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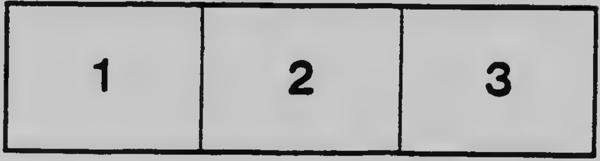
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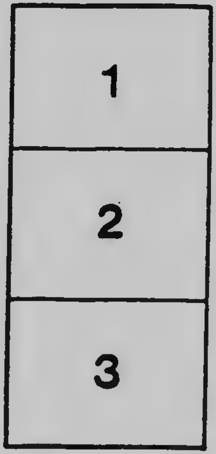
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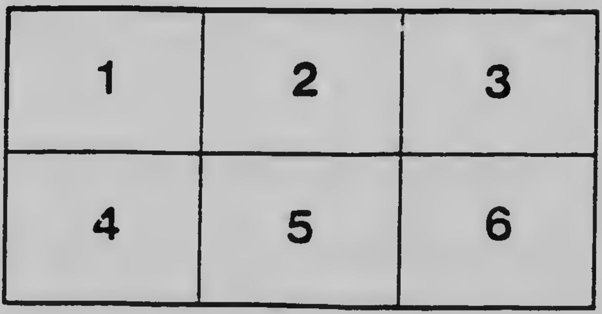
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O. H. M. S.

W. J. Gerald
Deputy Minister.

LABORATORY

OF THE

INLAND REVENUE DEPARTMENT

OTTAWA, CANADA.

BULLETIN No. 149

THE INSPECTION OF DOMESTIC WELLS

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BULLETIN No. 149

THE INSPECTION OF DOMESTIC WELLS

OTTAWA, March 23, 1908.

W. J. GERALD Esq.,
Deputy Minister of Inland Revenue.

SIR,—Two established facts regarding typhoid fever, and enteric fevers generally, are the following:— 1st, the contagion of these fevers is essentially water-borne; 2nd, they are characteristic of the Country rather than the City.

It is true that, when one case of typhoid fever originates in a city, we may generally expect to find it not a solitary case; indeed, a more or less extended epidemic is the usual history. In country places, it is on the contrary, quite usual to find the malady restricted to individual families; and most physicians, having large country practice, are acquainted with households in which a more or less continuous succession of fever patients are found from one year's end to another.

It requires no great ingenuity to explain these phenomena. They are just what one might expect, who is at all well acquainted with the conditions of domestic water supply.

The procuring of a satisfactory supply of water; the maintenance of such supply in a state of purity; and the more or less frequent inspection of the article, to ascertain its character, are matters which must chiefly interest the localities concerned.

When, as in the case of most cities and towns, the municipal supply is obtained from a single source, the problem of inspection becomes a comparatively simple one.

It is otherwise with smaller towns and villages, and with farms, where wells, usually the property of individuals are in use.

It is true that the widespread danger to health and life which results from the pollution of the single supply, in the case of a city or town, does not obtain in the case of wells. Excepting the wells of public schools, hotels, and a few of more or less public character, the danger is usually restricted to a single family. But wells supplying lodging houses, eating houses, factories, and especially bakeries, breweries and creameries, must not be forgotten.

While it is practicable and sometimes not difficult to effectively protect from pollution the river, lake, or other source of city supply, the protection of well supplies is much less easy. This is partly due to their great number, partly to their usually being placed in close proximity to the house, stables, privy, &c., and chiefly to the ignorance and thoughtlessness of those who use them.

The chief danger of water pollution lies in the readiness with which sewage may find entrance to an otherwise satisfactory supply.

The term *Sewage* has primary reference to the waste water carried by the sewers of towns having systematic drainage. It is applied generally to water rendered impure by having dissolved in it, the soluble matter from manure, privies, or household waste. It is characterized by both organic and inorganic impurities. The organic matter in sewage is partly living (microbial), and partly non-living (albumin, urea, &c.).

These contents of sewage are not necessarily poisonous, in the strict sense; but, among the bacteria there may be those of specific disease (typhoid, diphtheria, &c.) In any case, sewage is an objectionable and disgusting constituent of water intended to be used for drinking and cooking, and it is dangerous, even if not actually toxic.

The organic matters of sewage are changed in character, and may even be completely destroyed, by filtration through sand or gravel, charged with such bacteria as are always found in what we may call *normal* conditions.

The characteristic feature of the most objectionable component of sewage, is its nitrogen. In whatever form this may originally have been present (urea, albumin or other proteid, &c.) it turns up under the influence of efficient filtration, as nitric acid, or may be completely removed, by the agency of plant life.

The inorganic impurities of sewage may be in part removed (phosphates, sulphates) but the chlorides remain.

Common salt (chloride of sodium) is the most characteristic and constant inorganic ingredient of sewage. It is present in most human food, is fed to cattle, horses, &c., as such; and in consequence of this, it finds its way into the urine and faeces, and into dish water and general household slops. It persists in sewage, even after this has been, as already described, purified by filtration. Hence the presence of chlorides in drinking water cannot be taken as a conclusive proof that such water is unfit for food. We may go so far as to say indeed, that no naturally occurring water is free from chlorides.

It remains true, however, that the ground water of every locality is characterized by a certain limit of chlorine (in chlorides), and any considerable increase in this normal limit, especially if it is a fugitive or temporary increase, must be held to indicate pollution by sewage, unless other explanation can be furnished.

The reasonableness of this statement will appear if we make a brief study of the conditions of well supplies.

In March, 1900, the writer presented this subject in an address to the Ontario Provincial Health Association, and may be permitted to make some quotations from that address.

"When rain falls to the earth it is either absorbed by soakage, or it flows along the surface to lower levels. Usually both flow and absorption take place, but the ratio between the quantity carried off by surface flow, and that absorbed, varies with the nature of the soil, the degree of slope, and other conditions.

When the surface is nearly level, and porous, as is the case with ordinary arable land, most of the water will disappear by soakage, and if the rainfall is heavy, the ground will be wetted to a great depth.

In the diagram (Fig. 1) the dotted portion represents a layer of porous soil, S—(which may be sand, loam, gravel, etc.), underneath which lies a non-porous layer, C

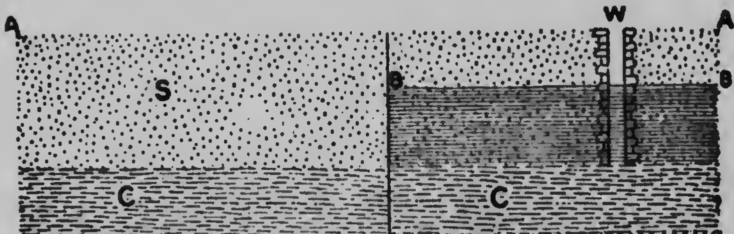


Fig. 1.

(clay), represented by short lines, and underneath this again is a layer of rock—R. The rain which falls on the surface A, will gradually sink through the porous soil till it reaches the impermeable clay; and shortly after the rain ceases, we may have the state of things represented at the right hand side of the diagram, which shows the porous soil thoroughly soaked from the surface of the clay up to the level B. This last is the so-called *ground-water level;* and it is evident that the depth of the ground-water level, below the surface level, will vary with the rainfall, and with the thickness of the stratum S: will be highest [illegible] heavy rain, and lowest after prolonged drought.

For every reg[illegible] average may be struck, which is known as the mean annual ground-water level, and we may suppose B to represent this mean level for the area under consideration. If now, a well be sunk, as at W, to the clay, this well will contain water to the depth of the average ground water of the locality. If the well be carried lower, *i.e.*, into the clay, the result will not be to change the character of the water, but merely to enlarge the storage capacity of the well. Extensive areas of level land, as in prairie regions, beaver meadows, etc., answer to the conditions described; but certain other characteristics of ground-water must be considered.

Ground-water is never stagnant, but is moving more or less rapidly towards some line of lower level, where a brook or river, or lake will generally be found. In Fig. 2, D represents a section of a stream, whose waters will evidently rise and fall with the level of the ground water, which supplies them; and we must discriminate between this rise and fall, which is always gradual, and that sudden rise, of short duration, which results from the surface flow immediately following heavy rain.

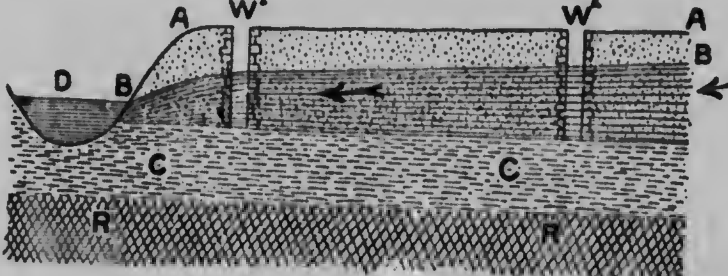


Fig. 2.

The flow of the ground-water will be in the direction indicated by the arrows, *i.e.*, at right angles to the course of the stream, and the line B B, will be a gradually sloping one, so that the well W¹ will contain less water than W^2 at the same time, although the wells may be of the same depth, and penetrate identical strata of sand, gravel, etc.

It must not, how[illegible] supposed that stratification of so simple a type as I have described, is at all com[illegible] Soil, by which I mean everything that is not rock, has resulted essentially from [illegible] operation of chemical and mechanical forces upon solid rock. The chief of these [illegible] have been, (1) the freezing of water in the pores of the rock, thus breaking it up; (2) the action of rain; (3) the alternate expansion and contraction by heat and cold; [illegible] attrition of stone upon stone at the bottom of rivers and lakes; (5) the movement of large ice masses (glaciers); (6) solution of certain rock components, with the consequent falling apart of the residue; (7) action of the roots of plants, which action is both mechanical and chemical; (8) chemical action by oxidation, formation of carbonates, etc. [illegible] of these changes have taken place under water, and every part of the earth's surface has again and again been the bottom of lake or sea, so that soil formed by the means [illegible] ribed, does not necessarily remain on the spot which produced it, but may lie hun[illegible] miles away. Thus, soils which have resulted from the attrition of rock masses [illegible] round about Algoma, now cover the fields of Southern and Eastern O[illegible] of thing has happened the world over; and the carriers of those immense masses of clay, sand, gravel and boulders, have been ocean and river currents; but above all glaciers and icebergs.

An iceberg is not a large block of clean, pure ice, but a section of a glacier, broken off by the lifting power of the ocean when the moving mass has been so far thrust into its waters that their buoyancy overcame the strength of the ice, and a huge mass snapped off, rose to the surface, and was carried out to sea. This ice mountain contains, frozen into it, perhaps thousands of tons of rock detritus. It floats out to sea, and wherever it melts, this soil-forming material is deposited, perhaps forming a heap or hill, perhaps being strewed along the course of the floating bergs. After a period of submergence, which may be hundreds of thousands of years in duration, subterranean forces cause, what was so long sea bottom, to become dry land; and we can imagine the condition of things described without too much difficulty, since a little observation of regions quite accessible to us, shows us very marked traces of the period itself. Of course the influence of new forces comes into play on what is now dry land. Atmospheric effects, vegetable and animal life, sunshine and storm play their part in altering the surface; and in the end this comes to be just what we find it, the very ground upon which we build our houses and in which we dig our wells.

In Fig. 3 we have a somewhat more complex section diagrammed, representing a state of things much more usual than the very simple conditions described in Figs. 1 and 2.

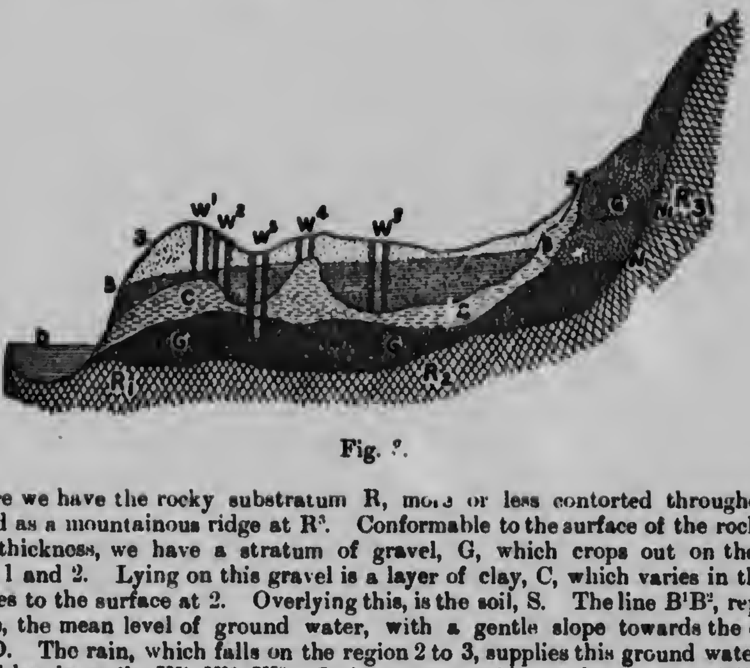


Fig. 3.

Here we have the rocky substratum R, more or less contorted throughout, and upheaved as a mountainous ridge at R^3. Conformable to the surface of the rock, but of varying thickness, we have a stratum of gravel, G, which crops out on the surface between 1 and 2. Lying on this gravel is a layer of clay, C, which varies in thickness, and comes to the surface at 2. Overlying this, is the soil, S. The line B^1B^2, represents, as before, the mean level of ground water, with a gentle slope towards the drainage stream D. The rain, which falls on the region 2 to 3, supplies this ground water, which is tapped by the wells, W^1, W^2, W^3. It is at once evident why a well at W^4 remains dry, or only contains water when the season is abnormally wet. The rainfall on the rocky surface to the right of 1, is of course not absorbed to any great extent, but flows down to the gravelly surface between 1 and 2, and together with the rain falling on this surface, is absorbed by the gravel, and finds storage in it between the rock (R) and the clay (C). Here it accumulates in a second and lower water-bearing stratum, and the normal level for this water supply may be represented by the line N. Now it is evident that if any of the wells W^1 to W^4 be continued through the clay, they will obtain a water supply from this lower gravel; and the well W^4 can get a permanent supply from no other source. W^4 then becomes an illustration of a so-called 'deep well,' and in wet seasons, when the level rises above the normal N, say as high as N^1, this well will over-flow, or becomes what is called a 'flowing well,' on the principle that water rises to the same height in all tubes connected with a common reservoir.

If I have succeeded in making my subject understood, we are now prepared to begin the special enquiry that I wish to propose for your consideration. Up to this point, I have merely defined and illustrated certain terms that I shall have to use repeatedly in the sequel. To recapitulate briefly, I have spoken of three classes of wells, viz.: those fed from the normal groundwater, those fed from a deep or secondary water supply, and those so-called surface wells, which, like W^4 in Fig. 3, receive soakage water only, and contain a supply only when the ground in the immediate vicinity is wet, as in Spring and Autumn. All the ground-water wells diagrammed, are represented as dug down to subjacent clay; but this is not a necessary condition. W^3 for example, would be none the less a ground-water well, had it been made no deeper than W^1 and W^2. We have now to consider the character of the water which fills these three types of wells.

Rain water is not the chemically pure substance which it is often described as being. In the later stages of a prolonged rainfall, it is indeed very nearly pure, but the first portions of every shower wash out from the air, not only the gaseous impurities, which are the products of animal and vegetable decay—(Ammonia, compound or organic ammonias, sulphuretted hydrogen, etc.)—but also those solid particles, rich in microbial life, which form the dust of the air, and are partly organic and partly inorganic in character. This rainwater, falling upon the surface of the ground, flows along this surface, or soaks into it, taking momentarily into solution more and more of the soluble matters with which it comes into contact. These are partly inorganic salts, chlorides, sulphates, carbonates, silicates, etc.—and partly organic matters of more or less complex nature, the products of the decay of vegetable and animal matter. If, for example, in Fig. 3, the region 2 to 3 is a cultivated farming country, somewhat sparsely inhabited, the organic impurities will chiefly be of a vegetable kind—rotting vegetation, the manure of the fields, etc.; but if it be a village or town, the organic matters will be more largely of animal, and especially of human origin. To these waste products the term sewage is properly applied. The ground-water of this region may be, therefore, much less pure than was the rain water that fell on the surface gathering-ground. I say *may be*, for reasons which will be presently given.

We may dismiss the *inorganic* impurities with a word, by saying that, unless they are present so largely as to give a distinct taste to the ground-water, they are rarely of a kind to be dangerous to health. The *organic* matters must be more carefully considered. If they have originated in normal decay, they may be harmless from the point of view of health, even though far from appetizing when we remember their origin; but if they come from those conditions of decay which we call *disease*, they may be actively poisonous, and may contain the living germs of specific diseases, such as fevers, diphtheria, cholera, etc.

Percolation, through a fully ærated soil, has, however, the effect of bringing about purification of such water by the process of oxidation, a process by which organic matter is changed and microbial life destroyed. That this should be effective, the water must filter through several feet of sand or gravel; and although it is impossible to fix a definite minimum limit to the depth of such a natural filter, it is safe to say that we should insist on ten feet, at least, and prefer as much more as we can get. To this end it is necessary that the upper ten feet of the wall of a well should be made quite impervious to water, and the accompanying diagram shows how such a construction can be brought about.

A well should be so constructed that no water could find entrance to it without filtration through a depth of soil, at least equal to the vertical distance between the ground level, and the lowest level of ground-water. To insure this it is necessary to have the mouth of the well raised a foot or more above the surface of the surrounding soil, and to have the brick (or stone) lining of the well backed up by a layer of puddled clay, a foot or more in thickness, and extending continuously from the level of the ground water quite up to the mouth of the well.

Diagram of well: showing a backing of puddled clay or other impermeable material between the brickwork and the porous strata through which the well is dug.

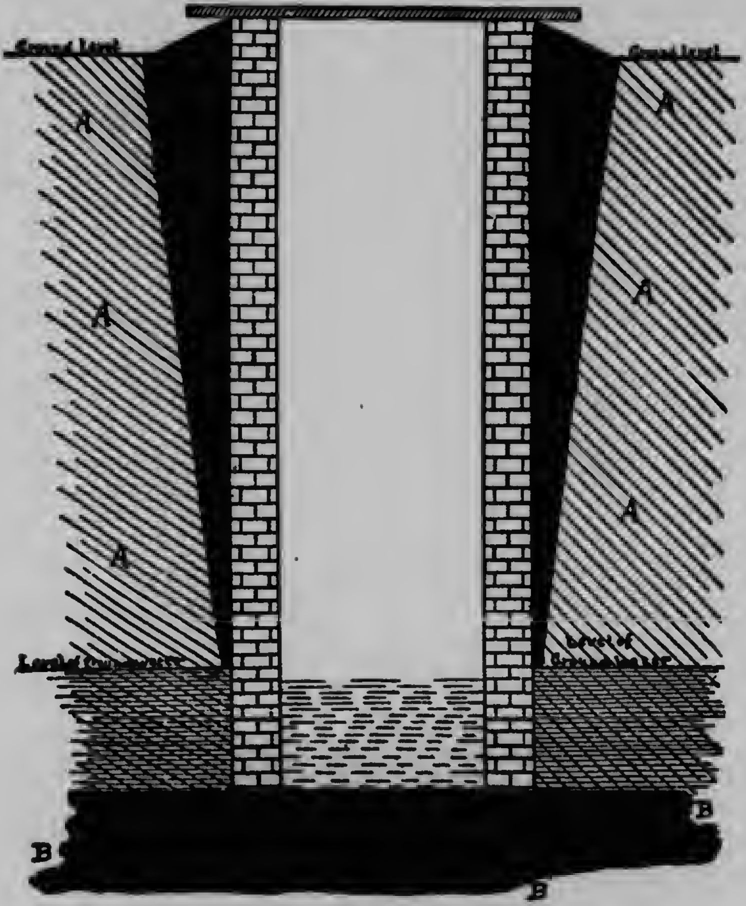


Fig. 4.

A—porous strata, such as sand, gravel, loam, shale, etc. B—impervious stratum, such as clay, rock without flaws, etc.

The accompanying diagram will serve to explain what is meant. By this construction surface water is prevented, by the impermeable clay backing, from getting entrance to the well until it has percolated through the earth to the line of level of the ground-water.

It will be quite clear that no one of the wells in Fig. 3 can be free from unfiltered, and consequently dangerous water, unless this precaution is taken, since even those which reach the ground-water may be polluted by the soakage of unfiltered surface water.

If now we study the gathering ground 1 to 2 in Fig. 3, we have a wild, rocky, and probably unsettled tract of land, free from animal impurity, and comparatively free from vegetable decay. Moreover, its distance from the point at which the water collected on it is used (W^5), ensures thorough filtration, and we can see at once why the water of this deep stratum should be eminently pure and wholesome. Such water is, for obvious reasons, apt to contain more mineral matter in solution, and may even conform to the type of a true mineral water. Unless this be the case, it is evidently a very desirable domestic supply, and wells like W^5 are always to be preferred when attainable. Even these, however, must be protected against soakage contamination, to which they are just as liable as those of any other type. This study has shown us that shallow wells, obtaining as they do, their supply from unfiltered soakage can never be safe for domestic use, although favorable circumstances may prevent them from becoming actively disease-producing; that ground-water wells, if properly protected from local contamination by soakage, are generally safe; while deep water wells, guarded from local soakage, are safest of all.

This study of well-water, in its origin, makes it quite easy to understand why the water contained in one well may be so different from that contained in other, and perhaps, contiguous wells.

Large towns and cities, as a rule obtain their water supplies from some single source, so that each family in a city of say 5,000 families is supplied with water of the same kind as the rest. It consequently becomes a matter of small cost to each family, to take care of this common source of supply, to have it examined from time to time, chemically and otherwise. There is generally a Board of Water Commissioners appointed to look after the matter, and an engineer whose special duty it is to see to the protection of the supply and its proper distribution.

Compare this with the case of 5,000 families resident in the country. It is probable that these obtain their supply from 5,000 different wells, each having its own peculiarities of situation and protection, and each well having a special interest only to the particular family drawing water from it. If the owner of one of these wells desires to have it examined with a view to determining its purity, the total cost of such examination falls upon himself, and any opinion procured by him, has no value for his neighbours, and does not help them to a conclusion as to the purity of their wells.

Can no way be devised whereby useful information regarding the safety of country wells may be obtained, which will be comparatively inexpensive, and therefore practicable? This is the question which I seek to answer affirmatively.

In the first place we may conclude that normal ground-water is a safe source of supply. Owing, however, to the fact, that the soil and sub-soil of one locality differs from that of another locality in nature of constituent materials. their depth, compactness or porosity; contiguity to neighbouring heights of land, or to swamp; as well as in amount of annual rainfall, we cannot expect ground-water to have the same characters everywhere. What we may expect is that in a given geological and topographical area, the ground-water will have a certain definite character. If the soil consist largely of limestone *debris*, we shall find bi-carbonate of lime in the water, if gypsum characterize the soil of the locality, we shall find sulphate of lime in the water, if chlorides be present in the soil, then chlorides will be found in the water, and so on. In a neighbouring area, separated, say, by a ridge of granite from the first, and having a soil resulting chiefly from the weathering and disintegration of granite, we shall find a ground-water much softer than the first, and having small quantities of silicates, and other products of the disintegration of granite in solution. Now all the wells, and there may be hundreds of them, which are dug into this ground-water, will fall into a class by themselves, and exhibit common characters, provided that local soakage is prevented and the water they contain be the uncontaminated ground-water of that region. How then will an individual well be affected, in whose case sewage finds entrance? Organic matter will increase, and especially will this be true of nitrogenous organic matter: phosphates and chlorides will be increased, nitrates and nitrites may be found in it, and a bacteriological examination may reveal the presence of the colon bacillus. To determine all this, a full analysis is of course needed. What I propose to do, is to confine attention to some one characteristic, and to select that one which is most surely and certainly determined. This I find to be the *Chlorine in Chlorides.*

The determination of chlorine, in chlorides, is one of the simplest and most definite estimations that a chemist can be called upon to make. Owing to the presence of common salt (chloride of sodium) in human food, and its use by domestic animals, it is always found in sewage, so that any notable admixture of sewage with a well water, at once raises the chlorine percentage.

Chlorine is, however, invariably present in normal ground-water, and the question arises for each region: "How much chlorine is normally present in the ground-water of this locality?" Of course the answer can only be given after analysis of normal samples, but once it is known, any marked variation from that standard, stamps a well of that region as suspicious, and justifies discontinuance of its use until fuller examination can be made. It must not, however, be forgotten that contiguous wells, like W^2 and W^5 in Fig. 3, may obtain their water from entirely different sources, so that it becomes necessary to take depth, and other factors into consideration. The lower or second water-bearing stratum may have a very different normal content of chlorine from the first, or ground-water proper; but its number will also be a fixed one, and if once known, it will be as easy to detect any sewage contamination in this kind of well as in the other.

It is also to be noted that the normal chlorine number for a given area, will vary from month to month, and will be especially affected, by unusually heavy rainfall, or by prolonged drought. But experience shows that variations, due to these causes, are insignificant in comparison with those resulting from sewage contamination.

For many years past I have endeavoured to put this method to the test of experiment, and for that purpose I have collected personally and by deputy, over 730 samples of well water, chiefly within the drainage area of the Ottawa Valley. The difficulties which lie in the way of any single individual's accomplishment of so gigantic a task as this, are almost insurmountable; and I can only hope to illustrate the subject in a very imperfect way from the data in my possession. The first difficulty is to obtain samples which represent the normal ground-water, and the normal deep water supply or supplies. Very few country wells are protected against surface soakage by the method indicated in Fig. 4, and I may say here, that I think the Provincial governments might profitably entrust to certain of their officials whose work takes them to different parts of the country, as in the case of the Road Inspectors, the Board of Health Officers, &c., the additional duty of seeing that new wells are properly protected from surface drainage. It costs very little more to properly protect the well by tamping clay behind the stones when the well is being made, or by using concrete, than to finish it in the unscientific way in which we find this important matter usually performed, and I am sure that it is ignorance rather than any wish to save a few dollars at the risk of health, which explains the unsatisfactory condition of nearly all the wells which I have visited.

If, in each topographical area, we could find a few thoroughly protected wells, of known depths, and of whose history a full record had been kept, we should possess the data which we require, and which we cannot now obtain with any such certainty as would give a sure basis for the illustration of the scheme I have suggested.

It is by so much the more important that new wells should be constructed in such a way as to fulfil these conditions.

On 13th October, 1899, I personally visited forty-three wells, chiefly on farms, in the district between Kinburn and Packenham, in the county of Lanark. This is an extensive clay region, fairly level, except quite near Packenham, where the land dips towards the Mississippi river. The Mississippi rises in a series of small lakes, about eighty miles west of Packenham, in the townships of Abingdon, Barrie and Clarendon, in Addington county. These townships are very thinly settled, and the whole course of the river is through a region but little affected by human habitation. With the exception of the towns of Perth and Almonte, it may be said to be quite as nature left it, and a purer gathering ground could not be wished. This is proved by the fact that a sample of the river water taken at Pakenham gave only two parts of chlorine per million. No doubt, this small content of chlorine is chiefly derived from sewage, for, although the organic matter of sewage may change by oxidation as already explained, the chlorine remains, to tell the tale of past sewage pollution. In the case before us, the amount is too small to give any concern for the purity of the river water. No doubt there are points on the river, (*e.g.* just below the town of Perth) where locally, a higher chlorine figure would be found, pointing to local and serious sewage contamination. But the volume of the river is so large, that by the time the sewage has distributed itself uniformly throughout it, the figure 2 per million, for chlorine, has been reached, and the organic impurities have been fully oxidized.

The following numbers were obtained for seven wells in the region referred to, the wells having a depth of less than 10 feet, and being of the kind called surface wells :—

Well.	Depth.	Chlorine per million.
1	9 feet	4
2	9 "	10
3	9 "	22
4	10 "	22
5	8 feet	26
6	7 "	32
7	8 "	180

Why are these numbers so much higher than the river water gave? There is but one answer—the wells are dug in soil which is more or less saturated with sewage. Not one of these wells, so far as I could learn, was protected by a clay backing (see Fig. 4) from soakage, and consequently. most of them are contaminated with sewage which has undergone no such amelioration by soil-filtration as would have resulted from proper construction. Not one of them is certainly a safe well, while No. 7 cannot but be a most dangerous supply.

In the following table I have placed the numbers resulting from examination of 21 wells, varying from 10 to 20 feet in depth. These samples were taken on the same day, and from the same region:—

Well.	Depth.	Chlorine.
1	20	4
2	12	4
3	16	4
4	18	6
5	18	14
6	15	16
7	12	22
8	15	24
9	13	32
10	14	32
11	12	44
12	17	84
13	20	54
14	17	88
15	12	90
16	13	92
17	13	98
18	12	114
19	18	128
20	18	194
21	12	370

It is quite likely that most of these wells derive the main portion of their supply from the ground-water of the locality, but it is very certain that most of them are contaminated with soakage water. The first four are among the deepest of these wells, and as likely to be true ground-water wells as any, yet their chlorine content is not high, in fact, the very highest chlorine numbers in this list correspond to decidedly shallow wells, whose contamination by sewage is beyond a doubt.

The following six wells are examples of deep wells, and should give pure water; if properly protected from soakage of surface water. This they are not, however, and I cannot feel sure that the chlorine they contain is not, at least in part, due to sewage.

Deep well.	Depth.	Chlorine.
1	25	24
2	35	56
3	46	58 (in rock)
4	25	170
5	25	195
6	25	240

Two wells in this region answer to the type of mineral springs. They contain respectively 3775 and 3700 parts of chlorine per million. It is quite evident that this chlorine has a mineral, and not a sewage, origin, and I mention them to show how marked a distinction exists between such wells, and the ordinary domestic well.

Later in October, I collected, partly in person, and partly by deputy, seventy samples of well waters along the Montreal road, through the villages of St. Joseph, Blackburn and Cyrville, and the adjacent country. Of the wells less than ten feet deep, eight contain less than eight parts chlorine per million and thirteen others gave chlorine varying from 16 to 250 parts, six wells yielding more than 100 parts per million. Most of these wells were so evidently unprotected that I was prepared to find them dangerously contaminated, as the result showed them to be.

Of thirty-one wells having a depth between ten and twenty feet, only two gave less than 10 parts of chlorine; fourteen gave more than 100 parts, and five more than 200. There can be no doubt whatever, that most of this chlorine has a sewage origin.

Of deep wells the following is the record :—

Deep wells.	Depth.	Chlorine.	Deep wells.	Depth.	Chlorine.
1	?	2	6	22	86
2	21	6	7	?	110
3	26	26	8	27	280
4	30	52	9	23	670
5	96	52	10	155	830

It is noteworthy that the increase in chlorine corresponds to an increase in depth, if we omit the numbers six, eight and nine in this list. Number six is in a hotel yard, and the well is not properly protected; number eight is twenty-five years old, has no pump, and shows every sign of neglect in its surroundings, and number nine is eighteen years old, not protected from soakage, and dug in soil which has been used as a garden and otherwise from immemorable time.

I have made, at different times similar collections of well-water samples from Peterboro, near Hamilton, and at several places nearer Ottawa. The analytical data have a special interest for the neighbourhood in question; but for such a general study as we are now making, it seems scarcely worth while to quote them. They emphasize the point to which I have already alluded, viz.: the difficulty of ascertaining the true chlorine value of normal ground water. If any considerable number of properly protected wells existed in a given locality, there would be no difficulty about this matter, or at least, the difficulty would be much lessened.

As already pointed out, this work is properly the duty of township and village municipalities. During the eight years which have elapsed since I brought it to the notice of the Provincial Board of Health of Ontario, no attempt has been made by any municipality, so far as I know, to carry out the plan then outlined.

Because I am impressed with the importance of the subject, I have asked and obtained your permission to make some further investigations; and the subjoined report upon inspection of wells in the towns of Oakville, Weston and Richmond Hill, forms a second attempt to demonstrate the usefulness of the method of testing well supplies, which I have just described.

I may explain that I do not consider the subject as one properly belonging to this Department of the Public Service; and it is rather as an object lesson, than with any view to its further prosecution, by the Department of Inland Revenue, that I have recommended the undertaking of the work now reported. The municipalities immediately concerned are the proper agents in the matter. They are best acquainted with the details necessary to give maximum value to the investigation. It will be seen that the information obtainable in a hurried visit to distant towns, is far from complete or satisfactory. The depth of the wells, their age, the frequency with which they are cleaned, their protection, construction and other features; the depth of water which they contain at different seasons of the year; the nature of the strata which they penetrate, and many other details, are either quite unknown, or very imperfectly known to me. It would be a matter of no great expense for each municipality interested to obtain and record this information; and such a record would be of immense value to the chemist in forming his opinion.

The work recorded in the accompanying tables has been done upon 32 wells in each of the towns of Weston and Richmond Hill, and 64 wells in Oakville Ont.

The information obtainable in regard to the wells was so very limited that I have sought to secure a basis for interpretation of analytical results, by doing a much greater amount of work upon these samples than is contemplated by the plan already described. Thus, in addition to determining the chlorine values, I have determined the alkalinity, and the temporary and permanent hardness. This is done in order to ascertain whether the water supplied by neighbouring wells, of similar depth, is derived from the same ground water.

The information thus obtained is far from satisfactory. Where a well is walled up with limestone, the hardness of the water will be much affected by this fact, and further influenced by the length of time that the water lies in contact with the stone.

By much the best way to get the information needed for interpreting results of analysis, is to have it at first hand, from the well-digger. The date of sinking, the depth, the nature of the soil, the protection of the well, the extent of flow, the variation of level with the season, frequency of cleaning, &c., these are the important facts needed, and they could easily be ascertained by local endeavour. A stranger visiting the town for a day or two, is fortunate if he secures the water itself, and a chance hint or two regarding the well.

The depth of the well, as given in the tables, is, in most cases mere guess work; an approximation made by the man employed as a guide.

The time of the year is favorable to the protection of wells from fresh sewage; so that much would be learned in regard to the safety of these wells, if a comparison could be instituted between their chlorine value as here recorded, and that found in April or May, when the frost is out of the ground.

Such conclusions as I think can safely be reached, are noted in the tables The number designating each well, enables its location in regard to other wells, to be seen by reference to the accompanying diagram.

The order in which the wells appear in each table is chosen so as to put contiguous wells together, as far as possible. Where a considerable distance is known to separate wells, a line is left blank in the table. It will not do, however, to interpret juxtaposition of numbers in the table, as indicating juxta-position in the wells. The linear distance between one well and the next, is unknown to me. In some cases it may not exceed 100 feet; in other cases it may be a quarter of a mile. It is evident that exact knowledge on this point, while easily attainable by the local authorities, would require the expenditure of much time and labour on the part of a visiting inspector.

All other information needed to make the tables useful, is contained in the column headed 'Remarks.'

Finally I would draw attention to the fact that the results contained in these tables cannot be expected to greatly interest others than the residents of Weston, Richmond Hill and Oakville, except in so far as they throw light upon the application of the method of inspection which I have already described.

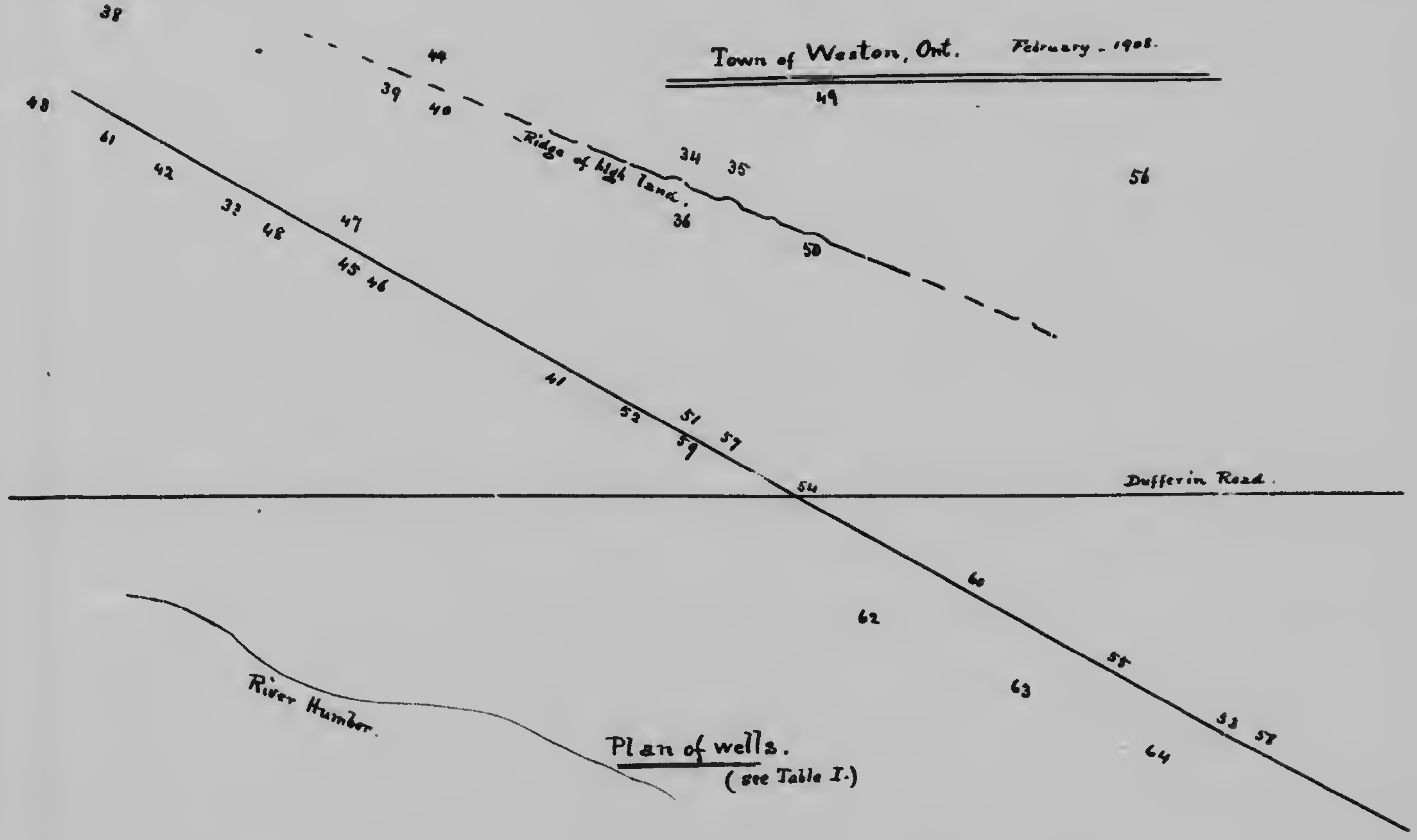
Even to the municipalities named, they only serve as the beginning of an investigation, which if completed at all, must be completed by themselves. The town of Oakville, probably contains over 500 wells. Thus it will be seen that the sampling of sixty-four, selected almost at random, and examined only once, cannot be regarded as more than a very superficial treatment of the question. I trust that we shall hear further of the matter.

This is not alone a subject of interest to country and village dwellers. Very large numbers of city people spend their summers in the country, and make use of well-water. Every autumn finds them bringing back to town a certain amount of typhoid fever, contracted doubtless, through the use of impure well-water. This is an aspect of the case which may reasonably appeal to city dwellers.

I beg to recommend the publication of this report as Bulletin No. 149.

I have the honour to be, sir,
Your obedient servant,

A. McGILL,
Chief Analyst.

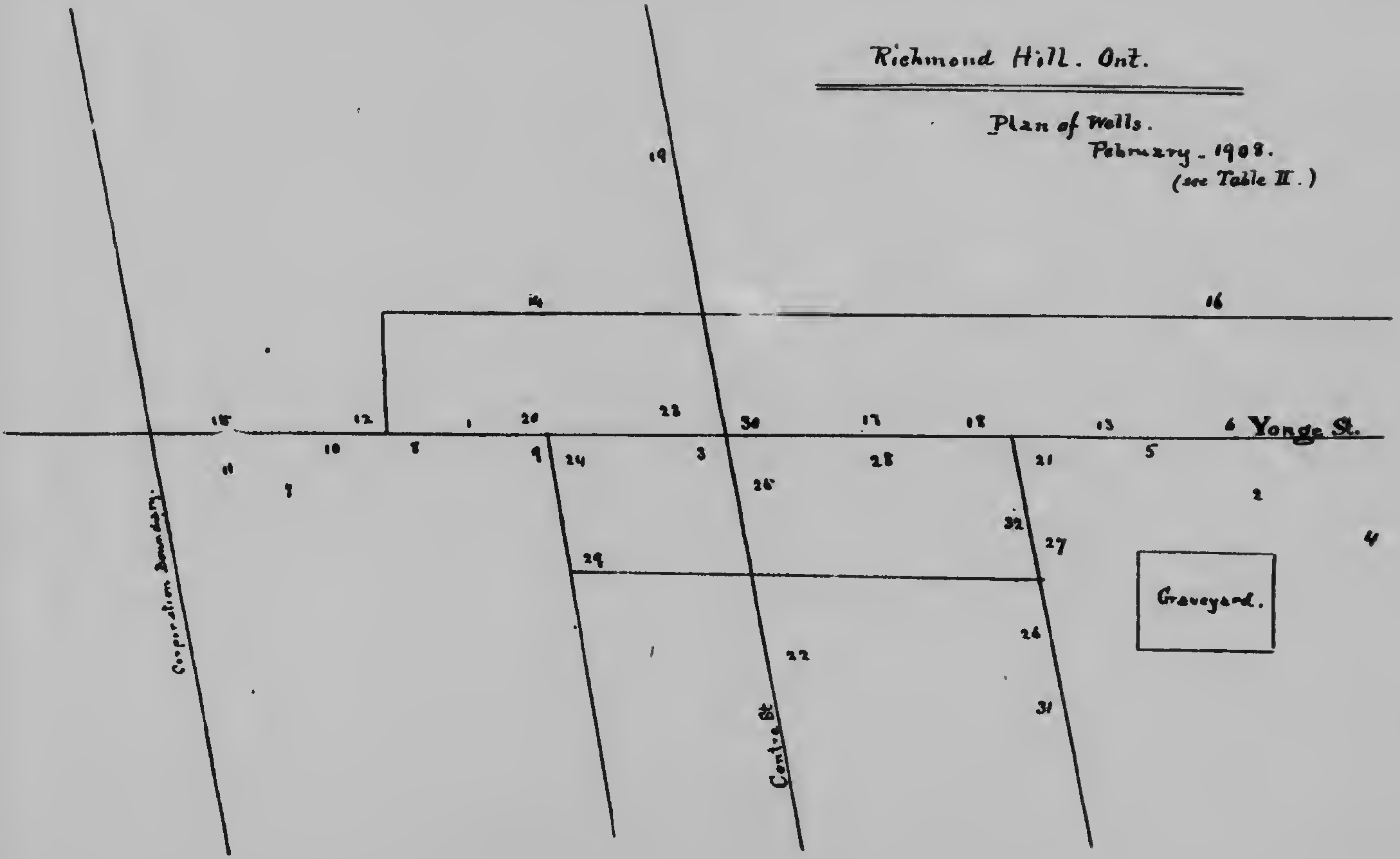


Town of Weston, Ont. February - 1908.

Plan of wells.
(see Table I.)

Richmond Hill. Ont.

Plan of Wells.
February - 1908.
(see Table II.)



Oakville. Plan of wells.

February, 1908. (See Table III.)

Blocks are 313 ft x 208⅔ ft.

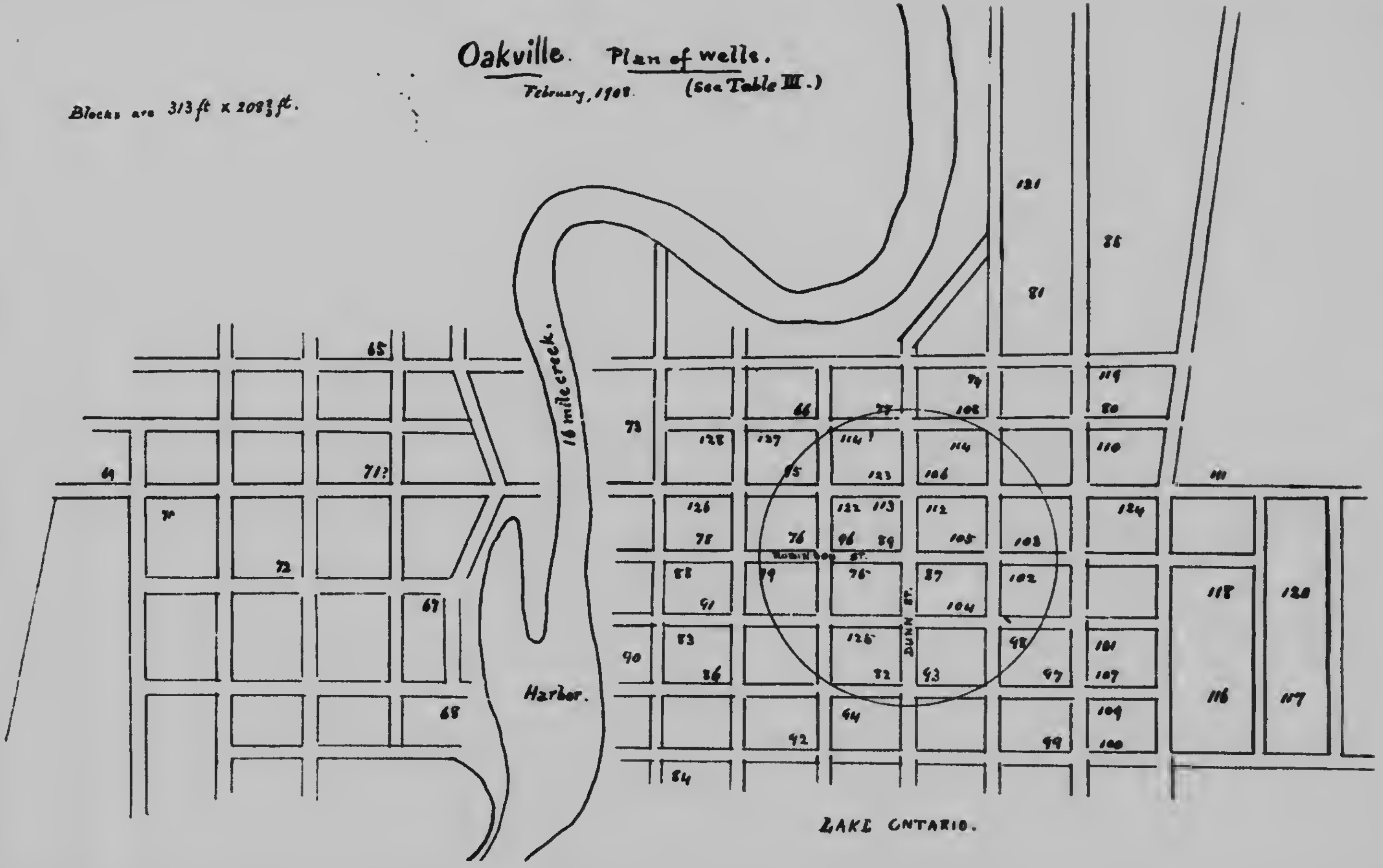


TABLE I.—WELL WATERS—TOWN OF WESTON, ONT., FEB., 1908.

Number.	Depth in Feet.	Description.	Chlorine per Million.	Alkalinity.	Hardness.			Remarks.
					Total.	Permanent.	Temporary.	
43	22	Old, brick, iron pump.	24	120	207	84	123	
61	?	Brick, wood pump.	28	112	146	28	118	
42	12	Brick, wood pump, with strainer..............	20	106	157	60	46	
37	?	New, stone, iron pump......	202	129	291	175	116	This may be mineral chlorine.
33	?	Brick, wood pump	40	112	140	22	118	
48	?	Old, stone, wood pump.. ...	162	140	246	118	128	
45	15	Iron pump.................	62	260	342	73	269	
46	Shallow.	Brick, iron pump.....	54	207	302	151	151	
47	14	Brick, wood pump	122	109	268	162	106	These high chlorides suggest sewage.
41	10	Old well, wood pump........	34	151	190	34	156	
52	16	Stone, wood pump..........	14	115	123	0	123	
51	17	Old, brick, wooden pump....	94	168	269	112	157	Is suspicious.
57	30	Iron pump, brick.	392	339	420	89	331	This should be looked into.
59	25	" "	56	154	235	90	145	
54	20	Wood pump, brick..........	36	168	241	90	151	
60	19	" "	42	120	235	140	95	
62	15	" "	16	87	64	0	64	The low chlorides in these wells proof that the normal ground water in the East end of Weston, does not contain mineral chlorine, except in traces.
55	10	" "	8	88	106	11	95	
63	30	Iron pump, brick...... .. .	18	154	185	28	157	
53	30	Wood pump, brick....... .	18	112	151	28	123	
58	?	" "	16	129	146	11	135	
64	20	Iron pump, brick...........	20	106	134	28	106	
38	102	Iron pump, new well.... ..	18	190	84	23	61	
39	?	Old well, brick......... ...	46	126	196	56	140	
40	20	Old well, brick.............	106	129	280	179	101	Very suspicious.
44	30	Old, wood pump............	76	146	151	28	123	
34	20	Wood pump, brick..........	14	95	140	39	101	
35	?	" "	54	109	174	95	79	Why are these wells higher in chlorine than is No. 34?
36	20	Iron pump, brick....	50	109	190	75	115	
49	30	" "	34	92	118	50	68	These are isolated wells, and no comparisons are possible.
50	22	Brick, cement, top, iron pump, 13 years in use..........	72	137	213	95	118	
56	20	Iron pump, brick.	32	160	207	78	129	

NOTE.—Alkalinity, is an expression, in terms of CaO, for the total bases existing as Carbonates. Hardness, is an expression, in terms of CaO, for the total alkaline earth bases (essentially lime and magnesia) present in solution. Hardness is known as 'permanent' when these bases are in combination as Sulphates or Chlorides, and as 'temporary' when they exist as Carbonates. When the Alkalinity is notably in excess of the temporary hardness, this is due to the presence of Sodium Carbonate in the water.

TABLE II.—WELL WATERS, TOWN OF RICHMOND HILL, ONT.—FEB. 1908.

Number.	Depth in feet.	Description.	Chlorine per Million.	Alkalinity.	Hardness.			Remarks.
					Total.	Permanent.	Temporary.	
15	20	Stoned, wood pump	80	123	235	112	123	The shallow well is higher in chlorides. This is suspicious.
11	30	Brick, wood pump	34	156	146	17	129	
7	75	Iron pump, wind driven	92	207	302	101	201	
10	20	Old well, wood pump	46	199	263	67	196	Water of similar character.
12	20	Iron pump, brick	68	207	235	28	207	
8	20	Old well, wood pump	148	232	392	208	184	The high permanent hardness is noteworthy also high chlorine. Compare with No. 9.
1	20	Iron pump, stoned	80	224	252	84	168	
20	20	Iron pump, brick	56	224	246	22	224	
9	25	Brick, old wood pump	110	168	297	129	168	
24	20	Iron pump, brick	60	157	202	45	157	
23	15	Wood pump, cement top, springs from quicksand	22	162	196	28	168	
3	38	Brick, wood pump	36	151	213	45	168	
30	33	Iron pump, brick, water salty	570	356	342	11	331	A 'mineral' water?
25	20	Old well, bricked, wood pump	94	132	280	168	112	
17	25	Brick, iron pump	48	216	224	0	224	
28	20	Brick, iron pump	46	148	179	28	151	
18	30	Wood pump, brick	780	216	414	218	196	Is this mineral chlorine? Is of suspicious character.
21	30	Brick, wood pump	52	174	224	50	174	
32	30	Wood pump, bad platform	178	194	386	185	201	Suggestion of past sewage pollution.
27	80	Wind mill pump, water from sand	164	235	409	234	175	
26	30*	Brick, cleaned 4 mos. ago	40	137	168	28	140	
31	55	Flowing well	26	132	129	0	129	
13	30	Stone, wood pump	52	168	252	95	157	
5	20	Wood pump, bricked	10	150	140	28	112	
6	26	Brick	98	160	274	129	145	
2	30	Iron pump	32	143	162	22	140	
4	?	Wood pump	22	160	162	0	162	
16	40	..	136	174	246	123	123	Chlorine is suspiciously high.
14	20	Brick, wood pump	76	179	224	62	162	
19	15	Brick, wood pump	48	140	174	45	129	
29	20	Brick, new well	56	126	123	11	112	
22	20	35 years old, brick, wood pump	132	134	308	168	140	Chlorine is high, but may have a mineral origin, as the permanent hardness suggests.

TABLE III.—WELL WATERS, TOWN OF OAKVILLE, ONT.—FEB., 1908.

Number.	Depth in feet.	Description.	Chlorine per Million.	Alkalinity.	Hardness. Total.	Hardness. Permanent.	Hardness. Temporary.	Remarks.
77	15	Iron pump, stoned	34	123	134	22	112	This group of 22 wells, situated within a square of about 16 blocks, would form an interesting study if they had the same depth, or if their individual depths were accurately known.
114	15	Open well, stoned	30	101	129	28	101	
95	16	Iron pump, cement curbing	60	148	190	50	140	
123	?	Iron pump, stoned	530	381	392	50	342	
106	16	Iron pump	56	171	241	101	140	
122	12	Pump in kitchen connects both with well and cistern.	96	[illegible]	[illegible]	140	112	Considering those of about 15 ft. deep, the chlorine content should apparently be less than 100 parts per million.
113	?	Iron pump, stoned	86	[illegible]	[illegible]	118	112	
112	13	Stone, iron pump, sand	36	[illegible]	[illegible]	62	89	
76	15	Open well, stoned, low ground	970	[illegible]	[illegible]	168	179	
96	?	Iron pump, stoned	160	[illegible]	[illegible]	140	142	What then is the meaning of the numbers found for No. 76, 96, 102 and [illegible]
89	15	Open well, stoned	74	[illegible]	[illegible]	112	[illegible]	
105	38	Stoned, iron pump	20	[illegible]	[illegible]	0	[illegible]	
103	16	Tiled, iron pump	24	[illegible]	[illegible]	6	[illegible]	Nos. 10[illegible] 103, 79 and 87 show a very low chlorine content. Why so high chlorine in the remaining wells of the group? These questions can only be answered by further examination. But they should be disquieting to the residents of this part of the town.
79	18	Iron pump, stoned	10	[illegible]	[illegible]	11	101	
75	15	"	70	[illegible]	[illegible]	91	129	
87	14	Open well, stoned	16	[illegible]	[illegible]	11	137	
102	15	No pump, stoned	170	[illegible]	[illegible]	151	135	
104	14	Open well	92	[illegible]	235	123	112	
125	?	Iron pump, stoned	72	[illegible]	202	84	118	
82	15	"	148	[illegible]	286	14[illegible]	140	
93	15	"	28	[illegible]	174	56	[illegible]	The hardness in Nos. 123, 76 and 96; also 102 and [illegible] implies that these may be fed from a distinct source.
98	12	Stoned, no pump	36	[illegible]	168	[illegible]	[illegible]	
97	?	Iron pump	20[illegible]	[illegible]	38[illegible]	[illegible]	[illegible]	So little is known about the wells of this group, that no certain inference is possible. If Nos. 107 and 109 fix the chlorine of the region, the others should be further examined.
101	?	No pump	7[illegible]	148	202	62	[illegible]	
107	?	No pump, stoned	1[illegible]	70	78	[illegible]	[illegible]	
109	?	Iron pump	1[illegible]	101	112	[illegible]	112	
100	?	"	19[illegible]	1[illegible]	392	25[illegible]	140	
99	15	No pump, stoned	[illegible]	104	1[illegible]	[illegible]	84	
92	18	Open well, stoned	[illegible]	224	[illegible]	[illegible]	[illegible]	
94	20	"	[illegible]	188	[illegible]	[illegible]	[illegible]	
83	?	Iron pump, stoned	78	188	[illegible]	[illegible]	163	
86	18	"	56	148	[illegible]	[illegible]	138	
88	?	Iron pump, stoned	144	151	[illegible]	[illegible]	[illegible]	
91	14	Open well, stoned	58	126	1[illegible]	[illegible]	[illegible]	
78	14	Open, stoned	24	92	101	[illegible]	[illegible]	Not used for cooking, &c. Why has this well a bad reputation?
126	?	?	190	231	188	0	[illegible]	
66	15	Open well, stoned	58	154	246	[illegible]	[illegible]	
127	?	Iron pump	80	171	213	[illegible]	[illegible]	
128	20	Iron pump, stoned	34	146	78	[illegible]	[illegible]	
74	?	"	64	146	202	112	9[illegible]	
108	13	Iron pump, tiled	32	87	84	6	78	
80	36	Open well, stoned	64	140	140	17	123	
119	15	Stoned, iron pump	30	120	118	0	118	
110	14	" "	64	179	224	84	140	
118	15	Open well, stoned	52	157	185	73	112	
120	20	Iron pump, cement platform, stoned	16	126	140	56	84	Said to have "sulphur" smell at times.
116	16	In shed, iron pump	96	165	252	50	202	
117	63	Iron pump, Artesian, 53 feet in rock	20	140	146	0	146	

TABLE III—WELL WATERS, TOWN OF OAKVILLE, ONT.—FEB. 1908—*Concluded.*

Number.	Depth in feet.	Description.	Chlorine per Million.	Alkalinity.	Hardness.			Remarks.
					Total.	Permanent.	Temporary.	
124	?	Stoned, iron pump........	78	123	185	84	101	
65	12	Open well, stored........	80	132	263	129	134	
66	15	" "	58	154	246	112	134	
67	15	Stone, wood pump.....	60	182	238	67	171	
68	16	Stone, iron pump.........	16	160	179	28	151	
69	?	Stoned, iron pump, in shed..	248	137	358	210	148	Of doubtful character.
70	?	Stoned, iron pump...... ..	178	148	280	168	112	" "
71	?	" "	98	92	252	151	101	
72	15	Open well, stone, cement platform.................	42	115	179	67	112	
73	16	Iron pump, stoned.	40	115	146	28	118	
81	30	" "	64	199	286	112	174	
84	13	" "	242	266	498	263	235	Should be further examined.
85	15	Open well, stoned..........	12	165	168	11	157	
121	13	" "	56	129	196	73	123	
90	15	Iron pump. stoned..........	50	165	224	50	174	
111	?	Stoned, Iron pump..........	34	126	157	28	129	
115	?	" "	164	132	286	151	135	" "

NOTE.—Judging by the number of wells in Oakville which shew less than 50 parts of chlorine, there is no apparent reason why any of these wells should contain more than this. The higher numbers are easily explained on the assumption that the gathering ground (the surface soil of the town) is more or less saturated with animal waste. It should be quite easy to demonstrate the correctness or otherwise of this suspicion.

APPENDIX.

I have been asked to describe apparatus, solutions, etc., needed to carry out the method of testing for Chlorine.

The following are needed :

Apparatus.

1 Burrette, 50 cc. graduated in 1-10	$2.00
1 " stand.	1.00
1 glass funnel (2 inch.)	0.10
stirrer	0.05
porcelain dishes (4 inch. diam.)	0.60
(White saucers will do.)	
1 10 cc. pipette.	0.20
1 50 cc. graduate flask-	0.20
	$4.15

Reagents.

1. Distilled water.
2. Solution of Nitrate of silver, 4.7887 grammes of the crystals to 1 litre.

Each 1 cc. of this solution corresponds to 1 milligramme of Chlorine, (in chlorides.)

3. Chromate of Potash, a 5 per cent. solution.
4. Solution of Sodium Chloride, 1.648 grammes per litre.

Each 1 cc. contains 1 milligramme of Chlorine.

The method of working is so simple that it may easily be learnt by any one having an elementary knowledge of chemistry, in a few hours. It is fully described in Sutton's Volumetric Analysis, (published by J. and A. Churchill, London) and in other similar works. Best, however, by personal instruction.

Exceptional samples of water may require preliminery treatment ; but these are so rarely met as to be negligible, or they may be sent to properly qualified analysts for an opinion.