T8.1 FRESHWATER HYDROLOGY

Nova Scotia has no shortage of fresh water. The total mean precipitation is fairly high: approximately 1300 mm as compared to 800–950 mm in central Ontario and 300–400 mm in southern Saskatchewan. Frequent coastal fog, cloudy days and cool summers combine to moderate evapotranspiration. The result is a humid, modified-continental climate with a moisture surplus. Large areas of impermeable rock and thin soils and the effect of glaciation have influenced surface drainage, resulting in a multitude of bogs, small lakes and a dense network of small streams. Groundwater quality and quantity vary according to the type of geology in different parts of the province. The following topics describe the cycle of water and the various environments and forms in which it manifests itself. Fresh water as a resource is discussed in T12.8.

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Hydrology is the study of water in all its forms and its interactions with the land areas of the earth. It deals with snow and ice on the land, moisture in the air, liquid water in lakes and rivers, as well as water occurring below the ground in the spaces between soil and rock, and within the soil.

Limnology and hydrogeology are specialized branches of hydrology. Limnology is the study of surface freshwater environments and deals with the relationships between physical, chemical, and biological components. Hydrogeology is the study of groundwater, emphasizing its chemistry, migration and relation to the geological environment.[1]

THE HYDROLOGIC CYCLE

The continuous process involving the circulation of water between the atmosphere, the ocean and the land is called the hydrologic cycle (see Figure T8.1.1). Solar radiation and gravity are the driving forces that "run" the cycle.

As water vapour cools, condensation occurs and clouds form. When rain or snow falls over land, a number of things can happen to the precipitation: some of it runs off the land surface to collect in catchment basins, some is returned directly to the atmosphere by evaporation and by transpiration in plants (evapotranspiration), and some percolates underground (infiltration) to become groundwater.

Underground formations that readily give up their water for wells are called aquifers (see T8.2). The

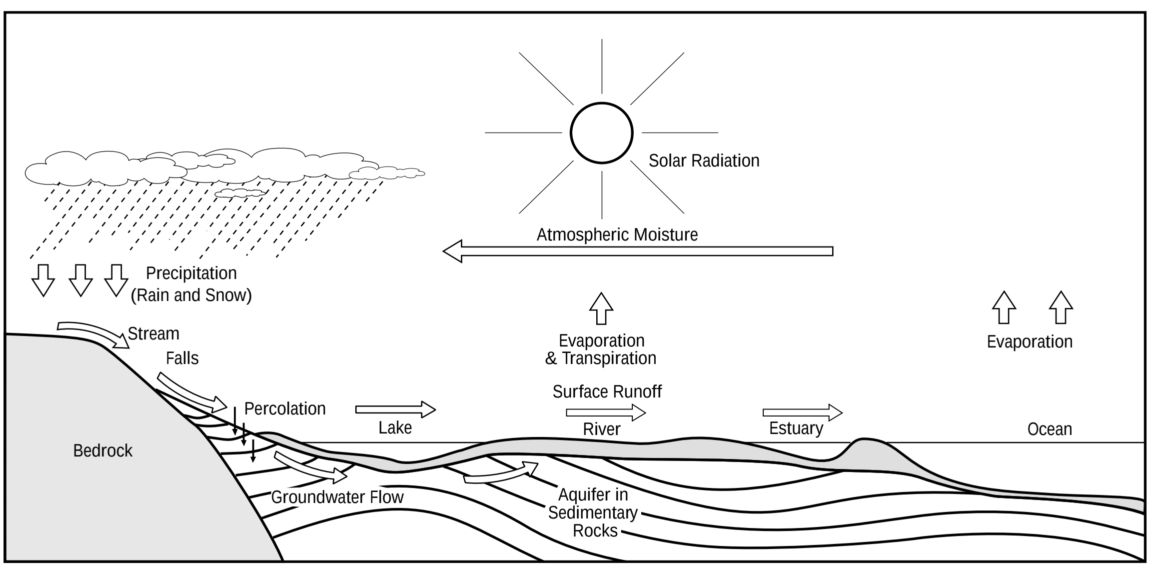

Figure T8.1.1: The hydrologic cycle.

upper water level in an aquifer is known as the water table. Water is continuously flowing underground and can move back to the surface by capillary action or be transported horizontally by subsurface flow, until it reaches a surface water system.[2]

Nova Scotia's cool climatic conditions produce a cycle where precipitation exceeds evapotranspiration. Due to the high rate of annual precipitation, rivers, lakes and aquifers are replenished or recharged, although the rate varies, depending on the amount of precipitation, the type of soil, the topography and the geology of the area. In areas dominated by rocky land surfaces, such as in southwestern Nova Scotia (Regions 400 and 800), the amount of runoff is very high and, subsequently, groundwater recharge is slow. Where more porous soils are found, such as in the Carboniferous Lowlands (Region 500), infiltration is much greater, and thus groundwater is higher.

WATERSHEDS

A watershed, or drainage basin, refers to the area of land from which surface water drains into a common lake or river system or directly into the ocean. The flow is generally inwards and downwards, according to the topography of the surrounding landscape. The boundaries of a watershed area are known as a drainage divide: precipitation falling on opposite sides of a divide falls into different watersheds. The underlying geology and type and depth of surficial overburden of every drainage basin are major factors in determining its characteristic drainage pattern (see T3.2). The watershed has become the unit used by water-resource planners and managers in dealing with developments within an area that may have an impact on water quality and quantity. Any activities that occur in the upper portions of a watershed will have an impact on water quality in downstream areas.

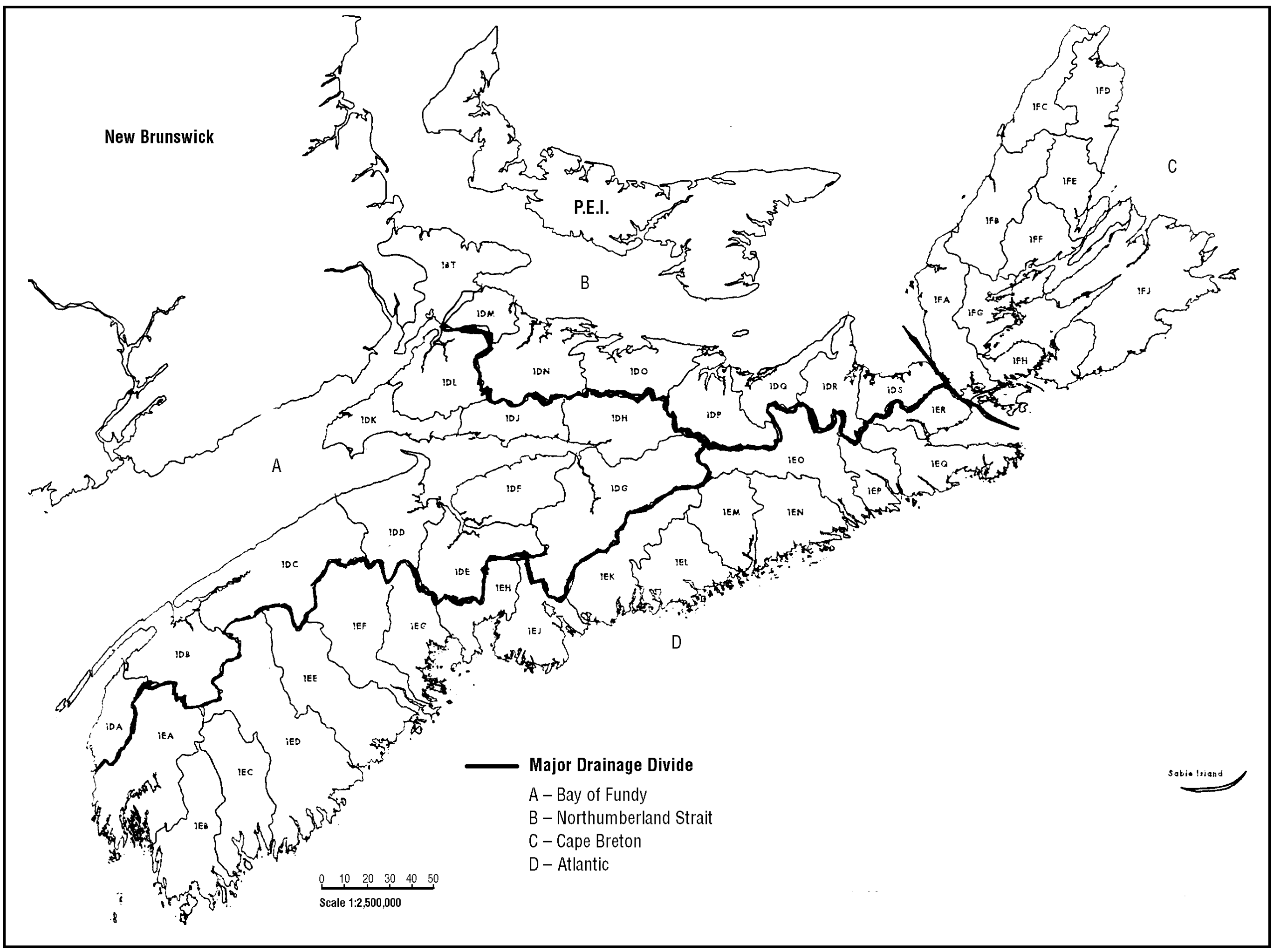

Figure T8.1.2: Locations of primary watersheds in Nova Scotia.

WATERSHED #	MAJOR RIVERS	TOTAL AREA (km^2)		
		Land	Water	Total
1DA	Meteghan	570	41	611
1DB	Sissiboo and Bear	1349	79	1428
1DC	Annapolis	2209	70	2279
1DD	Gaspereau	1316	58	1375
1DE	St. Croix	1306	61	1368
1DF	Kennetcook	1116	9	1125
1DG	Shubenacadie and Stewiacke	2540	73	2614
1DH	Salmon and Debert	1164	4	1168
1DJ	Economy	790	3	793
1DK	Parrsboro	856	2	858
1DL	Kelley, Maccan and Hebert	1295	9	1304
1DM	Tidnish and Shinimicas	475	4	479
1DN	Philip and Wallace	1475	19	1494
1DO	John	1111	6	1117
1DP	East, Middle, West (Pictou)	1190	7	1197
1DQ	French	735	1	736
1DR	South and West (Antigonish)	898	9	907
1DS	Tracadie	580	6	586
1EA	Tusket	1982	194	2177
1EB	Barrington and Clyde	1243	79	1322
1EC	Roseway and Sable and Jordan	1350	84	1435
1ED	Mersey	2690	339	3030
1EE	Herring Cove and Medway	1845	166	2012
1EF	LaHave	1611	89	1700
1EG	Gold	972	57	1029
1EH	East and Indian	695	69	765
1EJ	Sackville	924	71	996
1EK	Musquodoboit	1316	93	1409
1EL	Tangier	974	111	1086
1EM	East (Sheet Harbour)	914	74	988
1EN	Liscomb	1136	66	1202
1EO	St. Mary's	1505	43	1549
1EP	Country Harbour	550	18	569
1EQ	New Hbr./ Salmon (Guys.)	1019	70	1089
1ER	Clam Harbour/ St. Francis	517	14	532
1FA	Inhabitants	1193	10	1204
1FB	Margaree	1308	67	1375
1FC	Cheticamp	802	3	806
1FD	Wreck Cove	1057	15	1072
1FE	Indian	882	7	890
1FF	North, Baddeck and Middle	764	2	767
1FG	Denys and Big	792	2	794
1FH	Grand	739	33	772
1FJ	Salmon and Mira	2779	134	2914
*	Isle Madame	145	6	151

Table T8.1.1: Characteristics of primary watersheds in Nova Scotia. The figures were calculated by the Maritime Resource Management Service for the Nova Scotia Department of Environment in 1981.
*Isle Madame is classified as a shoreline direct inflow to salt water on the 1:50 000 watershed maps for Nova Scotia.

Most of the forty-four primary watersheds in the province are relatively small, ranging in size from 151 to 3030 km², especially those near the coastal zone, where numerous small streams flow directly into the ocean.[3] There are three major drainage areas in Nova Scotia. One large divide runs in an east–west direction across the mainland of the province. A second divide cuts across the top of the Cobequid Hills and the Pictou/Antigonish Highlands (District 310). The Canso Strait serves as another divide by separating Cape Breton from the mainland. Figure T8.1.2 shows the distribution of the major watersheds. On Cape Breton Island, most of the watersheds are quite small, mainly due to the fragmented topography and the existence of the Bras d'Or Lake system (District 560, Unit 916). The two exceptions to this are the Margaree (1375 km²) and the Salmon-Mira River system (2914 km²)

Some of the largest watersheds are found in the Atlantic interior (Region 400), such as the Medway, 2012 km²; the LaHave, 1700 km²; and the Shubenacadie-Stewiacke River system, 2614 km². The largest watershed in the province belongs to the Mersey River, which drains an area of 3030 km². A complete list of primary watersheds is provided in Table T8.1.1. Primary, secondary and tertiary watersheds in Nova Scotia have been mapped at a 1:50 000 scale. These maps are available through the Nova Scotia Department of Environment.

In addition to the primary watersheds outlined above, Environment Canada has also divided the province into three separate hydrological zones.[4] The criteria for making these divisions are based primarily on mean annual precipitation.

Due to the Shubenacadie Canal, the Shubenacadie River is Nova Scotia's longest river. The canal cuts perpendicularly across a major drainage divide and consequently water flows both north towards Cobequid Bay and south into Halifax Harbour.

WATER BUDGET

Nova Scotia averages 1300 mm of precipitation annually; however, there are times when water levels in lakes and rivers are low and wells run dry. It is estimated that less than 20 per cent of the total amount of rain and snow seeps underground to recharge the water table.[2] This occurrence relates directly to the amount of runoff, which has been estimated at 1018 mm per year (based on the average annual value for data recorded by Environment Canada).[5] Runoff is influenced by many factors, including soil type, soil moisture conditions, slope of the land and the amount of vegetation cover. In general, coarse soils with low to moderate runoff potential occur throughout the province. The exception occurs in central and northern Nova Scotia, which have more finely textured soils with higher runoff potential. Runoff can be accelerated by the removal of vegetation or infilling of wetlands. The accelerated runoff can in turn increase erosion, leading to higher levels of sediment loading and turbidity within streams. Figure T8.1.3 shows the mean annual runoff pattern for the province.[4]

Evapotranspiration is the evaporation from soil and waterbodies combined with transpiration from

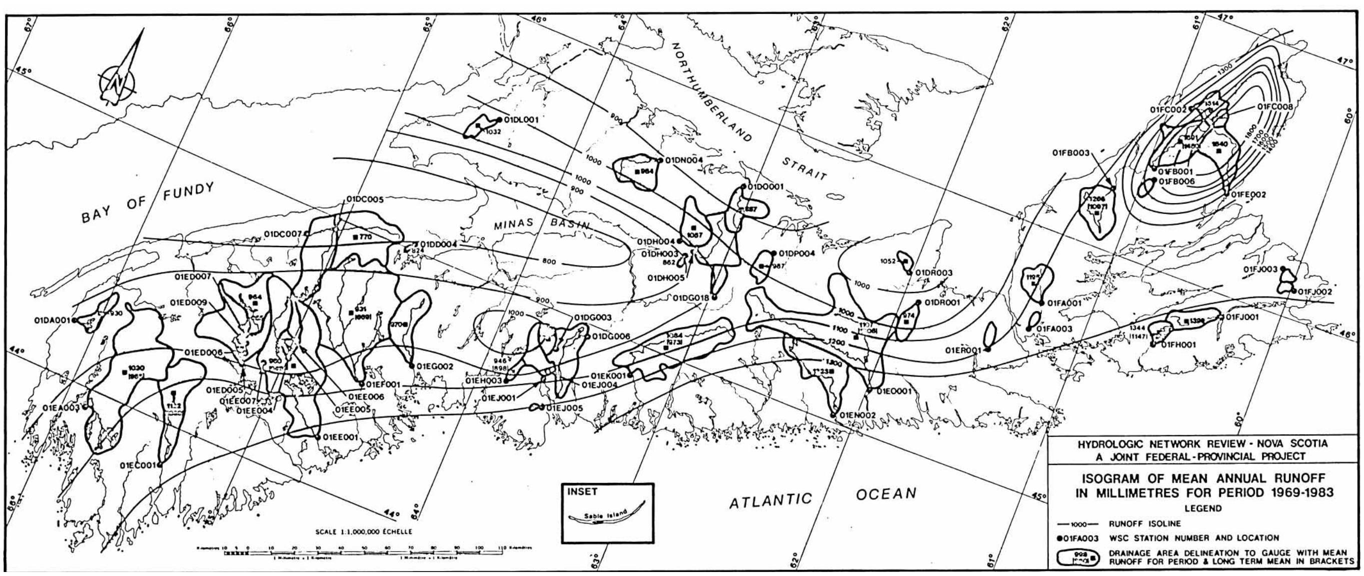

Figure T8.1.3: Mean annual runoff for Nova Scotia.

vegetation. Frequent coastal fog, combined with cloudy days and cool summers, results in moderate levels of evapotranspiration over most of the province. Levels have been estimated at between 200 and 400 mm a year. When this value is added to the runoff rate, it indicates that only a small percentage of the total rainfall infiltrates groundwater-storage areas or aquifers. The minimum annual groundwater recharge in Nova Scotia is estimated at 125 mm to 150 mm over a drainage basin, or approximately 10 per cent of the mean annual precipitation.[6]

DISCHARGE PATTERNS

Nova Scotia has a temperate climate which is characterized by ample and reliable precipitation, resulting in few prolonged dry seasons. There are, however, some notable variations in discharge patterns.

Precipitation is highest in the fall and winter months and usually lowest in June and July. It then begins to rise again during August with the arrival of the late-summer storms tracking up from the Caribbean region (see T5). Stream discharge normally peaks in March and April, as the result of snowmelt, and then drops dramatically to its lowest level in late summer and early fall. Figure T8.1.4 shows the mean monthly discharge pattern for selected Environment Canada monitoring sites throughout the province.[5]

The seasonal variation in water discharge has a direct effect on the chemical composition of surface water. The conductivity of lakes is often measured to determine the amount of dissolved solids (e.g., calcium, magnesium, sodium and potassium) which, in turn, may influence the level of productivity. Conductivity is high in the spring, when the amount of discharge is greatest, and low during the summer, when discharge is also very low. The *Historical Water Level Summary* published by Environment Canada provides water-level data for lakes in Nova Scotia.[7]

STREAMFLOW

Water flow in streams that drain the thin soils overlying igneous-rock formations is maintained primarily by surface runoff. As a result, the water level of these streams tends to drop during the drier summer months, and many smaller streams go completely dry. In contrast, the deeper soils found in areas of sedimentary rocks are drained by fewer streams.

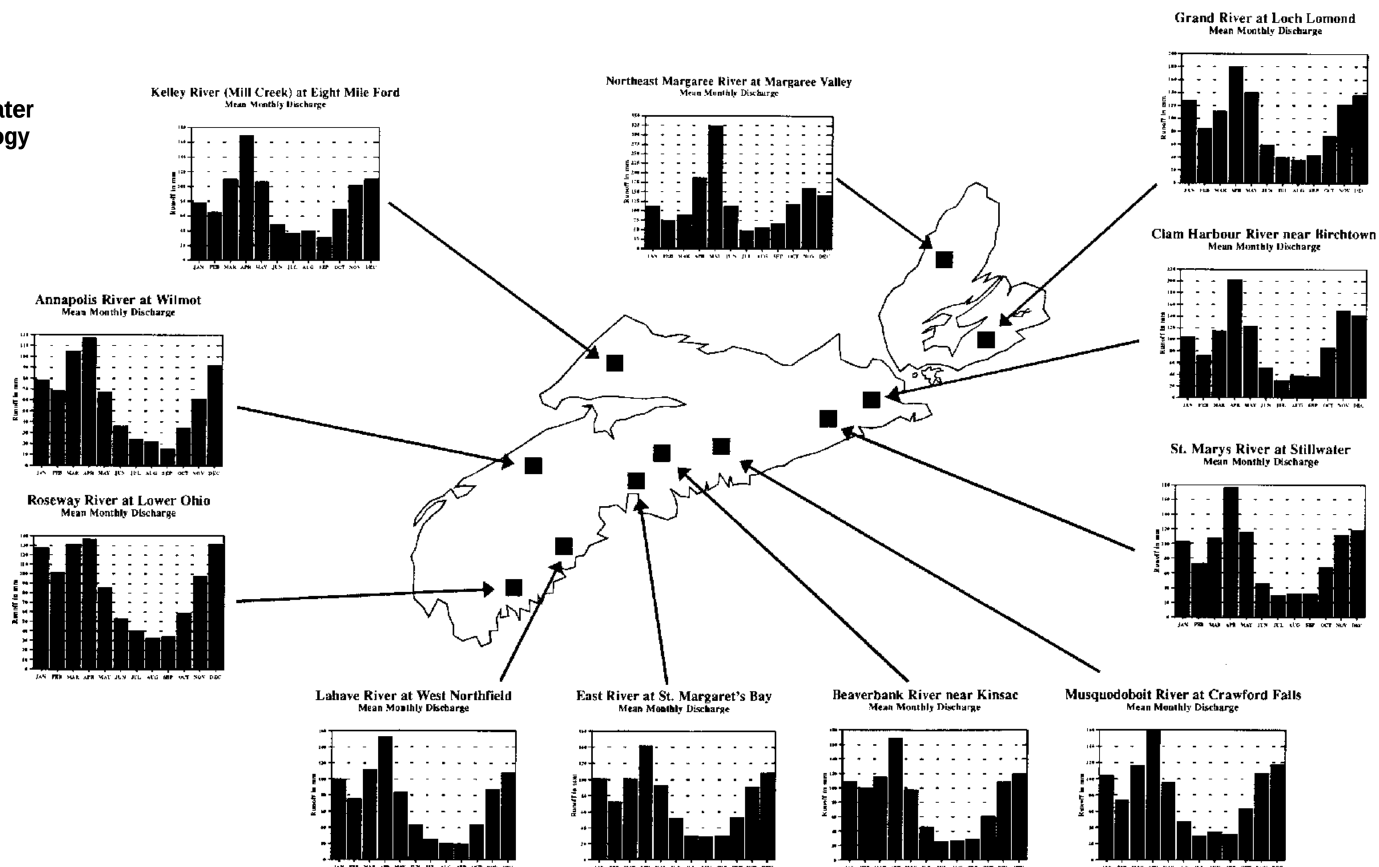

Figure T8.1.4: Mean monthly discharge pattern at selected monitoring sites.[5]

However, spring seepage from groundwater sources ensures a more constant flow of cooler water throughout the year.

The response of stream flow to precipitation controls the interaction between water, soils and bedrock, thus influencing chemical composition. Topography influences the collection of mineral sediments and the accumulation of peat deposits in and around lakes.

Streamflow data is usually obtained by measuring the velocity of flowing water with a current meter. The cross-sectional area of the stream multiplied by its velocity yields the flow rate or amount of discharge.

Records of streamflow have been collected in Nova Scotia since 1915. At present, a network of gauging stations operates throughout the province under the direction of a joint federal/provincial program. These stations provide continuous data allowing for the determination of mean and extreme discharge for natural and regulated flow. The network is maintained by Environment Canada, and updated information is available as computer data or in hard-copy format. Historical data are available from the *Historical Steamflow Summary* and the Surface Water Data Reference Index.

GROUNDWATER PROCESSES (SUBSURFACE FLOW)

Underground water flows both vertically and horizontally. Earth materials below the land surface can be divided into two zones: the upper, unsaturated zone and the underlying saturated zone[6] (see Figure T8.1.5). When saturation level is reached in the upper-soil-water belt, gravity pulls the water down vertically through the unsaturated zone until it hits the water table. On the way, water passes through an intermediate zone which contains variable amounts of water in the soil openings. In dry periods, the capillary action may draw the moisture back to the upper layer. If enough water is present, it passes through the intermediate zone to the saturation zone. The water table is the upper boundary of this zone and it can vary in depth seasonally. The water which fills all of the pores in this zone is the groundwater. Groundwater can flow horizontally through the medium depending again on gravity as the driving force.

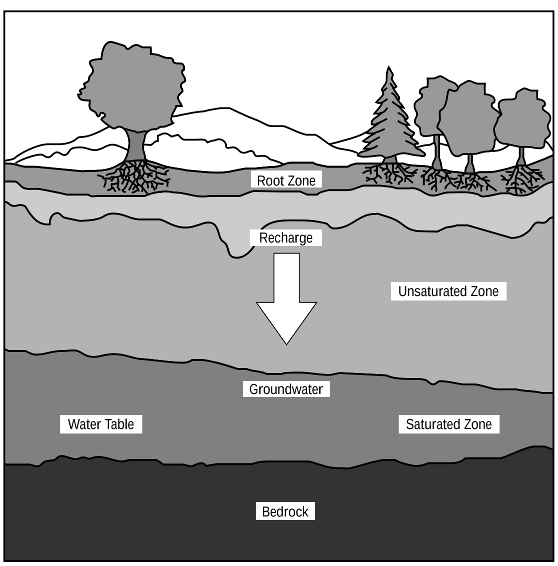

Figure T8.1.5: Groundwater originates from recharge, which is water percolating downward through the soil.

The province has initiated a number of regional-groundwater studies since 1964. These were begun by the Department of Mines, but later carried out by the Department of the Environment. Qualitative and quantitative groundwater data were collected from a number of test wells constructed for these projects.[8] Areas surveyed include the Annapolis–Cornwallis Valley (District 610);[9] the Musquodoboit River valley (unit 511a);[10] the Truro area (District 610);[11] Pictou County (Regions 300 and 500);[12] Cumberland County (Districts 520 and 580);[13] the Windsor –Hantsport–Walton area (Unit 511a);[14] southwestern Nova Scotia (Region 400);[15] the Sydney Coalfields (Unit 531);[16] and Sable Island (District 890).[17]

The Nova Scotia Department of the Environment maintains a groundwater-observation-well network. This currently consists of thirty-six stations across the province, some of which have been monitoring groundwater levels since 1965.

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Associated Topics

T3.2 Ancient Drainage Patterns, T5.1 The Dynamics of Nova Scotia's Climate, T5.2 Nova Scotia's Climate, T6.1 Ocean Currents, T6.2 Oceanic Environments, T8.2 Freshwater Environments, T8.3 Freshwater Wetlands, T11.5 Freshwater Wetland Birds and Waterfowl, T11.13 Freshwater Fishes, T11.15 Amphibians and Reptiles, T11.16 Land and Freshwater Invertebrates, T12.8 Fresh Water and Resources

Associated Habitats
H3 Freshwater, H4 Freshwater Wetlands

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T8.2 FRESHWATER ENVIRONMENTS

Surface fresh water can be described according to two distinct categories: lentic (standing water) and lotic (running water). Lentic environments include surface waters, such as lakes, ponds and wetlands. Lotic environments comprise rivers or streams. Freshwater environments also occur as continuously moving groundwater which has percolated through the upper layer of soil to underground storage areas (aquifers). Groundwater can naturally reach above ground as a spring.

This Topic deals with surface and underground aquatic freshwater environments. Wetlands are discussed in T8.3.

SURFACE WATER

Lakes and ponds are formed where an interruption of the drainage pattern, either by the formation of a basin or by a barrier, restricts the flow of water. Water in surface channels forms the rivers and streams which ultimately discharge into the ocean.

Ecology of Surface Water

Both lentic and lotic environments support diverse biotic communities or groups of organisms living in a given area. The interaction of a biotic community with the abiotic environment forms the basis of an ecosystem.

Lake ecosystems are dominated by autotrophic organisms (i.e., self-nourishing organisms with the ability to produce organic material from simple chemical compounds and sunlight) and are dominated by phytoplankton, periphyton and aquatic plants. Lakes can also receive nutrients from outside sources and may include meteorological, geological or biological inputs to the system.[1]

River ecosystems are dominated by heterotrophic organisms (i.e., those requiring organic material or food from other sources) and are characterized by input of detritus from terrestrial sources. Larger systems which are exposed to sunlight can have autotrophic components. Primary production from algae and rooted plants then becomes an important energy source.

Water Coverage

Approximately 5 per cent of the land area of Nova Scotia is covered by fresh water in the form of lakes, rivers and wetlands, representing a total of 2408 km^2. There are 6674 lakes in the province which are greater than one hectare in surface area, with a mean surface area estimated at 34 hectares.[2] Water coverage is not

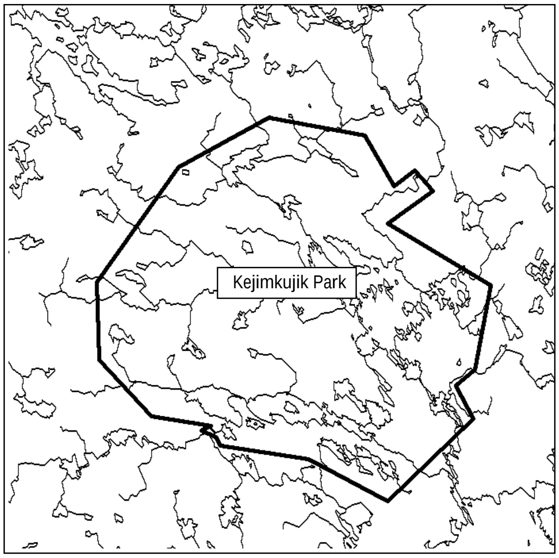

Figure T8.2.1a: Abundant surface water in the granite and quarzite areas of southwestern Nova Scotia (Region 400).

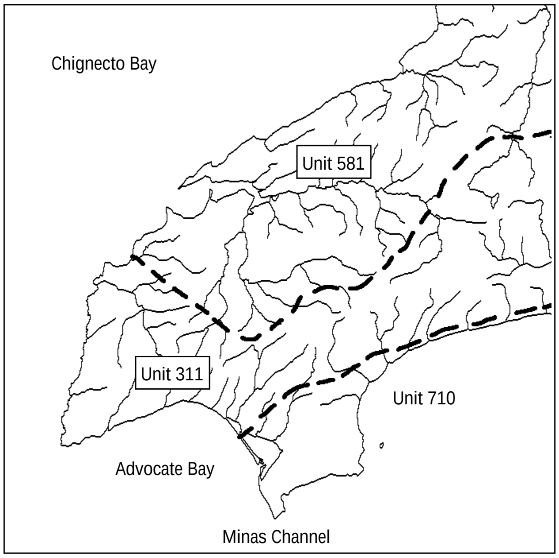

Figure T8.2.1b: Surface water coverage of the permeable rocks of the Chignecto Peninsula where lakes are scarce.

Plate T8.2.1: Mavilette, Digby County (District 820). A small stream flowing through lowlands, showing meander and tidal marsh development. Photo: LRIS

evenly distributed throughout the province, as the southwestern section has many more lakes than the northern portion. In general, surface water is more abundant on the granite and quartzites of the Atlantic Interior (Region 400) than on the more permeable sedimentary formations in the Carboniferous and Triassic lowlands (Regions 500 and 600) and basalt formations of the Bay of Fundy (Region 700) (see Figure T8.2.1a and b).

Table T8.1.1 in Freshwater Hydrology indicates the amount of water coverage per primary watershed across the province. In some watersheds the freshwater coverage has been substantially increased by the construction of dams.

LAKES

Origin of Lakes

The majority of lakes in the province are of glacial origin and are generally aligned with the direction of the ice movement. The lakes of Nova Scotia may be categorized by their origin as follows:

- *Glacial Lakes*—formed either as a basin scoured out by ice movement or by the interruption of the original drainage by the deposition of glacial till.
- *Oxbow Lakes*—formed when river meanders are cut off from the main channel, examples can be found in the Stewiacke Valley (District 510).
- *Levee Lakes*—formed when river sediments

deposited during periods of high water cause a separate waterbody to be formed.

- *Solution Lakes*—formed from dissolving materials such as salt, limestone and gypsum. These lakes can be alkaline and have a higher salt content than most other lakes and occur particularly in the Windsor (Sub-Unit 511a) and Margaree (Unit 591) areas. Gypsum sinkholes found in karst topography may contain solution lakes (see T3.4).
- *Barrier or Barachois Lakes*—these are created mainly behind sand or gravel bars in coastal areas and have higher salinity than fresh water. This brackish water condition either is due to tidal flow or is the result of salt spray. Prime examples are found between Gabarus and Fourchu Harbour on Cape Breton Island (District 870).
- *Beaver Ponds*—these are constructed and maintained by beavers but are regularly abandoned if and when the local food supply (i.e., poplar, willow, birch and alder) within reach of the water is exhausted. Some persist for years; others is only used during the winter (see Plate T11.11.1).

Human-made Lakes

- *Dammed reservoirs*—created principally to regulate water flow for lumbering, flood control, municipal water supplies or power generation and usually contain substantial quantities of coarse to fine woody debris. Lake Rossignol, in Sub-Unit 412a, is a good example of this occurrence. Waterfowl impoundments can increase the area of open water in marshes such as those found in the Tantramar Marsh area near Amherst (Unit 523).
- *Excavated lakes*—formed through quarrying and other related activities for example in the gravel quarries at North River near Truro.

Classification of Lakes

Lakes may be classified according to their trophic status (i.e., their available phosphate content and biological productivity):

- *Oligotrophic Lakes*—those with low phosphate concentrations and resulting low productivity
- *Mesotrophic Lakes*—those with moderate phosphate concentrations and resulting moderate productivity
- *Eutrophic Lakes*—those with high phosphate concentrations and resulting high productivity

Highly coloured, low pH lakes resulting from high humic concentrations are termed dystrophic. These lakes can have nutrient concentrations and productivity within the trophic states defined above.

Both clearwater and highly coloured (brownwater) lakes exist in Nova Scotia; however, the latter predominate. Most lakes in the province are oligotrophic, although some have become eutrophic due to the impacts from agricultural runoff, domestic sewage and other human activities. Eutrophication is the natural process of lake "aging," whereby a lake shows a gradual increase in nutrient concentrations and productivity, slowly infilling with accumulated organic material. In extreme cases, the decay of the plant biomass can remove oxygen to the detriment of the other organisms. Hydrogen sulphide and other gas production can cause unpleasant odours. The process can be greatly accelerated by human activities and is known as cultural eutrophication.

Succession and Zonation

In geological terms, lakes in Nova Scotia are only temporary features on the landscape, generally infilling to become wetlands, such as peat bogs. This is the primary or initial successional stage which may lead to the development of an organic mat within a wetland system.[3] Peatlands in Nova Scotia were formed in this manner. In some systems (e.g., marshes), the deposition is primarily comprised of mineral sediments. Refer to T8.3 for continued discussion on wetlands and succession.

Typically, lakes have three distinct zones: the littoral or lake edge (hydrosere), the limnetic or surface water, and the profundal or deep water (see Figure T8.2.2). In deep-water lakes, the water column can

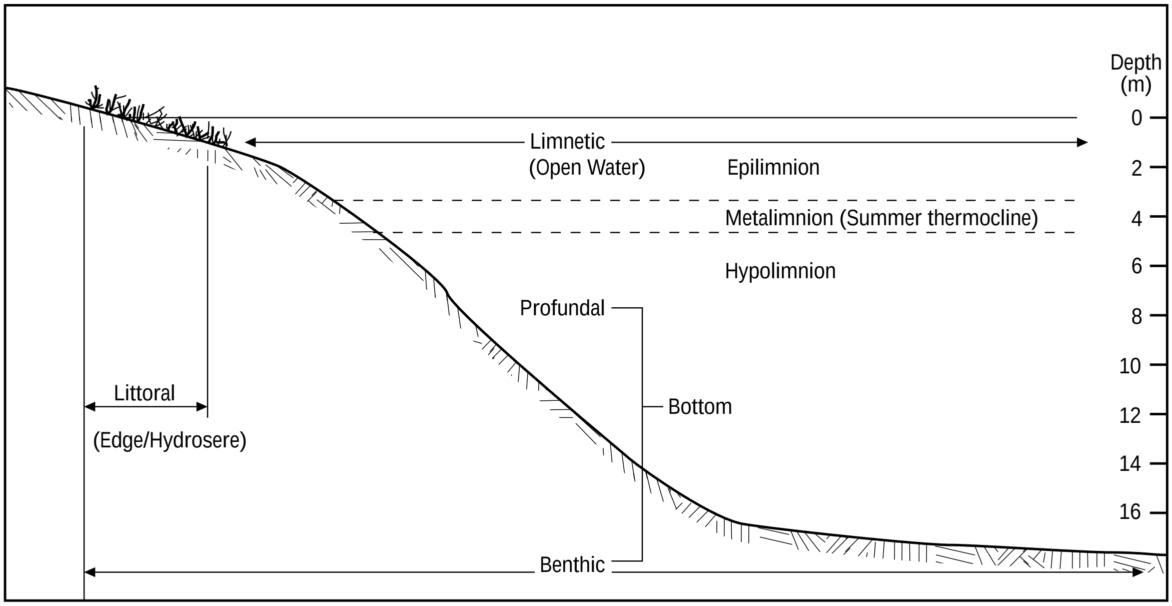

Figure T8.2.2: Ecological features of a large lake, seen in diagramatic cross section.

also be divided into three zones: the surface water or epilimnion, the bottom water or hypolimnion, and the area of transition in between called the metalimnion. Thermal stratification can occur where the surficial zone becomes much warmer than the profundal zone during the summer, due to atmospheric warming of surface waters and lack of mixing. This creates an area with a steep temperature gradient between the two zones, called the thermocline. When these conditions exist, the surface waters cannot readily mix with the bottom layer and thus the lake bottom may become oxygen deficient. Larger lakes with deeper waters are more likely to stratify. Even though Nova Scotia's lakes are relatively shallow, approximately half of them can exhibit thermal stratification. A list of some of the larger lakes in the province is provided in Table T8.2.1.

RIVERS

Origin of Streams

Streams originate in headwater areas as outlets of ponds or lakes, or arise from springs and seepage areas. As the water drains away from its source, it travels in a direction determined by the slope of the land and the underlying rock formations. Water associated with a steep gradient carries with it a load of debris and continues to cut the channel until the material is eventually deposited within or along the stream.

Close to its source, a stream may be straight and fast flowing, with many rapids. As the water reaches more-level land, its velocity is greatly reduced and the sediment it carries is deposited as silt, sand or mud.[4] At this stage, a river is referred to as mature, with meanders which form in large and small loops as the channel erodes its floodplain (e.g., Meander River in Sub-Unit 511a). Meanders sometimes become so exaggerated that they cut off from the main river channel to form oxbow lakes (see Figure T8.2.3).

The rejuvenation of a river sometimes occurs when the it encounters a geological obstacle pro-

LAKE	SURFACE AREA (km^2)
Bras d'Or (salt water)	1100
Rossignol*	168
Ainslie	56
Mira River	32
Kejimkujik	23
Gaspereau*	22
Grand	18
Panuke	15
Pockwock*	8
Sherbrooke	6
*enlarged by impoundments	

Table T8.2.1: Some large lakes in Nova Scotia.

ducing a waterfall or fast-flowing rapids. Thus, the mature stream then regains some of the characteristics of a young stream. Rejuvenated streams are characteristic of much of the Atlantic Coast (Region 800). Rejuvenation can also occur in response to climate changes (including sea-level change), tectonic events and human activities.

The Musquodoboit River is a classic example of a mature river reverting to a fast-moving stream. The river meanders slowly through the softer sedimentary rocks of the Windsor Lowlands (Sub-Unit 511a) and gains momentum again as it cuts through the more resistant Meguma rocks of the Granite Ridge (Unit 453).

Classification of Rivers

River or stream systems can be extensive and are an important feature of the landscape. A system generally consists of a number of tributaries that join together to form the main drainage channel. Each stream can be classified according to stream order, which determines the position of the stream in the hierarchy of tributaries. First-order streams have no tributaries and when two meet they become second-order streams. Higher-order streams can be fed by tributaries from any number of lower orders.[5]

Floodplains

In times of flood, the material carried by streams is deposited on the land adjacent to the stream banks, which is commonly called the floodplain. These floodplain areas, often referred to as intervales, are utilized by the stream during times of high water and can help reduce water velocity. As a result, the loss of river habitats is minimized. Floodplains also provide important habitat for a variety of plants and animals known as intervale species (see Sugar Maple, Elm (Floodplain) Forest in H6.1 .

Floodplains generally contain rich alluvial soils and tend to have been settled extensively. Problems associated with development on floodplains initiated a joint federal/provincial mapping program to identify flood-risk areas in Nova Scotia (see T12.8). The Flood Damage Reduction Program defines a flood-risk area as land which is subject to severe flooding on the average once in 100 years (or there is a 1 per cent chance of being flooded in any given year to a particular elevation—i.e., the 100-year elevation). A smaller area, known as the designated floodway, is the part of the floodplain subject to more frequent flooding. In this zone, flooding occurs on average once every 20 years (or there is a 5 per cent chance of being flooded in a given year to the 20-year elevation). The designated floodway fringe lies between the floodway and the outer limit of the flood-risk area. Within this fringe area, any new building or alteration of an existing building requires appropriate flood-proofing measures if it is to receive federal or provincial assistance.[6,7] From a biological perspective, defining flood-plain areas by the frequency of flooding is very important. Plant and animal species and communities are adapted to flooding regimes.

Comprehensive studies have been conducted for a number of floodplain areas throughout the province between 1984 and 1989. These include the

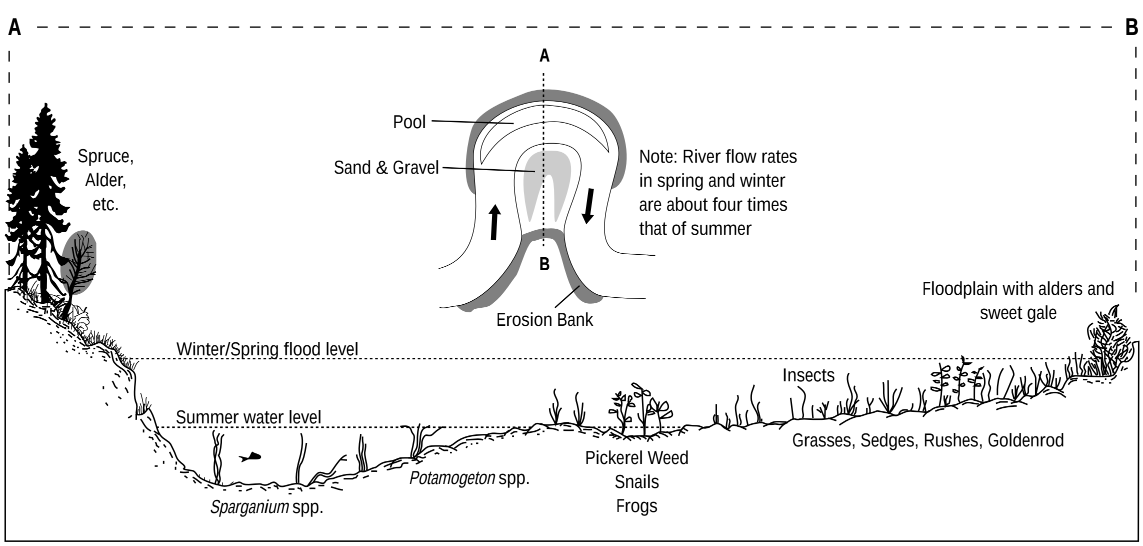

Figure T8.2.3: Physical and ecological features of a meander of a mature river.

Sackville River and the Little Sackville River (Sub-Units 413a and 436a), East River (Pictou in Units 521a and 582a), Antigonish-area rivers (Units 521b and 583a) and the Truro-area rivers (District 620).

Estuaries

An estuary is that area where the river enters the sea. The runoff of a river into an estuary produces a distinct circulation pattern where the flow of fresh water over the top of the salt water causes nutrient-rich bottom water to be drawn into the estuary and upwelled to the surface. For this reason, estuaries are particularly productive. The strongest influences occur at times of heaviest runoff, usually in the spring. A more detailed description of estuaries can be found in T6.4.

SURFACE-WATER QUALITY

Water quality is influenced by the interaction of many natural factors, including bedrock composition, watershed size, response to precipitation, topography, vegetation and proximity to the ocean. Cultural influences are also significant (see T12.8). General limnological regions have been delineated on the basis of geology and soils as shown in Figure T8.2.4.[6] The Nova Scotia Department of Environment identifies forty-eight of the fifty-six municipal surface-water supplies as having significant water-quality problems, some natural and some culturally induced.[7] These may include colour, taste, odour, bacterial or metal and organic contamination.

Nature's Pottery

While wading in shallow water of lakes, one may sometimes notice curious cookie-shaped, concentrically ringed rocks lying on the bottom. These unusual stones, known as ferromanganese or manganese nodules, are a naturally occurring phenomenon in lakes with high levels of manganese. The nodules are formed when tiny bacteria, Pseudomonas, *become attached to a rock surface and begin to coat themselves with a thick crust of dark-brown manganese dioxide. The bacteria then become buried in this substance as successive generations build upon each other over hundreds and even thousands of years. Scientific studies of these nodules have revealed some profound effects on the metals in lakes, as the uptake of manganese from the water by these bacteria is up to 100,000 times greater than the natural loss due to "rusting" or chemical oxidation of manganese.*

Bedrock Composition—Conductivity

In areas of resistant granite and metamorphic bedrock, where most lakes in the province are found, waters generally exhibit low levels of conductivity, which implies they are low in dissolved solids. These lakes would have little or no buffering capacity and are very susceptible to acidification. Underwood and Schwartz estimated that 78 per cent of Nova Scotia lakes are underlain by granite or metamorphic bedrock.[10] The conductivity of lakes and streams in Nova Scotia is generally low and shows little variation between or among most localities. However, somewhat higher levels of conductivity characterize the surface waters which drain areas of Carboniferous sandstone and shales in Cumberland County (Region 500). Elevated conductivity is found in areas where sedimentary rocks consist mostly of limestone and gypsum and thus provide a high buffering capacity. In a specific study of 781 lakes in Nova Scotia, the mean conductivity ranged from 26.4 micromhos/cm (µmho/cm = level of dissolved solids) for lakes in Lunenburg County (Region 400) to 655.8 µmhos/cm for those in Cumberland County.[2] The mean conductivity for Nova Scotia was 69.5 µmho/cm.

Bedrock Composition—Productivity

In areas underlain by igneous metamorphic rocks, the water contains low electrolyte levels and lakes are generally oligotrophic. This indicates low levels of dissolved solids, and consequently the amount of primary production in the majority of Nova Scotia lakes is also considered to be low. Most lakes in the province have been classified as relatively unproductive.[11,12] Since the level of primary production is directly related to fish production, this method has been used to determine the biomass of fish that lakes can support.[13]

Surface waters draining the Carboniferous sandstones and shales of Cumberland County have relatively higher levels of conductivity; hence, productivity is considered to be greater. Comparatively strong mineralization and high productive capacity are also found in areas where sedimentary rocks provide a good source of lime, such as in the Triassic Lowlands of the Annapolis Valley (District 610) and in the Carboniferous Lowlands of the Stewiacke River valley (Sub-Unit 511a). In these areas, agricultural activities are often responsible for additional nutrient enrichment.

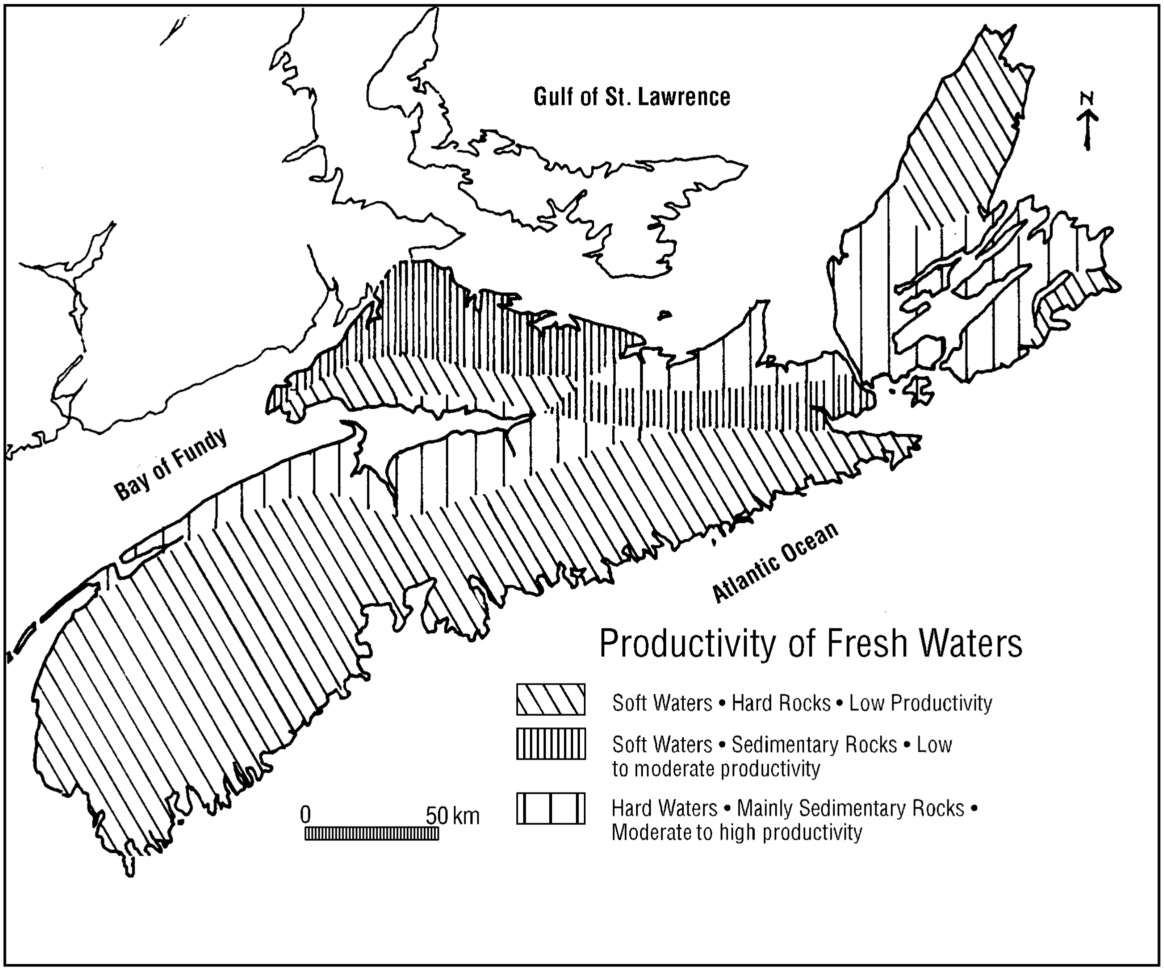

Figure T8.2.4: Productivity of surface fresh waters in Nova Scotia.[8]

Watershed size

The ratio of watershed area to lake size influences the nutrient availability to a large extent and determines the flushing rate. Water bodies with undeveloped watersheds and lower water-renewal rates usually have a low concentration of soluble reactive phosphorous, an important nutrient for plant growth. An increase in phosphorous from human activities within the watershed could lead to eutrophication and reduce water quality.

Precipitation

Precipitation influences the rate of runoff, which controls the interaction between water, soils and bedrock, thus influencing chemical composition. Seasonal variations in precipitation, combined with the saturation of the ground, determines the quantity of runoff. During times of high discharge, the amount of dissolved solids entering the watercourse will be much greater than in times of low water. When certain rock formations are exposed to surface water, serious water-quality problems can occur. A prime example of this is the arsenopyrite slate which is found near Halifax and in other areas underlain by Meguma-bedrock formations. Highly acidic runoff is produced when this type of bedrock is exposed to air and water. The interaction between pyrites, water and oxygen produces sulfuric acid, which can lead to fish kills. Acid precipitation can also influence surface-water quality (see T12.8).

Topography

Topography contributes to the rate of flow in streams and rivers and to the width of the floodplain, thus influencing the collection of mineral sediments and the accumulation of peat deposits in the vicinity of lakes. Where the land surface is relatively flat, sedimentation rates are quite high. The topography of an area also determines the shape and size of lakes, whether they are big or small, deep or shallow, round or irregular. Shallow lakes with irregular shorelines can provide more favourable conditions for rooted

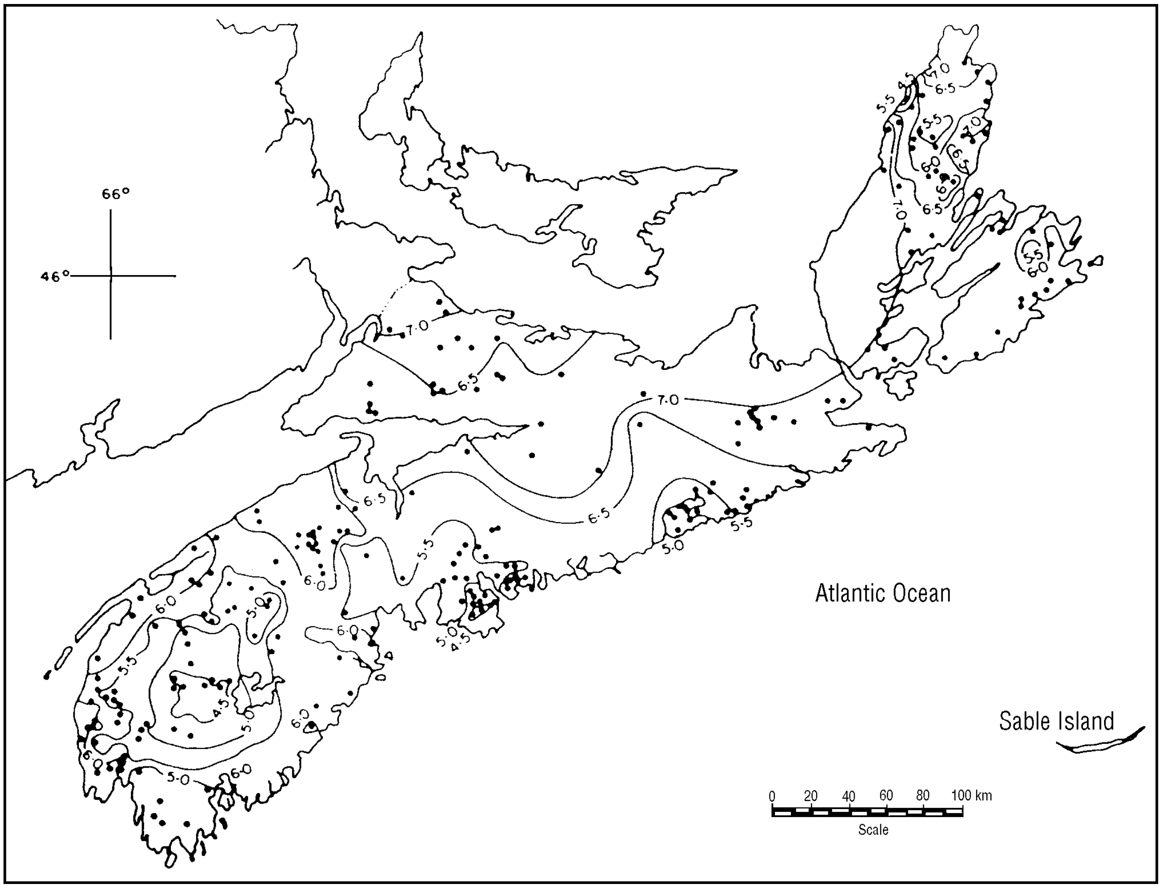

Figure T8.2.5: pH values for Nova Scotia.[18]

plants than large, deep lakes, resulting in more productive waters.

Vegetation

Coniferous needles can contribute to the organic-acid content of aquatic habitats. They are resistant to decomposition and add few primary nutrients, unlike deciduous litter, which releases nutrients more readily and is an important food source for aquatic animals.

Salinity

The salinity of lakes can be attributed both to the ocean and to land-based salt sources, including road salt. Proximity to the ocean often results in high chloride concentrations from sea spray being carried by precipitation to nearby lakes. Since lakes in Nova Scotia are no more than 50 km from the ocean, many reflect a marine influence.[14] There is a direct relationship between increased freshwater chloride concentrations and proximity to the coast.[15]

Meromictic lakes (i.e., lakes exhibiting incomplete mixing) may become permanently stratified by the intrusion of saline water or salts liberated from sediments, creating a density difference between surface and bottom layers.[2] Examples include Park Lake in Cumberland County (Sub-Unit 521b), where the meromictic conditions are attributed to the gypsum and salt deposits in the area; Layton Lake in Amherst Point Game Sanctuary (Unit 521a), where conditions are attributed to past inundations by the sea.[16]

Acidity

Surface-water acidity or pH is a measure of the mineral nutrients and organic acids present. Distilled water is neutral (i.e., 7.0); however, most surface water in Nova Scotia is higher or lower, depending on the relative contributions from humic materials, acidic precipitation and runoff, as well as the buffering capacity of the bedrock and soils. In areas containing high concentrations of limestone, the presence of calcium carbonate in association with magnesium strongly influences the buffering capacity and solubility and hence moderates the acidity of the water. Low pH values have been shown to affect reproduction of aquatic biota as well as lowering species diversity.[17] The mean pH

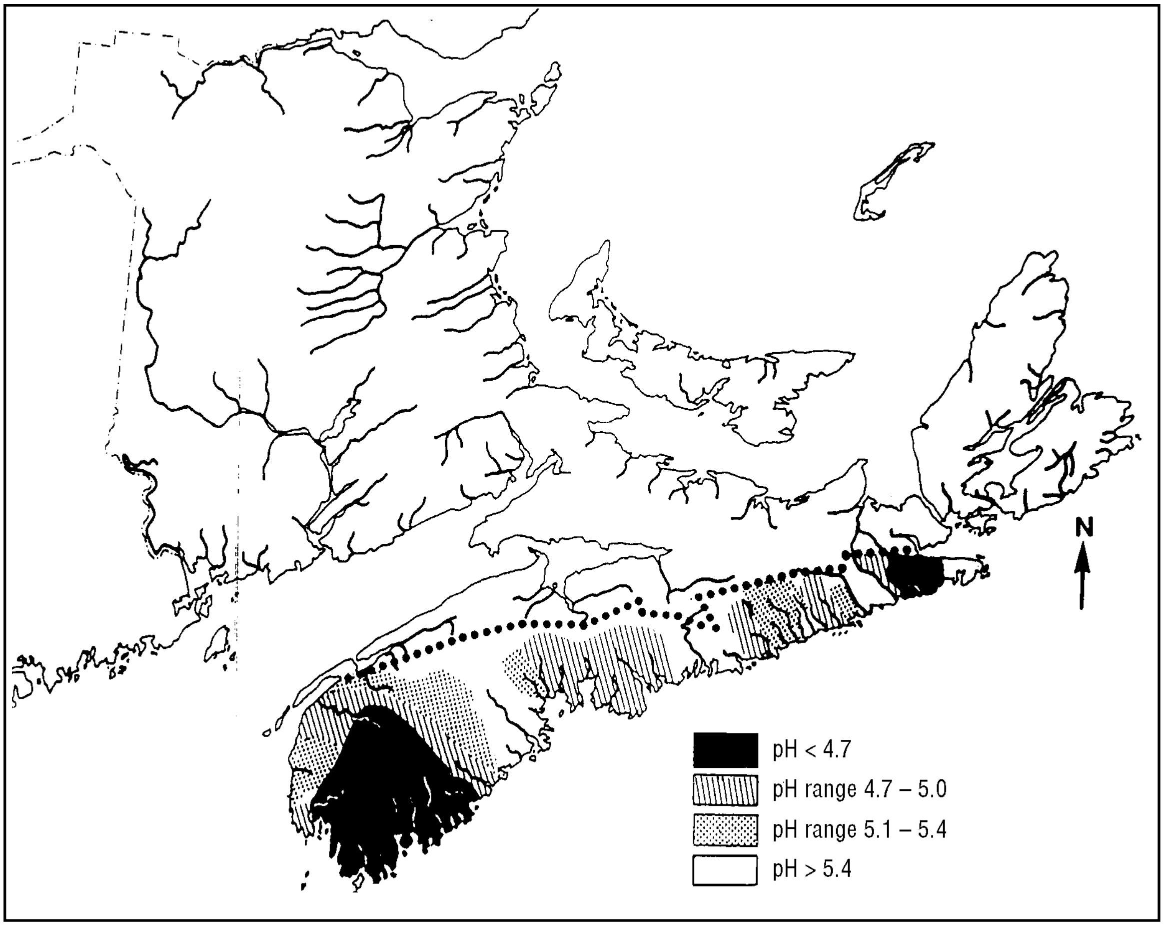

Figure T8.2.6: Surface-water surveys (1975–85 data) show that the mean annual pH of Atlantic Salmon rivers in the Maritime provinces are above 5.4 (considered the danger threshold for salmon), except in Nova Scotia's Southern Upland, which lies south of the dotted line.

of lakes surveyed in a 1987 study ranged from 5.5 in Shelburne County to 7.4 in Inverness County. The average pH in Nova Scotia was 6.2.[18] Figure T8.2.5 shows the distribution of pH values throughout the province.

In Nova Scotia, low pH values (i.e., less than 5.1) are usually associated with bogs and dystrophic waters, as well as areas receiving high levels of acid precipitation or acidic runoff from freshly exposed pyritic slate formations. The southwestern mainland, parts of the Eastern Shore and the highlands of Cape Breton are considered the most sensitive to the effects of acid rain.[19] Low pH levels have affected fisheries, especially salmonids, in several southwestern Nova Scotia rivers.[20,21] A relationship has also been established between sulphate concentrations in lakes and proximity to the urban centres[18] (see T12.8).

Environment Canada has conducted extensive research into the effects of long-range transportation of air pollutants (LRTP) in the vicinity of Kejimkujik National Park.[22] Figure T8.2.6 indicates the mean annual pH values for the most severely acidified rivers of the province.

GROUNDWATER

Groundwater is defined as subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.[23] Most groundwater is precipitation that has infiltrated through the upper layers of soil into underground storage areas. It exists nearly everywhere, although quantity, quality and depth can vary according to the type of rock and strata. Groundwater fills the pores or openings between rock particles or the cracks in consolidated rock. Sediment or sedimentary rock is generally permeable where the pores are connected and water can be transmitted. Groundwater moves much more slowly than surface water but can travel great distances, depending on the topography and the geology, and ultimately emerge at the surface again. In Nova Scotia, however, most flow paths are relatively short, mostly due to geological obstructions. The

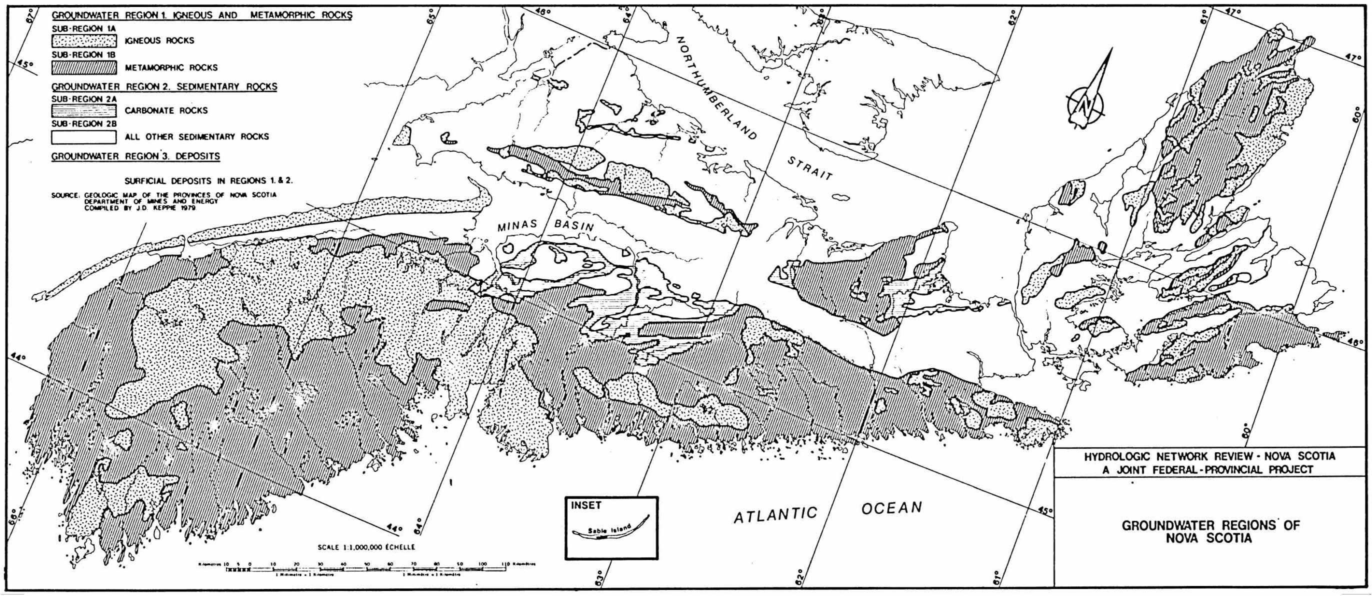

Figure T8.2.7: Groundwater Regions: Nova Scotia has been divided into three groundwater regions. These regions are based on the possibility of conditions, in various bedrock and surficial aquifers, for the occurrence of groundwater[16]. They are briefly described as follows:

Groundwater Region 1: Igneous and Metamorphic Rocks.
Groundwater Sub-region IA: Plutonic Igneous Rocks.
Groundwater Sub-region IB: Metamorphic Rocks.
Groundwater is available in these rock types through fractures and joints, and along fault and contact zones. All have similar characteristics in their abilities to store and transmit water.

Groundwater Region 2: Sedimentary Rocks
Groundwater Sub-region 2A: Carbonate Rocks
The porosity and permeability of carbonate rocks can vary greatly, ranging from situations where the rock is only slightly fractured to conditions where extensive fracturing has occurred. In areas which have carbonate rocks at the surface, enlarged pore spaces in the rocks provide easy movement for contaminants and very little treatment by natural filtration. This results in the aquifers being vulnerable to any sources of pollution.

Groundwater Region 3: Deposits
Most of Nova Scotia is covered by glacial deposits which occurred during the ice ages and range in thickness up to 30 m in some locations. Some of this material was also transported by meltwaters from glacial retreats. The end result is a wide variety of moraines and eskers, as well as glacial and fluvial outwash found throughout the province. Appreciable depths of overburden can affect the occurrence of groundwater.

volume of groundwater is often much greater than surface water.

Nova Scotia has been divided into three groundwater regions based on the occurence of groundwater in relation to various bedrock or surficial aquifers[24] (see Figure T8.2.7).

AQUIFERS

Soil or rock strata that contain sufficient saturated material to yield usable quantities of groundwater for wells are called aquifers (see Figure T8.1.1 Freshwater Hydrology). These saturation zones may be of two types: unconfined or confined. An unconfined aquifer is comprised of porous materials such as sand and gravel. A confined aquifer is a layer of water-bearing material confined within two layers of less pervious material, like clay and shale. The size of aquifers can vary greatly according to the type of strata. There may also be several small aquifers in an area, separated by a layer of less-permeable rock .

A large part of Nova Scotia is dominated by bedrock at or near the surface and most aquifers occur in fractures. Some larger aquifers occur in gypsum or sandstone and in overlying surficial deposits. Extensive aquifers are found in sand and gravel deposits and in the Triassic Wolfville sandstones of the Annapolis Valley (District 610)[25] and in the Carboniferous formations in the Margaree Valley (Unit 591). Large aquifers also occur in other parts of Region 500, in particular in the gypsum areas of Colchester and Cumberland counties and in parts of Cape Breton.

Water Table

The water table is the boundary between the upper, unsaturated zone, in which the pores are empty or only partially filled with water, and the underlying, saturated zone, in which the pores are full of water. In most cases the water table is not flat but generally follows the relief of the local topography. In Nova Scotia, there is relatively little topographic variation, and the water table is close to the surface.

The water table explains the changes in the flow of springs and streams and water-level fluctuations in lakes. It is also an important factor in determining the productivity of wells (see T12.10). In Nova Scotia, wells are typically artesian and occur when the water level in the well rises above the upper boundary of the aquifer. An artesian system requires a confined aquifer with impermeable layers above and below and hydrostatic pressure created by a higher elevation of the water elsewhere in the aquifer. Some artesian wells can flow constantly and must be capped in order not to waste water from the aquifer.

A perched water table is a special condition where an unconfined aquifer is situated at some height above the main groundwater body and usually occurs after periods of heavy rain or spring thaw. This phenomenon most commonly occurs along the side of a valley.[26] Wells tapping perched water tables yield only temporary or small quantities of water.

GROUNDWATER QUALITY

Groundwater quality depends on the geochemical composition of the strata through which it moves and the length of contact time. Minerals dissolving from the bedrock may contribute to taste, colour, acidity and hardness. Hard water is caused by high levels of dissolved ions, particularly calcium and magnesium, which affect the lathering of soap and leave scaly deposits. Soft water is low in dissolved ions and is more prone to acidification.

Groundwater is less vulnerable to airborne pollutants than surface water; however, natural deposits such as uranium and arsenic can cause serious health problems. High concentrations of naturally occurring iron and manganese in groundwater are widespread across the province but are not considered to be a health risk. Of the twenty-five major municipal groundwater supplies located throughout the province, nineteen have some identifiable water-quality problems, including colour, taste, odour, bacterial or metal contamination. Arsenic pollution and sulphide mineralization are associated with mines, because the geology that produces gold also tends to produce arsenic from the arsenopyrite in gold veins.[27,28,29]

Poor-quality groundwater is associated with karst topography in the Windsor area (Unit 511a). Karst develops where carbonate rocks such as limestone are dissolved, often resulting in sinkholes and underground cave networks (see T3.4). Groundwater in these areas is very high in dissolved minerals.

Soil acts as a natural groundwater filter; however, in many areas of the province the thin till cover combines with a shallow water table and reduces the filtration capacity. These areas are susceptible to groundwater contamination from human activities such as landfilling, septic fields and road salting.

Salts and minerals can also be present in groundwater inland. There are several references to brine springs in a report by A.O. Hayes in 1920.[30] The author describes the chemical contents of salt springs located in St. Patrick's Channel (District 560, Unit 916), Antigonish (Sub-Unit 521b) and Avondale (Unit 521a) among others. (The locations of these springs have not been recently verified.) It is suspected that some plant species associated with salt springs are similar to species found on tidal marshes. Roland [31] reports both Glasswort and Sea-blite growing around salt springs.

The waters of Spa Springs (District 610) were reputed to possess healing properties which attracted many eighteenth-century visitors to that area. Today the community is renowned for its bottled mineral water. The major dissolved mineral in the groundwater is gypsum which is attributed to the gypsum, lenses found in the late Triassic siltstones and shales of the Blomidon Formation.[7,32–34]

Saltwater Intrusion

Saltwater intrusion can occur in coastal areas where wells are constructed close to the ocean. Normally, pressure from the groundwater will restrict sea water to a zone of diffusion where fresh and salt water meet; however, during dry periods, water withdrawn by prolonged well use reduces the seaward pressure and allows the salt water to move underground and thus contaminate the well. This may be prevented if shallower wells are constructed or by reducing the amount of pumping during dry seasons.

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Associated Topics

T2.1-T2.7 Geology, T3.2 Ancient Drainage Patterns, T3.4 Terrestrial Glacial Deposits and Landscape Features, T5.2 Nova Scotia's Climate, T6.4 Estuaries, T8.1 Freshwater Hydrology, T9.1 Soil-forming Factors, T10.5 Seed-bearing Plants, T11.5 Freshwater Wetland Birds and Waterfowl, T11.11 Small Mammals, T11.13 Freshwater Fishes, T11.15 Amphibians and Reptiles, T11.16 Land and Fresh Water Invertebrates, T12.8 Freshwater and Resources, T12.11 Animals and Resources

Associated Habitats

H2.5 Tidal Marsh, H3 Freshwater, H4 Freshwater Wetlands, H6.1 Hardwood Forest

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T8.3 FRESHWATER WETLANDS

Wetlands are all surface areas of land that are saturated with water for at least part of the year. They are characterized by poorly drained soils, hydrophytic vegetation and biological activity adapted to wet environments. Wetlands occupy the transitional zone on the landscape between the aquatic and upland areas and exhibit some properties of each.

The development of a wetland depends upon the climate, the surface configuration of the land, the type of bedrock and soil (mineral or organic), the degree of inundation or flooding and the nutrient status of the water supply that feeds it. Marshes are wetlands dominated by emergent aquatic vegetation such as grasses, sedges and rushes. Wetlands dominated by wooded vegetation are swamps.

The majority of wetlands in Nova Scotia are peatlands—wetlands characterized by an accumulation of peat. Those that are dependent on precipitation for moisture and nutrients are ombrotrophic bogs and are dominated by sphagnum mosses. Peatlands fed by water moving through mineral soil and dominated by sedges are known as fens.

Wetlands usually occur in areas containing a high water table or where surface-water flow becomes obstructed. A lake or pond becomes slowly infilled with organic and inorganic sediments and is then invaded by peat-forming vegetation.[1] (A gradual build-up of peat can eventually transform some wetlands into peatlands.) Paludification is the process where bogs expand to cover previously dry land due to a gradual rising of the water table. Another process known as primary peat production can take place where peat-forming plants establish themselves on moist but not waterlogged soils.[2] This is most often characteristic in areas with high rainfall and low evaporation, such as in southwestern Nova Scotia (Region 400) or the Cape Breton highlands (Region 200).

Peat is the partially decomposed remains of plants which have been accumulating in Nova Scotia since the last glacial period at an approximate rate of 0.5 mm per year. This is the source of the peat moss that we use as a soil conditioner in gardening.

Wetlands can also be artificially created either indirectly by construction projects, such as hydroelectric dams, or directly by the building of impoundments for wildlife habitat (see T12.8).

ECOLOGICAL FUNCTIONS

Wetlands are environmentally important for a number of reasons: they provide natural filtration and storage of water (water recharge); they aid in flood reduction and control, acting like a sponge for releasing water in dry seasons or retarding surface flow, thus slowing down the rate of overland flow to streams; they are a natural storage base for carbon by absorbing carbon in the form of peat; they are a natural sink for pollutants; they assist in stabilizing shorelines and riverbanks, thus reducing erosion; and they provide wildlife habitat for plants and animals, including some rare and endangered species, such as the Thread-leaved Sundew and the Four-toed Salamander (see T10.12 and T11.18).

WETLAND CLASSIFICATION

A number of wetland classification systems have been devised in order to group wetland types into units that can be defined and characterized, primarily for management and conservation purposes. Surveys can then be conducted and inventories compiled which provide important information on the size and distribution of wetlands, as well as their resource values.

Wetlands Inventory

An extensive wetlands inventory has been carried out by the Nova Scotia Department of Natural Resources, with the Canadian Wildlife Service, for the whole province. Wetlands are classified according to the dominant vegetative type and the depth and permanence of surface water and are scored according to their wildlife value.[3] The eight wetland categories are: bog, shrub swamp, wooded swamp, deep marsh, shallow marsh, meadows, seasonally flooded flats, and open water. All wetlands of 0.25 hectares or greater in Nova Scotia are included in the inventory and compiled into a data base. Wetlands scoring 65.0 or higher have been identified in the *Atlas of Important Freshwater Wetlands and Coastal Wildlife Habitats*.[4]

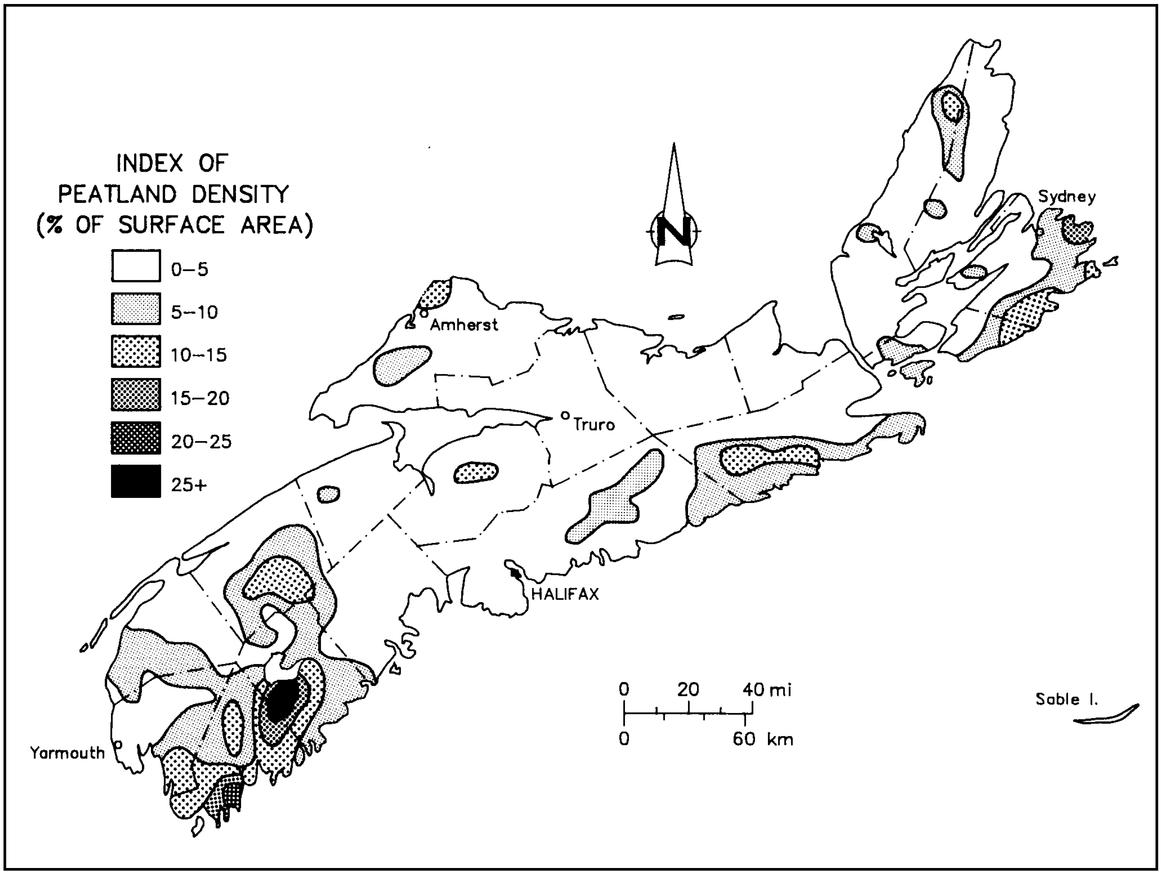

Figure T8.3.1: Peatland density of Nova Scotia.[5]

Peatlands Inventory

The Nova Scotia Peatland Inventory was compiled by the Nova Scotia Department of Natural Resources in response to a need for information on potentially valuable peat resources throughout the province. Peatlands greater than 10 hectares were mapped and each area coded to reflect the dominant peatland form. Information on peat quality, quantity and composition was collected. The inventory has been divided into three main classes: bog (raised, sloping or flat), fen (sloping or flat) and swamp (flat). Figure T8.3.1 shows the distribution of peatlands in Nova Scotia.[5]

Canadian Wetland Classification System

The Canadian Wetland Classification System represents a synthesis at the national level of existing classification systems which have been devised across Canada. It is based on ecological parameters that influence wetlands. It consists of five wetland classes (bog, fen, marsh, swamp and shallow water), which have been further subdivided into two more specific levels: wetland form and wetland type.[6] Within Nova Scotia, two wetland regions (including four subregions) have been identified. These are described in detail in the *Wetlands of Canada*, published by the National Wetlands Working Group.[7]

Other Classification Systems

Another relevant document concerning wetland classification in Nova Scotia assesses wetlands in relation to their landscape context. "A Landscape Approach to the Interpretation, Evaluation and Management of Wetlands"[8] regionalizes wetlands based on the Peatland Areas of Nova Scotia[5] and divides the province into fourteen wetland regions (six of these have been subdivided). The dominating wetland type determines the region. Subregions are delineated based on changes in the amount of landscape covered by wetlands and major differences in geology.

The Natural History of Nova Scotia divides freshwaters into several habitat types. Lakes and ponds are represented by open water-lentic, bottom-lentic and edge-lentic. Rivers and streams are categorized as open water-lotic, bottom lotic and edge-lotic. Peatlands are defined as either bogs or fens. Other wetlands described are swamps and freshwater marshes (see H3 and H4).

The terminology used by the various classification systems is not always consistent. Table H.1 in the Introduction to **Habitats** compares the terms employed in this document with those found in the Nova Scotia Wetland Inventory, the Nova Scotia Peatland Inventory and the Canadian Wetland Classification System.

WATER QUALITY OF WETLANDS

The water quality of wetlands can be affected by inflowing water and runoff, groundwater inflow, precipitation, vegetation and the relative contributions of all these factors.

Wetlands can affect water quality within a watershed in a number of ways. Highly productive freshwater marshes may disperse nutrients to the rest of the drainage system. Conversely, in wetlands with low productivity, such as peatbogs, waters may become more acidified and nutrients absorbed. All wetlands generate dissolved carbon, which increases colour, thus lowering light penetration. They also provide natural organic acids which lower pH levels. This phenomenon is much more pronounced in bogs.

The effects of wetlands on water quality in Nova Scotia are substantial, considering they represent a comparatively small percentage of the total surface area of the province. Wetlands occupy about 5 per cent of the province; however, approximately 50 per cent of lakes and rivers in the region show relatively high colour levels, indicative of natural organic acids (NOA), measured as dissolved organic carbon (DOC) in wetland soils.[9]

Wetlands contain some plants that function as filters and have been used as part of natural waste treatment systems.

ACID RAIN

Acidic precipitation can have a negative impact on some types of wetlands. A wetland-sensitivity rating system has been proposed by Kessel-Taylor in which wetlands are divided into four classes of sensitivity:[10]

1. Low sensitivity (marshes, rich fens and shallow waters): These wetlands possess adequate buffering capacity to neutralize acid precipitation
2. Moderate sensitivity (bogs): Some adverse effects from acid precipitation can be expected on some of the raised hummocks in bog systems however, since most bogs are already acid, acid precipitation would generally have no appreciable effect
3. Moderate to high sensitivity (swamps): In nutrient-poor swamps, buffering capacity is small, due to minor minerotrophic input. A high volume of acid precipitation could not be neutralized and therefore the potential for increased acidification is high
4. High sensitivity (poor fens): characterized by low alkalinity and low mineral input; consequently their buffering capacity is minimal.

A study of sources of sulphate ions and acidity in wetlands and lakes in Nova Scotia revealed that, during the ice-free period, sea-salt-corrected sulphate concentrations were nearly three times higher in the south end of the province than those found in northern areas. This reflects the atmospheric deposition of sulphate.[11]

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Associated Topics

T3.2 Ancient Drainage Patterns, T8.1 Freshwater Hydrology, T8.2 Freshwater Environments, T10.12 Rare and Endangered Plants, T11.5 Freshwater Wetland Birds and Waterfowl, T11.13 Freshwater Fishes, T11.15 Amphibians and Reptiles, T11.16 Land and Freshwater Invertebrates, T11.18 Rare and Endangered Animals

Associated Habitats

H3 Freshwater, H4 Freshwater Wetlands

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Additional Reading

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