CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
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GEOLOGICAL SURVEY
WATER SUPPLY PAPER NO. 284

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

By

J. F. Caley T. H. Clark, and E. B. Owen

OTTAWA
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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 tranmits 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. When no 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 smallltributary 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]

[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

MARKHAM TOWNSHIP, YORK COUNTY, ONTARIO

Physical Features

Markham township is situated in the east-central part of York county, and has an area of approximately 120 square miles. The village of Markham, the largest of a number of small villages within the township, has a population of about 1,000, and lies about 20 miles northeast of the city of Toronto.

The surface of Markham township is fairly flat, though numerous, low, rounded hills produce a gently undulating aspect in many localities. Surface elevations decrease from about 825 feet above sea-level in the northern part of the township to about 600 feet in the southern part. An irregular, hilly region in the extreme northwest corner of the township rises to an elevation of 1,025 feet.

Rouge River and Little Rouge Creek, together with their numerous, small tributaries cross the township in a general southerly direction. Many of the smaller creeks, which are dependent upon ground water for their flow, are dry or nearly so except at times of spring floods, or after heavy and prolonged rain. Most of the valleys have gently sloping sides, with stream beds less than 50 feet below the general level of the surrounding country. In many places the smaller valleys lose their identity or become mere ditches in the surface.

Geology

Bedrock Formations. No exposures of bedrock are to be seen in Markham township, and no records of wells penetrating bedrock were available. However, both outcrops and deep-well records outside the township indicate that the entire area is underlain by a fine-grained, thin-bedded, marine shale of Ordovician age, which is at least 300 feet thick. In the eastern part of the township this consists of the dark grey to nearly black shale of the Billings formation, and in the western part of the bluish grey shale of the overlying Dundas formation. Interbedded with these shales are thin limestone beds and sandy layers from 2 to 6 inches thick.

Unconsolidated Deposits. Throughout most of the township the upper part of the drift consists of ground moraine, which is chiefly a heterogeneous mixture of clay, boulders, and pebbles, and which encloses irregularly distributed lenses and pockets of water-laid sand and gravel.

The hilly region in the extreme northwest part of the township is composed of boulder clay, sand and gravel. Exposures occur in road cuts at or near the tops of the hills. Some of these exposures are entirely boulder clay, others entirely sand. At one locality a 6-foot layer of boulder clay overlies well-bedded sand and is in turn overlain by more sand and loess. The whole area probably represents a terminal moraine, the sand and gravel being a mixture of outwash and kame deposits, and the combination a result of local readvances of the ice-sheet.

Sand is plentiful immediately south of the village of Unionville. As this seems to be superficial at many places and thickest in the valley of Rouge River, it may be an ancient flood-plain deposit of the river made before it had cut down to its present channel. Elsewhere along the river these sands are associated with varying quantities of gravel, and in lot 26, con. I, as well as in other localities, many freshwater shells (pelecypods and gastropods) occur. Similar sands and gravels, containing minor quantities of clay, may be seen at various places along the smaller streams. They are especially common in Don River Valley throughout concessions I and II and along its tributary to the east in concessions II and III.

Drumlins are scattered throughout the northern half of the township. These are low, smooth, elliptical or dome-shaped hills composed chiefly of boulder clay with some gravel. They average $\frac{3}{4}$ mile in length, and are roughly two or three times as long as they are wide. Many are less than 25 feet high, although some rise to nearly 50 feet.

The variations in the thickness of drift were not determined, as only one of the recorded wells appears to have reached bedrock. Well No. 26[1], on lot 20, con. III, was drilled to a depth of 450 feet, and although the aquifer was reported as glacial drift, analysis of the water shows a sodium chloride content sufficiently high to suggest that the water has been in contact with the underlying marine shale. The well is of the flowing artesian type, and it is probable that it has passed through the drift and is drawing its supply from the contact of drift and underlying bedrock. This would indicate a thickness of 450 feet of unconsolidated deposits at that locality.

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

Well No.	Concession	Lot	Depth (Feet)	Aquifer
23	I	28	120	Drift
60	I	30	125	Sand
55	I	30	140	Drift
62	I	30	120	Gravel
65	I	30	120	Gravel
72	I	30	110	Gravel
13	I	32	128	Gravel
25	I	34	110	Drift
31	I	34	172	Gravel
72	I	35	150	Sand
2	I	37	190	Sand
9	II	2	100	Drift
14	II	3	148	Drift
23	II	5	120	Gravel
8	II	7	146	Sand
28	II	12	100	Sand
5	II	33	150	Drift
1	III	1	140	Drift
12	III	10	160	Gravel
1	III	26	160	Drift
8	III	26	200	Drift
11	III	4	140	Sand
12	III	10	160	Gravel
9	III	13	125	Gravel
11	IV	4	130	Drift
15	IV	14	130	Gravel
14	IV	33	202	Drift
2	V	6	140	Clay
10	V	24	100	Drift
26	V	35	160	Gravel
29	V	35	340	Gravel

[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.

Well No.	Concession	Lot	Depth (Feet)	Aquifer
9	VI	1	126	Gravel
29	VI	5	150	Gravel
10	VI	23	135	Sand
2	VI	31	135	Sand
13	VII	5	144	Gravel
9	VII	7	107	Sand
5	VII	16	175	Drift
15	VII	23	100	Drift
9	VII	28	169	Quicksand
7	VII	32	136	Sand
10	VIII	17	202	Gravel
10	IX	3	185	Sand
37	IX	10	104	Clay
5	IX	12	225	Gravel
3	IX	21	180	Gravel

Logs of most of the wells in Markham township are not available. The following logs, furnished by Mr. Hiltz of Whitevale, illustrate the character of the materials intercepted in drilling wells in parts of the township.

Well No. 16, con. I, lot 28	Feet
Clay	50
Quicksand	55
Gravel	26
Total depth	131

Well No. 9, con.II, lot 2	Feet
Drift	99
Gravel	1
Total depth .	100

Well No. 20, con. V, lot 4	Feet
Clay	100
Gravel	11
Total depth ...	111

Well No. 2, con. V, lot 6	Feet
Drift	140
Gravel	2
Total depth ..	142

Well No. 9, con. IX, lot 27	Feet
Clay	48
Gravel	?

Well No. 14, con. IX, lot 29	Feet
Clay	85
Sand	3
Total depth ..	88

Well No. ?, con. V, lot 6	Feet
Clay	50
Gravel	4
Total depth ..	54

Well No. ?, con. IX, lot 21	Feet
Clay	15
Gravel	2
Clay	58
Sand	2
Total depth	77

Water Supply

Markham township is well supplied with ground water for domestic and stock purposes, and it is believed that supplies sufficient for municipal and smaller industrial uses are obtainable in some parts. About 86 per cent of the wells are of the dug type and about 83 per cent are supplying water from depths of 40 feet or less. A survey of the well records shows that about 83 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).

All wells in Markham township, with one possible exception, derive their water supply from glacial deposits. In describing the principal water-bearing beds, no account is taken of their age with respect to the successive advances and retreats of the ice-sheet, 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 outwash sands and gravels and porous beds lying between successive layers of boulder clay, are the chief sources of ground water in the township. In most wells the statements of owners and drillers as to the character of the aquifer were accepted. In many wells the principal aquifer is listed as glacial clay, material that normally yields little water. In wells where the yield is considerably greater than should be expected it is possible that the glacial clay may be mixed with sand or even consist of fine sand or silt with a pore space large enough to yield at least part of its water.

The intake area includes almost the entire surface of Markham township as well as areas to the north and northwest. Rain falling upon sand and gravel will penetrate rapidly, and such material is widespread in various parts of the township, as well as to the north. 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 Markham township.

There are two areas in which a relatively large percentage of the wells are periodically or permanently dry. The larger of these comprises lots 1 to 10, cons. V and VI, in which about 30 per cent of the wells fall under the above class. With the exception of flood-plain sands and gravels along Rouge River, the area is occupied by ground moraine showing chiefly a clay soil at the surface. Water-table contours indicate a dome that conforms approximately with the surface topography. Most of the wells that go dry in this region are less than 30 feet deep, and most of them are reported to be either in clay or glacial drift. However, several wells have secured adequate supplies from more favourable source beds at greater depths. Well No. 30, lot 4, con. V, secured water in gravel at a depth of 111 feet; well No. 2, lot 6, con. V, obtained a permanent supply at a depth of 140 feet; well No. 9, lot 1, con. VI, encountered a good supply in gravel at a depth of 126 feet; and well No. 29, lot 5, con. VI, obtained water in sand and gravel at a depth of 150 feet. In this region the drift is thick, and the possibilities of penetrating water-bearing sand and gravel beds apparently increase with depth. Hence, deeper drilling may be expected to result in more permanent water supplies.

In the extreme southeast part of the township is an area comprising lots 1 to 5, con. IX, and lots 1 to 10, con. X, in which about 33 per cent of the wells go dry intermittently. Some of these wells have gone dry gradually, others during the autumn, and still others only after extended periods of exceptionally dry weather. When visited, some of these wells were supplying water for as many as thirty head of stock, but the supply is apparently not permanent. With few exceptions, all the wells are 30 feet deep or less, and all are reported as having clay aquifers. It is probable that wells in clay aquifers go dry periodically, not as a result of any fluctuation of the general ground-water level, but rather as a result of the rate of consumption being greater than the rate at which the aquifers will yield water to the wells. Such wells may easily be depleted if drawn upon heavily, but may gradually regain their former water level if allowed to stand unused, or if the consumption is materially reduced. In this district, the intermittent nature of the wells seems to be due largely to the poor water-yielding quality of the source beds, and deeper drilling is advised to penetrate more porous aquifers.

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 groundwater. The occurrence in any locality of a few drift wells that are appreciably deeper than the average might indicate the presence of an underground channel, but the deep drift wells are scattered throughout the township and hence no reliable conclusions as to buried channels can be made.

Small springs are fairly numerous throughout the township. They occur chiefly where porous sand and gravel beds or lenses resting upon boulder clay are exposed by natural slopes or stream valleys. In general they are not an important source of groundwater in Markham township, although in places they supply both stock and domestic demands. Many of the springs, especially those that draw their water from porous beds of limited extent, give an intermittent flow. There are, however, some permanent springs, as in the valley of the east tributary of Little Don River on lot 48, con. I, immediately east of the Canadian National Railway. The permanent flow indicates a relatively large extent for the source bed, which appears to be sand overlying clay.

There are about thirty-five flowing artesian wells in Markham township, and they are present in every concession, except concessions IX, X, and XI. The wells range from a few feet to 450 feet in depth, and all are reported to be drawing their water from glacial deposits. In about one-third of these wells the water rises to between 1 and 5 feet above the surface; in the remainder it rises just high enough to overflow at the surface. The rate of flow of the wells was not determined, but the following approximate figures were reported: well No. 1, lot 42, con. I - 1,000 gallons an hour; well No. 17, lot 19, con. II - 15 gallons an hour; well No. 1, lot 26, con. III - 240 gallons an hour. It is not possible to outline areas in the township that are favourable for flowing wells, as the aquifers are probably beds within the boulder clay that are irregular in extent, distribution, and porosity. Flowing wells mi ht be encountered almost anywhere within the township.

Village Supplies

<u>Markham</u>. Springs are the source of water for Markham village. They are located on the side of Rouge River Valley about one-half mile north of two concrete reservoirs into which the water flows by gravity. The aquifer is reported to be quicksand. The village has a population of about 1,000, but the daily consumption from the springs is not known. The supply is reported to be adequate under ordinary conditions, but hardly sufficient during the summer when increased demands are made for watering lawns. These springs have supplied the village since 1916, and must have source beds of considerable extent.

Analyses of Water Samples

Fifty-six samples of well water from Markham township were analysed for their mineral content in the laboratory of the Geological Survey. The samples were taken from depths of from 7 to 450 feet, and, with one possible exception, are all from glacial drift. They show little variation in either the total dissolved solids or the quantities of the individual constituents. Sample Nos. 9, 12, 13, and 17 show a great increase in the iron and aluminium oxide content over the other samples analysed; the excess iron of No. 17 may have been dissolved from the iron pump and well casing. Sample No. 23 deserves special attention.

mention. The total dissolved solids is greatly in excess of that reported in the other samples due to an increase in the sodium chloride content. The water has a salty taste. The well producing this water is 450 feet deep, and, in view of the high sodium chloride content, it is probable that the well either penetrates the marine shale underlying the glacial drift or derives its water supply from the contact of the shale and drift.

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

Constituent	Water from glacial drift (55 analyses)		
	Maximum	Average	Minimum
Total dissolved solids	1,160	421.4	160
Silica	26	15	2
Iron (Fe_2O_3) and alumina (Al_2O_3)..	62	7.1	2
Calcium	212	80.2	11
Magnesium	81	25.2	10
Sodium	107	26.3	3
Sulphate	284	56.7	10
Chloride	203	29.9	2
Total hardness	1,050	354	160

* In parts per million

CONCLUSIONS

This investigation warrants the following conclusions:

1. Ground-water supplies of Markham township are adequate for domestic, stock, and municipal purposes.

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

3. The existence of numerous small streams with relatively shallow valleys indicates that the water-table occurs within about 50 feet of the surface. This is borne out by the fact that 83 per cent of the wells are less than 41 feet deep.

4. All the ground water is being derived from glacial deposits, except possibly in one well.

5. The source beds are lenses and pockets of gravel, sand, quicksand, and sandy clay in the glacial drift.

6. The water-bearing beds are irregular in size as well as in vertical and lateral distribution.

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

8. Even though the water-table may occur within a few feet of the surface, the type of material encountered at that depth may yield its water so slowly that wells in it are not satisfactory.

9. It is possible to obtain groundwater at nearly all localities throughout the township, but it is not always possible to predict the depth at which favourable aquifers will be penetrated.

10. In the areas of kame and outwash sand and gravel water is obtained within 17 feet of the surface. At most places in the ground moraine areas water is obtained at a depth of 40 feet or less. In the alluvial areas water is obtained at depths of 10 to 30 feet.

11. So far as mineral content is concerned, the groundwater recovered in Markham township is of good quality and quite satisfactory for all ordinary uses.

12. Drilling into the marine shales underlying the glacial drift is not advised. Water recovered from these shales will, in all probability, be too salty for domestic use.

ANALYSES OF WELL WATERS FROM MARKHAM TOWNSHIP[1]

					Constituents as analysed (parts per million)								Soap Hardness (parts per million)			Constituents as calculated in assumed combinations (parts per million)								
Sample Number	Lot	Concession	Depth of Well (feet)	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron and Aluminum (Fe_2O_3 and Al_2O_3)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sulphate (SO_4)	Chloride (Cl)	Alkalinity	Total	Permanent	Temporary	Calcium Carbonate ($CaCO_3$)	Calcium Sulphate ($CaSO_4$)	Magnesium Carbonate ($MgCO_3$)	Magnesium Sulphate ($MgSO_4$)	Sodium Carbonate (Na_2CO_3)	Sodium Sulphate (Na_2SO_4)	Sodium Chloride (NaCl)	Calcium chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)
1	31	IX	35	500	12	4	114	17		56	22	265	360	200	160	265	27		46					31
2	30	VIII	35	520	10	6	103	21		51	15	270	360	220	140	257		11	64					20
3	28	IX	25	780	14	4	112	19		130	127	300	420	220	200	280		17	69		111	210		118
4	25	IX	20	840	12	4	155	28	10	85	50	365	440	280	160	365	30		79			25		47
5	21	IX	40	440	14	4	74	22	21	44	17	250	360	220	140	185		55	30		30	28		
6	16	IX	45	220	14	4	17	20	28	13	9	160	200	70	130	43		69		37	19	15		
7	18	VIII	202	260	20	6	43	18	26	10	27	190	170	100	70	108		62		8	15	45		
8	19	VIII	14	240	12	2	52	24	5	14	33	190	240	110	130	130		50	41			13		8
9	20	VII	15	900	16	52	146	49	22	172	69	340	650	520	130	340	34		185			56		47
10	25	VII	29	460	14	6	103	29	12	64	38	285	460	280	180	258		23	80			30		24
11	25	VIII	28	400	14	2	57	16	35	46	15	215	280	150	130	142		55		7	68	25		
12	34	VII	20	760	20	62	100	31	34	67	42	325	520	400	120	250		63	64		22	69		
13	32	VI	7	320	14	60	66	16	22	34	9	230	280	170	110	165		56			50	15		
14	30	V	24	360	18	4	80	28		38	15	230	360	300	60	200		25			48			20
15	33	IV	202	220	14	6	46	22	18	16	5	220	220	100	120	115		76		15	24	8		
16	35	V	340	400	6	6	72	37	10	51	36	250	400	200	200	180		59	64			26		27
17	1	VII	80	520	18	40	97	34	23	69	53	285	540	440	100	243		35			86	58		24
18	4	VI	25	660	22	6	132	25	21	154	42	260	460	200	260	260	95		109			54		12
19	4	V		580	12	4	140	34		130	31	300	560	340	220	300	68		102					41

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

ANALYSES OF WELL WATERS FROM MARKHAM TOWNSHIP

					Constituents as analysed (parts per million)								Soap Hardness (parts per million)			Constituents as calculated in assumed combinations (parts per million)								
Sample No.	Lot	Concession	Depth of Well (Feet)	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron and Aluminum (Fe_2O_3 and Al_2O_3)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sulphate (SO_4)	Chloride (Cl)	Alkalinity	Total	Permanent	Temporary	Calcium Carbonate ($CaCO_3$)	Calcium Sulphate ($CaSO_4$)	Magnesium Carbonate ($MgCO_3$)	Magnesium Sulphate ($MgSO_4$)	Sodium Carbonate (Na_2CO_3)	Sodium Sulphate (Na_2SO_4)	Sodium Chloride (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)
20	4	IV	24	520	18	4	117	36	7	62	43	330	500	260	240	292		32	77			18		43
21	13	III	125	380	24	8	52	23	71	13	55	285	300	100	200	130		80		64	19	91		
22	18	III	21	500	16	6	134	21	13	64	25	355	400	220	180	335		17	79			41		
23	20	III	450	1580	16	6	80	30	391	37	34	135	420	360	60	135	4					996	70	117
24	22	III	20	360	20	4	100	24	7	51	20	285	360	180	180	250		28	64			18		12
25	26	III	200	300	22	12	46	22	35	15	23	235	280	120	160	115		76		31	22	38		
26	29	III	25	240	20	8	40	25	15	15	8	210	240	90	150	100		87		7	22	13		
27	31	III	18	440	12	6	92	31	26	46	46	305	440	200	240	230		63	58			66		8
28	32	IV	12	310	12	4	83	17	10	44	12	235	310	190	120	207		23	50		6	20		
29	33	III	22	280	26	6	46	16	36	30	23	195	240	90	150	115		55		15	44	38		
30	3	IX	185	400	18	4	97	32	16	51	42	295	400	140	260	243		44	64			40		2[illegible]
31	12	IX	225	380	14	6	66	47	15	77	16	290	360	70	290	165		105	84		15	26		
32	21	IX	180	980	24	20	212	34	107	141	107	605	700	350	350	530		63	79		115	177		
33	29	IX	90	320	18	4	46	11	53	84	20	160	200	120	80	115		38			124	33		
34	31	VIII	75	360	18	6	94	12		49	19	210	360	180	180	210	34		31					25
35	33	VII	136	160	14	4	11	10	48	31	4	135	160	90	70	28		35		69	46	7		
36	31	VI	135	280	12	4	80	13	9	39	3	230	280	90	190	200		25	30		22	5		
37	30	VI	90	200	20	4	34	24	14	16	9	200	200	50	150	85		83		6	24	7		
38	30	VII	160	280	4	6	37	24	32	44	20	190	260	120	140	93		81	5		59	33		

ANALYSES OF WELL WATERS FROM MARKHAM TOWNSHIP

					Constituents as analysed (parts per million)								Soap Hardness (parts per million)			Constituents as calculated in assumed combinations (parts per million)								
Sample No.	Lot	Concession	Depth of Well (Feet)	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron and Aluminum (Fe_2O_3 and Al_2O_3)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sulphate (SO_4)	Chloride (Cl)	Alkalinity	Total	Permanent	Temporary	Calcium Carbonate ($CaCO_3$)	Calcium Sulphate ($CaSO_4$)	Magnesium Carbonate ($MgCO_3$)	Magnesium Sulphate ($MgSO_4$)	Sodium Carbonate (Na_2CO_3)	Sodium Sulphate (Na_2SO_4)	Sodium Chloride (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)
39	27	VII	169	240	2	8	14	17	37	28	7	140	200	40	160	35		54		43	41	12		
40	23	VII	100	200	14	8	26	10	41	15	8	170	160	25	135	65		35		67	22	13		
41	20	VIII	70	320	12	6	49	23	18	28	15	205	280	120	160	123		69	15		24	25		
42	17	VII	175	240	4	4	29	16	36	15	17	180	220	90	130	73		56		42	22	28		
43	1	VI	126	280	22	4	37	28	16	34	4	170	280	80	200	93		92	10		39	7		
44	2	VI	150	280	4	4	57	44	83	143	33	260	480	260	220	143		139	20		188	55		
45	6	V	140	180	18	4	43	20	4	39	4	140	180	90	90	108		38	45		4	7		
46	23	VI	135	1160	14	4	180	81		167	203	320	1050	950	100	320	177		53					272
47	14	IV	130	400	8	4	60	27	64	18	78	270	380	130	250	150		94		9	27	129		
48	9	III	100	360	12	8	66	20	58	10	61	275	280	90	190	165		69		29	15	101		
49	1	III	140	340	8	4	109	17		31	4	305	340	160	280	272		28	39					4
50	1	II	84	360	6	4	94	22	12	49	9	285	360	110	250	235		42	50		13	15		
51	10	III	160	320	14	6	89	22	12	20	2	315	280	80	200	222		76		3	30	3		
52	12	II	100	320	18	8	77	23	19	16	4	305	320	70	250	192		80		19	24	7		
53	21	I	67	280	8	6	89	23	3	28	4	270	280	120	160	223		39	35			7		
54	18	I	86	340	20	4	86	25	3	23	4	295	320	130	190	215		67	29			7		
55	9	V	25	820							34	70	360	260	100									
56	10	V	27	660	40	4	132	35	6	284	4	185	440	300	140	185	197		173		10	7		

SUMMARY OF WELL DATA

	Concession I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Total number in Township	Per cent of total
Total number of wells	322	169	158	155	205	241	155	158	139	94	8	1,804	
Dug	245	149	137	148	180	222	134	146	121	79	7	1,563	86
Drilled	77	16	20	7	21	18	21	11	18	15	1	225	12
Bored	0	4	1	0	4	1	0	1	0	0	0	11	0.6
Number of flowing wells	8	1	7	2	8	5	3	0	0	0	0	34	2
Non-flowing wells	312	168	151	153	197	236	152	158	137	93	8	1,765	97
Dry holes	2	0	0	0	0	0	0	0	2	1	0	5	0.2
With permanent water supply	292	143	127	125	167	195	136	144	119	60	6	1,541	84
Non-permanent water supply	28	26	31	30	38	46	19	14	18	33	2	285	16
Number from 0 to 40 feet deep	230	139	127	132	163	184	119	142	111	71	8	1,426	79
41 to 80	23	14	13	13	18	33	13	12	15	16	0	170	9
81 to 120	38	11	4	0	3	0	5	1	5	1	0	68	4
121 to 160	12	2	7	4	3	5	3	0	1	0	0	37	2
161 to 200	5	0	1	0	0	0	2	0	2	0	0	10	0.5
Over 200	0	0	1	1	1	0	0	1	1	0	0	5	0.3
Of unknown depth	14	3	5	5	17	19	13	2	4	6	0	88	4
Number with gravel aquifer	60	18	28	24	24	20	20	37	20	11	0	262	14
Sand aquifer	44	30	27	7	15	22	27	15	14	5	0	206	11
Quicksand aquifer	27	9	30	35	32	24	11	6	1	3	0	178	9
Aquifer reported as glacial drift[1]	79	33	29	32	46	55	34	14	20	25	3	375	20
Clay aquifer	113	79	43	52	86	120	63	86	84	48	5	779	43
Aquifer in bedrock	0	0	1	0	0	0	0	0	0	0	0	1	
Number with hard water	317	159	143	140	189	232	154	154	137	90	8	1,723	95
Soft water	3	0	1	1	4	5	1	2	0	0	0	17	
Salty water	0	0	1	0	0	0	0	0	0	0	0	1	1
Not used	0	10	13	14	12	15	14	9	6	2	0	95	5

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