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NOTES ON THE HYDROGEOLOGY OF NOVA SCOTIA

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INTRODUCTION

This excursion will provide you an opportunity to familiarize yourself with the hydrogeology of the Province of Nova Scotia, with a special emphasis on the impact of the Pleistocene glaciation on the groundwater resources of the region. Results of various studies conducted and published by the Groundwater Section, Nova Scotia Department of Mines, will be made available for your reference. At present, a field project in cooperation with the Federal Groundwater Subdivision, Inland Waters Branch, Canada Department of Environment, is being undertaken to study fracture flow phenomena in the Halifax-Dartmouth area. The following notes serve as a guide to the more important hydrostratigraphic units, water supply and potential problems along and adjacent to, the route of this excursion. Detailed information will be discussed when passing through.

ANNAPOLIS-CORNWALLIS VALLEY

The Annapolis-Cornwallis Valley is a long, narrow lowland in Digby, Annapolis and Kings Counties, Nova Scotia. Flanked on one side by the North Mountain Highland (Basalt) and on the other by the South Mountain Highland (Slate, quartzite and granite), it has developed largely on softer Triassic sedimentary rocks. The valley proper is 62 miles long from Annapolis Royal to the Minas Basin and varies in width from three to eight miles (Figure 1).

According to Trescott (1968), the annual groundwater runoff of the valley proper is about 170,000 acre-feet, of which only 3.7% or 6,400 acre-feet is being utilized. The major aquifers are present in the Mississippian and Triassic bedrock and in the overlying surficial deposits. The Horton Group sandstone and shale of Mississippian age underlies only a small part of the valley near the Minas Basin. Because of the predominance of the fine grained strata, wells tapping Horton rocks will not yield much more than domestic supplies. In cases where coarse grained strata are encountered, a well yield of 10 to 100 igpm may be possible and very often the groundwater occurs under flowing artesian conditions.

The Triassic aquifers include the Wolfville and Blomidon Formations with the Wolfville sandstones and conglomerates the most extensive bedrock aquifers of the valley. The transmission of water through these rocks, however, is limited because of poor sorting and secondary cementation. Where large volumes of water are required, wells 200 to 400 feet in the Wolfville aquifer can produce up to 300 igpm. The Blomidon Formation is composed mainly of siltstone and claystone which yield only small amounts of water, primarily through joints. Often, water supplies from the Blomidon Formation can be obtained by gravity feed from springs along the scarp of the North Mountain.

Surficial deposits overlying the valley floor include estuarine silt and clay, glacial till, outwash sand and gravel, ice-contact sand and gravel, and sand and silty alluvium, with a total thickness varying from 0 to 200 feet depending on the bedrock topography. Because of the high silt and clay content, the estuarine, glacial till, and alluvial deposits are relatively impermeable and seldom yield more than a domestic water supply. Although the ice-contact deposits are relatively permeable, the water table is often in the underlying bedrock. Results from piezometer measurements, as well as steady state digital modelling, indicate that some ice-contact deposits are located in a recharge area as shown in Figure 2 (Trescott, 1970). Therefore, the outwash sand and gravel deposits found mostly in eastern and central parts of the valley are the only potential surficial aquifers with a high coefficient of transmissibility and a shallow water table. A well constructed in one of these aquifers is capable of yielding over one thousand imperial gallons per day.

It must be pointed out that the use of the outwash deposits as potential aquifers is subject to several drawbacks: (I) As the saturated thickness of the aquifer is usually small, large production from a single well is not always possible, (2) The outwash aquifer can be easily subject to pollution if exploitation is not well planned because the aquifer is very close to the ground surface. One of such examples will be seen at an apple processing plant at Coldbrook, Kings County, and (3) Excessive pumpage from the outwash aquifer underlying the dykeland of the valley may result in salt water intrusion.

SALMON RIVER WATERSHED

The Salmon River watershed located in Colchester County, Nova Scotia, consists of three distinctive physiographic units: the Triassic Lowland, the Carboniferous Upland and the Cobequid Highland - each of which is closely related to the underlying bedrock geology (Figure 3). It covers an area of approximately 265 square miles with the Salmon River flowing westward and discharging into Cobequid Bay of the Minas Basin near Truro, the largest community of the area.

The total volume of groundwater runoff was estimated to be 70,555 acre-feet per year, of which only 4% is being utilized (Hennigar, 1968). The main aquifers of the watershed are present in the Triassic bedrock and in the overlying outwash channel deposits. Similar to the Annapolis-Cornwallis Valley, the sandstones and conglomerates of Triassic age are the most important bedrock aquifers of the Salmon River watershed. Pump tests carried out in these aquifers indicate that wells between 200 and 300 feet deep should yield at least 500 igpm for a 20-year period. Among various surficial deposits, the outwash sands and gravels along the buried channels underlying the courses of the present North River and Salmon River, are well sorted, with a coefficient of transmissibility in the order of 5.0×10^4 igpd/ft. As the saturated thickness of the outwash aquifer in some places is generally less than 20 feet, a well yield of more than 200 igpm is not always practical. Therefore, for large quantities of water in some areas, a multiple shallow well system could be employed. At North River, however, just outside Truro, thicker outwash deposits (70 feet plus) are found and individual wells with capacities of up to 1000 igpm can be developed.

Studies on the sanitary quality of the Salmon River reveal. in general, an increase in coliform bacteria counts of the surface water in a downstream direction. Furthermore, the higher coliform counts tend to occur when the river discharge is low, whereas the lower coliform counts are associated with higher river flows as shown in Figure 4 (Hennigar, 1968).

Presently, the Town of Truro relies for its water supply largely on surface water although they have some wells. To cope with the needs for future expansion, however, the almost untapped groundwater resources underlying and adjacent to the community will have to be used. At present, tractors and trucks are scraping off the sand and gravel deposits along the North River Channel, in some cases, down to and below the water table in some areas for material for highway and building construction. These deposits are susceptible to gasoline and oil pollution and without proper protection, contamination could get into the groundwater flow system resulting in the pollution of these deposits and thus preventing their use as a water supply source.

Fraser Brook watershed (3.5 square miles), located approximately seven miles east of Truro, within the Salmon River watershed, will be visited. This watershed forms part of Nova Scotia's contribution to the International Hydrological Decade and is a joint project among various provincial and federal government agencies. On this watershed are several instrumental sites where the meteorological surface and subsurface components of the hydrological cycle are monitored. A more detailed explanation of the geology and hydrology and instrumentation of the watershed will begin at the time of the site visitation.

INVERNESS WATER SUPPLY

The Town of Inverness located in the west coast of Cape Breton Island has a population of 2000. The total water consumption in the town is about 85,000 gallons per day. The town is supplied by a gravity flow dam and reservoir system constructed in 1904. The dam is located about two miles southwest of the town. It is a concrete dam seven feet high and about sixty feet across retaining about 75,000 gallons of water. The water is carried about one mile in a 6" and 4" pipe to a rock-lined reservoir which holds about 0.5 million gallons and from there in a 12" main to the Town. A head of about 250 feet is developed from the reservoir to the town.

The present supply meets the town's needs for most of the year, but shortage results during a dry summer and in the winter. In the summer, the dammed creek fails to supply sufficient water to meet the demands of the town and a plea to reduce consumption is often necessary. In the winter, taps must be left running to prevent pipes from freezing.

Inverness is underlain by conglomerates, sandstone, shale, coal and minor limestone of Pennsylvanian age. Little information is available for the groundwater potential of the bedrock. Surficial mapping of the Inverness area reveals that the outwash sand and gravel which occurs as valley fill deposits near the town has a thickness of greater than 150 feet with high permeability and a water table at shallow depth. Wells constructed in these deposits could provide large sustained yields (500 - 1000 igpm) sufficient for municipal supplies (Pinder, 1966; Jones et al, 1967). The groundwater quality is good and the water is no harder than that presently used by the town.

Nearby to the Town of Inverness at Gillisdale is April Brook watershed (2.0 square miles), another of Nova Scotia's International Hydrological Decade representative Basins. At this watershed, instrumentation similar to that of Fraser Brook can be found. This watershed although similar in size to that of Fraser Brook has much more topographic relief, ranging from 200 feet to 1100 feet above sea level. Comparison in groundwater surface water runoff relation among the different International Hydrological watersheds (Pinder and Jones, 1969; Turker, 1969) will be given during the field trip.

MUSQUODOBOIT RIVER VALLEY

Although the excursion will not cover this area, the Musquodoboit River Valley, situated in Halifax and Colchester Counties, deserves special mention for two reasons: (1) the mystery of the Musquodoboit River (Golthwait, 1924; Lin, 1971) and (2) the development of two aquifer models (Pinder, 1968 b; Pinder and Bredehoeft, 1968; Lin, 1970 a).

The valley is about 35 miles long and eight miles wide and covers an area of approximately 275 square miles. It is underlain by Ordovician quartzite and slate, Devonian granitic intrusive and Windsor evaporates of Mississippian age (Figure 5). Hydrogeologically, these bedrock units are not potential sources of large amounts of groundwater because of low permeability or inferior water quality. The only potential source of groundwater of sufficient quality and quantity is the surficial outwash sand and gravel deposits. Numerous such occurrences covering an area of slightly less than one square mile have been delineated along many segments of the Musquodoboit River Valley. The outwash aquifer at Musquodoboit Harbour was investigated by Pinder (1968 a,b) who modelled the aquifer with a digital approach based on an implicit finite-difference method. Results of his study indicate that this aquifer would easily provide an adequate supply for the village of Musquodoboit Harbour at a rate of 6.0×10^5 imperial gallons per day. Another digital model based on an irregular mesh matrix was proposed for the outwash aquifer at Elmsvale under ideal unconfined assumptions (Lin, 1970 a). Numerical solutions are hence obtainable to the otherwise formidable Boussinesq equation in groundwater hydrology. In addition, an extensive groundwater sampling programme was carried out to assist in the refinement of the outwash deposit at Middle Musquodoboit (Lin, 1970 b). Results of the field analysis indicate that waters coming from permeable sand and gravel aquifers are softer and have lower pH and silica concentrations than that from the impermeable clay tills (Figure 6). These field relations together with test drilling indicate that the areal extent of the outwush sand and gravel deposit was more restricted than previously thought, especially at the centre of the village.

During the test drilling at Elmsvale (N.S.D.M. TH #404) 551 feet of unconsolidated coloured clays and quartz sands of Cretaceous age was encountered. This together with the shallowness of the bedrock channel of the Musquodoboit River at Crawford suggest that before Pleistocene glaciation, the upper segment of the river was a tributary stream of the Shubenacadie drainage system (Lin, 1971). The implications of these findings are as follows: (1) the Cretaceous deposits including both the pottery clays and permeable quartz sands in Nova Scotia appear to be much more extensive than previously thought, and (2) along the buried channel, groundwater underflow would be an important water resource yet to be examined.

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Figure 1. Bedrock geology of the Annapolis-Cornwallis valley, Nova Scotia (After Trescott, 1968, p. 6).

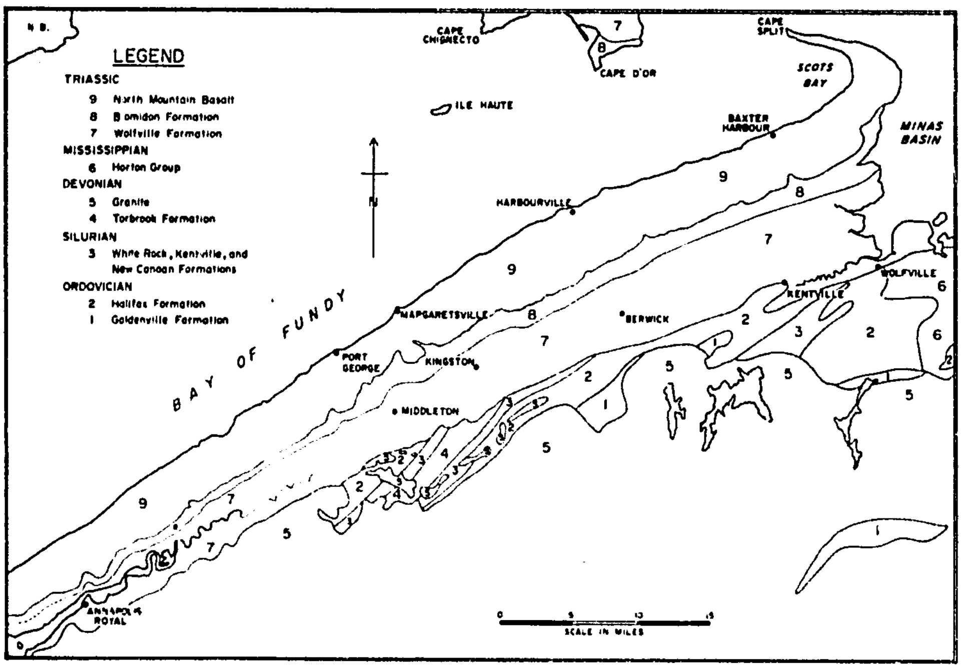
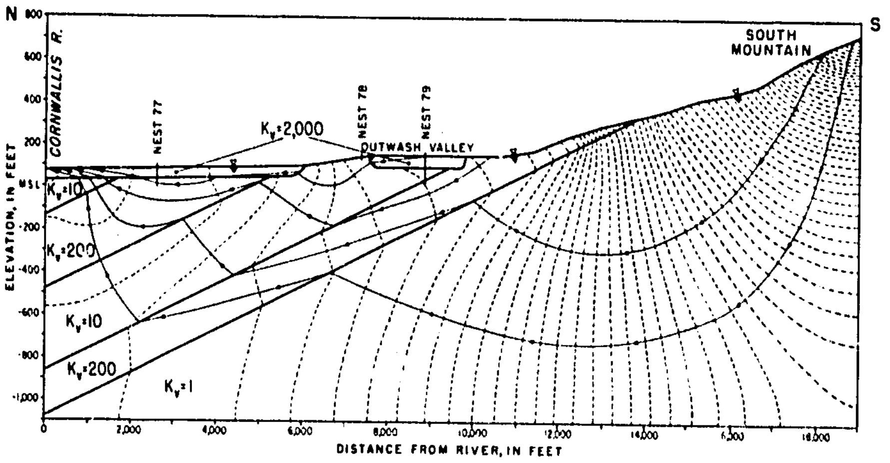

N.B.
LEGEND
TRIASSIC
9 North Mountain Basalt
8 Blomidon Formation
7 Wolfville Formation
MISSISSIPPIAN
6 Horton Group
DEVONIAN
5 Granite
4 Torbrook Formation
SILURIAN
3 White Rock, Kentville, and New Canaan Formations
ORDOVICIAN
2 Halifax Formation
1 Goldenville Formation
CAPE CHIGNECTO
CAPE D'OR
CAPE SPLIT
SCOTS BAY
ILE HAUTE
BAXTER HARBOUR
MINAS BASIN
N
HARBOURVILLE
WOLFVILLE
KENTVILLE
BERWICK
MARGARETSVILLE
BAY OF FUNDY
PORT GEORGE
KINGSTON
MIDDLETON
ANNAPOLIS ROYAL
0
5
10
15
SCALE IN MILES

Figure 1

Figure 2. Regional groundwater flow model for a vertical section perpendicular to the strike of the Annapolis-Cornwallis valley (After Trescott, 1970, p. 18).



LEGEND

K_v	
2,000	Glaciofluvial sand and gravel
200	Sandstone, clean
10	Sandstone, silty, and arenaceous shale
1	Granite, slate and quartzite

(Note: K_h = 25 K_v in every formation)

—— Geologic boundary

▽ Water table

- - - Equipotential line, interval 10 feet

—•— Direction of groundwater flow

(Note: vertical exaggeration = 5:1)

gure 2

Figure 3. Physiography of the Salmon River watershed and its vicinity (Modified from Hennigar, 1968, p. 5).

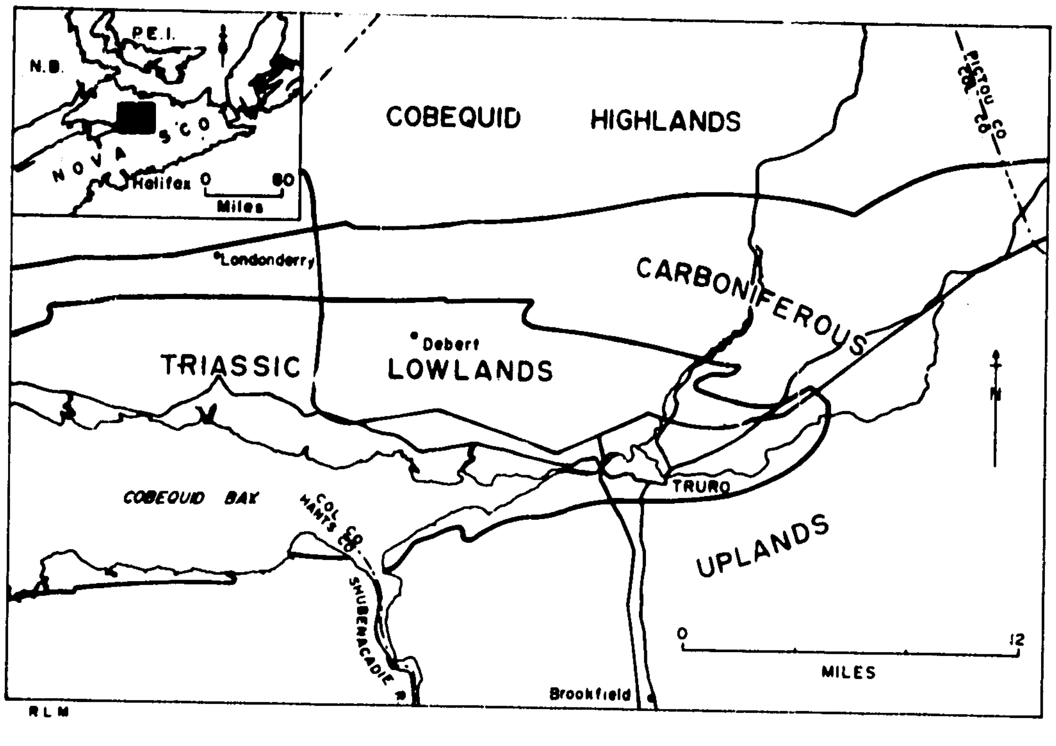

N.B.
P.E.I.
NOVA SCO
Halifax
0
80
Miles
COBEQUID HIGHLANDS
PICTOU CO
COL. CO
Londonderry
CARBONIFEROUS
Debert
TRIASSIC LOWLANDS
COBEQUID BAY
COL CO
HANTS CO
SHUBENACADIE
TRURO
UPLANDS
N
0
12
MILES
Brookfield
RLM

Figure 3

Figure 4. Relation between Salmon River discharge and coliform counts near Truro (After Hennigar, 1968, p. 127).

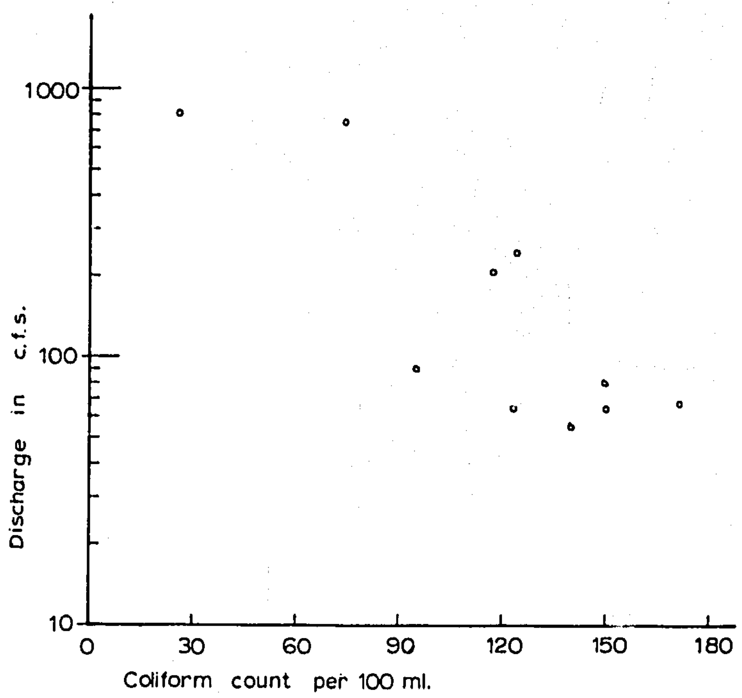

1000
100
10
Discharge in c.f.s.
0
30
60
90
120
150
180
Coliform count per 100 ml.

Figure 4

Figure 5. Bedrock geology of the Musquodoboit River Valley, Nova Scotia (After Lin, 1970 b, p. 13).

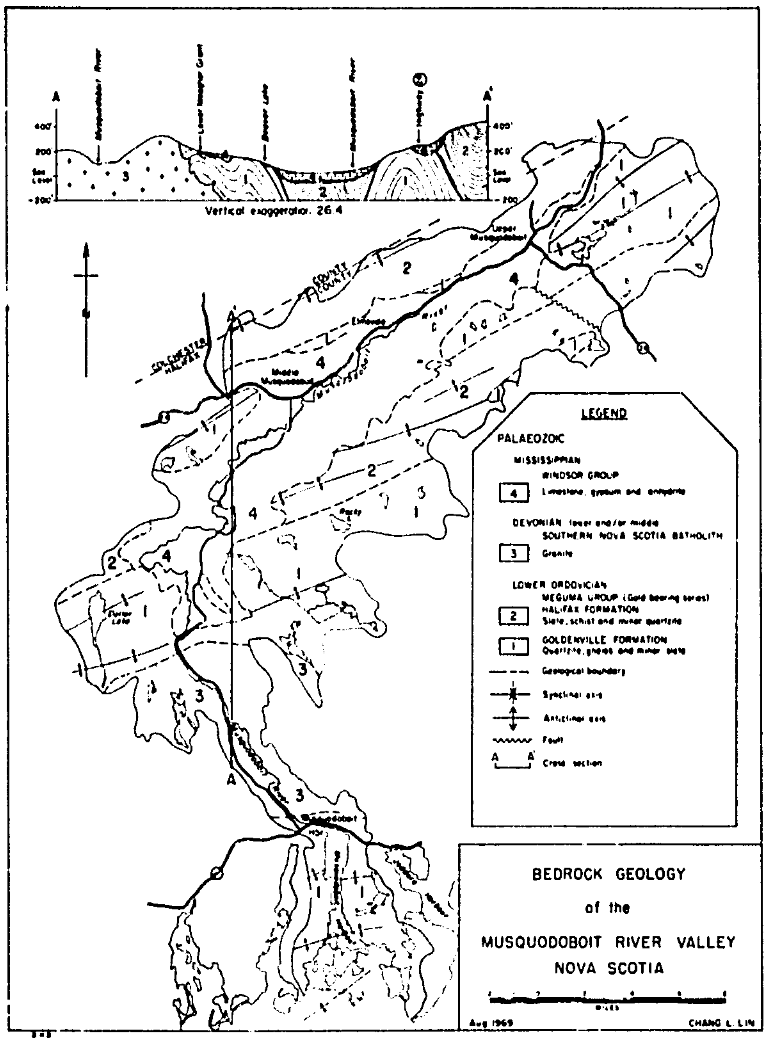

A
A'
400'
200
Sea Level
-200'
Musquodoboit River
Lower Meagher Grant
Beaver Lake
Musquodoboit River
Highway ②④
Vertical exaggeration 26.4
COLCHESTER
HALIFAX
COUNTY
COUNTY
Upper Musquodoboit
Middle Musquodoboit
Elmsvale
Musquodoboit River
Caribou Lake
Musquodoboit Hbr.
LEGEND
PALAEOZOIC
MISSISSIPPIAN
WINDSOR GROUP
4 Limestone, gypsum and anhydrite
DEVONIAN lower and/or middle
SOUTHERN NOVA SCOTIA BATHOLITH
3 Granite
LOWER ORDOVICIAN
MEGUMA GROUP (Gold bearing series)
HALIFAX FORMATION
2 Slate, schist and minor quartzite
GOLDENVILLE FORMATION
1 Quartzite, gneiss and minor slate
Geological boundary
Synclinal axis
Anticlinal axis
Fault
Cross section
BEDROCK GEOLOGY
of the
MUSQUODOBOIT RIVER VALLEY
NOVA SCOTIA
0 1 2 3 4 5 6
miles
Aug 1969
CHANG L. LIN

Figure 5

Figure 6. A tentative correlation among silica, pH, total hardness and surficial deposits. All measurements were taken in the field (After Lin, 1970 b, p. 46).

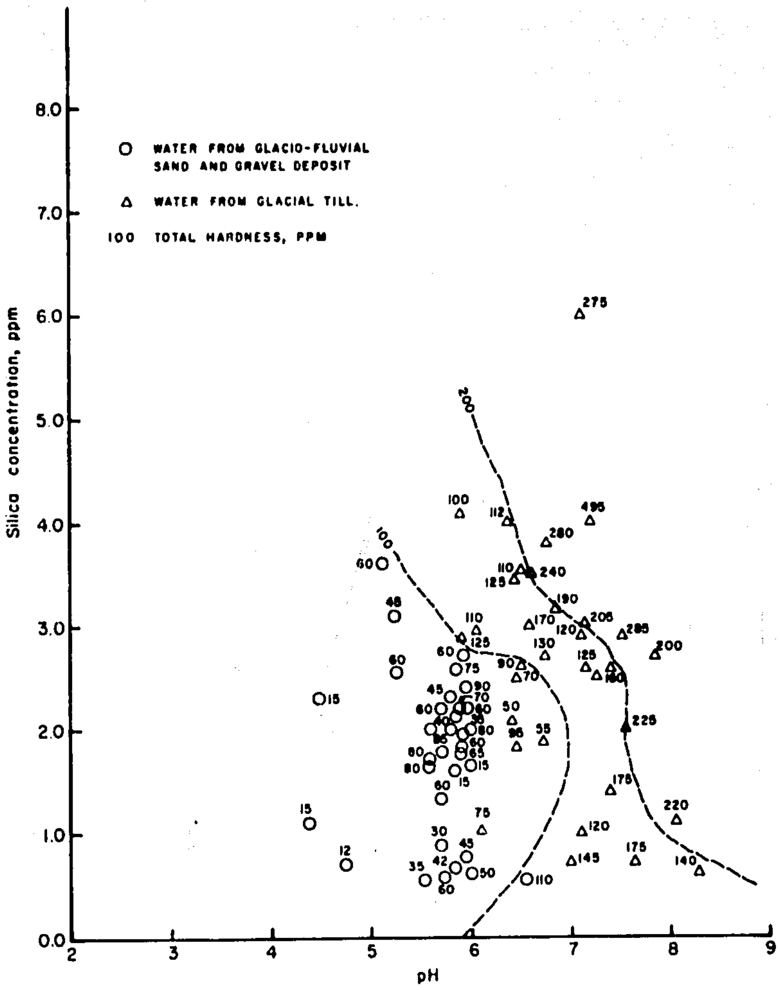

○ WATER FROM GLACIO-FLUVIAL SAND AND GRAVEL DEPOSIT
△ WATER FROM GLACIAL TILL.
100 TOTAL HARDNESS, PPM
Silica concentration, ppm
pH
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
2
3
4
5
6
7
8
9
100
200
275
100
112
495
280
110
240
125
190
60
48
110
170
206
120
285
125
130
200
60
60
75
90
70
125
180
15
45
90
70
60
50
225
35
80
96
55
60
65
80
15
60
15
178
15
60
75
220
120
12
30
45
175
35
42
50
145
140
60
110

Figure 6