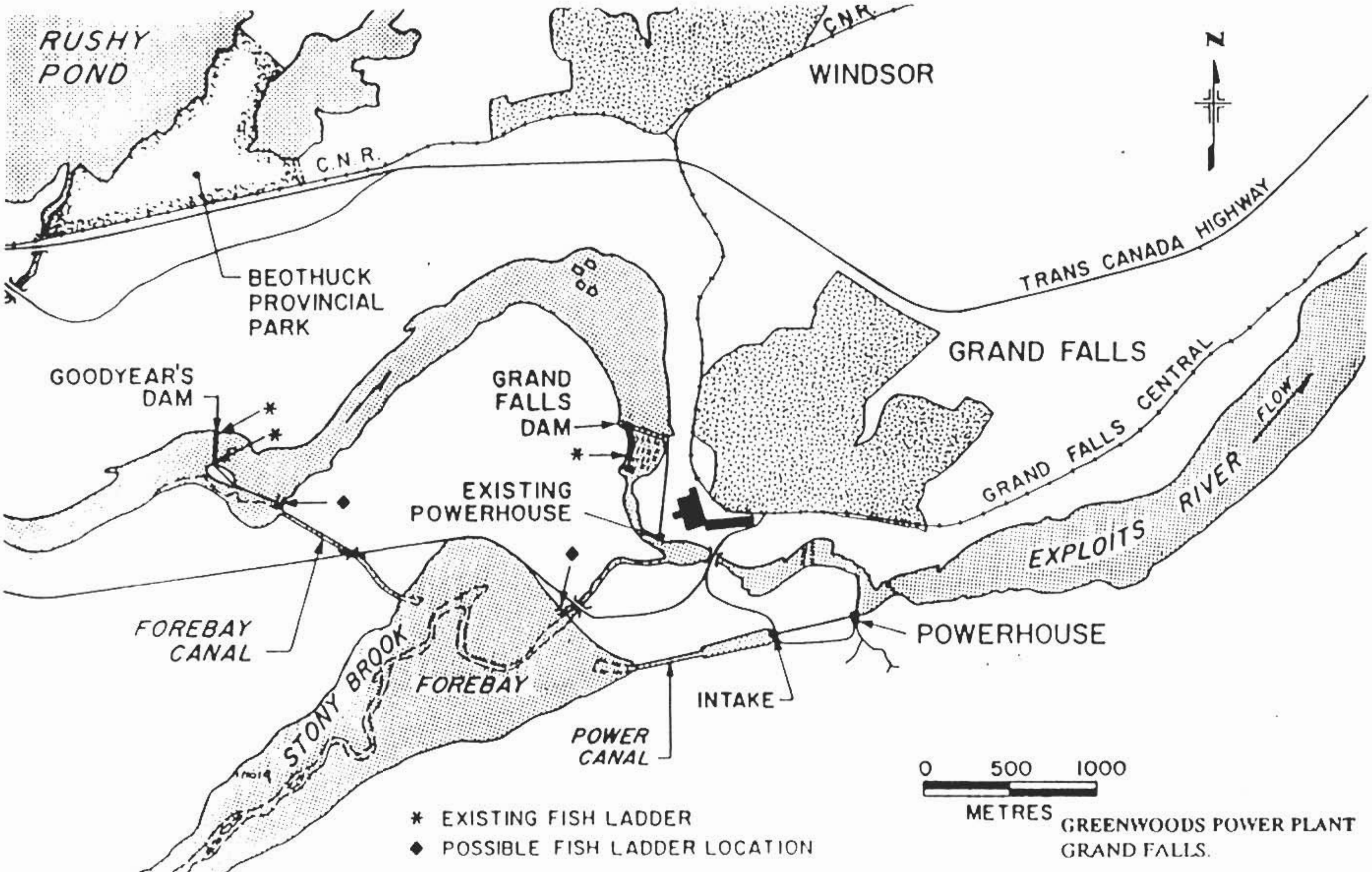
According to the registration, the existing plant at Grand Falls has eight units (1 @ 26 MW, 4 @ 4 MW, and 3 @ 1.5 MW) using a gross head of 33 m and a rated flow of 170 m^3/s. The Green Wood project would utilize the entire available gross head of 51 m (a 17.7 m, or 74%, increase over the existing plant), have a rated flow of 190 m^3/s, and produce about 510 GWh more energy per year. Flow in excess of plant capacity would be passed through the existing plant, so that no spills should occur.

The figure provided in the registration which illustrates the plant layout, as well as that of the proposed Green Wood plant, is reproduced herein as Figure 6-2. [This figure was prepared for the registration by Acres International.]

The upstream basin has 1480 MCM of live storage. This is shown on Figure 6-3, which is also taken from the registration. [This figure was also prepared by Acres.] A better illustration of the hydraulic developments in the Exploits River basin is Figure 4-3 of the Atlantic Development Board study (1968).

The major storage is provided by Red Indian Lake reservoir. This is typically drawn down to its lowest level (144.3 m) before spring melt and subsequently rises to 153.3 - 153.6 m, for a live head of 9.0 - 11.3 m. Despite the considerable storage, substantial spill still occurs. This is illustrated on Figures 6-4 and 6-5 (also from the registration) for 1988 (a typical year) and 1987 (a drought year). The 1988 figure shows a substantial spill during the spring runoff period. Large spills even occurred in 1987.

Modifications to the control structure on Red Indian Lake would permit the reservoir to be drawn down to El. 143.3 m, providing an additional 1.0 m of live head. This, in turn, would give an additional 468 MCM of live storage.



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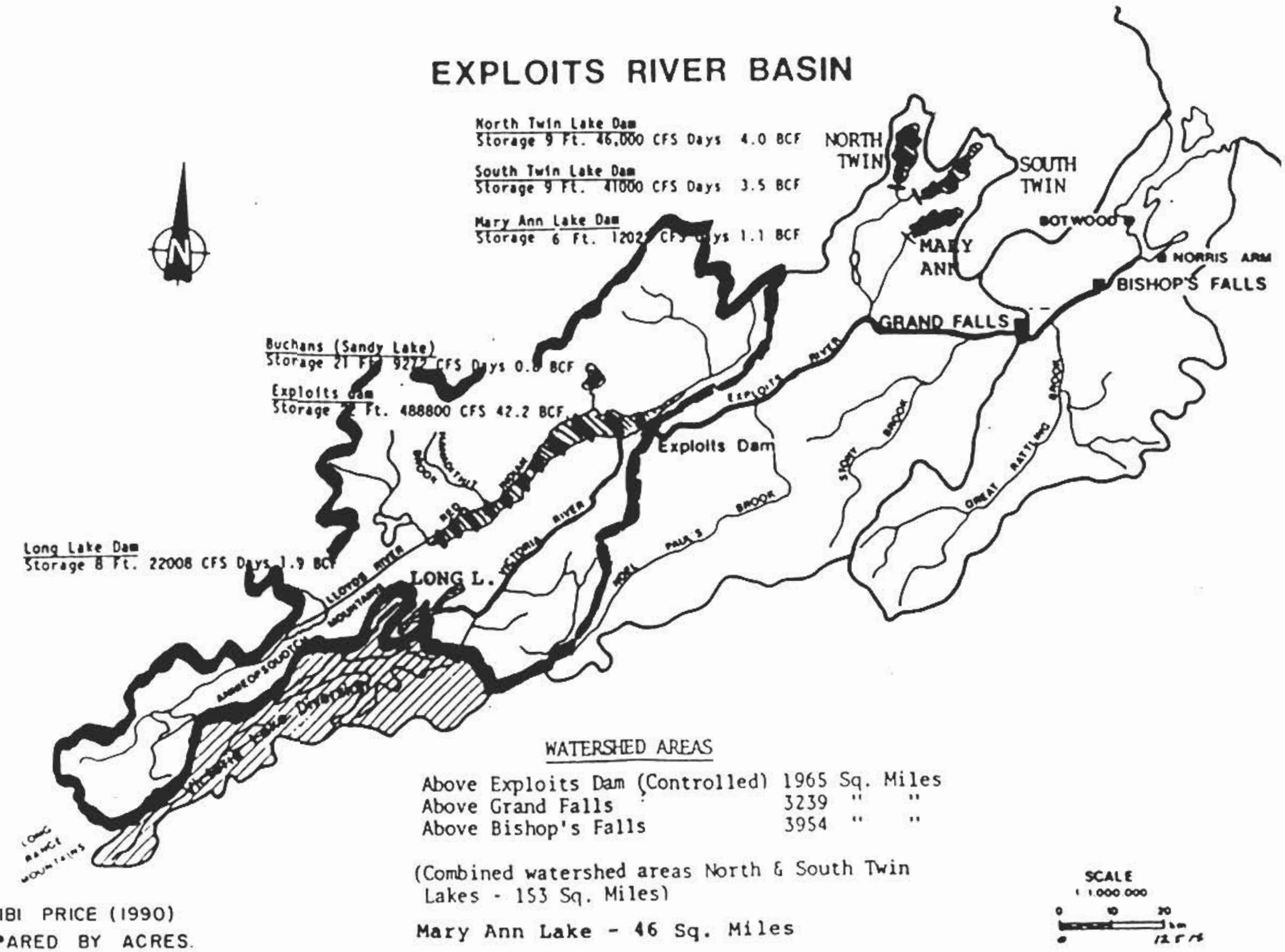
PROPOSED GREEN WOOD POWER PROJECT FIG.6-2

SOURCE: (ABITIBI PRICE (1990); PREPARED BY ACRES.



SOURCE: ABITIBI PRICE (1990)
PREPARED BY ACRES.

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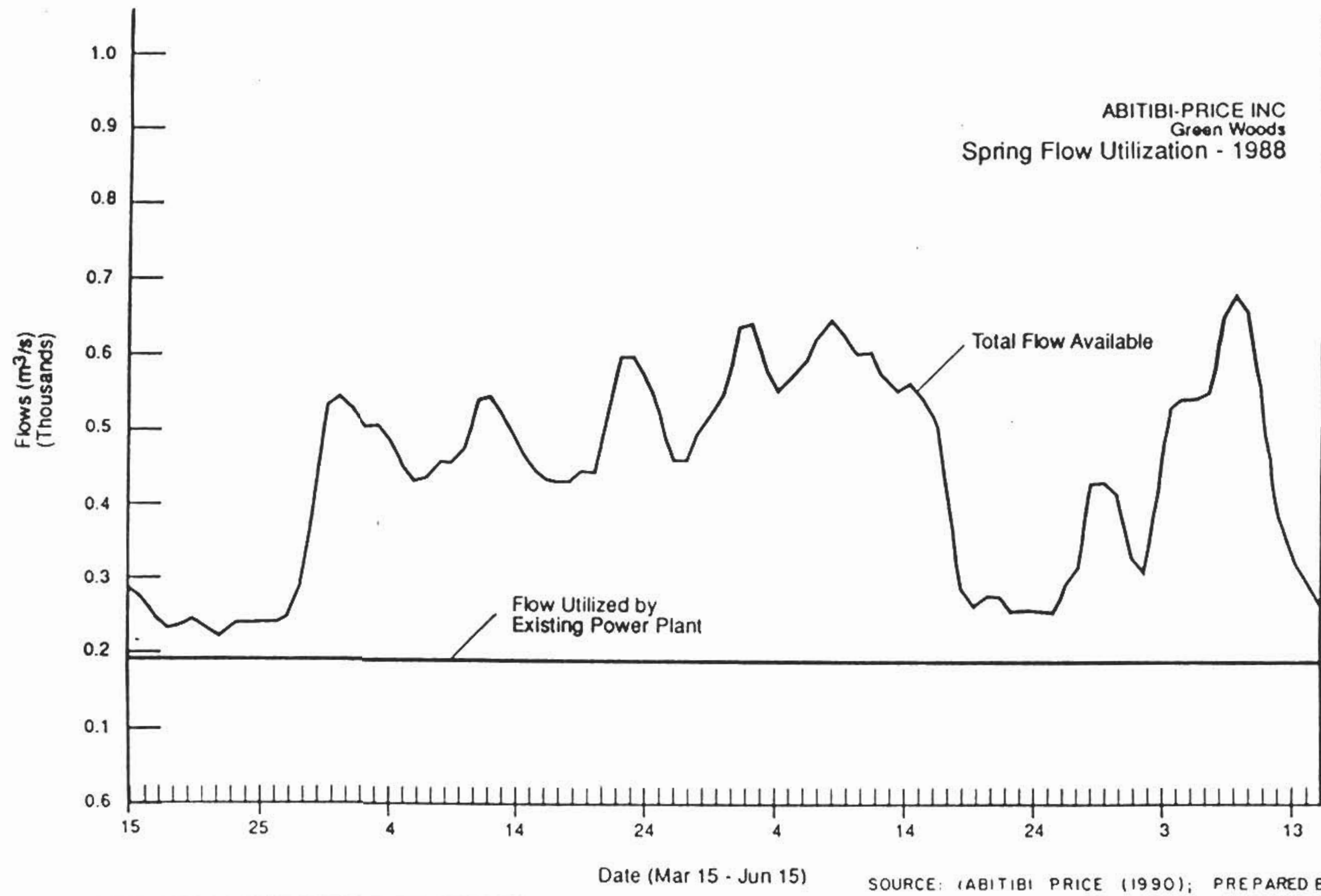
HYDRAULIC CONTROLS IN STUDY AREA

FIG.6-3



SOURCE: (ABITIBI PRICE (1990); PREPARED BY ACRES.

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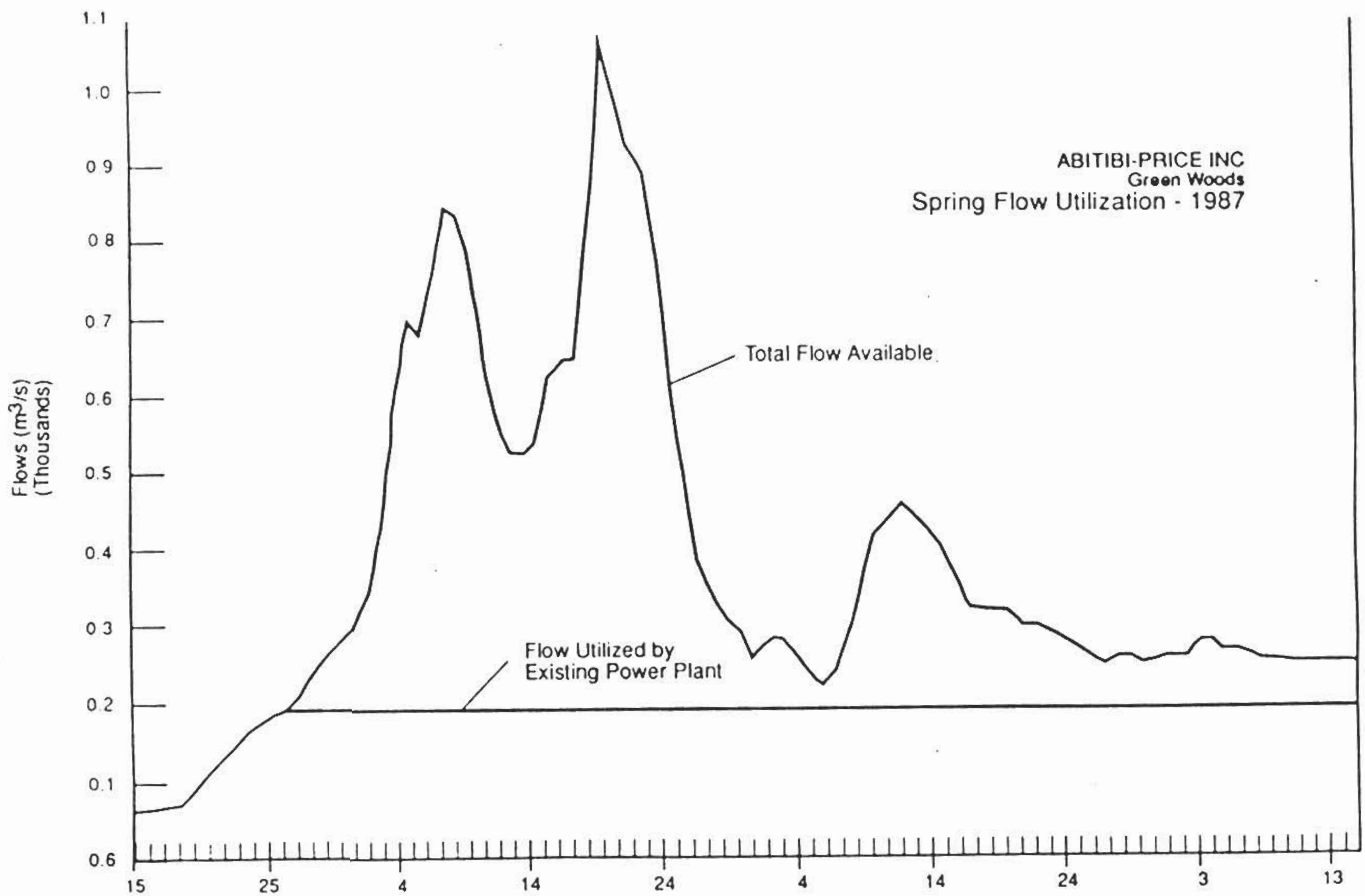
SPRING FLOW UTILIZATION BY GRAND FALLS G.S. 1988

FIG. 6-4



SOURCE: ABITIBI PRICE (1990)
PREPARED BY ACRES.

SOURCE: (ABITIBI PRICE (1990); PREPARED BY ACRES.

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SPRING FLOW UTILIZATION BY GRAND FALLS G.S. — 1987

FIG.6-5

The additional live storage should permit more constant downstream flows, thereby permitting better pollution attenuation, navigation, temperature control, and fish passage. The effects upon the receiving estuary are not known.

6.2.3 Other New Hydro

We reviewed the surveys of potential hydro sites (NLH, 1987, ShawMont, 1986) at the Department of Mines and Energy library. None of the highest-rated sites was located in the study region. Neither Newfoundland Light & Power, nor Newfoundland & Labrador Hydro, plans to install additional capacity in Central for the foreseeable future. There are no obvious sites for diesel replacement for the diesel-supplied communities in the study area (Little Bay Islands and Purbeck/Westport).

6.2.4 Value of Water for Hydro Power

An estimate is given of the value of water for hydro power and energy in the study region. To be consistent with other beneficial uses, we prefer a method using market-based final prices to the extent possible; and estimating gross value rather than net, since the latter depends upon the application to which the energy is put.

It needs to be borne in mind that economic analyses do not yield a "correct" answer, as engineering ones often do. The value of hydro energy depends upon the marginal costs of the next alternative to the purchaser, or the next production method to the producer. In an imperfect market, these can be quite different between producers and between consumers. For instance, Abitibi-Price can purchase energy at special industrial rates, so its marginal value is lower than that of less favoured industrial or domestic consumers. Newfoundland Hydro's marginal production alternative is burning oil at Holyrood; however, the cost for new hydro capacity at the margin is much higher. Thus an imputed value must rest upon an assumed economic scenario with attendant assumptions. Several appropriate ones are listed below.

<u>Abitibi-Price</u>

Abitibi-Price currently pays no fee for its considerable generating capacity under the terms of its lease. Its plant is probably fully depreciated, so that its costs of production are largely operating and maiantenance and, thus, very low. Use of costs to impute a value for the hydropower would be inappropriate.

Should the plant cease to function, or should it lose access to the resource if its lease were cancelled, Abitibi-Price would have to purchase the power it currently generates. According to Newfoundland Hydro, for <u>new</u> commercial contracts, Hydro charges $8.25/KW per year for power plus 25.36 mills/KWh for energy plus special allocation charges where applicable (eg. for hookup). Using this standard commercial price, the avoided cost to Abitibi is:

Power	58,000 KW * $ 8.25/KW-yr =	$ 478,500/yr	(6-1)
Energy	405 GWh/yr*25.36 mills/KWh =	10,270,800/yr	(6-2)
Sum		$10,749,300/yr	(6-3)

However, Abitibi-Price's purchases from Hydro are governed by several contracts, including an Industrial Incentive contract, which provide better rates. (It even receives some energy for free, as compensation for diversion of some Exploits River headwaters to the Baie d'Espoir project.) Thus the value of the hydropower and energy to Abitibi-Price is less than $10.75 million, but use of a subsidized value to impute an opportunity cost would be inappropriate.

Newfoundland & Labrador Hydro

From Newfoundland Hydro's perspective, two scenarios are possible. First, should Hydro acquire the existing Abitibi-Price generating station at its depreciated value, and then sell the energy to Abitibi at the standard commercial rate, then Hydro would be better off by the $10.75 million (see equation 6-3).

Should Hydro sell the energy at a typical retail rate of $0.06/KWh, it would have a value of

$$405 \text{ GWh/yr} * 60 \text{ mills/KWh} = \$24.3 \text{ million/yr} \qquad (6\text{-}4)$$

Thus, Hydro would be better off selling the energy at retail rates. The $14.0 million discrepancy between equations (6-4) and (6-3) indicates that the general commercial rate represents a subsidy (even allowing for lower distribution costs), and thus is inappropriate for estimation of an opportunity cost.

A third way of approaching the issue is to assume that Hydro's avoided cost is generation of the Abitibi energy by burning oil at Holyrood. This will be the case until demand reaches existing capacity on the Island. Hydro estimates the cost of generation at Holyrood to be:

$$\frac{\$US20}{\text{barrel of oil}} * \frac{\$C}{\$.85US} / (605 \text{ KWh/barrel}) + 2 \text{ mills/KWh cost} \qquad (6\text{-}5)$$

$$= 40.89 \text{ mills/KWh} \qquad (6\text{-}6)$$

If the costs of generating electrical energy at Grand Falls and Bishop's Falls are assumed to be negligible, then the marginal avoided cost for 405 GWh/year is $16,561,094/year. If Hydro were to spend 40.89 mills to generate the energy at Holyrood, and then sell it to Abitibi at an industrial rate of 25.36 mills plus power charge, then its net avoided cost would be -$5,811,794.

If the alternative to NLH were to replace the energy generated at the Abitibi plants with "new" hydro, then the marginal cost would be that of recent hydro projects. This falls in the $0.11-$0.13/KWh range for Cats Arm and Paradise River. The cost of delivering new Labrador power to the Island should be lower, but is not known at present.

In summary, the value of the hydropower generated depends upon the avoided marginal costs of the producer and consumer. In an imperfect market, these are not equal.

A summary of the several "models" discussed above for the use of the Abitibi plants at Grand Falls and Windsor is given in Table 6-3.

Since energy is linked through the grid and is indistinguishable with respect to the costs and method of production, an imputed value should be based upon the highest marginal market price, which is estimated to be $0.06/KWh on the basis of current retail rates. An estimate of the gross value of water for energy in Central is thus:

Venam's Bight & Snook's Arm	7.0 GWh/yr		$ 420,000/year
Rattling Brook	71.7 GWh/yr		4,302,000/year
Sandy Brook	25.9 GWh/yr		1,813,000/year
Grand Falls	315.0 GWh/yr		18,900,000/year
Bishop's Falls	90.0 GWh/yr		5,400,000/year
		Total Existing:	$30,835,000/year
Green Wood	510.0 GWh/yr		30,600,000/year
Less 90% existing Grand Falls	283.5 GWh/yr		17,010,000/year
		Total Existing and Proposed:	$44,425,000/year

Table 6-3

Economic Value of Hydro Energy and Power at Grand Falls and Bishop's Falls

Model	Perspective	Cost/Price	Rate mills-KW	Value $M/yr
1	Abitibi-Price	Avoided Commercial	25.36 mills $ 8.25/KW	$10.75
2	NLH	Commercial	25.36 $ 8.25/KW	10.75
3	NLH	Retail	60	24.3
4	NLH	Generate at Holyrood	40.89	16.56
5	NLH	Generate at Holyrood, sell at commercial	40.89 - 25.36 + $ 8.25/KW +	- 5.81
6	NLH	Generate at Holyrood, sell at retail	40.89 - 60 +	7.74
7	NLH	Replace with new hydro	120 -	- 48.6
8	NLH	Replace with new hydro, sell at commercial	120 - 25.36 + $ 8.25/KW +	- 37.9

NOTE:

For Models 1, 2, 3, 4, and 7, it is assumed that the Abitibi-Price plants are fully depreciated and that O & M costs are negligible.

6.2.5 Some Suggestions Relating to Hydro

1. The Water Resources Division should re-examine the appropriateness of payments to the Province for hydro water rights in light of current retail prices; (it is suggested that inappropriately-low fees do not encourage modernization). The current water charges essentially provide substantial subsidies to Abitibi-Price, Newfoundland Power, and NLH. These subsidies do not appear to have been reinvested in the hydro plant sites.

2. The Division should assess older depreciated small hydro plants to ascertain if their efficiencies and outputs can be economically improved.

3. The Water Resources Division should intervene actively in the Green Wood EIS to ensure maximum returns are obtained from the water allocations.

   While the grant of water resources of the Exploits River basin to Abitibi-Price will not expire until 2004, it is effectively almost expired since the amortization and physical life of the Green Wood project will extend well beyond the expiration date. The Division should have an opportunity to regain control of the water resources of the Exploits River basin as part of the Green Wood project.

   Clearly, the issue of extending the lease will have to be resolved before the Green Wood project can proceed. The Division will have to decide whether Abitibi should continue to use the water resource on such favourable terms in the future.

The Green Wood project is currently under environmental assessment. DFO wishes to have some water allocated for salmon passage, which will reduce the energy benefits. The major conflict will be between the hydro development and the Upper Exploits River salmon enhancement project. The salmon project involves colonization, so that there is no history of prior use of the water for salmon spawning. Clearly the allocation of water between them should be based on relative economic returns. The economics of the enhancement project are discussed in some detail in Sections 6.4.3 and 6.4.4. It is concluded there that a reanalysis and updating of DFO's project economics is in order before an allocation decision is made.

The salmon issue notwithstanding, Green Wood appears to be a good project if the economics pan out. The latter depend on Abitibi's demand and avoided retail costs, as well as the price for energy produced in excess of Abitibi's needs. As Abitibi is seeking cofinancing for the project, it would be appropriate for Newfoundland Hydro to justify not participating in developing this resource.

In summary, except for the large plants on the Exploits River, the Central region has a relatively small portion of the Island's hydro resources and potential. Nevertheless, all of the plants in the region are old and have not been significantly renovated. The water use charges paid by the owners of the plants do not appear to provide the Province with a reasonable rate of return for the water resources allocated and used by them, nor encourage modernization of the plants.

6.3 Recreation and Tourism (except fishing)

6.3.1 Provincial Parks

Most organized water-based recreational tourism likely occurs in the 11 provincial parks in the Central/Notre Dame Bay region, 10 of which have a water body as a feature attraction (see Table 6-4). A map showing their locations is presented as Figure 6-6.

6.3.1.1 Analysis of Park Use

Park use by visitors for recreation is only one of the mandates of the Parks Division; nevertheless, it is the easiest to quantify. Overall, use of provincial parks peaked in 1977 with 2,985,312 visitors. Camping use peaked in 1979 at 497,032 camper nights. Use declined in the mid-eighties, after which it has been increasing slowly. This temporal change appears to reflect a fashion as Newfoundland followed a national trend. In 1989, the last year for which data are available, the peak use was 1,596,202 visitors (down 47% from 1977, but up 9% from the low of 1985), and 428,072 camper nights (down 14% from 1979, but up 50% from 1985). With such volatility, it appears that the system has gone through a growth and decline cycle and is now in an intermediate recovery mode. As camping constitutes an inexpensive vacation, it might be expected to be countercyclical; however, use appears to follow the business cycle with a time lag. At any rate, the demand for the water resource for provincial park recreation is unlikely to exceed past peak levels for some time. The Department of Environment & Lands has no plans to build new recreation-oriented parks in the Province.

Statistics on total visitors to the parks in the study region for 1989 and 1985 are given in Table 6-5. Nineteen eighty-

Table 6-4

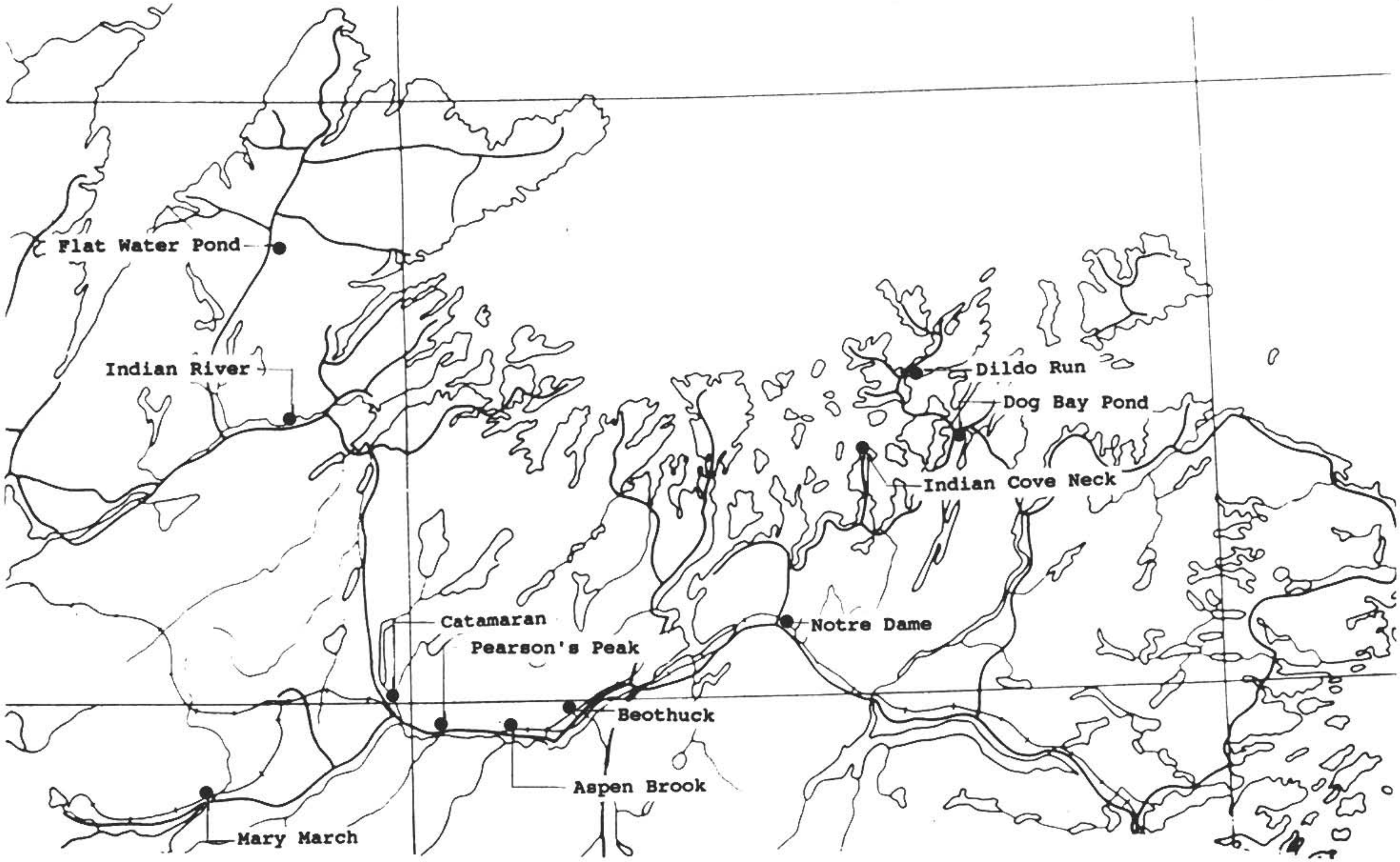
Provincial Parks in the Central/Notre Dame Bay Region

	Type	Park	Water Recreation	Water Body
1. Flat Water Pond	1	28	yes	Flat Water Pond
2. Indian River	1	29	no	Indian River
3. Catamaran	2	30	yes	Joe's Lake
4. Aspen Brook	3	32	no	Aspen Brook
5. Pearson's Peak	2	33	no	---
6. Beothuck	2	34	yes	Rushy Pond
7. Notre Dame	2	36	yes	Small Pond
8. Indian Cove Neck	3	37	no	Indian Arm (sea)
9. Dog Bay Pond	2	39	yes	First Pond
10. Dildo Run	1	38	no	Dildo Run (sea)
11. Mary March	2	31	no	Red Indian Lake

1 - National Environment Parks

2 - Outdoor Recreation Parks

3 - Natural and Scenic Attraction Parks



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PROVINCIAL PARKS
IN THE STUDY AREA

FIG.6-6

Table 6-5

VISITOR INFORMATION
Central/Notre Dame Bay Provincial Parks

	Park No.	Total Visitors 1989	1985	%	% Nfld. Visitors 1989	1985	%
Flat Water Pond	28	10,503	10,169	+ 3.3	86.0	91	- 5.5
Indian River	29	15,194	18,757	-19.0	75.5	75	+ 0.7
Catamaran	30	85,350	94,965	-10.1	64.6	86	-24.9
Beothuck	34	106,483	88,695	+80.9	92.6	95	- 2.5
Notre Dame	36	94,905	80,522	+17.9	91.9	95	- 3.3
Dildo Run	38	20,278	17,803	+13.9	74.4	82	- 9.3
Mary March	31	7,182	15,344	-53.5	79.0	80	- 1.3
		-------	-------	-----	----	--	-----
Totals:		393,841	326,255	+20.7	80.6 avg.*	86 avg.*	- 6.6

* unweighted

nine is the latest year for which information is available; 1985 represents the beginning of the current use cycle.

Note also in Table 6-5 that a very high percentage (80%) of park visitors were Newfoundland residents. This indicates either that the parks do not attract out-of-province visitors, or that the province does not. Thus the park system essentially provides a recreational service by the Province to its residents.

In 1989, 393,841 people visited parks in the study area, an increase of 20.7% since 1985 (an average compound annual increase of 4.8%). Note that the popularity of the different parks varied widely, as did the visitor growth changes. The parks providing convenient recreation to the Grand Falls area (Beothuck and Notre Dame) were more successful, while the more remote parks had declining use. Evidently the water at the Beothuck, Notre Dame, and Catamaran facilities is a valuable resource for recreation.

The Parks Division suggested that camper night data were more reliable than total visitors, since the latter data were subject to estimation. Accordingly, the analogous camper night data are presented in Table 6-6. These show a larger growth rate for camping than day use, but campers represented only 22% of total visitors in 1989. More surprisingly, Newfoundland residents still represented over 80% of campers.

In summary, the provincial park system in Central provides a predominantly water-based recreation experience for about 400,000 visits per year, of whom 80% are Newfoundland residents. It is suspected that most of the latter are from Central since day use represents about 78% of total visitors and since similar parks exist throughout the province.

Table 6-6

Camper Nights - Provincial Parks

Central/Notre Dame Bay

	PARK NO.	Camper Nights 1989	1985	Δ %	% Nfld. Campers 1989	1985	Δ %
Flat Water Pond	28	2,644	2,000	+32.2	75	83	- 9.6
Indian River	29	7,304	4,892	+49.3	83	73	+13.7
Catamaran River	30	10,036	13,740	-27.0	91	93	- 2.2
Beothuck	34	20,832	14,952	+39.3	90	89	+ 1.1
Notre Dame	36	40,332	24,468	+64.9	93	93	0
Dildo Run	38	5,232	4,016	+30.3	57	59	- 1.7
Mary March	31	1,116	788	+41.6	80	75	+ 6.7
TOTALS		87,496	64,856	+32.9*	81*	81*	+ 0.9

* average

* unweighted

6.3.1.2 Economics and Marketing

In order to shed further light on the value of the water resource in the park system (without digressing too far from the point of the study), it is worthwhile to briefly examine what market the parks may be serving, and whether the value of the water and land resources allocated to parks is appropriate.

As it is self-evident that one may camp by a pond in most places in Newfoundland without paying to use the park system, the question arises as to why 400,000 people per year in Central do choose to use the park system. The Parks Division hypothesized that the attraction is the services offered: an organized area, facilities, and safety and security.

User fees per day visits were $1 in 1985 and $2 in 1989. Camper fees were $5/night in 1985 and $6/night in 1989. After correction for inflation (24%), these are constant and nominal. It is estimated by the Parks Division that fees cover about 25% of operating costs. Since Newfoundlanders constitute about 80% of park visitors, it is evident that there is a transfer of wealth from persons who do not use the parks to those who do. The availability of parks, even if they are subsidized, may assist nonresident tourist attraction.

However, the Parks Division also stated that fee rates were set by Treasury Board and not by itself. To its knowledge, no estimate had been made of the sensitivity of park use to fee price (elasticity).

If the goal of the park system is to maximize usage, fees should be set at zero. If it is to maximize revenue, fees should be set at onset of diminishing net returns. A fee of $1 per day would not appear to satisfy either criterion, although such a nominal amount indicates a goal of maximum usage irrespective of operating cost. In such a situation the value of the park system, and its water resource, cannot be reliably calculated.

6.3.1.3 Estimate of Value of Water

Since the services provided by the park system are relatively spartan (no hookups, drive-throughs, few commercial services, etc.), it is reasonable to expect that the access price predominantly reflects demand for the water resource. Since the demand has fluctuated wildly irrespective of entrance price, the price is too low to be the constraining variable. The marginal alternative would be another activity to engage one's recreational time. If this is given a non-zero value of, say, $8/hour, reflecting the typical net wage income of a family, and the park-day were 6 hours, then the value of the water-driven park resource in Central is estimated to be 400,000 x $8 x 6 hr = $19.2 million per year. If, conservatively, water constitutes 10% of the parks' attractive value, and the services and features 90%, then the value of water to parks recreation in Central/Notre Dame Bay may be roughly estimated as $2 million/year. It is again noted that there has been no directed attempt to optimize the return on this demand.

6.3.1.4 Adequacy of Water for Park Needs

According to our survey, the Parks Division is satisfied with the quality and quantity of water in its parks in the Central/Notre Dame Bay study area.

6.3.1.5 Future Developments

There are no plans for new recreation-oriented parks in the province. The reasons include a policy to enhance the conservatory mandate of the Division, and the fact that demand for park recreation is substantially lower than in the 1970s.

6.4. Freshwater Fisheries Resources

6.4.1 Introduction

The Central region has an important freshwater fisheries resource which is exploited by both the recreational and commercial sectors. The primary species of interest in the freshwater zone are trout and Atlantic salmon (which is anadromous).

While the scope of this water resources survey precludes an exhaustive review of the fisheries issue, an attempt has been made to provide an extensive one for two reasons:

(1) The fishery is an important freshwater benefit/ resource in the Central region which is economically important through the associated recreational and commercial fisheries.

(2) There are direct tradeoffs and impacts with regard to the regional Green Wood hydroelectric project at Grand Falls, and the proposed pollution mitigation at Abitibi.

A list of scheduled salmon rivers is given in Table 6-7. These are illustrated on Figure 6-7.

DFO provided recreational angling data for most of the scheduled rivers for the period 1987-1990. These are presented in Table 6-8. Note that the Gander River (at the edge of our study area) is the most popular, followed by the Exploits river.

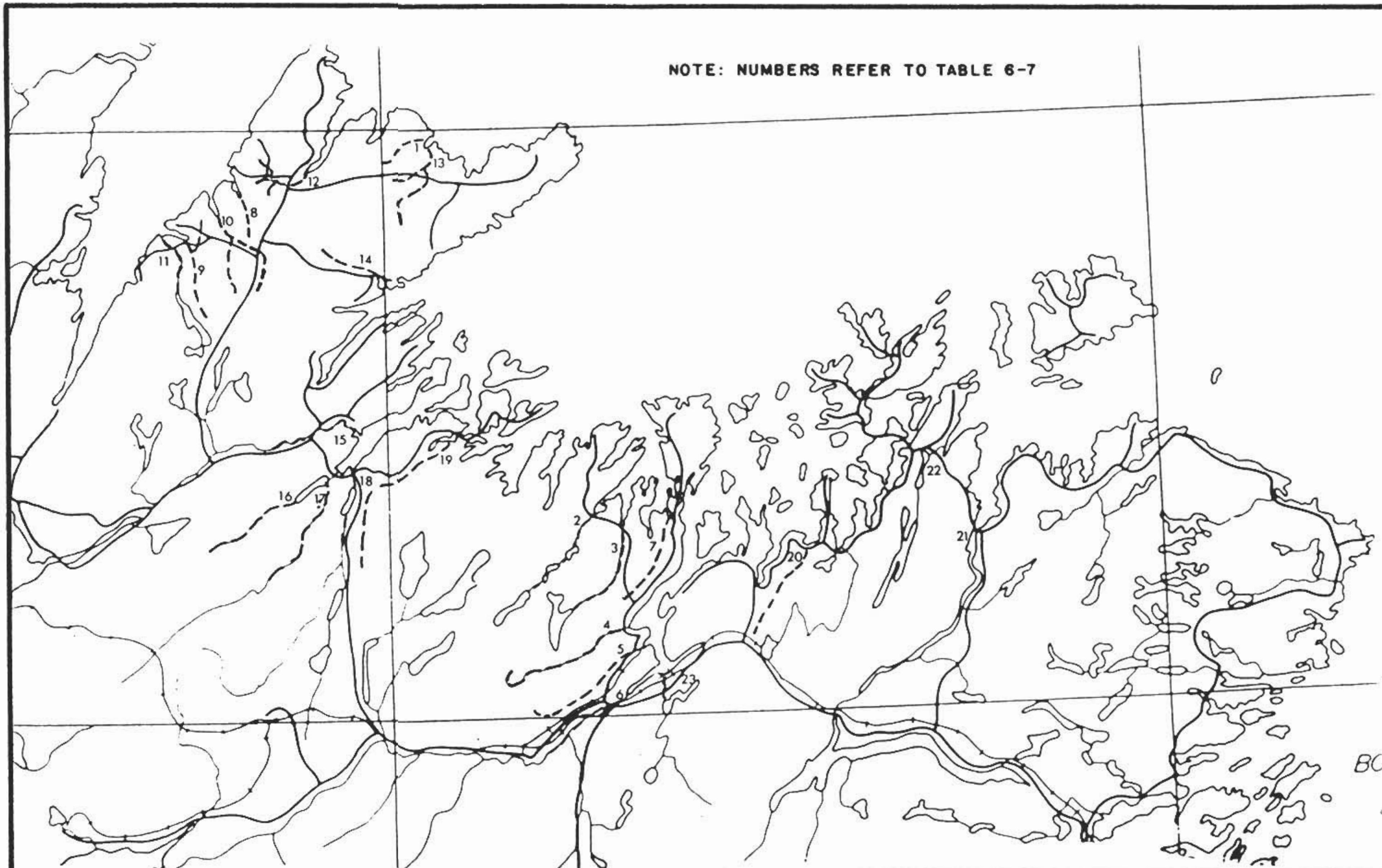
Table 6-7

SCHEDULED SALMON RIVERS IN STUDY AREA

11	Wild Cove Brook, White Bay
9	Western Arm Brook, White Bay
10	Middle Arm Brook, White Bay
8	Southern Arm Brook, White Bay
12	Baie Verte River and Tributaries
13	Woodstock River
14	Burlington River
15	Indian River (Hall's Bay), including Burnt Berry Brook below falls, Davey's Brook, and Black Brook from Indian Pond upstream to the falls
16	West Brook (Hall's Bay)
17	Barney's Brook
18	South Brook (Hall's Bay), including tributary streams
19	Tommy's Arm River and tributary streams
1	Northwest Arm Brook
2	Western Arm Brook
3	Leamington River
5	Peter's River, Bay of Exploits
4	Northern Arm River, Bay of Exploits
7	Charles Brook, Bay of Exploits
6	Exploits River and tributary streams
23	Rattling Brook downstream from the power house
20	Campbellton River and tributary streams, including Neyles Brook
22	Dog Bay River, including Southwest Brook and all tributary streams
21	Gander River, including Northwest and Southwest Gander and all tributaries

NOTE: Gander River is at the boundary of the study area, but is important.

Source: DFO. (numbers refer to Figure 6-7)



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SCHEDULED SALMON RIVERS
IN STUDY AREA

FIG. 6-7

Table 6-8 SALMON ANGLING STATISTICS IN STUDY AREA (1987-1990)

	River Name	1987 Rods	1987 Fish	1988 Rods	1988 Fish	1989 Rods	1989 Fish	1990 Rods	1990 Fish	Average Rods	Average Fish	CPUE
1	Northwest Arm Brook	51	27	121	58	18	nd	6	nd	49		
2	Western Arm River	254	102	622	266	330	123	530	243	434	184	0.42
3	Mill River (Pt Leamington)	443	172	942	452	445	154	895	441	681	305	0.45
4	Northern Arm River	303	114	560	230	340	41	370	80	393	116	0.30
5	Peters River	301	180	518	174	348	59	313	63	370	119	0.32
6	Exploits River	5888	1935	6176	1731	3815	590	5875	1099	5439	1339	0.25
7	Charles Brook	186	nd	157	90	207	14	117	25	167		
8	Southern Arm Brook	nd	nd	64	nd	56	nd	nd	nd			
9	Western Arm (WB)	nd	nd	98	nd	52	nd	nd	nd			
10	Middle Arm Brook	nd	nd	219	35	100	26	140	38			
11	Wild Cove Brook	nd	nd	118	nd	69	nd	36	nd			
12	Baie Verte River	nd	nd	357	17	86	nd	198	29			
13	Woodstock River	nd	nd	110	98	62	13	nd	nd			
14	Burlington River	nd	nd	204	68	75	9	108	22			
15	Indian River	701	191	2069	959	1100	328	1412	589	1321	517	0.39
16	West Brook	450	103	831	300	533	174	899	363	678	235	0.35
17	Barney's Brook	275	73	658	366	329	117	634	285	474	210	0.44
18	South Bk (Hall's Bay)	311	82	967	426	627	191	1184	414	772	278	0.36
19	Tommys Arm River	193	55	735	270	432	126	674	314	509	191	0.38
20	Cambellton River	803	169	1898	636	969	161	693	106	1091	268	0.25
21	Horwood River	570	284	1387	537	nd	nd	921	260			
22	Gander River	6566	1444	7917	2694	6299	1173	6879	1155	6915	1617	0.23

										Average
Sum	10729	3487	18811	6713	9993	2126	15005	4371		0.34423

Sums and statistics do not include the Gander River

CPUE - Catch per Unit Effort (ie probability of catching a salmon per angler-day)

nd - no data

Source :DFO

Some statistics are calculated in Table 6-9 for these scheduled rivers for which complete data for the 1987-1990 period are available.

From Table 6-8 note that 15,005 rod-days were counted in the study region in 1990 with 4,371 fish being caught; resulting in a catch per unit effort (CPUE) of 29%.

In comparing those streams with complete data from Table 6-9, note that the larger rivers (Exploits and Gander River) are the most popular, and have the least interannual variation in fishing effort (the coefficient of variation is 17% for the Exploits River and only 9% for the Gander River). This relative popularity is surprising given that they have relatively low CPUEs (25% and 23% vs. the study area average of 35%).

The relationship between rod-days and fish caught varies. For instance, it is near-linear and highly-correlated for the Indian River (r = 0.99), while less so for the Exploits River (r = 0.83). These are illustrated on Figures 6-8 and 6-9. In this instance it is difficult to tell which is the independent variable, but DFO experts believe the fishermen are highly responsive to the perceived availability of fish. If so, then the positive correlations imply that increasing the fish resource would result in more rod-days.

Another approach to estimating demand and use might be to analyze fishing license data. Licenses are sold by NDOEL, rather than DFO. This information was requested from NDOEL but was not received. If deemed possibly fruitful, the Client may wish to pursue it internally.

Table 6-9

SALMON ANGLING STATISTICS IN STUDY AREA (1987-1990)
(Stations With Complete Data)

Name	1987 Rods	1987 Fish	1988 Rods	1988 Fish	1989 Rods	1989 Fish	1990 Rods	1990 Fish	CPUE	Avg Rods	Avg Fish	S.D. Rods	S.D. Fish	C.V. Rods	C.V. Fish
2 Western Arm River	254	102	622	266	330	123	530	243	0.42	434	184	148	72	34%	39%
3 Mill River (Pt Leamington)	443	172	942	452	445	154	895	441	0.45	681	305	238	142	35%	47%
4 Northern Arm River	303	114	560	230	340	41	370	80	0.30	393	116	99	71	25%	61%
5 Peters River	301	180	518	174	348	59	313	63	0.32	370	119	87	58	24%	49%
6 Exploits River	5888	1935	6176	1731	3815	590	5875	1099	0.25	5439	1339	945	531	17%	40%
15 Indian River	701	191	2069	959	1100	328	1412	589	0.39	1321	517	500	293	38%	57%
16 West Brook	450	103	831	300	533	174	899	363	0.35	678	235	191	102	28%	43%
17 Barney's Brook	275	73	658	366	329	117	634	285	0.44	474	210	173	120	37%	57%
18 South Bk (Hall's Bay)	311	82	967	426	627	191	1184	414	0.36	772	278	332	147	43%	53%
19 Tommys Arm River	193	55	735	270	432	126	674	314	0.38	509	191	215	105	42%	55%
20 Cambellton River	803	169	1898	636	969	161	693	106	0.25	1091	268	476	214	44%	80%
22 Gander River	6566	1444	7917	2694	6299	1173	6879	1155	0.23	6915	1617	614	633	9%	39%
									Avg			Avg	Avg	Avg	Avg
Sum	9922		15976		9268		13479	3176	0.35427	12161.	3762	309	169	33%	53%

Sums and statistics do not include the Gander River

Source :DFO

FIG. 6-8

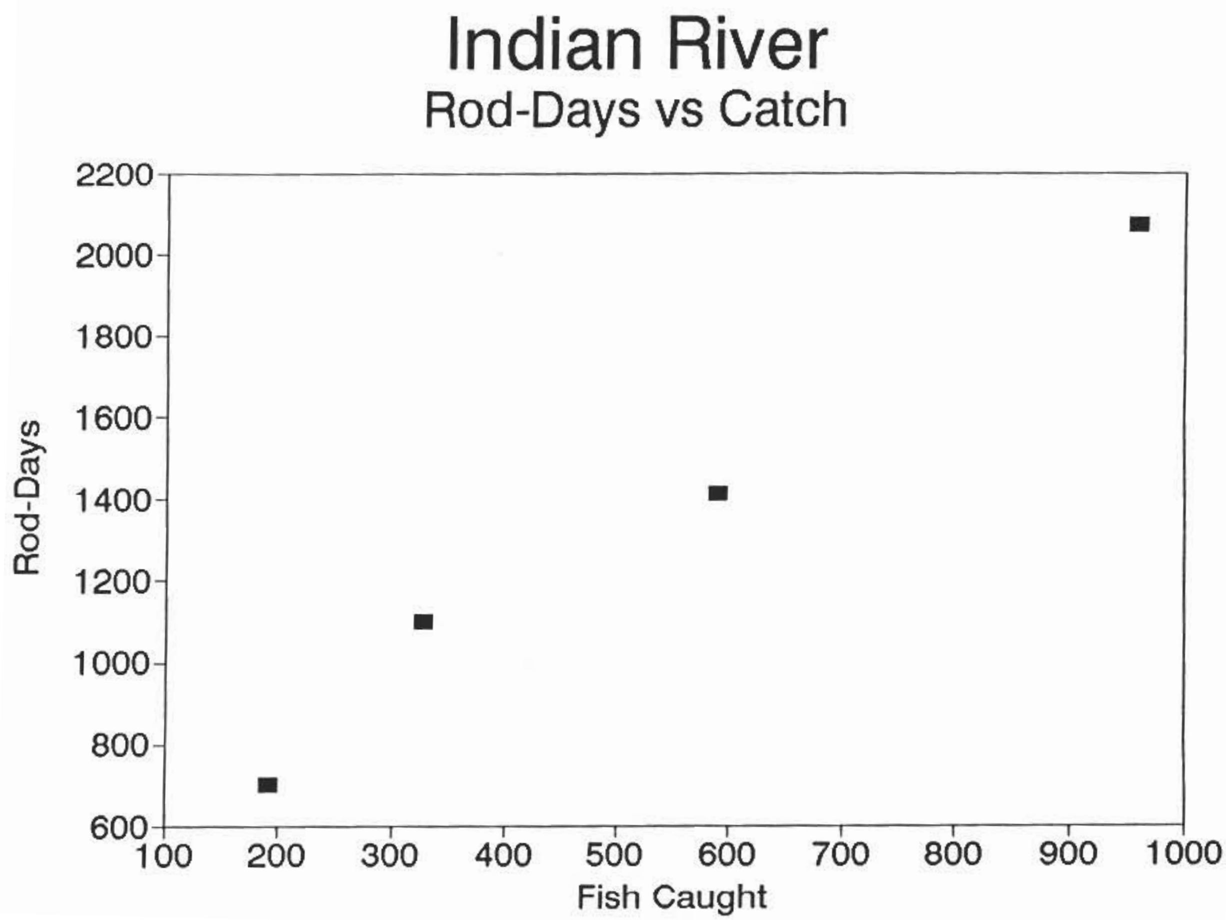
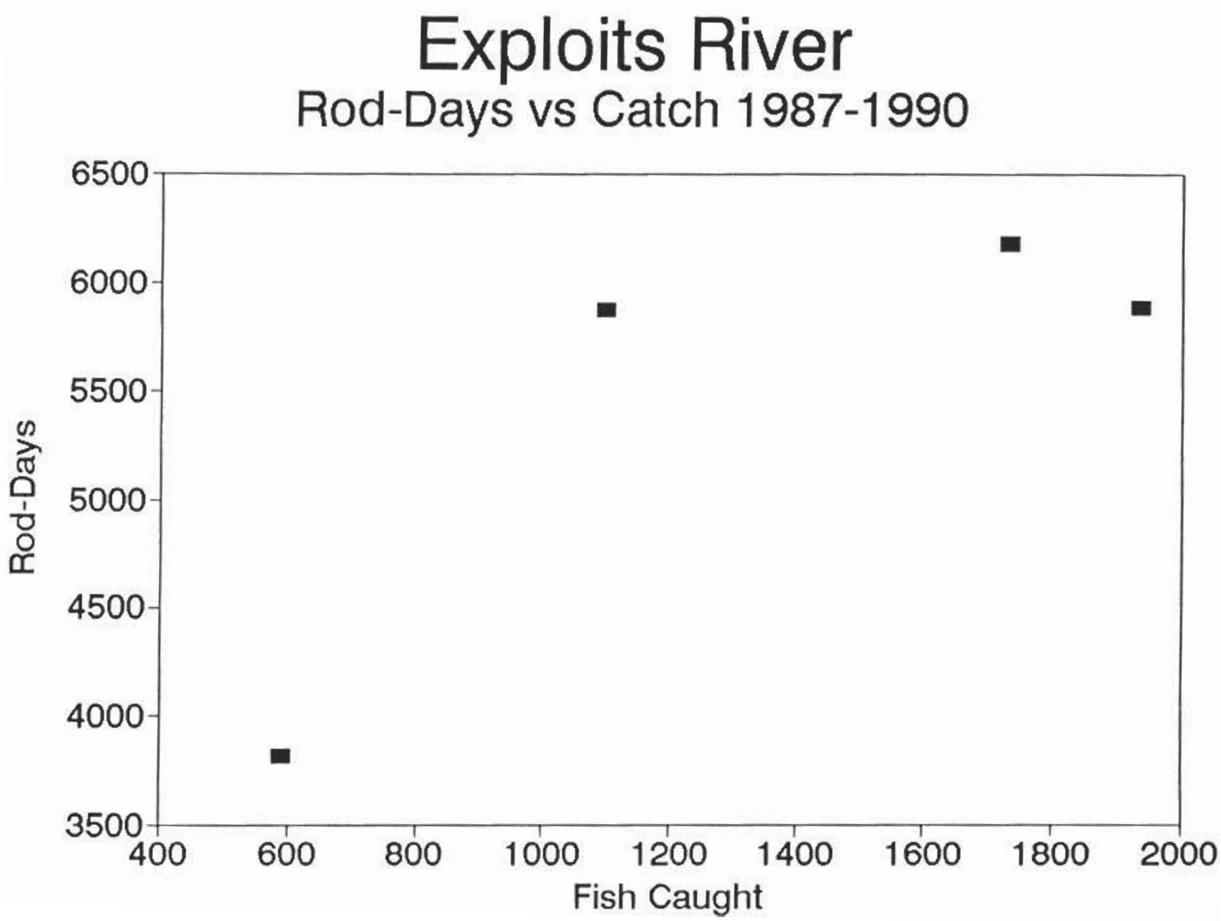

Indian River
Rod-Days vs Catch
Rod-Days
2200
2000
1800
1600
1400
1200
1000
800
600
100
200
300
400
500
600
700
800
900
1000
Fish Caught

FIG: 6-9



Exploits River
Rod-Days vs Catch 1987-1990
Rod-Days
6500
6000
5500
5000
4500
4000
3500
400
600
800
1000
1200
1400
1600
1800
2000
Fish Caught

6.4.2 Enhancement Projects

DFO has a very active salmon enhancement program in Central, comprising four salmon enhancement projects:

(1) Great Rattling Brook fishway (finished)
(2) Upper Exploits River (on-going, but largely finished) [colonization]
(3) Black Brook (pond ranching)
(4) South Brook (pond ranching)

Fishways have been installed at Grand Falls and on Great Rattling Brook to assist upstream salmon passage.

In general, the number of salmon produced is proportional to spawning area. Large potential spawning zones in Central, particularly the Exploits River above Grand Falls and Great Rattling Brook above the falls, were inaccessible to migrating salmon. There are now fishways on Great Rattling Brook and at Grand Falls.

Enhancement projects in Central are discussed in Gardner, Pinfold (1990) and a DFO pamphlet (1989). The information provided by Gardner, Pinfold about these projects is given in Table 6-10. Evidently the Exploits River project is, by far, the largest. Because of this and because of the upcoming hydro and water quality tradeoffs, this project will be reviewed in this study.

The enhancement program on the Exploits River, which has been ongoing since 1962, has resulted in an increase in returning salmon from 1,000 in 1959 to 14,000 in 1988, according to DFO (1989). See Figure 6-10. Stock originally from the Great Rattling Brook watershed were used to provide eggs for an incubator facility

Table 6-10

Summary Characteristics of 10 Salmon Enhancement Projects
Newfoundland and Labrador

River	Project Type	Project Capital Cost + ($000 1984)	Operation & Maintain-ance # ($000 1984)	Increase in Salmon Production Steady State Targets (# of Fish)			Proposed Allocation*			
				Total	Grilse	Large Salmon	Brook	Coastal Harvest	Recrea-tional	Other*
Exploits	Colonization	$2,453.2	$106.3	66000	46000	20000	17600	29800	5400	13200
Terra Nova **	Colonization	14.8	27.0	7300	5100	2200	1800	3100	1300	110
Canairik-tok	Colonization	4,663.5	44.0	36500	14600	21900	11500	19500	1100	4400
South Brook	Pond Ranching	603.9	22.0	22100	15470	6630	1763	9939	1835	8563

NOTES:

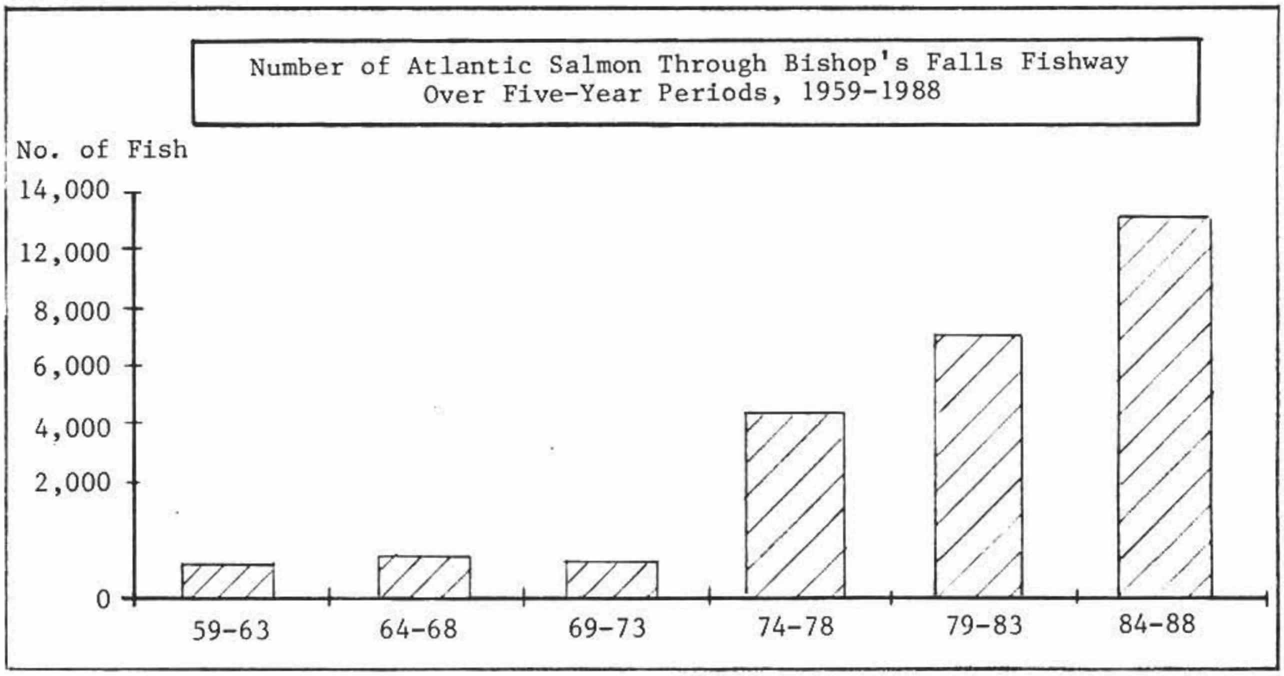
* Includes West Greenland commercial fishery, possible estuarial harvest.

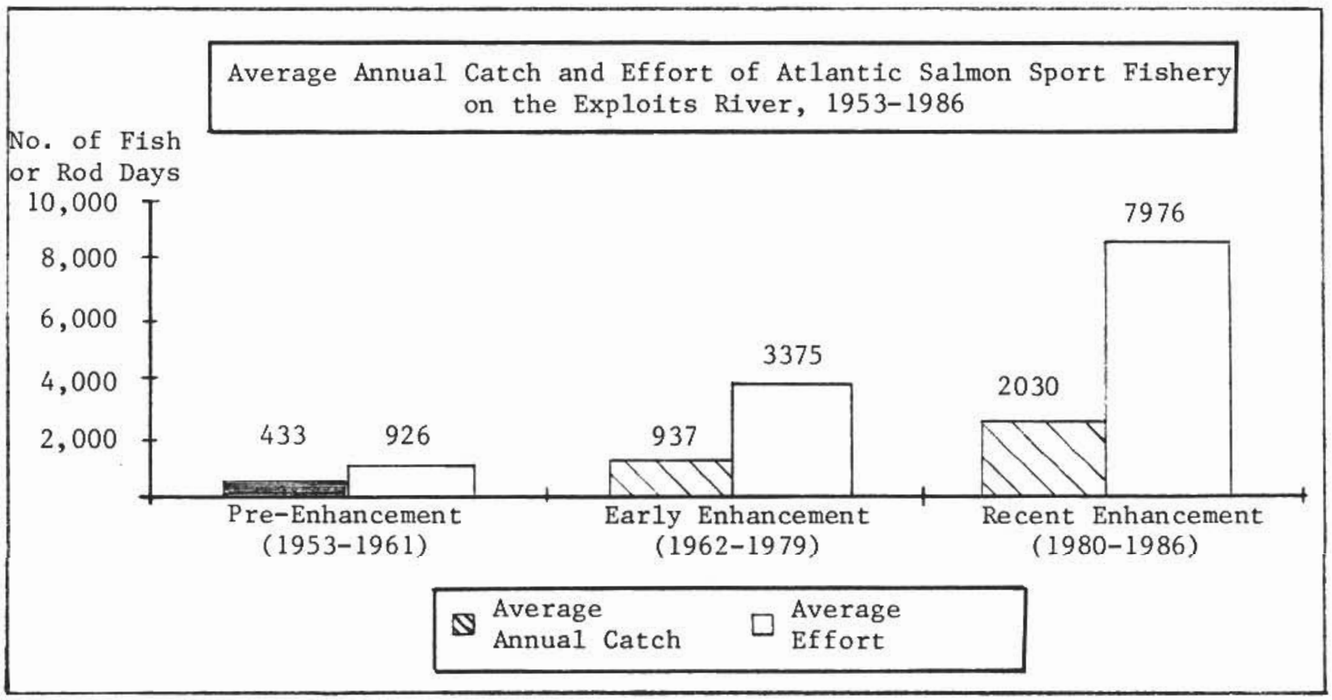
\+ Total capital cost incurred over periods ranging from one year to eight years.

\# Average over ten years.

** Terra Nova River is outside the study area.

SOURCE: Gardner, Pinfold (1990)





SOURCES: from Gardner Pinfold (1990); Original from D.F.O.

FIG. 6.10

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on Noel Paul's Brook. Fry are released in the watershed. A fishway and ladder were built at Grand Falls this summer, which should permit a complete life cycle to be initiated. Clearly DFO's efforts are producing an important new salmon resource.

6.4.3 Review of Fish Economics

What is a fish worth? To what extent should Central's freshwater resources be allocated to fish? This is not an academic problem at all since there are direct conflicts between DFO's enhancement program on the Exploits River and the proposed Green Wood hydroelectric development (see Section 6.2.2), as well as with permitted pollution by Abitibi Pulp & Paper and municipalities.

The economic value of a fishery is a very complicated, contentious, and indeed somewhat obscure topic.

There are essentially two competing salmon fisheries - the recreational and the commercial. Both groups are strongly contesting what appears, in general, to be a diminishing (according to the anglers), or a stable (according to the commercial interests) resource.

The trout fishery is also recreational; but, as noted earlier, data could not be obtained with regard to usage via licenses as a surrogate; nor are data on angling effort, CPUE, and numbers of fish readily available. Data for salmon are better, and the angler would likely be satisfied with either. It is recommended, though, that the Department estimate trouting effort in Central, and impute a dollar value for it.

Perhaps the best point of departure for a discussion of the economics of the salmon fishery is a quotation from the publicity pamphlet provided for the Exploits River enhancement program (DFO, 1989):

> "From its modest beginnings in 1957, the Exploits River project has grown to become one of the largest and most successful salmon enhancement projects in Atlantic Canada.
>
> The project has a positive benefit:cost ratio. This is based on developmental costs versus actual and projected returns over a 25-year period. By 1990/91 the Exploits watershed is expected to produce an annual Atlantic salmon production of 100,000 adults. Of these, about 50,000 are expected to be harvested in the commercial fishery (annual value - $432,000) and 10,000 in the recreational fishery (annual value - $750,000). The remaining 40,000 will be required for spawning. The total benefits upon program completion is (sic) estimated at approximately $1.2 million annually."

Note that no discount rate is given; that maximization of net discounted benefits is not a criterion; that four times more fish are allocated to the commercial fishery than to the recreational one, despite the fact that a fish has an attributed value 8.7 times lower ($8.64 vs. $75/fish) for the commercial use; and that the numbers of fish allocated to recreation do not correspond meaningfully with catch statistics in Table 6-8.

This skepticism is reflected in a (draft) DFO discussion paper by Carew (1987). Thus, there was some internal dissension with the economic justification of the Exploits River enhancement project. Obviously either the project would have to be considered uneconomic and risk being rejected, or discontinued[1]; or another

----

1 We note here that DFO has other criteria besides economics for project justification. We also note that we believe (subjectively) that environmental quality has an intrinsic value which cannot be completely accounted for by microeconomic analyses.

method of attributing value to benefits had to be used. The latter option was selected (Carew, 1987, p. 1):

> "As a result of the negative outcome of the Upper Exploits analysis, in July 1987 the Freshwater and Anadromous Fisheries Division requested that the Branch re-evaluate the current benefit-cost methodology with respect to the valuation of recreational benefits resulting from salmon enhancement projects. They also proposed that the expenditure valuation method and the angler expenditure data from the "1985 Survey of Sport Fishing in Canada" be used to evaluate salmon enhancement projects."

Summarizing Carew's review, DFO essentially uses/used (Newfoundland's approach being somewhat different from Ottawa's) three methods of attributing value to the nonmarket-based recreational fishery:

- opportunity cost method
- expenditure method
- willingness-to-pay method.

In addition to the foregoing, DFO recently retained an economic consulting firm in Nova Scotia (Gardner, Pinfold Consulting Economists) to assess and propose a more comprehensive methodology for Newfoundland recreational salmon fishery valuation. its methodology, termed the "GDP approach", is also briefly discussed.

6.4.3.1 Opportunity Cost Method

The essence of this approach is that a salmon caught recreationally is, self-evidently, not available to be taken commercially. The value of a salmon caught in the recreational fishery (in Newfoundland) was assigned a value twice the opportunity cost of lost sales to the commercial fishery (Carew, 1987). For the Upper Exploits River enhancement project the commercial rate was $4.32/kg (1985$), so the imputed value for the recreational fishery was $8.64/kg (1985$) [or $15.75 per fish, assuming a mass of 1.83 kg/salmon, which appears to be used as an informal conversion factor].

Obviously, the opportunity cost method has no strong theoretical basis and, compared with other methods, yields a relatively low value for a recreationally-caught fish. Its advantage is that it is closely linked to a real market price.

With regard to the Upper Exploits salmon enhancement project, Carew (1987) noted: "[Our] analysis, in fact, indicated that a recreational value of five times the commercial price or $21.60/kg (1985$) would be required in order to achieve a positive NPV and a benefit-cost ratio greater than 1.00. At this value the recreational benefits would total approximately $369,000."

Another variation of the opportunity cost method that has been proposed in the US literature is to assume that one would work at his occupation if one were not angling, and that the value of angling to the participant must at least equal his net hourly wage. This approach has not been used by DFO to date. Application of this approach to Newfoundland would be difficult because of the high incidence of un- and underemployment, and lack of commercial activity on weekends and holidays.

6.4.3.2 Expenditure Method

This approach involves using survey data in which fishermen were asked to compile a sum of all expenditures related to a day of angling. This would include meals, lodging, travel costs, costs of boat, bait and tackle, and so forth.

We offer a simple analysis below to illustrate the technique:

NDAL Simple Model

At a minimum, the cost per day of angling for a Newfoundland resident would be the cost of a license ($10), gear ($500 purchase, annual payment of $52.30 at 10%, n = 10 years), and travel (say 100 km each way at $0.31/km = $62). Thus the first fishing trip would cost $124.30/day, and subsequent ones $62/day. The average CPUE in Central is 35.4% (Table 6-9) so the cost per fish on the first trip is $351.13, and on subsequent trips $175.14

DFO-DPA Model

The expenditure-based approach used by DFO is reviewed by Carew (1989):

> "[B]ased on major purchases and investments and the number of days fished, the 1985 survey arrived at a value of $42.75 for Newfoundland and Labrador. Using 1986 dollars and a 1985 catch per unit effort (CPUE) of $32 salmon per rod-day, the Enhancement and Aquaculture Section are (sic) proposing to extrapolate the angler day value to $152 per salmon. Furthermore, recognizing economists' concerns with the quality of the sport fishing survey data, they are proposing a valuation of one-half this price, or $75 per salmon, in order to inject enough caution in costing until a desirable study can be conducted. At this value, the annual recreational benefits on the Upper Exploits would total $700,500 or $41.03/kg (1987$)."

Note that, after 15.2% inflation between 1987 and 1990, the estimates of the two models are identical ($152 1985$ = $175 1991$).

The problem with the expenditure method is that it measures the gross economic impact of recreational angling on the total regional economy, and it fails to consider the value of the angling activity net of alternatives. For example, if anglers were forbidden to angle, they would undoubtedly spend money on alternative recreational activities. The difference in total expenditures, if any, between angling and the preferred alternatives are properly attributable to a valuation of the recreational fishery; as are angling-related total expenditures of tourists attracted from outside the regional economy who otherwise would not go there.

Relative to other methodologies, the expenditure method tends to produce high estimates of a recreationally-caught salmon. It has been strongly critized internally in DFO because of this (Carew 1989).

6.4.3.3 Willingness-to-Pay Method

This method arrives at a shadow price based upon the maximum amount that an angler would be willing to pay to gain *access to a fishing* site. This approach has greater validity in cases like the United Kingdom where salmon rivers are privately-owned and steep access fees are charged.

Fortunately, in Newfoundland access is only limited by the cost of a license, transport, and requisite fishing equipment. So, the results of <u>willingness-to-pay</u> method and <u>expenditure</u> method-based analyses are similar.

(For the case of private fishing lodges catering to mainland sportspeople, a higher and more precise value could be found, but this would be a separate category than that of Island-based residents.)

DFO

Carew (1987) states that studies by the DPA Group Inc. using the opportunity cost of travel approach resulted in values of $16.24 (1985$) per angler-day in the Province of Newfoundland, and $25.44 (1985$) for the eastern U.S. and Canada.

Using a CPUE of 35.4%, the values per fish are $45.88 (1985$) and $71.88 (1985$), respectively. The latter is close to the $75/fish (1986$) which was derived with the opportunity cost method and which was used for the upper Exploits River enhancement project benefit/cost study; but the former is only 64% of the $75/fish value (1986 $).

6.4.3.4 Gross Domestic Product (GDP) Approach

Given the lack of satisfaction with the previous three methodologies for estimating the value of recreational salmon angling, a consulting firm in Nova Scotia (Gardner Pinfold Consulting Economists Ltd., 1990) was engaged by DFO to propose a methodology. Essentially, its approach was to examine the direct and indirect GDP impacts of both the recreational and the commercial salmon fishery. This is a broadly-based approach for estimating benefits and, like the expenditure method, is not appropriate for project-specific analyses and comparisons.

Recreational Fishery

Gardner, Pinfold estimates the total creation of GDP (the aggregate value of goods and services within the regional economy) by recreational salmon expeditures uses in the North Coast Region (Region 4, Cape Freels to Cape St. John's) in 1988 was $1.39 million direct and $2.32 million total. (Note that this implies a multiplier of 67%, which we consider unreasonable for a largely resident fishery.)

Prorating their figures to Central and the Exploits River, on the basis of a ratio of 1988 rod-days (Table 6-8) with those estimated for Region 4, gives:

Central (Direct): $1.39 M * (18,811/40,889) = $640,000
Central (Total): $2.32 M * (18,811/40,889) = $1.07 M

Exploits R (Direct): $1.39 M * (6,176/40,889) = $210,000
Exploits R (Total): $2.32 M * (6,176/40,889) = $350,000

Values per fish landed are:

Central (Direct): $640,000/6,713 = $ 95.34
Central (Total): $ 1.07 M/6,713 = $159.39

Exploits R (Direct): $210,000/1,731 = $121.32
Exploits R (Total): $350,000/1,731 = $202.20

Commercial Fishery

According to Gardner, Pinfold, the total 1988 catch in the North Coast fishery was 310.8 Mg, and thus the value per Kg of fish, according to the consultants, was:

Market value: $1.4674 M/310.8 Mg = $4.73/Kg (1988 $)

Direct GDP value: $1.04 M/310.8 Mg = $3.35 Kg

Direct & Indirect GDP value: $1.34 M/310.8 Mg = $4.31 Kg

Accepting the multiplier as reasonable, the total value of a fish caught commercially is thus estimated to be (4.73 + $4.31) = $9.04/Kg.

Note that this approach differs from that of the opportunity cost model which assumes that a fish was worth its market price. Clearly if indirect benefits are to be attributed to a recreationally-caught salmon (or not), then they should also be similarly attributed to a commercially-caught one.

Again, the GDP appoach is not appropriate for project evaluation.

6.4.3.5 Summary

Given the foregoing brief review, a summary of the values of a salmon caught in the recreational and commercial fisheries is presented as Table 6-11. These values have been normalized by using a unit of 1990 dollars per kilogram of fish mass (using a conversion factor of 1.83 Kg/salmon).

In Table 6-11, assuming #1 has an error in the commercial value (should be $9.95), that #5 is too low because it does not include travel costs, and that the recreational value in #2 is arbitrary and low, it can be seen that the best estimates of existing recreational value are $94, $175, $175, $105, and $94 per fish. We conservatively adopt a value of $100/fish (1990 $). Note that these are gross benefits to the economy, not net benefits to the enhancement project. The value of a fish to the commercial fishery is assumed to be $11.50 (1991 $) [logic $5/Kg * 1.83 Kg/fish * 1.25 multiplier].

Table 6-11

NORMALIZED SUMMARY OF VALUES OF SALMON

All values on table revised to
end of 1990$ and 1.83 Kg/salmon

	Source (model)	Recreational	Commercial	Ratio
1.	DFO[a] (expenditure method)	$ 95.34	$19.89	4.74
2.	DFO (opportunity cost)	$ 19.89[b]	$ 9.95	2.0
3.	DFO (expenditure method)[c]	$175.14	not available	
4.	NDAL (expenditure method)[d]	$175.12	not available	
5.	DFO (willingness to pay)[e]	$ 57.71	not available	
6.	Gardner, Pinfold (GDP Model)	$105.48	$18.30	5.76
7.	Corbett (Terra Nova project)[f]	$ 94.01	$ 8.53	11.01

a 1989 public information pamphlet. Commercial value is believed to be erroneous; should be $4.32/Kg (1986$). Recreational value is arbitrarily reduced by half from $152/fish (1985$). Dollar-years vary in original and were not adjusted for inflation.

b Arbitrarily set at twice commercial rate.

c Includes all direct and indirect costs.

d Simplified model based on per-day access cost.

e Direct only.

f Latest DFO enhancement project, not in study area.

6.4.4 Value of Existing Salmon Fishery

The value of the existing fishery in the study area is estimated.

Exploits River

The Exploits River will be examined first since more information is available as a result of enhancement projects. Mr. C. Bourgois of DFO (pers. comm.) estimated "typical" annual production in the Exploits watershed is now about 32,000[1] adults/year. As most of the enhancement work has been completed, this value should remain characteristic. Of this, about 60% (19,200 fish) were caught commercially. Of the remaining 40%, 20% were estimated to be caught recreationally (i.e. 8% of the total , or 2,560 fish)[2]. The remaining 20% go to spawning, poaching, and natural mortality. [Note that the economic returns of a poached fish should equal those of one caught legally, and are perhaps greater since taxes are avoided.] At $100/fish, the value of the recreational fishery is then $256,000/year. At $11.50/fish, the value of the commercial fishery is $228,800/year. The total value is $476,800.

Central/Notre Dame Bay

Equally good information is not available for the Central/Notre Dame Bay region. An estimate is made by prorating average 1987-1990 catch for the region (excluding the Gander River) from Table 6-8 to those of the Exploits River:

----

1 Note that the DFO publication (1989) stated that the 1990/1991 project goal is 100,000 adults. The allocation would be 50% commercial, 10% recreational, and 40% for spawning.

2 Note in Table 6-8 that average catch on the Exploits 1987-1990 was 1,339 fish. However, this period is believed by DFO to be below average for production because of the 1987 drought.

$$\frac{\text{Regional Sum}}{\text{Exploits Sum}} = \frac{3,762}{1,339} = 2.81$$

Thus, the value of the regional salmon fishery is (2.81 * $476,800 =) $1.340 million/year.

Value of the Existing Trout Fishery

Not enough information on the level of effort expended to catch trout in Central, and the CPUE, could be obtained to perform an analysis. Certainly the CPUE for trout is higher than that for salmon, and the recreational fishery for trout is correspondingly much greater. An internal study of fish licenses and trout management within NDOEL might be useful in order to provide reliable data upon which to assess value. At any rate, it is more than reasonable to assume the value of the trout fishery is as great as that of the recreational salmon fishing, i.e.

(2.81)* $256,000/year = $719,360/year

Total Value of Freshwater Fishery

The value of the freshwater fishery in the region is thus estimated to be $2.059 million/year.

6.4.5 Allocation of Fish

From Table 6-11 it is evident that fish allocated to the recreational sector have a greater economic value, yet the fish allocation is not based upon economic criteria.

It could be argued that the commercial value of fish reflects a real market value, and thus is "correct." However, most fishermen are highly subsidized so that either too many persons are in the market, or the selling price is too low. Thus market arguments on the commercial side are not convincing.

The value attributed to a recreationally-caught fish (about $100) seems, at the outset, ridiculously high given that the item can be purchased in the marketplace for about $20. It is often argued that the multiplier and direct expenses are too high since most of the fishermen (fisherpeople?) are residents who would eat, burn gas, and otherwise consume in their spare time even if they were not fishing. A converse argument is made that salmon fishermen are so avid that they would pursue the sport elsewhere if it were not available in Newfoundland, so the $100 reflects a real "vacation-at-home" opportunity benefit.

Clearly, given that a fish taken for recreation has a value several times that of one taken commercially, it is logical to allocate as many fish as possible to the recreational fishery until the marginal values of fish in each of the two fisheries become equal. This raises the issues of elasticity and diminishing marginal returns.

In his paper, Carew (1987) notes that DFO (1989) predicts a recreational allocation of 10,000 fish to the Exploits river in 1990/1991, yet the average 1987-1990 catch rate [Table 6-8] is only 1,339 fish/year. If half the available fish are taken [C. Bourgois, pers. comm. 22/02/91], then an additional 3,661 fish are either available, or not being taken. This is a 173% increase of the 1987-1990 fish catch. Would such a large increase in supply result in greater fishing activity (by increasing the CPUE), or reduce the value of a recreational fish to commercial levels? The answer is not really known. Carew (1987) cites an average elasticity of 0.98 in the literature (with a range of 0.8 to 5.0), but proposes 0.65 for enhancement projects. Corbett (pers. comm, 1991) prefers an elasticity coefficient of 1.0. The Indian River data (Figure 6-8) indicate a linear relation between demand and supply, while the Exploits River data (Figure 6-9) do not.

The issue of fish allocation is important, since the Economic Recovery Commission recommended to Cabinet in February 1991 that the policy for the salmon allocation be changed from commercial to recreational [Mr. Mike Doyle, pers. comm., February 1991]. Certainly such policy decisions need to be made in the context of elasticity information. Similarly, financial assessments of enhancement projects and decisions to allocate water between enhancement and other competing beneficial uses require the same information. DFO should supply this information.

6.4.6 Aquaculture

Most aquaculture projects in Newfoundland are being initiated in the marine environment, which is outside the freshwater zone being reviewed for this study.

Most aquaculture projects in the study region are mussel-farms in sheltered locations in Notre Dame Bay. Such projects are not allowed to locate in polluted waters, so the opportunity costs of pollution are not well-known.

Mussel farming is the easiest type of aquaculture to engage in. More sophisticated projects are likely in the future.

We are aware that an arctic char project is proposed in the Springdale area in order to use the abundant and high quality groundwater resources of that area. In the previous subsection an ongoing DFO salmon hatchery on Noel Paul's Brook on the Upper Exploits, and two pond ranching projects on Black Brook and South Brook, were noted.

Potential Conflicts

Marine aquaculture projects are typically located in sheltered coastal bays. These bays are prone to pollution from influent rivers and from untreated municipal discharges. Areas of particular impact in the study region are the Exploits River estuary, and the marine zones around the larger communities. Further study needs to be done to assess the opportunity costs of foregone aquaculture projects in comparison with the savings accruing from Newfoundland's policy of not requiring treatment of sanitary wastes before disposal. Such a study would be well beyond the scope of this report. In many instances it is preferable to undertake aquaculture projects at sites which do not have winter ice. Thus, the study region may be relatively less desirable for some types of aquaculture projects than fjords on the south coast.

Nevertheless it is recommended that coastal pollution be monitored because local pollution resulting from disposal of untreated municipal wastes will preclude siting of aquaculture projects. The financial benefits accruing from not treating wastewaters are, to some extent, lost in opportunity costs for aquaculture. Further study will be required to ascertain the extent of the tradeoff. It may well be that the current situation is acceptable; however, if coastal pollution is seriously affecting the growth of an aquaculture industry, then a change in policy may be warranted.

6.4.7 Summary and Recommendations - Freshwater Fisheries

The following observations, conclusions, and recommendations are made to the Water Resources Division with regard to freshwater fisheries:

1. Good management of the freshwater fishery resource and good management of the freshwater resource go hand in hand. The Water Resources Division should be actively involved in fishery management and enhancement projects.

2. <u>The Exploits River Basin</u> Since no other agency has an analogous role of viewing the water resource in a multidisciplinary light, the Division should take special interest in the issues involving this basin, which include the proposed Green Wood hydroelectric plant, and the proposed pollution reduction at the Abitibi plant. An EIS has been called on the Green Wood project. The fisheries-related issues would appear to involve:

   (a) An estimated 30% mortality rate through the turbines if there is no mitigation, which would severely impact the Upper Exploits River salmon enhancement project. Can these impacts be mitigated? At what cost? Do the benefits of mitigation exceed the costs?

   (b) Will changes in the live head of Red Indian Lake reservoirs adversely or beneficially affect the fishery? Are the benefits worth the adverse impacts? Is mitigation economic?

   (c) Will changes in releases help the downstream fishery by reducing the incidence of low flows? Can this benefit, if any, be recovered?

   (d) The original economic analysis of the Upper Exploits River enhancement project is now about a decade old. As noted in our review, some of the methodologies used and assumptions made are questionable. The freshwater fishery generates only a modest level of wealth and, according to some reasonable criteria, the entire enhancement project may not have been economic. Nevertheless residents of the Grand Falls region see a high-quality salmon fishery as having a good potential for local tourism-related economic growth and spinoffs. Before fisheries-related issues can be properly addressed in an EIS, it would appear that the analysis of economic value of the fisheries should be updated and refined by DFO, so that it is appropriate for project-specific analysis. A fundamental decision needs to be made as to whether a fishery created from de novo by an enhancement project is worth preserving if it appears to be relatively uneconomic.

(e) The existing salmon production needs to be compared with that proposed when the enhancement project began. To what extent is this project meeting its goals, and is the water allocated to it being well used?

(f) Abitibi may be required to provide secondary treatment by 1993 or 1995 if proposed Federal guidelines are adopted. There is some question as to the degree to which migrating salmon are impacted by polluted water (if at all) en route to the upstream spawning beds. This needs further investigation as the costs of pollution reduction (preliminarily estimated to be in the $30 - $50 million range) would appear to greatly exceed the net benefits of the fishery for reasonable discount rates.

(g) Even if uneconomic, to what extent is a healthy fishery desirable? What economic costs or disbenefits are acceptable to have one?

(h) Once some of the foregoing issues have been analyzed in detail, a comprehensive basin plan optimizing the water resource allocation for fish, hydro, pollution disposal, and water supply, should be developed.

6.5 Pollution Assimilation

6.5.1 Introduction

The fresh waters of the study area provide a valuable, if undesirable, beneficial use in assimilating pollution. Some aspects of this use have already been covered in Section 4 on water quality; however, the matter warrants some further discussion in this section.

There are three major types of pollution sources in the study region: (1) pulp and paper, (2) mining, and (3) municipal sewage discharges. Pollution directed to the marine environment is not considered.

With the possible exception of mine leachate at Buchans, the technology to treat wastewaters polluting the study area exists; the reason for choosing to not treat these wastewaters appears to be economic.

6.5.2 Municipal Wastewaters

6.5.2.1 Survey and Review

Information on the status of municipal wastewaters in the study region was obtained from K. Dominie and H. Card of NDOEL, as well as the NDOEL publication "Exploits River Lower Basin, 'A Water Quality Survey', 1978-1982", by H. Card (undated). Since further information is readily available from NDOEL internally, this review will be brief. A summary table of estimated loadings in the Exploits River Basin from Card (undated) is given as Table 6-12.

Buchans

Buchans discharges raw wastewater directly to Buchans Brook. This is adversely impacting (i.e. polluting) the receiving water body. The Civil/Sanitary Division is currently actively addressing this discharge.

Buchans Junction

Discharges from Buchans Junction are impacting Mary Marsh Brook.

Millertown

Surprisingly, Millertown has a wastewater treatment plant (WWTP). According to Card (pers. comm.), this works marginally and sporadically.

Table 6-12

Sewage Discharge Loading
Exploits River

TOWN	POPULA-TION	LOCATION	SEWAGE DISCHARGED* m^3/day	BOD* kg/day	SUSPENDED SOLIDS* kg/day
Buchans	1,655	Buchans Brook	745	132	150
Buchans Jct.	250	Mary March Brook	---	---	---
Millertown	228	Red Indian Lake	103	4	5
Badger	1,090	Exploits River	491	18	20
Grand Falls	8,765	Exploits River	3,944	700	790
Windsor	5,747	Exploits River	2,586	460	520
Bishop's Falls	4,395	Exploits River	1,980	350	400
Botwood	4,074	Exploits Estuary	1,830	325	365
Peterview	1,119	Exploits Estuary	500	90	100
Norris Arm	1,216	Exploits Estuary	550	19	21
TOTAL S	28,539		12,729	2,098	2,371

* Figures tabulated according to Dept. of Environment guidelines, 1980. Calculations exclude industries, commercial establishments, and institutions.

Source: Card, NDOEL, undated.

Badger

Badger also has a WWTP. Its performance is described by Card as being marginally acceptable at the best of times.

Norris Arm

Norris Arm has a WWTP. Its performance is described as similar to that of Badger.

Botwood/Peterview

About 2500 m^3/d of municipal wastewater is discharged untreated to the estuary.

Gander

Gander has two WWTPs which work reasonably well. The effluent from the Beaverview Plant reaches Gander Lake via the Soulis Pond watershed so that very effective treatment is afforded. The effluent from the Gander Bay Road WWTP goes to the lower Gander River via Johnston Pond.

Glenwood/Appleton

These communities at the outlet of Gander Lake also have package WWTPs which operate marginally. Usually the discharges are effectively assimilated by the large river discharges; however, during low-flow periods some impacts near the outfalls are noticeable [Card, pers. comm.].

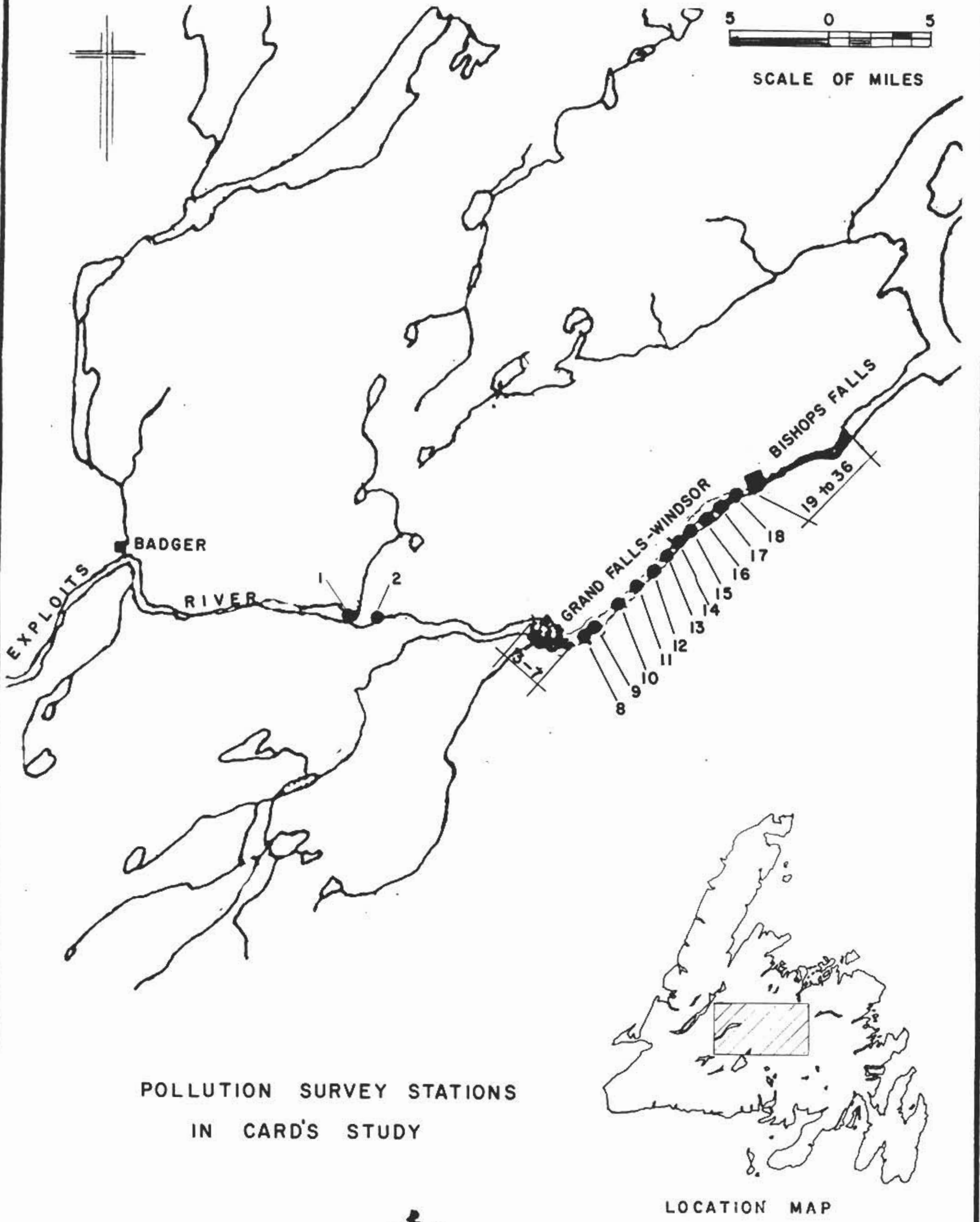
Grand Falls/Windsor/Bishop's Falls

The communities discharge about 8500 m^3/d (combined) of raw wastewater to the Lower Exploits River via several outfalls. This is in addition to the substantial pollution caused by the Price plant. Card (undated) surveyed pollution along the Exploits River. His survey stations are depicted on Figure 6-11. As shown on Figure 6-12 [from Card (undated)], the river is bacterially polluted at least 15 miles downstream (where sampling terminated). "On that section of the Exploits River from the Abitibi-Price Mill and downstream, the number of coliform colonies per 100 mL of sample are (sic) well in excess of recommended levels for recreational use." (p. 16.) This staggering level of pollution obviously conflicts with other uses - especially recreation and fish.

In fairness, the communities see little point in treating their wastewater discharges while Abitibi-Price does not. Clearly all discharges should be treated, as the pollution of the lower Exploits is a disgrace. According to Ken Dominie (of NDOEL), a report on the costs of sewage treatment is currently being prepared for Grand Falls/Windsor by Newfoundland Design Associates Limited. This should be available in the near future. Mr. Mike Pinsent, Town Engineer of Grand Falls, confirmed that a draft should be available by March 29, 1991. [He said he desires to see the river cleaned up so that a sports fishery can be established which will stimulate the local economy.]

6.5.2.2 Future Developments

Except for the aforementioned study, no projects to reduce municipal wastewater discharges are planned. The Civil/Sanitary Division of NDOEL will be reviewing the Grand Falls

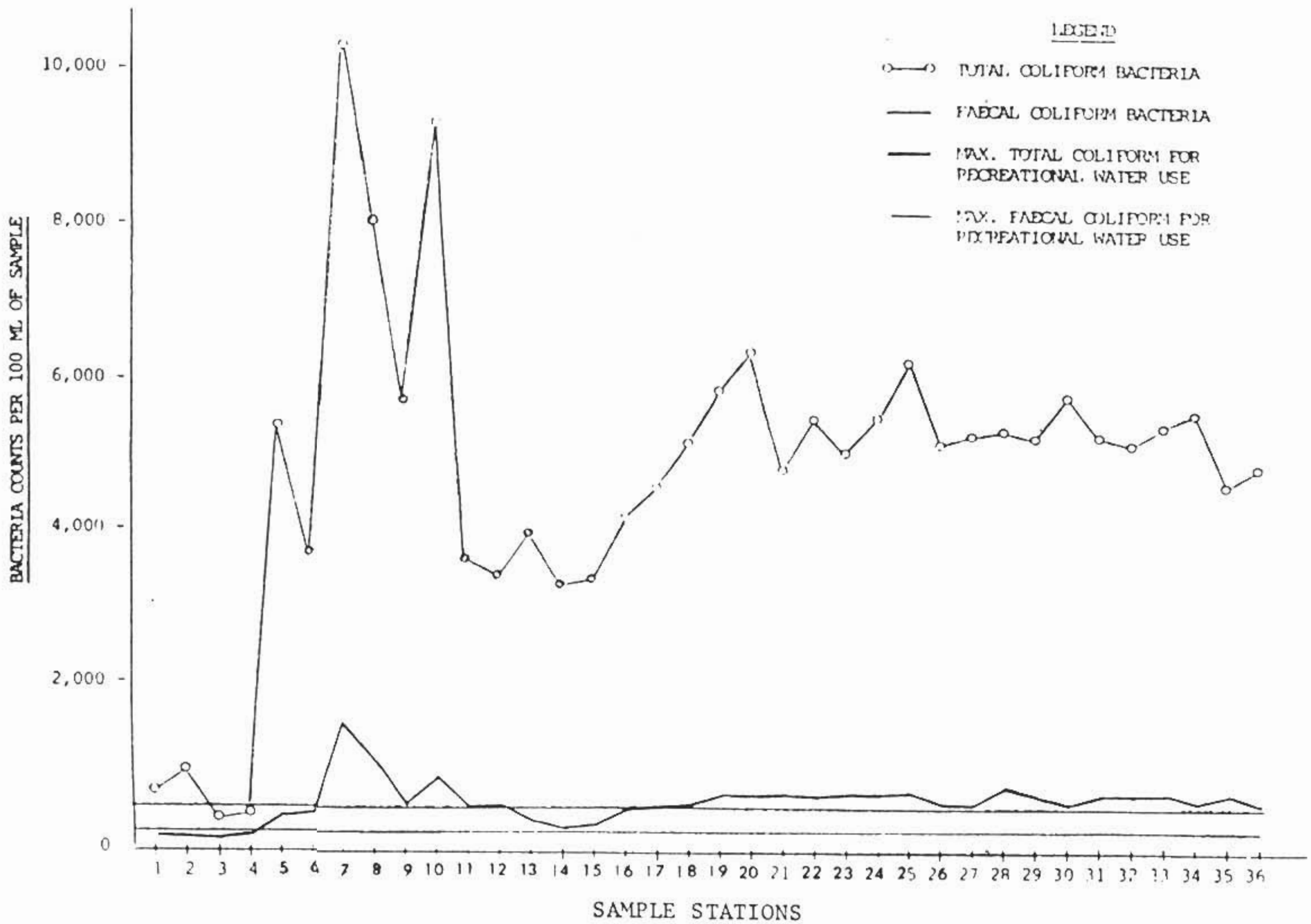


POLLUTION SURVEY STATIONS IN CARD'S STUDY

DEPARTMENT OF ENVIRONMENT AND LANDS

WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA—CENTRAL NEWFOUNDLAND REGION.

FIG. 6-11



DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA
CENTRAL NEWFOUNDLAND REGION

TOTAL AND FECAL COLIFORM COUNTS PER 100ML OF SAMPLE

SOURCE: CARD N.D.O.E.L (UNDATED)

FIG. 6-12

study, and the Grand Falls regional office is working with most communities to improve the performances of their WWTPs.

Even if more WWTPs were built, there is a need for funds and trained personnel to operate and maintain them. Given the financial status of the communities in the region, and of the Department of Municipal & Provincial Affairs, it is likely that the existing situation will only slowly improve.

6.5.2.3 Value of Water For Municipal Pollution Assimilation

Information on the costs of wastewater treatment in Newfoundland is not readily accessible. Use of mainland data is risky because of rapidly declining unit costs with population size, and substantially lower overall costs in the U.S.A.

We obtained data from Conception Bay South regarding costs of its 11-year-old plant, which cost $3 million 11 years ago to serve a design population of 5,000 people. The current unit capital cost is thus:

$$\$3E6*11^{1.035}/5000 = \$876/\text{capita } 1991\$ \qquad (6\text{-}1)$$

Annual costs amortized over 20 years at 10% are $103/year per capita. Operating costs are $140,000/year for 4,000 people, or $35/year per capita. Annual costs for secondary treatment are thus $138/year per capita.

A national survey of water treatment systems [Goldstein and Mokey (1979), p. 207] of small and rural communities (1972$) gives a typical capital cost of $250,000 U.S. (1972$) for 200 residents. Assuming 3.5 people per residence:

$$US\ \$250{,}000*1.04^{20}*\frac{1.18\ C\$}{1\ US\$}/(200*3.5)$$

$$= \$921/year/capita \qquad (6-2)$$

Annual costs at 10% over 20 years are $108.18

Operating costs are estimated to be $0.29/1000 gallons of sewage; thus:

$$US\$0.29*1.04^{20}*\frac{1.18}{1.00}*\frac{120\ gpcd}{1000\ gal}*365\ d/yr$$

$$= \$32.74/year \qquad (6-3)$$

The initial annual per capita cost is thus $108.18 + 32.74 = $140.92.

The two results are very comparable and a typical value of the avoided cost of discharging untreated sewage into fresh water is estimated to be $140/year per capita.

From Table 8-6, the population of all municipalities discharging untreated municipal wastewater into fresh water (and into the Exploits River estuary) in the study area was 64,649 (1986 census). Thus the value of municipal pollution assimilation is estimated to be (64,649*$140/year=) $9.05 million/year.

The population of municipalities discharging untreated sewage to the Exploits River system is about 25,742 (1986 census), so the value of municipal pollution assimilation in the Exploits basin is estimated to be about $3.60 million/year.

6.5.3 Industrial Discharges

6.5.3.1 Abitibi-Price

The Abitibi-Price pulp and paper mill at Grand Falls discharges large quantities of untreated wastewater to the Exploits River. Typical average loadings, according to J. Newhook of EPS (pers. comm.), are:

17 to 20 tonnes/day of TSS
9 to 15 tonnes/day of BOD_5
150,000 to 210,000 m^3/d of water.

The effluent also contains other undesirable pollutants, including toxic ones such as resin acids. These discharges adversely impact the river for many miles downstream, although a thorough receiving water study does not appear to have been performed. Organic material, such as bark, collects on the bottom further adding to the ambient pollution as it decays.

According to Card (undated), the following chemical parameters increase noticeably at the Abitibi effluent point of discharge (POD): acidity, colour, nitrite, total phosphorous, turbidity, COD, BOD, Mn, Fe, Zn, TSS, and TDS.

Value of Water and Future Development

The ability to pollute the Exploits River with impunity has been one of the incentives offered by the Dominion and Province to the pulp and paper operation in Grand Falls over the years. This represents a transfer of environmental opportunity costs to benefit shareholders of the firm. The opportunity costs are hard to quantify; however, proposed Federal water quality guidelines it would cost Abitibi-Price between $30 to $50 million to meet

(J. Newhook, pers. comm.). Using the 20-year 10% amortization again, this represents an annual cost of about $4.7 million, 1994$, or about $4.1 million 1991$ for 5% inflation.

At the time of writing of this report, the Federal regulations have not been enacted, and the intended compliance date has been proposed to be moved from 1993 to 1995. There is active lobbying by the industry for a delay of or exemption from these regulations. It is thus not clear whether the mill will install water treatment facilities in the near future due to Federal regulations. There does not appear to be any Provincial impetus to require the mill to treat its effluent. According to Card (undated) some Provincial water quality regulations are not being met below the mill.

This section will end with a quotation from Card (p. 9-10):

> "The hydrology of the Exploits River is sufficient to provide dilution and dispersion (sic) of sewer effluent so that it is not readily apparent. The only exceptions being those areas immediately downstream of sewage outfalls where slime and algae accumulations develop. During the warmer summer periods with low water levels, odorous and pest conditions develop in these localized areas. In certain stretches of the river where there is inadequate flow velocity for flushing, as is the case in the Mill Pond, wood fibres, chips, spent sulfide, sewer solids, and a number of toxic components have an opportunity to flocculate and settle to the river bottom. Accumulations in these areas result in the formation of a sludge mat which in the absence of oxygen turns septic through the bacteriological and chemical breakdown process. Gases, including nitrogen, methane, and carbon dioxide are generated, which cause portions of the sludge mat to break off and float to the surface. During sampling trips on the Exploits, large floating sludge mats as well as debris and oil slicks have been seen

floating on the Mill Pond. Similar conditions were experienced at the estuary by a diving survey conducted by the Environmental Protection Service of Environment Canada in 1972. Bottom deposits varied from 100 mm to over 1 m in depth. The typical profile of the river bottom was a layer of fresh appearing fibre over a deeper layer of black sludge."

6.5.3.2 ASARCO

Card notes (p. 5):

"Until recent years, the American Smelting and Refining Company Limited (ASARCO) discharged monumental amounts of mining and milling wastes directly to Red Indian Lake via Buchans Brook. Dissolved copper, lead and zinc in the effluent was carried (sic) from Red Indian Lake directly into the Exploits River, and the solid wastes, which also contained precipitated heavy metals, settled out over the bottom of the lake in the vicinity of Buchans Brook. Recent closure of this operation has eliminated the effluent problems at the source for the time being; however, heavy metal contamination, although somewhat reduced, may be apparent for some time to come."

J. Newhook (EPS, pers. comm.) estimates the yield of zinc from mine effluent to have been 20 tonnes in 1989. Evidently this source of pollution will have to be cleaned up. The costs of doing so are not known, but the policy of the Dominion and Provincial governments of permitting ASARCO to pollute may not have been wise, if viewed in hindsight. Heavy metals are relatively toxic, and could affect both fish and drinking water in sufficiently high concentrations. No communities draw their drinking water from the Exploits River, however.

6.5.4 Summary

Of the two major river basins in the study area - the Gander and the Exploits - the Gander is relatively unpolluted while the Exploits is heavily impacted. A clean-up of the Exploits is evidently required. Pollution is currently in conflict with the beneficial uses of drinking water, fisheries, and recreation. The lower Exploits may even be a public health hazard.

The value of pollution assimilation is estimated to be:

municipal	\$ 9.05 million/year
industrial	\$ 4.10 million/year
total	\$13.15 million/year

The environmental costs are more difficult to quantify.

6.5.5 Recommendations - Municipal Pollution

From an overall perspective, the following recommendations regarding water pollution are made:

(1) The NDOEL and Municipal Affairs departments should continue to try to improve the marginal performances of the package WWTPs through training and funding, since these capital investments are already in place.

(2) Buchans discharges should be reduced, ideally in concert with mine discharges, for overall cost-effective pollution reduction.

(3) The Civil/Sanitary Division study (Card, undated) should be extended downstream into the estuary to determine the extent of pollution impact.

and, most importantly,

(4) Pollution of the lower Exploits should be reduced to, at least, levels acceptable for recreation and fish. This would ideally require an approach which would provide the greatest improvement in receiving water quality per dollar spent, assuming that funding for a complete clean-up is not readily available. This would require at least three studies: one of costs of reducing municipal discharges (ongoing), one of costs of reducing industrial discharges (presumably ongoing), and one of receiving water assimilation capacity. These should then be integrated to form a cost-effective site-specific pollution impact reduction plan.

6.6 Discussion of Conflicting Beneficial Uses

In general the region has an abundance of water, so that conflicts can be avoided or minimized to a large extent. Some potential conflicts are described below.

6.6.1 Fisheries - Hydro Power Conflicts

Fishways have been built at Grand Falls and on Rattling Brook, thereby providing fish passage at the expense of hydro power production.

The proposed Green Wood project represents a more serious conflict since optimal use of the site for hydro could wipe out the salmon fishery. These issues are being addressed in the EIS. To date about $7 - $15 million (depending on the value attributed to the labour) has been spent on the Upper Exploits salmon enhancement program. The program has established a salmon fishery where none had previously existed.

While the numbers of fish produced appear to have been well below projections, the population appears to have stabilized. The salmon enhancement project has been undertaken in spite of adverse economics.

Since the enhancement project is essentially one of colonization, the salmon fishery has no <u>a priori</u> "moral" right to exist. Clearly the cost of any water allocated to salmon (in terms of lost hydropower production) should be approximately matched at the margin by the value of the salmon. This will require, at a minimum, an update by DFO on the economics of its enhancement project since the previous ones are specious and out-of-date.

If the arguments about the value of a recreationally <u>vs.</u> commercially-caught salmon are accepted, it should be difficult to justify allocations of salmon to the commercial fishery at all; and more so if the option is to allocate the water required for that portion of the fishery to hydropower.

In addition to absolute values of the competing beneficial uses at the margin, the Department will also have to consider to whom the costs and benefits accrue. Benefits and costs to Abitibi-Price accrue largely to its shareholders, while a popular fishery will predominantly influence the local economy.

The proposed slight increase in the live storage of Red Indian Lake might affect the fishery in the reservoir, as well as temperatures of releases. These issues should be addressed in the project EIS.

While fisheries/hydropower conflicts can be mitigated to some extent by creative hydraulic structures, the appropriate allocation of water for the two in the Green Wood project will require a considerable investment of time and expenditure by the Division.

6.6.2 Fisheries - Pollution Conflicts

The major area of conflict in beneficial use is the lower Exploits River. The value of pollution is estimated to be $7.66 million/year in avoided cost, while the value of the salmon fishery is estimated to be only $476,800/year. However, the environmental costs of water pollution are considered to be socially unacceptable, so that a reduction of industrial and municipal loadings by treatment is essential.

It is not known to what extent ambient pollution adversely affects the salmon fishery since the fish merely transit the polluted reach en route to the spawning grounds upstream. It is difficult, however, to imagine that it would not be a disincentive to the fish.

Of far greater economic importance is the fact that the pollution is seriously inhibiting the development of a recreational salmon fishery since the quality of the water is unacceptable, and may even constitute a public health hazard in places. If the fishery enhancement project is to be justified on the basis of a potential recreational fishery, then pollution of the river will have to be substantially reduced as well.

To date the Federal government, rather than the Province, has taken the initiative to reduce pollution of the lower Exploits. It is recommended that the Province assess the costs of water pollution, as well as the benefits, to ensure that its current policy on the matter is appropriate.

There is an occasional mention in the literature, or when speaking to officials, about the potential adverse effects of heavy metal leachates from the former ASARCO operation upon the fishery, since even low concentrations of heavy metals can be inhibiting or toxic. This should be investigated further.

6.6.3 Pollution - Water Supply

Since Grand Falls/Windsor/Bishop's Falls do not receive their drinking water from the Exploits River, the conflict with pollution has been avoided, but at a high cost. According to a review report by the Exploits Regional Water Supply System (October, 1989): "the reality is the people serviced by the Exploits Regional Water Supply have completely lost confidence in the quality of their drinking water ..... a professional opinion poll ... found that 54% do not drink water out of the tap (i.e. *faucet*). Sixty-two percent of these have not done so since the boil-order of 1985. The 46% who admit to drinking the water, rate at 3.6 out of 10 with regards to healthiness." (pp 11-12)

Briefly, in the late 1960s the town of Bishop's Falls found the quality of the water from its wells to be unacceptable. [It could not draw from the polluted Exploits River.] Grand Falls found the supply from the pulp mill to be inadequate with regard to pressure and storage. A regional system was built which was supplied from Northern Arm Pond, but this had quality problems relating primarily to silt. The Exploits Regional Water Supply

System (ERWSS) could not afford a proper treatment plant without a subsidy. The problem still exists.

On the other hand, the untreated municipal discharges of these communities are a significant source of pollution. The communities agree that it would be pointless to pay for treatment costs unless Abitibi-Price also reduces its discharges. The converse is also true. Thus a coordinated clean-up strategy is required which takes into consideration the natural assimilation capacity of the river and water-quality goals set on beneficial use objectives.

6.6.4 Pollution - Tourism

Except for the lower Exploits River, there are few conflicts between pollution and water-based recreation in the study region.

6.6.5 Pollution - Land Use

There are concerns that forestry operations may be adversely affecting water quality, especially in the Gander Lake watershed. There is insufficient information available to address this concern.

6.6.6 Hydro Power - Tourism/Recreation Conflicts

These are unlikely, unless the Green Wood project seriously adversely affects the salmon fishery. Changes in the drawdown of Red Indian Lake might affect shore-based recreation and its fishery to a slight extent.

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SECTION 7.0

INDUSTRIAL WATER SUPPLY REQUIREMENTS

7.0 Industrial Water Supply Requirements

7.1 Introduction

The economy of the study region is not heavily industrialized. There are only a few industrial processing operations with significant water requirements, and these are discussed by category.

7.2 Abitibi-Price

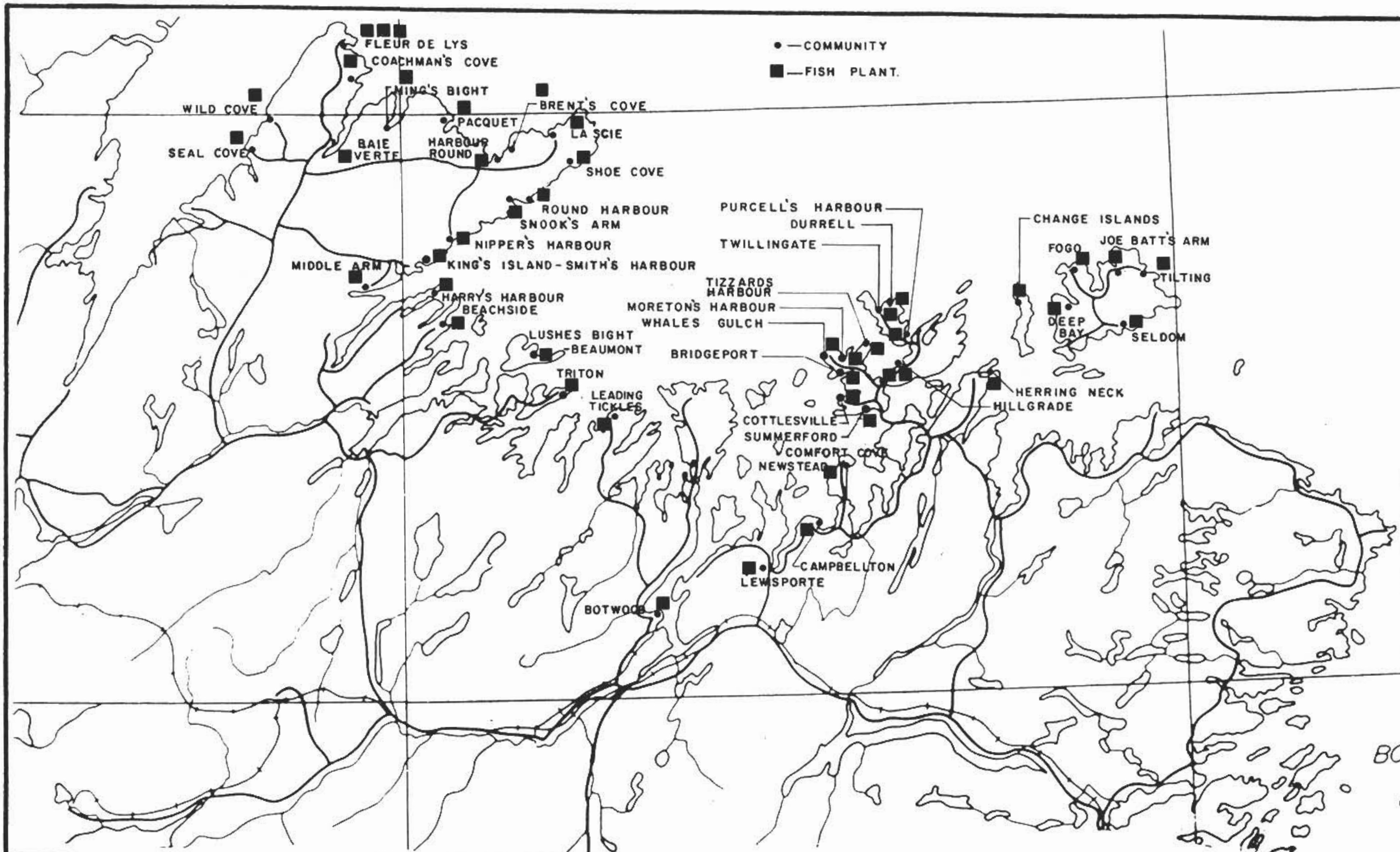
By far the largest water user is the Abitibi-Price pulp and paper mill at Grand Falls which uses water for its industrial processes, for hydroelectric generation, and for wastewater disposal.

Abitibi's hydroelectric water use has been previously discussed in Section 6.2. Its wastewater effluents were covered in Section 6.6.3. Thus, only its freshwater requirements are noted here. These typically range from 150 000 to 210 000 m^3/d, with a typical average value of 196 000 m^3/d (52 mgd). It is withdrawn above the dam and discharged via four outfalls (woodroom sewer, north sewer, south sewer, and No. 3 sewer) below it.

7.3 Fish Plants

7.3.1 General Information

There are 45 fish plants in the study area. Their locations are depicted on Figure 7-1. Fleur de Lys has three plants, and this is indicated on the figure with multiple squares.



DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES STUDY OF THE NOTRE DAME BAY AREA
CENTRAL NEWFOUNDLAND REGION

FISH PLANT LOCATIONS IN STUDY AREA

FIG. 7-1

A listing of information we were able to compile about fish plants in the study area is given in Table 7-1. Sources included the 1989 NDOEL investigation for the water atlas project, the Department of Fisheries, and the fish companies during our site visits.

Even during a site visit reliable information about water use was often hard to come by as water is usually not metered. The exact water requirements for a given plant have commonly not been determined. Usually the plant uses all the fresh water it can obtain, and uses salt water for the remainder of its requirement. Provision of fresh water for all plant requirements would undoubtedly be of assistance to the plants. However, it is not clear whether the initiative should appropriately come from the industry or the Water Resources Division.

A perusal of Figure 7-1 shows that the fish processing industry is widely distributed. It is important to understand the functional structure of the collection and processing system in order to appreciate plant requirements. At the apex of the system are the large secondary plants, usually owned by major players in the industry. An expansion or shutdown of any of these plants would have implications for local water demand. There are two to three tiers below each large secondary plant. The lowest level consists of a collection zone out in the wharf area, often with no structures. Snook's Arm is an example. These have a modest water requirement. Local fish are trucked from these facilities to collector, primary, and secondary plants.

A step above this is a plant in which fish are collected, washed, and perhaps gutted and iced. Nippers Harbour is an example. These are termed feeder or collector plants and have a greater fresh water requirement.

Table 7-1 FISH PLANTS IN STUDY AREA

Plant Location	Company Name	Plant Owner	Plant Function	Water Supply Owner	Type of Supply	Use in Plant	Amount of Fresh Water Used	Waste Water Discharge	Chemical Treatment	Protected Watershed?	Pounds of Fish Rec'd per Year	Water Fees	Comments
Baie Verte	M&J	Not Known		Town	Surface	7		Sewer System	Cl-Town	Y	800000	$236/yr	Buys fish for La Scie
Botwood	Thimble			Saltwater User									
Boyd's Cove	Dildo			Private	Artesian Well	7		Sewer System	Cl-Plant	N			
Brent's Cove											1132000		
Bridgeport	Conpak	Province	Groundfish	Saltwater User							3000000		Figure for fish processed is from 1970's
Campbellton		Ed Noftle	Primary	Town	Surface	1,7		Saltwater	Cl-Town	N			
Change Islands	ISL			Private	Well	1		Saltwater	Cl-Plant	N			
Coachman's Cove	NSPL										600000		
Comfort Cove	NDBSI	R.Eveleigh	Secondary	Town	Surface	1,3			Cl-Town	Y	10000000	$10000/yr	
Cottlesville	BFL			Saltwater user		8		Saltwater		Y			
Deep Bay	Fogo		Collector	Saltwater User									Ships to plant at Seldom
Fleur De Lys	NESealers			Town	Surface	1,2		Saltwater	Cl-Town	N			Not open, no information
Fleur De Lys	Quinlan	Not known	Secondary	Town	Surface/Salt	1		Saltwater	Cl-Town, Plant	N	5000000	$6000/yr	Water use is 50% salt 50% fresh
Fleur De Lys	NSPL	Not known		Town	Surface			Saltwater	Cl-Town, Plant	N	500000	$360/yr	Water quality not satisfactory
Fogo	Fogo		1mry.&Secondary	altwater&Town		1,2,6		Saltwater	uperchlorination	N	5000000		
Hants Harbour	Janes			Town	Surface	1,3,6		Saltwater	Cl-Town, Plant	Y			
Harbour Round											980000		
Herring Neck	ISL	Joey George	Primary	Town	Surface/Salt	1,6	6.7m^3/day	Saltwater	Cl-Town, Plant	Y	6600000	$100/mo	Would use less salt water if fresh were available
Hillgrade	ASL		Prim&Secondary	Town	Surface	7		Saltwater	Cl-Town	N	1130000		Water use is 30% fresh, 70% saltwater
Hillgrade				Town	Surface	7		Septic System	Cl-Town	Y			
Joe Batts Arm	DSL		Primary	Town	Surf/Art	1,2,6		Saltwater	Cl-Plant	N	7185000		Existing water supply constrains plants operation
La Scie	NSPL		Primary	Town	Surface	8		Saltwater	Cl-Town, Plant	Y	25000000	60000/year	Town water supply originally built for the plant
Leading Tickles	COPL	C.Blackwood	Primary	Private	Artesian/Saltwater	7		Saltwater			2000000	Bus. Tax	30% from well, 70% from sea
Lewisporte	EOPL			Town	Surface	8		Saltwater	Cl-Town, Plant	Y			Plant Closed
Little Bay Islands	Jones			Town	Surface	8		Saltwater	Cl-Town, Plant	Y			
Middle Arm	Mermaid	B&B	Secondary	Private	Surface	8		Saltwater	Cl-Town, Plant	Y	4500000	$120/yr	Plant closed 2 summers in row due to water shortage
Ming's Bight											880000		
Morton's Harbour	Oceans		Collector										
Nippers Harbour	NSPL*	L. Gov't	Collector	Province	Surface	1,3		Saltwater			521000		Feeder plant to La Scie
Pacquet	NSPL		Processing	Town	Surface	2		Saltwater	Cl-Town	Y	1150000	$7/mo	
Port Albert	NDBFL												
Purcell's Cove	Commun.	L.S.D.	Collector	Town	Surface					Y	1000000	$15/month	Community stage
Round Harbour	Commun.		Collector		Saltwater			Saltwater			532000		Community stage only, seawater pump
Seal Cove	Mussel	Rice&Smith	Mussels	Town	Surface					Y	40000	$14/mo	Mussels only; uses town water supply on occasions
Seldom	Fogo		Primary	Private	Artesian Well	1,2	28800 m^3/yr	Saltwater	Cl-Plant	N	2500000		Present water supply is inadequate;ice is shipped in
Shoe Cove	NSPL@										1023000		Collector plant for Nat Sea La Scie plant

Table 7-1 FISH PLANTS IN STUDY AREA (continued)

Plant Location	Company Name	Plant Owner	Plant Function	Water Supply Owner	Type of Supply	Use in Plant	Amount of Fresh Water Used	Waste Water Discharge	Chemical Treatment	Protected Watershed?	Pounds of Fish Rec'd per Year	Water Fees	Comments
Smith's Harbour			Collector								304000		
Snook's Arm	NSPL@	Not Known	Collector								359000		No structure; only buy and ship from wharf area
Southport	COPL			Town	Surface	7		Saltwater	Cl-Town, Plant	Y			
Tilting	Fogo		Collector	Saltwater User							1150000	none	
Tizzard's Harbour	Commun.	Community	Stage	Town	Surface					Y			Uses town water for washing out pans, no rights
Triton	FPI			Town	Surface	1,3,6	632 m^3/day	Saltwater	Cl-Town, Plant	Y		0.05c/gal	
Twillingate	Conpak	Receivers	Primary	Private	Surface/salt	8		Saltwater		Y	3500000	.035c/gal	Has own line to dam, pays Munic. Affairs.
Valley Pond	Committee	Committee	Mussels	Private	Surface	1,6	7.58 m^3/day	Saltwater	Cl-Plant	N			Processes mussels only
Wild Cove	NSPL		Feeder	Private	Surface	7		Sewer System	Cl-Plant	N	676000		Plant has private dammed water supply

Legend: 1 – Clean Up, Wash Down 2 – Primary Processing
3 – Machinery 4 – Freezer Units
5 – Secondary Processing 6 – Ice Making
7 – Domestic 8 – All Aspects

Table 7-1 (continued)

Notations Used For Fish Processing Companies

DSL	Doyle W. Sansome & Sons Ltd.
ASL	Alex Sansome & Son Ltd.
BFL	Breakwater Fisheries Ltd.
Campbellton	Campbellton Fisheries Ltd.
Committee	Fisherman's Committee
Commun.	Community stage
Conpak	Conpack Seafoods
COPL	Clarenville Ocean Products Ltd.
Dildo	Hubert Simms, Dildo Run Enterprises
EOPL	Eastern Ocean Products Ltd.
Fogo	Fogo Island Co-op Society Ltd.
FPI	Fishery Products International
ISL	Island Seafoods Ltd.
Janes	P. Janes & Sons Ltd.
Jones	S. T. Jones & Son (1989) Ltd.
Mermaid	Mermaid Fisheries Ltd
Mussel	Southern Arm Mussel Farm
M&J	M & J Fisheries Company Ltd.
NDBFL	Notre Dame Bay Fisheries Ltd
NDBSI	Notre Dame Bay Seafoods Inc
NESealers	NE. Coast Sealers Co-op Society Ltd.
NSPL	National Sea Products Ltd.
NSPL*	National Sea (Lessee)
NSPL@	National Sea (Buyer for La Scie Plant)
Oceana	Oceana Seafood Processors Ltd.
Quinlan	Quinlan Brothers Ltd.
Thimble	Thimble Bay Farms

The next step above is the primary processing plants. These have significant fresh water requirements for processing and ice making.

Finally, the large secondary plants provide final processing. These are often open most of the year and require a reliable water supply of good quality. Triton, La Scie, and Seldom are examples.

In this context the higher priority is to provide an ample supply of good quality fresh water to these plants highest in the system; plants lower in the hierarchy should receive a lower priority.

The water supply sources for these plants listed in Table 7-1 as having municipal supplies can be found in the municipal descriptions of Appendix A.

A summary appears below for all the larger plants, and smaller ones with known water supply problems.

7.3.2 Field Survey Summary

Triton

The Fisheries Products International regional secondary processing plant uses the town water supply, which is reported to be adequate for its needs. The supply is metered. Typical use is 250 to 300 m^3/day, with peaks of about 630 m^3/day.

La Scie

The National Sea Products regional secondary processing plant has an adequate supply of fresh water, which it uses for all its requirements. The system was built in 1955 for the plant and was subsequently transferred to the Town. NSP now pays the town $60,000 per year for water. The plant is unmetered.

Bridgeport

The Compak plant (owned by Government) primarily uses salt water. There is makeshift fresh water supply during the operating season. The Town has no municipal supply.

Twillingate

The Compak primary processing plant uses a metered line for fresh water supply. Since it pays Municipal Affairs $0.35/1000 gal for fresh water, it prefers to use salt water for ice making, fluming, and all processing. If required, it would switch totally to fresh water.

Leading Tickles

The primary processing plant obtains 30% of its water requirement from a 16 gpm artesian well, and the remainder from salt water. The plant spokesman reports that there is not enough fresh water to operate the plant at times. In the fall of 1990 a new municipal surface supply went onstream from Cooks First Pond. As a later phase of this project, it is proposed to extend this surface water supply system to the fish plant.

Herring Neck

The secondary processing plant reports using an estimated 1500 gal/day fresh water for wash basins and ice-making. The remaining water requirement is met with salt water. They state that, if more fresh water were available from the Town water supply, they would like to use it.

Fleur de Lys

The National Sea Plant prepares fish for shipment to the La Scie plant. It uses only fresh water for ice and the washroom. They report the water quality to be unsatisfactory.

The Quinton Bros. plant carries out secondary processing. It uses 50% fresh and 50% salt water. They say that the fresh water supply is not adequate.

Seldom

A secondary processing plant operated by Fogo Island Co-Op Society uses 100 gal/min freshwater and 1000 gal/min seawater for 12 hours/day for 3 months/year. A private fresh water supply is obtained from a nearby pond and two artesian wells. A better fresh water supply is needed. Ice has to be trucked to the plant from the Co-Op's Fogo and Joe Batt's Arm plants.

Fogo

The Co-Op plant in Fogo draws from the town water supply and also uses salt water. The fresh water supply consists of a low pressure system from two 2" lines running over the ground from a nearby hydrant. It is currently not metered, but is expected to be in the future. Fresh water is used for washrooms and ice.

Joe Batt's Arm

Joe Batt's Arm has a Fogo Island Co-Op primary processing plant with a new supply (as of 1990) consisting of a 35 psi 2" diameter line running full from May to October. Fresh water is augmented by salt water as required. System pressure is reported to be too low. Again the ability of the fresh water supply to meet combined municipal and industrial demand should be investigated.

Middle Arm

A secondary processing plant operated by Mermaid Fisheries Ltd. uses all fresh water from a town supply. The plant had to close the past two summers due to inadequate fresh water supply. The plant currently pays $120/year for water.

7.3.3 Conclusions and Recommendations

It is difficult to generalize about the fish processing industry because it is widely distributed, locally focused, and often substantially subsidized. Newfoundland has over 200 fish plants, many of which are economically marginal. A rational industry would probably have far fewer; however, it is perceived to be socially desirable to spatially distribute the work. The result is that financially marginal plants are located in small communities with limited capacity to provide sufficient industrial water supply and treatment systems. From a water perspective only, the options for improvement are essentially: (1) a consolidation of the industry so that economies of scale in providing a reliable adequate fresh water supply can be realized (such as has occurred at Triton and La Scie); or (2) Government assistance to improve the water supplies where possible and necessary at existing plants. While there is an ability to substitute salt water for fresh in many processes, fresh water is always preferred because it is less corrosive and usually of better quality.

While many plants complain of a water problem, few of them have metered their supplies and most pay a token amount or nothing for their water. The unsatisfactory supply situation is thus not surprising.

Several of the plants in the preceding section had inadequate fresh water supplies, or distribution systems which left much to be desired (such as running lines above ground from a low pressure hydrant, or trucking ice in from other plants). It is inferred that the sample in the study area is representative. Clearly the first step to addressing the situation is to require all plants to meter their water use, both fresh and salt; and to measure line pressure. General information on water use requirements for each process should be obtained; although a generic approach might be suitable for this task. Production information should be related to water use so as to determine unit requirements (eg. gallons per pound), and to ascertain if the amounts used in a particular plant are typical, below average, or excessive.

While the plants could pay for the meter installation and monitoring, it would appear that either government (Fisheries or Environment Departments) or consultants engaged by an industry consortium would be needed to analyze the data. Given the expected improvement in plant performance, this initial exercise would likely be very cost-effective.

We note that some plants may prefer not to install meters since they are charged for water. This is why meter installation should be mandatory.

Once the individual plant requirements are more quantitatively known, the hydrologic potential and incremental costs of providing an increased and/or more reliable supply can be assessed on a case-by-case basis. In any event, this should be conducted as part of the Municipal Affairs' municipal water supply grants/loan program.

In addition to the foregoing, it is recommended that the Environment, Municipal Affairs, and Fisheries departments jointly follow up on the reported fish plant supply shortfalls noted in the previous section. It may be possible to apply inhouse expertise to develop ad hoc improvements which could assist the plants.

7.4 Mines

There are no mines currently operating in the study region. The ASARCO zinc mine at Buchans has been closed for over a decade and will not reopen. The Baie Verte asbestos mine, which had a renovated water supply in 1988, closed permanently in late 1990. It is now in receivership. There are plans for a tailings reprocessing operation and an asbestos disposal operation at the site; but, at present, it is not certain when, or if, they will operate. The existing mine water supply will meet their more modest requirements if they do begin to operate.

7.5 Future Developments

Briefly, the economy of Central is resource-based, consisting of forest harvesting, pulp and paper processing, fishing, fish processing, and some hydroelectric generation. Unfortunately none of these sectors is likely to be economically vibrant for the foreseeable future. Reasons include:

- Overharvesting of trees relative to replacement rates, and lack of adequate replanting programs by the Dominion of Newfoundland and the Province of Newfoundland, have led to a supply shortage of pulp timber (The Sunday Express, December 10, 1989, p. 31). Due to slow arboreal growth rates in the Newfoundland climate, it will take several decades to develop a balanced wood supply.

- Paper recycling can be expected to reduce demand for virgin paper.
- In apparent response to decreases in groundfish stocks, DFO is reducing quotas. The timescale for recovery of the fishery resource is much less than that for forestry, however.
- A rationalization of the fish processing industry is inevitable. Newfoundland has about 200 fish processing plants serving a declining resource. The number of plants may be reduced in response to a decreasing supply and to achieve economies of scale. Thus water demands for closed plants will be lost.
- Few preferred developable hydroelectric sites are located in Central. The Exploits River sites have been lost to the public sector by leases; the advantage, however, accrues to the Grand Falls paper plant.

The Central region does not appear to have a competitive advantage for other types of large-scale commercial/industrial development and, to our knowledge, there is none envisaged to be located there in the foreseeable future. In general, during visits and telephone calls, the goal of most towns and businesses was to remain at the current level.

7.6 Value of Water

A very approximate estimate of the value of fresh water is given.

Abitibi-Price

The Price plant typically draws 196 000 m^3/d for process use. It does not pay for this water by virtue of its grant. Some water treatment (filtration) is done, so a cost is incurred; however, the water need not be potable so an imputed municipal treatment and supply cost is inappropriate. The only foregone alternative benefit is hydroelectric production. The annual energy foregone can be estimated as:

$$P = 9.804 \; e \; Q \; H \qquad (7\text{-}1)$$

$$= (9.084)(84\%)(2.269 \; m^3/s)(33.2 \; m) \qquad (7\text{-}2)$$

$$= 620 \; KW \qquad (7\text{-}3)$$

$$E = PF * P * (24 \; h/d) * (365.25 \; d/y) \qquad (7\text{-}4)$$

$$= 100\% * 46\;500 \; KW * 24 * 365.25 \qquad (7\text{-}5)$$

$$= 5{,}437{,}064 \; KWh/yr \qquad (7\text{-}6)$$

So the opportunity cost, at $0.06/KWh, is $326,333 per year, or 219 m^3/$.

<u>Fish Plants</u>

For fish plants, a typical municipal supply price of 3757 litres/$ (as developed in Section 8.9) can be used. If there are 45 fish plants, each drawing 100 m^3/d for 6 months/year (May through October) at this price, then the value is:

$$45 * 100 \; m^3/d * 184 \; days * 1000 \; l/m^3 \; / \; 3757 \; l/s \qquad (7\text{-}7)$$

$$= \$220{,}389/year \qquad (7\text{-}9)$$

<u>Sum</u>

The total value of water for industrial processing purposes is the sum of the above amounts, i.e. $546,722/year.

SECTION 8.0

REVIEW OF ADEQUACY OF WATER SUPPLY TO COMMUNITIES

8.0 Review of Adequacy of Water Supply to Communities

8.1 Introduction

The assessment of the adequacy of fresh water supplies (in terms of quantity) to the communities in the study area is given in this section.

The format involves:

- a review of current populations of communities and trends
- a review of economic prospects and possible future developments on the basis of discussions with community officials
- estimation of current demand, and demand in the year 2015
- estimation of the existing supply in terms of a firm yield and a mean flow using a standard procedure
- comparison of supply and demand, both at present and in 2015
- identification of communities with potential supply problems, according to the results of the screening model
- a brief review of the community field survey (the survey results are placed in Appendix A)
- discussion of those communities with potential supply problems, using results of the community field survey, discussions with local officials, information from Municipal Affairs, and so forth
- an estimation of the value of the beneficial use of community water supply
- a discussion of possible conflicts and their minimization.

In general, supply problems caused by poor water quality and inadequate pumping and distribution systems are not covered in detail in this section nor in this study. Some brief review comments are given below about them.

Quality

Natural water quality is generally good in the study region so that water treatment beyond simple chlorination is usually not required. The value, both in terms of avoided treatment costs and general public health, of a high-quality potable water supply cannot be overestimated. A simple method of protecting this asset is to protect the water supply from adverse competing uses. The Water Resources Division has a commendable watershed protection program in effect. Those watersheds in the study area which have been afforded protected status are listed in Table 8-1.

During our field survey only Chanceport and Stoneville reported generic water quality problems from a surface supply. Both already have protected watersheds. Of the two, Stoneville was the more serious as it has frequent boil orders. The source of the problem is thought by Town officials to be about 20 to 25 cabins on Second Pond in the supply watershed. Further investigation to confirm this is required. Otherwise, no request was made by Town officials for additional watershed protection in the study area.

The system serving Grand Falls/Windsor and Bishop's Falls often has excessive turbidity. A filtration system is required. To date sufficient funds are not available to complete it, according to Town officials. When completed, a proper filtration system should solve the problem. Otherwise, high pollution levels in the lower Exploits River preclude its use as a public drinking water supply.

Table 8-1

Protected Water Supply Watersheds in Study Area

NDOEL ID No.	Community Served	Topo Map	Date Approved	Source
60	Buchans	12A/15	01/11/77	Buchans (Sandy Lake)
125	Buchans Junction	12A/15	16/05/84	Lapland Pond
4	Baie Verte	12H/16	28/05/84	Baie Verte River
136	Springdale	12H/9	15/08/85	Sullivan's Pond/ Huxter'sPond
171	King's Point	12H/9	26/08/88	Bulleys Pond
72	Herring Neck	2E/10	18/01/79	Gut Pond
56	Chanceport	2E/10	26/03/77	Bridgers Cove Pond
159	Tizzards Harbour	2E/10	22/02/88	Rocky Pond
15	Purcells Harbour	2E/10	03/07/74	Purcells Harbour Pond
158	Newville	2E/10	16/02/88	Beaver Pond
88	Twillingate	2E/10	07/06/84	Stockeys Pond
163	Miles Cove	2E/12	29/03/88	Paddocks Pond
102	Silverdale	2E/12	15/12/82	Nickey's Nose Cove Pond
165	Lushes Bight - Beaumont	2E/12	06/04/88	Gull Pond - Milkboys Pond
73	Loon Bay	2E/2 2E/7	22/01/79	Southeast Pond
61	Phillips Head	2E/3	01/11/77	Dogberry Brook
152	Norris Arm	2E/3	07/10/87	Mill Lake
157	Northern Arm	2E/3	16/02/88	Muddy Hole Pond
86	Lewisporte	2E/3 2E/6	18/06/80	Stanhope Pond
35	Botwood	2E/3 2E/4 2D/13	26/05/75	Peter's River
41	Bishop's Fall - Grand Falls/ Windsor	2E/4	04/07/75	Northern Arm Lake
70	Pilley's Island	2E/5	10/01/79	Loadabats Pond
87	Point Leamington	2E/6	18/06/80	Little Pond

Table 8-1 (cont'd)

NDOEL ID No.	Community Served	Topo Map	Date Approved	Source
27	Embree	2E/6	05/12/74	Trokes Cove Pond
43	Cottrell's Cove	2E/6 2E/11	08/09/75	Cottrell's Pond
94	Campbellton	2E/7	23/11/81	Indian Arm Brook
116	Birchy Bay	2E/7	07/10/83	Jumpers Pond
144	Comfort Cove - Newstead	2E/7	02/10/86	Steady Cove Pond
150	Stoneville	2E/7	25/03/87	Dog Bay Pond
75	Summerford	2E/7 2E/10	26/02/79	Long Pond

Distribution

Many communities have supply problems which can be attributed to the distribution system (intakes, pumps, lines, and so forth). These problems differ from those of hydrologic supply deficiencies in that they can almost always be solved by available engineering and technology. The usual problem is the financial ability to pay for them. Responsibility for problems in the distribution system lies with the Department of Municipal & Provincial Affairs, rather than Environment and Lands, and is thus not within the Water Resources Division's mandate. Nevertheless, in our field survey we noted distribution system characteristics, and these comments appear in the notes in Appendix A.

8.2 Municipal Population Trends and Characteristics

As there is no significant agricultural base, most people in the study area live in settlements and towns. Census data for these (including Gander) for 1981 and 1986 are presented in Table 8-2. Unfortunately the next census will be in 1991, so the census information is not current.

Percent changes between the 1981 and 1986 censuses have also been calculated and are given in Table 8-2. Due to the small population base of most communities, these are often large.

The general trend in the region has been a slow rate of population decrease. An anomaly is the relatively high growth rates in "unorganized" areas, probably reflecting sprawl into inexpensive land at the outskirts of communities as the density and the quality of the road network improves. As these residences are likely not served by community water supplies, but rather by groundwater, there will be a shift in water source occasioned by this trend. The mild depopulation trend in an area of generally

Table 8-2

Population Data for Central - Notre Dame Bay Region, Newfoundland From 1981 and 1986 Censuses

	1981	1986	Percent Change
CENSUS DIVISION 6	42,008	40,714	- 3.08
SUB-DIVISION 6A - BUCHANS			
Buchans	1,655	1,281	- 22.6
Millertown	228	214	- 6.1
Sub. 6A - Unorganized	275	209	- 24.0
TOTAL	2,158	1,704	- 21.0
SUB-DIVISION 6C - GRAND FALLS			
Badger	1,090	1,151	+ 5.6
Bishop's Falls	4,405	4,213	- 8.0
Botwood	4,074	3,916	- 3.9
Grand Falls	9,228	9,121	- 1.2
Northern Arm-Exploits	298	342	- 14.8
Peterview	1,119	1,130	- 1.0
Windsor	5,747	5,545	- 3.5
Sub. 6C - Unorganized	155	194	+ 25.2
TOTAL	26,116	25,612	- 1.9
SUB-DIVISION 6D - NORRIS ARM			
Norris Arm	1,216	1,127	- 7.3
Sub. 6D - Unorganized	333	1,461	+ 0.3
TOTAL	1,549	1,461	- 5.7
SUB-DIVISION 6E - GANDER			
Appleton	420	502	+ 19.5
Gander	10,404	10,207	- 1.9
Glenwood	1,129	1,038	- 8.1
Sub. 6E - Unorganized	232	190	- 18.1
TOTAL	12,185	11,927	- 2.0

Table 8-2 (cont'd)

	1981	1986	Percent Change
CENSUS DIVISION 8	54,542	54,225	- 0.6
SUB-DIVISION 8A - WHITE BAY SOUTH			
Baie Verte	2,491	2,049	- 17.7
Brent's Cove	356	365	+ 2.5
Coachman's Cove	279	265	- 5.0
Fleur De Lys	616	526	- 14.6
Lascie	1,422	1,429	+ 0.5
Ming's Bight	437	434	- 0.7
Pacquet	395	336	- 14.9
Seal Cove	751	698	- 7.1
Westport	467	495	+ 6.0
Woodstock	345	333	- 3.5
Sub. 8A - Unorganized	534	537	+ 0.6
TOTAL	8,093	7,467	- 7.7
SUB-DIVISION 8C - HALL'S BAY-LITTLE BAY			
Beachside	282	320	+ 13.5
Little Bay	350	202	- 42.3
Miles Cove	202	237	+ 17.3
Port Anson	154	183	+ 18.8
Robert's Arm	1,005	1,111	+ 10.5
South Brook, Hall's Bay	786	780	- 0.8
Springdale	3,501	3,555	+ 1.5
Sub. 8C - Unorganized	175	329	+ 88.0
TOTAL	6,862	7,093	+ 3.4
SUB-DIVISION 8D - PILLEY'S ISLAND			
Brighton	320	328	+ 2.5
Lushes Bight-Beaumont-Beaumont North	491	465	- 5.3
Pilley's Island	539	528	- 2.0
Triton	1,235	1,253	+ 1.5
Sub. 8D - Unorganized	-	-	-
TOTAL	2,585	2,574	- 0.4

Table 8-2 (cont'd)

	1 9 8 1	1 9 8 6	Percent Change
SUB-DIVISION 8E - NOTRE DAME BAY CENTRE			
Leading Tickles West	641	607	- 5.3
Point Leamington	848	850	+ 0.2
Point of Bay	252	251	- 0.4
Sub. 8E - Unorganized	1,004	980	- 2.4
TOTAL	2,745	2,688	- 2.1
SUB-DIVISION 8F - LEWISPORTE			
Embree	846	838	- 0.9
Lewisporte	3,963	3,978	+ 0.4
Little Burnt Bay	482	437	- 9.3
Sub. 8F - Unorganized	1,143	1,163	+ 1.7
TOTAL	6,434	6,416	- 0.3
SUB-DIVISION 8G - NOTRE DAME BAY SOUTH			
Baytona	356	370	+ 3.9
Birchy Bay	707	709	+ 0.3
Campbellton	703	686	- 2.4
Comfort Cove-Newstead	706	702	- 0.6
Sub. 8G - Unorganized	619	637	+ 2.9
TOTAL	3,091	3,104	+ 0.4
SUB-DIVISION 8H - NEW WORLD ISLAND			
Cottlesville	409	415	+ 1.5
Summerford	1,198	1,169	- 2.4
Sub. 8H - Unorganized	3,397	3,308	- 2.6
TOTAL	5,004	4,892	- 2.2

Table 8-2 (cont'd)

	1981	1986	Percent Change
SUB-DIVISION 8I - TWILLINGATE			
Bayview	625	603	- 3.5
Crow head	318	297	- 6.6
Durrell	1,145	1,060	- 7.4
Twillingate	1,506	1,506	0.0
Sub. 8I - Unorganized	339	333	- 1.8
TOTAL	3,933	3,799	- 2.2
SUB-DIVISION 8N - FOGO AND CHANGE ISLANDS			
Change Islands	580	562	- 3.1
Fogo	1,105	1,153	+ 4.3
Joe Batt's Arm-Barr'd Islands	1,155	1,232	+ 6.7
Seldom-Little Seldom	560	633	+ 13.0
Tilting	427	414	- 3.0
Sub. 8N - Unorganized	781	769	- 1.5
TOTAL	4,608	4,763	+ 3.4
SUB-DIVISION 8O - BURLINGTON			
Burlington	405	416	+ 2.7
Middle Arm, Green Bay	575	597	+ 3.8
Nippers Harbour	259	234	- 9.7
Tilt Cove	45	28	- 37.8
Sub. 8O - Unorganized	576	647	+ 12.3
TOTAL	1,860	1,922	+ 3.3
SUB-DIVISION 8P - KING'S POINT-GREEN BAY			
King's Point	825	923	+ 11.9
Sub. 8P - Unorganized	671	653	- 2.7
TOTAL	1,496	1,576	+ 5.3

abundant water indicates few residential or municipal source supply problems for the foreseeable future.

The only relevant historical information about the region available from CHMC is given in Table 8-3. These data are the number of starts in the Gander and Grand Falls regional areas from 1979 to 1990.

Note in Table 8-2 that Gander had a 19.5% increase in population from 1981 to 1986, while its region had a 2% decline. Grand Falls/Windsor had a 3.5% to 3.9% decline; its region had a 1.9% (504 persons) decline, while the associated unorganized area had a 25.2% (39 persons) increase in population. Thus, new starts would appear to represent replacement housing or population redistribution within each region. These might affect local water supply and distribution requirements, but such changes could be managed best at the local level.

The data of most interest in Table 8-2 are for those communities with the largest changes in population. Those with percent changes exceeding 10% (absolutely) are listed in Table 8-4. An annualized compound change over five years has also been calculated. On the basis of our municipal survey, we have also attempted to offer an explanation for the changes on the Table. Some conclusions are that:

1. the largest decreases occur in mining towns where the mine has closed or reduced its operations (not unexpectedly),

2. small fishing settlements within commuting distance of larger towns show relatively high growth rates (due, presumably, to new opportunities afforded by better roads, and a small base population), and

3. "unorganized" areas have high growth rates (same reasons as #2, presumably).

Table 8-3

HOUSING STARTS IN CENTRAL

YEAR	GANDER	GRAND FALLS
1979	*	51
1980	*	42
1981	*	60
1982	37	33
1983	27	26
1984	4	26
1985	17	59
1986	45	43
1987	42	99
1988	50	124
1989	91	187
1990	92	88

* Gander area not surveyed prior to 1982

Source: CHMC

Table 8-4

Census Areas with Population Changes Exceeding 10% per Year Between 1981 and 1986

NAME	PERCENT CHANGE 1981 - 1986	ANNUAL CHANGE 1981 - 1986	EXPLANATION/ HYPOTHESIS
DIVISION 8			
Baie Verte	- 17.7	- 3.83	mine
Fleur De Lys	- 14.6	- 3.11	mine (commute)
Pacquet	- 14.9	- 3.18	mine (commute)
Little Bay	- 42.3	- 10.4	mine closed
Miles Cove	+ 17.3	+ 3.25	Springdale (commute)
Port Anson	+ 18.8	+ 3.51	woods hauling
Robert's Arm	+ 10.5	+ 2.03	woods hauling
8C Unorganized	+ 88.0	+ 13.46	sprawl
Seldom/L. Seldom	+ 13.0	+ 2.48	Fogo Is. Co-Op main fish plant on Fogo
Tilt Cove	- 37.8	- 9.05	abandoned mine
8O Unorganized	+ 12.3	+ 2.35	sprawl
King's Point	+ 11.9	+ 2.27	Springdale (commute), woods hauling
Buchans	- 22.6	- 4.99	mine closed
6A Unorganized	- 24.0	- 5.34	mine closed
N. Arm/Exploits	- 14.8	- 2.79	Botwood (commute) railroad closing
6C Unorganized	+ 25.2	+ 4.55	sprawl

There appears to be some concentration of population on Fogo Island at the location of the main fish processing plant at Seldom/Little Seldom. This community would bear watching. The Springdale region appears to have enjoyed moderate growth; our staff reports anecdotal reports of relatively intensive woods harvesting during the census period.

Finally, updated population estimates for the larger towns were obtained from town officials (these are unconfirmed estimates). Ten-year data and percent changes for those towns are listed in Table 8-5. With the exception of Buchans, these have had a static population over the past ten years. Baie Verte has shown high volatililty over five-year periods.

8.3 Specific Municipal Responses

Managers or clerks for the larger towns were all contacted to obtain their views on future development and water supply implications.

To their knowledge, the only significant new facility which may go into the region in the near to medium-term is the proposed Central Newfoundland Campus of Memorial University. Several towns are vying for the campus, so it would be imprudent to discuss it in terms of a given community. We could not readily obtain an estimate for the water requirement of this campus, so one is provided here based on the St. John's campus of Memorial University.

MUN uses 220 to 250 million gallons/year, with the peak demand in the September to May academic year period and lesser demand in summer. Academic year population is 13,643 undergraduate students, 250 graduate students, and 4,000 faculty/staff support - for a total of 17,893. The average demand is thus about 38.3 gpcd.

Table 8-5

POPULATION OF MAJOR TOWNS IN CENTRAL

1981 - 1986 - 1991

	Population					1981-1991
Town	1981	Δ %	1986	Δ %	1991	Δ %
Buchans	1655	- 4.99	1281	- 4.83	1000	- 4.91
Lewisporte	3963	+ 0.4	3978	-	na	-
Bishop's Falls	4405	- 0.44	4203	+ 0.20	4300	- 0.24
Springdale	3501	+ 0.31	3555	0.00	3555	+ 0.15
Grand Falls	9228	- 0.23	9121	+ 0.40	9305	+ 0.08
Windsor	5747	- 0.71	5545	+ 0.54	5695	- 0.09
Baie Verte	2491	-17.74	2049	+19.57	2450	- 1.65

na - not available

For a 2,000-student campus the demand would be (proportionately) 76,506 gpd.

Also, assume that 50% of faculty and staff support is imported to the university community, and 60% of students will reside temporarily in the town (i.e. assumes 50% of staff labour can be obtained from the local market, and 40% of students already reside in the community). Using these assumptions, the community will grow by (2,000 x 28.8% =) 576 workers. Assuming 1.5 dependents per new worker, the community would grow by 864 persons. About (2,000 x 60% =) 1,200 students would reside in the community during the academic year. Thus the increase in peak community population would be about 2,000 persons. Using a typical demand value of 100 gpcd, the increase in water demand due to population growth would be 0.2 mgd.

Adding the campus demand value to this, the demand would be 0.28 mgd (1,050 m^3/d). [MUN information provided by Mr. Miller Ewing.]

A town-by-town summary is given below.

Grand Falls/Windsor

These towns are now amalgamated. No new major industries are expected, but they are not discouraged either. Currently 600 to 700 people (about 20% of the labour force) work at Abitibi. If the plant closes or reduces its employment, then a decrease in water demand would likely follow in time.

The water supply, which is managed by a regional authority, is considered to be adequate. About 2.5 mgd are withdrawn from Northern Arm Pond located 16 km northeast of the town. Before 1976, water was first treated by the mill (including filtration) before being transported to the Town. Subsequently, it has not been treated by the mill, but only screened and chlorinated. Silt has been an occasional problem, and a boil order was issued in 1983. The Town wishes to install a sand filter, but the project has been interrupted.

About 2 mgd of municipal wastewater are issued without treatment to the Exploits River. The Town sees no point in treating this while the mill issues 60 mgd of industrial wastewater daily to the river.

In summary, the only foreseeable new demand is a regional university. The Town believes there is sufficient water for a campus, but quality is certainly a problem.

Springdale

Springdale has had a stable population and economy for several decades. The Town does not foresee any major changes in its population or economy. It hopes to remain the same for the medium term (i.e. not decline). There is a concern that the Green Bay Health Care Centre may be downgraded to a clinic, and the hospital services moved to Grand Falls. This would not likely significantly affect water demand.

The supply is gravity feed from Sullivan's Pond, which the Town believes is adequate. A new dam has been constructed recently. Wastewater is discharged to the sea without treatment.

Buchans

Buchans has had a rapid decline in population since the mine closed. The Buchans Development Corporation is actively searching for new industry. A GE plant has recently decided to set up in Buchans, but it will have only five or six employees and is not expected to use much water. The Development Corporation is trying to find a firm which might have an interest in using the warm groundwater in the abandoned mine for a heat source. (A similar project has been implemented in Springhill, Nova Scotia.) The groundwater may thus have an economic value at Buchans.

Bishop's Falls

Bishop's Falls is tied to the regional water system for Grand Falls/Windsor. Major employment is provided by the mill at Grand Falls and at Newfoundland & Labrador Hydro. The reduction in scope and recent closing of the railroad reduced local employment.

Nevertheless, a shortage of housing is perceived to exist and there is a proposal for a new residential subdivision, to be developed ten lots at a time, to meet the shortage. Current demand at Bishop's Falls is about 600 gpm, which is supplied by the regional system. Except for the lack of filtration, there are no extraordinary problems.

The regional university might locate in Bishop's Falls, and, according to the Town, there is enough water to service it.

All sewage is directed to the Exploits River via outfalls; however, it is currently the policy that no new outfalls will be permitted for new developments.

Lewisporte

Lewisporte has had a static population over the last decade. Its economic base is as a harbour and regional service centre. Major industries include Lewisporte Wholesalers, Brookfield Dairies, the North Haven Senior Citizens Centre (about 100 cottages), and, for water use, a laundromat facility. A major harbour redevelopment has been proposed (value of $15 million based on an initial study) in the Hann's Point area, but progress is at a standstill pending funding. It is not expected to be a major user of fresh water.

Lewisporte may also be the site of the proposed regional university. The Town believes the water supply would be sufficient for the facility, but another supply line would be required.

Current water demand is 19.3 litres/second (0.44 mgd), with peaks of 48.7 to 57.9 l/s. Chlorination is the only treatment provided. There is a problem with underpressure in the part of Town near the tank farm. A booster pump is in the Town plan.

There is no sewage treatment. Currently sewage is discharged to the harbour via outfalls, but no problems are reported.

Baie Verte

Baie Verte is also a regional service centre. Up to 350 employees may be affected by a closure of Baie Verte Mines Inc., resulting in outmigration. However, the Town's experience is that, as housing prices drop due to outmigration, people from neighbouring small communities move to Baie Verte to enjoy the services. Therefore, the Town anticipates a stable population in the long term.

The Town considers the current water supply to be adequate, but the pumping capacity to be inadequate.

8.4 Demand

8.4.1 Domestic Demand

Estimates of domestic demand are based upon per capita demand rates. We used a value of 450 litres per capita per day (100 gpcd), which is that currently in general use in the Department of Municipal & Provincial Affairs. For larger communities with light industrial requirements, this was increased by 20% to 540 litres/capita/day (119 gpcd). These values differ from those used by Acres (1990) (520 and 820 litres/c/d, respectively) in the Northern Peninsula/Humber Valley study.

The demand rate is assumed to be constant over the 25-year planning period.

To arrive at total demand, unit rates were multiplied by population. Current population figures were obtained from our field survey and thus should reflect 1990 conditions, although a few communities have not informally updated the 1986 census results.

Future demand was estimated using the following assumptions:

(1) If census data were available for the community, the annualized growth rate for the last intercensal period (1981-1986) was used. We considered hard data superior to a subjective estimate.

(2) Smaller communities in the region typically have static or declining populations. To be conservative a growth rate of 0.1% per year was assigned to the remaining communities.

Demand and growth parameters are explicitly included in the demand spreadsheet (Table 8-6) so that other assumptions can be readily tested.

Even the foregoing assumptions about demand may be liberal. As shown in Table 8-2, Census Division 6 experienced a 3.08% decline in population between 1981 and 1986, and none of its main resource-based economic bases (forestry, fishing, mining) is likely to prosper in the 25-year planning period due to resource shortfalls. A worse case may well be continuing depopulation, which will reduce the domestic demand for water.

The population and demand estimates for 1990 and 2015 in the study area are listed in Table 8-6.

8.4.2 Fish Plant Demand

Estimated fish plant demands are also listed in Table 8-6 for those communities with fish plant and whose plants draw on the municipal water supply. These estimates are drawn from Table 7-1. The only plant in the study area which is metered and for which records were available is the FPI plant in Triton. This plant typically uses about 150 m^3/d, but use can reach 600 m^3/d during peak season (1990 data). For purposes of estimation, we set peak demand at twice usual demand (2 * 150 m^3/d). This value was also assigned to the La Scie plant, which is the NSP analog. Values for other plants were subjectively assigned on the basis of plant function and hierarchy position, as discussed in Section 7.3.2. A minimum value was 100 m^3/d. It is emphasized that these values are subjective and approximate. Further work is needed to refine them.

The same demand figures are used for the year 2015.

Table 8-6. ESTIMATES OF DEMAND FOR SURFACE WATER SUPPLIES FOR THE YEARS 1990 AND 2015

Community	Population	Growth Rate	Population	Demand Rate	Demand 1990 m^3/day			Demand 2015 m^3/day		
	1990	(% per year)	2015	(m^3/d/c)	Domestic	Fish Plants	Total	Domestic	Fish Plants	Total
Appleton	517	3.63	1261	0.45	232.7	0	232.7	567.3	0.0	567.3
Baie Verte	2049	-3.18	913	0.54	1106.5	100	1206.5	493.2	100.0	593.2
Bayview	600	-0.69	505	0.45	270.0	0	270.0	227.1	0.0	227.1
Beachside	320	2.57	603	0.45	144.0	0	144.0	271.6	0.0	271.6
Birchy Bay	750	0.1	769	0.45	337.5	0	337.5	346.0	0.0	346.0
Botwood	5030	-0.77	4146	0.54	2716.2	100	2816.2	2238.9	100.0	2338.9
Brent's Cove	400	0.5	453	0.45	180.0	100	280.0	203.9	100.0	303.9
Brighton	350	0.1	359	0.45	157.5	0	157.5	161.5	0.0	161.5
Buchans	1100	-4.16	380	0.54	594.0	0	594.0	205.3	0.0	205.3
Burlington East Side	215	0.53	245	0.45	96.8	0	96.8	110.4	0.0	110.4
Burlington West Side	200	0.53	228	0.45	90.0	0	90.0	102.7	0.0	102.7
Campbellton	686	-0.48	608	0.45	308.7	100	408.7	273.7	100.0	373.7
Chanceport	80	0.1	82	0.45	36.0	0	36.0	36.9	0.0	36.9
Comfort Cove/Newstead	800	0.1	820	0.45	360.0	100	460.0	369.1	100.0	469.1
Cottlesville	415	0.48	468	0.45	186.8	100	286.8	210.5	100.0	310.5
Cottrell's Cove/Moore's Cove	500	0.1	513	0.45	225.0	0	225.0	230.7	0.0	230.7
Crow Head	300	-1.29	217	0.45	135.0	0	135.0	97.6	0.0	97.6
Durrell	1060	-1.43	739	0.45	477.0	0	477.0	332.8	0.0	332.8
Embree	836	0.1	857	0.45	376.2	0	376.2	385.7	0.0	385.7
Fairbanks	300	0.1	308	0.45	135.0	0	135.0	138.4	0.0	138.4
Fleur De Lys	175	-2.76	87	0.45	78.8	75	153.8	39.1	75.0	114.1
Fleur De Lys	175	-2.76	87	0.45	78.8	75	153.8	39.1	75.0	114.1
Fleur De Lys	176	-2.76	87	0.45	79.2	75	154.2	39.3	75.0	114.3
Fogo	1150	0.85	1421	0.54	621.0	250	871.0	767.3	250.0	1017.3
Glenwood	1038	-1.57	699	0.45	467.1	0	467.1	314.5	0.0	314.5
Grand Fls/Windsor/Bishop's Fls	18879	-3.4	7965	0.54	10194.7	0	10194.7	4301.2	0.0	4301.2
Herring Neck	250	0.1	256	0.45	112.5	200	312.5	115.3	200.0	315.3
Hillgrade	200	0.1	205	0.45	90.0	100	190.0	92.3	100.0	192.3
Indian Cove	80	0.1	82	0.45	36.0	0	36.0	36.9	0.0	36.9
Jackson's Cove	150	0.1	154	0.45	67.5	0	67.5	69.2	0.0	69.2
Joe Batts Arm	1250	1.31	1731	0.45	562.5	200	762.5	778.8	200.0	978.8
King's Island/Smith's Harbour	250	0.1	256	0.45	112.5	0	112.5	115.3	0.0	115.3
King's Point	923	2.27	1618	0.45	415.4	0	415.4	728.0	0.0	728.0
La Scie	1450	0.1	1487	0.45	652.5	300	952.5	669.0	300.0	969.0
Leading Tickles	350	-1.04	270	0.45	157.5	200	357.5	121.3	200.0	321.3
Lewisporte	3978	0.4	4395	0.54	2148.1	0	2248.1	2373.6	0.0	2473.6
Little Bay	30	0.1	31	0.45	13.5	0	13.5	13.8	0.0	13.8
Loon Bay	200	0.1	205	0.45	90.0	0	90.0	92.3	0.0	92.3
Lushes Bight/Beaumont	450	-1.04	347	0.45	202.5	0	202.5	155.9	0.0	155.9
Merritt's Harbour	100	0.1	103	0.45	45.0	0	45.0	46.1	0.0	46.1
Middle Arm	720	0.74	866	0.45	324.0	200	524.0	389.6	200.0	589.6
Miles Cove	240	3.25	534	0.45	108.0	0	108.0	240.3	0.0	240.3

Table 8-6 (continued). ESTIMATES OF DEMAND FOR SURFACE WATER SUPPLIES FOR THE YEARS 1990 AND 2015

Community	Population	Growth Rate	Population	Demand Rate	Demand 1990 m^3/day			Demand 2015 m^3/day		
	1990	(% per year)	2015	(m^3/d/c)	Domestic	Fish Plants	Total	Domestic	Fish Plants	Total
Millertown	213	-1.2	158	0.45	95.9	0	95.9	70.9	0.0	70.9
Ming's Bight/South Brook	445	0.1	456	0.45	200.3	100	300.3	205.3	100.0	305.3
Newville	200	0.1	205	0.45	90.0	0	90.0	92.3	0.0	92.3
Nippers Harbour	275	-1.87	172	0.45	123.8	0	123.8	77.2	0.0	77.2
Norris Arm	1127	-1.4	792	0.45	507.2	0	507.2	356.5	0.0	356.5
Northern Arm	500	-2.8	246	0.45	225.0	0	225.0	110.6	0.0	110.6
Pacquet	350	0.1	359	0.45	157.5	100	257.5	161.5	100.0	261.5
Peterview	1130	0.1	1159	0.45	508.5	0	508.5	521.4	0.0	521.4
Phillip's Head	275	0.1	282	0.45	123.8	0	123.8	126.9	0.0	126.9
Pilley's Island	528	0.1	541	0.45	237.6	0	237.6	243.6	0.0	243.6
Pleasantview	85	0.1	87	0.45	38.3	0	38.3	39.2	0.0	39.2
Point of Bay	250	0.1	256	0.45	112.5	0	112.5	115.3	0.0	115.3
Point Leamington	850	0.1	872	0.45	382.5	0	382.5	392.2	0.0	392.2
Port Albert	150	0.1	154	0.45	67.5	0	67.5	69.2	0.0	69.2
Port Anson	200	3.51	474	0.45	90.0	0	90.0	213.2	0.0	213.2
Purbeck's Cove	50	0.1	51	0.45	22.5	0	22.5	23.1	0.0	23.1
Purcell's Harbour	80	0.1	82	0.45	36.0	100	136.0	36.9	100.0	136.9
Rattling Brook	150	0.1	154	0.45	67.5	0	67.5	69.2	0.0	69.2
Robert's Arm	1200	2.03	1983	0.45	540.0	0	540.0	892.5	0.0	892.5
Rooms	76	0.1	78	0.45	34.2	0	34.2	35.1	0.0	35.1
Seal Cove (Western Bay)	750	-1.38	530	0.45	337.5	100	437.5	238.5	100.0	338.5
Shoe Cove	300	0.1	308	0.45	135.0	0	135.0	138.4	0.0	138.4
Snooks Arm	50	0.1	51	0.45	22.5	0	22.5	23.1	0.0	23.1
South Brook	750	0.1	769	0.45	337.5	0	337.5	346.0	0.0	346.0
Springdale (Sullivan's Pond)	3377	1.5	4900	0.54	1823.7	0	1823.7	2646.1	0.0	2646.1
Stoneville	500	0.1	513	0.45	225.0	0	225.0	230.7	0.0	230.7
Summerford	1584	0.48	1785	0.45	712.8	0	712.8	803.4	0.0	803.4
The Beaches	100	0.1	103	0.45	45.0	0	45.0	46.1	0.0	46.1
Tilt Cove	24	-6.62	4	0.45	10.8	0	10.8	1.9	0.0	1.9
Tilting	414	-0.6	356	0.45	186.3	100	286.3	160.3	100.0	260.3
Tizzard's Harbour	150	0.1	154	0.45	67.5	100	167.5	69.2	100.0	169.2
Triton	1250	0.1	1282	0.54	675.0	300	975.0	692.1	300.0	992.1
Twillingate	769	0	769	0.54	415.3	125	540.3	415.3	125.0	540.3
Twillingate	770	0	770	0.54	415.8	125	540.8	415.8	125.0	540.8
Valley Pond	200	0.3	216	0.45	90.0	0	90.0	97.0	0.0	97.0
Westport	500	-1.17	373	0.45	225.0	0	225.0	167.6	0.0	167.6
Wild Cove	112	0.1	115	0.45	50.4	100	150.4	51.7	100.0	151.7
Woodstock	400	0.69	475	0.45	180.0	0	180.0	213.8	0.0	213.8
Sums	69034		59649		34533	3625	38158	29290	3625	32915

8.4.3 Total Demand

Total demand is the sum of domestic and fish plant demand. This is also shown in Table 8-6. Total municipal demand (excluding Gander) in 1990 is estimated to be 38 058 m^3/d.

8.5 Supply (Surface Systems)

Estimates of firm and annual average supply for surface water systems were calculated using the results of Section 2.5. The calculations are shown in Table 8-7. A column-by-column explanation follows:

(1) Impoundment Surface Area - Area of the storage impoundment in hectares taken from a topo map, or measured during the field survey. This was set to zero for run-of-river cases. Gander Lake was set at 40 000 Ha.

(2) Live Storage - This is the storage available for withdrawal, usually between the spillway and intake elevations. These data were noted in the field. If the live storage were small, it was set to a default of 0.3 m.

(3) Drainage Area - The drainage area above the intake, measured from topographic maps.

(4) Storage Volume - Impoundment Surface area (Column 1) multiplied by live storage (Column 2), converted to m^3.

(5) Mean Annual Runoff (m^3/s) - Drainage area (Column 3) multiplied by a constant value of 0.027179 m3/s-km^2, on the basis of the hydrology study presented in Section 2.

(6) Mean Annual Flow Volume (m^3/year) - Column 5 multiplied by the number of seconds per year.

(7) Storage Ratio (S/Qv) - The live storage (Column 2) divided by the mean annual flow volume (Column 6), with units of 1 per year.

Table 8-7 ESTIMATES OF SURFACE WATER SUPPLIES

Community	Impoundment Surface Area (ha)	Impoundment Live Storage (m)	Drainag Area (ha)	Storage Volume (m^3)	Mean Annual Runoff (m^3/s)	Mean Ann Flow Vol. (m^3/year)	Storage Ratio (S/Qv) (1/year)	Yield Ratio (Q/<Q>)	Yield From Storage (m^3/sec)	Yield From Low Flow (m^3/sec)	Days Flow Can Be Drawn From Storage	Ratio of Yields from Storage to Low Flow	Classification	Yield for Demand (m^3/sec)	Yield for Demand (m^3/day)
Newville	10.0	1.5	44	150000	0.012	3.77E+05	3.97E-01	1.28E+00	1.53E-02	1.39E-04	113.7	110.2	reservoir	1.53E-02	1320
Nippers Harbour	0	0.3	240	0	0.065	2.06E+06	0.00E+00	5.74E-02	3.75E-03	9.36E-04	0.0	4.0	run of river	9.36E-04	81
Norris Arm	55.0	3.0	315	1650000	0.086	2.70E+06	6.11E-01	1.93E+00	1.65E-01	1.27E-03	115.5	130.0	reservoir	1.65E-01	14289
Northern Arm	0.0500	2.1	185	1050	0.050	1.59E+06	6.62E-04	5.94E-02	2.99E-03	6.99E-04	4.1	4.3	run of river	6.99E-04	60
Pacquet	0.0036	0.5	1920	16	0.522	1.65E+07	9.84E-07	5.74E-02	3.00E-02	9.74E-03	0.0	3.1	run of river	9.74E-03	842
Phillip's Head	0.0300	1.0	157	300	0.043	1.35E+06	2.23E-04	5.81E-02	2.48E-03	5.81E-04	1.4	4.3	run of river	5.81E-04	50
Pilley's Island	12.0	1.9	112	222000	0.030	9.61E+05	2.31E-01	7.67E-01	2.33E-02	3.97E-04	110.1	58.8	reservoir	2.33E-02	2016
Pleasantview	7.0	2.1	83	147000	0.023	7.12E+05	2.06E-01	6.91E-01	1.56E-02	2.83E-04	109.1	55.1	reservoir	1.56E-02	1347
Point of Bay	160	2	5200	3200000	1.413	4.46E+07	7.17E-02	2.78E-01	3.92E-01	2.99E-02	94.4	13.1	reservoir	3.92E-01	33900
Point Leamington	14.0	2.0	4020	280000	1.093	3.45E+07	8.12E-03	8.23E-02	9.00E-02	2.24E-02	36.0	4.0	reservoir	9.00E-02	7773
Port Albert	7.0	1.5	58	105000	0.016	4.97E+05	2.11E-01	7.05E-01	1.11E-02	1.89E-04	109.3	58.8	reservoir	1.11E-02	960
Port Anson	3.0	1.5	25	45000	0.007	2.14E+05	2.10E-01	7.02E-01	4.77E-03	7.33E-05	109.3	65.0	reservoir	4.77E-03	412
Purbeck's Cove	0.0	0.3	205	0	0.056	1.76E+06	0.00E+00	5.74E-02	3.20E-03	7.84E-04	0.0	4.1	run of river	7.84E-04	68
Purcell's Harbour	9.5	1.8	300	171000	0.082	2.57E+06	6.65E-02	2.61E-01	2.13E-02	1.20E-03	92.9	17.7	reservoir	2.13E-02	1841
Rattling Brook	0.01	2.0	260	200	0.071	2.23E+06	8.97E-05	5.77E-02	4.08E-03	1.02E-03	0.6	4.0	run of river	1.02E-03	89
Robert's Arm	0.4	3.0	120	13200	0.033	1.03E+06	1.28E-02	9.68E-02	3.16E-03	4.29E-04	48.4	7.4	reservoir	3.16E-03	273
Rooms	0.006	1.2	990	72	0.269	8.49E+06	8.48E-06	5.74E-02	1.55E-02	4.62E-03	0.1	3.3	run of river	4.62E-03	399
Seal Cove (Western Bay)	12.0	1.8	450	216000	0.122	3.86E+06	5.60E-02	2.29E-01	2.80E-02	1.90E-03	89.2	14.7	reservoir	2.80E-02	2422
Shoe Cove	8.0	1.8	470	144000	0.128	4.03E+06	3.57E-02	1.67E-01	2.13E-02	2.00E-03	78.1	10.7	reservoir	2.13E-02	1844
South Brook	930.0	0.3	58000	2790000	15.764	4.97E+08	5.61E-03	7.46E-02	1.18E+00	4.53E-01	27.4	2.6	reservoir	1.18E+00	101643
Springdale (Sullivan's Pd)	23	5.5	386	1265000	0.105	3.31E+06	3.82E-01	1.23E+00	1.29E-01	1.60E-03	113.5	80.7	reservoir	1.29E-01	11150
Stoneville	0.0	0.3	38000	0	10.328	3.26E+08	0.00E+00	5.74E-02	5.93E-01	2.81E-01	0.0	2.1	run of river	2.81E-01	24294
Summerford	9.0	2.6	215	234000	0.058	1.84E+06	1.27E-01	4.47E-01	2.61E-02	8.27E-04	103.7	31.6	reservoir	2.61E-02	2256
The Beaches	0.004	1.2	196	48	0.053	1.68E+06	2.86E-05	5.75E-02	3.06E-03	7.45E-04	0.2	4.1	run of river	7.45E-04	64
Tilt Cove	8.0	1.3	30	104000	0.008	2.57E+05	4.04E-01	1.30E+00	1.06E-02	9.00E-05	113.7	117.6	reservoir	1.06E-02	914
Tilting	56.0	2.4	1952	1344000	0.531	1.67E+07	8.03E-02	3.04E-01	1.61E-01	9.93E-03	96.5	16.2	reservoir	1.61E-01	13925
Tizzard's Harbour	4.5	3.0	136	135000	0.037	1.17E+06	1.16E-01	4.13E-01	1.53E-02	4.94E-04	102.4	30.9	reservoir	1.53E-02	1318
Triton	12.0	3.0	430	360000	0.117	3.69E+06	9.76E-02	3.57E-01	4.17E-02	1.81E-03	99.9	23.1	reservoir	4.17E-02	3605
Twillingate	25.0	1.4	263	350000	0.071	2.26E+06	1.55E-01	5.34E-01	3.81E-02	1.04E-03	106.2	36.7	reservoir	3.81E-02	3296
Twillingate	20	3	200	600000	0.054	1.72E+06	3.50E-01	1.13E+00	6.15E-02	7.63E-04	113.0	80.6	reservoir	6.15E-02	5311
Valley Pond	7.5	1.5	28	112500	0.008	2.40E+05	4.68E-01	1.50E+00	1.14E-02	8.33E-05	114.4	136.6	reservoir	1.14E-02	983
Westport	0.0	0.9	375	0	0.102	3.22E+06	0.00E+00	5.74E-02	5.85E-03	1.55E-03	0.0	3.8	run of river	1.55E-03	134
Wild Cove	0.0375	3.8	2550	1425	0.693	2.19E+07	6.52E-05	5.76E-02	3.99E-02	1.34E-02	0.4	3.0	run of river	1.34E-02	1159
Woodstock	5.0	1.7	235	85000	0.064	2.02E+06	4.22E-02	1.87E-01	1.19E-02	9.15E-04	82.4	13.0	reservoir	1.19E-02	1031

Table 8-7 ESTIMATES OF SURFACE WATER SUPPLIES (continued)

Community	Impoundment Surface Area (ha)	Impoundment Live Storage (m)	Drainag Area (ha)	Storage Volume (m^3)	Mean Annual Runoff (m^3/s)	Mean Ann Flow Vol. (m^3/year)	Storage Ratio (S/Qv) (1/year)	Yield Ratio (Q/<Q>)	Yield From Storage (m^3/sec)	Yield From Low Flow (m^3/sec)	Days Flow Can Be Drawn From Storage	Ratio of Yields from Storage to Low Flow	Classification	Yield for Demand (m^3/sec)	Yield for Demand (m^3/day)
Appleton	40000	2.4	416000	960000000	113.065	3.57E+09	2.69E-01	8.83E-01	9.99E+01	4.17E+00	111.3	24.0	reservoir	9.99E+01	8627509
Baie Verte	0.6	3.0	8500	18000	2.310	7.29E+07	2.47E-04	5.82E-02	1.34E-01	5.21E-02	1.6	2.6	run of river	5.21E-02	4497
Bayview	21.0	1.0	65	210000	0.018	5.58E+05	3.77E-01	1.21E+00	2.14E-02	2.15E-04	113.4	99.7	reservoir	2.14E-02	1852
Beachside	0.3	2.0	25	6000	0.007	2.14E+05	2.80E-02	1.43E-01	9.74E-04	7.33E-05	71.3	13.3	reservoir	9.74E-04	84
Birchy Bay	44.0	2.5	3620	1100000	0.984	3.10E+07	3.54E-02	1.66E-01	1.63E-01	1.99E-02	77.9	8.2	reservoir	1.63E-01	14124
Botwood	0.0	0.3	17700	0	4.811	1.52E+08	0.00E+00	0.00E+00	0.00E+00	1.19E-01	0.0	0.0	run of river	1.19E-01	10275
Brent's Cove	3.5	1.4	95	49000	0.026	8.15E+05	6.01E-02	2.42E-01	6.25E-03	3.30E-04	90.8	18.9	reservoir	6.25E-03	540
Brighton	4.0	2.7	58	108000	0.016	4.97E+05	2.17E-01	7.24E-01	1.14E-02	1.89E-04	109.6	60.3	reservoir	1.14E-02	986
Buchans	0.0	1.5	50800	0	13.807	4.36E+08	0.00E+00	0.00E+00	0.00E+00	3.90E-01	0.0	0.0	run of river	3.90E-01	33691
Burlington East Side	0.0160	0.9	12225	144	3.323	1.05E+08	1.37E-06	5.74E-02	1.91E-01	7.84E-02	0.0	2.4	run of river	7.84E-02	6772
Burlington West Side	0.0170	1.2	940	204	0.255	8.06E+06	2.53E-05	5.75E-02	1.47E-02	4.36E-03	0.2	3.4	run of river	4.36E-03	377
Campbellton	0.0	1.2	28300	0	7.692	2.43E+08	0.00E+00	5.74E-02	4.42E-01	2.02E-01	0.0	2.2	run of river	2.02E-01	17432
Chanceport	1.3	1.2	62	15000	0.017	5.32E+05	2.82E-02	1.44E-01	2.43E-03	2.04E-04	71.6	11.9	reservoir	2.43E-03	210
Comfort Cove/Newstead	14.0	2.4	220	336000	0.060	1.89E+06	1.78E-01	6.04E-01	3.61E-02	8.49E-04	107.7	42.5	reservoir	3.61E-02	3120
Cottrell's Cove/Moore's Cove	5.0	1.8	72	90000	0.020	6.18E+05	1.46E-01	5.05E-01	9.88E-03	2.41E-04	105.5	40.9	reservoir	9.88E-03	853
Crow Head	6.0	1.5	62	90000	0.017	5.32E+05	1.69E-01	5.77E-01	9.72E-03	2.04E-04	107.2	47.7	reservoir	9.72E-03	840
Embree	40.0	2.3	445	912000	0.121	3.82E+06	2.39E-01	7.91E-01	9.56E-02	1.88E-03	110.4	50.9	reservoir	9.56E-02	8263
Fairbanks	1.3	1.2	52	15000	0.014	4.46E+05	3.36E-02	1.61E-01	2.27E-03	1.67E-04	76.5	13.6	reservoir	2.27E-03	196
Fleur De Lys	2.0	1.7	16.7	34000	0.005	1.43E+05	2.37E-01	7.86E-01	3.57E-03	4.65E-05	110.3	76.7	reservoir	3.57E-03	308
Fleur De Lys	4.2	2	29.3	84000	0.008	2.51E+05	3.34E-01	1.08E+00	8.63E-03	8.76E-05	112.7	98.4	reservoir	8.63E-03	745
Fleur De Lys	2.5	1.5	69	37500	0.019	5.92E+05	6.34E-02	2.52E-01	4.72E-03	2.30E-04	91.9	20.5	reservoir	4.72E-03	408
Fogo	14.5	2.2	165.5	319000	0.045	1.42E+06	2.25E-01	7.47E-01	3.36E-02	6.16E-04	109.9	54.5	reservoir	3.36E-02	2904
Glenwood	40000	2.0	416000	800000000	113.065	3.57E+09	2.24E-01	7.46E-01	8.43E+01	4.17E+00	109.8	20.2	reservoir	8.43E+01	7283070
Grand Fls/Windsor/Bishop's F	170	3.1	6025	5270000	1.638	5.17E+07	1.02E-01	3.70E-01	6.07E-01	3.53E-02	100.6	17.2	reservoir	6.07E-01	52406
Herring Neck	4.5	2.0	19	90000	0.005	1.63E+05	5.52E-01	1.75E+00	9.05E-03	5.38E-05	115.1	168.2	reservoir	9.05E-03	782
Hillgrade	20.0	2.0	120	400000	0.033	1.03E+06	3.89E-01	1.25E+00	4.08E-02	4.29E-04	113.5	95.1	reservoir	4.08E-02	3523
Indian Cove	2.0	1.5	12	30000	0.003	1.03E+05	2.91E-01	9.52E-01	3.10E-03	3.21E-05	111.8	96.8	reservoir	3.10E-03	268
Jackson's Cove	35.0	2.0	210	700000	0.057	1.80E+06	3.89E-01	1.25E+00	7.14E-02	8.06E-04	113.5	88.6	reservoir	7.14E-02	6165
Joe Batts Arm	6.5	1.8	604	113750	0.164	5.18E+06	2.20E-02	1.25E-01	2.05E-02	2.65E-03	64.3	7.7	reservoir	2.05E-02	1770
King's Island/Smith's Harbour	0.0180	1.8	950	324	0.258	8.15E+06	3.98E-05	5.75E-02	1.49E-02	4.41E-03	0.3	3.4	run of river	4.41E-03	381
King's Point	3.0	1.5	1860	45000	0.506	1.60E+07	2.82E-03	6.61E-02	3.34E-02	9.40E-03	15.6	3.6	reservoir	3.34E-02	2886
La Scie	98.0	4.0	690	3920000	0.188	5.92E+06	6.62E-01	2.09E+00	3.92E-01	3.08E-03	115.7	127.4	reservoir	3.92E-01	33869
Leading Tickles	3.3	2.0	118	65000	0.032	1.01E+06	6.42E-02	2.55E-01	8.16E-03	4.21E-04	92.2	19.4	reservoir	8.16E-03	705
Lewisporte	75.0	2.1	2640	1575000	0.718	2.26E+07	6.96E-02	2.71E-01	1.94E-01	1.39E-02	93.8	13.9	reservoir	1.94E-01	16794
Little Bay	0.4	1.5	10	6000	0.003	8.58E+04	7.00E-02	2.72E-01	7.40E-04	2.61E-05	93.9	28.3	reservoir	7.40E-04	64
Loon Bay	0.0720	2.7	7400	0	2.011	6.35E+07	0.00E+00	5.74E-02	1.15E-01	4.45E-02	0.0	2.6	run of river	4.45E-02	3847
Lushes Bight/Beaumont	4.0	2.0	55	80000	0.015	4.72E+05	1.70E-01	5.78E-01	8.64E-03	1.78E-04	107.2	48.5	reservoir	8.64E-03	746
Merritt's Harbour	3.6	2.4	30	86400	0.008	2.57E+05	3.36E-01	1.09E+00	8.87E-03	9.00E-05	112.7	98.6	reservoir	8.87E-03	766
Middle Arm	0.0720	2.7	1585	1944	0.431	1.36E+07	1.43E-04	5.79E-02	2.49E-02	7.85E-03	0.9	3.2	run of river	7.85E-03	678
Miles Cove	0.0800	3.0	90	2400	0.024	7.72E+05	3.11E-03	6.70E-02	1.64E-03	3.10E-04	17.0	5.3	run of river	3.10E-04	27
Millertown	6.0	2.0	88	120000	0.024	7.55E+05	1.59E-01	5.45E-01	1.30E-02	3.02E-04	106.5	43.1	reservoir	1.30E-02	1127
Ming's Bight/South Brook	6.0	1.8	225	108000	0.061	1.93E+06	5.60E-02	2.29E-01	1.40E-02	8.71E-04	89.2	16.1	reservoir	1.40E-02	1211

(8) Yield Ratio - This follows from Figure 2-27 of Section 2, which is the suggested storage-yield curve for the region. Since the values of storage ratio (Column 7) fell in the range 10^{0} to 10^{-6}, only the near-linear range of Q/Qavg between 0.1 and 0.4 of Figure 2-27 was used to calculate a linearized estimate of Q/Qavg as a function of S/Qv. This procedure is described in Section 2.5, and the relation is depicted on Figures 2-30 and 8-1. As shown on the figure, it is possible to force a zero intercept (i.e. Q = 0 for S = 0), but the fit is not good. This is likely because some low flow will exist in the absence of storage. Accordingly, the relation used for Column 8 is:

$$Q/Qavg = 0.057415 + 3.069077 * (S/Qv) \quad (8\text{-}1)$$

This represents the normalized firm yields over the most serious episodes of flow deficiency during the periods of record of the stations considered, as described in Section 2.

(9) Yield from Storage - The yield ratio (Column 8) is converted to flow by multiplication by the mean annual runoff (Column 5).

(10) Yield from Low Flow - This parameter is estimated for the 7-day 10-year low flow from the appropriate equations presented in Table 2-17, viz.:

$$Q10@7 = 0.3493325*DA(km^2)^{1.126356}/1000 \quad (8\text{-}2)$$

where Q10@7 is in m^3/s.

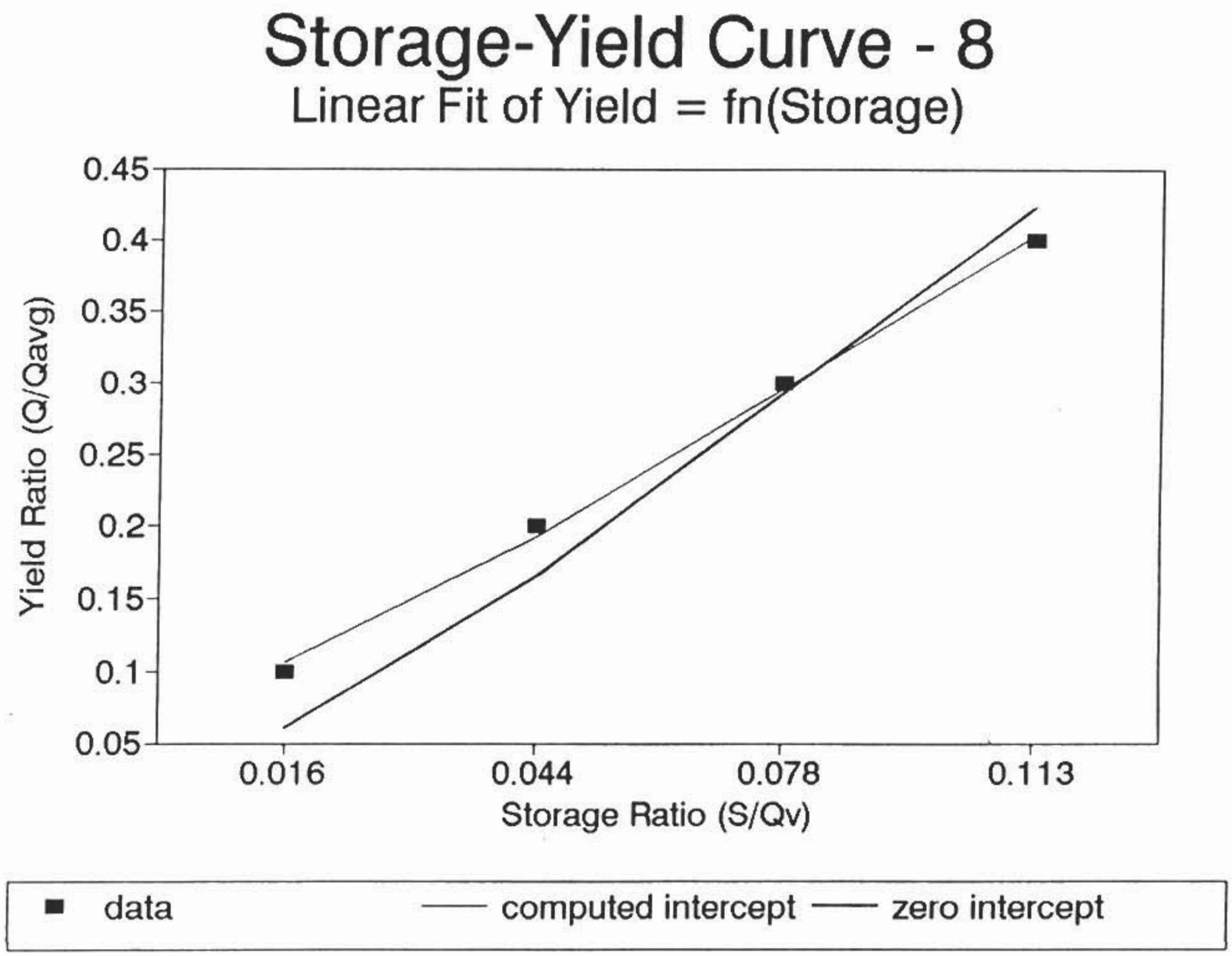
(11) Days Flow Can Be Drawn from Storage - This is calculated by dividing storage volume (Column 4) by the yield from storage (Column 9). It tells the number of days the design firm yield will persist for the available storage volume.

(12) Ratio of Yields of Storage to Low Flow - This is simply the ratio of Columns 9 and 10.

(13) Classification - The system is classified as being "run of river" or "reservoir", depending upon three logical tests which cover most cases. The system is "run of river" if:

(1) the impoundment surface area (Column 1) is less than 0.1 Ha, or

FIG. 8-1


Storage-Yield Curve - 8
Linear Fit of Yield = fn(Storage)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Yield Ratio (Q/Qavg)
0.016
0.044
0.078
0.113
Storage Ratio (S/Qv)
data
computed intercept
zero intercept

(2) the yield from low flow (Column 10) exceeds the yield from storage (Column 9), or
(3) the number of days the flow can be drawn from storage (Column 11) is less than 14.

(14) Yield for Demand (m^3/s) - This is the value of Column 9 if the classification is "reservoir", and of Column 10 if the classification is "run of river."

(15) Yield for Demand (m^3/d) - This is Column 14 multiplied by the number of seconds per day.

Several special cases not completely covered by the model system existed. These are explained in the Legend column of Table 8-7. For instance, the systems with a two-pond supply (Fleur de Lys, Twillingate) were computed twice even though the flows are combined in the distribution system. For these cases the population is divided between the sources as a stratagem. An exception is Springdale where one of the supplies (Huxter's Pond) is no longer in use, but is available as a backup.

Also noted are systems where only a portion of the population is on a surface supply, with the remainder drawing from groundwater.

8.6 Adequacy of Supply

8.6.1 Introduction

Having estimated demand and supply, they can be compared and communities with potential supply problems identified. We wish to emphasize that this is a screening procedure only. Each case, particularly in rural Newfoundland is unique; and a standardized screening procedure will not apply as well to each one. Using the statistical analog, two types of error can occur: (1) the model can identify a community as having a potential supply problem when, for various reasons, it does not, and (2) the model does not identify a community as having a potential supply problem when, in fact, it does. We have attempted to minimize the first error category by following up on communities identified by the model as having potential supply problems. The investigation involved review of field notes and telephone discussions with town officials. In some cases the cause was able to be resolved. For the remainder we offer preliminary advice about means to solve the supply problem. These investigative discussions appear later in this section.

To address the second error category we rely upon the discussions with municipal officials during our site visits. To the best of our knowledge there were no instances of this error; it can thus be concluded that the screening model is effective.

8.6.2 Supply/Demand Table

A comparison of demand for 1990 and 2015 and supply for both low flow (firm yield) and mean annual flow is presented in Table 8-8. The purpose of including the mean annual flow ratios is to assess the adequacy for the case where no long-term incremental supply from storage creation is possible.

Those communities where the supply/demand ratio was less than 1.0 are indicated with a (*) in Table 8-8.

Communities that were selected for follow-up investigations are:

Beachside
Miles Cove
Nippers Harbour
Northern Arm
Phillips Head
Robert's Arm
Westport

Table 8-8 ESTIMATES OF ADEQUACY OF SUPPLY TO MEET DEMAND 1990 AND 2015

COMMUNITY	TOTAL DEMAND		LOW FLOW			MEAN FLOW		
	1990	2015	Supply	Supply/Demand Ratio		Supply	Supply/Demand Ratio	
	m^3/day	m^3/day	(m^3/d)	1990	2015	(m^3/d)	1990	2015
Appleton	232.7	567.3	8627509	37083.6	15207.0	9768785	41989.2	17218.7
Baie Verte	1206.5	593.2	4497	3.7	7.6	199603	165.4	336.5
Bayview	270.0	227.1	1852	6.9	8.2	1526	5.7	6.7
Beachside	144.0	271.6	84	0.6 *	0.3 *	587	4.1	2.2
Birchy Bay	337.5	346.0	14124	41.8	40.8	85007	251.9	245.7
Botwood	2816.2	2338.9	10275	3.6	4.4	415643	147.6	177.7
Brent's Cove	280.0	303.9	540	1.9	1.8	2231	8.0	7.3
Brighton	157.5	161.5	986	6.3	6.1	1362	8.6	8.4
Buchans	594.0	205.3	33691	56.7	164.1	1192919	2008.3	5809.7
Burlington East Side	96.8	110.4	6772	70.0	61.3	287075	2967.2	2599.9
Burlington West Side	90.0	102.7	377	4.2	3.7	22074	245.3	214.9
Campbellton	408.7	373.7	17432	42.7	46.6	664559	1626.0	1778.3
Chanceport	36.0	36.9	210	5.8	5.7	1456	40.4	39.4
Comfort Cove/Newstead	460.0	469.1	3120	6.8	6.7	5166	11.2	11.0
Cottlesville	286.8	310.5	853	3.8	3.7	1691	7.5	7.3
Cottrell's Cove/Moore's Cove	225.0	230.7	853	3.8	3.7	1691	7.5	7.3
Crow Head	135.0	97.6	840	6.2	8.6	1456	10.8	14.9
Durrell	477.0	332.8	196	1.5	1.4	1221	9.0	8.8
Embree	376.2	385.7	8263	22.0	21.4	10450	27.8	27.1
Fairbanks	135.0	138.4	196	1.5	1.4	1221	9.0	8.8
Fleur De Lys	153.8	114.1	308	2.0	2.7	392	2.6	3.4
Fleur De Lys	153.8	114.1	745	4.8	6.5	688	4.5	6.0
Fleur De Lys	154.2	114.3	408	2.6	3.6	1620	10.5	14.2
Fogo	871.0	1017.3	2904	3.3	2.9	3886	4.5	3.8
Glenwood	467.1	314.5	7283070	15592.1	23158.9	9768785	20913.7	31063.0
Grand Fls/Windsor/Bishop's Fls	10194.7	4301.2	52406	5.1	12.2	141483	13.9	32.9
Herring Neck	312.5	315.3	782	2.5	2.5	446	1.4	1.4
Hillgrade	190.0	192.3	3523	18.5	18.3	2818	14.8	14.7
Indian Cove	36.0	36.9	268	7.5	7.3	282	7.8	7.6
Jackson's Cove	67.5	69.2	6165	91.3	89.1	4931	73.1	71.3
Joe Batts Arm	762.5	978.8	1770	2.3	1.8	14184	18.6	14.5
King's Island/Smith's Harbour	112.5	115.3	381	3.4	3.3	22309	198.3	193.4
King's Point	415.4	728.0	2886	6.9	4.0	43678	105.2	60.0
La Scie	952.5	969.0	33869	35.6	35.0	16203	17.0	16.7
Leading Tickles	357.5	321.3	705	2.0	2.2	2771	7.8	8.6
Lewisporte	2148.1	2373.6	16794	7.8	7.1	61994	28.9	26.1
Little Bay	13.5	13.8	64	4.7	4.6	235	17.4	17.0
Loon Bay	90.0	92.3	3847	42.7	41.7	173772	1930.8	1883.1
Lushes Bight/Beaumont	202.5	155.9	746	3.7	4.8	1292	6.4	8.3
Merritt's Harbour	45.0	46.1	766	17.0	16.6	704	15.7	15.3
Middle Arm	524.0	589.6	678	1.3	1.2	37220	71.0	63.1
Miles Cove	108.0	240.3	27	0.2 *	0.1 *	2113	19.6	8.8
Millertown	95.9	70.9	1127	11.8	15.9	2066	21.6	29.2
Ming's Bight/South Brook	300.3	305.3	1211	4.0	4.0	5284	17.6	17.3

Table 8-8 ESTIMATES OF ADEQUACY OF SUPPLY TO MEET DEMAND 1990 AND 2015 (continued)

COMMUNITY	TOTAL DEMAND		LOW FLOW			MEAN FLOW		
	1990	2015	Supply	Supply/Demand Ratio		Supply	Supply/Demand Ratio	
	m^3/day	m^3/day	(m^3/d)	1990	2015	(m^3/d)	1990	2015
Newville	90.0	92.3	1320	14.7	14.3	1033	·11.5	11.2
Nippers Harbour	123.8	77.2	81	0.7 *	1.0	5636	45.5	73.0
Norris Arm	507.2	356.5	14289	28.2	40.1	7397	14.6	20.7
Northern Arm	225.0	110.6	60	0.3 *	0.5 *	4344	19.3	39.3
Pacquet	257.5	261.5	842	3.3	3.2	45087	175.1	172.4
Peterview	508.5	521.4	412	4.6	1.9	587	6.5	2.8
Phillip's Head	123.8	126.9	50	0.41 *	0.40 *	3687	29.8	29.1
Pilley's Island	237.6	243.6	2016	8.5	8.3	2630	11.1	10.8
Pleasantview	38.3	39.2	1347	35.2	34.3	1949	51.0	49.7
Point of Bay	112.5	115.3	33900	301.3	293.9	122110	1085.4	1058.6
Point Leamington	382.5	392.2	7773	20.3	19.8	94400	246.8	240.7
Port Albert	67.5	69.2	960	14.2	13.9	1362	20.2	19.7
Port Anson	90.0	213.2	412	4.6	1.9	587	6.5	2.8
Purbeck's Cove	22.5	23.1	68	3.0	2.9	4814	214.0	208.7
Purcell's Harbour	136.0	136.9	1841	13.5	13.4	7045	51.8	51.5
Rattling Brook	67.5	69.2	89	1.3	1.3	6105	90.5	88.2
Robert's Arm	540.0	892.5	273	0.5 *	0.3 *	2818	5.2	3.2
Rooms	34.2	35.1	399	11.7	11.4	23248	679.8	663.0
Seal Cove (Western Bay)	437.5	338.5	2422	5.5	7.2	10567	24.2	31.2
Shoe Cove	135.0	138.4	1844	13.7	13.3	11037	81.8	79.7
Snooks Arm	22.5	23.1	3605	3.7	3.6	10098	10.4	10.2
South Brook	337.5	346.0	101643	301.2	293.7	1361994	4035.5	3935.9
Springdale (Sullivan's Pd)	1919.7	2785.4	11150	5.8	4.0	9064	4.7	3.3
Stoneville	225.0	230.7	24294	108.0	105.3	892341	3966.0	3868.1
Summerford	712.8	803.4	2256	3.2	2.8	5049	7.1	6.3
The Beaches	45.0	46.1	64	1.4	1.4	4603	102.3	99.8
Tilt Cove	10.8	1.9	914	84.7	469.2	704	65.2	361.5
Tilting	286.3	260.3	13925	48.6	53.5	45838	160.1	176.1
Tizzard's Harbour	167.5	169.2	1318	7.9	7.8	3194	19.1	18.9
Triton	975.0	992.1	3605	3.7	3.6	10098	10.4	10.2
Twillingate	540.3	540.3	3296	6.1	6.1	6176	11.4	11.4
Twillingate	540.8	540.8	5311	9.8	9.8	4697	8.7	8.7
Valley Pond	90.0	97.0	983	10.9	10.1	658	7.3	6.8
Westport	225.0	167.6	134	0.6 *	0.8 *	8806	39.1	52.5
Wild Cove	150.4	151.7	1159	7.7	7.6	59881	398.1	394.8
Woodstock	180.0	213.8	1031	5.7	4.8	5518	30.7	25.8
Woodstock	180.0	213.8	1031	5.7	4.8	5518	30.7	25.8
Totals	38058	32815	16388383	430.6	499.4	25748932	676.6	784.7

* – Communities with potential supply problems

Upon discussing the municipal systems further with Town officials, it was found that upstream control structures were <u>in place</u> for the communities of Westport and Northern Arm, but were not being used.

For the case of <u>Westport</u>, use of the additional 115 000 m^3 of 1.0 m live storage on an 11.5 Ha pond would raise the firm yield to 1460 m^3/d and increase the supply/demand ratio to 6.5 in 1990 and 8.5 in 2015 (due to depopulation).

For <u>Northern Arm</u>, an additional 280 000 m^3 of storage is available on a 28.0 Ha pond with 1.0 m of live storage. Utilization of this storage would increase the firm yield to 2611 m^3/d, and increase the supply/demand ratio to 11.6 in 1990 and 23.6 in 2015.

On the other hand, <u>Robert's Arm</u> was found to have three ponds with available storage as follows:

	Area Ha	Live Storage m	Storage Volume m^3
Pond 1	0.4	3.0	13 200
Pond 2	2.5	1.0	25 000
Pond 3	4.0	1.0	40 000
	6.9		78 200

However, the firm yield from all ponds is only 819 m^3/d, resulting in supply/demand ratios of 1.5 for 1990 and 0.9 for 2015, which is only marginally adequate. Thus, despite the extra storage capability, Robert's Arm's supply system will still require upgrading.

After deliberation, it was decided not to modify the spreadsheet program (Tables 8-6 through 8-8) to accommodate the special cases described above since: (1) the program successfully highlighted communities with facilities that had been previously overlooked (and thus it worked!), and (2) the modifications would vitiate the general integrity of the program.

Cut-down spreadsheets for communities with special situations, such as these described above, or with proposed, but as yet unbuilt, systems are provided on the accompanying diskette.

Note that the ratio of the sum of low flow supply to the sum of low flow demand is 431 for 1990 and 499 for 2015. This means that, overall, the supply of water is more than adequate in the region, and that the supply of water per capita is increasing due to depopulation.

8.7 Review of Water Supply Field Survey Procedures

During the fall of 1990, 105 incorporated towns and communities were visited by field personnel. Because of the potential for more complex water system infrastructure, towns servicing more than 3,000 people (total of six) were visited by a senior municipal engineer. The remaining locations were investigated by a senior municipal technician.

Preliminary discussions were held at each location with those council officials most knowledgable of the supply facilities and distribution systems. During these discussions, pertinent data were obtained and recorded on standard information forms which had previously been forwarded to all the towns and communities within the study area. Subsequent to these initial discussions and completion of information forms, each supply source was visited by the field investigator accompanied by either the system maintenance man or, as was more commonly the case for the smaller communities, a councillor or member of the local service committee.

Inspection of each supply source was carried out in two parts. First a visual examination of all existing structures (e.g. pumphouses, chlorination buildings, wet-wells, and dams) was carried out wherein the material of construction, age, condition, and adequacy was noted and photographs taken. Also included in the visual evaluation was an assessment of the potential to increase live storage through construction of new dams and/or dikes or by expansion of existing facilities.

Following this initial assessment, the physical dimensions of dams, intake works, and other system structures were recorded. Particular emphasis was placed on confirming the water depths over intake pipes to facilitate calculation of live storage capacity.

The standard forms for each town and community, as well as a 1:50,000 scale map showing the prominent features of its water supply system, are presented in Appendix A.

Fish plants located in communities and towns within the study area were also visited. Through discussion with each fish plant manager, efforts were made to complete a standard information form. Unfortunately, data acquired, in particular relative to consumption of both fresh and salt water, were very limited as water supplied the plants is rarely metered.

8.8 Discussions of Communities with Potential Supply Problems

In Section 8.6.2 five communities were identified as having potential supply problems, on the basis of the results of the screening model. Our preliminary assessment of each case, with recommendations, is given below. The assessment and recommendations are based solely upon the available field information. More detailed follow-up is required before specific design recommendations can be made.

Beachside

The Anchor Pond Brook system servicing Beachside has been recognized by the community and the Department of Municipal & Provincial Affairs as marginally adequate relative to the 1991 domestic demand. Projected population for the year 2015 is nearly double that existing in 1990, and hence the Anchor Pond Brook will at some point in the not-too-distant future become inadequate. To alleviate projected shortages, the community's engineering consultant has already identified the Long Pond watershed as a supplementary source of supply. Incorporating this source into the existing system will be quite expensive and involve construction of new intake works and pumping system at Long Pond, together with a supply main discharging directly into the recently-constructed Anchor Pond Brook Reservoir. According to the spreadsheet model (appropriately modified), the additional supply from Long Pond will result in an acceptable low flow supply/demand ratio for the year 2015 of 2.1.

Miles Cove

The settlement is presently serviced from a small dam structure located on Paddock's Pond River. The unacceptably low supply/demand ratio of 0.2 for the present and 0.1 for projected 2015 domestic demand are reflective of the run of river system presently utilized. Assurance of a continuous reliable yield for present and projected demands can be provided through installation of a 1.5 m high control structure across the outlet stream on Paddock's Pond. Through construction of this facility the new supply/demand ratio for the year 2015 would increase to an acceptable value of 4.8.

Nippers Harbour

The community of Nippers Harbour is presently serviced with an inadequate supply of water from its existing reservoir on Blackhead Pond River. Plans and specifications have already been prepared to replace the existing dilapidated concrete dam with a new structure farther upstream. Notwithstanding the increase in firm yield that the proposed new dam will provide, the screening process developed for this study identifies an immediate shortage which at best will improve through depopulation to be marginal by the year 2015. Thus the proposed new dam will presumably not solve the supply problem.

Recognizing the unacceptably high construction cost associated with extending the supply main upstream and installing an intake in Blackhead Pond, it is proposed that, as an alternative, a control structure should be installed across the outlet brook. By raising the existing pond 1.0 m the present supply/demand ratio could be increased to 10.0. The corresponding year 2015 ratio would be 16.0 (due to depopulation).

Philip's Head

The existing intake facility and impounding reservoir on Dogberry Brook, as evidenced from the screening process, is inadequate to supply present and future domestic demand. This situation can be eliminated through installation of a dam/control structure on Rocky Pond. Unfortunately, Rocky Pond is situated approximately 1.5 km upstream of the existing reservoir and hence proposed works will be costly. Construction of a facility designed to provide 1.0 m of live storage, however, will result in an acceptable supply/demand ratio of 3.4 over the next 25 years.

Robert's Arm

The existing supply watershed servicing the Town of Robert's Arm includes four ponds. Two of the three ponds located upstream of the Water Pond intake reservoir already have control structures. Even so, the supply/demand ratio for the year 2015 is slightly less than 1.0. The projected supply shortage can readily be offset by increasing the height of the existing structures on Young's Pond and Big Bear Cove Pond by 0.5 m. This modest increase in live storage at each pond will result in an acceptable supply/ demand ratio by the year 2015 of 1.2. Alternatively, each dam can be raised an additional 1.0 m which would increase the supply/ demand ratio to 1.5.

8.9 Value of Water for Municipal Water Supply

Two methods of attributing value to the beneficial use of municipal water supply are provided in this section.

Since price should reflect a value at which marginal supply and demand are balanced, sunk capital costs are not relevant to it. However, since water is a common good which is usually provided on a system basis almost irrespective of cost, the first method attributes a value on the basis of typical annual charges which are presumably reflective of what people are willing to pay *for access* to the resource.

The second method provides an estimate of the average value of the systems in place.

8.9.1 Value Based on Water Charges

No community in the study area pays for water; hence it is a free good which is typically in plentiful supply. The availability of adequate supplies of water of good quality is a great asset to the communities of the Province. In its recent national survey, Environment Canada (1989) found Newfoundland to have the least expensive municipal water rates in Canada -- so much so that it is almost a separate case. According to their survey, the mean price in Newfoundland was $8/month (1986$) [$10.76/month (1991$)], with a range of $4/month (1986$) [$5.40/month (1991$)] to $11/month (1986$) [$14.80/month (1991$)].

Nolan, Davis' experience in rural Newfoundland has been a range $84 to $212 per year for water supply charges, with a typical value being $140. This is comparable to the Environment Canada result [$10.76 * 12 mo/yr = $129/year].

Accepting a value of $140/year per residence, assuming 3.2 people per residence, and use of 450 litres/capita/day, the price then is:

525 960 litres/year / $140/year = 3 757 litres/$ (8-3)

It is proposed that the price paid for water service is a good signal of value since many residences have the alternative option of a groundwater supply, and there is no real scarcity value. It could be argued that an annual charge does not explicitly include initial capital costs; however, in Newfoundland these are usually subsidized to a large extent by the Province (and, through equalization payments, by other Provinces). Because of the substantial subsidies, a water charge price is more appropriate.

From Table 8-8 (and including a demand of 4681 m^3/d for Gander), the total 1990 municipal demand is 43 635 m^3/d. Converting to litres per year, and using equation (8-3) above, the estimated annual value is $4,144,912.

8.9.2 Value of Surface Water Systems

For purposes of continuity and consistency with previous reports in this series, an estimate of the value of surface water systems is provided. Acres (1990) used a value of $18,000 (1990$) per service connection, based on a recommendation from DMPA engineers. Note that is the estimated average value per service connection, not replacement value.

Assuming new construction has kept the average age of the existing systems the same, no correction for depreciation is required. Thus Acres' $18,000 (1990$) value is increased by 6.5% to $19,170 (1990$) to account for general inflation between 1990 and 1991. The inflation of system replacement value will be lower because of the replacement of the 13% Federal Sales Tax by the 7% Goods and Services Tax on materials. Assuming 20% of water and sewer project costs to accrue to labour, we estimate the inflation of replacement value to be about 2.1%.

A list of communities, populations, number of homes serviced (from the community sheets in Appendix A), persons per service connection, and system values is given in Table 8-9. The total value of surface water systems in the study region is estimated to be $346,133,520.

Table 8-9

Value of Municipal Water Systems

	Community	Population 1990	Number of Connections	Population per Connection	Approximate Value
1	Appleton	517	262	2.0	$5,022,540
2	Badger	1151	325	3.5	$6,230,250
3	Baie Verte	2049	540	3.8	$10,351,800
4	Bayview	600	205	2.9	$3,929,850
5	Beachside	320	85	3.8	$1,629,450
6	Birchy Bay	750	68	11.0	$1,303,560
7	Bishop's Falls	4213	1193	3.5	$22,869,810
8	Botwood	3900	1130	3.5	$21,662,100
9	Brent's Cove	400	83	4.8	$1,591,110
10	Brighton	350	76	4.6	$1,456,920
11	Buchans	1100	525	2.1	$10,064,250
12	Burlington East Side	215	57	3.8	$1,092,690
13	Burlington West Side	200	70	2.9	$1,341,900
14	Campbellton	686	90	7.6	$1,725,300
15	Chanceport	80	18	4.4	$345,060
16	Comfort Cove/Newstead	800	120	6.7	$2,300,400
17	Cottlesville	415	65	6.4	$1,246,050
18	Cottrell's Cove/Moore's Cove	500	55	9.1	$1,054,350
19	Crow Head	300	87	3.4	$1,667,790
20	Durrell	1060	150	7.1	$2,875,500
21	Embree	836	130	6.4	$2,492,100
22	Fairbank	300	63	4.8	$1,207,710
23	Fleur De Lys	526	140	3.8	$2,683,800
24	Fogo	1150	50	23.0	$958,500
25	Glenwood	1038	306	3.4	$5,866,020
26	Grand Fls/Windsor	18879	4253	4.4	$81,530,010
27	Harry's Harbour	300	70	4.3	$1,341,900
28	Herring Neck	250	72	3.5	$1,380,240
29	Hillgrade	200	36	5.6	$690,120
30	Indian Cove	80	0		$0
31	Jackson's Cove	150	143	1.0	$2,741,310
32	Joe Batts Arm	1250	26	48.1	$498,420
33	King's Island/Smith's Hr	250	0		$0
34	King's Point	923	220	4.2	$4,217,400
35	La Scie	1450	443	3.3	$8,492,310
36	Leading Tickles	350	90	3.9	$1,725,300
37	Lewisporte	3978	1200	3.3	$23,004,000
38	Little Bay	30	45	0.7	$862,650
39	Loon Bay	200	122	1.6	$2,338,740
40	Lushes Bight/Beaumont	450	142	3.2	$2,722,140
41	Merritt's Harbour	100	24	4.2	$460,080
42	Middle Arm	720	124	5.8	$2,377,080
43	Miles Cove	240	60	4.0	$1,150,200
44	Millertown	213	70	3.0	$1,341,900
45	Ming's Bight/So. Bk.	445	119	3.7	$2,281,230
46	Newville	200	0		$0
47	Nippers Harbour	275	85	3.2	$1,629,450
48	Norris Arm	1127	387	2.9	$7,418,790
49	Northern Arm	500	119	4.2	$2,281,230
50	Pacquet	350	74	4.7	$1,418,580

Table 8-9 (cont'd)

Value of Municipal Water Systems

	Community	Population 1990	Number of Connections	Population per Connection	Approximate Value
51	Peterview	1130	275	4.1	$5,271,750
52	Phillip's Head	275	42	6.5	$805,140
53	Pilley's Island	528	108	4.9	$2,070,360
54	Pleasantview	85	32	2.7	$613,440
55	Point of Bay	250	60	4.2	$1,150,200
56	Point Leamington	850	280	3.0	$5,367,600
57	Port Albert	150	40	3.8	$766,800
58	Port Anson	200	60	3.3	$1,150,200
59	Purbeck's Cove	50	6	8.3	$115,020
60	Purcell's Harbour	80	20	4.0	$383,400
61	Rattling Brook	150	45	3.3	$862,650
62	Robert's Arm	1200	320	3.8	$6,134,400
63	Rooms	76	19	4.0	$364,230
64	Seal Cove (Western Bay)	750	227	3.3	$4,351,590
65	Sheppardville	130	26	5.0	$498,420
66	Shoe Cove	300	73	4.1	$1,399,410
67	Snooks Arm	50	7	7.1	$134,190
68	South Brook	750	245	3.1	$4,696,650
69	Springdale	3555	1051	3.4	$20,147,670
70	Stanhope	500	4	125.0	$76,680
71	St Patrick's	55	19	2.9	$364,230
72	Stoneville	500	107	4.7	$2,051,190
73	Summerford	1584	120	13.2	$2,300,400
74	The Beaches	100	24	4.2	$460,080
75	Tilt Cove	24	13	1.8	$249,210
76	Tilting	414	44	9.4	$843,480
77	Tizzard's Harbour	150	40	3.8	$766,800
78	Triton	1250	262	4.8	$5,022,540
79	Twillingate	1539	500	3.1	$9,585,000
80	Valley Pond	200	4	50.0	$76,680
81	Westport	500	100	5.0	$1,917,000
82	Wild Cove	112	33	3.4	$632,610
83	Woodstock	400	33	12.1	$632,610
				Median	
	Sums	74253	18056	3.8	$346,133,520

8.10 Future Developments

As the region is depopulating, the supply of water per capita is increasing; and thus general municipal supply problems are not expected to increase within the planning horizon. A review of Table 8-8 shows that the only small communities with an adverse supply trend that might bear watching are Port Anson, Joe Batt's Arm, and Fogo.

It was noted in Section 3 that meteorological data indicated that Fogo Island is drier than the regional hydrology suggests; and in Section 7.2 that fish plants on Fogo Island experience supply shortfalls. The overall supply situation on Fogo Island might warrant further study, especially if the fishery recovers.

8.11 Conflicts

Quality

With the exception of the pollution of the lower Exploits River causing the water to be unfit to drink, no general quality-related conflicts were reported.

The Chanceport and Stoneville situations were discussed in Section 8.1. The latter appears to be a water-use conflict with recreation.

Industry

Water supplies in several communities are inadequate to supply both the community and to provide all the fresh water the fish plant would like to have. These cases are discussed in Section 8.1.

No other conflicts of note were reported. As noted in Section 8.1, many municipalities have protected watersheds. This program provides a low-cost method of avoiding unnecessary conflicts in the first place.

8.12 References - Section 8.0

Acres International Ltd., St. John's, "Final Report, Regional Water Resources Study of the Northern Peninsula and Humber Valley", prepared for NDOEL, Government of Newfoundland & Labrador, June 1990.

Environment Canada, Inland Waters Directorate, "Municipal Water Rates in Canada, 1986 -- Current Practices and Prices", Social Science Series No. 21, 1989.

SECTION 9.0

OVERALL WATER RESOURCE ASSESSMENT

9.0 OVERALL WATER RESOURCE ASSESSMENT

9.1 Surface Waters

9.1.1 Review

In general, there is an abundance of water in the region; and an adequate amount, in terms of quality and quantity, is available for most demands. Because of the abundance, there has been little attempt to optimize or "micromanage" the resource.

A large portion of the water resources of the region is privately controlled by virtue of Abitibi-Price's lease. Essentially the Upper Exploits basin is managed to provide hydropower for Abitibi-Price, while the lower Exploits serves its waste disposal needs. We estimate the approximate value of this lease to be about $28.95 million/year. The existing allocation of water also precludes maximization of other beneficial uses, such as a drinking water supply for the Grand Falls regional system, tourist development, and fishery enhancement. While the Exploits River system is intensively utilized for industry, it may be underutilized in terms of its aggregate economic potential.

The Gander River system, which lies on the boundary of the study area, is not industrialized. As such, the system appears to have a significant fishery and relatively good water quality. Since the water serves Federal installations, both water and wastewater treatment are excellent. The Town Council of Gander has expressed concern about the effects of nonpoint source pollution from various land use activities in the basin degrading the quality of Gander Lake, and a preliminary study to assess this is being proposed. Compared with the Exploits River basin, though, the Gander River basin is in good shape. Some management effort will be required to maintain it.

In general, the smaller basins in Central have adequate water and few problems with water quality. However, several communities do complain of water supply and quality problems. Almost all of these problems could be solved technically if sufficient funds were available. Few, if any, suffer from a problem relating to an insufficient supply. There appear to be some generic quality problems with groundwater sources in certain sedimentary units, and these are being switched to surface supplies.

Several fish plants report supply problems but, with the exception of major secondary plants owned by National Sea Products and Fishery Products International, they have not taken the necessary engineering measures to rectify them.

The most intensive demand for available surface water supplies is on the islands of the Twillingate/New World Island complex. There is some indication that the limit of inexpensively-available water supplies is being reached there. Additional supplies might become increasingly expensive. Fogo Island has a similar situation if fish plant demands are considered. The populations on these islands are relatively stable, so the present situation may not exacerbate. However, there are no streamgauges in the area and climatic data indicate that it may be drier than the regional average. If any portion of the region warrants a follow-up supply study, it would be these islands.

9.1.2 Value of Surface Water Resources - Summary

Estimates of the gross value of beneficial uses of water resources were provided in Sections 6 to 8. These are reviewed and summed in this section. Recalling, they are:

	$Million	
Hydro (existing)	30.84	(A-P $24.30) (NLH 0.42) (NLP 6.12)
Parks/Recreation	2.0	
Salmon/Recreation-Commercial)	1.34	
Trout/Recreational)	0.72	
Municipal Supply	4.14	
Industrial Supply (A-P)	0.55	
Pollution Assimilation		
- municipal	9.05	(freshwater only)
- industrial (A-P)	4.10	(freshwater only)
Sum:	$52.74 million/year	

Of this, the private sector (excluding fish plants) receives:

Abitibi-Price	$24.30+$0.55+$4.10 = $28.95 million/year or 54% of the total
NLP	$6.12 million/year or 12% of the total

Thus, about 66% of the value of the region's water resources are allocated to private enterprise. The provincial government (including NLH) receives the remaining 34% of the water resource's beneficial value, or about $17.62 million/year.

The economic benefits to the Newfoundland public would depend on the extent to which it owns shares in Abitibi-Price and Fortis, from employment provided, taxes received, and so forth. The environmental costs, however, are borne entirely by the government and people of the province.

Finally, it is clear from the economic breakdown given above that reallocation of water from hydro and pollution assimilation to other uses (such as recreational salmon angling) could be quite costly, unless the marginal returns from water allocated to other uses clearly exceed those of hydro and pollution. However, we note that the estimated gross value of pollution assimilation does not include ecological costs, public health costs, nor opportunity benefits foregone (drinking water, recreation, and so forth). The net benefits of pollution assimilation are certainly much lower than gross ones.

9.2 Exploits Leases

Abitibi-Price effectively controls the water resources of the Exploits River basin by virtue of two leases. The major one accrues from the Pulp and Paper Act of 1905 [Cap. 10, 5 Ed. VII, pp 83 et seq.] in which the Anglo-Newfoundland Development Company received a 99-year lease which expires on June 14, 2004. This lease essentially provided a royalty-free supply of electrical energy and power to the firm. It could be argued in hindsight that the terms of the lease should have been more favourable to the Province; nevertheless, the Act achieved its goal of establishing a pulp and paper plant.

The lease has a renewal clause [Section 14(b)]:

> (b) That if the demise shall not have been determined under the power of re-entry hereinbefore contained, the Government will, at the request and cost of the Lessee, at the expiration of the term hereby granted and again at the expiration of every further term of ninety-nine years which may be hereinafter granted under this covenant, grant to the Lessee at the same rents and royalties, and containing the like covenants, provisions and agreements as are in and by these presents reserved and contained, by way of renewal for the further term of ninety-nine years, to be computed from the expiration

> of the term hereby granted, a new lease of the demised premises together with all rights and privileges hereby granted.

While noting that the consultant does not practice law, we recommend that the Province investigate means to renegotiate or prevent renewal of this lease as soon as possible, or on June 14, 2004 at worst. The terms of the lease are overly generous, prevent management of the water resources by the appropriate government bureaus, have no implicit environmental component, and preclude economic maximization of the water resource.

Abitibi-Price controls the Bishop's Falls hydroelectric site by a separate lease (from the Reid grants) which expires about 2038. This lease is less comprehensive, and expires later; so its revision is not so crucial. Nevertheless, if it can also be renegotiated on terms more favourable to the province, this should also be done.

9.3 Groundwater

Groundwater sources provide a reliable water supply to many communities and homes if the pumping and surface equipment is maintained. Lack of equipment maintenance, however, rendered some otherwise adequate community groundwater supply systems in the Notre Dame Bay region inoperative. It is suggested that, when a groundwater supply system is installed, financial provision should also be made for maintenance of the system.

Of the hydrostratigraphic units reviewed in Section 5, surficial sand and gravel deposits, when they occur below the water table in sufficient quantities, have the best aquifer potential. However, sand and gravel deposits meeting these criteria are relatively rare in Newfoundland. They are also prone to contamination by the activities of man. When used as a water supply source,the surface recharge areas of surficial deposits should be protected.

Of the competent rock formations reviewed, all are capable of acting as aquifers if they have a sufficient density of open fractures. Some formations are more able to support open fractures than others and are therefore usually the best of the competent rock aquifers. The volcanic and igneous plutonic rocks, especially granite, seem to be the most productive competent rock aquifers.

The water quality of groundwater is usually good in the Notre Dame Bay region, though manganese and iron seem to be a problem on Fogo Island. It is difficult to draw conclusions about which formations produce poor-quality water as the number of sampling stations in the Notre Dame Bay region, and the frequency of sampling, is so low. It is also worth noting that the number of elements tested in any sample are small. Generally, neither mercury nor arsenic is tested for and it is suggested that, because of their high toxicity, at least these two should be added to the sampling protocol. It is also suggested that both the number of sites sampled and the frequency of groundwater sampling should be increased to provide more information on water quality from different formations and spatial and temporal variability in groundwater quality.

9.4 Summary

The region is slowly depopulating, and regional economic decline is likely for the medium term because of shortages of timber and fish. Therefore, it is unlikely that pressure upon the water resources will increase in the medium term. The goal should be to better manage the water resources to increase their significant contribution to the economy of the region, and to improve their ecological health.

SECTION 10.0

CONCLUSIONS AND RECOMMENDATIONS

10.0 CONCLUSIONS AND RECOMMENDATIONS

Throughout the text recommendations and conclusions specific to each section have been made. Thus only a few of the more general and important ones are made here.

(1) The abundance of high-quality water is a major asset to the region, estimated to have a gross value of $52.7 million/year. The regional economy is dependent upon three renewable natural resources [water, forests, and fish] and water is the only one which is still in good supply. Good management of its water resources is thus very important to the regional economy. Past management has been diffuse and, to a large degree, passive. A more active goal-oriented management of the water resource will be required to obtain the best return from it and conserve its ecological integrity.

(2) A significant portion of the water resources of the region are in private control by virtue of a lease which expires in 2004. Of the estimated $52.7 million/year value from beneficial uses of the resource, $29.0 million/year, or 55%, accrues to Abitibi-Price for which it pays absolutely nothing. The long-term gross value of this lease can be appreciated by several examples. At a zero percent discount rate its total gross value over 99 years is (99 * $29 M/yr=) $2.87 billion. If compounded at a rate of 3% (a typical return rate net of inflation), its value is $17.07 billion! Over the next 13 years (June 1991 to June 2004) its uncompounded value is (13 * $29 M/yr =) $377 million; if compounded at 4% the remaining value is $482.18 million. This does not include the opportunity costs of other foregone beneficial uses of the water. The Province should

carefully study any proposal to renew this lease, particularly in reference to the proposed Green Wood Project.

(3) The lower Exploits River should be cleaned up. The cost of a treatment plant for Abitibi-Price (estimated to be $20-$40 million) is large, although not in comparison to the $29 million in benefits per year given above. The Province should establish a clean-up program which is reasonable for Abitibi; is coordinated with the proposed Federal regulations; includes a municipal treatment as a component; considers the site-specific transport properties and assimilative capacity of the river; and incorporates specific objectives for beneficial uses (e.g. a better salmon fishery, improved tourism, and so forth).

The river bed itself will likely require some remediation, even after some self-flushing following a cessation of untreated discharges to it. A preliminary assessment of the scope of the problem should be undertaken.

(4) Following on (3) above, the water quality survey of the lower Exploits (Card, undated) undertaken by the Civil/ Sanitary Division should be extended downstream through the Exploits estuary to ascertain the full extent and magnitude of the pollution.

(5) A desk study and brief field assessment should be made of the magnitude, extent, and effects of heavy metal leachates from the ASARCO mine at Buchans. Are these heavy metals adversely affecting the biota of Red Indian Lake? If so, a remediation plan should be developed.

The efficacy of the environmental components of the mine shutdown plan should be reviewed in hindsight.

(6) While there is no explicit evidence of generic degradation of Gander Lake, there is some concern by the Town of Gander that it may be occurring. The Town has authorized a terms of reference to be prepared to assess the problem. A survey-type assessment should highlight any problems and document the current environmental situation. It is recommended that the province provide support for the proposed assessment study. Since Federal installations draw water from Gander Lake, some Federal support may also be obtainable.

(7) Following on the above, it is recommended that basin management boards be established for both the Exploits and Gander River basins. These boards should set goals, priorities, and policies for the management of water resources in these basins; and include representatives of significant users and regulators. Basin plans should be developed for each basin to reflect existing conditions, and development of goals and policies applicable to them.

While a coordinated basin plan for the Exploits River is the more pressing of the two, Abitibi's control through its lease would certainly complicate the process. Thus it is recommended that the process be initiated on the Gander basin where a positive political will appears to exist.

(8) It was noted that several fish plants experience problems with quantity and quality of fresh water, or would prefer to substitute more fresh water for salt. Since the

government is already so heavily involved in the fish processing industry, there would not appear to be a philosophical barrier for NDOEL, DMPA, and the Department of Fisheries pooling inhouse resources to determine if some of these supply problems can be remedied at reasonable cost in order to make the plants more efficient.

(9) The Towns of Grand Falls/Windsor and Bishop's Falls have problems with the quality of their water supplies from Northern Arm Pond. This problem is due, in part, to the inability to take sufficient drinking water from the Exploits River. Provision of an adequate water supply is necessary for the continued economic development of the urban region and should be a priority for the government.

(10) Economic and marketing studies should be undertaken to assess the potential of a tourist industry based upon a world-class salmon fishery in the lower Exploits, so that water for that industry can be properly allocated given that substantial real and opportunity costs, in terms of lost hydropower and wastewater treatment costs, will be incurred to provide it.

It is likely that the angling industry in the lower Gander River can be enhanced as well. If recreationally-caught salmon really do have a value to the economy of about $100 each, a significant economic opportunity based on the water resource may exist. It would also appear that, to the extent they are taken, salmon should be reallocated from the commercial to the recreational fishery.

(11) Most WSC gauge stations are located near the Trans Canada Highway. This provides a convenient distribution with good east-west resolution; however, the network is deficient for analyzing the hydrology of certain areas. For water resources applications and analyses, the deficiency is particularly acute in the New World Island/Fogo Island area since significant demand exists there. It is recommended that a gauge be established on New World Island, and a temporary gauge (5-10 years) be established on Fogo Island to provide better runoff information in this area. [AES station data indicate that these islands may be significantly drier than the zone along the TCH.] It is recommended that the Fogo Island gauge be installed in association with the Fogo Island Co-Op which experiences water supply problems at its plants on Fogo Island.

(12) While no part of the study area experiences a generic water shortage, the resources on New World Island/ Twillingate Island appear to be approaching the limit of inexpensive supply. Fogo Island appears to be in a similar, if somewhat less pressing, situation. The problem is not critical for several reasons, including declining or stable population; nevertheless, a more intensive study of the water resources of New World Island and Fogo Island may be warranted. It would be appropriate to undertake this in conjunction with the recommended gaging program.