CANADA
DEPARTMENT OF MINES
AND
TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
WATER SUPPLY PAPER NO. 290

GROUND-WATER RESOURCES
OF
SCARBOROUGH TOWNSHIP,
YORK COUNTY,
ONTARIO

By
H. N. Hainstock, E. B. Owen, and J. F. Caley

OTTAWA
1948

C A N A D A

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MINES, FORESTS AND SCIENTIFIC SERVICES BRANCH

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PART I

INTRODUCTION

This report deals with the ground-water conditions of part of an area in southern Ontario investigated by the Geological Survey in 1936 and 1937. The entire area covers approximately 800 square miles. It consists of King, Markham, Scarborough, Vaughan, and Whitchurch townships, York county; Albion and Toronto Gore townships, Peel county; and Pickering township, Ontario county.[1]

A gradually diminishing annual rainfall over the 5-year period 1931 to 1936, culminating in the extremely dry season of 1936, brought about a lowering of the ground-water level that resulted in serious water shortages in many localities. Many farmers found themselves virtually without water, and the supplies of some villages dwindled to quite insufficient amounts. The water supplies throughout the entire area are derived for the most part from ground water. The principal object of this report is, consequently, to aid those who are in need of new or further supplies.

As the ground water is directly related to the geology, both bedrock and superficial deposits were studied and mapped. All available information pertaining to some 8,700 wells was recorded and 280 water samples were collected for analysis. T. H. Clark (1936) and H. N. Hainstock (1937) mapped the superficial geology, and also directed the collection of water data. Dr. Clark was ably assisted in the field by J. H. Douglas, J. W. Britton, D. K. Stadleman, G. W. Matheson, M. E. Woods, and E. C. S. Gould, and Mr. Hainstock by J. H. Douglas, P. D. Bugg, M. E. Woods, W. B. Gray, E. A. Gray, W. E. Tweed, and J. P. Clancy. J. F. Caley, assisted by M. C. Gardiner, studied the bedrock formations.

Thanks are here extended to the farmers throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was given by the well drillers and by several municipal authorities who willingly supplied all available data.

To H. C. Rickaby, Deputy Minister of Mines for Ontario, and R. B. Harkness, Ontario Natural Gas Commissioner, thanks are here expressed for their hearty co-operation in the work.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports covering each township in the area. Township authorities will be supplied with the information covering their respective townships. In addition, pertinent data on each well have been compiled, and may be obtained from either the Chief Geologist, Geological Survey, Ottawa, or the Provincial Geologist, Ontario Department of Mines, Toronto. When requesting such additional information, the applicant should clearly state the exact location, giving the lot and concession of the district about which data are required.

With each report is a map consisting of two figures: Figure 1 shows the surface formations that will be encountered, and Figure 2 shows the position of all wells for which records are available, together with the class of well at each location.

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1. The material contained in Part I of this report refers to the entire area comprising all the townships mentioned. The general discussion of ground water is universally applicable. Part II deals specifically with the ground-water conditions of one township.

GLOSSARY OF TERMS USED

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material in lake beds and in the flood plains of modern streams.

Aquifer. A geologic formation or structure that tranmmits water in sufficient quantity to satisfy pumping wells and springs.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Contour. A line on a map passing through points that have the same elevation above sea-level.

Continental Ice-Sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood Plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term. It includes all the loose unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. Glacial drift occurs in several forms:

(1) Terminal Moraine or Moraine. A ridge or series of ridges formed by glacial drift that was laid down at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Kame Moraine. Assorted deposits of sand and gravel laid down at or close to the ice margin. The topography is similar to that of a terminal moraine.

(3) Drumlin. A smooth, oval hill composed mainly of glacial till, which has its long axis parallel to the direction of ice movement at thattplace.

(4) Ground Moraine. A boulder clay or till plain deposited at the base of the ice-sheet. The topography may vary from flat to gently rolling.

(5) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(6) Shore Line. A discontinuous escarpment, which indicates the former margin of a glacial lake.

(7) Bay-mouth Bar. A ridge of interbedded sands and gravels formed across the mouth of a glacial-lake bay.

(8) Glacial-lake Deposits. Sand, silt, and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. The sub-surface water below the water-table in the zone of saturation.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Impervious or Impermeable. Beds such as fine clays or shale are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium or glacial drift consisting of loose sand, gravel, clay, silt, and boulders that overlie the bedrock.

Water-table. The upper limit of the part of the ground saturated with water. This may be very near the surface or many feet below it.

Perched Water. Water separated from an underlying body of ground water by unsaturated rock.

Wells. Holes sunk into the earth so as to reach a supply of water. Whenmno water is obtained they are referred to as dry holes. Wells are divided into four classes:

(1) Flowing Artesian Wells. Wells in which water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer but not above the level of the ground at the well.

(3) Non-artesian wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are intermittently dry.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams as run-off; part evaporates either directly from the surface and from the upper mantle of soil, or indirectly through transpiration of plants; and the remainder sinks into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that sinks below the ground will depend largely upon the type of soil or surface rock, and on the topography; more water will sink into sand and gravel for example, than into clay; if, on the other hand, the region is hilly and dissected by numerous streams, more water will be immediately drained from the surface than in a relatively flat area. Light, continued precipitation will furnish more water to the underground supply than brief torrential floods, during which the run-off may be nearly equal to the precipitation. Moisture falling on frozen ground will not usually find its way below the surface, and, therefore, will not materially replenish the ground-water supplies. Light rains falling during the growing season may be wholly absorbed by plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish an adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this area, for example, is about 30 inches, it will be seen that each year some 435,600,000 gallons fall on each square mile. If we estimate that only 10 per cent of this, namely 43,560,000 gallons, is contributed to the underground supplies, it will be seen that the annual recharge for the entire area of 800 square miles is 34,848,000,000 gallons. The annual consumption of water in this area is not known, but an estimate based upon per capita consumption shows it to be only about one-tenth of the annual recharge as estimated above. It seems reasonable then, to conclude that precipitation is adequate to furnish supplies of ground water for the area.

In most regions of the world where precipitation is effective, there is an underground horizon known as the ground-water level or "water-table", which is the upper surface of the zone of water-saturation. Water that sinks into the ground finds its way downward to where it either reaches this water-table or comes in contact with an impervious layer of rock. Such a layer may stop further downward percolation, resulting in perched water. If the water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley.

All rocks are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute open spaces or pores. Water stored within the rocks fills these spaces. A fine-grained rock such as shale, limestone, or clay may have such small pores that the contained water will not flow readily, and wells sunk in such rocks may obtain little or no supply of water. Such rocks are considered impervious. Those rocks on the other hand that readily yield their water to wells are called water-bearing beds or aquifers. Sand and gravel, porous sandstone, and sand form good aquifers. A clean gravel constitutes one of the best types of aquifer, as it is sufficiently porous to yield its water freely.

Many shallow wells that derive their water from below the water-table have become dry. In many cases this is due to the lowering of the water-table below the bottom of the well. So long as the annual recharge is equal to or greater than the loss through consumption and underground drainage, there will be no lowering of the water-table, and hence wells sunk below this level will have a permanent supply. If, however, the annual precipitation were to decline over a period of years, the quantity of water available for recharging the underground supply would necessarily decrease, and if it were to decrease to a point where loss through consumption and underground drainage was greater than the annual recharge, the level of the water-table would be lowered and some wells would go dry. Such a decline in precipitation occurred in the general area under consideration during the 5-year period 1929 to 1935.

Although springs are utilized in some parts of this area, the chief method of recovering ground water is by means of wells. The quantity of water obtained from springs is usually small, but the town of Markham, with a population of about 1,[illegible]00, obtains its public water supply from such a source. Two types of wells are in common use, namely dug wells and drilled wells, the former outnumbering the latter by about ten to one. In places where the aquifer yields its water slowly, dug wells, because of their greater storage capacity, are more satisfactory than drilled wells. However, if proper precautions are not taken, dug wells are more likely to become contaminated by polluted surface waters, especially in barnyards. Ground water for industrial and commercial uses, where large quantities are required, is commonly obtained from the deeper drilled wells. When drilling such wells, the more shallow and perhaps smaller supplies can be cased off and drilling continued to where adequate supplies are encountered.

The wells have been classified as artesian and non-artesian, and artesian wells are subdivided into flowing artesian and non-flowing artesian. A fourth class, called intermittent non-artesian, comprises those wells that dry up periodically.

DESCRIPTIONS OF FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Bedrock Formations

The bedrock formations that underlie the area are listed in the following table:[1]

[1]Caley, J. F.: Palaeozoic Geology of the Toronto-Hamilton area, Ontario, Geol. Surv., Canada, Mem. 244, p. 12 (1940).

Table of Formations

System	Formation	Thickness (Feet)	Lithology
Silurian	Lockport	151 ±	Light grey dolomite; some brownish, bituminous, dolomite at top.
	Medina	74 ±	Red, green, and grey shale; grey, sandy, and shaly dolomite (Cabot Head); grey, magnesian and argillaceous limestone (Manitoulin); grey sandstone (Whirlpool).
Ordovician	Queenston	340 - 400	Red, in part sandy, shale.
	Meaford	120 ±	Grey, bluish, and brownish shale, with thin layers of limestone; calcareous sandstone and arenaceous shale.
	Dundas	550 ±	Grey and blue shale; thin, sandy beds; thin, lenticular, limestone beds.

	Billings	100 - 250	Dark grey to nearly black, slightly bituminous shale.
	Trenton and Black River	550	Chiefly grey limestone, in places dolomitic and shaly; sandstone and arkose at the base.
Precambrian			Granitic and altered volcanic and sedimentary rocks.

Precambrian

These rocks consist of granitic and altered volcanic and sedimentary formations that underlie the Palaeozoic sediments unconformably. They are not an important source of water in the area. Water contained in these rocks probably occurs in joints and fissures. From the few wells that have reached the Precambrian, the water is reported to be highly mineralized.

Trenton and Black River Formations

The Trenton and Black River formations consist predominantly of grey and blue-grey limestone, and are at least 550 feet thick. Thin layers of shale occur in some parts of the succession, and dolomitic limestone may be present in the lower part of the Black River beds. Coarse sandstone or arkose, resting unconformably on the Precambrian, is known to occur in some localities.

Water found in these rocks occurs in cracks, fissures, or solution channels, and along bedding planes. The limestone itself is too fine grained and compact to be water yielding, but the coarse sandstone or arkose may contain a considerable quantity of water. Water derived from these formations is commonly highly mineralized and unfit for domestic use.

Collingwood Formation

The Collingwood formation consists of dark grey to black, fine-grained, thin-bedded, bituminous shale. It is about 30 feet thick. Water recoverable from these rocks occurs largely in fractures and along bedding planes; the shale itself is too fine grained to yield its water freely. The water obtained is usually too saline for either domestic or stock purposes.

Billings Formation

The Billings formation is a thin, and evenly bedded, soft, bituminous shale that weathers dark grey, bluish, or even yellowish. On fresh surfaces it is dark grey to nearly black, with distinct brown and green shades in many places. Much pyrite occurs in the darker parts.

The shales are exposed on both Rouge and Little Rouge Rivers a short distance above highway No. 2. They also outcrop on Duffin Creek, where they may be seen on lot 15, cons. II and III, and on lot 13, con. IV, Pickering tp. No other exposures of this formation occur in the area, but the shales underlie all that part east of a line joining the mouth of Rouge River and Lemonville.

Some water occurs along the bedding planes of this formation, but the quantity recoverable is small and the water saline.

Dundas Formation

The Dundas formation is prevailingly a bluish grey, thin-bedded shale that weathers somewhat lighter. There is, however, some variation from compact, blue, argillaceous shale to buff or yellowish, silty, and frequently arenaceous rock. Hard bands, both calcareous and arenaceous, occur interbedded with the shale; they rarely exceed a foot in thickness, the average being only a few inches. The formation is about 550 feet thick. It outcrops on Humber and West Humber Rivers in Vaughan and Toronto Gore townships respectively, and underlies the drift throughout most of Vaughan and King townships together with the western part of Whitchurch, Markham, and Scarborough townships and a small part of each of Albion and Toronto Gore townships.

Water occurs along the bedding and joint planes of the shales, but the rock itself is too dense to yield its water readily to wells. Where the formation occurs at or near the surface, small quantities of water suitable for domestic needs may be obtained from the upper 50 feet. Water obtained deeper in the formation is commonly too saline for either domestic or stock uses.

Meaford Formation

The Meaford formation as a whole consists of grey to bluish and even brownish, fissile shale with interstratified hard layers that vary in composition from impure calcareous sandstone to rather pure crystalline limestone. It is exposed on a small tributary of West Humber River in Toronto Gore and underlies the glacial drift near the extreme western part of the area. It is known to be about 115 feet thick on Credit River a short distance southwest of the area.

The shale of this formation is too compact to be a good source of water. Wells penetrating the formation have yielded moderate quantities of water presumably from bedding planes and joint cracks, but in most instances the water is saline and not suitable for domestic needs.

Queenston Formation

The Queenston formation consists of brick-red, thin-bedded, compact shale. It does not outcrop in the present area, but underlies the glacial drift in the northwest part of Albion and Toronto Gore townships. The rock is a very poor source of water. It has been penetrated by a few wells, but the quantity of water obtained is small and commonly too saline for domestic use.

Medina Formation

The Medina formation overlies the Queenston, and forms the basal part of the Silurian system in Ontario. It has been divided into three members, which, in ascending order, are: Whirlpool sandstone, Manitoulin dolomite, and Cabot Head shale.

Whirlpool Member. This member is typically a resistant, light grey, fine to medium-grained sandstone. It usually occurs in beds of considerable thickness, but, where seen in its entirety, the upper few feet are commonly more thinly bedded than the lower part. Wave marks are common, but are best developed in the upper, thinner beds. The sandstone outcrops in the northwestern corner of Albion township, where it lies at the base of the Niagara escarpment. Its thickness within the area is not known, but wells drilled for natural gas a few miles to the west of the area show 20 feet of sandstone present. No wells have penetrated this rock, so that its water-bearing properties are not definitely known. However, where it lies below the water-table this type of rock should form a good aquifer, due to its relatively high porosity.

Manitoulin Member. This member does not outcrop within the area, but, as seen a few miles to the west, it consists essentially of buff weathering, grey, magnesian limestone, in part argillaceous, and disposed in even beds from 2 to 8 inches thick. The lower few feet show thin interbeds of soft grey or bluish grey shale from 2 to 4 inches thick. This rock underlies the glacial drift in the northwestern part of Albion township, and is about 25 feet thick.

Small quantities of water can be expected to occur along bedding planes and in solution cavities in this rock, but, as none of the wells examined penetrates this member, little definite information is available regarding its water-bearing properties.

Cabot Head Member. This member consists typically of red, green, and grey shales, sandy dolomite, shaly dolomite and ferruginous limy beds. It does not outcrop within the area, but can be seen in the railway cut at Limehouse a few miles to the west. It underlies the glacial drift only in the extreme northwest part of Albion township and is at least 40 feet thick. The shales do not form good aquifers due to their fine-grained texture, and the calcareous beds are few and too thin to hold much water. None of the wells examined penetrates the Cabot Head beds, but they are not thought to be an important source of water in the area.

Lockport Formation

The Lockport formation consists of magnesian limestone and dolomite, commonly light grey to bluish, fine to coarsely crystalline, in places quite porous, and disposed in beds from 2 to 4 feet thick, with both thicker and thinner beds locally developed. Jointing is general throughout the formation; it is commonly vertical but very irregular. Weathered surfaces may show joint cracks as much as a foot wide. These rocks may be seen in the extreme northwest part of Albion township, where they constitute the upper, cliff-forming member of the Niagara escarpment. The formation is perhaps 150 feet thick, with only the lower 50 feet occurring in the area of this report.

Appreciable quantities of water may occur in joint cracks, in solution cavities, and along bedding planes in this formation. Wells encountering these openings yield sufficient water for farm requirements. Numerous springs issue at the base of the Lockport formation where the contact with the underlying impervious Cabot Head is exposed by the topography. Some of these springs are reported to flow as much as 3,000 gallons an hour.

Unconsolidated Deposits

During the Pleistocene or glacial epoch, great accumulations of ice formed at various centres in northern Canada. This ice moved out in all directions from these centres and covered large regions with what has been called the continental ice-sheet. As the ice advanced, it picked up great quantities of loose rock debris, which was deposited when the ice finally melted. This material is unconsolidated, and is commonly called glacial drift. The ice-sheet advanced and retreated several times and on each retreat left an accumulation of drift on the surface over which it passed.

The area was entirely covered by one or more continental ice-sheets during Pleistocene time, and the final retreat of the ice left the bedrock surface covered to a variable depth with a mantle of glacial drift. This drift, together with flood plain deposits of alluvium, constitutes the unconsolidated deposits in the area. Most of the glacial drift consists of boulders and pebbles of various compositions and sizes embedded in a matrix of clay to form a more or less impervious mass known as boulder clay. Irregularly intermingled with this impervious mass, and also lying above, below, and between successive boulder-clay sheets, are beds, pockets, and lenses of sands and gravels that form the water-bearing members or aquifers of the drift. The following types of unconsolidated deposits occur in the area: (1) ground moraine; (2) terminal moraine; (3) kame moraine; (4) outwash sand and gravel; (5) glacial-lake deposits; (6) interglacial deposits; and (7) alluvium.

Ground Moraine. This type of glacial drift is chiefly boulder clay laid down at the base of the ice-sheet, and consists of a heterogeneous mixture of clay, boulders, and pebbles enclosing irregularly distributed lenses and pockets of water-laid sand and gravel.

Pore spaces in the boulder clay are very small, and much of the contained water is not recoverable through wells. However, where the clay is sandy, small domestic supplies may be obtained from it, and larger supplies, for industrial or municipal purposes, can be expected from the included lenses and pockets of sand and gravel.

At most places in the ground-moraine areas, water is obtained at depths of about 40 feet or less, but owing to the heterogeneous character of the deposits, it is not possible to predict the depth at which water may be encountered in any particular locality.

Terminal Moraine. Part of the load carried by the continental ice-sheet was dropped at its front or margin during pauses in the general retreat of the melting glacier. This load consisted of material gathered during the advance of the ice-sheet, and was deposited as a mixture of boulder clay, silt, sand, and gravel. Streams flowing from the melting ice carried away a large part of the silt, sand, and finer gravel, leaving chiefly compacted boulder clay and heaps of loose boulders as terminal moraine. In general, such material carries very little recoverable water, except where small lenses of sand or gravel are present.

Kame Moraine. The hilly region in the extreme north part of Markham and Vaughan townships is composed of boulder clay, sand, and gravel. Exposures show in road cuts at or near the tops of the hills; some of these are of sand, others of boulder clay. At one place a 6-foot layer of boulder clay overlies well-bedded sand, and wedges out southward; it is overlain by still more sand. This hilly area probably represents a terminal moraine, the sand and gravel being a mixture of outwash and kame deposits resulting from local readvances of the ice-front during its general retreat.

The typical terminal moraine part of the hilly region contains favourable aquifers at depth, but shallow wells do not, in general, yield adequate supplies. Water is obtained at depths of from 38 to 150 feet, with the deeper wells producing the more permanent and larger supplies. In the sand and gravel areas, however, where the deposits represent outwash and kame conditions, domestic supplies are obtained within about 17 feet of the surface.

Outwash Sand and Gravel. Sand and gravel carried out from the front of the melting ice-sheet and deposited on plains at or near such a front may form important aquifers. These deposits are porous, and readily absorb rain falling upon them. If they rest on impervious clay, which would prevent downward percolation of the water, they may become saturated to within a few feet of the surface. Shallow wells in such deposits can be expected to yield adequate domestic supplies. If the deposits are thick and contain extensive gravel lenses, they may yield supplies sufficient for industrial or municipal uses.

Glacial-lake Deposits. These deposits include the silt, sand, and gravel deposited in glacial Lake Iroquois. Most of the deposits consist of fine sand and silt, with the gravel occurring in the form of bay-mouth bars. The sandy deposits vary from a thin veneer to at least 10 feet in thickness; the gravel deposits reach a thickness of 40 feet. Such deposits are very porous, and will yield their water freely to shallow dug wells.

Interglacial Deposits. These deposits are exposed in Scarborough and Pickering townships, along the shore of Lake Ontario, where they consist typically of stratified sand overlying a grey, peaty clay. The clay is almost impervious and very little water can be expected from it. The stratified sand, however, does contain water, and springs issue from the contact of the sand and underlying clay in the cliffs along Lake Ontario. Unless the sand is so fine as to partly clog wells that are dug or drilled in it, a fair supply of water should be obtained.

Alluvium. Alluvial deposits consist of clay, silt, sand, and gravel laid down as flood-plain deposits along the valley bottoms of many streams. Locally these deposits may become very extensive. The water-bearing properties of alluvial deposits are variable, but, in general, such deposits form favourable aquifers. They are porous, and readily yield a part of their contained water, although, in places their porosity may be greatly reduced by the presence of fine silt and clay. This type of deposit may be expected to yield moderate domestic supplies through shallow wells, and larger supplies if the deposits are extensive.

WATER ANALYSES

Both the kind and quantity of mineral matter dissolved in a natural water depend largely upon the structure and chemical composition of the rocks with which the water has been in contact. Water may be polluted by organic matter or its decomposition products.

Two hundred and eighty samples of well water from the area were analysed for their mineral content in the laboratory of the Water Supply and Borings Section, Geological Survey, Department of Mines and Resources, Ottawa. The analyses are given in parts per million, that is, in parts by weight of the constituents in 1,000,000 parts by volume of water. No examination was made for bacteria, and hence a water that may be termed suitable for use on a basis of its mineral content might be condemned by reason of its bacterial content. Bacteriological analyses are made by the Provincial Department of Health, Toronto. As a rule, waters high in bacteria have been contaminated by polluted surface water.

The following mineral constituents include all that are normally found in natural waters in quantities sufficient to have any practical effect on the value of waters for ordinary uses.

Silica (SiO_2) is dissolved in small quantities from almost all rocks. It is not objectionable except in so far as it contributes to the formation of boiler scale.

Iron (Fe) in combination is dissolved from many rocks as well as from iron sulphide deposits with which the water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable, but separates as the hydrated oxide upon exposure of the water to the atmosphere. Excessive iron in water causes staining on porcelain or enamelled ware, and renders the water unsuitable for laundry purposes. In the table of analyses accompanying this report, alumina is included with the iron and both are reported as the oxides.

Calcium (Ca) is dissolved from almost all rocks, though in greater quantities from limestone, dolomite, and gypsum. Magnesium (Mg) is similarly dissolved from many rocks, but particularly from dolomite. These constituents impart hardness to water and are active in contributing to the formation of boiler scale. The sulphate of magnesia ($MgSO_4$) combines with water to form "Epsom salts", and renders the water unwholesome if present in large amounts. Calcium salts in minor quantities have no injurious effects.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or with that enclosed in marine sediments. No estimate of potassium (K) has been made, and any that may be present has been included as sodium. Moderate quantities of these constituents have little effect upon the suitability of a water for ordinary uses, but waters containing sodium in excess of about 100 parts a million may require careful operation of steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts may be so large as to render a water unfit for nearly all uses.

Sulphate (SO_4) is dissolved from deposits such as gypsum and sodium sulphate. It is also formed by oxidation of iron sulphides and is, therefore, found in mine waters. Sulphate, in combination with calcium and magnesium, causes formation of boiler scale; it also increases the cost of softening the water.

Chloride (Cl) is a constituent of all natural waters and is dissolved in small quantities from rocks. Waters from wells that penetrate brines or salt deposits contain large quantities of chloride, usually as sodium chloride (common salt) and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage, and any locally abnormal quantity suggests pollution from this source. However, such abnormal quantities should not, in themselves, be taken as positive proof of pollution in view of the many sources from which chloride may be derived. Chlorides impart a salty taste to water, and if present much in excess of 300 parts a million, render it unfit for domestic use.

The term "total dissolved solids" is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts a million. Waters containing up to 500 parts a million may be accepted for domestic use provided they are otherwise satisfactory, but a content of 1,000 parts a million does not prohibit domestic use if no better supply is available. Residents accustomed to the waters may use those that carry much more than 1,000 parts a million of total dissolved solids without inconvenience, although persons not used to highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as "permanent hardness" and "temporary hardness". Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing large quantities of sodium carbonate and small amounts of calcium and magnesium compounds are soft, but if the latter compounds are present in large quantities the water is hard. The following table[1]
t^ 1'

[1]Thresh, J. C. and Beale, J. F., "The Examination of Waters and Water Supplies", London, 1925, p. 21.

may be used to indicate the degree of hardness of a water:

Total Hardness

Parts per million	Character
0- 50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 +	Very hard

The water samples analysed were taken from depths of from 7 to 462 feet, and with 51 exceptions all are from glacial drift. They show little variation in either the total dissolved solids or the quantities of the individual constituents. As far as mineral content is concerned, the waters are quite suitable for domestic and stock purposes as well as for most industrial uses. Softening would be desirable for laundry purposes. None of the drift waters analysed contains sufficient salts to render it injurious to crops and so unsuitable for irrigation.

PART II

SCARBOROUGH TOWNSHIP, YORK COUNTY, ONTARIO

Physical Features

Scarborough township is in the southeast corner of York county, and has an area of approximately 71 square miles. Danforth and Scarborough Junction, suburban communities of the city of Toronto, are in the southwest corner of the township.

The surface of the township is fairly flat, though numerous, low rounded hills provide a gently undulating appearance in many localities. Surface elevations increase gradually northward from 246 feet above sea level at Lake Ontario to more than 650 feet in the northwest corner of the township. Two prominent topographic features are worthy of note. One is a discontinuous ridge or bluff that represents the former shoreline of glacial Lake Iroquois. It has been studied and described by A. P. Coleman[1]. The shoreline trends northeasterly across the east half

[1]Coleman, A.P.: Lake Iroquois; Ont. Dept. of Mines vol. XLV, pt. VII, pp. 1-36 (1936).

of the township, following the 450 and 475-foot contour lines. The area to the south of the shoreline is more level than that to the north, due largely to the deposition of glacial-lake sands and silts carried from the higher ground to the north. Prior to the formation of glacial Lake Iroquois, this area was largely morainic, with ridges of till and undrained hollows; however, wave action cut down hills and ridges and filled the depressions leaving a plain with a gentle southward slope. The second prominent topographic feature is represented by steep, wave-cut bluffs along the shore of Lake Ontario. These bluffs, which rise almost perpendicularly above the lake to a maximum height of about 350 feet, are known as Scarborough Bluffs. They have the distinction of being the first place in America where an interglacial formation was recognized[1].

[1]Coleman, A.P.: Pleistocene of the Toronto Region; Ont. Dept. of Mines, vol. XL1, pt. V11, pp. 16-19 (1932).

Rouge River, Little Rouge River, and Highland Creek, together with their numerous, small tributaries, cross the township in a general southeasterly direction. Many of the smaller creeks that depend upon ground water for their flow are dry, or nearly so, except at times of spring floods or after heavy and prolonged rains. Except in places where the creeks have cut through the Lake Iroquois shoreline, the valleys have gently sloping sides, with stream beds less than 50 feet below the level of the surrounding country. In many places the smaller valleys lose their identity or become mere ditches in the surface.

Geology

Bedrock Formations. Scarborough township is underlain by two bedrock formations of Ordovician age. The older of these formations, the Billings, which underlies the glacial drift in the east half of the township, consists of thin-bedded, dark grey to nearly black, soft, bituminous shale. Outcrops of the Billings occur along Rouge and Little Rouge Rivers in lot 2, con. 11, and lot 1, con. III. The succeeding Dundas formation underlies the west half of the township. It consists of grey and blue shale, thin sandy beds, and thin, lenticular beds of limestone. No outcrops of the Dundas have been observed in the township.

Unconsolidated Deposits. The greater part of the glacial drift in the area to the north of the Lake Iroquois shoreline is ground moraine. This consists chiefly of a hetergeneous mixture of clay, boulders, and pebbles enclosing irregularly distributed lenses and pockets of water-laid sand and gravel.

A small terminal moraine, whose southern border forms the shoreline of glacial Lake Iroquois,, extends east from the west boundary of Scarborough township to a point about 2 miles east of Scarborough Bluffs. The relief is small, and in places it is difficult to distinguish the terminal moraine from the ground moraine. The materials comprising the former consist predominately of boulder clay, with scattered pockets and lenses of sand and gravel. Both the quantity and quality of ground water derived from water-bearing materials in the terminal moraine are good.

One drumlin, observed in lots 13 and 14, con. V, is a low, smooth, dome-shaped hill composed chiefly of boulder clay enclosing small, scattered deposits of sand and gravel.

The greater part of the area lying south of the Iroquois shoreline is covered by deposits of clay, silt, sand and gravel laid down in the waters of that glacial lake. These deposits, which overlie ground moraine similar to that found north of the shoreline, vary in thickness from a thin veneer to at least 10 feet. It is reported that 100 feet of Lake Iroquois sand occurs in a cliff on Lake Ontario at Victoria Park in the city of Toronto.

Several large deposits of well stratified gravel occur along the Iroquois shoreline. They represent bay-mouth bars that were built by wave action across the mouths of bays along the shore of glacial Lake Iroquois. The largest of these deposits is in lots 29 to 35, con. A; smaller deposits occur in lots 8 to 10, con. 11, and lot 1, con. lV. These gravels are being used for road-building, railway ballast, and making concrete, and have proved to be the most valuable of Lake Iroquois deposits.

Interglacial deposits are exposed in Scarborough township along the shore of Lake Ontario. According to A. P. Coleman[1], a typical section

[1]Coleman, A.P.: Pleistocene of the Toronto Region; Ont. Dept. of Mines, vol. XLI, pt. VII, p. 17 (1932).

of the glacial drift, including the interglacial deposits, along Scarborough cliffs, is as follows:

Material	Feet	Remarks
Boulder clay....................	28	
Stratified clay and sand.........	24	
Stratified clay, probably varves.	15	
Boulder clay....................	43	
Stratified sand..................	21	
Boulder clay....................	4	
Stratified sand, cross bedded....	45	
Boulder clay....................	25	
Stratified sand..................	58	Cool climate; interglacial
Peaty clay (to level of Lake Ontario).............	85	
Peaty clay continued below water level................	5	
Stratified sand with wood and shells...............	35	Warm climate
Total...........................	388	

Part, at least, of the interbedded sand and boulder clay deposits exposed along Scarborough Bluffs probably extends north from Lake Ontario and underlies the southern part of Scarborough township. The fact that these deposits contain porous beds of sand interbedded with relatively impervious beds of boulder clay would suggest conditions suitable for flowing-artesian wells. However, unless the porous parts of the interglacial deposits outcrop inland from Scarborough Bluffs or are very extensive, their supply of water would not be sufficient to produce such wells, and the present small quantity of water issuing as springs from the interglacial deposits at Scarborough Bluffs would indicate that the possibility of obtaining flowing-artesian wells from these deposits is small. The quality of water derived from the interglacial deposits may be impaired by the decomposition of organic materials present in the deposits, as suggested by excess amounts of chlorides and sulphates present in some wells in the township.

Alluvial deposits of clay, silt, sand, and gravel occur along the flood plains of some of the streams in the township. The deposits are thin, and are unimportant as sources of ground water. The material is derived mainly from the reworking of glacial drift.

The following table indicates the minimum thickness of drift at several localities:

Well No.	Concession	Lot	Depth (Feet)	Aquifer
3	C	14	110	
4	C	35	100	sand (?)
10	D	35	110	sand
1	I	35	112	drift
3	II	12	80	gravel
7	II	34	160	sand
2	III	1	6[2]	shale
3	III	1	10[2]	shale
6	III	24	19	drift
41	III	27	90	drift
4	III	35	127	gravel
3	IV	18	100	gravel
3	IV	25	100	sandy gravel
6	IV	27	130	sand
26	IV	28	160	drift
9	IV	34	245	sand
3	V	22	175	gravel
1	V	25	195	drift
2	V	32	233	sand

[1] Well numbers used in this report refer to those wells on which data have been compiled, as indicated on page 2 of this report.

[2] To bedrock

Water Supply

The supply of ground water in Scarborough township is not abundant, but in years of normal precipitation it is sufficient for local needs. Most residents in the southwest part of the township, which is a sub-urban area of the city of Toronto, obtain their water supply from the Toronto Water Works system. Although a satisfactory supply of ground water at shallow depths can be obtained, most of the wells in this area are not in use. Throughout the remainder of the township, water supplies are derived entirely from wells and springs.

About 92 per cent of the wells in the township are of the dug type, and about 81 per cent obtain their water supply from depths of 40 feet or less. A survey of the well records show that about 88 per cent of the wells have a permanent water supply sufficient for the present demands made upon them; the remainder constitute dry holes, wells that go dry periodically, and wells that went dry apparently as a result of the last period of extremely dry weather (1931-1936).

Of the 2,195 producing wells and springs in Scarborough township, 2,178 obtain their water from glacial deposits, 4 from the underlying bedrock, and the remaining 13 from unknown sources. As the extent of the interglacial deposits in Scarborough township is not known, no account is taken of the relative ages of the principal water-bearing beds, as the water-bearing properties of the aquifers seem to be independent of their position within the drift.

Sand and gravel pockets and lenses within the glacial drift, as well as glacial-lake deposits of sand and gravel overlying boulder clay, are the chief sources of satisfactory ground water in the township. In most wells the statements of owners and drillers as to the character of the aquifer were accepted. In some wells the principal aquifer is listed as glacial clay,material that normally yields little water. Commonly boulder clay is a poor reservoir for ground-water storage, as it takes up water slowly, and holds relatively little. Furthermore, due to the sluggish circulation, the quality of ground water obtained from boulder clay is commonly poor. In wells where the yield is considerably greater than might be expected, it is possible that the boulder clay is mixed with sand or even consist of fine sand or silt, with a pore space large enough to permit more ready circulation. There is no way of ascertaining where a water-bearing deposit of sand or gravel may occur in the boulder clay, unless it outcrops at the surface or has been located by a well or test boring. Wells that depend entirely upon boulder clay for their water are not satisfactory, and probably go dry, not as a result of any fluctuation in the general ground-water level, but because the rate of consumption is greater than the rate at which the clay aquifer will yield water to the wells. Such wells may be easily depleted if drawn upon heavily, but may gradually regain their former water level if allowed to stand unused, or if consumption is materially reduced.

Many wells obtain their water from glacial-lake deposits of silt, sand, and gravel overlying boulder clay, south of the Iroquois shoreline. The average depth of these wells is about 20 feet. In the southwest part of this area, the glacial-lake deposits become thinner, and the supply of ground water obtained from them is not sufficient to meet both domestic and stock requirements. It is thought that the supply might be increased by deepening the wells into the underlying boulder clay and thus forming a larger reservoir for the water to collect in. The most satisfactory supply of ground water yielded by deposits of Lake Iroquois is obtained from extensive gravel beds along the Iroquois shoreline.

The intake area for the ground water includes almost the entire surface of Scarborough township, as well as areas to the north . Rain falling upon sand and gravel will penetrate rapidly, and such material is widespread south of the Lake Iroquois shoreline. Contours drawn through the water levels of non-artesian wells show a gradual slope from north to south across the township. The movement of water through an aquifer takes place down the hydraulic gradient, and hence it is probable that areas to the north contribute to the ground water supplies recovered in Scarborough township.

The bedrock formations immediately underlying the glacial drift in Scarborough township are not a good source of ground water. Three wells located in lots 1 and 4, con. III, derive ground water from the Billings formation at depths of 8, 17, and 85 feet from the surface of the ground. The water yielded by the shallow 8-foot well is sufficient to supply both domestic and stock needs of a farm; the supply from the 17-foot well is small and intermittent; and the water obtained from the 85-foot well contains a large amount of sodium chloride (common salt), which renders it unfit for domestic use. A well, 404 feet deep in lot 27, con. B, is obtaining water from the Dundas formation. The water is reported to contain a large quantity of dissolved salts and cannot be used for domestic or stock purposes. From the little evidence available, it is thought that water obtained from wells drilled only a short distance into bedrock is much more satisfactory than that from deeper wells. This is due largely to the fact that water obtained at depth has been longer in contact with the rock, and thus has had more opportunity to take into solution various soluable salts in the rock. There is also the possibility that some of the water from deep wells in bedrock is connate water, that is, sea water that was trapped in the rock at the time of its formation.

Buried stream channels could not be recognized from the evidence of the wells. Such channels should contain quantities of sand and gravel, and hence form favourable source beds for large supplies of ground water. The occurrence in a limited area of several drift wells that are appreciably deeper than the average might indicate the presence of such an underground channel, but the deep drift wells in Scarborough township are so scattered that no reliable conclusions as to the location of buried channels can be drawn.

Of the eight, flowing-artesian wells in Scarborough township, all but one are in shallow valleys. It is probable that the underground conditions that produce these flowing-artesian wells are local, and that elsewhere the possibilities of obtaining such wells in the township are not good.

Small springs are fairly numerous throughout the township. They occur chiefly along the cliffs at Scarborough and along the base of the Iroquois shoreline, where porous sand and gravel beds and lenses resting upon impervious boulder clay are exposed by natural slopes. In general, they are not an important source of ground water, although in places they supply both domestic and livestock needs. Many of the springs, especially those that draw their water from porous beds of limited extent, are intermittent, and therefore, unsatisfactory. It was reported that the flow from springs along Scarborough Bluffs had increased when shallow, non-artesian wells in that vicinity were no longer used. This would suggest that the springs are due to the exposure of the water-table at the Bluffs and are not the result of flowing-artesian conditions in the area.

Village Supplies

All the villages in Scarborough township obtain their water from privately owned wells; the supply coming entirely from the glacial drift. The water supplies in all communities were reported to be sufficient.

Analyses of Water Samples

Fifty-five samples of well water from Scarborough township were analyzed for their mineral content in the laboratory of the Geological Survey of Canada. The samples were taken from depths of from 4 to 233 feet, and with one exception are all from glacial drift. Sample No. 32 is of water derived from the Billings formation. Although this water is reported to be used for domestic purposes, the extremely high sodium chloride content would indicate that it is not satisfactory. The waters from the glacial drift were found to be suitable for domestic and farm use, but great care should be taken to prevent their contamination by surface waters. Several wells in the township are reported to yield water with a sulphur taste and odor, due to the presence of hydrogen sulphide. This contamination may have resulted from the decomposition of organic matter in the drift.

Amounts * of Dissolved Mineral Matter in Waters Collected in Scarborough Township

Constituent	Water from glacial drift (54 analyses)		
	Maximum	Average	Minimum
Total dissolved solids..............	2,200	417.4	140
Silica.............................	56	12.8	2
Iron (Fe_2O_3) and alumina (Al_2O_3)....	22	5.6	2
Calcium............................	300	86.3	17
Magnesium..........................	58	22.6	2
Sodium.............................	58	14.3	1
Sulphate...........................	241	72.4	13
Chloride...........................	540	31.3	4
Total hardness.....................	900	300.6	140

* In parts per million.

Conclusions

This investigation warrants the following conclusions:

1. Ground-water supplies of Scarborough township are not abundant, but are adequate for stock, domestic, and municipal purposes.

2. Precipitation appears sufficient to furnish adequate supplies of ground-water. In times of drought, or during extended periods of decreased rainfall, annual consumption may be greater than annual recharge, resulting in a lowering of the water-table. Some wells may go dry at times, and it may be necessary to deepen such wells.

3. The water-bearing beds in the ground moraine deposits that cover the surface north of the glacial lake Iroquois shoreline consist of irregular lenses and pockets of gravel, sand, and sandy clay.

4. The water-bearing beds in the glacial-lake deposits south of the Iroquois shoreline consist of sand and gravel deposits overlying relatively impervious boulder clay.

5. The quality of water derived from the glacial drift is quite suitable for domestic use.

6. Water obtained from the upper part of the bedrock, where it is at or near the surface, may be satisfactory, but that obtained at depth, or from the upper part of the bedrock where it is overlain by a thick accumulation of drift will probably be too saline for use.

7. The quantity of water recoverable from a well depends upon the porosity, thickness, and extent of the aquifer penetrated.

8. It is possible to obtain ground water nearly everywhere in the township, but it is not always possible to predict the depth at which favourable aquifers may be reached.

9. As the conditions that produce flowing-artesian wells in the township appear to be local, the possibilities of obtaining further flowing-artesian wells, except in areas where they now exist, are not considered to be good.

ANALYSES OF WELL WATERS FROM SCARBOROUGH TOWNSHIP[1]

Well No.	Con.	Lot	Depth of well in feet	CONSTITUENTS AS ANALYSED (parts per million) Total dissolved solids	SiO_2	Fe_2O_3 Al_2O_3	Ca	Mg	Na	SO_4	Cl	Alkalinity	Total Hardness	CONSTITUENTS AS CALCULATED IN ASSUMED COMBINATIONS $CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl	$CaCl_2$	$MgCl_2$
1	C	14	110	700	4	8	117	58	51	13	35	580	550	293		201		51	19	58		
2	C	14	11	420	12	4	132	17		90	10	265	260	265	88		35					13
3	C	17	13	500	16	4	123	20	8	97	12	290	400	290	224		99		1	20		
4	C	17	75	200	12	4	31	21	18	16	5	160	240	78		73		16	24	8		
5	C	19	70	380	16	4	92	27	7	41	7	305	320	230		63	45		7	12		
6	C	20	7	440	22	6	134	17	6	77	12	315	280	315	27		74			15		4
7	D	4	90	320	56	4	60	0		59	11	105	200	105	61		20					15
8	D	19	50	280	16	4	72	21	5	43	8	220	280	160		34	54			13		
9	D	19	23	800	26	6	123	51	12	203	45	270	750	250	51		209			31		35
10	D	19	12	1040	12	2	152	24		136	45	260	440	260	163		26					60
11	I	5	31	280	18	6	67	17	3	23	3	220	220	172		40	25		4	5		
12	I	5	15	320	12	6	63	16	7	51	27	145	200	145	17		49			17		23
13	I	6	12	300	10	0	72	3	5	34	0	155	240	155	34		13			13		
14	I	9	11	240	6	4	67	6	2	30	9	150	240	150	31		20			5		8
15	I	9	14	520	12	6	109	2		47	37	175	300	175	70						50	7
16	I	11	11	320	10	4	77	7		36	10	170	260	170	31		18					13
17	I	11	9	340	12	4	56	9	11	44	11	140	220	140			45		12	18		
18	I	31	24	2020	26	4	300	55	53	116	540	210	900	210	165					135	464	216
19	I	31	26	640	8	4	112	24		102	88	135	420	135	145						61	40
20	I	35	30	580	14	6	77	37	32	107	40	305	440	243		52	119		18	66		
21	II	6	4	300	8	4	74	7	7	30	10	175	280	175	14		35			17		
22	II	7	6	340	10	4	83	9	3	38	8	200	280	200	10		37			8		4
23	II	9	16	300	8	6	80	8	5	41	7	190	220	190	14		37			12		
24	II	10	3	280	12	4	63	9	5	33	4	165	220	158		6	335		7	7		
25	II	10	78	740	6	6	160	26	58	241	75	275	480	275	170		129		27	124		
26	II	12	60	340	8	4	86	21	0	47	16	250	300	215		29	61			21		4
27	II	14	50	660	16	4	94	36	5	95	30	250	460	235		13	119			12		31
28	II	18	42	380	12	4	87	18	3	62	16	220	340	220	3		75			8		13
29	II	22	20	520	10	6	89	21	19	72	17	250	170	222		24	69		25	8		
30	II	26	16	600	8	4	107	27	30	129	26	250	460	250	31		134		40	43		

1 Analyses by F.J. Fraser and A.H. Bray.

* Sample from the Billings formation.

Well No.	Con.	Lot	Depth of well in feet	Total dissolved solids	SiO_2	Fe_2O_3 Al_2O_3	Ca	Mg	Na	SO_4	Cl	Alkalinity	Total Hardness	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl	$CaCl_2$	$MgCl_2$
			CONSTITUENTS AS ANALYSED											CONSTITUENTS AS CALCULATED IN ASSUMED COMBINATIONS								
31	II	31	48	420	6	8	29	38	39	77	56	155	340	73		69	89		9	92		
32*	III	4	85	6080	8	168	332	106		20	2790	1055	1350	830		189	30			4385		180
33	III	9	21	280	12	6	54	11	45	64	22	95	200	95	54		32			12		20
34	III	14	91	260	8	8	63	22	9	33	7	225	240	158		56	30		13	12		
35	III	21	37	700	22	8	123	8		92	39	190	280	190	130						25	31
36	III	34	114	360	14	6	100	23		18	18	255	280	250		4	22					24
37	III	35	127	360	20	10	97	24		28	13	265	340	243		18	35					17
38	IV	18	100	280	8	2	83	17	7	28	5	255	200	207		40	25		12	8		
39	IV	21	42	400	4	4	69	16		64	32	125	340	125	65		18					43
40	IV	22	100	240	8	2	83	8	4	44	6	195	200	195	17		40			10		
41	IV	24	?	180	14	4	37	21	8	26	4	165	180	93		60	20		15	7		
42	IV	25	100	200	14	4	23	31	12	53	5	150	200	58		77	44		27	8		
43	IV	28	28	420	18	4	97	28	10	82	15	270	340	160	242		23	103		26		
44	IV	28	160	340	24	22	86	23	19	39	6	300	260	215		71	10		46	10		
45	IV	30	25	320	8	6	80	22	5	61	8	230	300	200		25	76			13		
46	IV	30	24	560	16	6	117	36		103	60	250	480	250	58		78					80
47	IV	35	178	340	8	10	37	37	34	69	6	235	320	92		120	10		90	10		
48	V	16	80	300	12	20	80	18	10	36	6	250	260	200		42	30		18	10		
49	V	22	175	260	16	6	57	28	8	25	3	245	240	143		86	15		19	5		
50	V	23	110	540	12	4	92	31	3	72	36	240	380	230		8	90		7	43		
51	V	25	195	280	12	4	63	28	7	33	7	245	260	158		73	35		7	12		
52	V	27	150	280	12	4	63	32	1	43	17	225	280	158		57	54			3		20
53	V	29	160	300	10	4	46	32	9	16	5	245	300	115		109	5		18	8		
54	V	32	233	140	2	6	17	13	18	23	14	90	140	42		40	5		28	23		
55	V	33	34	680	14	4	80	50	5	220	27	150	580	150	68		215			12		27

SUMMARY OF WELL DATA

	Concessions									Total in Township	Percentage of total
	A	B	C	D	1	11	111	1V	V		
Total number of wells	20	128	301	417	465	336	300	179	62	2208	
Dug	19	117	282	386	447	314	273	145	50	2033	92.1
Drilled	1	5	12	24	10	16	22	34	11	135	6.1
Bored	0	1	1	2	1	1	1	0	1	8	0.3
Driven	0	0	0	1	4	4	0	0	0	9	0.4
Springs.	0	5	6	4	3	1	4	0	0	23	1.0
Number of flowing wells	0	0	0	0	3	4	1	0	0	8	0.3
Non-flowing wells	19	120	293	408	458	331	294	179	62	2164	98.0
With permanent supply	19	113	278	373	416	296	260	147	50	1962	88.4
With non-permanent supply	0	7	15	35	45	39	35	32	12	220	10.0
Dry holes	1	3	2	5	1	0	1	0	0	13	0.6
Not used	19	64	68	37	25	25	14	20	3	275	12.5
Number from 0 to 40 feet deep	9	102	239	374	413	277	230	115	36	1795	81.3
41 to 80	11	22	43	31	44	48	55	36	16	306	13.8
81 to 120	0	2	5	6	4	2	7	12	5	43	1.5
121 to 160	0	0	1	1	0	1	1	2	2	8	0.3
161 to 200	0	0	0	0	0	0	0	3	2	5	0.2
Over 200	0	1	0	0	0	0	0	1	1	3	0.1
Of unknown depth	0	1	13	5	4	8	7	10	0	48	2.2
Number with sand aquifer	16	67	97	193	275	105	72	26	15	366	39.4
Gravel aquifer	2	9	20	30	39	77	25	26	19	247	11.2
Clay aquifer	0	19	65	92	75	51	78	48	11	439	19.8
Aquifer reported as drift[1]	1	29	117	94	70	100	120	78	17	626	28.3
Aquifer in bedrock	0	1	0	0	0	0	3	0	0	4	0.1
Unknown aquifer	0	0	0	3	5	3	1	1	0	13	0.6
Number with hard water	19	125	298	412	464	336	299	179	62	2194	99.4
Soft water	0	0	1	0	0	0	0	0	0	1	0.01
Salty water	0	1	0	0	0	0	1	0	0	2	0.01

[1] Sand, silt, sandy clay, or sand and gravel