province of nova scotia

DEPARTMENT OF MINES

groundwater section report 70-3

HYDROGEOLOGY OF THE MUSQUODOBOIT RIVER VALLEY, NOVA SCOTIA

by

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PREFACE

The Nova Scotia Department of Mines initiated in 1964 an extensive program to evaluate the groundwater resources of the Province of Nova Scotia. This report on the hydrogeology of the Musquodoboit River valley forms part of this broader provincial program.

The field work for this study was commenced in the summer of 1967 by George F. Pinder with preliminary results on the hydrogeology of the lower Musquodoboit River valley published in Groundwater Section report 68-2. Chang L. Lin continued this study during the summers of 1968, 1969 and 1970, part of which formed a doctoral dissertation at the University of Illinois. This comprehensive project on the whole Musquodoboit River valley until 1970 was a joint undertaking between the Canada Department of Regional Economic Expansion (ARDA project No. 22042) and the Province of Nova Scotia. Use of Dalhousie University's IBM/360-50 model computer was secured through the cooperation of the Department of Geology.

It is hoped that the information in this report will be useful for agricultural, municipal and individual water needs and that the report will serve as a guide for the future exploration, development, use and management of the important groundwater resources of the Musquodoboit River valley.

John F. Jones
Chief, Groundwater Section
Nova Scotia Department of Mines

Halifax, January 15, 1971

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HYDROGEOLOGY OF THE MUSQUODOBOIT RIVER VALLEY
NOVA SCOTIA

ABSTRACT

Numerous isolated glaciofluvial deposits covering an area of slightly less than one square mile have been delineated in the Musquodoboit River valley. Two pumping tests conducted on two such deposits located at Elmsvale and Musquodoboit Harbour indicate a high coefficient of transmissibility and an intimate interconnection between the glaciofluvial aquifers and the perennial Musquodoboit River. The quality of water from glaciofluvial deposits is generally good. Along the valley, most of these deposits have not yet been effectively utilized for water supply.

A great number of residents obtain their water supply from shallow dug wells constructed in glacial till. During period of prolonged drought, when the regional water table is lowered, numerous shallow wells often fail to provide an adequate yield for domestic supply. To improve the situation, the permeable sand and gravel deposits should be more fully utilized. Additionally, if the Cretaceous quartz sand deposits in the upper Musquodoboit River valley could be proven to be extensive, their groundwater potential would be a considerable asset to the valley.

The groundwaters from bedrock aquifers such as quartzite, slate, granite and limestone, are limited in quantity. The chemical quality of the water from granite and quartzite is generally good. The water from slate is often deteriorated by excessive concentrations of iron. For practical purpose, waters from rocks of the Windsor Group in the valley are largely unsuitable for domestic and livestock consumption because of the high concentrations of total dissolved solids, total hardness, sulfate, and iron.

An extensive groundwater sampling program was carried out to assist in mapping the gravel and sand deposit at Middle Musquodoboit. The areal extent of the deposit was found to be more restricted than previously thought, especially near the center of the village.

In correlating groundwater chemistry with the local geology, field measurements of the chemical constituents seem to indicate that pH, silica, and total hardness are related to the permeability of the aquifer.

INTRODUCTION

Purpose and Scope of the Investigation

The purpose of this study was to describe the hydrogeology and to evaluate the quality and quantity of the groundwater resources of the Musquodoboit River valley. Test drilling was used to assist in mapping the surficial deposits of the area and to outline promising aquifers. Two pumping tests were carried out on aquifers located at Elmsvale and Musquodoboit Harbour to determine their potential for future use. Selected groundwater samples were collected to provide basic information on the groundwater chemistry of the bedrock and surficial aquifers. Field studies of the chemistry of groundwater in relation to the surficial deposits were carried out at Middle Musquodoboit to provide a better understanding of the surficial geology.

General Description of the Area

Location, Access, and Extent of the Area

The Musquodoboit River valley, situated in Halifax and Colchester Counties, Nova Scotia, is about 35 miles long and eight miles wide, and covers an area of approximately 275 square miles (Fig. 1). The Musquodoboit River valley is readily accessible by road, with route 24 connecting the village of Middle Musquodoboit with highway 2 at Shubenacadie, and with highway 7 at Sheet Harbour, via Upper Musquodoboit. The Musquodoboit Harbour road conveniently joins route 24 at Middle Musquodoboit and highway 7 at Musquodoboit Harbour. A branch of the Canadian National Railways links the Musquodoboit River valley villages to Dartmouth. Additionally, many logging roads provide easy access to the less inhabited parts of the study area.

Physiography and Drainage

The Musquodoboit River valley consists of two distinctive physiographic highland and lowland units — each of which is closely related to the underlying bedrock geology. The highland unit is part of the "Atlantic Upland" (Goldthwait, 1924) covering the entire Musquodoboit River valley and is underlain by three major rock types: granite, quartzite, and slate.

The granite country is characterized by the presence of a great number of large boulders as if they had popped out of the ground. In quartzite territory, the ground is mosaicked by more angular boulders and displays a barren and broad landform, with smooth ridges. In contrast to the above landforms, the slate

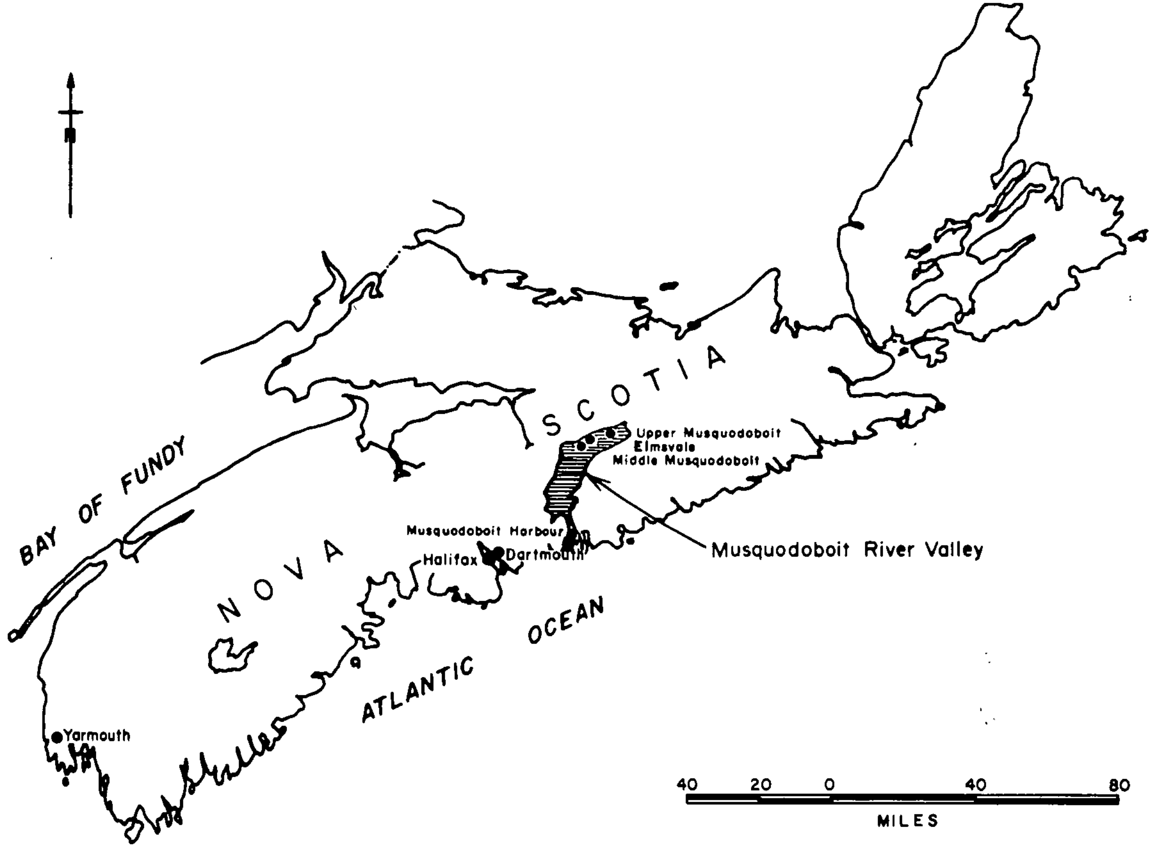

FIGURE 1. Location of the study area.

region is locally bestowed with a mantle of glacial drift displaying a peculiar landform of drumlins.

The lowland unit is underlain by Windsor rocks. The land surface is generally poorly drained with the Musquodoboit River meandering over the broad valley floor. Where the relief is slight, runoff is sluggish and the land boggy.

The entire course of the Musquodoboit River is about 60 miles long. Except for the uppermost portion of the valley, the stream profile is gently concave and has a gradient of 3.7 feet per mile (Fig. 2). Pleistocene glaciation has to some extent modified the profile as is evident from the well preserved U-shaped valley easily seen in the uppermost and lower segments of the valley.

Records obtained from the Water Survey of Canada stream gauging station located near Crawford Bridge indicate the following (MMRA, 1964, p. 1): (1) the present river can handle approximately 0.4 inch runoff from the whole watershed or 2,780 cubic feet per second or c.f.s., and (2) the frequency of flooding for discharges between 2,000 c.f.s. and 3,000 c.f.s. is two to four times yearly.

The Canada Department of Forestry and Rural Development, Nova Scotia Department of Agriculture and Marketing, and Municipality of the County of Halifax have jointly sponsored an extensive project for flood protection of farm land adjacent to the river. As a result of this project, 15 retardation dams have been or will be constructed on tributary-streams throughout the valley. A by-product of the project will include development of both recreational and wildlife resources of the area.

Agriculture and Soils

With few exceptions, the soils in the valley are mainly developed on glacial drift with the glacial till strongly reflecting the composition of the underlying bedrock (Table 1). It may also indicate the short distance of transportation of the till during glaciation. Commonly, the granite and quartzite terrains are blanketed by a thin stony till indicating its proximity to the bedrock. Soils developed on this till are often deficient in lime and suitable only for forest production. Areas underlain by slate are mantled by moderately fine- to coarse-textured soils which with the exception of some stony areas, are fair to good croplands.

The soils in areas underlain by Windsor Group rocks are fine textured and rich in lime and are best suited for most crops (MacDougall et al., 1963, p. 25). Frequently, the farming practice on this soil is severely restricted by poor drainage conditions. For soils developed on glaciofluvial deposits, however, excessive drainage may be a hindrance to land use.

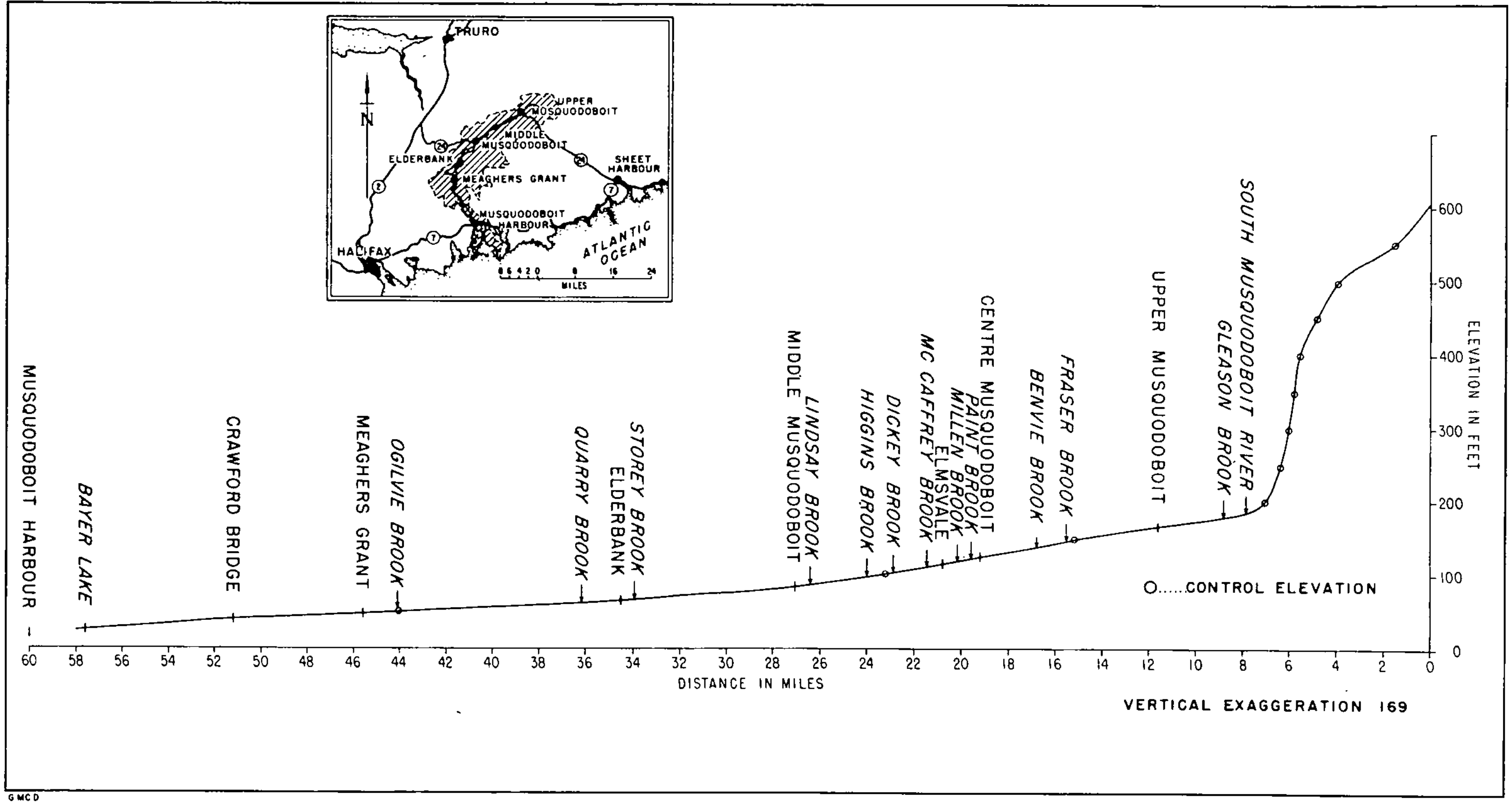

FIGURE 2. Stream-profile of the Musquodoboit River.

Table 1. Soils and their suitability for agriculture in the Musquodoboit River valley*

Parent Material	Soil	Classes of Land	Limitations
quartzite and granite tills	sandy loam	forestry and wildlife	stoniness, steep or shallow soils
slaty till	sandy loam	fair cropland	topography and stoniness
till developed on Windsor Group rocks	sandy clay loam	good to fair cropland	poor drainage
glaciofluvial deposits	sandy loam	fair to poor cropland	excessive drainage
alluvial deposits	silty loam	good cropland	flooding
organic remains	peat and muck	unsuitable	poor drainage

* modified from MacDougall et al. (1963, Figure 12).

The soils developed on recent alluvium in the middle and upper segments of the valley are very fertile and highly productive. However, they are subject to periodic flooding of the Musquodoboit River not only in the spring and fall, but sometimes during the growing season.

The farming practice of the valley includes dairying, livestock production, mixed farming, poultry production and forestry. Among various farm crops, oats, barley, hay, potatoes, turnips, strawberries, blueberries and market vegetables are by far the most important (Connor, 1964, p. 24).

Population and Industry

Because of limited prospects for economic development in the map area, there has been little addition to the population over the last ten years. According to the Dominion Bureau of Statistics, the census of 1966 indicates a population distribution as follows: Upper Musquodoboit (328), Middle Musquodoboit (745), and Musquodoboit Harbour (749).

Forestry, farming, and fishing are the basic industries of the valley. The great proportion of the area's forest operations are directed toward the production of sawn products, pulp, and the selling of Christmas trees. The manufacturing of the agricultural lime at Upper Musquodoboit is the largest single enterprise having a reasonably secure future. The socio-economic study conducted by Connor (1964, p. 47) reveals that cash incomes of the valley are lower than those expected in nearby urban societies and that employment opportunities within the valley are often lacking in security. Furthermore, the farming practice is mostly tied to a well established family experience and tradition.

As far as recreation and conservation are concerned, much of the potential wildlife resources and fishing activities afforded by the valley still awaits future improvement and sound management.

Climate

The climate of the valley is temperate and humid typical of Nova Scotia. The proximity of the ocean tends to prevent the climate of the area from reaching extremes. The so-called "Atlantic Upland" modifies considerably the climate of the valley. In other words, the physiography of the valley dictates the local climatic pattern.

Climatic records of short duration are available for Middle Musquodoboit and recently Upper Musquodoboit. However, they are believed to be typical only for the lowland region. To get a true picture of the entire valley, it is therefore necessary to extrapolate records from meteorological stations adjacent to the valley (Chapman and Brown, 1966). Table 2 is the summary of the result.

Land Survey System

The grid system used by the Nova Scotia Department of Mines for locating wells in the Province of Nova Scotia is adopted in part from the National Topographic System. Under this system, Canada has been subdivided into numbered primary quadrangles, each 4° latitude by 8° longitude. The Musquodoboit River valley is included in primary quadrangle 11. Each quadrangle is further subdivided into 16 sections identified by letters, and the sections are divided into 16 standard topographic map sheets identified by numbers starting from southeastern corner. The Musquodoboit River valley is covered by four such standard topographic maps: 11D11, 11D14, 11E2 and 11E3. Each standard map is divided into four reference maps designated with letters A, B, C, and D. Each reference map consists of 108 mining tracts subdivided with letters into 16 claims, each containing about 40 acres. Figure 3 shows the location of a hypothetical well in claim 11 E 3 A 47 H.

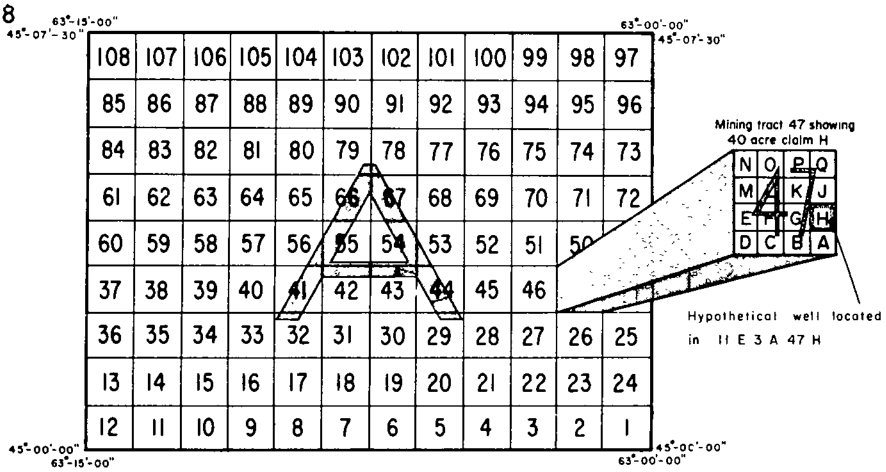

FIGURE 3. Reference map 11 E 3 A subdivided into mining tracts.

Table 2. Generalized climate of the Musquodoboit River valley

	Upper Musquodoboit	Middle Musquodoboit	Musquodoboit Harbour
Mean Daily Temperature (°F)	42.5 — 43	42.5 — 43	43 — 44
Annual Precipitation (inches)	45 — 50	45 — 50	55
Evaporation (in.)			
Potential	20 — 21	20 — 21	21.5
Actual	20 — 21	20 — 21	21.5
Moisture Deficiency (inches) (May-Sept.)	0	0	0
Degree-Days above 42°F	< 2500	< 2500	> 2600
Mean Frost Free Period (days)	110-120	110-120	130
Mean Frost Date (Spring)	May 31	May 31	May 25 — 31
Mean Frost Date (Fall)	September 20 — 25	September 25	September 30
Growing Season (Start)	April 25	April 25	April 25 — 30
Growing Season (End)	October 26 — 31	October 26 — 31	November 5

Previous Investigations

The bedrock geology of the valley was first studied by Faribault (1913) and later by Stevenson (1959). A general description of the bedrock and surficial deposits were included in the discussions of Goldthwait (1924). The surficial geology of the Shubenacadie map-area including Middle Musquodoboit and its vicinity was investigated by Hughes (1957). Soil surveys by MacDougall et al. (1963) constitute the first comprehensive treatment of the surficial deposits of the valley. Although the possibility of using outwash plains as an aquifer was mentioned by Hughes (1957, p. 10), a formal hydrogeological study, employing modern quantitative techniques was first conducted by Pinder (1968a, b) who investigated the lower segment of the Musquodoboit River valley.

Additionally, the Nova Scotia Department of Mines recently conducted a study on the Cretaceous clay and sand deposits of the valley lowland from Middle Musquodoboit to Center Musquodoboit (Wright, 1969a, b, c). A socio-economic survey of the valley was conducted by Connor (1964).

Field Work and Maps

Field work in the Musquodoboit River valley initiated in 1967 can be described as follows:

George F. Pinder started the investigation in the summer of 1967 during which the following tasks were completed: (1) preliminary mapping of the surficial geology south of Middle Musquodoboit, (2) groundwater discharge and its effect on stream chemistry, and (3) a pumping test of a promising aquifer at Musquodoboit Harbour.

Chang L. Lin, the present writer, has continued this project since the summer of 1968. Thus far, the following studies, in chronological order, have been attempted beginning with the summer of 1968: (1) preliminary mapping of the surficial geology north of Middle Musquodoboit, (2) relating groundwater chemistry to the surficial deposits at Middle Musquodoboit, and (3) a pumping test at Elmsvale to determine aquifer coefficients and potential.

During the summer of 1969 (1) mechanical analyses including water content determination of the glacial tills of the Musquodoboit River valley were carried out along with (2) stream gauging at Elmsvale.

Areal photographs at a scale of 1:15,840 were initially employed in the field for surficial mapping. The geological information was later transferred to 1:50,000 National Topographic Series maps which were reduced photographically to the present form of the surficial map of the report (in pocket).

Acknowledgments

This investigation, under the direction of John F. Jones, Chief, Groundwater Section, Nova Scotia Department of Mines, was initially a joint undertaking between the Canada Department of Forest and Rural Development and the Province of Nova Scotia (ARDA project no. 22042). Recently the administration of the ARDA Act was transferred to the Canada Department of Regional Economic Expansion.

The Department of Mines provided field vehicles, power aguer, portable chemical Hach kit, aerial photographs, topographic maps, and other equipment necessary for this study. Very able assistance was received during the summers, 1967 and 1969 from David Stonehouse, the summer of 1968 from Gary Grove and Stewart Hattie and part of the summer of 1970 from Lynn B. Thomas. The effort contributed by the Department of Mines rotary drill crew in the test drilling and pump testing was deeply appreciated. The map and illustrations in this report were prepared by D. Bernasconi and his staff of the Cartographic Section, Nova Scotia Department of Mines. Without the cooperation and help of the residents of the valley and many others too numerous to mention, this study would not have been possible.

GEOLOGY

Introduction

This section of the report provides background information on the general geology of the valley. Included are descriptions of the areal distribution, lithology, structural relations and age of the various bedrock units and surficial deposits (Table 3). The geological formations of the valley can be grouped under

Table 3. Stratigraphy of the Musquodoboit River valley

Era	Period or Epoch	Formation or Group		Lithology
CENOZOIC	Recent			Stream alluvium: silts Bar and beach deposits: sands, peat and muck
	Pleistocene			Glaciolacustrine silt deposits Glaciofluvial sand and gravel deposits Glacial till
		Disconformity		
MESOZOIC	Early Cretaceous			Lignites Gravelly quartz sand, clays of red, white and grey colors
		Disconformity		
PALAEOZOIC	Mississippian	Windsor Group		Limestone, gypsum, anhydrite,salt and shale
		Angular and Nonconformities		
	Lower and/or Middle Devonian	Southern Nova Scotia Batholith		Porphyritic granite
	Lower Ordovician	Meguma Group	Halifax Formation	Slate with minor quartzite
			Goldenville Formation	Quartzite with minor slate

two main catagories; rock units and surficial deposits. The rock units include the metamorphosed slates and quartzites of the Meguma Group of lower Ordovician age, the granitic intrusive of Devonian age, and the evaporites of the Windsor Group of Mississippian age (Fig. 4). The surficial deposits consist of colored clays and quartz sands of Cretaceous age, glacial till and glaciofluvial deposits of Pleistocene age, and recent alluvial deposits along the lowlands of the valley (Map 1).

Rock Units

Meguma Group

The Meguma Group consists of two metamorphosed formations, the Goldenville and Halifax of lower Ordovician age, with the latter conformably overlying the former. Together these two formations occur in tightly folded anticlines and synclines trending parallel to the Atlantic seacoast. An estimated thickness of 30,000 feet was given for the entire Meguma Group deposited in the Meguma geosyncline of Nova Scotia (Poole, 1967, p. 18).

The Goldenville Formation occurs extensively in the southern half and northeastern tip of the valley, whereas the greater portion of the Halifax Formation forms the highlands in the upper segment of the valley. The Goldenville Formation is mainly composed of quartzite with slate making up 5 per cent of the whole sequence. The quartzite is a dense, uniformly textured, chloritic fine grained rock. The slates are extremely fine grained and vary widely in color, composition, and degree of metamorphism. Oxidation of the iron pyrite and other sulfides contained in the bedrocks often imparts a brownish staining on the surface.

The Halifax Formation is predominently slate with a minor amount of quartzite. The slate is typically a bluish ferruginous graphic slate with a fibrous texture. Alternation of light silicious layers and dark carbonaceous material contributes to a banded appearance with individual beds rarely exceeding an inch or so in thickness (Stevenson, 1959, p. 13). Throughout the entire formation, the slaty cleavage and bedding planes are rarely parallel to each other and therefore the rock fragments occur most frequently in rhombohedral form.

Granite

The granitic intrusive which trends east-northeast across the south-central portion of the valley is part of the large batholith that extensively underlies most of central and southern Nova Scotia. It is a coarse-grained porphyritic

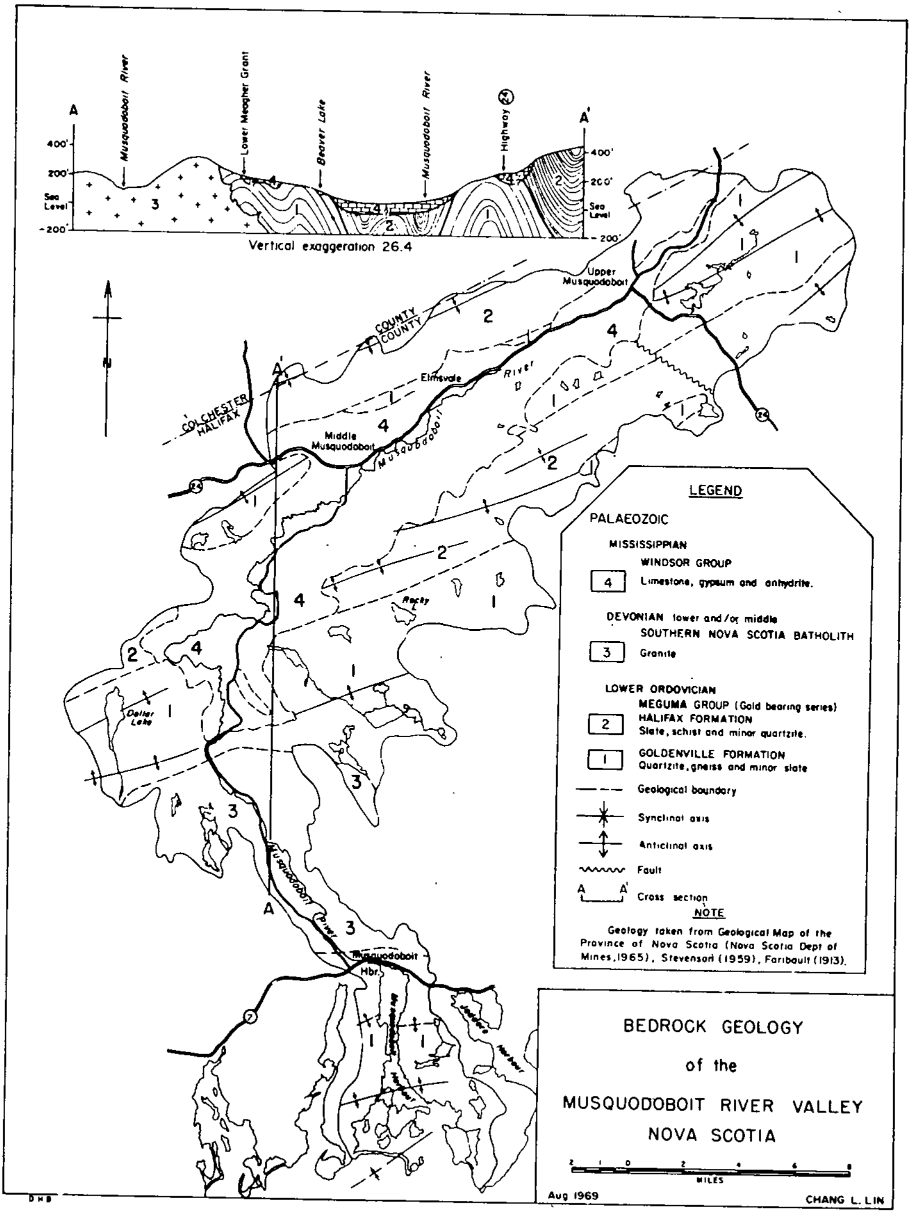

FIGURE 4. Bedrock geology of the Musquodoboit River valley, Nova Scotia.

granite with large whitish or pinkish feldspar as the phenocrysts. Both radioactive dating and field occurrence suggests that large scale intrusion took place in Nova Scotia during lower Devonian age (Smitheringale, 1960, p. 25; editorial note in Crosby, 1962, p. 31). Furthermore, because little or no disturbance has been done to the structure of the host rocks, mainly the Meguma Group, the granitic intrusion is considered to be a quiet one, although, locally, contact metamorphism is common near contact zones.

Windsor Group

Overlying the Meguma Group and the granitic intrusive with an angular unconformity, are rocks of the Windsor Group, of late Mississippian age. Present only in the valley lowlands, the younger Windsor rocks are mainly composed of flat-lying limestone interbedded with gypsum, anhydrite and salt. Available exposures on valley sides indicate that Windsor Group once occupied a much larger area and possessed a thicker sequence. Lithologically, the limestone of the valley is mostly dolomitic in composition, and of lower Windsor age (Stevenson, 1959, p. 25, 73).

Surficial Deposits

Cretaceous Quartz Sands and Clays

Unconsolidated interbedded red, grey and white clay, quartz sand, and lignite deposits are known to occur for a distance of at least 7 miles between Middle and Centre Musquodoboit. Similar deposits with lignite located at Shubenacadie have been dated as early Cretaceous in age (Stevenson, 1959, p. 35; Stevenson and McGregor, 1963, p. 355).

In Department of Mines, Groundwater Section Test Hole #404, located at Elmsvale, carbonaceous material was encountered in the following log of the bore hole:

Depth, feet	Well Log
0 - 41	Fine outwash gravel
41 - 58	White clay
58 - 282	Grey and red clays interbedded with gravelly quartz sands (Carbonaceous material at 247'-255')
282 - 520	Alternation of red and grey clays (Carbonaceous material at 460'-510')
520 - 592	Alternation of red and grey clays or shales (?) (Carbonaceous material at 570'-592')
592 - 597	Limestone (Windsor Group?)

Two carbonaceous samples recovered from the 480' to 490' and 570' to 580' intervals were forwarded to the Coal Research Section*, Geological Survey of Canada. They reported the following assemblage of microspores from both samples which were identified and dated as early Cretaceous in age.

Cyathidites (Leiotriletes) australis Couper
Cicatricosisporites dorogensis R. Potonié and Gelletich
Gleicheniidites senonicus Ross
Lygodioisporites sp. cf. Trilobosporites bernissariensis (Delcourt and Sprumont)
  R. Potonié
Abietineaepollenites spp.
Appendicisporites sp.
Cycadopites sp.
Eucommiidites sp.
Deltoidospora (Leiotriletes) spp.
Lycopodiumsporites sp.

As a result of this evidence, these unconsolidated deposits in the Musquodoboit River valley are considered to be early Cretaceous in age. Available data at the present time are not sufficient enough to accurately delineate the full areal extent and thickness of the deposit.

To the south of Elmsvale, quartz sand is exposed on or near the ground surface. A thick quartz sand bed of more than 156 feet was encountered, underlain by 55 feet of red-brown till, in Department of Mines Groundwater Section T.H. #380, north of Elmsvale. Recently test drilling south of Elmsvale suggests that the quartz sand is a depression-filling deposit on the surface of the clay (Wright, 1969a, p. 6). According to Wright (1969c, p. 7), some of the sections intersected in test drilling indicate a high grade silica, but others require beneficiation to upgrade the silica content for industrial uses.

Most of the clay deposits contain iron oxides, silica and micas as impurities and require some type of beneficiation to make them suitable for high- and super-duty refractory products. However, a large-tonnage of clay would be available if the removal of the iron oxides by hydrochloric acid bleaching could be economically feasible (Wright, 1969a, p. 14).

Glacial Till

Except for outcrops of bedrock, the entire valley is mantled by a thin blanket of Wisconsin glacial till (Hughes, 1957), varying in thickness from less

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* Both samples are recorded at Coal Research Section, Geol. Surv. Can., as CRS No. 1376/B1219 and CRS No. 1377/B1220.

than 1 foot to more than one hundred feet. The till is generally believed to be thicker in the valley lowland than over upland area. Because of the thin till cover, the type of bedrock strongly influences the composition and characteristics of the overlying till. No gumbotils, paleosols, or topographic unconformities were found among the various tills, suggesting a possible lack of multiple glaciation.

Based upon the nature of the composition and the conditions of field outcrops, the till can be subdivided into four main units: red-brown or silty, slaty, sandy, and bouldery tills (Map 1).

The red-brown silty till is a clayey, compacted lodgement till consisting mainly of sandstone, granite, and slate fragments. It is plastic when wet, and very dense and hard when dry. This till is most extensive throughout the valley especially in the upper and middle segments of the valley lowland where Windsor Group rocks form the bedrock. The color is a very diagnostic property for this basal till.

The sandy till is less cohesive, less compacted, and contains less clay than the red-brown till. It is a thin ablation till, resulting from the final downwasting of the ice. Stratigraphically, the sandy till always lies above the red-brown till.

Slaty till is mainly a red-brown till mixed with a large amount of slate fragments locally derived from the Meguma slate. Occasionally, it may also be a separate till unit underlain by red-brown till. However, the latter type of the slaty till is generally too small to be mappable. A good contact between it and the red-brown till can be seen in a road cut half way between Wyse Corner and Meagher Grant. The abundance of slaty fragments causes the till to become grey or dark in color.

Bouldery till is very sandy having a high percentage of boulders of various sizes. It occurs extensively in the southern half and northeastern portion of the valley where the bedrock is either granite or quartzite.

The occurrence of the bouldery, slaty, and red-brown silty tills can generally be related to the bedrock geology of the valley (Fig. 4). To further understand the regional variation of the red-brown basal till, mechanical analyses including water content* determination of 108 till samples have been attempted (Fig. 5). There seems no significant deviation from the apparent trend of the cumulative curves suggesting a possible lack of multiple glaciation (Flint, 1957, p. 116). However, it is a surprise to note that the percentage of

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* The water content of a soil is defined as the ratio of the weight of water to the dry weight of the aggregate and is usually expressed as a percentage.

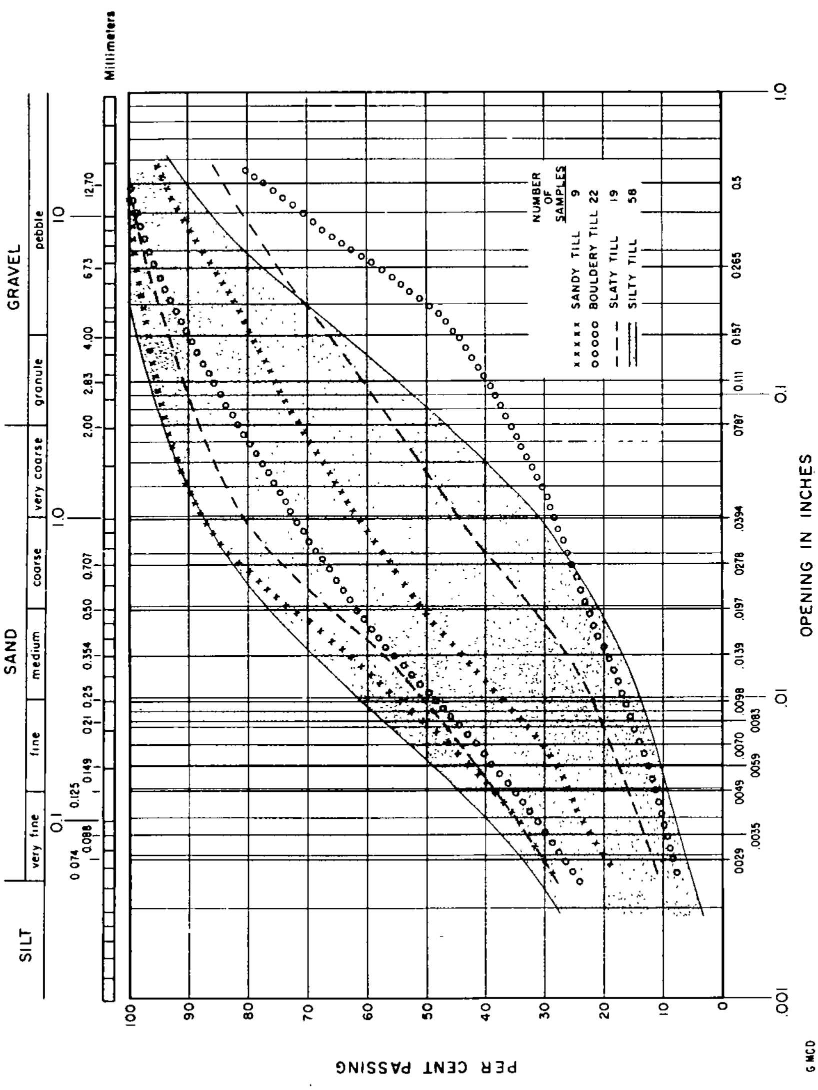


FIGURE 5. Mechanical analyses of the glacial tills

clay and silt content of the till is consistantly low. Geologically speaking, high silt and clay content is generally confined within or not too distant from the slate and granite terrains. This may also account for the high water content of the till (Fig. 6). However, both the sand and gravel content vary considerably (Fig. 7). The region having a sand and gravel ratio less than unity closely matches with the slate, quartzite and granite bedrock areas. The middle segment of the valley is transversed by a "sandy zone" with a sand and gravel ratio greater than 3. The presence of the sandy zone in tills is not clear at the present time and geological implication must await further results from a regional study of glacial tills.

Glaciofluvial Deposits

The glaciofluvial sand and gravel stratified deposits such as outwash plains, kames, and valley train result from the transportation and deposition of melt waters.

Outwash plains are most common in the upper segment of the valley and occur mainly along the Musquodoboit River at the mouths of tributary-streams. The areal extent of each outwash plain is less than one square mile. Most frequently, the sand and gravel are rudely bedded and not well sorted.

Most kame deposits are small and randomly scattered along the valley lowland. The main sand and gravel body at Middle Musquodoboit is a kame deposit. Along the sides of the U-shaped granite valley below Wyse Corner, numerous kame deposits of angular, medium to coarse sand and fine gravel are present. Additionally, the sand and gravel deposits in the bottom of the U-shaped granite valley can be considered as valley trains. The best example of such an origin is the sand and gravel deposit at Musquodoboit Harbour.

Along the valley, seven main glaciofluvial deposits have been delineated. Detailed studies have been made of these deposits located at Elmsvale and Musquodoboit Harbour (see discussions in hydrostratigraphic units) and Middle Musquodoboit (see discussions in local properties of the groundwater in the surficial aquifers).

Glaciolacustrine Deposits

In an area immediately south of Middle Musquodoboit, there is a relatively large deposit of glaciolacustrine silt and clay which is quite plastic when wet.

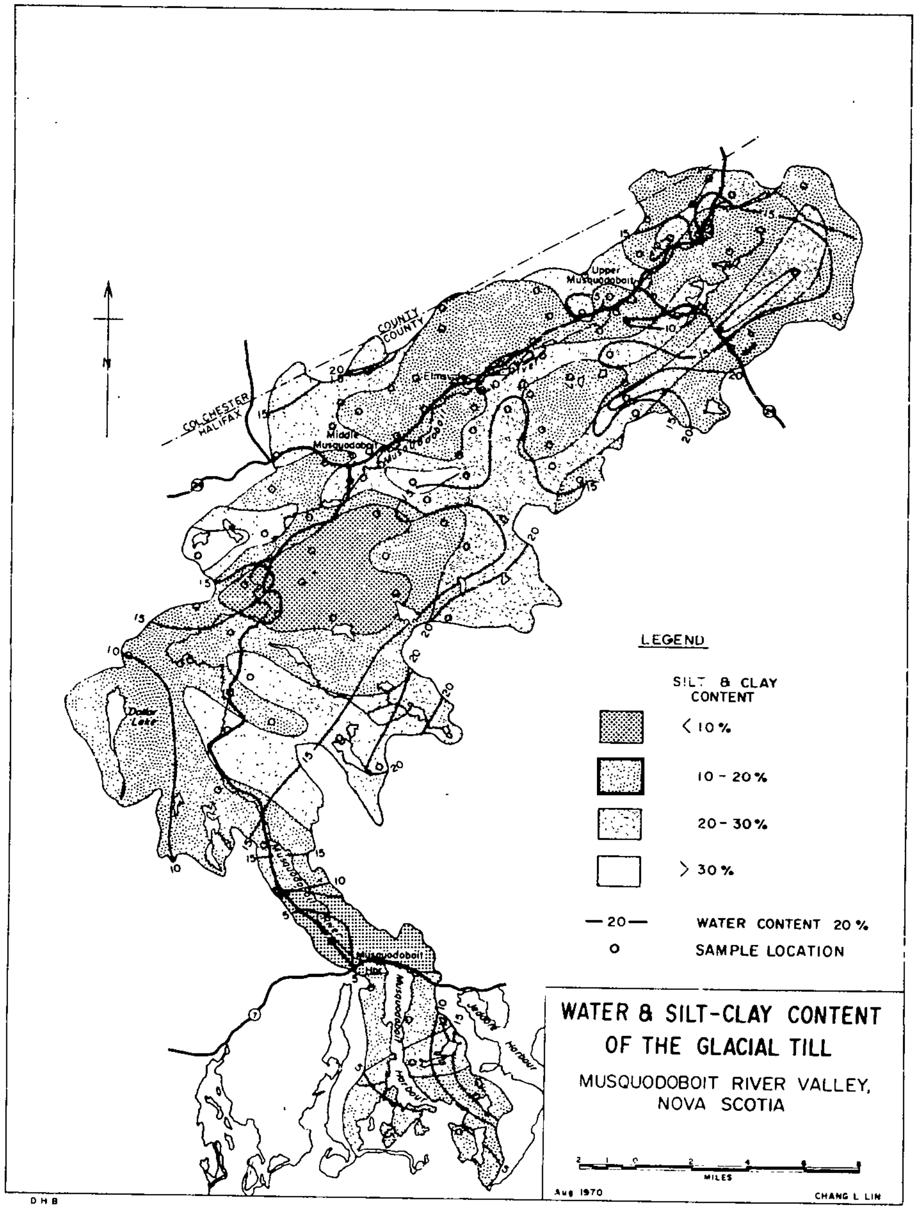


FIGURE 6. Water content and silt and clay content of the glacial tills.

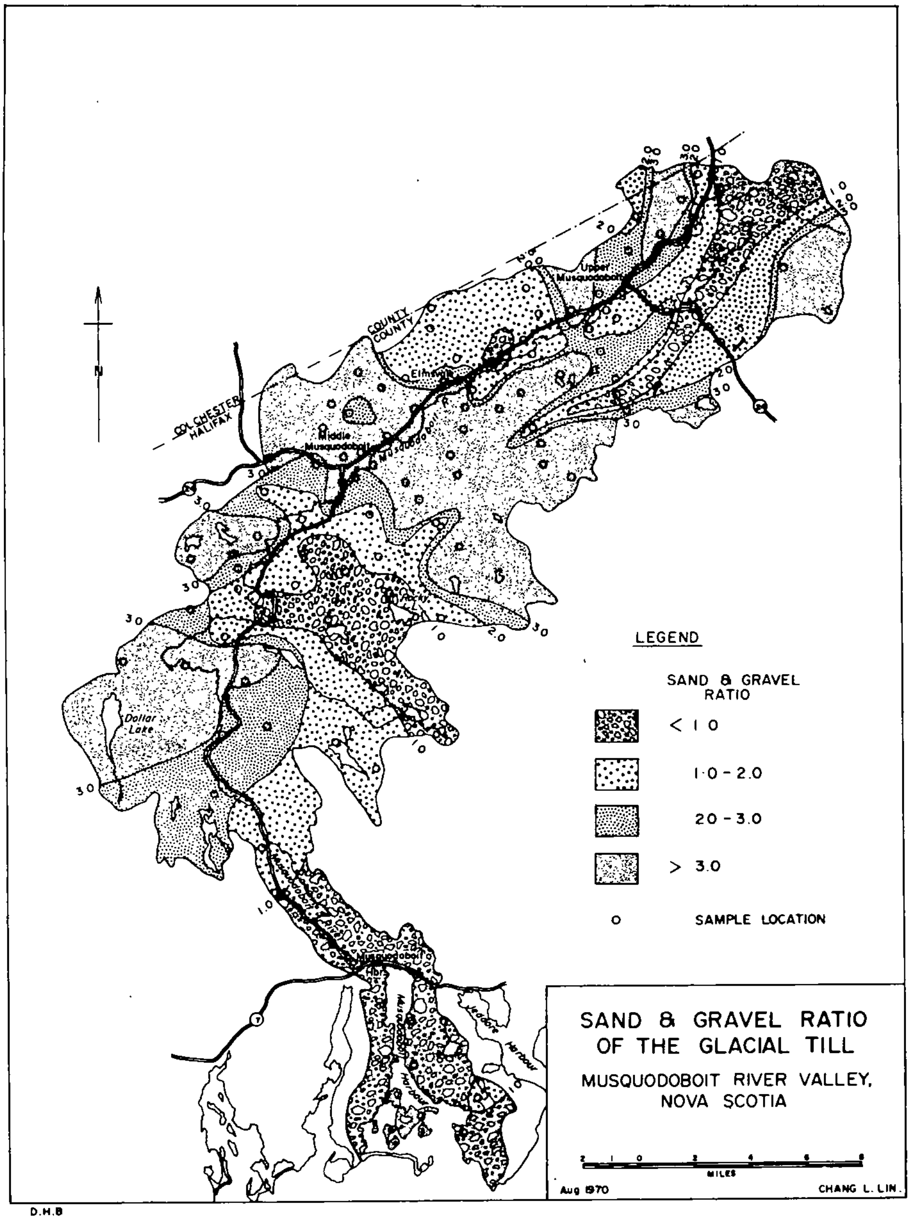


FIGURE 7. The sand and gravel ratio of the glacial tills.

Recent Beach and Salt Marsh

There are several recent beach and bar deposits along the Atlantic coast port of the valley at Martinique Beach and Nauffts Point. The deposits are grey in color and vary in texture from fine sand to coarse gravel. Also, two salt marshes are present along the coast as tidal deposits. The salt marshes consist of grey silt or silt loam and are subject to tidal flood periodically (MacDougall et al., 1963, p. 37).

Stream Alluvium

Recent silty alluvium derived from seasonal flooding blankets the valley lowland adjacent to the main streams. A particularly well developed deposit is found immediately south of Middle Musquodoboit. The presence of an alluvial blanket often masks the areal extent of the underlying outwash deposits in many parts of the valley bottom.

Peat and Muck

Swampy deposits of muck and peat are found in many depressions both in the lowland and on the upland areas. Presence of extensive swampy areas suggests poor drainage conditions.

Structure

The structure of the area is a part of the Appalachian folded belt (Stevenson, 1959, p. 37; Poole, 1967, p. 33). The Meguma rocks are characterized by high angle, tight folds which parallel the Atlantic sea coast and by low grade of metamorphism. An angular unconformity separates the Meguma Group rock from the overlying Windsor Group which forms a broad syncline along the valley lowland.

The studies of the fault systems are severely limited by the extensive covering of the glacial drift of the area. According to Stevenson (1959, p. 39), the Meguma Group is generally dissected by two distinctive sets of faults: the northwest- and northeast-striking faults. The slaty cleavage in the Meguma slate generally strikes parallel with the fold axis of the rocks and are steeply inclined.

Available information suggests that the fault systems in the Meguma Group may also be related to the regional joint (or fracture) systems developed in granite intrusive. There seems little doubt that all the structures of the valley are resulted from the unique regional tectonics of Nova Scotia (Brunton, 1926).

Geomorphology

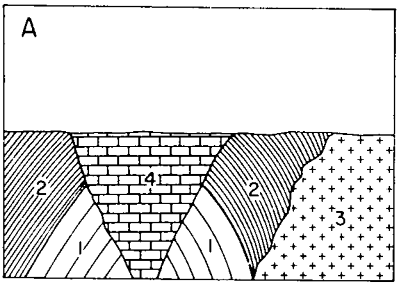
The highlands of the valley are remnants of the "Atlantic Upland" (Goldthwait, 1924), a peneplain formed during early Cretaceous age or earlier. Subsequent uplift of this surface resulted in an active erosion and downcutting (Fig. 8).

The origin of the Musquodoboit River has been discussed at length by Goldthwait (1924, p. 46). Above Wyse Corner, the stretch of river is subsequent, developed by headward growth of a lateral stream through the soft Windsor bedrock area. Near Wyse Corner, the river makes a sharp bend and enters a deep narrow gorge cutting through the granitic bedrock. Goldthwait (1924, p. 46) speculates that the Musquodoboit River may have had its headwaters north of the Minas Basin and that the old Musquodoboit River was pirated by the developing Minas Basin.

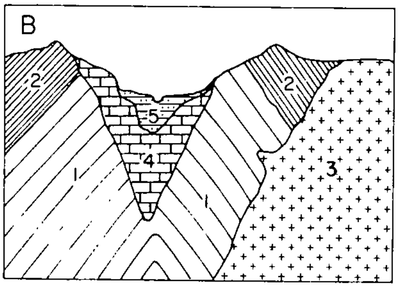
The presence of extensive Cretaceous clays and quartz sands along the upper segment of the valley lowland, strongly suggests that the upper Musquodoboit River was indeed a tributary-stream of the Shubenacadie River discharging into the Minas Basin to the north. It appears that the Shubenacadie drainage system was well established long before Pleistocene glaciation under the guidance of the less-resistant Windsor rock units.

Pleistocene glaciation has actually done little modification to the preglacial landform. Mapping of glacial erratics and striations indicates that the main front of the ice sheet mainly moved in a southeastern direction (Goldthwait, 1924). During early stages of glaciation, the local ice front was held stationary by the existing highlands around the Windsor Basin in the Shubenacadie drainage system. When the ice sheet was thicker, the stationary ice mass was forced to find an outlet. Naturally the existing lowland along the lower Musquodoboit River dictated the movement of the feelers' ice longue. The present narrow, rugged U-shaped granite valley was thus enlarged and modified from an ordinary small channel such as those commonly found along the Atlantic coast of the Province. When the entire area was covered by ice, the local topography was no longer important.

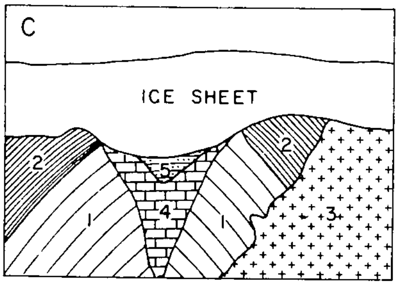
When the ice sheet started to retreat, deposition of glacial till in the form of recessional moraines (Pinder, 1968b, p. 10) resulted in partial damming of the tributaries of the lower Musquodoboit Rvier at Wyse Corner and the southwestward extension of the upper Musquodoboit River near Chaswood. Again, the local topography became important and dictated the course and direction of melt waters. Available information suggests that during active stages of deglaciation, the melt waters discharged not only into Musquodoboit Harbour, via the granite valley near Wyse Corner but into the Minas Basin, via Cook Brook, and the Shubenacadie River. When the glacial ice finally became very thin, damming near Chaswood resulted in an effective barrier diverting the discharge of the upper Musquodoboit River into the Atlantic Ocean. This long, complicated



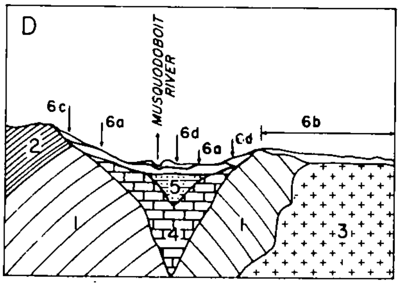
A Peneplain was formed during Early Cretaceous or earlier.



1. Regional uplift resulted in active downcutting and erosion in early Cretaceous.
2. Subsequent drainage system developed in soft Windsor Rocks.



Pre-Pleistocene topography was slightly modified by glaciation.



Deglaciation results in present surficial geology of the area.

LEGEND

PLEISTOCENE

6d	Sandy till
6c	Slaty till
6b	Bouldery till
6a	Red brown silty till

EARLY CRETACEOUS

5	Colored clays, quartz sands, and lignites

MISSISSIPPIAN

Windsor Group

4	Limestone, gypsum, anhydrite, salt, and shale

LOWER AND/OR MIDDLE DEVONIAN

Southern Nova Scotia Batholith

3	Granite

LOWER ORDOVICIAN

Meguma Group

2	Halifax Formation Slate, minor quartzite
1	Goldenville Formation Quartzite, minor slate

FIGURE 8. Hypothetical evolution of the Musquodoboit River valley near Elmsvale.

geomorphological evolution of the valley was highlighted by the birth of the Musquodoboit River. It is likely that the continuous headward erosion of the Shubenacadie drainage system will eventually recapture the upper Musquodoboit River.

The presence of the offshore beaches and bars today is the result of the regional isostatic readjustment of land mass after glaciation.

HYDROSTRATIGRAPHIC UNITS

Introduction

A hydrostratigraphic unit is defined as a group of geological materials which have similar water-storage and -transmitting properties (Trescott, 1968). Only interconnected or continuous interstices, pores, or pore space in earth materials can serve as conduits for groundwater movement. All interstices fall into two main systems: primary and secondary. The primary (or original) interstices were formed by geological processes which governed the origin of the geological units and are found in sedimentary and igneous rocks (Todd, 1959, p. 15). Secondary interstices such as joints, fractures, foliations, solution channels, and openings formed by plants and animals, were developed after the rock was formed. In general, the number and the operature of interstices decrease with depth, resulting from the increasing confining pressure of the overburden materials.

The main hydraulic properties of geological materials are the water-transmitting and water-storage properties, corresponding respectively to the coefficient of permeability and the coefficient of storage. The coefficient of the field permeability expressed in gallons per day per square foot or ft/sec can be defined as the rate of flow in gallons per day through a cross-section of an aquifer one foot thick. The permeability (K) values of various sizes of material can be generalized as follows:

Size	Gravel	Sand	Silt	Clay
K ft/sec	$>10^{-2}$	$10^{-2}-10^{-4}$	$10^{-5}-10^{-7}$	$<10^{-8}$

In practical applications, the coefficient of transmissibility, expressed in terms of imperial gallons per day per foot, is frequently employed and equals the product of the coefficient of permeability and the saturated thickness of the aquifer. The coefficient of storage is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of the head normal to that surface. Under confined conditions, the coefficient of storage equals that part of the water contributed from the elastic expansion of water itself and the compression of the aquifer matrix. None of the porosity under confined conditions contributes to the refilling or dewatering of the aquifer because the saturated thickness remains unchanged. Therefore., the coefficient of storage is small and generally ranges in value from 1.0×10^{-5} to 1.0×10^{-3} (Ferris et al., 1962, p. 76). However, under unconfined conditions, a third source of water is the specific yield which is a major one. The specific yield is defined as that portion of porosity contributing directly to the refilling or dewatering of the aquifer under unconfined conditions. When dewatering processes become effective, the volume of water derived from gravity drainage overshadows the volume of water derived from elastic behavior. Typical values of the coefficient of storage range from 5.0 x 10^{-2} to 0.30 (Ferris et al., 1962, p. 78).

The aquifer constants, namely, the coefficients of storage and transmissibility (and permeability) can be determined from a properly run field pumping test. They are used to evaluate the long-term rate of fluid withdrawal and associated drawdowns, with time and space from aquifers and allow for better water management, be it for individual, municipal or industrial use. Pumping test data from which the coefficients of transmissibility and storage were determined are available for the surficial aquifers located at Elmsvale and Musquodoboit Harbour (see p. 27-30).

Bedrock Hydrostratigraphic Units

Slate, Quartzite and Granite

Practically speaking, solid dense slate, quartzite and granite yield no water if they are unfractured. However, interstices of either primary or secondary or of both are present in these rocks. For the extremely fine-grained slate, the significant interstices are the slaty cleavages and the relic bedding planes, in addition to the joint systems related to the regional structure of Nova Scotia. Owing to the preponderance of the solitary orientation of the slaty cleavage, the permeability of the rock mass as a whole may tend to be anisotropic (Davis and De Wiest, 1966, p. 320). The granular interlocking of mineral particles is the main reason effectively preventing the fluid passage through quartzite and granite. However, similar to slate, quartzite and granite commonly are dissected by several systems of joints which make permeability in these rocks less anisotropic.

Subsequent removal of the overburden materials and surficial weathering will increase the permeability of the upper fractured zone of the bedrock. As the confining pressure increases with depth, the apertures of most fractures become tighter and eventually prohibiting the fluid flow through them. Hence, chances for locating a satisfactory well water supply diminish with depth and it is doubtful that satisfactory water supply will easily be obtained at depths below 250 feet (Trescott, 1969b, p. 26).

According to data obtained from well drillers' logs, the average well yield for 10 wells in slate was around 6 igpm, ranging from 2 to 15 igpm. In quartzite and granite areas, the recorded average was about 8 igpm, ranging from 1 to 26 igpm. In another part of the Province, Trescott (1969b, p. 26) reported an estimated average of 1.5 to 2 igpm for Windsor-Hantsport-Walton area.

As the drillers' bail test generally is of short duration, the well-yield would be less than the bail-test data when local boundary conditions are considered. However, for domestic purpose where the pumping is intermittent, the writer believes that 2 or 3 igpm should be a fair estimate for a well depth of 100 feet or more.

Windsor Group

Fractures, joints and solution openings are important in most typical limestone aquifers. Besides, diagenetic change of calcite into dolomite also results in an additional 13 per cent of void space (Davis and De Wiest, 1966, p. 353). All of these, theoretically tend to increase the bulk porosity and permeability of the rock. However, yields in limestone usually are not high despite the fact that solution channels are frequently cited in literature as a typical feature associated with limestone aquifers. Two drillers' bail tests from Windsor Group of the valley give an average yield of 6 igpm. Also, relatively thick sequences of glacial drift are usually associated with the limestone aquifers in the lowland portion of the valley, creating an additional factor to be considered when exploiting the limestone aquifer.

Surficial Hydrostratigraphic Units

Cretaceous Quartz Sands and Clays

The Cretaceous sand bed encountered at the Department of Mines T.H. #380 is a well sorted, coarse sand to fine gravel. If the areal distribution could be proven to be extensive, it would be a considerable asset to the groundwater resources of the valley. Because of the covering of the Pleistocene till, the underlying Cretaceous sand deposit occurs mostly under confined conditions. Hydrogeologically, the stratified nature of the Cretaceous colored clays are for practical purposes impermeable to water and this limits their use as an aquifer.

No hydrogeological study has been made on the enitre deposit.

Glaciofluvial Deposits

Elmsvale Sand and Gravel Aquifer

The Elmsvale aquifer is a NE-SW trending outwash deposit with a maximum length of one mile and a width of three quarters of a mile. The average saturated thickness of the aquifer at the well field is about 50 feet.

The Musquodoboit River, discharging a base flow at a rate of 6.5 cubic feet per second during summer time, forms the eastern boundary of the aquifer along most of its course of the area. The well log of the pumping well consists of the following:

Depth, feet	Well Log
0 - 30	silty gravel and sand
30 - 73	sandy gravel
73 - 80	colored clay

At the site of well no. 2, which is closest to the river, two well casings were intalled at different depths, resulting in different static levels (measured from ground surface): 4.30 feet (well no. 2A, 37 feet deep) and 4.50 feet (well no. 2B, 8 feet deep). The shallow water level was equal to the river stage of Musquodoboit River. This information suggests that Musquodoboit River is an effluent stream and also the stream bed may be treated as a semi-confining layer.

A pumping test was conducted during early September 1968. At the end of 72 hours of pumping at a rate of 250 igpm, the observed drawdowns were as follows:

Well no.	Distance from Pumping Well, feet	Drawdown, feet
1	164.0	2.7
2A	383.8	0.8
2B	383.8	0.2
3	147.8	2.0
4	164.4	2.3
5	231.0	2.3
Pumping Well	0.0	17.7

Comparison of the water level measurements before and after the pumping test at well no. 2 suggests pumping had converted the Musquodoboit River from an effluent into an influent stream.

.The calculated coefficients of transmissibility range from 3.8×10^4 to 1.7×10^5 imperial gallons per day per foot. The coefficient of permeability thus calculated varies from 0.002 to 0.008 ft/sec, corresponding to clean sandy gravel (Todd, 1959, p. 53). The short-term pumping test gives a coefficient of storage ranging from 6.0×10^{-4} to 6.3×10^{-3} which is hardly the typical value for unconfined case (p. 26). The efficiency of the pumping well was calculated from a step-drawdown test conducted after the end of pumping test. The well loss thus calculated is equal to 33%. Literally, it means only 67% of the observed drawdown is the real formation loss at pumping well.

Digital simulation studies of this aquifer (Lin, 1970) indicate that the system would approach the apparent steady state condition at the end of 6-day duration of pumping. An intimate interconnection between the aquifer system and the superposing Musquodoboit River was revealed. The vertical permeability of the stream bed, assuming a thickness of 4 feet, was calculated to be at least 5.0×10^{-6} ft/sec. Under a given set of conditions, the steady state drawdown is a function mainly of the distance to and the rate of recharge from the Musquodoboit River. A slight change in hydraulic conductivity of the stream bottom will result in a pronounced effect on the drawdown curve.

Overall information suggests that a properly constructed well would be capable of yielding at least 1,200,000 igpd which is roughly 800 igpm for a 20-year period. If a larger supply is needed in the future, a multiple well system can be employed.

As pointed out by Trescott et al. (1970), seasonal variation in stream discharge is probably an important factor contributing to the silting of a stream bottom. In the Musquodoboit River valley, another important element should be considered. As fifteen retardation dams for flood protection have been built along the valley, the stream velocity will undoubtly be slowed down, causing the settling of finer particles which originally were present as a suspended load of the river. This may be detrimental to a well field if the infiltration capacity of the stream bed is reduced by some future siltation.

Musquodoboit Harbour Sand and Gravel Aquifer

The outwash aquifer at Musquodoboit Harbour was investigated by Pinder (1969a, b). The following descriptions are based essentially on his study.

The Musquodoboit Harbour aquifer is approximately 4800 feet wide and extends along the river about 5700 feet. The areal extent and basal configuration are almost entirely delimited by granite bedrock. The only exception is found at the southern end where slate and glacial till predominate. The aquifer is fairly uniform in thickness near the river. At the pumping well, 75 feet of interbedded medium sand to fine gravel was encountered. The static water level was 4 feet below the ground surface.

The aquifer constants, based on a 36-hour duration of pumping at a rate of 350 igpm, are 150,000 igpd/ft (coefficient of transmissibility) and 7×10^{-2} (coefficient of storage). This coefficient of transmissibility is the highest average value yet determined for a glaciofluvial aquifer in Nova Scotia. Results of a digital model computation show that the aquifer could easily supply the village of Musquodoboit Harbour at a rate of 600,000 imperial gallons per day.

Other Glaciofluvial Aquifers

The glaciofluvial deposits of gravel and sand are most permeable and readily subject to replenishment from either rainfall or streamflow or both. The aquifers of Elmsvale and Musquodoboit Harbour are just two such many glaciofluvial deposits delineated in the valley (Map 1). Preliminary results do convincingly indicate that the groundwater storage in shallow aquifers is more than adequate to meet the demands of the valley during periods of prolonged drought. Most importantly, the presence of many such highly permeable surficial deposits in the valley should be attractive to industry in need of large water supplies.

Glacial Till

The red-brown basal till is most extensive throughout the upper segment of the valley. Because of its clay content and compact nature, it is highly impermeable and may act practically as an effective barrier for downward infiltration of precipitation. A great number of residents obtain their water supply from hand-dug wells constructed in glacial till. Except for the summer time, sufficient quantities of water may be obtained from dug wells because of the large storage capacity of the wells. During the summer time when the regional water table is lowered, water shortages may develop.

The sandy ablation till in most of the cases is too thin to have any great significance to the entire groundwater picture of the valley. Occasionally, when permeable sand lenses are encountered interbedded with, or outcropping with the till, a rather reliable water supply of larger quantity and better quality may be developed for domestic purposes.

In the highland area, the bouldery till is very sandy and permeable and the water quality is usually quite good. However, because they occupy mostly the sloping and rugged areas, few dug wells are found. In the Meguma slate areas, the abundance of slaty fragments causes the till to become greyey or dark in color. Because of the high argillaceous nature of the till, only very limited water supplies can be expected. Occasionally, springs issuing iron-bearing waters due to oxidation of the ferrous iron in slate contaminate the local groundwater flow.

Other Surficial Deposits

The other surficial deposits such as peat, muck and glaciolacustrine clay are predominently fine grained and are poor aquifers. However, in places where the alluvial sediments are coarse grained, the stream alluvium may be an important source of water supplied for local domestic and livestock requirements.

CHEMICAL QUALITY OF GROUNDWATER

Introduction

The chemical, physical, and bacteriological qualities of groundwater depend upon the types of porous media through which the water passes and the length of time the water is in contact with these environments. Although in detail the chemistry of groundwater can be exceedingly complex, the number of major dissolved constituents and the natural variations in groundwater are actually quite limited (Davis and De Wiest, 1966, p. 97).

The cations and anions commonly found in groundwater together with minor constituents are as follows (Todd, 1959, Table 7.1, p. 180):

Cations	Anions	Minor Constituents
Calcium (Ca)	Carbonate (CO_3)	Iron (Fe)
Magnesium (Mg)	Bicarbonate (HCO_3)	Aluminum (Al)
Sodium (Na)	Sulfate (SO_4)	Silica (SiO_2)
Potassium (K)	Chloride (Cl)	Boron (B)
	Nitrate (NO_3)	Fluoride (F)
		Selenium (Se)

The dissolved solids in groundwater are conventionally expressed in parts per million (ppm) and in equivalents per million (epm). One ppm means one part by weight of dissolved matter in a million parts by weight of solution. Water quality standards are generally cited in ppm. Equivalents per million are calculated by dividing the parts per million by the equivalent weight of the respective ion under consideration. This provides a useful means in checking the relative abundance of various ions and the completeness of the analyses.

The quality criteria required of a groundwater supply vary widely according to its purposes. As most groundwater pumped in the valley is for domestic use, the "Canadian Drinking Water Standards" (Table 4) recommended by the Department of National Health and Welfare, Canada (1969) should be met.

For various other uses, the quality standards are readily available from most standard textbooks. In other parts of the Province of Nova Scotia, Trescott (1968, 1969a, b) and Hennigar (1968) have discussed at length the quality of groundwater in various hydrostratigraphic units and their use. Information presented therein is mostly applicable to the Musquodoboit River valley. Interested readers are referred to their publications for further details.

Table 4. Canadian Drinking Water Standards*

	Chemical constituent	Objective ppm	Acceptable limit, ppm	Maximum Permissible ppm
Chemical Standards	Arsenic	not detectable	0.01	0.05
	Chloride	<250	250	-
	Copper	< 0.01	1.0	-
	Iron	< 0.05	0.3	-
	Lead	not detectable	0.05	0.05
	Manganese	< 0.01	0.05	-
	Nitrate and Nitrite	<10.0	< 10.0	-
	Sulfate	<250	500	-
	Total dissolved solids	< 500	<1000	-

	Parameter	Objective	Acceptable limit
Physical Standards	Turbidity	<1	5 (Jackson Turbidity Unit)
	Color	<5	15 (Platinum-Cobalt Scale)
	Odor	0	4 (Threshold Odor Number)
	Taste	inoffensive	inoffensive
	pH	-	6.5 - 8.3

Bacteriological Standards	The average monthly coliform bacteria content is limited to an MPN (most probable number) of one per 100 ml.**

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* Modified from "Canadian Drinking Water Standards and Objectives 1968" by the Department of National Health and Welfare, Canada, 1969.

** Modified from Todd (1959, Table 7.4, p. 185).

The complete analyses of 102 groundwater samples collected in the Musquodoboit valley are given in Appendix A. Discussed below are those constituents of groundwater quality having significant bearing on the domestic use in the valley.

Relationship of Groundwater Quality to Use

Hardness

Hardness is caused almost entirely by compounds of calcium and magnesium. According to U. S. Geological Survey's classification (Swenson and Baldwin, 1965, p. 17), the hardness of water may be rated as follows:

Hardness, ppm	
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
180	Very hard

Soft water is suitable for many domestic purposes without further treatment. Water of moderately hard may not seriously affect its use. However, for water with hardness greater than 120 ppm, often proper softening is required.

Iron and Manganese

Both iron and manganese when present in excessive amount will produce a brownish color staining in laundered goods and impairs the taste of beverages including coffee and tea. The highest iron concentration encountered in the valley is 15 ppm from slate. Generally speaking, the iron concentration is less than 0.3 ppm, the recommended limit for domestic use without treatment.

Sulfate

The presence of an excessive amount of sulfate in drinking water may contribute to a laxative effect. Calcium and magnesium sulfates are very soluble and hence, boiling of water will not cause the sulfates to precipitate. Fortunately, most of the water samples in the valley has a sulfate ion concentration much lower than the upper limit of 250 ppm.

Nitrate

The occurrence of excessive amount of nitrate in groundwater may generally be attributed to agricultural fertilization. Locally, it may also be traced to pollution from barnyards and similar sources (Hem, 1970, p. 182). High concentration of nitrate ($>$ 10 ppm) may be poisonous to children, especially responsible for the methemoglobinemia in new born babies and their mothers (Swenson and Baldwin, 1965, p. 16). The nitrate content is very low in bedrock units. A few water samples taken from the surficial aquifers show a nitrate concentration in excess of 10 ppm, but none of them exceeds the practical limit of 45 ppm (U. S. Public Health Service, 1962).

Total Dissolved Solids

Theoretically, the total dissolved solids are the numerical sum of all chemical constituents in groundwater, with exception of suspended sediments, colloids, or dissolved gases. However, only limited number of constituents are reported in routine analyses. In practice, the total dissolved solids in solution are approximated from the specific conductance by:

$$\text{Total dissolved solids (ppm)} \approx \text{Specific conductance } (\mu \text{ mhos}) \times A$$

where A is an experimental constant generally ranging from 0.55 to 0.75 (Hem, 1970, p. 99).

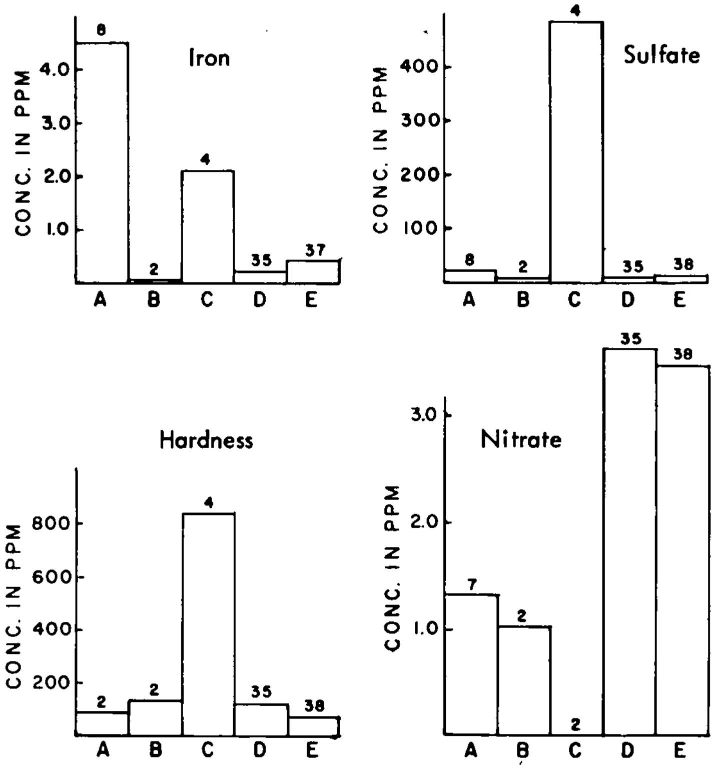
Excessive amounts of total dissolved solids will give to the water a bad taste and may be harmful to animal and plants (Trescott, 1968, p. 94). With the exception of a few deep wells tapping the Windsor Group rocks, the total dissolved solids reported are less than the recommended limit of 500 ppm.

Chemical Quality of Groundwater in the Hydrostratigraphic Units

Slate, Quartzite and Granite

Groundwaters in slate, quartzite and granite are typically low in hardness and total dissolved solids. In slate terrain, waters are deteriorated by an excessive amount of iron. The average content of iron from eight samples is as high as 4.5 ppm (Fig. 9) and water from slate may have to be treated.

No analyses of water from granite are available in the map-area. However, according to Trescott (1968, 1969a), waters from granite are usually of



NOTE:

A	Slate
B	Quartzite
C	Windsor Group–limestone, gypsum and anhydrite
D	Glacial till
E	Glaciofluvial sand and gravel
35	Number of samples

FIGURE 9. Bar graphs of the average iron, sulfate, hardness and nitrate content for water samples collected from wells in different hydrostratigraphic units.

good quality although some of them are moderately hard. The concentration of sulfate is in the order of 20 ppm which is too low to have any effect on water quality.

Windsor Group

The quality of groundwater from Windsor Group of the valley is usually characterized by the presence of high concentrations of total hardness, sulfate, total dissolved solids as well as iron (Fig. 9). Only in the cases where a well is tapping sandstone and shale associated with the evaporates, water of better quality may be encountered. The occurrence of high concentrations of sulfate and hardness results from the fact that the Windsor limestone of the valley is dolimitic in composition and interbedded with anhydrite and gypsum. If salt is present, the water will possess high concentrations of both sodium and chloride (for example, sample WD20 Appendix A). The high iron content of waters from Windsor Group could at least in part be syngenetic with the evaporites, although Trescott (1969b, p. 36) attributes it mainly to the corrosion of well casing and plumbing fixtures.

Cretaceous Sand and Gravel Deposits

There are only two wells tapping the quartz sand of Cretaceous age. The water has a moderate hardness of 145 ppm. Interbedded with colored clays, the water from quartz sand bed contains a relatively high iron concentration (0.55 ppm). The average sulfate concentration is 27 ppm. It is anticipated that water of better quality in terms of iron and hardness may be obtainable from thicker deposits such as that encountered at Elmsvale (Dept. of Mines T.H. #380).

Glaciofluvial Deposits

Waters from glaciofluvial deposits are low in hardness, sulfate, and total dissolved solids (Fig. 9). The hardness is generally less than 100 ppm. The closeness of the glaciofluvial deposit to the ground surface may have two different effects on its water supply potential: (1) the aquifer is easily accessible at shallow depth, (2) in a densely populated area, it may be subject to pollution from sewage effluent and other similar sources of discharge, if the proper precautions are not taken.

Occasionally, a relatively high concentration of iron resulting from corrosion of casing and iron fixtures may be encountered if water is allowed to sit too long in improperly protected plumbing and other fixtures. As far as overall quality is concerned, the glaciofluvial sand and gravel deposits are the most promising aquifers of the valley.

Other Surficial Deposits

A great number of residents obtain their water supply from dug wells constructed in red-brown till which widely occurs throughout the middle and upper segments of the valley. The water from this basal till is usually low in sulfate, and has a hardness slightly greater than 100 ppm. Where the till outcrops on a slope, slope wash will increase the permeability of the till and dilute the concentration of the dissolved solids, including hardness. The concentration of iron in till is more consistant than that in the glaciofluvial deposits. The reason for this may be due in part to the relatively higher pH of the groundwater and the homogeneity of the basal red-brown till. Because of their closeness to the ground surface the concentration of nitrate in both glaciofluvial and till deposits is higher than that in other hydrostratigraphic units (Fig. 9).

LOCAL PROPERTIES OF THE GROUNDWATER IN THE SURFICIAL AQUIFERS

Introduction

As the glaciofluvial deposits are potential sources of water supply in the valley, a particular effort has been attempted to relate the physical and chemical characteristics of the groundwater to the surficial deposit at Middle Musquodoboit. On all surficial maps published prior to this work (Hughes, 1957; MacDougall et al., 1963), a glaciofluvial deposit with dimensions one mile long and 1/3 mile wide was shown at the center of the village of Middle Musquodoboit. During the summer of 1968, a long drought resulted in failure of numerous shallow wells and water had to be hauled by truck from other sources. This was unexpected, as the aquifer was considered to be fairly extensive in the vicinity of the village and the village's water needs were not excessive.

Results of remapping and a careful examination of well logs revealed that the areal extent of the gravel and sand deposit was much more restricted than previously thought, especially at the center of the village (Fig. 10). Along route 24 west of the village, the gravel and sand mound is actually a kame deposit. The sand and gravel deposit becomes a very narrow wedge toward the center of the village. Near the Fina Station, a measurement along a diversion ditch indicated that it was only 70 feet wide.

To assist in the investigation of the groundwater situation at Middle Musquodoboit an extensive groundwater sampling program was undertaken. This included measurements of temperature, pH, turbidity, iron, silica, sulfate and hardness made in the field by means of a portable Hach Kit*. Selected water samples were also submitted for complete analyses to the Chemical Laboratory of the Nova Scotia Agricultural College at Truro. The purpose of the laboratory analyses was two-fold: (1) to check the consistency of the field measurements, and (2) to evaluate the deviation between laboratory and field results. During the entire course of study, it was necessary to assume that the errors introduced in field determinations were small and consistent.

Variation of Temperature with Depth

Although the regional relief of Nova Scotia is quite small (Goldthwait, 1924), a local relief of more than 300 feet is not uncommon in the valley. The steep local relief together with a narrow valley favors the development of a local flow system (Toth, 1962). In many parts of the valley, therefore, the groundwater circulation is relatively rapid. The perennial Musquodoboit River collects the groundwater discharge from both sides of the valley.

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* Portable field kit, DR-EL, Hach Chemical Co., Ames, Iowa.

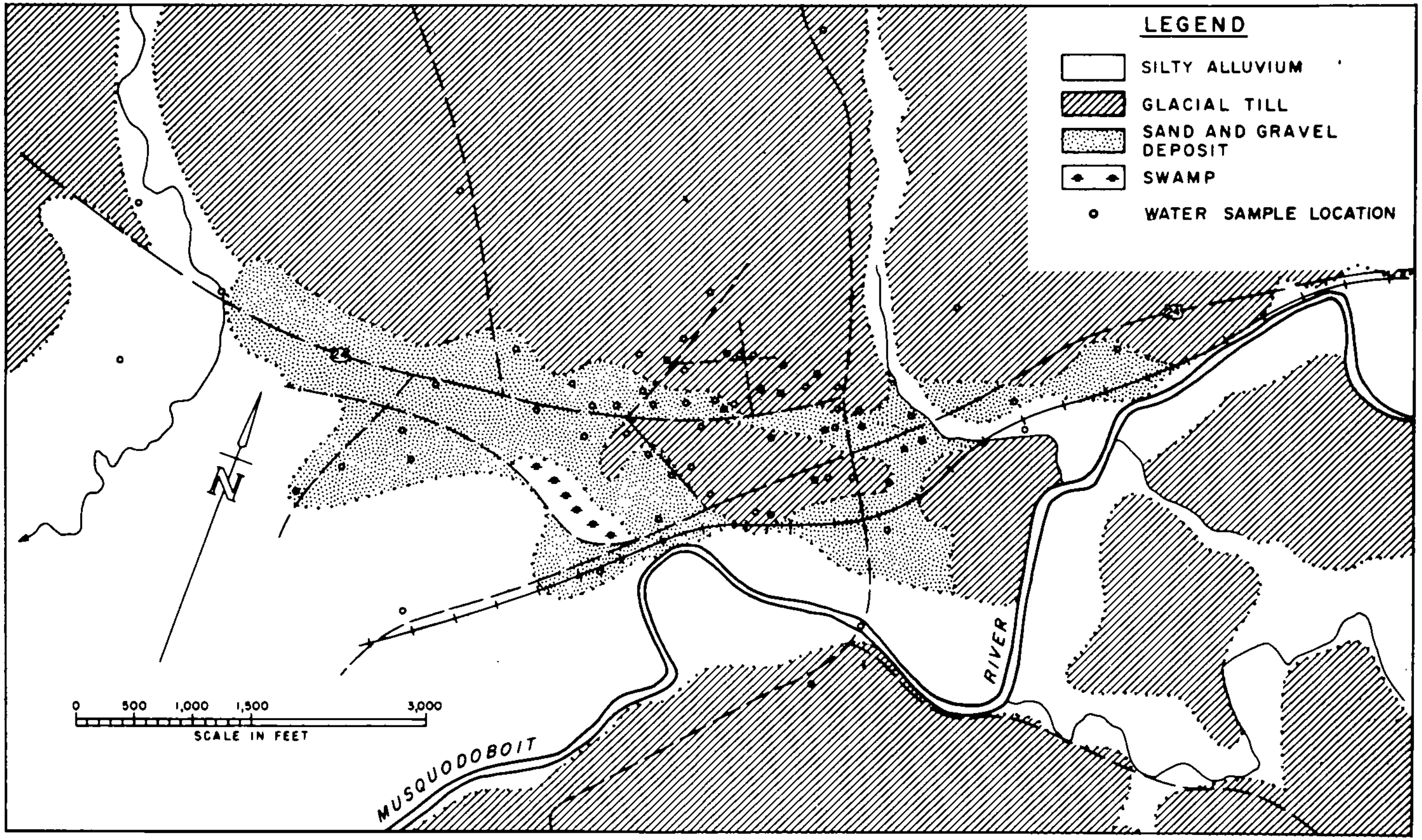

FIGURE 10. Surficial geology near the village of Middle Musquodoboit.

Correlation of the field temperatures with the depth to the water table suggests a control other than that of geothermal gradient (Fig. 11). The differerence was found to be as great as 14°F, ranging from 45°F to 59°F. The temperature generally decreases with depth and becomes steady at about 30 feet. The temperature distribution of the water samples taken from both sand and gravel deposit and glacial till is unique and essentially follows an identical pattern. Furthermore, an extrapolation of the temperature curve gives for zero depth a temperature of 64°F, which closely corresponds to the temperature of the surface water of Musquodoboit River during summer months. As most of the shallow wells rarely exceed 30 feet, Figure 11 strongly suggests that the temperatures of surface waters and shallow aquifers are likely related to the heat transfer from the ground surface. In addition, available information fails to realistically show whether this thermal profile is affected by local flow systems at all.

A model study of the local flow system taking into consideration the thermal properties of shallow flow would seem desirable in order to understand the flow system in the valley.

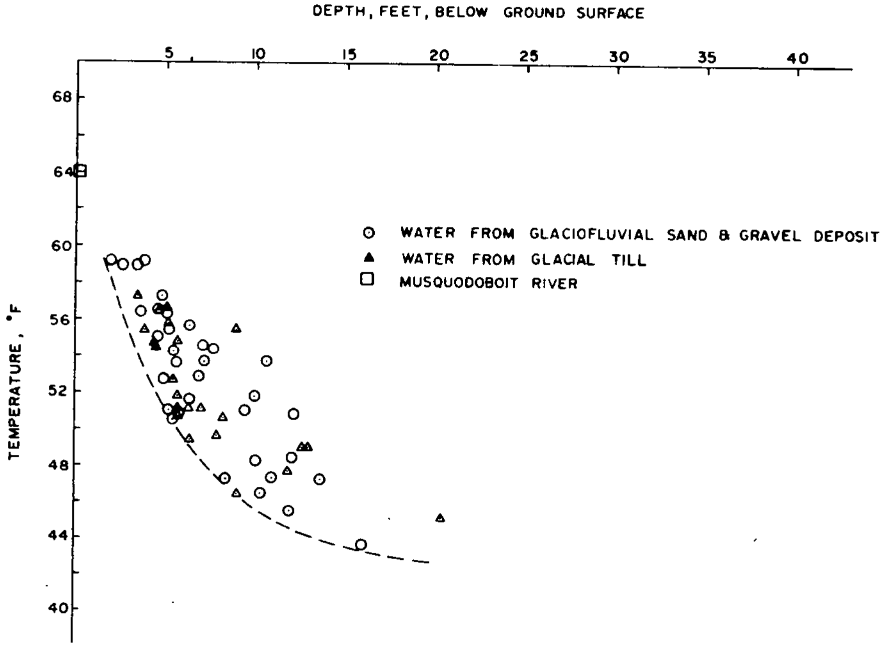

FIGURE 11. Field temperature of groundwater in relation to the depth to the water table.

pH Values

The pH is defined as the negative logarithm of the hydrogen ion concentration. For pure water where the concentrations of hydrogen and hydroxyl ions are both equal to 10^{-7} mole/liter, the pH value is 7. Obviously, the more hydrogen ions present, the less the pH will be.

Field measurements indicate that all water contained in the gravel and sand deposit have a pH varying from 5.5 to 6.0, whereas water from tills and other less permeable materials, such as silty and clayey alluvium, have a pH greater than 6.0.

As an approximation, the 6.0 contour line provides a useful boundary separating the permeable gravel and sand deposit from other deposits at Middle Musquodoboit (Fig. 12). The possible reasons for this include: (1) the gravel and sand deposits are more permeable, and (2) the gravel and sand deposit is readily subjected to recharge from precipitation where the supply of carbon dioxide is abundant. Again, it is reminded that material of reasonable permeability can also be developed from tills on slopes through the processes of weathering and erosion.

A comparison of field pH with laboratory values shows an average absolute difference of 1.4. Seventy-six out of 80 comparisons indicate that field pH is less than laboratory pH by an amount varying from 0.1 up to 2.7, with an average of 1.4. Only four pH values were found to be higher than laboratory pH by an amount varying from 0.1 to 0.4. The observed discrepancies between the laboratory and field measurements may be attributed to the following: (1) the pH value in groundwater sample has a significant tendency to become neutral with time because of the change in temperature and the loss of gases (Trescott, 1968, p. 83), and (2) the great majority of water samples available for this comparison were taken from sand and gravel deposits where the pH is usually low.

A discussion of the change of pH in groundwater can be found in papers dealing with chemistry and thermodynamics of groundwater (Back, 1961; Roberson et al., 1963; Trescott, 1968; Hem, 1970).

Silica Concentration

The silica concentration is usually reported as silicon dioxide in the groundwater analyses. Under normal temperatures and pH ranges of groundwater, silica is probably present as monomeric silica acid, H_4SiO_4 and essentially does not ionize (Krauskorpf, 1956, Davis and De Wiest, 1966, p. 100). Theoretically, the solubility of silica is directly proportional to pH in solution (Correns, 1949). However, because most of the silicate compounds are very insoluble, high concentrations of silica is therefore rarely found in groundwater.

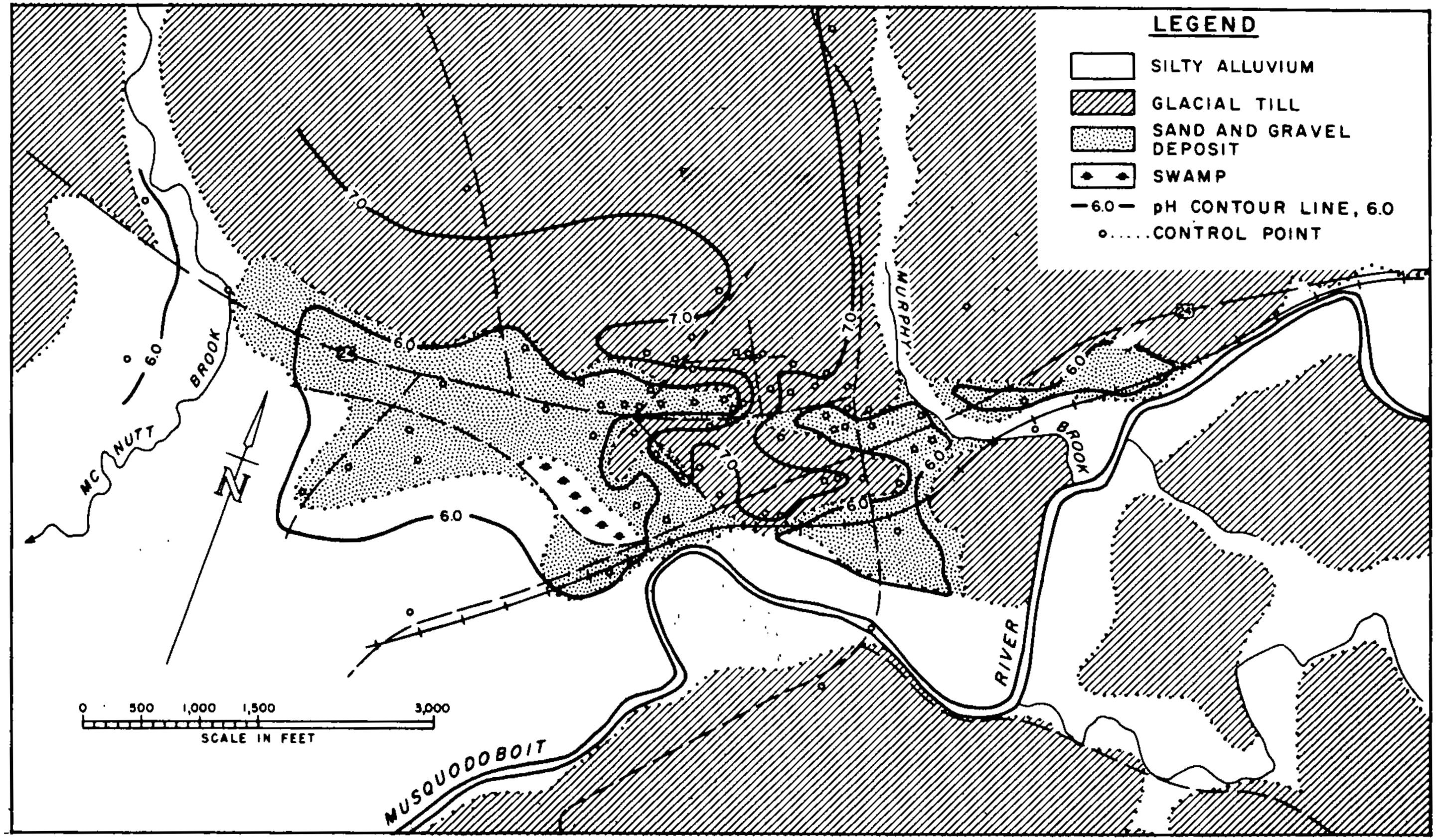

FIGURE 12. The pH values of groundwater in relation to the surficial geology at Middle Musquodoboit.

According to Krauskopf (1956), the pH of groundwater has only a small effect on the amount of silica going into solution. Since the pH is found to be a very sensitive indicator as to the type of surficial deposit, it is logical to expect little connection between silica concentration and the surficial deposits. Figure 13 illustrates this point. It can be seen that distribution of silica has little relation to the type of surficial deposit.

Total Hardness

The water coming from gravel and sand deposit contains less calcium and total hardness than that from the other less permeable materials (Fig. 14). As pointed out previously, the weathered surficial tills also yield softer water. For surficial deposits of this region, hard water (greater than 100 ppm) is associated with tills which have not been intensively weathered. Therefore, wells penetrating deeper into the till may have greater opportunity to encounter hard water. The 100-ppm contour line (Fig. 14) is closely related to the natural boundary of the gravel and sand deposit. High concentration of hardness is clearly shown at the center of Middle Musquodoboit.

Field and laboratory measurements of hardness are in general agreement. Slight discrepancies probably result because of the following factors: (1) loss of carbon dioxide, (2) changes in temperature, and (3) changes in pH.

Tentative Correlation among Silica, pH and Hardness

From Figure 13, one probably would have concluded that no relation exists between silica content and surficial deposits. However, if total hardness is added to the pH-silica plot, a distinct pattern is immediately apparent (Fig. 15). Chemically the increase of the calcium and magnesium carbonate content in solution will tend to shift the chemical equilibrium of groundwater in the direction of fewer hydrogen ions, or a higher pH value. In the meantime, a higher pH would tend to dissolve more silica in solution (Correns, 1949). As can be seen from the plot, the silica content is very low in all samples tested and more importantly has little regard to the pH values alone. Figure 15 discloses a possible relation among silica, pH, total hardness and the surficial deposits. The waters coming from gravel and sand deposits are centered near the origin and those from fresh tills are located near the outer margin of the plot. In the transition zone between gravelly sands and clay tills lie the silty alluvium and weathered tills. As both hardness and pH become higher, the material becomes finer and denser, grading into a clay till. This gradational change is essentially corresponding to the decrease in permeability of the aquifer. Similar relations also hold for other surficial deposits in upper parts of the valley studied. These field relations provide a useful guide in locating the boundaries of the surficial aquifers. It must be pointed out at this stage, that this correlation is based entirely on local relations. No corrections were made with respect to operation

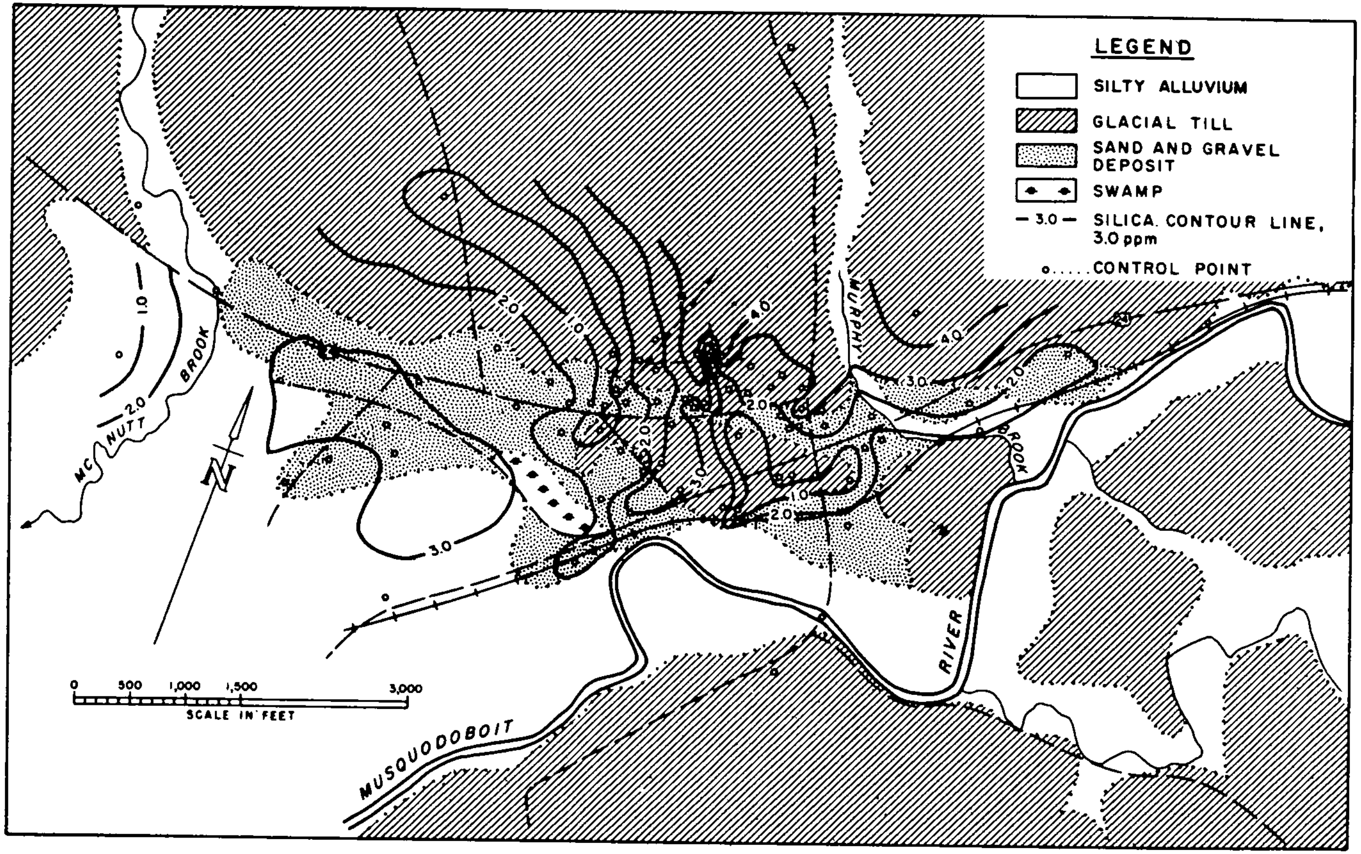

FIGURE 13. The silica concentration of groundwater in relation to the surficial geology at Middle Musquodoboit.

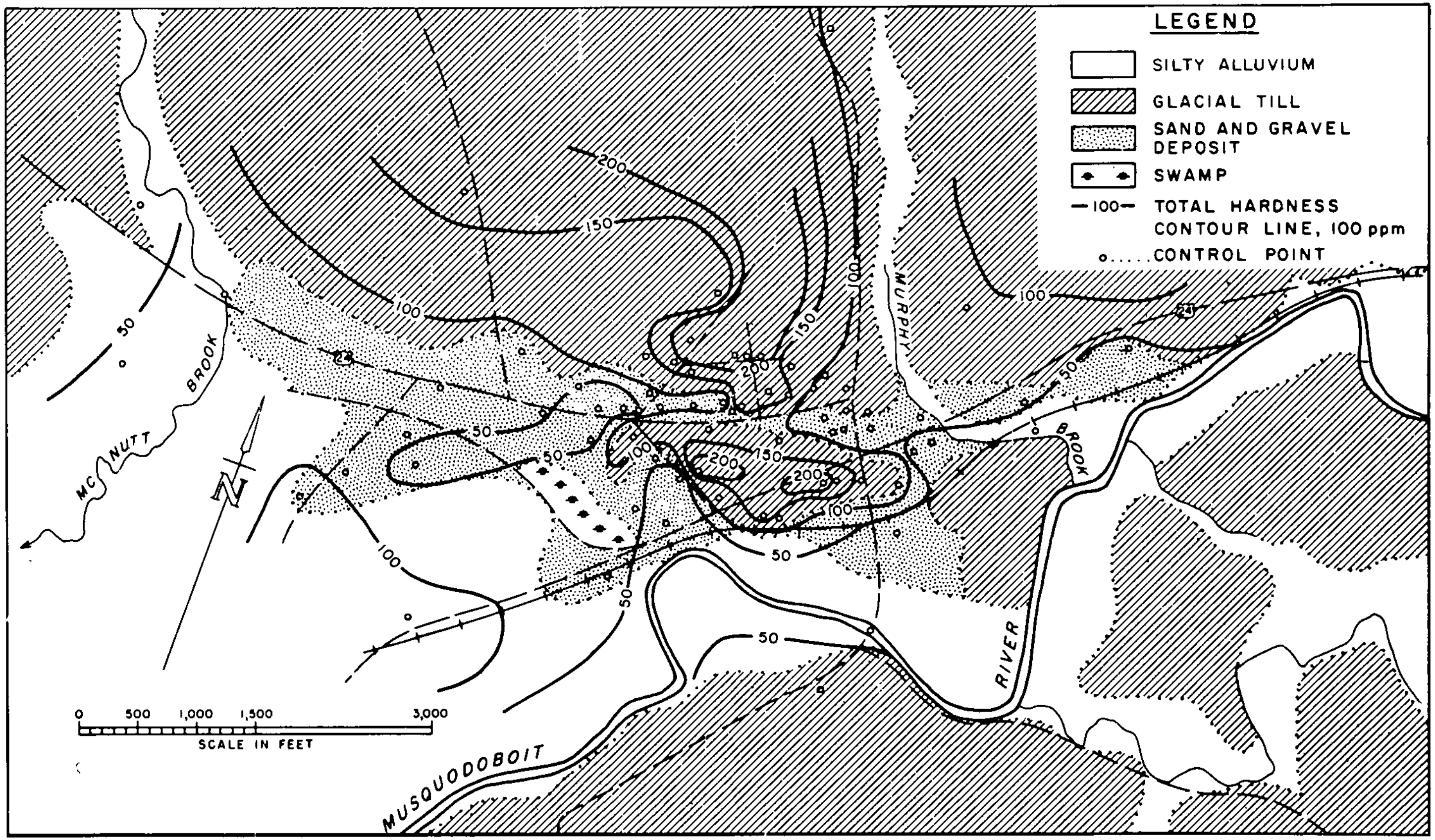

FIGURE 14. The total hardness of groundwater in relation to the surficial geology at Middle Musquodoboit.

errors, field temperature, barometric pressure and so forth. The relations presented above should best be viewed as a qualitative rather than a quantitative correlation. Any application outside this area should specifically keep the following in mind: (1) the surficial deposits investigated are hydrologically connected to a common aquifer system, and (2) the chemical parameters used here were all determined in the field, (3) the pH value is the most critical parameter and must be determined in the field.

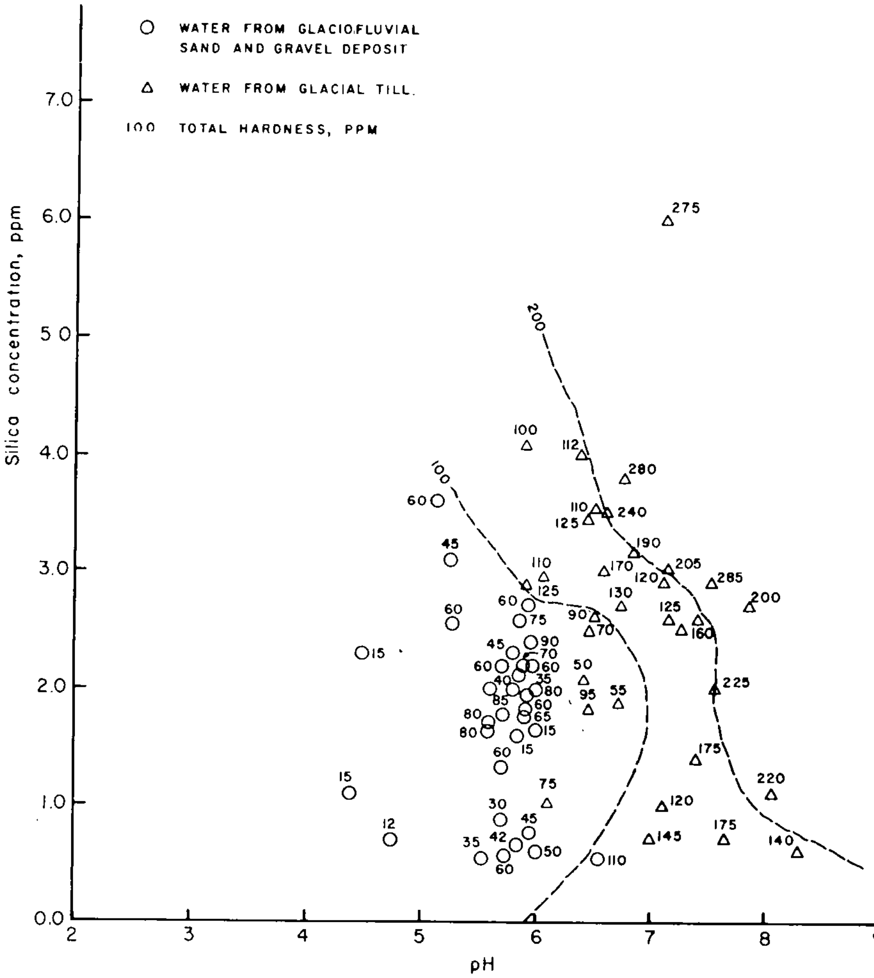

FIGURE 15. A tentative correlation among silica, pH and total hardness.

GROUNDWATER UTILIZATION AND DEVELOPMENT

Introduction

The use of groundwater rather than surface water for water supply often has the following advantages: (1) the yield from groundwater is more reliable with seasonal variations having little effect, (2) the chemical and bacteriological qualities of groundwater are more consistant and predictable, whereas in the Musquodoboit valley the presence of many mucky and swampy areas often impairs the color of the surface water, especially during and immediately after storms, and (3) the groundwater is present and available almost everywhere, whereas the surface water occurs only along stream channels. Additionally, the increasing hazard of pollution (Stephenson, 1964) often makes it necessary that surface waters be treated (coagulation, filtration and chlorination, etc.) before use. Consequently, future development and growth of the valley will depend in part on the availability of adequate fresh water supplies, especially groundwater, for municipal, industrial, and irrigation use.

Domestic and Livestock Water Supplies

The estimated requirements for daily domestic and livestock consumptions are as follows (Anderson, 1963, p. 38):

each member of a family	100	gallons	per	day
each horse	10	"	"	"
each steer or dry cow	12	"	"	"
each milk-producing cow	25-30	"	"	"
each hog	2	"	"	"
each sheep	1.5	"	"	"
each 100 chickens	4	"	"	"

The typical figures on the amount of water necessary for certain home operations are as follows (Leopold and Langbein, 1960, p. 32):

flush a toilet	3	gallons	per	day
tub bath	30 - 40	"	"	"
shower bath	20 - 30	"	"	"
wash dishes	10	"	"	"
run a washing machine	20 - 30	"	"	"

Generally speaking, a well capable of yielding 1 to 3 igpm on a long-term basis would be sufficient for average domestic and livestock requirements, provided that adequate water storage is available. There should be little difficulty to construct drilled wells with such capacities almost anywhere in the valley. Actually, in many instances, hand-dug wells are sufficient enough to meet domestic needs.

Chemical as well as bacteriological qualities of water are important considerations for domestic and livestock water requirements. For example, the groundwaters from Windsor rocks are mostly unsuitable for domestic and livestock consumptions because of the high concentrations of total hardness, sulfate, total dissolved solids and iron.

A great number of the domestic supplies in the valley are obtained from shallow hand-dug wells. As a result, wells of proper construction and location are necessary in order to prevent pollution from septic tanks, barnyards and other sources of pollutants. This is particularly important in highly permeable surficial aquifers such as the glaciofluvial sand and gravel deposits in densely populated villages such as Middle Musquodoboit and Musquodoboit Harbour. For proper protection of both hand-dug and drilled wells, exercising the precautions issued by the Department of Public Health and complying with regulations under the Well Drilling Act is the best guide.

Irrigation Water Supplies

Irrigation is hardly a common practice in the valley with lawn watering the most important irrigation use of water. If larger quantities of water are required, damming of the surface runoff is probably the most economical and practical. However, because of the localization of the highly transmissive deposits along the valley bottom together with steep local relief of the valley sides, large scale and continued pumping of groundwater for irrigation is restricted to those areas not too distant from the valley floor.

Municipal and Industrial Water Supplies

There are no central supply systems from either groundwater or surface water sources for all the villages along the valley. This section outlines the potential groundwater supplies for the future development and growth of three important communities: Musquodoboit Harbour, Middle Musquodoboit, and Upper Musquodoboit.

Musquodoboit Harbour

Musquodoboit Harbour is underlain by rocks of the Meguma Group of Lower Ordovician age which largely have a thin covering of bouldery till along with glaciofluvial sand and gravel deposits. The domestic waters are mostly from bedrock wells constructed in the Meguma Group and which often contain an excessive iron content (Pinder, 1968a, p. 43). Some residents obtain their water supply from shallow dug wells in bouldery till with the shallow drift wells often susceptible to depletion during periods of prolonged drought (Jones, 1967, p. 271).

One of the important results of this project was the delineation and evaluation of a highly permeable glaciofluvial sand and gravel deposit located near the northwestern end of the village. Well logs, surficial mapping, chemical data as well as the results of both electrical analog and digital studies indicate that this unconsolidated aquifer is capable of providing an adequate supply of very good quality of water. The Musquodoboit River in this area would provide a constant source of replenishment to this aquifer if a large well field were developed in it (Pinder, 1968a, b).

Since the overlying surficial alluvium is very thin, the glaciofluvial outwash deposit is easily subject to pollution if exploitation is not well planned. It is therefore quite feasible to develop a central water supply for the village from this aquifer. A reliable water supply system would undoubtly be attractive to industry in need of large water supplies, in addition to alleviating the groundwater problems of the villagers.

Middle Musquodoboit

Middle Musquodoboit, the second largest community in the valley, is underlain by rocks of the Windsor Group of Mississippian age. The Windsor Group in the valley consists mainly of limestone, gypsum, anhydrite and possibly salt. The groundwaters associated with bedrock aquifer are usually of inferior quality.

The hydrogeology at Middle Musquodoboit is complicated by the following factors: (1) the highly permeable glaciofluvial sand and gravel deposit is more restricted than previously thought, especially near the central portion of the village, (2) the Windsor bedrock as well as Cretaceous colored clays are present at shallow depth, and (3) during the summer months when the regional water table is lowered, shallow wells constructed in glacial till often fail to provide an adequate supply even for domestic needs.

In light of the present knowledge of the water supply sources of the village, several suggestions are offered as a guide for future development:

(1) It seems very unlikely that larger quantity of water of good quality can be obtained from deep wells in the center of the village; (2) future development of groundwater supply should be concentrated within the glaciofluvial sand and gravel deposit west of the village; (3) a detailed study on the subsurface stratigraphy is necessary in the area west of the village, as it is very likely

that a buried channel of Cretaceous age extends from Middle Musquodoboit to Cook Brook. Along this buried valley floor, it is possible to encounter a highly permeable and thick quartz sand aquifer, and (4) the groundwater shortage during the summer months may be alleviated at least in part by enlarging and deepening the existing shallow wells constructed in glacial till.

Upper Musquodoboit

Upper Musquodoboit, the third largest community in the valley is underlain by rocks of the Windsor Group of Mississippian age. The waters from these Windsor aquifers are of inferior quality largely unsuitable for most purposes.

Most of the residents obtain their water supply from shallow dug wells constructed in glacial till. Surficial mapping indicates that there are no highly permeable or thick glaciofluvial sand and gravel deposits in or nearby the village of Upper Musquodoboit; hence, production of large quantities of water from wells is not very likely.

Others

There are many other small communities such as Centre Musquodoboit, Elmsvale, Meagher Grant, Elderbank, and etc., in the valley. As water supplies are mainly for domestic and livestock needs, there has been but little difficulty regarding water supplies for these communities.

Many of the permeable glaciofluvial sand and gravel deposits delineated in or near these communities have not been fully utilized and are potential aquifers for additional water supplies and immediate expansion of these communities.

Additionally, at Elmsvale, in addition to outwash sand and gravel deposits, there is a thick sequence of gravelly quartz sand of Cretaceous age. The lateral extension and vertical variation of the deposit should be thoroughly investigated further before any hydrogeological appraisal is made.

SUMMARY AND CONCLUSIONS

Farming, forestation and fishing are the main economic activities of the Musquodoboit River valley. Because of the lack of other forms and prospects for economic development, the valley has shared very little in the growth and prosperity of modern Nova Scotia during the last decade.

The soils developed on Meguma Group and granite regions are mostly very stony and are suitable only for forestry. In areas underlain by Windsor rocks, the soils are fine textured and very productive croplands. However, they are often subject to poor drainage conditions and periodic flooding. The situation maybe improved at least in part by the recent flood-alleviation projects in the valley.

The pre-Pleistocene unconsolidated deposits of the valley have been dated to be Early Cretaceous in age based on an assemblage of microspore fossils. The important implications of the finding are stated as follows: (1) prior to Pleistocene glaciation, the upper segment of the Musquodoboit River valley was probably a tributary-stream of the Shubenacadie drainage system discharging into the Minas Basin, (2) the Cretaceous deposits including both the pottery clays and permeable quartz sands of the valley appear to be much more extensive than previously thought and further investigation to delineate the areal extent of the buried channel should be undertaken.

Studies of the gross mechanical composition of the red-brown till indicate that it reflects the lithology of the underlying bedrock which in turn has an important effect on the permeability of the till. Further studies of the gross mechanical composition of the till should be carried out because many dug wells are constructed in the till throughout the valley.

The significance of the fractured zones in dense quartzite, slate, and granite is practically limited to relatively shallow depth. Adequate water supplies from drilled wells should be obtained from depths less than 250 feet. The chemical quality of groundwater from granite and quartzite is generally good. However, water from slate is often deteriorated by excessive concentrations of iron.

The chemical quality is the main concern on the water supply from Windsor Group rocks. For practical purpose, waters from rocks of the Windsor Group in the valley are largely unsuitable for domestic and livestock consumption because of the high concentrations of total dissolved solids, total hardness, sulfate, and iron.

Numerous isolated glaciofluvial deposits covering an area of slightly less than one square mile have been delineated along the valley. Detailed studies have been made on two such deposits located at Elmsvale and Musquodoboit

Harbour. Preliminary results indicate that these glaciofluvial sand and gravel aquifers are promising and capable of yielding large quantities of good quality water. Additionally, the superposing Musquodoboit River can provide a constant source of recharge by induced infiltration to these aquifers when a well field is developed. Along the valley, many of these deposits have not yet been effectively utilized for water supply.

A great number of residents obtain their water supply from shallow dug wells constructed in glacial till. During the summer time when the regional water table is lowered, numerous dug wells often fail to provide an adequate yield even for domestic uses. To improve the situation, the permeable glaciofluvial gravel and sand deposits should be more fully utilized. Available data suggest that groundwater resources in the valley are more than adequate to meet the demands for the immediate future.

The preliminary correlations between the groundwater chemistry and the surficial deposits at Middle Musquodoboit result in the following conclusions: (1) the local groundwater chemistry is indicative of its environment and can be very useful in the delineating areas of high permeability, (2) many post-sampling changes can affect the true chemistry of groundwater. Field measurements of certain chemical and physical properties of groundwater, especially the temperature, pH, silica, and hardness are recommended for additional study.

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APPENDIX A CHEMICAL ANALYSES OF GROUNDWATERS IN THE MUSQUODOBOIT RIVER VALLEY

Index No	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm)														Specific Conductance (mhos x 10^-5)	pH		Field Temp °F	Colour	Turbidity	Ions in equivalents per million (epm)						SSP	SAR
						Ca	Mg	Na	Fe	Mn	SO4	Cl	NO3	Alkalinities		Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter		Field	Lab				Ca	Mg	Na	SO4	Cl	NO3		
														Phenolphthalein as CaCO3	Methyl Orange																		
WD2	11E3A41Q	Mid. Musq	9	gravel & sand	27/6/68	77.3	6.1	3.1	0.15	T	6	5.3	7	0	82.7	93.2				25	6.8	7.8		20	5	1.36	0.50	0.13	0.12	0.15	0.11	6	0.13
WD4	11E3A42L	Mid Musq.	22	"	29/6/68	7.9	2.5	2.1	0.44	T	7	3.5	T	0	20.0	30.0				12	5.8	7.3	51	40	35	0.39	0.21	0.09	0.15	0.10		13	0.19
WD5	11E3A42E	Mid. Musq.	7	"	29/6/68	4.8	3.2	4.0	0.07	T	16	7.1	4	0	6.5	25.2				14	5.6	6.3		15	0	0.24	0.26	0.17	0.33	0.20	0.06	25	0.34
WD6	11E3A31N	Mid Musq.	6	till	1/7/68	22.3	5.7	2.8	0.10	T	5	4.4	T	0	76.5	79.2				22	6.8	7.4	50	10	0	1.11	0.46	0.12	0.10	0.12		7	0.13
WD8	11E3A42D	Mid. Musq	9	"	1/7/68	38.2	8.3	13.2	0.05	T	14	21.3	12	2	86.5	129.2				40	6.8	7.9	57	10	0	1.91	0.68	0.57	0.29	0.60	0.19	8	0.50
WD9	11E3A42E	Mid. Musq		gravel & sand	1/7/68	16.4	5.1	71.3	0.21	T	11	104.6	5	0	20.5	61.6				50	5.8	6.8	54.5	5	3	0.82	0.42	3.10	0.23	2.95	0.08	71	3.92
WD10	11E3A41K	Mid Musq.	25	"	2/7/68	12.2	4.8	12.8	8.65	1.0	19	20.4	1	0	32.0	50.0				25	5.9	6.5	51	40	2	0.61	0.39	0.56	0.40	0.58	0.01	36	0.79
WD11	11E3A42D	Mid Musq.	11	till	2/7/68	50.7	50.7	13.1	0.03	T	26	24.8	15	0	130.5	174.4				55	6.8	7.6	52	10	2	2.53	0.96	0.66	0.54	0.70	0.24	16	0.50
WD12	11E3A51Q	Newcomb Corner	11	"	3/7/68	9.5	4.0	1.9	0.05	T	5	3.5	T	0	37.0	40.0				13	6.4	7.5	55	20	0	0.47	0.33	0.08	0.10	0.10		9	0.12
WD13	11E3A51Q	Newcomb Corner	6	"	3/7/68	15.9	6.8	0.4	0.04	T	24	3.5	10	0	64.3	67.6				19	6.1	7.2	57			0.79	0.56	0.02	0.50	0.10	0.16	1	0.02
WD14	11E3A70H	Newcomb Corner	6	"	3/7/68	25.2	6.8	1.9	0.24	T	24	3.5	T	2.0	61.3	90.8				22	5.9	8.0	56			1.26	0.56	0.08	0.50	0.10		4	0.08
WD15	11E3A42E	Mid. Musq	5	gravel & sand	7/7/68	13.8	4.0	7.2	0.67	T	30	5.3	T	0	12.0	41.6				14	5.9	7.4	54.5	75	28	0.69	0.33	0.31	0.62	0.15		23	0.43
WD16	11E3A42S	Mid Musq			8/7/68	12.3	2.6	3.0	0.67	T	30	5.3	T	0	12.0	41.6				14	6.7	7.4	58	75	28	0.61	0.21	0.13	0.62	0.15		13	0.20
WD20	11E3A42E	Mid. Musq	12	McNutt River Evaporite	8/7/68	64.3	11.8	294.0	0.38	T	18	451.2	10	1.0	69.0	209.2				180	6.6	7.9	60.5	25	3	3.31	0.97	12.79	0.37	12.73	0.16	75	8.80
WD21	11E3A42E	Mid. Musq.	14	till	8/7/68	24.5	3.9	2.0	0.60	T	6	3.5	T	2.0	75.0	77.2				21	6.7	8.3	56.5	60	0	1.22	0.32	0.09	0.12	0.10		5	0.10
WD22	11E3A42E	Mid Musq	18	"	8/7/68	19.2	4.9	14.4	0.05	T	27	23.0	5	0	52.0					29	6.5	7.9	56.5	30	2	0.96	0.40	0.63	0.56	0.65	0.08	31	0.76
WD23	11E3A42E	Mid Musq.	12	"	8/7/68	21.8	4.0	2.6	2.00	0.03	3	4.4	T	1.7	68.0	70.8				19	6.7	8.0	60	40	3	1.09	0.33	0.11	0.06	0.12		7	0.13
WD24	11E3A42E	Mid Musq	17	gravel & sand	9/7/68	30.6	9.1	51.8	0.15	T	14	83.3	T	0	47.5	114.0				48	5.6	7.7	47	20		1.53	0.75	2.25	0.29	2.35		49	2.10
WD25	11E3A42E	Mid Musq	49	quartz sand	9/7/68	38.6	10.1	11.3	0.68	T	8	17.7	T	3	131.5	138.0				39	7.8	8.2	56	20	0	1.93	0.83	0.49	0.17	0.50		15	0.40
WD26	11E3A42E	Mid Musq	21	gravel & sand	9/7/68	13.5	6.4	39.2	0.52	T	10	60.3	10	0	21.5	60.0				35	5.6	7.2	48.5	5	0	0.67	0.53	1.70	0.21	1.70	0.16	58	2.20
WD27	11E3A42E	Mid Musq.	21	"	9/7/68	14.1	6.5	40.3	2.32	0.01	12	65.6	10	0	23.0	62.0				53	5.6	7.3	48.5	5	0	0.70	0.53	1.75	0.25	1.85	0.16	58	2.22
WD28	11E3A42E	Mid. Musq	22	till	9/7/68	35.3	13.6	11.8	0.7	T	16	17.7	10	5.5	105.1	144.0				37	6.4	8.2	45	20	0	1.76	1.18	0.51	0.33	0.50	0.16	14	0.42
WD29	11E3A41H	Mid Musq.	25	"	9/7/68	45.9	9.9	8.9	T	0.01	7	14.2	T	8.5	135.0	155.2				37	7.4	8.5	62.5	5	2	2.29	0.81	0.39	0.15	0.40		11	0.31
WD30	11E3A41H	Mid. Musq.	16	"	9/7/68	101	19.4	15.2	0.05	T	3	24.8	20	0	134.0	331.6				100	7.2	7.8	52.5	5	0	5.04	1.6	0.66	0.06	0.70	0.32	9	0.36
WD31	11E3A41H	Mid Musq	11	"	9/7/68	70.1	9.2	7.9	0.45	T	8	12.4	T	40.5	212.0	213.2				55	7.1	8.4	49.5	5	0	3.5	0.76	0.34	0.17	0.35		7	0.23
WD32	11E3A41H	Mid. Musq.	14	"	9/7/68	48.6	8.3	6.5	0.11	0.01	10.0	10.6	T	17.0	117.0	155.2				36	7.6	8.4	51	5	2	2.43	0.68	0.28	0.21	0.30		8	0.22
WD33	11E3A41H	Mid. Musq.	18	"	9/7/68	65.9	30.3	20.2	0.10	T	57.0	31.9	T	6.0	247.5	288.2				75	7.3	8.0	56	5	5	3.29	2.49	0.88	1.19	0.90		13	0.52
WD34	11E3A42D	Mid. Musq	13	"	11/7/68	42.2	8.9	13.3	0.10	T	11	22.2	7	4.0	120.0	142.0				37	7.0	8.3	46.5	5	7	2.11	2.73	0.58	0.23	0.63	0.11	17	0.48
WD35	11E3A41H	Mid Musq.	15	"	11/7/68	29.3	11.4	5.9	0.05	T	7	8.9	2	6.0	130.0	120.0				38	7.5	8.2	50	30	16	1.46	0.94	0.26	0.15	0.25	0.03	9	0.24
WD36	11E3A41H	Mid. Musq.	8	"	11/7/68	37.4	6.5	14.2	0.17	T	4	22.2	T	4.0	124.0	120.0				34	7.1	8.3	49.5	30	16	1.87	0.53	0.61	0.08	0.63		20	0.55
WD37	11E3A41A	Mid. Musq.	13	"	11/7/68	41.7	9.3	14.0	0.23	T	7	21.3	5	6.0	128.0	142.4				36	8.3	8.2	55.5	20	37	2.08	0.77	0.60	0.15	0.60	0.08	17	0.50

T = concentration <0.01 ppm

SSP = soluble sodium percentage

SAR = sodium adsorption ratio

CHEMICAL ANALYSES OF GROUNDWATERS IN THE MUSQUODOBOIT RIVER VALLEY CONT'D

Index No.	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm) Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Alkalinities Phenolphthalein as $CaCO_3$	Alkalinities Methyl Orange	Hardness	Ignition Loss	Total Dissolved Solids	Suspended Matter	Specific Conductance (mhos x 10^{-5})	pH Field	pH Lab	Field Temp °F	Colour	Turbidity	Ions in equivalents per million (epm) Cations Ca	Cations Mg	Cations Na	Anions SO_4	Anions Cl	Anions NO_3	SSP	SAR
WD38	11E3A41A	Mid. Musq.	18	till	11/7/68	23.7	25.7	17.1	0.07	T	28	29.3	15	6.0	122.0	164.8				56	7.5	8.2	49.0	5	6	1.18	2.11	0.74	0.58	0.83	0.24	18	0.54
WD39	11E3A41A	Mid. Musq.	13	gravel & sand	11/7/68	22.1	19.1	4.0	0.47	T	3	6.2	T	8.0	150.0	133.6				37	5.9	8.4	47.5	5	21	1.10	1.57	0.17	0.06	0.17		6	0.15
WD40	11E3A41A	Mid. Musq.	10	-	11/7/68	26.1	4.0	19.9	1.1	0.01	9	28.4	T	2.0	64.0	81.6				28	5.8	8.1	55.5	5	18	1.30	0.33	0.87	0.19	0.80		35	0.96
WD41	11E3A41B	Mid. Musq.	38	-	11/7/68	27.7	4.6	12.6	0.08	0.01	7	17.7	10	2.0	54.0	88.0				24	5.9	8.1	54.5	5	7	1.38	0.38	0.55	0.15	0.50	0.16	24	0.58
WD42	11E3A32O	Mid. Musq.		-	11/7/68	37.4	5.5	52.2	0.03	0.05	27	77.1	10	0	28.0	116.0				44	5.9	7.6	51	5	7	1.87	0.45	2.27	0.56	2.17	0.16	49	2.10
WD43	11E3A32G	Mid. Musq.	74	quartz sand	11/7/68	34.6	7.4	5.4	0.58	0.03	46.0	8.0	T	2.0	88.0	121.6				32	8.0	8.3	48.5	5	10	1.83	0.61	0.23	0.96	0.23		9	0.20
WD44	11E3A32P	Mid. Musq.		gravel & sand	11/7/68	20.5	11.5	15.0	3.6	3.0	13	2.04	T	2.0	68.0	98.4				26	6.0	8.2	58	40	78	1.02	0.95	0.66	0.27	0.58		25	0.54
WD45	11E3A32Q	Mid. Musq.	7	-	11/7/68	16.8	4.9	42.7	0.05	0.10	11	61.5	5	0	12.0	62.0				30	5.6	7.4	51	5	8	0.84	0.40	1.86	0.23	1.73	0.08	60	2.36
WD46	11E3A42D	Mid. Musq.	11	till	12/7/68	31.7	14.1	6.6	0.11	T	14	9.8	T	4.0	136.0	137.2				46	8.0	8.2	55	5	2	1.58	0.16	0.29	0.29	0.28		9	0.25
WD47	11E3A41A	Mid. Musq.	22	-	12/7/68	21.3	12.2	4.2	0.35	T	18	7.1	T	4.0	106.0	103.2				37	7.3	8.3	47.5	5	3	1.06	1.0	0.18	0.37	0.20		8	0.17
WD48	11E3A41A	Mid. Musq.	11	-	12/7/68	19.4	5.1	52.2	0.07	T	7	83.3	5	0	38.0	69.2				42	5.7	7.4	59	5	8	0.97	0.42	2.27	0.15	2.35	0.08	62	2.72
WD49	11E3A41A	Mid. Musq.	17	gravel & sand	12/7/68	9.9	2.7	1.9	0.14	T	3	3.5	T	0	36.0	36.0				11	7.9	7.7	54.5	5	8	0.49	0.22	0.08	0.06	0.10		10	0.13
WD50	11E3A41A	Mid. Musq.	12	till	12/7/68	34.9	10.4	17.8	0.05	T	27	25.7	12	6.0	98.0	130.0				40	6.4	8.3	52.5	5	2	1.74	0.85	0.77	0.56	0.72	0.19	23	0.67
WD51	11E3A41A	Mid. Musq.	8	gravel & sand	12/7/68	6.4	1.9	16.9	0.05	T	7	24.8	5	0	30.0	24.0				20	6.5	6.9	54.5	5	5	0.32	0.16	0.73	0.15	0.70	0.08	60	1.50
WD52	11E3A41A	Mid. Musq.	10	-	12/7/68	21.3	6.9	24.9	0.04	T	3	32.8	3	2.0	78.0	81.6				32	8.4	8.2	55.5	5	9	1.06	0.57	1.08	0.06	0.93	0.05	40	0.94
WD53	11E3A41A	Mid. Musq.	19	till	12/7/68	56.9	11.5	237.4	0.05	T	19	420.6	10	2.0	50.0	184.2				190	6.5	8.1	49.0	5	8	2.84	0.95	10.33	0.40	17.51	0.16	73	7.50
WD56	11E3A41B	Mid. Musq.	40	gravel & sand	12/7/68	20.5	5.5	7.4	0.05	T	14	11.5	3	0	48.0	74.0				22	5.8	8.0	52.5	5	2	1.02	0.45	0.32	0.79	0.32	0.05	18	0.37
WD58	11E3A76H	Elmsvale	16	-	15/7/68	1.6	0.8	3.9	0.03	T	2	7.1	3	0	8.0	7.2				2	5.7	7.5	49.0	5	7	0.08	0.07	0.17	0.04	0.20	0.05	53	0.63
WD59	11E3A75K	Centre Musq.	21	-	15/7/68	3.2	1.2	3.5	0.01	T	2	6.2	T	0	12.0	12.8				2	5.7	7.3	43.5	5	1	0.16	0.10	0.17	0.04	0.17		39	0.47
WD60	11E3A41A	Mid. Musq.	21	till	15/7/68	23.4	23.7	7.9	0.04	T	7	12.4	T	4.0	152.0	156.0				47	6.7	8.1	54.5	5	10	1.68	1.95	0.34	0.15	0.35		8	0.25
WD61	11E3A41A	Mid. Musq.	16	-	15/7/68	30.1	10.9	26.6	0.04	T	28	35.5	5	6.0	82.0	120.0				44	6.5	8.3	51	5	20	1.50	0.90	11.6	0.58	1.00	0.08	82	10.50
WD62	11E3A42D	Mid. Musq.	110	-	15/7/68	41.7	4.4	13.1	0.38	T	7	20.4	1	6.0	114.0	122.0				34	7.1	8.5	57	10	8	2.08	0.36	0.66	0.15	0.58	0.02	21	0.60
WD64	11E3A76B	Elmsvale		gravel & sand	18/7/68	5.1	2.0	3.0	0.04	T	8	5.3	T	0	18.0	21.2				10	5.7	7.3	54.5	5	7	0.25	0.16	0.13	0.17	0.15		24	0.28
WD65	11E3A69P	Elmsvale	13	-	18/7/68	1.6	T	2.9	T	T	3	5.3	T	0	8.0	4.0				2	4.4	5.9	47.5	5	3	0.08		0.13	0.06	0.15			
WD66	11E3A42P	Mid. Musq.	103	Evaporites	19/7/68	217.4	68.0	6.7	2.40	0.02	700	10.6	T	2.0	82.0	822.0				150	8.4	8.0	56.0	45	11	10.85	5.59	0.29	37.60	0.30		1	0.10
WD67	11E3A42F	Mid. Musq.	9	gravel & sand	19/7/68	35.6	3.9	15.7	1.35	0.20	8	23.9	1	4.0	86.0	104.8				31	5.7	8.4	59.0	30	10	1.78	0.32	0.68	0.17	0.67	0.02	24	0.66
WD68	11E3A42K	Mid. Musq.	10	-	19/7/68	8.5	1.8	30.3	0.07	T	7	46.1	T	0	16.0	28.4				24	5.5	7.6	53.5	5	7	0.42	0.15	1.32	0.15	1.30		70	2.50
WD69	11E3A32N	Mid. Musq.	9	-	19/7/68	36.2	3.8	5.7	0.28	0.05	5	8.9	1	6.0	92.0	106.0				26	5.9	8.4	51.0	10	10	1.81	0.31	0.25	0.10	0.25	0.02	10	0.24
WD71	11E3A76C	Elmsvale	12	-	22/7/68	3.7	2.6	0.8	0.21	T	T	1.8	T	0	24.0	20.0				7	5.6	7.4	59.0	5	4	0.18	0.21	0.03		0.05		7	0.06
WD72	11E3A76C	Elmsvale	6	-	22/7/68	10.2	3.9	7.2	0.11	T	6	10.6	1	0	32.0	41.6				15	5.8	6.7	59	5	2	0.51	0.32	0.31	0.02	0.30	0.02	27	0.48
WD73	11E3A76C	Elmsvale	14	-	22/7/68	14.7	6.0	2.1	0.17	T	7	3.5	1	0	50.0	61.6				18	5.7	8.0	59	10	3	0.73	0.49	0.09	0.15	0.10	0.02	7	0.11

T = concentration <0.01 ppm SSP = soluble sodium percentage SAR = sodium adsorption ratio

CHEMICAL ANALYSES OF GROUNDWATERS IN THE MUSQUODOBOIT RIVER VALLEY CONT'D

Index No	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Analyses in parts per million (ppm)																				Ions in equivalents per million (epm)							
														Alkalinities							pH					Cations			Anions				
						Ca	Mg	Na	Fe	Mn	SO_4	Cl	NO_3	Phenol-pthalein as $CaCO_3$	Methyl Orange	Hardness	Ignition Loss	Total Dis-solved Solids	Suspended Matter	Specific Conductance (mhos x 10^{-5})	Field	Lab	Field Temp °F	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
WD74	11E3A76C	Elmsvale	18	gravel & sand	22/7/68	9.6	4.5	1.9	T	T	4	3.5	1	0	44.0	42.4				13	5.8	7.9	48.5	5	1	0.48	0.37	0.08	0.08	0.10	0.02	8	0.12
WD75	11E3A69P	Elmsvale	15	"	22/7/68	8.3	1.8	8.2	0.02	0.05	5	12.4	T	6.0	118.0	28.4				12	5.9	7.8	62.5	5	0	0.41	0.15	0.36	0.10	0.35		39	0.68
WD76	11E3A76B	Elmsvale	13	"	22/7/68	48.3	4.2	50.9	0.04	T	12	70.8	1	0	26.0	137.6				54	6.7	8.4	50.0	5	0	2.41	0.35	2.21	0.25	2.00	0.02	44	1.90
WD77	11E3A76C	Elmsvale		McCaffrey Brook	22/7/68	3.4	1.2	0.9	T	T	T	1.8	T	0	30.0	13.2				1	6.8	7.3	44	5	8	0.17	0.10	0.04		0.05		13	0.11
WD78	11E3A42F	Mid. Musq.	5	gravel & sand	22/7/68	33.0	4.3	26.4	0.21	T	32.0	37.2	T	0	42.0	100.0				37	6.4	8.3	55	10	11	1.65	0.35	1.15	0.67	1.05		36	1.15
WD79	11E3A41H	Mid. Musq.	13	"	22/7/68	35.4	7.5	18.1	0.05	T	12.0	23.0	6	2.0	82.0	119.2				36	5.9	8.2	54.5	5	0	1.17	0.62	0.79	0.25	0.65	0.10	30	0.83
WD80	11E3A42E	Mid. Musq.	16	till	24/7/68	26.3	3.3	0.8	0.51	T	8.0	1.8	T	4.0	88	75.2				20	7.1	8.9	50.0	25	3	1.31	0.27	0.03	0.17	0.05		2	0.03
WD82	11E3A76B	Elmsvale	14	"	24/7/68	13.0	1.7	21.5	0.08	T	17.0	30.1	1	0	32	39.2				22	5.7	7.7	52.0	5	12	0.65	0.14	0.94	0.35	0.85	0.02	54	1.49
WD83	11E3A76D	Elmsvale	11	"	24/7/68	8.2	1.9	0.8	0.10	T	2.0	1.8	T	0	40	28.4				8	5.9	7.5	50.0	5	1	0.41	0.16	0.03	0.04	0.05		5	0.05
WD84	11E3A76G	Elmsvale	17	"	24/7/68	30.9	8.9	2.2	0.17	T	4.0	3.5	T	8	128	113.6				29	7.1	8.6	56.0	5	3	1.54	0.73	0.10	0.08	0.10		4	0.09
WD85	11E3A76B	Elmsvale	9	gravel & sand	24/7/68	16.8	5.0	2.7	0.26	0.05	7.0	4.4	T	2.0	68	62.4				19	5.9	8.2	52.0	10	11	0.84	0.41	0.12	0.15	0.12		8	0.15
WD86	11E3A41D	Mid. Musq.	7	"	24/7/68	17.0	4.6	48.4		0.30	13.0	63.8	T	0	104	61.2				44	5.9	7.9	53.5	110	34	0.85	0.38	2.11	0.27	1.80		63	2.70
WD89	11E3A32Q	Mid. Musq.	10	"	24/7/68	22.6	3.1	20.7	1.71	T	14	35.4	3	0	36	69.2				29	5.3	7.7	47.5	25	22	1.13	0.26	0.90	0.29	1.00	0.05	39	1.08
WD90	11E3A42D	Mid. Musq.	8	"	25/7/68	16.0	5.4	48.7	0.23	T	12	63.8	6	0	24	62.0				40	5.8	7.3	52.5	10	7	0.80	0.44	2.12	1.80	0.10	0.10	63	2.68
WD91	11E3A41H	Mid. Musq.	9	"	25/7/68	26.9	4.3	44.3	0.16	T	11	56.7	5	20	72	84.8				42	5.9	8.1	52.5	10	16	13.4	0.35	1.93	0.23	1.60	0.08	12	0.74
WD92	11E3A41A	Mid. Musq.	12	"	25/7/68	39.8	3.2	50.1	0.21	T	11	24.8	18	10	140	112.4				49	6.0	8.4	50.0	10	0	1.99	0.26	2.18	0.27	2.05	0.02	49	1.94
WD93	11E3A41B	Mid. Musq.	10	"	25/7/68	9.8	3.1	19.2	0.02	T	11	24.8	18	0	56	37.2				42	5.9	7.4	54.5	5	6	0.49	0.26	0.84	0.23	0.70	0.20	52	1.37
WD94	11E3A41B	Mid. Musq.	39	"	26/7/68	13.0	4.3	3.3	0.02	T	9	5.3	6	0	36	50.0				17	5.9	7.9	56.5	5	2	0.65	0.35	0.14	0.19	0.15	0.10	12	0.20
WD122	11E3A69P	Elmsvale	73	"	2/9/68	52.1	5.8	2.2	0.02	T	125	3.5	T	0	26	130.0				37		6.3		5	5	2.34	0.48	0.10	2.60	0.10		3	0.84
WD123	11E3A69P	Elmsvale	73	"	3/9/68	54.5	6.8	3.7	0.22	T	150	6.2	T	0	30	164.0				43		6.1		5	0	2.45	0.56	0.16	3.12	0.17		5	0.13
WD124	11E3A69P	Elmsvale	73	"	5/9/68	26.8	8.9	3.7	0.06	T	160	6.2	T	0	45	178.0				44		7.0		5	0	2.55	0.73	0.16	3.33	0.17		4	0.12
G19	11D11D77P	Ostrea Lake	7	shallow	21/7/67		1.5	7.9	0.07	0.02	6	12.4	T	0	20	6				1		5.5		15	1		0.123	0.394	0.125	0.35		8	1.39
G20	11D11D77P	Ostrea Lake	15	"	21/7/67	15.1	4.1	10.2	0.16	0.04	8	15.9	T	0	56	55.3				16		6.3		35	8	0.75	0.34	0.44	0.17	0.45		29	0.60
G21	11D14A32K	Musq. Hbr.	12	"	21/7/67	31.3	4.3	62.9	0.08	0.02	14	97.5	7	0	38	96.6				47		6.1		5	1	1.56	0.35	2.74	0.29	2.75	0.11	59	2.78
G22	11D14A32Q	Musq. Hbr.		"	21/7/67	3.8	2.3	21.7	0.70	0.03	8	33.7	T	0	34	20.0				20		6.0		20	7	0.19	0.19	0.94	0.17	0.95		71	2.17
G23	11D14A31N	Musq. Hbr.		"	22/7/67	12.3	1.5	10.2	0.14	0.01	4	15.9	2	0	48	37.7				16		6.8		20	7	0.61	0.12	0.44	0.08	0.45	0.03	35	0.23
G24	11D14D92A	Ostrea Lake	7	"	21/7/67	27.6	1.1	9.7	0.13	0.01	10	15.1	8	4	66	74.1				24		6.8		45	9	1.38	0.09	0.42	0.21	0.43	0.13	23	0.49
G26	11D14D37A	Meagher Grant	6	till	24/7/67	23.2	12.5	5.1	0.28	0.02	10	7.9	T	8	108	110.2				26		7.5		35	25	1.16	1.03	0.22	0 21	0.22		9	0.21
G27	11D14D38D	Meagher Grant	1	"	24/7/67	32.7	17.2	5.1	0.03	0.01	4	8.9	T	12	144	153.5				35		7.6		2	8	1.63	1.41	0.22	0.08	0.25		7	0.18
G28	11D14D60C	Meagher Grant	12	"	24/7/67	21.8	4.9	3.4	0.18	T	5	5.3	T	4	80	76.6				20		6.8		15	12	1.09	0.40	0.15	0.10	0.15		9	0.17
G13	11D11D77Q	Ostrea Lake	219	quartzite	8/7/67	37.8	6.9	14.8	0.05	0.08	12	23.1	T	2	120	122.4				33		7.9		5	2	1.88	0.57	0.65	0.25	0.65		21	0.59

T = concentration <0.01 ppm

SSP = soluble sodium percentage

SAR = sodium adsorption ratio

CHEMICAL ANALYSES OF GROUNDWATERS IN THE MUSQUODOBOIT RIVER VALLEY CONT'D

						Analyses in parts per million (ppm)																				Ions in equivalents per million (epm)							
														Alkalinities							pH					Cations			Anions				
Index No	Grid Location	Area	Depth of Well (feet)	Aquifer	Date Sampled	Ca	Mg	Na	Fe	Mn	SO$_4$	Cl	NO$_3$	Phenol-pthalein as CaCO$_3$	Methyl Orange	Hardness	Ignition Loss	Total Dis-solved Solids	Suspended Matter	Specific Conductance (mhos x 10^{-5})	Field	Lab	Field Temp °F	Colour	Turbidity	Ca	Mg	Na	SO$_4$	Cl	NO$_3$	SSP	SAR
G14	11D11D77Q	Ostrea Lake	72	quartzite	8/7/67	40.2	6.9	15.4	0.03	0.05	7	23.9	2	0	136	128.4			T	33		7.2		5	1	2.01	0.56	0.67	0.15	0.67	0.03	21	0.58
G25	11D14D60C	Meagher Grant	119	limestone	24/7/67	80.2	23.6	5.7	>6	0.6	36	8.9	T	16	254	298.0				79		7.3		80	130	4.00	1.94	0.25	0.75	0.25		4	0.14
G9	11D14D86H	Elderbank	108	"	1/7/67	73.5	22.2	4.0	0.19	0.08	95	6.2	T	0	245	275.6			T	65		7.6		<5	7	3.67	1.83	0.17	2.08	0.17		3	0.10
G8	11E3A19M	Brookvale	169	shale	30/6/67	222.3	19.2	45.4	0.55	0.40	650	69.9	T	0	120	635.0				150		7.6		15	28	11.1	1.60	1.97	13.53	1.97		13	0.70
G17	11D14A31Q	Musq. Hbr.	60	slate	12/7/67	10.4	7.5	10.3	3.0	0.6	44	15.9	5	0	8.8	56.4			Low	19		5.6		<5	12	0.52	0.62	0.45	0.92	0.45	0.08	28	0.60
G12	11D14A31M	Musq. Hbr.	253	"	8/7/67	15.8	5.2	12.6	0.25	0.2	12	19.5	3	0.4	98	60.8			T	27		8.0		5	0	0.79	0.43	0.54	0.25	0.55	0.05	31	0.69
G16	11D14A32J	Musq. Hbr.	35	"	12/7/67	21.3	6.4	13.7	1.7	0.5	7	21.3	1	0	96	79.2			T	26		7.4		5	8	1.06	0.53	0.64	0.15	0.60	0.16	27	0.67
G11	11D14A41A	Musq. Hbr.	111	"	8/7/67	14.9	5.6	9.2	6.0	0.08	14	14.2	T	0	64	60.0			Low	17		6.6		40	12	0.74	0.46	0.40	0.29	0.40		25	0.51
G10	11D14A31C	Musq. Hbr.	190	"	2/7/67	28.8	9.8	70.8	1.8	.6	10	108.9	T	0	57	114.2			T	44		7.0		25	35	1.44	0.81	3.08	0.21	3.07		58	2.90

T = concentration <0.01 ppm SSP = soluble sodium percentage SAR = sodium adsorption ratio