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GROUNDWATER HYDROLOGY AND WATER SUPPLY OF PRINCE EDWARD ISLAND

(Report, 7 figures and Map 16-1964)

L. V. Brandon

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ABSTRACT

Groundwater is effluent to rivers on Prince Edward Island. An approximate annual hydrologic balance can be made for various river basins, but the range in annual precipitation shows that this balance may vary widely. The movement of groundwater is permitted both by intergranular permeability and interjoint flow in the bedrock.

Excellent supplies of groundwater are available and towns and industries obtain their water supply from well fields. Salt-water contamination occurs in a few wells close to the seashore, and may be the main water supply problem if larger well fields are constructed for industrial and municipal growth.

GROUNDWATER HYDROLOGY AND WATER SUPPLY OF PRINCE EDWARD ISLAND

INTRODUCTION

The people of Prince Edward Island rely on groundwater supplies from municipal well fields or from farm wells and springs. The purpose of this report is to provide information on the groundwater potential within the island. It is hoped that it will be useful to new industries and growing municipalities requiring greater supplies of water.

Methods of Investigation

The writer spent two months on the island during the summer of 1962 and a further three weeks in 1963. During these visits information was obtained on the yield of wells in some localities, springs were examined, and samples of water were obtained for chemical analysis from many wells and springs. Two continuous groundwater-level recorders were established in river basins where surface-water discharge measurements are in progress.

Other hydrologic and geologic data were gathered.

Previous Investigations

Because Prince Edward Island is both a beautiful and fertile land it has been the subject of many surveys. Many early descriptions of the island provide information that indicates the abundance of good water supplies available from springs.

In 1751 Colonel Franquet, a French engineer who reported on the economy and fortifications of the island to the government of France, described several of the excellent springs that provided water to the Acadian residents. His report is in the Public Archives of Canada (Franquet, 1751)*.

The first complete topographic survey of the island, and in fact the first complete survey of an area of Canada that ultimately became a province, was begun in October 1764 by Captain Samuel Holland and completed a year later. His excellent map and report (1765) are the first technical descriptions of the island.

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*Names and/or dates in parentheses refer to publications listed in the References.

During the nineteenth century a number of geologists, including Dawson and Ells, visited the island and described the geology (Dawson and Harrington, 1871; Ells, 1884).

Borings were carried out on the island in 1909 by the Geological Survey of Canada in a search for coal (Ingall, 1909). A report on the geology of the island was published by Milligan (1949), and recent maps of bedrock and surficial deposits of various parts of the island have been published, Owen (1949), Crowl (1960a, b), Frankel (1960), and Prest (1962). Groundwater inventories of the west part of the island were carried out by Pollitt (1952, 1953).

Acknowledgments

The author is grateful for the reliable and industrious assistance of M. Rutulis, who worked as the author's field assistant in 1962. He also wishes to thank the following: J.E. Peters and R. McBride of the Water Resources Branch, Department of Northern Affairs and National Resources, for helping to maintain groundwater-level recorders and for data on stream discharge; the Department of Agriculture's Experimental Farm in Charlottetown, for climatic data; W.H. Crandall and Associates, consulting engineers of Moncton, N.B., for information on wells; and the well-drilling companies on the island for the information they supplied. The writer also wishes to thank B. Graham Rogers, for his great help in providing information on the island.

PHYSIOGRAPHY AND CLIMATE

The island is situated in the Gulf of St. Lawrence and extends in an east-west crescent for a length of about 145 miles. Its width is from 4 to about 35 miles. The total land area is 2,184 square miles.

The island comprises a low plateau. Headlands and rock cliffs rising more than 50 feet in height extend along the shore at many locations on the east, south, and west sides. Bays and estuaries penetrate inland so that no part of the island is more than 10 miles from salt water. These bays and estuaries, evidence of a drowned shoreline, are so long that they almost divide the island into three parts. The largest part is east of Hillsborough River. This is rolling farmland, mainly over 100 feet above sea-level, rising to almost 400 feet at one place. The central part of the island, between Hillsborough River and Summerside, is also rolling farmland of topography similar to the east part. West of Summerside in Prince county, the island narrows at one place to 4 miles where Bedeque Bay on the south and Malpeque Bay on the north encroach upon the land. This region is flat and low lying.

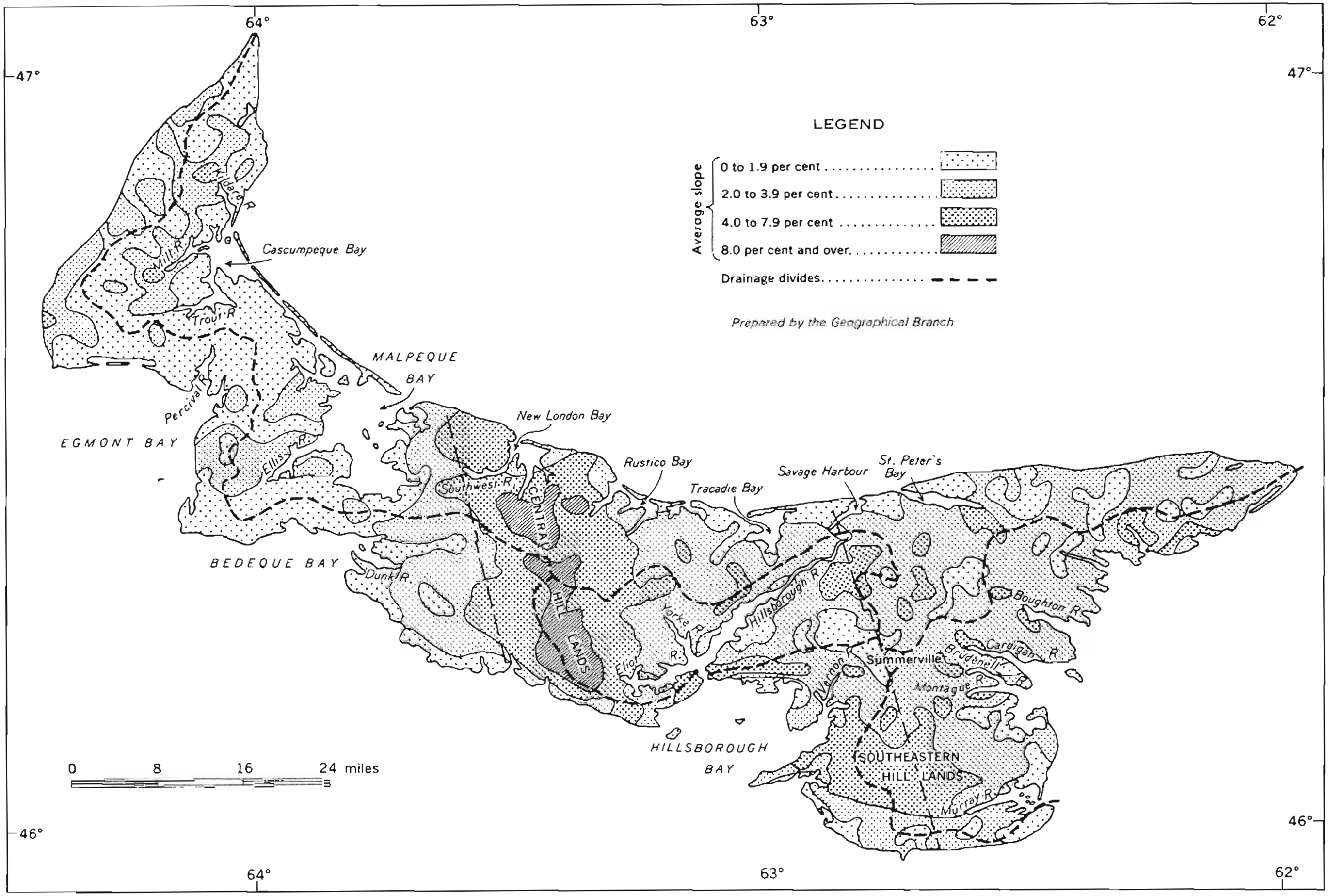

Figure 1. Average land slope in per cent and main drainage divides, Prince Edward Island (from Raymond, McLellan and Rayburn, 1963, Geographical Branch Memoir 9, page 100)

The humid and temperate climate of the island is controlled by the presence of the cold waters of the Gulf of St. Lawrence. There is a long and fairly cold winter, a cool summer with a relatively long frost-free period, and frequent precipitation.

Table I

Mean Monthly Temperature (°F) at Charlottetown Experimental Farm

(Department of Agriculture records)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
18.8	17.6	26.9	37.0	48.6	58.4	66.6	65.9	58.4	48.8	37.7	25.2

The frost-free period extends from about the middle of May to the middle of October.

GEOLOGY

Rock

Bedrock of Permo-Carboniferous age outcrops extensively along the shorelines throughout the island and is generally within 10 feet of the surface on hill slopes.

Rock consists of weakly cemented red beds of sandstone, siltstone, and claystone with some sand-shale breccias and conglomerate beds. The beds of sandstone and shale are nearly flat lying and appear to be broad structures with dips of less than five degrees. Crossbedding and facies changes are apparent in many outcrops. Weathering has reduced the top 2 feet of sandstone to sand in several localities.

In thin-section examination the sandstones are composed of angular to subangular grains of quartz with feldspar and minor amounts of mica, chlorite, and magnetite. The minerals are bonded within a ferruginous cement.

A fine-grained dolerite dyke intrudes the sandstone at George Island in Malpeque Bay. Milligan (1949) described this dyke and gave more detailed descriptions of the island bedrock.

The greatest thickness of sediments on Prince Edward Island is reported to be 14,696 feet by Howie and Cumming (1963) in their report on basement features, which records the location of ten recent deep borings. Further descriptions of well logs are given by Barss, Hacquebard and Howie (1963).

Bedrock outcrops appear to be well jointed with two sets of joints almost vertical to the bedding plane and with laminar beds varying in thickness from a few inches to several feet parallel to the bedding. The evolution of the drainage pattern may have developed along the lines of the vertical joints.

Surficial Geology

The island was glaciated in Pleistocene time and a mantle of glacial till covers bedrock in most areas. On the west side of the island erratic boulders of crystalline rock from the mainland are common, thus providing evidence of the presence of a continental ice-sheet. However on the east side of the island the till is entirely derived from local bedrock.

The till varies between clay till and sand till depending on the nature of local bedrock and includes pebbles derived from bedrock. Large boulders are rare, owing to the decomposition of the bedrock.

Fluvio-glacial deposits such as eskers and kames, comprising sand and gravel, are present in a few valleys. Dune sands extend along much of the north shore where long sand bars guard the entrances to the bays and estuaries. Peat bogs and alder swamps are present in low-lying parts, particularly in the west.

Much of the surficial geology of the eastern side of the island has been mapped by Crowl (1960a, b) and Frankel (1960). Owen (1949) and Prest (1962) have described surficial deposits in the western part of the island.

SOILS, LAND USE, AND VEGETATION

The soils have been mapped and described by Whiteside (1950), who observed that they are podzols, i.e. strongly leached soils, comparatively low in plant nutrients and acid in reaction. Such soils develop in the cool and moist climate where forest litter accumulates on the surface and decomposes slowly.

Whiteside classified the soils into three groups: (1) those developed on glacial till and material derived from bedrock — these have varied drainage characteristics and are the largest group; (2) those developed on fluvial or glacio-fluvial deposits, which generally have good drainage characteristics; and (3) miscellaneous land types such as peat, salt marsh, and dune sands, which are all without a soil profile.

The original forest land of the island consisted of mixed hardwood and conifer forests in the uplands where beech, maple, and birch were predominant among white pine and hemlock and red spruce. Erskine (1960) has described the plant associations in the following five principal groups: forest; fresh-water communities; bog communities; maritime associations; and cultivated vegetation.

The growth of settlement and agriculture have profoundly altered the vegetation of the island. A.H. Clark (1959), in his scholarly book "Three Centuries and the Island", described the historical geography in a most interesting manner for any student of the island's economic growth.

Raymond et al. (1963) recently classified present land use into six categories (Table II).

Table II

Land Use on Prince Edward Island

(from Raymond et al., 1963, Table 8)

Land Use	Acreage	Percentage of Total Land Area
Crop land	504,950	36.1
Improved pasture	149,180	10.7
Abandoned grasslands	100,590	7.2
Woodland	594,560	42.6
Other (bogs, beaches, etc.)	36,770	2.7
Urban	9,710	0.7
	1,395,760	100.0

HYDROLOGY

The hydrologic map accompanying this report shows the location of dams, gauging stations, well fields, and other features.

Precipitation

There are nine stations recording data on precipitation on the island, and of these the Department of Agriculture Experimental Farm in Charlottetown has the longest record. The mean annual precipitation there is 42.3 inches with a maximum of 54.6 inches and a minimum of 29.8 inches. Figure 2 shows the maximum, mean, and minimum monthly precipitation at Charlottetown.

The records show that there have been successive years of relatively dry weather followed by a succession of wet years for varying periods. Figure 3 shows a three-year moving mean of annual precipitation with a maximum of 49 inches and a minimum of 36.5 inches. Figure 4 shows a cumulative departure from mean annual precipitation and shows that between 1919 and 1925 there was a dry spell at the end of which there was a departure of less than 30 inches of precipitation from the mean. Conversely between 1939 and 1945 there was a period of wet years, which accumulated a surplus of more than 28 inches above the mean.

The main months of snowfall are from December to March, though snow does fall sometimes at the end of October or as late as May. Break-up occurs during April.

The west side of the island has 2-3 less inches of precipitation per year than the central and eastern parts.

Evaporation

The potential evaporation computed by the Thornthwaite (1948) method amounts to 21.9 inches at Charlottetown.

Measurements of evaporation have been made for many years at the Experimental Farm in Charlottetown. From 1936 to 1944 readings were taken from a Pische Evaporimeter; from 1945 to 1959 readings were from a 4-foot open tank; and from 1960 from a Black Bellani plate. Readings for 1960-63 are shown in Table IV.

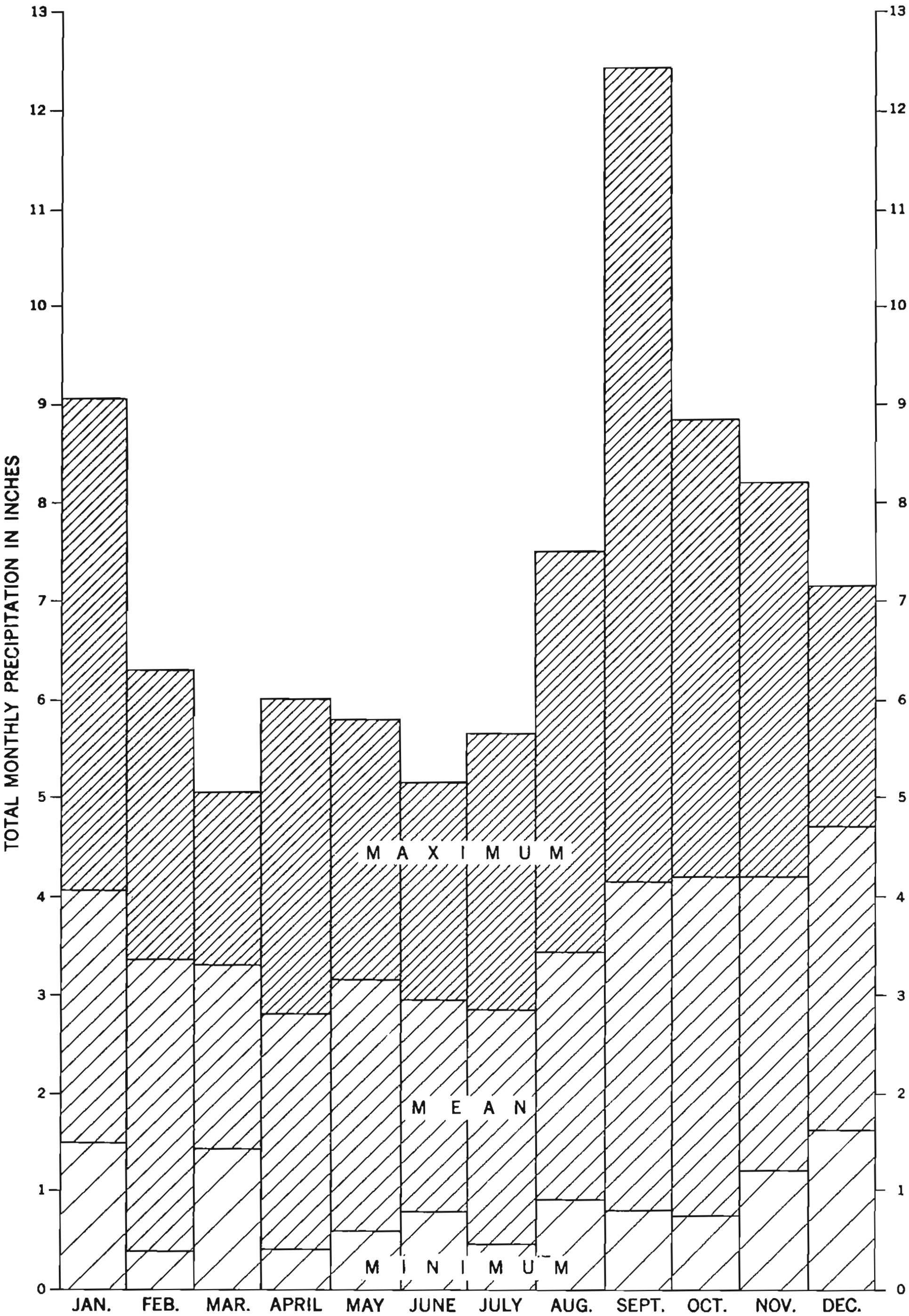

Figure 2. Maximum, mean, and minimum monthly precipitation at Experimental Farm, Charlottetown (fifty years of record)

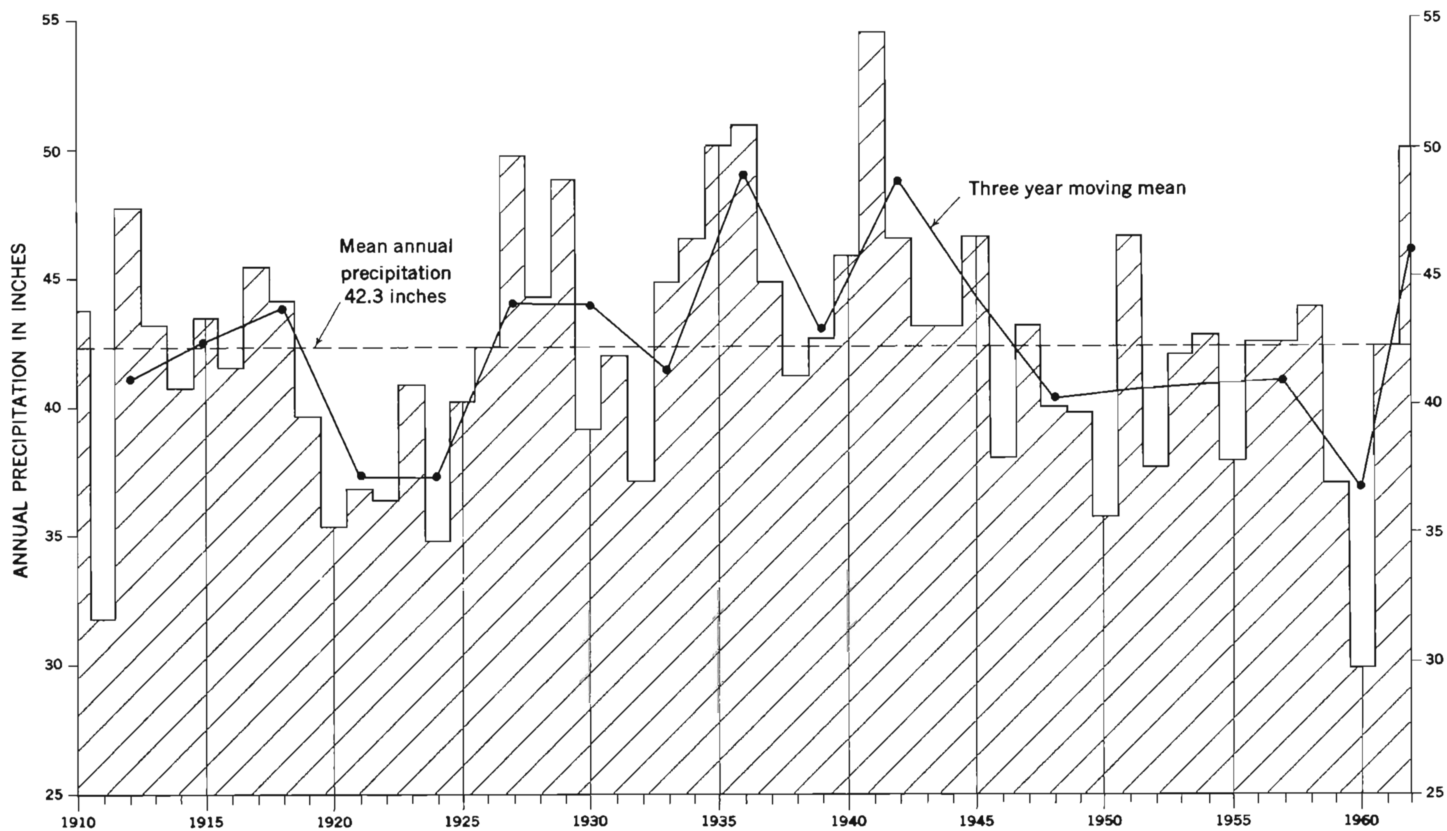

Figure 3. Annual precipitation and three year moving mean from 1910 to 1962 at Charlottetown (from Experimental Farm records, Department of Agriculture)

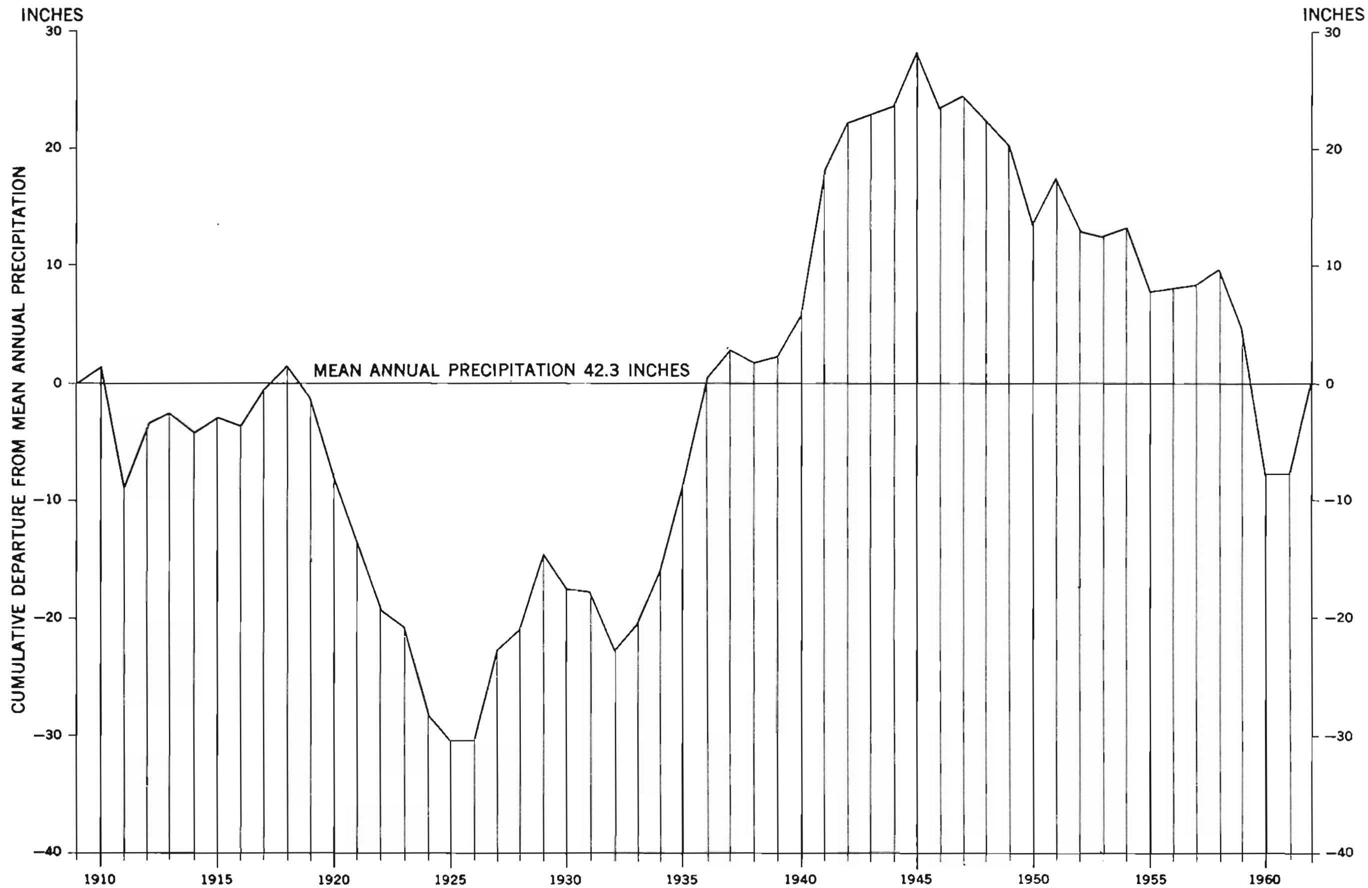

Figure 4. Cumulative departure from mean annual precipitation of 42.3 inches at Charlottetown, from 1910 to 1962 (Experimental Farm records, Department of Agriculture)

Table III

Potential Evaporation for the Period April to November

Month	Potential Evaporation (inches)
April	0.6
May	2.4
June	3.8
July	5.2
August	4.6
September	3.1
October	1.7
November	0.5
Total	21.9

Table IV

Mean Monthly Discharge by Evaporation, Charlottetown

	June	July	Aug.	Sept.	Total (cc)	Total (inches)
1960	965.5 cc	1,160.9 cc	1,338.7 cc	929.1 cc	4,394.2	12.9
1961	1,054.9 cc	1,243.5 cc	1,289.5 cc	803.5 cc	4,391.4	12.9
1962	1,078.1 cc	695.7 cc	828.5 cc	517.7 cc	3,120.0	9.2
1963	1,228.7 cc	1,067.6 cc	857.7 cc	813.7 cc	3,967.7	11.7

These figures are a measure of latent evaporation, i.e. the latent ability of the meteorological environment to evaporate water from a standard surface. Robertson and Holmes (1957) have shown that a comparison of calculated evaporation by the Penman method and a measure of latent evaporation by the Black Bellani plate can be made by converting latent evaporation in cc to calculated evaporation in inches by the factor .0034. Therefore the total in inches recorded in Table IV may be close to the calculated evaporation by the Penman method for the four months of measurement. As the Black Bellani plate can only be used during the summer months when there is no danger of frost, measurements for other months are not available.

Table V

Summary of Mean Monthly Discharge, 1919-1932

(From Water Resources Paper No. 73.)

River	Drainage Area (sq miles)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Mean
Dunk	37	41.7	48.1	49.4	59.0	52.0	92.0	168	132	53.0	38.5	33.6	34.0	67.0
Montague	25	23.9	29.2	30.1	39.9	50.0	68.0	75.0	58.0	32.6	24.5	21.1	21.8	38.5
Vernon	5	8.2	9.7	9.6	10.9	8.9	16.7	26.0	17.7	8.5	6.0	5.5	5.8	11.1

The wide range in measurement (between about 9 and 13 inches for the four years) and the Thornthwaite estimate of 16.7 inches for the same four months of the year indicate the range of values that can be taken for evaporation. The Thornthwaite method of calculating potential evaporation is of value because of the humid climate of the island; it seems probable that the actual annual evaporation ranges between about 12 and 19 inches.

Table VI

Run-off Depth in Inches

Year	Drainage Basin		
	Dunk	Montague	Vernon
1919-20	21.60	24.68	31.70
1920-21	15.76	16.23	24.75
1921-22	14.99	16.44	30.10
1922-23	33.03	-	41.29
1923-24	29.85	21.04	32.78
1924-25	17.05	19.79	20.85
1925-26	31.57	-	39.12
1926-27	27.21	20.22	30.33
1927-28	30.20	28.38	39.24
1928-29	22.16	21.82	21.60
1929-30	20.59	20.00	28.47
1930-31	23.74	18.99	23.76
1931-32	30.44	22.81	28.63

Run-off

Records Available

River discharge records for seven rivers were started after 1918. The following records are available.

River	Location of Gauge	Records Available for:
Dunk	Rogers mill	1919 to June, 1933
Hunter	Hunter River	1918 to March, 1922
Mill	Howlan	1919 to March, 1922
Montague	Power house	1919 to June, 1933
Morell	Morell	1919 to June, 1922
Trout	Tyne Valley	1919 to March, 1922
Vernon	Glencoe road	1919 to June, 1933

Records of discharge have been published by the former Water Resources Branch. Table V summarizes the mean monthly discharge, from 1919 to 1932, of the Dunk, Montague and Vernon Rivers. Figure 5 shows graphically the mean discharge per square mile of drainage area. The figure reveals a difference between winter mean flows and smaller late summer mean flows when there is a greater water loss, which may be attributed to evaporation. Table VI shows the run-off depth in inches during the same period.

Discharge measurements were restarted in 1961 by the Water Resources Branch at new stations on the Dunk, Morell, and Mill Rivers.

Similarity of Basins

Because of the similarity in physiography, geology, land use, and climate on the island similarities in hydrology and run-off occur.

Comparisons of the basins of the Dunk, Morell and Mill Rivers are illustrated by their similar drainage density, flow-duration curves, and run-off. Table VII shows the drainage density, i.e. length of stream and tributaries per square mile of basin, for the three rivers.

Table VII

Drainage Density

River	Station	Area (sq miles)	Length of All Streams (miles)	Drainage Density
Dunk	ICB_1	43	58	1.35
Morell	ICD_1	48	62	1.29
Mill	ICA_1	18	21	1.17

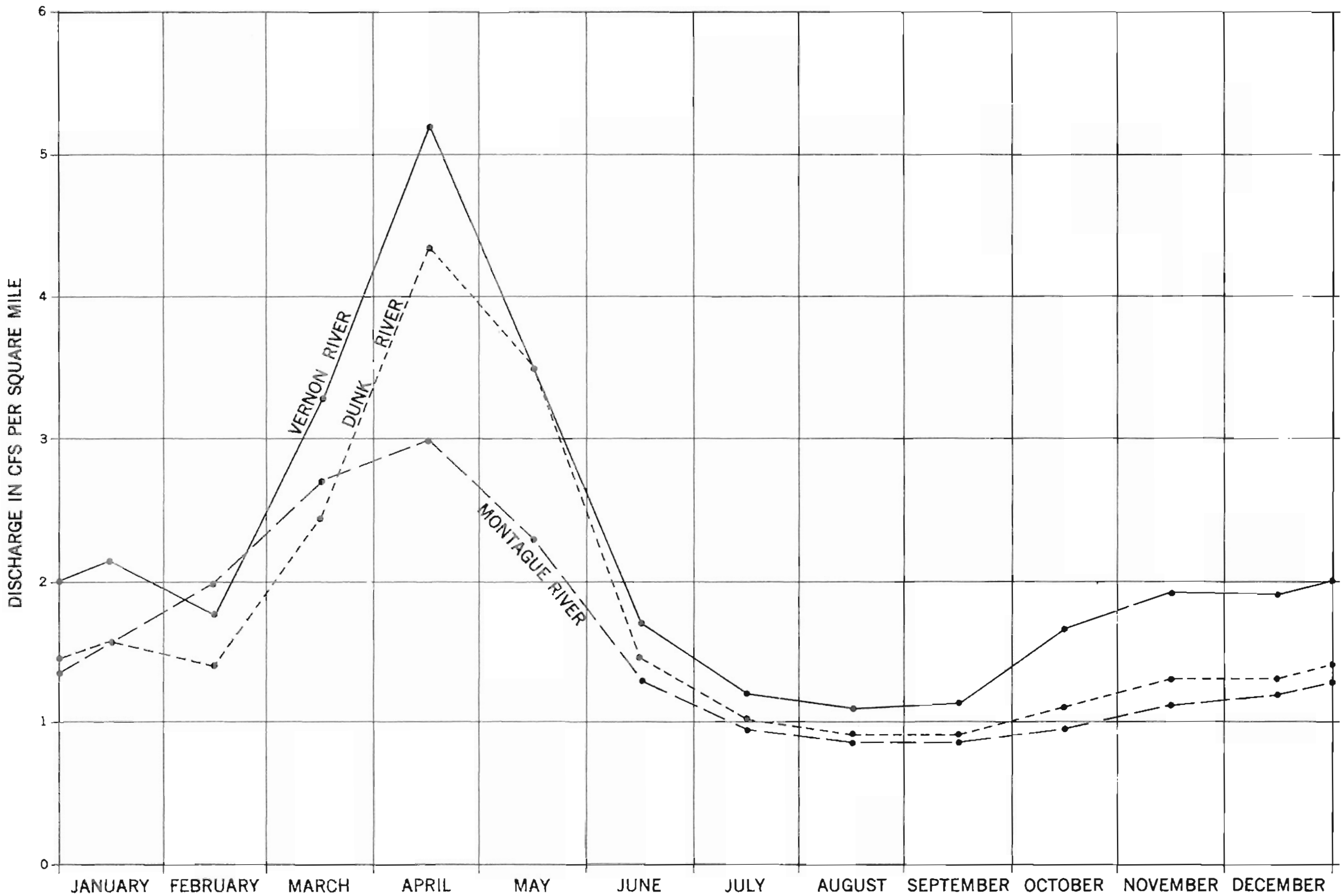

Figure 5. Mean monthly discharge per square mile of Dunk, Montague and Vernon Rivers

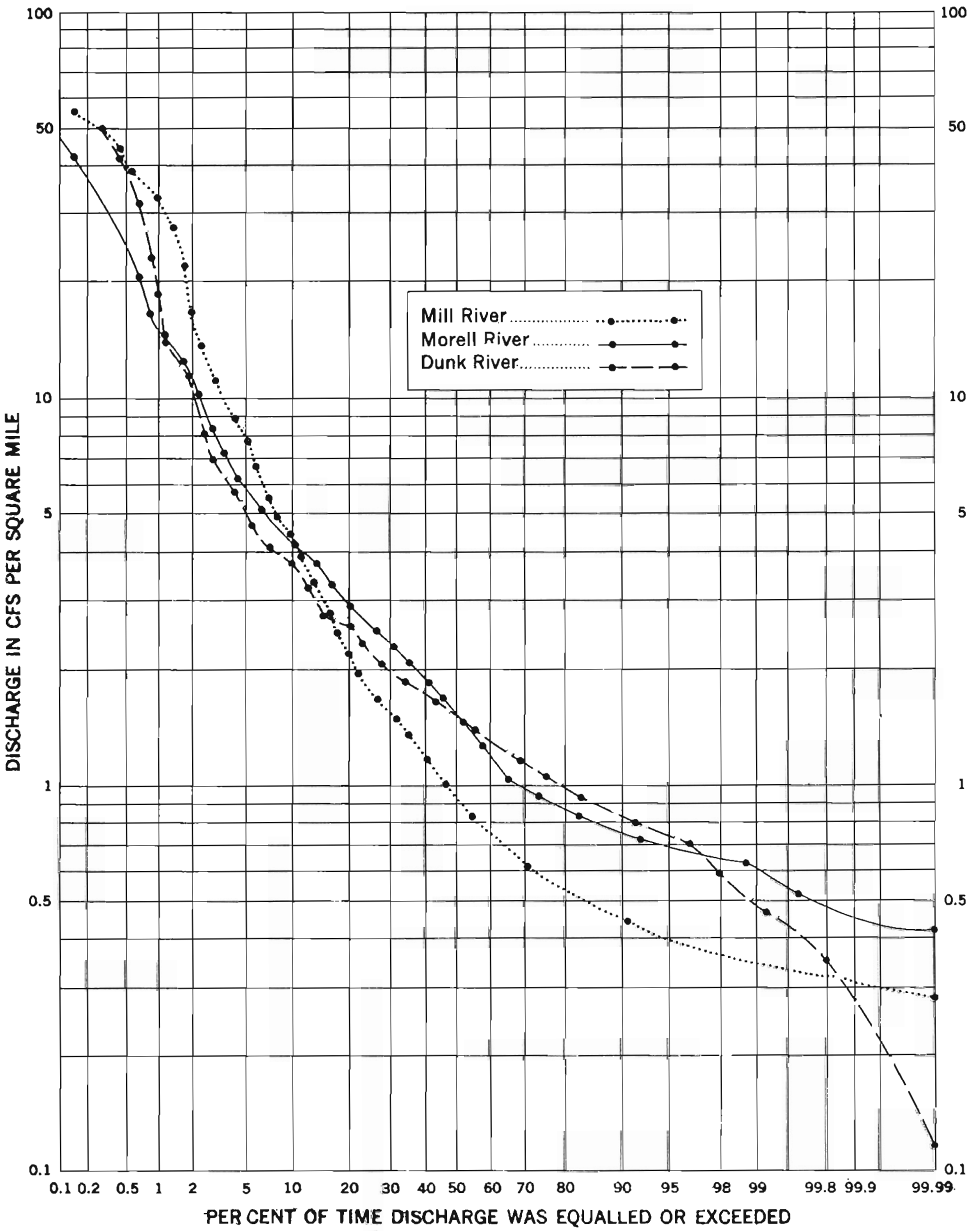

Figure 6. Flow duration curves for Mill, Morell and Dunk Rivers

Figure 6 (discharge data provided by the former Water Resources Branch) shows the flow-duration curves of discharge per square mile against percentage of time when discharge was equalled or exceeded. The similar shape of these curves reveals a similar discharge pattern, and the divergence of the curves at the low-flow period may be attributed to the presence of dams.

The run-off of the three river basins for the years 1961-62 and 1962-63 is given in Table VIII.

Table VIII

Run-off in Inches per Square Mile, 1961-63

River	1961-62	1962-63
Dunk	29.5	34.5
Morell	27.1	36.4
Mill	27.4	34.3

These tables and the figure indicate a hydrologic similarity even though Mill River is a smaller basin and has a gentler topography than the other two.

Components of Run-off

The water being drained from the land in the rivers of the island is derived entirely from precipitation and has reached the rivers in three phases of flow. The first is the immediate storm run-off after heavy rainfall and from the melting of snow and ice in the spring. This causes the peak flows. The second is from water that has entered the soil and drained downslope to the rivers. This is sometimes referred to as the "interflow". The third is the water that has percolated through the ground after precipitation and reached the groundwater table, from where it passes through a slow-moving flow system in the bedrock to a discharge point in a stream or to the sea. This is the type of flow known as "baseflow", which maintains the stream flow during the coldest period of winter when recharge does not occur and also during dry spells in the summer. An estimate of the quantity of baseflow can normally be made by examining river hydrographs. However, there are inevitable inaccuracies in trying to draw conclusions on low flow from these hydrographs owing to the small dams on the rivers. No hydrographs are presented for this reason. Therefore it is

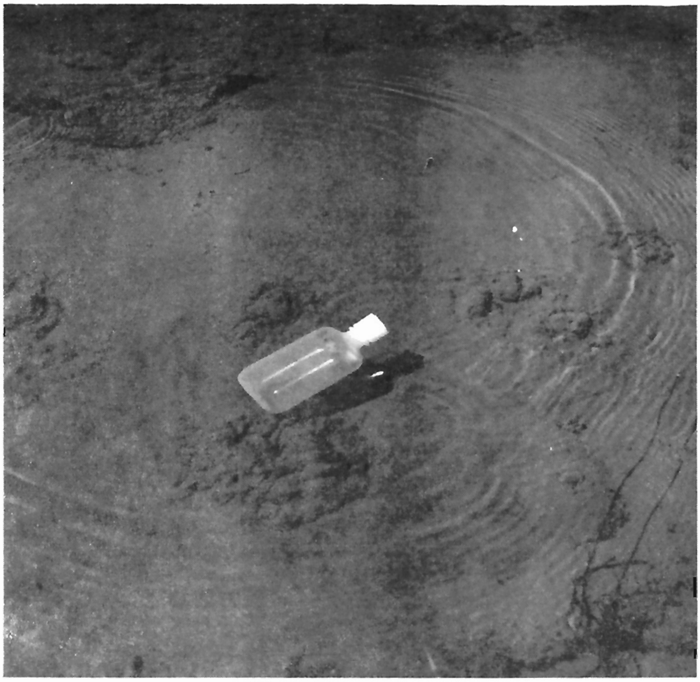

PLATE I.

Groundwater bubbling up through sand in a spring.

L.V.B. 1-12-62

PLATE II.

Pisquid spring showing "sand boils" where groundwaters enter the pool.

L.V.B. 1-8-62

necessary to find other evidence of groundwater discharge and estimates of the quantity of this discharge.

Evidence for Baseflow

The field evidence to show that groundwater is effluent and maintains the flow of rivers on the island is as follows:

(1) Springs are found in many depressions throughout the island. Many have flows ranging from 50 to 500 gpm and have formed pools where water can be seen bubbling upwards, indicating upward leakage of groundwater through joints in the bedrock or from highly permeable beds of sand. Plates I and II illustrate this flow in a large spring in the Pisquid River valley, Queens county.

(2) Borings for wells or foundation testing show that the depth to water on high ground may be 30 to 110 feet, but when drill-holes are put down in river valleys it is found that the water level rises as the drilling proceeds. Many flowing wells are found in rivers or in depressions. Thus upward leakage of groundwater is occurring at these places and a simple flow system, similar to that shown by Hubbert (1940), may be present. It has not been practicable to draw any flow-nets from well data across any valleys because wells are uncased and are not true piezometers.

(3) The poor drainage conditions and rich vegetation in valleys are further indications of effluent groundwater flow. Farming on the island is generally carried out on the high ground and slopes and not in the valley bottoms, which are swampy in many localities. Plate III illustrates this condition. It is an air photo showing the dense vegetation along Dunk River in Prince county and is typical of many river valleys on the island.

(4) Groundwaters emerging from springs into streams have a temperature of 44-45°F. These cold temperatures are noticeable to persons wading in streams during the summertime. The cold calcium bicarbonate groundwaters enrich the streams and are one of the reasons for the high yield of brook trout in this part of the Maritime Provinces. Smith (1963) has commented on this high yield, which he also attributed (1959) to phosphorus derived from fertilizers applied to the potato fields.

Springs of fresh water are also noticeable at low tide along the river estuaries and the shorelines where groundwaters are discharged directly into the sea. Flowing wells of fresh water have been drilled at fish canneries where the wells are below high-tide level.

RCAF
Photo
A-16109-1

PLATE III. Dunk River valley showing timbered area in low ground where drainage is poor owing to effluent groundwater.

(5) An estimate of groundwater contribution to rivers can be made by examining the low-flow figures at two periods in the year. Little recharge occurs during freezing periods of January and February and during the drier spells of summer when evaporation exceeds precipitation. From the available flow records it can be estimated that minimum discharges are of the order of 0.5 to 0.8 cfs per square mile of drainage basin. In dry summers when evapotranspiration along rivers is high discharge may be even less, as groundwaters are lost to evaporation. In winters after a wet summer or autumn the figure may be higher owing to greater groundwater discharge after infiltration; the higher flows during the period January to March of 1963 may be attributed to this.

Groundwater Fluctuations

Two continuous groundwater-level recorders were established on the island in 1962 and two other sites for weekly measurements of groundwater level were also selected.

Recording observation wells were set up in the Morell and Dunk River basins at well sites within 200 yards of the stream gauging station. Freezing conditions in winter, as well as technical difficulties have interrupted the sequence of records. The recorder on Morell River has shown groundwater-level fluctuations between depths to water of 5.2 feet and 45.5 feet and the recorder on Dunk River shows fluctuations that may be attributed to changes of level in the dam about 1 mile upstream.

A well at the Experimental Farm has shown water-level fluctuations between depths of 64 and 68 feet and one in the Montague basin has fluctuated between depths of 28 and 33 feet.

The number of records and period of recording are at present inadequate to draw any conclusions relating groundwater level to other hydrologic factors.

Hydrologic Balance

The water balance of any simple drainage basin may first be expressed in the form:

$$P = E + R_s + R_g$$

where P represents the inflow of precipitation in inches and E and R represent the outflow in inches. E is the actual evaporation by transpiration from plants and by evaporation from open water and soil moisture. R_s is the measured run-off at a gauging point in a stream, and, because groundwater is effluent to streams it combines the surface run-off and groundwater contribution to the stream above the gauging station. R_g is the groundwater that is discharged out of the basin into estuaries or directly along the coastline into the sea.

Tables and figures given above showing precipitation, evaporation, and run-off indicate a wide annual fluctuation each year. Therefore it is not possible to write out a balanced annual hydrologic equation. It is worthwhile however, to indicate the order of magnitude of the four factors, and this can be done for the two most recent years of record, which were "wet" years, i.e. the precipitation was above average for these years. The values are approximate and are recorded to the nearest inch, taking the precipitation at Charlottetown, the measured evaporation for four months at Charlottetown and an estimated evaporation for the remaining months, and the average of run-off for the Dunk, Morell and Mill Rivers.

$$P \approx E + R_s + R_g$$

$$1961\text{-}62 \quad 49 \approx 9 + (4) + 28 + (8)$$

$$1962\text{-}63 \quad 48 \approx 12 + (4) + 35 - (3)$$

In a dry year the run-off is low. Thus there was a dry spell in 1921-22 when gauging was begun and an approximate equation for 1921-22 would be:

$$P \approx E + R_s + R_g$$

$$1921\text{-}22 \quad 36 \approx (16) + 15 + (5)$$

It is apparent that much more detailed measuring is required over a period of several years to produce proper estimates of the water balance. Evaporation measurements, particularly of soil moisture changes, and groundwater-level fluctuations are the most important as the figures quoted above in brackets are no more than gross estimates.

Aquifer Transmissibility

The coefficient transmissibility of an aquifer is defined (Todd, 1959) as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness under a hydraulic gradient of 1 foot per foot at the prevailing temperature of the water. The coefficient indicates the capacity of the aquifer to transmit water and is equal to the coefficient of permeability multiplied by the saturated thickness of the aquifer.

It is generally measured in the field by a prolonged, steady pumping test, during which time many measurements of drawdown in adjacent non-pumping wells are made. Aquifer tests are of great value when it is necessary to space wells in a new field and when it is believed that there is uniformity in the aquifer and that the flow lines towards the well are horizontal. No proper aquifer tests have been carried out on the island, therefore no coefficients of transmissibility have been calculated from field data. However, it is apparent from the varied specific capacities (yield in gallons per minute per foot of drawdown) reported in wells that there is a wide range of transmissibility values throughout the island. The writer found, enquiring of the yield of deep wells (those in excess of 100 feet), that the specific capacities of different wells range from 1 gpm per foot of drawdown to 18 gpm per foot of drawdown, after steady pumping for 24 hours. These different specific capacities are obtained because the wells are sited in sandstones of varied transmissibility and because of different well diameters. Also, different situations in a flow system result in different yields, the wells in low ground generally having a better yield.

Table IX lists seventeen different wells of varying specific capacity. A rule-of-thumb method of estimating transmissibility is to multiply the specific capacity by the factor 2,000. By doing this and by converting the assumed thickness of each aquifer to 100 feet it can be shown that transmissibility for a 100-foot section of rock varies from about 800 gpd per foot to 12,000 gpd per foot.

Field observations of rock outcrops and springs show that a range in transmissibility is to be expected, owing to variations in intergranular permeability of rock and owing to variations in jointing and the flow of water in joints. On Prince Edward Island groundwater flow is apparently both intergranular and joint flow, the joint flow probably being the greater. Evidence for this may be obtained from (a) well-drillers' logs, (b) field observations, and (c) laboratory measurements of permeability.

(a) Well drillers' logs show that sudden flows of water are encountered during the drilling of a well. This is illustrated by the following log of a well drilled near the shore of the Montague estuary at a new food-processing plant. (The log has been provided through the courtesy of Douglas Brothers and Jones Ltd.)

Table IX

Specific Capacity of Seventeen Wells

Location	Depth (feet)	Diameter (inches)	Pumping rate (gpm)	Drawdown at Steady Pumping after 24 hrs. (ft)	Specific capacity (gpm/ft)	Estimated Transmissibility of a 100-foot Section of Aquifer (gpd/ft)
Charlottetown Federal Building	203	12	100	11	9	9,000
Parkdale — McKay well	336	6	200	11	18	12,000
Parkdale — new well	418	10	200	75	2.7	1,500
Souris — #1	510	10	200	22	9	4,500
Souris — #2	338	10	200	52	3.9	3,000
Montague — frozen food #1	603	12	450	42	10	3,300
Montague — town fire well	250	12	150	150	1	800
Seabrook Farm #1 Kensington	561	12	500	182	2.8	1,000
St. Eleanors #1	450	10	280	100	2.8	1,500
St. Eleanors #2	400	10	225	30	7.5	4,300
Summerside #1	420	6	275	16	17	12,000
Summerside #3	156	6	250	33	7.5	6,000
Summerside #4	250	10	500	46	11	9,000
Summerside #5	590	10	120	115	1	500
Summerside #6	555	10	600	156	3.8	1,400

Depth (feet)

0 to 47	- Sandy with boulders and water after 22 feet
47 to 49	- 2 feet brick clay
49 to 62	- 13 feet sandstone
62 to 72	- 10 feet sandstone and a small stream of water; level of water from surface 23 feet
72 to 115	- 43 feet, 75% sandstone and 25% brick clay
115 to 137	- 22 feet, 90% sandstone and 10% brick clay, some water at 125 feet
137 to 164	- 27 feet, 60% sandstone and 40% brick clay
164 to 192	- 28 feet hard sandstone, drilled through, water at 182 feet
192 to 230	- 38 feet, 90% sandstone, 10% brick clay, water at 208 feet
230 to 257	- 27 feet, 75% sandstone, 25% brick clay
257 to 290	- 33 feet medium hard sandstone, drilled through, stream at 278 feet
290 to 315	- 25 feet, 80% sandstone, 20% brick clay
315 to 355	- 40 feet, 45% sandstone, 55% brick clay
	- Water level at this depth - 11 feet from top of ground -
355 to 370	- 15 feet, 30% sandstone, 70% brick clay
370 to 465	- 95 feet, 40% sandstone, 60% brick clay
465 to 485	- 20 feet, 50% sandstone, 50% brick clay
485 to 488	- 3 feet, very hard rock
488 to 521	- 33 feet, 70% sandstone, 30% brick clay; heavy flow of water at 492 feet
521 to 529	- 8 feet very hard rock
529 to 573	- 44 feet, 60% sandstone, 40% brick clay
573 to 575	- 2 feet very hard rock
575 to 595	- 20 feet medium sandstone producing water
595 to 602	- 7 feet very hard rock
	- Static water level at 600 feet is ground-level -

The drill log shows that a noticeable increase in flow to the well was encountered at different depths during the drilling. The log also shows that there was a rise in the static water level of the well with increased depth of drilling (from 23 feet to water, to 0 feet to water). This is typical of wells in low ground and shows that the drilling is in a place of groundwater discharge. The sudden flows of water may be attributed to very permeable beds or, more probably, to open joints parallel to the bedding plane.

(b) Observations of springs along the shorelines show that water appears to emerge along joints parallel to bedding in rock.

(c) Laboratory measurements of permeability were made by Chemical and Geological Laboratories Ltd., Edmonton, on four hand

Table X

Porosity and Permeability Measurements of Four Rock Samples

	Effective Porosity		Water Permeability (Millidarcies)		Transmissibility of 100-foot Section (gpd/ft)	Description
	Vertical	Horizontal	Horizontal	Vertical		
1.	26.7	27.0	2,055	661	4,315	70% quartz, subangular to angular; orthoclase, chlorite and magnetite present; grains 1/2 mm - 1/3 mm; ferruginous cement
2.	26.8	25.8	274	164	575	60-70% quartz, subangular; orthoclase, biotite, magnetite present; grains 2/5 mm; ferruginous cement
3.	16.7	14.4	33	2.6	69	80% quartz, subangular to angular; chlorite and magnetite present; grains 1/2 mm; ferruginous cement
4.	24.4	25.4	294	283	617	50-60% quartz, subangular to rounded, chlorite, orthoclase, biotite present; grains 1/5 - 2/5 mm; ferruginous cement

specimens of sandstone selected at random. The permeability and porosity results and thin section descriptions of each sample, given in Table X, indicate that there is a wide variation in permeability. One millidarcy is equal to 0.021 gpd/foot for 1 square foot of permeable medium. Therefore transmissibility (T) can be expressed by the equation:

$$T = 0.021\ k \times t \text{ gpd/foot}$$

where k = horizontal permeability in millidarcies;
and t = aquifer thickness in feet.

One column in Table X shows what the transmissibility of a 100-foot section of uniform sandstone would be. The low transmissibility values suggest that there is more joint permeability than intergranular permeability in the sandstones on the island.

CHEMISTRY OF GROUNDWATERS

Groundwaters in the island may be classed as calcium bicarbonate water, which ranges from about 100-300 parts per million (ppm) sum of constituents in drilled wells and about 60-130 ppm in springs. Chemical analyses, expressed in parts per million, of 48 wells and springs are shown on Table XI and the places where the samples were taken are shown on the map accompanying this report. Eighty-eight chemical analyses from the western part of the island were reported by Owen and Pollitt (1950) and by Pollitt (1952, 1953).

The quality of groundwaters is excellent except in those places where the nitrate content is high, e.g. around Miscouche (analyses 38-41) and a few other localities; and in those places near the shore where salt-water intrusion has occurred.

Salt-water intrusion from the sea can be anticipated whenever a well adjacent to the shoreline is pumped heavily. A way of assessing the extent of salt-water intrusion is to calculate the chloride:bicarbonate ratio when analyses are expressed in equivalents per million. The normal chloride:bicarbonate ratio of groundwaters on the island is less than 0.5.

Table XII lists eight wells that indicate salt-water intrusion. The wells at Miscouche and Boughton Island have slight salt-water intrusion; both are near the shore and are shallow. The Boughton Island well was drilled many years ago at a fishing wharf, which is now abandoned. The well is below high-tide level and flows at low tide.

Table XI

Chemical Analyses of Prince Edward Island Wells, in Parts per Million
(Analyses by J.F.J. Thomas, Industrial Waters Section, Mines Branch, Ottawa.)

Number	1	2	3	4	5	6	7	8	9	10	11	12
Source	well	well	well	well	well	well	well	well	well	well	well	well
Location	lot 62 Northumberland Park, Port Wood	lot 19 Seabrook Farm Ltd.	lot 47 East Point lighthouse	lot 46 East Baltic	lot 46 Red Point	lot 45 Hermanville	lot 38 Fanning Brook	lot 46 Priest Pond	lot 37 Mt. Stewart	lot 46 Baltic	lot 50 Glencoe	lot 60 Caledonia
Well depth (feet)	99	561	82	84	145	125	84	100	74	72	75	210
Date of sampling	14/6/62	15/6/62	15/6/62	16/6/62	16/6/62	18/6/62	19/6/62	15/6/62	19/6/62	19/6/62	28/6/62	26/6/62
Appearance	Clear	Clear	Some iron ppt.	Clear	Clear	Clear	Clear	Clear	Some iron ppt.	Clear	Clear	ppt.
CO_2 (calculated)	8	5	8	10	7	4	6	5	5	11	7	4
pH	7.3	7.7	7.4	7.5	7.5	7.7	7.3	7.6	7.9	7.2	7.5	7.5
Colour (Hazen units)	0	0	0	0	0	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$ (total)	76	134	112	159	128	115	57.8	106	216	90.8	128	68.9
Conductance, micromhos at 25°C	203	281	541	557	381	278	173	1049	514	266	340	238
Hardness as $CaCO_3$ (total)	88.8	100	171	214	165	132	72.4	590	251	111	161	105
Hardness as $CaCO_3$ (non-carbonate)	13.0	0.0	58.8	55.5	37.5	16.8	14.6	484	35.3	20.0	33.5	35.9
Calcium (Ca)	32.8	28.1	49.8	45.5	34.3	25.9	14.1	148	58.8	23.0	33.0	21.3
Magnesium (Mg)	1.7	7.3	11.4	24.5	19.3	16.3	9.0	53.4	23.3	13.0	19.1	12.5
Sodium (Na)	6.1	22.2	41.5	28.7	12.2	7.8	4.9	9.1	10.1	8.7	6.2	4.4
Potassium (K)	0.8	1.6	1.7	2.4	1.3	1.5	1.0	2.0	1.2	1.6	1.7	1.2
Iron (total) (Fe)	0.44	0.02	1.54	0.05	0.15	0.01	0.27	0.21	High	0.10	0.04	0.52
Manganese (total) (Mn)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.10
Ammonia (NH_3)	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbonate (CO_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO_3)	92.4	164	137	194	155	140	70.5	130	263	111	156	84
Sulphate (SO_4)	7.0	6.0	19.2	19.7	18.8	4.7	10.7	462	24.9	11.5	17.6	9.4
Chloride (Cl)	14.1	6.2	87.5	41.7	22.7	15.0	7.5	12.5	21.9	13.6	11.1	16.7
Fluoride (F)	0.08	0.03	0.10	0.07	0.05	0.04	0.05	0.66	0.08	0.06	0.10	0.05
Nitrate (NO_3)	0.2	0.0	6.0	50	20	6.5	2.6	0.4	0.0	6.5	16.0	15.4
Silica (SiO_2)	5.8	12.9	5.1	6.1	5.1	6.6	4.3	8.0	8.5	5	5.4	4.5
Sum of constituents	114	165	290	314	210	153	88.8	760	280	137	187	127

Number	13	14	15	16	17	18	19	20	21	22	23
Source	spring	spring	spring	spring	spring	spring	spring	spring	spring	spring	Morell River
Location	lot 38 Above Pisquid Pond	lot 38 Fanning Brook	lot 38 Head of Hillsborough	lot 53 Cardigan	lot 39 Morell Rear	lot 40 Bangor	lot 43 New Acadie	lot 37 Dromore	lot 67 Breadalbane	lot 51 St. Teresa	lot 52 Morell Gauging Stn.
Date of sampling	19/6/62	19/6/62	19/6/62	19/6/62	21/6/62	22/6/62	22/6/62	26/6/62			28/6/62
Appearance	Clear	ppt.	ppt.	ppt.	Clear	some particles		ppt.	Clear	Iron ppt.	ppt.
CO_2 (calculated)	6	6	9	8	8	6	7	5	12	4	9
pH	7.3	7.3	6.9	7.2	7.2	7.4	7.4	7.5	6.8	7.5	7.1
Colour	0	0	0	0	0	0	0	0	10	5	70
Alkalinity as $CaCO_3$ (total)	69.9	65.4	39.5	62.4	65.1	88.4	83.9	71.9	36.4	67.7	57.6
Conductance, micromhos at 25°C	192	187	146	190	197	222	238	179	101	185	148
Hardness as $CaCO_3$ (total)	82.8	80.6	55	83	82.0	96.4	94.0	80.6	47.0	84.2	67.2
Hardness as $CaCO_3$ (non-carbonate)	12.9	15.2	15.5	20.6	16.9	8.0	10.1	8.7	10.6	16.5	9.6
Calcium (Ca)	16.8	16.4	10.9	17.1	15.0	19.9	19.5	16.1	9.3	17.8	13.2
Magnesium (Mg)	9.9	9.6	6.7	9.8	10.8	11.3	11.0	9.8	5.8	9.7	8.3
Sodium (Na)	4.8	4.8	5.0	4.6	6.0	6.7	10.0	3.8	4.1	4.7	4.5
Potassium (K)	0.9	1.0	2.3	1.2	1.3	1.1	1.3	0.9	0.9	1.1	1.2
Iron (total) (Fe)	0.02	0.02	0.03	0.02	0.01	0.01	0.05	0.03	Trace	0.02	0.37
Manganese (total) (Mn)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
Ammonia (NH_3)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1
Carbonate (CO_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO_3)	85.2	79.7	48.2	76.1	79.4	108	102	87.6	44.4	82.5	70.2
Sulphate (SO_4)	7.2	8.1	9.0	10.9	5.8	5.4	7.1	5.1	5.7	8.1	5.1
Chloride (Cl)	8.1	8.5	8.6	8.8	10.6	11.7	17.8	7.2	6.1	9.1	7.8
Fluoride (F)	0.06	0.06	0.05	0.04	0.06	0.04	0.05	0.07	0.11	0.11	0.13
Nitrate (NO_3)	3.3	4.4	5.8	5.7	8.3	0.5	0.5	0.9	1.0	4.6	1.3
Silica (SiO_2)	4.9	4.8	3.8	4.3	4.4	4.7	5.1	5.2	4.9	4.9	3.1
Sum of constituents	97.9	96.9	75.8	99.9	101	114	123	92.2	59.8	101	79.2

Number	24	25	26	27	28	29	30	31	32	33	34	35
Source	well	well	well	well	well	well	well	well	well	well	well	well
Location	lot 51 Riverton	lot 53 Martinvale	lot 38 Peake Stn.	lot 36 Fort Augustus	Souris #1 town well	Souris Eastern Fisheries Ltd.	Souris Lighthouse	lot 26 Kinkora	lot 25 Freetown	lot 67 Rose Valley	lot 67 Shamrock	lot 67 Springton
Well depth (feet)	85	100	104	150	510	442	117	90	114	60	150	85
Date of sampling	22/6/62	22/6/62	22/6/62	29/6/62	16/7/62	16/7/62	22/6/62	15/8/62	15/8/62	15/8/62	15/8/62	15/8/62
Appearance	ppt.	Clear										
CO_2 (calculated)	8	8	8	7	5	7	7	5	9	7	8	10
pH	7.2	7.4	7.2	7.3	7.6	7.5	7.5	7.5	7.4	7.4	7.1	6.9
Colour (Hazen units)	5	5	5	5	10	10	5	5	10	10	5	10
Alkalinity as $CaCO_3$ (total)	64.8	106	65.4	71.5	86.9	105	101	82.2	125	76.4	50.5	46.7
Conductance, micromhos at 25°C	163	245	183	205	236	2696	818	263	343	184	194	133
Hardness as $CaCO_3$ (total)	73.8	116	80.0	88.8	107	770	186	113	154	86.2	81.9	56.2
Hardness as $CaCO_3$ (non-carbonate)	9.0	10.1	14.6	17.3	20	665	85.2	30.4	29.5	9.8	31.4	9.5
Calcium (Ca)	15.2	24.1	16.4	18.7	21.9	142	30.7	42.0	57.5	18.7	15.5	16.2
Magnesium (Mg)	8.7	13.8	9.5	10.2	12.7	101	26.6	1.9	2.5	9.6	10.5	3.8
Sodium (Na)	3.7	4.5	4.4	4.7	7.7	270	86.9	5.8	7.5	3.4	5.5	3.6
Potassium (K)	0.9	1.3	1.0	1.2	1.0	5.4	3.5	0.7	0.7	0.8	1.2	0.9
Iron (total) (Fe)	0.17	0.06	0.12	0.15	0.05	0.04	0.14	0.02	0.01	0.05	0.76	2.4
Manganese (total) (Mn)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia (NH_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.2
Carbonate (CO_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO_3)	79	129	79.7	87.2	106	128	123	100	152	93.1	61.6	56.9
Sulphate (SO_4)	6.4	5.8	8.3	8.4	13.4	287	39.6	13.2	6.0	5.5	11.2	6.7
Chloride (Cl)	5.2	7.5	8.0	9.1	13.1	683	167	11.9	18.4	6.2	12.4	6.9
Fluoride (F)	0.09	0.06	0.09	0.07	0.08	0.33	0.16	0.08	0.02	0.11	0.11	0.06
Nitrate (NO_3)	1.9	3.8	4.0	7.4	5.3	2.0	6.6	16	13	5.3	14	2.7
Silica (SiO_2)	4.2	4.9	4.8	4.6	4.8	7.6	4.9	8.3	9.5	7.5	5.5	5.8
Sum of constituents	85.2	129	95.7	107	132	1.561	426	149	190	103	106	74.7

Number	36	37	38	39	40	41	42	43	44	45	46	47
Source	well	well	well	well	well	well	well	well	well	well	well	well
Location	lot 22 Fredericton Station	lot 26 Central Bedeque	lot 17 Miscouche	lot 17 Bentinck Cove	lot 17 Miscouche	lot 17 Miscouche	Boughton Island, Cardigan Bay	Federal Building, Charlotte-town	Souris, Well at Federal Wharf	Summer-side #1	Rustico Island Park	Summer-side #6
Well depth (feet)	185	356	261	30	65	32	40?	300		420	300	555
Date of sampling	15/8/62	15/8/62	15/8/62	15/8/62	15/8/62							
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	ppt.	Clear	ppt.	ppt.	ppt.
CO_2 (calculated)	7	6	8	8	8	12	6	6	3	7	5	6
pH	7.2	7.5	7.5	7.3	7.4	7.2	7.5	7.7	7.8	7.5	7.7	7.6
Colour (Hazen units)	0	5	0	5	10	10	0	0	5	5	10	5
Alkalinity as $CaCO_3$ (total)	60.5	112	146	87.1	97	104	90.2	151	96.6	111	124	109
Conductance, micromhos at 25°C	180	365	489	357	374	448	342	2376	795	836	324	328
Hardness as $CaCO_3$ (total)	79.7	159	222	160	152	159	112	547	364	240	106	141
Hardness as $CaCO_3$ (non-carbonate)	19.2	47.6	76	72.6	55.1	55.1	21.6	396	268	128	0.0	32.1
Calcium (Ca)	15.6	56.8	81.7	58.1	53.6	57.4	19.4	104	65.8	76.4	19.4	52.4
Magnesium (Mg)	9.9	4.2	4.5	3.5	4.4	3.8	15.4	69.6	48.6	11.8	14.0	2.4
Sodium (Na)	4.0	10.0	12.8	8.3	11.2	22.8	22.6	260	26.0	64.0	26.2	9.8
Potassium (K)	0.9	1.5	0.7	0.7	1.9	3.5	1.7	34.0	3.0	1.2	1.7	0.8
Iron (total) (Fe)	0.01	0.30	0.03	0.05	0.02	0.14	Trace	0.16	0.03	0.02	0.04	0.02
Manganese (total) (Mn)	0.0	0.0	0.0	0.0	0.0	0.0	Trace	0.8	0.0	0.0	0.0	0.0
Ammonia (NH_3)	0.0	0.0	0.0	0.0	0.0	0.0						
Carbonate (CO_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO_3)	73.7	136	179	106	118	127	110	184	118	136	151	132
Sulphate (SO_4)	7.4	20.2	32.9	35.6	23.4	15.6	12.8	191	101	42.5	9.0	15.8
Chloride (Cl)	10.8	20.0	30.9	22.1	21.1	44.4	42.1	549	158	148	20.9	18.1
Fluoride (F)	0.08	0.08	0.11	0.11	0.11	0.21	0.05	0.42	0.16	0.11	0.09	0.09
Nitrate (NO_3)	7.6	24.9	28.2	28.4	31.7	33.5	0.2	39.6	0.4	21.0	0.9	14.6
Silica (SiO_2)	6.1	8.0	9.5	6.5	7.7	6.1	5.0	2.6	8.3	11	6.8	11
Sum of constituents	98.7	213	289	216	213	250	174	1341	470	444	173	191

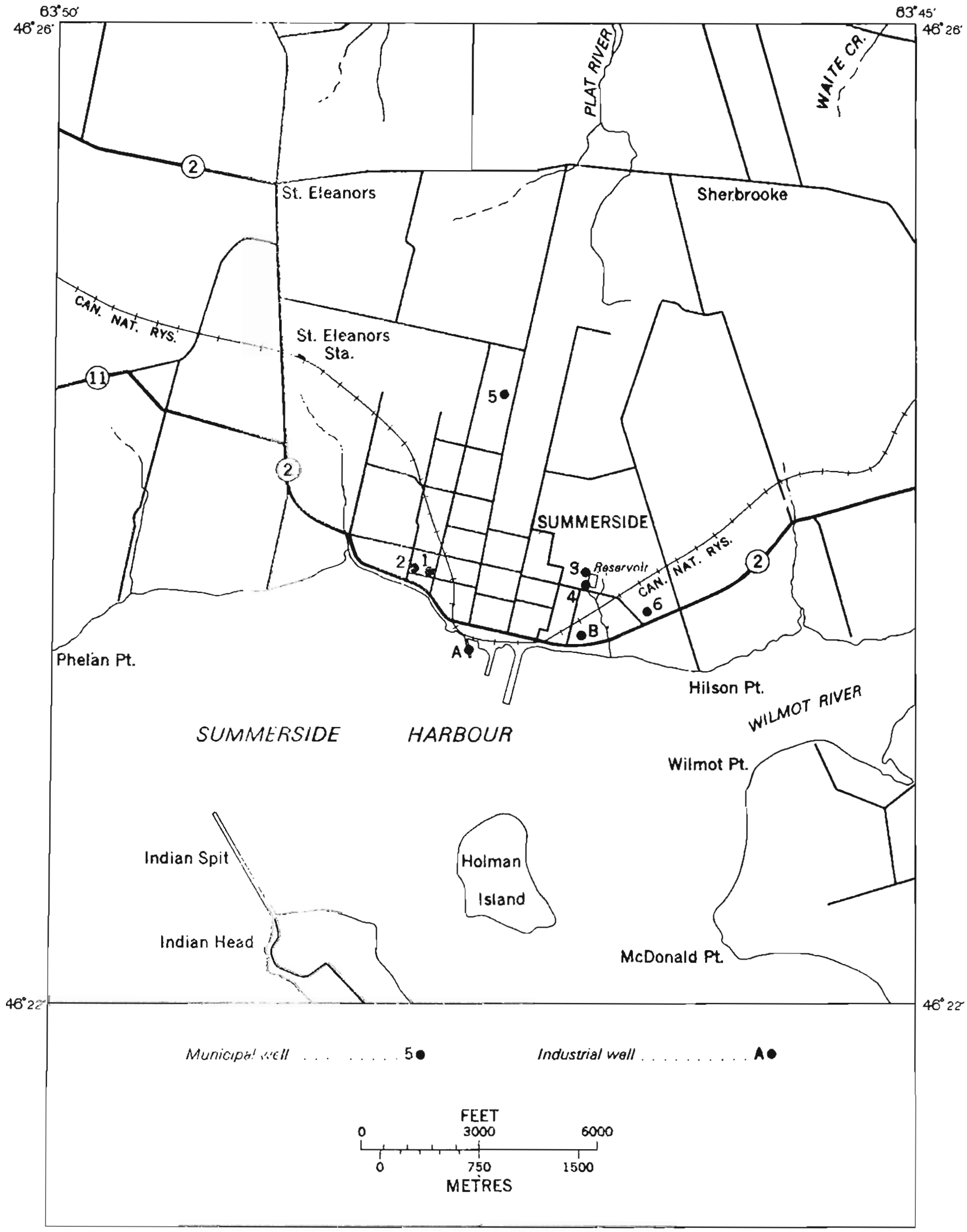

Figure 7. Recorded wells at Summerside, Prince Edward Island (see Table IX)

Wells near the shore at Summerside and Souris may have moderate salt-water intrusion. If heavier pumping is undertaken at these places the salt-water intrusion will probably increase sufficiently to be a serious problem.

The two wells with serious salt-water contamination are deep wells, which are not used for drinking water. The salt content of the well drilled in Charlottetown was reported to increase with depth.

It is probable that any well drilled on the island to more than 300 feet depth near open shoreline will become saline after heavy pumping, and any well drilled inland to depths greater than 800 feet may also be saline.

WATER SUPPLY

Well Fields

Charlottetown obtains its water from well fields at West Royalty and on Brackley and Union roads. The pumphouse at West Royalty obtains water from a 24-foot-diameter cistern and from a 520-foot-deep well. The deep well is reported to pump 300 gpm with a drawdown of 160 feet. The well field on the Brackley road is north of the railroad and comprises 18 shallow small-diameter holes at the headwaters of Winter River. A smaller well field with 10 holes is located in the same valley near Union road. The well fields have a combined capacity of more than two million gallons per day. There are several industrial wells in the city and the adjoining residential area of Parkdale has two wells, which are recorded on Table IX.

Summerside has six wells, which are recorded on Table IX; locations are shown on Figure 7. Some salt-water intrusion occurs in Well No. 1. Well No. 2 is closed down and sealed owing to salt water. There are several industrial wells in the town area.

If expansion of industry and population continue in the vicinity of Summerside, a careful spacing of wells will probably have to be planned. Present consumption exceeds one million gallons per day.

Other well fields are at Souris, Montague, St. Eleanors, Kensington, and Seabrook Farms. Their locations are shown on the map accompanying this report.

Table XII

Chloride:Bicarbonate Ratio of Eight Wells

Well Location	Number	epm Chloride	epm Carbonate and Bicarbonate	Ratio	Degree of Contamination
Miscouche lot 17	41	1.25	2.08	.6	Slight
Boughton Island	42	1.19	1.80	.6	Slight
East Point lighthouse	3	2.47	2.25	1.1	Moderate
Summerside No. 1	45	4.18	2.22	1.9	Moderate
Souris wharf	44	4.47	1.93	2.3	Moderate
Souris lighthouse	30	4.69	2.01	2.3	Moderate
Federal Building, Charlottetown	43	15.48	3.02	5.1	Serious
Eastern Fisheries, Souris	29	19.25	2.10	9.1	Serious

Conclusions

As Prince Edward Island has a humid climate and its bedrock is well jointed and permeable, it is possible to obtain abundant domestic supplies of groundwater almost anywhere on the island. At no point on the island is it possible to drill a dry hole. The depth to water on hills may be more than 100 feet; in valley bottoms water is encountered within a few feet and wells drilled to a hundred feet in a valley may flow. Deep wells of more than 600 feet are not necessary; at these depths the water level may rise in the well to the same as sea-level and fluctuate with the tide.

All wells drilled near the seashore are likely to have salt-water intrusion, as the sea water may flow to a pumping well along joints in the sandstone. Therefore such wells should be as shallow as is practicable.

All well fields for industry or large municipalities should be tested before complete lay-out of wells, because the transmissibility of the bedrock aquifer is variable and an economic spacing of wells can only be made after test drilling.

Most groundwaters have an excellent quality for drinking and for many industrial purposes, except in those places where salt-water enters the well or where the nitrate content is high. The temperature of the groundwater is 44-45°F.

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