CANADA
DEPARTMENT OF MINES
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GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER NO. 287

GROUND-WATER RESOURCES OF VAUGHAN 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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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 200 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 tranrmits 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. Whenno 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 1,000, 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] t- l-

[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

VAUGHAN TOWNSHIP, YORK COUNTY, ONTARIO

Physical Features

Vaughan township is situated in the west-central part of York county and has an area of approximately 106 square miles. Woodbridge, a village in the southwest part of the township, lies about 10 miles northwest of the city of Toronto.

The surface of the greater part of Vaughan township is fairly flat. In the northeast corner however, the topography becomes more rugged due to the presence of many ridges and rounded hills. Surface elevations vary from less than 450 feet in Humber valley, lot 1, con. VII, to 1,075 feet in lot 33, con. II. In the west part of the township, Humber and East Branch Humber Rivers have cut deep valleys into the nearly level plain. These valleys are 50 to 75 feet deep, steep sided, and in some localities attain a width of about half a mile. A few springs occur along the sides of the valleys.

The township is well drained by Don, Little Don, East Branch Humber, and Humber Rivers. Don and Little Don Rivers originate in the hilly region in the northeast part of the township and flow in a southeasterly direction across the east half of the township. East Branch Humber and Humber Rivers cross the west part of the township flowing in a southerly direction. These rivers are all permanent, but do not carry a great deal of water except at times of spring floods or after heavy and prolonged rains.

Geology

Bedrock Formations. Except for a small area in the extreme northwest corner, Vaughan township is entirely underlain by the Dundas formation of Ordovician age. These rocks consist of blue and grey shale, thin sandy beds, and thin, lenticular beds of limestone. Outcrops of the Dundas occur on the banks of a small creek in lots 6 and 7, con. VIII, about one-half mile west of the village of Woodbridge. The Meaford formation, which underlies the northwest corner of Vaughan township, consists of grey, bluish, and brownish shale, with thin layers of limestone, calcareous sandstone, and arenaceous shale.

Unconsolidated Deposits. The greater part of the glacial drift in Vaughan township is ground moraine. This consists chiefly of a heterogenous mixture of clay, boulders, and pebbles enclosing irregularly distributed lenses and pockets of water-laid sand and gravel. Excellent sections of ground moraine, ranging in thickness from 40 to 60 feet, occur along the valley of Humber River.

The hilly region in the extreme northeast part of the township is composed of boulder clay with sand and gravel. This material probably represents part of a terminal moraine that formed during a local readvance of the ice-sheet. A second, less pronounced terminal moraine extends along the northern boundary of the township. The relief of this moraine is so slight that in places it is difficult to distinguish it from the ground moraine. It appears to unite with the larger moraine in the northeast part of the township.

An extensive area of kame deposits occurs in lots 25 to 34 cons.I, II and III. These deposits consist of crossbedded silts, sands,

and gravels overlain in places with a thin deposit of clay. The thickness of these kame deposits is not known, but it is excess of 100 feet.

Alluvial deposits of clay, silt, sand, and gravel ranging in thickness from a few inches to 5 feet, occur along the flood plains of almost all the streams in the township.

The thickness of the unconsolidated deposits in Vaughan township varies from a few feet in the area just west of Woodbridge to about 420 feet in the north and northwest parts of the township. The following table indicates the minimum thickness of drift at several localities:

Well No.[1]	Concession	Lot	Depth (Feet)	Aquifer
19	I	7	641[2]	
21	I	7	249	sand
6	I	34	200	drift
16	II	5	225	sandy gravel
13	II	34	240	drift
8	III	35	245	sand
8	IV	2	214	sand
20	IV	30	315[x]	shale
1	V	6	190	gravel
22	VI	5	270[x]	shale
12	VI	7	124[x]	shale
15	VI	19	250	drift
5	VII	6	15[x]	shale
6	VII	6	10[x]	shale
15	VII	7	30[x]	shale
42	VII	9	32[x]	shale
6	VII	27	250	sand
15	VII	34	290	sand
13	VIII	9	12[x]	shale
14	VIII	10	95[x]	shale
1	VIII	11	62[x]	shale
2	VIII	28	224[x]	shale
7	VIII	33	420	gravel
14	IX	5	55[x]	shale
16	IX	5	50[x]	shale
4	IX	12	72[x]	
13	IX	20	100[x]	
18	IX	35	250	gravel
13	X	24	240[x]	shale
1	X	26	200[x]	shale
1	X	31	180	drift

[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

In years of normal precipitation, Vaughan township is well supplied with ground water, and except for a few localized areas, no

difficulty should be experienced in obtaining sufficient water for domestic and stock needs. About 74 per cent of the wells are of the dug type, and about 77 per cent obtain their water supply from depths of 40 feet or less. A survey of the well records shows that about 82 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 the result of the last period of dry weather (1931-1936).

Of the 1,814 wells and springs in Vaughan township, 1,766 obtain their water from glacial deposits and the remaining 48 from bedrock. In describing the principal water-bearing beds in the glacial deposits, no account is taken of their age in 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 in the drift.

The main supply of water in Vaughan township is obtained from lenses and pockets of sand and gravel that occur at various depths in the glacial drift. In most wells, the statements of owners and drillers as to the character of the acquifer were accepted. In many wells the principal aquifer was 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 ground moraine deposits of boulder clay with lenses of sand and gravel, which cover most of the township, yield a fair supply of water. Wells obtaining their water from a sand or gravel bed in the boulder clay are the most satisfactory and usually have a permanent supply. On the other hand, wells that are dependent entirely upon the boulder clay for their water are not satisfactory. Because of the slow-yielding property of the boulder clay, these wells can be depleted very rapidly and require a considerable time to replenish themselves.

The water-bearing properties of the terminal moraine deposits in the north and northeast parts of Vaughan township do not differ greatly from those of the ground moraine. The most satisfactory water is obtained from scattered lenses of sand and gravel in the boulder clay. The kame deposits of sand and gravel yield a good supply of water.

The alluvial deposits in Vaughan township are not an important source of water, as they are quite thin and contain a large amount of clay and silt, which yield water slowly.

The Dundas formation, which underlies Vaughan township, is not a good source of water, although at least 45 wells are known to be deriving their water from it. Most of these wells are in the western part of the township, notably west and north of the village of Woodbridge, where the glacial drift overlying bedrock is thin. The depth of these wells varies from 10 to 404 feet. The water from the shallow wells is satisfactory, but that from the deeper ones contains a large amount of sodium chloride (common salt), which renders it unfit for domestic use. In those areas where the Dundas formation is overlain by a thick accumulation of glacial drift, drilling into the rock in search of water is not recommended. A sufficient supply of water, satisfactory for most domestic purposes, may be obtained from the rock where it occurs near the surface, but the supply will be small and might readily be affected by drought.

Two wells, 1,200 and 4,635 feet deep respectively, were reported to have reached the Precambrian rocks. These are in lot 7,

con. I and lot 2, con. III. The 1,200-foot well encountered a considerable supply of water at the contact of the Precambrian rocks with the overlying formation. This water is under sufficient hydrostatic pressure to overflow the surface. The 4,635-foot well yields a good supply of water, which is under sufficient hydrostatic pressure to raise it to within 130 feet of the surface. The water obtained from both these wells contains an excessive amount of mineral salts in solution and can not be used for domestic or stock purposes. The water from the 4,635-foot well has been sold as a mineral water for medicinal purposes.

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 any locality of a few drift wells that are appreciably deeper than the average might indicate the presence of an underground channel, but deep drift wells are so widely scattered that no reliable conclusions as to the positions of buried stream channels can be made.

At least thirty springs in Vaughan township are being used for domestic and stock purposes. They occur chiefly where porous sand and gravel beds or lenses resting upon impervious boulder clay are exposed by natural slopes or stream valleys. In general, they are not an important source of ground water. Many of the springs, especially those that draw their water from porous beds of limited extent, yield an intermittent flow, and therefore, are unsatisfactory.

There are about fifty-four flowing artesian wells in Vaughan township, and with the exception of one, all derive their water from the glacial drift. The exception is the 1,200-foot well in lot 7, con. I that obtains its water in the basal sandstone at the contact of Ordovician and Precambrian rocks. With the exception of a small area centred around the village of Maple and another in the eastern parts of lots 16 to 20, con. I, no definite localities can be described in which the possibilities of obtaining flowing wells are good. In the village of Maple, forty flowing wells, ranging in depth from 15 to 42 feet, obtain their water from deposits of sand and gravel. These deposits are overlain and underlain by confining beds of clay. They are thought to be continuous and to extend northward into the terminal moraine country, which would act as the intake area for the water. The southern limit of the deposits is not known, but flowing artesian wells in lots 15 and 5, con. III are 1½ and 4 miles respectively south of the village of Maple. Three flowing artesian wells in the eastern parts of lots 18 and 19, con. I obtain water from sand at depths of 60, 75, and 110 feet. It is possible that other flowing artesian wells may be obtained in the area north and northwest of these wells toward the terminal moraine. The remaining flowing wells are scattered throughout the southern parts of cons. II and IV. Most of them are in river valleys and derive their water from source beds of limited extent.

Village Supplies

Richmond Hill. Richmond Hill, with a population of about 1,400, obtains its water partly from privately owned wells and partly from a municipal water works. Most of the wells yield sufficient water for domestic needs. They average less than 40 feet deep, and derive their water entirely from glacial deposits. The municipal supply is obtained from a permanent, spring-fed creek in lot 23, con. 1. In 1936, the annual water consumption of the village of Richmond Hill was 20,531,000 gallons, or a daily average consumption of 56,250 gallons.

Woodbridge. Woodbridge, with a population of about 1,100, obtains its water partly from privately owned wells and partly from a municipal waterworks. Most of the wells obtain their water from glacial deposits. The municipal water supply is obtained from a 12-foot well in gravel about 100 feet from Humber River. This well is capable of supplying 288,000 gallons a day.

Maple. The village of Maple obtains its water from privately owned flowing and non-flowing artesian wells. These wells all obtain this water from an extensive glacial deposit of sand and gravel, which is thought to extend northward to the terminal moraine. The village is well supplied with water.

The villages of Edgeley, Kleinburg, Langstaff, Leston, Nashville, Pine Grove, and Thornhill all derive their water from privately owned wells.

Analyses of Water Samples

Sixty-nine samples of ground water from Vaughan township were analysed for their mineral content in the laboratory of the Geological Survey of Canada. The samples were taken from depths of from 10 to 404 feet and with eight possible exceptions are all from glacial drift. Samples Nos. 46, 47, 49, 54, 55, 56, 60, and 62 are from the Dundas formation. The water from this formation contains a relatively large amount of mineral salts in solution, with the total dissolved solids of the samples analyzed ranging from 320 to 12,620 parts per million. Chlorides are generally the most abundant salts present, occurring mainly as sodium chloride (common salt) and in lesser amounts as calcium chloride and magnesium chloride. The samples of water derived from glacial deposits do not contain as large a quantity of mineral salts in solution as does the water from the bedrock. The total dissolved solids of the samples from glacial deposits analyzed range from 180 to 1,160 parts per million. It is possible that the water of those samples that contain a relatively large amount of mineral salts in solution, such as samples Nos. 36 and 52, is being derived from the contact of the glacial drift and bedrock. The water derived from the glacial drift in Vaughan township is quite suitable for all farm needs.

Amounts[x] of Dissolved Mineral Matter in Waters Collected in Vaughan Township

Constituent	Water from glacial drift (61 analyses)		
	Maximum	Average	Minimum
Total dissolved solids	1,160	397	180
Silica	26	17	4
Iron (Fe_2O_3) and Alumina (Al_2O_3)	12	5	2
Calcium	172	71	20
Magnesium	272	39	8
Sodium	221	32	1
Sulphate	491	66	12
Chloride	119	18	3
Total Hardness	500	306	180

[x]In parts per million.

Conclusions

This investigation warrants the following conclusions:

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

2. Precipitation is sufficient to furnish this 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 such times, and it may be necessary to deepen those wells so affected.

3. The presence of springs and seepages along the sides of the numerous river valleys, plus the fact that 77 per cent of the wells in the glacial drift are less than 40 feet deep, indicates that the water-table is shallow and probably occurs within about 50 feet of the surface throughout most of the township.

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

5. The water-bearing beds in the glacial drift are irregular in size as well as in vertical and lateral distribution.

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

7. 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.

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 will be penetrated.

9. So far as mineral content is concerned, ground water derived from glacial deposits in Vaughan township is of good quality and quite satisfactory for all ordinary uses.

10. Drilling into the bedrock underlying the glacial drift is not advised. Water obtained from this source will, in all probability, be too salty for domestic use.

Table of Analyses of Well Waters from Vaughan Township

Sample NO.	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	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	$NaCO_3$	$NaSO_4$	NaCl	$CaCl_2$	$MgCl_2$
					CONSTITUENTS AS ANALYSED										CONSTITUENTS AS CALCULATED IN ASSUMED COMBINATIONS								
1	15	1	6	160	320	10	4	83	18	7	74	16	195	260	195	17		77			17		8
2	31	1	9	176	340	12	6	74	17	40	33	4	300	220	185		59		48	49	7		
3	32	1	9	118	260	16	10	29	17	55	30	5	225	260	73		59		87	44	8		
4	33	1	9	128	220	12	4	57	14	4	20	6	180	220	143		31	25			10		
5	36	1	10	160	340	8	8	86	19	15	13	5	305	300	215		66		13	19	8		
6	19	1	28	90	320	12	6	60	21	38	41	8	265	300	150		73		30	61	13		
7	6	1	34	200	360	14	4	74	24		89	3	190	260	185		4	111					4
8	8	11	3	166	360	26	6	74	27	18	30	10	285	340	185		84	10		33	17		
9	12	11	13	150	200	6	4	31	14	15	44	5	115	200	78		31	25		36	8		
10+	1	11	26	105	180	14	6	51	13		33	4	145	180	128		14	41					5
11	8	11	33	230	300	18	4	69	23	13	30	3	260	260	173		73	10		33	5		
12	13	11	34	240	320	16	6	94	16	3	26	3	275	280	235		34	30		3	5		
13	14	11	35	220	240	20	6	26	39	4	15	3	215	240	65		126	15		4	5		
14	5	111	1	145	320	18	6	57	27	22	30	7	260	300	143		94		6	44	12		
15	8	111	2	145	320	12	4	54	27	17	13	5	265	320	135		94		19	19	8		
16	11	111	3	150	360	20	8	74	27	23	39	9	280	340	185		80	20		34	15		
17	13	111	3	134	360	10	2	52	26	24	12	55	270	300	130		90		35	18	8		
18	23	111	5	150	240	12	4	31	16	39	26	7	190	200	78		55		49	38	12		
19	7	111	6	155	360	16	6	72	16	41	18	10	300	340	180		56		57	27	17		
20+	13	111	18	20	520	16	4		24		54	16	275	400									
21+	12	111	21	35	340	18	2	94	17		33	5	265	260									
22	5	111	26	100	240	14	4	63	20	3	54	7	180	240	158		18	68			7		4
23	13	111	28	140	400	18	4	100	17	17	56	6	290	300	250		34	35		41	10		
24	5	111	32	208	320	10	4	92	17	8	30	4	280	240	230		42	25		15	7		
25	8	111	35	245	260	12	4	20	36	11	16	5	200	280	50		125		1	24	8		
26	8	1V	2	214	360	16	6	74	27	18	18	14	295	360	185		94			27	17		
27+	19	1V	5	10	380	12	4		21		25	4	300	280									
28+	15	1V	8	22	420	12	2		41		54	13	300	320									
29	4	1V	11	125	260	14	4	40	27	20	15	4	235	280	100		94		24	22	7		
30+	11	1V	18	118	640	16	2		31		105	62	260	360									
31	40	1V	25	62	300	14	6	40	40	12	21	6	260	340	100		134	5		25	10		
32	16	1V	28	180	320	20	8	89	19	2	8	3	295	300	223		60	10			5		
33	14	1V	35	100	360	18	6	97	23	11	59	10	285	320	243		35	64	12	12	17		

+ Analyses incomplete.
* Samples from the Dundas formation.
1 Analyses by F.J. Fraser and A.H. Bray, Geological Survey.

Sample NO.	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	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	$NaCO_3$	$NaSO_4$	NaCl	$CaCl_2$	$MgCl_2$
							CONSTITUENTS AS ANALYSED								CONSTITUENTS AS CALCULATED IN ASSUMED COMBINATIONS								
34	15	V	4	150	380	24	6	72	24	19	18	7	290	320	180		83		12	27	12		
35	7	V	8	16	360	14	4	80	15	26	61	25	220	300	200		17	50		31	41		
36	10	V	12	20	860	16	2	157	41	221	75	90	300	550	300	126		108			56		75
37	15	V	19	16	560	12	4	100	19	50	92	50	270	360	250		17	69		54	83		
38	4	V	22	105	340	14	4	94	17	1	38	4	260	280	235		21	48			2		4
39	5	V	28	85	335	16	4	86	20	16	30	6	295	320	215		67	5		38	10		
40+	8	V	33	15	380	4	6		15		44	6	225	320									
41+	10	V1	2	25	620	12	2		33		82	35	260	475									
42+	5	V1	16	23	540	14	2		44		69	31	335	350									
43	16	V1	19	80	300	18	6	57	33	11	13	3	290	340	143		115		6	19	5		
44	4	V1	23	88	365	10	4	103	21	9	36	7	315	360	258		48	35		12	12		
45	15	V11	3	22	340	12	2	60	8	21	36	9	180	300	150		25	5		47	15		
46*	9	V11	6	135	340	12	4	77	33	9	23	13	310	340	193		98	25		4	21		
47*	15	V11	7	30	920	16	4	174	31	15	176	64	325	650	325	150		87			38		55
48+	2	V11	12	47	660	14	2	152	27		66	39	330	500									
49*	3	V11	16	150	1100	20	4	97	41	206	28	410	255	375	243		6	35			522		126
50	6	V11	25	225	260	10	4	43	24	36	15	18	245	280	108		83		40	22	30		
51	11	V11	28	225	220	12	6	29	18	46	16	46	165	220	73		62		19	24	76		
52	5	V11	32	55	1160	12	4	172	73	75	382	119	330	750	330	136		358			191		4
53	6	V111	3	35	340	12	4	63	25	6	44	30	185	320	158		23	55			15		28
54*	3	V111	11	90	380	14	4	69	30	29	61	40	240	360	173		56	69		9	66		
55*	4	V111	16	210	1880	18	8	206	60	226	110	620	265	950	265	156					574	150	236
56*	6	V111	23	404	12,620	24	8	901	198	238	205	660	150	3000+					159	30	5735	2505	778
57+	9	V111	28	20	440	10	2		23		62	10	325	350									
58	18	V111	35	250	300	16	12	46	28	43	20	19	275	300	115		97		48	30	31		
59	6	1X	3	35	480	14	10	83	44	22	18	12	400	625	208		153		11	27	20		
60*	7	1X	7	125	4,840	14		226	801	216	132	370	180	1300	180					19	3072	428	314
61	16	1X	15	50	960	12	10	83	55	161	326	67	350	650	208		119	104		360	111		
62*	7	1X	17	200	320	8	6	54	25	29	31	37	220	280	135		71	25		16	61		
63+	12	1X	26	18	560	10	2	80	23		30	24	180	320									
64+		1X	32	spring	280	10	4		8		39	9	200	260									
65	3	X	22	125	620	8	2	49	171	44	491	158	230	220	123		59		39	73	261		
66+	13	X	30	46	420	12	4		17		72	10	220	260									
67+	1	X	31	14	440	6	6		17		26	13	300	280									
68+	3	X	31	spring	380	12	4		9		61	18	195	300									
69	1	X1	31	180	860	10	8	63	272	01	383	03	135	340	135	31		18			437		90

Summary of Well Data

Number and Character of Wells and Springs	CONCESSIONS											Total in Township	Percentage of Total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI		
Total number of wells	512	117	214	188	131	125	159	144	138	74	12	1814	
Dug	414	78	131	134	84	92	127	108	105	55	10	1338	74
Driven	0	1	1	1	3	0	1	0	0	0	0	7	0.4
Drilled	94	37	81	50	42	32	27	30	32	12	2	439	24.2
Springs	4	1	1	3	2	1	4	6	1	7	0	30	1.6
Wells 0-40 feet deep	401	83	163	148	84	91	121	100	99	56	8	1354	76.0
41-80	34	14	13	12	25	11	16	15	16	6	2	164	9.0
81-120	31	8	11	6	16	10	5	9	8	3	0	107	6.0
121-160	25	6	19	7	3	5	6	5	6	1	1	84	4.8
161-200	7	2	0	6	1	2	4	2	5	2	1	32	1.8
over 200	3	4	4	2	0	2	4	9	3	2	0	33	1.0
depth unknown	11	0	4	7	2	4	3	4	1	4	0	40	2.2
Wells that yield hard water	508	117	213	188	129	125	156	142	135	73	12	1798	99.1
soft water	1	0	1	0	0	0	0	2	1	0	0	5	0.3
salty water	0	0	1	0	1	0	1	0	7	1	0	20	1.1
Wells with aquifer in sand	200	49	110	74	57	26	45	34	44	20	0	659	36.3
in gravel	64	23	36	27	20	16	40	16	13	6	1	270	14.8
in clay	136	27	30	48	25	51	31	47	43	26	9	473	26.0
in drift[I]	107	18	37	38	27	29	20	32	23	18	2	351	19.3
in bedrock	2	0	1	1	0	2	12	15	12	3	0	48	2.7
unknown	0	0	0	0	0	1	0	0	1	0	0	1	0.01
Flowing wells	5	1	30	17	0	0	0	0	1	0	0	54	2.9
Non-flowing wells	500	115	183	168	127	124	152	138	134	66	12	1719	94.7
Wells with permanent supply	439	107	197	169	111	94	118	95	104	49	7	1490	82.1
Wells with non-permanent supply	69	9	16	16	18	30	37	43	33	16	5	294	16.2
Dry holes	3	0	0	0	2	0	3	0	2	1	0	11	0.6
Wells not used	30	1	6	10	13	6	14	16	9	6	0	111	6.1

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