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CANADA

DEPARTMENT OF MINES

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GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 243

GROUND-WATER RESOURCES OF THE RURAL MUNICIPALITY OF NORTH BATTLEFORD NO. 437 SASKATCHEWAN

Records Collected by C. O. Hage

Compilation by G. S. Hume and C. O. Hage

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DEPARTMENT OF MINES AND RESOURCES

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GEOLOGICAL SURVEY

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Figure 1. Map showing bedrock geology;

2. Map showing topography and the location and types of wells.

INTRODUCTION

Information on the ground-water resources of east-central Alberta and western Saskatchewan was collected, mostly in 1935, during the progress of geological investigations for oil and gas. The region studied extends from Edmonton in the west to Battleford in the east, and from township 32 on the south to township 59 in western Alberta, township 63 in eastern Alberta, and in part as far north as township 56 in western Saskatchewan.

This region is crossed by North Saskatchewan and Battle Rivers, and includes other more or less permanent streams. Most of the lakes within the area, however, are alkaline, and water is obtained in wells from two sources, namely, from water-bearing sands in surface or glacial deposits, and from sands in the underlying bedrock.

A division has been made in the well records, in so far as possible, between glacial and bedrock water-bearing sands. In investigations for oil and gas, however, the bedrock wells were used to trace the lateral extent of geological formations, with the result that the records deal more particularly with this type of well. No detailed studies were made of the glacial materials in relation to the water-supply, nor were the glacial deposits mapped adequately for this purpose. In almost all of the region investigated in Alberta, and in all but the northeast part of the region studied in Saskatchewan, water can be obtained from bedrock. In a few places, however, the water from the shallower bedrock sands is unsatisfactory, and deeper drilling may be necessary.

The water records were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to farmers, town authorities, and drillers in their efforts to obtain water supplies adequate for their needs.

In collecting this information several field parties were employed. These were under the direction of Professors R. L. Rutherford and P. S. Warren of the University of Alberta, C. H. Crickmay of Vancouver, and C. O. Hage, until recently a member of the Geological Survey. The oil and gas investigations of which these water records are a part were undertaken under the general supervision of G. S. Hume.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Government Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the reports are defined in the glossary.

How to Use the Report

Anyone desiring information concering ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that provided on bedrock formations, pages 4 to 8, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by substracting its elevation, as given in the well record tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the bedrock formations that will be encountered beneath the unconsolidated surface deposits. Figure 2 shows the position of all wells for which records are available, the class of well at each location, and the contour line or lines of equal surface elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is likely to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

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

Aquifer or Water-bearing Horizon. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channels. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

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.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining 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 by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during its retreat. The surface is characterized by irregular hills and undrained basins.

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

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is 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 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 and glacial drift consisting of loose sand, gravel, clay, and boulders that overlie the bedrock.

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

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes.

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which the water does not rise above the water table.

BEDROCK FORMATIONS OF WEST-CENTRAL SASKATCHEWAN AND EAST-CENTRAL ALBERTA

The formations that outcrop in west-central Saskatchewan are an extension of similar formations that occur in east-central Alberta. They are of Upper Cretaceious age, and consist entirely of relatively soft shales and sands, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Formation	Character	Thickness Feet
Edmonton	Grey to white, bentonitic sands and sandstones with grey and greenish shales; coal seams prominent in some areas, as at Castor, Alberta.	1,000 to 1,150
Bearpaw	Dark shales, green sands with smooth black chert pebbles; partly non-marine, with white bentonitic sands, carbonaceous shales or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster claw nodules and marine fossils; at other horizons are abundant selenite crystals.	300 to 600 thins rapidly to the north-west
Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	950 to 1,200 in Czar-Tit Hills area; may be thinner elsewhere
Birch Lake	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 in west, but less to east and south
Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter	Maximum, 100
Ribstone Creek	Grey sands and sandstones at the top and bottom, with intermediate sands and shales; thin coal seam in the vicinity of Wainwright; mostly non-marine, but middle shale in some areas is marine.	Maximum, 325 at Viking; thins eastward
Lea Park	Dark grey shales and sandy shales with nodules of ironstone; a sand 70 feet thick 110 feet below the top of the formation in the Ribstone area, Alberta.	950 to 1,100

Edmonton Formation

The name Edmonton formation was first applied to the beds containing coal in the Edmonton area, and later to the same beds in adjoining areas. The formation has a total thickness of 1,000 to 1,150 feet, but is bevelled off eastward and the east edge of the formation

follows a northwest line from Coronation through Tofield to a point on North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. No Edmonton beds occur northeast of this line, but the formation becomes progressively thicker to the southwest due to the fact that the beds incline in that direction and the surface bevels across them.

The Edmonton formation consists of poorly bedded grey and greenish clay shales, coal seams, and sands and sandstones that contain clay and a white material known as bentonite. This material when wet is very sticky and swells greatly in volume, and when dry tends to give a white appearance to the beds containing it. Such beds are relatively impervious to water, and at the surface produce the "burns" of barren ground where vegetation is scanty or absent.

Water is relatively abundant in the Edmonton formation, which contains much sand, commonly in the form of isolated lenses distributed irregularly through the formation. Consequently, there is little uniformity in the depth of wells even within a small area. Water also occurs commonly with coal seams and, unlike the sand lenses, these beds are much more regular and persistent. In contrast with the water from the bentonitic sands, which is generally "soft", water from the coal seams, as the water from the shallow surface deposits, may be "hard". The basal beds of the Edmonton formation usually contain fresh water, but this may become brackish locally where the underlying Bearpaw beds contain highly alkaline or salty water.

Bearpaw Formation

In southern Alberta, where the Bearpaw formation is thickest, the beds composing it are mainly shales that have been deposited in sea water. In the area north of township 32 the formation thins to the northwest and becomes a shoreline deposit composed of shales containing bentonite, impure sands, and thin coal seams. In some areas, as at Ryley and near Monitor, and in the Neutral Hills, the Bearpaw contains pebble beds. At Ryley these are consolidated into a conglomerate, but mostly the pebbles are loosely distributed in shale or sandy beds.

In the area immediately north of township 32 the Bearpaw occupies a widespread belt beneath the glacial drift, but farther northwest the belt narrows, and at Ryley and northwestward it is only a few miles wide. This belt crosses North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. Bearpaw beds form the main bedrock deposits of the Neutral Hills. Farther south, where they have an exposed thickness of at least 400 feet, they contain green sands, and beds of marine shale interfinger with the bentonitic shales and sands of the underlying formation. To the north, on the banks of North Saskatchewan River, the division between the Bearpaw and the overlying and underlying formations is indefinite, and the thickness of beds of Bearpaw age is relatively small.

The water in the Ryley area is from the Bearpaw formation, and is salty. In other areas to the south the marine Bearpaw formation carries green sand beds that yield fresh water, but commonly a much better supply is found by drilling through the Bearpaw into the underlying Pale Beds.

In Saskatchewan, Bearpaw beds occur southeast of Maclin and south of Luseland and Kerrobert. Only the basal beds are present, and these contain green sands that are commonly water-bearing.

Pale and Variegated Beds

Underlying the Bearpaw formation is a succession of bentonitic sands, shales, and sandy shales containing a few coal seams. The upper part of this succession, due to the bentonitic content, is commonly light coloured and has been described as the Pale Beds, whereas the lower

part is darker, and is known as Variegated Beds. In part, dark shales are present in both Pale and Variegated Beds; others are greenish, grey, brown, and dark chocolate, carbonaceous types. The sands may also be yellow, but where bentonite is present it imparts a light colour to the beds. Both Pale and Variegated Beds are characterized by the presence of thin seams of ironstone, commonly dark reddish, but in part purplish, Selenite (gypsum) crystals are, in places, abundant in the shales.

The best sections of Pale Beds exposed in the region are in the Tit Hills, southwest of Czar. These hills carry a thin capping of Bearpaw shales, beneath which, and around Bruce Lake, more than 200 feet of Pale Beds are exposed. The total thickness of Pale and Variegated Beds in the Tit Hills area is about 970 feet. Variegated Beds outcrop near Hawkins on the Canadian National Railway west of Wainwright, but no area exposes the complete succession, which is considered to comprise about 200 feet of beds.

Records of wells drilled into the Pale and Variegated Beds do not, in general, indicate lateral persistence of sands for long distances, nor any uniform average depth to water-bearing sands in a local area. This points to the conclusion that the sands are mainly local lenses, but as such lenses are numerous, few wells fail to obtain water. In the Cadogan area many flowing wells have been obtained from sands about midway in the succession. In western Saskatchewan Paleland Variegated Beds occur over a wide area from Maclin and Kerrobert northeast through Wilkie to the Eagle Hills, south of Battleford. Numerous outcrops occur in the area south of Unity at Muddy Lake, but south and east around Biggar these beds are almost wholly concealed by glacial drift.

The water from the sands of the Pale and Variegated Beds is generally soft. The supply, apparently, is dependent in part on the size of the sand body that contains the water and in part on the ease with which water may be replenished in the sand. Small sand lenses surrounded by shales may be filled with water that has infiltrated into them, but when tapped by a well the supply may be very slowly replenished. In many instances such wells yield only a small supply, although this is commonly persistent and regular.

Birch Lake Formation

The Birch Lake formation underlies the Variegated Beds, but in many areas the division is not sharp. The type area of the formation is along the north shore of Birch Lake south of Innisfree, where a section 65 feet thick, composed mostly of sand, is exposed. The total thickness of the formation in this area is about 100 feet, and although this is dominantly sand a central part is composed of alternating thin sand and shale beds. At the base of the formation, in a number of places, is an oyster bed, and this is exposed in a road cut in a section 73 feet thick on the east side of Buffalo Coulée in sec. 3, tp. 47, rge. 7, W. 4th mer. In both upper and lower parts of the formation the sand is commonly massive and outcrops tend to consolidate into hard, nodular masses from a foot to a few feet in diameter. Apparently these are formed through the deposition of salts from the water that finds an outlet at the outcrops. In fact, in some areas the sand may be traced along the side of a hill by the presence of small springs or nodular masses of sandstone.

The Birch Lake formation occurs under the drift and in outcrops in a large area south of North Saskatchewan River and northeast of a line from Willingdon to Innisfree and Minburn. East of this area the southwest boundary is more irregular, but outcrops are persistent on the banks of Battle River from a few miles north of Hardisty to and beyond the mouth of Grizzly Bear Coulée in tp. 47, rge. 5. It is believed, too, that a large area near Edgerton and Chauvin is underlain by the Birch Lake formation and that it extends southeastward into Saskatchewan around Manitou Lake and southeast to Vera.

It is thought that the Birch Lake formation thins eastward from its type section at Birch Lake, and that it loses its identity in western Saskatchewan. Deep wells drilled at Czar, Castor, and elsewhere no longer show the Birch Lake as a clearly recognizable sand formation, so that its southern limit beneath younger formations is unknown. Wherever it occurs as a sand, however, it is water-bearing, although in some areas the sand is apparently too fine to yield any considerable volume of water. In other areas, however, it persistently yields good wells. There is no apparent uniformity in the character of the water, which is either hard or soft in different wells in the same general area. Direct contact with surface waters that contain calcium sulphates may in time change a "soft" water well to a "hard" water well, and many wells are not sufficiently cased to prevent the percolation of water from surface sands into the well, and hence into the deeper, soft water producing sands. In part this accounts for the change in character of the water in a well, a feature that has been noticed by many well owners.

Grizzly Bear Formation

The type locality for the Grizzly Bear formation, which underlies the Birch Lake beds, is near the mouth of Grizzly Bear Coulée, a tributary of Battle River with outlet in tp. 47, rge. 5. The formation is mainly composed of dark shales that were deposited in sea water. At the mouth of Grizzly Bear Coulée two shale sections, each about 100 feet thick, are separated by a zone of thin sand beds. It is now recognized that the upper section is the Grizzly Bear shale, and that the lower one, very similar in character and also deposited in sea water, occurs in the next lower formation, the Ribstone Creek. The Grizzly Bear shale contains a thin nodular zone about 50 feet above the base, that is, at about the centre of the formation. This zone is sandy, and is believed to yield water in various wells. Other thin sands, in places water-bearing, are also present. The impervious nature of the Grizzly Bear shales makes the overlying Birch Lake sand a strong acquifer, as water collects in the sand above the shale. The contact of the Birch Lake and Grizzly Bear formations can be traced in some places by the occurrence of springs issuing from the base of the Birch Lake sand even where this is not exposed.

Grizzly Bear shales occur in a road cut on the south side of Battle River near the highway bridge at Fabyan. The shales in this area are about 100 feet thick. It is thought they extend as far west as the Viking gas field, where they have been recognized in samples from deep wells. It is probable, however, that the shales thin westwardrand thicken eastward so that their general form is a wedge between both higher and lower sand beds. The position of the thin edge of the wedge to the west is unknown, but evidently the Grizzly Bear marine shale underlies a large area in east-central Alberta extending into Saskatchewan mainly in the area south of Battle River.

Ribstone Creek Formation

The type area of the Ribstone Creek formation is on Ribstone Creek near its junction with Battle River in tp. 45, rge. 1, W. 4th mer. At this place the lower sand beds of the formation are well exposed. The upper part of the lower sand member of this formation outcrops on the north side of Battle River, in the northeast part of sec. 26, tp. 47, rge. 5, near the mouth of Grizzly Bear Coulée. Above it, higher on the bank and at a short distance from the river, there is a 12 foot zone of carbonaceous and coaly beds in two layers, each about 2 feet thick, separated by 8 feet of shale. Above this are 90 feet of dark shales that are thought to have been deposited in sea water, that is, they are marine shales. These marine shales in turn are overlain by a sandy zone about 20 feet thick containing oysters in the basal part. This sandy zone is the upper sand member of the Ribstone Creek formation.

It thickens to the east and west from the Grizzly Bear area but is probably at no place much more than 50 feet thick.

The lower sand member of the Ribstone Creek formation also varies in thickness from a minimum of about 25 feet. On the banks of Vermilion Creek, north of Mannville, the basal sand is at least 60, and may be 75,feet thick. It is overlain by shaly sand and sandy shale beds, which replace the shale beds in the central part of the formation as exposed at the mouth of Grizzly Bear Coulée. In the Wainwright area, where the formation has been drilled in deep wells, the basal sand is 60 feet thick, with the central part composed of shale containing sand streaks. The upper sand member is about 20 feet thick in this area. The total thickness of the formation in the Wainwright area is 100 to 200 feet, but this increases to the west and in the Viking area exceeds 300 feet.

The Ribstone Creek formation is widely exposed in a northwest-trending belt in east-central Alberta. The southwest boundary of this northwest-trending belt passes through the mouth of Grizzly Bear Coulée in tp. 47, rge. 5, and beyond to the Two Hills area in tp. 54, rge. 12, whereas the northeast boundary crosses North Saskatchewan River southwest of Elk Point and extends northwest to include an area slightly north of St. Paul des Metis and Vilna to tp. 60, rge. 14. Within this belt water wells are common in the Ribstone Creek sands, which are almost without exception water-bearing in some part of the formation. The limits of the belt to the northeast determine the limits of water from this source, but to the southwest of the belt, as here outlined, water may be obtained in this formation by drilling through the younger beds that overlie it. The Ribstone Creek sands are a prolific source of water in many places and hence the distribution of this formation is of considerable economic importance. Where the formation consists of upper and lower sands with a central shale zone only the sands are water-bearing, although thin sand members may occur in the shale. Where the formation is largely sand the distribution of water may be in any part of the formation, although the upper and lower sands are perhaps the better aquifers. To the east of Alberta, along Battle River and Big Coulée in Saskatchewan, the Ribstone Creek sands are marine. Marine conditions apparently become more prevalent to the southeast and it is believed that in this direction the sands are gradually replaced by marine shales. Thus at some distance southeast of Battleford the Ribstone Creek formation loses its identity and its equivalents are shales in a marine succession.

Lea Park Formation

The Lea Park formation is largely a marine shale, and only in the upper 180 feet is there any water. In the Dina area south of Lloydminster the upper beds of the Lea Park consist of silty shales about 110 feet thick underlain by silty sands 70 feet thick. Below these sands are marine shales only, and these yield no fresh water either in east-central Alberta or west-central Saskatchewan. The sand in the upper Lea Park formation is thus the lowest freshwater aquifer within a very large area. The extent of this sand in the Lea Park, particularly to the northeast, is not known, but as the strata in east-central Alberta have a southwest inclination, progressively lower beds occur at the surface to the northeast. Thus at a short distance beyond the northeast boundary of the Ribstone Creek formation, as previously outlined, the sand in the upper Lea Park reaches the surface, and represents the last bedrock aquifer in that direction. Farther northeast water must be obtained from glacial or surface deposits only. In Alberta this area without fresh water in the bedrock includes the country north of North Saskatchewan River in the vicinity of Frog Lake and a large area extending to and beyond Beaver River. In this area, however, more fresh water streams are present than farther south, and bush lands

help to retain the surface waters. The area northeast of North Saskatchewan River in Saskatchewan is almost wholly within the Lea Park formation, where water can be found only in surface deposits.

WATER ANALYSES

Introduction

Analyses were made of water samples collected from a large number of wells in west-central Saskatchewan. Their purpose was to determine the chemical characteristics of the waters from different geological horizons, and thereby assist in making correlations of the strata in which the waters occur. Although this was the main objective of the analyses, it was also realized that a knowledge of the mineral content of the water is of interest and value to the consumer. The analyses were all made in the laboratory of the Water Supply and Borings Section of the Geological Survey, Ottawa.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO_4), chloride (Cl), and carbonate (CO_3) radicals.

The analyses indicate only the amounts of the previously mentioned radicals, thus neglecting any silica, alumina, potash, or iron that may be present. It will be noticed that in most instances the total solids are accounted for by the sum total of the radicals as shown by the analyses. Actually, the residue when the water is completely evaporated still retains some combined water of crystallization, so that the figures for the "total solids" are higher than the sum total of the radicals as determined. These radicals are also "calculated in assumed combinations" to indicate the theoretical amounts of different salts present in the water. The same method was followed in each analysis, so that the table presents a consistent record of the different compounds present.

Mineral Constituents Present

Calcium. Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$).

Magnesium. Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesia ($MgSO_4$) combines with water to form "Epsom salts" and renders the water unwholesome if present in large amounts.

Sodium. Sodium (Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salt" and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio

of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes[1]. Sodium sulphate is less

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1 "The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)" Frank Dixey in "A Practical Handbook of Water Supply", Thos. Murby & Co., 1931, p. 254.

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harmful.

Sulphates. The sulphate (SO_4) salts referred to in these analyses are calcium sulphate ($CaSO_4$), magnesium sulphate ($MgSO_4$), and sodium sulphate (Na_2SO_4).

Chloride. Chlorine (Cl) is with a few exceptions, expressed as sodium chloride (NaCl), that is, common table salt. It is found in all of the analyses, most of the waters containing less than 200 parts per million, but some as much as 2,000 or 3 ,000 parts. These waters have a brackish taste.

Alkalinity. The alkalinity determined in these water analyses is based on the assumption that the only salts present in the samples that will neutralize acids are carbonates, and that, consequently, the degree of alkalinity is proportional to the amount of the carbonate radical (CO_3) present.

Hardness. The hardness of water is the total hardness, and has been determined by the amount of a standard soap solution required to form a lather that will stand up (persist) for 2 minutes. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. The two forms of hardness are not distinguished in the water analyses. Waters grade from very soft to very hard, and can be classified according to the following system[2]:

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2 The "Examination of Waters and Water Supplies", Thresh & Beale, page 21, Fourth Ed. 1933 .

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.
A water with 50 to 100 degrees of hardness may be said to be moderately soft.
A water with 100 to 150 degrees of hardness may be said to be moderately hard.
A water with more than 200 and less than 300 degrees of hardness may be said to be hard.
A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, especially those not associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sand and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillinite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction[1].

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[1] Piper, A. M. "Ground Water in Southwestern Pennsylvania", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consequently, be a factor in determining the extent of the reaction.

The amount of iron present in the water was not determined, owing to the possibilities of contamination from the iron casings in the wells. Iron is present in most waters, but the amount may be small. Upon exposure to air a red precipitate forms, the water becomes acid, and, hence, has a corrosive action. When iron is present in large amounts the water has an inky taste.

WATER ANALYSES IN RELATION TO GEOLOGY

Glacial Drift

The quality of the water from glacial drift depends largely on the nature of the deposit from which it comes and on the depth of the aquifer below the surface. Glacial deposits may be divided roughly into three types.

(1). Sand and gravel beds that form the surface deposit, such as outwash material and glacial lake sands.

(2). Buried outwash and interglacial deposits between two tills of boulder clay.

(3). Pockets or lenses of sand and gravel irregularly distributed through the till.

Water from surface sand deposits is normally low in dissolved salts, the total being generally less than 1,000 parts per million. Where large amounts of limestone occur in the glacial sand and gravel beds a characteristic constituent of the glacial water is calcium carbonate, the amount present varying from 300 to 700 parts per million.

Water from buried outwash deposits contains more dissolved salts than the surface sands, as the water in order to reach them has to percolate through overlying till. Rain water contains carbonic acid, which acts as a solvent and dissolves a great deal of calcium, magnesium, and sodium from the rock-forming minerals. Sulphate salts are commonly present, though their proportions vary greatly in the different waters. The shales that are incorporated in the drift are high in calcium sulphate, so that the amount of shale present will modify the quality of the water. The oxidized upper part of the drift contains less sulphate than the deeper, less oxidized boulder clay. The character of the water in the buried outwash deposits will, therefore, depend largely on the composition and amount of till that overlies it.

Water from irregularly distributed sand and gravel beds will vary in its content of dissolved salts depending upon the character of the material surrounding the reservoir beds. As the water in this type of deposit does not flow to any marked extent, it is apt to be more highly impregnated with soluble salts than where the underground movement is more rapid. Soft water in the drift is mostly confined to shallow wells in sands low in calcium carbonate. Waters from glacial lake clays are sometimes high in soluble salts. The sample from a well in glacial lake clay on N.W. $\frac{1}{4}$ sec. 27, tp. 42, rge. 17, has 11,040 parts per million of soluble salts, largely magnesium sulphate and sodium sulphate. The sample from SE. $\frac{1}{4}$ sec. 13, tp. 42, rge. 16, which is believed to come from glacial lake silts, has a very different composition. The total solids in it are only 440 parts per million, of which 250 are calcium carbonate. The great difference in these waters is due to the high soluble salt content that is associated with the lake clays but absent in the silts. Average drift water contains between 1,000 and 3,000 parts per million of dissolved mineral salts.

Bearpaw Formation

The Bearpaw formation consists of dark marine shales and beds of green sand. Water from these sands has a total solid count ranging from 300 to 1,600 parts per million and a hardness of more than 300 degrees. Calcium carbonate is very marked in all samples, due, perhaps, to the proximity of the water sands to the glacial drift. Sodium sulphate is the chief salt present, followed by calcium carbonate, magnesium sulphate, magnesium carbonate, and sodium chloride in decreasing amounts. These waters are distinguished from the overlying drift waters by being relatively low in total dissolved solids, and in containing no calcium sulphate and only moderate amounts of sodium sulphate, magnesium sulphate, and magnesium carbonate.

Pale Beds

Pale Beds underlie the Bearpaw formation. Total solids in waters from these beds vary from 700 to 1,300 parts per million. The water is, in most instances, soft, as it contains sodium carbonate in excess of calcium and magnesium carbonates, but when mixed with surface water high in calcium carbonate, it will become hard. The high concentration of sodium salts, especially sodium carbonate, in contrast with the calcium and magnesium salts distinguishes this water from that in Bearpaw sands. The Pale Beds include much bentonite, and it is this mineral that acts as a water softener within the formation. The following analyses are typical of waters from the Pale Beds:

Salts	SE. sec. 16, tp.38, rge. 21	NE. sec. 3, tp.39, rge. 25,	SW. sec. 7, tp.37, rge.24,	SE. sec. 21 tp. 38,rge.23
$CaCO_3$	73	18	53	35
$CaSO_4$	-	-	-	-
$MgCO_3$	52	14	45	38
$MgSO_4$	-	-	-	-
Na_2CO_3	297	679	464	562
Na_2SO_4	297	158	266	437

NaCl	31	45	46	130
Total solids	760	1,020	940	1,260
Hardness	100	20	30	75

Variegated Beds

In Senlac Rural Municipality, Saskatchewan, are a number of wells that have water very similar in character to that found in the Bearpaw formation. These wells tap an horizon that corresponds with the Variegated Beds in Alberta, although they have not been separated from the Pale Beds. They are less bentonitic than the Pale Beds and darker in colour. The water is hard and has a low dissolved solid content. The three analyses given below show a great deal of similarity and suggest a common horizon.

Salts	NW. sec. 21, tp.41,rge.26	NW. sec. 3, tp.41,rge.28	SE. sec. 28, tp.40,rge.28
$CaCO_3$	250	305	125
$CaSO_4$	-	-	-
$MgCO_3$	1109	80	155
$MgSO_4$	149	104	69
Na_2CO_3	-	-	-
Na_2SO_4	98	132	386
NaCl	12	12	18
Total solids	640	640	780
Hardness	600	600	500

Ribstone Creek Formation

Chemical analyses of water from the Ribstone Creek formation vary more than in the Pale Beds, the reason being that at several different horizons the sediments show considerable lateral variation. The formation includes both marine and non-marine beds, thin coal seams being present in the basal part of the formation around Paynton, whereas south of Lashburn, on Battle River, marine fossils were found in strata considered to be at approximately the same horizon. The water analyses show similarities within limited areas, but long distance correlations cannot be made safely except for the saline waters that occur in the flowing wells at Vera, Muddy Lake, and at the south end of Tramping Lake. Analyses of these waters are given in the following table:

Salts	SE.sec.25, tp.41,rge. 24	SE.sec.22, tp.41,rge. 24,	NE.sec.36, tp.41,rge. 24,	SW.sec.7 tp.41,rge. 24,	SE.sec.30, tp.38, rge. 22,	SW.sec10, tp.35, rge.20,
$CaCO_3$	73	73	73	198	108	90
$CaSO_4$	-	-	-	-	-	-
$MgCO_3$	38	38	38	52	69	52
$MgSO_4$	-	-	-	-	-	-

Na_2CO_3	129	119	129	11	106	125
Na_2SO_4	55	55	61	61	49	43
NaCl	2,929	3,036	2,690	2,863	3,531	3,861
Total solids	3,840	3, 460	3,120	3,200	3,860	4,460
Hardness	135	90	110	100	130	130

The similarity in these anlayses suggests a common source bed. The distance between the Tramping Lake well and the Vera wells is about 40 miles. This water, which is thought to come from the basal sand of the Ribstone Creek formation, is not typical of water from the same stratigraphical horizon in the vicinity of Battle River, one reason being, possibly, that at Battle River the stream has cut through the Ribstone Creek formation exposing the sand members along its banks. This may cause a more rapid movement of the underground water in this area than farther south, and it is known that the rate of flow is a controlling factor that governs the change of calcium carbonate to sodium carbonate when the softening reagents of bentonite or glauconite are present in the sand.

Some of the soft waters from the Ribstone Creek formation cannot be distinguished from those of the Pale Beds, whereas others are quite different. The following analyses illustratetsome of the different types of water from this formation:

Salts	Se.sec. 11, tp. 46, rge. 28	Ind.Agent Little Pine I.R.	SW.sec. 24, tp. 46, rge. 21	NE.sec. 36, tp. 43, rge. 18	Se.sec. 26. tp. 43, rge. 18	NE.sec. 36. tp. 41, rge. 24	NW.sec. 22. tp. 42. rge. 23
$CaCO_3$	90	90	410	73	35	73	125
$CaSO_4$	-	-	-	-	-	-	-
$MgCO_3$	97	59	168	38	31	38	97
$MgSO_4$	-	-	64	-	-	-	-
Na_2CO_3	217	392	-	283	592	129	196
Na_2SO_4	1,644	777	2,518	225	522	61	1,541
NaCl	249	63	76	12	83	2,690	71
Total solids	2,220	1,340	3,000	620	1,280	3,120	1,900
Hardness	280	160	750	110	35	110	600

The above chemical analyses show such a wide range in the dissolved salts present in the different waters in the Ribstone Creek formation that they cannot be used for correlation purposes over a large area.

Conclusions

(1) In most instances water from glacial drift is quite different from water from bedrock.

(2) Some of the bedrock horizons carry waters that show definite chemical characteristics.

(3) Most waters from glacial till carry total solids amounting to between 1,000 and 3,000 parts per million.

(4) Bedrock waters are commonly low in dissolved salts. Exceptions to this are to be found in water from the Ribstone Creek formation.

(5) Water from the Bearpaw formation is hard. An average of ten wells gave a total solid content of 1,100 parts per million.

(6) Water from the Variegated Beds resembles that from the Bearpaw formation.

(7) Waters from the Pale Beds is mostly soft. An average of ten wells gave a total solid of 1,000 parts per million.

(8) All soft waters contain sodium carbonate (Na_2CO_3), which is present in water from the Pale Beds and Ribstone Creek formations but absent from the Bearpaw formation and Variegated Beds.

WEST PART OF RURAL MUNICIPALITY OF NORTH BATTLEFORD, NO. 437, SASKATCHEWAN

Physical Features

The highest elevations in this municipality are in the northeast corner, and the regional slope is toward North Saskatchewan River. Mostly the country is very gently rolling, with an abrupt descent in the north and a more gradual slope in the south to river level, 150 to 200 feet below.

Geology

A few outcrops of Lea Park shale occur on the river bank south and east of North Battleford and near the mouth of Jackfish River. Elsewhere bedrock is covered by a deposit of glacial till, with a maximum thickness of probably more than 150 feet. To the northeast of this municipality is a large terminal moraine in front of which outwash deposits, sloping gradually to the southwest, are buried in the drift. This outwash is now buried beneath later glacial materials, which also contain a few sand and gravel beds.

Water Supply

The main source of water is the outwash deposit that covers part of this municipality. It consists mostly of sand and is undoubtedly mixed with a considerable amount of clay, which, in places, interfers with its permeability. Above it, in a few places, are sand beds in the drift and these also have proved to be commonly water-bearing. Below the drift is the Lea Park shale. In an outcrop on the road from the bridge over North Saskatchewan River to the Mental Hospital the Lea Park contains a poorly defined sand bed, and may carry water. However, such sands are believed to be rare in these shales. Undoubtedly also the weathered top of the shale might contain water in joints and cracks, but wells deep into the shales are not likely to find water. The glacial drift in this area, therefore, is the only dependable source of water supply.

Township 43, Ranges 15 and 16, East of North Saskatchewan River. In these townships the land slopes gently from an area above an elevation of 1,900 feet to North Saskatchewan River at an elevation of less than 1,550 feet. The entire surface is covered with glacial materials to a depth, in places, of probably as much as 150 feet. Most of the wells get their water from sand or gravel beds in the drift. Below the drift is Lea Park shale, and except for the upper weathered part where water could be retained in cracks and joints, deep drilling in the shale offers no prospect of a water supply. In the upper part, however, a few discontinuous sand beds might afford a poor supply, as seems to be the case in the well, 150 feet deep, on SE. sec. 24, tp. 43, rge. 15. It is probable that the shale surface beneath the drift slopes toward North Saskatchewan Valley, as wells in the northeast part of this area apparently strike the shale at higher elevations than those in the southwest part. The sand and gravel beds are irregularly distributed through the drift, and their depth at any particular location cannot be predicted.

Township 44, Range 15. Most of this township has an elevation varying only slightly from 1,850 feet, but the depths of the wells range from 18 to 90 feet. An examination of the well records indicates, however, two fairly constant water-bearing zones in the drift. The upper of these has an elevation of 1,760 to 1,780 feet, and the lower zone, reached by four wells in widely separated parts of the township, has an elevation of 1,730 to 1,740 feet. Both are evidently in outwash deposits in the drift. One well obtains water from an horizon intermediate between the two zones, and three wells encountered water-bearing sands above the upper limit of the upper zone and, consequently, were not sunk to any lower level. It is inferred that the two zones are fairly persistent aquifers in this township. The depth to the base of the drift is not known. A well 65 feet deep on NE. section 18 reached gravel at an elevation of 1,732 feet, and another well, on SW. section 35, reached probably the same gravel horizon at 1,731 feet. It is not known how thick the drift is below this gravel deposit. Prospects of obtaining water in the underlying Lea Park shale are not favourable, although certain isolated but rather poor sand bodies are known in the upper part; at greater depths no potable water can be expected.

Township 44, Ranges 16 and 17, East of North Saskatchewan River. Township 44, range 16, is comparatively flat, but west of it the surface slopes rather rapidly from an elevation of 1,750 feet to less than 1,550 feet at North Saskatchewan River. Very little uniformity in level can be discerned in the aquifers of this area. It may be that the sand zone at an elevation of 1,760 to 1,780 feet in the range to the east is continued into this area at the slightly lower elevation of 1,750 to 1,760 feet, and that the lower zone at an elevation of 1,730 to 1,740 feet in the area to the east is here at an elevation of 1,720 to 1,730 feet, but these zones are here much less clearly defined, and other irregularities are apparent. One well, on SE. sec. 17, tp. 44, rge. 16, at a depth of 108 feet or an elevation of 1,657 feet, is believed to have reached the top of the Lea Park shale, but it seems improbable that any other wells in the area penetrated the glacial drift. In this township, as in this whole municipality, there is little prospect of obtaining water in the underlying Lea Park shale.

Township 45, Range 15. Several wells in this township obtain water between elevations of 1,750 and 1,770 feet, as in the township to the south. This source evidently represents a buried outwash deposit in the glacial drift. A few wells get water at higher elevations, and a few dry holes have been drilled. Two of the latter did not reach the outwash sand and gravel deposit in which they might have obtained water, and the third may have passed through the deposit into Lea Park shale without encountering water. Evidence from the well records indicates, therefore, that except for irregularly distributed sands found everywhere in the glacial drift, the best prospect for water in this township is the outwash gravel and sand deposit. Because this deposit was spread out by stream action in front of the ice it could not be expected to be of uniform composition, but its persistence in this and the townships to the south is evidence of its widespread nature.

Township 45, Range 16. The outwash deposit in tp. 45, rge. 15, persists into this township between elevations of 1,720 and 1,780 feet. Here it appears to be considerably thicker than

in the area to the east, but about as thick as the two zones in tp. 44, rge. 15. This is quite in harmony with the northwest and southeast trend for deposits of this kind, and here as to the southeast the deposit can be grouped roughly into a lower zone between elevations of 1,720 to 1,740 feet and an upper zone between 1,760 and 1,780 feet. A few wells, as in the area to the southeast, have also found water between these zones. This deposit, then, is the main source of water supply for the area, and such other wells as do not reach it obtain water from irregularly distributed sand bodies in the drift. It is quite probable that the outwash deposit is mixed with large amounts of clay, and that only the more porous parts yield water in any quantity. This would serve to explain the variability in the elevations at which the individual wells found water.

Township 45, Range 17, East of North Saskatchewan River. The land in this township slopes gently to the valley of North Saskatchewan River, where there is an abrupt drop from an elevation of 1,700 feet to less than 1,550 feet. It may be that the outwash deposit present to the east slopes rapidly and disappears westward, as in this area it seems to occupy a zone between 1,690 and 1,730 feet in elevation. All wells of which records are available, except one on the river bank, obtain their water within this zone, so that it forms probably the only source of water present in this area. Here, as elsewhere, the Lea Park shales underlying the drift offer little prospect for a further water supply.

ANALYSES OF WATER SAMPLES FROM WEST PART OF RURAL MUNICIPALITY OF NORTH BATTLEFORD, NO. 437, SASKATCHEWAN

No.	¼ Sec.	Tp.	Rge.	Depth in feet	Elev. of Aquifer	Total dissolved solids	Constituents as Analysed						Total Hardness	Constituents as Calculated in assumed Combinations							Source of Water
							Ca	Mg	Na	SO_4	Cl.	Alk.		$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl.	
1	SE 22	43	15	149	1686	3840	386	133	556	2161	91	340	1900	340	850		658		1533	150	Glacial drift
2	SW 23	43	15	117	1775	2720	279	164	337	1486	31	510	2100	510	255		812		977	51	do
3	NE 24	44	15	75	1768	1840	257	124	118	939	11	415	1700	415	309		614		342	18	do
4	SW 27	44	15	75	1760	3360	400	242	216	1771	18	595	3000+	595	551		1198		630	30	do
5	SE 26	44	16	65	1635	2640	529	194	54	1689	16	455	2300	455	1179		960		135	26	do
6	NW 12	45	16	107	1726	3000	415	168	121	1468	15	440	2700	440	812		832		342	25	do

RECORD OF WELLS OF WEST PART OF RURAL MUNICIPALITY OF NORTH BATTLEFORD, NO. 437, SASKATCHEWAN

Well No.	LOCATION ¼ Sec.	Tp.	Rge.	Mer.	Type of Well	Depth of Well Ft.	Altitude of Well	WATER LEVEL Above (+) or Below (-) Surface	Elev. Above Sea Level	PRINCIPAL WATER-BEARING BED Depth Ft.	Elev.	Geol. Horizon	Character of Water	Use to Which Water is Put[x]	Yield & Remarks
1	S.W. 3	43	15	3	Bored	24	1688	-14	1674	24	1664	Blue clay	Hard	D.S.	Sufficient
2	S.E. 4	"	"	"	Dug	18	1676	-16	1660	18	1658	Glacial gravel	" Alk.	"	Limited
3	S.W. 8	"	"	"	"	22	1624	-20	1604	20	1604	" "	" "	"	Poor supply
4	N.W.14	"	"	"	Bored	100	1814	-78	1736	100	1714	" "	" "	"	Sufficient
5	N.E.15	"	"	"	Dug	60	1876	-42	1834	60	1816	Blue sand	Hard	"	"
6	S.W.16	"	"	"	"	18	1748	-14	1734	16	1732	Glacial gravel	"	"	Limited
7	S.W.18	"	"	"	Bored	24	1689	-20	1669	20	1669	Fine sand	"	"	Sufficient
8	N.E.18	"	"	"	Dug	16	1640	-13	1627	16	1624	Sand	" Alk.	S.	Poor supply
9	N.E.20	"	"	"	Bored	80	1812	-65	1747	80	1732	"	" Fe.	"	Sufficient
10	S.E.20	"	"	"	Dug	32	1767	-28	1739	32	1735	Sandy clay	" "	D.S.	Limited
11	S.E.22	"	"	"	Drilled	149	1835	-84	1751	149	1686	Gravel ?	" "	"	Sufficient
12	S.E.24	"	"	"	Bored	150	1904			150	1754	Sand	" Alk.	S.	Poor supply
13	S.W.25	"	"	"	Drilled	117	1892	-60	1832	117	1775	Yellow Sand	" Fe.	D.S.	Sufficient
14	S.E.26	"	"	"	Bored	166	1918								Dry Hole in Blue Clay
15	S.E.26	"	"	"	"	36	1918			36	1882	Sand	" Alk.	"	Sufficient
16	N.E.26	"	"	"	"	56	1870	-44	1826	56	1814	"	" "	"	
17	S.W.28	"	"	"	Dug	16	1820	- 8	1812	16	1804	Coarse Sand	Soft	"	Sufficient
18	S.W.30	"	"	"	"	38	1764	-33	1731	38	1726	Sandy clay	Hard Fe.	S.	Limited Supply, Well 35' deep in Sand.
19	N.E.30	"	"	"	Dug	25	1834	-23	1811	25	1809	Glacial sand	Hard	D.	Limited Supply, Well 25' deep for Stock use.
1	S.E.14	43	16	3	Dug	18	1604	-15	1589	18	1586	Blue Clay	Hard	D.S.	Poor supply
2	N.E.24	"	"	"	Bored	40	1708	-25	1683	40	1668	Coarse Sand	" Fe.	S.	Limited supply
3	N.E.34	"	"	"	Dug	28	1774	-26	1748	28	1746	Fine Sand	Hard	D.S.	" "
1	S.E. 5	44	15	3	Dug	40	1924	-32	1892	40	1884	Glacial sand	Hard	D.S.	Sufficient
2	S.W. 6	"	"	"	Bored	146	1853	-80	1773	146	1707	Black "	" Alk.	"	"
3	S.W. 9	"	"	"	Dug	30	1890			30	1860	Glacial sand	Hard	"	"
4	N.E.10	"	"	"	Bored	15	1846			15	1831	Coarse "	Soft		

x - D. Domestic Fe.- Iron
S. Stock. Alk.- Alkaline.

Well No.															
5	N.W.14	44	15	3	Bored	90	1826			90	1736	Coarse sand	Hard	Alk.	D.S.	Sufficient
6	N.E.18	"	"	"	"	65	1797	-62	1735	65	1732	Glacial gravel	"	"	"	Limited
7	S.E.18	"	"	"	Dug	24	1810	-14	1796	24	1786	Sand			"	Good supply, Dry Hole 78'.
8	S.W.22	"	"	"	Bored	90	1850	-70	1780	90	1760	"	Hard	Fe.	"	Sufficient
9	S.E.23	"	"	"	"	70	1836	-67	1769	66	1770	Glacial gravel	Hard		"	"
10	N.E.24	"	"	"	"	80	1848	-70	1778	80	1768	Black sand	"		"	"
11	N.W.24	"	"	"	"	80	1862	-72	1790	80	1782	" "	"		"	"
12	N.E.25	"	"	"	Dug	18	1856			18	1838	Glacial sand	"	Alk.	"	"
13	S.W.27	"	"	"	Bored	75	1835	-60	1775	75	1760	sand	"	"	"	"
14	S.E.29	"	"	"	"	73	1840			65	1775	White "	"		"	"
15	N.E.30	"	"	"	"	100	1838	-95	1743	100	1738	sand	"	Alk.	S.	Limited supply
16	S.W.30	"	"	"	Dug	25	1790	-17	1773	25	1765	Glacial sand	Soft		D.S.	
17	N.W.31	"	"	"	Bored	92	1843	-88	1755	92	1751	Fine "	Hard	Fe.	"	Limited
18	N.W.33	"	"	"	Bored	80	1860	-68	1792	80	1780	" "	Hard		"	Sufficient
19	S.E.34	"	"	"	"	89	1868			50	1818	" "	"		"	"
20	S.W.35	"	"	"	"	125	1856	-65	1791	125	1731	Glacial gravel	"	Alk.	"	"
21	N.E.36	"	"	"	"	42	1854	-22	1832	42	1812	Black sand	"	"	"	"
			2													
1	S.W. 2	44	16	3	Bored	80	1778			80	1698	Fine sand	Hard	Alk.	S.	Poor supply
2	S.E.13	"	"	"	"	125	1837	-110	1727	125	1712	"	"	"	D. S.	Sufficient
3	S.W.13	"	"	"	"	120	1872	-95	1777	112	1760	"	"	Fe.	S.	"
4	N.W.14	"	"	"	"	88	1838	-18	1820	88	1750	Blue "	"	Alk.	D.S.	"
5	N.E.14	"	"	"	"	62	1840	-50	1790	62	1778	" clay	"	"	"	Good supply, Good Well 104'.
6	S.E.17	"	"	"	"	114	1765	-90	1675	108	1657	Top of Shale	"		"	Sufficient
7	N.E.20	"	"	"	Dug	22	1751	-17	1734	22	1729	Fine sand	"		"	
8	N.W.22	"	"	"	Bored	43	1692	-40	1652	40	1652	" "	"	Alk.	"	Poor supply
9	S.W.23	"	"	"	"	40	1710	-30	1680	40	1670	" "	Soft		"	Good " Dry Hole 95'.
10	N.W.25	"	"	"	"	60	1815	-59	1756	60	1755	Coarse "	Hard		"	Limited
11	N.E.25	"	"	"	"	46	1798	-40	1758	46	1752	Fine "	"	Alk.	"	"
12	S.E.26	"	"	"	"	65	1700	-62	1638	65	1635	" "	"		"	Sufficient
13	S.W.26	"	"	"	"	125	1778	-110	1668	125	1653		"	Alk.	"	Good supply
14	S.E.28	"	"	"	Dug	35	1715	-32	1683	35	1680	Fine gravel	Soft		"	Limited
15	N.W.28	"	"	"	Bored	60	1784	-45	1739	60	1724		Hard	Alk.	"	
16	N.W.29	"	"	"	"	100	1775			100	1675	Fine sand	"	"	S.	Good Well 22' in Gravel.
17	S.W.32	"	"	"	"	50	1790	-48	1742	50	1740	sand	Hard		D.S.	Sufficient
18	N.E.32	"	"	"	Dug	24	1750	-20	1730	24	1726		"	Alk.	S.	Limited supply

Well No.															
19	S.W.33	44	16	3	Bored	35	1765	-30	1735	35	1730	Sandy clay	Hard	Alk.	D.S.	Sufficient
20	N.W.34	"	"	"	"	26	1786	-23	1763	26	1760	Fine sand	"		"	Limited
21	S.W.36	"	"	"	"	72	1810±	-52	1758	66	1744	Glacial gravel	"	"	"	
1	S.W.24	44	17	3	Bored	72	1810	-70	1740	72	1738	Fine sand	Hard	Alk.	S.	Limited supply
2	N.E.36	"	"	"	Dug	14	1692	-12	1680	14	1678	Glacial gravel	Hard		D.S.	" "
3	S.W.36	"	"	"	"	30	1730	-25	1705	30	1700	" " "	Soft		"	Sufficient
1	N.W. 1	45	15	3	Bored	53	1886			53	1833	Glacial clay	Hard	Alk.	S.	Limited
2	N.W. 4	"	"	"	"	82	1848	-78	1770	82	1766	Fine sand	Hard		D.S.	Sufficient
3	S.W. 5	"	"	"	"	102	1854	-97	1757	102	1752	" "	"	Fe.	S.	Limited supply sand trouble.
4	N.W. 7	"	"	"	Bored	80	1844	-75	1769	75	1769	Glacial gravel	Hard	Alk.	D.S.	Good supply
5	S.W. 7	"	"	"	"	78	1849	-75	1774	78	1771	" "	"	"	"	" "
6	N.W. 8	"	"	"	"	103	1853	-80	1773	103	1750		"	Fe.	S.	" "
7	S.E.14	"	"	"	"	96	1941	-60	1881	96	1845	Gravel & sand	"	"	D.S.	Limited "
8	S.W.18	"	"	"	"	66	1843	-63	1780	63	1780	Sand & gravel	Hard		"	Good "
9	S.W.20	"	"	"	Dug	35	1878	-33	1845	32	1846	Fine sand	"		"	Limited
10	N.W.20	"	"	"	Bored	103	1870	-100	1770	100	1770	" "	"	Fe.	"	Poor supply
11	N.E.21	"	"	"	"	120	1925									Dry Hole in Blue Clay Water in Well 25' deep
12	N.W.23	"	"	"	"	115	1901									Dry Hole in Blue Clay. Water in gravel at 20'.
13	N.W.30	"	"	"	"	70	1889			70	1819		Hard		D.S.	Poor supply
14	S.E.30	"	"	"	Dug	45	1904	-43	1861	40	1864	Coarse gravel	"	Alk.	"	Good " "
15	N.E.31	"	"	"	Bored	71	1825									Dry Hole possibly in shale.
16	N.W.32	"	"	"	Bored	40	1824	-36	1788	40	1784	Sand & gravel	Hard		D.S.	Good supply
17	N.E.33	"	"	"	Dug	33	1854	-25	1829	33	1821	Glacial clay	"	Alk.	"	" "
1	S.W. 1	45	16	3	Bored	40	1845	-20	1825	40	1805	Coarse sand	Hard		D.S.	Sufficient
2	S.W. 2	"	"	"	"	80	1791	-40	1751	80	1711	White "	"	Alk.	"	Good supply
3	N.W. 3	"	"	"	"	40	1786	-28	1758	40	1746	Coarse "	"		"	" "
4	S.E. 4	"	"	"	"	41	1791	-38	1753	40	1751	Fine "	"		"	Sufficient
5	N.E. 4	"	"	"	"	50	1786	-30	1756	50	1736	Blue clay	"	Fe.	"	"
6	S.W. 5	"	"	"	Dug	22	1759	-20	1739	22	1737	Fine sand	"		"	"
7	S.W. 9	"	"	"	Bored	80	1789			80	1709	Blue clay	"	Alk.	"	Poor supply
8	N.W.12	"	"	"	"	107	1826	-80	1746	100	1726	Coarse sand	"	Fe.	"	Good "
9	S.W.14	"	"	"	"	80	1799			80	1719	Blue clay	"	Alk.	"	Sufficient

Well No.															
10	N.E.16	45	16	3	Dug	16	1795			16	1779	Coarse sand	Hard	D.S.	Sufficient
11	N.W.18	"	"	"	Bored	30	1764			29	1735	" red "	" Alk.	"	"
12	S.E.18	"	"	"	Dug	12	1768	-10	1758	10	1758	Fine sand	Soft	D.	"
13	S.W.23	"	"	"	Bored	35	1799	-30	1769	34	1765	Coarse "	Hard Alk	D.S.	"
14	S.W.24	"	"	"	"	42	1796			40	1756		" "	"	" another Well 16'
15	N.W.24	"	"	"	"	68	1796	-60	1736	68	1728	Fine sand	" Fe.	"	Sufficient
16	N.E.24	"	"	"	"	35	1810	-32	1778	35	1775	Gravel	" Alk.	S.	Good supply
17	N.W.26	"	"	"	"	60	1789	-20	1769	60	1729	Coarse sand	" Fe.	D.S.	Sufficient
18	S.W.27	"	"	"	Dug	19	1790			17	1773	Fine "	Hard	"	"
19	S.E.31	"	"	"	"	27	1773			25	1748	" "	" Alk.	"	"
20	N.E.33	"	"	"	"	19	1775			19	1756	" "	" "	D.	"
21	S.E.36	"	"	"	Bored	68	1934	-65	1869	40	1894	Sand & clay	" "	S.	Poor supply
1	N.E.10	45	17	3	Bored	37	1588			36	1552	Blue sand	Hard Alk.	D.S.	Sufficient
2	N.E.12	"	"	"	Dug	50	1747			50	1697	Coarse "	" "	"	"
3	S.E.13	"	"	"	"	30	1760			30	1730	Sandy material	" "	"	"
4	S.E.14	"	"	"	"	42	1736			40	1696	Coarse sand	" Fe.	"	Poor supply
5	S.E.15	"	"	"	Bored	55	1734			35	1699	Gravel	"	"	" "
6	N.E.16	"	"	"	"	100	1713								Dry Hole in Blue Clay.
7	N.W.23	"	"	"	"	64	1732			40	1692	Sand	Hard Alk.	D.S.	Sufficient another Well
8	N.E.24	"	"	"	Dug	19	1767			19	1748	Coarse sand	" "	"	Sufficient. 25'.
9	S.W.28	"	"	"	"	22	1719	-17	1702	22	1697	Glacial gravel	Hard	"	"
10	S.W.31	"	"	"	"	18	1724	-16	1708	18	1706	Fine sand	"	"	
11	S.E.32	"	"	"	"	22	1739	-20	1719	22	1717	sand	" Alk.	"	Poor supply
12	S.E.35	"	"	"	Bored	50	1753	-20	1733	50	1703	Fine yellow sand	" "	"	Sufficient
13	N.E.36	"	"	"	"	30	1753	-22	1731	30	1723	" " "	" Fe.	"	"