PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES
Groundwater Section

Report 69-1

GROUNDWATER RESOURCES AND HYDROGEOLOGY of the WESTERN ANNAPOLIS VALLEY, NOVA SCOTIA

by

Peter C. Trescott

HON. PERCY GAUM
MINISTER

J.P. NOWLAN, Ph.D.
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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 Western Annapolis Valley supplements the Annapolis-Cornwallis Valley report (Department of Mines Memoir 6) by discussing the groundwater resources of the area southwest of Annapolis Royal.

The field work for this study was carried out during the summer of 1968 by the Groundwater Section, Nova Scotia Department of Mines, and is a joint undertaking between the Canada Department of Forestry 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.

It should be pointed out that many individuals and other government agencies cooperated in supplying much valuable information and assistance throughout the period of study. To list a few: Dr. J. D. Wright, Director, Geological Division and the staff of the Mineral Resources Section, Nova Scotia Department of Mines, the Nova Scotia Agricultural College at Truro, and the Nova Scotia Department of Agriculture who made available manuscript soil maps of Annapolis County.

It is hoped that information in this report will be useful for agricultural, industrial, municipal and individual water needs and that the report will serve as a guide for the future exploration, development and use of the largely undeveloped groundwater resources of the Western Annapolis Valley.

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

Halifax, October 1, 1969

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GROUNDWATER RESOURCES AND HYDROGEOLOGY OF THE WESTERN ANNAPOLIS VALLEY, NOVA SCOTIA

ABSTRACT

The investigation of the groundwater resources of the Annapolis-Cornwallis Valley is extended in this report to cover the Western Annapolis Valley from Annapolis Royal to St. Marys Bay and adjacent areas on the North and South Mountains. The hydrogeologic map with this report illustrates at a scale of 1 inch to 1 mile the bedrock and surficial geology of the area and the locations of water wells reported in selected drillers' logs.

With few exceptions, groundwater of good quality can be developed for domestic use throughout the area. Development of groundwater for municipal, industrial and irrigation use, however, will be limited to the Triassic lowland, particularly the Digby area and the area from Karsdale to Granville Ferry. These areas are underlain by Wolfville Formation sandstone and conglomerate aquifers in which wells can be completed to yield from 50 to 300 gpm. Screened wells in glaciofluvial deposits at Sea View, Clementsvale, Lequille and along the lower Allain and Moose Rivers may be able to sustain well fields yielding up to several hundred gallons per minute.

Except for a few places where the hardness and iron content of the water are problems, the chemical quality of groundwater in the area is good to excellent for most uses. Saltwater intrusion may be a problem in the future if wells of high capacity are completed near the sea.

INTRODUCTION

Purpose and Scope of the Investigation

The investigation of the groundwater resources and hydrogeology of the Annapolis-Cornwallis Valley (Trescott, 1968) covered an area from Avonport, Kings County to a point northeast of Annapolis Royal, Annapolis County. This report on the Western Annapolis Valley extends the investigation to include the remainder of the Triassic lowland in Annapolis and Digby Counties, and adjacent areas on the North and South Mountains. Included in this report are discussions of:

(1) the geology of the area,
(2) the yields which can be expected from wells in the various geologic units,
(3) the chemical quality of groundwaters, and
(4) the potential for developing irrigation, industrial, and municipal groundwater supplies.

General Description of the Area

Location, Access, and Extent of the Area

The area of investigation (also called the study area) lies between north latitudes 44°30' and 44°50' and between west longitudes 65°25' and 66°00', and covers a land area of about 270 square miles (Fig. 1). The main access to this area is provided by the Dominion Atlantic Railway, and by highways 1 (Halifax to Yarmouth), 8 (Annapolis Royal to Liverpool), and 17 (Digby to Freeport). In addition to the main highways, numerous county, farm and logging roads provide access to most of the area. Port facilities for small, ocean-going vessels are provided at Annapolis Royal and at Digby which is the terminal for ferry service to St. John, New Brunswick. The nearest commercial airport is at Yarmouth.

Physiography and Drainage

The area investigated contains parts of three physiographic units - the South Mountain highland, the Triassic lowland, and the North Mountain highland - each of which is closely related to the underlying bedrock and structural geology. South Mountain, which is underlain by erosion resistant granite and metamorphic rocks, is a gently undulating highland which slopes south and west toward the Atlantic Ocean (Goldthwait, 1924, p. 6). Lakes and swamps, mostly formed during Pleistocene glaciations, are scattered about the highland. In the study area the highland gradually decreases in altitude from the northeast, where a few places are above an elevation of 700 feet, to the southwest where

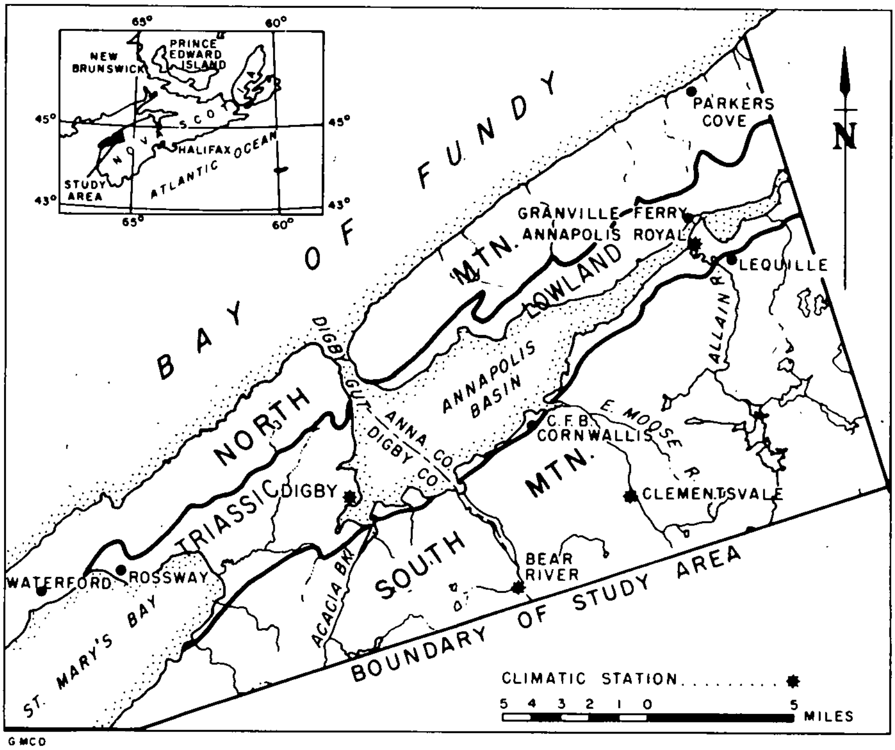

FIGURE 1. Location and physiography of the study area.

the altitude is generally less than 400 feet. Local relief on the upland usually is less than 200 feet except along the major streams, e.g. Bear River, where the relief is up to 500 feet.

In the study area, over half of the Triassic lowland, which is formed on easily eroded sandstone and shale beds, is below sea level and underlies St. Marys Bay and the Annapolis Basin. The lowland above sea level is gently rolling and rises to a maximum altitude of over 200 feet at Digby (Fig. 2). It varies in width between 2 1/2 and 4 1/2 miles.

The North Mountain highland is a cuesta capped by Triassic basalts with the scarp-slope facing the Triassic lowland and the gently dip-slope facing the Bay of Fundy. In places two distinct ridges form the crest of the cuesta; lakes and swampy areas often occupy the depressions between these ridges. Breaks in North Mountain at Rossway and Digby Gut are probably related to major, cross-cutting faults.

Drainage within the area of investigation can be resolved into three components: drainage to the Annapolis Basin, drainage to St. Marys Bay, and drainage to the Bay of Fundy. Major streams draining to the Annapolis Basin include the Annapolis River (only the estuarine part is within the study area), and the Allain, Moose, and Bear Rivers and Acacia Brook, which drain South Mountain. All other surface drainage in the area consists of short streams draining directly to the sea.

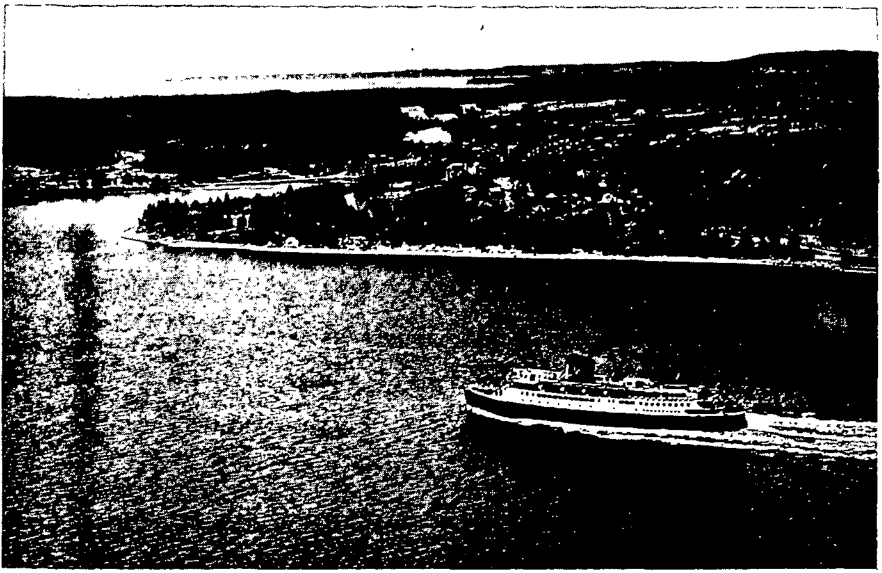

FIGURE 2. Triassic lowland from Digby to St. Marys Bay (photo by D. B. Field).

Agriculture and Soils

Most of the soils in the Western Annapolis Valley area are developed on deposits of glacial till. Glacial till is composed predominantly of material eroded and deposited within a short distance by glacial ice, and consequently it reflects the nature of the underlying bedrock. Areas underlain by granite, quartzite and basalt are mantled by thin, stony soils and rock outcrops are common. *These areas generally are suitable only for forest.* Areas underlain by slate, sandstone, and shale are mantled by moderately fine- to coarse-textured soils which generally can be classified as fair to good crop land with use restricted in places by topography, stoniness, and drainage (Hilchey, Cann, and MacDougall, 1962). Good soils are also found on the marshlands which have been reclaimed by dyking along the Annapolis River estuary and at the head of St. Marys Bay (Harlow and Whiteside, 1943). Excessive drainage conditions exist in a few areas underlain by glaciofluvial deposits. Depressional areas with poor drainage often contain organic deposits of peat.

Commercial farming in the study area consists of dairying, livestock production (including hogs, cattle, and sheep), mixed farming, and forestry. Improved land (probably less than 7 per cent of the land in the study area) is used mainly for pasture and the production of hay. Other crops include grains, potatoes, small acreages in vegetable production, and orchards which consist mainly of apple trees. Small fruit farming (mainly strawberries) is becoming more important, particularly since the start of the government horticultural project at Beaverbrook Farms near Digby. Most of the unimproved land can be classified as productive forest (perhaps 75 per cent of the study area); the remainder includes depleted forest, unproductive land and forest, and waste land (Hilchey, Cann, and MacDougall, 1962; and N. S. Dept. of Trade and Industry, 1964, 1968a, and 1968b).

Population and Industry

The population of Annapolis and Digby Counties was 41,406 in 1966, only 15 per cent greater than it was in 1900 according to the Dominion Bureau of Statistics. This lack of growth is reflected in population statistics for the larger communities and towns in the study area (Table 1).

Table 1. Population Changes in the Western Annapolis Valley, 1951-1966

Community	Population* 1951	1956	1961	1966	Per Cent Change 1951-1966
Annapolis Royal - Lequille	1,260	1,246	1,298	1,315	+ 4
Bear River	1,064	1,142	830	679	-36
Clementsport	497	389	519	424	-15
Digby	2,047	2,145	2,308	2,305	+13
Granville Ferry	608	376	471	381	-37
Totals	5,476	5,307	5,426	5,104	- 7

* Dominion Bureau of Statistics

Those living in the towns of Annapolis Royal and Digby are classified as urban dwellers; all others in the study area, perhaps 80 per cent of the population, are classified as rural dwellers.

The economy of the area is based on fishing, agriculture, forestry, the recruit training base at CFB Cornwallis and on tourism. Digby is the principal port where fish are landed, processed and exported. Annapolis Royal is the port through which most of the forest products of the area (mainly pulpwood) are exported. Manufacturing is only of minor importance and mining is limited to removal of sand and gravel from glaciofluvial deposits for aggregate and road fill (N. S. Dept. of Trade and Industry, 1967, 1968a, and 1968b).

Climate

Nova Scotia's humid, temperate, continental climate is modified by the Atlantic Ocean which almost completely surrounds the province and by the Gulf Stream which runs northeasterly parallel to the Atlantic coast. The proximity of the ocean tends to prevent extreme temperatures in the summer and winter, and minimizes the number of severe atmospheric storms (N. S. Dept. of Trade and Industry, 1965). In the Western Annapolis Valley, the North and South Mountains modify precipitation, temperatures and winds to some extent.

Climatic records are available for four locations in the study area: long-term records are available for Annapolis Royal and Digby; shorter records for Bear River and Clementsvale (Fig. 1). Precipitation and temperature data for Annapolis Royal and Digby are given in figures 3 and 4. Annapolis Royal has a mean annual snowfall of 76 inches whereas mean annual snowfall at Digby is only 46 inches, a large difference for stations only 14 miles apart. This is probably due to slightly lower temperatures and higher precipitation at Annapolis Royal during the winter months. The mean frost-free period decreases up the valley from 159 days at Digby (39 years of record) to 126 days at Kentville (50 years of record).

For high yields from fruit and vegetable crops, optimum soil moisture conditions should be maintained during the growing season. Soil moisture deficits during this season, therefore, are of concern to farmers who grow cash crops. Soil moisture is a function of many variables including precipitation, potential evapotranspiration, vegetation, soil infiltration capacity and soil moisture storage capacity. Potential evapotranspiration, that amount of water which would be evaporated and transpired if continuously available, has been calculated for Annapolis Royal using Thornthwaite's (1948) method. These values have been used to calculate Holmes and Robertson (1959) moisture budgets (Fig. 5) for a sandy loam soil at Annapolis Royal for the years 1965-1968 (calculations were made with a computer program by Freeze, 1967). The Holmes and Robertson (1959) moisture budget considers the fact that evapotranspiration decreases below the potential rate as soil moisture storage is utilized. When a moisture surplus occurs during a month, it is assumed to contribute to groundwater recharge and direct runoff. During those months when there is a deficiency of

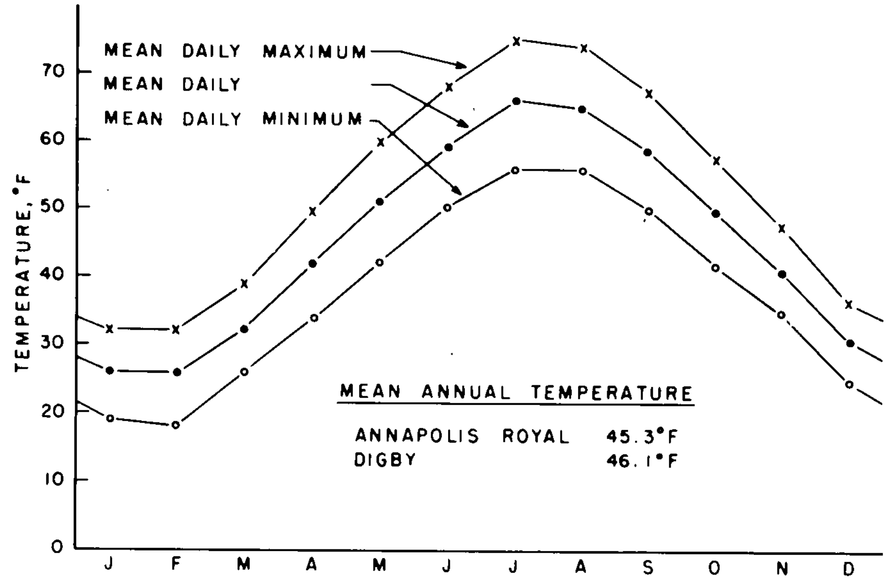

FIGURE 3. Mean temperature distribution in the Western Annapolis Valley (based on 30-year normals for Annapolis Royal and adjusted normals for Digby, Canada Dept. of Transport, Met. Branch, 1967).

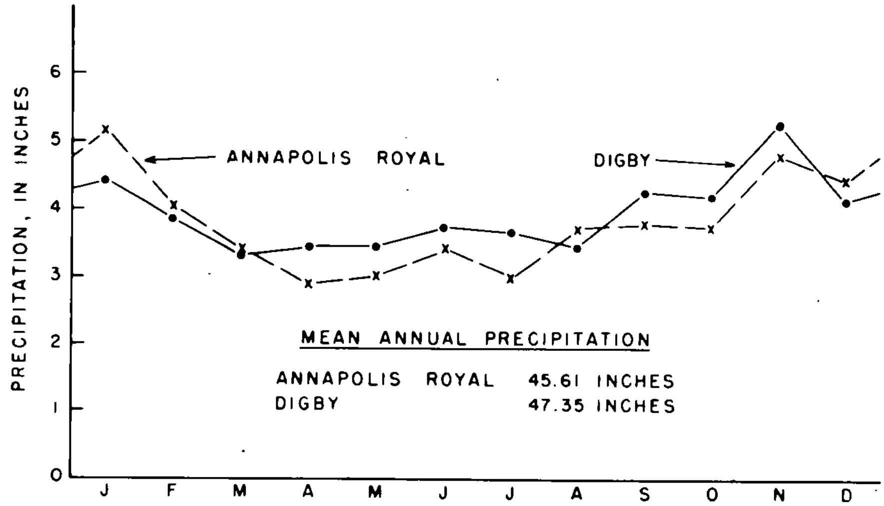

FIGURE 4. Mean precipitation distribution in the Western Annapolis Valley (based on 30-year normals, Canada Dept. of Transport, Met. Branch, 1967).

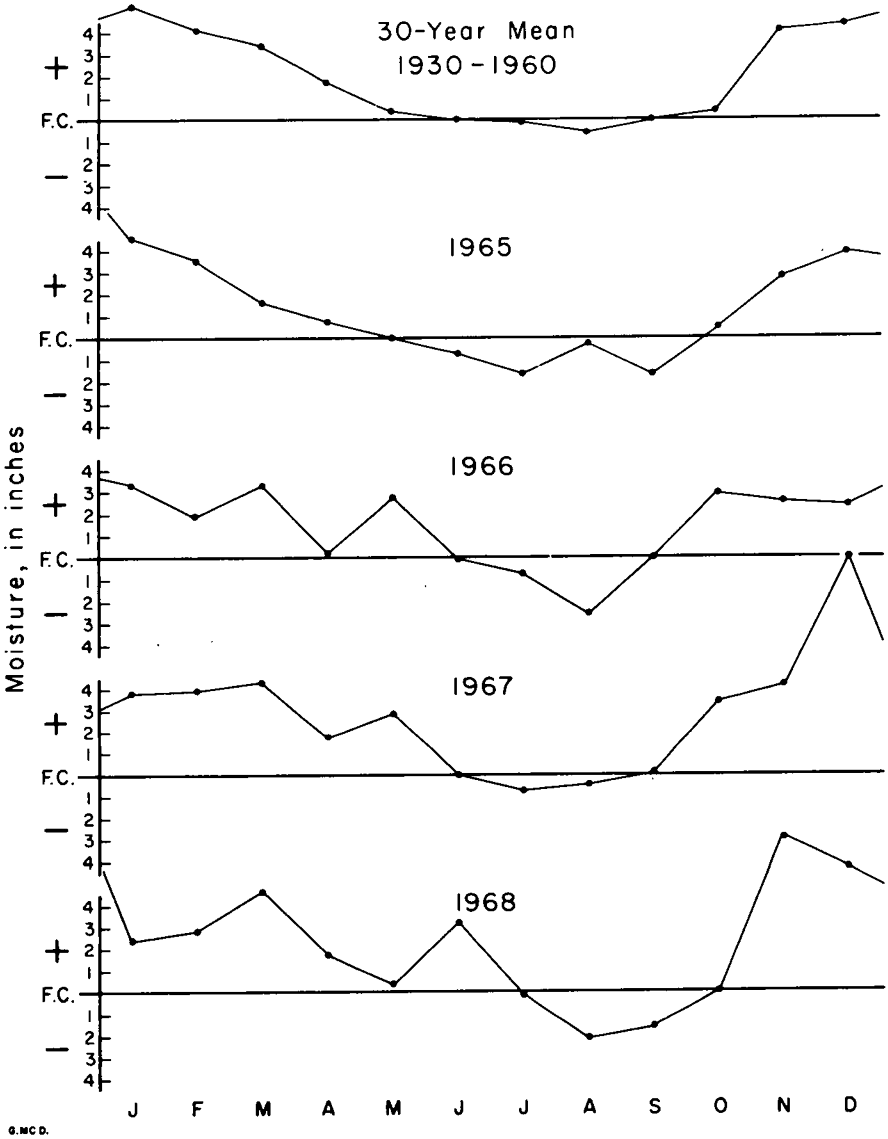

FIGURE 5. Moisture budgets for a sandy loam soil at Annapolis Royal for the years 1965 - 1968 and mean values for a 30-year period (+ = moisture surplus, - = moisture deficit, F.C. = field capacity).

precipitation, the moisture deficit is the monthly average, in inches, below soil field capacity (the amount of water retained in the soil after gravity drainage). Soil moisture deficits during the growing seasons for loam, silty loam, clay loam and silty clay loam soils are usually less (only 60 per cent of that for sandy loam soils in some cases) because of their larger moisture storage capacities. If mean monthly precipitation for Annapolis Royal could be depended upon, very little irrigation would be needed to maintain optimum soil moisture conditions. It is apparent from figure 5, however, that large soil moisture deficits may develop in individual years due to a deficiency of rainfall for several weeks or months during the growing season. Consequently supplemental irrigation should be available to assure maximum crop yields. A discussion of irrigation requirements for various crops and soil types is beyond the scope of this report. For detailed information refer to pertinent Dept. of Agriculture publications (for example, Coligado, Baier, and Sly, 1968).

Land Survey System

The grid system used by the Nova Scotia Department of Mines for locating wells in the province is based partly on the National Topographic System. Under this system, Canada has been divided into numbered primary quadrangles, each 4° latitude by 8° longitude; the study area is included in primary quadrangle 21. The quadrangles are divided into 16 sections identified by letters, and the sections are divided in turn into 16 standard topographic map sheets identified by numbers. The Digby Map (21 A 12) includes most of the study area (see Map 1). For location by mining tract and mining claim, each map is divided into four reference maps with the 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 6 illustrates the location of a hypothetical well in claim 21 A 12 A 47 H.

Previous Investigations

Aside from climatic records, information on the hydrology of the Western Annapolis Valley is limited to water-well drilling records filed with the Nova Scotia Department of Mines since the inception of Well Drilling Act of 1965 and pertinent information in Trescott (1968). In adjacent areas, discharge records are available from the Water Survey of Canada for the Metegan River at Metegan (since 1964) and for the Annapolis River at Wilmot (since 1963).

The first important and comprehensive geologic report and map of Nova Scotia was compiled by Dawson (1855 and later editions). Southwestern Nova Scotia was mapped at a scale of 1 inch to 8 miles and discussed in greater detail by Bailey (1896). Recent work in the area includes unpublished maps by Smitheringale (1959) and Klein (1960), a map of 21 A published at a scale of 1 inch to 4 miles (Taylor, 1962), and a synthesis of Silurian stratigraphy in south-

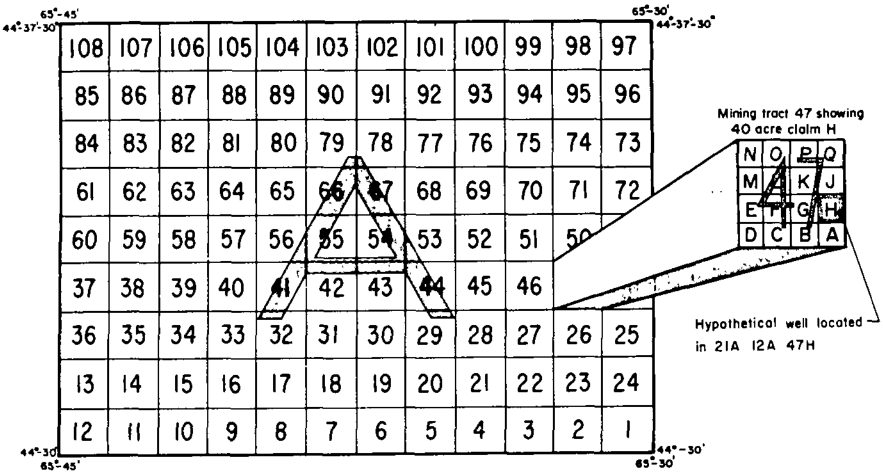

FIGURE 6. Reference map 21A12A subdivided into mining tracts.

western Nova Scotia (Taylor, 1965).

The Triassic age of the rocks forming the Annapolis-Cornwallis Valley was suggested by Dawson (1848). Powers (1916) made the first regional stratigraphic study of the Triassic rocks in Nova Scotia and included all Triassic sedimentary strata underlying the North Mountain Basalt in the Annapolis Formation. The lower member of the Annapolis Formation was named the Wolfville sandstone and the upper member, the Blomidon shale. Klein (1962) studied the stratigraphy, depositional environments, and petrology of Triassic rocks in the Maritime Provinces, and proposed including all of them in the Fundy Group and elevating the Wolfville and Blomidon members to formational status. Recent studies have been made of the geology of North Mountain (Lollis, 1959; Hudgins, 1960; and Koskitalo, 1967).

Dawson (1893) made early observations on the glacial features of Nova Scotia. Goldthwait's (1924) description of the physiography of Nova Scotia includes discussions of geomorphic evolution and effects of glaciation in Nova Scotia. Pleistocene deposits in the Digby area were mapped by Swayne (1952). Soil maps (Harlow and Whiteside, 1943; Hilchey, Cann, and MacDougall, 1962; and of Annapolis County, in press) were used as a guide to the distribution of surficial deposits.

Field Work and Maps

Field work, carried out during the summer of 1968, included mapping of surficial deposits, mapping boundaries of Triassic formations, location of wells reported in selected driller's logs, collection of groundwater samples for chemical analysis, and supervision of test drilling and pumping tests at Digby. Mapping was done in the field on aerial photographs at a scale of 1:24,000 (flown 1967) and was transferred to 1:50,000 National Topographic Series maps. Chemical analyses of groundwater samples were made at the Nova Scotia Agricultural College, Truro.

Acknowledgments

This investigation, under the direction of John F. Jones, Chief, Groundwater Section, Nova Scotia Department of Mines, was jointly sponsored by the Canada Department of Forestry and Rural Development (under authority of the Agricultural and Rural Development Act) and the Province of Nova Scotia.

Jim Gunn provided very able assistance in the field. Mapping and gathering of basic data were facilitated by the co-operation of the water-well drillers who operate in the area and by many of the residents of the Western Annapolis Valley. The hydrogeologic map and illustrations in this report have been drafted by D. Bernasconi and his staff of the Cartographic Division, Nova Scotia Department of Mines.

GEOLOGY

Introduction

This section is intended as a background for the following section on the water-bearing properties of the various rock units and surficial deposits. Description of the bedrock units includes their distribution, thickness, lithology, structural relations, metamorphism and age. Surficial deposits are grouped according to their origin and composition. The structural deformation and geomorphic evolution which are responsible for the present distribution of geologic units are summarized at the end of this section.

Rock Units

Meguma Group

From Upper Clements southwestward in the study area, South Mountain is formed primarily on rocks of the Meguma Group. The older Goldenville Formation (Lower Ordovician or earlier) underlies the area southwest of Marshalls Town. It is composed primarily of quartzite and greywacke but includes a few slate beds. The younger Halifax Formation (Lower Ordovician) is present between Marshalls Town and Upper Clements. It is composed mostly of "... thinly interlaminated, medium to light grey, fine-grained quartzite and dark grey, argillaceous siltstone ..." (Smitheringale, 1960, p. 11). Slaty cleavage in these rocks strikes northeasterly and dips steeply to the southeast. The total thickness of Meguma rocks is unknown but probably exceeds 10,000 feet in the study area. "The Goldenville-Halifax contact is probably conformable" (Smitheringale, 1960, p. 7).

White Rock, Kentville and Torbrook Formations

In the area from Bear River to Clementsvale, rocks of the White Rock, Kentville and Torbrook Formations are present in a synclinal structure. In the study area, the White Rock Formation (Upper Silurian or earlier) comprises siltstones, two quartzite beds and a thin bed of basic volcanic rock with dark grey, 'featureless', arenaceous siltstone the dominant rock type (Smitheringale, 1959, cited in Taylor, 1965). The overlying Kentville Formation (Upper Silurian) is lithologically similar to the Halifax Formation and is characterized in the study area by "... a 'featureless' siltstone with rare limy, arenaceous lenses ..." (Smitheringale, 1959, cited in Taylor, 1965, p. 12). The youngest formation in this metamorphic sequence, the Torbrook Formation (Lower Devonian), is composed of fossiliferous sedimentary iron formation and interbedded shales, siltstones, quartzites and limestones. The total thickness of these units in the study area is estimated at 7,500 feet.

> "The contacts between the Halifax, White Rock, Kentville, and Torbrook formations are gradational. [These formations] ... represent more or less continuous accumulation, from Ordovician through Lower Devonian time, of about 19,000 feet of marine-shelf sediments and minor volcanics" (Smitheringale, 1960, p. 7).

Granite

In the area from Upper Clements to Lawrencetown, South Mountain is formed on the Southern Nova Scotia Batholith. This batholith is typically composed of a quartz-feldspar-biotite granite (often including large phenocysts of feldspar) which intruded the lower Palaeozoic metamorphic rocks. The granite intrusions are probably post-Lower Devonian and may be as young as Late Devonian in age (Smitheringale, 1960, p. 25).

Wolfville Formation

The Western Annapolis Valley is formed on rocks of the Upper Triassic Wolfville Formation. These rocks dip gently from 6 to 12 degrees to the northwest and overlie with angular unconformity the deformed Palaeozoic rocks forming the South Mountain highland. Assuming an average dip of 8 degrees and an outcrop width of 12,000 feet, the formation is about 1,700 feet thick.

Due to the thick cover of glacial drift, outcrops of the Wolfville Formation are rare within the study area. Stratigraphic information, therefore, is based on samples from five test holes drilled in the Digby area. They penetrate a total of 1600+ feet of section, but this includes an unknown amount of stratigraphic over lap (see graphic logs, Appendix A). The formation is composed of interbedded, reddish brown (and a few grey) sandstones, conglomerates, siltstones and claystones. Silty sandstones (poorly sorted mixtures of sand, silt and clay) constitute over 50 per cent of the total section. Relatively clean sandstones with fair to good sorting are next in abundance (about 30 per cent). Poorly consolidated, clean, fine-grained conglomerates over 30 feet thick were penetrated in two test holes within the Town of Digby. Claystones and siltstones constitute about 13 per cent of the section.

According to Klein (1962) the coarse- to medium-grained clastic rocks represent alluvial fan, transition zone alluvial fan-flood plain, and some deltaic deposits. These depositional environments typically produce rapid variations in lithology, both vertically and horizontally. It is difficult, therefore, to correlate test holes even a thousand feet apart. The even-bedded siltstones and claystones are a minor facies in the Wolfville Formation but they predominate in the overlying Blomidon Formation where they represent lacustrine deposition (Klein, 1962).

Blomidon Formation

From Rossway to the Minas Basin, the scarp-slope of North Mountain is formed on rocks of the Blomidon Formation (Upper Triassic). Assuming an average dip of 8 degrees the formation is estimated to be 750 feet thick.

The Blomidon Formation is well exposed along and northwest of Red Bluff near Rossway. In this area Klein (1960) measured two sections which illustrate the type of lithology typical of this formation (see graphic logs, Appendix A). The predominate reddish brown, even-bedded siltstones and claystones (nearly 90 per cent of the measured sections) are interbedded with a few sandstone channels and beds (Fig. 7). The coarser clastics are more prevalent near the base of the formation but may be found scattered throughout the section. The coarser facies represent incursions of fluvial and deltaic deposition in a dominant lacustrine environment.

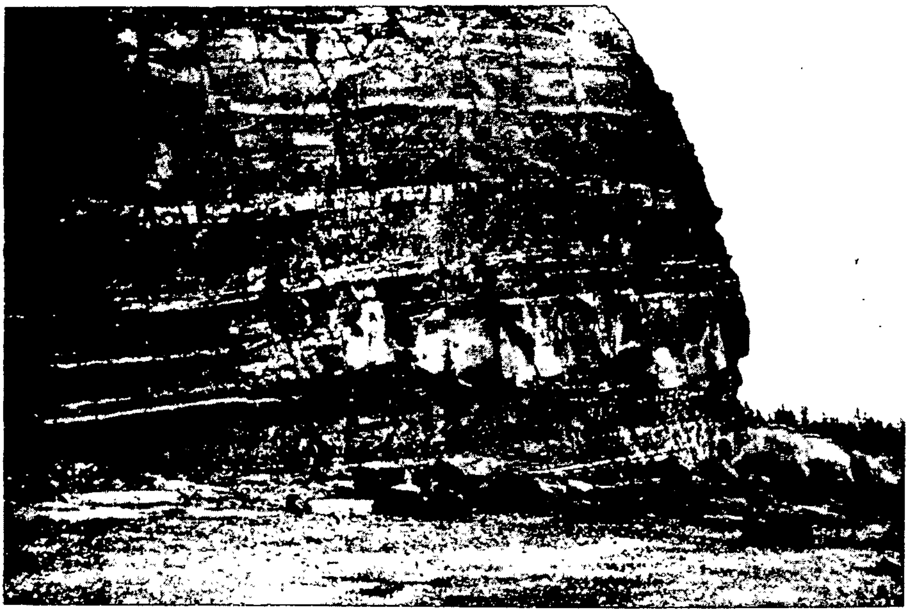

FIGURE 7. Sandstone channel (maximum thickness 12 feet) in Blomidon Formation at Red Bluff (21A12B64H).

The Blomidon Formation may contain thin gypsum lenses although none were seen in the study area. A borehole at Margaretsville, for example, penetrated 546 feet of the Blomidon Formation including a few gypsum lenses up to 6 inches thick (Koskitalo, 1967). Blomidon strata that have been baked and bleached by heat from the overlying basalt can be observed north of Granville Ferry and near Victoria Beach. These contact metamorphic effects, though not present everywhere, have been noted elsewhere, e. g. at Margaretsville where a borehole penetrated 9 feet of bleached shale below the base of the North Mountain Basalt (Koskitalo, 1967).

North Mountain Basalt

Capping North Mountain and conformably overlying the Blomidon Formation are the flows and sills (?) of the North Mountain Basalt (Upper Triassic). All of the basalts can be classified as tholeiites (Klein, 1957; and Lollis, 1959). West of the study area they have been grouped into three members which can be distinguished at least as far east as Digby Gut (Lollis, 1959). The lower and upper members are relatively resistant to erosion and form two ridges which are prominent southwest of Digby Gut. The middle member, more susceptible to erosion, underlies the depression between the ridges.

The lower member, 600 feet thick, probably crystallized from a single melt. Its increasing density with depth, coarse grain size, mineralogical composition and thickness are all evidence that the unit is a sill. "Only amygdules near the top suggest that the unit is a flow" (Lollis, 1959, p. 30). The middle member, 300 feet thick, consists of three or more flows. The upper member is massive except for a columnarly jointed zone at the base and apparently formed as a single unit 500 feet thick either as a flow or possibly as a sill (Lollis, 1959). In determining the thicknesses given above, Lollis (1959) assumed an average dip of 10 degrees at Petit Passage where the sections were measured. Boreholes located near Freeport and Westport (Koskitalo, 1967) penetrated sections similar to those measured at Petit Passage.

The North Mountain Basalt has a somewhat different composition northeast of Digby Gut where the ridge representing Lollis (1959) upper member is not as prominent. The stratigraphy in this area may be more like that at Margaretsville where a borehole penetrated eighteen flows of which the upper seventeen are an average of 32 feet thick (Koskitalo, 1967). The basal flow [sill ?] is a massive basalt 200 feet thick which may correlate with Lollis (1959) lower member.

A large variety of minerals including zeolites and various forms of quartz are present in the amygaloidal part of the basalt and as joint fillings.

Surficial Deposits

Glacial till

Glacial till is the most common surficial deposit found in the study area. Its composition and thickness strongly reflect the nature of the underlying bedrock. Thin sandy tills including numerous boulders are present in areas underlain by quartzite, granite, and basalt. Relatively thick, heavier-textured tills, sometimes including lenses of sand and gravel, mantle areas underlain by sandstones, shale and slate. (For the distribution and composition of various till deposits, see Hilchey, Cann, and MacDougall, 1962; and the Soil Survey of Annapolis County, in press.) Glacial drift (which includes till and stratified drift) reported in drillers' logs for thirty-four wells selected from Appendix B is an average of 65 feet thick in the area underlain by the Wolfville and Blomidon Formations. Drillers reported penetrating over 200 feet of drift in places.

Glaciofluvial Deposits

Glaciofluvial deposits in the study area are all ice-contact stratified drift. Such deposits were "... built in immediate contact with wasting ice" (Flint, 1957, p. 136). These deposits, principally kames and a few eskers, are found along the south side of the Triassic lowland, scattered along South Mountain, and on North Mountain northeast of Delap Cove.

Kame deposits are mainly irregular hills of stratified sand but usually include interbedded silt, gravel and boulders in varying amounts depending on the nature of the source material (Fig. 8). In some areas it is difficult to map these deposits, particularly in granite terrane where stratified sand and gravel may

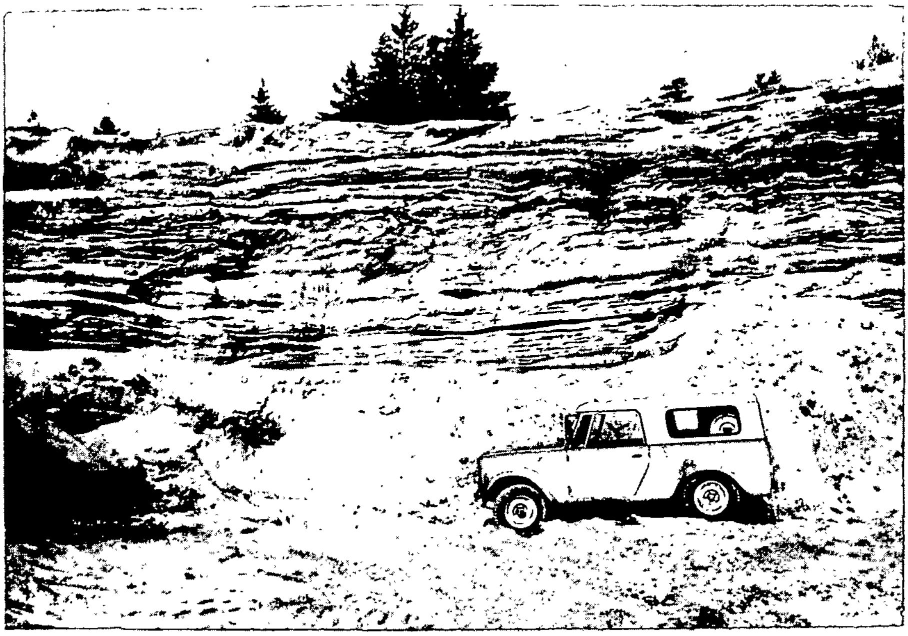

FIGURE 8. Kame deposit consisting mostly of stratified sand at Upper Clements (21A12D70G).

grade into unstratified sand and gravel (till). In other areas where several feet of poorly sorted ablation till often overlie stratified drift, it is difficult to establish that suspected kames are present without the benefit of road cuts and gravel pits. A few kame deposits cover an area up to a square mile or more and may be more than 100 feet thick in places (e.g. at Lequille, Seaview and Clementsvale). One driller has reported 150 feet of sand and gravel at Seaview (see Index No. 53, Appendix B). Most kame deposits in the study area, however, are smaller features. Some thin deposits of stratified sand and gravel along the shore of St. Marys Bay and Annapolis Basin may be raised beach deposits (Hilchey, Cann, and MacDougall, 1962, p. 37). Rather than spending time in the field determining their precise origin, the writer mapped these deposits as stratified drift, a classification suitable for the purposes of this report. Along the Bay of Fundy shore, however, several deposits composed almost exclusively of basalt detritus have been classified as raised beaches.

Eskers, linear ridges of stratified sand and gravel which were deposited in subglacial channels, are found mostly on North Mountain in the vicinity of Parkers Cove.

Estuarine Deposits

Estuarine deposits of silt and clay are present in places adjacent to the Annapolis River estuary near Annapolis Royal. The silt and clay beds were deposited during ablation of the last ice sheet while the sea was above its present level. The deposits are even bedded, reddish brown or brown in colour, and are composed of moderately stiff clay, silt and very fine sand.

Southwest of Deep Brook estuarine deposits are exposed in a few places along wave-cut cliffs (see Map 1). These silt and clay beds are usually overlain by stratified sand and gravel which may be either beach deposits or stratified glacial drift (see discussion above).

Dykeland, Salt Marsh and Tidal Flat

Since the sea stabilized at its present level, tidal flats have formed along the estuarine part of the Annapolis River and at the head of St. Marys Bay, partly in response to the large tides experienced in this area. (Mean tidal range at Annapolis Royal, for example, is 23.5 feet.) Many of these areas have been reclaimed by dyking to form rich farm land. Active deposition of silt and clay continues on salt marsh and tidal flat beyond the protection of the dykes and on former dykeland where the dykes have been breached (e.g. south of Annapolis Royal).

Stream Alluvium

Recent alluvium is being deposited in a few places where streams have formed flood plains within the study area. Most alluvial deposits are fine textured, consisting of clay, silt and fine sand. The flood plain along the lower reach of the Moose River, however, is composed of sand, gravel and boulders. This deposit, probably formed mostly during the late Pleistocene glaciations, may extend to a depth of a hundred or more feet. Department of Highways borehole logs reveal that similar deposits extend to a depth of more than 150 feet below sea level at bridge sites over the Allain and Bear rivers.

Peat and Muck

Glaciation left much of the drainage on South Mountain deranged. Many shallow lakes soon became swamps and filled with peat and muck. A few similar swampy areas are found on North Mountain.

Structure

The most significant structural feature in the area is the Fundy Homocline (MacNeill and Take, 1966), the gently dipping southeastern limb of a large synclinal structure which underlies the Bay of Fundy. This structure may be, in part, an accentuation of the slowly subsiding late Triassic sedimentary basin in which the Fundy Group was deposited. The Fundy Homocline, together with the erosional history of the region, is responsible for the linear configuration of the Western Annapolis Valley and North Mountain.

North Mountain has been offset in several places by major north-striking faults which dip, in general, to the east (MacNeill and Take, 1966). Two of these faults, at Rossway and Digby Gut, are shown on Map 1. The one at Digby Gut probably extends to the south where its existence would explain the offset of Triassic rocks at Acaciaville. MacNeill and Take (1966) show two other faults which may explain offsets in the North Mountain scarp near Thorne Cove and Karsdale.

Geomorphology

The South Mountain highland and the crest of North Mountain are the remains of an erosional surface formed throughout eastern North America in the Cretaceous. During uplift of this surface in the late Cretaceous or early Tertiary, the Annapolis River, tributary to the ancestral Bear River which drained northward through Digby Gut, eroded the relatively weak Triassic sedimentary rocks of the western Annapolis Valley east of Digby (Haycock, 1900, p. 297, Goldthwait, 1924). The western part of the study area was drained by a subsequent stream ancestral to St. Marys Bay. Bedrock depressions at the mouth of the Allain and Bear rivers (based on Dept. of Highways borehole logs) indicate that the sea was 150 or more feet below its present level at times during this erosion cycle.

Glacial erosion and deposition during the Pleistocene are responsible for many local topographic features, but did not alter the gross features of the region which are bedrock controlled.

Raised estuarine and beach deposits mapped in and adjacent to the study area by the writer and others (Goldthwait, 1924, p. 151; Lollis, 1959, p. 97; Hickox, 1962, p. 28; and Trescott, 1968, p. 62) indicate that the sea during ablation of the last ice sheet was up to 80 feet above its present level in this area. Sea level in the last few thousand years, however, has been relatively stable (Goldthwait, 1924, p. 173).

HYDROSTRATIGRAPHIC UNITS

Introduction

A hydrostratigraphic unit is defined as a group of geologic materials which have similar water-storage and -transmitting properties. The coefficient of storage is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface (Theis, 1935). Under water-table conditions, the coefficient of storage with time approaches the specific yield, the ratio of the volume of water that can be obtained by gravity drainage to the total volume of the material (common specific yield values range from 0.01 to 0.2). Under artesian conditions, water released from storage is derived chiefly from compression of the aquifer skeleton and secondarily from expansion of the water itself (common values range from 0.0001 to 0.001).

A material's water-transmitting property is termed its permeability. In this report the coefficient of permeability is defined as the rate of flow of water through a one square foot cross-section of aquifer under a gradient of one foot per foot. The permeability of an aquifer times its thickness is the aquifer's coefficient of transmissibility which in this report has the units of imperial gallons per day per foot (gpd/ft.).

The aquifer coefficients of transmissibility and storage, which can be determined from properly run pumping tests, can be used to calculate pumping rates suitable for long-term production and to predict drawdown in the aquifer after given pumping periods. In the study area, reliable pumping-test data are available only for two wells constructed in the Wolfville Formation. For other geologic units, average well yields have been estimated from drillers' bail tests and from other information. Driller's tests are most useful if the drawdown has been recorded. If information on the drawdown is not available, the discharge rate during the test should be used judiciously as an estimate of the long-term well yield because this rate is often a function of the equipment used and may range from considerably less than to much greater than the long-term well capacity. Furthermore, the tests are usually of short duration (1 to 2 hours). In many reports the average yield of wells in various units is given without consideration of the depth of individual wells. In this report, to eliminate the depth variable, average yields are given in terms of gallons per minute (gpm) per hundred feet of section below the water-table.

Bedrock Hydrostratigraphic Units

Slate and Quartzite

The Palaeozoic metamorphic sequence from the Goldenville through the Torbrook Formations consists of dense rocks which, for all practical purposes, yield no water in the unfractured state. These strata, however, are all fractured and consequently have some capacity to store and transmit groundwater. The most numerous fractures in slate, siltstone and shale follow their northeast trending bedding and cleavage, making permeability in these rocks strongly anisotropic. As a consequence of the more even distribution of joints in various directions in greywacke and quartzite, permeability in these rocks is less anisotropic.

Based on drillers' tests for sixteen wells in the study area and on pumping tests conducted on three wells at Kejimkujik Park, the average yield from wells in slate and quartzite is estimated to be 2 gpm per hundred feet of saturated section. Where pumping is intermittent (e.g. for domestic demand), pumping at rates of 4 to 5 gpm per hundred feet of saturated section can be sustained for short periods while storage in the well is utilized.

Where wells producing more than a few gallons per minute are required in metamorphic terranes, it is sometimes possible to locate zones with exceptional permeability. For example, the zone of slightly weathered rock commonly found at the base of glacial till and above fresh rock may be ten times more permeable than the unaltered rock (Davis and DeWeist, 1966, p. 320). Often, however, this zone of 'broken rock' is cased off even though water in this zone could be recovered through screens or even perforated casing. Where brittle greywacke and quartzite are present, above average permeability can be expected along the crests of folds and in fault zones except where the fractures in these areas have been filled by secondary mineralization. The maximum number of water-bearing fractures in slate, siltstone and shale terranes will be penetrated by wells drilled perpendicular to cleavage and bedding. In many locations, however, this will mean drilling nearly horizontal wells which are usually practical only near the base of hills. No wells in slate with exceptional yields are known in the study area, but in Kejimkujik Park, one well drilled 250 feet in slate has been rated at 50 gpm.

Granite

Permeability in granite is due almost entirely to joints except near the surface where weathering has produced some intergranular permeability. The most common joints in granite tend to parallel the regional surface and have been attributed to release of confining pressure as the overlying rock is eroded. These joints decrease in number and tend to close with depth due to the weight of the overlying material. Consequently, the best prospects for finding an adequate water supply in granite are in the upper 250 feet. Several workers (summarized in Meinzer, 1923) recommend that a well drilled to such a depth without success should be abandoned and another well drilled a hundred or more feet away.

The average yield (based on drillers' reports) for three wells in granite in the study area is estimated to be 2 gpm per hundred feet of section. The yield from such wells, however, may range from less than 1 gpm to more than 40 gpm per hundred feet of section. Of two wells in granite near Lawrencetown, for example, one was a failure and the other on a neighboring property was tested at more than 45 gpm (Trescott, 1968, p. 41).

Wolfville Formation

The most important aquifers in the Western Annapolis Valley are the clean sandstones and conglomerates in the Wolfville Formation. Some of the original intergranular porosity in these rocks is still available for groundwater storage and transmission because the rocks are only partly cemented. (Many of these rocks are so poorly cemented that sand is eroded from them during pumping from an open borehole.) Pumping tests were conducted on two test wells drilled into the Wolfville Formation near the Town of Digby (see Fig. 9). One well (Index No. 26) is 433 feet deep and has 165 feet of casing; the other (Index No. 27) is 400 feet deep and has 56 feet of casing. At both sites the aquifer coefficients of transmissibility and storage were calculated to be 2,600 gpd/ft. and 1.2×10^{-4}, respectively. The transmissibilities are essentially the same because each well penetrates about 130 feet of clean sandstones although the stratigraphic sections overlap only in part. The coefficient of storage is similar to that calculated for Wolfville Formation aquifers elsewhere in the Annapolis-Cornwallis Valley (Trescott, 1968, p. 42).

The permeability of poorly sorted, silty sandstones is considerably less than that of the clean sandstones and conglomerates because the larger voids in silty sandstones are filled with fine sand, silt and clay. Consequently permeability in silty sandstones, as in siltstones and claystones, is primarily through fractures and in thin stringers of relatively clean sandstones. Although these fine-grained rocks are essentially confining beds, they store water which may be released slowly as the potential is lowered due to a pumping stress in adjacent artesian aquifers. This leakage, when summed over the area of the cone of depression, is often enough to sustain the yield from a well and considerably increase its projected life.

The safe yield for each of the two wells at Digby (assuming proper construction with screens and gravel packs, a 20-year life, and no leakage from confining beds) was calculated to be 210 gpm. Including pumping test information from six other wells drilled in the Wolfville Formation in the Annapolis-Cornwallis Valley, the average long-term well yield is 95 gpm per hundred feet of saturated section. Yields from wells drilled primarily in silty sandstones will be considerably less than this value while yields from wells which derive water from clean, well-sorted conglomerates like those underlying the Town of Digby will be considerably more. Well yields will be limited along the south side of the Triassic lowland where the Wolfville Formation wedges out and in areas adjacent to the sea where wells pumped at full capacity may cause saltwater intrusion.

FIGURE 9. Pumping test conducted on test well 3 (Index No. 27) at Digby (discharge during test was 90 gpm).

Blomidon Formation

Wells in the Blomidon Formation derive their water primarily from thin sandstone stringers and lenses and secondarily from joints in siltstones and claystones. The nature of permeability in the Blomidon Formation can be observed along Red Bluff near Rossway where groundwater seeps from the more permeable beds and joints near the base of the cliff. The sandstone stringers are responsible for many of the springs along the North Mountain scarp. Other springs, some of which are shown on Map 1, appear along the contact between the Blomidon Formation and the North Mountain Basalt.

The average well in the Blomidon Formation will yield no more than a few gallons per minute per hundred feet of section. A well (Index No. 9) drilled at Rossway is typical. In a few places wells should penetrate enough sandstone lenses to yield up to 40 gpm per hundred feet of section. A well (Index No. 28) north of Digby, for example, has an above average yield. Near the base of the Blomidon Formation, wells commonly tap the more productive aquifers in the upper beds of the Wolfville Formation.

North Mountain Basalt

Much of the original fracture permeability in the North Mountain Basalt has been lost due to secondary mineralization. The remaining permeability is found mostly along the contacts between flows. Groundwater can be observed seeping from some of these contacts along the sea cliffs of the Fundy shore. Columnar joints and vesicular zones probably store and transmit small amounts of groundwater.

For the five wells in basalt reported in Appendix B, the yield per hundred feet of saturated section ranges from less than 1 gpm (Index No. 33) to 20 or more gpm (Index Nos. 8 and 94). Wells in massive basalt are sometimes failures. For example, a well drilled in massive basalt at Valley View Park north of Bridgetown was continued into the underlying Blomidon Formation before enough water was obtained for a domestic supply.

Surficial Hydrostratigraphic Units

Glaciofluvial Deposits

Glaciofluvial deposits are more permeable and store more water per unit volume than any other hydrostratigraphic unit in the study area. The permeability of these deposits, for example, is from ten to one hundred times greater than that of the best aquifers in the Wolfville Formation, and the storage coefficient of sand and gravel deposits often approaches their specific yield.

The deposits at Sea View, Clementsvale and Lequille may be large enough to support two or more wells producing up to 100 gpm. Long-term development will depend on the amount of recharge (natural and induced) to the system because storage is limited. Where these deposits are hydraulically connected to the sea, development will be limited to skimming off the freshwater layer. Development of smaller kames and eskers will be restricted to domestic supplies obtained from sand points, dug wells, and springs emerging from the base of the deposits. In some places stratified sand and gravel lenses may be found in glacial till (Fig. 10). Screened wells in these lenses may yield moderate amounts of water. (Note that the few wells in sand and gravel reported in Appendix B *should not be considered indicative of the potential of these deposits.)*

Other Surficial Deposits

Except for the scattered glaciofluvial deposits, surficial deposits in the

FIGURE 10. Glacial till overlying stratified sand near Digby (pick head is at the contact; 21A12B96E).

study area are predominately fine grained and are poor aquifers. (The only exception is the coarse alluvium of the lower Moose River which may be primarily glaciofluvial in origin.) Although intergranular permeability predominates in the sandy tills which commonly mantle granite terranes, permeability in heavier-textured till is confined to joints and thin sandy stringers and lenses.

Probably the majority of domestic water supplies in the study area are obtained from dug wells constructed in glacial till. Dug wells are usually sufficient to meet domestic demand because of the storage capacity of the well itself. Dug wells are often a problem during dry summers, however, when their storage capacity is reduced due to recession of the water-table.

CHEMICAL QUALITY OF GROUNDWATER

Introduction

The dissolved solids in groundwater depend on the material through which the water passes and on the length of time the water is in contact with these materials. In humid regions like Nova Scotia where groundwater circulation is relatively rapid, groundwaters which pass through rocks of low solubility have a low concentration of dissolved solids. Furthermore the uplands, which, for the most part, are groundwater recharge areas, often contain groundwaters with fewer dissolved solids than do the lowlands which are the discharge areas for regional groundwater flow systems.

The complete analyses, both in parts per million (ppm) and in equivalents per million (epm), of groundwater samples collected in the Western Annapolis Valley are given in Appendix C. Statistical comparisons of the quality of groundwaters among the hydrostratigraphic units, based on more than three hundred water samples collected northeast of the study area, were made by the writer (Trescott, 1968). Some of the statements in the discussion below are based on the results of these comparisons.

The chemical composition of groundwater may be represented on Piper (1944) trilinear diagrams (Fig. 11). The major cations in groundwater (calcium, magnesium, and sodium plus potassium) are given as per cents of total equivalents per million in one triangular field; in the other, the major anions (carbonate plus bicarbonate, chloride, and sulphate) are given as per cents of total equivalents per million; and the combined chemistry is plotted in the diamond-shaped field. It can be noted in figure 11 that most of the waters can be classified as calcium bicarbonate waters.

Relationship of Groundwater Quality to Use

The quality of most groundwaters in the Western Annapolis Valley is good to excellent for most uses. Salty groundwater is a problem in a few areas where wells have been constructed in flat lowlands (e.g. dykeland) where the freshwater lens is relatively thin. Elsewhere salty water is not a problem because the land (and the water-table) rise rapidly away from the sea, insuring a thick freshwater lens over the salt water. Even though most of the population in the study area lives adjacent to the sea, saltwater intrusion (deterioration of water quality due to flow of salt water towards a cone of depression) is not a problem at the present because most wells produce only a few gallons per minute. In the future, however, the possibility of saltwater intrusion near the sea should be considered and evaluated before high capacity wells are installed.

The various ionic constituents and other chemical properties which together determine the chemical quality of a water have been discussed elsewhere

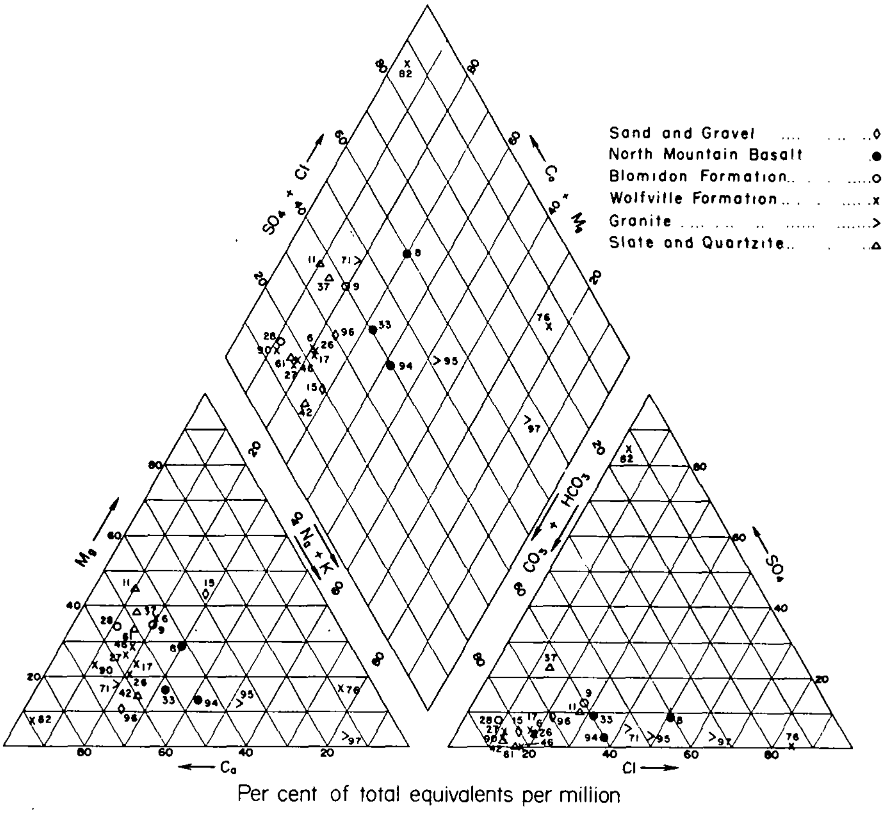

FIGURE 11. Trilinear plot of chemical analyses for water samples (identified by Index No.) collected in the Western Annapolis Valley.

(see, for example, Hem, 1959 and for a brief discussion, Trescott, 1968). In this section only those chemical properties that are pertinent to the various uses of the water will be reviewed.

Most groundwater pumped in the Western Annapolis Valley is used for domestic purposes. For such use it should meet the mandatory and recommended limits of the U.S. Public Health Service Drinking Water Standards (1962). The recommended limits for the constituents given in Appendix C are: iron - 0.3 ppm, manganese - 0.05 ppm, sulphate - 250 ppm, chloride - 250 ppm, nitrate - 45 ppm, and total dissolved solids - 500 ppm. Although total dissolved solids were not determined in the analyses, they are approximately related to the specific conductance by

$$\text{specific conductance } (\mu \text{ mhos}) \times 0.55 \cong \text{total dissolved solids (ppm)}$$

for most of the groundwaters in the Western Annapolis Valley.

Iron and manganese, which may cause stains and impart objectionable taste to water, exceed the recommended limits in a few of the water samples. It is suggested that these samples may have been contaminated by the corrosion of well casing and plumbing fixtures. Sulphate, chloride and the total dissolved solids may have adverse physiological effects and give water an objectionable taste if present in excess of the recommended limits. Most groundwaters in the study area contain these constituents in concentrations considerably less than the recommended limits. The few cases where excess chloride or sulfate and total dissolved solids are present are discussed in the section on quality of water in the hydrostratigraphic units. None of the groundwaters collected in the Western Annapolis Valley contain an excess of nitrate which may be poisonous to small children in concentrations greater than 45 ppm. Relatively high concentrations of nitrate may be found locally, however, because of pollution from septic tanks, barn yards, broken sewer mains and other sources.

For laundry, cooking and heating purposes, the hardness of the water is important. Hardness is caused by calcium and magnesium sulphates and carbonates which form insoluble residues with soap and contribute incrustations. Since the hardness of water for domestic purposes does not become particularly objectionable until it exceeds 100 ppm (Hem, 1959), waters with a hardness less than 100 ppm are considered to be "soft" (a category including most of the waters sampled in the Western Annapolis Valley) and waters with a hardness in excess of 100 ppm are "hard".

In classifying water as to its suitability for irrigation, the important factors to be considered are the total dissolved solids, the concentration of some individual constituents, particularly boron, and the relative concentration of sodium. The sodium or alkali hazard is indicated by the soluble sodium percentage (SSP) which is defined by

$$SSP = 100\,(Na+K)\,/\,(Ca+Mg+Na+K)$$

or by the sodium adsorption ratio (SAR) which is defined by

$$SAR = Na\,/\,\sqrt{(Ca+Mg)/2}$$

where all ions are expressed in epm. The two commonly used methods of classifying irrigation waters (Wilcox, 1948, and Richards, 1954) both use the specific conductance as an indication of the total dissolved solids or salinity hazard. Water is considered to be good to excellent for irrigation when the SSP is less than 40, the SAR is less than 10 and the specific conductance is less than 750 μ mhos (75 mhos x 10^{-5}). All groundwaters sampled in the study area, except a few samples (discussed below) high in sulphate and chloride, fall in this classification.

Industrial water quality criteria range widely depending on the use. For example, for boilers of very high pressure, water exceeding the quality of commerical distilled water is sometimes required; fish plants, on the other hand, often need large amounts of sea water (for a comprehensive discussion of water quality criteria, see McKee and Wolf, 1963). Groundwaters in the Western Annapolis Valley are of such a quality that they require little, if any, treatment for many industrial uses.

Groundwater is particularly suited for use as cooling water because of its relatively constant temperature. Many of the field temperatures given in Appendix C reflect some heating of the water in the distribution system before sampling. Most groundwaters in the study area should have a temperature between 47 and 50°F because near-surface groundwater temperatures generally exceed the mean annual air temperature by 2 to 3°F (Collins, 1925).

Chemical Quality of Groundwater in the Hydrostratigraphic Units

Slate, Quartzite and Granite

Groundwaters in slate, quartzite and granite are typically calcium bicarbonate waters low in dissolved solids and hardness. Waters in metamorphic rocks are often slightly acid and sometimes contain iron and manganese in objectionable amounts. The high iron and manganese content in water from a well (Index No. 11) in Marshalls Town, however, was probably due to contamination from the casing because the well had not been used for several months prior to sampling.

Groundwater in granite, such as that from a well (Index No. 71) at Upper Clements, may be moderately hard. Other hard waters in granite were sampled at Nictaux West (Trescott, 1968, p. 150). Water from a well (Index No. 97) in granite at Annapolis Royal contains a relatively large amount of sodium chloride. This well, which is over 200 feet deep, probably taps the upper fringe of the zone of diffusion between fresh and salt water. Note also the plot of this water on the trilinear diagram (Fig. 11).

Wolfville Formation

The Wolfville Formation contains good quality groundwaters (low in dissolved solids and hardness, usually low in iron, and usually slightly basic). Two groundwaters cited in Appendix C, however, are exceptions. Near Karsdale a well (Index No. 82) contains an excessive amount of calcium sulphate which is probably due to gypsum lenses in the formation. Since gypsum lenses are normally found only in the Blomidon Formation, this occurrence suggests that the assumed Wolfville-Blomidon boundary shown on the hydrogeological map is in error in the Karsdale area.

Water from a well (Index No. 76) on dykeland near Annapolis River contains over 800 ppm chloride. This water undoubtedly is being pumped from the freshwater-saltwater zone of diffusion. The high iron and manganese content of this water may be due to the corrosive action of the salty water on the well casing and plumbing fixtures. Note where this water and the high sulphate water described above plot on the trilinear diagram (Fig. 11).

Blomidon Formation

Although the two Blomidon Formation waters cited in Appendix C are good quality waters, groundwater in this unit typically has more dissolved solids and more hardness than do waters in other hydrostratigraphic units in the Annapolis-Cornwallis Valley area (Trescott, 1968, p. 87). One major contributor to dissolved solids is calcium sulphate which, in places, gives groundwater a composition like that from the well (Index No. 82) near Karsdale. The other major contributor to dissolved solids is calcium bicarbonate which increases the alkalinity and hardness and keeps the waters basic.

North Mountain Basalt

The North Mountain Basalt contains groundwaters of good to excellent quality (low in total dissolved solids, hardness and iron). Although waters with a hardness in excess of 100 ppm have been sampled, the presence of zeolite minerals in the basalt probably contributes to the predominance of soft waters.

Glaciofluvial Deposits

Based on analyses of numerous samples collected northeast of the study area (Trescott, 1968) and on the two samples collected in the study area, the quality of water in surficial sand and gravel deposits is good to excellent. In relation to waters in the Wolfville Formation, waters in glaciofluvial deposits generally contain less calcium bicarbonate and consequently have lower alkalinity, pH and hardness and fewer dissolved solids than do waters in the Wolfville Formation.

Other Surficial Deposits

Although no samples from dug wells were collected in the study area, the writer (Trescott, 1968, p. 89) found that the relative chemical composition of water from glacial till is similar to that found in the underlying bedrock. In some cases, however, water in till contains significantly fewer dissolved solids than do waters in the underlying bedrock.

GROUNDWATER UTILIZATION AND DEVELOPMENT

Introduction

Groundwater, the most important fresh water resource in the Western Annapolis Valley, is utilized only to a minor extent at the present. Most wells in the area have been drilled for domestic use although the Town of Digby is supplementing its surface water supply with water from wells drilled in 1968. Future growth and development of the area will depend, to a large extent, on the availability of adequate freshwater supplies for potential urban growth centers and for supplemental irrigation in rural areas. In this section, therefore, are summarized the possibilities of developing groundwater supplies in rural areas and in the vicinity of the towns and larger communities in the Western Annapolis Valley.

Domestic and Livestock Water Supplies

Daily domestic and livestock water requirements have been estimated by Anderson (1963) to be: 100 gallons per day (gpd) for each member of a family, 10 gpd for each horse, 12 gpd for each steer or dry cow, 25-30 gpd for each cow producing milk, 2 gpd for each hog, 1 1/2 gpd for each sheep and 4 gpd for each 100 chickens. Normally a well which will yield 1 to 3 gpm on a long-term basis is sufficient to meet the average domestic and livestock watering requirements. With rare exceptions, it should be possible to construct drilled wells with such a capacity anywhere in the study area. In metamorphic and igneous rocks, a few wells have been failures, but it is often possible to construct a successful well elsewhere on the same property. In many locations dug wells are sufficient to meet domestic needs.

The major problem with rural groundwater supplies is proper location and construction to avoid pollution of the supply. Very few dug wells are properly constructed to keep out surface runoff or are in the best location to avoid subsurface seepage from septic tanks, barn yards and other sources of pollution. Drilled wells are no less subject to pollution if they are improperly constructed and located, particularly in areas underlain by metamorphic and igneous rocks. Where the cover of glacial drift is thin, pollutants have direct access to rock fractures which have - relative to granular materials - little filtering effect on bacteria and other pollutants. In these areas surface casing should have a minimum length of 20 to 25 feet and preferably the annular space between the casing and borehole should be cement grouted. To minimize the chance of pollution of both dug and drilled wells, Department of Public Health regulations and regulations under the Well Drilling Act should be strictly observed.

Irrigation Water Supplies

Irrigation is not a common practice in the Western Annapolis Valley. As noted in the introduction to this report, however, there are often periods during the growing season when optimum soil moisture conditions can be maintained only by supplemental irrigation. Except for watering gardens, irrigation usually requires a water source which will yield several tens to a hundred or more gallons per minute. The most economical source in many areas is a pond created by damming a perennial stream. On the North and South Mountains, ponds and lakes are the only sources in most places which will yield enough water for an extensive irrigation system. In a few rare locations drilled wells in metamorphic and igneous rocks will yield 30 to 50 gpm; glaciofluvial deposits are not extensive enough on the highlands, except perhaps at Clementsvale, to yield much water to screened wells.

In the Triassic lowland, however, particularly in the Digby area and between Karsdale and Granville Ferry, it should be possible to construct irrigation wells in the Wolfville Formation which will yield from 50 to 300 gpm. Although some wells in this formation have been completed successfully as open boreholes, such wells often yield silt and sand eroded from poorly consolidated beds. To avoid this problem the producing zones in high capacity wells should be screened and gravel packed. It is easier and less expensive to construct such a well initially than it is to repair wells after they start producing sand.

Municipal and Industrial Water Supplies

The towns and larger communities in the Western Annapolis Valley have central water supplies from surface water sources. Existing data on these water-supply systems, many of which are barely adequate for present needs, have been summarized by Jones (1967). This section outlines the potential for developing groundwater supplies to support future urban and industrial growth near these towns and communities.

Annapolis Royal and Lequille

Annapolis Royal and most of Lequille occupy a peninsula bounded on three sides by salty water of the Annapolis and Allain River estuaries. Because of the low relief and small area of this peninsula, bedrock wells 100 to 200 feet deep probably would be affected by the freshwater-saltwater zone of diffusion. At Lequille, for example, a well (Index No. 97) 214 feet deep in granite is slightly affected by salty water. Although large production wells are possible in the Wolfville Formation which underlies Annapolis Royal, they certainly would be affected by saltwater intrusion in a relatively short time.

Some groundwater can be developed from the glaciofluvial deposits which underlie Lequille and the lower reach of the Allain River. Judging from the length of casing used in the well mentioned above, the sand and gravel deposits at Lequille may be over 80 feet thick in places. It may be possible to construct a few wells yielding up to 100 gpm in this deposit although development probably will be limited to smaller screened wells for domestic use and light industry.

The best prospect for developing water from sand and gravel deposits is along the Allain River (above the estuary) where it is suspected that 50 or more feet of stratified sand and gravel underlie the river bed. This suspicion is supported by Department of Highways borehole logs which reveal sand and gravel deposits extending from depths of 100 to more than 150 feet below sea level at the highway 1 bridge crossing 1 1/2 miles downstream. If exploration confirms the existence of this deposit, several screened wells could be designed to produce a total of several hundred gallons per minute with the yield sustained by water induced from the Allain River. Production would be limited partly by the head required to keep the freshwater-saltwater interface from migrating upstream through the alluvium. An additional advantage to developing groundwater from this source is the fact that the town water line follows highway 8 adjacent to the Allain River.

In the future much more groundwater can be developed from properly designed well fields which utilize aquifers in the Wolfville Formation in the vicinity of Granville Ferry. Wells properly located to eliminate the possibility of saltwater intrusion can be designed to yield from 50 to 200+ gpm. The causeway across the Annapolis River provides a convenient right-of-way for water transmission lines.

Bear River

Bear River Village, which does not have a central water supply system, is underlain by metamorphic rocks, principally slates and quartzites. There is little prospect of developing a central water system based on groundwater because individual drilled wells will rarely yield more than a few gallons per minute. Except for the possibility of developing a surface water supply, the residents of Bear River will have to continue relying on individual wells to supply their needs. Residents and drillers should take particular care in the location and construction of wells in a relatively densely settled area such as Bear River where groundwater pollution could easily be a problem.

CFB Cornwallis and Clementsport

Although CFB Cornwallis is mostly underlain by the Wolfville Formation, the few wells constructed at the base have shown that the formation contains poor aquifers in this location. Even if good aquifers were present and wells yielding 50 to 100 gpm were possible, they would probablybe affected by saltwater intrusion within a relatively short time in this location.

Most of the residents of Clementsport live in an area underlain by slate which commonly yields only a few gallons per minute to drilled wells. A glaciofluvial deposit on the north side of the Moose River estuary is too small to support more than a few domestic wells. A few people living in the western parts of Clementsport may be able to construct domestic wells in the Wolfville Formation.

The best possibility for developing a groundwater supply in this area is in the sand and gravel alluvium of the lower Moose River. A minimum thickness for these deposits in 80 feet, based on the log of a well (Index No. 63) at Clementsport. Upstream from this well, a properly designed well field should yield a total of several hundred gallons per minute with the yield sustained by infiltration from the Moose River. The sand and gravel alluvium would filter out bacterial pollution and other undesirable properties of Moose River water. Development would be limited partly by the head required to keep salt water from migrating upstream through the alluvium. An additional advantage to developing this groundwater source is the convenient location adjacent to the Moose River of the water line supplying CFB Cornwallis.

Digby

Digby is located in the most favorable area in the Western Annapolis Valley for developing groundwater supplies. Test drilling has revealed that the Digby area is underlain by good sandstone and conglomerate aquifers in the Wolfville Formation (see logs in Appendix A). The area is large enough and has enough relief so that wells can easily be located where saltwater intrusion is only a remote possibility.

Of the three test wells drilled in Digby in 1968, the one (Index No. 24) near the reservoir in town penetrated over 50 feet of clean, well-sorted, fine-grained conglomerates - some of the best aquifer material in the Wolfville Formation. At this location, however, these beds are relatively close to the surface, the water-table is deep, and the beds are so poorly consolidated that construction of a well as an open borehole is impossible. In the future, consideration should be given to utilizing this aquifer by locating a well at a lower elevation where the water-table would be closer to the surface, and up the section stratigraphically so that the conglomerate beds would be penetrated at a greater depth. A properly constructed, screened well in these deposits, of course, is a necessity.

The other two test wells (Index Nos. 26 and 27) near the town chlorination plant were completed as 6-inch diameter, open boreholes and are pumped at 125 gpm each - about half of their full capacity - with no sand-erosion problems to the present (see the section on hydrostratigraphic units). As permanent installations, the inside diameter of these wells should be increased to 8 inches and the producing zones should be screened and gravel packed to insure stability of the formation.

Digby is in the fortunate position to being able to expand its well field as demand increases without any limits in the foreseeable future.

Granville Ferry

The Granville Ferry water system, normally supplied by springs along the North Mountain scarp, has been supplemented in the past by two wells near the town reservoir. The capacity of the wells is not known, but their yield is estimated at less than 40 gpm because they were drilled in the Blomidon Formation. Granville Ferry can easily develop additional groundwater supplies by constructing wells which utilize aquifers in the Wolfville Formation. As long as relatively high capacity wells (from 50 to 200+ gpm) are located from three-quarters to one mile from the Annapolis River estuary, saltwater intrusion is only a remote possibility. As noted above, this is an area where Annapolis Royal could construct a well field in the future.

SUMMARY AND CONCLUSIONS

The economy of the Western Annapolis Valley, a predominantly rural area, is based mainly on fishing and agriculture. Although the area is not growing at the present, agriculture can be expanded significantly because of favorable soil and climatic conditions. Soils in the Triassic lowland and on South Mountain in the area underlain by slate make fair to good cropland. Precipitation, although on the average fairly evenly distributed during the year, usually is deficient at times during the growing season. This is not a problem, however, if supplemental irrigation is available for use during these periods. An expanded agricultural economy will justify the establishment of food-processing industries (in addition to fish-procession plants) in the area.

The South Mountain highland is formed on a sequence of early Palaeozoic metamorphic rocks, mainly slates and quartzites, which have been intruded by Devonian porphyritic granite. These rocks are overlain unconformably by the Triassic Fundy Group which dips gently to the northwest and consists of easily eroded sandstones, shales and conglomerates capped by erosion-resistant basalt lava flows and sills(?). Bedrock in the area is mantled mostly by glacial till which is over 200 feet thick in places. Glaciofluvial deposits, consisting of kames and a few eskers, are generally small features found mainly along stream valleys.

The water-storage and -transmitting capacity of the dense metamorphic and igneous rocks on the North and South Mountains is found in their fractures. This fracture permeability will yield on the average about 2 gpm per hundred feet of saturated section for the upper few hundred feet where fractures are relatively open. A few wells in these rocks can be classified as failures and a few, at the other extreme, are known to yield 50 or more gpm.

The best aquifers in the Western Annapolis Valley are the clean sandstones and conglomerates which constitute about 30 per cent of the Wolfville Formation. The intergranular and fracture permeability in these rocks on the average will yield about 95 gpm per hundred feet of saturated section. Poorly sorted silty sandstones, siltstones and claystones store groundwater which is released slowly as 'leakage' when water is pumped from the clean sandstone and conglomerate aquifers. The yield of wells in the Blomidon Formation depends primarily on the total thickness of clean sandstone beds and lenses penetrated because the predominate siltstones and claystones yield only about 2 gpm per hundred feet of saturated section.

A few of the larger glaciofluvial deposits at Lequille, Sea View and Clementsvale may yield up to 100 gpm to screened wells. Stratified sand and gravel deposits which may underlie the lower reach of the Allain and Moose Rivers probably can be developed to yield several hundred gallons per minute on a long-term basis if proper precautions are taken to avoid saltwater intrusion. Smaller kames, eskers, and other surficial deposits will usually yield only a few gallons per minute to dug wells and sand points.

Most groundwaters in the Western Annapolis Valley have a chemical quality that is good to excellent for most uses (low in iron, hardness, dissolved solids, and a low sodium hazard). A few waters, particularly in slates, have an objectionable amount of iron and manganese. Gypsum lenses give a few waters in the Blomidon Formation a high concentration of calcium sulphate and consequently make these waters excessively hard. Salty water is a problem only where wells are drilled in flat lowlands adjacent to the sea. Saltwater intrusion is not a problem at the present, but is a possibility in the future if large capacity wells are installed near the sea.

A considerable potential exists for developing groundwater for municipal, industrial and irrigation use in the Western Annapolis Valley. In the Digby area and from Karsdale to Granville Ferry, wells in the Wolfville Formation can be developed to yield from 50 to 300 gpm. Elsewhere, wells in the Wolfville Formation will not yield as much because of the limited thickness of the formation or cannot be pumped to their full capacity because of the danger of saltwater intrusion. Glaciofluvial deposits at Lequille and along the Allain and Moose Rivers may prove to be convenient sources of supply for Annapolis Royal and CFB Cornwallis. Along the North and South Mountains, groundwater development generally will be limited to domestic supplies except in a few areas, such as at Clementsvale, where higher yielding wells may be completed in glaciofluvial deposits or where exceptional fracture permeability is found in the metamorphic and igneous rocks.

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APPENDIX B.

SELECTED WATER WELL RECORDS IN THE WESTERN ANNAPOLIS VALLEY

Water well records given in this appendix are mostly those which include a lithologic log. These wells have been located in the field and are shown on Map 1. The lithologic logs have been used as an aid in mapping the geology and for determining the aquifer from which the well is producing. In cases where the lithologic log is questionable for a well drilled near a geologic boundary, the designation of the aquifer may also be in doubt.

The following abbreviations are used in the table:

Driller

1. Atlantic Coast Well Drilling Ltd.
2. Albert Frizzell
3. Edwards & Jodrey Ltd.
4. Hopper Brothers Well Drilling Ltd.
5. L. E. Veinotte & Sons Ltd.
6. Maritime Well Drilling Co.
7. Nodland Well Drilling Co.
8. O. V. Kennedy & Son Ltd.
9. S. G. Trask & Sons Ltd.
10. S. J. Jodrey Ltd.

Use

D = domestic
M = municipal

Pump or Bail test

gpm = imperial gallons per minute
DD = drawdown
REC = recovered to

Lithologic log

cl = clay
sd = sand
gr = gravel
dr = drift
sh = shale
ss = sandstone
sl = slate
bldrs = boulders

Note: Only records for drilled wells are given in this appendix whereas the index numbers also include dug wells and springs. Pertinent data on the dug wells and springs are given on Map 1.

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam. (in.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
3	21A12B28C	Bloomfield	1965	Waterman, H.	8	95		6	18	D		15 gpm DD-95'3 hrs. REC-14'4 hrs.	slate	0-15 dr; 15-95 sl
4	21A12B30M	Barton	1967	Lowe, Donald	3	140	28	6	135	D		5 gpm DD-5'1 hr. REC-28'15 mins.	Wolfville Formation (?)	0-50 cl; 50-100 bldrs & cl 100-140 cl & gr
5	21A12B43Q	Brighton		Kransnick, W.	8	244	14			D		1 1/2-7 gpm	Wolfville Formation	0-64 hard pan, cl, gr; 64-87 hard cl; 87-244 ss
6	21A12B43Q	Brighton	1966	Wyman, H. W.	3	100	2	4	74	D	X	4 gpm DD-70'30 mins. REC-2'30 mins.	Wolfville Formation	0-30 cl; 30-48 sd & gr; 48-58 grey cl; 58-69 cl & bldrs; 69-110 white ss & red sh
8	21A12B60K	Waterford	1960	Raymond, V.	8	161	80	6	22	D	X	24 gpm	Basalt	
9	21A12B65N	Rossway		Gidney, John W.	8	170	105	6	48	D	X	6 gpm	Blomidon Formation	0-20 cl, gr; 20-170 sh
11	21A12B70Q	Marshalls Town	1967	Marshall, G.	3	112	8	6	20	D	X	4 1/2 gpm DD-85'2 hrs. REC-8'30 mins.	slate	0-10 cl & gr; 10-21 broken sl; 21-112 sl
13	21A12B75G	Marshalls Town	1968	Jamerson, M. E.	9	90	20	6	35	D		4 gpm DD-50'20 mins. REC-20'1 hr.	Wolfville Formation	0-38 cl & dr; 38-90 ss & sh
17	21A12B93Q	Seabrook	1967	Beaver Brook Farms	9	100	17	6	83	D	X	10 gpm DD-83'1 hr. REC-17'20 mins.	Wolfville Formation	0-81 cl & sd; 81-100 ss
19	21A12B100D	Seabrook		Smith, C. W.	8	156	82		124	D		8 gpm	Wolfville Formation	0-120 sd, cl & sh; 120-156 ss
20	21A12B97D	Digby	1966	Stark Sales	3	216	105	6	210	D		24 gpm DD-150'72 hrs. REC-105'15 mins.	Wolfville Formation	0-70 red cl; 70-100 black silt; 100-150 quick sd; 150-180 fine gr; 180-190 ss; 190-210 red ss; 210-216 ss
21	21A12B95J	Digby	1966	White, M.	3	203	78	6	167	D		23 gpm DD-120'16 hrs. REC-78'20 mins.	Wolfville Formation	0-78 cl; 78-100 sd; 100-120 cl; 120-130 sd & gr; 130-140 quick sd; 140-203 ss
22	21A12B95A	Digby	1954	Woof, James	8	305	114	4	205	D		10 gpm	Wolfville Formation	0-202 sd, cl & bldrs; 202-305 ss
24	21A12B97C	Digby	1968	Town of Digby	4	358	120	6	114	M			Wolfville Formation	(see log Appendix A)

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam. (in.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
26	21A12C2K	Digby	1968	Town of Digby	4	433	23	6	165	M	X	122 gpm DD-89'7 hrs. REC-26'15 hrs.	Wolfville Formation	(see log Appendix A)
27	21A12C2G	Digby	1968	Town of Digby	4	400	19	6	56	M	X	90 gpm DD-56'3 1/2 hrs.	Wolfville Formation	(see log Appendix A)
28	21A12C23M	Digby	1967	Smith, Fred	3	110	29	6		D	X	15 gpm DD-40'2 hrs. REC-29'5 mins.	Blomidon Formation	0-15 cl; 15-45 gr & cl; 45-110 sh & ss
33	21A12C48N	Bay View	1966	Doerr, H. E.	9	125	20	6	20	D	X	2 gpm DD-105'30 mins. REC-20'2 hrs.	Basalt	0-10 dr & broken rock; 10-125 trap rock
34	21A12A66L	Bear River	1966	Brenton, Harold	5	150	17	6	10	D		1 1/2 gpm DD-100'30 mins. REC-17'1 hr.	slate	0-3 mud; 3-150 rock
35	21A12A78D	Bear River East	1966	Fraser, Keith	5	68	6	6	22	D			slate	0-10 mud; 10-68 rock
37	21A12A99P	Clementsvale	1966	Wright, Donald	9	78	10	6	20	D	X	5 gpm DD-68'30 mins. REC-10'30 mins.	slate	0-18 dr; 18-78 sl
39	21A12A86N	Smiths Cove Sta.	1952	McPherson, J. D.	8	194	flowing	6	152	D		2 3/4-5 gpm	Wolfville Formation	0-152 cl, gr, bldrs; 152-194 soft ss
40	21A12A86L	Imbertville	1965	Bell, George R.	9	90	11	6	47	D		6 gpm DD-17'30 mins. REC-11'1 hr.	slate	0-42 dr, cl; 42-90 sl
41	21A12A86O	Imbertville	1953	Rice, Jennie M.	8	175	45	6	105	D		4-5 gpm	slate	0-103 cl & bldrs; 103-175 sl
42	21A12A86Q	Imbertville	1966	Oliver, Howard M.	3	98	28	6	43	D	X	1 3/4 gpm	slate	0-12 cl; 12-29 gr; 29-98 s
43	21A12A86Q	Imbertville	1954	Paxton, Stan	8	120	10	6	44	D		2 gpm	slate	0-43 cl & bldrs; 43-120 sl
44	21A12A107A	Imbertville	1951	Cossett, Ralph	8	167	0			D		1 1/2-5 gpm	Wolfville Formation	0-74 cl, gr & bldrs; 74-167 ss
45	21A12A87N	Imbertville	1965	Saulis, Harold	3	63	12	6	59	D			Wolfville Formation	0-12 dr; 12-63 ss
46	21A12A107H	Imbertville		Charman	8	60	30	6	30	D	X	60 gpm	Wolfville Formation	0-30 cl & gr; 30-60 ss
47	21A12A106D	Smiths Cove	1952	Winchester, John	8	55	8	4	36	D		15 gpm	Wolfville Formation	0-36 cl & gr; 36-55 ss
48	21A12A106D	Smiths Cove	1952	Weir, Elmer	8	39	4	4	36	D		5 gpm	Wolfville Formation	0-31 cl & bldrs; 31-39 ss
49	21A12A106D	Smiths Cove	1951	Berry, A. H.	8	170	42	4	46	D		2 gpm	Wolfville Formation	0-40 cl & bldrs; 40-70 ss

50	21A12A106D	Smiths Cove	1952	Adams, G.	8	180	19	6	70	D		1 1/2 gpm	Wolfville Formation	0-70 cl & bldrs; 70-180 ss
52	21A12A106D	Smiths Cove	1952	Bryant, E. W.	8	62	10	6	34	D		9 1/2 gpm	Wolfville Formation	0-34 cl & gr; 34-62 ss
53	21A12A105O	Seaview	1967	Meuse, Eugene	9	150	40	6	150	D		4 gpm DD-45'1 hr. REC-40'1 hr.	Sand & gravel (?)	0-150 sd, cl & gr
54	21A12D9H	Seaview	1951	Moore, Raymond	8	175	16	6	60	D		2 gpm	slate	0-60 sd & gr; 60-175 sl
55	21A12D8E	Seaview	1966	Morenay, Steward	6	200	19	6	34	D		2 1/4 gpm	slate (?)	0-25 red cl; 25-34 red ss; 34-90 grey sl; 90-200 grey sh (?)
57	21A12D8K	Deep Brook	1966	Wagner, Leroy	6	190	15	6	45	D		11 gpm	slate	0-28 red cl & light gr; 28-163 grey sl; 163-190 white sl
58	21A12D8P	Deep Brook	1952	Purdy, R. A.	8	350	30	6	55	D		1 gpm	slate	0-60 cl, bldrs & sd; 60-350 sl
59	21A12D17A	Deep Brook	1966	Lowe, Donald	9	86	15	6	33	D		4 gpm DD-70'30 mins. REC-15'30 mins.	slate	0-30 cl & sd; 30-86 ss (?)
60	21A12D18L	Deep Brook	1966	Anna. School Board	3	200		6	130	D		4 gpm	Wolfville Formation	0-40 cl; 40-200 ss
61	21A12D30C	Clementsport	1966	Melanson, Herman	3	115	4	6	37	D	X	4 1/2 gpm DD-90'2 hrs. REC-4'1 hr.	slate	0-10 cl; 10-29 gr & bldrs; 29-115 sl & sh
63	21A12D30J	Clementsport	1968	Assiff, A.	2	80		6		D		3 gpm	Sand & gravel	0-80 sd & gr
64	21A12D30P	Clementsport		Crosby, W. A.	8	228	80			D		1 1/2-2 1/2 gpm	slate (?)	0-185 cl, bldrs, gr & sd; 185-228 sl or bldrs
65	21A12D43B	Clementsport		Burrell, James	8	170	63			D		5 gpm	slate (?)	0-134 sd & gr; 134-170 sh (?)
66	21A12D43J	Clementsport	1954	Bent, Raymond	8	105	20	4	70	D		12 gpm	Wolfville Formation	0-63 cl & gr; 63-105 ss
68	21A12D69E	Upper Clements	1952	Wallis, H.	1	155				D		4 gpm	Wolfville (?) Formation	whin (?)
70	21A12D69K	Upper Clements	1968	Dept. of Lands & Forests	2	136		6	41	D		4 gpm	Wolfville Formation	0-35 sd & gr; 35-136 ss
71	21A12D75G	Upper Clements	1944	Marshall, Leigh	8	200	21	4	24	D	X	2 gpm	Granite	0-20 dr; 20-200 granite
72	21A12D75K	Upper Clements	1965	Acker, W. A.	3	122	20	6	109	D		3 1/2 gpm DD-62'2 hrs. REC-30'1 hr.	Wolfville Formation	0-32 dr; 32-122 sh
74	21A12D95G	Annapolis Royal	1966	Kennedy, A.	3	120	30	6	48	D		3 gpm DD-50'2 hrs. REC-30'1 hr.	Wolfville Formation	0-22 cl; 22-120 ss

Index No.	Grid Location	Area	Year Drilled	Owner	Driller	Well Depth (ft.)	Water Level (ft.)	Hole Diam. (in.)	Csg. Lgth. (ft.)	Use	Chemical Analysis Appendix C	Pump or Bail Test	Aquifer	Lithologic Log & Remarks
76	21A12D97D	Annapolis Royal		Irving Service Sta.	8	147	21		67	D	X	6-15 gpm	Wolfville Formation	0-47 cl & gr; 47-147 ss
77	21A12C49J	Victoria Beach	1965	Hedgepath, Harold	3	40	11	6	14	D			Basalt	0-2 dr; 2-40 trap rock
78	21A12D38K	Port Wade	1955	Davidson	8	250	69	6	202	D		4 1/2-15 gpm	Wolfville Formation	0-215 cl, gr & bldrs; 215-250 ss
81	21A12D65K	Thorne Cove	1953	Covert, Arch	8	98	24	4	31	D		15 gpm	Wolfville Formation	0-31 cl & gr; 31-98 ss
82	21A12D65J	Thorne Cove	1953	Bogart, Eugenia	8	145	15	4		D	X	3 1/2-15 gpm	Wolfville Formation	0-47 cl & bldrs; 47-145 ss
84	21A12D79H	Karsdale	1967	Wade, C. P.	3	130	28	4	103	D		3 1/2 gpm DD-55'3 hrs. REC-28'15 mins.	Wolfville Formation	0-30 cl & gr; 30-50 sd & cl; 50-100 cl; 100-130 sd
85	21A12D78E	Karsdale	1965	Harris, George D.	8	107	4	6	85	D		8 gpm DD-60'3 hrs. REC-4'1 hr.	Wolfville Formation	0-80 cl & gr; 80-107 ss
86	21A12D78E	Karsdale	1965	Jefferson, Arthur	3	105		6	54	D		5 1/2 gpm DD-20'2 1/2 hrs.	Wolfville Formation	0-18 dr; 18-105 ss
90	21A13A1M	Granville Ferry	1965	Karnes, Danny	3	90	15	6	70	D	X		Wolfville Formation	0-15 dr; 15-90 ss
91	21A13A1K	Granville Ferry	1967	Harris, Walter & Son	7	120	22	6	80	D		9 gpm	Wolfville Formation	0-73 red cl; 73-120 ss
94	21A13A50G	Parkers Cove	1967	Longmire, Walter	9	93	60	6	22	D	X	10 gpm DD-0'30 mins.	Basalt	0-6 dr; 6-93 trap rock
95	21A11C85E	Lequille	1959	N. S. Light & Power	8	125	6	6	22	D	X	5 gpm	Granite	
96	21A11C108D	Lequille		West	self driven	21	6	2	19	D	X		Sand & gravel	
97	21A11C108D	Lequille	1949	Pettitt, James B.	8	214	46	4	90	D	X	2 gpm	Granite	
98	21A11C108G	Lequille	1965	Mailman, Don	8	110	24	4	66	D		1 1/2-5 gpm	Wolfville Formation	0-66 bldrs; 66-110 ss
106	21A14B14J	Granville Centre	1966	Chartton, Ira C.	3	93	29	4	62	D		5 gpm	Wolfville Formation	0-23 red cl; 23-45 sd & gr; 45-60 blue cl & loose rocks; 60-90 sh; 90-93 ss
108	21A14B61O	Parkers Cove	1953	Hudson, Delmar	8	168	146	6		D		4 gpm	Basalt	0-6 dr; 6-168 trap rock
111	21A12D53M	Upper Clements	1968	Brinton, Perry	10	147	32	6	65	D		3 1/2 gpm DD-80'1 1/2 hrs.	Wolfville Formation	0-62 cl, bldrs & gr; 62-147 ss

APPENDIX C. CHEMICAL ANALYSES OF GROUNDWATERS IN THE WESTERN ANNAPOLIS VALLEY

						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-phthalein as $CaCO_3$	Methyl Orange	Hardness	Specific Conductance (mhos. x 10^{-5})	Field	Lab	Field Temp. °F	Colour	Turbidity	Ca	Mg	Na	SO_4	Cl	NO_3	SSP	SAR
8	21A12B60K	Waterford	161	Basalt	July4,68	24.2	9.9	19.8	0.18	T	12	35.5	25	0.0	56.5	101.2	40	6.6	7.2	52	< 5	2	1.21	0.81	0.86	0.25	1.00	0.40	30	0.86
33	21A12C48N	Bay View	125	"	July8,68	14.6	2.7	10.1	0.05	T	7	17.4	T	0.0	46.5	47.6	20	6.8	7.5	52	< 5	2	0.73	0.22	0.43	0.15	0.49	0.00	32	0.64
94	21A13A50G	Parkers Cove	93	"	July24,68	25.7	4.5	26.6	0.02	T	3	32.8	T	0.0	76.0	82.4	30	7.2	8.2	56	5	0	1.28	2.37	1.16	0.06	0.93	0.00	41	1.27
9	21A12B65N	Roxway	170	Blomidon	July5,68	18.8	8.2	8.8	0.12	T	12	15.6	5	3.2	55.5	80.4	30	6.7	7.4	54	< 5	5	0.94	0.67	0.38	0.25	0.44	0.08	19	0.43
28	21A12C23M	Digby	110	"	July24,68	31.7	11.7	7.3	0.02	T	14	11.5	T	10.0	138.0	127.2	31	7.1	8.4	58	< 5	0	1.58	0.96	0.32	0.29	0.32	0.00	11	0.28
46	21A12A107H	Smiths Cove	60	Wolfville	July24,68	16.8	5.4	6.4	0.01	T	T	10.6	T	0.0	66.0	64.0	20	6.3	8.1	47	< 5	0	0.84	0.44	0.28	0.00	0.30	0.00	18	0.35
6	21A12B43Q	Brighton	100	"	July5,68	14.3	6.8	7.1	0.25	T	3	11.5	T	4.0	62.0	63.6	22		7.9	53	10	5	0.71	0.56	0.31	0.06	0.32	0.00	20	0.39
17	21A12B93Q	Seabrook	100	"	July5,68	15.9	4.0	6.9	0.20	T	3	10.1	T	2.8	56.5	56.0	21	7.4	8.5	50	8	5	0.79	0.33	0.30	0.06	0.28	0.00	21	0.40
27	21A12C2G	Digby	400	"	Nov.26,68	24.5	6.6	8.6	0.23	T	5	8.9	T	12.0	80.0	90.6	22	8.6	8.1	49	5	19	1.22	0.54	0.37	0.104	0.25	0.00	17	0.40
26	21A12C2K	Digby	433	"	Nov.5,68	22.8	4.8	9.2	0.02	T	4	13.3	T	2.0	74.0	76.4	22	8.7	8.3	50	5	0	1.14	0.39	0.40	0.083	0.38	0.00	21	0.46
82	21A12D65J	Karsdale	145	"	July24,68	173.6	8.9	6.9	0.07	T	480	11.5	T	2.0	74.0	470.0	102	6.9	8.1	57	< 5	0	8.66	0.73	0.30	10.0	0.32	0.00	3	0.14
76	21A12D97D	Annapolis Royal	147	"	July24,68	53.1	59.0	524.0	1.72	1.0	6	834.2	5	24.0	196.0	375.2	330	6.9	8.2	57	65	19	2.65	4.85	22.8	0.12	23.53	0.08	75	11.77
90	21A13A1M	Granville Ferry	90	"	July24,68	23.4	4.9	4.3	0.01	T	3	8.0	1	2.0	86.0	78.4	22	7.4	8.1	54	< 5	0	1.17	0.40	0.19	0.06	0.23	0.02	11	0.21
42	21A12A86Q	Smiths Cove	98	Slate	July24,68	17.8	2.6	8.9	0.01	T	4	14.2	T	8.0	136.0	55.2	39	7.0	8.5	54	< 5	0	0.89	0.21	0.39	0.08	0.40	0.00	26	0.52
37	21A12A99P	Clementsvale	78	"	July24,68	7.2	3.5	2.2	T	T	8	3.5	T	0.0	24.0	32.4	12	6.3	7.7	51	< 5	0	0.36	0.29	0.10	0.17	0.10	0.00	13	17.00
11	21A12B70Q	Marshalls Town	112	"	July5,68	19.2	3.7	4.9	11.75	0.07	7	10.3	7	2.0	42.5	63.2	23		8.2	54	30	7	0.96	0.30	0.21	0.15	0.29	0.11	14	0.27
61	21A12D30C	Clementsport	115	"	July24,68	17.3	6.8	6.4	0.01	T	T	10.6	T	2.0	76.0	71.2	21	6.9	8.3	52	< 5	0	0.86	0.56	0.28	0.00	0.30	0.00	16	0.33
95	21A11C85E	Lequille	125	Granite	July24,68	9.3	1.9	15.7	0.05	T	2	21.3	T	0.0	30.0	31.2	16	6.3	7.8	53	< 5	0	0.46	0.16	0.68	0.04	0.60	0.00	52	1.23
97	21A11C108D	Annapolis Royal	214	"	Oct.30,68	16.4	2.04	107.0	0.18	T	7	112.6	12	4.0	88.0	49.2	64	8.6	8.3	51	5	0	0.82	0.17	4.65	0.146	3.18	0.194	82	6.61
71	21A12D75G	Upper Clements	200	"	Oct.9,68	41.0	6.8	14.1	0.02	T	9	41.7	4	8.0	70.0	130.4	42	8.6	8.0	50	< 5	0	2.05	0.60	0.61	0.19	1.18	0.065	19	0.54
96	21A11C108D	Lequille	21	Sand & gravel	July24,68	29.3	2.9	12.1	0.04	0.02	10	16.0	3	4.0	78.0	85.2	30	6.2	8.3	56	< 5	0	1.46	0.24	0.53	0.21	0.45	0.05	24	0.57
15	21A12B88B	Gulliver Cove	Spring	"	July5,68	3.7	3.3	4.1	0.03	T	4	8.9	T	0.0	69.5	22.8	10	6.2	6.9	47	< 5	2	0.18	0.27	0.17	0.08	0.25	0.00	28	0.37

*denotes till overlying this unit T = concentration < 0.01 ppm SSP = soluble sodium precentage SAR = sodium adsorption ratio