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FLOWING WELLS AND MUNICIPAL WATER SUPPLIES

IN THE

MIDDLE AND NORTHERN PORTIONS

OF THE

SOUTHERN PENINSULA OF MICHIGAN

BY

FRANK LEVERETT AND OTHERS

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FLOWING WELLS AND MUNICIPAL WATER SUPPLIES IN THE MIDDLE AND NORTHERN PORTIONS OF THE SOUTHERN PENINSULA OF MICHIGAN.

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INTRODUCTION.

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SCOPE OF REPORT.

A large amount of data on water supplies was collected by the writer in the course of glacial investigations made under the direction of Prof. T. C. Chamberlin in the last five years in the Southern Peninsula of Michigan. These investigations resulted in a partial acquaintance with conditions in about 200 separate flowing-well districts and brought out matters of such exceptional importance that arrangements were made to extend them by examining each of the flowing-well districts in the State sufficiently to determine its essential characteristics, present state of development, and probable capacity for future development. It was arranged also that the quality of various classes of water, both surface and underground, as well as water supplies of cities and villages, should be given attention. As the mineral waters of the State had already been discussed in some detail by the State geologist, Dr. A. C. Lane, in Water-Supply Paper No. 31 of the United States Geological Survey, it was deemed unnecessary to prepare another report on that subject, but arrangements were made with Doctor Lane for embodying in this report the large amount of material which had accumulated at his office relative to other classes of water supply, and also for furnishing reports on certain counties in which special investigations had been carried on by the State survey. The results of all these studies, so far as they apply to the middle and northern counties (see fig. 1, on next page), are embodied in the present report; the remainder appears in a companion report on the southern counties of the Southern Peninsula of Michigan.

In completing the necessary field work for this report several persons were employed for a short time and were assigned to separate districts, as follows: Jon Andreas Udden, of Rock Island, Ill., was employed from July to December, 1904, in an investigation of the southern counties, chiefly those south of Kalamazoo River, and parts of Macomb and Oakland counties in the eastern part of the State. Mr. Isaiah Bowman, of Yale University, was engaged for six weeks in August and September, chiefly in the region tributary to Grand River.

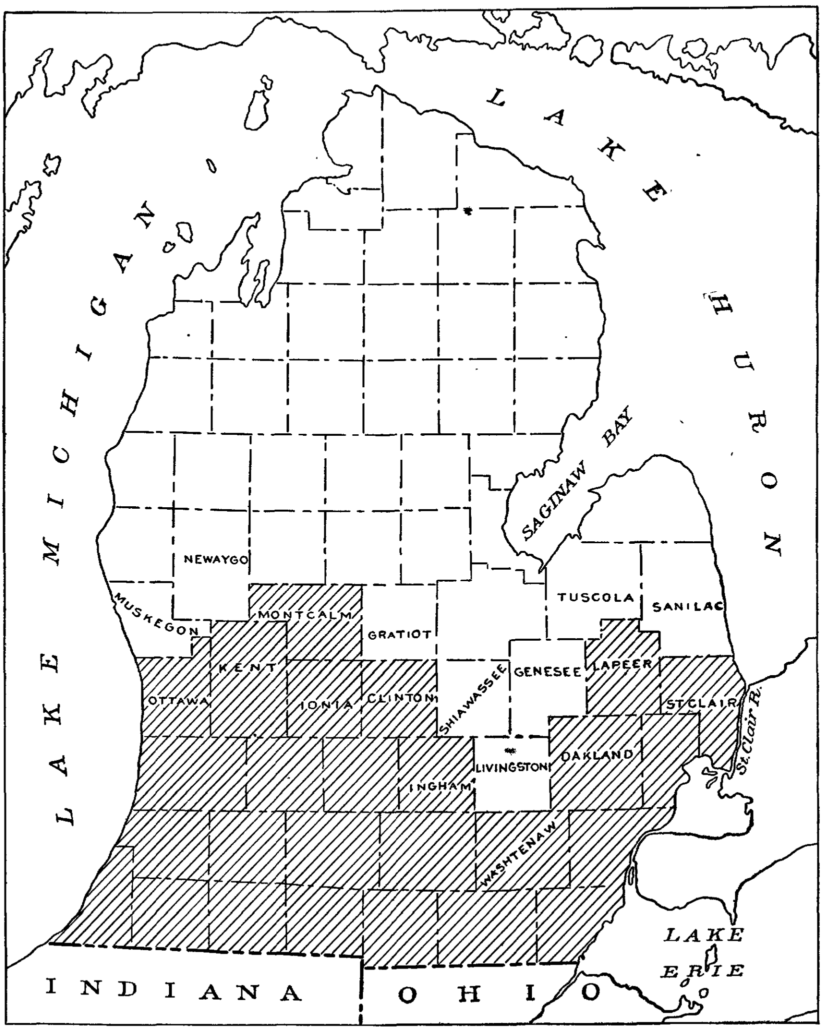


FIG. 1.—Sketch map, showing area covered by report. The ruled area is discussed in Water-Supply Paper No. 182.

Prof. C. A. Davis, of the University of Michigan, was employed during July, August, and September in the investigations of the southern and eastern portions of the basin of Saginaw River. Mr. W. M. Gregory, of the department of physiography in the Cleveland, Ohio, high school, was employed during July, August, and part of September in the investigation of the northwestern portion of the Saginaw River basin, and also of flowing-well districts in the northern part of the peninsula, in Cheboygan, Emmett, Grand Traverse, Benzie, and Manistee counties, to which he had previously given some attention in connection with stream measurements under Mr. Robert E. Horton. Mr. M. L. Fuller, of the Geological Survey, under whose direction the work was carried on, visited several of the men in the field and spent August and part of September in an investigation of the deficiency of water supplies along the Huron River Valley near Detroit, and in a detailed study of the flowing wells in four western counties, Oceana, Newaygo, Mecosta, and Osceola. Muskegon County was investigated by Mr. C. D. McLouth, of the department of physics of the Muskegon high school; Kent County, by Mr. J. F. Nellist, a civil engineer of Grand Rapids; Bay County, by Mr. W. F. Cooper, of the State Geological Survey; and Wayne County, by Prof. W. H. Sherzer, of the State normal college at Ypsilanti, who also furnished the data for the report on Monroe County. Doctor Lane, the State geologist, investigated and reported on conditions in the vicinity of Lansing and also prepared a brief report on Huron County, condensed from his more elaborate State report. The present writer's investigations during the last season were chiefly in Sanilac, Lapeer, and St. Clair counties on the eastern border of the State, and in Charlevoix, Antrim, and Benzie counties in the northwestern part. Mr. S. J. Lewis, of the United States Geological Survey, was detailed for a special investigation of the quality of waters and spent about a month in the State, in January and February, 1905, during which time he made about 90 analyses. Dr. V. C. Vaughan, dean of the medical school of the University of Michigan, kindly placed at the disposal of the Survey a large number of analyses made for sanitary purposes, but including determinations of hardness, chlorides, and sulphates. Field analyses were also made by Messrs. Fuller, Gregory, and Bowman, which will be found in connection with their reports herewith presented. Reports were submitted by all those engaged in this investigation with the exception of Mr. Udden, who merely turned in his tabulated data and notebooks. Much work, however, was necessary in order to bring the several reports to a more nearly uniform standard, and the present writer has amplified portions, inserted additional data at many points, and supplied most of the geologic and other general descriptions. The several reports, however, naturally differ somewhat in mode of treatment, according to the personal standards of the individual writers.

GEOGRAPHIC FEATURES.

The Southern Peninsula of Michigan is bordered on its entire western coast by Lake Michigan, on the north by the Straits of Mackinac, and on the east, from north to south, by Lake Huron, St. Clair River, Lake St. Clair, Detroit River, and Lake Erie, successively. Its only land border is on the south, and this is divided between the States of Ohio and Indiana. The range in latitude is a little more than 4°, from about 41°45′ to about 45°50′ north. The area is 40,761 square miles, or about 71 per cent of the entire State (57,430 square miles). Lansing, the State capital, is situated south of the center of this peninsula.

The population of the Southern Peninsula, as given in the census of 1900, is 2,169,620, or about 90 per cent of the population of the entire State (2,420,982). The population is very largely in the southern half. If a line be drawn midway between the northern and southern ends, only two cities, Manistee and Alpena, with populations exceeding 10,000, will be found to the north, while there are 14 such to the south. Fifteen counties of the northern half of the peninsula, with an aggregate area of 8,160 square miles, had in 1900 a combined population of only 93,704, or less than one-third the population of the city of Detroit (285,704). In consequence of this unequal distribution of population there is an unequal development and utilization of water resources. In the northern counties there are entire townships which have no records of wells or tests of underground water supplies, while in the southern counties the underground water supplies have been tested sufficiently to afford a fair basis for this report.

The map, Pl. II, presents the principal reliefs of the peninsula. It will be observed that a plain 20 to 40 miles wide runs along the southeastern edge of the State, rising from less than 600 to about 800 feet above sea level. This plain was covered by ice from the Huron and Erie basins and later by large Glacial lakes. West of this is a prominent belt of rolling country about 25 miles wide interspersed with numerous small lakes and representing a strong development of morainic topography. Its altitude ranges from about 800 to 1,300 feet, with a general elevation of nearly 1,000 feet. This constitutes a catchment area from which the waters are distributed to the east and the west both in surface streams and underground courses. The head furnished the underground waters in this catchment area gives rise to numerous flowing wells which are found on the plains to the southeast and to the northwest.

A broad plain extends from Saginaw Bay southwestward well toward the southern edge of the State. Through this plain an ice lobe, known as the Saginaw lobe, is found to have flowed, its extreme limits on the southeast being marked by the belt of morainic country just mentioned, on the northwest by an equally prominent morainic belt, and on the southwest by moraines of less prominence lying in the southern end of the State. During the retreat of this ice lobe there were halts at several lines which are marked by small morainic ridges. These small ridges serve as catchment areas for flowing-well districts on the inner or iceward border of the moraines.

West of the district covered by the Saginaw ice lobe is another rolling belt of country running from the southwestern part of the State northward nearly to Grand Traverse Bay. Like the belt in the southeastern part of the State, this contains numerous small lakes. Its altitude ranges from about 800 to 1,700 feet, the highest point being a few miles south of Cadillac, in northern Osceola County, near latitude 44° 15′ and longitude 85° 20′. This is by far the highest point in the Southern Peninsula, there being few others which exceed 1,500 feet. This belt was formed between the Saginaw ice lobe and a still larger ice lobe occupying the Lake Michigan basin. It is a catchment area for flowing-well districts on each side, and there are also depressions in it found to be favorable points for the development of flowing wells. This belt is crossed by the principal rivers of southern Michigan (the Grand, Kalamazoo, and St. Joseph), while Muskegon River has its source in it in the north-central part of the State and leaves it only a few miles before entering Lake Michigan.

Along the eastern border of Lake Michigan, from the southern end of the State northward to Oceana County, or to about the middle of the western border of the Southern Peninsula, the country is generally low for a few miles back from the lake, with the exception of a strip of dunes formed adjacent to the present beach. But from Oceana County northward to the Straits of Mackinac there come out to the lake shore at frequent intervals headlands which are the termini of prominent ridges that form or connect with moraines a few miles back. The low tracts between these headlands are favorable places for the development of flowing wells.

The interior of the northern half of the Southern Peninsula is an elevated tract in which extensive sand plains have been developed in connection with the moraines. On these plains and on some of the moraines connected with them there formerly stood extensive tracts of pine forest, now largely cut away. Since the lumbering days the plains have been developed somewhat for agriculture, but are still in large part sparsely settled.

On the northeastern border of the peninsula, from near Alpena to the Straits of Mackinac, rock ledges become conspicuous as a topographic feature; but elsewhere in the State they are subordinate to the glacial features outlined above. The rock ledges have low escarpments facing the northeast, along the base of which are occasional small lake basins. The drift in this region is thin, and wells are consequently largely in rock.

On the projecting point between Little Traverse and Grand Traverse bays, in the northwestern part of the peninsula, is a drumlin area to which attention is directed in the discussion of Antrim and Charlevoix counties, in which it appears (pp. 333–335).

The features of the State thus briefly outlined receive fuller treatment in connection with the discussion of each county.

On the retreat of the ice from the basins bordering and including the Great Lakes large bodies of water were held between the ice and the rims of these basins. One, in the Lake Michigan basin, was known as Lake Chicago and discharged southwest from the site of that city to Illinois River. Another, in the Saginaw basin, was known as Lake Saginaw and discharged westward through Grand River into Lake Chicago. A third, covering the western end of Lake Erie and the southern part of Lake Huron, stood at several successive levels in accordance with the lowest available outlet, the highest being known as Lake Maumee with its outlet past Fort Wayne to the Wabash and later past the present site of Imlay, Mich., westward into Grand River and Lake Chicago. Below this is the largest shore line of the series, known as the Belmore beach, which borders Lake Whittlesey, whose outlet was westward from the present site of Ubly, Mich., into Lake Saginaw. A little lower than the Belmore beach is the Arkona, which antedates the Belmore and was submerged at the time the Belmore was forming. The lake which formed the Arkona beach was probably confluent with Lake Saginaw and discharged westward through Grand River to Lake Chicago. Two lower beaches, known as the Upper Forest and the Lower Forest, mark the border of Lake Warren, which covered the Saginaw and southern part of the Huron basin as well as Lake Erie, and discharged westward, for a time at least, through Grand River to Lake Chicago. Below the Forest beaches are two others, known as the Grasmere and Elkton, which appear to be the shores of a lake that discharged eastward past Syracuse, N. Y., to Mohawk and Hudson rivers. At still lower levels are beaches which are conspicuous on the borders of the Lake Huron and Lake Michigan basins, especially in the vicinity of the Straits of Mackinac. One is known as the Algonquin beach; Lake Algonquin, which formed it, discharged along the present line of drainage through Lake Erie to the Ontario basin into a Glacial lake known as Lake Iroquois, whose outlet was through the Mohawk and Hudson. A lower beach, known as the Nipissing beach, borders a post-Glacial lake, Lake Nipissing, and was formed as the lake was changing from a discharge eastward from Georgian Bay through Mattawa and Ottawa rivers into the St. Lawrence to the present line of discharge through St. Clair River.

The sand and gravel in these beach ridges and on the lake beds frequently serve as sources of supply in shallow wells, water being found at the base of the sand or gravel.

WATER-BEARING FORMATIONS.

The greater part of the Southern Peninsula is covered so deeply with drift that wells do not reach rock. The shaded portions of the map, Pl. I, show the parts of the State where rock is within easy reach of the drill and is drawn upon to some extent for drinking water. In the northern end of the peninsula water is found chiefly in limestone if not in the drift. There is also a limestone district in the southeastern part that serves extensively as a source for drinking water; in some cases in southeastern Lenawee County the wells are driven through shale to reach the limestone. The extensive district running from Hillsdale and Calhoun counties northeastward to Saginaw Bay obtains water chiefly from sandstones of the coal measures and from the Marshall sandstone, if water is not found in the drift. There are, however, small limestone districts in this region the full extent of which have not been worked out. Sandstone is also drawn upon occasionally in western Wayne, southern Washtenaw, and northern Lenawee counties in the deep flowing wells. The Sylvania sandstone of Monroe County is also an important water bearer, yielding a good quality of water. There are small areas around Grand Rapids—in Kent and eastern Ottawa counties—and around Wayland, in northeastern Allegan County, where wells are driven to the Marshall sandstone.

Water is found in the glacial formations at various horizons, wherever gravel or sand chance to be present. The clay plains bordering St. Clair River, Lake St. Clair, and Detroit River are deficient in gravel and sand, and are perhaps the poorest water bearers in the peninsula. As a rule, water in large quantities is easily obtained in the drift. Even in the regions where wells are driven to rock, as indicated by the shaded portions of Pl. I, there are numerous wells obtaining water from the glacial deposits. The water from rock is usually softer in sandstone areas than that from the overlying drift, and for that reason is preferred and is the cause for going to the rock in many instances.

The sand along the present shore, and also along abandoned shores of the Great Lakes, is often of sufficient depth to furnish water, though not that of the best quality in many cases. It so happens that these sand deposits occur on parts of the lake plain where the glacial formations are deficient in water-bearing beds and thus become of great importance locally. In general, however, the water from the underlying glacial formations is preferred and is used wherever it can be easily obtained.

The newest formations drawn upon for water are the beds of bog lime bordering the little lakes. Pipes are driven down into the marl sometimes with a sledge hammer far enough to get the water. In some cases, in the northern part of the State, flowing wells have been obtained by penetrating the marl a few feet. Conspicuous instances are found on the borders of Pine Lake at East Jordan, South Arm, and Boyne, and on the borders of Intermediate Lake near Bellaire.

STRUCTURE OF DRIFT.

The structure of the drift is intimately related to the drainage conditions that attended the melting of the ice. It is more variable in Michigan, both on the surface and below, than in a large part of the neighboring States of Ohio, Indiana, and Illinois. In those States the till or commingled drift greatly predominates over the sand and gravel or assorted drift and contains a large percentage of fine clayey material. In Michigan, sand and gravel form a large part of the drift, and much of the till is loose textured. The great amount of loose-textured drift seems attributable to the voluminous discharge of water resulting from the convergence of ice lobes. It is best developed on the high portions of the State, which were built up between the ice lobes. The most clayey portion of the drift is found in plains bordering the lake basins. On these plains more difficulty is found in obtaining adequate supplies of water than in the higher tracts bordering them. Portions of the plains have a thin coating of sand deposited in the beds of the Glacial lakes that covered them after the withdrawal of the ice, and in these localities many wells draw their supply from the surface sand.

Flowing wells are usually found under a bed of clayey drift, and for this reason, as well as because of topographic conditions, the largest artesian districts are found on the old lake plain.

The clayey drift differs greatly in degree of induration at different horizons, and the sand and gravel also become cemented at certain horizons. The induration in the clay or till seems to be largely a result of secondary changes produced slowly, and is in some cases an index of age. The surface-till sheet, which is of the Wisconsin stage, is generally a soft, adhesive clay, even where very fine textured, and well diggers and drillers find very little difficulty in penetrating it. Below this the drift is found to be extensively indurated, so that excavation is difficult, and the till approaches a shale in its resistance. The precise nature of the induration has not been ascertained. It is thought that much of this indurated clayey drift was deposited in a Glacial stage earlier than the one that formed the upper part of the drift—probably the Illinoian stage. In some places a soil appears between the two sheets of till, showing that an interval separates them. The buried soils are much more abundant in northern Indiana than in southern Michigan, but they have been noted in well borings as far north as Bay and Oceana counties.

Another kind of induration of the drift is very common in flowing-well districts. Just above the water bed which yields the flow is found a cemented crust, having a thickness usually of only a few inches.

This crust is apparently due to contact with the water, but the precise chemical or physical changes that have produced it have not been given much attention. In some cases it has the appearance of bog-iron ore and in others it is chiefly carbonate of lime. Probably the quality of the water determines the nature of the crust. A crust has also been frequently noted in sand and gravel deposits just above the water table, where it is somewhat constant at a definite horizon.

It is a common experience to find sand so close textured that it will not furnish water fast enough to supply the wells. Such sand is encountered in the plains, perhaps, more frequently than in the rolling or morainic belts. It is the custom in such places to continue the drilling to a looser textured bed, though in some localities no such bed is found. If a looser textured bed is reached, the water often rises in the pipe to a higher level than in the overlying sand, the sand apparently serving as a cover to prevent the upward escape of water from the porous bed. In a few places flowing wells have been obtained in which nothing but sand was penetrated from the surface down to the coarser bed that yielded the flow.

CHARACTER OF DRAINAGE.

The character of the drainage depends on the structure of the drift, as well as on the topography. Where the soil is very loose textured, as on gravel plains and on many of the larger moraines, very little surface run-off occurs, so that even the steep hillsides show little or no gullying. Basins are numerous on the gravel plains and to some extent along the moraines. When of sufficient depth to extend below the water table, they contain water, but a large proportion of them are so shallow as to have dry bottoms. The drainage lines are therefore best developed in the clayey portions of the State, where the rainfall can not be quickly absorbed by the soil.

The regimen of the stream varies also in accordance with the structure of the drift. Where the drift is loose textured, the streams are supplied by seepage from the underground drainage and are not subject to freshets nor to very low stages, but in the clayey tracts, where the surface drainage is the principal factor, there is a marked difference between the high- and low-water stages of the streams. Often, however, the sources of the streams are in districts having a loose-textured drift, while the lower courses run through clayey districts. In such cases the streams have a correspondingly regular flow. Data concerning the flow of the principal streams of the peninsula may be found in the reports on stream measurements, which appear in the water-supply series of the United States Geological Survey. The regularity of flow, as well as the considerable fall of the principal streams of the peninsula, renders them valuable for water power to an exceptional degree, considering the small size of their drainage basins. The subject of water power, however, is not taken up in the present report.

RAINFALL.

From the reports of the Weather Bureau it appears that the rainfall is greatest in the southern tier of counties and decreases northward to a little beyond the middle of the peninsula, where a change occurs toward heavier precipitation. This is set forth in the following table, which gives the average precipitation by tiers of counties from south to north, each tier having a uniform width of 24 miles:

Average annual precipitation in the Southern Peninsula of Michigan.

	Inches.
First or southern tier (Monroe to Berrien County)	34.59
Second tier (Wayne to Van Buren County)	31.99
Third tier (Macomb to Allegan County)	30.81
Fourth tier (St. Clair to Ottawa County)	31.19
Fifth tier (Sanilac to Muskegon County)	30.66
Sixth tier (Bay to Oceana County)	27.21
Seventh tier (Arenac to Mason County)	25.44
Eighth tier (Iosco to Manistee County)	26.62
Ninth tier (Alcona to Benzie County)	33.04
Tenth tier (Alpena to Leelanau County)	32.53
Eleventh tier (Presque Isle to Charlevoix County)	28.07
Twelfth tier (northern Cheboygan and Emmett counties)	31.41
Average for the peninsula	30.30

The distribution of precipitation by months and the percentages by seasons in the southern, central, and northern sections of the peninsula are given in the following tables, which are based on the monthly rainfall data of the Weather Bureau:

Average monthly rainfall in the Southern Peninsula of Michigan.

[Inches.]

Month.	Southern third.	Central third.	Northern third.
January	2.33	1.96	2.42
February	2.31	2.16	1.60
March	2.68	3.09	2.20
April	2.34	2.16	1.86
May	3.68	2.73	2.70
June	3.54	3.00	2.80
July	3.43	2.96	4.47
August	2.64	2.58	2.08
September	2.76	2.98	3.41
October	2.48	2.40	3.10
November	2.82	2.44	2.28
December	2.47	1.53	1.60

Distribution of precipitation in the Southern Peninsula of Michigan by seasons.

[Per cent.]

Season.	Southern third.	Central third.	Northern third.	Entire peninsula.
Winter (December to February)	21.23	18.73	18.40	19.45
Spring (March to May)	26.00	26.43	22.15	24.86
Summer (June to August)	28.70	28.28	30.63	29.20
Autumn (September to November)	24.07	26.56	28.82	26.48
	100.00	100.00	100.00	99.99

It appears from the above tables that the rainfall is most deficient in the winter months at a time when the frozen ground would prevent its absorption, but is well distributed throughout the growing season all over the peninsula. It should be noted that the greater evaporation in the southern part of the peninsula causes it to be a drier region than the northern part, notwithstanding the fact that it has a little more rain. Determinations made at signal-service stations, and discussed by T. Russell in the Monthly Weather Review for September, 1888, show that the evaporation near the southern border of the State is 37 to 38 inches a year, while in the latitude of Port Huron and Grand Haven it is about 29 inches, and at Alpena 24.3 inches. Only a small part of the evaporation occurs in the winter months or during the time of deficient precipitation, so the deficiency is not noticeable. Indeed, as a rule snow remains continuously over much of the peninsula from December to March.

GROUND-WATER TABLE.

The ground-water table as ordinarily understood marks a level to which the saturation of the earth's crust rises. In a region of heavy rainfall it is commonly very near the surface, but in arid regions it may lie at a considerable depth and is sometimes beyond the general direct percolation of the rainfall, there being a moist layer at the surface supplied by the rainfall under which the material is dry down to the ground-water table. Ordinarily the ground-water table in the Southern Peninsula of Michigan lies only a few feet below the surface, within easy reach of the roots of trees and other plants. A few places, however, have been revealed by well borings in which comparatively dry material is present between the moist surface beds and the ground-water table. The most conspicuous instance is found in Emmett County north of Little Traverse Bay, where the wells on an elevated table-land underlain by gravel and sand reach depths of 350 to 400 feet before striking the water table; instances of this are cited in the discussion of the county (p. 364). The rainfall in that region appears to moisten chiefly the surface portion, but is yet adequate to the needs of the forests, orchards, and crops. On many of the elevated gravel plains the water table is 40 to 60 feet, and occasionally 100 feet below the surface, and wells must be driven to these depths to obtain water, and yet vegetation ordinarily thrives on these plains. Similar conditions are found in a number of the prominent moraines, in which a sheet of bowldery till at the surface is underlain by sand and gravel of considerable depth. The till at the surface is kept moist by the rainfall, so that the crops obtain the necessary water. In all these localities there are probably places where conditions are such that the rainfall percolates directly down to the water table, but there does not appear to be a general percolation to this depth.

Where the ground-water table lies only a few feet below the surface, and the percolation of the rainfall to it is general, marked fluctuations are found in its level corresponding with the amount of rainfall. The underground drainage into the streams is maintained in times of drought as well as in wet seasons, and the water table drops down or flattens out beneath the hills to depths sufficient to seriously affect not only the crops but the supply for wells. As a result the so-called surface wells (which are merely basins sunk into the upper part of the ground-water table) are being rapidly abandoned and driven wells reaching to deeper supplies substituted. This condition is also conducive to health, for many of these shallow or surface wells are receptacles for all sorts of filth.

There is a slight variation in the ground-water table due to barometric changes, the level of water in the open wells being highest in times of low barometer or just before a storm. It is barometric fluctuation of this sort which produces the blowing wells reported at various points in the State. According to the testimony of well owners the barometric conditions also affect flowing wells, an increase in the rate of flow resulting from a decrease in atmospheric pressure.

An instance of remarkably high water table is found in the dunes along the shore of Lake Michigan, where a fine or uniform textured sand in sharp ridges with a height of 200 feet above the lake is found to be wet to within a very few feet of the surface. Because of this condition some of the dunes are covered with hardwood forests.

WELLS AND APPLIANCES.

One of the most common types of well is the large open or dug well, walled or curbed, which furnishes a basin in which the water collects or stands. This kind of well is in very common use on the farms, and is also in use as a collecting reservoir in the villages for the waterworks supply. In districts where the drift is of a clayey texture and the yield of water is small, these large wells serve a valuable purpose as collecting basins, and in many cases can not be dispensed with even though known to be more or less subject to surface contamination.

A type in use locally, especially in clayey districts, is known as the bored well, the excavation being made by means of a large auger. These wells are usually lined with tile. They can be sunk without difficulty to depths of 50 to 100 feet. Some of the oldest flowing wells in southeastern Michigan are of this type.

A type which is coming into very general use throughout the State is known as the tubular well. It is made with the ordinary churn drill, the material being brought up by means of a sand pump. The size of these wells ranges from 2 inches or less to about 8 inches. They are in very common use in the villages for obtaining public water supplies, as well as throughout the country districts. Ordinarily they are driven some distance into the water bed, making up in vertical direction for the small diameter of the well, no casing being used after entering the water bed. Where flowing wells are obtained, however, it is customary to stop the drilling about as soon as the water bed is reached. The drills used in making wells of this type are usually handled by steam or horsepower, but in some instances only hand power is used, the drill being lifted by a windlass a few feet and dropped into the hole.

In some cases no drill is used, but the pipe is driven to the water bed, the material being removed by a sand pump if the well is deep or if it has a large-sized pipe. Shallow wells with small pipe are often driven through to the water bed without sand pumping. It is common to attach a sharp perforated cone or "point" to admit the water, which aids in reducing the resistance to driving the pipe. In some cases these wells are made by simply using a maul to drive the pipe.

In the discussion by Mr. Davis attention is directed to strainers or screens, which are employed in the tubular wells, and to the clogging which they experience (pp. 128–130).

Windmills are in very common use throughout the State as a means for lifting the water to the surface. In some of the deeper wells on elevated tracts the windmill has become a necessity, for the water in some instances has to be lifted about 200 feet—one case was found in which the lift was 400 feet. In this well a 12-foot wheel was in use.

Many flowing wells are allowed to discharge the water without restriction, but there is a growing sentiment in favor of using reducers or faucets to prevent waste.[a] In some cases pumps have been attached in order to prevent the slop attending the flow or, where the wells are weak, to increase the supply.

[a] For State laws on this point see p. 21.

QUALITY OF WATER.

The chemical character of the water, both surface and underground, has been considered at some length by Doctor Lane in Water-Supply Paper No. 31, where numerous analyses are presented. The present report contains many additional analyses, some of them made by chemists in the laboratory and some by men in the field. Although the latter are designed to show the general characteristics of the waters, without pretense to the accuracy of a laboratory analyses, the results are usually correct within a few parts per million.

In general, the waters from all horizons, both surface and underground, in the Southern Peninsula are hard compared with waters found in regions in which readily soluble rocks, like limestone and gypsum, are not present. There are very few waters in which the carbonate of lime is less than 50 parts per million.

Salt is present in varying amounts, from a mere trace up to several thousand parts in a million. An analysis of one water from the drift made by Mr. Lewis shows 2,829 parts per million of chlorine, the well being supplied presumably from water contributed to the drift from the underlying sandstone. Ordinarily the drift waters show less than 25 parts per million.

Sulphated and sulphureted waters are found at various points in the State, both in the drift and in the underlying rock, but ordinarily the drift waters have very small amounts of sulphureted hydrogen gas and sulphates seem to be principally in the portions of the State where gypsum forms a conspicuous ingredient in the drift, as in the region bordering Saginaw Bay, and reached by the Saginaw glacial lobe and in the region near the gypsum outcrops around Grand Rapids.

Iron is commonly supposed to be present in large amount in the flowing wells, and in wells of similar character whose waters are confined below impervious beds. In some cases its presence is proved by the staining of objects over which the water passes, but in many instances what seems an abundant iron-oxide precipitate is in the main a vegetable growth of algæ. The few available analyses indicate that the amount of iron is small compared with other mineral constituents.

SUBTERRANEAN-WATER TEMPERATURE.

Considerable attention has been given to the temperature of the water in flowing wells in order to obtain information concerning the heat gradients due to depth and to latitude. It was found, however, that the temperatures obtained are of very little value in showing the increase of heat with depth, for as a rule wells in a given district having variations of 100 or even 200 feet in depth, if in the glacial deposits, are very similar in temperature. The circulation of subterranean waters appears, therefore, to be such that little value can be determined concerning the heat gradient within 200 feet of the surface.

The change in temperature corresponding to the latitude, however, is very marked, there being a difference of about 5.5° in about 4° of latitude between the northern and southern ends of the peninsula. The air temperature shows a similar range, but averages about 4° lower than the water temeprature. The true temperature of the water at the bottom of a well can be obtained only in wells of rapid flow having but little exposure of pipe. Nor can the pipe be carried horizontally through the soil without affecting the temperature. It was not possible in the hasty examinations in the field to determine the causes of variation from the bottom temperature in any given well, since this would necessitate much inquiry into all the surrounding conditions. As a result many of the temperatures given in the numerous tables of data concerning flowing-well districts are liable to be misleading.

Interesting variations in temperature of the wells of a given latitude suggest several problems. For example, wells in swamps are generally a little cooler than wells of similar depth on the dry land, especially if the wells are comparatively shallow in both cases. Thus the wells in the celery swamp south of Ann Arbor have a temperature of a little less than 50° F., while those on the dry land in the vicinity are commonly 51°. The question arises whether the evaporation from a swamp, being greater than that from the dry land, may not prevent the heating of the soil beneath to the degree experienced in that region on ground where evaporation is less; also whether the slow heat conductivity in a swamp may not cause waters beneath it to have exceptionally low temperature.

The flowing-well district in southeastern Oakland County known as the Troy district has salt water in its eastern portion and fresh water in its western portion from wells of similar depth, and the temperature of the salt water averages somewhat lower than that of the fresh water. The salt water probably comes up from the underlying rock, and one would naturally expect it to be warmer instead of colder than water supplied entirely from the drift.

The observations on temperature were made in 1904, when the air temperature was considerably below the normal, the average temperature for the year being 2.7° below the normal throughout the peninsula. This raises the question whether flowing wells of moderate depth may not have suffered a slight lowering of temperature because of this deficiency in heat received by the surface. On the whole flowing wells less than 30 feet in depth are found to present a slightly lower temperature than do wells exceeding that depth, but there are so many exceptions that some doubt is felt as to the lowering effect of the low air temperature of 1904 on even the shallowest of the flowing wells. Some of the very shallow flowing wells may, however, receive contributions of water from considerable depths, from beyond the influence of the low air temperature. In the city of Ann Arbor there are springs having a uniform temperature of 51° throughout the year which must come from depths sufficiently low to have been unaffected by the low temperature of 1904, or even by the winter severity of cold.

There are certain districts in which the temperature is different from what would be expected for that part of the State, a conspicuous case being the wells in the vicinity of Grand Traverse Bay, in Antrim and Grand Traverse counties, the temperature of which is generally 48° to 50,° whereas about 47° is to be expected. The high temperature at Traverse City may be referable to the great depth of the wells, the general depth being over 300 feet, but this would not apply to the shallow wells at Williamsburg and around Intermediate Lake. There is, however, a possibility that these shallow wells are supplied by water rising from considerable depths.

The observations on temperatures were taken by several thermometers which have not as yet been standardized. They were, however, compared by tests made on the same wells at Ann Arbor and found to agree within a fraction of a degree. Errors from this source are not likely, therefore, to be appreciable.

In the table below the general averages of air and water temperatures are presented for each tier of counties, as in the rainfall table already given, the counties being of the uniform width of 24 miles. The excess of the water temperature above the air temperature is probably in large part due to the blanketing effect of snow, which prevents the earth from reaching the low temperature which the severity of winter might otherwise give it. The extent to which this and other factors, such as the topography, the character of the soil, etc., apply, is a matter difficult of determination.

General averages of air and water temperatures in the Southern Peninsula of Michigan.

[Degrees F.]

	Air.	Water.	Excess of water temperature.
First or southern tier (Monroe to Berrien County)	48.25	52.25	4
Second tier (Wayne to Van Buren County)	48.1	51.3	3.2
Third tier (Macomb to Allegan County)	47.0	50.3	3.3
Fourth tier (St. Clair to Ottawa County)	46.4	50.1	3.7
Fifth tier (Sanilac to Muskegon County)	46.5	49.4	2.9
Sixth tier (Bay to Oceana County)	45.5	48.9	3.4
Seventh tier (Arenac to Mason County)	44.5	48.1	3.6
Eighth tier (Iosco to Manistee County)	43.4	47.7	4.3
Ninth tier (Alcona to Benzie County)	43.6	47.8	4.2
Tenth tier (Alpena to Leelanau County)	41.3	47.2	5.9
Eleventh tier (Presque Isle to Charlevoix and Emmet counties)	43	46.8	3.8

The averages of water temperatures given in the above table are based on the temperatures of strong wells which appear to have been subject to little surface heating. They fall slightly below an average based on all the wells, weak and strong. The accompanying

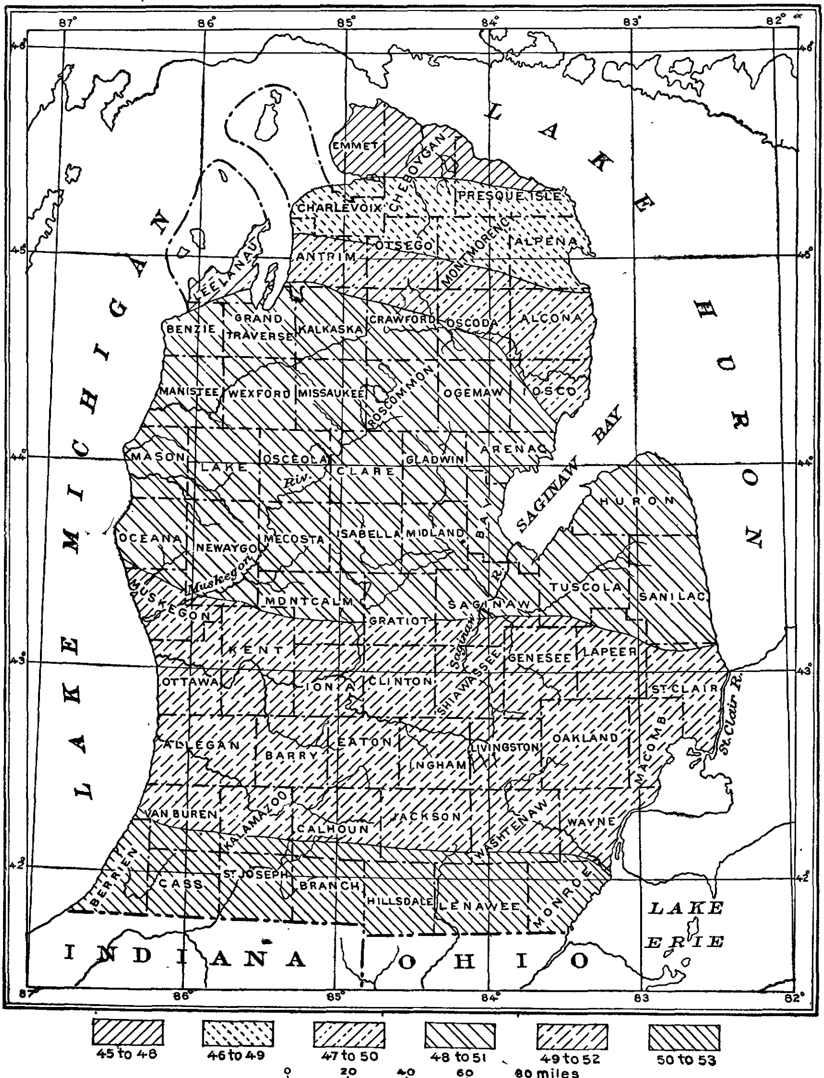


FIG 2.—General average of flowing-well temperatures in the Southern Peninsula of Michigan.

map (fig. 2) presents the results of a grouping of all the wells except those that are known to be subject to surface heating.

Monthly observations were made between May, 1904, and May, 1905, at Ann Arbor, Mich., on the temperature of springs and wells of various classes, an attempt being made to include all the classes within easy reach of the city. Three springs were selected—one on State street issuing from the base of a gravel deposit, another on the White estate west of the city issuing from the base of a till bluff, and a third which bubbles up from the bed of a ravine on the Rash property in the western part of the city. Five shallow dug wells and one deep dug well were taken because of the various conditions which they include, one being in a ravine, another on the brow of a bluff, another on a gravel terrace, and two others on an elevated moraine, one being covered and the other open. The deep dug well maintains a water level 40 feet below the surface, while the shallow wells have water within 5 to 22 feet of the surface. Two shallow tubular wells, in one of which the water stands near the surface and in the other at a depth of 18 feet, were selected, and two deep tubular wells which overflow. The tubular wells showed very little range in temperature, but the dug wells varied greatly. The bubbling spring showed a steady temperature, while the springs issuing from the hillside were influenced by the seasons. The lagging of the effect of summer heat and winter cold was a matter of principal interest in connection with the observations on the dug wells, the effect of the former culminating in October and that of the latter about April. The accompanying diagram (fig. 3) sets forth this feature, while the observations are presented in the following table:

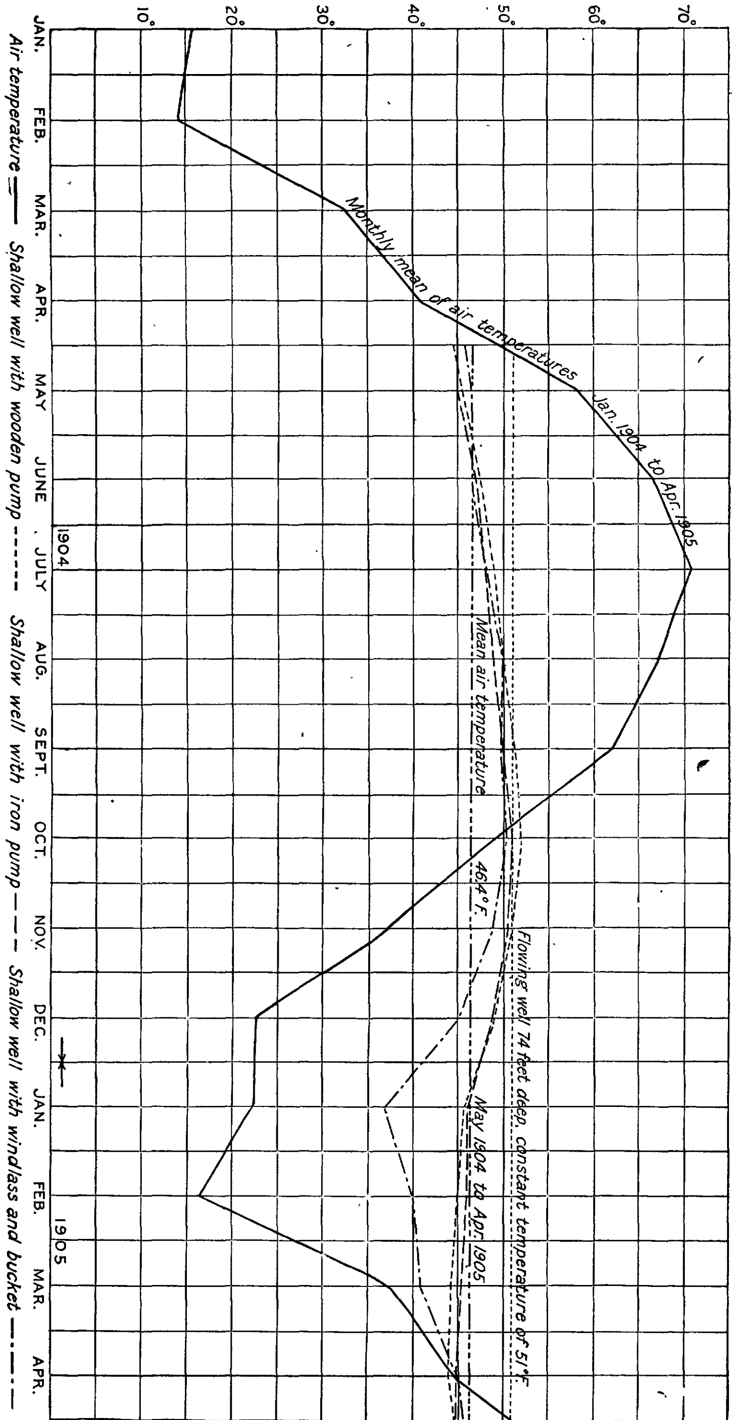


FIG. 3.—Diagram showing fluctuations in air and well temperatures at Ann Arbor, Mich.

Observations on wells and springs in and near Ann Arbor, Mich., May, 1904, to April, 1905.

Name and location.	Class.	Pump.	Depth in feet.	Head in feet.	Temperature (°F.).												
					May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Annual averages.
State street spring; base of gravel, piped several rods.	Issuing		0	0	51.2	53	54.5	55.5	54.8	53.5	50.3	47	45	42.5	42.5	46	49.8
White estate spring; base of bluff, piped several rods.	do		0	0	50.8	51	51.3	51.5	51	50.3	49.8	49	49	......	49	49.7	50.2
Rash spring; bed of ravine	Boiling		0	0	51	51	51	51	51	50.8	50.7	51	51	51	51	51	50.95
Buehler well, in ravine	Dug	Wooden	12	−5, −10	45.5	47.5	49	50	51.2	52	51	49	45.8	45	44.3	44	47.86
Rash well, on bluff, 34 feet above Rash spring.	do	Iron	23	−22	45	47	48	48.9	49.9	51	50.5	48.8	46	46	45.5	45	47.6
Schaeberle well; on gravel terrace capped by clay.	do	Wooden	18	−9, −17	46.5	48.5	49.5	51.6	52.4	53	52	49	47.5	45.5	44	45.8	48.77
Levy well; on terrace sunk through gravel into till.	do	Iron	80	−40	48.3	49	49.8	50.5	51	51	50.5	50.5	50.3	46	48.3	48.3	49.5
Observatory well; on moraine, with plank cover.	do	None	15	−11, −14	45	46.5	48	51	52	52.5	50	46.9	41	37	43	41.6	46.2
Carroll well; on moraine near observatory, no cover.	do	Windlass	24	−20, −22	46.5	46.5	48	50	49.6	50.3	48.9	45	37	40	41	45	45.57
Niederhammer well; on slope of ravine	Tubular (2-inch)	Iron	36	−18	50	51	51	51.15	51.15	51.1	51.4	50.3	49.7	50	50.2	49.8	50.57
Dunn well; on South State street, in old Huron River channel.	Tubular	do	28	−2	49.8	50.5	50.3	51	51	51.5	50.8	50.5	50.5	50	50	49.5	50.45
Lutz flowing well; in ravine	Tubular (2-inch)	None	112	+3	51.1	51	51	51	51	51	51	50.8	50.8	50.8	50.8	51	50.9
Hutzel flowing well; in ravine	do	do	72	[a] +5	51	51	51	51	51	51	51	51	51	51	51	51	51
Air temperatures at Ann Arbor, from daily observations at the observatory.					58.4	66.7	70.8	67.3	62.2	49.4	37.2	22.9	22.7	16.5	37.7	44.8	46.4

[a] Original head +22 feet; loss of head due in part to leakage around pipe.

LEGISLATION.

There are two important legislative acts in reference to Michigan water supplies, copies of which are presented below:

[Act No. 43, Public Acts of 1897; 4484–4486, Compiled Laws, 1897.]

AN ACT to provide for the analysis of water in use by the public in certain cases.

The people of the State of Michigan enact:

SECTION 1. That in any case where any city, village, or township in this State shall be supplied with water for domestic uses by any individual, company or corporation, city or village, or where there is within such city, village, or township any water in swales, wells, rivers, or other places, which might be the cause of disease or epidemic, a sample of such water may be sent to the University of Michigan for analysis, by the mayor of such city or village, or by any alderman or trustee of such village, or by the supervisor of any such township, upon the resolution of the common council of such city, or board of trustees of such village, or the township board of such township, for that purpose duly passed.

SECTION 2. Upon receipt of such sample the regents of the University of Michigan shall cause a correct analysis of such sample of water to be made, and a correct statement of the properties contained therein, with a further statement whether or not such sample contains any substance deleterious to health, and return such analysis together with the statement aforesaid to the person so sending the same, free of charge, except the actual cost of materials and animals used in making such analysis and experiment.

SECTION 3. It shall be the duty of the board of regents of the University of Michigan to cause a record to be kept of every sample of water received under and by virtue of this statute, and in no case shall a second analysis be required of the same water within one year except in the case of the breaking out of some disease among the consumers of such water, and then only upon the certificate of at least two physicians engaged in active practice in that community that in their opinion such disease arises from the use of said water.

Approved March 26, 1897.

[Act 107, session of 1905.]

A BILL to regulate the use of artesian and other wells to prevent the waste of waters therefrom, and provide a remedy therefor.

The people of the State of Michigan enact:

SECTION 1. Any artesian or flowing well, the water of which is unnecessarily allowed to run to waste in an unreasonable manner to the depletion or lowering of the head or reservoir thereof to the detriment or damage of other wells supplied from the same head or reservoir, shall be deemed a nuisance, and its owner and the owner of the land on which it is situated shall be subject to all the actions for abatement and damages in favor of the person or persons injured that are or may be provided by law for other nuisances or tortious acts.

SECTION 2. Where any well is supplied by a head, reservoir, stratum, or vein, or by percolating waters common to other streams or wells, and the owner thereof or his lessee or licensee puts its waters to a use unreasonable or unnecessary, in view of the condition and situation of the land on which it is situated, and through such unreasonable or unnecessary use, lowers or depletes the head, pressure, or supply of water of any spring or well dependent on the same head, vein, or stratum, to the detriment or injury of the owner or any person entitled to the use thereof, the well so unreasonably and unnecessarily used shall be deemed to be a nuisance, and its owner and the owner of the land on which it is situated shall be subject to all the actions for abatement and damages in favor of the person or persons injured that are or may be provided by law for other nuisances or tortious acts.

SECTION 3. Where any decree is rendered under this act declaring any well a nuisance because of the waste or unreasonable use of its waters and directing the abatement thereof, such decree shall specify in some practicable manner the daily amount or volume of water that may be used or allowed to flow therefrom without violating such decree, and specify such reasonable time as to the court shall seem just within which the provisions thereof shall be carried into effect: *Provided*, That any such decree may be reopened at any time after entry on the question of reasonable use on a proper showing of change of circumstances or other equitable reason therefor.

FLOWING WELLS.

Although the number of flowing-well districts already exceeds 300, it is probable that many more can be developed in low places either among or along the borders of the moraines and in the valleys of streams. The fact that wells are usually placed near the dwellings and that the sites of the dwellings are naturally on well-drained and usually elevated points account for the small amount of testing that has been made on the lower land, where flows might be expected.

The flowing wells already in operation have been put to comparatively little use and there seems to be a general lack of appreciation of the applications that can be made of these fountains. It is a common thing to find flowing wells running to waste in dooryards in rural districts in seasons of drought when the gardens and lawns are suffering for lack of water. In many cases it would be necessary only to attach a hose to obtain means for properly irrigating the premises. The wasted water might also in some instances, by the installation of a hydraulic ram, be forced to tanks in the attics of farmhouses, where it would have pressure necessary for distribution through the buildings and would also afford a supply for fire protection. In some cases the wells have been used to fill ponds stocked with fish and thus yield a valuable resource for farm and market—a device which might be more generally adopted. The principal use to which flowing wells have been put, however, aside from furnishing water for domestic and farm use, is that of cooling milk in the dairy houses, the very uniform temperature of the water fitting it admirably for this purpose.

In some flowing-well districts a loss of head has been reported, and in many districts individual wells are either losing head or have fallen short of the full head customary at the time of their construction. Where the loss of head is general throughout a district it may be inferred that there is an overdevelopment by which the water is drawn out faster than it can be supplied from the surrounding formations. The Ann Arbor waterworks furnishes a case in point, the water drawn from the small field in which the wells occur having been sufficient to stop those on the border of the field from flowing. Often a single strong well on ground lower than the neighboring wells will draw down the head sufficiently to stop the wells from flowing. In cases of this kind the law pertaining to the restriction of artesian wells should be enforced. There seems to be a growing appreciation of the need for checking the flow of the strong wells and reducing the waste which is sure in time to work to the detriment of the district.

Flowing wells are often deficient in head and rate of flow because of defects in the casing which allow leakage into upper strata where the water pressure is less than in the lower portion of the well. The head is also deficient where water is allowed to rise around the casing. This is in some cases due to imperfect driving of the casing and might be guarded against. Any obstructions either in the bottom of the well or at the top tend to reduce the head. Instances are found where, through carelessness, wells which had been cut off near the surface of the ground were so filled by sand washed in from above as to cease flowing.

The district in southeastern Michigan in which a large number of flowing wells have failed was investigated and is reported upon by Mr. Fuller, who attributes the loss of head chiefly to drought and surface drainage.

Wells in certain regions have lost head through subsurface drainage, several instances of which are found in the coal-mining region bordering Saginaw Bay. The extensive pumping necessary to remove water and permit mining operations to be carried on draws down the head for considerable distances around, and often deprives the border district of its flows.

The conditions under which flowing wells may be obtained are so various that the reader is referred for detailed information to the special reports presented below.

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES.

In the entire State there were at the beginning of the year 1906 about 250 cities and villages and at least 15 State institutions provided with waterworks systems. About 50 of the villages, however, use water chiefly for fire protection, and in some cases they have no distribution systems. The population of the towns and institutions provided with waterworks aggregated about 1,150,000 in 1900, when the last Federal census was taken, but in most of the towns a large part of the people have not connected with the public supplies and still continue the use of private wells. On the basis of the number of taps reported it is estimated that in the cities with a population between 10,000 and 100,000 about two-thirds of the people are connected with the public supply, and in towns of less than 10,000 population one-half or less are thus connected, while in Detroit, the only city with more than 100,000 population, nearly all are connected. From this it appears that the probable actual users of public supplies are between 750,000 and 800,000, say 775,000, or 32 per cent of the entire population of the State in 1900 (2,420,982). Of these, nearly 600,000, or about 24 per cent of the population, are supplied from surface water and less than 200,000 from wells. Of those not connected with public supplies probably not more than

20,000 depend upon springs and surface waters, while about 1,625,000, or two-thirds of the State's inhabitants, depend upon private wells.

There are 37 towns on the borders of the State, with a population of about 510,000, which obtain public supplies from the Great Lakes and their connecting streams—St. Marys, St. Clair, and Detroit rivers. The metropolis, Detroit, with a population of about 300,000, is among the number. The water from this source is not so hard as from the majority of the wells, and is therefore especially suitable for boiler use. In an unfiltered state it is often found to be unwholesome and in some cases dangerous for drinking, because of contamination in the vicinity of intake pipes. The worst epidemics of typhoid in the State have prevailed in towns taking their supply from this source. It is therefore incumbent on the cities and villages thus situated to put in filtration plants with up-to-date methods of purification. Indeed, all surface water, including that from springs, streams, and inland lakes, should be properly filtered before it is used for drinking or other domestic purposes.

Many of the inland towns have taken public supplies from the streams and inland lakes, the population of such towns aggregating about 300,000. In not a few cases, however, the domestic use of the public supply is largely restricted to closets, baths, and lawn sprinkling, while private wells are used for drinking, there being considerable prejudice against drinking the public supply, not alone for fear of its contamination, but because it is less palatable than the well water. This is especially true in hot weather, when the surface water becomes too warm to readily quench thirst. The streams and lakes are seldom rendered objectionable for drinking because of a muddy condition due to freshets, for on account of the prevalent porosity of the soil the rainfall is absorbed, and except in clayey districts is largely supplied to streams by underground seepage. Only the most violent rains cause much disturbance of the streams. Michigan is more highly favored in this respect than the neighboring States.

Of the cities drawing public supplies from wells only 5 had in 1900 a population of more than 10,000, namely, Jackson, Kalamazoo, Lansing, Ann Arbor, and Manistee. The supply at Jackson is from deep wells in sandstone and probably is not excelled by any city in the State. Lansing also obtains its supply from sandstone. The three others obtain supplies from glacial deposits or from the overlying gravel. Many smaller cities, the majority of villages with public supplies, and several of the State institutions are entirely supplied from wells, there being 29 using wells in rock and 104 using wells in the drift, while 15 others are supplied in part from wells and in part from surface water. The rock wells are chiefly from sandstone, those from limestone being almost wholly restricted to the Northern Peninsula and to the northern part of the Southern Peninsula. Many data concerning the public as well as private supplies from wells will be found in the special reports herewith presented.

WATER SUPPLIES OF MUSKEGON COUNTY.

By C. D. McLouth.

TOPOGRAPHY.[a]

Muskegon County borders Lake Michigan near the middle of the east side of the lake, the city of Muskegon being the county seat. It is drained centrally by Muskegon River, while White River crosses its northwest corner and Crooked Creek, a tributary of Grand River, its southeast corner. Along the shore of Lake Michigan are several wide-mouthed streams, some of which head but a few miles inland. Muskegon and White rivers also enter lakes near their mouths. The county is very largely a sand plain, though there are prominent moraines in the eastern end and weaker ones in the northwestern part, in which productive land is found. On the sand plains water is ordinarily obtained at depths of 25 to 50 feet, the water table being in harmony with neighboring streams, but on the moraines the wells vary greatly in depth within short distances, irrespective of elevation, because of the irregular distribution of water beds.

WATER-DISTRIBUTING SYSTEMS.

In Muskegon County four communities have public distributing systems, viz, Muskegon, North Muskegon, Whitehall, and Montague, while Casnovia has fire cisterns. In all of these the water is used for fire protection and for lawns and gardens, and in all except Montague and Casnovia for general domestic use as well. In Muskegon a considerable quantity of the water is used for general mill purposes. In Whitehall such use is limited to refilling boilers.

In the Muskegon system water flows from the lake by gravity into two wells at the pumping station, from which it is distributed by direct pressure through 4 miles of 24-inch, 2 miles of 16-inch, 3 miles of 12-inch, 1 mile of 10-inch, 1 mile of 8-inch, 26 miles of 6-inch, and 11 miles of 4-inch mains.

At Whitehall the ordinary supply is pumped from four wells described on pages 28–29. The water is stored in large tanks, from which it is drawn and forced through the mains by a pump larger than those working in the wells. Before the wells were opened the supply was drawn from White Lake, and the old intake is still con-

[a] By Frank Leverett.

nected with the distributing pump and is used in case of fire or other emergencies.

At Montague water from a small brook is collected above a dam and pumped into the mains.

Casnovia has a municipal supply stored in cisterns for use in fire protection.

The following table gives the statistics for the waterworks systems in the towns. All are owned by the municipality and all use steam power for pumping.

Statistics of water-distributing systems, Muskegon County.

Town.	Population (1900).	Source of water.	Depth of well.	Water bed.	Quality of water.	Pump.
			Feet.			
Muskegon	20,818	Lake Michigan, at 41 feet.	20	Sand	Medium hard	Holly vertical.
North Muskegon	513	Bear Lake, at 7 feet.	None.	do	Soft	Walker.
Whitehall	1,481	Four wells	67	do	Medium soft	Downie deep well double-acting.
Montague	998	Brook reservoir		Mucky	Soft	

Town.	Pressure.	Daily capacity.	Mains.	Hydrants.	Taps.	Cost.	When built.
	Pounds.	*Gallons.*	*Miles.*				
Muskegon	a40, b85	6,000,000	48	600	21,000	$450,000	1891
North Muskegon	c40, b160	1,000,000	5	40	175	28,000	1884
Whitehall	c40, b120	72,000	4	40	160	20,000	1892
Montague	b170		1.5	17		4,350	

a Domestic. b Fire. c Ordinary.

MISCELLANEOUS VILLAGE SUPPLIES.

Village supplies in Muskegon County.

Town.	Source.	Depth of wells. From—	To—	Common.	Depth to water bed.	Head.	Springs.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Bailey	Open and driven wells	10	30	25	30	—15	Small.
Canada Corners	Wells and springs	9	20	20	20		Large.
Casnovia	Open and driven wells; cisterns for fire.	25	100			—40	Small.
Holton	Driven wells	25	30	25	25		Large.
Lake Harbor	Driven wells and lakes	25	35	30	30	—20	Small.
Ravenna	Bored wells	10	130	30	130		Do.
Slocum	Driven wells	12	20				Medium.
Sullivan	do	24	32	24		—20	None.

FLOWING WELLS.

GENERAL STATEMENT.

The flowing wells known in this county seem to indicate seven districts, which may be designated (1) White Lake, (2) Muskegon Lake, (3) Lake Harbor, (4) Spring Lake, (5) Moorland, (6) Fruitland, and (7) Casnovia.

The first four of the districts named are very much alike in surface features. Each includes a lake, from which it is named, and the narrow shore margins and the underlying portions of the more or less extensive marshes and river valleys continuous therewith. The elongated lake troughs all have a general direction from northeast to southwest and extend from about 4 to 7 miles inland from Lake Michigan, into which all have outlets. The principal feeders of these lakes enter through marshes and the valleys in which they flow exhibit such features of continuity with those of the lakes as to leave little doubt that the lakes are but drowned valleys where the streams once flowed directly into Lake Michigan, when its level was lower relatively to the land surface. The land in the region including these districts is mostly a plain of glacial sand, having an elevation of about 50 feet[a] at the north and descending gradually to lake level at the south. A moraine traverses all these districts, except perhaps that of Spring Lake at the extreme south, its prominence compared with the sand plain being much greater northward. Throughout this region the surface stratum of coarse sand generally extends to some depth below the lake surface, consequently the water that falls upon the land in the vicinity of the lakes and their larger tributary streams filters down near to surface level of the lakes, thus making the water table low.

The other three districts differ from the lake districts so greatly and have so little in common among themselves that no general description is applicable.

WHITE LAKE DISTRICT.

Topography.—In the vicinity of White Lake the crest of the moraine is of medium height and has a general direction nearly at right angles to the length of the lake. It is intercepted by the marsh, White River seeming to have cut a gap about 1½ miles long in the moraine. Montague lies north from the head of the lake and Whitehall on the east about a mile down the lake. The crest of the moraine lies outside both corporation limits, running northward on the east side of Whitehall and nearly northwest on the north side of Montague. The morainic till, at an elevation of about 50 feet, extends into the northern part of Montague and to the lake bluff in the northern part of Whitehall, constituting perhaps one-half the area of the latter place. From White Lake to Lake Michigan the surface is mostly a sand plain, which is 50 or more feet above lake level where it meets White Lake, in the vicinity of Montague, and seems to overlap the edge of the moraine. The same sandy features continue to the south and east of the lake, but with less even surface.

[a] All altitudes, unless otherwise stated, are given in feet above Lake Michigan.

Wells.—All the wells, except one at the United States life-saving station at Lake Michigan, are in Montague and Whitehall. Thus a large part of the district is undeveloped. Most of these wells are situated near the border of White Lake, the farthest being not more than 1,000 feet from the water margin, and a number are on docks built into the lake. More than one-half of the wells are less than 5 feet above Lake Michigan. The shallower ones, which are also the most remote from the lake shore, are on higher ground, between 10 and 15 feet above lake level.

The wells which have flowed in this district number somewhat more than 25. Most of them are still active and yield about 70,000 gallons daily, including 50,000 gallons pumped from four wells at the Whitehall municipal plant.

The depth of the wells varies greatly. The shallower ones referred to above are near the edge of the moraine in Montague and vary from 28 to 40 feet in depth, one of them being possibly only 18 feet. There are eight wells clearly belonging to this group.

The most satisfactory record obtained was that for the well in the village hall, driven by R. D. Hall, the village marshal, in the autumn of 1903. The record follows:

Record of well at Montague.

	Depth (feet).
Muck	4–5
Red clay	5–6
Quicksand	7–8
Blue clay	15
Fine sand, coarse sand, and water.	

Another well which should probably be classed with those just described is in the Montague iron works, about 400 feet toward the lake from the village hall well. Its record is very indefinite, although it was driven in the spring of 1904 and is the latest well opened in that vicinity. The depth is stated to be between 40 and 50 feet. It is remarkable in having water which stands several feet lower than in the others. The water from all these wells is soft.

Nearer the lake and on lower ground are two old wells said to be between 60 and 70 feet in depth, both of which are more "sulphury" and "irony." No definite records were obtained. The temperatures were 0.5° and 1.5° C. higher than that of the water from the well in the village hall, the difference of 1° between the two evidently being caused partly by unequal exposure.

On the Whitehall side the four 6-inch wells from which the village supply is pumped are 67 feet deep, the strata being as follows:

Record of Whitehall village wells.

	Depth (feet).
Sand	12
Blue clay	57
Sand	67

About one-half of the wells in Whitehall are stated to have depths running between 55 and 70 feet, and presumably their records are represented in a general way by that of the village wells. The well of the Nufer Cedar Company, located some 700 feet southwest from the pumping station, may be taken as an example. Its elevation is several feet lower and its depth 57 feet, all through blue clay below a level 10 feet lower than that of the water of White Lake.

The deepest well found is the one at the life-saving station. This has a well-authenticated depth of 153 feet, entirely through blue clay below 12 feet. The nature of the water bed is not known. The well was driven by W. H. Dennis in 1887.

At the office of L. T. Covell, very near the head of the lake, is a well 129 feet deep, which, so far as known, is next in depth to the Government well. Its water is decidedly strong in mineral quality. The character of the strata is not remembered by the owner, but he states that there were sand, clay, and some marl, and that turbid flowing water was found at 54 feet. The well was driven by Peter Denneau, of Montague.

It appears, therefore, that there may be several sources of the flowing wells in this district. The two deepest ones must penetrate nearly to bed rock, if, indeed, they do not reach it. It seems fair to suppose that the shallow wells in Montague have their sources in the moraine and that the veins tapped are not essentially different from those that break out in numerous springs along the foot of the bluff. The municipal wells of Whitehall represent another class supplied from a sand stratum between strata of blue clay which probably lie below the greatest depth of White Lake.

Mr. W. F. Nufer, of Whitehall, asserts positively that the first well to flow in this district is the one farthest to the south in Whitehall and located on the property of the New York Mill Company. It was put down about 1868 by Mr. George M. Smith of the firm of C. A. Alley & Co. Its depth is 107 feet. It is still flowing.

Mr. J. W. Young, of Montague, claims that the well in the blacksmith shop at the corner of Water and Spring streets antedates all others in Montague and Whitehall. The well was dug with a spade, evidently without expectation of finding a flow. After the hole overflowed with water a pipe was inserted and the earth was returned. Mr. Young places the date at 1873.

The well of Mary Reed (see p. 31) is stated to have been put in about 1870.

Quality and uses of water.—The character of the water has been referred to above in relation to the various depths. Mr. S. J. Lewis, of the United States Geological Survey, analyzed samples from well No. 25 in the Montague village hall, 37 feet deep, and from No. 18 on village property near Church street, said to be 62 feet deep, and found the chlorine content to be very low compared with that in water from Muskegon wells. (See p. 37.)

Most of these wells were opened to get water for drinking purposes. Three of the shallow Montague wells along Water street are in private houses, and the water serves for general household uses. The one in the Montague iron works supplies water for cooling. The water from the well at the life-saving station is reported to be "soft" and suitable for "family use." The Whitehall village supply is taken in houses, stores, and stables, and used on lawns and gardens, for fire protection, and in the mills for refilling boilers.

Head.—Except in a very few cases the water head is not known. Mr. Berndt Carlson, keeper of the life-saving station, found by careful trial that the water there would rise 8.5 feet above Lake Michigan. Water from the well in Montague village hall has been carried in a pipe that was found to be about 12 feet above the Pere Marquette rail at the station, which indicates a head of 20 feet or more above lake level, and from appearances a similar head is present in the shallow wells, except in that at the Montague iron works, which does not flow, although, according to the statement of Mr. R. D. Hall, who was present when the well was finished, the water then rose about 2 feet above ground.

The Whitehall municipal wells now rise only a foot or two above the ground, or about 6 or 7 feet above the lake. Mr. J. H. Williams, who was president of the village at the time the wells were opened in 1892, states that the rise then was fully 6 feet above the ground.

It is notable that the wells which are pumped, viz, those at the Whitehall plant and the Montague iron works, have suffered a loss of head. At the iron works the maximum amount pumped per minute is estimated at 10 gallons, and this is sometimes continued for hours. The supply has not been noticed to fail. At Whitehall waterworks the four wells are placed so that the lines joining them form a trapezium, the least distance between two wells being about 25 feet, the greatest about 50 feet. When one of these wells is pumped alone at full capacity the water is lowered slightly in the others. When all the wells are in good order and are pumped simultaneously the yield per well is estimated at about 80 per cent of that when pumped singly.

The opening of these wells caused a striking instance of loss of head in a well located about 200 feet northward and owned at that time by Mr. A. T. Linderman. This well was 82 feet deep and would flow at a height a little above ground, but ceased when the village wells began to flow. The depleted well appears to be on slightly higher ground. It is stated that by digging down and lowering the pipe the water was found to have fallen about 4 feet, and that the flowwas kept up at the lower level for a time. The well is now not in use.

About 120 feet still farther north is a flowing well formerly owned by Charles Johnson, but now the property of E. Duttenhoefer. The flow of this well was diminished at the same time as that of the Linderman well, but not to so great a degree. It does not flow at present.

Many of the wells continue to yield water nearly or quite as abundantly as when they were put in. A well by the mill of L. T. Covell, which was flowing about 5 gallons a minute in the summer of 1900, was not flowing in November, 1904. The cause is not known. The flow of the well at the life-saving station is stated to have diminished. A well at the corner of Colby and Lake streets in Whitehall, owned by Mary Reed, was put in about the year 1870 and had ceased to flow about ten years ago from accumulation of sand and silt. When it was pumped out, the flow was restored, and it now yields about one-half gallon a minute. The pipe is 4½ inches in diameter and the depth 96 feet. This is possibly the oldest flowing well in the district, although the claim it disputed.

In November, 1904, three of the Whitehall public wells were useless, and the entire ordinary supply was being drawn from one well. In February following one of the three was being pumped with a moderate yield. The cause of stoppage was not definitely known. Mr. Charles Deane, the engineer, thought that "magnesia" had accumulated on the sieves and that this, with the fine sand in which the sieves lie, effectively clogged the meshes when the pressure of the pump was applied. Mr. Deane asserts that the sieves do not corrode.

Cost of wells.—A few typical wells cost as follows:

Cost of wells in White Lake district.

Owner.	Depth.	Diameter.	Cost.	
			Total.	Per foot.
	Feet.	*Inches.*		
United States Life-Saving Service	153	2	$174	$1.20
Montague village	37	2	25	.67
Nufer Cedar Co	57	2.5	57	1.00
Whitehall village	110	2	100	.91

MUSKEGON LAKE DISTRICT.

Topography.—The moraine occurs here nearly parallel to the shore of Lake Michigan and about 3 miles inland. It is decidedly lower than it is to the north, barely exceeding 55 feet at its greatest elevation, and being entirely covered by sand except at a prominence on the south shore of Muskegon Lake, known locally as "Brewery Hill." About 1 mile of the moraine has been cut out in forming the trough occupied by Muskegon Lake, and the section of the bluff where the moraine meets the lake on the north side shows 20 feet of sand overlying the ridge.

This district properly includes Bear Lake, a tributary of Muskegon Lake from the north. The water head, as shown below, seems to decrease toward the upper end of Muskegon Lake, and the same decrease continued would extinguish it 2 or 3 miles upstream from the head of the lake, thus making the limit of the district some 10 miles inland from Lake Michigan. These indications, however, are not borne out by a well belonging to Leon J. Smith in the marsh in the NE. ¼ sec. 17, T. 10 N., R. 16 W. The well is about 2 miles northeast from the upper well in the lake proper and flowed with a head of 12 feet when first opened in 1898. The surface is probably not less than 6 feet above the lake, thus making the head above the lake about 18 feet. It would seem, therefore, that the river valley may be expected to afford flowing wells for many miles up.

Wells.—With very few exceptions, the wells in this district are on the water side of the original shore line. They were located on docks and built land adjacent to the sawmills to furnish drinking water for the mill crews, and their elevations therefore are generally very low. The highest well, which belongs to Frank Alberts, is on the north shore of Muskegon Lake, on natural land 9.5 feet above the lake.

About 15 flowing wells have been opened here. The total natural flow of water from those remaining active is about 15,000 gallons daily, to which must be added 50,000 to 100,000 gallons pumped from the well at the plant of the Central Paper Company. About 10 wells are now flowing.

In this district most of the wells are so old that reliable information as to their strata is not obtainable. Three comparatively new wells, two on the north side and one on the south side of the lake, have records that are presumed to be accurate. Of these three, the one on the south shore, owned by the Central Paper Company, located in the SW. ¼ NW. ¼ sec. 35, T. 10 N., R. 17 W., has a record as follows:

Record of well of Central Paper Company, Muskegon.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	40	40
Blue clay (lake clay?)	197	237
Hardpan	2	239
Sandstone	57	296

Depth to water, 237 feet. Surface elevation, 13 feet above Lake Michigan.

Across the lake, 2 miles slightly east of north from the site of the paper mill, in the SE. ¼ sec. 23, T. 10 N., R. 17 W., is a well on land owned by Dr. J. G. Jackson, which was drilled by C. C. Jacks in December, 1901. The record stated for this well is as follows:

Record of Jackson well near North Muskegon.

	Thickness.	Total.
	Feet.	*Feet.*
Clay (probably morainic till)	50	50
Quicksand	3	53
Clay	7	60
Quicksand	2	62
Clay (probably marly lake clay)	170	232
"Hardpan"	2	234
"Soft material"	2	235
'Hardpan"	1	237

Surface elevation, 1.5 feet above Lake Michigan.

The third recent well is 4 miles nearly due northeast from the paper mill in the SE. ¼ NW. ¼ sec. 18, T. 10 N., R. 16 W. It was drilled for Gow & Campbell by C. C. Jacks in 1901. The record was given as follows:

Record of Gow & Campbell well, Muskegon.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	40	40
Clay	164.5	204.5
"Water rock"	1	205.5
Water	1.5	207

Surface elevation, Lake Michigan level.

The surface stratum of clay in the Jackson well is doubtless the edge of the moraine of till, the crest of which lies about one-half mile east under a cover of sand, as stated above. The well is by the edge of the water at the outlet of Bear Lake, where the sand cover has been worn away. The other two wells are probably beyond the extent of the moraine, one west, the other east.

Nearly due south, 1½ miles from the Gow & Campbell well and about 3 miles east-northeast of the paper mill well, is a deep hole, drilled several years ago in search for oil. The record was carefully taken and is as follows:

Record of well about 3 miles east-northeast of paper mill, Muskegon.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	65	65
Lake clay (?)	160	225
Till or "hardpan"	10	235

Surface elevation, about 10 feet above Lake Michigan.

The four records given exhibit a uniformity that is significant. The quadrilateral drawn with the wells at the angles includes about one-half of Muskegon Lake and more than 50 per cent of the deep wells on its borders. It is probable that the records of all the wells are essentially like those given. The bed rock penetrated in the two borings on the south side is a white micaceous sandstone of the Marshall group. None of the flowing wells are known to extend into this rock, but it is presumed that all, with one exception, reach it and that it forms their water bed. The water pumped from the well at the paper mill is evidently from the same source and would flow if the elevation of the well were a few feet less.

The exceptional well to which reference has just been made is in the shade-roller factory of the Stewart Hartshorn Company, near the foot of "Brewery Hill," mentioned above as a conspicuous part of the moraine. The well is 57 feet deep, and the strata penetrated were given as follows by Hubert Young, the driller:

Record of well of Stewart Hartshorn Company, Muskegon.

	Thickness.	Total.
	Feet.	*Feet.*
Sawdust	7	7
Lake sand	10	17
Marly clay	10	27
Sand and clay	3	30
Sand and gravel	10	40
Open water-bearing sand	3	43
Quicksand	7	50
Sand and clay	7	57

At 40 feet water was found that rose about 6 feet above Lake Michigan. At 57 feet the head was about 10 feet.

Assuming the depths of wells approximately correct as given, the inference follows that there is a general and decided dip of bed rock to the west, but by comparison of the two most reliable records only (those of the experimental oil well and the paper-mill well) the dip appears much less.

Head.—The head evidently varies somewhat in the wells of this district, appearing to rise westward and northward. The highest rise of water was observed at the Alberts well, located near the mouth of Greene Creek in the NW. ¼ NW. ¼ sec. 22, T. 10 N., R. 17 W., where there is a strong flow of water at about 12 feet above Lake Michigan. The owner states that about twenty years ago the water from this well was piped into the second story of a boarding house near by, rising 18 feet above the surface or about 16 feet above the present exit, making about 28 feet above Lake Michigan. The statement of Mr. Alberts can be questioned only on the supposition that the house stood on somewhat lower ground, so that he was deceived as to the actual height. A man living near the well states that the present head is about 15 feet above Lake Michigan.

At the paper-mill well, nearly 2½ miles to the south, the rise of water is between 10 and 12 feet above the lake. At the Jackson well, somewhat less than a mile south of east, the head is about 9 feet. Four miles north of east from the Alberts well, one of the Gow & Campbell wells, on the site of a mill formerly operated by John Torrent, had a head of 7 feet at the time of Mr. Torrent's ownership. At the well of the Racine Boat Company, about 3 miles up the lake from the paper mill, the head is 7½ feet. This well is 3 miles from the Alberts well also, and thus indicates a loss of head of about 1 foot a mile northeastward and of somewhat more than twice that amount southeastward.

Very few instances can be found in this district in which a well is known with certainty to have lessened the flow or lowered the head of others. As indicated before, the Alberts well (No. 6) has undoubtedly decreased in both flow and head. The owner believes that the pipe leaks underground, but whether the change is due wholly to this or to the tapping of the water bed in a number of other places is uncertain.

About 200 feet from the paper-mill well and on the same premises is another well of like diameter (8 inches), which was made about the same time, but was drilled to a depth beyond 1,600 feet in search of oil. Only a trace of oil was found, and the inner tube was withdrawn, leaving the casing, so that the water was admitted at the bed-rock level. It was intended to use water from both wells, but trial proved that when one well was pumped at the maximum rate of 150 gallons a minute the water was lowered decidedly in both to about the same level. It seemed that nothing was to be gained by operating both wells, and the deeper one was abandoned. Evidence of free communication between the wells now appears constantly in the presence of oil with the water pumped from the shallower well.

When the well by the mill of Gow & Campbell, at North Muskegon, was opened in 1901, no effect was noticed in the flow of the other three wells in the immediate vicinity. But when the new well was tested, by putting on a boiler injector, which drew about 150 gallons a minute, the flow of one of the wells, 700 feet distant, ceased while the injector continued in action. The combined natural flow of the two wells is about 1 gallon a minute.

According to the evidence collected, the yield of wells in this district has not materially changed in the aggregate, and in very few instances have individual wells ceased or greatly diminished their flow except from causes having no relation to the source or supply. Well No. 2, known commonly as the Blodgett well, has become isolated from the shore by the wearing away of the dock on which it was built, and is said to have ceased flowing because of obstructions thrust into the upper part of the pipe by meddlesome persons. A case has been mentioned in which it was believed that leakage in the pipe had diminished the apparent yield. Incrustation doubtless chokes the pipes of old wells more or less. Engineer Metcalf of Gow & Campbell's mill stated that 700 feet of pipe conducting water from well No. 8 was half filled with "magnesia" during one summer.

A well on the Magoon & Kimball dock is stated by Mr. Jacks to be choked with "muck," by which he means a material like quicksand or silt that has filled the lower part of the pipe.

In the severe winter of 1903–4, two of the four wells on the premises of Gow & Campbell (Nos. 8 and 9) stopped flowing for about two months. Observers of the phenomenon think the cessation was not caused by freezing in the pipes.

A well near the intersection of Western avenue and Eighth street was probably the first to flow in the district. It was put down beyond 2,000 feet about the year 1868 by parties prospecting for salt. Mr. Hubert Young states that two pipes were afterwards planted so that water was delivered by one from a depth exceeding 300 feet and by the other from a shallower source, the deeper water being much the stronger in mineral qualities. This well flowed until a few years ago, and furnished an abundant public supply greatly relished by horses. The site is now owned by the Pere Marquette Railroad Company and is covered by a shed used in storage of coal. The well is supposed to have been stopped by plugging the pipe.

Quality and uses of water.—With a single known exception these numerous wells were opened to obtain suitable water for drinking. The flavor of the water, which is variously called "irony" and "sulphury" as well as salty, is not pleasant to many at first, but becomes agreeable after continued use. The healthfulness has always been found superior in comparison with water obtainable from any other source except Lake Michigan. Before a satisfactory public supply was obtained for the town, people living near carried water from these wells to their houses. The water from Doctor Jackson's well is now used in culinary processes.

The water from the well of the Central Paper Company is used for general mill purposes, especially for cooling. The temperature given is 11° C. or 51.8° F.

The only complete analysis found is that of the well belonging to the Central Paper Company, which follows:

Analysis of water from well of Central Paper Company, Muskegon.

	Parts per million.		Parts per million.
Silica	12	Total evaporating residue	2202
Alumina	22	Total hardness	181
Iron oxide	Trace.	Temporary hardness	87
Sulphate of lime	227	Permanent hardness	94
Carbonate of lime	156	Nitrites and nitrates	0
Calcium chloride	87	Phosphoric acid	Present.
Magnesium chloride	254	Free ammonia	0
Sodium chloride	1307	Combined ammonia	1.7
		Albuminoid ammonia	.425
	2065	Sediment	36

Color, none. Appearance, turbid. Odor, none. Taste, salty. Reaction, neutral.

On the following table are given, in addition, the results of a number of partial analyses of water in the vicinity of Muskegon. The high chlorine constituent is considered as due to leakage from deep saline rock wells in the vicinity. The Montague samples were from wells in the village street sunk to obtain water for fire protection and other purposes. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of water near Muskegon and Montague.

[Parts per million.]

	1	2	3	4
Color	Not det.	10	5	5
Iron (Fe)	Minute trace.	Slight trace.	Trace.	Strong trace.
Chlorine (Cl)	59	64	1.5	1.5
Carbon dioxide (Co_2)	63.32	62.88	77.39	84.86
Sulphate trioxide (SO_3)	83	99	10	10
Hardness (as $CaCO_3$)	Not det.	139+	139+	139+

S. J. Lewis, analyst. 1. J. G. Jackson; depth, 237 feet. 2. Hackley & Hume; depth, 230 feet. 3. Montague village; depth, 60+ feet. 4. Montague village; depth, 37 feet.

The water from the shallow well belonging to the Stewart Hartshorn Company was analyzed for sanitary purposes by Davenport Fisher, of Milwaukee. The analysis follows:

Analysis of water from well of Stewart Hartshorn Company, Muskegon.

[Parts per million.]

Total solids	440	"Free ammonia"	.03
Chlorine	33	"Albuminoid ammonia"	.068
Sulphate of calcium	.184	Nitrogen as nitrates	110

The following comments are culled from a letter by Mr. Fisher, which accompanied the report:

The water is contaminated with sewage or vault seepings. * * * The salt, represented by chlorine, also comes from the same source. * * * Though such water may be safe for a long time, it might at any time bring disease germs and any health officer would condemn it.

LAKE HARBOR DISTRICT.

Topography.—In the lower portion of the district the sand plain has an elevation of about 15 feet, increasing gradually away from Lake Michigan and reaching about 40 feet above the bed of Black Creek or 50 feet above the lake at the location of the upper well near Cloverville. The moraine lies about 2 miles inland. It is very low, appearing only as a clay bed a few feet under the level sand surface.

Wells.—Only one flowing well is known in this district. It is in the valley of Black Creek on land owned by Doctor Gordon, of Muskegon, in the NE. ¼ NE. ¼ sec. 2, T. 9 N., R. 16 W. This well is about 6 miles from the Lake Michigan shore line and about 5 miles from the only other deep well known in the district.

No accurate record of the well could be found, but it was put down to a depth of 1,500 feet or more in the season of 1903 by parties prospecting for oil. The elevation is estimated to be about 6 feet above the bed of Black Creek under the Grand Rapids and Indiana Railroad, somewhat less than half a mile distant, indicating an elevation of between 15 and 18 feet above Lake Michigan. Bed rock is stated to be more than 300 feet below the surface, and the water is thought to come from a crevice in the rock at a depth of 340 feet. The temperature is 11° C., or 51.8° F., which would indicate a depth of not more than 250 feet.

The 8-inch casing put down to bed rock by the drillers was not removed and stands about 3 feet above ground. The inner pipe was removed and the casing plugged at the top with a block of wood, leaving a hole about 1 inch in diameter. From this opening water gushes up about 10 inches, flowing 16 gallons a minute, or nearly 25,000 gallons daily. A resident of the neighborhood asserts that he saw the water rise at least 10 feet above the surface when the pipe was being driven. This shows a head of no less than 25 feet above lake.

The quality of the water, judged by taste, is essentially like that of the deepest Muskegon wells but probably less salty.

The only other deep well found in the district is the property of the Forest Park Association and is located in the SE. ¼ SE. ¼ sec. 12, T. 9 N., R. 17 W. The surface is between 25 and 30 feet above the lake and the water rises to about 12 feet below the surface, or to 13 to 18 feet above the lake. The record given by C. C. Billinghurst is: Sand 15 to 18 feet, clay to 6 inches from bed rock; total depth 218 feet. The water bed is called "shaly," but is undoubtedly the same sandstone found in the Muskegon wells. The water is used for drinking and by some for cooking, but others find it undesirable for the latter purpose on account of its "mineral" qualities. When raised with an ordinary hand pump, the water has always been turbid. An attempt to siphon it over the lake bluff has not been entirely satisfactory, but the turbidity was corrected while the siphon flowed. A summer population of about 30 people is supplied from the well, which is said to have cost $250.

Although the elevation of the land has prevented this well from flowing, it is believed that the water is from the same source as that of the deep Muskegon wells and the Cloverville well. Comparing its head with that of the latter well about 5 miles distant, it is seen that there is an average gain in head of at least 1 foot a mile up the valley of Black Creek.

SPRING LAKE DISTRICT.

Topography.—Only a small portion of the upper part of Spring Lake is in Muskegon County. The land is generally sandy, with clay lying near the surface in many places. The general surface elevation is between 25 and 30 feet. In the near vicinity of Fruitport village, where the wells are located, water saturates much of the soil to the surface where not removed by artificial drainage.

Wells.—The only flowing well found in the portion of the district lying in Muskegon County is in the SW. ¼ sec. 35, T. 9 N., R. 16 W. This well is on the property of the Spring Lake Iron Company and has flowed since 1883, when it was bored to furnish water for the employees of the company working at the furnace. The present measurable flow is about 5 gallons a minute, which is less than formerly, but some of the water is known to escape through a leak in the pipe below ground. The surface elevation is 16 feet, and the head about 26 feet.

A partial record of the well was given by an employee who aided in the boring, as follows:

Record of well of Spring Lake Iron Company, Fruitport.

	Thickness.	Total.
	Feet.	*Feet.*
Surface sand	10	10
Quicksand	22	32
Blue clay	60	92
Light sandstone	⅓	92⅓
Gravelly clay	8	100⅓
Solid gravel	4	104⅓
Yellowish mucky clay	3	107⅓
Blue shale	2	109⅓
Sand and clay in thin alternate layers	12	121⅓
Blue sandstone	½	121⅚
Grayish limestone	2	123⅚

The total depth of the well was stated to be 150 feet, and that depth was verified by Mr. J. C. Ford, president of the company. The temperature, 12° C., or 53.6° F., suggests a greater depth. A partial analysis of the water follows:

Analysis of water from well of Spring Lake Iron Company, Fruitport.[a]

	Parts per million.
Sodium chloride	3,467.17
Magnesium chloride	327.15
Calcium chloride	937.14
Potassium sulphate	91.43
Calcium sulphate	76.72
Calcium bicarbonate	1,119.15

The only other deep well in this portion of the district is on the resort property now owned by the Grand Rapids, Grand Haven and

[a] Expressed by analyst in grains per gallon; recomputed to parts per million at United States Geological Survey.

Muskegon Railroad, and located in the NW. ¼ SW. ¼ sec. 36, T. 9 N., R. 16 W. This well does not flow, the elevation being over 25 feet above Lake Michigan. It was opened about 1871. The record on file in the office of the Spring Lake Iron Company follows:

Record of well of Grand Rapids, Grand Haven and Muskegon Railroad, sec. 36, T. 9 N., R. 16 W.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	30	30
Blue clay	140	170
Hardpan and gravel	9	179
Blue sand rock	24	203
Blue shale	5	208
Marshall sand rock	41	249
Blue shale	6	255

Some claims of medicinal properties have been made for the water. Before the well became the property of the railroad it was on public ground and the water was freely used by citizens of Fruitport. Formerly the water was shipped in carloads to places as distant as New Orleans and used for curative purposes in cold and hot baths.

MOORLAND DISTRICT.

Topography.—This district, indicated by a single well, is presumed to be coextensive with the great marshy region that covers about one-half of Moorland Township and extends into the eastern part of Eggleston. The main branch of Black Creek, which flows into Lake Harbor, has its origin in the marsh. At Moorland station, where the well is located, the surface elevation is about 95 feet. On the south the marsh area terminates in gradually rising land that merges into a rolling surface of till. On the east it is separated from the valley of Crockery Creek by a morainic ridge. On the north and west the confine is sandy and somewhat higher. The soil of the marsh is generally sandy with a few streaks of loam. It was found covered with water by the pioneers, but by an extensive drainage system supplementing and deepening the natural lines most of the surface water now flows away.

Well.—The well is located in the NE. ¼ SE. ¼ sec. 29, T. 10 N., R. 14 W., on property now owned by N. A. Cook, of Moorland. The depth is stated to be 115 feet, but no one was found who knew the record of the strata, though it may possibly be among the papers of the State geologist. The well at first yielded a considerable amount of an inflammable gas, which was collected and burned experimentally by elevating the pipe and reducing the exit. The gas is not so evident now, if it is delivered at all. The water is strongly mineral in quality. The head of the water is about 8 feet above the surface or not far from 100 feet above the lake. The flow is 6 gallons a minute.

It is notable that this well is in the catchment of Lake Harbor and on the same drainage line with the well near Cloverville. The location is somewhat more than 16 miles in a direct line from the outlet of Lake Harbor and about 10 miles from the Cloverville well, and, while the indications are strong that the water of the two wells rises from entirely distinct strata, yet their locations, height of head, and abundant flow, suggest the probability that the Lake Harbor and Moorland districts are continuous.

FRUITLAND DISTRICT.

Topography.—The extent of this district, which is represented by a single well, can only be conjectured. The well is located in the SW. ¼ sec. 36, T. 11 N., R. 17 W. The moraine, which gradually loses prominence, as it extends southward from Whitehall, appears to terminate somewhat abruptly on the same section near the northeast corner. In fact, the moraine probably continues unbroken to the point where it appears in the bluff of Muskegon Lake, but is so low that it is covered by 10 feet, more or less, of sand. The soil is sandy with spots slightly loamy. The surface is a plain interrupted by numerous swells and knolls that appear like very low dunes. The region was originally swampy, and Greene Creek, which flows southward about 4 miles into Muskegon Lake, has its origin here. The elevation is probably between 40 and 50 feet.

Well.—This well was probably driven about 1890 for Mr. John Miller, who then resided on the place. It has since become the property of Jacob Johnson, of Whitehall. When seen several years ago, the pipe stood about 5 feet above ground and the flow of water was very slow, seeming to indicate that the top of the pipe was about at the height to which the water would rise. The depth is stated to be 88 feet.

The existence of a flowing well at the mouth of Greene Creek and another at the source suggests the probability that flowing water can be found throughout the course of the creek, although the great difference in depths of the two wells and in the quality of water, which is decidedly less mineral in the Fruitland well, tend to negative the inference that the so-called Fruitland district is a part of Muskegon Lake district.

CASNOVIA DISTRICT.

Topography.—The region in which the Casnovia wells are found has very pronounced features in the form of morainic prominences of till and gravel. The highest land in Muskegon County lies in Casnovia Township. The railroad track at Casnovia station is 300 feet above Lake Michigan. This elevation is greatly exceeded by hills in the immediate vicinity and much of the surface in the township is not far from 800 feet above the sea. The depth to bed rock is probably as great as 600 feet in some places and not less than 300 feet at any place. It is extremely improbable, therefore, that a flowing well from any except a local source would be found here. The high land in Casnovia village has been deeply penetrated, in one instance more than 300 feet, without encountering water.

Wells.—A flowing well belonging to Mr. D. Neff is located in the NW. ¼ NE. ¼ sec. 33, T. 10 N., R. 13 W. (Casnovia Township). The well was driven in 1895 by May Doubledee, of Casnovia village. It is 45 feet deep, in clay and gravel, and flows 1 gallon a minute, the yield not having varied appreciably since the well was put in. The head is only about 1 foot. The cost was $45.

Near the northwest corner of sec. 28, slightly more than a mile from the Neff well, Mr. Charles Fraligh has a flowing well, the record of which is not known.

The territory in which these wells are located abounds in natural springs, some of which are remarkable for their size and form the heads of small streams.

SUMMARY.

The flowing wells of the county are distributed as follows: White Lake, Nos. 15 to 37, inclusive; Muskegon Lake, Nos. 1 to 14, inclusive, and Nos. 46 and 47; Lake Harbor, Nos. 38 and 39; Spring Lake, Nos. 41 and 42; Moorland, No. 40; Fruitland, No. 43; Casnovia, Nos. 44 and 45.

Data of flowing wells and of other deep wells having similar source and head, Muskegon County.

No.	Location.				Owner.	Elevation.	Depth.	Diameter.	When made.	Driller.	Water bed.		Quality of water.	Daily yield.[a]	Temperature.[b]	Remarks.
	Township N.	Range W.	Section.	Part of section.							Depth.	Character.				
						Feet.	*Feet*	*Ins.*			*Feet.*			*Gallons.*		
1	10	17	33	SW. ¼ NW. ¼	Central Paper Co., Muskegon.	13	296	8	1903	Central Paper Co.	237	Sand rock	See analysis (p. 36)	P. 100,000	11 / 51.8	Head about 10 feet.
2	10	17	26	SW. ¼ SW. ¼	J. M. Gerrish, Muskegon.	1	237	2	1886	C. C. Jacks, Muskegon.	237	......	Hard and salty.	Choked.	......	Choked in upper part of pipe.
3	10	16	30	NW. ¼ NW. ¼	Hackley & Hume, Muskegon.	1	220	1	1889	do	220	Sand rock	do	250	14 / 57.2	
4	10	16	19	NE. ¼ SE. ¼	Racine Boat Co., Muskegon.	5.5	208	2.5	......	do	208	do	......	2,200	12.5 / 54.5	Head 7.5 feet.
5	10	16	20	NW. ¼ NW. ¼	John Torrent, Muskegon.	1	204	......	1887	do	......	do	......	......	......	
6	10	17	22	NW. ¼ NW. ¼	Frank Alberts, Muskegon.	9	240	2.5	1883	do	240	......	Hard and salty.	2,760	10.5 / 50.9	Head about 15 feet.
7	10	17	23	SE. ¼ NW. ¼	Dr. J. G. Jackson, Muskegon.	1.5	237	2.5	1901	do	237	Sand rock	do	400	12 / 53.6	Head about 9 feet.
8	10	16	18	SE. ¼ NW. ¼	Gow & Campbell, Muskegon.	5.5	......	......	......	......	......	......	......	800	13 / 55.4	
9	10	16	18	SE. ¼ NW. ¼	do	1	207	3.5	1901	C. C. Jacks	207	Sand rock	Hard and salty.	700	13 / 55.4	
10	10	16	18	SE. ¼ NW. ¼	do	1	......	......	......	......	......	......	......	800?	......	
11	10	16	18	SE. ¼ NW. ¼	do	......	......	......	......	......	......	Sand rock	Salty	......	......	Head formerly 7 feet.
12	10	16	19	NE. ¼ SW. ¼	W. H. Dewees, Muskegon.	1	......	......	......	......	......	......	......	......	......	Isolated by destruction of dock and flowing into lake.
13	10	17	25	SW. ¼ NE. ¼	Stewart Hartshorn Co., Muskegon.	5	57	2	1900	Hubert Young, Muskegon.	40 / 57	......	See analysis (p. 37)	Closed	......	Head about 10 feet. Water source local and contaminated.
14	10	16	19	NE. ¼ SW. ¼	Magoon & Kimball, Muskegon.	1	......	......	......	C. C. Jacks	......	......	......	Choked.	......	"Muck" in pipe.
15	11	18	2	SW. ¼ SE. ¼	United States Life-Saving Service.	5.5	153	2.5	1887	W. H. Dennis, Montague.	153	......	"Soft"	1,320	......	Head 8.5 feet.
16	12	17	28	SE. ¼ NW. ¼	L. T. Covell, Whitehall.	2	129	2	......	Peter Denneau, Montague.	54 / 129	......	Salty	480	10 / 50	Turbid water at 54 feet.

[a] P under "Daily yield" indicates that the well is pumped.

[b] The upper number in temperature column is the temperature as read in Centigrade. The lower number is the same value reduced to Fahrenheit.

Data of flowing wells and of other deep wells having similar source and head, Muskegon County—Continued.

No.	Location.				Owner.	Elevation.	Depth.	Diameter.	When made.	Driller.	Water bed.		Quality of water.	Daily yield.	Temperature.	Remarks.
	Township N.	Range W.	Section.	Part of section.							Depth.	Character.				
						Feet.	*Feet.*	*Ins.*			*Feet.*			*Gallons.*		
17	12	17	29	NE. ¼ NE. ¼	Montague village	1		2	1870				Salty	1,440	11.5 / 52.7	
18	12	17	28	NW. ¼ NW. ¼	do	2	62	2	1878				See analysis (p. 37)	260	12.5 / 54.5	
19	12	17	28	NE. ¼ NW. ¼	L. T. Covell, Whitehall.	2		2		Peter Denneau.				Extinct.		Water was much liked by horses; pipe probably clogged.
20	12	17	21	SW. ¼ SW. ¼	W. E. Osmun, Montague.	16	37	2					Soft	2,880	9.5 / 49.1	In public place. Water much sought by people.
21	12	17	21	SW. ¼ SW. ¼	Charles Wyard, Montague.	10	30		1873	J. W. Young, Montague.	30		do	900	9 / 48.2	Dug with spade; flowing vein found unexpectedly.
22	12	17	21	SW. ¼ SW. ¼	——— Dieske, Montague.	9							do			Said to have checked flow of No. 21 for a short time.
23	12	17	21	NW. ¼ SW. ¼	Charles Rathbun, Montague.	8	18			Peter Denneau.			do	1,080		Stated depth of 18 feet is doubted.
24	12	17	21	NW. ¼ SW. ¼	Herman Runcil, Montague.	10	28		1903				do	1,440		
25	12	17	21	SW. ¼ SW. ¼	Montague village	9	37	2	1902	R. D. Hall, Montague.			do	2,880	11 / 51.8	
26	12	17	21	SW. ¼ SW. ¼	W. E. Osmun	12	40	2	1900	do			do	1,440	9.25 / 48.6	
27	12	17	21	SW. ¼ SW. ¼	Montague iron works, Montague.	10	50	2	1904	Frank Coleman, Montague.			do	P. 3,000		Head much lower than in other similar wells in vicinity.
28	12	17	28	¼ line W. ½	Whitehall village	8	67	6	1892				do	P. 50,000	11 / 51.8	A group of four wells furnishing Whitehall public supply.
29	12	17	28	¼ line W. ½	do	5	110	2	1904	R. Saxton, Whitehall.						Flow slight. Frozen in winter. Shows clay bed of No. 28.
30	12	17	28	SE. ¼ NW. ¼	Carrie Mears, Chicago.	7	82							Extinct.		Robbed by No. 28, about 200 feet distant.
31	12	17	28	SE. ¼ NW. ¼	E. Duttenhoefer, Whitehall.	7								do		Said to have been gradually affected by opening No. 28.
32	12	17	28	SE. ¼ NW. ¼	Mary Reed, Whitehall.	6	96	4.5	1870					720		One of the old wells; date not certainly known.

33	12	17	28	NE. ¼ SW. ¼	Nufer Cedar Co., Whitehall.	1	57	2.5	1875	Peter Denneau.	......	......	Soft	100	......	
34	12	17	28	SW. ¼ SW. ¼	Eagle Tanning Co., Whitehall.	......	......	......	......	......	......	......	......	......	......	
35	12	17	33	NW. ¼ NW. ¼	New York Mill Co., Whitehall.	......	......	......	......	......	......	......	......	......	......	
36	12	17	33	NW. ¼ NW. ¼	......do	......	107	......	1868	......	......	......	......	......	......	Oldest well in White Lake district according to W. F. Nufer.
37	12	17	28	NW. ¼ NW. ¼	Boom Co., Whitehall.	3	......	......	......	......	......	......	......	......	......	One of the older wells; date about 1873.
38	9	17	12	SE. ¼ SE. ¼	Forest Park Association, Muskegon.	25	218	2.5	1885	C. C. Jacks	218	Sand rock?	Salty	P.	......	Head 12 feet below surface.
39	9	16	2	NE. ¼ NE. ¼	Doctor Gorden, Muskegon.	16	1,600	8	1903	Fred Vance, Geneva, Ind.	340?	Sand rock	....do	23,000	11 51.8	Stated depth seems about 100 feet too great. Head 25 feet.
40	10	14	29	NE. ¼ SE. ¼	N. A. Cook, Moorland.	95	115	......	1895	......	......	......	Mineral	8,640	......	Formerly emitted combustible gas abundantly.
41	9	16	35	SE. ¼ SE. ¼	Spring Lake Iron Co., Fruitport.	16	150	2	1883	C. C. Jacks	......	......	Salty	7,200	12 53.6	Flow decreased by leakage. Head 25 feet.
42	9	16	35	SE. ¼ SW. ¼	Grand Rapids, Grand Haven and Muskegon R. R., Grand Rapids.	26	255	......	1871	......	......	......	Mineral	P.	......	Formerly sold in carloads for medicinal use.
43	11	17	36	SW. ¼ SW. ¼	Jacob Johnson, Whitehall.	50?	88	......	......	......	......	......	......	......	......	
44	10	13	33	NW. ¼ NE. ¼	D. Neff, Ravenna, R. F. D.	......	45	2	1895	M. Doubleday	......	......	Hard	1,440	......	Head 1 foot.
45	10	13	28	NW. ¼ NW. ¼	Charles Fraligh, Canada Corners.	......	......	......	......	......	......	......	......	......	......	
46	10	16	30	NW. ¼ NW. ¼	Pere Marquette R. R.	8	2,200	......	1868	......	......	......	Salty	Choked.	......	Finally plugged to stop flow.
47	10	16	17	SE. ¼ NE. ¼	Leon J. Smith, Muskegon.	6	......	2	1898	......	......	......	......	......	......	Head about 18 feet

WATER SUPPLIES OF OCEANA COUNTY.

By Myron L. Fuller.

TOPOGRAPHY.

Oceana County borders on Lake Michigan about midway of the eastern side of the lake, the village of Hart being the county seat. The southeastern part is occupied by a gravel plain, through which White River flows. North of this gravel plain is a very prominent morainic system about 12 miles in width running across the county in a course north of east, the villages of Hart and Crystal Valley being on its inner border and New Era, Walkerville, and Ferry near its outer border. White River drains its southern part and Pentwater River most of its northern. The south branch of Pere Marquette River drains a small tract in the northeastern part of the county, and there are small streams directly tributary to Lake Michigan along the western edge. In the northwestern part are sandy plains which have been covered by the glacial lake waters, but elsewhere the glacial lakes extended but little beyond their present limits of Lake Michigan. The morainic system reaches altitudes of more than 1,000 feet, or about 450 feet above Lake Michigan, and has a general elevation of about 300 feet above the lake. The rock surface appears to lie nearly 300 feet below the lake, as indicated by borings at Hart and Shelby. The drift may therefore reach a depth of fully 700 feet in places within the county. Numerous wells in the high parts are 100 to 180 feet in depth, and water there shows the very little rise. Flowing wells are obtained in recesses along the borders of the morainic system and in valleys traversing it.

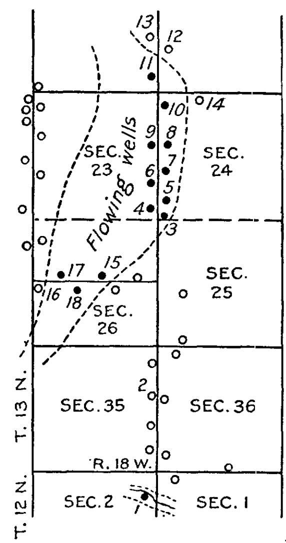


Fig. 4.—Sketch map of Flower Creek artesian district, Oceana County.

FLOWING WELLS.

FLOWER CREEK DISTRICT.

The Flower Creek district lies along lowlands, mainly in secs. 11, 13, and 26, T. 13 N., R. 18 W., including a small area in secs. 12 and 24. It is situated in the southwestern part of the county near where Flower Creek post-office was formerly located, and is about 5 or 6 miles northwest of Montague. The thirteen flowing wells of the district (see fig. 4) are located along the flat terrace bordering the creek, some 30 feet or more above it. Back of the terrace, on both the east and the west, the morainal hills rise to a considerable height. The statistical data relating to the wells are presented in the table below. Sufficient agreement of depths is shown to indicate for the northern wells at least (Nos. 3 to 11) a uniform source of supply from a water-bearing layer sloping somewhat rapidly to the northwest and drawing its water from the morainal hills to the southeast. Of the three wells (Nos. 15, 17, and 18) at the southern end of the district, Nos. 15 and 18, or the two easterly wells, yield a medium hard water containing iron, while No. 17, although drawing its supply at the same depth as No. 18, gives a soft water free from iron. This probably indicates a separate source of the water in the different wells, due either to the presence of two distinct beds or to a single bed receiving additions of water from both the east and the west, the former hard and irony and the latter soft. It seems probable that Nos. 15 and 18 are not on the same vein as Nos. 3 to 11, as the flow under similar conditions is many times greater. The source, however, as in the case of the latter, is in the hills to the southeast. The Charlotte Smith well (No. 1) belongs to a separate and very limited district occurring along the creek bottom in secs. 1 and 2, T. 12 N., R. 18 W.

Wells of Flower Creek artesian district.

No. on fig. 4.	Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water bed.	Flows at—	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Feet.		*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	Charlotte Smith [a]		611		2	Deep.		+ 1	$\frac{1}{36}$	56		Slight iron.
2	Unknown				2	30						
3	Jacob Conrad [b c]	William Dennis	649	1890	2	103	546	+ 4	$\frac{3}{4}$	$49\frac{1}{2}$	Quicksand	Iron; very hard.
4	Conrad & Fuller [c]	do	638	1901	2	107	531	+ 7	$1\frac{1}{4}$	$49\frac{3}{4}$	do	Iron; medium hard.
5	J. H. Conrad [d]	Dennis	645	1891	2	105	540	± 0	$\frac{1}{2}$		do	Do.
6	George Kinkie	Dennis (?)	640	1884	2	120	520	+ 5	$\frac{1}{2}$	$50\frac{1}{2}$		Slight iron.
7	Peter Delemater [e]	Peter Dennis	649	1872	2	112	537	+ 5	$\frac{1}{3}$	$49\frac{3}{4}$	Sand and gravel	Iron; medium hard.
8	Aug. Lohman [f]	Sykes	654	1895	2	130	524	+ 2	$\frac{1}{8}$		Gravel	Iron; hard.
9	George Kinkie [f]	Dennis (?)	649		2	130	519	+ 3	$\frac{1}{8}$			Medium hard.
10	William Grumm [g]	Sykes	663	1886	2	139	524	+ 2	$\frac{1}{8}$		Sand	Iron; medium hard.
11	Peter Shirtum [h]	Dennis	673	1886	2	180	493	− 3			Quicksand	No iron; hard.
12	Joe Schailler		678		2	100+	578	− 3				
13	Carl Strohl [i]		685		2	150+	535	− 9				
14	Unknown		685		2	90	595	−Many.				
15	J. T. Fohlbrook	Dennis	635	1899	2	117	518	+ 5	27	$49\frac{3}{4}$	Quicksand	Iron; medium hard.
16	Eagle [j]		600		2	40	560	− 20				
17	Richard Fohlbrook	Dennis	630	1899	2	150	480	+ 4	$\frac{1}{2}$			No iron; soft.
18	Pfund	do	635		2	153	482	+ 3	10	$49\frac{3}{4}$	Sand	Iron: medium hard.

[a] Located on a low terrace, less than 10 feet above the creek, and has flowed a tiny stream for many years, indicating a very close-textured water horizon. The outlook for wells in that vicinity is therefore not good.

[b] Encountered clay all the way to the quicksand except through a few feet at the top. Flow varies with the season.

[c] Used in a creamery and in boilers, the latter requiring cleaning every two months. Well reduced to one-half inch. Soil, 2 feet; clay, 5 feet; alternating clay and sand to bottom, with water between 35 and 60 feet. No decrease of supply. A curious statement is made that the wells on the west side of the road do not vary in flow, but that those on the east fluctuate with the level of a swamp 2 miles east, but it is doubtful if the fluctuation is anything more than a coincidence.

[d] Formerly flowed, but now piped into barrel set in ground and supplying the barn at lower level by an overflow pipe.

[e] First flowing well of the district. Nothing but clay was found except a thin water bed at 70 feet and the sand and gravel at the bottom. The water at 70 feet rose but little.

[f] Decreased since first sunk; show seasonal variations of flow.

[g] Now pumped.

[h] Ceased to flow in dry spell about 1895, and has not flowed since, possibly because of the clogging of the well.

[i] On a knowl in a rolling morainal country, some of the hollows being low enough to give a flow if the same water bed which occurs in the wells to the south is present. They have not therefore been tested.

[j] No attempts to obtain flow. Houses along road bordering secs. 23 and 26 on the west have only shallow wells, mainly less than 40 feet.

The water of the Flower Creek wells carries a much larger amount of iron than most Michigan waters, but is of about the average hardness. Wells Nos. 15 and 18 are highest in iron and lime. Wells Nos. 3 and 11 carry somewhat less iron, but are about as hard. No. 17 is low in iron and unusually soft.

It is probable that wells drilled anywhere along the road between Nos. 3 and 11 would obtain flows, but they would not be large, since the supply, as indicated by the seasonal fluctuations, is limited, being about all utilized by the present wells. Wells drilled some distance west of the road and nearer the center of the district would also probably obtain flows. The best wells will perhaps be found at the southern end of the district, where the supply seems to be more abundant. It is not probable that the flowing area will be extended much to the west, as the land begins to rise rapidly within a short distance, but it is not impossible that deep wells east of No. 15 and not far away would obtain good flows. The water bed at the Charlotte Smith well (No. 1) seems to be too close textured to give up water rapidly, hence the prospects for satisfactory flows in this vicinity are small.

SHELBY DISTRICT.

The Shelby district in western Oceana County is in secs. 30 and 31, T. 14 N., R. 17 W., and secs. 25 and 36, T. 14 N., R. 18 W., and is about 3 miles southwest of Shelby village. It lies along the east-west valley near the south line of secs. 25 and 30, and is bordered by high

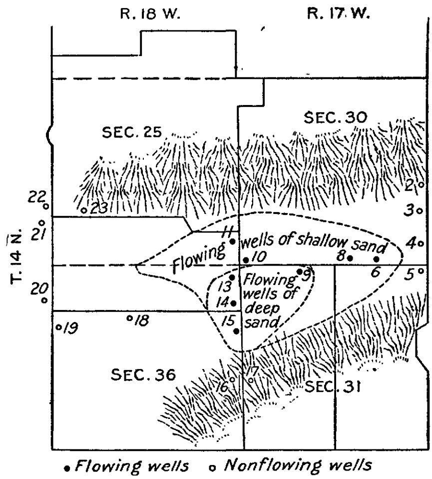


FIG. 5.—Sketch map of Shelby artesian district, Oceana County.

morainal hills on both the north and the south. The creek has cut its channel to a considerable depth below the rolling terrace on which the wells are located. The character of the wells surrounding the district is shown in the table given below. (For locations, see fig. 5.) With only one or two exceptions, every house in the district has a deep well which flows. All are stopped down to small pipes.

Wells of Shelby artesian district.

No. on fig. 5.	Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water.	Head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Feet.		*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*	° *F.*		
2–4	Several [a]		700		2	All shallow.					Sand	Soft.
5	F. Perkins [b]	Wm. Dennis	705		2	112	593	−5			Sand or gravel	Hard.
6	John Lewis [c]	do	685		2	115	570	+18	8	48½	do	Do.
7	I. Floyd [d]	J. Round	677		2	125	552	+Many.	18	48¾	do	Do.
9	G. O. Anderson [e]		685	1891	2	174	511	+15	Many.		do	Iron; hard.
10	A. Anderson [f]		675	1894	2	125	550	+Several	Many.		do	Hard.
11	John Anderson [g]	Wm. Dennis	675	1892	2	100	575	+6	Several.		do	Do.
13	Geo. Nelson [h]	do	667	1894	2	220	447	+6	10	49½	do	Iron; medium hard.
14	John Josephson [i]	Chas. Denno	657	1890	2	182	475	+20			do	Iron; hard.
15	Moses Burke	do	666	1893	2	180	486	+20		47¾	do	Iron; medium hard.
16	S. E. Lewis	(*j*)	687	1865		50	637	−Few.			do	Hard.
17	L. Lewis [k]	(*j*)	693			20	673	+0			do	Do.
18	P. J. Esperhaug		650	1892	2	55	595	−0			do	Do.
19	H. Hendrickson		655			50	605	−0			do	Do.
20	Andrew Myrmal		640			40	600	−0			do	Do.
21	Thos. Kelley		680			12	668	−8			do	Medium soft.
22	Schoolhouse		665			85	580	−12			do	Hard.
23	B. Karstad		660			80	580	−0			do	Good.

[a] All shallow, being simply short pipes driven into the sand and other material, and using suction pumps.
[b] Small flow, a mere drizzle at 90 feet, but lost it on going deeper.
[c] Used for the irrigation of strawberries.
[d] Started with a small flow, which rapidly increased. Sand 5 feet, hardpan 3 feet, sand 5 feet, quicksand 47 feet, clay 65 feet.
[e] Piped to a residence, a house across the street, a barn, and a watering trough in the road.
[f] Under cover in a house.
[g] Threw a 2-inch jet 5 feet high at first, now piped to residence, milk-house, and barnyard.
[h] In sinking well 100-foot length of pipe sunk under its own weight and disappeared in the soft gravel.
[i] In clay for practically entire depth.
[j] Dug.
[k] Went 20 feet without getting water, but during a thunder shower, when the workmen were away, the water broke through from below, filled it to the top, and overflowed. The breaking through was possibly due to the lessening of the atmospheric pressure during storm and the weakening of the stratum below which the water was held under pressure.

If the records of the wells are studied two interesting points are evident: (1) Wells Nos. 9, 13, 14, and 15 are much deeper than the others of the district, and (2) the waters of these wells contain much iron, while the others do not. Constructing a section from the records (see fig. 6) we have not only evidence of two distinct water beds along the township line, but evidence of slopes toward the valley in both directions, presumably due to the bending of the beds into a trough, which probably accounts in part for the unusually large flows.

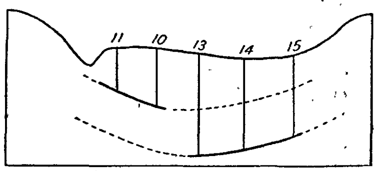


FIG. 6.—Diagrammatic section across Shelby artesian district from north to south, showing upper and lower artesian horizons and trough-like structure.

The water of the Shelby district is considerably softer than the average Michigan water, and is therefore unusually satisfactory for domestic purposes. There is a very slight amount of iron in the waters from the upper sand, but about three times as much in the lower sand. Partial analyses of the John Anderson water, representing the upper sand, and the Nelson water, representing the lower sand, are given on page 91.

The area in which flowing wells may be expected is outlined in fig 5 (p. 49). This area might be extended slightly by wells at low points

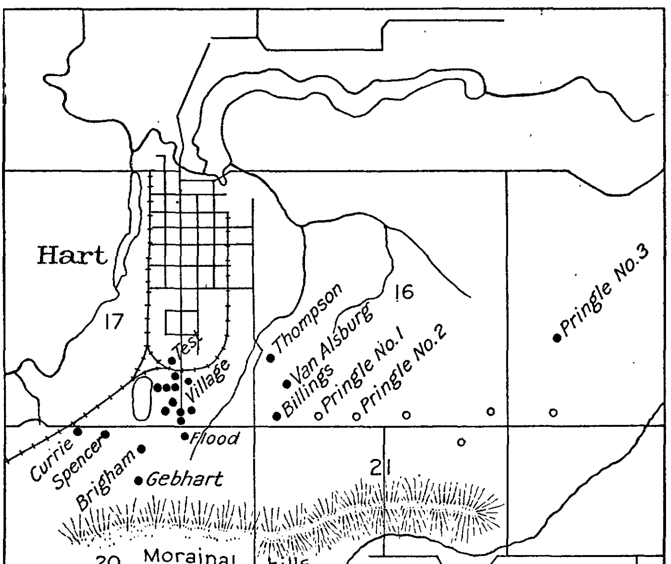


FIG. 7.—Sketch map of Hart artesian district, Oceana County.

of the valley to the east or to the west, but not to the north or to the south, as the land rises steeply in these directions. There is sufficient water in the district to supply the needs of a much greater number of people than now live there.

HART DISTRICT.

Hart, the county seat of Oceana County, is located on a somewhat irregular sloping terrace. At the north edge of town it is cut by a valley occupied by ponds and a large creek some 30 feet below the railroad. To the south, or away from the creek, the surface rises gently for three-fourths of a mile or more to the foot of morainal hills of some height (see fig. 7).

The shallow-water supplies at Hart have been found to be irregular in depth and in amount, but in general only small amounts of water have been obtained. At present very few shallow wells are used, nearly every house at the upper end of town having either a flowing well or a deep well pumped by windmill, while in the town itself nearly all supplies are obtained from the public water system (p. 59), which furnishes an abundant supply from an unusually complete system of mains. The location of a portion of the wells is shown in fig. 7, while data relating to these and to others not shown on the figure have been compiled into the following table:

Wells of Hart artesian district.

Owner.	Driller.	Elevation of well.	When drilled.	Diameter.	Depth.	Elevation of water bed.	Head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
		Ft.		*In.*	*Ft.*	*Ft.*		*Gals.*	*°F.*		
Robt. Currie	....	747	1900	2	110	637	+0	....	....	....	
Ed. Spencer[a]	....	736	1903	2	135	654	0	....	....	....	
B. Gebhart[b]	....	742	1901	2	160	582	−1½	....	....	....	
S. C. Brigham[c]	Joe Mull.	730	1904	2	100	630	+18	36	49¾	Sand, gravel	Hard.
J. K. Flood[d]	.....do..	730	1900	3	117	613	+9	Many.	....	.....do......	Medium hard.
Village (see p. 59)	Jacks...	730	{1895, 1898}	6	{112, 152}	{578, 618}	+20	Many.	....	.....do......	Do.
John Billings[e]	Joe Mull.	710	1901	2	107	603	+20	Many.	....	....	Hard.
Van Alsburg[f]	.....do..	700	1900	2	150	550	+40	Many.	....	Sand, gravel	Iron; hard.
H. B. Thompson[g]	....	690	......	2	.....	.....	+2	2	49½	....	
F. M. Pringle No. 1[h]	....	720	......	2	120	600	−0	....	....	Sand	
F. M. Pringle No. 2	....	715	......	2	40	675	−0	....	....	Clay	
F. M. Pringle No. 3[i]	....	710	......	2	65	645	+4	....	....	.....do......	

[a] Obtained water at 82 feet and below, but on reaching depth of 135 feet it was all lost in the hardpan at that point.
[b] Originally about 50 feet deep, but deepened to 160 feet on account of failure of the supply.
[c] Shallow water was encountered above clay at 40 feet; flow from the lower horizon is a strong one but it is restricted to a small pipe; not affected by the village wells.
[d] No water above the main flow except at the surface. Piped to barn, house, and watering trough. There are several hydrants on the place to which fire hose and hose for sprinkling can be attached. The supply is said to be affected by the town wells.
[e] Threw jet to top of porch 15 feet high when first sunk.
[f] Located near south line of block 137, several hundred feet south of a slaughter house, and one-eighth of a mile from the road. Head tested to height of 40 feet; a 2-inch jet was thrown 8 feet. Much sand and gravel was brought up by the water at first. Soil 3 feet, hardpan 1 foot, sand 15 feet, clay 127 feet sand and gravel 4 feet. Water is piped to barn, slaughterhouse, and residence and used for all purposes. No effect by the town wells is noted.
[g] Formerly owned by Mr. Waller; is small well, but is used by 5 families.
[h] Encountered only sand.
[i] Penetrated only clay until near the bottom.

The deepest well at Hart is the test boring made just north of the railroad opposite the warehouse, at an elevation of about 730 feet (see p. 59), which was drilled by Mr. Jacks to a depth of 412 feet.

Sandstone was encountered at 371 feet and the bottom of the well was in shale. The vein furnishing the flows in the vicinity was drilled through without stopping, and the final well furnished little water. A boring known as "Henman's boring," said to be located some 40 feet lower than the preceding and to be 200 feet deep, is reported, but could not be located. Four wells are reported at the warehouse: One is said to be 171 feet deep and flows; the other three are noted in connection with the waterworks on page 59; the materials penetrated were: Clay 5 feet, sand 25 feet, clay with pebbles to bottom. The water was from sand and gravel, surface supplies being encountered at 7 and 20 feet. These wells were drilled in 1902 and are 4 inches in diameter.

Beginning with the Brigham well and going north to the warehouse there is a very regular increase in the depths of the wells. This indicates a uniform source of supply from a bed tilting gradually northward. The Gebhart well, if its depth is correctly stated, draws its supply from a bed probably 75 feet lower, while the Currie and Spencer wells seem to draw from a higher horizon, although if the bed furnishing supplies to the waterworks wells rises sufficiently abrupt it may be present at the depths indicated by the two wells mentioned. The Billings and Van Alsburg wells probably draw from the same bed, which possibly is the same as that at the waterworks. The Thompson well, judging from its small flow, is probably from a higher horizon, although its depth could not be ascertained. The horizon at the Pringle No. 3 well can not, with the present information, be correlated with any of the water beds nearer town.

The water carries a small amount of iron, a considerable amount of salt, and is of average hardness. A partial analysis is given in the table on page 91.

The conditions, while sufficiently variable to make prediction of the exact depth at which water will be found uncertain, appear to be unusually favorable to artesian flows, which can probably be obtained almost anywhere on the lowlands to the north of the morainal hills, indicated in fig. 5, where the altitude is less than 730 feet (or that of the Brigham well), and when the distance is not more than one-half to three-fourths mile from the hills. At distances greater than this flows are less likely because of the liability of the water-bearing sands to pinch out. The depths of the wells will generally vary from 125 to 175 feet, although it may be necessary to go deeper in some cases. If the well is properly sunk, the flow should be large.

CRYSTAL VALLEY DISTRICT.

The village of Crystal Valley, in northern Oceana County, is located on a terrace bordering a small stream, to the north and south of which the morainal hills rise to a considerable height. (See fig. 8.) There is only one well (No. 1) actually flowing at the point where drilled, although several (Nos. 2, 3, and 4) rise nearly to the surface, and one (No. 5) is piped sidewise to flow at a slightly lower level. Statistical data relating to the wells at this point are given in the following table:

Wells of Crystal Valley district.

No. on fig. 8.	Owner.	Driller.	Elevation of well.	Date drilled.	Diameter.	Depth.	Elevation of water bed.	Head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Ft.		*In.*	*Ft.*	*Ft.*	*Ft.*	*Galls.*	°*F.*		
1	H. C. Lockwood.	S. Cree.....	712	1898	2	97	615	+11	5	*a*50½	Gravel.	Iron.
2	Mrs. Linn Kinney	....	720	......	2	40	680	− 2	Many.	....		
3	L. C. Beadle.....	L. C. Beadle.	720	1898	2	16	704	−15	....	....	Sand..	Soft.
4	J. W. Perkins...	S. Cree.....	725	1899	2	126	599	− 2	....	....	Gravel.	Iron; medium.
5	R. W. Kittridge.	.....do......	730	1899	2	87	643	− 2	1	*a*50½	...do...	Soft.

a Both measurements of temperature were made after the water had flowed through a pipe of some length and are possibly one-half degree too high.

An examination of the table shows that there is no general water-bearing bed, unless, as is very likely the case, the Lockwood and Perkins wells draw from the same horizon. If this is so, its slope is decidedly to the south, and the source of supply is doubtless in the hills to the north. The water of the Kinney well, although having approximately the same head as the others, is not from the same bed. The Beadle well is inserted simply as a type of the shallow wells. The Kittridge well may possibly be from the same horizon as the Perkins and Lockwood, but in the absence of wells in the mile stretch intervening this can not be certainly determined.

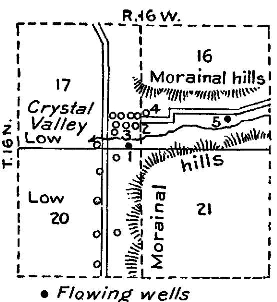


FIG. 8.—Sketch map of Crystal Valley artesian district, Oceana County.

The deep-well water is of about the average quality. It tastes of iron, is hard, and gives considerable scale. The supplies from the surface wells are considerably softer.

Flows can probably be obtained at almost any point which is not more than 6 or 8 feet above the level of the creek. The head is sufficient to give flows on the terrace on the south side of the stream, but not on the north. The volume is such that hydraulic rams attached to wells at creek level would pump sufficient water to the houses for domestic supplies.

ELBRIDGE DISTRICT.

The Elbridge district, at present represented only by a single flowing well, is located a few miles east of Hart along the broad valley bordering the streams in the northern portion of secs. 8 and 9, T.

15 N., R. 16 W., the supply coming from the high morainal hills about Elbridge settlement, one-half mile to the south. (See fig. 9.)

The flowing well (No. 2) is owned by Isaac Timmons. The data are as follows: Altitude, 712 feet; drilled in 1901; depth, 93 feet; water from blue gravel; flows at +4 feet; tested to 18+ feet; yield, 3 gallons a minute; temperature, 49½°. The materials are: Sand, 35 feet; clay, 55 feet; gravel, 3 feet. The well is located several feet above the level of the creek bottoms.

At the mill one-half mile east and a little north of Timmons a well failed to get water on the flats at 100 feet, although most wells in the vicinity (as No. 1) get abundant surface water. Near by are large sulphur springs, which form a considerable stream and deposit a white coating of sulphur. A deep well (No. 3), one-fourth mile north of Timmons, failed to get a flow, which was to be expected, as it is many feet higher. A well at the corner blacksmith shop in Elbridge (No. 4) went through 20 feet of sand and 40 feet of clay into water-bearing gravel at 60 feet, the water rising to within 16 feet of the surface. Surface water was obtained at the store on the opposite side of the road at 16 feet. A well 60 feet deep in the hollow back of the blacksmith's and 20 feet lower got water rising to within 1 foot of the surface. Gus May, 2 miles east and one-half mile south of Timmons well, drilled 92 feet and obtained about 1 quart a minute. The well was drilled by Hardy. The wells in the morainal hills are generally 50 to 100 feet deep.

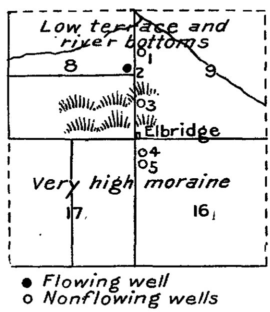


FIG. 9.—Sketch map of Elbridge artesian pool, Oceana County.

The water of the Timmons well is of average quality as regards iron and lime. For partial analysis see page 91.

The only good prospects for flows are along the flats of the creek bottoms adjacent to the base of the morainal hills. The majority of wells sunk at such locations to 100 or 150 feet would probably be successful, although an occasional failure is to be expected, as was the case at the mill. Abundant water supplies, however, are generally to be had at slight depths, and will doubtless prove satisfactory as long as the country is not too thickly settled.

TIGRIS DISTRICT.

The Tigris district is a short distance east of Hart. Like the Elbridge district it has at present only one flowing well, although the drilling of others is contemplated. The conditions are illustrated in fig. 10. Along the north and east side of sec. 13, T. 15 N., R. 17 W. the land rises into morainal hills of considerable height, while the remaining portion of the section is moderately flat. Along the base of these hills occur a considerable number of springs, a few of which have formed mounds of silt of some size.

It was near the base of the hills that the Amos Relinger well was sunk in 1902. It is a 2-inch well, 115 feet deep, and obtains its water from gravel. The water, which will rise 15 feet or more, is piped into the house. The yield is 12½ gallons a minute. It tastes slightly of iron and is medium hard, though giving little scale.

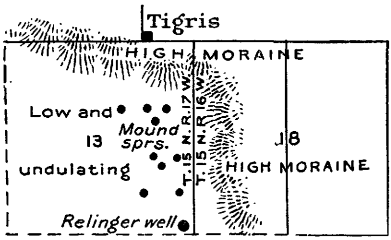


FIG. 10.—Sketch map of Tigris pool, Oceana County.

The water of the Relinger well doubtless comes from the east, although in the northern portion of the section supplies may also be received from the north. It is probable that deep wells almost anywhere along the base of the hills would obtain flows.

LATTIN DISTRICT.

The postmaster at Lattin reports the wells in the neighborhood to be from 30 to 250 feet deep, the largest supplies being at about 100 feet, which is the common depth in the vicinity. The water in both the shallow and the deep wells is hard. He states that some flowing wells are obtained at the surface without pumping.

WEARE DISTRICT.

This district is located in secs. 34 and 35, T. 16 N., R. 17 W., a mile or two west of Weare and 3 or 4 miles northeast of Hart. The flowing wells are on a gently rolling slope pitching away from the high morainal hills in the northern portion of the sections (fig. 11). The ground is still lower to the south, but because of lack of persistence of the water-bearing beds and the loss of head no flows are obtained. Data relating to the wells are given in the following table:

Wells of Weare district.

No. on fig. 11.	Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water bed.	Head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Ft.		*In.*	*Ft.*	*Ft.*	*Feet.*	*Gal.*	*°F.*		
1	Several		750		2	90	660	—75			Sand and gravel.	Slight iron, moderately hard.
2	Victor Symonds	Joe Mull	690	1899	2	58	632	—2	¼		Gravel	Do.
3	H. Warmuskarker	do	690	1900	2	58	632	—2			do	Do.
4	Unknown		680		2	(a)		(b)			Sand	Do.
5	John Lipp	Joe Mull	670	1897	2	128	542	+5	¾	49¾	Gravel	Do.
6	Henry Baker		665		2	6	659	—1			do	Do.
7	John Lipp, jr	K. Clay	662	1904	2	428		None.			Clay	Do.
	do	do	662		2	150	512	—15			do	Do.

[a] Shallow.

[b] Several feet below surface.

The wells at the crest of the hill (No. 1), of which there are several, get plenty of water, although it rises but little. The Victor Symonds and Henry Baker wells are piped sidewise to lower ground to give flows. The surface material is sand to a depth of 15 to 20 feet, after which clay is struck, which continues, with the exception of a few thin sandy beds, to a depth of at least several hundred feet. Several attempts to obtain water were made at the John Lipp, jr., place. Except for 10 feet of sand at the top all was clay to the bottom of the deepest well at 428 feet. Another well a few feet away was sunk to 150 feet and found water at the bottom, which rose to within 15 feet of the surface, but the clay from which it came so clogged the pipe that the well could not be used. Another well 135 feet deep gave similar results. These wells are said to have been located by means of the "switch" or divining rod and are notable failures.

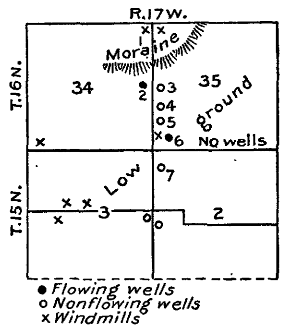


FIG. 11.—Sketch map of Weare pool, Oceana County.

The water is low in iron and of about average hardness. A partial analysis is given on page 91.

The prospects of additional flows in this locality are poor, because of the presence of a great thickness of clay with very few porous seams capable of carrying water. Doubtless such seams occur locally, but their location can not be foretold.

FERRY DISTRICT.

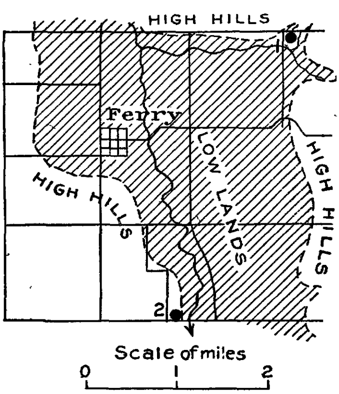


FIG. 12.—Sketch map of Ferry district, Oceana County

This is not a district in the proper sense, as the two flowing wells in the vicinity are several miles apart and of diverse occurrence. The name is simply given for convenience of discussion.

The locations of the wells are shown in fig. 12.

Well No. 1, the James Osborn well, is located on a flat lying between the high morainal hills which rise along the northern edge of sec. 23, T. 14 N., R. 16 W., and the westward flowing stream one-fourth mile to the south. The elevation is about 950 feet, diameter 2 inches, depth 90 feet. The materials were alternating clay, sand, and gravel, with some water for 40 feet, then clay for 50 feet to the water-bearing sand at the bottom. The well ran a small stream for a year and suddenly the flow changed to a strong stream, as if the water had broken through a hitherto impervious layer. It was drilled in 1900 by

Charles Cushman. The flow is through a ⅛-inch perforation in the well cap 3 feet above the surface, but the water would probably rise considerably higher. Shallow waters are readily obtained in the vicinity and no other deep wells have been sunk. The water is unusually soft for Michigan and has but little iron. For partial analysis see page 91.

Well No. 2 was sunk in 1898 for B. A. Wiswell by Charles Cushman, driller. It is located on a slope between the stream flats in the SE. ¼ sec. 34, T. 14 N., R. 16 W., and the morainal hills rising immediately to the west. Its altitude is probably about 955 feet. The well is 2 inches in diameter, 78 feet deep, and penetrated 8 feet of clay loam, 10 feet of quicksand, and 60 feet of clay. The flow is three-fourths of a gallon a minute at 6 feet, but will be nearly as strong 10 feet above the surface. It has no taste, but has slight sulphur odor. It forms little scale. The flow increases before a storm. The temperature is 48¾°. No other wells in the vicinity go deep enough to obtain flows.

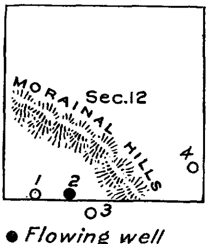


FIG. 13.—Sketch map showing flowing and adjacent wells, Greenwood district, Oceana County.

The lowland area bordering the stream passing through Ferry and the position of the bordering highlands are indicated in fig. 12. The hills are high and sandy and present ideal catchment conditions. The two deep wells which have been sunk near its edge have been successful in obtaining flows, and it is probable that similar flows could be obtained elsewhere along the border and probably for a distance of one-fourth to one-half mile distant from the margin. It is possible that flowing wells might be had, even in the middle of the lowland area. As yet, however, because of the abundance of shallow water supplies, no deep wells have been sunk in this region. At Ferry the wells are all probably under 30 feet in depth. The materials are very variable, but some clay is reported. It is probable that at Ferry a depth of 100 feet or less would be sufficient to give flows.

GREENWOOD DISTRICT.

The name of Greenwood Township is applied, for want of a better one, to the district containing the wells about 3 miles southwest of Hesperia in sec. 12, T. 13 N., R. 15 W. and vicinity, the location of which is shown in fig. 13.

The flowing or nearly flowing wells are located near the base of a series of morainal hills of some height bordering the flats in the southwest corner of the section. A few details regarding the wells are given in the accompanying table:

Wells of Greenwood district.

No. on fig. 13.	Owner.	Elevation of well.	Date drilled.	Diameter.	Depth.	Elevation of water bed.	Head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
		Feet.		*In.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*° F.*		
1	Unknown	950		2	40	920	—16				
2	Isaac Bronstrom	960	1898	2	46	916	+18	4	48½	Gravel.	Iron; very hard.
3	J. Donahue	970			71	899					
4	Unknown	1,000		2	200	800	— 0				

The Bronstrom well was driven 28 feet and drilled the rest of the way in "pebble rock," possibly cemented gravel. It may be, however, that bed rock was actually encountered, as rock is reported in other wells in the region and bowlders are unusually numerous a short distance farther west. The casing extends only 36 feet. The original flow was 8 gallons a minute, but the well is now stopped down to about half. The Donahue well originally flowed a small stream 2 feet above the surface, but ceased a few hours after the Bronstrom well was opened, thus furnishing an interesting case of a higher well affecting the supply of a lower well on the same vein.

WATERWORKS.

HART.

The Hart waterworks are located on a terrace at the southern edge of the town, 45 feet or more higher than the lower or northern edge and 75 feet higher than the creek. (See p. 52.) The supply is from 6 flowing wells 112 to 152 feet deep, the individual depths being 152, 138, 125, 116, 114, and 112 feet. The altitude of the wells is about 730 feet, which would make the elevation of the water bed 578, 592, 605, 614, 616, and 618 feet, respectively. Three of the wells were sunk in 1895; the others in 1898. Mr. Jacks was the driller. The diameter of the wells is 6 inches; head, 16 feet; supply, large; temperature, 49¾°; no taste; slight scale; medium hardness. For partial analysis, see page 91.

The water flows directly from the wells into the pipes, the pressure being about 8 pounds at the station in winter. In summer this is reduced to zero. The capacity of the pumps is 750,000 gallons a day, but 500,000 gallons is the greatest amount so far used, this draft lowering the water to 15 feet below the surface. There are 30 fire hydrants and about 400 taps, supplying somewhat over 1,000 people. The supply is not as large as could be desired and a reservoir is talked of.

An additional supply is derived at times from three wells at the Slaght warehouse, which are owned by the village, but leased with the building. They are 4 inches in diameter and 157, 164, and 166 feet deep.

SHELBY.

Shelby is located in a valley between hills of morainic drift, the elevation at the railroad station being 807 feet. The hills are 100 feet or more higher. The wells in town vary from about 45 to 120 feet in depth, the most common depth being between 50 and 100 feet. The largest supplies are said to be obtained at about 70 feet. The water was mostly quite hard.

The deepest well in the town is at George Getty's mill, at an elevation of 807 feet. The depth of the well is 516 feet. Near the bottom the pipe struck a stone and was deflected, making it necessary to abandon the well. Very little water was obtained, and it did not originally rise near the surface, but it was thought that a flow was passed through on the way down. The well was capped and allowed to stand for some time. On taking the cap off the well flowed weakly, but ceased soon after. An attempt was made to dynamite the pipe at the supposed water horizon, but the shot was exploded by a blunder at 50 feet and the well was ruined. It is not impossible that flows may be obtained along the valley near Shelby.

The public water supply is derived from two wells located at the electric-light and water plant on the east side of the village and owned by the town. The wells are 125 feet deep, but the water rises to within 70 feet of the surface and is pumped to a circular brick reservoir on the hill east of and above the waterworks, and from there it is distributed. It is under a pressure of 72½ pounds. The daily supply is usually from 100,000 to 200,000 gallons.

PENTWATER.

Pentwater, in northwestern Oceana County, is located on a sandy flat about 5 to 15 feet above Pentwater Lake, an inclosed bay connected with Lake Michigan by an artificial channel. The country back of the town rises more or less gradually to a broad terrace 100 feet or more above the lake level.

The wells in town are generally very shallow, extending to lake level or less, 16 feet being about the average depth. The material near the shore is mainly sand; farther back there are some thin clay seams. In a well sunk by Sands and Maxwell at the corner of Hancock and Fourth streets to a depth of 187 feet, the material was all till below the upper 15 to 20 feet, which was sand. The well did not flow.

The public supply is obtained mainly from 40 to 45 wells, 8 to 10 feet above lake level, situated along Hancock street between Second and Third, and west along the latter streets for half a block or more. The depths are from 16 to 24 feet and the diameter from 2 to 4 inches. Three-foot strainers are used with the 2-inch pipe and 5-foot strainers with the 4-inch pipe. Strainers 4 inches in diameter were formerly connected with 1½-inch pipes, but the flow was so sluggish through them that they soon became clogged. The strainers now used are only slightly larger than the well pipe and much less trouble is experienced. The water, though not tasting of iron, deposits a reddish sediment. There is also a distinct organic taste, variously attributed to lack of proper flushing of the pipes or to the drawing in of lake water when pumping is excessive. It should be noted, however, that the taste is less conspicuous at the wells than in the more remote parts of the system.

While the water is only moderately hard and there is nothing in its analysis to indicate any difference from other Michigan waters (see analysis, p. 91), the supply can not be regarded as an entirely safe one. There is no clay or other impervious layer to prevent the seepage from privies, cesspools, etc., from passing directly downward and polluting the ground waters, especially near the surface. It is true that natural sand acts to a certain extent as a filter and through its bacteria tends to break down the dangerous substances present, but when new polluting matter is constantly being added a time will come when the ground is saturated and the ground water inevitably polluted. The remedy ordinarily would be to go deeper, where the water would be from a more remote and less thickly settled source. At Pentwater, however, glacial till, which carries very little water, is encountered a few feet below the surface. Wells sunk above the town on the east would give safe supplies, but it is not known whether sufficient volume could be obtained there. The next best source would doubtless be from wells across the harbor on the Lake Michigan shore or even from that lake itself.

The waterworks are owned by the village, but are leased to the Oceana Electric Light Company (B. C. Lindly, manager), which for the sum of about $165 per month supplies the town with water and twenty 1,000 candle-power lights. The franchise is for ten years. The average daily supply is said to be 250,000 gallons, but this can be increased to 600,000 from the wells alone, and to 1,000,000 if the lake is drawn upon. The water is distributed from a trunk main, 10 inches in diameter, along Hancock street, and by various smaller laterals. The ordinary pressure is 40 pounds, which can be greatly increased in case of fire.

MISCELLANEOUS VILLAGE SUPPLIES.

The following table gives data on village supplies:

Village supplies in Oceana County.

Town.	Source.	Depth of wells.			Depth to principal supply.	Head.	Springs.
		From—	To—	Common.			
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Allen Creek	No returns						
Cabmoosa	Driven wells, creeks	12	205	100	100	− 0	Small.
Crystal Valley	Driven wells, creeks, and artesian wells.	25	100	50	100	± 0	Do.
Elbridge	Driven wells (artesian wells near).	10	80	50	75	−40	None.
Ferry	do	12	30	25	25	− 8	Medium.
Gale	Driven wells	10	60		60	− 0	
Hart	Driven wells, artesian wells	98	197	175	175	+30	Large.
Hesperia	Driven wells, artesian wells, springs.	15	175		175	+35	Medium.
Houseman	Driven wells	30	104	90		− 0	Do.
Klondike	No returns						
Lattin	Driven wells	30	250	100	100	± 0	
Mears	do	32	112	50		− 0	
New Era	do	16	100	25	25	− 0	Small.
Peachville	No returns						
Pentwater	Driven wells	15	50	25	25	− 0	Medium.
Rothbury	do	26	30	28	28	− 0	
Shelby	Driven wells (artesian wells near).	44	121	50	70	− 0	Large.
Tigris	No returns (artesian wells near)						
Wagar	do						
Walkerville	Driven wells	6	90	60	60	− 0	Small.

WATER SUPPLIES OF NEWAYGO COUNTY.

By Myron L. Fuller.

GENERAL STATEMENT.

Newaygo County is situated immediately east of Oceana and Muskegon counties, about midway of the western side of the Southern Peninsula. It was covered by the Lake Michigan glacial lobe, at whose junction with the Saginaw lobe is in an interlobate moraine which occupies the eastern part of Newaygo County and the western part of Mecosta. This moraine has points within the county whose altitude exceeds 1,200 feet, and its general elevation is more than 1,000 feet. It is traversed by Muskegon River, which leaves it on the west at about 700 feet above tide and descends to about 600 feet at the southwest corner of the county. West of the interlobate moraine is a gravel plain several miles in width occupying much of Home, Monroe, and Wilcox townships and parts of Everett, Brooks, and Grant townships. The western half of the county is occupied by prominent morainic tracts, which are interrupted by a network of valleys, which served as lines of glacial drainage, and which are now traversed by the South Pere Marquette and White rivers and their tributaries and by Muskegon River. Flowing wells have been found at Newaygo, in the valley of Muskegon River, at Hesperia, in the valley of White River, in and near Fremont, on a plain on the western border of a prominent moraine, and near Grove, in the southeastern part of the county on the western border of the interlobate moraine. The writer has examined all but the last of these districts and that is discussed by Mr. Bowman. As in Oceana County, wells on the elevated morainic tracts are often 100 to 180 feet in depth with but little rise of water. Much of the county is unsettled, and its water supplies are thus only partly developed. The village supplies as well as the flowing wells are discussed below.

FLOWING WELLS.

There are four artesian-well districts of some importance in this county—at Hesperia, Fremont, and Newaygo, and in Ensley and Grant townships. Several scattered flowing wells are also reported from a number of other points. A small district southwest of Hesperia is described under Oceana County.

Hesperia is located on the boundary between Newaygo and Oceana counties, the county line passing through the principal street. Two of the three wells are located in Oceana County, but as the largest well which furnishes a private water supply for a part of the town is located in Newaygo County, this district is considered here.

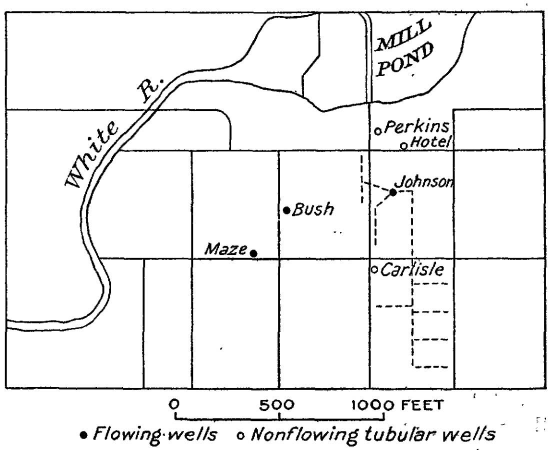


FIG. 14.—Plat of Hesperia, Newaygo County, showing locations of wells and private waterworks.

HESPERIA.

Fig. 14 shows the locations of the three wells. They are situated on a terrace adjoining White River and some 15 feet above the stream. The approximate elevation is 750 feet. The statistical data of the various wells are presented in the accompanying table for purpose of comparison.

Wells of Hesperia district.

Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water bed.	Head.[a]	Flow per minute.	Temperature.	Water bed.	Quality of water.
		Ft.		*In.*	*Ft.*	*Ft.*	*Feet.*	*Galls.*	*° F.*		
Hotel		750		2	50	900	−20				
C. M. Perkins		750		2	100	850	0				
O. H. Johnson	R. Wilson et al.	750	Old.	2	180	770	T +34	Many.		Sand	Some iron.
H. K. Bush	J. F. Bush	750	1880	2	119	831	T + 5	8	48½	Gravel.	Sulphur, iron
D. M. Maze		750	1888	2	118	832	T + 5	2			Do.
John Carlisle		750		2	65	885	− 3				

[a] T=tested head.

The Johnson well encountered many seams of sand and gravel with water all the way down, as did the Bush and Maze wells, but, with the exception of a small supply in the Johnson well at 70 feet, no flows were obtained. The water at 180 feet in the Johnson well was found beneath 20 feet of clay, which stands without casing. In the Bush and Maze wells the upper part was predominatingly sand and the lower part predominatingly clay, with water in gravel at the bottom.

Mr. F. B. Henry, well driller, Wilcox Township, reports a 2-inch well, drilled for Robert Wilson, of Hesperia, in 1900. The depth is 170 feet, the head is 38 feet above the surface, and the flow is very strong. No such well was heard of when inquiry was made on the ground, unless it may be the Johnson well (formerly owned by G. E. Eldridge).

There are at least four different water horizons being drawn upon in the town. The first general horizon is about 50 to 60 feet below the surface, and, although not furnishing flows, it is the source of most of the town wells, including the hotel and Carlisle wells. The next horizon is that encountered by the Perkins well at 100 feet, and the water rises near enough to the surface to be piped laterally to a trough on lower ground. The third horizon is at 120 feet and was encountered in the Bush and Maze wells; it gives moderate flows. The fourth is at 180 feet, yielding large flows and a strong head. A very shallow horizon was also struck in 1899 by S. Hagerdorm at 10 feet, but the flow was poor and the well was abandoned.

The surface water is probably lowest in mineral matter, and as it underlies a clay can be regarded as a safe drinking water. The water from the 100-foot or 120-foot horizons carries little iron, but is marked by a large amount of sulphates, which is very unusual for Michigan drift waters. The 180-foot water shows no sulphates, but a considerable amount of iron. Partial analyses are given in the table on page 91.

The wells are put to all ordinary uses—store, barn, hotel, and domestic. The Johnson well is especially important, since it affords the supply of a private water system, furnishing water to 15 buildings, including a hotel, barber shop, market, and several private residences (see fig. 14). The water at the highest house will rise 8 feet above the ground or 20 feet above the well. A large fountain in the yard of the owner also gets its supply from the well.

It seems almost certain that many more flows could be obtained from both the 120-foot and 180-foot horizons by wells located almost anywhere on the flat on which the town is situated. Flows may possibly be obtained on the high terrace at the southern edge of the town, but they would be less satisfactory than on the lower land. An amount sufficient for the town could probably be obtained from wells without much difficulty, and the sources are probably ample to supply a large number of private wells if not allowed to flow too freely. The water appears to come from the morainal hills south of town.

FREMONT DISTRICT.

In this district are included two clusters of wells in the town of Fremont itself, a group at Fremont Lake, a mile southwest of town, and outlying wells in the SW. ¼ sec. 8, T. 12 N., R. 13 W., and in the E. ½ sec. 22, T. 12 N., R. 14 W.

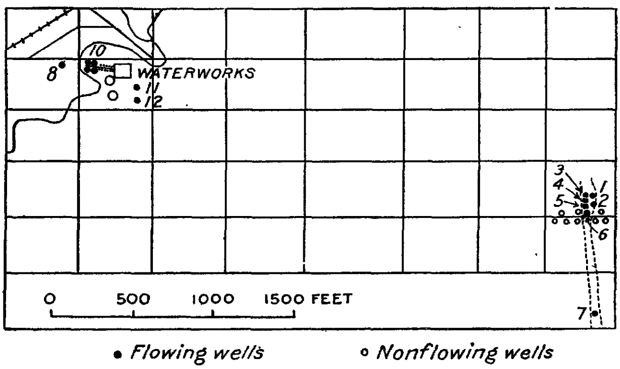


FIG. 15.—Plat of Fremont, Newaygo County, showing location of waterworks, mains, and important wells.

The location of the town wells is shown in fig. 15 and that of the outlying wells in fig. 17 (p. 69).

FREMONT.

The town of Fremont has for many years obtained its water from wells, the first being sunk about 1883. They were twenty in number, four being 6 inches in diameter and the remainder 2 inches, and were arranged along a trunk pipe extending west and a little north from the pumping station, the four large wells being at the end of the pipe. (See fig. 15.) The depths varied from 60 to 97 feet, and the materials encountered were gravel, sand (some of it much like clay), and a little clay. Ninety-mesh screens were placed at the bottom, but soon became clogged, as the water carried much iron and lime. The old wells failing to give an adequate supply, two new 2-inch wells were sunk in 1902 to 225 and 226 feet, respectively, which together yield 125,000 gallons daily. Much clay was encountered and some cemented material, like sandstone. The water is from immediately under a clay bed, and is strongly mineralized, carrying much iron, lime, and sulphates. (See table, p. 91, for partial analysis.) Some sand is brought up with the water.

The wells, which have a head of 20 feet, flow into two cisterns or reservoirs back of the station, from which the water is pumped into the mains. The ordinary pressure maintained is 60 pounds, but this can be raised to 120 pounds if necessary in case of fire. There are 18 fire hydrants.

The wells at and near the Hagerdorm Laundry, in Fremont, are located in a depression among low, rolling, drift hills, at an altitude of about 775 feet. The land rises distinctly both to the north and to the south.

The laundry is on the site of a former creamery. In digging a hole, about 1901, in which to dispose of the refuse of the creamery flowing water was encountered, and this led to the sinking of six wells. (Fig. 15, Nos. 1–6.) No. 6 is located in the laundry, and supplies the boiler; the others are situated in the rear of the building. No. 5 is the largest, and is said to have thrown a jet 3 feet high from a 3-inch pipe the top of which is about 3 feet above the ground. The water flows into a sort of reservoir. No. 2 feeds a small fish pond, and will throw a 2-inch jet 1 foot high. The water was found underneath a rather uniform clay bed at approximately the same depths in all the wells, the different depths depending upon the distance the pipe was driven into the underlying sand.

The water is free from iron and sulphates, and has only about half the lime usually present in Michigan drift waters, which makes it an ideal supply for the purpose for which it is used. A partial analysis will be found in the table on page 91.

The success of the laundry wells led the owners of adjoining property to try for flows, but none were obtained, notwithstanding the fact that trials were made within 50 feet on both sides, one neighbor putting down 6 test holes. The houses along the opposite side of the road are only about 50 feet apart, but, although all have wells deep enough to have encountered flows, none were obtained. A block and a half south, however, Mullins & Bode obtained a flow from the same horizon as the laundry, as was determined by the fact that its supply was cut off in three hours when the largest laundry well was allowed to flow freely (No. 5). This would indicate that the water seam continues for some distance, but that it is very narrow. The width can not be much over 50 feet, as it was not encountered by the neighboring houses. Its form suggests an old sand-filled stream channel afterwards covered by clay. The source of the water is probably the low hills to the south. There is some talk of utilizing the wells for a fish hatchery or public park.

The character of the materials in the adjacent wells is very variable. Some find sands with nonflowing water, others all clay, still others clay in part and sand, with water rising nearly to the surface. One well a block north went 200 feet without getting water at all. There seems to be some clay in the water-bearing bed at the laundry, as the water was roily during thunderstorms when the wells were first sunk. The flow is said to slacken when the wind is northwest.

The largest well in Fremont outside of those already mentioned is the tannery well, which is variously reported as from 200 to 280 feet deep. What appears to be the best information places it at 225 feet, or the same as the adjacent waterworks well. A shallow well, 18 feet deep, which will flow at 1 foot above the surface, is reported at the house of John Timmer, but a pump is used to raise the water to the sink. Mr. Yergin, at the west end of town, is said to have a small flow, while still another has been reported at the planing mill beyond the railroad.

FREMONT LAKE.

The wells at Fremont Lake are located on a low, flat, sandy terrace a few feet above the water's edge and within a few hundred feet of the shore. A short distance farther back the land rises abruptly some 20 feet or more to a rolling terrace, while still farther north it becomes hilly. The materials penetrated in the different wells are quite variable. In the Chamberlain well they were as follows: Sand 95 feet, clay 30 feet, sand 18 feet (water at 54 feet and at bottom), while in the Hain well there was sand to 50 feet, then clay to 100 feet. A well

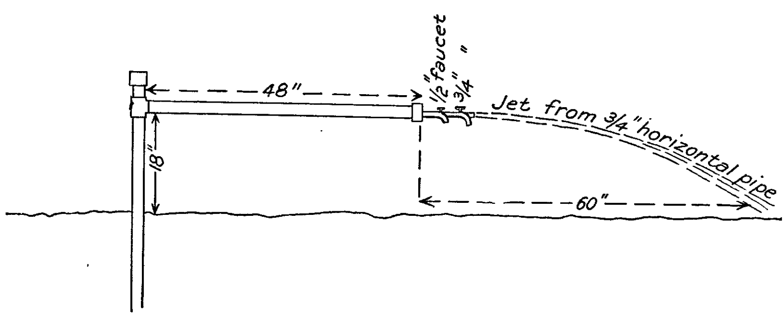


FIG. 16.—Arrangements at Hain well, Fremont Lake, Newaygo County.

sunk by Gerber, Raider, Schoolmaster, and others went 300 feet through alternating clay and sand. It is said some water was obtained at 150 feet and at the bottom, but the pipes clogged and the supply was lost. It is reported that it was intended to dynamite the well at 100 feet, but by accident the charge went off at 50 feet and spoiled the well. No flows were reported. Further data relating to the wells are given in the table on page 70.

The Hain well is so piped that it is possible to determine the flow under a number of different conditions. The results are presented below. The well is 2 inches in diameter, the casing projecting about 2 feet above the surface. At 1½ feet a 2-inch horizontal pipe 4 feet in length is attached, at the end of which is a ¾-inch pipe with two faucets, ½- and ¾-inch, respectively. (See fig. 16.) The results of the measurements were as follows:

Measurements of flow of Hain well.

	Gallons per minute.
Both faucets flowing:	
¾-inch faucet	22
½-inch faucet	8
Combined flow	30
One faucet flowing:	
¾-inch faucet	23
½-inch faucet	11
Faucets removed:	
¾-inch horizontal pipe	40
Estimated yield if flowing from 2-inch horizontal pipe	[a] 286

OUTLYING WELLS.

The schoolhouse well (fig. 17) is located in sec. 8, T. 12 N., R. 13 W., on a southwest-facing slope, about 10 feet below the crest of a rise immediately behind it and about 10 feet above the creek bottom in front. South of the creek, in the SE. ¼ sec. 7, are low, rolling, drift hills. All other wells in the vicinity are shallow. The water presumably comes from the north, probably for some distance, as the hills in the immediate vicinity are thought to be too low to give the observed head. The water tastes of iron. A partial analysis is given in the table on page 91. For additional data see table on page 70.

The H. B. Markle well (fig. 17) is located in sec. 22, T. 12 N., R. 14 W., on the north slope of the morainic hills in the S. ½ sec. 22, about 10 feet above the west-east valley extending across the center of the section. The water probably comes from the south. The flow has decreased considerably on account of clogging. The water is high in iron and carries about the usual amount of lime. The table on page 70 gives additional data.

[a] Dependent on the quantity drawn upon and the ability of the sand to give up its supply with sufficient rapidity.

SUMMARY.

The number of flowing wells at Fremont is greater than in the majority of districts, largely because a greater number of deep wells have been sunk on account of lack of satisfactory shallow supplies such as are commonly present in Michigan. There is no single horizon of any great extent, each well or group of wells drawing from an independent bed, often of very limited extent. At the laundry, as has been described, the water-bearing bed is less than 50 feet wide, and even at

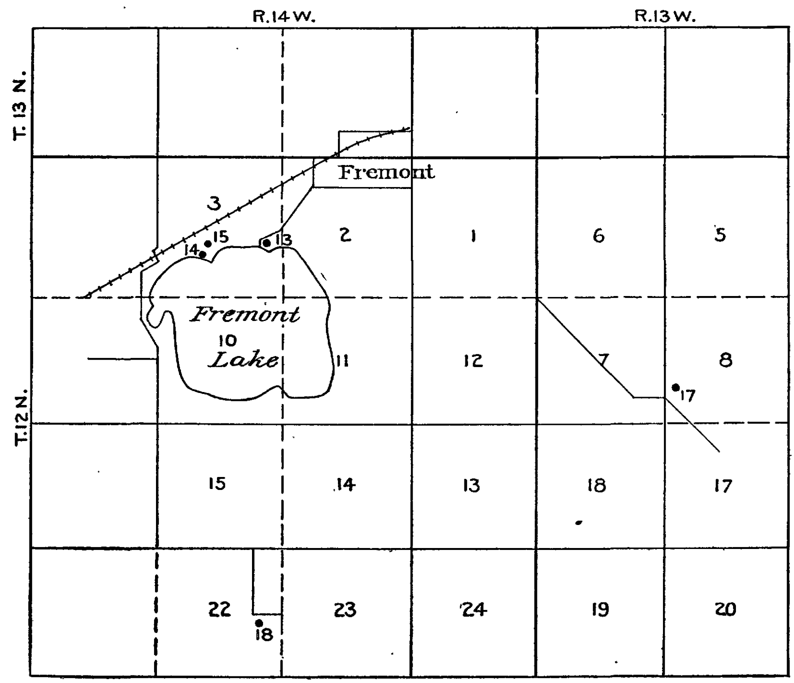


FIG. 17.—Map showing relation of outlying flowing wells of Fremont district.

the lake, where the conditions for flow are most favorable, one 300-foot well failed to get water. Near the schoolhouse well flows may possibly be had along the creek valley or a few feet above, but they will probably be small. Somewhat larger flows might be found in the valley near the Markle well. The points most favorable for flows are on flats adjacent to hills of considerable elevations. Flows would probably be quite general about the shores of Fremont Lake.

The statistical data of all the wells are given in the table below:

Wells of Fremont district.

No. on figs. 15 and 17.	Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water bed.	Flows at—	Maximum head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Ft.		*In.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Gals.*	F.°		
1	S. Hagerdorm.	S. Hagerdorm.	775	1901	2	20	(*a*)	+2	+ 8	Cap.	$48\frac{1}{2}$	Sand	Very soft.
2	do	do	775	1901	2	15	(*a*)	+2	+ 8	M.	$48\frac{1}{2}$	Coarse gravel	Do.
3	do	do	775	1901	2	20	(*a*)	+2	+ 8	Cap.	$48\frac{1}{2}$	Sand	Do.
4	do	do	775	1901	2	20	(*a*)	+5	+ 8	1	$48\frac{1}{2}$		Do.
5	do	do	775	1901	3	18	(*a*)	+2	+ 8	M.	$48\frac{1}{2}$	Pocket	Do.
6	do	do	775	1901	2	29	(*a*)	+2	+ 8	M.	$48\frac{1}{2}$		Do.
7	Mullins & Bode.	Heinde	780	1903	2	23	757	$+\frac{1}{2}$	+ 2	4	$48\frac{1}{2}$		
8	Tannery		780		2	224	556		+20	M.			Hard.
10	City waterworks.	Company and J.A. Heinde.	780	1883	6, 2	60–100		+0	+20	Med.		Sand	Iron.
11	do	do	780	1902	2	226	554	+0	+20	M.		do	Hard.
12	do	do	780	1902	2	225	555	+0	+20	M.		do	Do.
13	Jas. Odell		770	1899	2	108	662		+16	36	$48\frac{3}{4}$	Sand, gravel.	Iron.
14	G. E. Hain		770	1904	2	101	669	+2	+12	40	$48\frac{1}{4}$	Coarse sand.	Do.
15	N. L. Chamberlain.	Biglow	772	1901	2	138	634	$+2\frac{1}{2}$	+14	8	$48\frac{1}{2}$		Slight iron.
16	D. Gerber et al.		770	1903	2	300		−0					
17	School		710		2	70	640	+1		1	$48\frac{3}{4}$		Do.
18	H. B. Markle.		720	1890	2	200	520	+6		2	$48\frac{3}{4}$		Hard.
19	John Timmer.[b]			1901		18		+1					Soft.

[a] Bottom of clay at 760; wells go different depths into the water-bearing sand.
[b] This well has cistern pump attached with spout high enough to prevent a flow.

NEWAYGO.

FLOWING WELLS.

The Newaygo district, which has about 10 wells, is located along the State road, the principal street in town. The wells (fig. 18) are all sunk to an imperfect terrace 15 to 30 feet above the flood plain of Muskegon River. Back of the lower terrace the land rises abruptly to the extensive upper terrace 100 feet or more above the river. The wells are within a few hundred feet of the base of the bluff. The catchment area is probably on the upper terrace, perhaps several miles back from the river.

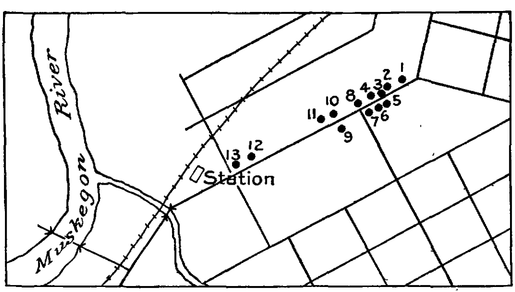


FIG. 18.—Plat of Newaygo, showing location of waterworks, mains, and flowing wells.

Much of the information relating to the wells is given in the table below. From this it appears, after making allowance for slight variations in the level of the ground and in the depths of the wells, that all the wells, with the exception of the Eckard and Whitman wells at the east end of town, obtain their supplies from a single shallow horizon 30 feet from the surface. The first flowing well was obtained about thirty years ago by Edwards (at hardware store). This was dug 20 feet and then bored with auger to a water bed at about 30 feet, at which depth a powerful stream, which filled the well and overflowed on the surface, was encountered. The well has since clogged up and is now pumped. In fact, all the wells show more or less loss of water from clogging, supposedly by clay, but possibly from the deposition of mineral matter on the screen. The materials encountered are alternating sands and clays, largely the latter, the water being generally found in gravel beneath the clay.

For description of the flowing wells at the waterworks see discussion of the public supply (p. 72).

Wells of Newaygo artesian district.

No. on fig. 18.	Owner.	Driller.	Elevation of well.	Approximate date drilled.	Diameter.	Depth.	Elevation of water bed.	Flows at—	Maximum head.	Flow per minute.	Temperature.	Water bed.	Quality of water.
			Ft.		*In.*	*Ft.*	*Ft.*	*Feet.*	*Ft.*	*Gal*	*F.*		
1	S. K. Riblet[a]	Unknown.	690		2	30	660	−0	−0				
2	J. F. A. Raider[b]	Raider.	690	1885	2	35	655	+2	+8			Gravel.	Iron; medium.
3	Thompson Bros. & Co.[c]	Teachout.	695	1884	2	32	663	+1½	+6	¼	48	Sand.	Iron sulphate; medium.
4	.....do.[c]	Unknown.	695	1889	2	30	665	+1½	+6	¾	48		Iron; medium.
5	Odd Fellows block.[d]	.....do.	695	1885	2	35	660	Pumped.	+12			Gravel.	Do.
6	R. Surplice[e]	.....do.	695	1883	3	40	655	Pumped.	+12			.....do.	Do.
8	Gleason's drug store.[f]	.....do.	695		2	30	665	+0					Do.
9	J. W. Brown[g]	Owner.	695	1883	2	30	665	+1		1			Do.
10	Mrs. McGraw[h]	Unknown.	690		2	30	660	−0	+0				Do.
11	J. F. A. Raider[i]	.....do.	690		2	30	660	+2½		7	48		Slight iron; medium.
12	Louis Eckard[j]	.....do.	670		2	50	620	−1½				Gravel.	Iron; medium.
13	Wm. Whitman[k]	.....do.	665	1885	2	49	616	±0		2			Do.

[a] Only known failure within limits of developed area; failure probably due to fineness of water-bearing material.
[b] In a cellar about 7 feet below sidewalk. Strong flow at first utilized in a fountain in the store, but as it prevented the flow of adjacent wells it was stopped down.
[c] Decreased in flow. Nos. 3 and 4 are only 50 feet apart, and when No. 4 at corner of the building inside sidewalk is allowed to flow freely No. 3 at the watering trough ceases or is greatly diminished.
[d] Does not flow now, but is drawn to the second story by a suction pump.
[e] First successful flow.
[f] In sidewalk in front of the store; now capped.
[g] Sulphur water, piped 250 feet to the next house west. Although the piping leaked badly when seen, there seemed to be considerable pressure and a good flow.
[h] Ceased to flow; remedied by forcing small pebbles through pipe into clay at bottom.
[i] In lot next west of Methodist Church.
[j] Roily water.
[k] Flowed for eight or ten years, but has now ceased.

The quality of the water is indicated in the table. It is medium hard and carries somewhat more than the average amount of iron. A partial analysis of the Thompson well (No. 4) is given on page 91.

The prospects for extending the district drawing from the present horizon are slight. If more wells were sunk, they would doubtless obtain flows, but would result in a loss to the other wells, since the supply is nearly all used. Surface supplies are to be had in abundance; in fact springs of some size formerly broke out where the road now is, but they would be dangerous to use for drinking purposes. It is stated that the flowing wells in town are affected by the drawing of supplies from the waterworks wells. If this is the case, it would point to a common water bed. It is not improbable that other flows could be obtained by going deeper, say from 50 to 150 or 200 feet. This may soon be desirable if the town continues to draw a portion of its supply from the creek.

WATERWORKS.

The water system of this place is owned by the town and has the reputation of being one of the cheapest in the State. The waterworks are located in a deep ravine cut by a creek crossing the terrace above the town. This terrace is about 70 feet above the village, but the waterworks are perhaps 60 feet lower. The supply is from about 14 wells, most of them 2 inches in diameter and 18 to 20 feet deep. Six are located in the large cistern in the rear of the plant and eight are outside. All but two flow, the water rising about 4 or 5 feet above the surface and being conducted into the cistern, which is 14 feet deep and 22 feet in diameter. The cistern fills to within about 2 feet of the top and would probably overflow if the supply was not drawn upon. The tops of the wells are about 6 feet below the top of the cistern.

The supply from the wells is about 500,000 gallons per twenty-four hours and was ample until recently, when the large cement plant began using water. It is now necessary to draw from the pond just above the pump house. The water carries some iron and is fairly hard, but is used in boilers.

The water is forced into the mains by means of pumps operated by water power, the pressure required to force it over the hills in volume sufficient for the demands being about 45 pounds. The pressure in town is 60 pounds. The location of the mains is shown in fig. 18. There are about 15 fire hydrants.

The use of the water from the stream or pond should be discouraged, as it is practically impossible to foresee or prevent pollution, even with the present small number of buildings on the watershed. The health of the users of the supply should not be endangered for the sake of the additional revenue derived from the sale of water to the cement plant or other manufacturing establishments. A safer way than drawing from the river would be to sink more wells or, perhaps, utilize the large springs near the station. The water, however, would be hard and would carry some iron.

ENSLEY DISTRICT.[a]

The Ensley flowing-well area is about 12 square miles in extent, and lies just east of Rice Lake in the two eastern tiers of sections of Ensley Township. There are eight flows in all, yielding a total supply of about 41 gallons a minute (fig. 19). The development of this area is of recent date, the first well being driven in 1894. The water contains a considerable amount of iron, which incrusts the pipes. Topographically the area is of strong relief in its central part, and is thus suitable for flows. It lies on the western border of a high sandy moraine, which is probably the catchment area for the artesian supply. Its northern part is flat, with a clayey subsoil. The whole is drained by small westward-flowing streams, which empty into Rice Lake or its outlet, River Rouge.

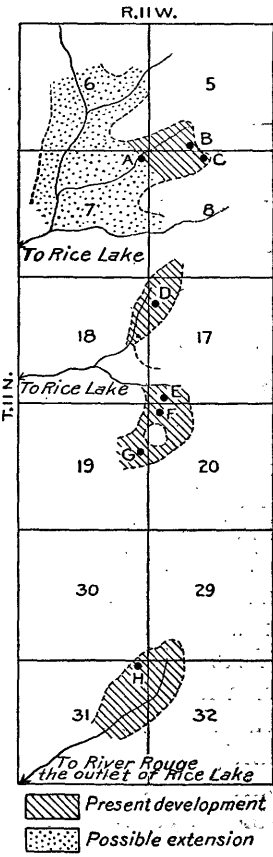


FIG. 19.—Location of Ensley flowing wells, Newaygo County, in relation to local drainage.

The following record of material illustrates the sandy portion of the district, but in places clay is at the surface.

Record of Albert Marvin well.

	Thickness.	Total.
	Feet.	*Feet.*
Very fine yellow sand, water-bearing	30	30
Compact drysand	15	45
Bluish clay with stones	15	60
Fine sand, growing coarser with increasing depth until coarse water-bearing gravel is encountered	21	81

The above well is exceptional in the area because its flow has decreased. This is ascribed by the owner to the corrosion of the pipe and the incrustation of the screen. With a small flow and water containing a high percentage of iron this occurs more quickly than with a strong flow. It is a condition, nevertheless, toward which all the wells furnishing chalybeate water are tending.

There is opportunity for much further development of the area, and no attempt to get a flow on the western and southwestern borders of the area has been unsuccessful so far as known. The ability to get a plentiful supply at a depth of a few feet often delays the complete development of an area, despite the fact that in the case of a flow at less than 200 feet there is a good return for the outlay.

[a] Data by Isaiah Bowman.

Wells in Ensley district (T. 11 N., R. 11 W.).

Letter on fig. 19.	Section.	Owner.	When made.	Depth.	Elevation.	Water rises to—	Flow per minute.	Temperature.
				Feet.	*Feet.*	*Feet.*	*Gallons.*	°*F.*
A	7	School district No. 3	....	113½	833?	849?	20	49.1
B	5	James Downing	1901	45	883	883	....	....
C	8	J. Hanson	1894	45	880	883	.33	51
D	17	J. Hunsinger	1901	30	883	889	.5	50
F	20	J. M. Small	1895	65?	884	886	.5	50.5
E	17	David Hotell	1900	54	888	900+	18	50.1
G	19	A. Marvin	1899	81	880	882	.75	50.5
H	31	School district No. 9	....	112	888	891	1	50.1

ISOLATED FLOWS.

In addition to the foregoing districts, a number of isolated flowing wells have been reported. These are given below:

Kirk.—A flow rising several feet above the surface is reported, but details are lacking.

Volney.—A well sunk by S. Hagerdorm on a ridge in village of Volney found water, which rose to surface at 40 feet. If located a few feet to one side, wells would flow. The conditions are not uniform, however, as another well near by went 80 feet in sand and gravel without getting a flow.

Lincoln Township.—A well with a small flow is reported on property of C. Kent, about 4 miles northwest of Whitecloud.

Wooster.—A well flowing a ½-inch stream is reported on the Murphy and Hill farm near Long Lake, Wooster station, Sherman Township, a few miles northeast of Fremont.

Brunswick.—A well is reported to have been drilled by S. Hagerdorm in NW. ¼ sec. 18, T. 12 N., R. 14 W., in 1902. It is located in a flat district, with elevation about the same as the railroad (approximately 750 feet). The depth is 28 feet and diameter 1¼ inches. The material is all clay down to water-bearing gravel. The well flows a ¼-inch stream of hard water, with much iron, giving considerable scale.

MISCELLANEOUS VILLAGE SUPPLIES.

Village supplies in Newaygo County.

Town.	Source.	Depth of wells.			Depth to principal supply.	Springs.
		From—	To—	Common.		
		Feet.	*Feet.*	*Feet.*	*Feet.*	
Aetna	No returns					
Ashland	Driven wells	20	45	35	35	Small.
Big Prairie	Driven and open wells	12	160	75	50	Medium.
Biteley	Driven wells, springs	8	16	12	16	Large.
Bridgeton	No returns					
Brunswick	do					
Croton	Driven wells open wells, river	12	40	20	18	
Diamondlock	Driven wells, springs, lake	20	120	80	80	Small.
Fremont	Driven wells (some flows)	15	250		250	Do.
Goodwell	No returns					
Grant	Driven wells	15	35	25	30	Do.
Hawkins	Driven wells, creeks, lakes	8	70	25		Do.
Huber	No returns					
Hungerford	Driven wells, creeks	20	150			Do.
Jewell	Driven wells, springs, creeks	8	12	12	12	Variable.
Kirk	Driven wells and open wells, creeks	12	60	40	40	Large.
Lake	Driven wells, creeks	12	32		30	
Lilley	No returns					
McLeans	Driven wells	10	25		25	Do.
Newaygo	Driven wells, river, and creek	20	130			Variable.
Otia	Springs and lake	14	75	35	70	Large.
Parks	Driven and open wells, creeks	16	100	30	30	Do.
Reeman	Driven wells	16	80			Small.
Shaw	do	20	105	35	35	Large.
Volney	Driven wells, creeks	8	25			Small.
Whitecloud	Driven wells, river			25	25	Do.
Woodville	Driven wells	15	25			
Wooster	do	50	70	65		Variable.

WATER SUPPLIES OF MECOSTA COUNTY.

By Myron L. Fuller.

TOPOGRAPHY.

Mecosta County, of which Big Rapids is the county seat, is situated a little west of the center of the Southern Peninsula. It was covered by the Saginaw Glacial lobe, its western part being in an interlobate moraine between the Saginaw and Lake Michigan lobes. This moraine and others closely associated with it cover the western half of the county. East of the morainic system is a gravel plain several miles wide, while on the eastern border of the county is another morainic system. Muskegon River traverses the interlobate moraine in the western part of the county in a deep valley a mile or more in width. The gravel plain referred to above is drained southwestward by the Little Muskegon, except in the northeastern part of the county, which is tributary to Chippewa River, which flows eastward. The same gravel plain thus contributes water both to Lake Michigan and to Saginaw Bay.

In the morainic belt many deep wells have been made, in which water stands far below the surface, flowing wells being obtained only on the low ground along the streams. In the gravel plain and in the valley of Muskegon River an abundance of water is found at moderate depths, but a few deep wells have been sunk at Big Rapids and Mecosta to get supplies below the surface water.

FLOWING WELLS.

BARRYTON DISTRICT.

The flowing-well district at the growing town of Barryton, in the northeastern township of Mecosta County, is the largest in the county. The flowing wells, five in number, are scattered over a large part of sec. 27, T. 16 N., R. 7 W., one being just across the road from the northeast corner of sec. 22. The developed area is something over one-half square mile, but it would doubtless be greatly extended if more wells were sunk.

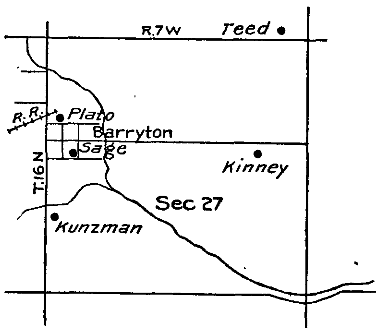


FIG. 20.—Sketch map of Barryton artesian district, Mecosta County.

The town and wells, except the Kunzman well, are located on the flood plain or terrace of Chippewa River, about 10 feet above the stream. On the south side of the river the land rises sharply into morainal hills, which also extend around to the west and north and west of the town, but at a greater distance from it.

For purposes of comparison the data relating to the wells have been grouped, as far as possible, into the tables given below. The location of the wells is shown in fig. 20.

Wells of Barryton district.

Owner.	Driller.	Elevation of well.	Date drilled.	Diameter.	Depth.	Elevation of water bed.	Head.[a]	Flow per minute.	Temperature.	Water bed.	Quality of water.
		Ft.		*In.*	*Ft.*	*Ft.*	*Feet.*	*Galls.*	*°F.*		
Plato, Renwick & Co.	Sam Shores..	970	1894	2	130	840	T 9	Small.	....	....	
Sage..........	....	970	1898	2	70?	900	F 10	1	....	....	
E. Kunzman...	Moyce Bros..	970	1903	2	60	910	T 8+	4	48	Sand....	Slight iron.
W. D. Teed....	....	980	1894	2	97	883	F 3	Small.	....	....	
John Kinney...	Moyce Bros..	975	1903	2	72	903	T 9	5	48	Gravel..	Hard.
H. Walroth....	....	975	......	2	120	(?)	....	....	....	....	

[a] T=tested; F=flows.

It is significant that the three wells of which records could be obtained, the Kinney, Teed, and Kunzman, all passed through essentially similar materials, consisting of a few feet of sand at top, then clay down to the thin water sand at bottom. The Sage well also draws from the same horizon, but the Plato-Renwick well comes from a bed about 55 feet lower. It is said that the Teed well is affected by the wells in town, and it is certain that its head, which was formerly 3 feet above the surface, has now been so reduced that the water only barely reaches the surface and has to be pumped.

The slope of the upper sand is clearly shown by the wells, its altitude being 910 feet in the Kunzman well, 900 in the Sage and Kinney wells, and 883 in the Teed well. Notwithstanding the good flows which it gives when the wells are properly sunk, it was drilled through in two instances—the Plato-Renwick and Sage wells—to the inferior sand below. The former, which still flows, draws from the lower sand, but the pipe in the latter was pulled up to the upper sand. The Sage well is now partly clogged, and the flow and head much reduced. It originally flowed as high as the second story of the house.

The water is about the same as the average drift water of the State, being fairly hard and containing some iron. A partial analysis of the water from the Kunzman well is given in the table on page 91. The water is used for store, domestic, and farm purposes, is perfectly safe for drinking, and is much preferable to the waters of the shallow wells, which are in general use in the town.

The source of the water is in the morainal hills south of town, as is indicated by the slope of the beds from that direction. It is almost certain that flows can be obtained almost anywhere in sec. 27 when the elevation is not more than 15 feet above the river. Flows could also probably be obtained on the flats at similar elevations with reference to the river, both above and below town. It is thought a supply sufficient to meet the demands of the town could be had by drilling a series of wells along an east-west line parallel to the creek on the west side of town.

The available supply of the water sand seems to be large, but if a considerable number of wells are drilled it would be wise to stop down the flow to a point where it just meets the need and not allow the water to run to waste.

SHERIDAN TOWNSHIP.

The school well of the first district is located at the crossroads on a hillside in the southwest corner of sec. 1, T. 15 N., R. 7 W., about 15 feet above the bottom of the valley. Its elevation is about 965 feet, but a short distance to the north the morainal hills rise considerably higher. The well, which is the property of the school district, was drilled in 1901 by Moyce Brothers. It is 2 inches in diameter, 59 feet deep, and flows 20 gallons a minute from a 1-inch discharge pipe. A much stronger flow was obtained from the original 2-inch casing. The water will rise 24 feet above the surface. It now issues into a circular cement tank 5 feet in diameter, protected by a spring house, an overflow pipe leading to a trough by the roadside. The water tastes strongly of iron, has a slight odor of sulphur, and is decidedly hard. A partial analysis is given in the table on page 91. Its temperature is 47½° F. Clay was encountered most of the way down to water gravel.

Other wells among the hills within a distance of a mile have gone for 100 to 180 feet without finding flows. There appears to be no general water-bearing horizon, and flows will be difficult to obtain, although they might be had by wells in the near vicinity of the schoolhouse well, and possibly elsewhere.

MECOSTA.

The village of Mecosta has a small flowing well at the watering trough on the main street near the eastern edge of town. It is located on a flat slightly above the adjacent valley on the west, at an elevation of about 950 feet. It was drilled by R. D. Parks, is 2 inches in diameter, 160 feet deep, and flows about one-half gallon a minute at 1 foot above the surface, although it is said that it will rise 2 feet higher. The flow has decreased considerably, owing to clogging of pipe. The temperature is 49°, and the water tastes slightly of iron. (See partial analysis in table, p. 91.) The materials penetrated were: Wet sand, 110 feet; clay, 45 feet (with water at 140 feet); sand, 5 feet. Probably other flows could be obtained on the flat on which the village is located, especially near the base of the surrounding hills. The elevation of these hills in the immediate vicinity, however, is not high, and large flows or strong heads are not to be looked for.

PARIS.

A flowing well is located at the fish hatchery about 10 feet below the Paris station, which has an altitude of 928 feet. It is 2 inches in diameter, 135 feet deep, and flows 8 gallons a minute. It was drilled in 1902 by J. K. P. Snyder & Son, and its head tested to a height of 7 feet above the surface. The materials penetrated were mainly sand and gravel, with about 15 feet of clay below 100 feet. The water tastes of iron and rapidly corrodes the pipes.

MILLBROOK.

It is reported that Philip Capen has a flowing well at Millbrook, in the southeastern part of the county, but it was not visited and no data concerning it were obtained.

TOWN SUPPLIES.

BIG RAPIDS.

About 1892 an attempt was made in Big Rapids by Mr. G. F. Waring to develop a water supply from wells, his intention being to dispose of it to the city if successful. It is said that nearly a hundred 2-inch wells were sunk. No flows were obtained, and because of the failure to pump successfully the project was abandoned. It is said that a similar difficulty was encountered at Jackson, but was finally overcome by the use of the air-lift process.

At present the supply is taken directly from the Muskegon River without filtration. There is generally more or less typhoid fever, and a few years ago a severe epidemic occurred. Although this was attributed to the use of open wells, and was possibly independent of any pollution of the river water, it is certain that as long as the river is used an outbreak is liable to occur at any time. The pollution from a single case of typhoid at a point within a distance of several miles upstream might lead to hundreds of cases in town. The river and shallow wells should be abandoned as a source of domestic supply. Deep wells located possibly along the river above town would afford the most desirable source.

In the present system direct pressure is used, but the erection of a standpipe is contemplated. The domestic pressure is 65 pounds at the pumping station, and the fire pressure is 110 pounds. The pressure in the town is 27 pounds less. The daily capacity of the two pumps is 1,300,000 and 500,000 gallons, respectively. There are 11 miles of pipe from 4 to 18 inches in diameter and 9 fire hydrants. The plant is owned by the city.

MISCELLANEOUS.

Village supplies in Mecosta County.

Town.	Source.	Depth of wells.			Depth to principal supply.	Head.	Springs.
		From—	To—	Common.			
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Altona	Driven wells, river	20	25	25	25		Small.
Barryton	Driven wells, artesian wells						Medium.
Big Rapids	River, driven wells	18	90	40			Small.
Borland	Driven wells	20	60	40	40	−25	Do.
Chippewa Lake	Cisterns, wells, lakes	14	90	90	90		Large.
Emerald	Driven wells, lakes	50	160	140			Do.
Mecosta	Driven wells, artesian wells	16	190		165	± 0	None.
Millbrook	do	9	90	30		+ 2	Large.
Morley	Driven wells	20	40	30	30	−20	Small.
Paris	Driven wells, artesian wells					± 0	
Pogy	Driven wells	80	152	125	125		Do.
Remus	do	12	120	50			Do.
Rodney	do	50	60	55	60		None
Sandy	Driven wells, dug wells						
Stanwood	Driven wells	15	20				
Stimson	Driven wells, springs	20	120				Small
Titus	Driven wells	15	80	25			Large.
Weaver	do	24	90	50	40		Small.

WATER SUPPLIES OF MASON COUNTY.

By Myron L. Fuller.

GENERAL STATEMENT.[a]

Mason County borders on Lake Michigan near the middle of the eastern side of the lake, Ludington being the county seat. It lies immediately north of Oceana County, and one of its flowing-well districts extends into that county. The southern half of the county is drained mainly by Pere Marquette River, the northern part by Great Sable River, and the intervening territory by Lincoln River. The streams all have wide mouths or lakes lying back of a range of dunes that border the shore of Lake Michigan. There is a belt of sandy country from Ludington northward along the shore of Lake Michigan, which is unsettled, the settlements beginning 4 to 6 miles back from the lake. The northern part of the county also is a sandy plain, with very few settlers north of Great Sable River. Along the south side of this river, from near Freesoil westward for about 10 miles, is a morainic belt, which is settled and has numerous wells 50 to 100 feet in depth. South of this is a sandy strip along Lincoln River, which is sparsely settled. There are few settlers in the eastern range of townships except in the vicinity of Branch, Bachelor, Tallman, and Millerton. As is indicated in the tabulated data below, the wells at these villages are generally shallow. The central and southwestern parts of the county are pretty well inhabited. Water is usually obtained at moderate depths except on the high range of hills fronting Lake Michigan south of Ludington, where some wells are 100 to 150 feet in depth. A few flowing wells have been obtained along the Pere Marquette Valley near Ludington and Amber, and there is a small district in the southwestern part of the county bordering Bass Lake.

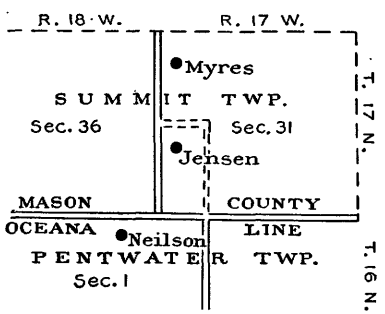


Fig. 21.—Sketch of Bass Lake artesian district, Mason County.

FLOWING WELLS.

BASS LAKE DISTRICT.

This district lies east and south of Bass Lake near the line of Mason and Oceana counties, two wells being in sec. 31, T. 17, R. 17 W., Mason County, and a third in sec. 6, T. 16, R. 17, Oceana County. The district is limited on the east by a till ridge capped by sand, but it may be

[a] By Frank Leverett.

extended westward and southward. It can not well be extended northward, as the country rises rapidly in that direction.

The locations of the wells are shown in fig. 21, and the data relating to them have been compiled in the following table:

Wells of Bass Lake district.

Owner.	When made.	Diameter.	Depth.	Elevation.	Head.[a]	Flow per minute.	Temperature.	Quality.	Water bed.
		Inches.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
Charles Myres	1901	2	102	600	T.+15	4	50.5	Hard; iron	Gravel.
J. Neilson	1901	2	85	585	T.+10	2	49.75	....do....	Sand.
C. C. Jensen	1892	2	122	590	F.+ 2	2	....	....do....	Gravel.

[a] T.=tested; F.=flows.

The Myres well penetrated gravel and sand 10 feet, clay 90 feet, and gravel 2 feet. In the Jensen well the clay was 83 feet thick. In the Neilson well much trouble was experienced in driving the pipe, and as it was finally broken it seems probable that clay was encountered, as in the other wells. The Myres well alone discharges in the ordinary way above the surface; the Jensen well is connected with a pump, which raises the water into the house, while the Neilson well opens into a plank-lined cistern, from which it overflows. No material decrease in flow has been noted except in the Neilson well, for which the broken casing is probably responsible, as some of the water now rises along the outside of the pipe.

There may be another flowing well on the Anderson farm, a mile south of the Neilson well, for near the house a pipe was found which overflows into a tank in the barnyard. This pipe is in a box inserted in the ground, from which a horizontal pipe leads toward the house, probably to a pump. No other data were obtainable.

The water of this district tastes quite strongly of iron and is harder than the average Michigan water. It is, however, used for all domestic and farm purposes. A partial analysis is given in the table on page 91.

The source of the water is probably in the bordering sand-covered clay ridge a short distance east of the wells, though it may be at a greater distance.

WATERWORKS.

Waterworks have been installed at Ludington and at Scottville. The Ludington supply is drawn from Lake Michigan. Though originally built by a private company, the system is now owned and operated by the city. The Scottville supply is from a well 54 feet deep, from which water is pumped to an elevated tank. The village owns the plant, which was installed in 1898.

MISCELLANEOUS VILLAGE SUPPLIES.

The following date concerning village supplies were obtained by correspondence with residents of the villages:

Village supplies Mason County.

Town.	Source.	Depth of wells.			Depth to principal supply.	Head.	Springs.
		From—	To—	Common.			
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Amber	Driven wells (some flow)	10	....	40	150	±0	Small.
Bachelor	Driven well	15	20	....	....	....	
Branch	No returns	....	....	....	....	....	
Buttersville	Driven wells, lake	25	500	....	500	±0	
Carrs	Driven wells, creek	15	98	30	30	....	
Custer	Driven wells, open wells	15	96	45	45	....	Large.
Fern	Driven wells	16	62	50	62	....	Small.
Fountain	Driven wells, river	14	94	40	97	....	Do.
Freesoil	No returns	....	....	....	....	....	
Ludington	Lake, wells (salt wells)[a]	6	2,000+	20	10	....	Do.
Manistee Junction.	No returns	....	....	....	....	....	
Millerton	Driven wells and creek	22	28	26	26	....	Do.
Scottville	Driven wells	25	77	45	50	....	Do.
Tallman	Driven wells, lake	20	35	30	30	....	Variable.
Weimer	No returns	....	....	....	....	....	

[a] The Ludington salt wells are nearly 2,000 feet deep, and are reported on in volume 5 of the Michigan Geological Survey. They penetrate about 600 feet of drift, mainly sand, which is a good water bearer. The rock surface here is about at sea level. No other borings in the county have reached rock, so it is not known whether it has a low altitude far back from the shore of Lake Michigan.

WATER SUPPLIES OF LAKE COUNTY.

By Frank Leverett.

Lake County is situated west of Osceola County, in the western part of the Southern Peninsula, Baldwin being the county seat. Its eastern range of townships are in the elevated interlobate moraine between the Saginaw and Lake Michigan lobes, the greater part of which lies in Osceola County. The highest points in Lake County are about 1,300 feet above sea level. The remainder of the county is largely a gravel plain; but the southwest township has morainic belts, and there are several small moraines in the northwestern quarter of the county. The settlements are mainly in the eastern part of the county on the interlobate moraine, the county seat being the only village west of the moraine. The gravel plain is dotted with lakes in the vicinity of Baldwin and southwestward to the edge of the county, and the water table in this part of the gravel plain is usually within 40 feet of the surface. There are also lakes in the northwestern part of the county, on the borders of which water is reached at convenient depths; but as a rule the gravel plains are so high above the lakes and streams that the water table lies at depths of 50 to 100 feet or more. The settlements in the eastern part of the county are mainly on the lower portions of the morainic belts, the high points being usually rather barren, gravelly, or sandy knolls. Wells have been obtained in these depressions at depths of 50 feet or less. At the Carr settlement in the southwestern part of the county, which is partly on a moraine and partly on a till plain west of it, wells range in depth from 25 to 100 feet or more. The drift in this county is probably several hundred feet in depth, but as yet no borings have reached the rock.

The following data on village supplies have been obtained by correspondence with the residents of the respective villages:

Village supplies of Lake County.

Town.	Population.	Elevation.	Source.	Depth of wells.			Depth to water bed.	Head.	Springs.
				From—	To—	Common.			
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Baldwin[a]	388	834	Driven wells	12	16	12	12	−10	Large.
Canfield	....	868	.....do	18	27	20	20	−18	None.
Chase	300±	1,075	.....do	25	65	25	60	−10	Small.
Forman	....	856	.....do	16	30	20	20	−16	Large.
Luther[b]	837	975	.....do	20	30	25	25	−24	Do.
Nirvana	....	975	.....do	8	25	20	20	−8	Do.

[a]The Pere Marquette Railroad furnishes a partial water supply and is to put in fire hydrants. The water is pumped from a well at the station to an elevated tank.
[b]The village has six cisterns averaging 200 barrels each, which are used for fire protection.

WATER SUPPLIES OF OSCEOLA COUNTY.

By Myron L. Fuller.

GENERAL STATEMENT.[a]

Osceola County has the distinction of containing the highest point in the Southern Peninsula. It is about 1,700 feet above tide and is located on the northern edge of the county in sec. 12, Sherman Township. The interlobate moraine between the Lake Michigan and Saginaw Bay lobes occupies the western half of the county, and its foothills extend eastward nearly to the eastern limits of the county, there being little or no flat surface, except in the valley of Muskegon River and in the swamps inclosed among the morainic knolls and ridges. The elevation of much of the interlobate moraine is above 1,300 feet, and that of Muskegon River is about 1,000 feet where it enters the moraine near Evart. The Lake Michigan lobe extended only into the western range of townships and into the edge of the range east, the remainder of the county being within the limits of the Saginaw lobe. The county is all tributary to the Muskegon, except the northwest corner, which drains to Manistee River, and the southeast corner, which drains to Chippewa River.

Much of the elevated morainic country is very sparsely settled, so that few borings for water have been made. The very high tract in the northern end of the county, however, is settled and has some deep wells. One on the farm of Albert Miller in sec. 11, Sherman Town-

[a]By Frank Leverett.

ship, is 337 feet, and one on the farm of Francis Goodman in sec. 3, 240 feet deep. There are numerous wells 100 to 200 feet in depth in that region. The water in nearly all has very little rise above the level at which it is struck. No wells within the county have ever reached rock, and it is possible that the highest points have 1,000 feet or more of drift. A boring at Reed City on ground only 1,025 feet above tide reached a depth of 276 feet without finding rock, the bottom of the well being nearly 1,000 feet lower than the highest point in the county. No borings in the northern part of the Southern Peninsula have found rock at an altitude more than 900 feet above tide, and it is scarcely probable that any points will be found within the limits of Osceola County at which the rock will reach an altitude of 900 feet. It is more likely to be entirely below 700 feet.

Flowing wells have been obtained in the vicinity of Marion, Rose Lake, Evart, and Reed City, and it is probable that they may be obtained in valleys and on the borders of lake basins in many other places in the county. Those in the southern part were examined by Mr. Fuller, who has prepared a report on them and on the village supplies of the county.

WATERWORKS.

EVART.

The public water supply of Evart is derived from two dug wells approximately 10 feet in diameter and 15 feet deep. They are located near the bank of Twin Creek, the surface of the ground being about 4 feet above the creek bed, about 30 feet above the railroad station according to barometer, and approximately 1,030 feet above sea level. The water stands 4 feet below the surface.

The wells were sunk and the waterworks constructed by the town about fifteen years ago. The pump has a capacity of 1,500,000 gallons per twenty-four-hour day. The domestic pressure maintained is 30 pounds to the square inch; the fire pressure, 80 pounds to the square inch. There are 5 miles of water mains and 30 fire hydrants.

Ordinarily the two dug wells furnish the entire supply of the town, but the amount is somewhat limited and sprinkling is allowed only between the hours of 5 to 8 a. m. and 5 to 9 p. m. The creek, however, can be drawn from in emergencies. A short distance back of the pumping station is a small flowing well, which could be made to furnish 3,000 additional gallons of water daily, but as yet no use is made of it. (See p. 86.) The location is such that additional supplies from shallow wells could be obtained at a very moderate cost. Small supplies from deep wells, similar to the one mentioned, could also probably be obtained at a depth of about 200 feet.

The water from the two wells is low in iron and of only medium hardness. A partial analysis is given in tables on page 91.

REED CITY.

The public supply of Reed City has been from a large dug well, 20 feet in diameter, supplemented by pond water in cases of emergency. The waterworks, which are owned by the city, are located on the bank of the mill pond in the northern part of the town, the well being just back of the pumping station and a few feet above the river. The elevation is approximately 1,005 feet. In 1904 the supply was short, and even with sprinkling hours limited to morning and evening it was necessary to draw from the river. Fifteen new driven wells, to be about 65 or more feet deep, are contemplated (1904), several of which will be located inside of the large dug well and the rest piped into it. It is expected that the water will rise about 6 feet above the level of the pond.

The pumps, which have a capacity of 1,500,000 gallons in twenty-four hours, draw directly from the dug well or cistern. The average consumption is 380 gallons a minute. There are several miles of mains and about 36 fire hydrants. A small supplementary water supply is obtained from a deep well sunk about fourteen years ago. This is not turned into the general supply, but is piped to one or two troughs and a drinking fountain.

The quality of the town water could not be determined at the time of the writer's visit, as it was then mixed with lake water. The water of the deep well resembles that of the J. H. Andrews well, an analysis of which is given in table on page 91.

FLOWING WELLS.

EVART DISTRICT.

What is here known as the Evart district does not consist of a continuous area in which artesian waters are universally found, but rather of a number of isolated wells scattered along the valley of the Muskegon River for several miles. (See fig. 22.) These are in the part of the valley immediately east of the great interlobate moraine formed between the Lake Michigan and Saginaw Bay ice lobes. This moraine, within 5 miles northwest of Evart, reaches an altitude 300 feet above the village, and being composed of loose-textured drift absorbs a large part of the rainfall. It thus seems well adapted to supply strong wells to the districts through which its waters pass underground. The full exploration of the valley above Evart, especially of the portion north of the river, may yield strong flows supplied from this catchment area. There were in the summer of 1904 only four flowing wells in the district; one at Evart, one in sec. 26, T. 17, R. 8 W., one in sec. 23 of the same township, and one in sec. 21, T. 17, R. 7 W. During the summer of 1904 E. C. Cannon drilled a well in the flats just south of Muskegon River in sec. 25, T. 17 N., R. 8 W.

In August the well had reached 350 feet, but at that time the tools were lost and the well was abandoned. No flows were encountered.

The only flowing well found in the village of Evart is located in the southwestern part just back of the waterworks, near Twin Creek, at a level about 3 feet above the creek bottom, and very nearly 1,030 feet above tide. It is 195 feet deep, and flows at 1½ feet above the surface. It was sunk about 1901 to supply a proposed fish hatchery. The water is said to have been analyzed and found suitable, but no use has yet been made of it. The yield is said to have decreased, but it now flows 2 gallons a minute from a 2-inch pipe. Its temperature is 48° F.

The water could be turned into the wells of the public water supply without difficulty and would add, if flowing at its present elevation, some 3,000 gallons daily. This flow would probably be considerably increased if it was piped into the waterworks wells at a depth of 3 or 4 feet below the surface.

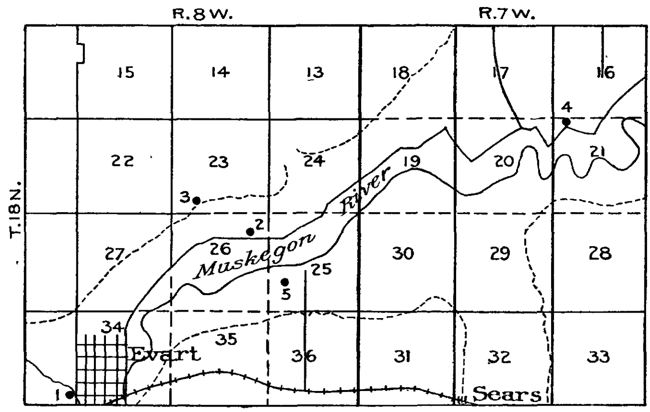


FIG. 22.—Sketch map of Evart artesian district, Osceola County.

The J. K. Grandy well (sec. 26, T. 17 N., R. 8 W.), which is one of the largest drift wells in Michigan, is located on a high terrace bordering Muskegon River, and half a mile southeast from the face of the moraine which crosses the southern half of sec. 23. The well was drilled by Jenkins and others in 1896, and is 2 inches in diameter and about 120 feet deep. No flows were encountered, except the one at 120 feet, which issues from a pipe at about 3 feet above the surface. Its full head has not been measured but is probably considerable, as the water issues with some force, throwing a 2-inch jet 5 feet horizontally in a vertical drop of 3 feet. The yield is 88 gallons a minute, and the temperature is 48° F. The water tastes slightly of iron, is medium hard, and gives a little scale. A partial analysis is given in the table on page 91.

The Henry Baker well (sec. 23, T. 17 N., R. 8 W.) is located on the steep southeast slope of a high moraine, about 35 feet above the edge of the adjacent flats bordering Muskegon River. The elevation is about 1,050 feet. The well is 2 inches in diameter, 60 feet deep, and was sunk in 1901. It yields a flow of 15 gallons a minute at 3 feet above the surface, but will rise at least 6 feet higher. The flow is said to have been over 75 gallons a minute before the well was stopped down to its present small orifice. No decrease of volume has been noted. The flow comes from sand at the bottom, no other flow being encountered. The water has no taste, is only medium hard, and gives but slight scale. It is used for dairy, household, and farm purposes.

The Charles Conn well (sec. 21, T. 17 N., R. 7 W.) is located on a flat terrace near what is known as the Elbow of Muskegon River. A seam giving a flow about the size of a pencil was found at 80 feet. The well was drilled deeper, but, as no other water was found, the casing was pulled back to the first-found flow.

Water is generally found at less than 50 feet throughout the flats, but is not under artesian head, and windmills on deep-well pumps are required to bring it to the surface. The few attempts made to get flows have been generally successful, but, owing to the difference in fineness of material and the pinching out of the water-bearing veins away from the moraine, the results are very variable and can not be predicted. It is probable, however, that along the northern side of the river and within half a mile of the morainal hills, flows could be obtained within 200 feet of the surface at most points. A drawback to development is the high charges made by drillers in this locality, it being cheaper to drive shallow wells and install windmills than to sink deeper for flows. More flows could also probably be obtained near creek level along the stream west of Evart on which the waterworks are located.

REED CITY.

Besides the deep well at the waterworks, mentioned on page 85, the only flowing wells in town are those owned and operated by J. H. Andrews, and situated at the electric-light station, at the foot of the mill pond on the eastern edge of town. At an elevation of about 1,000 feet are two wells 230 and 168 feet deep, respectively, drilled by Jacob Null in 1902. Small flows were obtained at 40 to 45 feet, but the water did not rise much above the surface. The wells are located on the flood plain of the small stream just below the mill pond, or about 10 feet below the pond level, and the water will rise from 12 to 14 feet above the surface. The flow of the deeper well is reported as 105 gallons a minute, and of the shallower as 65 gallons, but they are now cased in and can not be measured. A ram is attached to one, which raises the water 15 to 20 feet into the electric-light plant and residence of Mr. Andrews. The water is high in iron and rather hard. For partial analysis see table on page 91.

The success of the well at the electric-light plant seems to indicate the possibility of obtaining good flows along the creek below the pond, and smaller flows from a low head could probably be obtained along the border of the pond itself. The head of neither the wells at the waterworks nor of those at the electric-light plant is sufficient to carry the water to the level of the flat on which the town is located, making it doubtful whether flows can be obtained in the business portion of the town, within reasonable distance of the surface.

MARION.

Marion is located in the northeast township of Osceola County near a branch of Muskegon River and east of the morainal hills occupying the greater part of the county. The wells are reported to vary from 20 to 80 feet in depth, the largest supply being at 60 or 70 feet. Some wells are said to have a weak flow, the head being sufficient to lift the water 6 to 8 feet above the surface. A public supply is maintained for fire purposes, but it is proposed to extend it by drawing from a pond. There is also a reported flow in the woods in the northeast corner of the county.

ROSE LAKE.

This village is located in the north-central portion of Osceola County in the hilly moraine. The wells vary in depth from 20 to 80 feet. In some instances the water has a weak flow and will rise about a foot above the surface. The shallow water is reported to be moderately soft, the deep water rather hard.

SPRINGS.

NO-CHE-MO SPRINGS.

The No-che-mo Springs near Reed City rank among the well-known mineral springs of Michigan, the waters being extensively advertised and sold throughout the country. A few years ago an attempt was made to develop the locality into a resort, and the springs were converted into flowing fountains, sometimes of considerable beauty. Over 100 springs are said to be found close together, but many of them are as yet undeveloped. The grounds are laid out with walks and trout ponds, and there is a bottling house of considerable capacity. The No-che-mo Springs are located about a mile north of Reed City in the marshy bottoms along Hersey River. They are mostly situated from 3 to 5 feet above the water level and are po sibly 10 feet above the dam at Reed City. They occur in a sort of shallow amphitheater marking a former meander of the river. The ground is marshy throughout, and the springs are found within an area of a comparatively few acres.

The following is a list of the more important of the developed springs, together with data regarding quality of water, volume, and temperature:

Data of No-che-mo Springs.

Name of spring.	Number of jets.	Total volume.	Temperature.	Taste.
		Gals. per minute.	*°F.*	
No-che-mo Spring	3	3	....	Strong iron.
Spiritual Spring	3	12	49	Iron.
Osceola Spring	1	4	....	
Fountain of Youth	4	5	48½	None.
Seven Springs	1	Several.	....	
Cold Spring Geyser	1	½+	....	
Good Luck Spring	1	½	49	Do.
Pontiac Spring	1	1	....	
Three Springs	3	3	....	
Spring	1	4	....	Strong iron.

The quality of the water as regards taste has been indicated in the above table. A complete analysis of the No-che-mo Spring, which is regarded as possessing the most valuable medicinal properties of any of the springs, is given below:

Analysis of water of No-che-mo Spring.[a]

[By Richard Fisher and Albert A. Prescott, Ann Arbor, Mich.]

	Parts per million.
Silica (SiO_2)	14.35
Phosphoric acid (PO_4)	.36
Iron (Fe)	2.00
Aluminum (Al)	.48
Magnesium (Mg)	18.36
Bicarbonate radicle (HCO_3)	265.12
Calcium (Ca)	50.04
Sodium (Na)	14.61
Chlorine (Cl)	8.30
	373.62

The water is bottled and extensively sold for table and medicinal purposes, shipments having been made to California and Hawaii. A sort of snuff, said to be very beneficial in cases of cold and hay fever, is made by passing the water through a series of square metallic cans, in which on the bottom a brownish sediment, mainly of the hydrous oxide of iron, collects.

The "springs" as they now exist are really all shallow artesian wells, although most of them were natural springs before being artificially confined by an impervious cover and made to rise through pipes into the fountains. It is reported that in a few instances flows were obtained by simply driving pipes 10 to 12 feet into the ground. The most interesting spring scientifically is the Geyser Spring, the

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

water of which is piped laterally for some distance underground. Most of the time it flows weakly, but about every two hours it is said to throw a jet several feet into the air. This flow continues for five to ten minutes, and then subsides. During the activity of the Geyser Spring the Osceola Spring, which is piped from the same source, stops flowing. The geyser-like activity is probably due to a peculiar method of piping, doubtless some form of siphon action.

MISCELLANEOUS VILLAGE SUPPLIES.

Village supplies in Osceola County.

Town.	Source.	Depth of wells.			Depth to principal supply.	Head.	Springs.
		From—	To—	Common.			
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Ashton	Driven wells, creeks	20	60	55	55	......	Large.
Avondale	No returns	......	......	......	......	......	
Chippewa station.	....do	......	......	......	......	......	
Dewings	Driven wells	10	85	40	40	......	Variable.
Dighton	Driven wells, open wells, and springs.	12	135	100	100	......	Small.
Evart	Driven wells, springs (flowing wells near).	10	197	50	......	......	Variable.
Garmer	Driven wells, open wells	20	100	......	......	−20	Do.
Hartwick	Driven wells	20	125	60	......	......	Small.
Hersey	No returns	......	......	......	......	......	
Ina	Driven wells, springs	160	225	190	......	......	Do.
Leroy	No returns	......	......	......	......	......	
Marion	Driven wells and river (some flows)	20	80	65	......	± 0	Large.
Orient	Driven wells, springs, creeks	25	125	75	......	......	
Orono	Driven wells	12	35	18	15	......	Small.
Park Lake	....do	12	65	......	......	......	Variable.
Reed City	Driven wells, pond, spring (some flows).	12	200	30	......	± 0	Medium.
Rose Lake	Driven wells (some flows)	10	80	20	20	± 0	Do.
Sears	Driven wells	20	196	25	25	......	None.
Tustin	Driven wells, open wells	......	......	40	......	......	

QUALITY OF WATER IN OCEANA, NEWAYGO, MECOSTA, AND OSCEOLA COUNTIES.

By Myron L. Fuller.

The following table gives miscellaneous analyses made in the field. The field apparatus did not determine the exact amount of sulphates present when there was less than 30 parts per million. The figures are based on estimates and are probably correct within 5 parts per million.

Field analyses of waters in Oceana, Newaygo, Mecosta, and Osceola counties.

[Parts per million.]

No.	Town, township, or district.	Location. Township.	Range.	Section.	Quarter.	Source.	Owner.	Color.	Iron.	Sulphates.	Chlorides.	Carbonates.	Page described.
1	Hart	15	17	17	SE.	Public supply (wells)	Town	None	1/4	Trace.	33	200	59
2	Pentwater	16	18	14	SW.	do	do	do	1	15	22	187	60
3	Summit Township	16	18	1	NE.	Well	Julius Neilson	Very slight amber.	2½	Trace.	8	290	80
4	Weare district	16	17	35	SE.	do	John Lipp	None	1/4	Trace.	1.5	200	56
5	Crystal Valley	16	16	17	SE.	do	H. C. Lockwood	do	1/4	Trace.	1.5	200	54
6	Elbridge	15	16	8	NE.	do	Isaac Timmons	do	1	5	4	200	55
7	Shelby	14	17			Public supply (wells)	Town	do	1/4	Trace.	11	158	60
8	Shelby district	14	18	25	SE.	Well	Geo. Nelson	do	3/4	Trace.	4	166	50
9	do	14	18	36	NE.	do	John Anderson	do	1/4	None.	4	166	50
10	Evart	19	8	33	SE.	Public supply (wells)	Town	do	1/4	None.	15	162	84
11	Evart district	19	8	26	NE.	Well	J. K. Grandy	do	1¼	None.	4	187	86
12	Reed City	18	10			Spring	No-che-mo Springs Co	Amber and opalescent.	4	Trace.	16	194	88
13	do	18	10			Well	J. H. Andrews	Slight amber.	3	None.	6	200	87
14	Barryton	16	7	27	SW.	do	E. Kunzman	None	3/4	None.	29	171	76
15	Mecosta	14	8			Public well	Village	do	1	None.	41	175	78
16	Sheridan Township	15	7	1	SW.	School well	School district No. 1	do	1¾	Trace.	14	242	77
17	Newaygo	12	12	19		Well	Thompson Bro. & Co.	do	1	None.	4	200	71
18	Fremont	12	14	2	NW.	Public supply (wells)	Town	do	2	30	9	335	65
19	do	12	14	2	NE.	Well	Hagerdorm's laundry	do	Trace.	Trace.	3	115	66
20	Fremont Lake	12	14	3	SW.	do	H. E. Hain	do	1	Trace.	1.5	240	66
21	Fremont district	12	13	17	SW.	School well	Garfield Township	do	3/4	Trace.	6	258	68
22	do	12	14	22	SE.	Well	H. B. Markle	Very slight amber.	2½	None.	4	240	68
23	Hesperia	14	14	30	SW.	do	O. H. Johnson	do	2½	None.	5	240	64
24	do	14	15	25	SE.	do	H. K. Bush	None	½	50	16	222	64
25	Ferry	14	16	23	NE.	do	Jas. Osborn	do	Trace.	Trace.	16	115	57
26	Flower Creek district	13	18	26	C.	do	Julius Fohlbrook	Slight amber.	3	None.	9	200	48

WATER SUPPLIES OF ISABELLA COUNTY.

By W. M. Gregory.

GENERAL STATEMENT.[a]

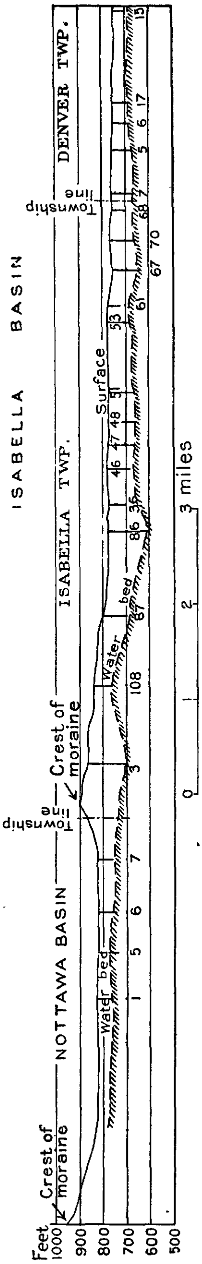


FIG. 23.—Profile of water beds and surface in Isabella County.

Isabella County, of which Mount Pleasant is the county seat, is called the central county of the Southern Peninsula. It lies entirely within the drainage basin of Saginaw Bay, and was covered by the Saginaw glacial lobe. It carries a concentric series of moraines, running in a curving course across the county, concave to the east. The drainage has a trellised arrangement because of the control exercised by these moraines. The principal stream is Chippewa River, which drains the central and northwestern parts of the county. The southwestern part is tributary to Pine River and the northeastern to Salt River. The Glacial Lake Saginaw extended a few miles into the eastern part of the county, and its bed is now a smooth plain sloping eastward. It is on this plain that some of the large flowing-well districts here discussed have been developed. There are also flowing-well districts in the sags between the morainic ridges.

On the moraines wells are often driven to depths of 50 feet or more, but as a rule water in plenty is found at moderate depths. Except for the flowing wells, which are sunk deep in order to obtain a flow, it is rare that a well is 100 feet in depth. The only wells which have reached rock are those at Mount Pleasant, known as the bromine wells, of which there are four or more sunk to depths of about 1,500 feet. The drift is between 400 and 500 feet in thickness at Mount Pleasant, and may exceed 700 feet in the western part of the county on the high morainic tracts, which stand more than 200 feet above the town.

FLOWING WELLS.

GENERAL RELATIONS.

Isabella County has three large flowing-well districts, which extend into the adjacent counties of Midland and Clare. One district in

[a] By Frank Leverett.

Nottawa and Gilmore townships lies between two morainic ridges, while the other two are on the eastern or lakeward slope of the more eastern of these moraines. The western district is called the Nottawa artesian basin; the large district in the eastern part of the county and in western Midland County the Isabella basin; and a district embracing the southeastern part of Isabella and southwestern part of Midland the Coe basin, each being named from the township in which flows are most widely distributed and most numerous. In addition there are two isolated flowing wells in the southwestern corner of Isabella County. The following table indicates the townships included in each basin, the number of flowing wells which have been located, and the total flow of 256 of these wells:

Summary of flowing wells of Isabella County and parts of Gratiot, Midland, and Clare counties.

COE BASIN.

County.	Township.	Number of wells.	Area.	Flow per minute.
			Sq. miles.	*Gallons.*
Isabella	Coe (T. 13 N., R. 3 W.)	38	9	66.1
Do	Chippewa (T. 14 N., R. 3 W.)	26	6	130.1
Midland	Jasper[a] (T. 13 N., R. 2 W.)	17	6	89.7
Gratiot	Bethany (T. 12 N., R. 2 W.)	3	2	65.0
		84	23	351.9

ISABELLA BASIN.

County.	Township.	Number of wells.	Area.	Flow per minute.
Isabella	Isabella (T. 15 N., R. 4 W.)	91	26	216.1
Do	Southeast Vernon (T. 16 N., R. 4 W.)	13	8	27.0
Do	Denver (T. 15 N., R. 3 W.)	25	5	52.4
Do	Wise (T. 16 N., R. 3 W.)	8	2	12.6
Midland	Geneva[b] (T. 15 N., R. 2 W.)	3	3	6.1
Do	Warren[b] (T. 16 N., R. 2 W.)	1	1	.8
		141	45	350.0

NOTTAWA BASIN.

County.	Township.	Number of wells.	Area.	Flow per minute.
Isabella	Nottawa (T. 15 N., R. 5 W.)	13	6	35.3
Do	Gilmore (T. 16 N., R. 5 W.)	6	3	72.3
Do	Northwest Vernon (T. 16 N., R. 4 W.)	8	11	19.0
Clare	Grant (T. 17 N., R. 4 W.)	4	5	8.1
		31	25	131.7

SUMMARY.

Basin.	Number of wells.	Area.	Flow per minute.
Coe basin	84	23	351.9
Isabella basin	141	45	315.0
Nottawa basin	31	31	134.7
	256	99	801.6

[a] Davis found a flow of about 110 gallons a minute from 52 wells in Jasper Township.
[b] The wells of Geneva and Warren townships are somewhat isolated and may not fall within the Isabella basin.

Isabella Township has the largest number of flows, and the wells are widely distributed, being highly prized by farmers for domestic, stock, and dairy purposes. The water is suitable for laundry use, although requiring in some cases the addition of softening compounds. In cheese factories and creameries it is used for cooling and makes it possible to dispense with the use of ice. The better methods of well drilling have lessened the cost and led to a great increase in the number in the last five years. The wells cost from 25 to 50 cents a foot and are drilled usually under a contract for a flow. They are allowed to flow freely, not being checked in any of the basins which were visited. There is little danger of a well diminishing the flow of its neighbors by this practice, because they are widely separated, but in time it may result in a general loss of head in the area, and this should be guarded against.

In the western half of Isabella County a supply is secured easily by shallow pump wells, or by deeper wells with water near the surface or even overflowing. The shallow flowing wells yield better water than

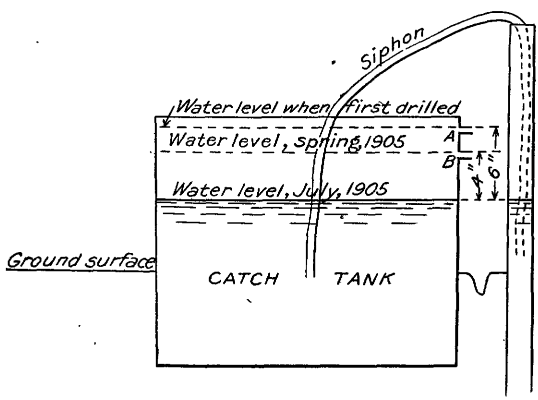


FIG. 24.—Sketch showing fluctuations of Abbott's well, 2 miles north of Shepherd, Coe Township, Isabella County.

the deeper, for the latter are apt to be slightly brackish, a condition found in some of the wells along Chippewa and Salt rivers.

The total flow of the wells in these three districts is about 800 gallons a minute, estimates having been made from 256 wells, which are distributed among the different basins, as shown above. In the Isabella basin the flows average about 2 gallons a minute. Several local failures of the supply were found in this basin, but there was no indication of any general change. In the Coe basin the wells average 4 gallons a minute and show no indications of any general decrease. Mr. Abbott, a well driller, has his well (No. 38, Coe Township) so arranged that its fluctuations have been determined. The well was drilled in 1898, and the head was 6 inches higher than at present (July, 1905). The annual variation in head is 4 inches, being highest in the spring and lowest in the summer, as shown by the sketch (fig. 24), which was made on the ground. It will be observed that the highest water level of the spring now falls 2 inches short of reaching the original level when the well was first drilled.

In the Nottawa basin the wells average about 3 gallons a minute, not considering Mr. George Cook's well, which flows 60 gallons a minute. None of the wells have shown any decrease, and the probable area from which these flows can be obtained is larger than that now developed, but it is limited by the moraines on the west and east.

COE BASIN.

In the Coe basin, in the southeastern township of Isabella County, and in the bordering parts of Gratiot and Midland counties, the slope

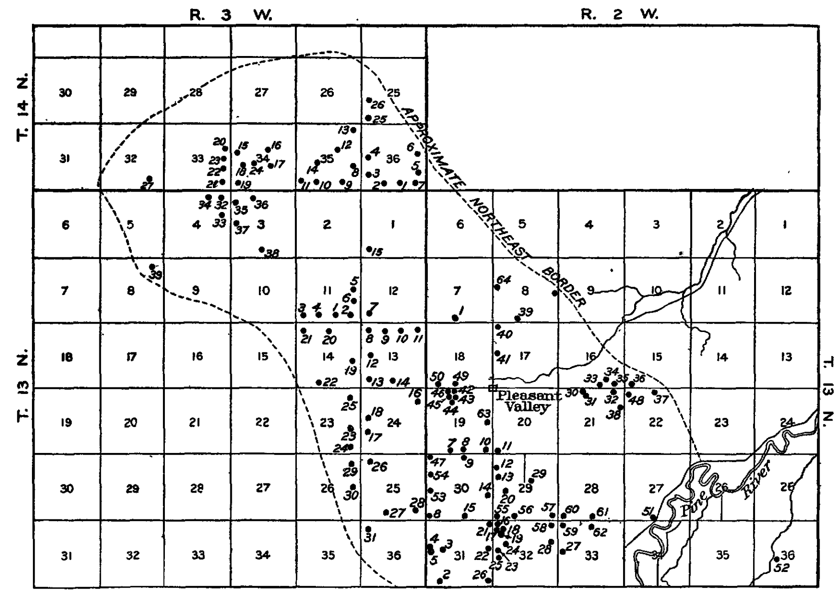


FIG. 25.—The Coe flowing-well district of Isabella and Midland counties.

of the water beds appears to be to the east (fig. 25). The western edge of this basin follows, in a general way, the borders of Lake Saginaw, an old Glacial lake, whose beaches in this region are about 750 to 765 feet above sea level. The material from which flowing waters are derived is more sandy than that of the other basins, and considerable trouble is experienced because of clogging and caving, which requires frequent sand pumping and repair. Many fragments of drift coal from the Michigan formation are encountered, but no bed rock is reached. The following record of J. L. Coon's well (No. 15, Coe Township) gives an idea of the material to be encountered:

Record of Coon well, Coe Township.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	20	20
Hardpan	14	34
Sand, gravel, and first flow, weak	44	78
Hardpan	10	88
Sand, gravel, and second flow, weak	10	98
Reddish clay above blue below; water in gravel at 205 feet	117	215

Mr. Abbott (No. 38, Coe Township) drilled three wells on his property, 205, 105, and 87 feet in depth, respectively. The last one flows a small stream, which fluctuates during the year. The deeper wells were some 200 feet distant from the flow, and, after passing through 50 feet of sand and gravel, the remainder was red and blue clay. In the northern part of the Coe basin, in Chippewa Township, Mr. Salisbury's well had the following record:

Record of Salisbury well, Coe basin.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	32	32
Hardpan and clay	53	85
Sand, with some water	12	97
Soft blue clay; flow from gravel under clay	15	112

Mr. Salisbury has an abundant supply of water, which is forced to the second story of his residence by a hydraulic ram. The well has been cased 97 feet. In the Coe basin, Midland County, the well owned by Mr. W. H. Fox (No. 18 Jasper Township, Midland County) found water-bearing beds at 40 feet and 55 feet, and the present supply, under hardpan, at 84 feet. The Coe basin extends south nearly to St. Louis, Michigan (see report by C. A. Davis, pp. 219–220).

Wells in Coe basin.

JASPER TOWNSHIP (T. 13 N., R. 2 W.), MIDLAND COUNTY.[a]

Section.	Owner.	When made.	Elevation.	Diameter.	Depth.	Head.	Water bed. Elevation.	Water bed. Character.	Flow per minute.	Temperature.	Quality of water.	Remarks.
			Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*		*Galls.*	°*F.*		
7	C. Baker				60			Sand				Wells about this depth along this road.
31	N. S. Baldwin				120	+ 1			0.5	50	Rather hard	House well, pump, dug, shallow, water soft.
31	A. W. Baldwin	1897	740		70	+ 1.75	670	Sand	2		do	Not flowing, filled with sand.
31	do	1897	740		50	+ 1.5	690	do	5		do	Flow too small, now pumped.
31	do		740		20	+ .5	720	do	.25		do	Head formerly 14 inches higher.
30	A. J. Austin	1901	730 / 725G		76	+ 1	654 / 649G	Gravel	.25	51	do	
19	L. A. Pierce	1880	728		17	+ 1.5	711	do	1G	50G		
19	Geo. Smock	1885	728		32	+12	696	Sand	1.12	52	Rather hard.	Formerly flowed 3 gallons a minute; needs sand pumping.
30	T. D. Martin	1896	725		32±	+ .3	693	do	1		do	
19	Willis Smart		730			+ 1.33		do	3	50	do	
20	N. Johnson		730		140?	+ 2	590	do	.25	51	do	J. Tuger, owner of farm.
29	J. Tuger		730		50±	+ 3	680	do	.25	51	do	
29	G. Roberson		730		47	+ 2	683	do	4	50	do	
30	M. Roberson	1889	730		41	+ 2	689	do	2	50	do	
30	R. C. Martin	1884	725 / 728G		42	+ 4	683G	do	3	50	do	
32	M. Roberson	1889	725		43	+ 4	682	do	2	50	do	Cost $15.
32	do		725		76		649	do	8-10		do	
32	do		725		55		670				do	
32	do		725		32		693				do	
29	W. Hanley		730		63	+ 3	667				do	Barn well No. 20; house well No. 21.
31	do		730		90	+ 1.5	640				do	
31	R. Bobazine		725		90	+ 4	635	Sand	1	50	do	Head 10 feet when put down.
32	J. Zimmerman		728		50	+ 3	678	do	2	50	do	House well No. 23; barn well No. 24.
32	do		728		86	+ 2.5	642	do	2	50	do	
32	do		725		87	+ 2.5	648	do	2-3		do	
31	George Carter		715		53	+ 1.5	662	do	8		do	
33	W. Billock		710		80	+ 2	630	do	1		do	
32	J. W. Fox	1903	718		60	+14	658	do	.5		do	Cost $20.
29	F. Preston	1901	725		20	+ 1	705	do	33	50	do	
21	C. Brown	1884	720		32	+ 1	688	do	Small		Hard; iron	These two wells are intermittent flows and stop in the dry season.
21	do	1884	720		33	+ 1	687	do	do			
16	W. Keefer	1895	720		66		654	do	do		do	Formerly flowed more, but stopped recently because of sand.
16	Myron Keefer	1895	718		33	+ 2.5	685					Well is now pumped.
16	do	1895	720		33	+ 0	687					Flows into crock and is dipped out.
15	Geo. E Brown	1890	720		42	+ 2	678	Sand	3	50.5	Hard	Flows at 21 feet also.
15	L. Pickens		722		33	+ 2	689	do	1		do	

[a] Data chiefly from C. A. Davis. The letter "G" after certain figures indicates that they are furnished by W. M. Gregory.

Wells in Coe basin—Continued.

JASPER TOWNSHIP (T. 13 N., R. 2 W.), MIDLAND COUNTY—Continued.

Section.	Owner.	When made.	Elevation.	Diameter.	Depth.	Head.	Water bed. Elevation.	Water bed. Character.	Flow per minute.	Temperature.	Quality of water.	Remarks.
			Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*		*Galls.*	*° F.*		
22	L. Orwig	1900	715		65	+ 2	650	Sand	1		Hard	
21	E. Stevenson		715		60±	+ 2	655	do	1.5	50	do	
8	E. Hartford	1898	725		42	+ 1.5	683	do	8	50	do	
17	J. McDougal		724		47±		676					
17	E. Sheldrake		720		87		633					
19	Old Turner place[a]		725		16		709					These five wells (Nos. 42 to 46) are not cased to bottom, and flow some of the time. When one is pumped for a short time, the others cease flowing until the pumping is stopped.
	do		725		27		698					
	do		725		28		697					
	do		725		25		700					
	do		725		30		695					
30	A. T. Shively[a]	1884	727		40		687					
22	M. Milligan[a]		722		50+	+ 2	672	Sand	4	50	Hard	
18	R. Turner[a]		725		26		699					Small flow.
18	Doctor Seares[a]		725		33		692					
27	School district[a]		705		90?	+ 2	615		2	49.5		
36	Ward (sawmill)[a]		727		30+	+ 2			2			Located in creek valley at sawmill site.
	E. Ostweld[b]		725	2	80		645		.8	50		House use.
	R. Martin[b]		728	2	60		668		1.5		Soft	House and barn.
	G. Smock[b]		730	2	20		710		.7	50	do	Do.
	H. Buletz[b]		710	2	80		630		.6		do	House use.
	George Glecker[b]		716	2	50		666		.7	50		House and barn.
	F. Ostweld[b]		717	2	29		688		.9	49.5	Soft	In field for stock.
	Wm. Hanley[b]		715	2	50		665					Small flow at house.
	J. Hanley[b]		710	2	30		680		1	49.5	Soft	House use.
	M. Pierce[b]		725	2	20		705		1			House and barn.
	H. Bailer[b]		715	2	45		670		1.5			In field for stock.
	Tuger & Son[b]		720	2	25?		695		10	49		Do.
	O. Edwards[b]			2	38				1.5		Soft	House use.

COE TOWNSHIP (T. 13 N., R. 3 W.), ISABELLA COUNTY.

Section.	Owner.	When made.	Elevation.	Diameter.	Depth.	Head.	Water bed. Elevation.	Water bed. Character.	Flow per minute.	Temperature.	Quality of water.	Remarks.
	M. O'Boyle		747		80	+20	667		7	51	Soft	Stock.
	E. Rivett		747		130		617		3	51	do	House and barn.
	M. Farran		747		43		704		.5			Stock.
	do		747		86		681		2	51		Do.

Mr. Hopper		740		68		672		1.5	51	Hard	Much sand and small pieces of black shale.
P. H. McConnell		739		79		660		2		do	House use.
P. M. McGrath		742		108		634		1		Soft	
M. Farran		740		43		697		2	50		Barn well; all clay.
do		739		47		692	(?)	1.5	50	Soft	House use.
do		739		49		690		2			In field.
do		710		38		672		2.5			In field for stock.
R. Robinson		738		49		689		2			House use.
G. Mills		740		51		689		1		Soft	Do.
W. E. Warner		742		60		672		1	50		
J. E. Coon		727		205	+ 4	667		1	50		House and barn.
D. Peters		725		70		655		2			Mostly clay; flow at 20 feet.
E. Frost		738		30		708		1		Soft	House and barn.
B. Trop		738		40		698		1.5	50		Domestic and piped to field.
R. Elliott		739		80		659		1	50	Soft	House use.
A. Clay		747		80		667					
M. Farran		749		92		657		1		Soft	Do.
W. B. Brooks		750		58		692		2		do	
R. Converse		743		88		655		1		do	Field and barn.
George Ross		730		30		700		1		do	
Chas. Boyden		745		92		653		1.5		do	House use.
H. Davenport		730		26	+ 9	704		.5		do	Weak flow.
Mrs. Hart		730		50		680		2.1		do	House use.
O. Bush		725		89		636		1		do	House and barn.
Mr. Dutt		746		25		721		1.5		do	Three wells on farm for stock.
A. Blenker		745		35	+ 7	710		2		do	House use.
H. G. Leonard		735		20		715		.5		do	House use; weak flow.
C. Freeman		766		50		716		1.5	49	do	House use.
Wm. Church		760		46		714		2	49	do	House use; no softening compounds used.
J. Robinson		777		80		697		2	49	do	Two flows.
J. Slates		767		50		717		2.5	49	do	At house; piped to barn.
Wm. Florence		735		50	+14	685		2.5	49	do	House and barn.
J. Kingsbury		766		60		706		3	49	do	House and field.
A. Abbott		730		87	+ 1	643		1	49½	do	Rate of flow varies.
R. E. Myers		790		74		716		2		do	Only 18 feet of pipe in well.

a Records furnished by Mr. Armstrong Kinney, well driller, from memory.

b Data by W. M. Gregory.

Wells in Coe basin—Continued.

CHIPPEWA TOWNSHIP (T. 14 N., R. 3 W.), ISABELLA COUNTY.[a]

Section.	Owner.	When made.	Elevation.	Diameter.	Depth.	Head.	Water bed. Elevation.	Water bed. Character.	Flow per minute.	Temperature.	Quality of water.	Remarks.
			Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*		*Galls.*	° *F.*		
	P. Allen		715	2	50 47	+10	665 668		1	48½	Hard	House and barn.
	N. Hill		718	2	71? 60		647 658		1			Do.
	S. J. Allen		715	2	86	+11	629		2	49		Do.
	B. Gardiner		710	2	76	0	634					Clogged by sand; weak flow.
	H. R. Kelley		710	2	36		674		1.5	48		House use; mostly clay.
	H. Reeves		712	2	82	+13	630		3			Stock use.
	E. Y. Kelley		710	2	80	+15	630		8			House and barn.
	E. P. Peat		719	2	57		662		2	49½	Soft	House, piped to barn; flow decreasing.
	E. J. Doyle		721		70		651		1.5			In field for stock.
	W. D. Seeley		720	2	62		658		2.5			House use; water from under hardpan.
	A. Strauble		721		62		659		3			House use.
	G. Johnson		715	2	89		626		1	48½	Hard	Not suitable for washing.
	Mr. Mullett		707						2			Stock use and house.
	A. Hixon		718	2	76	+11	642		12	48	Hard	Heavy flow found under 5-foot bed of hardpan.
	B. Wing		730	2	80		650		3			Sand 12 feet, remainder clay.
	D. Johnson		718	2	46		672		5		Hard	House use.
	D. Hall		719	2	76		643		2			Hardpan and clay; no sand.
	F. Vandecar		720	2	30		690		1			House use.
	B. Wing		730		64	+12	666		10	48½		At stock barn; good flow.
	Geo. Harris		738	2	54		684		1.5			In field for stock.
	M. Curran		735		20 35		715 700		2		Hard	House use.
	J. Kern		725	2	36 15		689 710		10 3	49½		Do.
	W. B. Wing		722		28	+14	694		40		Soft	Barn, for stock use.
	J. Sioux		720	2	49	+13	671		4	49½	do	House use.
	F. C. Coomey		710	2	100	+6	610		1			House use and stock.
	B. Walters		705		90	+12	615		5.1		Hard	Barn and house.
	E. Salisbury		685	2	112		573		2	50	do	Low ground on river flat.

[a] Wells Nos. 9, 11, 13, 19, 21, 23, and 26 have a diameter smaller than 2 inches.

ISABELLA BASIN.

The water beds of the Isabella basin yield small, uniform flows. The beds extend eastward from the crest of the moraine which separates it from the Nottawa basin into the western townships of Geneva and Warren of Midland County, and are distributed over the gradual slope of the plain on the lakeward side of the moraine (fig. 28, p. 107). Along the western border of the basin many trials have been made to obtain water, but when the elevation is above 820 feet flows have never been obtained, and on the morainal crest the water is very scarce. In sec. 7, Isabella Township, several trial wells from 90 to 191 feet deep have failed to secure sufficient water, and the largest part of the material drilled through was tough clay. This experience has been repeated at a number of places on the western border of the Isabella basin, as shown by the records of Nos. 3, 35, 102, 104, 105, and 108 (Isabella Township). One of the strongest flows in the basin has 30 feet of clay, 18 feet of hardpan with pebbles and gray clay, and 16 feet of consolidated sand and gravel over

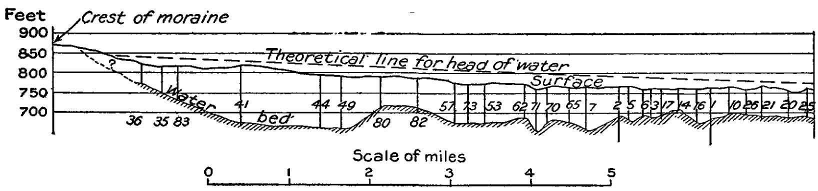


FIG. 26.—Cross section from Isabella to Denver Township.

the water bed. In the eastern extension of the Isabella basin, in Denver Township, beds are found under the same conditions. The following record of George Cole's well (No. 2, Denver Township) is typical:

Record of Cole well, Denver Township.

	Thickness.	Total.
	Feet	*Feet.*
Sand	5	5
Clay	22	27
Sand	20	47
Clay with pebbles	10	57
Sand and gravel	15	72
Hardpan	1	73

No rock has been reached in any of the wells. Mr. Mal Bloom drilled a well (No. 22, Denver Township) 200 feet without reaching rock, and the water was so scarce that the pipe was pulled back to a small flow at 28 feet. In this well the material was clay under 90 feet of sand and gravel. Several wells of this region are quite high in chlorides, but no rock has been revealed by any of the trials. Several large springs, some of which are salty, occur in this basin along Salt River. One of the "salt licks" is in the northwest corner of sec. 23, Denver Township. A number of these salty springs are found farther east along the river in Geneva Township, Midland County. The wells in the southeast corner of Vernon Township are in the Isabella basin, as are those to the east in Wise Township. The crest of one of the Saginaw moraines is the western border of the Isabella basin in Vernon, where the water beds range from 15 to 88 feet below the surface and is scarce in the lower bed and more abundant in the upper layers. Flows ought to be obtained at any place in sec. 24, 25, 26, 35, and 36, Vernon Township, and in Wise Township good flows will be found at moderate depths in secs. 29, 30, 31, and 32. The limit of the bed to the east in Midland County has not been determined, but at Coleman a test well 300 feet deep was made for water, and the material passed in drilling was reported as sand at the surface and the remainder clay. No shallow wells have an abundant supply of water at Coleman, and driven wells 100 to 180 feet deep have only a scant supply. Excellent flows are reported about Coleman in secs. 7, 11, 16, 17, and 18, Geneva Township. Northeast of Coleman, Edenville Township, a few have been reported, showing that the belt of flows, of which the Isabella and the Coe basins are parts, is nearly continuous along the slope of the Saginaw moraine from St. Louis, in Gratiot County, through Isabella and Midland to Gladwin County, near Highwood, and thence past Bourrett Township to West Branch, in Ogemaw County.

Wells in Isabella basin, Isabella County.

DENVER TOWNSHIP (T. 15 N., R. 3 W.).

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*°F.*		
1	Wm. Brophy	770	150	620		2	49½		House and barn.
2	Mr. Hommell	765	60	705		.5		Hard	House use.
3	P. J. Marty	760	65	695		1.2	51	do	House and barn: 2 wells.
4	do	751	80	671		.3		do	Stock farm; salty water.
5	J. Epple	765	82	683		1.1		do	House use.
6	J. Lloyd	760	65	695		2.5	51	do	Storeroom for butter.
7	R. Harrison	765	105	660		1.5	51		At barn, for stock.
8	S. Sherbeneau	760	65	695		2	50	Hard	House use.
9	A. Muterspaugh	760	77	683		1.5	50		Decreased by No. 8; house use.
10	Wm. Brown	765	64	701					House use.
11	George Cole	760	73	687		1.9	49		Used for drinking at store.
12	Mrs. P. Epple	769	50	719		1.2			House use.
13	J. Day	765	115	650					In field, for stock; no flow.
14	T. T. Tompkins	760	50	710		2.3			
15	Wm. Blendheim	759	70	689		4.5	48½		House; drinking and cooling.
16	Mrs. Monroe	760	81	679		1.2	49	Salt	Used for drinking only.
17	Fred Thorpe	760	60	700		2.4		Hard	House and barn.
18	Mr. Spalsbury	750	30	720		1.5	48½		At house on river flat.
19	P. Goether	755	50	705		2.5			At barn, for stock.
20	O. Allen	755	60	695		3.6	49½		Domestic and stock use.
21	George Cole	765	78	587		1.8			House.
22	Wm. Bloom	758	92	666		1.2			Domestic and stock use.
23	Mal. Bloom	763	28	735		2.5	48½		House and stock; no water at 200 feet.
24	J. Mahon	765	125	640		5.6			House and stock.
25	J. Granger	760	64	696		2.3			Do.
26	Joe. Bloom	760	55	705		1.5			Do.
27	Geo. Loylard	755	60	695		3.8	49	Salt	Stock and domestic use.

Wells in Isabella basin, Isabella County—Continued.

ISABELLA TOWNSHIP (T. 15 N., R. 4 W.).

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*°F.*		
1	T. Graham	870	30	840				Hard	No flow; water scarce.
2	Unknown [a]	870	130	740					
3	H. Johnson	866	160	706					No water; all clay.
4	Kennedy's mill	780	130	630	789	0.5	49½	Hard	Decreased since 1901.
5	Neil Morrison	770	104	666		.3		do	Do.
6	H. Terry	780	150	630		.1	49½		Small flow.
7	B. Hourse	785	115	670					No flow; little water
8	T. McFarlane	783	100	683		2	49½		House and barn.
9	Jas. Figett [b]	789	50	739	795	.9			House use.
10	J. McLong [c]	770	100	670		1			Do.
11	H. Fitzpatrick	778	90	688		1	49½		House and barn.
12	J. McLaughlin	771	75	696		.8	48½		House use.
13	O. H. Philips	775	90	685		1.5			Stock and house use.
14	E. Robinson	778	100	678		2.5			All clay to water bed.
15	R. Dunn	780	90	690		1			Stock use.
16	Bush House	782	180	602		1.1			House use.
17	W. Spaulding	775	106	669	790	1.5	49½	Hard	Decreasing.
18	Joan Archer	775	142	633		1.5			House use.
19	School	777	100	677		2.5	50		Drinking.
20	Wm. Brown	780	90	690		1	49		House use.
21	C. Brogan	770	160	610	770				Weak flow; decreasing.
22	Wm. Busholder	772	40	732		1.5	49		Weak flow.
23	Sam Wark	765	95	670					House use.
24	Mr. Fall	765	80	685		3	49½		At barn, for stock.
25	J. Burr	760	100	660		1.5			House and stock.
26	Mr. Mitchell	763	100	663		1			House use.
27	H. Fitzpatrick [d]	770	90	680		.9		Hard	In field; only 8 feet of pipe
28	Jas. McKnight	778	100	678		.5	51		Mostly clay; water hard.
29	Hugh Graham	780	150	630		2.1	50		House use.
30	Ed. Johnson [e]	780	115	665		3.5			House and stock.
31	W. Neif	779	90	689		1.5			House use.
32	J. Ragan	788	180	608		2.6			Stock barn.
33	Mr. Allen	796	90	706					No flow; little water.
34	School	808	100	708	820	.8	49½		Flow decreasing; water hard.
35	Mr. Priest (?)	815	70	845					Pump well.
36	A. Miller	829	53	776		2.8	49		House.
37	Geo. Hughs	820	55	765		3.2			House and barn use.
38	J. McNerney	821	82	739	818				
39	Matt. Johnson	810	200	610					Water scarce.
40	H. Lewis	798	100	698					All clay; no flow.
41	J. H. Edwards	820	146	674		4.2	50		House and barn.
42	Dave Conway [f]	783	64	619	801	30	49½		Domestic and stock use.
43	W. Neif	782	120	662		5.2			In field.
44	J. Neif [g]	794	130	664		3.2	49½		House use; water soft.
45	Geo. Wyley	784	110	674		2	49½		House and barn.
46	Mr. Nelson	780	98	692		1.3	49½		House use; water soft.
47	J. Graham [h]	779	105	674	790	4.2	49		3 wells.
48	Tom. Frazer [i]	770	100	670		2	50		
49	J. L. Thorne	790	120	670		.5			
50	Mr. Pelcher	790	103	687		1.3			
51	Mr. Trainer	790	100	690		2.5	49½		
52	T. Swindelhurst	795	90	705		1.5	48½		In field; water soft.
53	W. Gayhart	777	90	687		2.5			Stock barn.
54	Kirk Connell	778	97	681	785	2.1	50		House use; water soft.
55	W. Angell	778	92	686		1.5			In field for stock.
56	T. Carroll	770	80	690		1		Soft	House and barn use.

[a] Several trials for water have been made here, depths varying from 90 to 193 feet. The water is scarce and hard to get. Most is present at 98 feet. Largest part of material is hard clay.

[b] Well drilled through sand and clay to water bed at 50 feet and continued to 100 feet in hopes of strong flow. No water found at deeper point. Pipe pulled back to flow at 50 feet.

[c] Clay 40 feet, remainder sand. Gravel at 100 feet, good flow.

[d] In field for stock use. Only 8 feet of pipe drilled through the hard clay to gravel bed. Flow has decreased.

[e] This well lowered No. 91 across the road on the property of Wm. Graham.

[f] Well at house. Record: Clay 30 feet; hardpan and gray clay, some pebbles, little water, 18 feet, consolidated sand and gravel, 16 feet; water at 64 feet; strong flow and has been difficult to control; coming up on outside of pipe. Much CO_2; some iron; water is hard.

[g] Water beds and flows at 50, 90, and 100 feet.

[h] Well at house 105 feet lowered heads of Nos. 46, 45, and 31. Two other wells same elevation as well at house are 110 feet and 95 feet, respectively. Combined flowage of wells exceeds 4.2 gallons per second. Water at house hard.

[i] Well mostly in gravelly clay. Three feet of hardpan at about 96 feet. A small water bed at 85 feet. Water rose 16 feet in pipe.

Wells in Isabella basin, Isabella County—Continued.

ISABELLA TOWNSHIP (T. 15 N., R. 4 W.)—Continued.

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	°*F.*		
57	F. Polwalker		90			1.8	50		House use.
58	Joe Bradley	760	85	675		2.5			Do.
59	D. Riegle	765	104	659		3	49½		House and stock use; water soft.
60	Wm. Pfohl	759	100	659		2.1			House use.
61	John Johnson	775	29	756	765				Pump well; water soft.
62	J. Develin	770	86	684		5.8			House use.
63	J. Harrison	759	97	662					In field, for stock.
64	Peter Mahan	760	84	674		1.6			House use.
65	J. Harrison [a]	760	80	680		1.5			Stock barn.
66	C. Goodsell	759	110	649	769	8	49½		Decreased by well east 300 feet.
67	Chas. Cooper [b]	750	114	636		8	51		In heavy gravel bed.
68	J. Gallagher	749	60	689	745	1.2	51		House use; water hard.
69	Wm. Kellar	747	100	647		1.3	51		Stock and house.
70	Wm. Watson	770	93	667		1.5		Hard	Water from sand bed.
71	J. Watson	760	100	660		2		do	Stock barn.
72	Wm. West	763	80	683		1.5	49½	Soft	In field, for stock.
73	M. Murphy	770	90	680		1			Decreased since drilling.
74	J. Conway	780	90	690		2.1	49		In field, for stock
75	J. Mang	783	44	739		.9			Barn.
76	School	780	38	642		1.3	49½	Hard	Drinking.
77	F. Wright	770	44	626		2.1	50	do	House and barn.
78	F. J. Clare [c]	767	83	684	775	1.4	49	do	House.
79	Ed. Roberts	771	80	691		2.5		do	House use; nearly all clay.
80	J. Hobson	790	68	722		.2	48	do	Barn and house; water from gravel bed.
81	A. Catlin	778	40	738		3.6	48	do	Stock barn; piped to house.
82	F. Roy	785	97	688	805	4.1			House and barn.
83	P. Folley	813	89	724		1.1	50		House use.
84	Wm. Elliot	800	90	710		1.2	51		Stock, in field.
85	I. R. Vincon [d]	815	186	629		1.5	50½		House and barn.
86	M. Johnson	775	170	605		2.3	50		
87	W. Swindlehurst	795	100	695		.8			Formerly good flow, but drained by No. 47.
88	Rosebush station	770	148	622		1.6		Hard	Drinking and steaming.
89	Joe Horn	772	201	571		1.1		do	House use.
90	Mr. Neiland	785	60	725					No water; mostly clay.
91	Wm. Graham	788	90	698		1.2		Hard	Stock and domestic use.
92	J. Potter	780	93	687		1.3	50		Domestic use.
93	M. McGuire	770	80	690		1.5			At barn; piped to house.
94	School	781	38	743		.3	51		Drinking.
95	Mrs. Beatha	773	38	735				Hard	House.
96	J. Kellar	768	50	718	779	1.8	50	do	Barn and house.
97	J. Roy	760	70						No water; several trials.
98	Ed. Roberts	753	130	623	778	8.2	49½	Hard	House use.
99	J. Campbell	748	50	698		1.5			Clay 25 feet, sand 10 feet, clay 15 feet.
100	Chas. Campbell	745	115	630		2.8			Domestic use.
101	Pat. Garwin	815	80	735		1.5			House use.
102	F. Miller	800	30	770	800			Soft	Pump well in sand.
103	J. Brooklins	790	80	710		9	49	do	House use.
104	E. Van Buren	810	30	680		2			Do.
105	O. F. Dart	815	30	685	829	5			Barn and house.
106	Lyman Munger	760	157	603		1.5		Hard	House, piped to barn.
107	Wm. Bellunger [e]	793	60	733		3			House use.
108	Jas. Daley	840	70	770	790				Pump well.

[a] Two water beds passed before this flow. Drift chiefly clay and gravel. Flow not as strong as formerly.
[b] Good flow. Mostly clay. Small flow at 70 feet.
[c] Said to be all clay to 60 feet, remainder quicksand. Much iron deposit and algæ.
[d] Record: Sand and gravel, 40 feet; clay, 70 feet; sand and gravel, 75 feet.
[e] Water at 32 feet. All clay.

Wells in Isabella basin, Isabella County—Continued.

WISE TOWNSHIP (T. 16 N., R. 3 W.)

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*°F.*		
1	James Owen	760	85	675	770	1.8	......	....	House and barn; water hard.
2	M. McGuire	764	113	651	778	2.3	48½	....	House.
3	Dan Walker	760	46	714	770	1.5	......	....	In field, for stock.
4	Jas. McConnell	762	45	717	765	1	49	....	House use.
5	W. Sharp	70	67	703	780	2	48	....	Do.
6	Geo. Hersey	779	70	709	719	......	......	....	Mostly clay; some sand at top.
7	R. McConnell	......	58	......	......	2.5	......	....	House use and stock.
8	C. L. Recher	......	60?	......	......	1.5	......	....	Decreased since drilling in 1900; water soft.
9	M. Mannery	750?	151	......	755?	......	......	....	Little water.

VERNON TOWNSHIP (T. 16 N., R. 4 W.), SOUTHEAST PART.

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
8	A. McDonald	800	27	773	815	1.8	......	Hard	House use.
9	T. Ragan	789	15	764	799	2	49½	...do	Flow from gravel under clay.
10	S. Leight	778	39	739	......	2	......	Soft	House use.
11	P. Mahar	790	25	765	......	3	48	...do	Water from sand under 20-foot clay bed.
12	G. Sterne	795	32	763	803	1.5	......	...do	House use.
13	F. Battle	809	27	782	......	1.6	49	...do	Water from gravel under clay.
14	R. McConnell	785	58	727	......	2	48	...do	House and barn.
15	F. Battle, jr	786	25	761	794	4.5	48½	...do	Water muddy before storm.
16	C. McElhenery	790	25	765	......	2.8	......	....	Barn and house.
17	J. Crawley	800	88	712	......	......	......	....	Failed to get flow.
18	J. McGuire	768	30	738	......	1.5	48½	Hard	House use.
19	John Owen	788	31	757	798	2.3	......	...do	House and barn use.
	W. Sharpe	770	60	710	......	2	49	....	House use.

NOTTAWA BASIN.

The limits of the Nottawa basin in Isabella County are roughly determined by the moraines of the Saginaw ice lobe, and the few wells already drilled show the water beds to be entirely in the drift. In the northward extension of the Nottawa basin Mr. S. A. Gleason has drilled a well in sec. 35, east of Clare village, Clare County, which has the following record:

Record of Gleason well, Nottawa basin, Clare County.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	20	20
Gravel	2	....
Sand	30	22
Gravel	15	52
Sand	25	67
Red clay	10	92
Blue clay	31	102
Water in gravel	....	133

In the northern extension of the Nottawa basin in Grant Township, Clare County, at a small sawmill south of Dover post-office, near the east quarter post of sec. 11, the water beds have been reached by three small flowing wells, as shown in fig. 27.

The water bed of sand and gravel is reached by wells A and B, 300 feet apart, with depths of 39 and 28 feet, respectively. In well B the water rises 16 feet in an open pipe and in A it rises 5 feet. If well B is opened and allowed to run twenty-four hours, the head in well A slowly decreases and the flow stops. These changes do not affect the 18-foot well which is half-way between the two deeper wells, and in which the water rises 20 feet in an open pipe. The July temperature of the deeper wells is 48° and that of the shallow well is 47°. The flow of the deeper well is 1.2 gallons a minute. The water of all the wells is soft and suitable for boilers and domestic purposes. To the

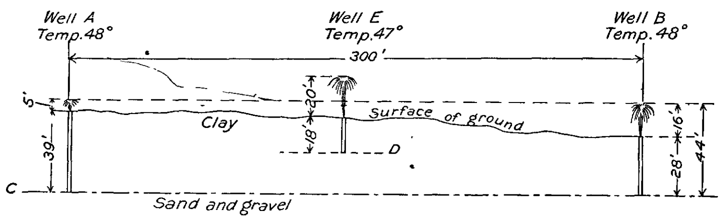


FIG. 27.—Relation of wells near Dover, Clare County.

west of the wells for one-fourth of a mile are hills of clay and sand, the tops being 35 feet higher than the mill, and this probably is the catchment area of the beds.

In Isabella County the Nottawa basin does not extend farther south than the lower tier of sections in T. 15 N., R. 5 W., and it takes in the southeast corner of Gilmore and the northwest half of Vernon townships. Duncan's well (No.4, Vernon Township) is a good representative of this part of the basin which is between the well-defined Saginaw moraines.

Record of Duncan well, Isabella County.

	Thickness.	Total.
	Feet.	*Feet.*
Gray clay	50	50
Hardpan	.5	50.5
Clay and gravel	3	53.5

Wells on the eastern and western edges of this basin pass through heavy clay under a covering of sand and gravel. Water is very scarce.

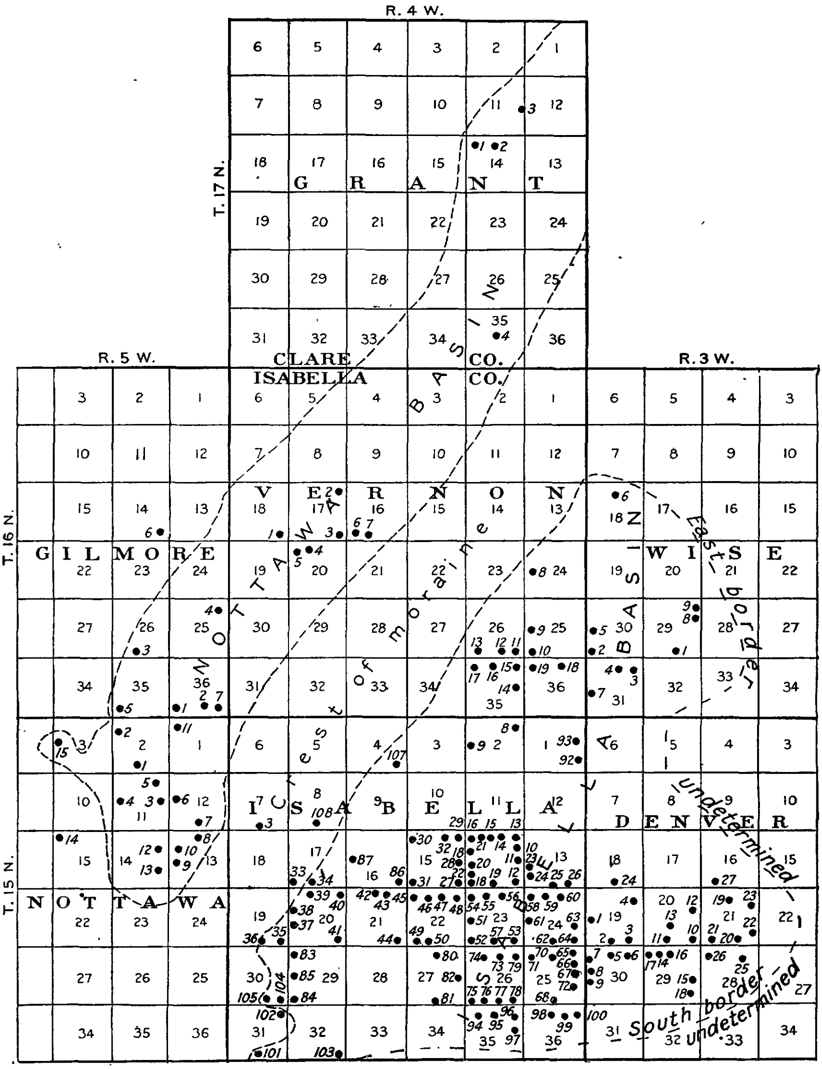


FIG. 28.—The Nottawa flowing-well district in Isabella and Clare counties, and the Isabella flowing-well district, Isabella County.

Wells in Nottawa basin.

NOTTAWA TOWNSHIP (T. 15 N., R. 5 W.), ISABELLA COUNTY.

No. on fig. 28.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Ft.	*Ft.*	*Feet.*	*Feet.*	*Gals.*	°*F*		
1	Anna Parish	835	60	775	......	1.2	......	Hard.	House use.
2	M. Riley	845	34	811	855	2	......	...do..	For house use and piped to barn.
3	Wm. Burch	815	40	775	......	2.5	48½	...do..	For stock.
4	M. Palmer	840	38	802	......	2.1	......	...do..	House use and milk house.
5	F. Cotter	825	60	788	......	1.8	......	...do..	House and barn.
6	D. Cotter	820	70	750	......	3.1	......	...do..	Do.
7	A. Kiblebeck	820	60	760	835	4	49	...do..	House use.
8	L. Kennedy	830	90	740	......	3.1	49	......	House use and stock.
9	Jas. McGuirk	830	47	780	......	2.1	49	Soft..	Water muddy before storm.
10	M. Doerr	822	47	775	832	4.1	......	...do..	House and barn.
11	A. C. Seymour	810	50	760	......	2.1	49	Hard.	House use.
12	Mrs. Blundy	828	14	804	......	3.2	......	......	House.
13	W. Garber	830	29	801	......	.5	......	Hard.	At house.
14	J. Lay	860	180	680	......	......	......	...do..	No flow (?).
15	J. Doerr	835	67	768	848	3.5	49	...do..	

GILMORE TOWNSHIP (T. 16 N., R. 5 W.), ISABELLA COUNTY.

1	G. Cook	830	50	770	859	60	48½	Soft..	House use.
2	C. Scofield	815	50	765	820	4	......	......	Two wells. Barn for stock.
3	School	830	48	772	......	1.5	48½	......	Drinking.
4	G. W. Gordon	820	30	790	828	2.3	48	Soft..	House and barn use.
5	T. T. Wood	840	......	......	......	3.5	48	...do..	A spring piped to road.
6	H. Glass	850	200	650	650	......	......	......	Very little water.
7	C. Scofield	815	35	780	......	1	48	Soft..	At house.

NORTHWEST VERNON TOWNSHIP (T. 16 N., R. 4 W.), ISABELLA COUNTY.

1	School	860	24	736	872	1.3	48	Soft..	Drinking.
2	W. Warren	850	30	820	......	2.3	......	......	All clay; flow in gravel.
3	F. Loomis	862	30	832	......	1.5	......	......	Stock barn.
4	Wm. Duncan	850	54	796	869	9.5	48½	Medium.	Drinking fountain, house and barn.
5	J. Hodkins	850	50	800	......	1	......	Hard.	House use.
6	S. Thrower	866	40	826	876	2.1	......	......	House use and piped to barn.
7	L. Simpson	870	49	821	......	1.3	49	Hard.	House use.

GRANT TOWNSHIP (T. 17 N., R. 4 W.), CLARE COUNTY.

1	Randall school	878	60	818	891	1.5	48	......	Drinking purposes.
2	Chas. Perry	880	60	820	895	2	48	Soft..	House use.
3	Sawmill and house	900	......	......	......	1.6	......	Hard.	
4	S. A. Gleason	848	133	715	861	3	......	...do..	Do.

NOTE.—The wells in the Nottawa basin are all 2 inches in diameter.

ISOLATED FLOWS.

Boyden.—The "magnetic mineral" flowing well, near Boyden, Deerfield Township, was obtained in prospecting for coal on the farm of Mr. W. Wykes in October, 1897. The drillers had reached a depth of 168 feet and left the work for the night. On returning in the morning they found a flowing well, which filled a 2-inch pipe to a height of 15 feet above the surface. The beds penetrated were as follows:

Record of Wykes well, Boyden.

	Thickness.	Total.
	Feet.	*Feet.*
Clay and gravel	20	20
Sand with some water	2	22
Gravel and sand	8	30
Clay and gravel	20	50
Clay	25	75
Gravel with water	5	80
Blue clay	35	115
Sand and gravel with water that overflows	15	130
No record	38	168

The water is hard, with some gas, probably CO_2, and much carbonate of iron is deposited about the well. It flows 6 gallons a minute and has a temperature of 49°. The following partial analysis was made by Dr. A. B. Prescott, of the University of Michigan, November 23, 1897:

Partial analysis of water from Wykes well, Boyden.

	Parts per million.
Total solids	187
Free ammonia	.08
Albuminoid ammonia	.007

Hardness, 140.

It is stated in connection with the analysis that there are light quantities of iron, sulphates, and chlorides, and larger quantities of carbonate.

This water is used commercially, the price for a 4-gallon case, including the packages, being $1.50, delivered at freight or express offices in Mount Pleasant, Mich. The water is also shipped in barrels, at the rate of 5 cents a gallon.

The well is situated on low ground near the Chippewa Valley, and the catchment area is probably on the higher land to the west.

Blanchard.—From a water-supply schedule obtained by W. F. Cooper it is learned that a flowing well was made on the farm of Stephen Pumfrey, 3 miles from Blanchard, in 1895. It was dug to a depth of 30 feet, with a diameter of 3 feet, and discharges about 3 buckets a minute at the well mouth. The water will rise several feet above the surface if confined in a pipe. The water is hard, with some iron. The cost of the well was $50.

There are springs along Pine River in this township which carry an oily scum, which is thought by the residents to indicate the presence of oil, but as the drift in that vicinity is very thick it is improbable that there would be oil issuing from the underlying rocks.

MOUNT PLEASANT WATER SUPPLIES.

Waterworks.—The public water supply of Mount Pleasant was originally obtained from a well 17 feet in diameter to a depth of 20 feet and 6 feet in diameter for 8 feet farther, in the bottom of which four short pipes were driven to the water bed. To this supply has been added seven 6-inch and 8-inch driven wells located on the river flat. These wells are 24 and 26 feet deep through 7 feet of surface soil, 16 feet of hardpan, and 2 feet of water gravel. The wells at one time flowed, one having sufficient head to flow 8 feet above the surface from an open pipe. The wells are all supplied from the same water beds, as is shown by the fact that pumping one well will lower the water in others 200 feet distant. These wells having failed to furnish a sufficient supply, several cisterns modeled after the original one used at the installation of the waterworks plant have been made, each being in part 25 and in part 6 feet in diameter and having driven wells in the bottom. This arrangement now supplies 750,000 gallons daily, but during a dry summer the supply is low.

Private wells.—The shallow pump wells of private citizens generally give a good supply of water at a depth of 15 to 20 feet in the northern part of the city, while in the southern part there is a marked difference in the shallow wells. Those in the vicinity of the normal school pass into clay under a slight covering of sand. The well drillers have found the change there quite sharp between a belt of gravel and sand bordering the river and the clay which sets in near the normal. None of the wells used to furnish water for domestic supply reach bed rock, all being in the drift, which in the vicinity of Mount Pleasant is about 435 feet thick.

Doctor Getchell, lots 3, 4, and 6 of block 31, has given the following record of a well drilled on his property:

Record of Getchell well, Mount Pleasant.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	30	30
Clay	30	60
Sand and water	5	65
Hardpan	8	73
Some coal pieces in clay	9	82
Sand	5	87
Water in gravel	14	101

This well caused some excitement because of the presence of the drift coal, and other wells 200, 255, and 355 feet in depth were drilled on various lots adjacent to Doctor Getchell's properties, but no rock was found. Later careful drilling by the Midland Chemical Company on their property on section 10, north of the city, on ground about 770 feet above sea level, has shown the rock to be reached at 435 feet below the surface and to have the drift covering shown in the following record:

Record of Mount Pleasant city and Midland Chemical Company well, (sec. 10, T. 14 N., R. 4 W.)

[From samples and notes of A. Borden; determinations by A. C. Lane.]

	Thickness.	Total.
	Feet.	*Feet.*
Gravel	80	80
Blue till	20	100
Quicksand	20	120
Blue till	160	280
Porous beds with water; coarse gravel on top, fine sand below	74	354
Red clay	26	380
Ground moraine till with broken coal measures	55	435
Black shale with streaks of coal (410, 435, and 560 feet), sandstone, limestone, or carbonate of iron and fire clay, mostly less than 5 feet thick	185	620
Fine white sand rock with mineral water	90	710
Gravelly sand rock with a strong flow of water not so salt	80	790
Shale and red limestone	30	820
White limestone	30	850
White sandstone (Parma) with very salt water	120	970
White limestone (Maxville) actively effervescing	55	1,025
Shale	5	1,030
Sandstone	20	1,050
Dolomite and shale	75	1,125
Anhydrite and dolomite	100	1,225
Anhydrite, nearly pure (gypsum)	45	1,270
Dolomite, shale, and anhydrite	103	1,373
Sandstone (top of Marshall)	8	1,381
Shale	5	1,386
Sandstone	4	1,390
Shale	15	1,405
Sandstone, dark, with heavy brine originally 1,463 feet deep, afterwards about 1,585 feet, ending in red rock	180	1,585

At the basket factory of J. Flynn, according to a statement from memory by L. J. Lincoln, a small flow was found at 150 feet and a small flow of brackish water at 355 feet. The future city supply is not likely to be obtained from deeper wells, as sufficient tests have been made to show that the water is not abundant in the lower part of the drift and that it is also too highly mineralized to be satisfactory.

WATER SUPPLIES OF CLARE COUNTY.

By Frank Leverett.

GENERAL STATEMENT.

Clare County, of which Harrison is the county seat, lies immediately north of Isabella County, near the center of the southern peninsula. The northwestern part is traversed by Muskegon River, on the borders of which there is a rather barren sandy plain from 5 to 10 miles in width. The extreme northwest corner has a few square miles of tillable land which has been settled and where wells have been obtained at moderate depths, usually less than 50 feet.

Southeast of the Muskegon River sand plain is a prominent morainic system running from the northeast corner of the county southwestward past Harrison into northwestern Isabella County. A large part of it is unsettled. The few wells indicate that the water table generally lies 75 to 100 feet or more below the surface. In Greenwood Township, however, there is a settlement in which wells have been found at 40 to 60 feet, the altitude being lower than in the part of the moraine to the east and south.

The southeastern part of the county slopes rapidly down to the old lake plain covered by the Glacial Lake Saginaw, and is traversed by weak morainic ridges. Flowing wells have been found in the valleys and low tracts in this part of the county, which are partly discussed in the report by Mr. Gregory (p. 106) and partly by the writer herewith.

WATERWORKS.

CLARE.

Clare, with a population of about 1,600, has a waterworks system supplied by a well about 40 feet in depth. The water is from gravel and rises nearly level with the surface. The supply is of good quality and adequate to the needs of the town. Tobacco River is also connected with the system and can be utilized in case of fire. The ordinary pressure is 20 pounds and the fire pressure 60 pounds. The wells of this village range in depth from 17 to 42 feet.

FARWELL.

Farwell, with a population of about 500, has a waterworks system supplied from a pond fed by a spring brook. Water is pumped direct, and an ordinary pressure of 40 pounds and a fire pressure of 140 pounds furnished. The wells of the town are 20 to 23 feet in depth and are in common use by the residents.

HARRISON.

The public supply of Harrison, the county seat, is pumped from Bud Lake direct to the mains, which have a length of 1½ miles. Very few private wells are in use.

MISCELLANEOUS TOWN SUPPLIES.

At Temple, which is located on the bank of the Muskegon River, wells are driven through sand about 40 feet and obtain an abundant supply.

At Clarence the wells vary greatly in depth, there being a range from 16 to 116 feet in the vicinity of the hamlet. The water in the deep wells stands about 20 feet below the surface.

At Crooked Lake driven wells and the lake constitute the water supply. The wells are from 25 to 50 feet in depth and have water standing about 12 feet below the surface.

FLOWING WELLS.

SHERIDAN TOWNSHIP.

In the central part of Sheridan Township, the southeast township of Clare County, at an altitude about 800 feet above the sea, is a small flowing-well district. It is 1 to 2 miles northwest and a little above the level of the highest shore of the Glacial Lake Saginaw.

Only five wells were noted, but possibly others occur, as the notes were made some years ago when tracing the shore line through the region. The strongest flow is at the residence of Joseph Schenck, on the east side of sec. 16, its yield being 5 gallons a minute from a 1¼-inch pipe. It is reported to have flowed 12 gallons a minute from a 2-inch pipe before the reducer was put on. The temperature is 47° F. The depth is 103 feet and water will rise to at least 5 feet above the surface. The well passed through a clayey till for 75 feet and then through sand to a crust at bottom, beneath which the strong flow was found. The other flows are: George Chunz well, in west part of sec. 15; schoolhouse well, in northeast part of sec. 15 (very weak flow from well 66 feet); John Smith well, in southwest corner sec. 11 (depth 106 feet, altitude 10 to 12 feet above schoolhouse well, and stronger flow); George Schunk well, in west side sec. 10 (depth 75 feet, weak flow). The catchment area is likely to be in higher land that lies immediately northwest of these wells.

WATER SUPPLIES OF GLADWIN COUNTY.

By Frank Leverett.

GENERAL STATEMENT.

Gladwin County is traversed nearly centrally from southwest to northeast by the shore line which marked the upper limits of the Glacial Lake Saginaw. There is a rapid rise from about 800 feet at the shore line to 1,100 feet or more in the northwest corner of the county. East from the shore line is a gradual descent to Tittabawassee River, followed by a slight rise to a water-laid moraine that lies east of the river.

Flowing wells have been obtained at several places along or near the old lake shore, and there is a possibility of much more extensive development not only in the vicinity of this shore line but in valleys and lowlands between morainic ridges to the west. Flows may perhaps be obtained along Tittabawassee River, but that portion of the county is still largely unsettled.

The catchment areas which supply the flowing wells are to be found, in all probability, in the more elevated country west and north of the wells, as in the neighboring larger flowing-well districts in Isabella County described by Gregory (pp. 92–111), of which this chain of flowing-well districts may be regarded as the continuation.

FLOWING WELLS.

GLADWIN DISTRICT.

This includes not only flowing wells in the village, but scattered flows to the south, between Gladwin and Beaverton, and a flow at the county infirmary north of Gladwin. The strip is nearly 10 miles long and lies along or near North Cedar River. The flows in Gladwin and at the infirmary are in the valley, but some of those south are on the bordering lake plain, not far below the old shore.

At the Gladwin waterworks, in the west part of the village, on ground about 15 feet lower than the railroad station, or 765 feet above tide, are two wells which flow with a head about 25 feet above the surface. One well was sunk to a depth of 465 feet, but found a bitter water in the lower part, so that it is shut out and the supply is obtained from 160 to 180 feet, in rock which immediately underlies the drift. The other well was sunk to a depth of only 165 feet. The first well is reported by Gregory to flow about 100 gallons a minute. The river is drawn upon in case of fire, and pumps (Gordon & Maxwell) are installed which have a daily capacity of 1,500,000 gallons.

The flowing well at the infirmary in sec. 25, T. 19, R. 2 W. is only 37 feet deep and has a head of at least 6 feet. It is from glacial deposits.

W. M. Bush, a short distance south of Gladwin, has a flowing well reported to be 230 feet deep and 4 inches in diameter. Gregory learned that its rate of flow is 5 gallons a minute.

About 5 miles south of Gladwin, on the W. H. McCulloch farm, in the east part of sec. 34, T. 18, R. 2 W., is a flowing well 68 feet deep. It stands near the bluff of the North Fork of Tobacco River, about 25 feet above the level of the stream.

In the south part of sec. 36, T. 18, R. 2 W. is a well on the farm of Frank Finsel, which has a head level with the surface. It stands near the beach of Lake Saginaw at an altitude very nearly 800 feet above tide. The depth is 135 feet, and the well is entirely through clay to the water-bearing gravel at bottom.

Fraser and Button, of Gladwin, made in 1902 a flowing well 400 feet in depth and 4 inches in diameter. The water is running to waste in large quantities.[a]

On the farm of A. Adams, 6 miles south of Gladwin, in sec. 36, a well 44 feet in depth and 2 inches in diameter was made in 1902 at a cost of $50. It flows 25 gallons a minute. The water is reported to be hard.[a]

McCLURE DISTRICT.

On the plain west of Sugar River, north of McClure post-office, several flowing wells have been obtained at moderate depths, none being more than 100 feet. Six of the wells are on the Jacob Schwartz farm

[a] Data collected by W. F. Cooper.

and one on the Dutscher farm. The altitude is about 810 feet or but slightly higher than the beach of Lake Saginaw, which comes to Sugar River south of McClure. This plain, however, is back of a moraine which, to the southwest, lies near the shore of the old lake. The catchment area is probably in the country which rises west or northwest from the wells. No data were obtained as to the strength of these wells further than the statement that they all had "good flows."

EDWARDS DISTRICT.

About a mile south of Edwards post-office, in the northern edge of the northeast township of Gladwin County, is a small group of shallow flowing wells 30 to 35 feet deep. They are in secs. 5, 8, and 9, T. 20, R. 2 E., on a plain of black, sandy loam, between the middle and east branch of Tittabawassee River, standing about 800 feet above tide. There is a slight depression where the wells are located, perhaps 10 feet below bordering tracts. The catchment area seems likely to be within a mile or two north, on sandy ground, near Edwards post-office, for the shallowness of the wells and the slight head which they show (scarcely 5 feet) seems consistent with a near, rather than a remote, catchment area. The wells appear to have passed through a few feet of clayey material under the sandy loam before striking water. The following were the wells in operation at the time of observation in 1901: Ira Mayes, east part sec. 5, depth about 30 feet; Ed. Hayes, north part sec. 8, depth about 30 feet; Lewis Harrell, northwest corner sec. 8, depth 33 feet; and Henry De Lord, west part sec. 9, depth about 35 feet.

WATER SUPPLIES OF BAY COUNTY.

By W. F. Cooper.

FLOWING WELLS.

The artesian area of Bay County (Pl. III) is in the lowlands lying west of Saginaw Bay and in the valley of the two forks of Kawkawlin River, though there are other small tracts on higher land. The greater part of the artesian water is from the drift.

WILLIAMS TOWNSHIP.

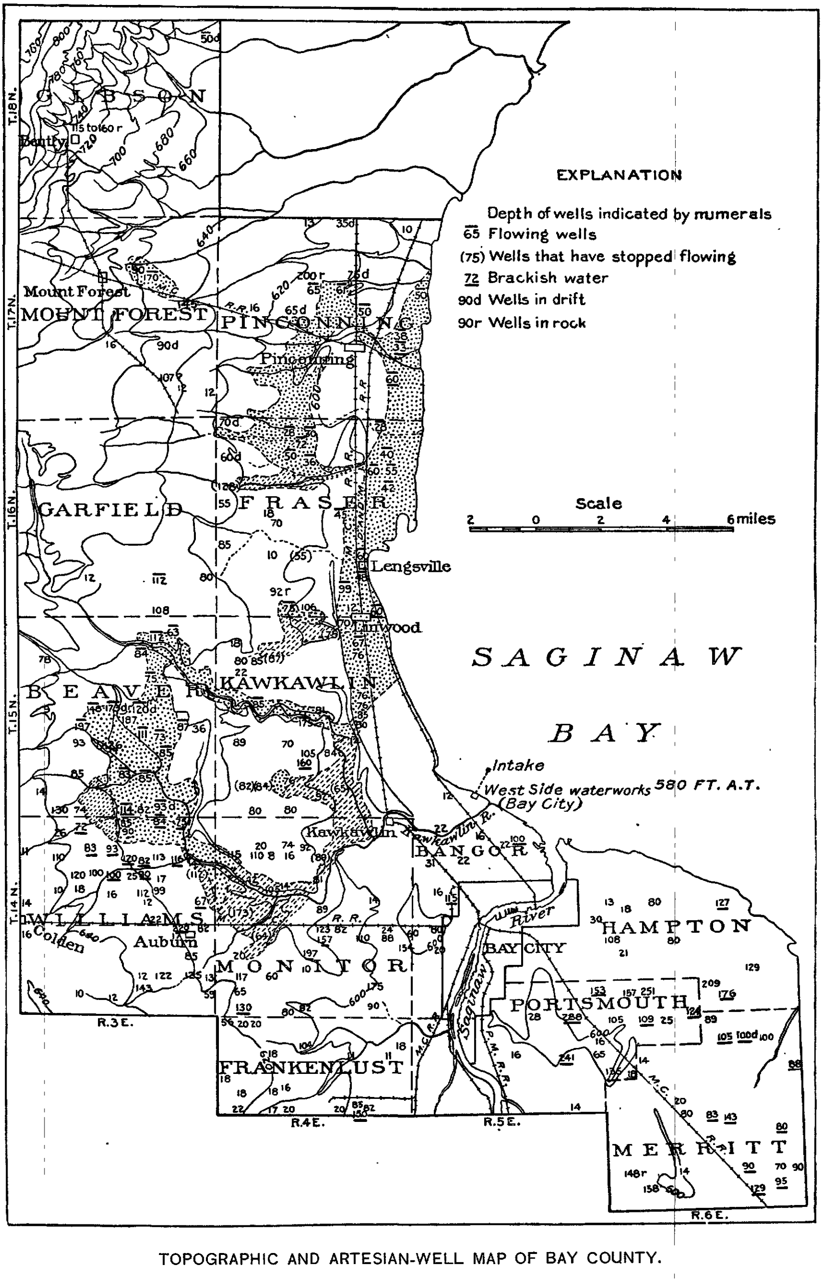
In the northeastern part of Williams Township (T. 14, R. 3 E.) the depth of flowing wells ranges from 80 to 95 feet, the wells being found in secs. 1, 2, 3, 4, 11, 12, and 13. The water is slightly salty and comes from gravel beds in the drift. This area formerly extended farther east into Monitor Township (T. 14 N., R. 4 E.), where flows were obtained in the valley of Culver Creek in secs. 7, 17, 18, 19, and 20. Quite recently Mr. Theodore Archambeau while drilling for coal in the valley of the south fork of Kawkawlin River obtained a flow near the north line of sec. 10, T. 14 N., R. 4 E., which seems to be a northerly continuation of the former Culver Creek area.

Numerous wells in the eastern half of Williams Township obtain their supply from the drift down to a depth of 220 feet, as in the deep well at Auburn, which penetrated first 80 feet of clay, then 138 feet of sand and 2 feet of gravel, the latter resting on the shale rock of the coal measures. The gravel is water bearing, but the overlying sand, although allowing the water to permeate it, will not furnish it in sufficient quantities for an adequate or stable supply. The drift-filled pre-Glacial drainage valley over which Auburn stands trends east to west and increases in depth westward. Along its course it would be well wherever possible to obtain water at a depth of less than 80 feet. The process of drilling through sand is difficult and expensive, besides added to the difficulty of keeping the casing free from clogging.

KAWKAWLIN VALLEY.

Northward from Williams, in Beaver Township (T. 15 N., R. 3 E.), the area of artesian water is in a general way contiguous to the basin of the two forks of Kawkawlin River, and to a drift-filled pre-Glacial channel which has a southwesterly course across Beaver Township, as indicated on the map. Beds of gravel, apparently of inter-Glacial age, deposited in the coal measures, within the limits of this old channel, furnish the conditions necessary for flows. The source of water is probably from the north and the west. Where such beds are tapped in this relatively depressed area, flowing wells are obtained. There are at least two and probably three water horizons in Beaver Township—the uppermost at a depth of 60 to 80 feet, a lower one at 110 feet, and a still deeper one at 173 to 197 feet. Some wells obtain flows both at 65 and 110 feet. The amount of flow does not seem to bear any relation to the depth. Two of the heaviest of the flowing wells have depths as widely different as 93 and 173 feet, one in the SW. ¼ sec. 35 being 93 feet and the Cherry well in the SE. ¼ sec. 16, Beaver Township, being 173 feet.

In Kawkawlin Township (T. 15 N., R. 4 E.) artesian waters have been obtained in rather limited areas adjacent to north fork of Kawkawlin River in the northeastern and southwestern portions of the township. This latter area formerly opened out to the south to include the lower reaches of the north fork down to its junction with the south fork in Monitor Township. The very limited area at the northeast corner of sec. 31 is in a swale (traversed by drain No. 1). The depth here is 82 feet to water, which comes from a gravel deposit overlying the rock. An artesian well from the rock is found in NE. ¼ sec. 21, the depth being 175 feet.



TOPOGRAPHIC AND ARTESIAN-WELL MAP OF BAY COUNTY.

FRASER FIELD.

In Fraser Township the artesian conditions appear comparatively simple, flows being obtained in gravel-bearing beds probably just overlying the rock, in a plain whose catchment area is on higher land to the northwest. The wells are restricted to the area adjacent to Saginaw Bay, a portion of the valley of Mitchie Creek, and the valley adjacent to the Chute Creek drainage in the western half of Fraser Township. The depth varies from 28 or 30 feet in the northern portion of the township to as much as 75 feet along the road west from Linwood, and follows very nearly the inequalities of the rock elevation. A subordinate area formerly extended a short distance up the swale now traversed by the Ryan drain at the line of secs. 21 and 28, 22 and 27. In the NW. ¼ sec. 18 is a well to bed rock, 128 feet deep, which has ceased flowing.

PINCONNING FIELD.

In Pinconning Township the Chute Creek area of artesian water is extended northward through the central part of the township, flows being obtained from depths ranging from 45 to 85 feet. Apparently the water is obtained from gravel beds overlying the rock, in a similar position to those southward. East of the Algonquin beach, along the State road, flows have occasionally been tapped at depths ranging from 38 to 60 feet. Detailed data regarding wells at Pinconning, collected by W. M. Gregory, are given on pp. 270–271.

MOUNT FOREST FIELD.

A small area of artesian water has been found in Mount Forest Township, which with further drilling may be considerably extended. The flows are obtained in the SE. ¼ sec. 10, where coal drilling was carried on for John Mansfield. There are flows at 90 feet (at the base of the drift), and in beds of sand rock in the coal measures. Prospectively the best area to test further would be to the north and west in the basin of Saganing Creek.

SUMMARY.

Taking the artesian waters as a whole almost all the flows are obtained from gravel beds, either at the base of the drift formation or interbedded with Glacial clays. Artesian water is also often obtained in relatively depressed areas in the line of pre-Glacial valleys. While it is not possible to determine precisely the origin of the flows in the central and northern part of the county, it seems probable that the elevated moraine, covered with sand and gravel, traversing the western portion of Gibson Township in a southwesterly direction, and thence running southerly through Gladwin and Midland counties, furnishes the catchment area. It is also thought that these beds of sand and gravel which hold the artesian water are inter-Glacial and were covered by beds of clay and hardpan deposited during a later ice advance.

The absence of flowing wells from the drift in the southeastern part of Kawkawlin and the northwestern part of Bangor townships, adjacent to the shore of Saginaw Bay, seems due to the upward rise of bed rock in that direction, and to the almost entire absence there of gravel beds in the drift. The artesian water seems to come from the northwest and to be thus ponded back by the bed rock.

No precise data were obtained concerning the actual amount of water running from the wells nor of the capacity of the nonflowing wells. Shallow wells show a tendency to become lowered in summer, and in some cases fail entirely. The flowing wells are on the whole diminishing slightly in flow and in area, which makes it seem important to keep the water shut off when not in use. The following record sets forth observations which are at hand:

Flowing wells in Bay County.

Township.	Section.	When made.	Remarks.
Beaver	16	1880	Cherry well; depth, 173 feet; no diminution; probably strongest flow in county.
Do	32	....	William People's well; depth, 74 feet; ceased flowing.
Fraser	2	1898	Depth, 28 feet; continued steady flow, 1900.
Do	6	....	Great decrease.
Do	28	....	Flowed in 1892; now ceased.
Kawkawlin	3	1871	Stopped flowing in 1884; now 4 feet below surface.
Do	34	1875	Original head, −2 feet; now much lower.
Do	8	1878	Flowed for 3 years; now −8 feet.
Do	19	1884	Flowed in 1900.
Do	34	....	−2 feet in 1892; −6 feet in 1900.
Do	5	1894	Flowed 1 year; −9 feet in 1904.
Do	31	1894	Flowed 2½ feet above surface; now 1 foot above; weak.
Do	27	1895	Original head +1 foot; in 1900, −6 feet.
Do	32	....	Flowed ½-inch stream 1½ feet above surface in 1896; ceased in 1900.
Do	32	1896	Original head −6 feet; now much lower.
Do	23	1897	Flowed 1½ feet above surface; ceased in 1900.
Do	34	1897	Flowed 1 foot above surface; 3½ feet below in 1900.
Williams	4	1887	Pioneer well; continued constant in 1900.

The first shaft of the Pittsburg Coal Company, near Amelith, struck a bed of water-bearing sand at a depth of about 40 feet. The great quantity which was pumped out at that time affected the water supply more than 2 miles away, as, for instance, in the case of the well at the Michigan House, which went dry.

NONFLOWING WELLS.

In Merritt and Portsmouth townships shallow surface wells having depths of from 15 to 20 feet often contain an insufficient amount of water, beside being otherwise objectionable on account of surface drainage and organic matters, while brackish water sets in at a depth of about 80 feet, thus leaving but a narrow zone from which water of good quality can be obtained.

In Hampton Township fresh water is obtained at depths ranging from 30 to 80 feet.

In Frankenlust Township fresh water may be obtained down to depths of at least 85 feet, and in general a fairly abundant water supply may be obtained at a depth of less than 50 feet.

In Bangor Township an abundant water supply of good quality is generally obtained at a depth of less than 30 feet, and fresh water is often found to a depth of 80 feet, but brackish water sets in at a little over 100 feet.

In Monitor Township there is no difficulty in obtaining water at depths of less than 90 feet, below which depth it is liable to be brackish.

In Williams Township troublesome sand deposits make deep drilling sometimes necessary; but the western portion of the township usually affords good supplies at moderate depths.

In Beaver and Kawkawlin townships, outside the areas of flowing wells already described, a sufficient supply of water is generally obtainable at a depth of less than 90 feet, though one well in the southwestern part of Beaver went down to 130 feet. Mr. Shaw, in sec. 28, Kawkawlin Township, found fresh water at 105 feet and also in the rock, but at a depth of 160 feet encountered brackish water.

In Fraser and Garfield townships, outside the area of the flowing wells of the Fraser field, fresh water supplies are obtained down to 112 feet, as at Crump post-office. However, in the southwestern portion of Fraser Township several wells 80 or 90 feet have become dry. This may be due to subsurface drainage, though the cause for failure is still an open question. It is probable supplies may be obtained by deepening the wells into the underlying bed rock, say to a depth of about 125 feet. Wells in the western part of Garfield Township are generally shallow and the water is of a quality that suggests a need for deepening to better supplies.

Wells in Pinconning Township usually obtain a sufficient supply at depths of less than 80 feet, but are occasionally much deeper. In the SE. ¼ sec. 9 a well 200 feet deep obtained a good supply of water without objectionable mineral properties.

In Mount Forest Township the wells are generally shallow, except in the southeastern portion, where a few have a depth of 90 to 145 feet, one deep one being at the schoolhouse in sec. 13. These deep wells seem to be free from any objectionable mineral matter.

In Gibson Township most of the wells are shallow, and many should be deepened to insure a permanent and pure supply. In the morainal region in the western part of the township wells have in some cases failed to reach a good supply at 100 feet. At Bentley, however, Mr. William Hinman obtained an abundant amount of good water in a sandstone of the coal measures at a depth of 160 feet.

In order to obtain a permanent supply in the morainal region in the western third of this township it may be necessary to go to a depth similar to that at the Hinman well.

QUALITY OF WATER.

The records of several wells east of Saginaw River in Hampton township show that water containing brine percolates upward in the coal measures to within about 125 feet of the surface, above which fresh water has been obtained at depths ranging from 30 to 80 feet.

A number of well records in Merritt and Portsmouth townships indicate that wells in the drift having a depth of 80 feet generally contain a small amount of saline matter.

A well in sec. 14, Frankenlust Township, obtained fresh water at a depth of 85 feet, but upon being extended to a depth of 135 feet became saline. For the central part of Frankenlust Township the upper limit of saline water is a depth of about 100 feet.

In Bangor Township the upper limit of the percolation of brines is not far from that in Frankenlust Township, while westward in Monitor Township the depth to brines is about the same as in Hampton Township, 125 feet, although wells in the drift are occasionally slightly brackish at about 90 feet.

WATER TEMPERATURES.

The following observations were taken with a standard thermometer, Green No. 7529:

Temperatures of Bay County waters.

	°F.
Shaft of Whatcheer mine, sec. 30, T. 13 N., R. 6 E. at 139 feet	54.5
Same shaft at 155 and 198 feet	54
Shaft 1½ miles east of Auburn, water pumped in large volume from a depth of 90 feet (tested also by Dr. A. C. Lane)	50
Flowing well near southwest corner sec. 27, Pinconning Township (Lane)	51.5
Rich's bakery well at Pinconning, August 6, 1901 (Lane)	48.5
Saginaw Bay:	
Average of 84 observations, September 12 to 26, 1904, between 5.30 a. m. and 7 p. m	72.11
Highest temperature, September 12 to 26, at 3 p. m.; seven observations	75.11
Night observations between 9 p. m. and 3 a. m., September 22 to 23 and September 25-26; eight observations, average	66.54
Lowest temperatures noted were at 3 a. m; average	65.25
Bay City, wells 80 feet deep (tested by Lane)	50

TOWN SUPPLIES.

BAY CITY AND WEST BAY CITY.

Bay City and West Bay City (now one corporation) obtain public supplies from Saginaw Bay, there being two pumping stations, one taking water near shore, the other 3 miles out. The water is not up to the standard desired, owing to the shallowness of the bay and consequent turbidity during storms, and to the dangers of contamination when an off-shore breeze carries the sewage into the bay. The present supply may be rendered more satisfactory by a further extension into the bay and fuller protection from contamination. As to other sources of water supply, it may be stated that it will be feasible to take water from wells in the Marshall sandstone in Huron County, where large quantities of fresh water are found, though perhaps this source would need to be restricted to supplies for drinking, leaving the factories, lawns, and fire protection to be supplied from the bay water. It will also be feasible to pipe water from the headwaters of Tittabawassee River, a scheme suggested by Superintendent Dunbar of the Bay City waterworks. There does not appear to be an adequate supply of fresh water obtainable either from the glacial deposits or the rock in wells within the limits of the city or on its immediate borders.

SAGINAW BAY DRAINAGE BASIN SOUTH OF BAY AND ISABELLA COUNTIES.

By Charles A. Davis.

INTRODUCTION.

LOCATION AND BOUNDARIES.

The district covered by this report forms a considerable part of one of the physiographic units which make up the Southern Peninsula—namely, the drainage basin of Saginaw Bay. It includes Midland County and counties lying south of Isabella and Bay counties. The natural boundaries of this area are, in general, moraines left by the Saginaw lobe of the last ice sheet as it melted back into Saginaw Bay. From an inspection of the map of the State showing the streams it is seen that the district under discussion includes the western part of Sanilac County, all of Tuscola, all of Lapeer except a small part of the eastern side, the northern half of Oakland, the northern half of Livingston, the northeast half of Shiawassee, all of Genesee and Saginaw, and the larger part of Gratiot County.

PHYSIOGRAPHIC FEATURES.

A brief account of the physiographic features of this region will make plain its peculiarities of water supply, and especially the infrequency of flowing-well areas in some parts and relative frequency in others.

There is a close relation between the development of the flowing-well areas and the physical features of the region.

The borders of the greater part of the district are rather rough and hilly, with more or less well-defined, but frequently ill-drained, valleys.

In other words, the bordering divide of the district is made up of a series of well-marked ridges of glacial origin, with valleys which represent either times of rapid melting, channels which originally carried off the water from the front of the melting ice, or, more rarely, preexisting valleys which were occupied by ice masses that persisted until masses around them melted.

The width of this hilly area is greatest in the southern and eastern parts of the district, where also the hills are more prominent and the valleys broader. It is very narrow and the ridges scarcely noticeable in the region extending from Owosso, in Shiawassee County, northeasterly into Gratiot County, where the divides between the headwaters of the streams running into Lake Huron through Saginaw Bay and those tributary to Lake Michigan are so flat in places as to be occupied by swamps.

Passing from any part of this outer rim of the drainage basin of Saginaw Bay toward the bay one usually traverses a number of ridges of successively lower height, with intervals of gently sloping plain, upon which are more or less extensive and continuous lines of low sand ridges. The plain is slightly undulating in places, but in the main gives a definite impression of being very flat and featureless. In it the valleys of the streams are narrow and shallow, with steep sides, and the streams themselves are generally sluggish and their waters muddy. Much of this basin is an old lake bottom covered by the waters from the melting ice impounded between the front of the ice and the bordering rim of the basin at the level of the lowest point on the rim that could serve as an outlet.

The sandy ridges which occur upon it are shore lines, marking various stages or halts, longer or shorter, in the subsidence of the temporary body of water. There are, therefore, two distinct types of territory covered by this investigation, the hill and valley type and the flat or slightly undulating plain.

Theoretical considerations would provide for flowing wells oftener in hilly districts than in plains, because conditions under which flows occur are more common in this type of country. Such, however, does not seem to be the case in the area under discussion, for the larger flowing-well areas and the larger number of wells exist in the plain and not always, by any means, in the vicinity of the ridges.

This is, however, due to several easily determined reasons, not the least of which is purely accidental and in no way connected with causes which do or do not produce flowing wells. Flowing wells are better developed on the plains than in rolling districts, for the simple reason that the farm buildings in the rolling districts are generally placed on the higher land, often on the tops of the hills, unless the valleys are very broad and well drained, and in this general location the wells are above the level to which artesian water will rise. Farmers often seem unmindful of the fact that the water table is farther from the surface at the top of an elevation than it is on the bordering lower ground if the water-bearing material is of the same character throughout the ridge.

If the water is in a bed of coarse material, such as sand or gravel, and this lies between much less permeable beds or deposits, all running from the top of a hill to the bottom, the water at the top of the elevation will have less tendency to rise in the well than it will halfway down the slope or at the bottom.

Moreover, the supply will be much more easily exhausted in a well near the top than near the bottom of the slope or in the valley bottom, for it is to the valley that the water of the entire bed is passing. In case there is pressure enough to create artesian or flow conditions the head is greatest at the valley bottom, and there, if anywhere, flows can be obtained. Thus the location of farm buildings on the high lands tends to discourage the exploration of lower ground for water, and many places in which good flows might in all probability be secured remain untested, while the owners of the land pump all the water which they use from considerable depths.

In the lake plain, on the other hand, the building sites are not usually elevated much above the general level, and, if flowing wells are found at all, the area is frequently fully explored and thoroughly developed.

Aside from the above considerations, the different origin of the surface deposits in the two districts must be taken into account. In the ridged district the coarse and fine materials are interbedded about as they were deposited by the melting of the ice which brought them to the place where they occur and are either entirely unsorted or incompletely sorted, with coarse rock fragments usually present in great abundance. As a consequence, water can find its way into the soil readily, and usually, also, into beds of sand or gravel, in which it may be stored and from which it is given up readily to wells. In the lake plain, which was developed under water, the surface deposits have been thoroughly sorted, the coarse material usually being left in the bottoms of the valleys draining into the plain and the finer sands or clays being carried to the lower-lying parts of the plain, where there was deep still water. Such materials are slow to take up water and very slow to give it up, and, in general, in this region there are few coarse beds near the surface to receive the water. Those which do occur seem generally thin and of small extent, so that the water is easily exhausted. Hence the average well is deeper and the water-bearing beds are more fully explored in the plain than in the ridged districts, and if flows can be had the fact is more likely to be known and the area fully developed.

The head of flowing wells is likely to be less in the plain than in the ridged areas, since the differences in surface level are generally slight, and unless it is assumed that the beds containing the water are widespread and continuous for long distances (many miles in some cases) the head must be derived from the slight elevations or slopes which do occur, but which, because of the friction, can not give much pressure. Even here, also, the head is strongest at the bottoms of depressions, and frequently it is in valleys alone that flows can be obtained.

WELLS.

TYPES OF WELLS.

In each of these types of country several kinds of wells are in use, but certain types may be considered fairly characteristic of each. In the ridged districts dug and walled wells of the basin type are most common. This is due to the ease with which water is found near the surface, to the abundance of stone for walling up the basin, and to the difficulty which often arises in getting enough water from the bored or tubular wells. Wells of the bored type are usually difficult to put down in these districts, because of the bowlders present in the soil. Drilling and driving are frequently hindered by the same cause. Since dug wells with open basins are always more in danger of contamination from surface drainage, those with iron tubes are coming into use. These are to be preferred, and when a well has been dug down to a good strong supply of water it is possible to convert it from a dug well into a tubular one, which will furnish plenty of water by inserting the proper length of pipe, with or without a strainer, and filling in around it, first, with clean cobble stones or coarse gravel for 3 feet or more, then with finer gravel, which should be carefully tamped down, and then with sand, ending with a few loads of clay at the top. Such a well does not need curbing and is generally guarded against contamination if the work is properly done and clean materials are used in filling in around the tube. Other types are the cemented well, the drain-tiled well, the timbered well (which is especially bad and probably now not common), and the bored, driven, or drilled wells. Flowing wells are usually of the tubular construction. In the plain the most frequent type is the tubular well. Apparently, this is due to the facts that permanent supplies of water are not found near the surface and that in many cases tubular wells are easily put down by boring. Along sand ridges and in other sandy areas in and bordering on the lake plain shallow dug wells are in general use and constitute an important source of supply for farm and house use.

Rock wells also are more frequent in the plain than they are among the ridges, largely because of the greater depth of rock in the latter region, but also because of difficulty with which water is obtained above the rock surface in parts of the plain.

Only a small proportion of the wells in the regions here discussed actually flow, and in areas where flows are known to occur the number of wells requiring pumps is often larger than the number of flowing wells. This is due to several causes, among which are the following: (1) The occurrence of good supplies of water above the water levels from which flows come. (2) Location of the mouth of the well above the level to which water will rise. (3) Irregularities in permeability and thickness of the water beds from which the flows come, so that water is not yielded with equal readiness from all parts of them. (4) Local development of "hardpan" or impermeable capping stratum, so that flows are to be had only locally. (5) Driving the pipe beyond and casing off the water by the driller through carelessness. This latter may be due to accident or to wilful cheating by dishonest drillers. (6) The shutting off of the flow by raising the casing so high that water will not run from it. This is sometimes done to escape the necessity of disposing of the waste water. (7) The smaller cost of shallow wells compared with deep ones, and some uncertainty of getting a flow tends to restrain residents from trying to get them.

Flowing wells occur in 129 districts, distributed as follows: Oakland County, northwestern part, 4; Lapeer County, including those discussed by Leverett, 9 (2 from rock); Genesee County, 15; Livingston County, 5; Shiawassee County, 5; Gratiot County, 21 (rock flows in part of 2 of these); Midland County, 7 (including rock flows); Saginaw County, 12 (not including rock flows); Tuscola County, 61 (29 from drift).

In this list flows from rock are of small consequence except in Tuscola County, and about one-half the number in Tuscola County are drift flows, many of which are within areas of flowing wells from the bed rock. Saginaw County would have a larger number if the areas of flows from bed rock were included in this list.

UTILIZATION OF FLOWING WELLS.

It often seems that there is too little appreciation of the possibilities of flowing wells, for, beyond the rather frequent use of the waste for cooling in dairies or milk houses and its rather rare use for irrigating gardens or grass plots, little utilization is made of the great volumes of water which many flowing wells pour out. Some additional uses which occur to the writer are the following: (1) Its more frequent use to irrigate lawns and gardens. This could often be arranged by attaching a hose to the outlet of the well or by dividing the flow by the use of underground pipes, as is occasionally done to conduct the water of a well to some distant building. (2) As source of supply for fish and ice ponds. Near Midland and at a few other points such ponds have been constructed and not only pay the owners largely for the investment but add materially to the beauty of their farms. The ponds are simple in construction and are apparently not expensive to build. Carp and other fish flourish in them, and the ice from them is of much greater purity than that from rivers. (3) To fill reservoirs. Most farms, where there are flowing wells, are without any protection against fire except the small amount furnished by the water held in the tanks at the wells. A large cistern or even an old dug well could be kept full all the time by turning the waste water through it. (4) By the use of a water motor, where the head is sufficient, the water could be automatically pumped from the well to the house or barn of the owner and then stored in tanks and all of the benefits of a waterworks system be enjoyed in both places, provided the tanks were placed high enough to give pressure. (5) By the use of a hydraulic ram, which is less expensive than a motor and very efficient, even with a very small flow and slight head (2 feet or more), the pumping could be done more cheaply and the water of flows at a considerable distance could be forced to the buildings. This means of pumping seems to have been entirely overlooked by the farmers throughout the region visited, and if used, would solve many problems relating to water supply.

LOSS OF HEAD.

Loss of head in flowing wells in the region may be due to overdevelopment in a given basin, either by sinking too many wells or by unwise distribution of wells, or by allowing wells to flow freely; leaks caused by splitting the casing in driving (a defect that is in some cases not apparent for some time); leaks caused by rusting of the casing; water rising around the casing because of imperfect driving; fine sand filling the bottom of the casing; filling at the bottom, by caving from the sides where the casing is incomplete; obstructions put in at the top of the casing; clogging of the strainer on the point; drought in the catchment area; excessive draining of the surface of the catchment area; or subsurface drainage.

OVERDEVELOPMENT.

This consists of putting down wells until the continued outflow is greater than the amount of water which flows into the water-bearing strata from all sources, and the loss of head which invariably follows is directly due to useless waste in most cases. In a considerable number of places it was reported that there had been a gradual loss of head or that some wells had ceased to flow, as the area had been fully developed. In many cases it was said that wells had ceased flowing when others were put down on lower ground near by.

There is no absolute remedy for this, but it is evident that a reasonable use and conservation of the supply of a given area will allow many more to use the supply and prolong the period of use. The easiest and cheapest method of conserving the supply is to reduce the size of the outflow pipes to such a diameter that the owner's needs are satisfied without great waste. The use of cocks or valves is to be recommended in some cases where there is no danger of the well silting up. Wooden plugs with small holes bored through them are effective and very quickly and cheaply provided. The need of intelligent means of checking overdevelopment and waste was observed in nearly every part of the region covered by this investigation. At Alma there was considerable discussion regarding the advisability of securing legislation to prevent further deterioration of the supply. At St. Louis the flowing wells of most private owners were stopped by the public wells, but after these were abandoned they were not properly plugged, and some at least are still flowing and keep the head permanently low.

LEAKS CAUSED BY SPLITTING THE CASING.

The splitting happens when the casing is being driven, but the results are not apparent for some time after this, because it takes time for the water to make a passage for itself through the ground, either to the surface, or to some stratum into which it can flow. The only remedy is to pull the casing out and replace the split pipe with a new section.

LEAKS CAUSED BY RUSTING OF CASING.

These leaks occur in wells which have been down a long time, especially where 1-inch or $1\frac{1}{4}$-inch black pipe was used for casing. The leaks frequently occur so near the surface that the water finds its way up around the casing and makes the trouble known. The use of galvanized pipe and of large-sized pipe with thick walls will probably prevent this sort of trouble for a very long time. The drift waters contain so much dissolved carbon dioxide that they have a marked corrosive effect upon unprotected iron.

IMPERFECT DRIVING.

This is a frequent cause of the loss of head in shallow wells of the bored or driven type. The pipe is not driven straight, and in trying to get it right the strata above the water becomes sufficiently disturbed for the water to find a way to the surface and thus less goes through the casing. This condition may sometimes be remedied by tamping clay, then cement, around the pipe where it comes from the ground. The clay alone will sometimes be sufficient, if a considerable thickness is used. In case the leak is a very large one some heavier material like cobble stones may be used first, and the clay put over them.

FINE SAND AND SILT.

In some areas trouble with fine sand was reported, as at Ortonville, where the sand was so fine that a sand screen could not be used. In several areas where the water-bearing strata were coarse, there was often enough fine material in them to fill up gradually the lower part of the casing or the point when this was present. Sand pumping is the usual remedy for this trouble, and was reported as fairly cheap and satisfactory.

CAVING IN AT THE SIDES.

In the Ortonville and Davison areas, and in other districts where the clays over the water-bearing beds are sufficiently compact, many of the holes are not cased beyond a single length of the pipe. Such holes sometimes break down at the sides, the débris stopping or reducing the flow. Such accidents may be repaired by reaming out the hole, but usually a new well is sunk.

OBSTRUCTIONS PUT IN AT THE TOP OF THE CASING.

A few cases came to notice where children had put pebbles and other obstructions in the pipe where flows were small, with the result that they were still further reduced or entirely stopped.

CLOGGING OF THE STRAINER ON THE POINT.

This is a subject to which the writer has given particular attention. The clogging is found to happen in three ways: (*a*) By the gradual accumulation of fine silt or sand in the meshes of the strainer and in the point itself, so that the water can no longer find its way into the pipe. (*b*) By the breaking of the screen during driving and subsequent filling of the point with sand or silt. (*c*) By the incrustation of the strainer by chemical precipitation.

Character of incrustation.—Of these, the first two can usually be remedied by sand pumping. The third is of such importance that it needs further investigation, but deserves notice here, in order that attention of other observers may be called to it. The "point" of the well tube is a section of galvanized-iron pipe, from 2 to 4 feet in length, and of the same diameter as the casing of the wall, in which holes a fourth of an inch or more in diameter are bored at frequent intervals. The lower end is provided with a solid conical point, the upper with a thread, all except the point is covered with brass-wire gauze, having 60 meshes per linear inch for ordinary sands and gravel and 80 or 100 meshes for finer quicksands. Outside this gauze jacket is a protecting sheet of perforated brass to keep the gauze from injury while being driven. It was found on inquiry among well drillers that in some tubular wells in the drift, both flowing wells and pump wells, in which these points were used, the strainers become "corroded" after a longer or shorter time, varying even in the same locality, and no water was to be had. Inquiry as to the nature of the corrosion failed to bring forth any satisfactory description of it or of the appearance of the strainer after it was corroded, but all agreed that the only remedy was to pull the pipe out and take the old strainer off and replace it with a new one. Efforts to secure one of the corroded points were finally successful through the kindness of Mr. H. Chivers, of Alma, a driller of much experience in putting down tubular wells in the drift, who furnished a "corroded" point from a pump well 62 feet deep, which had been in use four or five years, and in which the water stood at about 12 feet below the surface. In this well the water came from fine gravel mixed with sand. It took but a glance to establish the fact that the point was not corroded, but incrusted by a dense coating of mineral matter which not only had filled up the meshes of the fine wire gauze but also had covered the outer protecting sheet. This coating was firm, hard though easily scratched with a knife, compact, of a bluish or grayish-white color, and in some places 2 millimeters or more thick but not uniformly spread over the entire surface. It was so firmly attached to the metal that it generally resisted the severe scraping which it received while being pulled from the ground, and was not easily scaled off, even when dry. Upon the lower part of the strainer, where the incrustation was thickest, large numbers of sand grains and small pebbles were cemented to the surface. Upon the upper part of the strainer the coating, while thinner and rather fragile, was still effective in closing the meshes of the screen. In some places it was brownish red (from the presence of iron), and in others dark bluish gray.

Composition of incrustation.—A qualitative analysis of the incrusting material showed that it was principally calcium carbonate mixed with fine silt and containing iron in small quantities. It dissolved very readily in acids with effervescence, and it is probable that incrusted points could be quickly freed from the coating by painting with dilute muriatic acid. It might also be feasible to devise some way of dissolving this coating off without drawing the pipe out of the ground, since the solubility is so great.

The incrustation was noticeably heavier at the bottom of the strainer than it was above, and even extended down on the cone at the end. This greater thickness may be due to the fact that only that part of the point and strainer penetrated the water-bearing stratum and that only that part which was in water was heavily coated.

Manner of coating.—A study of the wire gauze under a hand lens made it apparent that the deposit was at first laid on around the wires and as it increased in thickness the openings of the mesh were filled and the deposit thus formed was then coated over by later deposition. It is evident that with a 100-mesh (linear to an inch) screen the deposit upon the wires has only to be one two-hundredth of an inch in thickness to practically close the opening.

Cause of the deposit.—The deposition was due to some chemical action, which apparently released the calcium carbonate from solution or decomposed the bicarbonate of calcium, probably the latter, freeing the carbonic acid and precipitating the calcium as monocarbonate upon the metal. This would be natural if the metal showed any effects of the action of the acid upon it, but none could be discovered in the material at hand. The suggestion also was made that there was a feeble electrolytic action set up by the contact of the brass and the zinc coating to the iron pipe, or to the iron itself, and this is somewhat the more worthy of investigation, since there is on the market the Walker sand screen for large-sized tubular wells, which is entirely constructed of brass and which is reported to keep entirely free from incrustation, even in water where the brass and iron screens soon coat over and stop the inflow.

Importance of incrustation.—In the course of the season's work it became apparent that in a region where the drift is an important source of water supply, incrustation may become a very important cause of the diminution or entire loss of water. In single cases the cost of repairing and restoring a well is not great, but in the aggregate the loss to the persons depending upon tubular wells, in both money and time consumed, must be very great. Moreover, towns depending on this type of wells for their public supply may find it failing and attribute this to some irreparable cause and abandon the wells entirely or go to the expense of putting down new ones when this cause is alone responsible. At St. Louis, Mich., the wells were abandoned when they began to fail, and the water now in use is pumped from Pine River. At Holly a new set of wells was being drilled, in part at least, because the old ones were so nearly stopped up. At Ann Arbor the tubes of some of the wells have been pulled out and the strainers removed and others abandoned. At Owosso several of the wells of the city waterworks were reported to be out of commission for no known reason unless from this cause. They had ceased to yield water and had been abandoned. These instances might be multiplied, but it is evident that the whole matter of the formation of such deposits needs careful study.

DROUGHT IN THE CATCHMENT AREA.

This is a very effective cause of failure in districts where the development of wells of a given area is so great that the amount of water used by them is nearly equal to the amount sent into the water-bearing stratum from the catchment area. A slight decrease in the rainfall affects the supply of the whole area very quickly, the head being lowered so that the wells may cease flowing entirely, either for a long period, where there is a prolonged drought, or simply during the dry season of the year. In Midland County a number of wells were reported to stop flowing each summer, unless the season was a very wet one. In Genesee County, near Flint, was a well which showed marked fluctuations in level according to the rainfall. Many other cases might be cited.

SURFACE DRAINAGE IN THE CATCHMENT AREA.

The effects of surface drainage are certain to make themselves felt in the near future, if they have not done so already. The last few years has witnessed an immense amount of ditching to carry off the surface waters and of drain laying to remove quickly the subsurface waters which may interfere with certain crops. The effect is to so rapidly carry off the water of rain and snowfall to the rivers that, except in very sandy soils, but little gets into the ground. As a result the ground-water level must be gradually lowered. In fact, it is already much lower than it was before ditching began, and, as is pointed out in several places in this report, has been the primary cause of the extensive use of deep wells to reach supplies far below the surface in areas where formerly abundant water was to be found near the surface. If the ditching is carried much farther, the rock supplies even may be affected and the farm owners be reduced to storing rain water. A remedy for this threatened danger lies in more intelligent planning of drains, such as following the contours instead of crossing them, and the use of devices to hold the water back on the land during seasons when it can do no harm by its presence.

SUBSURFACE DRAINAGE.

In mining operations it is sometimes necessary to pump from the shafts enormous amounts of water or to drain sand and gravel beds which are passed through in sinking shafts. In most cases such beds furnish the whole or part of the water used by the people of the region, and the result of the draining is to cause either entire loss of supply, as where gravels are drained, or partial loss where the workings enter water-bearing strata at some distance from the wells. Thus the coal mines in Huron, Saginaw, and Bay counties have stopped the flows in a number of districts of rock wells which formerly used to flow and are reported to have drained dry considerable areas of shallow drift wells. The same thing happens locally when large waste from flowing wells on low ground is allowed to go on unchecked, and sometimes where for some manufacturing purpose large amounts of water are pumped from shallow strata, or where a group of wells is put down for public supply and is pumped sufficiently to affect the amount of water in the water-bearing strata of a district with a limited catchment area.

QUALITY OF WATER.

In general, all waters from the drift are hard, but in varied degree, some much more so than others. The cause of hardness is the presence of lime or calcium salts, usually the carbonate, but in the lake-plain region sometimes the sulphate or gypsum. In Midland County the drift waters from the deeper wells were of a remarkably low degree of hardness when compared with those of other localities. These hard waters usually have considerable amounts of iron present also, sometimes sufficient to give reddish scale when evaporated. Both the lime and iron are derived much more abundantly from clay beds than from sand, hence the waters drained from clays are harder than those drawn from sand. The calcium and iron carbonates thus derived from the soils are usually acidic rather than normal salts, and are generally accompanied by an excess of carbonic acid, which when the water is exposed to the air at normal pressure and temperature soon escapes as free carbon dioxid. It is this acid, and not the iron in the water, which attacks and destroys unprotected iron pipes and utensils and rusts tinware in which it is allowed to stand. The rusting in the case of the tinware seems usually to start at some point where the tin coating on the iron is thin or broken and spreads from this until holes are dissolved in the iron. The use of so-called galvanized or zinc-coated pipe and utensils or of "granite" ware is recommended as a partial protection against loss in this way.

The drift waters are sometimes saline, but not to a marked degree except in a few areas in the lake plain. It is probably true, however, that the salt content of the waters of the drift in the district covered by this report is abnormally high, because of the great abundance of salt waters in the rocks below the drift, from which they escape through faults or other fissures or abandoned salt wells. More rarely, salt may have been retained after inclusion in the drift. Compounds of magnesium are also present. For fuller statements regarding the waters of the drift, the reader is referred to the separate accounts of the various areas.

The character of the water from the bed rock varies with the nature of the rock, but is usually less hard than that from the drift. It is nearly soft (free from lime) when from certain sandstones, harder from shales, and very hard from limestones or rocks with calcareous cement or from gypsiferous beds. The rock water in certain parts of the lake-plain district is highly salty and in others brackish, and in many cases, where the rock from which it comes is a shale, magnesium compounds are present in considerable amount and may give well-marked tastes which are characteristic. In case the water comes from rocks with iron pyrites or iron sulphide present in it in quantity the water may become impregnated with hydrogen sulphide, a gas which gives the characteristic "sulphur" odor to it, and is particularly prized in medicinal waters. From the change of the pyrites to the sulphate of iron (copperas), which may occur in certain cases, the water may acquire an astringent taste, which is not uncommon in water from the shales, especially those of the sub-Carboniferous and Carboniferous formations.

It may be stated here, however, that the best water for any and all uses, except the manufacture of certain chemical compounds, is that which is free from mineral matter and from organic matter. While small quantities of gases and minerals may do no serious harm in water used for domestic purposes, large quantities demand that the water should be distilled, if possible, for drinking purposes.

Taken as a whole, both the quantity and the quality of drift as well as rock waters in the region studied are excellent, and the local areas where the supply is not adequate or the quality is very poor are few in number and comparatively small in extent. The natural waters from the drift and rock are undoubtedly wholesome, and it is only where they are contaminated from the surface through the medium of the open-basin type of well or through careless disposal of sewage that they become the cause of disease.

WATER SUPPLIES OF TUSCOLA COUNTY.

GENERAL STATEMENT.

The report on the water resources of this county is based on notes gathered by the writer for the Michigan geological survey, made available by the courtesy of State Geologist Alfred C. Lane, who has kindly placed at the disposal of the writer these notes and all other material bearing on the question in the records of the Michigan survey. With this are a small amount of new material gathered by the writer in a two-days' trip into the more recently settled parts of the county at the end of the field season of 1904 and some data collected by correspondence during the same period by Mr. Leverett.[a]

TOPOGRAPHY AND WATER SUPPLY.

Tuscola County is situated on the southeast side of Saginaw Bay. From the level of the bay the land surface rises very gradually from 12 to 15 miles to the foot of a well-marked morainal ridge and then rapidly to the top of the ridge, which is from 50 to 125 feet in height and from 1 to 3 or more miles in breadth. This ridge enters the county a short distance west of the northeastern corner and runs diagonally nearly across it, about parallel to the shore of the bay,

[a] A more extended discussion of the same subject will be found in the forthcoming bulletin of the Michigan Geological Survey on the resources of Tuscola County.

gradually getting lower until it fades into the plain a short distance southwest of Vassar. To the east the ridge descends abruptly to Cass River; in fact, it forms the western boundary of the broad valley in which this stream runs. From this valley, which makes a third distinct area in the county, the land ascends on the eastern side by broad terraces to a sandy plain several miles broad, from which to the southeast there rises sharply a massive moraine which occupies the southeastern part of the county.

The soil of the plain is principally a heavy compact clay or clay-loam, with narrow ridges and broader strips and areas of sand or sandy loam winding across and scattered over it, while that of the morainal ridges is a gravelly clay, or even, locally, a pure gravel, on the whole much more porous than the clay soil of the plain.

In the valley the surface is usually covered with sand, generally of rather shallow depth, but frequently piled up in ridges of considerable extent and height, and the same condition prevails until the ridged or morainal district to the southeast is reached. Below the sand, at varying distances, is a compact, tough, dark clay. In a few places the stream cuts down to bed rock, which is generally a sandstone where exposed.

Corresponding to the peculiarities of topography and soil are variations in the ease with which water is obtained, the quantity obtainable, and to some extent the quality. In the lake-plain district (that bordering upon the bay) the soil is too fine grained and too compact to permit of rapid percolation of water, and the clays are too homogeneous and fine throughout to furnish water in large quantity. In the morainal districts, on the other hand, the surface soils are gravelly and much more porous and permeable, while below the surface strata of sand and gravel are common, easy to reach, and usually contain an abundance of water. Rarely, in the higher parts of the southeastern district, the ridge is wholly made up of compact clay or dry gravel, in which case it is necessary to seek water deep down in the drift or to drill down to rock.

The valley of Cass River, above Vassar, is generally so sandy that most of the rainfall is absorbed by the surface soil and soaks rapidly through to the clay, which lies at varying distances beneath. The usual supplies in this area are obtained from wells sunk to the top of these underlying clays and from springs which appear in the valleys of streams that have cut through the rather shallow sand into the clay. These springs result from the water running along on the surface of the clay to the valley, where it finds an outlet. Below Vassar the conditions are less favorable for the absorption of the rainfall, but are still such that good supplies are usually obtainable near the surface.

LAKE-PLAIN REGION.

It is evident from the foregoing that the only district of this county where there is any especial difficulty in obtaining a supply of water for ordinary domestic uses is that bordering on the bay and lying between it and the foot of the central morianal ridge, for here the soils being very fine grained are not absorbent, and have few coarse layers between the surface and the bed rock, making it difficult to secure readily an adequate supply of water.

SOURCE OF WATER.

SURFACE WATERS.

In the early days of the settlement of the region this part of the county was covered by a heavy swamp forest, and the ground-water level was near the surface; in fact, in many places the ground was flooded during the rainy part of the year, and especially when the snow was going off in the spring. At this time water was easily obtained from shallow dug wells. As settlement, accompanied by clearing and draining, progressed, more and more of the rainfall was carried rapidly away, and, as a natural result, the ground-water level sank until the dug wells gave out or were deepened. In a few cases they were carried down nearly a hundred feet. Usually, however, they were deepened, not by digging, but by boring with large-sized well augers, 4 to 8 inches in diameter. This method was in use some time, but it was soon found that in many areas no permanent supply of water could be had in the clays above the bed rock, and the next development was the driven well, reaching down nearly to the rock surface, where, as in other parts of the lake plain, a fairly satisfactory supply of water is frequently to be found. In many cases, however, conditions seem to have been unfavorable for storing such a supply, and the drilled well in the rock was the last resort. At the present time, since the region has become more thickly settled and the system of drains has been largely developed, drilled wells reaching down considerable distances into the bed rock are the usual type over a large part of the district.

The surface waters, as they are termed—that is, those which are obtained from shallow dug wells—vary in quality according to the type of surface material, whether of clay or sand. The clay soils were originally so swampy that the water in the wells of the old dug-basin type was never looked upon with favor, and was probably justly condemned, as the conditions were all in favor of contamination from the surface, and the waters probably were frequently the cause of disease, especially when the supply was diminished by drought.

It is evident that the original swamp soil could be easily infected by disease germs, as it was damp, contained large amounts of organic matter, and was easily warmed by the sun in the summer time; that in flood times, which were frequent, the waters from cesspools, drains, and other sources of infection would be spread over the ground and might, and often did, find their way to the wells; and that in dry times cracks would open up in the clay, on account of shrinkage, and through these water from the contaminated surface, from sinks and other drains, and often from privy vaults, could find a way to the wells. Under such conditions it is not difficult to understand that the dug wells were not in favor in the clay regions. In addition to these considerations, it must be taken into account that the soil contains much finely pulverized limestone, which renders the water hard. And, as was usually the case, when the water contained considerable amounts of organic matter, iron, as well as lime, was dissolved and gave it a strong astringent taste.

In places where there were several feet of sand, however, the water of shallow wells was more wholesome, better in quality, and more abundant, this being due to the filtering power of the sand, which removes and holds near the surface organic matter and disease germs, to its greater permeability, and to the scarcity of lime and iron salts. Cracks and fissures do not easily develop in sandy soils, and hence direct channels between the well water and the sources of contamination are less frequent or entirely wanting. For these reasons, and because the supply of water is so much greater in the sand, dug wells are general in the sandy areas, where the sand is deep enough to afford any permanent supply. Upon sand ridges, especially, the wells are generally shallow open basins dug through the sand to the underlying clay.

DEEP DRIFT WATERS.

In general there is very little water in the clay between surface and bed rock. The clay is too fine and too compact to be porous and on this account absorbs little water, and is too slowly permeable to yield it up readily even where nearly saturated. The clay seems to have been laid down under water, and has very little embedded gravel or sand into which water can penetrate and accumulate. Where water-bearing strata are found, however, the water is healthful, but is hard and contains much iron. These water-bearing strata in the clay are thin, limited in area, and occur at all depths, but are not generally depended on as sources of supply in the flat lands.

A more constant source of supply utilized over a wide area, and not infrequently yielding flows, is a porous stratum just above the bed rock. This seems often to be bowldery gravel lying on the rock surface, and is from one to several feet thick. This generally yields a good supply of water, which is frequently so like that from the rock itself that the natural inference is that the water comes from the rock and is forced from it into the overlying gravel by pressure. On the other hand, it not infrequently happens that the water in the rock will be brackish while that above will not taste of salt at all, in which case it seems probable that the water in the gravel is derived from above rather than forced up from the rock. All of these water-bearing beds may be reached by dug, bored, or driven wells.

ROCK WATERS.

These are of varying character according to geologic formation and the type of rock from which they come. As a full account of these will be published by the Michigan Survey, and as this report deals especially with the drift and its waters, no discussion of the formations and types of rock will be entered upon here, except to state that the water comes from sandstone, or rarely from shales, of the Michigan formation in the eastern and central parts of the district under discussion, and from those of the Carboniferous in the western part. It should also be stated that a large part of the present supply of water for farm and house use in this district comes from bed rock.

The rock water is, in a marked degree, less hard than that from the drift, and in many cases it is so free from dissolved lime or calcium compounds as to give no trace of these by ordinary tests; in a few cases it was reported as "softer than rain water." This softness may be attributed to the absence of calcium minerals from the sandstones in which the water is moving, and also to the probable fixation of the calcium by the action of sodium or magnesium sulphates upon the more soluble calcium compounds. In many cases the purity of the water is such that the first explanation seems reasonable and probable, but in the case of salt and bitter waters, the second is quite as likely to be correct. Three well-marked districts may be distinguished by the character of the water from the rock in this region, as follows:

1. The district of fresh, soft, or relatively soft, water, extending from the foot of the low central moraine westward to the northwest corner of Columbia Township (T. 14 N., R. 8 E.), and thence diagonally southwestward nearly to Reese, whence it runs more nearly due south, finally leaving the county near the northwest corner of Arbela Township (T. 10 N., R. 7 E.). This district may extend still farther eastward than the moraine, but there are few rock wells to show its limits in this direction.

2. A belt a mile or two, rarely more, in width lying just west of the first district in which the rock water is all more or less bitter to the taste of a person not accustomed to it, and is frequently slightly brackish as well. This belt is not well marked at the northern end, but is easily traced across the county. This bitter water is so free from lime and its compounds that it seems probable that a chemical

precipitation of the calcium salts as the sulphate has occurred, and that soluble magnesium chloride has been formed, to which substance the water owes its bitter taste. In general these bitter waters show only a small amount of sulphate present, but considerable amounts of chlorine, leading to the conclusion that the bitter taste came from magnesium chloride rather than the sulphate; however, no very careful examination of the water was made.

3. An area immediately west of the last, lying between it and the bay, contains brackish water from the rock, or, frequently, salt to such an extent that it is unfit for cooking and can be used for watering cattle or for drinking only when one has acquired a taste for it. The saltness of the water increases as the district is crossed from east to west. In the western part also the waters near the rock surface are more likely to be usable, the deeper ones much less so. In one small area in Wisner Township, near Saginaw Bay, the drift wells, even where shallow, were said to be salty and it was reported that in early days "deer licks" were formed in this vicinity, an indication either of a percolation upward from the rock surface by the salt water or the pressure of direct fissures, not improbable in a region where the bed rock is known to be more or less faulted. These salt waters were often very nearly without hardness, showing only small traces of the calcium salts.

The salt comes from the shales and sandstones of the coal measures, which are strongly saline in this region. The deeper beds of the Marshall sandstone are also salt bearing, while the upper ones yield little or no trace of salt, this substance having been leached out, possibly, as suggested by Lane, by the great draft on the lower brines by the salt-manufacturing industry in Saginaw Valley. Whatever the cause the salt is gone from these beds, but at lower depths the water, even from the Marshall sandstone, is salt, so that wells in the lake plain more than 300 feet in depth are usually salt or brackish.

Depth to rock.—The drilled wells in the district under consideration are so distributed as to make it apparent that the rock surface is a gently-sloping plain, with at least one well-marked valley in it, and possibly more than one. The slope of the surface of the rock is toward the west and about the same as that of the present land surface (on an average about 10 feet to the mile). Local elevations of the land surface do not usually coincide with those of the rock surface, so there are minor areas in which considerable variations in depth of rock are shown, which would entirely disappear if the land surface were a true plain. On the other hand, there are equally great differences where the land surface is flat.

In the following table it will be seen that the average depth to rock in the various townships is relatively uniform, varying only about 20 feet from the lowest, found in the northern and western part of the area, to the highest, found in the extreme southern part. Wisner Township has the lowest average and the least variation, but three others, Akron, Columbia, and Fairgrove, show an average depth but 6 or 7 feet greater, although the surface of the county is more uneven and rises many feet higher.

Rock wells of Tuscola County.

Township.	Township, N.	Range, E.	Number of wells reported.	Number of wells in which rock is over 100 feet deep.	Depth of rock.		
					Greatest.	Least.	Average.
					Feet.	*Feet.*	*Feet.*
Wisner	14	7	7	0	85	70	77
Gilford	13	7	76	11	170	70	86
Denmark	12	7	45	8	140	60	89
Tuscola	11	7	9	3	200	49	79.5
Arbela	10	7	2	1	120	70	95
Akron	15	8	51	9	229	60	83
Fairgrove	13	8	60	6	230	55	84
Juniata	12	8	6	4	112	84	98
Columbia	14	9	70	11	+160	50	83.6
	....	....	326	53	+230	49	81

The greatest depths occur in certain restricted areas which seem to be definitely related to each other and indicate that there is a buried valley extending from Huron County southwestward beneath the village of Unionville, across Akron and Fairgrove townships into Gilford and Denmark, where it is lost track of. This valley is of interest, since in places it furnishes abundant supplies of water, sometimes with strong head, so that fine flows are obtained from it, but in other places it seems to contain little water, and when struck increases the cost of well driving by adding to the number of feet of casing required to reach bed rock.

FLOWING WELLS.

Distribution.—Over a considerable part of the lake-plain area the water from the rock is under sufficient pressure to rise nearly to, if not above, the surface of the ground, and there are in consequence many flowing-well districts. It might almost be said that the whole area constitutes a single district, for the water will overflow the surface when this is low or when very permeable strata are struck; but in places where the surface elevation is high or the water-bearing strata are very fine grained a flow will not be obtained. The low-lying districts, depressions, and valleys, then are the places where flows are found in the largest numbers. Even slight ridges are sufficient to shut off the flows. The largest areas of flows were found in Columbia Township, where depressions of several square miles in extent exist, over the whole of which it may be possible to secure good flows of excellent water from the rock, and in occasional wells almost equally good supplies from the drift near the rock surface.

Extending west and southwest from this township are numerous other areas, usually of small extent, in which both rock and drift flows are found, the water usually flowing in good quantity, but being, as already pointed out, often brackish or salty in the western part. The water from the drift where flows of this type occur was reported to come from near the surface of the rock and may get its pressure from the rock itself.

Loss of head.—In northern Akron Township, north and west of Unionville, are several small flowing-well areas in which the flows have greatly diminished or in many cases entirely ceased. The date at which the failure began was so closely connected with the opening and working of the coal mines at Sebewaing that the owners attribute the loss of head to the immense drain on the underground waters which the operations in these mines entailed. The connection between the two phenomena is the more close when it is considered that the wells to the eastward of what is assumed to be the border of the lowest beds of the coal measures were not affected, as they draw their supplies of water from beds which are below the ones worked for coal at Sebewaing.

Loss of head was noted at many other points where single wells, usually on high ground as compared with the others in the same area, were reported to have flowed formerly. Not infrequently the time when the flow ceased could be fixed by the date when some neighboring well on lower ground was completed. In a few cases, deepening a well was reported to have restored the flow after it had ceased.

During the excitement attendant upon the development of the coal deposit about Saginaw many holes were drilled by coal prospectors, which after the drilling was completed were plugged more or less perfectly and the casing pulled out. In some cases, because of imperfect plugging, the water from the rock worked its way out to the surface, and, flowing freely, was the cause of diminution or loss of head for several wells in the neighborhood.

It has already been pointed out that the rock surface rises from the bay eastward. At the shore of the bay the altitude of the rock surface is about 520 feet above sea level, or about 60 feet below the bay; near Cass City it crops out in the bed of the river at an elevation of about 700 feet above the sea; while to the northeast at Tyre it rises in places to about 800 feet. These elevations are important, as they show a steady increase in the height of the rock surface, sufficient to give pressure to the water at the lower elevations, especially since the dip is from the higher to the lower elevations. That these differences are really sufficient is evident when it is remembered that the majority of areas of flows occurring in the lake-plain district are below the 660-foot surface-contour line, and none are above the 680-foot contour, that is, the surface in the flowing-well areas in Columbia, Akron, and Fairgrove townships is from 30 to 50 feet or more below the surface of the rock in the valley of the river a few miles to the east, and much more below what it is a little farther northeast. In the same regions, where the rock surface is higher, the surface deposits are very absorbent, and a much larger percentage of the rainfall penetrates the ground and finds its way into the permeable sandstone than in the clay-covered districts. These areas supply much of the water as well as the pressure of the flowing wells.

In this connection it may be well to note that the rather porous moraine, or high ridge, between Cass River and the flowing-well areas under consideration is also a catchment area of considerable importance, and if the clay underlying it is as penetrable to water as its own surface a large part of the rock water, and the head as well, could be derived from it. One objection to such an hypothesis is the great scarcity of lime in the rock water compared with the amount of lime and other mineral matters in water from the drift, which could hardly be eliminated in the passage of the water through the rock. The sandy areas to the northeast and east would not yield the soluble minerals, hence are the more probable sources of supply.

Flows from drift.—In the lake-plain district flows from the drift are rare compared with those from the rock. The largest area is situated a mile southeast of Unionville, and is about a square mile in extent, the group consisting of eight or ten wells which have good flows, with a head of from 3 to 5 feet. The depth of these wells is from 50 to 75 feet, and most of them get their water from a stratum of quicksand which lies upon the surface of the bed rock, from which neighboring wells draw their supply at slightly greater depth.

The water of these wells is generally of about the same character as that from the rock, and it is probable that it finds its way into the sand from the rock, rather than from the clay above.

A small group of flowing wells from the drift also occurs a mile west of the town of Akron. As in the Columbia area, these go down nearly to the rock surface and get their water from quicksand or fine gravel just above the rock.

Aside from these areas there are about thirty small areas with one or two wells each, located near or in areas of flows from the rock, which present about the same characteristics as the two areas mentioned above. In all of these wells, with possibly one or two exceptions, the water comes from near the surface of the rock, and it is difficult to say whether the wells should be classed as drift or rock wells, since it seems probable that the water comes from the rock, while the wells extend only into the quicksand, which is part of the drift.

It was reported by one of the early settlers that the first well to flow in the northern part of Tuscola county was a dug well about half a mile south of Unionville, put down, or deepened in a very dry time, until it had penetrated the clay about 90 feet. The diggers left the hole at noon to go to dinner, and when they returned the well had a large amount of water in it, and soon was flowing over the top. This well was the means of showing the farmers of the region that abundant water was to be obtained near the rock or from it, and deep wells, bored or driven, soon became common.

As has already been pointed out, the districts where the soil is sandy or gravelly get sufficient water for ordinary uses from shallow dug wells from 10 to 40 feet deep. The eastern border of the plain, where it approaches the foot of the ridge which marks the limits of the flat lands, becomes sandy or loamy, and is much more permeable than the clays, and furnishes much more water in the upper layers of the drift. Here also are ridges of gravel or sand making former shore lines and extending for many miles parallel to the high ridge to the east, and these furnish extensive reservoirs of water which appears in dug wells, or in the form of springs at the edges of the ridges, or in marshy areas bordering them. The whole length of one of the best marked of these wave-formed ridges is bordered by large springs, some of which are impounded for domestic uses, in one or two cases forming good-sized fish ponds. The water from these springs is medium hard, fresh, and of excellent quality, and often the quantity is large, especially after the outlets have been enlarged. The wells in such localities are usually only a few feet deep and yield an abundance of water.

MORAINAL REGION.

GENERAL CONDITIONS.

The height of these districts above the level of the bay, amounting to about 200 feet in the western and from 300 to 400 feet in the southeastern portion, makes the rock surface hard to reach, and precludes getting flowing waters from the rock, and on the highest land from the drift. The greater permeability of the surface soils of the ridges compared with the clays of the lake-plain district permits a much larger percentage of the rainfall to be absorbed, while the unsorted and loosely compacted subsurface materials serve to give storage to the water thus absorbed at no great distance down. In these districts the wells are usually of the open dug type, of depths varying from 12 to 60 feet, beyond which they are sometimes deepened by boring or drilling. In a few cases it was found that wells had been drilled through the drift to the rock, sometimes nearly 300 feet down; but this is rarely done.

The location of wells in the morainal districts is often most disadvantageous, since they are placed on or near the top of the ridges, where the water table or zone of permanent ground water is the farthest possible from the surface, and is much more subject to fluctuations than it is in the depressions or near the bottoms of the slopes. Even when a well gets its water from a gravel vein it is evident that the water is much more quickly exhausted, at least so far as a given well is concerned, if it is tapped near the top of a slope than at or near the bottom, because of the effect of gravity, which is constantly drawing the water down the slope and away from the higher levels. The deepest well of which record was obtained in these districts was one in the northwest corner of Watertown Township, which was reported to be 352 feet deep, with bed-rock at 272 feet from the surface, the altitude of the surface being 900 feet above sea level.

The water from the wells of the morainal districts is variable in the amount of the dissolved mineral matter which it contains, consisting chiefly of lime or of calcium and iron compounds. It is harder in clay strata than where it passes through sand and gravel. No saline or brackish water known to come from the drift was found in these areas.

FLOWING WELLS.

Near the foot of the steeper slope from the high morainal district toward Cass River are five small areas of flowing wells from the surface deposits or drift and one from the rock. On the southward slope from the same ridge, extending also into Lapeer County, is still another group.

Two of these districts are situated in Arbela Township, one in Watertown, one in Fremont, and one in Wells, on the north side of the ridge, and one in Dayton Township on the south side. The others are small in the extent of area covered, embracing from one to three wells.

ARBELA TOWNSHIP.

The first area in Arbela Township is on the line between secs. 14 and 15, where the wells are about 30 feet deep, with a slight head of rather hard water. The well on the farm of D. N. Van Wormer, for instance, is 27 feet deep, having surface clay and gravel to 10 or 11 feet and hardpan thence to the bottom.

The second area is on the east side of sec. 13, and consists of two wells 60 feet deep. These are at the foot of the sharp slope of a ridge, and the water was reported to come from gravel, was hard, and contained iron. It flows with a head of about 2 feet, and discharges less than 1 gallon a minute.

The sources of head and the catchment area are apparently in the ridge lying to the south, which is the westward extension of a higher moraine to the east.

If this ridge is the catchment area, there seems to be no good reason why the present areas should not be extended both east and west of the present development over an area extending a mile, more or less, from the foot of the steeper slopes and flows obtained from various depths. This seems the more probable because in Saginaw County the same ridge and conditions exist, and the area of flows is much larger than here.

In the center of Arbela Township, at the town hall, is a flowing well 270 feet deep. The record is as follows:

Record of well in Arbela Township.

	Thickness.	Total.
	Feet.	*Feet.*
Surface clays and hardpan	70	70
Shales	194	264
White sand rock yielding a flow	6	270

FREMONT AND WATERTOWN TOWNSHIPS.

Both of these townships, which have each a single well in the present stage of their development, lie near the foot of the high moriane in the southeastern corner of the county 4½ miles west of Mayville. The Fremont well was not visited, but was reported to be about 70 feet deep and to flow a good stream. From the situation and topography it seems likely that flows might be had northeast and southwest of the present location. The well of Mr. Arthur Wills, in Watertown Township area, is situated 1 mile south and 5½ miles west of Mayville, on the north side of sec. 6. It is 65 feet deep, has a 2-inch casing, which is reduced at the outlet to one-half inch by a valve used to shut the water off so it will flow to the barn. The flow is about 5 gallons a minute, with a head of more than 6 feet, and but for the reduction of the size of the outlet the water would apparently flow the full size of the pipe to this height. The water has a temperature of 49° F., is hard and contains considerable iron, and is of good quality. It seems probable that this area could be connected with the Fremont area and extended to the west and south along the gentle slopes at the foot of the high ridge, but the district is at present sparsely settled and the rather sandy till yields sufficient water for general uses in open dug wells of slight depth.

WELLS TOWNSHIP.

This area is situated in a recently cleared district on secs. 27 and 34, 1 mile north and 4½ miles west of the village of Kingston and about 11 miles southeast of Caro. The district is at present less than 1 mile long and contains two wells 43 and 48 feet deep, respectively, which derive their water from gravel. The head is about 18 inches and the flow from 1 pint to 1 quart a minute. As these wells are near the foot of the slope from a high ridge to the south, they probably derive their head and supply from this source, and the area may be capable of extension both east and west along the same level and possibly also north of the present area.

Along the foot of the moraine, where it crosses secs. 25 and 36 of Wells Township, is the outcropping of a more compact, less permeable clay, under a gravel deposit of considerable extent. The clay exposure forms the lower part of an extensive slope, down which the water which runs out upon it from under the gravel finds its way, often forming springs of considerable size. One of these springs appears by the road on the northeast quarter of sec. 36 and flows into the roadside ditch. The water comes from sand, is hard, contains iron, and is of excellent quality. The amount of water furnished by this spring was about 15 gallons a minute after a long period of drought. The whole district along the base of the ridge is more or less favorable for such springs.

VALLEY REGION.

Cass River Valley, in Tuscola County, is a well-defined district in which the water-supply conditions differ from those in either of the other districts. The Glacial or lake history of the valley explains the generally sandy nature of the surface deposits throughout the upper and central parts of the districts, but can not be entered into in this place except to state that this valley was first occupied by ice, then by an arm of the Glacial Lake Saginaw, into which flowed a large stream from the melting ice to the north. This lake subsided by slow stages, leaving shore and shallow-water deposits in the form of sand, which was either heaped up into ridges or spread out in thin layers over the surface by the falling waters. The stream constantly brought down more sand, which was built into bars and deltas. All of these deposits are readily permeable to water, and nearly all of the rainfall upon the surface is readily taken in by the coarse soils. This either runs off below the surface or remains in hollows upon the top of the clay subsoil or upon the top of the rock, where this was the underlying stratum, as it is in the northeastern part of the county.

As the result of this structure and history, in most parts of the area shallow wells, dug down to the surface of the clay or into it a short distance, furnish a good supply of water.

Aside from this ease of getting water in shallow wells, the district is much more fully watered than either of the other districts by small streams tributary to the river. These and the river furnish water for stock in large quantity. The valleys of the streams, and of the river as well, in many places cut through into the clay underlying the sand. This clay is dark colored, very hard and compact, and is probably of greater age than the surface clays of the other districts. It is nearly impenetrable to water. Along the junction of the sand and clay the water flows out into the valleys, forming springs, which vary in size from seepage lines scarcely recognizable to large outflows of many gallons to the minute, such as the springs from which the town of Caro draws its water supply.

This area, however, is the least thickly settled in the county and is likely to remain so, because of the small agricultural value of much of the land; hence the water resources are poorly developed and little utilized.

At Tuscola, Vassar, and Caro, and in the immediate vicinity of these towns are a few rock wells, which will be considered in connection with the water supplies of these towns.

MISCELLANEOUS TOWN SUPPLIES.

Each of the districts described above has some of the towns of the county located within it, and in general it may be said that the village supplies in each district are characteristic of that area in which they are obtained.

LAKE-PLAIN REGION.

UNIONVILLE.

This village, with a population of 457, has no public supply and gets the water for domestic use and for manufacturing from wells, which in many cases penetrate the rock here from 90 to 150 feet below the surface. The greater depths occur in the eastern part of the town, where the depth varies abruptly from the least to greatest, indicating a valley in the rock, as the land surface is nearly level. A few of these wells flow, but usually the water is pumped, and is soft and fresh and in good quantity for all present needs.

In case a public supply is required the rock should, from present indications, furnish a good and very pure supply, and if the wells were put down in the lowest possible places they would in all probability flow.

AKRON.

This village is situated on a low, broad, sand ridge. It has two sources of supply, the clay under the sand and the rock deep down below the clay. There is no public supply, and a large number of the people get water for domestic use from shallow dug wells 10 to 15 feet deep.

As this supply chiefly comes from water which leaches through the shallow sand, it is more or less likely to be contaminated by percolation from cesspools, drains, and vaults. Such wells, especially in dry times, are unsafe unless every precaution is taken to guard against pollution. As the population increases, these shallow wells will have to be abandoned, as the supply is limited because of the small catchment area, and even at present is noticeably affected by dry weather.

Bored, driven, and drilled wells in the neighborhood reach rock at about 70 feet and same penetrate it to a depth of 100 or 150 feet. Some of these rock wells flow 3 or more feet above the surface. The water is fresh and nearly soft, but has a slightly bitter taste, not noticeable except to those unaccustomed to its use. If the town ever develops a public water supply, the rock will be the best available source, though wells to it probably will not flow unless located on the low ground or off from the ridge. The upper strata of rock seem to be shales, so, for a large supply, the wells must be sunk to underlying sandstone at considerable depth.

FAIRGROVE.

This village is situated on a low, broad, morainal clay ridge, somewhat above the surrounding plain, and is too high to have flowing wells even from the rock. The town has a public water supply for fire protection and sprinkling purposes, the water being obtained from surface supplies distributed from cisterns. Supplies for domestic and farm use are obtained from dug wells ranging from 12 to 35 feet in depth, and from driven or drilled wells which reach or enter the rock. The water of the dug wells comes from sand or gravel beds in the drift and is hard, but otherwise of good quality, except in the shallowest wells, in which it is liable to contamination from the surface.

The depth to the rock surface is from 90 to 100 feet and more. The deepest well in the village is probably that at the railroad station, drilled by Mr. McMillen in February, 1895, of which the following record has been preserved:

Record of well at Fairgrove station.

	Thickness.	Total.
	Feet.	*Feet.*
Glacial till (earth, clay, etc.)	98	98
Lime rock(?) solid and hard	2	100
Sand and gravel cemented[a]	4	104
Gray shale	11	115
Light shale	13	128
Dark-colored shale	7	135
Black shale	26	161
Gray shale	54	215
Hard flinty sandstone	10	225
Gray shale	18	243
Black shale	34	277
Soapstone	6	283
Dark shale	16	299
Fine clay	6	305
Hard gray lime rock	7	312
Gypsum	3	315
Very hard gray lime rock	10	325
Brown sandy shale	8	333
Gray lime rock	12	345
Fine clay	2	347
Gray lime rock	10	357
Gray sandstone	31	388
Brown lime rock	½	388½

[a] This sand and gravel had plenty of water in it, which rose to within 12 feet of the surface. No water above this.

This well furnished a large supply of good water. If the record is typical of the locality, it is evident that the most easily obtained supply is from the layer of cemented gravel near the surface of the rock. Below this level shales are likely to predominate, and do not furnish good supplies of water.

REESE.

This village, with a population of 427, is located on the slopes of a somewhat gravelly morainal ridge, and spreads out upon a plain at its base. As in all cases where there is a porous surface stratum with less pervious strata below, shallow dug wells are the chief source of water supply for domestic use. Here this type of well is reported to vary from 12 to 20 feet, rarely more, in depth, and to furnish a sufficient supply of hard water. The public supply comes from wells of this type, and is pumped for fire protection, sprinkling, etc., but is not used much as yet for other purposes. Aside from these shallow wells, others are drilled and driven down to and into the rock, which here ranges from 80 to possibly 100 feet from the surface. The following record of wells in Reese shows the character of the strata passed through:

Record of well No. 1 at Reese.

	Thickness.	Total.
	Feet.	*Feet.*
Stiff blue clay	45	45
Soft blue clay	27	72
Sand and small sandstone	7	79
Soft soap rock (shale)	7	86
Harder soap rock	3	89
Soft soap rock	14	103
Soap or white chalk rock	2	105
Sand rock	1	106
White hard slate rock	1	107
Black soap rock	4	111
Soft soap rock	3½	114½
Hard slate rock	1½	116
White soap rock	1	117
Black soap rock	4	121
White soap rock	3	124
Sand soap rock	4	128
Sand rock with 4-inch coal bed	5⅓	133⅓
Brown soap rock	9⅔	143
Gray sand rock	4	147
Brown soap rock	3¼	150¼

Record of well No. 2 at Reese.

	Thickness.	Total.
	Feet.	*Feet.*
Red clay	12	12
Blue clay	66	78
Gravel and sand	2	80
Hard lime rock	6	86
Soft brown soap rock	3	89
Hard white chalk rock	9	98
Soft soap rock	13	111
Hard white sand rock	4	115
Quite hard soap rock	2½	117½
Gray flint rock	½	118
Blackish soap rock	9	127
Black slate rock	2½	129½
White chalk or soap rock	1	130½
Hard sand rock	3	133½
White chalk rock	½	134
Hard sand rock	3¾	137¾
Dark slate	¾	138½
Sand rock	4½	143
Dark slate	2½	145½
Brown slate	5	150½

The water from the rock wells here is brackish or salty; the deepest, which formerly flowed, found strong brine from white sandstone at about 430 feet.

RIDGE REGION.

Of the ridge region nothing need be said aside from what has already been noted in connection with the general discussion of these districts.

GAGETOWN.

This town, with a population of 400, is near the northern county line, upon the crest of the western moraine. Dug wells with a depth of 10 to 40 feet or occasionally more are the most common source of supply for domestic use. The water comes from sand or gravel beds in the clay, is hard, of sufficient quantity for ordinary demands, and is said not to be affected by the seasons. It rises in some of these wells to within 10 feet of the surface.

Wells are occasionally drilled to rock, but no records of the depth were available. The deepest well in Gagetown is reported to be 140 feet.

KINGSTON.

This village, with a population of 350, is located on a morainal ridge, 30 to 40 feet above the bottom of the valley in which the railroad runs. The wells are generally dug, and range from 20 to 50 feet in depth, with an average of 35 feet; the water is hard, but of good quality, and sufficient quantity for domestic use, and is said not to vary with the season. The supply comes from sand or gravel beds in some of the wells.

A waterworks system owned by the village was installed in 1902, the water being pumped from a 4-inch drilled well 217 feet deep, which reaches rock at about 150 feet. The water comes from sandstone and rises to within 10 to 12 feet of the surface, giving ample supplies. It is distributed from a standpipe, and is used for fire protection, sprinkling, and boilers. There is also a well 215 feet deep, in rock, at the schoolhouse, having the same characteristics as the waterworks well.

Along the railroad and at the bottom of the valley west of it, both of which lie 15 to 20 feet below the water level in the waterworks well, it is probable that water from the same source would be reached at about 185 feet or a little more, and would flow with strong head. In this valley is a small stream, and along the margin of it are seepage springs, the water from which is sometimes used.

MAYVILLE.

This town, with a population of 750, is the most elevated in Tuscola County, the moraine rising to nearly 1,000 feet above sea level within its limits. As a result of this situation the wells for domestic supply are often deep, but do not reach the rock surface. There is no waterworks system; one was projected some years ago, but was abandoned on account of the difficulty of getting water in sufficient quantity.

A test well was drilled 400 feet and bed rock was reached at 285 feet. In this well water rose from sandstone about 300 feet or to within 100 feet of the surface.

The dug wells are often shallow, from 15 to 20 feet deep, the shallowest being only 10 feet, but driven wells in the higher parts of the town often go down nearly or quite 100 feet to water of sufficient quantity. The water in the shallow wells is said to come from sand or gravel beds in the till, is hard, and is never large in amount; yet the supply is fairly constant, so that moderate demands on it are met except in very dry weather, when it may fail.

Bed rock is the most available source for a large supply for the town, but the great depth to which it is necessary to go to reach rock, and the depth from which water must be pumped makes it an expensive source. If, however, wells were put down in the lowest part of the town, or, better still, in the valley north, and pumped from these to a reservoir in the highest part of the town from which it could be distributed, it seems probable that a satisfactory supply may be had. Nearly 100 feet in the depth of the wells could be saved by locating them in the lowest part of the valley, which runs through the eastern part of the town.

MILLINGTON.

Millington, with a population of 632, is situated on a broad, gently sloping, sandy, and gravelly plain, which is on the edge of the rolling country and is morainal in its origin. The surface soil is permeable enough to take in a considerable amount of the rainfall, and this accumulates in the underlying gravels, which lie from 15 to 20 feet below the surface. This supply is easily reached by open dug wells, and is largely drawn upon, the majority of the houses of the town depending on wells about 20 feet deep for their supply for domestic uses. This supply is uncertain and affected by drought. Persons requiring larger supplies drill down to bed rock for water, reaching it at from 90 to 112 feet. In this rock, which is sandstone, water may be found at varying depths in good quantity and of excellent quality.

In 1904 the village completed its public waterworks, the water being obtained from two 4-inch drilled wells 187 feet and 200 feet deep, respectively, located near the center of the town. The rock surface is about 110 feet down, and the rock was reported as sandstone the whole distance until water was struck. The water rises within 17 feet of the surface and is said to be of excellent quality and abundant. It is distributed from an elevated tank or standpipe, into which it is pumped from the wells.

FOSTORIA.

This village lies on a slope from the high moraine to the north and, so far as learned, gets its supply for domestic use from dug wells 20 to 40 feet in depth. A stream flows through the edge of the town, and from this some water is taken for use in boilers.

CASS RIVER VALLEY REGION.

CASS CITY.

This village, with a population of 1,212, has for its site a broad gravelly terrace about 40 feet above the bed of Cass River and has behind it, to the north, a well-marked morainal ridge. The gravel gives abundant water in dug wells about 20 feet deep, some going deeper, and these are the common sources of supply for domestic use.

CARO.

This town, with a population of 2,268, is located at the foot of a well-marked morainal ridge upon a gently sloping or nearly flat gravelly terrace of the river valley. It is well situated for the development of a system of waterworks, depending on gravity for the distribution of the water from a properly located standpipe. For several years such a system, owned and operated by a private company, has been in use, the water being pumped, in part, at least, from springs located across the stream opposite the town. Recently the supply has been augmented by drilling wells into the rock. The standpipe is situated in the northern part of the town upon a morainal ridge about 100 feet above the principal business street. The water is of good quality and that from the springs is relatively soft. The springs have their catchment areas to the east of the river in the gravel and sand terraces, the town standing on the west, the water percolating through the gravel and sand down to a dense clay substratum, upon which it finds its way until it reaches some place where streams cut this in running to the river, when it flows out as springs. The water is used for all purposes, including domestic and drinking, but there are many dug wells in the town from 16 to 20 feet deep which, upon the gravel flat, reach through the gravel to the top of the clay and intercept some of the water moving along upon it. This water is reported as soft and pure, but unless care is taken to dispose of sewage eventually the gravel will become so contaminated that the wells in the more thickly-settled parts of the town may be unsafe to use and will afford breeding places for the germs of various diseases.

The following is the record of the deep well of the Peninsular Sugar Company; the altitude of the mouth is 15 feet above Cass River, and about 645 or 650 feet above the sea level:

Record of Peninsula Sugar Company's well, Caro.

	Thickness.	Total.
	Feet.	*Feet.*
Drift (sand, gravel, hardpan, and bowlders)	113	113
Limestone	7	120
Shale (blue)	25	145
Sandstone (very soft; first flow of water, 50,000 gallons in 24 hours, soft; rose 5 feet above derrick floor)	40	185
Limestone	5	190
Sandstone	50	240
Shale, black	2	242
Sandstone	10	252
Shale	1	253
Sandstone	29	282
Streak of sandy limestone.		

At 275 feet a flow yielding 350,000 gallons in 24 hours was struck. The water has a slight mineral taste, leaving a sweet aftertaste, probably of magnesium sulphate. The well is 8 inches in diameter; temperature, 47° F.

VASSAR.

This village, with a population of 2,032, is the third important valley town to be considered, and like Caro is located upon the terraces of Cass River, but unlike that town reaches across the stream to the eastern bank. A considerable part of the town also lies upon the morainal ridge, here relatively low and inconspicuous. The ridge is covered with gravel, and hence is more permeable than such ridges usually are.

The village owns its waterworks system, the water being derived from seven drilled flowing wells, which average about 200 feet deep. The deepest well is 230 feet, but is cut off at 200 feet. At the depth of about 125 feet a small flow was struck, and this increased with the depth until it reached its greatest volume at 175 feet, when the flow was about 100 barrels an hour. The total depth of one of the other wells is 207 feet, with the rock surface at about 50 feet. The water rises 4 or 5 feet above the surface and is pumped to a standpipe on the ridge, from which it is distributed. It is relatively soft, giving only a slight powdery scale after prolonged use in boilers. The following analysis by Dr. R. C. Kedzie, of the agricultural college, was made about the time the system was installed:

Analysis of Vassar public water supply.[a]

	Parts per million
Total solids	271.43
Volatile at red heat	71.43
Total mineral matter	200
Mineral composition:	
Calcium (Ca)	65.49
Carbonate radicle (CO_3)	100.82
Sulphate radicle (SO_4)	20.16
Magnesium (Mg)	6.17
Chlorine (Cl)	4.32
Sodium (Na)	2.82
	199.78
Nitrates and nitrites	None.
Free ammonia	.05
Albuminoid ammonia	.04
Hardness by soap test	85.71
Permanent hardness	57.14
Total hardness	142.85

The amount of water yielded by these wells is about 110,000 gallons a day. Two deep wells were put down at Vassar; one near the railroad junction, which has a depth of about 600 feet, flows a considerable quantity of brackish water, which has been bottled and sold for medicinal purposes; the other, which was put down as a test well about the time the waterworks were established, is 467 feet deep, and gave salt water of 6 degrees of saltness. This well was reported to be plugged and abandoned.

Dug wells from 20 to 30 feet deep are frequently used, furnishing sufficient water for domestic use, and private drilled wells from 45 to 200 feet deep are not uncommon. Most of the latter flow when located on the lower terraces of the river. The rock water is generally softer than that from the drift, especially that from sandstone, the most common source.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

TUSCOLA.

This village, with a population of 275, lies a few miles southwest of Vassar on the lower terraces of the river valley, here somewhat sandy and relatively narrow. The town is spread over both banks, the parts being connected by a bridge. The general sources of water for domestic use and for stock are shallow dug wells from 12 to 40 feet deep, the most common depth being about 20 feet. The water usually comes from strata in the clay which underlies the shallow surface sand and rises within 6 feet of the surface in some of the wells. The water is hard and the supply constant and sufficient in most cases for the needs of the owners.

A few drilled wells on the higher slopes of the valley yield excellent supplies of somewhat brackish water from the rock at about 175 feet in depth. A drilled well at the north side of the village is reported to be 175 feet deep in sandstone, the rock surface being struck at 49 feet. This well flows several gallons a minute, with a head of 2 feet. It is situated on land 30 feet above the level of the river, higher than most of that on which the village is located, hence it would seem probable that other flows could be developed by going down into the rock. The rock surface was reported as 70 feet in another well, but as it appears in the bed of the river a short distance northeast of the town it is probable that this well was on higher ground than the flowing well above cited.

WILMOT.

This small village is situated on the southern edge of the broad sloping plain which rises to the morainal region on the south. The generally sandy or loamy character of the soil, and the fact that it is underlain by clay at moderate depths, makes the water supply good and easily obtained. The wells average about 20 feet in depth and give a good supply of hard water, which is not easily exhausted. No rock wells have been put down in this vicinity.

DEFORD.

This is the next station north of Wilmot on the Pontiac, Oxford and Northern Railroad, and is in much the same situation as Wilmot. The plain is slightly flatter and somewhat sandier. Water is obtained from shallow dug wells at about the same depth as at Wilmot.

SILVERWOOD.

This is a small village on the Pere Marquette Railroad, on the southern border of the county, and is interesting from the fact that a part of its water supply is obtained from flowing wells from the drift. The area extends southward into Lapeer County, forming a good-sized district.[a] The few wells which flow in the village are about 40 feet deep. Dug wells from 15 to 30 feet deep are also common sources of water for domestic uses. The water tank at the railroad station is filled with water from a flowing well 40 feet deep.

WATER SUPPLIES OF GENESEE COUNTY.

TOPOGRAPHY.

Genesee County lies in the southern part of the district tributary to Saginaw Bay, its county seat being at the city of Flint. The northwestern part is a plain which was covered by a glacial lake, the shore of which enters the county from southwestern Tuscola County, near the middle of its north line, and runs southwestward, near Clio and Flushing, to leave the county west of the latter village. There are small flowing-well districts on the plain or in valleys leading into it from the southeast. A prominent morainic belt, the continuation of the one lying south of Cass Valley in Tuscola County, already described, passes across Genesee County in a southwesterly course a short distance southeast of the border of the Glacial lake and crosses Flint River at the city of Flint. Southeast of this morainic belt is a plain in which one of the best flowing-well districts in Michigan (the Davison district) is located, together with several small districts. East and south of this plain is another morainic belt with a few small flowing-well districts located in depressions among its ridges. The extreme southern edge of the county from Fenton westward embraces gravelly plains, with numerous lakes and marshy depressions separating the morainic belt just mentioned from a much higher one south of it in Livingston County.

The writer gave attention principally to the flowing-well areas, but was informed by well drillers and residents that throughout the county wells are generally obtained at moderate depths. The deep wells are mainly along the western morainic belt that passes near Flint, and there they seldom exceed 200 feet; wells exceeding 100 feet in depth are comparatively rare.

Throughout the county a clayey till is the predominating deposit. The beds of sand and gravel from which wells are obtained appear to be in thin strips intercalated at various levels in clayey till. The bedrock surface is from 50 to 200 feet or more below the drift surface, with an average of perhaps 100 feet for the county.

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[a] Discussed by Leverett in Water-Sup. and Irr. Paper No. 182.

PUBLIC AND PRIVATE SUPPLIES.

OTISVILLE DISTRICT.

This village, which stands in a rolling tract in the northeastern part of the county, has a public supply pumped from a small lake into reservoirs in case of fire, but this supply is not used for cooking or for manufacturing purposes. Dug wells are the most common source of supply and are shallow, about 15 feet deep. Driven wells are from 25 to 100 feet deep, an excellent supply being struck at about 60 feet, the water rising in some places within 6 feet of the surface.

The following data of two recent wells that struck rock have been supplied by Grant Parker, a well driller at Otisville. The well of C. D. Doan, in Otisville, reached rock at 158 feet and continued to 220 feet. The rock is sandstone, and the water in it rises to 16 feet below the surface. The well of Robert Hammill, one-half mile north of Otisville, struck rock at 160 feet and entered it only 4 feet. The water rises within 7 feet of the surface.

Southeast of Otisville, at the Traver schoolhouse, in sec. 26, Forest Township, a boring reached a depth of 240 feet without striking rock. Sand in the lower part of the boring rose in the pipe and prevented further drilling. The altitude is perhaps 15 to 20 feet lower than at Otisville, or not more than 800 feet above sea level.

At the gristmill of Mr. Peter Hart, in Otisville, is a flowing well 26 feet deep which has a head of 2 feet and flows 3 gallons a minute. The water is soft enough to be used in the boiler at the mill without forming any scale. This well was put down in 1904 near an old one which had formerly flowed but had become clogged. The elevation of the surface at this well is about 20 feet less than at the railroad station.

CLIO DISTRICT.

In the valley of Pine Run, east of the village of Clio, are two flowing wells which were not visited, but were reported through correspondence with Mr. Fred Tinker, of Clio. One well, in sec. 13, owned by Fred Tinker, is 68 feet deep and flows 1.5 gallons a minute with a head of about 3 feet. The water is from gravel under a hard clay. A weak vein of water was struck at 13 feet. The well shows no perceptible change in rate of flow since it was made ten years ago. The other well is in sec. 23, within a mile east of Clio, and is owned by J. V. Valiquet. It is of similar depth and strength to the Tinker well.

Dug wells in the vicinity of Clio are only 12 to 14 feet deep, too shallow to be safe for continued use, on account of the danger of contamination from the surface. Some driven wells range from 60 to 85 feet in depth, and in some of these the water rises nearly to the surface. The water from the shallow wells is harder than that from the deep ones.

MONTROSE TOWNSHIP.

MONTROSE.

Water in Montrose Township is mainly from dug wells 20 to 40 feet deep. Rock is struck at about 45 feet, and an excellent supply of water is obtained from it at about 65 feet. The water rises to within 16 or 18 feet of the surface. A public supply for sprinkling and fire protection only is obtained from dug reservoirs.

Near the bottom of the valley of a small tributary of Flint River, 5 or 6 miles southwest of Clio, in the northeast corner of Montrose Township (T. 9 N., R. 5 E.), is a group of six flowing wells (see fig. 29). The water in these is excellent, not very hard and with little iron. The rate of flow is not large in any of them, but is sufficient for the owners, who use it for stock and all domestic purposes. The water rises to about 12 or 15 feet above the level of the creek; hence further development must be confined to the area below that level, which is only a narrow strip along the creek.

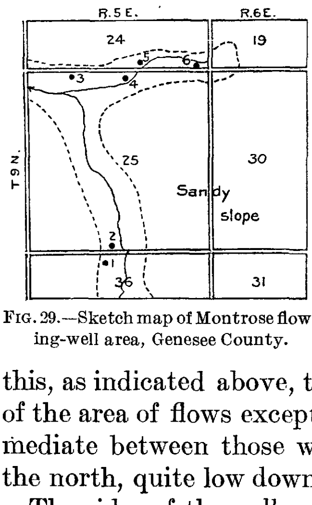

FIG. 29.—Sketch map of Montrose flowing-well area, Genesee County.

The deeper wells for a mile or more to the west were reported to strike water, which rose within 2 or 3 feet of the surface, and it is possible, since the slope is in that direction, that still deeper wells would strike a water bed with greater head and flows might be obtained. Other than this, as indicated above, there seems to be no possibility of extension of the area of flows except in the valley of the stream at points intermediate between those where they are now present and beyond to the north, quite low down in the valley.

The sides of the valley, especially a broad sandy slope on the west side of it, may well serve as the intake and storage reservoir.

Fig. 29 is a sketch map showing the approximate location of the wells and the relationship of the valley, etc. The accompanying table gives particulars regarding the wells of the area. They are obtained from gravel below a bed of tough clayey hardpan.

Wells of Montrose area (T. 9 N., R. 5 E.).

No. on fig. 29.	Section.	Owner.	When made.	Diameter.	Cost.	Depth.	Elevation.	Head.	Temperature.	Flow per minute.	Quality.	Water bed.
				In.		*Feet.*	*Feet.*	*Feet.*	°*F.*	*Gals.*		
1	36	W. Parmelee and C. McKenna.	1903	2	$60	62	735	+8	52	0.5	Hard; iron	Gravel.
2	25	F. Brown	1902	2	60	60	735	+9	51	2	.....do....	Do.
3	25	William Parker	......	2	50±	50±	725	+8	51	1	.....do....	Do.
4	25	William Hobson	......	2	......	60±	725	+7	52	1	.....do....	Do.
5	24	John Hobson	......	2	......	60±	725	+7	51	2	.....do....	Do.
6	24	J. Francisco	......	2	......	60±	723	+9	51	3	.....do....	Do.

BRENT CREEK.

In the vicinity of Brent Creek the shallow wells are 20 to 30 feet deep and are dug. The drilled wells reach 100 feet, and the water from them is slightly salty. The best supply of water is obtained from 75 to 100 feet.

FLUSHING.

Flushing is located on the terraces and sides of the valley of Flint River, in the western part of the county. The soil is generally porous, and the border plains are part of an old lake plain.

The water for the waterworks is pumped from the river, and is only used for fire protection, sprinkling, etc., and not for drinking and cooling. Wells were put down 350 or 400 feet, but struck water too salty to use.

Private wells are the source of supply for domestic use, and are usually from 15 to 20 feet deep, finding water in gravel. Rock is struck at 30 to 80 feet; and some wells have been put down into it, obtaining good supplies of rather soft water at about 100 feet. The deepest well is about 200 feet. Water rises in the deep wells to within 12 to 16 feet of the surface.

FLINT TOWNSHIP.

FLINT.

The city of Flint is located in the valley of Flint River at the mouth of Thread Creek, a southern tributary. The public waterworks take water directly from Flint River above the town, and pump it chiefly for fire protection, sprinkling, and manufacturing.

The following partial analysis shows the composition of the water in the deep wells in the streets of Flint. This water is highly esteemed throughout the town, and is supposed to be of medicinal character; the high percentage of salt and sulphate constituents are its most noticeable features. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analysis of deep-well water at Flint.[a]

	Parts per million.
Color	32
Iron (Fe)	1.2
Chlorine (Cl)	1,042
Carbon dioxide (CO_2)	94.38
Sulphur trioxide (SO_3)	478
Hardness (as $Ca Co_3$)	139+

S. J. Lewis, analyst. Depth, 376 feet.

The valley in which the river now runs is partly filled with coarse dry gravel lying directly on the bed rock, which ranges from about 25 feet deep near the level of the river to 70 feet or more in higher parts of the town. Tubular wells extending into the rock are common. They furnish good water and supply many of the residents.

A flowing well 376 feet deep on Saginaw street supplies a city drinking fountain. The water is mineral, containing among other constituents salt and hydrogen sulphide, which gives it a decided taste and odor. It is very largely used during the summer months.

At the Oak Grove Sanitarium is a well 265 feet deep, with a large flow of mineral water. The following analysis was made by Dr. J. E. Clark, of Detroit:

Analysis of well water at Oak Grove Sanitarium, Flint.[a]

	Parts per million.
Sodium (Na)	663.42
Potassium (K)	26.64
Magnesium (Mg)	42.25
Calcium (Ca)	128.46
Bicarbonate radicle (HCO_3)	365.88
Sulphate radicle (SO_4)	165.46
Chlorine (Cl)	1,059.43
Iron and alumina ($Fe_2O_3Al_2O_3$)	9.93
Silica (SiO_2)	Trace.
Lithium	Trace.
	2,461.45

The following record of the strata passed through in the Oak Grove Sanitarium well was furnished by Mr. George De Witt, of Flint, who drilled the well:

Record of Oak Grove Sanitarium well, Flint.

	Ft.	in.
Surface (mostly gravel)	33	
Light sandstone	85	
Flint rock		8
Black slate		10
Coal		10
Slate	2	
Hard sandstone	15	
White slate (fine clay)	5	6
Flint		8
White slate	9	6
Sulphur rock		7
Blue slate	16	
White slate		6
Blue slate	28	
Sand rock	67	6
	265	8

At a schoolhouse about 2 miles south of the city limits in a creek valley on the Fenton road, at the southeast corner of sec. 25, Flint

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Township, is a well from rock, small flow, which supplies a watering trough. There are no other flowing wells in that locality. The accompanying table gives the statistics of these wells:

Wells at Flint.

No.	Section.	Owner.	When made.	Cost.	Depth.	Elevation.	Head.	Temperature.	Quality.	Depth to rock.	Kind of rock.
					Feet.	*Feet.*	*Feet.*	°*F.*		*Feet.*	
1	25	School district [a]	1900	$120	111	750	+1.33	52.2	Iron; soft.	±70	Sandstone.
2	25	Oak Grove Sanitarium [b]	......	200	265	735	+8	51	Mineral water.	33	Do.

[a] In valley of creek; flow, 1 gallon a minute.
[b] Used for baths and medicinal purposes; flow, 7 gallons a minute.

OTTERBURN.

The wells in this vicinity range from 12 to 200 feet in depth. Bed rock is struck about 150 feet from the surface, and is reported to yield a good supply of rather soft water, while the water from the drift is hard. The water rises in some of the deep wells within 3 feet of the surface.

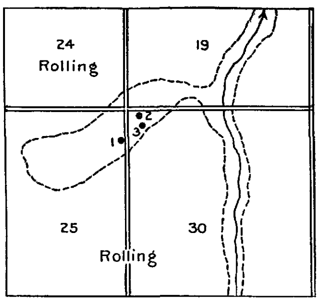

FIG. 30.—Sketch map showing valley in which flowing wells occur in Genesee and Richfield townships, Genesee County.

RICHFIELD AND GENESEE TOWNSHIPS.

Richfield Township, which is on the eastern border of Genesee County, is rather strongly morainic or rolling and is crossed by Flint River. The surface is sandy along the river and through the central and northern sections. There are very strong springs along the north side of Flint River in sec. 1, one of which, on the farm of R. J. Whaley, is carried by hydraulic rams to the dwelling and barns. It issues from the bluff as a 4-inch stream. Wells were generally reported as shallow, and mostly of the open, dug type, although some are tubular. The depth was said to be from 12 to 40 feet or more, with the supply and quality generally good.

Flows occur in three isolated areas, as follows: A group of two wells on the farm of Peter Cimmerer on NW. ¼ sec. 30 (see fig. 30); a single shallow well on the north side of sec. 28 on the farm of J. F. Armstrong, near a spring in a pasture, and one on the north side of sec. 34, belonging to Dr. J. F. Roemmer. None of these seem favorably situated to make any marked extension of the present development possible. Those on Mr. Cimmerer's place are in a shallow valley connecting with one of the tributaries of Flint River, and it is probable that along the stream other flows might be struck if wells were put down near the bottom of the valley, but because of the slight head it is probable that they could not be obtained on higher levels.

Other probable places for flows were noted along the valley of Flint River, but as the houses are all on high ground above the river no wells have been sunk to test the matter. Leverett says: "On the south bluff just east of the county line a flow has been obtained at a level of 50 feet or more above the river."

In Genesee Township, which lies west of Richfield, one flowing well has been obtained near the Cimmerer wells and in the same valley. It is on the farm of C. and G. Galing in the NE. ¼ sec. 25. The drainage relations are shown in fig. 30.

There are a few deep tubular wells in this township which do not flow. One on the farm of K. B. Todd, in sec. 11, on a plain about 60 feet above Flint River, is 222 feet in depth, and strikes rock at 194 feet. The water, as reported by the owner, stands 50 feet below the surface, the temperature is 50° F., and the water soft, with a trace of oil in it. The rock resembles a grindstone in texture. The drift is largely a hard, stony clay. Mr. Todd furnished the following data concerning a well at the schoolhouse in sec. 2 on the same plain. Rock was struck at 175 feet, and the well carried to a depth of 194 feet. The water stands 33 feet below the surface, and its temperature is 50° F.

Wells of Richfield and Genesee townships.

No. on fig. 30.	Township.	Range.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Remarks.
						In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	8	7	25	C. and G. Galing	1890	2	60	785	+3	0.5	51	Hard	Stock use.
2	8	8	30	P. Cimmerer	1896	1.5	65	788	+1.5	.75	51	Hard; iron	House well.
3	8	8	30	do		1.5	±60	785	+1.5	.5		do	Stock well.
	8	8	28	J. F. Cartwright		1.5	20	800		2	49		In pasture.
	8	8	34	Dr. J. F. Roemmer.		1.5	50?						

DAVISON AND BURTON TOWNSHIPS.

A flowing-well area lies in and about Davison village, in the northern part of the township of Davison, extending southwest into Burton, the next township to the west. The area covers approximately 10 square miles, 8 of which are in Davison. (See fig. 31.)

DAVISON.

Davison village and the flowing-well district about it is situated on the plain which lies on the western or inner slope of the morainic ridge running southwestward through the southeastern part of the county. Through the village a low, sandy spur runs nearly east and west, the top of which is about 15 feet higher than the bottom of a shallow stream valley, along which most of the flowing wells occur.

The largest number of wells which flow is in Davison village, on the Grand Trunk Railroad, where about one-half of all those in the district are located. The whole number of wells recorded is 156. A few are no longer flowing, however, but were noted as indicating the possibilities of the locality for properly constructed wells.

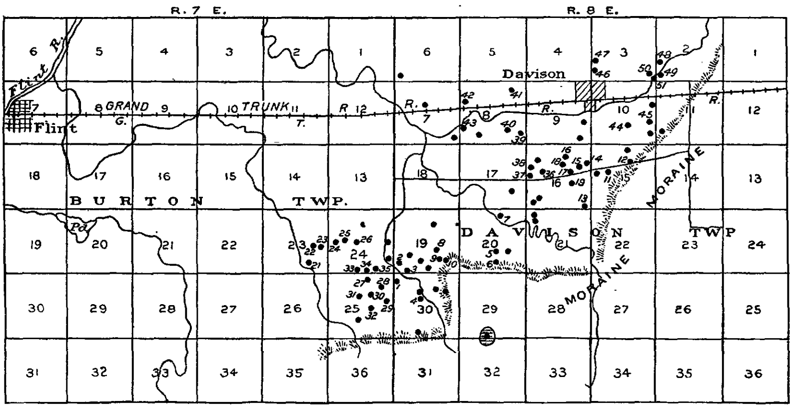

FIG. 31.—Sketch map showing flowing-well district in Davison and Burton townships, Genesee County.

The water comes from sand or gravel strata ranging from 20 to 80 feet, and in one case (L. Raisin, No. 24) from 95 feet below the general surface. A large percentage were reported as less than 40 feet deep. As in all districts where there are several water-bearing strata there is much variation between the depths of adjacent wells, owing to irregu-

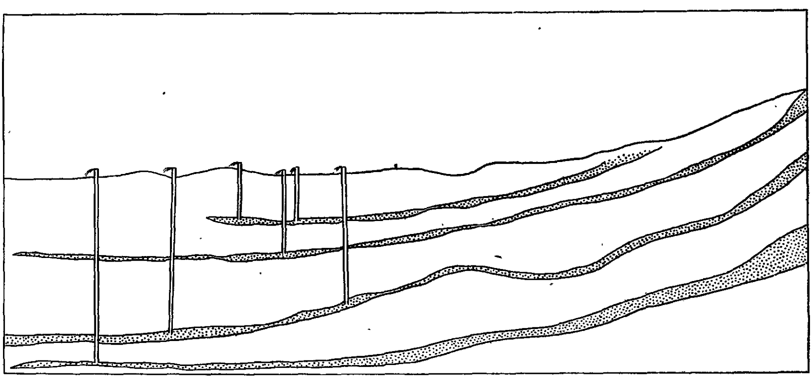

FIG. 32.—Diagram showing probable relationship of the water beds across secs. 10 and 11, Davison Township.

larity in the thickness of the strata, apparently in some such manner as is shown in the ideal section (fig. 32).

This water is of about the same quality in all of the wells—rather hard with some iron present, but in other ways excellent. That from the deeper wells seems rather less impregnated with mineral matter than that from the shallower ones, but no accurate determination was made. The water should be healthful and as pure as ground water in this type of territory ever is.

A tough hardpan is reported as generally present over the water-bearing strata, which were said to be usually of fine sand for the upper and gravel for the deeper ones. Mr. A. Armstrong, however, reported

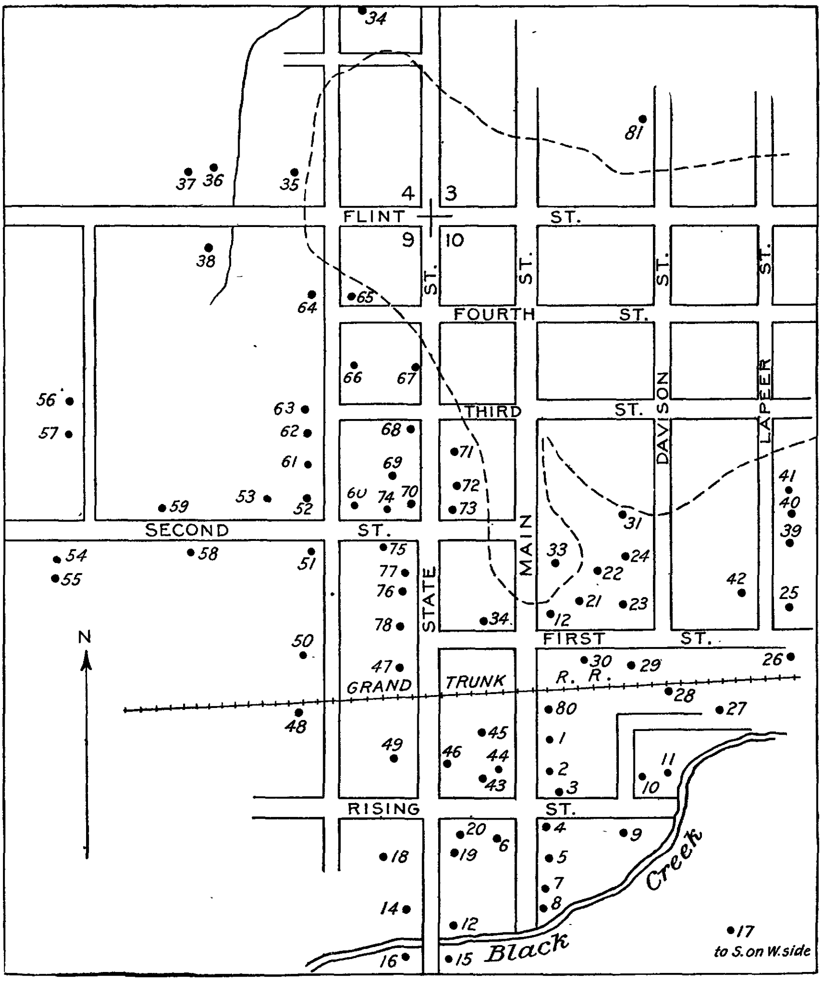

FIG. 33.—Plat showing distribution of flowing wells in Davison village, Genesee County.

that the well at the creamery, 66 feet deep, if shut off, always started roily, and when first put down discharged more than a wagon load of fine sand.

The wells in many instances were reported to be cased down into the clay for a few feet only, and but few of them had sand screens on the points.

The deeper wells have the greater head and the stronger flows, except a well near the stock yard of the railroad company, which was reported to be only about 16 feet deep and which flowed 10 gallons per minute at a height of 8 feet above the ground, quite equaling any other well visited. The well of Mr. L. Raisin when first put down was said to have flowed over the top of 32 feet of pipe, and while now reduced still has a strong head. One other well, that of J. F. Cartwright, the first to be put down to 70 feet, was reported to have a head of about 30 feet at first, but slowly fell as others were put down and is now below 8 feet. The 30-foot wells are all apparently of slight head and small flow.

At present the village has no public water system, and fire protection is obtained by allowing the water from some of the flowing wells to run into reservoirs. It is apparent, however, that it would be possible to get a good supply for public service by putting down a few wells in the lowest part of the valley to the depth of the lowest stratum, which, being least used, would give the best supply and would also interfere least with the existing wells.

The well of Mr. A. Tenney (No. 56) was on slightly higher ground than any other flow and proved to be a rock well 115 feet deep and said to be about 15 feet into the shale rock. In case this is a correct record, the 95-foot well of Mr. Raisin is probably in gravel lying on top of the rock.

Fig. 33 shows the location of wells in Davison village; the data are given in the following table:

Wells in Davison.

No. on fig. 33.	Owner.	When made.	Diameter.	Depth.	Cost.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
			In.	*Ft.*		*Ft.*	*Ft.*	*Gal.*	*°F.*			
1	A. N. Trumbull	1904	2	72	$72	785	+10	8¼	50	Iron; lime.	Gravel	
2	A. J. S. Seeley	1904	2	75	78	785	+ 8	7	....	do	do	Slight flow because of No. 1.
3	do		1½	30	30	785	+ 1	½	51	do	Sand	
4	do		1½	30	30	784	+ 1½	¼	51	do	do	
5	Mr. Uptograff		1¼	30	30	784	+ 1	¼	51	do	do	
6	do		1¼	....	30	785	0	½	51	do	do	Flows at surface.
7	do		1¼	....	30	784	+ 1½	½	51	do	do	
8	do											Flows in cellar.
9	do		1¼	....	30	784	+ 2½	½	51	Iron; lime.	Sand	
10, 11	Brickyard		1¼	....	30	784	+ 1½	½	51	do	do	Used in boilers; does not scale badly.
12												No data.
13												Do.
14	G. Moore		1¼	....	30	782	+ 1	⅛	....			
15	G. Soper		1¼	....	30?	782	+ 2	¼	53			Formerly flowed more.
16	J. Reeser		2	....	20 or 30	788	+ 1	⅕	52	Iron	Sand	Water not hard.
17	Chas. Hurd		2	95	94	790	+ 2	⅙	....		do	Flow has decreased.
18	Chas. Blackmore		1¼	....	30	785	+ 1	¼	54	Iron; lime.	do	Flows in crock.
19, 20	do		1¼	....	30	785	+ 1	....	....			Flows in cellar.

Wells in Davison—Continued.

No. on fig. 33.	Owner.	When made.	Diameter.	Depth.	Cost.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
			In.	*Ft.*		*Ft.*	*Ft.*	*Gal.*	*°F.*			
21	J. J. Schweitzer		2		$70	787	− 6?	1		Iron; lime.	Gravel	In cellar.
22	do		2		60	786	+ 2	1		do	do	At barn; flows on ground below well mouth.
23	A. Bird											No data.
24	L. Raisin		2	90	95	788	+32	4	49	Iron; lime.	Gravel	Flow controlled; said to have overflowed a 32-foot pipe at first.
25	E. Pettis		1½	40	40	783	+ 1	½	50	do	Sand	Used for irrigating garden.
26	Mrs. Yearns		1		20	780	+ 3	¾	49	Hard		Do.
27	Storehouse of elevator company.		3		16	780	+ 7	10	50	do		Water mostly wasted.
28	Grand Trunk R. R.		2		20?	780	+ 1					Not flowing now.
29	do		2		40?	782	+ 3	¼		Hard; iron		Piped to town drinking fountain.
30	Warehouse					785						Abandoned; clogged.
31	Wm. Foote											No data.
32	Davison House		2		73	785	+ 1	2		Hard; iron	Gravel	
33	Store building				30 30	784 785	− 5 − 5					Both in basements.
34	J. Smith		1¼		32	786	+ 1½	½	50	Hard; iron	Sand	
35	J. Taggart		1½		37	785	+ 1	1	50	do	do	Flows into tank.
36	C. S. Lucas	1903	1½		70	783	+ 2	1	50	do		
37	W. Shoemaker	1902	1½		50	785	+ 1½	½		do		Waste runs to village reservoir.
38	M. Smith	1902	1½		40?	783	+ 1⅓	1½	50	do		
39	H. Welsh	1902	1¼		25?	785	+ 1	1	49	do		
40	W. F. Burdick	1902	1½	25	27½	786	0	¼				Lowered by No. 39.
41	Mrs. Fenton		1½		27	786	0	⅛				Do.
42	Frank Blackman		1¼		18	785	+ 7½	¼	51		Gravel	Pioneer well; head +30 feet at first; piped to house.
43	J. F. Cartwright		2	70	70	785	+ 8	2			do	
44	do		1¼		30	785	− 4	¼			Sand	In cellar; flow decreased.
45	Cartwright (elevator).		1½		30	785	+ 2	½			do	
46	Cartwright (old house well).		1½		30	785	+ 1	1/10				Just drops now.
47	Sawmill		1¼		30	786	+ 1½					Does not flow now.
48	A. Armstrong	1891	2	66	66	786	+12	8	50	Soft	Sand and gravel.	Small flow at 30 feet; used in boiler and creamery.
49	H. Newbaker			78	78	786	+12	8	50	do		
50												No data.
51	George Hill		1½		32	784	+ 2	½	50			
52	Mrs. Cottrell		1¼		30?	785	+ 1	⅓	50			
53	H. C. Dayton		1½		104	787	+ 1					Small flow; pump well.
54	J. Austen		2		92	794	+ 2	½	50			
55	do		1		26	794	+ 1	½	51			Flows at bottom of tank.
56	A. Tenney		2	115	115	804	+ ½	¾	50		Rock	Water slightly mineral; 15 feet in rock.
57	Wm. Hall		1½		30	795						Intermittent.
58	C. J. Adams	1904	2	65	93	789	+ ⅓	⅓	50.5	Hard		Water hardly rises above surface.
59	Mr. Johnson	1902	2							Hard; iron		Incomplete.
60	Mrs. Towar		1½		30	785	+ 3	½				Too hard for laundry.
61	S. Lane		1½		360	785	+ 1	1	50			
62	C. N. Sallick	1897	1½		40	785	+ 4			Hard; iron		In cellar.
63	J. Hibbard				60	789	− 6					
64	G. Haynes		2		35	786	+ 2	⅓	50	Hard; iron		
65	L. Shales				(?)	789	+ ½	½		do		Flows in bottom of tank.
66	Wm. Travis		1½		(?)	791	0	⅛				
67	George Hall		2		60?	786	+ 3	½	50	Hard; iron		
68	Barney Cole		1½		(?)	786	+ 3	½	50.2	do		
69	L. Gifford		2		(?)	786	+ 3	¼	53	do		Flows from pump.

Wells in Davison—Continued.

No. on fig. 33.	Owner.	When made.	Diameter.	Depth.	Cost.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
			In.	*Ft.*		*Ft.*	*Ft.*	*Gal.*	°*F.*			
70	C. A. Uptegraff					786	+ 3	1	50.2	Hard; iron		Piped to shop.
71	J. P. H. Bradshaw.		3		$62	785	+ 3	2	50.2	do		Lawn sprinkling.
72	Mr. Wagner					788	+ ½	⅛				Flows into crocks.
73	F. H. McGreggor		2		80	787	+ 3	2	50.2	Hard; iron		Do.
74	J. Deal		1½		25?	785	+ 1	½		do		
75	Mrs. Black		1½		60	785	+ 2	⅛		do		Flow decreased.
76	J. F. Cartwright		2		70	785	+ 1	1	50	do		
77	Mr. Cummings		1½		30	785	+ 1	¼		do		Loses largely by leaky casing.
78	D. Cobus	1876	1¼		30?	786	+ 1	¼		do		Gravel, 5 feet; hardpan, one-half foot; clay, 25 feet.
79												In cellars; use discontinued; about 50 feet deep.
80												(Same as 79.)
81	H. Southworth	1898	2		60	787	+ 4	1½	50	Hard; iron		

VICINITY OF DAVISON.

In the country district south and west of the village the wells were generally reported as bored by the owners and at most only a single length of pipe used for casing. This method of putting down makes the cost of construction very small, but it is not conducive to permanency. From the varying depths at which water was reported in this part of the area, it seems likely that the strata are not continuous with those of the village, nor is it probable that they are.

It seems probable that the rolling land east of the area serves as the catchment area and gives the head necessary to make the wells flow. The diagram, fig. 32, and the sketch map, fig. 31 (p. 162), show the supposed relation of the strata in vertical section, and the approximate position of the wells of the area to the rolling lands to the east.

In sec. 29, Davison Township, there is a single light flow in the bottom of a small marshy depression in the moraine. The marsh is but a few acres in extent and surrounded by hills. The well was remote from any house, and no data were obtained regarding it, but from the way it was constructed and its location it was evidently shallow. This was the only flowing well in the township found in the rolling country.

BURTON TOWNSHIP.

On the farm of A. C. Skinner, 3 miles southeast of Flint, in the NE. ¼ sec. 28, in the valley of Thread River, is a tile well 25 feet deep. The water flowed the year round until recently, when it was purposely shut off, and now in a wet season it rises 4½ feet above the surface and runs from the spout of the pump. The well is about 5 feet above the level of the water in the stream and 25 feet below the level at which any of the neighboring houses stand. This well suggests the possibility of putting down other wells in the valley of the stream, with the reasonable expectation of getting flowing water from no great depth.

In the central part of the township the wells are commonly shallow, dug or bored 12 to 20 feet deep. One tile tubular well was reported to be 50 feet deep, with a good supply of water. Doctor Chase's well, at the northwest corner of sec. 16, flows from the rock, which is said to be 75 to 80 feet from the surface. Below 20 feet, until rock is reached, water is rather scarce in this part of the county.

In the southeastern part of the township, especially in secs. 23 and 24, water is abundant, and there are numerous flowing wells, which form the eastern extension of the Davison area.

SUMMARY.

The following table gives data of the wells in Davison and Burton townships, exclusive of those in Davison village, which are given on pages 164–166.

Wells in Davison and Burton townships.

No. on fig. 31.	Township N.	Range E.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
						In.	*Ft.*	*Ft.*	*Ft.*	*Gls.*	*°F.*			
1	7	8	30	H. R. Thomas	1902	20	14	790	−5	....	....	Hard	Gravel	This well is in neighborhood of flows, but on higher ground.
2	7	8	19	Bert Thomas	1894	1½	25	782	+3	1	50.5	do	do	
3	7	8	19	E. Thomas	....	1½	30	785	+2	½	50	do	do	Has two wells.
4	7	8	30	A. A. Thomas	....	1½	30	780	+2	1	....	do	do	Well in pasture; another at house.
5	7	8	20	Fred Knapp	1884	1½	40	785	+2	1	50	do	do	Well in pasture.
6	7	8	20	do	1884	1½	40	780	+2	1½	50	do	do	Do.
7	7	8	20	F. Blackman	1898	1½	48	780	....	1	....	....	....	
8	7	8	19	Israel Hill	....	1½	50	780	0	½	50	Hard	Gravel	Water flows at surface; rock at 90 feet.
9	7	8	19	do	....	1½	50	780	+1	½	....	do	....	Drilled well at bar, 111 feet deep, 16 feet in rock.
10	7	8	19	do	....	1½	60	780	+1	1	....	do	....	
11	7	8	15	Oscar Harris	1894	1½	40	810	+3	¼	54	do	Sand	
12	7	8	15	W. Walterhouse	1892	2	40	812	+3	½	52	do	do	Another well about the same on back of farm.
13	7	8	16	E. B. Terrill	....	2	....	808	+1	⅛	....	....	do	Water nearly soft.
14	7	8	16	Mrs. Wm. Fagin	1902	2	55	790	+2	1	50	....	do	Do.
15	7	8	16	do	1902	2	55	790	+1	3	50	....	do	Do.
16	7	8	16	do	....	1½	30	785	+2	....	....	....	....	Flow very small.
17	7	8	16	L. S. McAllister	1880	2	30	795	+½	½	50	Hard	....	
18	7	8	16	do	....	2	30	790	+3	1½	50	do	....	In hollow in field.
19	7	8	16	G. M. Gaylord	....	1½	30	790	+1½	½	50	do	....	In field.
20	7	8	30	Fred Blackmore	....	....	....	785	....	....	....	....	....	Bored well; small flow.
21	7	7	23	J. Phelps	....	2	20	770	+2	3	50	Hard	....	
22	7	7	23	R Van Tifflin [a]	....	2	15	775	+1½	1	50	do	....	Easy to get flows here anywhere at about 15 feet.

[a] W. Skellinger, a driller at Davison, states that the Van Tifflin wells are 30 to 40 feet deep. The strongest has a head of 12 to 14 feet.

Wells in Davison and Burton townships—Continued.

No. on fig. 31.	Township N.	Range E.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
						In.	*Ft.*	*Ft.*	*Ft.*	*Gls.*	*°F.*			
23	7	7	23	R. Van Tifflin[a]	....	2	15	775	+1½	2	50	Hard	....	
24	7	7	24	....do	....	2	15	775	+2	2	50	....do	....	
25	7	7	24	....do	....	2	15	775	+2	3	....	....	....	
26	7	7	24	....do	....	2	15	775	+2	1	....	....	....	
27	7	7	25	H. A. Day	....	....	....	....	....	....	....	....	....	These and others in neighborhood said to be 25 to 35 feet deep. Flow varies from one-half gallon to 3 gallons. Mostly old wells.
28	7	7	25											
29	7	7	25											
30	7	7	25											
31	7	7	25											
32	7	7	25											
33	7	7	24	Chamberlin place	....	2	30	780	+1½	1½	50	....	....	Rather hard water.
34	7	7	24	Mrs. Clark Day	....	2	35?	780	+2	4	50	....	....	Do.
35	7	7	24	A. Burns	....	2	30	780	+2	1	50	....	....	
36	7	8	16	P. P. Hill	....	2	30	785	+2	½	50	....	....	
37	7	8	16	....do	....	2	30	785	+2	6	50	....	....	
38	7	8	16	....do	....	2	30	785	+2	1	50	....	....	
39	7	8	8	M. H. Flint	....	2	....	789	+1½	¼	50	....	....	In stream valley.
40	7	8	8	....do	....	2	....	789	+1½	¼	50	....	....	In woods.
41	7	8	8	E. N. Demanois	....	2½	....	790	+1½	¼	51	....	....	Water medium hard.
42	7	8	8	F. Hill	1898	2	114	785	....	....	....	....	....	Flowed 2 years, then stopped; water medium hard.
43	7	8	8	B. Cartwright	....	2	....	780	+2	2	50	Medium.	....	
44	7	8	10	I. W. Cole	....	2	25	785	+2½	5	50	....do	....	
45	7	8	10	....do	....	1½	40	788	+2	1	50	....do	....	
46	7	8	3	J. J. Worden	....	1¼	40	790	+2½	¼	50	....do	....	In marshy pasture.
47	7	8	3	N. Haines	....	1¼	40	790	+1	⅓	50	....do	....	
48	7	8	2	W. Dillenbeck	....	1½	30	785	+2	½	....	Hard	....	In pasture.
49	7	8	2	....do	....	2	60	785	+1½	½	50	....do	....	
50	7	8	3	V. Henderson	....	2	50	785	+1½	¼	50	....do	....	
51	7	8	3	....do	....	2	50	785	+2	½	50	....do	....	

[a] W. Skellinger, a driller at Davison, states that the Van Tifflin wells are 30 to 40 feet deep. The strongest has a head of 12 to 14 feet.

GAINES AND MUNDY TOWNSHIPS.

SWARTZ CREEK.

The village of Swartz Creek is situated on the side of the ridge bordering the valley of the stream of the same name and is about 20 feet above it.

In the village the wells are said to be generally shallow—from 12 to 30 feet in depth—the water coming from below a thin layer of hardpan.

The well of Mr. William Clark, on the broad flat terrace of the stream, usually flows with a head of about 2 feet, but had just ceased when visited by the writer. The flow was said to be a small one. The well is about 25 feet deep.

From this single well it seems likely that tubular wells put down in low places on the terrace of the creek would give flows, and especially so since the ridge bordering the valley gives a good catchment area and head.

GAINES AND MUNDY AREA.

This area lies 2 to 3 miles south and from 1 to 2 miles east of Swartz Creek in a flat trough or plain, with a low ridge to the north. (See fig. 34.)

Both rock and drift flows occur, but the drift or gravel flows occupy, as would be expected, much the smaller part of the area. No attempt was made to get a full list of the flowing wells from the rock in these townships.

The area where flowing wells occur covers only about 1 square mile and is entirely without features, being so flat that little difference of level can be seen over the whole of it. The wells are shallow, ranging from 10 to 12 feet in depth at the western end of the area to 40 or even 80 feet in other parts, though most of them were reported as being about 25 feet deep. The water usually flows in sufficient quantity for the owners' needs, but a few wells had ceased flowing or had become so feeble that pumps were used. This seems to indicate that the catchment is small and local, being affected by the local weather conditions, the head of many of the wells being reported as less in the summer than in the winter.

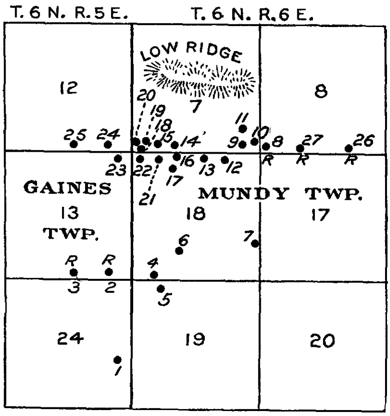

FIG. 34.—Map showing flowing wells in the Gaines-Mundy area, Genesee County.

The water is medium hard, with a small quantity of iron present.

The catchment area may be a low ridge to the north of the area where the larger number of wells are, or it might be any tributary higher land near by, since the head is so low.

Rock wells are situated around the border of the area of drift wells. The rock surface is reported to vary from about 100 feet in most of the wells to 180 feet in the well of Mr. J. H. Short, in which the rock is remarkably deep considering the showing in the wells on either side. The water is from sandstone, is fresh and sweet, is usually softer, has less iron than the waters from the drift, and the supply is likely to be more permanent because of the much greater area from which the water can come. The table on the next page gives data relating to this group of wells.

Wells in Gaines and Mundy area.

No. on fig. 34.	Township.	Range.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
						In.	*Ft.*	*Ft.*	*Ft.*	*Gal.*	*°F.*			
1	6	5	24	J. H. Short	....	1½	17	820?	+1½	5	50	Hard	Gravel	Bored in creek valley.
2	6	5	13	....do	1903	2	280	830?	+1	⅓	....	Soft	Rock	Sandstone at 180 feet; cost, $168.
3	6	5	13	G. S. Eigentrager	1902	2	130	800	+2	1½	55.2	....do	....do	Water from top of sandstone.
4	6	6	18	A. D. Stevens	1896	2	132	830	+3	3	51	....do	....do	25 feet in sandstone.
5	6	6	19	R. N. Barlow	1897	2	130	835	0	3	51	....do	....do	15 feet in sandstone.
6	6	6	18	J. B. Coqingue	....	2	30	830	+2	½	51	Hard; iron	Gravel	Bored with auger; affected by drought.
7	6	6	18	J. D. Perry	....	1	37	835	+2	⅛	....	....do	....do	Very feeble flow; well near has ceased.
8	6	6	8	School district	1898	3	101	820	+3?	1	50.6	Soft	Rock?	Said to be just to rock.
9	6	6	7	L. Close	....	1½	25	820	+1½	⅛	....	Hard; iron	Gravel	Affected by seasons; used for cooling.
10	6	6	7	....do	....	1½	25	820	+1	....	....	....do	....do	
11	6	6	7	....do	....	1½	15	820	+2	1	50	....do	....do	Low ground in pasture.
12	6	6	18	L. Shelton	....	1½	40	820	−3	....	....	....do	....	Small flow.
13	6	6	18	I. D. Gazley	1902	2	80	820	+2½	½	52	....do	Gravel	Flow has decreased.
14	6	6	7	W. Beebe	1900	1½	25	820	+8	3	52	....do	....do	
15	6	6	7	C. W. Curtis	....	1½	29	820	+2	½	51	....do	....do	Flows.
16	6	6	18	Wm. Cummings	....	1½	30	818	+2	½	....	....do	....do	
17	6	6	18	....do	....	2	25	818	+2	1	50	....do	....do	
18, 19, 20	6	6	7	J. D. Burnham	....	....	....	....	....	....	....	....	....	Three small flows; one pumped.
21	6	6	18	Mrs. C. Wood	....	....	25	....	....	....	....	....	....	Flows no more.
22	6	6	18	M. N. Wood	....	....	30	....	....	....	....	....	....	Do.
23	6	5	13	J. W. Wood	....	1½	20	816	+½	2½	49	Hard; iron	Gravel	Bored; flows in tub.
24	6	5	12	M. N. Wood	....	2	12	815	+2	5	50	....do	....do	On bank of ditch.
25	6	5	12	W. A. Stoner	....	....	10	813	+½	1	....	....	....	Crock well; overflows.
26	6	6	8	Chas. Allen	1903	2	100	820	+2	2	50	Soft	Rock	Well in sandstone.
27	6	6	8	W. S. Blass	....	....	....	....	....	....	....	....do	....do	Sandstone.

GAINES.

The wells at Gaines range from shallow dug ones to deep drilled ones—from 120 to 195 feet. Good supplies of water are found in sand and gravel below clay at from 20 to 175 feet. Rock has not been reached in any of the wells.

GRAND BLANC.

Grand Blanc village is located in a rolling district, and is perched on a low ridge overlooking the valley of Thread Creek. Wells on the ridge, to obtain permanent and sufficient supplies for ordinary use, have to be sunk into the rock (which is reported as being from 160 to 200 feet below the surface) to a total depth of 200 to 360 feet. Shallow wells vary from 25 to 70 feet deep, but usually do not give good supplies. The water rises in the deep wells to within 25 feet of the surface. On the edge of the valley on the east side of the town there are some quite shallow wells. A well of Mr. M. Frazer, bored to a depth of 20 feet, has the water within 3 or 4 feet of the surface, rising from below a thin bed of hardpan. The locality is a springy one, and another well only 8 feet deep has the water nearly to the surface. The well on the place next south of Mr. Frazer's is said to be 56 feet deep, partly dug and partly bored, and the water rises to within 4 feet of the surface.

Springs are reported to occur along the edge of the valley on the north side of the town.

In case the village ever attempts to incorporate a public system of water supply the best place to make preliminary tests will be in the bottom of the creek valley at as low level as possible. The test wells would determine the best location for a pumping station. In the valley the water would be more likely to be abundant, land would be cheaper, and the chances of getting a flow either from the gravel or from the rock are excellent. The water could be pumped to a standpipe in the highest part of the town and good pressure thus assured.

ARGENTINE.

The wells in Argentine are from 15 to 30 feet deep, usually through a clay bed into water-bearing gravel.

FENTON TOWNSHIP.

LINDEN.

The village of Linden is situated in the valley of Shiawassee River, and gets a considerable part of its domestic supply from dug wells 20 to 35 feet deep. The drilled wells are from 75 to 175 feet deep, reaching rock about 100 feet from the surface. The quality of the water is good, though hard, as is usual in the region. That from the rock wells is reported as softer than that from the dug wells. The water in the rock wells rises to within 20 feet of the surface.

FENTON.

Fenton is built on the terraces of Shiawassee River, which has here cut a narrow valley in the bottom of a line of glacial drainage. The pumping station is on the bank of the stream at the lowest possible level, about 20 feet lower than the railroad station. The water is from a group of nine or ten flowing wells with slight head, ranging from 70 to 240 feet in depth, the majority of them being about 90 feet deep. The water flows into a brick reservoir of about 50,000 gallons capacity, from which it is pumped at the rate of 155,000 gallons in twenty-four hours, in spite of which fact there is a constant overflow into the stream. The pumps are connected with the stream in case of emergency, although the wells furnish 500,000 gallons a day.

The quality of the water is excellent, and seems less hard and has less iron than is usual in supplies of this sort.

The low bottom on which flows are obtained being subject to overflow, few if any dwellings have been built on it. For this reason the bottom has not been well tested for flows, but it seems probable that all along it flows might be obtained near the level of the river.

The larger number of these private wells were said to be of the shallow basin type, 12 to 40 feet deep. The water in those from the rock in the country around is said to be soft.

ATLAS TOWNSHIP.

ATLAS AREA.

These wells occur in the part of Atlas Township immediately adjacent to Oakland County on the slope of a stream valley about 5 miles south and west of Goodrich, just east and south of a low ridge. This flowing-well area is practically continuous with the Groveland area in Oakland County. The Atlas area is a small one, containing about 1 square mile, with six wells, one of which is from the rock. The drift wells are noticeably deep, and seem to come from near the top of the bed rock. The water probably rises out of the rock and accumulates under the overlying clay in a sand and gravel stratum lying on top of the rock.

There seems to be a locally developed shallow stratum, with slight head, in the eastern part of sec. 33, where two wells (one abandoned) of small flow from 20 feet down were reported.

Wells in Atlas area (T. 6 N., R. 8 E.).

No. on fig. 35.	Section.	Owner.	Cost.	When made.	Diameter.	Depth.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
					In.	*Feet.*	*Feet.*	*Galls.*	*° F.*		
1	33	G. S. Horton	$95	1896	2	96	+15	8+	51	Medium; iron.	Gravel.
2	33	Drew Ries [a]	80	1892	2	78	+ 3	10	50	Hard	Sand, gravel.
3	33	James Ferguson	81	1893	2	81	+ 3	4	51	Iron; hard	Gravel.
4	33	Milo Van Tyne	91	1891	2	91	+ 1	3	51	do	Do.
5	34	C. Groves [b]			1	20	+ 2	2		do	Do.
6	33	J. P. Platt [c]	186	1892	2	186	+ 3			do	Sandstone.

[a] Piped to house, horse barn, and barnyard. Mr. Ries formerly had a well in the low part of his garden 20 feet deep, with a small flow of 2 feet head.
[b] Located in springy place in the woods.
[c] Flows just above the surface; piped to barn and flows there a ½-inch stream.

GOODRICH.

The village is situated in Atlas Township in a rolling district on the side of the valley of Hartley Creek, which is dammed at this point for power purposes.

The wells are said to be mainly shallow, from 20 to 30 feet deep. They are dug or of the tile basin type, and have abundant hard water of good quality.

There are several rock wells in and near the village in which, generally, the water rises within 8 to 15 feet of the surface. The water comes from a fine gray sandstone, and is of good quality, with some mineral matter, mainly iron, in it. It is softer than the waters from the gravel above the rock. Doctor Whelock's well is 171 feet deep, 40 to 50 feet into the rock, and the water stands 14 feet below the surface. The deepest rock wells are said to be over 200 feet.

The well at the schoolhouse, 235 feet deep, is 105 feet into the rock. It flows 2½ gallons a minute, 2½ feet above the surface. The water has a temperature of 51° F. as it flows from the pipe, is slightly saline, and has considerable iron in it. The well was drilled about 1898, at a cost of $91.

This well is on ground high enough to make it seem probable that good flows could be secured in other parts of the village by going down to the same stratum.

The stream and pond at this place suggest the practicability of securing water for fire protection easily and cheaply, and eventually these sources of supply will probably be utilized for the purpose.

ATLAS-HADLEY AREA.

This area occupies a valley that lies between morainic ridges, and embraces perhaps 10 square miles in the townships of Atlas (Genesee County), Hadley (Lapeer County), and Brandon (Oakland County). (See fig. 35.) The Ortonville and Brandon Township flows are near its south end and are treated separately[a] because of their great development. From Ortonville the flows extend as far as Hadley, Lapeer County, 7 miles to the northeast, appearing at frequent intervals along the valley and the lower part of its slopes.

The area includes six or seven wells in Atlas Township, and at least eight in Hadley Township, and there may be some which escaped notice in both of these townships. The number in Brandon Township, which should properly be included, is about 100.

It is probable that in many places in the lower parts of the valley flows could be obtained, but because of the undrained character of the soil and the scattered population of the district there are relatively few houses at low enough levels to be within the limits of flow. The fact that the porous gravels along the sides of the valley yield good supplies of water for shallow wells does away with the necessity of putting down deep ones. Along the road between secs. 15 and 16, Hadley Township, is the greatest development of any place in the

[a] See Water-Sup. and Irr. Paper No. 182, pp. 184-187.

area. Here the first well to flow was a dug well, in which, at the time of construction, in the early sixties, the water rose so rapidly that the bottom had to be choked with stones to enable the owner to have it walled up. This well is still flowing several gallons a minute into a tile drain.

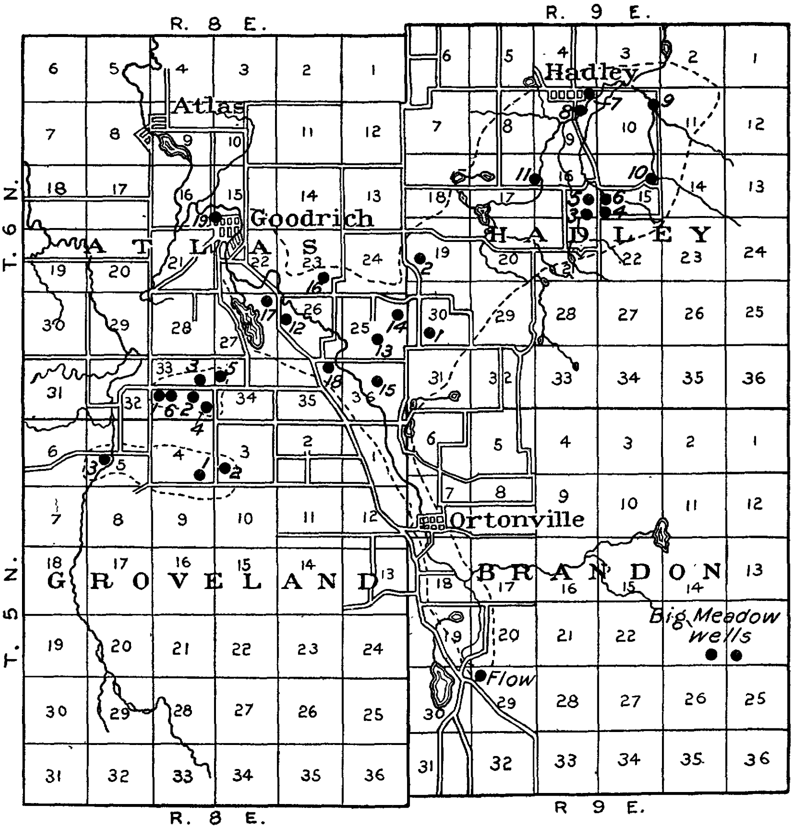

FIG. 35.—Sketch map of the Ortonville, Hadley-Atlas, Groveland, and Atlas flowing-well areas.

At Hadley, the well on the school grounds, 147 feet deep, is 14 feet into the rock, and flows just above the surface. North of Hadley no flowing wells were found. The well of Mrs. Jones, in the northern part of sec. 22, Hadley Township, was reported as 284 feet deep, with rock at 274 feet. It passed through 50 feet of till at the top, and white sand thence to the rock.

Wells in Atlas-Hadley area.

No. on fig. 35.	Township.	Range.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
						In.	*Ft.*	*Ft.*	*Ft.*	*Gal.*	*° F.*		
1	6	9	30	J. Toady		2	80	950	+ 4		51	Hard; iron	Gravel.
2	6	9	19	C. Gregory [a]			4		+ 1			Iron	Do.
3	6	9	16	D. Riley [b]		2	31	900	+ 1		51	Hard	Do.
4	6	9	15	C. S. Riley		2	67	890	+10	3	51	do	Do.
5	6	9	16	D. Riley [c]		2	50	890	+ 1		52	do	Do.
6	6	9	15	Silas Riley [d]	1864		38	895		4	52	do	Do.
7	6	9	9	Hadley school	1902	2	147	895	+ 1	1	51	Medium	Rock 14 ft
8	6	9	9	Hadley creamery [e]	1901	2	110	885	0			Hard; iron	
9	6	9	10	A. Eckers	1904	2	47	880	+ 5	2	50	do	
10	6	9	15	Spring [f]		1	5	875	+ 2	2	60	do	
11	6	9	15	R. Hartwig [g]		2	35		− 4	1		do	
12	6	8	26	Calvin Rhodes		2	68	888	+ 1	2	50	do	
13	6	8	25	J. R. Kipp [h]		2	60						
14	6	8	25	W. Armstrong [i]		2	125	930	− 1			Hard	
15	6	8	36	Jas. Sheldon [j]		2	165	910	+ 4	4		do	
16	6	8	23	S. Spicer [k]		2	131						Sandstone
17	6	8	27	Mrs. Rhodes [l]		2	133						Do.
18	6	8	15	Goodrich school									Rock.

[a] Spring boxed in woods with spout to trough.
[b] Flowed until within two months when it lowered 4 inches and is now pumped; flows at barn.
[c] Used to flow ½-inch stream; very small flow now.
[d] First flow of the area; dug well; partially filled with stone to check overflow.
[e] Would flow at surface, but is pumped.
[f] From a near-by spring; used for watering stock.
[g] Pumped at barn, but piped to stock trough on hillside and flows there.
[h] In pasture; piped to farmhouse.
[i] Piped to barn, where it flows.
[j] Sand 55 feet, clay 10 feet, gravel with water at bottom.
[k] Piped to barn, where it flows.
[l] Flows at barn; water at 118 feet in gravel; best flow from rock.

WATER SUPPLIES OF LIVINGSTON COUNTY.

TOPOGRAPHY.

Livingston County, of which Howell is the county seat, is west of Oakland County. The interlobate morainic system which traverses Oakland County centrally from northeast to southwest passes across its southeastern part, and Huron River traverses it in a southwesterly course about on the line between the Saginaw and Huron-Erie portions of the interlobate system. There are numerous lakes along the river and in the moraines on either side. From this interlobate moraine there is northwestward drainage to Cedar and Shiawassee rivers. The former drains the western part of the county to Grand River and thence to Lake Michigan, while the latter drains the northern part of the county northward into Saginaw Bay. The northwestern part of the county is occupied by a much smoother tract than the southeastern, though feeble moraines are traceable, and there are several gravel ridges or eskers which lead up into the interlobate moraine.

Wells are obtained throughout the county at moderate depths, usually without reaching the rock. A number of wells, however, in the northwestern portion have been sunk a short distance into the rock, which is reached at about 100 feet. This part of the county is embraced in the discussion, by Doctor Lane, of the region around Lansing.[a]

SUPPLIES BY DISTRICTS.

HOWELL.

The town of Howell is situated on a gently undulating plain near the geographic center of Livingston County. To the south is a depressed area, in the bottom of which are marshes and several small lakes.

WATERWORKS.

Howell has a waterworks system, which obtains its supply from a group of ten 6-inch tubular drilled wells, located in a shallow drainage valley near the Pere Marquette Railroad station, in the western part of the town. These wells have been in use since 1894, and the water is said to come from gravel, lying at a depth of 65 feet below the surface, and to rise to within a foot of the surface when the pumps are not in operation. When pumped at the rate of 600 gallons a minute, the water is lowered 7 or 8 feet, but at the usual rate of pumping during the summer season (from 275,000 to 300,000 gallons in twenty-four hours) the lowering is only 4 feet. The supply was said to show some signs of failure, but this is attributed to the tendency of the strainers to become clogged, as all the wells show this tendency after a few months of use, and unless the wells are frequently sand pumped the supply is reduced. The supply is, however, adequate for all the present demands, and the water is of good quality, though hard and containing some iron. It is used for fire protection, lawn sprinkling, for boilers, and for general domestic purposes.

(1) There are many shallow dug wells in Howell, which are used commonly as sources of drinking water and as domestic supply. The depth of these wells ranges from 15 to 50 feet and the water is generally less hard than that of the city supply described above.

FLOWING WELLS.

In the southeastern part of the town, in one of the areas of marsh land mentioned above, is a group of flowing wells (see fig. 36) of slight head and generally small flow, which forms the largest group of this type in the county.

From their situation in relation to the higher lands around it is difficult to determine whether the sources of supply for this area are in the morainal hills and sandy slopes to the south or in the long, rather sandy slope to the north, as either or both might contribute water. The small flows and slight head would indicate, however, that there is

[a] See Water-Sup. and Irr. Paper No. 182, pp. 170-175.

either a small catchment area or one in which the porosity is too slight to yield any considerable amount of free water. The general configuration of the locality and direction of drainage seems to favor a catchment area to the south, where the area of porous soils is more limited than to the north.

The obtainable records of wells put down in this locality indicate that there are two water-bearing strata generally available. The upper, of about 1 foot in thickness, is a coarse sandy gravel, which yields a good supply of water at depths varying from 6 to 12 feet. This is usually capped by a clay bed, and the water has sufficient head to give slight flows at or slightly above the surface. The usual practice is to shut off this vein and go down to the lower one, a wise

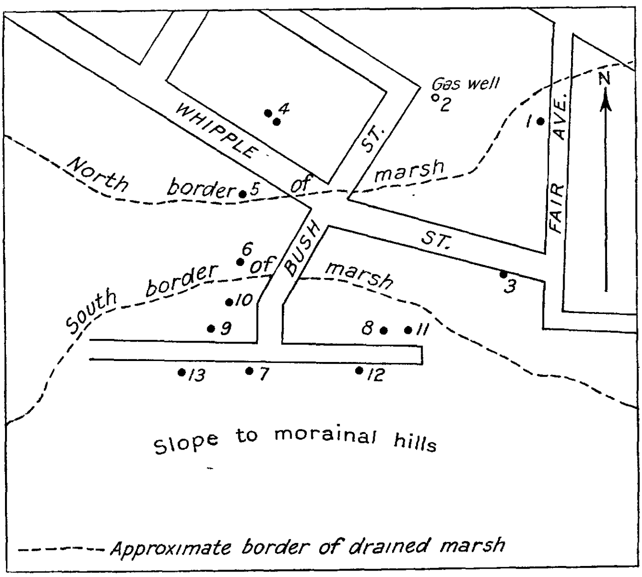

FIG. 36.—Plat of portion of Howell, Livingston County, showing flowing-well district.

practice, since there is no general sewer system, and the chances of contamination from cesspools, etc., are considerable under existing conditions. The only wells obtaining their supply from this vein are those of Mr. Charles Arnold and his neighbor across the street.

The lower water-bearing stratum is from 40 to 60 feet below the surface and is of unknown thickness. It is covered by a thick bed of blue clay so free from stones as to be easily bored through with the small auger commonly used in sinking the wells, and so compact that usually no casing is used, except enough to shut off the water from the upper vein. In most of the wells this water-bearing gravel is said to be white, rather coarse, and free from sand. The water is hard, with considerable iron in it.

The valley extends east, west, and southwest, but at present is not inhabited, because of its marshy character. Wherever the surface is sufficiently low the conditions would seem to be favorable for finding flows, either from the stratum from which the present supply is obtained or at a greater depth, and as the marshy area becomes settled the present area of flows may be extended.

The only other flowing well near Howell is that on the farm of E. P. Gregory, in sec. 2, Marion Township. This is a bored well, said by Mr. Gregory to be 34 feet deep, but by the driller, Mr. Andrew Feeley, from memory, to have the following record:

Records of E. P. Gregory's well, Marion Township.

DRILLER'S RECORD.	Total (feet).	MR. GREGORY'S RECORD.	Total (feet).
Sand	12	Sand and gravel	7
Clay, very stony	57	Tough blue clay	33
Clay	67	Water gravel; strong flow	34
Water gravel; strong flow.			

This well is situated 20 feet above and 60 rods north of Shiawassee River on the slope of a well-marked drift ridge. The head is about 7 feet, and the flow, as arranged at present, is about 12 gallons a minute. The water is hard and with considerable iron, but of excellent quality. It is used to cool milk, to water stock, and for all domestic purposes.

From the situation of this well, so much above the stream level, it is probable that the side of the valley farther down the slope would yield flows, but there are few residences in the neighborhood, and these are all on higher ground, while the pastures bordering the stream are sufficiently watered to make the sinking of wells unnecessary.

Mr. W. S. Papworth, in putting down a well some sixteen or eighteen years ago, struck a small flow of gas in the sand under the upper clay. When first struck, the gas was said to burn at the mouth of the pipe with a flame "as large as a barrel." The gas was piped to the house and supplied a single burner for six months with sufficient gas to give a constant bright flame. The sand constantly clogged the well so that the water could not be pumped, and the well was finally abandoned and filled up. The gas was in all probability "marsh gas," which in some way had accumulated in the sand as the result of decaying vegetation in the neighboring marshy area.

Wells at Howell.

No. on fig. 36.	Owner.	When made.	Diameter.	Cost.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Water bed.
			In.		Feet.	Feet	Feet.	Gals.	°F.	
1	W. S. Papworth [a]	1897	2	$12	55	910	+3	0.5	51	Gravel.
2	W. S. Papworth [b]	1888	1	5	20	915	−3	......	......	
3	Jos. Feeley [c]	1896	2	4	45	905	+5	1.5	49.2	Do.
4	Chas. Arnold [d]	1895	2	2	12	915	+ .5	1	50.5	Coarse gravel.
5	Wm. Duncan [e]	1897	2	......	35	909	+1.5	1	51	Gravel.
6	Wm. Barrett [f]	1900	1	3	37	912	+1.5	.5	50	Do.
7	Fred Mischke [g]	1899	1	3	35	912	......	1	......	Do.
8	Mrs. L. Tilden	1901	1	4	42	914	+ .5	1.5	49.5	Do.
9	F. Crandall [h]	......	1	4	40	913	+2	1	50	Do.
10	J. R. Austen [i]	......	2	......	40	910	+2	2.5?	52	
11	George Perry [j]	1900	1	4	44	914	0	1	50	Do.
12	E. Bennett	......	1	4	42	910	+2	1	51	Do.
13	C. Cooper	......	1	......	40	912	+1	......	......	Do.

[a] Forty-five feet blue clay; 20 feet of casing.
[b] Well flowed gas for a year, then filled with sand.
[c] Muck, 5 feet; sand, 15 feet; blue clay, 20 feet; reddish hardpan, 5 feet; water gravel at bottom.
[d] This well now flows in basin; used to flow above surface; pumped now. Sand, 6 feet; clay, 5 feet; gravel, 1 foot. Mr. Arnold has two similar wells.
[e] Flow affected by pumping Arnold's well across street. Sand, 8 feet; clay, 26 or 27 feet.
[f] Sandy loam, 2 feet; clay, 35 feet.
[g] Has pump, but would flow if owner cut down to head and deepened slightly.
[h] Surface sandy soil 4 feet; clay, 6 feet; gravel with water, 1 foot; blue clay to 40 feet. The lower gravel is coarse, white, and has little sand; more than 4 feet thick.
[i] Best flow in group, but runs into tank.
[j] Cut off just below surface; flows into basin.

The following are partial analyses of the public supply and a shallow well at Howell. The city water has to be mixed with rain water from cisterns for use for laundry purposes. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of well waters at Howell.

[Parts per million.]

	1.	2.
Color	51	65
Iron (Fe)	2	2
Chlorine (Cl)	11	27.6
Carbon dioxide (CO_2)	89.39	139.96
Sulphur Trioxide (SO_3)	10	51
Hardness (as $CaCO_3$)	+139	322

S. J. Lewis, analyst. 1. William Barrett; depth, 38 feet; water at 15 feet. 2. City; depth, 68 feet.

PINCKNEY AREA.

This area consists of a group of three wells in a shallow valley 1½ miles east and 2 miles north of the village of Pinckney.

These wells are about 60 feet deep, and flow 2 or 3 gallons a minute, 2 feet above the surface.

No explorations were known to have been made to determine whether this area can be extended, but it seems probable that it could be to the east, toward Hay Creek.

COHOCTAH AREA.

Cohoctah Center is a small village located on one of the branches of Shiawassee River. The houses generally stand on a sandy terrace 10 or 15 feet above the level of the stream, and water is obtained from shallow dug wells.

Near the stream level are three tubular wells which flow (fig. 37), but the quantity is small and the head slight, so that at one well a basin has been built into which the water flows and another has been fitted with a pump. The cost of one of these wells (No. 2) was but $4.50. The indications are in favor of a possible greater development along the valley of the stream if conditions should arise making this desirable. It is also quite probable that deeper wells would give larger flows with greater head. These wells were bored with an auger. The accompanying table gives the statistics of these wells and fig. 37 shows their approximate location:

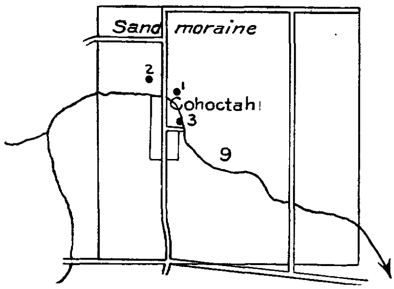

FIG. 37.—Sketch map of Cohoctah flowing-well area, Livingston County.

Wells in Cohoctah area.

No. on fig. 37.	Owner.	When made.	Diameter.	Depth.	Elevation of well.	Elevation of water bed.	Head.	Flow per minute.	Temperature.	Water bed.	Quality.
			In.	*Ft.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	J. S. Gordon		1.5	33	915	882	+2	.5	49		Hard, with some iron. An old well.
2		1903	1.25	31	918	887	+ .5	.5	49	Sand	Hard; some iron.
3	J. Trowbridge [a]	1892-3	2	49	918	868	0			Gravel	Hard.

[a] This well had just ceased flowing. Said to flow during the wet part of the year over the end of pipe, which is cut off near the surface of ground.

Cohoctah station is situated on the Ann Arbor Railroad, above the level of the old village. It has shallow dug wells from 23 to 67 feet in depth, the usual depth being about 50 feet. The water in them rises from a gravel bed to within 18 to 23 feet of the surface. The water is hard and has considerable iron in it.

DEERFIELD.

About 2½ miles east and 1 mile north of Oak Grove, on the north side of sec. 29, Deerfield Township, is the sawmill and cider mill of Wm. H. Wenk. This is placed on the edge of the terrace of a swampy valley running off to the north, and at the foot of the terrace, in the boiler room of the mill, is a well 72 feet deep, which, if it were not shut off, would flow the full size of the pipe. The water comes from a stratum of sandy gravel 11 feet thick, and has a head of 16 feet. It was put down in 1896 by the owner, who furnished the following record:

Record of Wenk flowing well, near Oak Grove.

	Thickness.	Total.
	Feet.	*Feet.*
Sand and gravel	6	6
Blue clay	64	70
Hardpan	2	72
Coarse gravel with sand	11	83
Hardpan.		

The pipe was drawn back to the top of the water-bearing stratum. The water was not hard, and had a temperature of 51° F. A bored well at the house of Mr. Wenk, across the road, showed nearly the same section, except that there were 22 feet of sand before the gravel was reached. This well is on high ground, and the water rises in it within about 7 feet of the surface.

It is quite probable that other flows might be obtained along the sides of the valley to the north by going down to the level reached by the Wenk well. With the large head and thick water-bearing stratum there should be abundant water with which to use a hydraulic ram or water motor for elevating water thus found to buildings at higher levels, but as yet, so far as learned, no other attempt than Mr. Wenk's has been made to strike a flow in this vicinity.

HARTLAND AREA.

Beginning a short distance west and south of Hartland post-office and extending northward along a swampy valley drained by one of the minor branches of Shiawassee River are four or five flowing wells. The limits of the area are as yet undetermined, because of the sparse population and the general location of the houses and farm buildings upon the higher ground, but it is probable that flows would be struck in both directions along the valley beyond the present wells. The flows are from tubular wells, are rather weak, with slight head, and present no phases of general interest. Their approximate location, and the area of the basin, as at present developed, is shown in fig. 38.

On the farm of J. B. Crause, sec. 17, T. 3 N., R. 6 E., Hartland Township, about a half mile west of Hartland post-office, is a remarkable spring, really a natural artesian well, although now given an improved outlet by the owner. It is located near to and east of the house and 12 or 15 rods south of the road, below the edge of the highest terrace of a marshy valley. The natural outlet of the spring has been dug out to a depth of 11 feet, down to the water-bearing stratum of fine gravel, and walled up with stone laid in cement, to a height of about 6 feet above the surface. The water rises to the top of this cistern and flows out in three streams; one, a waste pipe 1 inch in diameter, is allowed to run full into a ditch to the stream valley. A second pipe 1½ inches in diameter runs into a cooling tank in the milk house, and a third pipe runs a hydraulic ram which pumps water to the house and barns. The waste water from the milk house runs through a series of watering troughs in the barnyard before it is allowed to go to waste. Besides these outlets, a considerable quantity of water runs off through cracks in the cement and stonework near the top of the cistern. The entire outflow from this spring can not be much less than 20 gallons a minute, as the quantity received in the milk house is about 8 gallons. While the improvements were being made on the natural spring the water was carried off at a low level by ditch. Simultaneously some of the wells to the northwest are reported to have stopped flowing, thus suggesting an underground connection with the wells.

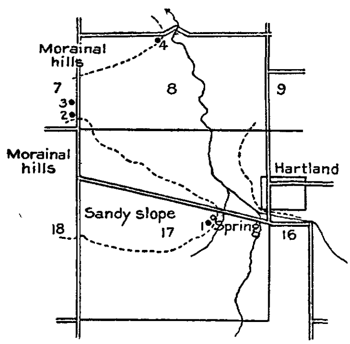

FIG. 38.—Sketch map of Hartland area, Livingston County, showing locations of wells.

Wells of Hartland area.

No. on fig. 38.	Owner.	Diameter.	Depth.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
		Inches.	*Feet.*	*Feet.*	*Galls.*	*°F.*		
1	J. B. Crause	1	15	+1.5	1	49.2	Hard, with some iron	Gravel.
2	C. Parsons	2	50	+2	1	50	do	Do.
3	A. M. Townley	2	62	+3	1.5	50	do	
4	Wm. Cullins	2	30	+3	1		do	Do.
5	J. B. Crause (spring)	48	11	+6	20	50	do	Do.

Below is given a partial analysis of the water from the Lockwood Hotel, at Fowlerville. It seems to be very highly contaminated from seepage from the livery stable across the road. It is probable that the typhoid, which has been prevalent in the town is due to the polluted supplies from wells of this sort. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analysis of well water at Fowlerville.

	Parts per million.
Color	46
Iron (Fe)	.5
Chlorine (Cl)	57.2
Carbon dioxide (CO_2)	137.58
Sulphur trioxide (SO_3)	55
Hardness (as $CaCO_3$)	139+

S. J. Lewis, analyst. Depth, 40 feet.

WATER SUPPLIES OF SHIAWASSEE COUNTY.

TOPOGRAPHY.

Shiawassee County lies west of Genesee County, and is traversed by the same system of moraines noted in the discussion of that county. The northern edge was occupied by the Glacial Lake Saginaw. The county is generally either plain or gently undulating. Between the moraines are large valleys which represent lines of glacial drainage leading westward to Grand River. One of them, which passes just north of Durand and south of Corunna and Owosso, is known as the Imlay outlet and carried the waters of the large Glacial Lake Maumee. The southwestern part of the county is now tributary to Grand River, but the remainder drains northward through Shiawassee River and tributaries of Flint River to Saginaw Bay. The southwestern part of the county is discussed by Doctor Lane in his report on the region about Lansing.[a]

SUPPLIES BY DISTRICTS.

OWOSSO.

FLOWING WELLS.

The Owosso flowing wells form the most important group in Shiawassee County. They are located in and near a subdivision of the city known as Maple Ridge, which lies on a slightly sloping terrace in the valley now occupied by Shiawassee River and south of the stream. It is a short distance north of a morainal ridge, which seems to be the catchment area for the wells, and which here runs nearly east and west for some distance.

The wells are in three groups; the larger one in Maple Ridge Park proper (see fig. 39) has about 25 wells, including those which would flow above or at the surface if not pumped, while the smaller one, five blocks west and one south, has only six wells. What is considered by the writer to be a third group in this area occurs still farther southwest near the south end of South Chipman street, where a single flowing well (No. 15 in table) and two pump wells which would flow occur in the same neighborhood and have the same characteristics.

The water in each group comes from a gravel stratum 18 to 25 feet below the generally even land surface, the cover being a compact clay till. The water is moderately hard and is somewhat impregnated with iron, and judging from the analysis of the sample from the mineral spring given below, has a considerable amount of magnesium salts as well.

[a] Water-Sup. and Irr. Paper No. 182, pp. 170-175.

The water in the wells on the highest part of the Maple Ridge district rises not more than 8 feet above the lowest part of the district, which is a shallow drainage valley. A well (No. 1) recently put down in this lowest part has, because of faulty construction, allowed the water to rise around the casing and run to waste in large quantities. Coincident with this large waste several wells at higher levels have lost head and either decreased in flow or ceased flowing altogether.

Some of the wells are on property which has frequently changed hands, and it was not possible to secure data regarding them. How-

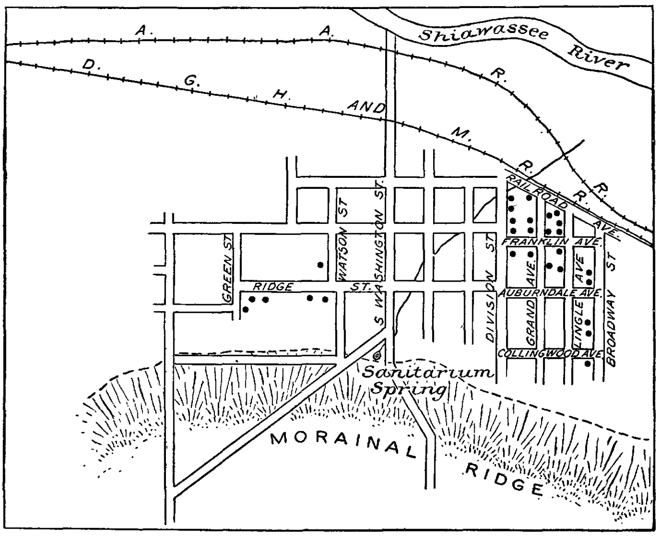

FIG. 39.—Sketch map of Maple Ridge Park and vicinity, Owosso, showing approximate locations of flowing wells.

ever, statistics relating to those of most interest, sufficient to show the characteristics of the area, are given in the accompanying table; the relation of the area to the river and moraine is shown in fig. 39.

The districts between these groups are not yet built up, and it seems probable that when they are the number of flows will be increased by new wells in the intermediate spaces unless the water is lowered so far by that time as to fail to give flows. This area should furnish a very constant and good supply of water for household use from tubular pump wells, at small expense, even where flows can not be obtained.

Wells at Owosso.

No.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.	Remarks.
		In.	*Feet.*	*Ft.*	*Ft.*	*Gals.*	*° F.*			
1	J. A. Armstrong	1.5	20	753	+2	2.5	50	Hard; iron	Gravel	Lowest in the series.
2	do	1.25	26	760	+1.5	1-2	49.2	do	do	
3	do	1.25	26	760	+1.5	1		do	do	6 feet from No. 2.
4	F. J. McDavid	1.25	25	760	+2.5	2	50	do	do	A second well used to flow.
5	L. A. Hamblin	1.25	20±	762	+ .5			do	do	Pumped to avoid sewer connections.
6	Dr. Sutherland	1.25	20±	765	+2	2	49		do	Water not very hard.
7	A. V. Leonardson	1.25	20±	765	+2	1.5	49.5	Hard; iron	do	Used to flow; now pumped.
8	Baldwin estate	1.5	25	765	+ .5			do	do	Now pumped.
9	do	1.5	28±	766	+0	1		do	do	
10	do	1.5	25±	767	+ .5		49.5	do	do	Just drops from pipe.
11	do	1.5	100±	765	+ .5	2	49.5	do	do	
12	do	1.5	18-20	765	+0	.25	49	do	do	Lowered by No. 1.
13	A. B. Pulver	1.25	20±	766	+1	2	47.4	do	do	Flows more after heavy and prolonged rains; 1884.
14	G. S. Kinney [a]	1.5	20±	765	+1.5	1	49	do	do	Flow varies with seasons; water medium hard.
15	D. D. Rust.	1.5	25±	768	+1.8	32	50	do	do	Westernmost flowing well in district.

[a] Owing to change of owners no data could be had concerning four other wells in this group, but they were said to be of about the same depth as the others. The flows are small.

The following is a partial record from a very shallow but good flowing well at Owosso, owned by Charles Terry. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analysis of well water at Owosso.

	Parts per million.
Color	5i
Iron (Fe)	1
Chlorine (Cl)	1.5
Carbon dioxide (CO_2)	121.36
Sulphur trioxide (SO_3)	56
Hardness (as $CaCO_3$)	139+

S. J. Lewis, analyst. Depth, 16 feet.

SPRINGS.

Associated with this area are two large springs, which may come from the same source. One is situated at the foot of the sharp slope of the moraine on South Washington street and is covered by a sanitarium and bath house, now closed, which were erected to utilize its waters as a remedial agent. The spring is a large one, issuing from an artificial basin in the basement of the cellar in several streams in such a way that it is hard to determine its amount; but the waste water finally runs off in a surface stream more than 2 feet wide and 6 or 8 inches deep. This spring water was for a time bottled and sold by the Owosso Sanitarium and Mineral Bath Company, but the enterprise was abandoned, and at present this large supply is entirely running to waste. The temperature of the water as it issues from the spring is 50° F.

A second large spring occurs at the foot of the same moraine about a mile farther east and is utilized by the city as a source of supply to supplement that obtained from the wells at the pumping station. The water from the spring is pumped to the large receiving well at the station and furnishes no insignificant part of the supply.

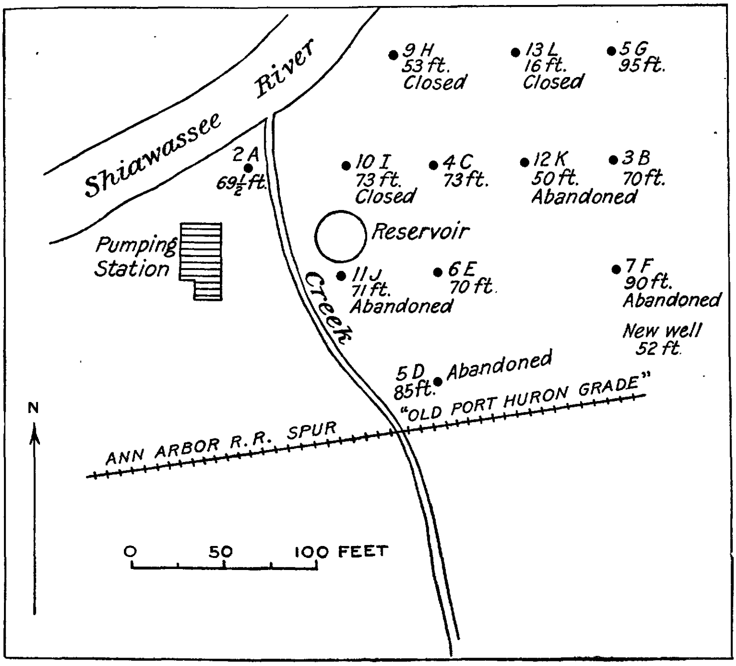

FIG. 40.—Distribution of wells at Owosso waterworks, on a terrace of Shiawassee River, 5 feet above low-water level.

WATERWORKS.

The records of the Owosso waterworks wells are of interest in showing the variations in depth, character, and thickness of the drift beds within a very limited area, and are therefore presented in full. Fig. 40 shows their relative positions.

Driller's record of Owosso salt well (waterworks well No. 1).

	Thickness.	Total.
	Feet.	*Feet.*
Muck	3	3
Gravelly clay	32	35
Gravelly mixture	10	45
Gravel	6	51
Clay	2	53
Quicksand	7	60
Coarse gravel	6	66
Quicksand	19	85
Blue clay	125	210
Sand rock	30	240
Salt water which flowed.		

"This well is located on the south side of the Ann Arbor Railroad tracks, about 200 feet west of the east line of the corporation of the city, in the low lands owned by J. L. Wright. It is 240 feet deep, cased for the first 85 feet with 5⅝-inch tubing. At the depth of 85 feet hard blue clay was reached, continuing down to the sand rock, which was struck at a depth of 210 feet. Drilling was continued into the rock a depth of 30 feet and there water was reached, which flowed at a height of 4 or 5 feet above the surface. The water was salt and the locality was abandoned, the drill being moved 150 feet northward and eastward across the track."[a]

Driller's record of waterworks well No. 2.

	Thickness.	Total.
	Feet.	*Feet.*
Soil	2	2
Clay	5	7
Sand	15	22
Coarse sand	5	27
Gravel	3	30
Clay	3	33
Gravel	2	35
Water flowed	5	40
Fine sand	6	46
Quicksand	6	52
Coarse sand	16	68
Gravel and water flow	1.5	69.5

This well was pumped 60 gallons a minute for eighty consecutive hours. The first few strokes of the pump lowered the water 12 feet, after which it did not lower it below 14 feet. The well is cased with 8⅝-inch tubing.

Driller's record of waterworks well No. 3.

	Thickness.	Total.
	Feet.	*Feet.*
Muck	7	7
Sand	5	12
Gravel	1	13
Clay	14	27
Sand	15	42
Clay	1	43
Gravel (with water)	12	55
Quicksand	13	68
Gravel with flow	3	71

This well is 71 feet deep and is located 200 feet east of well No. 2 on the same line.

[a] Record in waterworks office.

Driller's record of waterworks well No. 4.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	3	3
Gravel	6	9
Clay	9	18
Quicksand	16	34
Clay	6	40
Gravel and flowing water, with strong smell of gas at 43 feet	13	53
Quicksand	13	66
Gravel	7	73
Water gravel.		

This well is 100 feet west of No. 3.

Driller's record of waterworks well No. 5.

	Thickness.	Total.
	Feet.	*Feet.*
Soft clay	3	3
Quagmire	6	9
Gravel	23	32
Quicksand	6	38
Clay	5	43
Gravel with flow	5	48
Clay	6	54
Quicksand	3	57
Clay	4	61
Quicksand	11	72
Gravel with flow	13	85

This well is 85 feet deep and is located 120 feet south of No. 4. "This well does not flow as strongly as the other wells do. There are large quantities of coarse sand mixed with the gravel, presumably keeping the water back."[a]

Driller's record of waterworks well No. 6.

	Thickness.	Total.
	Feet.	*Feet.*
Muck	4	4
Gravel	3	7
Clay	11	18
Gravel	8	26
Clay	13	39
Gravel with flow	2	41
Quicksand	16	57
Coarse sand	10	67
Gravel with flow	4	71

"This is the best well obtained as yet."[a]

[a] Record in waterworks office.

Driller's record of waterworks well No. 7.

	Thickness.	Total.
	Feet.	*Feet.*
Soft mire	22	22
Gravel	17	39
Clay	4	43
Gravel with flow	11	54
Coarse sand	13	67
Gravel	3	70
Quicksand	15	85
Blue clay	5	90
Quit drilling.		

This well is 100 feet east of No. 6. "This well is a failure. The gravel at 70 feet has quicksand below it, which prevents the flow of water."[a]

Driller's record of waterworks well No. 8.

	Thickness.	Total.
	Feet.	*Feet.*
Yellow clay	4	4
Sand	12	16
Clay	21	37
Gravel with flow; stronger flow at 44 feet	10	47
Clay	10	57
Sand	9	66
Gravel; no water	2	68
Quicksand	9	77
Clay	4	81
Fine sand	9	90
Hard blue clay.		

"This well was a failure at this depth, but a dynamite cartridge placed at 43 feet blew the casing off at that depth. The well then flowed at a tremendous rate for several months and was called the banner well of the lot."[a]

Driller's record of waterworks well No. 9.

	Thickness.	Total.
	Feet.	*Feet.*
Clay and sand	5	5
Gravel	7	12
Clay	38	50
Gravel with flow	2	52

"This well is 20 feet south of the bank of the river. The gravel at the bottom of the well is very clean."[a]

[a] Record in waterworks office.

Driller's record of waterworks well No. 10.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	6	6
Gravel	9	15
Clay	7	22
Sand	12	34
Clay	16	50
Sand	20	70
Gravel with flow	3	73

This well is 65 feet southwest of No. 9 and 50 feet east of No. 2. "There is considerable coarse sand and fine gravel at the bottom of this well. The well was nearly lost by driving through the vein of water-bearing gravel, hoping to shut out the sand."[a]

Driller's record of waterworks well No. 11.

	Thickness.	Total.
	Feet.	*Feet.*
Muck	4	4
Sand	6	10
Gravel	20	30
Clay	10	40
Gravel with flow	5	45
Clay	3	48
Sand	3	51
Clay and sand mixed	5	56
Clay	13	69
Gravel with flow	1.5	70.5

This well is 60 feet south of No. 9 and 50 feet west of No. 6. "Not a strong flow; about the same as No. 5."[a]

Driller's record of waterworks well No. 12.

	Thickness.	Total.
	Feet.	*Feet.*
Sandy clay	3	3
Clay	3	6
Sand	23	29
Clay	44	33
Gravel with flow	17	50

This well is 50 feet west of No. 3 and in line with Nos. 2, 3, and 4.

Driller's record of waterworks well No. 13.

	Thickness.	Total.
	Feet.	*Feet.*
Sandy clay	3	3
Clay	4	7
Sand	3	10
Sand and clay	15	25
Clay	7	32
Gravel with flow	2.5	34.5

This well is 60 feet north of No. 12 and 60 feet west of No. 8. "The effect on this well of dynamiting No. 8 was to almost stop the flow of water in it."[a]

[a] Record in waterworks office.

BURNS TOWNSHIP.

This small area, covering about 1 square mile (fig. 41), is in the valley of one of the minor branches of Shiawassee River, 3 miles west of Byron, and at present has two wells. One of these has a fair flow, but with a slight head. The other has a pump attached to it, but flows through a branch pipe to a watering trough at a level below the pump platform and sometimes flows from the spout of the pump. It seems probable that other flows would be obtained by putting down wells near the level of the stream, but at present the lands adjacent are used only for pastures and fields and the need of wells is not great.

Fig. 41 shows the approximate locations of the wells. Tabulated data follow:

Wells of Burns Township area.

No. on fig. 41.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute. Present.	Flow per minute. Former.	Quality.	Temperature.	Water bed.
			In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*Gals.*		°*F*	
1	F. Robacher	1901	1.25	25	845	+5	0.75	1.5	Hard; iron	50.2	Sand.
2	J. A. Holcomb	(?)	1.50	20±	835	+2	1.5				

There is reported to be a flowing well in sec. 3, Burns Township, in a creek valley on the farm of J. S. Smith. It is 84 feet deep and 2 inches in diameter, and was made in 1884 at a cost of $30. It flows about a barrel an hour and has a head of about 1 foot. These data are from a water-supply schedule obtained from Mr. Smith by W. F. Cooper.

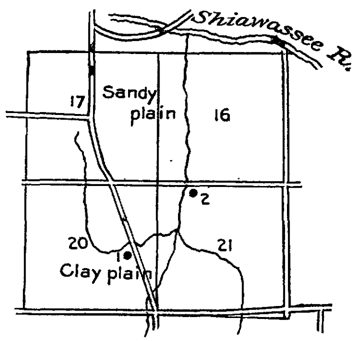

FIG. 41.—Sketch map showing location of flowing wells in Burns Township, Shiawassee County.

Byron is located on a broad gravelly terrace, 30 or 40 feet above Shiawassee River. The water supply is mostly from dug wells or from tubular driven wells 15 to 50 feet or more deep, none of which flow.

A small amount of water is pumped from the river for use in boilers and for watering stock.

On the lowest river terrace, near the dam, there was formerly a spring of considerable size, the water of which was strongly impregnated with iron salts, as shown by the pebbles in the vicinity of its outlet. This spring is now closed up by the owner, who filled it with clay.

It is probable that good supplies of water could be had by sinking tubular wells on the lowest terraces of the river, with excellent chances of flows, if the town should ever need a public supply.

VERNON TOWNSHIP.

DURAND.

Durand is located on a very gently undulating plain. The town has a public waterworks, the water being obtained from a group of driven wells near the business center of the town, where the pumping station is situated. The wells are from 40 to 75 feet deep, with one which has brackish water at 150 feet. The shallower wells have fresh water. They were put down in 1901. The supply is not large, and test wells have been put down in other parts of the town to locate additional sources of supply.

There is a flowing well in the western part of the town, which is said to be 287 feet deep and goes a short distance into rock. The water from this well is rather strongly impregnated with mineral matter and slightly brackish to the taste, but is used for drinking and domestic purposes by the people in the vicinity. The flow now is only about 2 gallons a minute, with a head of more than 2 feet. The temperature was 51.8° F. in July, 1904. Near by this well is a second flowing well, of whose depth no record could be obtained, but as the water is of different character and temperature from that of the first, it is probable that it is from the drift above the rock. This water is hard and contains considerable iron, but is not saline. The head exceeds 18 inches, the rate of flow is 1.5 gallons a minute, and the temperature 50.9° F. This lower temperature would indicate a less depth than that of the first.

In the same block, to the east of these two wells, is a third, which formerly flowed at a height of 6 or 7 feet, but which was stopped apparently by the putting down of the deep well. The water at present just reaches the surface of the ground.

It was reported that feeble flows of a temporary nature had been secured a short distance south of town by driving short lengths of pipe into the ground in a swampy area of pasture land. None of these wells, however, are now in operation.

VERNON.

This village is situated on a morainal ridge and is without any public water supply. The wells are all from the drift, the deepest being about 50 feet. The depth to rock surface ranges from 50 feet in the valley of the river to 80 or even 100 feet on the higher ground. The supply of water obtained from the wells here is probably sufficient for present needs and is of good quality.

On the farm of John Pierce, one-half mile south of Vernon, is a well from the rock, 100 feet or more deep, the water from which is too salty for use.

CORUNNA.

Corunna, the county seat of Shiawassee County, is situated on the slope of a faint morainal ridge on the south side of Shiawassee River.

The greater number of the wells of the town are shallow, but give an abundant supply of good water.

In 1903 a public system of waterworks was installed, the pumping station being located near the railroad station, on the south side of the town. A considerable part of the water now in use comes from driven wells only 30 to 40 feet deep, which give very good water, but a part of the wells are from 90 to 120 feet deep, penetrating sandstone from 40 to 60 feet. The water from these deep rock wells is said to be soft and free from lime compounds.

An interesting fact is reported regarding these rock wells, namely, that pumping one of them affects the others 300 or 400 feet away, suggesting a coarse texture in the sandstone or communicating fissures along which the pressure is carried.

A block east of the court-house, in the lumber yard of H. T. Wilson, is a shallow bored well 18 feet deep, which in wet seasons flows from the spout of the pump, 2 feet above the ground. It was formerly a flowing well, but the pump was put on to insure a supply at all seasons. Other wells of the same depth in the neighborhood were said to flow formerly, but all ceased some time ago.

The valley between Owosso and Corunna seems favorable for the occurrence of flowing wells, as the water in the wells along the margin of the valley, even the shallow ones, shows a tendency to rise in the pipes in some cases nearly to the surface of the ground.

The depth to rock at Corunna near the railroad station was stated by a driller at work there to be 72 feet. According to another driller, a resident of the town, rock is from 60 to 75 feet below the surface. A well in the park is said to be 120 feet deep and about 35 feet into the rock. This is near the river at the lowest level of the town. Another informant says the rock surface is only 50 feet down.

WATER SUPPLIES OF SAGINAW COUNTY.

GENERAL STATEMENT.

This county was not visited in 1904, because it had already been studied by State Geologist Alfred C. Lane and his assistant, W. F. Cooper, a short time before. Their notes were placed at the writer's disposal, and from them the present report is principally compiled. As the State inquiry was made with somewhat different ends in view, it was found impracticable to construct tables for the county such as accompany the reports on other areas.

Saginaw County lies south of Saginaw Bay, within the region formerly covered by a Glacial lake at a higher level than the present bay, and is very flat, with practically no relief forms except the shallow valleys of the numerous streams which cross it, and a few low, narrow, and irregular ridges of sand, sometimes blown up into dunes. The surface rises gently from the level of Saginaw Bay to about 100 feet above it along the southern, eastern, and western borders. The soils are principally heavy clays and clay loams, generally rather impervious to water, with scattered, more or less irregular, tracts of con siderable extent composed of sands and sandy loams, deposited chiefly by the Glacial lake. These are easily penetrated by water, and differ greatly in this respect from the clay types of soils.

The depth to bed rock is somewhat variable in spite of the flat surface of the county, and is remarkably irregular in some localities, with variations of about 200 feet in short distances, showing that the rock surface here had hills and valleys before the present deposit of drift was left upon it. So far as is known the rock is nearest the surface a mile or two south of St. Charles, where it is from 35 to 45 feet below, and ranges from this to 200 feet below about Merrill, 250 feet below just west of Saginaw, and more than 260 feet below in the northern part of Swan Creek Township. The variations in depth are sometimes so abrupt that a well-marked valley can be traced for some distance, where drill holes are frequent, and such valleys afford an excellent supply of water, because they are generally filled with relatively coarse material. In such cases it is probable that no inconsiderable part of the water comes from the rock walls of the valley, where the eroded strata come into contact with the material which fills the valley.

The county is watered by four large but sluggish rivers and by numerous smaller streams which come in from various directions. The rivers finally unite near the city of Saginaw, forming Saginaw River. These numerous waterways, and the low gradient of most of them, produce extensive overflows during the wetter parts of the year, causing a large part of the low land to be swampy before the settlement and draining of the region.

Because of the type of soil and because the overflows continued more or less frequently after the land had been cleared and drained, the water obtained from open, dug, shallow wells throughout the greater part of the county, was never entirely satisfactory or wholesome for drinking and other domestic purposes. The compactness of the soils, especially after drainage had been artificially improved, made the supply from this type of wells small and uncertain in quantity.

As a result of these conditions, early attempts were made to secure better and more certain supplies, and bored, driven, and drilled wells of considerable depth, drawing on the water from lower water-bearing strata, became common. In many cases these deeper wells extended down into bed rock, and here, while abundant water was found, in many cases it was brackish or salty, sometimes so much so that it was impossible to use it for many purposes.

In the sandy districts and the higher parts of the county the upper ground waters are often more abundant and wholesome, and here dug wells may give a sufficient supply, although even in these districts the deep tubular wells are frequent and are the most reliable.

The impurity of the water from shallow wells was due in part to the great accumulations of organic matter in the soils and in part to the readiness with which unwholesome and disease-impregnated matter found its way from the surface into the shallow basin wells, both by washing in at flood time and through fissures in the soil formed during drought. Aside from this, water from the clay is usually very hard and liable to be roily from the ease with which the finer matter of the clay is washed into the wells and the length of time which it remains suspended after it once mixes with the water. The water of such dug wells is sometimes colored brownish or blackish by organic matter.

The water from the deeper layers of the drift, or clays, is usually hard, with considerable iron in it, but not enough to make any change in its appearance. The amount of hardness is variable, and without apparent reason, except that the beds from which it comes are variable in the amount of soluble calcium salts they contain.

It is frequently true that the best and most certain supply of water from the drift is found just above the rock surface and in districts where the drift is very compact and fine grained, as in and around Saginaw; this supply is the one most depended upon for ordinary farm and domestic uses. This water is fresh, or only slightly saline, and often very hard. In and near Saginaw this supply is somewhat affected by leakage from abandoned salt wells, and is more or less brackish in consequence.

The rock waters, though often brackish, and occasionally so salty that they are not used for drinking or cooking, are in some cases, where sandstones are the source, much freer from hardness than those from any other source.

At from 200 to 300 feet down the salt content increases and becomes too high for any ordinary use; even stock will not drink it. At a depth of 300 to 500 feet a strong impure brine is struck, and below this, at from 650 to about 1,000 feet, the brines are found from which the Saginaw Valley salt wells have drawn supplies, which have yielded enormous quantities of salt, and which are still capable of great development.

WASTE WATER.

In a region so flat as this, where the soil is not absorbent, the disposal of the waste water from flowing wells is often a rather difficult matter. The usual method is to turn it into the roadside ditches and give it no further attention. Here it forms stagnant pools, in which mosquitoes and gnats breed in abundance, and in which various water-loving plants flourish and help by their growth to clog the ditches, thus impairing their efficiency and shortening their period of usefulness to a very considerable extent. A much better method of procedure would be to turn the water over some considerable area of cultivated land by means of irrigating ditches, or better still, probably, to carry the pipe or casing up nearly to the level of the head into a large tank, and allow the water to rise in this to the level of the head, but not overflow, as at the level of the head the water would stop flowing until it was needed and drawn off, when it would begin to flow again. A properly fitted valve or cock could be placed in the casing to draw off water for domestic use, while the water could be distributed automatically to various points where it is needed, as it often is where a windmill pump is used to fill a tank. Such a method would not only make it unnecessary to dispose of waste water, but would tend to conserve the supply. The cost of this type of trough or tank would not usually, where the head is slight, be great, and in most cases would be less than the cost of putting in a drain to carry off the waste.

CATCHMENT AREA.

The shallowness of some of the wells (from 10 to 25 feet) is an indication that the water-bearing strata are not, for these depths at least, extensive, nor can they be continuous for any great distance. Hence it is not likely that they reach to the nearest high land, which is several miles away to the west. These facts would lead to the conclusion that the catchment area is in the immediate vicinity, and it may lie in a district of heavy sand to the west and northwest, 2 or 3 miles from the shallowest wells, especially as the land rises slightly in these directions. The sands would readily absorb a large amount of the rainfall; and if the underlying strata are sufficiently permeable to take in this supply, or a large part of it, it is probable that this is the catchment area.

FLOWING WELLS.

FLOWS FROM ROCK.

Flowing wells are numerous, and from a number of horizons, both in the rock and in the drift. Of the rock it may be said that, if the well is drilled deep enough, flowing water would be obtained in almost any part of Saginaw County; but it must be remembered also that this water would generally be salty if the well penetrated the rock for any considerable distance. Hence it is not wise to go too deep for water for farm use when trying for a flow.

A well on the north side of sec. 2, Chesaning Township, 350 feet deep, with rock at 60 feet, flows salty water. Another in the same neighborhood is 180 feet deep with fresh water, and is 130 feet in the rock. Still another is 150 feet deep, and flows slightly salty water. On the east side of sec. 1 is a flow 120 feet deep, with rock at 47 feet. On the south side of sec. 5 is a flow 117 feet deep, with rock at 45 feet, and on sec. 17 is a flow 250 feet deep, with rock at 65 feet. The temperature is reported as 54° F.

The pump wells range, for drilled wells, from 61 feet deep with 10 in the rock, to 465 feet deep with 405 in the rock. In this last the water was fresh down to 260 feet, below which it was salty. The rock surface is reported as 119 feet deep on the north side of sec. 23, 45 feet deep on the south side of sec. 5 and the north side of sec. 2, 47 feet on the east side of sec. 1, and 70 feet on the south side of sec. 2.

FLOWS FROM DRIFT.

The flows from the drift are confined to definite areas. If a line is drawn from north to south through the middle of the county, all but one group of flows from the drift will be found on the western side of it. The exception is the area in Birch Run Township, in the extreme southeast corner of the county. All of these areas are on plains, with no noticeably higher land near by, yet the gradual rise toward the border of the county is sufficient to furnish head.

There are seven areas in which three or more flows occur and five isolated wells apparently remote enough from other developments to be considered independent areas, thus making 12 in all. These areas are located as follows: (1) The Merrill area, in T. 12 N., R. 1 E., extending from Merrill north and northeast; (2) a single well in sec. 1, Lakefield Township (T. 11 N., R. 1 E.); (3) an area of considerable extent in Marion Township (T. 10 N., R. 1 E.); (4) the Brant area, in the northwest part of T. 10 N., R. 2 E.; (5) a single well in the south part of the same township (sec. 33); (6) the Fremont area, in the eastern part of T. 11 N., R. 2 E., and along the line between this and the next township east; (7) the Swan Creek area, in the northeast corner of T. 11 N., R. 3 E., near Swan Creek post-office; (8) an isolated well on sec. 18 (T. 10 N., R. 4 E.); (9) three wells near Luce post-office, in Albee Township (T. 10 N., R. 4 E.); (10) the Birch Run area in the southeastern part of T. 10 N., R. 6 E.; (11) a single well in sec. 1, Chesaning Township (T. 9 N., R. 3 E.); (12) a single well at Frost post-office.

As the slope of the country is toward the north and east, it is probable that the valleys of streams and other depressions in that direction may yield flows beyond the limits of the present development.

FLOWS BY DISTRICTS.

MERRILL AREA.

This is known to cover about 10 square miles, and is the most extensively developed area of flowing wells from the drift in Saginaw County. Merrill lies on the southern border of the area, from which it extends north and northeast; in it the majority of the flowing wells of the district are found, about 25 being reported from there, the water coming from depths varying from 35 to 150 feet from sand or gravel strata.

It is possible that conditions here are similar to those of Alma (see p. 207), with coarser layers interspersed with the finer. The fact that wells near together are of very different depths points to this as a possibility, but in the absence of accurate records of the wells nothing definite can be stated.

North of Merrill the depth is generally 60 to 70 feet, but some wells are only 10 feet deep. None that flowed is more than 100 feet deep, so far as learned.

The water in the flowing wells, as in the other wells of the Merrill area, is hard and more or less impregnated with iron and carbon dioxide. It is otherwise of excellent quality and is wholesome and good.

In general, the head of wells of this area is slight, being only 1 to 3 feet above the surface. But the well of Mr. Dubay, 1 mile east and three-fourths of a mile north of Merrill, is reported to have had a head of 11 feet. This well is also reported to have the largest flow in the area—10 to 15 gallons a minute—from a depth of 65 feet. The average flow of wells in this area is, however, small, 1 to 5 gallons a minute, except in a few cases where the flow is from a dug basin, in which case the amount of water running away seems to be larger.

MARION TOWNSHIP.

The Marion area is about 6 square miles in extent, is narrow, and trends from northwest to southeast. It includes about 20 wells, ranging from 60 to 102 feet in depth. The records available indicate that after a shallow bed of sand and gravel 2 or 3 feet deep has been passed there is a thick bed of clay, with occasional thin beds of gravel from which the water comes. The flows are usually small with slight head, but sufficient for farm and domestic uses.

BRANT AREA.

The Brant area is about 7 square miles in extent and as developed has 11 flows, all but one being from the drift. These wells range from about 75 to 140 feet in depth, several of them being between 90 and

100 feet, and only two more than 100 feet deep. At Brant post-office is a flowing well from the rock, 282 feet deep. It is probable that in this area a larger number of flowing wells may be developed. The low ground along the streams and the sags in the general surface would be the most favorable places to test.

The single well in the southwest corner of sec. 33 of Brant Township is 80 feet deep, and from its location would seem to be independent of the area to the north of it. It is possible that explorations along the creek valley in this vicinity would yield other flows.

FREMONT TOWNSHIP.

The Fremont area covers 4 or 5 square miles and, as developed in 1900, included about a dozen wells which flow from the drift. In this area the majority of the flowing wells were reported to be 42 to 85 feet deep, but one, in the southeast corner of sec. 12, is said to be 212 feet deep, entirely in drift. This is the more probable, since about 1 mile north and one-half mile east is a pump well 260 feet deep, in which the rock was not reached; on the other hand, there is a well on sec. 14, only 2 miles southwest, in which rock is reported at 145 feet. In these wells the general report is that they are in clay from the surface down, the water coming from gravel or sand strata. The flows are reported as medium or small.

SWAN CREEK AREA.

The Swan Creek area is located 3 miles east and 1 mile north of the Fremont area and is much smaller, consisting of three wells along the north and south road between secs. 3 and 4. The wells are all of different depths, that of the southernmost being 58 feet, that of the northernmost 78 feet, and that of the one between 69 feet. These wells are all reported as being through clay to the water-bearing stratum, which is sand or gravel.

This area may possibly be extended both north and south along the valley of Swan Creek, which lies one-half mile to the east of the present development, but at present this district is not settled thickly.

LUCE AREA.

Near Luce post-office, in Albee Township, is a group of three small flows, 32 feet deep, which are reported to pass through 3 feet of sand, then shallow sand and gravel, and then clay to the water-bearing gravel. Further testing may increase the extent of this area, particularly to the west.

ALBEE AREA.

The single well on sec. 17, Albee Township, is 49 feet deep, with a small flow, in a relatively unsettled region. Further prospecting may extend this area to the north.

BIRCH RUN AREA.

This area is about 5 square miles in extent and is situated on the inner slope of a low morainal ridge, which just touches the southeast corner of the township and county. The slope of this ridge is gentle, but the differences in elevation here reach the maximum for this county, and amount to 30 or 40 feet to the mile. The flowing-well district lies near the foot of this slope and has its greatest length parallel to the axis of the ridge.

The development of this area is small, only 8 wells being reported in it, and these range in depth from 25 to 65 feet. The water in some of the wells is reported to come from sand sufficiently fine to work into the casing and obstruct the flow. The rock surface within the limits of the area is from 60 to 90 feet below the soil surface and flows from the rock are not infrequent in the vicinity of the area. The drift flows give hard water in sufficient quantity for ordinary farm uses, though the wells tend to clog rather quickly, as mentioned above.

The catchment area is probably the morainal ridge, from which is also derived the pressure which develops the head of the wells. The area might be extended to the northeast and to the southwest of its present development if care were taken to locate the wells in depressions below the general surface.

CHESANING AREA.

The single well from the drift in Chesaning Township, of which any record was obtained, is that of C. M. Johnson, which is only 18 feet deep, from a small vein of gravel in the clay. The water is hard and fresh. This is probably due to a purely local development of conditions favoring a flow.

THOMASTOWN TOWNSHIP.

As developed at present, this area has but a single flowing well from the drift, that of William Wurtzel, at Frost, 10 miles west of the city of Saginaw. This well is situated in the valley of a small stream, being developed in 1896 while boring for silver. The flow was struck at 40 feet, the water spouting out of the casing several feet above the ground. The flow is still good and the temperature is about 45° F.

This water is sold under the name of the "Wurtzel Saginaw Magnetic Mineral Spring Water," and its character is shown by the following analysis:

Analysis of Wurtzel Saginaw Magnetic Mineral Spring Water. [a]

	Parts per million.
Chlorine (Cl)	1,460.90
Sodium (Na)	949.82
Calcium (Ca)	260.62
Sulphate radicle (So_4)	201.89
Magnesium (Mg)	54.76
Iron (Fe)	1.48
Silica (Si_2O_4)	16.44
Carbonate radicle (CO_3)	255.25
	3,201.16
Organic matter:	
Free ammonia	15
Albuminoid ammonia	05
	20

Dr. R. C. Kedzie, analyst.

It is not known that any other flows have been struck in this vicinity, but it seems probable that by making careful explorations others might be developed near the stream level.

SAGINAW WATER SUPPLY.[b]

The city of Saginaw has two pumping stations, inherited from the time when there were two corporations. Both of them draw water from the river, the West Saginaw plant from the center of town, near Court street, the East Saginaw plant from farther up the river, being located at the corner of Lane and Douglas streets, about one-fourth mile below the junction of Tittabawassee and Shiawassee rivers. Neither of the supplies is considered wholesome. They are used primarily for fire protection and incidentally for lawn sprinkling, etc. For drinking purposes the city has put down a large number of drilled wells. The last detailed list of these at hand gives 20 on the east side and 10 on the west side, the depths ranging from 120 to 185 feet. Many have been made since, and probably there are now (1905) twice as many. All draw their supply from sandstones of the coal measures. Bed rock is usually encountered at 80 to 100 feet, and not infrequently water is found in pervious beds at the base of the drift, but never in such quantity and quality as to be satisfactory for a water supply for so large a population (52,428).

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] By A. C. Lane.

Besides these city wells most of the hotels and many of the factories and private institutions have similar wells. Analyses of well water and of Saginaw River water are given in Water-Supply Paper No. 31.

Saginaw River is practically a dead-water estuary as far up as Saginaw, and the current runs up or down, according to the wind, the rainfall, and the fluctuations of the Great Lakes. A table of elevations showing the height of the river each day and month from 1887 to 1890 is given in the first annual report of the board of public works in 1891, which shows plainly a correspondence between these fluctuations and those of Saginaw Bay. The range is from 6 feet above to 3 feet below the datum. There is no especial safety to be gained by going upstream, and there is no available safe supply within easy reach. A thoroughly effective system of filtration seems to be the proper means of obtaining a safe city supply.

Some years ago a well was dug and bricked down about 80 feet, but then encountered such a rush of water and quicksand as to endanger the life of the man in the well and to fill the well with quicksand. More recently, in the spring of 1903, a well was put down in the "middle ground," a former island in Saginaw River, to test the water supply. It passed through lumber waste and sawdust, and at 12 feet struck river sand, then clay; at 42 feet it reached fine gravel, and from 44 to 53 feet coarse gravel. While there was quite a volume of water, it was contaminated from the old salt wells, and ran up to 2,809 parts per million of solids and 87 per cent hardness.[a]

WATER SUPPLIES OF GRATIOT COUNTY.

GENERAL STATEMENT.

Gratiot County is just west of Saginaw County, and is partly within the morainal region and in part within the area formerly covered by a Glacial lake. The western half, approximately, is rolling, the ridges running in a general north and south direction, while the eastern half is a plain sloping to the east and south. The western and northern parts of the rolling area are higher and usually more sandy or gravelly than the eastern, and have been cleared and settled but a short time.

The principal stream of the county is Pine River, which flows along the western border and northwest corner. The southern half drains into Maple River, and thence to Lake Michigan, while the northeastern third is drained by small tributaries of Shiawassee River, which leads to Saginaw River and the bay. The streams are small, and in the smaller ones there is little or no water during a large part of the year. These natural waterways have been extensively added to, in the flat portions of the county, by large ditching

[a] Heim Brothers, analysts.

operations, so that portions of the area are overdrained except for a short flood time in the spring.

The rolling portion of this county, as in the others discussed, has the more penetrable soils, with strata capable of storing large amounts of water near the surface. Hence in this area the wells are not usually deep, many of them being of the open dug type, with stone sewer tile or cement curbing. Such wells are often as shallow as 10 or 12 feet, while they sometimes reach a depth as great as 60 feet. They frequently yield abundant supplies of excellent water; but where they are in the depressions and valleys the supply is larger and less affected by drought than it is when they are on the slopes or tops of the ridges.

Tubular wells are general in almost every neighborhood in the rolling portion of the county. In a list of over 200, furnished by Mr. Chivers, of Alma, the greatest depth reported was 195 feet, reached in attempting to increase the flow of a shallow well, while the shallowest was 13 feet deep. About one-half the entire number were less than 55 feet deep, while less than one-eighth were over 100 feet. Of the entire number nearly 25 per cent were flowing wells, located chiefly in the Alma area.

In a list of wells on the farms of Mr. A. W. Wright, of Alma, in the townships of Arcada and Pine River, in the same region, 17 wells are reported. Of these all but four are more than 100 feet deep and two are over 200 feet, the deepest being 218 feet and the shallowest 45 feet. These are nearly all pump wells, equipped with windmills.

There are several areas of flowing wells in this part of the county, the most extensively developed being in Alma.

On the lake plain the supply varies with the character of the surface deposits, whether they are sandy or loamy, as they are in certain parts of th ; district, notably along its border, and in the vicinity of Ashley, Breckenridge, and Wheeler, or whether they are compact clays, as they are over the greater part of the district. Where the surface is covered with sand or gravel strata, overlying clay, the wells are shallow dug basins from 8 to 20 feet deep, and where the clay type of soil is general, the wells are tubular and may be very deep, in a few cases running down over 300 feet and then getting only small supplies of water. The deepest drift wells in the county are found in Lafayette township, where a few wells nearly 400 feet deep have been drilled. In this part of the lake plain tubular wells are more common than in the rolling country, and probably average deeper. In the western part of the lake plain shallow dug wells are the main water supply.

The only rock wells in the northwestern part of the county are the salt wells at Alma and St. Louis, where the rock surface is down 325 to 500 feet.

In the southeast corner of the county, around Ashley and Bannister, the rock surface is not so deep as farther north, and here are many rock wells, a considerable number of which flow. In the same part of the county are areas of flows from the drift, while dug, bored, and drilled wells of various depths reach small supplies of water in the more porous strata of the drift, but the largest and most permanent supplies in this district come from the rock, which ranges from about 20 feet in sec. 24, Elba Township, to about 150 feet in the vicinity of Ashley.

The western part of the district depends mainly on shallow bored or dug wells for its water supply.

SUPPLIES BY DISTRICTS.

ARCADA TOWNSHIP.

ALMA.

Alma is situated in the northern part of Gratiot County, on the broad terraces and slopes of the shallow valley, here a mile or more wide, in which Pine River flows.

Public and private supplies.—The public water supply is furnished by a well-equipped municipal plant in charge of a public board, which has leased the pumping for a term of years to a private company which controls the water power developed by a dam in the river. The water is pumped from Pine River, below the dam, the direct system of distribution being used, and serves to give fire protection and street, lawn, and garden sprinkling, and also water for flushing, sanitary purposes, and manufacturing. There is a well-planned and partly developed sewer system.

Since the public supply is not safe to use for cooking, drinking, and other potable purposes, a supply is obtained for these uses from dug and driven wells of various depths—from less than 10 to 150 feet. Shallow dug wells are the only source of water for domestic use in some parts of town, and in a number of cases the water used by a family was reported to come from a basin made by sinking a single sewer tile of large diameter in the cellar of the house, the water rising in this sufficiently to be dipped or pumped out. This type of well is found at the foot of a low ridge with sandy slopes which runs irregularly across from the western to the northeastern part of the city.

A second kind of well, common in the higher parts of town, is made by sinking a cement cylinder through the clay to some water-bearing stratum 15 to 30 feet down; this and the sewer-tiled well are about equally popular. Deeper wells are generally drilled or driven, and are 50 to 100 feet deep.

Flowing wells.—In the parts of the city on the terraces of the river valley, however, the greater part of the water used for domestic purposes comes from flowing wells, a great development of this supply having been made here (fig. 42).

The area of the present development is small considering the large number of wells, for the total length of it is somewhat less than 1¼ miles

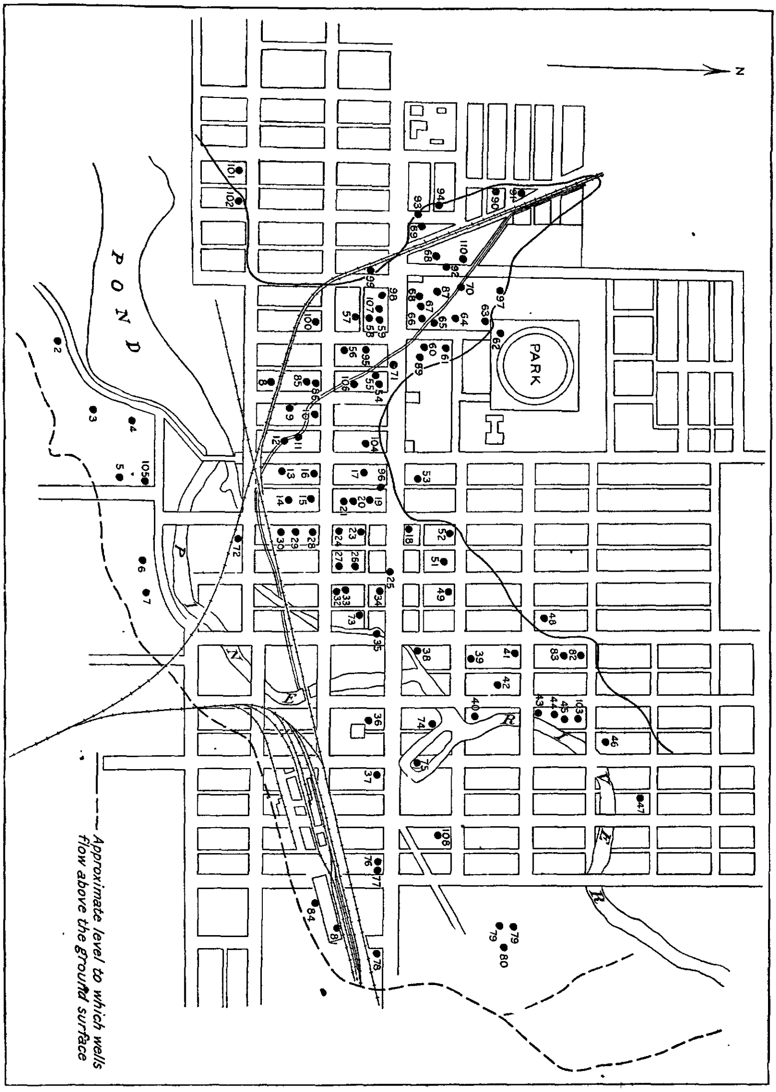

Fig. 42.—Plat of Alma, showing distribution of flowing wells.

along the lower terraces of the river and the greatest width about a quarter of a mile.

The wells are all or nearly all driven or drilled, and are from 20 feet or less to 150 feet in depth, and vary in the rate of flow from less than a pint to 20 or more gallons a minute. The head where greatest is only about 18 feet above the level of the mean water level of the river.

The water is invariably hard, and contains a considerable amount of iron in the form of the acid carbonate; enough to give a distinct blackish coloration to strong tea if turned into it when fresh from the well. The water also deposits these salts in the form of abundant reddish or yellowish incrustation on the surface of the glass and crockery ware in which it is allowed to stand. This incrustation is so closely adherent that it can be removed only by the use of some acid. The water also actively attacks tinware and soon rusts holes in it.

The water when fresh from the wells contains an excess of carbonic acid, which decomposes on exposure to the air, the carbon dioxide passing off and the calcium and iron bicarbonates (which are also decomposed) being in part precipitated as the normal carbonates, forming the incrustations mentioned above and the tea-kettle scale. The carbonic acid is probably the active agent in rusting the tin.

The water, although somewhat heavily charged with mineral matter, is a good chalybeate (iron) water, and except in certain cases should be as healthful as any ground water in this region. A certain amount of the excess of lime and iron may be removed by boiling if in any case this is considered desirable.

The water is reported to come from a thick bed of sand, with gravel intermixed, apparently in beds of small lateral extent and rather slight thickness. The only well which has been put down to the bed rock is the deep mineral well at the Alma Sanitarium. The driller's record of this is as follows:

Driller's record of Alma Sanitarium well.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	60	60
Quicksand and water sand	97	157
Gravel	3	160
Clay and gravel	315	475
Sand and gravel to bedrock	25	500

This record is in part confirmed by the report of Mr. Harry Chivers, of Alma, who kindly furnished the following record of the east town well, put down by him in 1904. Aside from those of the sanitarium this is the deepest well in the city.

Record of east town well, Alma.

	Thickness.	Total.
	Feet.	*Feet.*
Hardpan (clay till, rather compact)	50	50
Sand	93	143

Mr. Chivers also reports that in general throughout the city the hardpan or clay on the higher elevations is about 70 feet thick, varying from this to about 40 feet near the bottom of the valley. Below this depth it is rather rare to find clay, but beds of coarser sand and gravel in the finer sand bed are not uncommon, and from these the flowing water comes.

It is apparent that this stratum of the drift consists of a very thick bed of permeable material, which has scattered through it coarser beds of greater or less extent, through which water can move more rapidly if opportunity offers. The fine sand is very greatly in excess of the coarser gravel, both in thickness and in area, and, while it contains water, probably to the point of saturation, will give it up to the more permeable gravel rather slowly. However, because of its greater abundance, the sand will yield a total amount of water which will always keep the gravel full unless the drafts on the latter are very heavy.

Although the sand itself, because of its relatively small capacity of transmitting water, will not yield flows or even supply pumps of ordinary capacity (unless large-sized pipe is used, a thing not commonly done), it nevertheless serves an important purpose, for, being more or less completely saturated, it serves as a capping stratum to the gravel, and, as back from the valley it rises to a greater altitude than the wells, it may be a chief agent in causing the flows from the coarser material.

It is probable that the whole or some part of the margin of this deposit of sand is more or less exposed, either directly at the surface or through permeable beds of surface material, to the rain water as it soaks into the ground. This exposure needs only to be far enough above the level of the height to which the water rises in the wells to hold the ground-water level sufficiently high (allowing for a certain loss due to friction) to give the existing pressure or head, which is about 18 feet above the river. This would not require land any higher than much of that which lies west and north of the city, and it is in this region, in all probability, that the catchment area lies, as the surface rises steadily in these directions. But it is also likely that all of the surrounding country to some extent contributes to the supply from its ground water. The head here could not have its origin in the region to the east and northeast, for this is too low, and the same may be said of the region to the south, where also the soil may not be sufficiently porous to take in the requisite amount of water.

As the development of the area at the lower levels, near the bottom of the valley, has gone on there has been a gradual lowering of the head of the wells of the higher parts of the town, and not a few wells which formerly had good flows have ceased entirely, and are now pumped or flow below the level of the surface.

A very large part of this permanent lowering of the head is due to entirely useless waste, which may even be a detriment to the owner in that it compels him to maintain a larger drain to carry off the water than would otherwise be necessary. Sometimes the waste is larger than necessary, because of thoughtlessness or indifference, but in most cases it seems to be due to the owner's vanity. He likes to have it said that his well has the largest flow in the neighborhood, and he does not consider that this spirit may eventually, or even immediately, cut off the supply to some other owner entirely and put him to the expense of providing a pump. By inspecting the list of wells it will be seen that some are allowed to flow at the rate of 10 gallons or more a minute, or more than 450 barrels per day—an amount enormously beyond the needs of any family or any neighborhood. Two wells at the lowest level of the river valley, very near the level of the water, were, at the time of the writer's visit, flowing the full size of the casing at the level of the ground and the water was not being used at all, as the wells were located on vacant land. These wells, because of the low level at which they are placed, have undoubtedly been a chief cause in lowering the general head of the area, as they have been running a number of years, except for brief intervals, when they have been temporarily closed.

Alma is justly proud of these flowing wells, and it would be wise for her citizens to guard against the waste of this important natural resource by reducing the size of the flows of the wells near the river and in other low places to something like the needs of the owners. If the structure of the water-bearing beds is as explained above, then the waste of any large amounts of water from any well will affect the whole supply and tend to decrease the flows of all the wells, and of course this tendency will be first noticed in the wells nearest the level of the head and later on the lower ground. The wise thing to do would be to reduce the size of the outlet pipes in all the wells to such a diameter as will give water enough for the needs of the owners, but not allow any large waste. It would be very rare, indeed, that any family could not get all the water it needed from the flow which would run through a pipe one-fourth of an inch in diameter, and except in special cases this should be the size used.

Aside from waste there are a number of other causes which in individual cases are responsible for diminution or cessation of the flow. Among these are leaking through or around the casing, the filling of the lower part of the well tube with fine sand, the clogging of the strainer by fine silt or mud or by incrustations, as discussed on pages 128–130, and probably also the general lowering of the ground-water level in the catchment area during dry times, which affects all the wells to a greater or less extent, those on higher ground first and most.

From consideration of the height to which the water will rise above the level of the river, it is evident that all parts of the river valley which are more than 17 feet above this level will be too high for flows, so any extension of the area will be confined to the lower parts of the valley.

Since the lower terraces of the valley are generally narrow, and in places, both above and below Alma, disappear almost entirely, it is evident that the area of flowing wells can not be greatly extended. Unfortunately, no records are available which give any correct idea of the directions in which the water-bearing sand extends, for, as will be seen by inspecting the tables of the Alma wells (pp. 210–211), the depth to water is variable in the area, some well getting its water from nearly every foot of the vertical distance within which the beds have been explored, a fact which makes it practically impossible to identify the strata in isolated pump wells beyond the area of flows. It is probable, however, that both up and down the river valley for some distance flows could be obtained on the lower terraces of the valley, and it is quite possible that the Alma, the St. Louis, and the Jasper Township areas may all eventually be connected along this valley by continuous lines of flowing wells.

The great depth to bed rock in this vicinity (nearly or quite 500 feet, as shown by the record of the Sanitarium well, p. 211) and the fact that the overlying drift contains abundant supplies of good water, have made it a rare thing for wells to reach down to the rock. At the sanitarium, however, is a rock well 2,860 feet deep. At this depth the water is very highly charged with salt and other mineral matters and is used only for medicinal purposes and baths and in the manufacture of several proprietary articles. The water in this well rises nearly to the surface.

The fact that at Alma the rock surface is 500 feet below the surface of the ground, while at St. Louis and Ithaca the depth is about 150 feet less, the ground surface being about the same level, indicates the presence in the rock surface of a valley which has been buried by clay and gravel deposits. Such buried valleys are often important factors in producing flowing-well areas, although here the bottom of the water-bearing stratum is so far above the level of the bluffs of the buried valley that this may not have any effect on the head in this area.

The data given in the following table are largely furnished by drillers or well owners. The drillers, except Mr. Hover, of St. Louis, all reside in Alma.

Wells at Alma.

No. on fig. 42.	Owner.	Driller.	When made.	Diameter.	Depth.	Head.	Flow per minute.	Temperature.	Remarks.
				In.	*Ft.*	*Ft.*	*Gals.*	*° F.*	
1	W. A. Thomas	H. Chivers	......	2	56	+2.5	2.5	......	Piped underground to outlet.
2	W. S. Turck	do	1895	2	68	+2	1.5	50	
3	do	do	1895	3	60	+1.5	1.5	50	Pasture well.
4	M. Ferris	do	1897	2	32?	+1.25	1.5	50	
5	J. M. Montigel	do	......	2	72	+1.16	.16	53	First lowered by wells of N. Church (No. 22), then by those of Union School (No. 36), from 3 feet to 0, and from 5 gallons to ¾ gallon.
6	I. Russell	do	......	2	77	+2	1.25	49.8	
7	A. W. Wright	do	1884	3	125	+0	.75	50	
8	F. C. Keenan	do	......	2	65	+1.8	1	50.6	
9	Railroad restaurant	do	1897	2	48	+2	2	49.8	
10	M. Pollasky	do	1900	2	57	+3	2.5	49.8	
11	I. N. Brainard	do	1896	2	48	+10	10	49.8	Flow at 25 feet.
12	M. Pollasky	do	1882	2	60	+6	4	50	One of the oldest in town; reduced by No. 13.
13	Mr. Griffeth	do	......	2	55	+8	6	49.8	
14	D. Adams	....	1882	2	55	......	......	......	
15	J. J. Glass	....	1880	2	75	+1.25	.5	51	Head and flow less than at first.
16	A. J. Hall	C. Hover	1893	2	103	+1	.5	50.5	
17	Hotel Fern	....	......	2	70	+ .5	.25	50	
18	J. F. Suydam	....	1900	2	100	+ .5	.25	......	
19	J. F. Schwartz	....	......	2	60	+6	......	......	In cellar; used to flow above.
20	G. S. Ward	....	1903	2	55	+4	......	......	Do.
21	W. S. Turck	....	......	2	{60 / 100}	+4	......	......	In cellar; flow here formerly at 100 feet.
22	Church Block	Chivers	......	3	98	+1.	1.25	50.2	
23	E. J. Emmer	....	......	2	73	......	......	......	Flow in cellar; pumped.
24	J. Caple	....	......	1	65	+1	.25	51	Improved by sand pumping.
25	Alma village (east)	Chivers	1904	3	143	+1.25	2.5	50	Town well, used as drinking fountain.
26	E. Brewbaker	....	......	2	60	+2.25	2	49.8	
27	E. Emsley	....	......	2	60	+2.5	1	51	
28	J. M. Montigel	....	1878	3	55	+1.5	1	51	
29	A. D. Woodward	....	......	3½	32	+ .5	.12	55	Head 2.5 feet lower than formerly.
30	do	....	......	2	50	+1.25	.25	52	
31	M. J. Dallas	....	......	2	55	+2.5	2	51	
32	S. Wetherel	....	......	2	......	+2	.25	52	
33	Chas. Deplanty	....	......	2	......	+2	.5	52	
34	H. Brewbaker	Chivers	1897	2	116	+2.5	1	52	Feed barn on Superior street.
35	Electric Light Co	....	1904	2	50	+16	.5	......	At power station, bank of river, 8 feet above water; 3 veins of water above this; clay with hardpan between.
36	Union school	....	1885	2	80	+1.5	1	......	
37	W. A. Bahlke	Chivers	1888	2	55	−6	1	......	Flows in cellar.
38	J. M. Montigel	....	......	4	65	+6	5	50	Used to cool engine cylinder.
39	G. W. Pringle	....	......	2	......	+2	1	50	
40	H. B. Currence	....	1903	2	65	+4.5	4	50	
41	George Young	....	1903	2	70	+3	2.5	50	Opposite residence.
42	T. M. Barker	....	1901	2	72	+2	3	50	
43	Doctor Pringle	....	1878	4	85	+3	10	50	Head much more, but cut off here.
44	Mr. Struble	....	......	2	71	+4	5	50	Flows at 20 and 40 feet also.
45	E. Amsberry	....	......	2	70	+4.5	8	50	
46	H. F. Thompson	....	......	1	......	+3	1	50	
47	W. S. Turck	....	......	2	70	+2.5	.25	50	At dairy barn.
48	George Young	....	......	2	78	+ .5	1	50	Cut off at −3 feet to secure good flow.
49	C. A. Hicks	....	......	2	70	+1.5	2	50	
50	O. M. Gargett	....	1880	1¼	90	+1.5	.25	50	
51	G. Bildson	....	......	2	......	+2	1.5	50.2	
52	N. F. McCullough	....	......	1	60	+ .5	.12	52	
53	Smith & Glass Co	....	......	2	103	+ .5	1	49	Formerly flowed above surface; now cut off in cellar.

Wells at Alma—Continued.

No. on fig. 42.	Owner.	Driller.	When made.	Diameter.	Depth.	Head.	Flow per minute.	Temperature.	Remarks.
				In.	*Ft.*	*Ft.*	*Gals.*	°*F.*	
54	Hotel Arcada	Chivers		2	87	+1.5	0.5	50	
55	S. Tubbs			1½	60	+2			Nearly stopped flowing; formerly good flow.
56	H. Clark			2		+2	.25		
57	Mrs. Wadleigh		1885	2		+1	.16	50	
58	E. P. Caldwell	Chivers	1898	2	73	+ .75	1	50	
59	Wm. Clubb			2	60	+1	1.5	50.5	
60	J. McCarthy			2	55	+6	5	50	
61	F. A. Leonard	Chivers		2	55	+3	1	50	
62	Alma Sanitarium Co.	do		2	56	−2.5	1	50	Park well, flows in bottom of well house; used for medicinal purposes.
63	M. Medler			2	55	+1	.5	51	
64	A. Fechting			2	60	+1	.5	50	
65	H. Hudson	Chivers		2	58	+2	1	50	
66	T. F. Timby			2	60	+1.5	.5	50	
67	P. M. Smith			2	100	+1.5	1	50	
68	M. Dearing			2	60	+1	.5	50	
69	Mrs. J. Paddock			2	65	+ .5	.25		Now pumped.
70	E. Hannah			2	70	+1.5	.5	50	
71	Alma village (west)	Chivers	1904	3	93	+1.25	2.5	50	Used for drinking fountain.
72	T. Hypolite			1	55	+3	.12	52	
73	Alma Creamery			3	58	+4	3	50	
74	Swigert & Moore		1888	3	40	+8	15	50.5	In 1904 flowing full size of pipe, but with diminished head; water entirely wasted.
75	do		1888	3	58	+8	10	50.5	
76	P. Bogardus			2	56	+0	2.2	50.2	Flows at surface, but pumped.
77	M. Wilcox			2	55	+ .5	.75	50	
78	Alma Sugar Co.?			2	55	+ .5	.5		
79	Storage Company		1903	2	63				Two wells flow in basement.
80	Alma Manufacturing Co.		1903	2	53				Flow in basement.
81	Sugar factory								
82	James Chase								No data.
83	F. L. Bennett								
84	Sugar factory								
85	A. Hodgkinson	Eagon		2	70	+1	1	50	
86	G. Hodgkinson	Chivers		2	67	+1	1	49.8	
87	W. Vliet	do		2	83	+1.5	.5	50	
88	Mrs. T. Nelson	do		2	80	+1.5	1	50	
89	Mrs. Conkite			2	65	+2.5	4	50	
90	John Glass			2	22	+1	.5		
91	G. Young			2	20	+ .5	.25		
92	M. Sloane								
93	P. M. Smith			2	77	+ .5			Pumped, but would flow a little.
94	Mrs. C. Lane			2	62	+ .5	.25		Now pumped.
95	I. Coleman			2	40	+ .5	2		
96	Caple & Vermenken								
97	Mr. Stoutenberg		1890		12	+ .5	.50		Do.
98	T. A. Ely				20				Flow small; pumped.
99	L. Bushnell				62	−1.5			Pumped.
100	M. Ring		1893	2	107				Flow in cellar.
101	E. Ingersoll	Chivers	1888	2	93	+ .5	.25		Still flowing, but pumped.
102	J. Cheney			2	93	+1	.33	50.5	Used to flow more; sand has clogged strainer.
103	Jas. Kress ?			2		+2	2.5	50.3	
104	Hotel Edwards	Chivers		2	93	+1	2	50	
105	H. Clark			1	55	+1.5	.5	49.5	
106	E. Adams	A. Eagon	1886	2	60	+1	.25		
107	V. M. Hollenbeck	do		2	45	+1.5	.5	50	
108	M. Van Valkenberg	Chivers		2	78	+1	1		
109	H. Burris	A. Eagon		2	90	+0	.5±		Flows top of ground.
110	J. Fullerton			2	65	+1.5	1	50	

The elevation of the wells in the above table ranges from 728 to 746 feet above tide. The waters of almost all are reported as hard, with some iron. The water bed in all is gravel.

Number of wells of different depths.

Depth in feet.	Number of wells.	Depth in feet.	Number of wells.
10 to 20	2	60 to 70	6
30 to 40	6	70 to 80	6
40 to 50	21	80 to 130	4
50 to 60	11		

VICINITY OF ALMA.

Aside from the large development of flowing wells at Alma, which is located in Arcada Township, there is a single small group of flowing wells 2½ miles southwest of the town, on the farm of John Wolf, in the northeast part of sec. 8. This group consists of two wells situated on the terrace of Pine River, a short distance west of the stream and about 15 feet above its level. The flows are small, rising about 6 feet above the surface from gravel 41 feet below it. The water is not so hard as that in old dug wells near by.

The catchment area is probably to the west or northwest, but the head may well be derived from the ground water in the slight ridge which lies only a short distance to the west. It is probable that this terrace at other points would yield flows from the same waterbed. Indeed for many years there was a small flowing well at the schoolhouse, across Pine River, in the northwest corner of sec. 17, which has now ceased flowing.

Water is reported to rise a considerable distance in tubular wells to the west and south, and in the "great swamp" district in this township some of the wells were said to have flowed at one time. These, however, have gradually lost head, until now the water stands 3 to 4 feet below the surface.

In this township the banks of the river have many places in which seepage springs occur at the junction of gravel and underlying clays. These springs are generally very small and unimportant. By the roadside in a stream valley, near the east and west quarter line of secs. 5 and 6, is a larger springy area, which, if it were developed and a basin provided, would yield a good supply of water for stock.

Wells southwest of Alma (sec. 8, T. 11 N., R. 3 W.).

Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
		In.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	*°F.*		
John Wolf[a]	1902	2	41	755	+6	0.5	....	Not very hard	Gravel.
John Wolf[b]	1902	2	41	755	+6	.5	52.2	.....do	Do.

[a] Inclosed in house. [b] Barnyard well.

SEVILLE TOWNSHIP.

RIVERDALE.

Riverdale is situated in the broad flat valley now occupied by Pine River, and is only a few feet above the level of the river. The soil is coarse gravel, underlain at from 3 to 6 feet or more by a stiff blue clay.

Wells are generally from 23 to 26 feet deep, the shallowest 16 and the deepest 100 feet. The water comes from a gravel stratum, and rises in the pipes nearly to the surface. A few wells in low places are allowed to flow into basins, and the water is then dipped or pumped. At Strong's hotel is a well 52 feet deep, in which the water rises from the bottom nearly to the surface.

It is evident from the above that at the lowest points in the town the water would rise above the surface. Indeed, one such well at Bryant's mill, nearly three-fourths of a mile south of town, in the NW. ¼ sec. 6, Sumner Township, flows at an altitude of 790 feet. This well is reported to be 25 feet deep. It used to flow about 1½ feet above the surface, but in dry weather lowered a foot, the supply lessening from 2 or 3 quarts to 1 quart a minute. The temperature is 51° F. The well was bored in 1903, and the following beds were passed through:

Record of well at Bryant's mill, near Riverdale.

	Thickness.	Total.
	Feet.	*Feet.*
Gravel	12	12
Blue clay	9 or 10	21 or 22
Gravel	3	24 or 25

There are several possible sources for public supplies: The river, which in the region north and west of Riverdale is a spring-fed stream flowing through a thinly-settled country, should furnish a good supply of pure water. Several brooks, fed by springs, are near enough to be considered, and would be more easily kept free from contamination than the river, because of smaller drainage areas. Mud Lake, a small lake near the town, should give a good supply of water in spite of its name, because of its situation and the amount of water which flows out of it. There are many strong springs within short distances of the town, and careful investigation might easily develop a good supply from this source. There is a very springy track a short distance south of town, across the river, which should furnish an abundant supply of pure water by enlarging the outlets and constructing artificial basins. A series of large tubular wells might be put down in the lowest part of the town, or a large cistern might be built down to the water-bearing stratum which most of the private wells reach, and a sufficient supply be obtained.

ELWELL.

This village in the northwestern part of the county has wells dug from 14 to 26 feet deep and tubular wells to 40 feet deep. Several tubular wells get a good supply of water in gravel below clay at 26 feet. The water is hard and rises to within 4 to 8 feet of the surface. The average depth of 17 wells is 23 feet, the deepest being 27 feet and the shallowest 14 feet.

NORTH OF ELWELL.

About 1½ miles north of Elwell there is a flowing well area, which lies on the south side of secs. 23 and 24, near the foot of the southeasterly slope of a high and gravelly morainal ridge, which here runs northeast and southwest. This ridge is the probable catchment area. There are two wells now flowing and three others in the area which were reported to flow when in order. One of these, a dug well, has purposely been partly filled to prevent the strong overflow and is now pumped. The flows were small with slight head, and the water is obtained from a depth varying from 9 to 110 feet, the supplies seeming very irregular in their distribution. The water is of medium hardness and rather free from iron. The table below gives the facts relating to these wells.

It might be possible to extend the area to the south of the present wells if the water-bearing strata continue in that direction, as seems probable. No wells in that part of the town flow at present, but this is probably because they do not go deep enough.

Three large springs in this vicinity were pointed out by Mr. Wm. T. Pitt, whose interest in this survey is highly appreciated. One of these, on the farm of Mr. George Sandel, in the SE. ¼ SW. ¼ sec. 23, is estimated to flow about 50 gallons a minute. The water boils up from coarse sand and gravel in the bottom of a shallow basin and flows off in a considerable stream. It is used only to water stock. The second of these springs is really a group of considerable size on the farm of Henry Carl, situated in the NW. ¼ NW. ¼ sec. 26. These are "mound springs," built up of calcareous tufa to a height of about 2 feet above ground level, from which height the water now issues. The outflow from these springs is at least 50 gallons a minute, probably much more, running off through many small channels.

The third "spring" is apparently a very shallow flowing well, dug to supply water for a portable sawmill. It is on the farm of Allen Sadler in the NW. ¼ sec. 34. The outlet is about 3½ feet square through 4 feet of clay to coarse gravel, with no attempt to wall it up. The water runs in at the bottom of the hole about 8 feet below the surface in a swift-flowing stream and overflows in an outlet 16 inches wide and 2 inches deep. It is now used only to water stock while in the pasture.

The water from all of these springs is cold and clear, quite hard, and with no large amount of iron present.

Wells north of Elwell (T. 12 N., R. 4 W.).

Section.	Owner.	Driller.	Cost.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
					In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
24	G. F. Taylor [a]	Chivers	$35	1895	2	50	775	+0.5	0.12	51	Hard; iron	Gravel.
24	Levi Hall [b]	Owner			1.5	9	778	+2				Sand.
24	S. Anchovy [c]	do	20	1900	2	32	775	+1			Hard; iron	Do.
23	L. Small	Chivers	85		2	113	775	+1	.25	50	do	Do.
23	E. A. Dailey [d]	Owner				14	780	0			do	Gravel.
24	A. Sadler [e]			1902	8		785	{ +50 75 }			do	Do.

[a] Hard clay from 2 feet below surface; sanded up.
[b] Not flowing at present because of loose casing.
[c] Said to flow 8 to 10 gallons a minute; now stopped by sand.
[d] Dug well; flowed a large amount formerly, but was partly filled at the bottom, and is now pumped.
[e] Called a spring.

PINE RIVER TOWNSHIP.

FLOWING-WELL AREAS.

Aside from the development of flowing wells in Alma and St. Louis, both of which were originally partly in Pine River Township, there are five small areas of flowing wells in the rural parts of the township which probably may be considered as independent of one another and of those in the towns, since they are getting water from different depths, and are separated from one another into well-marked and distinct basins by low ridges.

Area No. 1.—The first area (see fig. 43) is in a shallow, rather narrow, poorly drained valley, 2 miles north of Alma, running from the east side of sec. 20 southeast and then east toward Pine River. The valley extends farther to the northwest, but no wells were reported in that part of it, possibly because it is not yet fully under cultivation. The area developed is less than 2 square miles.

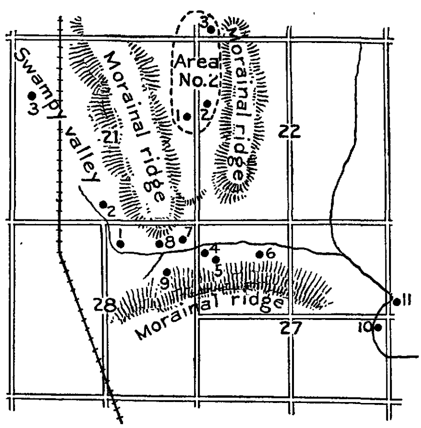

FIG. 43.—Sketch map of flowing-well district in areas 1 and 2, Pine River Township, Gratiot County.

The wells are shallow, from 15 to 30 feet deep, bored or driven, and have slight head, which has already been lowered by increasing the number of wells and allowing the water to waste. The wells number about a dozen. The largest flow is that of George Weeks (No. 1), which flows 6 gallons a minute. The water is medium hard, with some iron.

The catchment area most probably lies in loose-textured morainal ridges either to the north or south of the area, but may possibly be in a more extensive district of rolling country to the west and north.

Conditions seem favorable for flows in the upper part of the valley, northwest of the present development, especially if the larger flows now running are reduced to conserve the supply. It is not probable that flows would be obtained from this water-bearing level on much higher land than that on which the present wells are located, because, as noted above, the head has already been lowered 3 or 4 feet by the existing development.

Area No. 2.—This second area (see fig. 43) is less than a mile north of No. 1, along and north of the line between secs. 21 and 22. It lies in a shallow valley between low ridges; covers less than one-half a square mile, and contains only three wells, two of which now flow. These wells might be considered a part of area No. 1, and possibly they come from the same stratum, but they are at a slightly higher level, and it was reported that they are considerably deeper, except that of Mr. Mills, although this statement could not be verified.

This area is not likely to be extended, because it already includes the area below the level of the head. The wells to the north for some distance are reported as having the water rise to within 5 or 10 feet of the surface. It is probable that one or both of the low ridges bordering the valley supply the water for this flowing-well area.

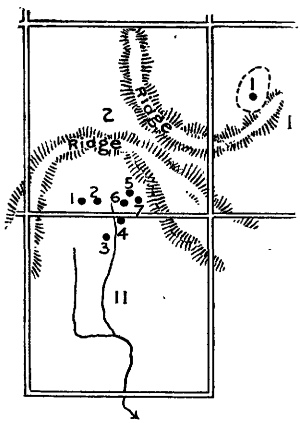

FIG. 44.—Sketch map showing approximate position of the flowing wells in areas 3 and 4, Pine River Township, Gratiot County.

Area No. 3.—The next area is 3 miles north and $1\frac{1}{2}$ miles west of St. Louis (fig. 44), and about the same distance north and east of area No. 1. It lies in a shallow depression which is the head of a drainage valley opening out to the south. Low hills of clay and gravel surround it on the three other sides. Like No. 2, this area is small—less than one-half a square mile in extent—and includes only seven wells, reported as varying in depth from about 15 to 42 feet. The flows are all of more than average size, ranging from 1 to 4 gallons a minute, of hard water of good quality. The head averages from $1\frac{1}{2}$ to 3 feet or more, although most are cut off about 2 feet above the surface. Just east of the area is a pump well at the schoolhouse, which was reported to be 129 feet deep, the water not rising very near the surface.

As the ground level rises rapidly in all directions, except to the south, this is the only direction in which further development may be made, and here only near the bottom of the valley.

Probably the ridges lying to the north and west of the area furnish the water for these wells, but it may come from the more porous areas 6 miles west.

Area No. 4.—The fourth area (fig. 44) contains a single well about 40 feet deep belonging to Mr. W. J. Brooks, which flows in wet seasons but not in dry. It is located in a depression, and lies about a mile to the northeast of area No. 3, and may possibly derive its water from one of the strata which the wells in that area strike, but there is a high ridge between the two areas and they are best considered distinct.

Area No. 5.—This is a fifth area with a small group of wells 2½ miles west and 2 miles north of Alma, and 1½ miles west of area No. 1, covering only one-eighth of a square mile as at present developed. The wells are located on the slope of a stream valley, bordered on the north and west by a low ridge with a sandy slope. At the time visited only two were flowing; the other had recently failed and had been equipped with a pump. The well with the best flow (Whitcraft's well) was near the foot of the slope, and was flowing 5 gallons a minute of excellent, nearly soft water, with a head of about 5 feet.

There seems to be no reason why this area should not be extended southward along the stream valley if the water-bearing stratum holds out in that direction, for the slope is favorable, and other conditions seem equally so. The catchment area is probably in the higher land to the north and west.

Summary.—The flowing table contains data of the. Pine River flowing wells, arranged by areas:

Wells in Pine River Township (T. 12 N., R. 3 W.).

AREA NO. 1.

No. on figs. 43 and 44.	Section.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
			In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	28	Geo. Weeks	2	26	762	+2	6	48.5	Hard; iron.	Gravel.
2	21	W. Lentz [a]	2	14	765	+3	3	49	Not very hard.	Do.
3	21	N. Johnson	2	16?	768	+1	2	48.8	Hard	Do.
4	27	Gordus Smith [b]	2	25±	765	+ .5	.25	49	do	Sand.
5	27	do	2	25	764	+ .5	.12	49	do	Fine gravel.
6	27	do	2	25	763	+1	.25	49	do	Do.
7	28	John Fafty	2	25±	764	+ .5	.25		do	Sand.
8	28	do	2	25±	765	+ .5	.5		do	Do.
9	28	E. Wilkinson	2	20+	760	+2			do	Gravel.
10	27	H. E. Kirby [c]	2	195	763	+2			do	
11	26	F. C. Olmstead								

AREA NO. 2.

No.	Section.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	21	T. J. Clark	2		770	+0	2	49.5	Hard	Gravel.
2	22	C. Sloane	2		770	+1	.5	49	do	Do.
3	15	D. Mills [d]	2	30±	772	+1				

AREA NO. 3.

No.	Section.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	2	A. Walls	2	50±	760	+1.5	1.5	49	Hard	Gravel.
2	2	C. A. Kiter	2	42	760	+2	3.5	49	do	Do.
3	11	S. Porter	1½	33	758	+2.5	4	49	do	Do.
4	11	G. W. Musser [e]	2	15?	756	+2	3	49	do	Do.
5	2	Barton Bailey	2	18	760	+2.5	2	51	do	Do.
6	2	do	2	20±	760	+2	1	49	do	Do.
7	2	do	2		762					

AREA NO. 4.

No.	Section.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	1	W. J. Brooks [f]	2	40±	770	+1				

AREA NO. 5.

No.	Section.	Owner.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
	30	N. Whitcraft	2	33	760	+5	5	49	Rather soft; iron.	
	30	do	2	80	760	−3				
	30	Daniel Wood	2		765	+ .5	1	49	Hard.	

[a] A 25-foot well on this place stopped flowing when this one was made.
[b] Pumping these wells affects all of them; head has lowered 6 to 8 feet.
[c] Said to have struck flow at 25 or 30 feet, but to have been deepened to present depth in hopes of getting a larger flow.
[d] Used to flow, but does not now.
[e] Flows from old pump log in two streams. Evidently old, but has good flow into ditch.
[f] Has a small flow in wet seasons, but does not flow in dry.

FOREST HILL

This village, on the Ann Arbor Railroad north of Alma, has dug wells from 18 to 20 feet deep, and drilled wells 80 to 150 feet deep, not reaching rock. The water is hard, and rises within 20 feet of the surface.

BETHANY TOWNSHIP.

This township lies in the north-central portion of Gratiot County, next east of Pine River Township, and is almost wholly east of the morainal ridges and is, therefore, free from the roughness of surface present in the rolling portion of the county.

ST. LOUIS.

The greater part of this city is on a flat gravelly terrace, which forms the bottom of the valley along Pine River, and which is 20 feet or more above the stream. The sides of the valley are morainal ridges, and these are occupied by part of the residence portion of the city.

A public supply was formerly obtained from a group of three or four flowing wells at the level of the mill pond, near the north end of the principal street, but because of a partial failure of these, due to the incrustation of the sand screens by calcareous matter deposited from the water or to sand clogging, or both, they have been abandoned, and the water now used in the town is pumped from the mill pond. This is used for sprinkling, fire protection, etc., and not for drinking.

Most of the flowing wells, which were said to derive their water from 50 to 75 feet below the surface, ceased to flow when the waterworks wells were put down. Many were abandoned; a few were deepened and the flow resumed; and some were furnished with pumps. Dug wells range from 15 to 40 feet in the clay on the ridges, and tubular wells have been drilled to various depths, some even reaching the rock at 325 to 350 feet.

St. Louis has long been famous for its "Magnetic Mineral Spring," which for thirty-five years has been pouring out its waters. This is a flowing well 270 feet deep, situated on the bank of Pine River near the level of the water and has a head about 16 feet above the river. It flows a large amount of water, but from the way in which it was piped no estimate could be made of the amount of flow. The water is used for baths and various other purposes at the sanitarium near by and from 15,000 to 18,000 gallons are sold and shipped to Saginaw each week and a considerable quantity to Chicago. This well also supplies a large number of the people of the town with drinking water for table use, for which purpose it is supplied free of charge. It is sold at $5 for a barrel of 30 gallons, with a rebate of $2.50 when the barrel is returned to the shipping point. It is also shipped in cases of 50 quarts, carbonated, at $5 a case.

A few other private wells in the town flow at the present time, and one, at least, of the old waterworks wells is still open, the water running to waste.

The following record of one of the wells at St. Louis was gathered by Alexander Winchell:

Record of drift well at St. Louis.

	Thickness.	Total.
	Feet.	*Feet.*
Clay, gravel, and bowlders	40	40
Blue clay	30	70
"Fire clay"	13	83
Sand and gravel	39	122
Bluish indurated shaly clay	15	137
Sand and gravel	55	192
Pebbles, water	8	200
Rock (not positively).		

There is a chemical manufacturing plant in the city which depends on deep drilled wells for the brine from which it obtains its product. No data could be obtained regarding these wells, as the plant was not in operation.

Wells at St. Louis.

Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Depth to rock.	Water bed.
		In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	°*F.*		*Feet.*	
Doctor Andrews[a]	1869	4	270	725	+16	10?	52	Hard; iron	350±	Gravel.
M. Hoffstetter		2	60	730	+ 1	.12	52	Hard	350	Do.
J. A. Burgess		2	45	730	+ 1	.12	51	do	350	Do.
City waterworks[b]		6		725	+ 2	3	52	do	350	Do.
East of Harrington Hotel[c]		2	40±	733	— 2	1		do	325	Do.

[a] Waters, "magnetic;" used externally and internally as remedy for diseases. Sanitarium in connection. Water shipped to sell in cities.
[b] Only waterworks well now flowing. Flow is through a hole in the cap of the casing.
[c] Flows into tank 2 feet below surface.

BRECKENRIDGE.

This village is situated on a slight gravel ridge 6 miles east of St. Louis. The depth of the wells is very variable, according to their nearness to the gravel tract. On this tract dug wells are from 8 to 20 feet deep and driven wells 16 to 20 feet. Away from the gravel area the driven wells are much deeper (some between 100 and 200 feet deep), while one hole in the village was visited which was 208 feet deep and had no water. At this well there was 15 feet of rather porous surface material with a small supply of water, and then 168 feet of compact clay, below which the material was variable, but chiefly clay with stony streaks in it.

There are no flowing wells here, but A. W. Stone's well, 115 feet deep, was reported to have water to within a foot of the surface. The water of this well has a strong taste resembling petroleum—"much stronger after pumping, so the horses will not drink it."

Those of the wells about 100 feet deep strike a large supply. The water in all of the wells but the one just referred to stands from 8 to 10 feet below the surface. Rock was not struck in the 208-foot well.

There is no system of public supply and no good prospect for sufficient supply except from deep wells, unless a supply should be found under the sand and gravel ridges lying north of the town a short distance. These serving as a catchment area should have considerable water below them if the condition of the soil is favorable for holding it.

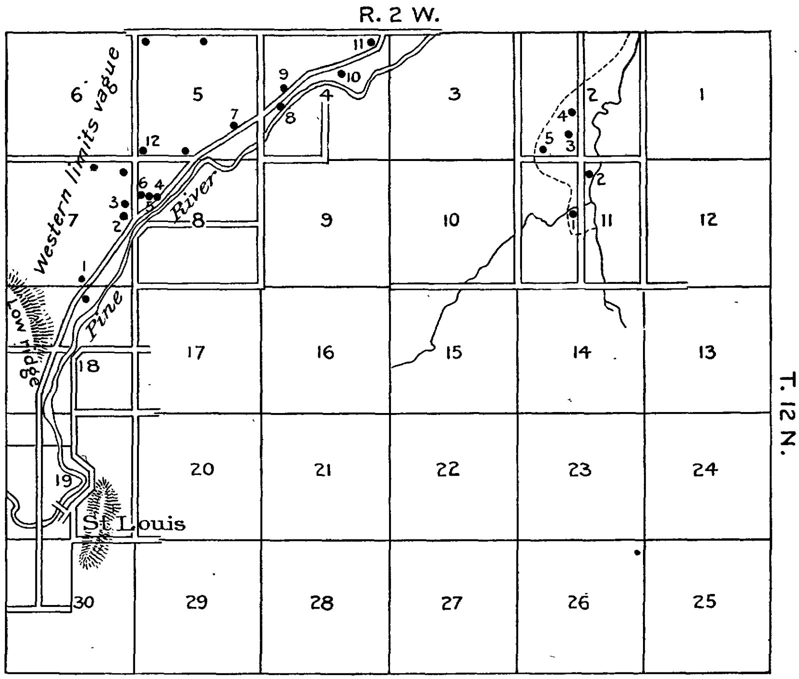

FIG 45.—Bethany Township flowing-well areas, Gratiot County.

WEST OF PINE RIVER.

Besides the development at St. Louis, Bethany Township has two small areas of flowing wells separated by Pine River, one lying to the west and the other to the east of the stream.

The first of these areas lies in the immediate vicinity and wholly on the west side of Pine River (fig. 45), extending down the river to the county line from a point $1\frac{1}{2}$ miles northeast of St. Louis. Its extent as at present developed is approximately $2\frac{1}{2}$ square miles, in which there are 15 or more flowing wells. It is possibly continued into the Coe district of southeastern Isabella and southwestern Midland counties.

The wells of this area, like some of the others studied, show considerable variation in depth, head, and size of flow, the deeper wells having the best supply of water, which is not always the case in this region, notably at Alma, where deep flows are small. The flows were reported to come from a number of depths—30 feet for the shallowest and about 100 for the deepest. As the surface is nearly flat, these probably represent variations in altitude of strata.

The most remarkable well is that of W. H. Fox, in sec. 4, about 3 miles northeast of St. Louis. This is located on the river terrace, is 86 feet deep, and is said to be 16 feet into the rock. It had a head of nearly 20 feet and was flowing the full size of the casing, at 4 feet above the ground, with such force that it was scarcely possible to fill a small vessel from it. The owner reported that the flow amounted to very nearly 3 barrels a minute, or more than 100,000 gallons a day, the greater part of which runs to the river as waste.

The water-bearing stratum was said to be 3½ feet thick, apparently, as it was described, an underground stream or basin below the rock. Small flows were struck at 45 and 56 feet. It is possible that the rock reported at this point is not a part of the underlying Carboniferous deposits, but a thick, hard bed of glacial material indurated by calcium carbonate, which acts as a cap stratum to confine the water. At St. Louis rock is reported at from 332 to nearly 400 feet below the surface.

The catchment area for the majority of these wells is the higher country to the west and north. If the Fox well is really in bed rock, the water may still come from the drift, working into the rock from the sides of exposed strata where these have been eroded.

As the land rises quite rapidly to the west from the river, there is no probability of extension of the flowing-well area in that direction, and as it was reported that no flows had been struck on the east side of the river, although there were some deep wells, it seems possible that no extension can occur there, because of the slightly higher level of the land. To the north along the river and at low levels generally the chances of getting flows in this area seem excellent if the wells are made deep enough.

EAST OF PINE RIVER.

The other area (fig. 45) is 3 miles north and 2 miles west of Breckenridge, or 2½ miles east of the first. It is in the northern half of sec. 11 and the southern half of sec. 2 in the scarcely perceptible valley of a small stream flowing northeast to Pine River.

The entire area as developed is less than a square mile in extent and contains but five wells, which are from 65 to 75 feet in depth, with slight head and small flows of hard water, the largest flow being but 2 gallons a minute. The Holton well (No. 4) is reported by the owner to receive most of its water from a fine sand at a depth of 35 feet.

The catchment area is probably the higher land to the west of the river, and the stratum from which the water comes may be an eastward extension of one of the upper strata of the western area. There is no evidence to demonstrate this, however, because of the lack of consecutive borings between.

The flows from the strata already reached seem to be limited to the shallow depression made by the stream; hence development of flows over a much larger area is not probable, except near the bottom of the creek valley to the northeast of the present area.

The wells on the east side of the creek which reach down to the depth of this stratum do not flow, but the water rises to within a few feet of the surface, the land being slightly higher than that on the west side.

SUMMARY.

The facts relating to the wells of this area appear in the table below:

Wells in Bethany Township (T. 12 N., R. 2 W.).

WEST OF PINE RIVER.

No on fig. 45.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
				In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*° F.*		
1	7	W. H. Walland [a]	1895	2	30	740	+2			Hard; iron	Gravel.
2	7	Noah Wilson [b]	1897	2	±100	740	+2.5	15	49.5	do	Rock?
3	7	Noah Wilson	1894	2	100?	735	+3	.25		do	(?)
4	8	Mrs. E. Shook [c]		1½	±80	743	+2	.75	50.5	do	Gravel.
5	8	Mrs. E. Shook		1½	50	735	+2	.12		do	Do.
6	8	do		1½	50	733	+2.5	.25	50	do	Do.
7	5	P. D. Smith		2	86	740	+2	.5	51.5	do	Do.
8	4	W. H. Fox [d]	1904	3	86	730	+18	100	50	do	Rock?
9	4	F. Quidart		2	85?	740	+2	8	50	do	
10	4	C. H. Colbey		2	100	735	+3	10		do	
11	4	F. Peach		2	100	738	+2	5		do	Gravel?
12	5	Lydia Crawford [e]			40	745	+1			do	Gravel.

EAST OF PINE RIVER.

No on fig. 45.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	11	D. D. Gidley [f]	1900	2	75	740	+1	0.5	52	Hard; iron	Gravel?
2	11	S. M. Barnes	1902	2	65	738	+2	1	50	do	Gravel.
3	2	A. Gidley	1900	2	68	733	+1	.33	51	do	Do.
4	2	Harvey Holton [g]	1902	2	65	730	+1.5	.2	51	do	Sand.
5	2	Jas. Hearne [h]	1904	2	65	735	+.75	2	49.8		

[a] Flows a few drops a minute; formerly flowed much more.
[b] Said to be in rock, but doubtful.
[c] Piped to house; No. 5 is in pasture, and No. 6 at barn for stock.
[d] Said to be from rock at 70 feet, hard rock at 78 feet. Flow said to be about 3 barrels a minute, but force too great to be measured with anything at hand. Water also at 45 and 56 feet.
[e] Flows into cistern and is dipped out.
[f] Cut off below surface and flows inside of gully. Will flow above surface at mouth.
[g] Cased 27 feet; water from 35 feet; used to flow more but filled in with sand. Hard smooth clay with few stones all the way down. Water from fine sand under crust of hardpan.
[h] Drill dropped 3 feet when water was struck. Cost about $45.

ELBE TOWNSHIP.

BANNISTER.

Bannister is situated in a very flat region on the bank of Maple River in the southeast corner of Gratiot County. The soil is a heavy compact clay loam, hence it is not very porous and lets in very little water, now that the drainage has been so highly developed, and therefore the shallow ground-water supply is poor and small.

There are, as in many villages, shallow dug and bored wells from 18 to 25 feet deep. In the western part of the town it was reported that a bed of gravel 16 to 18 feet below the surface furnishes a small supply of water, usually enough for family purposes, but the shallow, dug, open wells, are not in good repute, and tubular flowing wells scattered over the town now furnish the greater part of the potable water used.

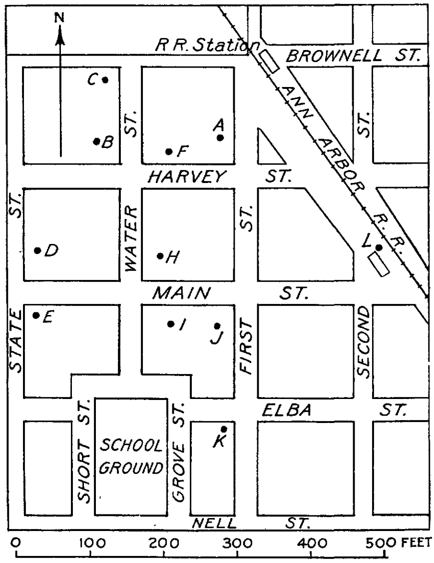

FIG. 46.—Plat of village of Bannister, Gratiot County.

The drift clays and gravels are reported to be about 150 feet thick in the village, and the predominance of rather compact stony clays makes the difficulty of getting flowing water from the drift very considerable, but there are five wells which are certainly not in the rock, and others are probably of this type. The characteristics of these wells are shown in the accompanying table. The water from them is rather hard and contains iron, but is as good as the waters from the drift usually are. The flows are rather small, with slight head. Wells here of this class are much more apt to fail than those from the rock, and the present tendency in the village seems to be to drill to the latter for water.

These wells are numerous in the village and surrounding country, and are of varying depths, those of the village generally being reported to be more than 200 feet deep. They enter rock at about 150 feet. The deepest reported was 390 feet, probably a mistake, and the shallowest about 200 feet. The flows from the rock are generally better and with more head than those from the drift.

In case the town desired a public water supply, it could be pumped directly from Maple River for fire protection and other general uses, and its potable water be secured from private flowing wells from the rock.

The cost of putting down wells in this locality is 75 cents a foot for drilling and casing, if a pump is required, but the drillers often hire out with their machine by the day, and the owners of the prospective wells may assist by their work or furnish casing themselves, thus reducing the cost of the wells materially.

Wells in Bannister.

Letter on fig. 46.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
			In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	°*F.*		
C	A. Evans		2	50	688	+1	0.12		Hard	Gravel.
D	R. Russell [a]		2	160?	688	+.5	1.25	50.5	Iron	Do.
F	Mrs. Davidson [b]		2	36	688	+1	.5		do	Do.
H	D. Campbell [c]	1885	2	±90	688	+3	2.5	52	do	Do.
J	E. Weston [d]		2	60	688	+6	.66	53	do	Do.
K	E. Bensinger [e]		2	−550	690	+1			do	Do.

[a] May be from drift as suggested by low head.
[b] Now pumped from tank used for refrigerator.
[c] Piped underground.
[d] Piped underground 10 feet.
[e] Not flowing now but crocked above head and pumped.

ASHLEY AREA.

Ashley.—Ashley is situated in the southeastern part of Gratiot County, in the flat bottom land which marks the bed of the Glacial Lake Saginaw, which at one time covered the region. The site of the village is a faint terrace, which extends northeastward some distance and which is elevated a few feet above the level of the land to the south and southeast.

The soil here is a compact clay, which, previous to the clearing and ditching, was covered with a heavy growth of swamp timber, and had its upper layers saturated with the product of decay of the abundant vegetation. As a result of this type and condition of soil the waters near the surface are impregnated with organic matter. The amount of water was small, and as clearing progressed became smaller, so that shallow dug wells were early found to be inadequate, going dry quickly and furnishing poor and unwholesome water.

Tubular wells were therefore resorted to, and deeper supplies of better water were obtained, so that at present the majority of the people get water for drinking and domestic purposes from deep-drilled wells, which reach down nearly to bed rock, or, in some instances, penetrate it for considerable distances.

Wells in the rock frequently flow with a good supply of water, and in all the rest the water rises nearly to the surface. The rock surface was reported to be from 100 to 120 feet deep in the village. The public well, near the railroad station, is a good example of this class of wells. It is 270 feet deep, about 170 feet in the rock, and the water flows 2 feet above the surface at the rate of 2½ gallons a minute. The water is of excellent quality, rather soft, and has a small amount of iron and other mineral matter in it. The overflow runs into a reservoir from which it may be pumped in case of need for use in protection against fires.

Within 150 feet from this well is a pump well, which was reported by the driller to be about 100 feet shallower but still deep in the rock, in which the water stands a few feet below the surface. When this well was vigorously pumped a very few strokes, the village well would cease flowing. This fact soon became a source of great annoyance to those using the flowing well on account of the temptation it afforded to play practical jokes, and after a time the authorities of the town purchased the pump well and dismantled it. This is an interesting case of transmission of change of pressure through considerable distances of rock very quickly. The raising of the water by the pump evidently reduced the hydrostatic pressure and buried the head sufficiently to stop the flow in the other well. This lowering of head manifestly need not be more than an inch or two, provided the outlet of the flowing well was about at the level to which the water would rise under the existing pressure.

One-half mile northeast of the village is a flowing well owned by Mr. Charles Kerr, which is reported to be about 600 feet deep. The water is strongly impregnated with mineral matter, the most noticeable constituents being hydrogen sulfid and salt. This water has been put upon the market, and is sold at the well at 1 cent a gallon. It is also used for mineral baths.

Aside from the few shallow dug wells, there are also in the village a few bored, driven, or drilled wells from 50 to 65 feet into the drift, the water having sufficient head to rise to within about 5 feet of the surface. Such wells are sometimes provided with a cistern of drain tile, from which the water is pumped.

The two partial analyses given below are from a deep sulphur well whose water is being bottled for medicinal purposes, and from a deep gravel well at Ashley, respectively. The analyses were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analysis of well waters at Ashley.

[Parts per million.]

	1.	2.
Color	15	10
Iron (Fe)	2.25	2.75
Chlorine (Cl)	384	29
Carbon dioxide (CO_2)	79.15	86.18
Sulphur trioxide (SO_3)	+522	383
Hardness (as $CaCO_3$)	+139	+139

S. J. Lewis, analyst. 1. Charles Kerr; depth 600 feet. 2. Village; depth 270 feet.

Vicinity of Ashley.—The country about Ashley, especially to the south, southeast, and southwest, has nearly the same soil characteristics as the village, being, if anything, more swampy. Hence it has been still more necessary to get supplies of water from the deeper gravel strata in the clay, or, failing in this, to go down to the sandstones and shales of the coal measures lying still deeper. This necessity has led to a large development of the deeper water-bearing strata, especially those in the bed rock, from which, in many cases, flows have been obtained in the east half of Washington and the south part of Elbe Township. (Fig. 47.)

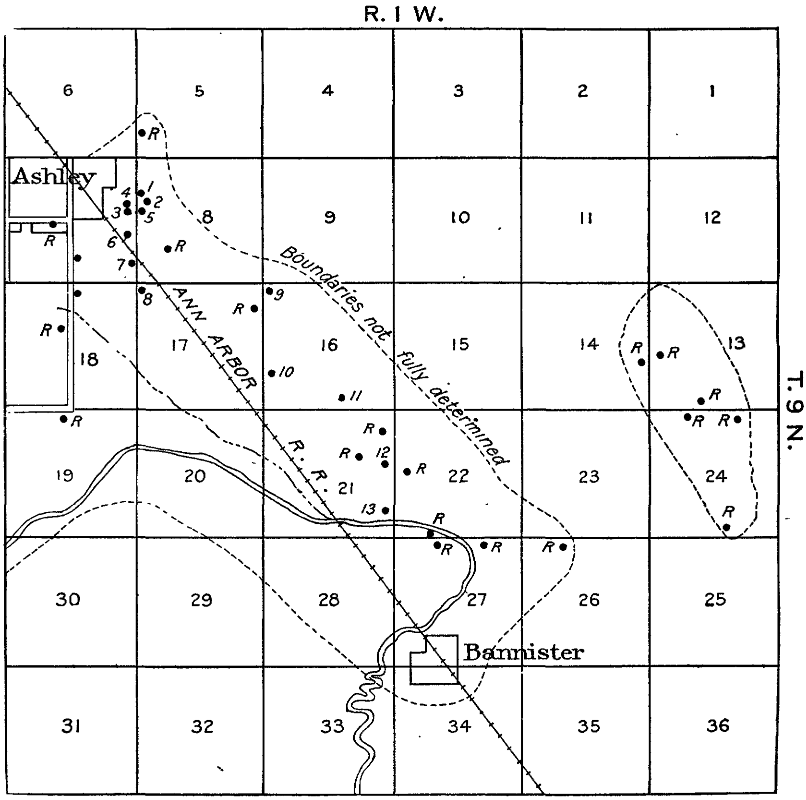

FIG. 47.—Ashley and Bannister flowing-well areas outside of village wells.

As this region has been carefully prospected for coal, many of the prospect holes have been utilized for water. The usual arrangement made is that the owner of the land shall have the hole for a well if water is struck, by paying for the pipe used in casing down to the rock. Some of the prospect holes, usually 4 inches in diameter, have yielded large supplies of water with strong heads, but the owners have wisely reduced the flow to their needs rather than try to care for the larger waste in the flat and not easily drained region.

East and south of Ashley, on the broad flat below the terrace on which the town stands, is an area of shallow wells deriving supplies from the strata of sand and gravel in the clays. The shallowest flowing well reported was 14 feet deep, but otherwise the range was from 25 to 72 feet. The flows usually are quite small, and show a tendency to decrease. The head is 1 to 4 feet and the water is hard, with some iron in it.

The area as now developed is approximately 7½ square miles, all north of the river, and in general it does not seem possible that this can be increased much, except in the number of wells, for in the eastern part of the township the rock surface rises until in places it is covered by less than 25 feet of drift. In this region also the material overlying the rock changes from clay to gravel, and as this is not covered by a compact stratum, the water is dissipated and does not rise in the wells. To the north of the area the ground rises above the level of the head, so there can be no flows in that direction.

Much more extensive is the area over which flowing wells may be obtained from the rock. These occur both east and north of the area in which the drift flows are struck, and also throughout the eastern half of Washington Township. The water from the rock wells usually contains less iron and is less hard than that from the drift, and the supply is not so likely to fail, both because of the greater extent of the water-bearing strata, and because of the less danger from clogging from the action of the water on the pipes, the working in of sand, or the clogging of screens. Ultimately the greater part of the water used in this region will be obtained from wells drilled in the rock.

The sources of supply of this area may be, and probably are, in the gently sloping districts of considerably higher level lying north of the flowing-well area, where a large part of the rainfall is absorbed by the ground because of its loamy and sandy character, and finds its way very gradually to the lower levels, from which it is forced by the pressure behind it when a well tube finds its way into a more porous stratum than usual.

Summary.—If, as assumed, the area to the north is an important source of supply, the present policy of developing an elaborate system of ditches across the contours in this region must operate to reduce enormously the supply of ground water, and one can not but view with concern the present activity in seeking means to carry off water which should have a chance to soak into the ground. Cultivation, as commonly carried on, tends still further to decrease the supply of ground water, by hastening evaporation, and of decreasing the absorbing power by rendering the surface of the soil hard and nonabsorbent.

Wells of Ashley area (T 9 N., R. 1 W.).

No. on fig. 47.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Depth to rock.	Water bed.
				In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*° F.*		*Feet.*	
1	8	E. J. Stratton[a]	1903	2	57	680	+2.5	4	50.3	Hard	150	Gravel.
2	8	E. J. Stratton	1885	2		680	+0	8	50	Hard; iron		Do.
3	7	Cyrus Stratton	1900	1½	45	678	+2	.5	50	...do		Do.
4	7	....do	1900	1½	65	678	+3	.25	50	...do		Do.
5	8	Chas. Green		2	30	680	+1	.2	51	Hard		Do.
6	7	Fuller & Lewis[b]	1895	2	30	680	+1.55	.12		...do		Do.
7	7	R. E. Parker	1895	2	25	676	+3	.25		...do		Do.
8	17	F. M. Baker	1900	2	47	680	+1	.12	51	Hard; iron		Do.
9	16	J. Hasper[c]		2	72	685	+1	3.5		...do	±125	Do.
10	16	C. J. Brubaker[d]		2	14	680	+1	±.5		...do		Do
11	16	Levi Smith[e]		2	85	680	+1			...do	±120	Do.
12	21	S. R. Hubbard[f]		2	55	680	+1	.25	52	...do	±133	Sand.
13	21	J. Sharp[g]	1894	2	72	685	+2	.25	52	...do		Do.
14	21	Wm. Sharp		2	50	685	+2	.5	52	...do		Do.

[a] Very little iron present; leaves granular scale in teakettle.
[b] Well at brickyard; casing leaks badly.
[c] Will flow 1 foot above surface, but is pumped.
[d] Will flow a small stream, but is pumped; bored.
[e] Will flow a small stream, but is pumped.
[f] Supply is decreased by clogged screen.
[g] Thought to be filling with sand at bottom.

MISCELLANEOUS VILLAGE SUPPLIES.

ITHACA.

Ithaca, the county seat of Gratiot County, is situated in the exact center of the county, with no stream or pond in its vicinity. It is built upon a low morainal ridge, which slopes off to the east into a broad plain and to the west into an extensive swamp. The moraine here is of compact till or clayey gravel, and does not yield much water. On its slopes it becomes more sandy, and shallow wells here give rather limited supplies.

The problem of a public water supply was settled two years ago by putting down a series of three 6-inch tubular wells 600 feet deep, through 300 feet of drift, into the sandstone below, from which a supply of hard but otherwise good water, which rises to within 50 feet of the surface and is sufficient for present needs, was obtained. The water is used for all purposes, domestic, fire protection, sprinkling, and boilers, and the supply is constant. The plant is a public one in charge of a water board.

The private wells are shallow, dug, open basins, or in a considerable number of cases tubular drilled wells, ranging from 50 to 90 feet deep. The water is hard and possesses the usual characteristics of water from the drift in this section.

BEEBE.

In the vicinity of Beebe, to the northwest of Ithaca, water is obtained either from open dug wells 25 to 30 feet deep or driven wells 30 to 40 feet or more. The water rises within 10 feet of the surface in some of these, and is hard, with considerable iron. It comes from gravel below rather stiff clay. There is a public well here, but nothing is known about it.

EDGEWOOD.

This hamlet, in the eastern part of the county, has dug wells 10 to 30 feet deep. The water is from sand or gravel, is hard, and rises within 6 to 10 feet of the surface.

ELM HALL.

This village lies in the shallow valley occupied by Pine River, which has here a gravel bottom. The wells are shallow, dug to the bottom of the gravel to abundant water at 12 to 20 feet below the surface. The deepest wells lying outside the valley are from 50 to 60 feet in depth. The water is hard and from gravel. Water for fire protection could easily be obtained from Pine River.

MIDDLETON.

Middleton, in the southern part of the county, has dug wells from 12 to 30 feet deep and driven wells 50 to 65 feet deep. A large supply of water, found at from 60 to 65 feet, is hard and rises within 10 to 15 feet of the surface. The wells in this vicinity are frequently bored with large augers, driven by horse power, and walled up with drain tile carefully cemented.

NEWARK AND NEW HAVEN.

These two hamlets, southwest of Ithaca, are well supplied with easily accessible water, usually reached by digging or boring from 20 to 40 feet and stoning or tiling up the sides of the well.

NORTH STAR.

This village, which is southeast of the county seat, has open or dug wells 12 to 16 feet deep and one drilled well, 214 feet deep, which obtains a large supply of water in sand and gravel at about 200 feet. No rock was struck at this depth.

OLA.

This village, in the southern part of the county, has open wells 12 to 30 feet deep and driven wells down to 60 feet. The water rises within about 10 feet of the surface.

PERRINTON.

This village is on the banks of Pine Creek, a tributary of Maple River, in the southern part of the county. The wells are from 12 to 34 feet deep, either dug or bored and tiled. The water, which is hard, is abundant, but does not rise much in the wells except in wet seasons.

POMPEII.

This village, in the southern part of the county, has dug and bored or driven wells from 20 to 40 feet deep. There is no difficulty in getting a plentiful supply of good, though rather hard, water. There are no flowing wells in the vicinity. In North Shade Township, west of Pompeii, the wells are generally dug 20 to 45 feet. Water is plenty and easy to get. Around Brice post-office, in this township, wells are usually 16 to 30 feet deep, but a few are 45 feet. The water rises within 8 to 20 feet of the surface and is rather hard.

RATHBONE.

Rathbone, which lies in the eastern part of the county, has open wells ranging from 10 to 15 feet in depth, with water within 4 feet of the surface. Driven wells are reported as deep as 160 feet, with the water rising within 20 feet of the surface.

WHEELER.

This town is located on a plain in the northeastern part of the county, which is here covered with a shallow deposit of gravelly loam. Most of the wells of the village are very shallow, from 6 to 15 feet deep, dug or bored through the gravel to the underlying clay. Those on the clay soils are dug somewhat deeper. At from 25 to 28 feet there is plenty of water, though rather hard. The deepest well was reported to be about 80 feet deep. One-half mile east of the village, on SW. ¼ sec. 22, Wheeler Township, there are wells 28 feet deep, in which the water rises within 9 feet of the surface, coming from a thick bed of gravel. In the vicinity of North Wheeler wells are often 60 feet deep, though some dug wells are only 12 to 14 feet deep.

WATER SUPPLIES OF MIDLAND COUNTY.

GENERAL STATEMENT.[a]

The examination of flowing wells in the western part of Midland County was made by W. M. Gregory. In the original plan Mr. Gregory was to have covered the entire county, but the time at his command did not admit his doing so. Mr. Davis therefore gave

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[a] By Frank Leverett.

such time as he could spare to this study, but it was scarcely sufficient to insure a thorough survey, and small districts in the northern part of the county were not visited.

It is probable that flows can be obtained along all the valleys in the county, and perhaps over wide areas between the valleys in the western half and the southeastern fourth of the county; the northeastern part is too high to expect flows. Much of the county is covered with sand, and wells are obtainable at its base at a usual depth of 20 feet or less. This fact and the sparseness of settlement accounts for the present limited development of flowing wells.

As in Saginaw County, the slopes are very gentle, and the catchment areas likely to be a little farther up the slope than the wells, rather than in some distant morainic ridge, though some water may be contributed from these remote sources. The very slight head is in keeping with the interpretation that the bordering parts of the sloping plain are the chief catchment areas.

SUPPLIES BY DISTRICTS.

LARKIN TOWNSHIP.

About 4 miles north and 1 mile west of Midland, lying along the shallow valley of a small tributary of Tittabawassee River, is a group of ten flowing wells, which differ from those of the other areas in Midland County in yielding water which is noticeably brackish.

These wells are from 45 to nearly 80 feet deep, the deeper ones occurring at the north and the shallower ones at the south end of the area. It is probable that the water comes from two or possibly three different strata. The flows are all of very moderate or small size, the largest being only about 2 gallons a minute. The head is slight, the maximum reported being only 5 feet.

This part of Midland County is a region of salt springs, some large ones existing in the valley of Tittabawassee River, a few miles west of this flowing-well area. These probably owe their origin to fissures in the bed-rock, extending down to the salt-bearing coal measures, or to the deeper Marshall sandstone. The salt water from these formations, which rises in salt wells nearly to or above the surface, in passing through the unconsolidated clays and gravels above the rock surface, would spread out in the more porous strata, and give a brackish taste to the water already present. It might also be true, in some cases, that the brine would find its way directly upward from the fissure into a bed of sand or gravel and spread laterally for a long distance without breaking out at the surface at all. An interesting feature of these wells is that those which are shallow are rather more brackish than the deeper ones, a fact that would lead to the conclusion that the water comes from different strata, since the heavy brine would naturally sink to the lowest part of the stratum in which it occurs, leaving the lighter mixed waters above.

It is possible that the deposits above the bed rock may have been largely derived from salt-bearing rocks, and that this material now gives the brackish taste to the water. The limited area over which this brackish water occurs, its nearness to known salt springs, and the known history of the sands and clays from which the water comes, however, favor the first theory.

The wells to the west of the present development which are deep enough to reach the water of these strata do not flow above the surface, although the water rises in some of them nearly to it, and if especial care were taken to find depressions in which to locate the wells, flows might be secured for a mile to the west. The area might also be extended near the stream, both north and south, if the strata which yield the water are present. As yet the country in these directions is not developed, and nothing is known of the extent of the water-bearing strata.

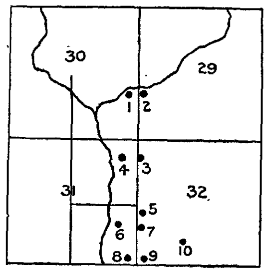


FIG. 48.—Sketch map of Larkin flowing-well district, Midland County.

The question of the wholesomeness of salty or brackish waters is often raised, and while the matter is not absolutely settled, the consensus of opinion seems to be that slightly salt waters are not in any way injurious to health. Their use probably should be accompanied by a lessened use of salt for seasoning food, and in this way the salt ration kept from running too high, as excess of salt undoubtedly has an irritating effect on the excretory organs.

The following table and the sketch map (fig. 48) give the data relating to these wells and show their approximate position with regard to the stream. The address of well owners and drillers is Midland.

Wells of Larkin Township (T. 15 N., R. 2 E.).

No. on fig. 48.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
				In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	30	G. W. Stearns [a]	1904	2	79	±625	+2	0.25	49.5	Brackish	Sand.
2	29	J. Putnam	1904	2	±75	±625	+1½	.12		do	Do.
3	32	R. Blaine [b]	1904	2	73	±625	+4	2	49.2	Brackish; bitter.	Gravel.
4	31	Geo. Jennings	1895	2	70	±625	+2	.25	49.8	Brackish	Do.
5	32	J. Cole [c]		2	±60	±620	+2	.12	52	do	Gravel.
6	31	W. Adams	1903	2	45	±625	+ .5	2	51	Hard; salty.	Gravel.
7	32	E. Town [d]	1901	2	±60	±625					
8	31	Ed. Caldwell [e]	1897	2	±50	±620	+3	1.5	49.2	Hard; slightly brackish.	Sandy gravel.
9	32	G. B. Weidemann	1897	2	±45	620	+1	2	49	Hard; slightly brackish; iron.	Gravel.
10	32	do		2		620	+2	.12			

[a] In barnyard. House supplied by seepage spring on bank of stream.
[b] Clay all the way down to gravel.
[c] Used for cooling milk, etc.
[d] Head near surface; flows small amount into underground reservoir from which it is pumped.
[e] Used in cooling milk.

MIDLAND TOWNSHIP.

MIDLAND.

The town of Midland is situated in the southeastern part of Midland County, on the banks of Tittabawassee River, at its junction with the Chippewa, which comes in from the west, shortly after uniting with Pine River from the southwest. The larger part of the town is on the north bank of the river valley, 35 or 40 feet above the low-water level of the stream.

The bank rises in a series of rather narrow terraces, the highest being a sandy ridge, which is probably part of a shore line of the Glacial lake which covered this county. The south bank of the river is much lower, and a broad flat terrace, the bottom of what may have been formerly a wide estuary or narrow bay connected with the lowest level of the Glacial lake, stretches away to the south for more than a mile before the south side of the valley is reached. Outside this broad shallow valley and others similar in origin, the greater part of Midland County is very flat, the soils varying from heavy clays to light wind-blown sand. The principal relief forms, as elsewhere on the "lake plain," are sand or gravel ridges which wind across the plain irregularly, forming low lines of elevations above the general surface. The plain in the vicinity of Midland is especially flat, and the river here is but a very few feet above the level of Saginaw Bay. There is a gradual rise of a few feet to the mile toward the west, northwest, and north. The whole county is exceptionally well watered by surface streams.

The town of Midland has a public water supply, the pumping station of which is situated on the lower river terrace, on the south side of the river near the point of union between the two streams. Formerly the supply was obtained from driven wells which flowed above the surface, but now it is drawn from the Chippewa River at its junction with the Tittabawassee, the wells having failed to give an adequate supply. The Chippewa is fed by springs along its entire course, and flows for a long distance through a practically uninhabited country, as does its tributary, the Pine, but the growing cities of Mount Pleasant, on the Chippewa, and Alma, and St. Louis, on the Pine, all turn their entire sewage into these streams, which ultimately will thus become highly polluted. At present the water is generally used for drinking and all domestic purposes, as well as for fire protection, etc.

The wells of the higher part of the town are generally dug or driven from 12 or 15 to 30 feet. The sandy upper stratum of the soil in this part of town is underlain, at a relatively short distance below the surface, by a compact clay on top of which it is usually easy to get water. Such shallow wells as are thus obtained, more especially the dug wells, in the more thickly peopled parts of town should be looked on with suspicion on account of the ease with which they may be contaminated from cesspools and outhouses. Driven wells from 25 to 200 feet or more deep are, however, frequent, and to these there can be no objection as sources of domestic supply. The deeper wells give the best supply of water, which, however, is often a trifle brackish and which rises in the casing to within a few feet of the surface.

On the north side of the river only two flowing wells were found within the town limits, and these were both in the river valley some distance below the general level (fig. 49). This seems to indicate that the head of the numerous flows on the south side of the river is not sufficient to raise the water to the height of the north bank. On the south side of the river, within the limits of the town, are many wells which flow. These are generally from 100 to over 200 feet deep, and the strongest have a head of 16 to 18 feet. The largest flows are from 10 to 22 gallons a minute, while the smallest ran but a thread of water. The Burt farm, on the lower terrace of the river, on sec. 21, has one of the most powerful wells, flowing more than 20 gallons a minute with a strong pressure. It was reported that in putting down the well small flows were struck at four levels above the one from which the present supply is obtained.

The water from the deeper flowing wells is nearly free from hardness, as is that of some of the shallower ones, and in many cases is slightly brackish. The salt probably comes from the neighboring salt wells, from some of which the brine may have leaked into the sands and gravels of the drift.

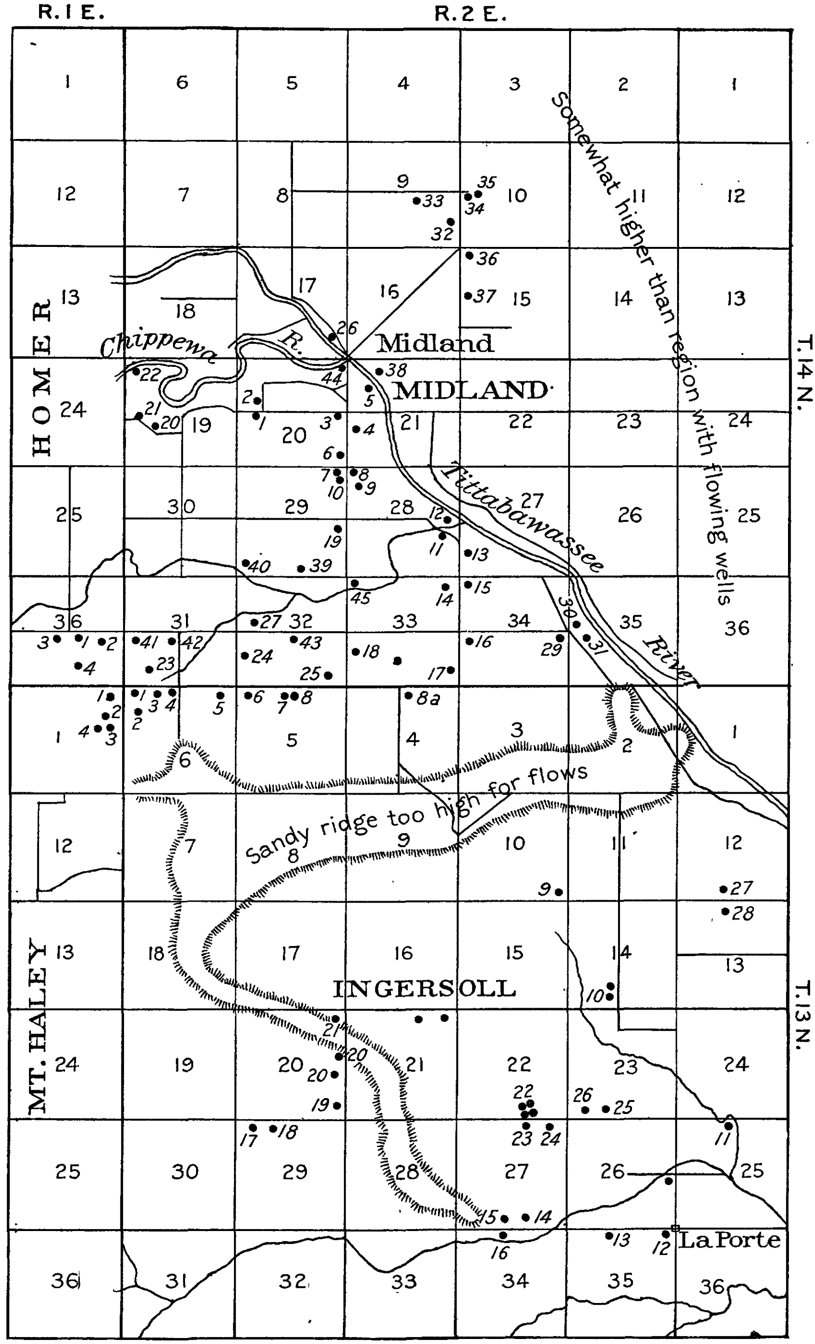


FIG. 49.—Map showing distribution of flowing wells in and near Midland.

The following partial analysis shows the composition of the water of the "Magnetic Mineral Spring" or well at Midland, owned by W. L. Stearns. The high iron constituent is a conspicuous feature, but may be due to the rust of the pipe. Water is from the rock. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analysis of well water at Midland.

	Parts per million.
Color	214
Iron (Fe)	6
Chlorine (Cl)	802
Carbon dioxide (CO_2)	63.76
Sulphur trioxide (SO_3)	+522
Turbidity	293

S. J. Lewis, analyst. Depth, 375 feet.

VICINITY OF MIDLAND.

The area over which flows are found beyond the limits of the town extends southward to the township line and into the southeast corner of Homer Township, the northeastern part of Mount Haley Township, and the northern part of Ingersoll Township. The entire area, as now developed, is about 14 square miles.

The flowing wells to the south of the river valley are generally much shallower, have less head, and flow with much less energy (rarely more than 1 gallon a minute) and it is probable that they are derived from entirely different strata. In these wells the water was not saline, was frequently hard, and contained iron.

Many of the wells in this and in the Ingersoll Township area were noticeably affected by the local drought which prevailed at the time of the writer's visit, and were commonly reported to be flowing much less than usual or to have ceased altogether since the drought had begun. North of Midland is a small extension of the area on secs. 9, 10, and 15, in which all but one of the drift wells, which was in a stream valley, had ceased to flow.

It is probable that in almost any part of the southwestern portion of Midland Township, in the lower places, flowing wells can be obtained by going deep enough. The rock surface is, however, irregular, and may rise in places in such a way as to interfere with the continuity of the water-bearing strata above, but so far as learned the rock was not usually struck at much less than 200 feet from the surface south from Midland. On the top of the higher sand ridges the level is usually above the head of the flows. Wells would best be driven in depressions if flows are desired. Good water, though often somewhat brackish, may be obtained from the rock, and there is head enough to bring it nearly or quite to the surface.

Some springs were reported along the river southeast of Midland running out from under the sand at its junction with the underlying clay. In this case the catchment area is undoubtedly the sand ridge, and such springs should be rather common in the sandy region north and west of Midland wherever a stream cuts through to the clay.

Mr. J. P. Sugnet kindly furnished the following record of his deep well on sec. 10, Midland Township:

Record of Sugnet well, Midland Township.

	Thickness.	Total.
	Feet.	*Feet.*
Surface clay	50	50
Hardpan	20	70
Clay	30	100
Sand and gravel	19	119
Red clay	19	138
Sand	3	141
Clay	114	155
Sand rock.		

It was reported also that in the neighborhood of Midland the surface clays and sands were only 10 to 12 feet deep, followed by a bed of sand, often full of water, below which was a hard dark-colored clay or hardpan with small bowlders in it, which was very hard to work. The top clay, often a relatively thin surface deposit, was as hard as the lower bed, and dark colored.

SUMMARY.

The following table gives well data in Midland Township:

Wells in Midland Township (T. 14 N., R. 2 E.)

No. on fig. 49.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Depth to rock.	Water bed.
				Ins.	*Feet.*	*Feet*	*Feet.*	*Galls.*	°*F.*		*Feet.*	
1	20	E. Shoupe [a]	1904	2	119½	600	+20 ?	1	49.5	Soft	......	Gravel.
2	20	W. Vance [b]	1893	2	120	600	......	.12	53.8	do	......	Do.
3	20	T. Dunn [c]	......	2	208	595	+20±	10±	......	do	......	Do.
4	21	W. M. Lee [d]	......	2	98	598	+3	1	49.2	do	......	Do.
5	21	Burt Farm	......	2	206	590	+3.5	20±	......	Soft; salt.	......	Do.
6	20	S. E. Taft	1890	2	98	595	+4	4.5	50	Soft	......	Do.
7	29	Chas. Hovey [e]	......	2	85 95	600	+3	4 6	......	do	......	Do.
8	28	C. Cromley [f]	1889	2	95	600	+20±	15	49.3	Fresh; soft.	......	Do.
9	28	do	1889	2	125	598	+4	.25	......	do	......	Do.
10	29	E. F. Abbott [g]	......	2	95	600	+4	.75	49.2	do	......	Do.
11	28	F. Clisdale [h]	1889	2	113	600±	+3.5	4	49.5	do	......	Do.

[a] 75 feet of tough clay, stony below that. Cost, $60.
[b] Flow cut off at 1½ feet.
[c] Formerly good flow; water has some salt.
[d] Piped into house.
[e] Three wells in small ice pond.
[f] Piped to house and barn and fish pond. Used for ice pond in winter. Would flow more, but cut down to prevent waste.
[g] Head about 15 feet when first put down; cased 15 feet; cost, $35.
[h] Piped to milk house for refrigerating, and to barn.

Wells in Midland Township (T. 14 N., R. 2 E.)—Continued.

No. on fig. 49.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Depth to rock.	Water bed.
				Ins.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	*°F.*		*Feet.*	
12	28	W. J. DeHarte		2	94	595	+4	3.5	49.5	Fresh; soft.		Gravel.
13	27	F. Bennett [a]		2	127	600	+4	1.5	50.4	do.		Do.
14	33			2		610	+2	.5	51	do.		Do.
15	34	H.E.Ackermann		2		610	+3.5	1.5	49.8	do.		Do.
16	34	Chas. Cone [b]		2	55±	615	+4	.12	51	do.		Do.
17	33	W. M. Stoats		2	45	620	+2	.06	51.5	do.		Do.
18	33	J. Stranahan		2	64	615	+ .5	.12	51.5	do.		Do.
19	29	B. Pessley		2			+3	.25	52	Soft; brackish.		Do.
20	19	J. Tolman [c]		2	80+	615	+0	.12		do.		Do.
21	19	A. Burgoon [d]	1904	2	68	615	−4	.12		do.		Do.
22	19	C. M. Sinclair [e]	1903	2	109	620	+2	.5	49.8	do.		Do.
23	31	S. H. Smith [f]		2	90 ?	630±	+1.5	.5				
24	32	R. C. Stokes		2	32	630	+1.5	.5	50	Medium; hard.		
25	32	T. J. Burgess [g]		2	11		+1	.25		Soft		Sand.
26	17	Reardon Bros [h]		2	192	610	+1.5			Soft; brackish.		Do.
27	32	S. Richardson [i]		2	45		+2.5			do.		Do.
28	31	H. Gifford [j]		2			+0	.25		Hard		
29	34	E. McArdle [k]	1900	2	106	590	+ .5	.12	51	Soft; brackish.		
30	35	County Farm		2	100±	590	+ .5	.25	50	do.	200±	
31	35	do. [l]		2	200±	590	+1	1		Salt	200±	
32	9	S. Leonard [m]		2	100±	600	−7			do.		Do.
33	9	J. Malony [n]	1903	2	79	608	+1	.12		Soft		Do.
34	10	J. P. Sugnet [o]	1898	2	116	605	+1	.25		Salt	155	Do.
35	10	J. P. Sugnet [p]	1902	2	288	605	+1	.25	50.5	do.	155	Sandstone.
36	15	C. Overton [q]		2	50		− .5			Hard		Gravel.
37	15	A. Hinkley [r]		2	60		+0			do.		Do.
38	21	Dow Chemical Co.	1900	2	127	600	+2	3	50	Salt	260±	
39	29	C. Martindale		2	124		+2 ±					Do.
40	29	J. Reardon		2	144							Do.
41	31	Wm. Haley		2	32		+1					Do.
42	31	T. Pear		2	100		+1					Do.
43	32	R. C. Stokes		2	210							
44	20	Midland water-works.	1884	2	190	592	+4	.5	50	Soft; salt.	260±	
45	33	A. D. Salisbury		2	106		+2	2	49.5	Soft		

[a] Cased only 16 feet.
[b] Used for cooling milk.
[c] Cut off at 3 feet below surface to flow into reservoir and is pumped. Flows to stock trough below tank.
[d] Flows in cellar and at trough at side of bank. Cost, $27.
[e] Used in milk house for cooling.
[f] Stopped flowing from barrel into which pipe runs.
[g] Flow smaller than usual; leaks around casing.
[h] Just drops from pipe; decreased from 1 gallon a minute.
[i] Barn well flows more in wet season; house well, 16 feet, has large supply good water; head, −3 feet.
[j] Flows into basin: water rises about to surface; two wells of same kind at barn.
[k] Flows more than formerly.
[l] Too salt to use.
[m] Pumped with chain pump from tile basin; used to flow small stream 1 foot above surface.
[n] In stream valley in pasture 10 feet below general surface.
[o] Being sand pumped when visited.
[p] Flow from 195 feet, smaller one at 116 feet, also at 157 feet.
[q] No. 36 stopped within an hour of the time No. 37 was completed; then had head of 2+ feet and flow of 1 gallon a minute; pumped now.
[r] Flows into reservoir and is pumped.

INGERSOLL DISTRICT.

There is a distinct area of flowing wells in the southern half of Ingersoll Township, extending into Mount Haley and Homer townships and separated from the southern part of the Midland area by a broad, low-ridged tract of sand which runs nearly west across the township from the river to the western town line and then southward and eastward. The flowing wells in the north part of the township belong in the Midland area (fig. 49).

The surface of this district is very flat, aside from sand ridges, and the soil, except on the ridges, is a heavy clay loam, which from its fineness of texture is relatively impermeable to water.

In the sandy areas water is easily obtained by digging or boring from 10 to 20 feet through the sand to the underlying clay. Such wells usually furnish a good supply of water, the sand acting as the catchment area and absorbing about all the water that falls on it. In this type of wells, however, care should be taken to locate the well at a considerable distance from all sources of contamination, such as barnyards, outhouses, etc.

In the early settlement of the township dug wells were general in the clay lands as well as on the sand, but as the timber disappeared and the land was cleared, the ground-water level became lower and the wells were deepened either by digging or, more commonly, by boring in the bottom of the basin of the old well.

It was found that over a considerable part of the township the water which was struck by boring at a relatively short distance down would rise to the surface or flow over it. As indicated above, these wells are usually relatively shallow, with a few exceptions in the eastern part of the township, where they are reported to be from 100 to 200 feet deep, their depth usually exceeding 50 feet. The head is slight, not often more than a foot or two, and frequently the water does not rise quite to the surface. Many of the wells of the area flow, not from a casing, but from the top of the dug basin, through an open ditch to the roadside. This is a probable source of contamination to the basin, since in this open ditch filth of all sorts may accumulate and, despite the fact that there is a constant current flowing from the well, will eventually find its way to the basin and pollute it. A glance at the condition of some of these open ditches would convince even a casual observer that they were foul in the extreme, and it is easy to see how a heavy rainfall might wash much of the filth into the basin. If this type of well is to be used and the overflow is to be allowed to run off near the surface, a tile drain should be carefully laid to replace the open ditch.

In every flat country where it is difficult to dispose of waste water, it would be a most excellent plan to construct a basin of concrete, which should be water-tight and built high enough above the ground to prevent overflow. The same purpose could be attained by the use oɪ large-sized sewer tile, or by piping the well above the surface and into a trough, which should be high enough to prevent overflow. In this way a surplus of water would always be on hand, and yet there would be no waste.

The water from these wells is of medium hardness in most cases. fresh, and of good quality.

The water is said to come from a thick bed of sand, lying under a relatively shallow clay deposit. In one well on sec. 4, the record was clay 60 feet, sand 116 feet. In another well farther south it was reported that the record was clay 35 feet, sand 72 feet. Neither of these wells flowed, and they were deepened in the hopes of securing flowing water.

It is frequently reported that there has been a loss of head in these wells. Several have ceased flowing entirely, and have been cut off and fitted with pumps. The cause of this loss is not apparent, unless it be the dry weather. It did not seem to be generally true that the supply had been drawn on too heavily by overdevelopment, for in no case were the wells closely crowded together, nor were there any very large flows found. The apparent cause, therefore, is the general lowering of the ground-water level by excessive drought, which has in turn reduced the pressure that caused the head.

An extension seems possible to the west when the country is fully settled, and it also seems likely that a greater number of flows might be had in the district at present developed if care is taken in putting down the wells and in properly casing them.

The sketch map of southeastern Midland County (fig. 49) shows the relation of this area to the Midland area, and the approximate extent of the area, while the facts relating to the wells are to be found in the table on the next page.

Wells in Ingersoll district.

INGERSOLL TOWNSHIP (T. 13 N., R. 2 E.).

No. on fig. 49.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
				In.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	6	Ellen Patrey	......	2	50±	630	+1	0.25	51	Soft	Gravel or sand.
2	6	.....do	......	2	50	630	+1	.12	......	.....do	Do.
3	6	Thos. Bailey [a]	1890	2	33	625	+2	.06	......	.....do	Sand.
4	6	Thos. Lindsay	1890	2	108	625	+2	.12	......	Medium	Do.
5	6	Jos. Yott [b]	......	2	625	625	+2	.25	52	Hardiron	Gravel.
6	5	Wm. Downs	......	2	112	625	+2	.25	50	Soft	Do.
7	5	F. Yott [c]	......	2	97	......	+2	.25	50	.....do	Sand.
8	5	.....do.[c]	......	2	110	......	+2	.5	49.6	.....do	Do.
8a	4	G. Warner	......	2	36	......	+1	.25	......	....	
9	10	W. Saas [d]	1895	2	180+	......	+0	4-8	......	Salt	
10	14	G. O. Walker [e]	1896	2	167	......	+5.	.33	......	Soft	Gravel.
11	25	Geo. Cook [f]	......	2	160	......	−3	......	......	....	
12	35	D. L. Chamberlin [g]	......	2	30	......	+0	5	......	Soft	Sand.
13	35	W. Gould	1894	2	37	......	+1.5	.25	......	.....do	
14	27	W. Baker [h]	1894	2	26	......	+1.5	.12	......	Hard	Do.
15	27	.....do	1888	2	30±	......	+0	.25	......	.....do	Do.
16	34	.....do.[i]	......	2?	25±	......	+0	1	......	.....do	
17	29	G. Stuart [j]	1903	2	22	......	+2	2	......	.....do	Do.
18	29	G. McDonald	1902	2	58	......	+1.5	1	......	.....do	
19	20	F. Compton [k]	1903	2	38	......	0	......	......	Medium hard.	
20	20	S. Locke [l]	1895	2	17	......	+2.5	......	......	....	
21	20	Cheese factory [m]	1901	2	50	......	−4	1	......	Medium hard.	
22	22	B. B. Bartlett [n]	1884	2	90+	......	+1	.5	......	....	
23	27	.....do.[o]	1884	2	70	......	+1.25	......	......	....	
24	27	G. Bartlett	......	2	60	......	+2.5	.5	50	Hard	Sand.
25	23	Mary Lee [p]	1898	2	20±	......	+0	5-10	......	Iron	Do.
26	23	....	......	2	20	......	+0	1-2	......	Hard	
27	12	L. O. Schoffler	......	2	36	......	0	......	......	....	
28	13	.....do	......	2	60	......	0	......	......	Iron	

HOMER TOWNSHIP (T. 14 N., R. 1 E.).

No. on fig. 49.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	36	A. McLaughlin [q]	1896	2	36	630	+1.5	0.55	49	Soft; iron	
2	36	C. Mudd [r]	1895	2	35	630	+1.5	......	51	.....do	Gravel.
3	36	.....do.[s]	......	....	40	630	−5	......	......	.....do	Do.
4	36	W. Blowers [t]	1895	2	35	635	−1	......	......	.....do	Do.

MOUNT HALEY TOWNSHIP (T. 13 N., R. 1 E.).

No. on fig. 49.	Section.	Owner.	When made.	Diameter.	Depth.	Elevation.	Head.	Flow per minute.	Temperature.	Quality.	Water bed.
1	1	H. A. Crane [u]	......	2	100	635	−2	0.06	......	Soft	Gravel or sand
2	1	.....do	......	2	55	635	+0	.12	50.2	.....do	Do.
3	1	.....do.[v]	......	2	65	635	+ .5	......	......	.....do	Do.
4	1	.....do	......	2	72	635	+1	.12	54	.....do	Do.

[a] Flows more in wet seasons.
[b] Flow has decreased. Dug well here formerly used to flow; head, −1 foot.
[c] Both wells flow less than in the spring.
[d] Flows into old dug basin from which a good stream of water runs into roadside ditch.
[e] Cut off into basin.
[f] Formerly flowed in barnyard on side of bank, but is stopped now.
[g] Dug 9 feet, drilled 21; flows from basin into ditch; pumped.
[h] Flows more in wet seasons.
[i] Partly dug; pumped with chain pump; flows into ditch.
[j] Pumped; lost head during dry weather; water turbid when pumped.
[k] Pumped.
[l] Flow stopped temporarily by sand.
[m] Flows into cemented tank. Factory uses 6 to 8 barrels a day.
[n] Mr. Bartlett has four or more wells of about this depth which formerly flowed; now pumped.
[o] House well, pumped from brick cistern 26½ feet deep.
[p] Bored in bottom of dug well; flows over surface in large stream.
[q] Flows less than formerly.
[r] Water just drops from pipe because of drought.
[s] Does not flow, but water comes near surface.
[t] In a pasture; water rises to within a foot of surface into a barrel.
[u] Flows into barrel near barn; flows better in wet parts of year.
[v] Much affected by drought; runs only about a drop a second.

GREENDALE TOWNSHIP.

This area is located in the south part of Greendale Township, about midway between Midland and Mount Pleasant, in the valley of a tributary of Chippewa River. (Fig. 50.)

The area includes four wells, all about the same depth, located within a mile of each other. All have small or medium flows presenting no peculiarities. It is probable that other flows could be developed along the stream valley east and west. The owner's post-office address is Stearns. The driller, Mr. A. Kinney, resides at Pleasant Valley. The following table sets forth the available facts:

Wells of Greendale Township (T. 14 N., R. 2 W.).

No. on fig. 50.	Section.	Owner.	When made.	Diameter.	Depth.	Head.	Flow per minute.	Quality.	Water bed.
				Inches.	*Feet.*	*Feet.*	*Galls.*		
1	28	T. C. Gibbs	1900	2	72	+2±	0.25	Good	Sand.
2	27	W. Conrad	1900	2	68	+3	.5	Soft	Do.
3	27	H. Gotham	1900	2	68	+2±	5	....do	Do.
4	28	G. W. Hitzmann	1900	2	±68	+2	3	....do	Do.

JASPER TOWNSHIP.

This area lies in the southwest corner of Midland County, 5 miles east of Shepherd and 5 miles north of St. Louis, and covers an area of about 10 square miles, a location that brings it well within the region formerly covered by a Glacial lake in the Saginaw basin. Because of this history its surface is nearly flat and its soils are usually clays or clay loams, broken by low, irregular ridges of sand.

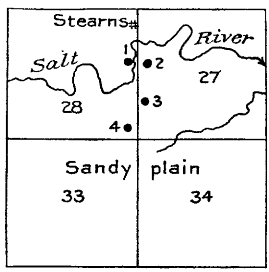


FIG. 50.—Map of Greendale Township flowing-well area, Midland County.

Depending on situation and the kinds of soils, there are two types of wells—shallow dug wells and deeper drilled or bored wells. The former are generally in sandy districts and the latter in the clay and loamy areas. The sand is usually rather shallow and superposed upon the clay. This allows the rain water to run through to the underlying clay, saturating the bottom layers of the sand, from which shallow wells may draw an abundant supply of water at a depth of 6 to 15 feet. Such wells are usually made by sinking a few lengths of sewer tile of sufficiently large diameter to the wet sand.

In the clay and loamy sections the dug wells are usually deeper than in the sandy areas, but there are many which were originally about 15 feet. These obtained their water from thin strata of sand or gravel in the clay. Since the settlement and clearing of the country these shallow wells have in many cases failed and have been deepened by boring. Tubular wells are very common in the clay lands, and range from 17 to 200 feet in depth, generally obtaining good supplies of rather hard water from sand or fine gravel interbedded with the clays.

Many of the tubular wells flow above the surface, and the whole southwestern part of the township is apparently underlain by water-bearing strata at depths varying from 15 to more than 200 feet, from which the water rises 6 to 14 feet or more above the surface. Mr. Armstrong Kinney, of Pleasant Valley, stated that one-half mile west of Pleasant Valley flows are obtained at from 16 to 30 feet. At Pleasant Valley post-office the shallow wells do not flow, and flows are only obtained from below 100 feet, but 1 mile east of the post-office there is a flow, said to be from about 200 feet. Farther east the flows are from nearer the surface, forming a distinct flowing-well area. The usual head is only from 1 to 4 feet, but J. M. Fox's well, in sec. 32, was reported to flow 14 feet above the surface when first completed. Mr. Kinney estimated the average height to which the water rises above the surface in the flowing wells of the township as 18 inches or less.

The water usually comes from fine sand, and drillers report it as too fine to be screened out. In confirmation of this some wells are said to become more or less turbid before a storm and to require frequent sand pumping. This turbidity, in part at least, is due to the effects of lessened pressure of the atmosphere at such times, which allows the water to flow from the outlet more rapidly and carry with it the finer particles of sand or gravel from the water bed.

The flows are generally of medium or small size, but sufficient for ordinary farm and domestic purposes. The wells of Messrs. M. Robeson and J. W. Fox, sec. 32, and J. Tuger, sec. 29, are among the largest flows in the area, while a few of those visited are apparently nearly clogged up from the packing in of sand at the bottom of the casing. A few wells were reported as affected by the weather, flowing more freely in the rainy seasons.

The water of the wells of this area is moderately soft and contains less iron than is usually present in waters from the drift.

This township may be considered as having two areas of flows, the deeper wells on the western side belonging to the Coe area, extending from Isabella County, and the shallow ones deriving water from local strata. The latter area is best developed along the east and west county line in secs. 15, 16, 21, and 22, where the wells give small flows with rather slight head at depths from 30 to 70 feet. These wells are affected by droughts, and several of them have ceased to flow.

Flows from shallow strata are obtained in various other parts of the township, notably in the southern sections. In sec. 32 are three wells arranged in a triangle about 100 feet on a side which are 32, 55, and 76 feet deep, respectively. These are on the farm of Mr. Mark Robeson, who has another well 43 feet deep which flows a 2-inch pipe full.

It is possible that these areas of flowing wells may be extended to the north and to the east beyond Pine River, as the need for deeper wells in these districts arises. At present, since there is considerable sand in these sections, the wells are mostly shallow. The well at the schoolhouse, sec. 27, is reported as being the most eastern flow in the township and the most northern in the vicinity of the river. If flows are desired, it should be borne in mind that here, as elsewhere, other things being equal, the wells put down where the ground surface is lowest, that is, in depressions, are most likely to flow and give large quantities of water. Where the owners' buildings are on elevations, the wells should be at the lowest possible point and the water from them forced to the buildings by a hydraulic ram.

For particulars relating to the flowing wells of this area and a map showing their distribution see pages 93–100, which include also data previously gathered by Mr. Gregory. In some cases where there is a slight disagreement the record obtained by the writer is supplemented by the data collected by Mr. Gregory, the latter being followed by the initial "G."

GENEVA AND WARREN TOWNSHIPS.[a]

There are a few flowing wells in secs. 16, 17, and 18, Geneva Township, and one in sec. 19, Warren Township, which are so remote from the wells of the Isabella basin that it scarcely seems advisable to include them in it. The data given below concerning the depth and flowage of these wells were obtained from a well driller, none of the wells being seen by the writer. Possibly other flowing wells occur farther east in the county, for the surface descends eastward and the underground water probably takes that course from the higher land in Isabella County. There was insufficient time at the writer's disposal to clear up that district properly.

Wells in Geneva Township, Midland County (T. 15 N., R. 2 W.).

Section.	Part of section.	Owner.	Depth.	Flow per minute.	Remarks.
			Feet.	*Gallons.*	
8	....	J. E. Curtiss	80	....	No flow.
16	NE. ¼	M. McDonald	106	....	Small flow from sandy bed.
16	N. side	D. A. Wilson	106	2.5	
17	W. side	Lyman Childs	115	....	Through clay; small flow.
17	NE. ¼	Albert Beuhke	90	....	
17	NE. ¼	Sam Walker	190	.5	
18	NE. ¼	D. McFarlane	80	3.1	
4	....	Wm. Tripp	29	2.	Cased 16 feet.

[a] By W. M. Gregory.

Wells in Warren Township, Midland County (T. 16 N., R. 2 W.).

Section.	Part of section.	Owner.	Depth.	Flow per minute.	Remarks.
			Feet.	*Gallons.*	
19	SE. ¼	L. A. Bliss	80	0.8	Small flow.
7	NE. ¼	Phil Preston	100	....	Water scarce.
19	Center	Test well	300	....	No flow; water scarce.
17	NE. ¼	J. Marihood	70	....	Do.

WATER SUPPLIES OF SANILAC COUNTY.

By Frank Leverett.

TOPOGRAPHY.

Sanilac County fronts on the southern part of Lake Huron. Along the border is a plain 3 to 5 miles wide, once covered by lake waters, on which several small flowing-well districts have been found. Back of this is the Port Huron moraine, filling the interval of 2 to 6 miles between the lake plain and Black River and forming a catchment area for the flowing wells east of it. Along and west of Black River are extensive swamps, and the western two-thirds of the county is largely level land. The Marlette moraine crosses the southwestern part of the county from Marlette to Melvin. Narrow ridges run from the inner or north border of this moraine northward several miles into the plain. There are also narrow strips of ridged drift, generally gravelly, scattered over the western part of the county. The northwestern part of the county, on each side of Cass River, is morainic and very thickly strewn with bowlders. There are a few small flowing-well districts west of Black River discussed below.

The western part of the county is tributary to Cass River through streams draining westward or northward. The central portion is drained southward through Black River, which enters St. Clair River at Port Huron. The eastern edge of the county drains directly toward Lake Huron. The waters of the Glacial Lake Whittlesey covered much of the swampy land along Black River and discharged through the Ubly outlet in southern Huron County into a lake across whose bed Cass River takes its course from Ubly southwestward.

The southern part of the county and all the shore except the northern third is thickly covered with drift. But in the remainder, or more than half the county, rock is struck at depths usually of 25 to 75 feet, and there are a few rock outcrops along Cass River in the northwestern part and along the lake shore in the northeastern part. The rock in the central, northern, and western parts is Marshall sandstone, and contains abundance of excellent drinking water. The southeastern part is underlain by shale, and this affords but little water and that generally of poor quality. The drift is therefore the main source for water in the southeastern part, but the sandstone is largely drawn upon in the remainder of the county. East of Black River in parts of the morainic ridge and in parts of the lake plain the drift is also a poor water bearer. As a result farmers on the lake plain have in some cases been obliged to haul water either from neighboring wells or from Lake Huron and have impounded water for stock by placing dams across small streams tributary to Lake Huron.

WATERWORKS.

The following villages have waterworks for fire protection and lawn sprinkling, but not for domestic use: Brown City, Croswell, Lexington, and Carsonville. Marlette has a supply for domestic use as well as fire protection.

BROWN CITY.

This town, in the southwestern part of the county, has several shallow wells, excavated to depths of 6 to 20 feet along the base of a drift ridge. These are drawn upon in case of fire. There is also a village well 217 feet deep and 3 inches in diameter, made in 1903, which is strong and is used for street sprinkling. It struck rock at about 190 feet. The water in it rises to 12 feet below the surface, or 787 feet above tide. Another well at the electric-light plant is about 200 feet deep, penetrating into rock a few feet. In it also water stands 12 feet below the surface, but it is not a strong well. The water is used in boilers. Other deep wells in the village similar to those just mentioned are at the Harrington Hotel, a creamery, and a canning factory. The Harrington Hotel, however, now obtains a supply at 140 feet from gravel. Wells in the northwest or main residence part of town get plenty of water in gravel below till at 50 to 70 feet.

MARLETTE.

Marlette, in the southwestern part of the county, obtains a waterworks supply from wells drilled into rock on low ground in the northern part of town. The water stands nearly level with the surface and is pumped direct to the mains with an ordinary pressure of 40 pounds and a fire pressure of 80 pounds The plant was installed in 1896 at a cost of $15,000.

CROSWELL AND LEXINGTON.

The village of Croswell, in the eastern part of the county, has a supply from Black River for fire protection and sprinkling. Water is pumped to an elevated wooden tank. The plant has been in operation since 1895. The domestic supply is from private wells, usually about 30, but in some cases 100, feet deep.

Lexington is the only village on the lake shore in this county that has water stored for fire protection. The wells used for this purpose flow into two underground wooden tanks 8 by 16 by 10 feet deep with which the hose and fire engine are connected. The wells are 21 to 23 feet deep. The public school has a flowing well 42 feet deep. (For flowing wells of the district see pp. 249–251.)

In the following table partial analyses are given of water from several sources at Croswell and Lexington. The Black River supply is used only for sprinkling and fire purposes and is as good as the water from the shallow wells. A safer supply is from deep wells, such as that at the Croswell Hotel. The deeper well at Lexington is in the rock. The data were furnished by M. O. Leighton, of the United States Geological Survey:

Partial analyses of waters near Croswell and Lexington.

[Parts per million.]

	1.	2.	3.	4.
Color	46	24	149	71
Iron (Fe)	1	1.25	3	2
Chlorine (Cl)	36.9	29.3	49	11.5
Carbon dioxide (CO_2)	90.53	58.88	105.70	94.32
Sulphur trioxide (SO_3)	36	5	15	5
Hardness (as $CaCO_3$)	139+	139+	139+	139+

S. J. Lewis, analyst. 1. Black River, Croswell. 2. Croswell Hotel, Croswell; depth, 101 feet. 3. R. Pabst, Lexington; depth, 910 feet. 4. School district No. 6, Lexington; depth, 42 feet.

CARSONVILLE.

There is a waterworks plant connected with a mill in Carsonville, but it is apparently not for general use. The water is pumped to an elevated tank.

SANILAC CENTER.

In 1904 plans were developed at Sanilac Center to install waterworks and draw the supply from drilled wells, which afford a large and excellent supply from 70 feet or less.

MISCELLANEOUS VILLAGE SUPPLIES.

The tabulated data on village supplies in 1904 were obtained largely by correspondence with residents. The data collected by C. H. Gordon some years earlier for the Michigan Geological Survey pertain both to village and rural supplies, and may be found in vol. 7 of the report of that survey published in 1899.

Village supplies in Sanilac County.

Town.	Population (1900).	Elevation.	Source.	Depth to rock.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Amadore		763	Open and driven wells		15	30	20	25		Small.
Applegate		740	Driven wells		10	30	20	20		None.
Argyle		800	Open and driven wells	40	16	104	25	65	−14	Small.
Brown City	603	811	Bored and driven wells	{190, +213}	14	217	60	{180, 200}	−12	Do.
Carsonville	400	767	Open and driven wells		15	65	30	30	−12	None.
Cash		760	Open and driven wells and creek.	40	20	152	22			
Croswell	606	731	Open and driven wells and river.		10	100	20			
Deckerville	398	{778, 830}	Open and driven wells	60	16	80	35	70	{−5, −20}	Small.
Elmer		790	do	20	20	60	26	26	−20	None.
Forestville	282	610	Open wells, Lake Huron.		10	33	25	25		Small.
Freiburger		800	Drilled wells	40	20	160	60	60	−20	Do.
Greenleaf		800	Open and drilled wells	36	8	70				Do.
Laing		780	do	40	8	165	20	75	{−0, −10}	None.
Lexington	619	{620, 660}	Flowing wells		18	72	20	20	+7	Strong.
Marlette	996	840	Open and drilled wells	60	20	150	60	100	−10	
Melvin		826	Bored wells	120	12	380	30	30	−30	Small.
Minden	408	818	Drilled wells	75	20	100	80	100		None.
Palms		812	do	60	13	176	100	100	−36	Do.
Port Sanilac	314	600	Open and drilled wells		12	60	40	40	−25	
Sanilac Center	578	780	do	50	10	100	80	80	−6	Small.
Wickware		780	do	{20, 100}	15	175	15	75	−10	

FLOWING WELLS.

LEXINGTON DISTRICT.

The flowing wells of the Lexington district are restricted to a narrow strip extending from the cemetery at the north end of Union street southward through the west part of the village between Union and Main streets and about a mile beyond, or into the southwest part of sec. 31, T. 10 N., R. 17 E., as shown in the sketch map (fig. 51). This strip is scarcely one-eighth mile in average width. The bordering tracts appear to have been thoroughly tested, several attempts to obtain flows at lower levels along Main street having been unsuccessful as well as those on the higher ground along and west of Union street. There are springs to the north of this strip of flowing wells and also to the south, which may belong to the same pool. The entire area of the flowing-well strip, not including the springs, is less than half a square mile, while the number of successful flows in operation in October, 1904, is not less than 21. They are at an altitude about 50 feet above Lake Huron or 630 feet above tide. The wells are from a bed of sand beneath a thin sheet of clay apparently till, and those in the village are just east of the Elkton beach. With one exception they are less than 25 feet in depth, while some, as indicated in the table below, are but 10 or 12 feet. The schoolhouse well on the west side of Valen street is 42 feet deep. It reached a deeper vein than the others, and apparently is at the eastern edge of the district, for a boring 88 feet in depth on the opposite or east side of Valen street failed to get a flow. The water is piped to the school grounds.

The first well was made about twenty years ago by John Bell near the north end of the present strip of flows. Others nearly as old are the Purkiss well on the north side of Lake street, west of Valen, and a well owned by Walters & Co., sunk only a few feet from the schoolhouse well.

It is the custom for two or more families to join in putting down a flowing well and then pipe the water to each residence. In this way nearly all the residents east of the flowing-well strip as well as in it have been supplied, for there is a rapid descent in the lake plain from the well strip to the lake bluff.

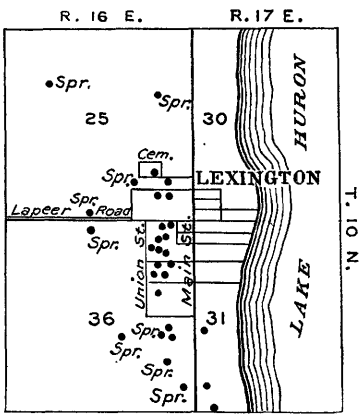


FIG. 51.—Map of Lexington, Sanilac County, showing flowing wells and neighboring springs.

The water is not very hard and contains only a moderate amount of iron. (See analysis of schoolhouse well, p. 248.) It is very highly prized by the residents because of its quality, and care is taken to prevent waste, most of the wells having faucets or other means for shutting off the flow when not needed.

The rate of flow where tests were made is about 2 gallons a minute from 1-inch pipes having half-inch nozzles. In most cases the rate is difficult to determine because of the distribution of water through two or more pipes.

The temperature tests were of more value in showing the warmth of the soil through which the pipes are conducted than the water temperature. Several wells had, on October 11, at 9 to 10 a. m., a temperature of 55.5° or about 7° above the usual temperature of the flowing wells in that region and 7.2° above that of a large flowing well 3 miles south of Lexington, discussed below. It is probable that the soil temperature at that time was sufficient to increase the temperature of the wells 7°. The winter and early spring temperatures of the water as it issues from the pipes are likely to be much below the normal water temperature. A series of carefully conducted water-temperature observations would, if carried through an entire year, be likely to yield important data on variations in soil temperature.

The following data concerning the wells, and the plat of the village, were furnished by the president of the village, J. F. Meyer:

Flowing wells at Lexington.

Owner.	Location.	Depth.
		Feet.
Cemetery Association	North end of Union street	18
John Bell	About 20 rods southeast of cemetery	19
S. C. Tewksbury	South side of Simmons street	19
M. Meyer	South side of Lapeer road	20
Hotel Cadillac	South of Lapeer road	21
Schoolhouse	West side of Valen street	42
Walters & Co	10 feet from schoolhouse well	21
S. Purkiss	North side of Lake street	21
Mrs. B. Miller	South side of Lake street	21
Village well	20 rods west of Miller well	21
D. Hicks	In sag between Lake and Hubbard streets	17
Village well	North of Hubbard street	23
J. F. Meyer	15 feet west of village well	23
F. E. Willard	200 feet east of Hicks well	20
A. Cruickshank	South of Lester street	19
Smith Bros	do	19
Mrs. P. Janett	West of Main street	18
H. Johnson	80 feet southwest of Janett well	18
Ira Lucia	Northwest corner of SW. ¼ sec. 31, T. 10 N., R. 17 E	10
D. Clark	West side of SW. ¼ SW. ¼ sec. 31	12
H. Ross	South side of SW. ¼ SW. ¼ sec. 31	12

Important springs near Lexington.

Owner.	Location.
A. M. Clark	SE. ¼ NE. ¼ sec. 25, T. 10 N., R. 16 E. (Boils up with great strength.)
John Davison	SW. ¼ SE. ¼ sec. 25.
Ira Armand	SE. ¼ SW. ¼ sec. 25.
E. G. Shipley	Near center of NW. ¼ sec. 25.
Geo. Armand	Northeast corner of NW. ¼ sec. 36.
D. Clark	East part of NE. ¼ SE. ¼ sec. 36.
F. Kaneill	South part of NE. ¼ SE. ¼ sec. 36.
Joseph Kenney	East part of SE. ¼ SE. ¼ sec. 36.
Mrs. Janett	NE. ¼ SE. ¼ sec. 36.

Mr. R. Pabst, of Lexington, sunk a well 900 feet deep in the valley of Mill Creek, 3½ miles south of Lexington and about one-fourth mile from the shore of Lake Huron, at a level 10 to 15 feet above the lake or 590 to 595 feet above tide. At a depth of 132 feet, near the base of the drift, a strong flow of water was obtained, which runs 15 gallons a minute and will yield by pumping ten times that amount. The water is fresh and of excellent quality, with a moderate amount of iron. (See analysis, p. 248.) Another vein with sulphur water was struck at 540 feet, which rises to the surface but does not flow with such strength as that from the glacial deposits. The temperature of the combined waters as they escape from the well mouth was 48.3° F. October 11, 1904. The same water was found by Doctor Lane some years earlier to have a temperature of 48°, but his observations were in colder weather. Whether this difference is attributable to a change of that amount in temperature of the water or is merely referable to differences in the graduation of the thermometers is not known. The water is going to waste at present, but may be developed if that part of the lake shore becomes a summer resort, for it stands in a very attractive piece of forest suitable for a park.

BUEL FIELD.

The main group of wells in Buel Township is on the western side of a sharply ridged belt of gravelly drift a short distance southwest of the center of the township. There are other flows at the south end of the ridge on the Fremont side of the line of Buel and Fremont townships and a very strong spring issuing from the base of the ridge between these groups of wells in the west part of sec. 33, Buel Township. It seems proper to throw all of them into a single field with the gravel ridge as the catchment area. There are two other flowing wells in Buel Township about 3 miles east of this ridge, which, though fed perhaps by the same catchment area, are on its opposite side and perhaps in a different pool, unless the flowing-well field completely surrounds the ridged belt.

The group of wells west of the ridge are at an altitude about 760 feet above tide, those at its south end about 770 feet, and those on the plain to the east of the ridge about 750 feet, while the ridge has an altitude of 800 to 810 feet along its crest. The water has barely sufficient head to flow, and probably would not rise more than 5 feet above the surface in any well. In some it rises barely level with the surface and escapes along ditches connecting with the wells. In some wells pumps are attached.

The oldest wells were made in 1871, and several have been made twenty years. The head seems to have decreased slightly, and this has led to the use of pumps, for it is considered more convenient to pump the water than to maintain a good drinking place for stock at a level a foot or two below the ground surface.

The wells on the west side and south end of the ridge are very shallow, ranging from 10 to 30 feet in depth. Those on the plain east are 40 to 50 feet. They all pass through clay before striking the water, which is obtained in sand or fine gravel.

The temperature showed a range from 49° to 53° in the different wells, all being taken in a single forenoon on October 8, 1904. The temperature of the large spring referred to above was 52° on that date. The varying effect of the warm surface layers of the earth on the waters rising through them seems a sufficient reason for the variations displayed.

Only one well, that of C. J. Nelson, was in good condition for testing the rate of flow, and this yields but a gallon in four minutes. The spring flows a stream several inches in diameter, producing a small creek as it runs across the plain west of the ridge, and yields much more water than the combined flow of all the wells.

The water is hard and has sufficient iron to produce the characteristic orange-colored scum upon objects over which it passes.

Wells in the Buel field (T. 10 N., R. 15 E.).

Section.	Part of section.	Owner.	When made.	Depth.	Head.	Temperature.	Remarks.
				Feet.	*Feet.*	*° F.*	
29	NE. ¼...	Aaron French........	1871	15	−1.5	....	Well stopped flowing in 1896.
28	NW. ¼..	.....do................	1874	17	−1	52	Well stopped flowing in 1901.
28	NW. ¼..	Aaron French (barn near house).	1894	25	(?)	50.5	Pump attached.
28	W. side.	Aaron French (in pasture).	1893	30	0	49	Water rises to surface and forms pool.
28	N. side..	W. Francis...........	1889	21	+2	49	Dug 12; bored 9 feet through clayey till to sand.
21	S. side..	W. J. Stratton.......	1895	20	+1	50.2	Pump attached.
36	N. side..	Thos. Coggin, Buel...	1884	50	+1	(?)	Well plugged.
25	S. side..	Geo. Carey, Buel.....	1880?	40	0	(?)	Head was lowered by flow of Coggin well.
14	SE. ¼...	A. Wheatley, Buel...	....	....	....	....	Not visited.
26	S. side..	W. H. Carey, Buel...	....	40	−10	....	On ground 770 feet above tide. Head higher than in wells to the east.
4	N. side..	C. J. Nelson, Fremont.	1894	13	+3	50.5	Crock well; flow 1 quart a minute.
5	N. side..	I. Johnson, Fremont.	(?)	12	(?)	53	Pump attached.

PECK DISTRICT.

The village of Peck stands on the eastern slope of a morainic spur that extends northward from the Marlette moraine in Speaker Township (T. 9 N., R. 14 E.) into the southern part of Elk Township (T. 10 N., R. 14 E.). The water in the wells on the flanks of this morainic spur, both east and west, rises nearly to the surface in a strip extending from the base of the spur in secs. 9, 10, and 11, Speaker Township, northward about 4 miles; seven flows have been obtained on low ground in the eastern part of the village of Peck, along the line of secs. 27 and 34, Elk Township. The first was obtained twenty years ago by Barney McGrory; it was dug 18 feet and bored 20 feet farther, where a strong gushing flow was obtained that filled the dug well and flooded the street and dooryard. The dug portion was filled with cobblestones and bowlders to prevent caving, but the water continues to rise through these stones and flow out into a gutter in the street. The other wells have been made within a very few years. In most cases they have been banked up and pumps attached to prevent a flow, the pump spout being above the height reached by the water, thus avoiding a muddy place around the wells. The head is apparently but 1 to 3 feet, and in one or two cases is barely level with the surface, so it is easy to prevent a flow. In all the wells the water is strong in iron and hard, and is not popular for domestic use. The temperature of the water is 49° F., if pumped sufficiently to bring it up from below the effect of atmospheric heating. The observations were made October 3, 1904, on which date some of the wells showed 54° F. as the result of atmospheric heating of the pipes near the surface of the ground. The rate of flow could not readily be determined, for the escape is not through pipes, but from a tile into a ditch a little below the surface of the ground.

Wells at Peck.

Section.	Part of section.	Owner.	When made.	Depth.	Diameter.	Head.	Temperature.	Mode of escape.
				Feet.	*Inches.*	*Feet.*	° *F.*	
27	S. side	Mrs. Barney McGrory	1884	38		+2	49	By pump and by ditch.
27	S. side	Mrs. Sunfield	1898	30	2	+2	(?)	
27	SE. ¼	John Welch		18		+2		Not visited.
34	N. side	Calvin Chrystler				+1	49	Pump.
34	N. side	Mrs. Caroline Allen						
34	N. side	Lemington Hall	1904	29	38	0	54	Do.
34	N. side	M. W. Henry				+1		

VALLEY CENTER AREA.

Two flowing wells have been obtained near Valley Center (T. 9 N., R. 13 E.), at the border of a plain that lies on the northwestern side of a moraine passing just south of the village. They are both shallow, one made by Andrew Cook in the SW. ¼ sec. 24, being 18 feet, and the other made by James Campbell in the east part of sec. 22 about 25 feet in depth. The latter well was dug 18 feet and then bored about 7 feet to the vein of water from which the flow was obtained. The former was dug to the water vein. The wells were not flowing at the time of the writer's visit in October, 1904. No definite information could be obtained as to their head in wet compared with dry seasons, though they appear to have a lower head in the dry seasons of the year. It is the opinion of residents that the draining of marshes near the wells has lowered the head sufficiently to stop the flow.

A well 876 feet deep one-fourth mile south of Valley Center in the west part of sec. 27, of which the record was published in the annual report of the State geologist for 1901, has water rising to 8 feet below the surface or 797 feet above tide. The supply apparently comes from near the base of the glacial deposits at a depth of 117 to 149 feet. This well is on ground a few feet higher than the two flowing wells, so may have fully as great head.

The shallow wells probably derive their supply and their head from the neighboring moraine southeast of them. The catchment area for the water supply in the deep well is perhaps in the same moraine, since the record shows the upper 95 feet of the drift to be fine sand, saturated with water, and separated from the lower water bed by only 22 feet of clay. Conditions seem favorable for a rise of water nearly to the surface all along the northwest border of this moraine, for in other wells than those mentioned the rise is within 15 feet of the surface. Yet it may not be possible to obtain flowing wells, since those already obtained seem to have suffered a permanent loss in head that has caused them to cease flowing.

PORT SANILAC FIELDS.

In Sanilac Township, on the shore of Lake Huron, southwest of Port Sanilac (T. 11 N., R. 16 E), flowing wells have been obtained in two distinct pools. One in the southern part of the township embraces a group of five wells, the other in sec. 10 has as yet but a single well. They are all on the old lake plain, less than a mile east of the shore of Lake Warren, and about 2 miles from Lake Huron, at an altitude 75 to 100 feet above the level of Lake Huron. The catchment area is apparently in each case on the inner or eastern slope of the Port Huron moraine. The sand and gravel ridges formed by Lake Warren are on this slope, and probably supply some of the water struck in wells farther east, though, as indicated below, much of the water thus absorbed comes out in springs along the eastern or lakeward base of the shore deposits. There is a rapid descent from the crest of the moraine past the flowing wells, the crest being 125 to 150 feet above the level of the wells and only 2 to 3 miles distant.

The topographic conditions found in connection with the flowing wells are continued along all of this slope of the Port Huron moraine, but the stratigraphic conditions seem to be favorable for flowing wells in only a few restricted areas where water-bearing beds are present between sheets of clayey drift. There are intervening places where wells do not encounter such beds, and what little water is obtained shows much less pressure than in the flowing wells. No predictions can be made as to the extension of the flowing-well areas because of this restricted distribution of water beds.

The flowing well in sec. 10 is at the residence of Joseph Pohizehl, on the west side of the northwest quarter of the section, at an altitude about 675 feet. It was made in 1895, and flows a very weak stream, at the rate of a gallon in six minutes from a pipe 2½ feet above the surface. The depth is 48 feet, and it enters a sandy gravel below blue till at 44 feet. Neighboring wells toward the south, on ground of similar altitude, have been sunk to depths of 80 feet or more without obtaining a flow, the water in some cases remaining fully 30 feet below the surface. A well in the NW. ¼ sec. 14 on ground 40 feet lower has a depth of 59 feet and only 15 feet of water.

The group of wells in the south part of the township are very shallow, the deepest being only 30 feet. They are at an altitude about 660 feet above tide. The Suerwier wells are on the lake plain, but the Roys and Cronkheit wells are in the valley of a small stream trenched 10 to 15 feet into the lake plain. The escape pipes in each are 1½ inches.

Wells in the southern part of Sanilac Township (T. 11 N., R. 16 E.).

Section.	Part of section.	Owner.	When made.	Elevation.	Diameter.	Depth.	Flow per minute.	Temperature.	Quality.
				Feet.	*In.*	*Feet.*		°F.	
34	Center..	Wm. Suerwier (at house).	1894	660	4	28	1 qt.......	49.5	Chalybeate.
34	Center..	Wm. Suerwier (at barn).	1888	660	4	30	1 pt.......	49.5	Do.
27	S. side..	C. Suerwier (at barn)[a]...	1886	665	18	28	Pumped..	49.5	Do.
34	SW. ¼...	David Roys[b]............	1904	660	4	20±	1 gal......	53	Do.
34	SW. ¼...	Chas. Cronkheit.........	1903	660	3	16	3 gals.....	49.5	Do.

[a] Original head 6 feet.
[b] Probably warmed by exposure of pipe in sunlight; date of observation on wells, October 12, 1904, a warm, sunny forenoon.

SANILAC CENTER FIELD.

A single flowing well was obtained in September, 1904, about a mile east of Sanilac Center, on the farm of James McCaren, in sec. 32, T. 12, R. 14 E. It is reported by the owner to obtain the flow from shale rock at depth of 78 to 83 feet, rock being struck at 40 feet. The well is 4 inches in diameter, and flowed a 1-inch stream that rose when struck, to 1½ feet above the surface, but within two months lowered 6 inches. The water is soft, with a slight taste of salt. This well is near the western edge of a swamp that stands only a few feet below the drier land to the west. It seems probable that other flows may be found in this swamp, or at least that water will rise nearly to the level of the well mouth.

In the village of Sanilac Center, in wells of a depth similar to the McCaren well, the water stands 6 to 20 feet below the surface in accordance with the altitude, those on the lowest ground having water nearest the surface; probably in all it rises to very nearly the same altitude as in the McCaren flowing well. The water is soft, and has very little taste of salt.

SNOOVER FIELD.

South of Snoover, at the edges of the swamp which is traversed by the south fork of Cass River, are a few flowing wells from the rock. The strongest is in sec. 25, LaMotte Township, in the pasture of T. J. Miller, and has a depth of 280 feet. It flows the full capacity of an escape pipe one-half inch in diameter at a level 3 feet above the surface. The water is not chalybeate and is apparently soft.

Samuel Moore's well, in the central part of sec. 32, Moore Township, has a pump attached, for it barely rises to the surface. The temperature (49.5°) was obtained by pumping.

Albert Jones well, in the east part of sec. 30, Moore Township, was made in 1904 and flows 1½ gallons a minute. This water is rather soft, with little or no iron, and flows 1½ gallons a minute.

A well across the street from the Jones well, on J. R. Dorman farm, in sec. 29, once flowed, though on ground several feet higher. It has stopped now, and as the head became less before the Jones well was made, that is not the entire cause for loss of head.

Wells in Snoover field.

Township N.	Range E.	Section.	Part of section.	Owner.	When made.	Depth.	Diameter.	Temperature.	Remarks.
						Feet.	*Inches.*	°*F.*	
12	12	25	S. side..	T. J. Miller	1903	280	3	49.3	Rock at 36 feet.
12	13	32	Center..	Samuel Moore .	(?)	100	3	49.5	
12	13	30	E. side..	Albert Jones....	1904	148	3	49.0	Rock at 40 feet.
12	13	29	W. side.	J. R. Dorman...	(?)	(?)	(?)	(?)	

ARGYLE TOWNSHIP.

Two flows are reported in Argyle Township, one at Laing post-office, the other on the farm of William Cole, in the southeast part of sec. 14. They are both on low ground along a tributary of South Cass River. The one at Laing post-office was not properly manipulated, and has become clogged, while the one on the Cole farm had so low a head and so slow a rate of flow that a pump is now attached. Each well enters rock a few feet, and the depth of each is not far from 70 feet.

MINDEN CITY FIELD.

A flow reported by Gordon [a] at the farm of E. Seaman, about 1 mile east of Minden City (T. 14 N., R. 14 E.), obtains its supply from the Marshall sandstone at a depth of 73 feet (67 feet to rock).

A neighboring well on the farm of G. Schweighert has a head only 2 feet below the surface. These wells are at an altitude of fully 800 feet and stand near the eastern edge of the sandstone. In the lower country to the east, underlain by shale, no flows are reported, though wells frequently reach depths of 60 to 80 feet, and occasionally 200 feet. The altitude to the west is higher than at the Seaman flowing well, being 850 to 860 feet along the crest of the Port Huron moraine, so no flows are to be expected. The favorable conditions for flows seem to be restricted to a narrow strip along the edge of the Marshall sandstone at the inner border of the Port Huron moraine.

WATER SUPPLIES OF HURON COUNTY.

By A. C. Lane.

GENERAL STATEMENT.

The water and wells of Huron County have been treated quite fully in the writer's Huron County report.[b] This county constitutes the thumb nail of the thumb of Michigan and is bordered, except on the south, by the waters of Lake Huron. The lake is so shallow around much of the county that it can not be highly recommended

[a] Geol. Survey Michigan, vol. 7, pt. 3, 1900, p. 26.
[b] Ibid., pp. 118-201.

as a source for water, though it is used as the town supply of Harbor Beach. Wells in rock are common and are from three distinct horizons within the county. Those on the east shore strike into shale with little or no water, and that likely to be salt; those in the central part of the county into the Marshall sandstone, where a good supply of water, such as that furnishing the Bad Axe waterworks, can be readily obtained; those in the western part of the county for an area of about 10 miles around Pigeon, pass through gypsiferous beds, but may obtain a good water from the Marshall sandstone if that from the overlying beds is cased out. Probably a more permanent water supply can be obtained from the Marshall sandstone throughout the region covered by it than from the drift.

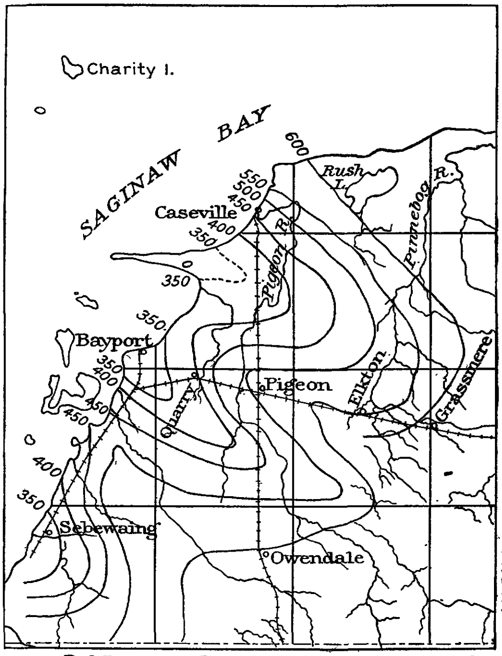


FIG. 52.—Contour map showing the elevation of the top of the Upper Marshall sandstone above sea level.

At the highest outcrops of the Marshall sandstone the water level is about 760 to 780 feet above tide, and probably continues so for about 10 miles north of Ubly. But toward the northwest it drops down to lake level. In general, it may be stated that flowing wells are obtainable on the west-sloping part of the county directly in front of the west-facing terraces and along the stream valleys, or that, at least, the water will rise very close to the surface of the ground. The altitude of the top of the Upper Marshall above sea level is shown in fig. 52, which is taken from the Huron County report. By comparing these contours with the altitude of the present surface the necessary depth of wells can be determined, remembering that the Upper Marshall or Napoleon should be penetrated a certain distance, not over 100 feet, to get the best results.

With the exception of some high ridges in the southern part of the county the surface was once beneath the waters of the lake, and numerous sand ridges running more or less parallel with the present shore indicate old lake beaches. On these sand ridges surface water can be obtained, but it is liable to contamination. Water can often be found on this old lake bottom at various depths in the drift, and especially just above bed rock. Flowing wells can be found all along the shore from Grindstone City to Sebewaing, and sporadically as far as Owendale, Elkton, Grassmere, and even to Bad Axe, but draw largely from the underlying rock or its top. Near the Bayport quarries is a small flowing-well area, in Fairhaven and Winsor townships, in which the water level fluctuates with that in the Bayport quarries, as indicated in fig. 53. Although prospects for flowing wells are generally good on the northwest slope of the county below the 750-foot contour line, there is not more than 3 or 4 feet of head in any well of which I have knowledge.

In the high ridges in the south part of the county, in Sheridan, Bingham, Paris, and the south part of Verona townships, it is not difficult to get an ample supply of water without going into the underlying rock. There are also some springs in this region. The ridges are often composed of clay till at the surface, but have gravel in the lower parts.

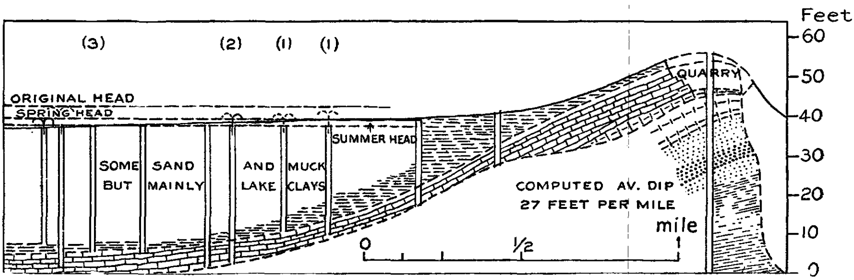


FIG. 53.—Cross section from Bayport quarries southwest, showing relations of the present surface, rock surface, flowing wells, etc.

WATERWORKS.

There are only two systems of village waterworks in this county—at Harbor Beach and Bad Axe.

HARBOR BEACH.

The Harbor Beach waterworks draw from Lake Huron, a supply pipe being carried 1,200 feet out into the lake and outside the harbor breakwater. It was put in by M. Walker, of Fenton, Mich., at a cost of $16,000, and is described in the Huron Times of September 17, 1897. It supplies 150,000 gallons a day, or about 100 gallons per capita, though more than half the supply goes to the starch factories.

BAD AXE.

The Bad Axe waterworks are supplied from a number of wells about 200 feet deep, from which water is pumped to a standpipe 200 feet high. The water originally rose 11 feet above the surface; now it is 15 feet below. It must be remembered that besides the draft on the formation by these and other wells, such as those put down recently in Bad Axe for the sugar factory, the region from which the water is derived has been extensively drained.

MISCELLANEOUS VILLAGE SUPPLIES.

The following table, made up in large part by correspondence with postmasters, presents a summary of conditions at the post-offices of the county:

Village supplies in Huron County.

Village.	Elevation.	Population.	Source.	Depth to rock.	Depth of wells.			Depth to water bed.	Head
					From—	To—	Common.		
	Feet.			*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Appin	780	(?)	Gravel, sandstone	40	43	102			
Ashmore	650	25	Drilled wells	30–40	30	90	60	50–60	(?)
Bad Axe	758	1,241	Marshall sandstone	30–50	12	400	180	40–180	+3
Bayport	602	250	Drilled wells	5–20	12	60	30	30	–8
Berne	627	150	Drift	40	28	36			
Canboro	680	25	Gravel	30					
Caseville	594	505	Wells and stream	30–40	12	145	22	20	–5
Center Harbor	590	(?)	Rock	5					
Crown	720	(?)	Marshall sandstone	30					
Eagle Bay	590	(?)	do	10	19	25			
Elkton	651	471	Sandstone	30–35	27	200	65	35–65	–20
Grassmere	694	25	Marshall sandstone	40					
Grindstone	590	450	do	10	19	25+			
Gotts	635	30	Drift	30+			28		
Harbor Beach	600	1,400	Lake Huron	30–50					
Hayes	612	25	Michigan series	30	100	218			?
Helena	716	35		90					
Huron	600	60	Drift, sand rock	5	12	70			
Ivanhoe	765	(?)	Gravel	60	30	60			
Johnston	645	75	Lower Marshall	20					
Kilmanagh	630	175	Sandstone	70					
Kinde	701	150	do	50					
Linkville	648	50	Drilled wells	75?	62	185			
North Burns	770		Gravel	(?)					
Owendale	651	75	Drilled wells	38–56	43	170	50–60	60	+2
Parisville	785	125	Sandstone	65					
Pawlowski	775	25	do	60					–10
Pigeon	633	582	Drift and sandstone	40	65	250	175	150	–20
Pinnibog	630	175	Marshall sandstone	30	87	110			–6
Popple	770	45	Gravel	80?	12	35	20	20	
Port Austin	595	507	Lake and drilled wells	10	35	150	75	75	–3
Port Crescent	595	25	Sandstone and drift	20	20	30			+?
Port Hope	597	319	Lake and rock wells	5	10	30	25	25	–6–10
Pointe aux Barques	597	(?)							
Rapson	740	25	Sandstone	50–70					
Redman	710	25		40					
Rescue	720	80	Drilled wells	57	73	126			–4
Ruth	754	180	Open and drilled wells.	70–90	10	100	30		
Sebewaing	593	1,431	Drilled wells	60–80	10	300	60+	100–200	Flow
Sigel	740	60	At edge of Marshall sandstone.	5					
Ubly	785	432	Driven or drilled wells.	70–80	10	100	10–12	90–100	–6
Wadsworth	781	20	do	30–40	20	115	80–115	100–115	–20

SUPPLIES BY TOWNSHIPS.[a]

SEBEWAING TOWNSHIP.

In Sebewaing Township (T. 15 N., R. 9 E.) there is very little water in the drift, for it is composed almost entirely of clay. In some cases, however, the wells obtain water just above the rock, but since coal mining has become extensive such wells are generally deepened into

[a] From detailed records of State survey; see report on Huron County.

the rock. These at first flowed, but pumping out the 100 feet of water from mines has stopped the flow. There are also shallow wells on the sand ridges supplied by surface water. A reference to the rock-contour map of the county (fig. 52) shows a pre-Glacial valley crossing the township southeast of Sebewaing. The extra thickness of drift seems to be due mainly to an addition of sand and gravel at the bottom. Possibly some of the sand and gravel is pre-Glacial, but all that has been inspected in the drillings is plainly Glacial. The three sections following illustrate the difference between a well in the pre-Glacial valley and those outside:

Record of Charles Winter well in pre-Glacial valley, sec. 20, Sebewaing Township.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	74	74
Sand and gravel	45	119
Carboniferous rock	97	216

Record of Joseph Green well, sec. 11, Sebewaing Township.

	Thickness.	Total.
	Feet.	*Feet.*
Red or oxidized clay	9	9
Blue clay	48	57
Hardpan and bowlders	2	59
Sand and gravel with water [a]	1	60

[a] Low in chlorides and strong in sulphates.

Record of well at Saginaw mine, sec. 17, Sebewaing Township.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	8	8
Clay and dry fine sand	12	20
Blue clay	28	48
Bowlders	5	53
Sand rock, etc	212	265

The waters vary in the amount of chlorine, are often strong in sulphates, and are not infrequently cathartic, especially in rock wells.

In secs. 32 to 34 there is a flowing-well district, in which the temperatures are from 50° to 52°. In one case a well in sec. 34 obtained its supply just above the bed rock in quicksand at a depth of 60 feet, the altitude was 629 feet and the head 2 feet.

The rock wells of the township may be divided into two groups: Wells from the Carboniferous limestone or from gravel just above it at from 56 to 100 feet, and wells from the Upper Marshall sandstone at depths of 150 to 200 feet. Since the latter pass through dolomitic shales and perhaps gypsum of the Michigan formation, there is need for casing off the sulphated and cathartic waters which these rocks carry.

BROOKFIELD TOWNSHIP.

Brookfield Township (T. 15 N., R. 10 E.) is very flat and except for a triangular tract of about 2 square miles in the southeast corner was originally swamp. The water rises generally above or nearly to the surface. The drift, like that of Sebewaing Township, is mainly clay, with sometimes a little sand or gravel above or below it. From secs. 10 and 14 southwestward the drift is not thick, being usually less than 50 feet, but in sec. 5 it is 115 feet, as shown in the record below, and in sec. 3, 135 feet. The water is variable in quality, chlorine being often perceptible and sulphates varying from nothing to strong.

Record of L. Wisner well, sec. 5, Brookfield Township.

	Thickness.	Total.
	Feet.	*Feet.*
Red clay	13	13
Blue clay	52	65
Hardpan and bowlders	8	73
Sand and gravel	2	75
Mainly sand	40	115
Sand rock with water	25	140

The well of Fritz Matz in sec. 3, 235 feet in depth, apparently penetrated 135 feet of drift, mainly blue clay.

GRANT TOWNSHIP.

In Grant Township (T. 15 N., R. 11 E.) the thickness of the drift varies from only 30 to 35 feet in the northwest corner to a very considerable thickness at the southeast and contains a larger proportion of sand than the townships to the west. Wells are usually obtained at 35 to 60 feet in the southeast part of the township without reaching rock, and the character of the drift is variable. The most detailed and accurate record is that of Mrs. Walsh's well, presented below:

Record of Mrs. Walsh's well, sec. 17, Grant Township.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	15	15
Quicksand	20	35
Red clay, gravelly and hard	22	57
Rock.		

SHERIDAN TOWNSHIP.

In Sheridan Township (T. 15 N., R. 12 E.) the wells are generally shallow, often getting an abundant supply in gravel at 12 to 20 feet, though occasionally bored 20 to 30 feet. No doubt a good supply of soft water from sandstone could be obtained within 200 feet. On the southeastern edge of the township are a few wells in rock, the distance to rock ranging from 24 to 102 feet, as follows: In sec. 13, 24 feet; in sec. 24, on a hill, 102 feet; in sec. 35, 73 feet; in sec. 36, 60 feet.

BINGHAM TOWNSHIP.

In Bingham Township (T. 15 N., R. 13 E.) the hills are largely of till, which is not a good water bearer, and the wells on them, often 100 feet deep, enter the underlying Upper Marshall sandstone. The well of R. Harrison, in the southeast part of sec. 2, at altitude 879 feet above tide, penetrated 130 feet of drift and has a water level 60 feet below the surface. There was 80 feet of hard till and blue clay beneath which was 50 feet of fine sand or silt. In the valleys sandstone is struck at 25 feet or less and the drift is largely gravel. Wells are often obtained around Ubly in the gravel at 10 to 12 feet, while at Wadsworth they are 20 to 40 feet deep. At Ubly there is a bed of till under the surface sand and gravel which in some cases is underlain by another gravel bed extending to bed rock at 70 to 80 feet.

PARIS TOWNSHIP.

In Paris Township (T. 15 N., R. 14 E.) the drift is thin at the northeast corner, but increases in thickness to the southwest, where the rock may be struck anywhere from 40 to 100 feet or more. Sandstone underlies the whole township.

SHERMAN TOWNSHIP.

In Sherman Township (T. 15 N., R. 15 E.) most of the wells are shallow and chiefly in the sand or gravel of the old lake shores, for the underlying drift appears to be a heavy clay and the rock is shale, in which salty water is struck in limited amounts.

WHITEROCK TOWNSHIP.

In Whiterock Township (T. 15 N., R. 16 E.) conditions are similar to those in Sherman Township, and the best reliance seems to be on shallow surface wells carefully protected from contamination. There are springs along the bank of the old Lake Algonquin.

SAND BEACH TOWNSHIP.

In Sand Beach Township (T. 16 N., Rs. 15 and 16 E.) the drift is mainly clay except for sand on the surface, and varies in depth from a feather edge to 83 feet or more. The wells into rock are likely to be salty. The village of Harbor Beach, as indicated above, is supplied by pumping from Lake Huron.

SIGEL TOWNSHIP.

In Sigel Township (T. 16 N., R. 14 E.) are large surface deposits of sand and gravel, and shallow wells using surface water are common. Good water may be obtained from the underlying sandstone.

VERONA TOWNSHIP.

In Verona Township (T. 16 N., R. 13 E.) the wells are either shallow, with a depth of but 10 to 12 feet, or are over 40 feet. There is usually 40 to 45 feet of clay above the sandstone. Wells in the sand rock flow at an elevation of 4 to 5 feet above the lowest level. The following are typical records:

Well records in Verona Township.

	Thickness.	Total.		Thickness.	Total.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Muck and shell marl	5	5	Gravel	12	12
Clay	20	25	Hardpan	20	32
Gravel	5	30	Blue clay	7	39
Hardpan	15	45	Gravel	3	42
Sand rock	30+	75+	Hardpan	2	44
			Sand rock	16+	60+

The flowing-well water has a temperature of about 47° F. and a hardness of 5° to 6° on Clark's scale.

Wells put down to test the possibilities of water supply for a sugar factory in Bad Axe near the Pere Marquette Railroad tracks, in sec. 19, Verona Township, at an altitude of 756 feet, are all reported to flow at times after storms, etc. At the time of the writer's visit, however, only one was flowing. This had a temperature of 47°. These wells are 340 feet deep and have 46 feet of 7-inch casing, reaching probably to bed rock. The Bad Axe public supply is discussed above.

COLFAX TOWNSHIP.

In Colfax Township (T. 16 N., R. 12 E.), which includes the western part of the village of Bad Axe, the Marshall sandstone is struck at no great depth, the drift being usually 20 feet or less in thickness, but in sec. 19 the drift is 60 feet. A cherty limestone, with gypsum and shale in places, immediately underlies the drift, but the three have a combined thickness of only about 50 feet, thus making the depth to the Marshall sandstone about 70 feet.

OLIVER TOWNSHIP.

In Oliver Township (T. 16 N., R. 11 E.) there were many flowing wells, but most of them have failed, the failure being attributed in part to the draft made by the railroad water tank, in which the pipe was cut off below ground and the water allowed to flow into the tank. No doubt the lowering of the ground-water level by ditching has something to do with the failure. Wells in sec. 8 obtain their water just above the rock at a depth of 50 to 65 feet. At Elkton sandstone was reached at 25 feet, and the depth to rock is 20 to 35 feet through secs. 20, 21, 22, 27, 28, and 33. Flows are not uncommon and have a temperature of 47.5° F. An interesting feature is reported from a well in sec. 36 only 13 feet in depth and charged with H_2S. When the wind is from the east the water becomes black. By some change of relative head an iron-bearing or chalybeate water may enter at such times.

WINSOR TOWNSHIP.

Winsor Township (T. 16 N., R. 10 E.) is a fertile, well-settled township full of wells, many of them deep. Some of those passing through the Michigan formation are highly mineralized. A pre-Glacial valley traverses the township from north to south, nearly following Pigeon Valley, and a limestone ridge with a steep escarpment toward this valley lies to the west of it, thus giving much variety in the wells. Near Berne, in secs. 1 and 2, wells 30 to 40 feet deep obtain, just at the top of the rock, water which rises barely to the surface. In sec. 6, also, wells almost flow, or flow until midsummer. They are obtained from the rock at depths of 20 to 29 feet, the rock being entered at 7 to 16 feet. Wells are shallow in secs. 4 and 5 and are liable to go dry. In sec. 7 wells 27 to 37 feet deep sometimes flow and give a temperature of 49° to° 50 F. In secs. 8 and 9 the rock is from 2 to 38 feet from the surface, and in the latter section wells 180 to 190 feet deep flow with temperatures of from 47° to 48°. Around Pigeon the drift is largely clay and reaches a depth of 90 feet. The lower part is slippery blue clay, which tends to close up the wells. Water is obtained from sandstone at about 120 feet. In secs. 13 and 14 dug wells 12 to 15 feet deep occur, but are liable to go dry. There are also wells 175 to 200 feet deep which flow. In secs. 15, 16, 17, and 18 many wells are put to the limestone 24 to 40 feet, and shallow wells are usually obtained in secs. 19 to 26. In secs. 27 and 28 they pass through a large amount of drift. One at school district No. 1 struck rock at 74 feet, as shown in the following section:

Record of schoolhouse well, sec. 28, Winsor Township.

	Thickness.	Total depth.
	Feet.	*Feet.*
Red or oxidized clay	12	12
Blue clay	39	51
Hardpan and bowlders	3	54
Sand and gravel	1	55
Hardpan and bowlders	19	74
Slate rock	12½	86½

In sec. 29, Winsor Township, wells range from 69 to 188 feet, the upper limit being the bed-rock surface. In sec. 30 bed rock is at about 60 feet and wells are from 40 to 200 feet. In this southwest part of the township they are likely to be strong in sulphates. In the southern sections the drift is thick, being about 60 feet in sec. 31, 64 to 80 feet in sec. 32, 70 to 80 feet in sec. 33, 104 to 120 feet in sec. 34, and 73 feet, at Linkville, in sec. 35. In these sections the drift is very largely clay, and water is obtained at its base or in the rock.

FAIRHAVEN TOWNSHIP.

In Fairhaven Township and Bayport (Tps. 16 and 17 N., R. 9 E.) a heavy belt of sand, the Algonquin beach and dunes, is present, on which surface wells can readily be obtained. Back of it is an old muck swamp under the north end of which limestone sets in at a very few feet and water comes nearly to the surface, rising a little above when the quarries are not pumped and falling below when they are pumped. The temperature of these wells when flowing in the summer was 50° to 51.5° F. A flowing well on sec. 28 struck bed rock at 60 feet and terminated at 100 feet; temperature of water 51.5°. Most of the wells at Bayport are in the sub-Carboniferous limestone, which is covered mainly by sand.

CASEVILLE TOWNSHIP.

In Caseville Township (Tps. 17 and 18 N., R. 10 E.) is a belt of sand dunes east of which the soil and drift is mainly clay. An abundant, though highly sulphated, supply of water is generally found at the base of the drift. Wells which terminate in the Michigan formation or which are not cased through that group are often highly mineralized. When the wells are sunk into the Marshall sandstone, it would be better always to case off the supply from the Michigan formation. Bored or dug wells when over the line of pre-Glacial channels penetrate 70 feet or more of drift, but elsewhere rock is struck at less depth. In Caseville the water comes to within about 5 feet of the surface.

CHANDLER TOWNSHIP.

In Chandler Township (T. 17 N., R. 11 E.) there are good wells in the sandstone in secs. 1, 2, 3, and 4, rock being entered at about 25 feet. The deeper wells in sec. 4 have a head close to the surface. On the west side of sec. 5 wells begin to be brackish because of the gypsum, whose line of outcrop runs from this section to Soule. Wells in sec. 6 are shallow, in sec. 7 deep and saline, and in sec. 8 strongly sulphated, being drilled into the gypsum. They sometimes flow even when only 18 to 25 feet deep. In secs. 10 to 13 rock is entered at 30 to 37 feet and in sec. 14 at 40 feet, the drift being largely blue clay, but supplied with water beds at 12 to 18 feet in sec. 14. Sulphated waters are struck at the top of the rock in secs. 16, 17, 18, and 20 at about 30 feet. In sec. 19 a fair water was obtained at 16 feet, but a well 45 feet deep was too highly mineralized. In the southern half of the township wells in the drift are not very reliable, and in several sections wells have been sunk to the Marshall sandstone. There are springs on the banks of the Pinnebog in sec. 26 and some dug wells 18 to 30 feet in depth. In sec. 33 is a till ridge flanked by gravel, in which very shallow wells are sometimes obtained.

MEADE TOWNSHIP.

In Meade Township (T. 17 N., R. 12 E.) the Upper Marshall sandstone is usually drawn upon and bed rock is sometimes practically at the surface. A series of sand and gravel ridges, which afford surface water, traverses the township from the southwest to the northeast corners.

LINCOLN TOWNSHIP.

In Lincoln Township (T. 17 N., R. 13 E.) there are a number of shallow wells in gravel beneath blue clay. Those at Kinde run from 11 to 20 feet deep. Rock is struck in sec. 19 at 37 feet and in sec. 20 at 50 feet. In the northern part of sec. 22 a well 21.5 feet deep has water which comes from sand under the clay within a foot of the surface. The well apparently has iron and organic matter derived from the marsh.

BLOOMFIELD TOWNSHIP.

In Bloomfield Township (T. 17 N., R. 14 E.) the Lower Marshall sandstone is struck at from 11 to 30 feet, though in secs. 20 and 22 the distance to rock is 40 feet or more.

RUBICON TOWNSHIP.

Rubicon Township (T. 17, R. 15 E.) is traversed diagonally by several sand ridges parallel to the lake shore, which furnish surface water at a depth of about 12 feet. The drift beneath is largely clay with a scanty yield of water, and the wells which enter rock are liable to obtain salty water.

LAKE TOWNSHIP.

In Lake Township (T. 18 N., R. 11 E.) is a heavy belt of dune sand bordering the shore behind, which is a swampy area from which the surface rises back from the lake. Sandstone is very probably not very far down, though in sec. 26 the distance to rock is 40 feet. In sec. 32 are pits that suggest the presence of cavernous limestone or gypsum.

HUME TOWNSHIP.

In Hume Township (T. 18 N., R. 12 E.) the shore-sand belt and general conditions are much as in Lake Township. The drift in places is but 5 to 7 feet, though in sec. 13 it reaches 32 feet. The only well that reports anything but clay before reaching bed rock is on sec. 26. It strikes quicksand or silt at 12 to 14 feet. On sec. 28 is a flowing well bored 40 feet. The distance to rock in sec. 31 is 30 feet and about the same in sec. 35.

DWIGHT TOWNSHIP.

In Dwight Township (T. 18 N., R. 13 E.) sandstone is in places at the surface, and numerous wells are obtained from it at a depth of 20 feet or less A flowing well on sec. 8 is 100 feet deep with a head of 1 foot, the ground being 10 or 15 feet above the neighboring stream. Aside from the sand ridges the drift is generally a blue clay, though on sec. 35 a well is said to have passed through 20 feet of coarse gravel above the clay.

HURON TOWNSHIP.

In Huron Township (T. 18 N., R. 14 E.) are numerous wells which enter rock at depths ranging from 3 feet to 40 feet; usually they are said to be through clay. In secs. 18, 19, and 30 wells are obtained in gravel or sand just above the rock at depths of about 25 feet. Along the Lake Huron shore there is a strip of country about 2 miles wide, where shale is penetrated immediately below the drift and yields salt water in scanty amount.

GORE TOWNSHIP.

In Gore Township (T. 18 N., R. 15 E.) the rock water is likely to be somewhat salty and the supply from the drift scanty, since the latter is largely clay. The best chance for water is at the junction of the drift and rock at 26 to 30 feet.

PORT AUSTIN TOWNSHIP.

In Port Austin Township (T. 19 N., Rs. 12 and 13 E.) rock is usually struck within 12 to 22 feet of the surface. In the village of Port Austin the shallow wells penetrate clay about 10 feet and gravel 3 feet, obtaining water at the top of the rock.

WATER SUPPLIES OF THE NORTHWEST BORDER OF SAGINAW BAY.

By W. M. Gregory.

GENERAL STATEMENT.

There is a gradual rise from the shore of Saginaw Bay northwestward across Arenac and Iosco counties to the upper limits of the Glacial lakes that once covered the region to an altitude about 800 feet above tide (Pl. IV). The lake plain is in places sand covered and barren. Clayey portions are rapidly becoming settled. In northern Iosco County there is a large sand plain standing 100 to 150 feet above the valley of Au Sable River, in which the water table is probably nearly as low as the stream, but as the country is unsettled no wells have been made in it, except along the borders. On the clay tracts wells are ordinarily obtained at less than 50 feet and often at but 10 to 20 feet.

WATERWORKS.

Waterworks are in operation at Au Sable, Oscoda, and East Tawas, which draw their supply from Lake Huron. At Standish is a waterworks plant used chiefly for fire protection, which draws from wells and a small creek.

FLOWING WELLS.

LOCATION.

In the belt of lowland bordering Saginaw Bay from Pinconning to East Tawas flowing wells are numerous. Some of these are from the drift, but the larger number are from the rock. There are also deep wells drilled for brine some years ago when the sawmills had plenty of fuel for the manufacture of salt. These are located at East Tawas, Tawas, Harmon, Augres, Standish, and Pinconning. At East Tawas one of the brine wells flowed. At Tawas after plugging the wells and drawing the upper part of the casing, thus allowing water from higher levels to enter, flows have been obtained in wells in which the brine rose only to 30 feet below the surface.

There is another flowing-well belt running nearly parallel with the one just mentioned, from Mount Pleasant, Isabella County, to Rose City, Ogemaw County. The district lying between the two belts has occasional flowing wells, usually along stream valleys, but generally no flows can be expected, and in places water is difficult to obtain. The western flowing-well belt is discussed on pages 92–115, the present discussion being confined to the belt bordering Saginaw Bay and the district with few flows lying back of it.

The flowing wells are most numerous at three villages in the belt bordering Saginaw Bay, namely, Pinconning, Twining, and Tawas, the remainder being scattered or in small groups. Data concerning them are assembled in the table on the next page.

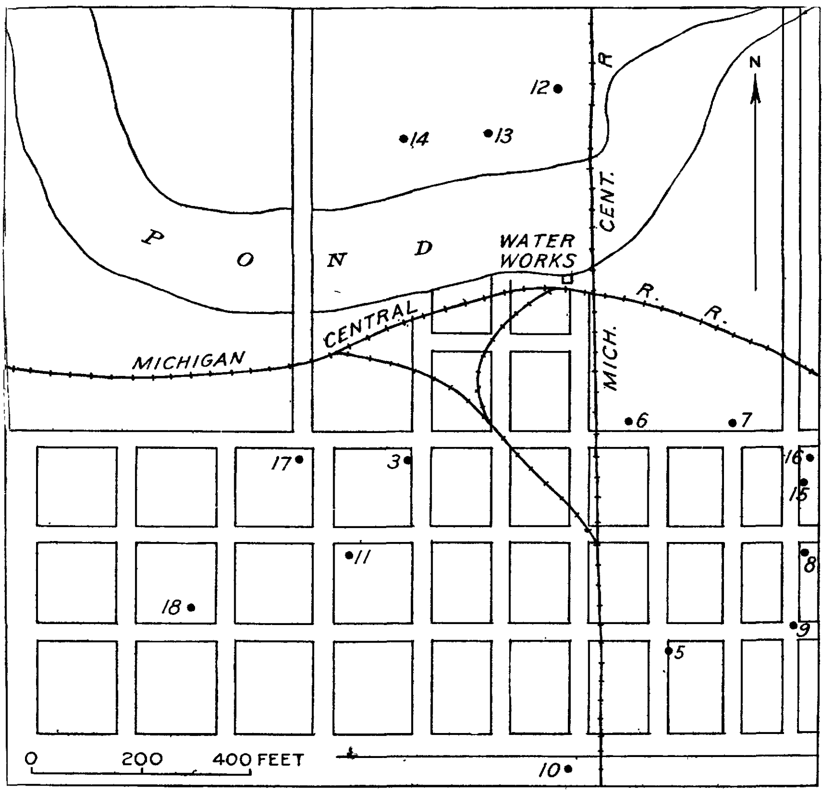
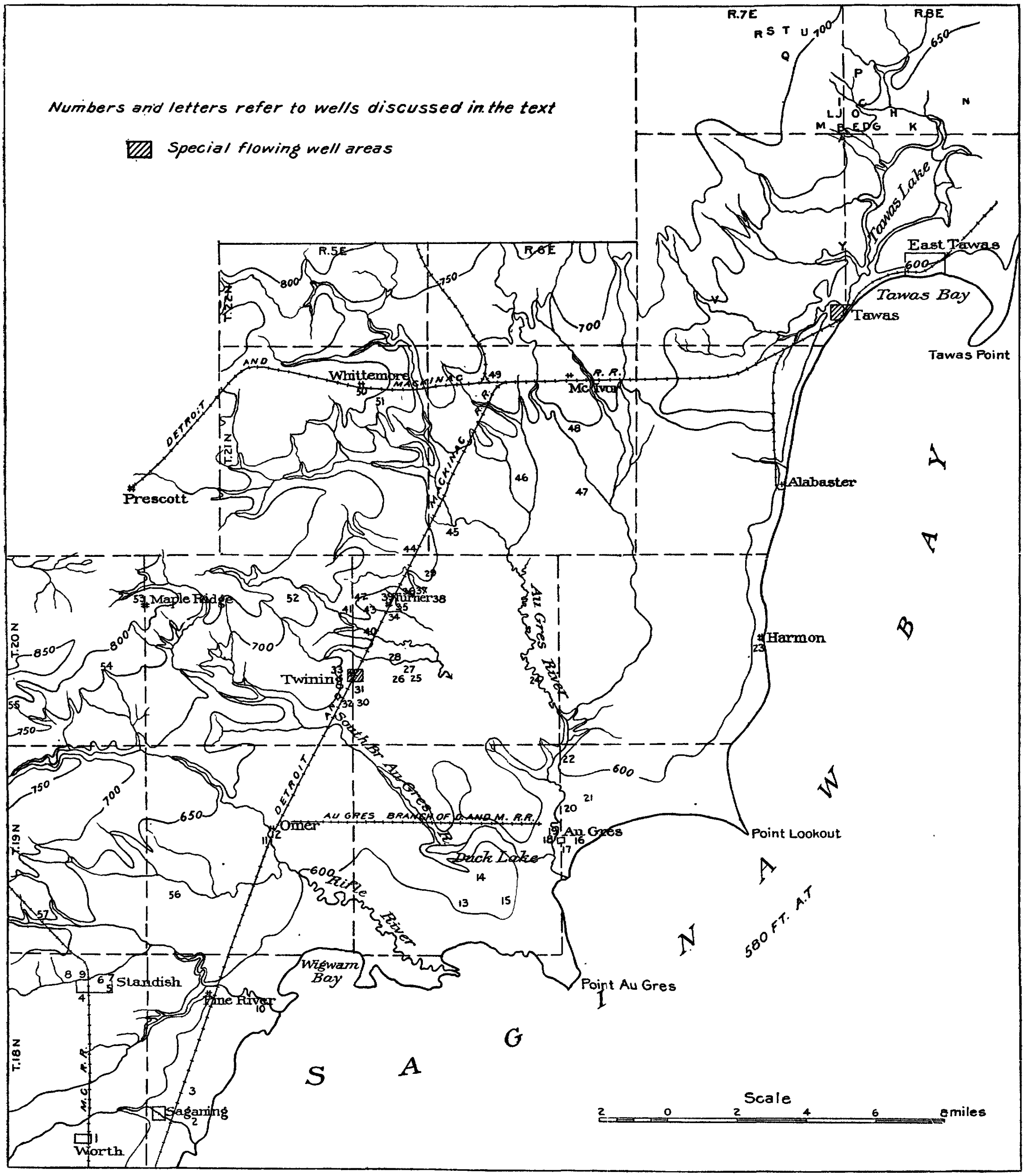


FIG. 54.—Map of Pinconning, Bay County, showing distribution of flowing wells.

PINCONNING.

General conditions in the vicinity of Pinconning are described under the discussion of Bay County, by W. F. Cooper. The detailed data in the table were collected by the writer in connection with other flowing-well districts bordering Saginaw Bay.



TOPOGRAPHIC AND ARTESIAN-WELL MAP OF THE NORTH SHORE OF SAGINAW BAY.

Wells at Pinconning.

No. on fig. 54.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	° F.		
1	D. Markwart	596	56	540	597	0.1		Hard	Weak flow.
2	Henry Shook	596	52	544	601	.3	51	Salty; hard	Decreased.
3	School	597	58	539	605	.9	51½	Salty	Drinking.
4	F. W. Klump	596	72	524		.8		Salty; hard	Store well; drinking.
5	W. A. McDonald	596	60	536		.5		Hard	Store.
6	F. W. Klump	595	53	542		.9		do	House use.
7	Louis Pelky	594	50	544	604	2			Just to rock.
8	Catholic Church	594	52	542		.3		Brackish, hard	Flow decreasing.
9	W. A. McDonald	596	48	548		.9		Salty	House use.
10	Stave mill	596	65	531	607	1	49½	do	Rock at 45 feet.
11	A. Grimshaw	596	60	536	606	1.5		do	Flow decreasing; rock at 50 feet.
12	Wm. Davis	598	28	570	596				Stopped flowing.
13	Ed. La Penie	597	42	555		1		Salty	Sand, 20 feet; clay, 22 feet; water from gravel.
14	Emery La Marsh	597	46	551		2	48½		House use.
15	M. Stevens	595	64	531	607	1	49	Salty; hard	Good flow at 60 feet; coal at 140 feet; salt water.
16	O. Sullivan	596	65	531		.9		Hard	House use.
17	Geo. Hartingh	597	59	538		.6			Do.
18	Ed. Jennings		65						Rock at 55 feet.

The diameter of each of these wells is 2 inches. There are six other flowing wells concerning which no data could be obtained owned by Doctor Grosjean, Peter Collie, M. Doan, A. W. Fisk, J. Morris, and John Francis, respectfully.

TWINING.

The water supply of the village of Twining in Arenac County is from rock wells, and the neighboring villages of Standish, Omer, Augres, and Turner (Pl. V, *A*) have a like source of supply. In Twining the largest number of village wells have been developed, but there are many more wells scattered over Arenac, Iosco, and Bay counties. In Twining the rock is covered by 12 to 20 feet of drift, which is largely clay with bowlders of limestone and gypsum from the Michigan formation, which is the bed rock of the region, outcropping at Alabaster and Harmon on the shore of Lake Huron.

Water is never obtained from the gypsum beds in the Michigan formation except in a few cases where crevices allow a small amount of percolating water. Where the gypsum beds are near the surface sink holes are frequently found in places where the water has dissolved a considerable passageway, a few being found southwest of Alabaster. Beneath the larger gypsum beds are the sandstone and limestone beds in which the smaller seams of gypsum are frequently entirely dissolved, and when these beds are opened by drilling through the gypsum plenty of water is found.

In the village limits the water supply is from thirty rock wells which have been drilled within the last twelve years and have been flowing uninterruptedly since they were made. A slight decrease in volume during the summer months has been observed by some of the well owners. The supply derived from these wells is valuable, and all wells should be carefully piped and properly controlled so that no unnecessary waste of the water would result, as it might cause permanent loss of head and volume.

It is necessary to case each well down to the rock to shut out the bitter water which collects above the rock. The presence of this bit-

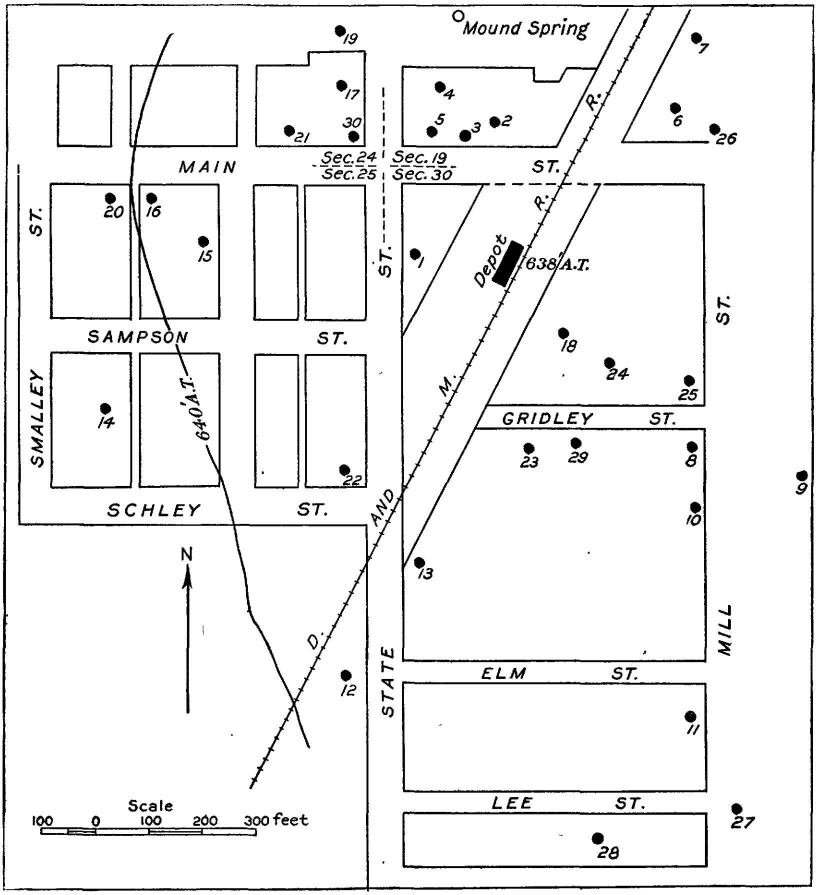
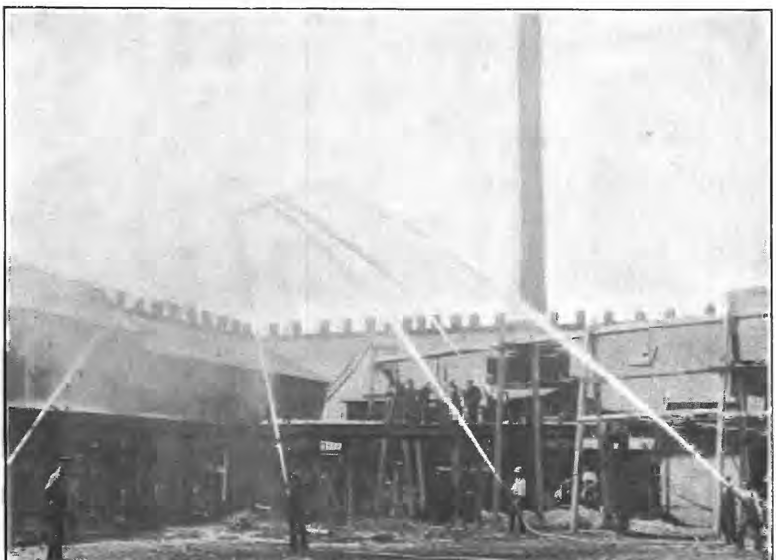


FIG. 55.—Map of Twining, Arenac County, showing distribution of flowing wells.

ter water in the drift often renders the supply from this source useless for stock and unfit for domestic purposes. The rock wells afford an abundant and suitable supply for all purposes, and failures to obtain a flow have seldom occurred when the drilling was properly done. The presence of sulphates in the water gives rise to deposits of calcium sulphate which tend to choke the pipe and decrease the flowage, but this is not general enough to seriously interfere with the supply. The cost

A. LARGE FLOWING WELL FROM ROCK, TURNER, ARENAC COUNTY.



B. FIRE-SERVICE TEST, ARCADIA, MANISTEE COUNTY.

Showing five streams from a single well under natural pressure.

of drilling averages about $0.75 a foot, which is cheap for wells in the rock, but higher than the price usually paid for obtaining flows from the drift.

The largest flow is 25 gallons a minute from a well (No. 6 of table) on the mill property of T. MacCrady. The flow of some of the wells varies at different times of the year. For instance, Mr. T. Reade's well (No. 14) ceased to flow during a drought in July and August, 1904, while at the time of the writer's visit, which was four days after the close of a week of heavy rainfall, there was a flow of 0.8 gallon a minute. Mr. F. L. Twining has had the same experience with a well (No. 5) which flows much stronger in the spring and late in the fall and shows a noticeable increase several days after a period of prolonged rain. In July, 1903, Mr. Twining's well at the store (No. 5) flowed 10 gallons a minute, while in July, 1904, its flow was very small and a pump was required. A number of other wells have shown a tendency to decrease. At the Hotel Normal in July, 1903, the well had a flow of 3 gallons a minute, while in July, 1904, the water level was 2 feet below the surface. That several of the wells have a common supply is shown by the decrease in the flow of wells Nos. 2, 3, and 5, when in May, 1903, well No. 6 was allowed to flow for three days. In July, 1903, Mr. George Dillon's well (No. 16) flowed nearly 10 gallons a minute, but in July, 1904, the flow was very small and varied from day to day, its variations depending on the rainfall, according to those who had observed it carefully. The flow differs somewhat with the character of the rock in which the well is drilled. If it is largely sandstone, the supply is more uniform than where the beds contain considerable gypsum. In the latter case the water follows dissolved passages from the surface and frequently brings to the well silt and plant remains after heavy rains.

The shallow wells which are deep enough to meet ordinary domestic needs furnish water high in sulphates and carbonates and are often quite bitter when from near the top of the rock. Of the wells which flow from the rock, the water highest in sulphates and carbonates comes from wells Nos. 1 and 9. In the latter the water was mixed with surface water for use in steaming, but has been discarded because of trouble with boiler scale. In Mr. J. W. Jaynes's well (No. 15) the water is so soft that it is used for laundry purposes without addition of the softening compounds that are necessary with much of the water in this region.

Wells at Twining.

No. on fig. 55.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to.	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	° *F.*		
1	Hotel Normal [a]	639	76	563	642		48	Hard	Hotel use.
2	J. March [b]	639	57	582			47	do	Domestic use.
3	E. F. White [c]	639	43	596			47	do	Do.
4	F. L. Twining [d]	639	33	606		12	48		
5	do. [e]	639	64	575			49	Hard	Store and house.
6	T. McCrady (saw-mill) [f].	632	32	600	641	25	47		Used in boilers.
7	B. W. Bodine [g]	632	28	604	649	10	46½	Soft	Used for steaming.
8	J. A. Patterson [h]	635	21	614		2	47		House use.
9	Stave mill [i]	633	52	581	635	5	51	Hard	Drinking.
10	Chas. Hinckley	635	25	610		.5	49	do	House use.
11	Geo. Hollister [j]	636	32	604		1	47		Do.
12	E. Brush	636	26	610	636.5	.3	48	Hard	Do.
13	Chas. Bartlett [k]	636	28	608		1.5	49	do	Do.
14	T. Reade [l]	642	26	616		1.2	47	do	Creamery.
15	J. W. Jaynes [m]	639	42	597		2	48	Soft	House use.
16	George Dillon [n]	640	46	594	641	1.8	47		Do.
17	Wm. Monroe [o]	639	21	618		1	48	Medium	Do.
18	Twining elevator	638	20	618		.5			Drinking.
19	F. L. Twining	639	22	617		.9	48		Stock.
20	School [p]	642	60	582	643	3	48		Drinking.
21	Stevens restaurant.	639	78	561				Hard	Well not used.
22	Mr. Hewett	638	22	618					
23	L. Brooks	638	37	601			47		
24	Hub Mill	638	27	611	648	3	48		
25	L. White	636	32	604		1.5	46½		House use.
26	J. E. Esler	633	51	582			46½		No flow; 19 feet to rock.
27	J. Reade	633	60	572					Pumped.
28	T. Stall	639				.6			
29	George Chubb	637	23	614		1.5			
30	Fred Arno	639	20	619		.4			

[a] Well not flowing in July, 1904; flow in July, 1903, 3 gallons a minute; water high in sulphates.
[b] Flow about 2 gallons a minute in July, 1903; no flow in July, 1904.
[c] Discharge of wells 2 and 3 decreased by well 7. Rock (bluish shale and gypsum) at 11 feet.
[d] Blue shale at 14 to 16 feet; then thin bed of gypsum; at bottom thin bed of sandstone. When this flow was made, the flow of wells Nos. 1, 5, 21, and 17 increased.
[e] Water used in a large butter room for cooling purposes. Mr. Twining says the large percentage of mineral salts in the water improves the quality of the butter. This well flowed 10 gallons a minute in 1903; in 1904 only 1 quart a minute. Much stronger in spring and late in fall; some increase after several days of heavy rain.
[f] 16 feet to rock. Well controlled by check valves. In May, 1903, was opened and allowed to flow for three days, lowering the head of Nos. 2, 3, and 5.
[g] Rock at 23 feet; water from beneath a shale.
[h] In 1903 good flow; decreased by well No. 11; drift 10 feet.
[i] Too hard for boiler use. High temperature of water caused by boilers located near well. 14 feet to gypsum; head lowered by No. 11.
[j] Flow decreased soon after No. 7 was drilled. Allowed to flow freely for a few hours.
[k] Drift, 12 feet; blue shale, 5 feet; gypsum, 5 feet; shale, 5 feet; gypsum, 3 feet; sandstone and shale, 6 feet.
[l] Rock at 13 feet (gypsum and shale); water in sandstone.
[m] Flow decreased by well No. 16 on George Dillon's lot.
[n] The flow of this well ceased during the drought in June and July, 1904. At the time of the writer's visit, four days after a week of heavy rainfall, the well was flowing about 8 gallons a minute.
[o] Rock at 17 feet (sandy shale rock). Water from sand veins at 19, 24, 30, and 42 feet.
[p] Flow decreased since 1903; it was then nearly 10 gallons a minute; rock at 21 feet.

TAWAS.

This area of flowing wells occupies nearly 1 square mile on the shore of Saginaw Bay in Tawas, the county seat of Iosco County (fig. 56). Two miles west of Tawas there is a low moraine which is the catchment slope of some of the wells. At East Tawas, 1 mile to the east, flows can not be obtained, although water rises just to the surface in some wells near the lake shore. To the north and west of Tawas flows are obtained on the plain between the town and the moraine.

In this area rock outcrops are entirely absent, but the first or upper rock formation is known, from the records of the deep brine wells, to be near the base of the Michigan formation and top of the Marshall sandstone. The sandstone yields abundant water when penetrated in regions to the southwest, and possibly part of the supply for the wells here may be derived from the same source. The Marshall sand-

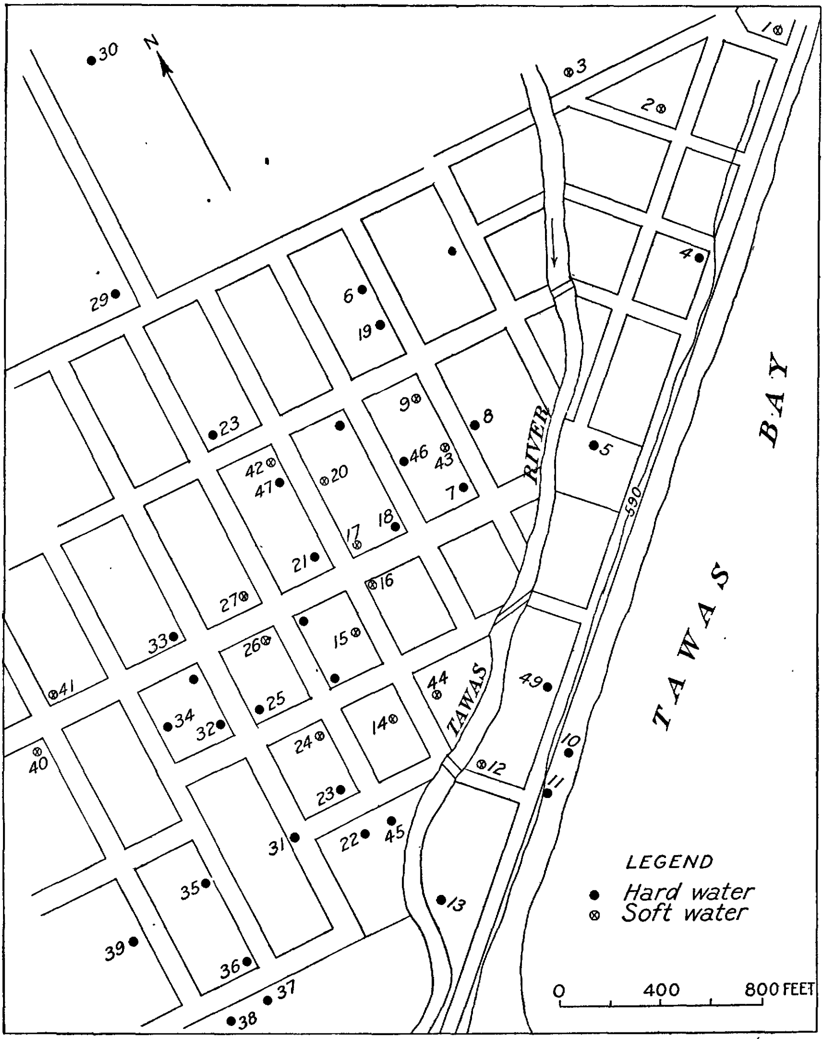


FIG. 56.—Map of Tawas flowing-well district, Iosco County.

stone dips to the southwest from Tawas, and 5 miles south, at a test shaft in the quarry at Alabaster, it was reached at 90 feet and water found in the sandstone with sufficient head to fill the shaft.

The drift at East Tawas and Tawas is 80 to 120 feet in thickness. Rock is reached at 84 feet in Frank Black's well in East Tawas, and in the same place on the property of the Michigan Brine Works rock is 100 feet from the surface. In Tawas the Wenona Salt and Lumber Company struck rock at 100 feet, and at the Bayside Hotel rock was found at 120 feet. In a cut on Dead Creek, in the western part of this village, is a hard compact clay containing minute shells, such as inhabit the lake, and some driftwood, overlain with 15 feet of lake sand and gravel. In several wells driftwood has been encountered at 50 to 75 feet. The drift material is not generally water bearing except at bottom where sand and gravel are found in thin layers. The wells are usually drilled by contract for a flow, the price averaging from $40 to $70, while some of the test wells which penetrate the rock some distance are made for $1 a foot without the pipe.

The total flow of 43 wells at Tawas is 137.3 gallons a minute. The strongest flow is from a well on the Blust estate (No. 34), which yields 19.3 gallons a minute. The flow is decreased in some cases by the escape of the water at a lower level, owing to corrosion of the pipes, while in other cases wells on lower ground have checked flows on higher ground. It is thought that the former is the cause of the decrease in flow of Joseph Minor's well, though possibly it may be drained by well No. 22 on the property of Mr. Davidson. The wells require frequent sand pumping and removal of the deposits inside the pipes. The Phelan well (No. 26) and German Lutheran Church well (No. 41) ceased to flow in the fall of 1903; after being sand pumped and cleaned, the flow returned to about the amount when the well was drilled. The wells which do not yield water readily are increased by a small blast of dynamite at the bottom. A greater flow in these wells following a prolonged season of rain is reported by some well owners, but not verified.

The quality of the water varies considerably with the depth of the well. It is common to find a soft water at a greater depth and evidently near the rock surface. The water in most wells over 90 feet in depth is soft, but in those less than 90 feet is usually hard and in some cases is so high in sulphates that it is unfit for domestic purposes, as at Grice's blacksmith shop (No. 11) and on the Blust estate. Following are analyses of water from some of the wells:

Analyses of water from wells in Tawas.

[Parts per million.]

	1.	2.	3.	4.
Sulphates	273	273	88	522
Hardness	616	536	321.6	600
Magnesia	Much.			Much.
Carbonates	180	140	190	95
Chlorides	173.4	120	81.6	204

1. Bayside Hotel. 2. Blust estate. 3. German Lutheran Church. 4. Grice's blacksmith shop.

The wells have been drilled rather uniformly throughout the village, going a little deeper in the eastern than in the western part, where water is reached at a higher altitude. The wells in the western part are from 70 to 80 feet in depth, and supply a harder water than that of the deeper bed, indicating a different source of supply. An examination of the above analyses and tests of several waters for hardness show a water bed supplying a hard water, beneath which is a bed supplying a softer water. The well owners are acquainted with these facts from the use of the water for laundry purposes. The lower bed is believed to be supplied by water forced upward into the gravel and sand from the underlying bed rock of the Michigan formation, which in other localities supplies a soft water. Mr. Van Way, owner of Bayside Hotel, gives the following record of well No. 10:

Record of Bayside Hotel well, Tawas.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	35	35
Sand and gravel	15	50
Hard blue clay	30	80
Sand and gravel, some water, flow	15	95
Clay	5	100
Sand rock with streaks of shale	25	125

Record of Davidson flowing well, Tawas.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	10	10
Clay	50	60
Hardpan	10	70
Sand and gravel	10	80

Mr. Gilbirth, a well driller, gives the following record for a flowing well (No. 29) on the property of G. A. Prescott:

Record of Prescott well, Tawas.

	Thickness.	Total.
	Feet.	*Feet.*
Clay	40	40
Sand	5	45
Hardpan	30	75
Sand and gravel	15	90

Wells at Towas.

No. on fig. 56.	Owner.	Elevation.	Depth.	Diameter.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*In.*	*Feet.*	*Feet.*	*Gals*	*°F.*		
1	N. C. Hartingh	590	104	2	486	.....	1.2	50	Soft	Flow has decreased.
2	John Bagley	592	86	2	506	602	.4	49	....do....	Flow from under clay bed; decreased.
3	Chas. Dixon	589	80	2	509	.....	.....	49	....do....	Crock well, drilled in bottom.
4	G. A. Prescott	592	106	2	486	572	.....	49	....do....	Rock at 98 feet; flow at 86 feet; pump well.
5	Court-house	589	146	3	443	.....	1.5	50	....do....	Sandstone at 120 feet; blue shale at 140 feet.
6	John Swartz	593	101	2	492	.....	.4	49	....do....	Domestic use; excellent water.
7	H. Woizeschke	590	93	2	497	.....	1.2	49	....do....	
8	Nelson Bradon	589	114	2	475	.....	2	49	....	Domestic use.
9	E. D. Schlecter	592	90	2	502	.....	6	48	....	Do.
10	Bayside Hotel	584	125	1½	459	594	2	49	Hard	Said to reach rock at 100 feet; cased, 40 feet; decreased; sulphates present.
11	Grice's blacksmith shop.	583	75	2	508	593	4	47	....do....	No change in flow; sulphates present.
12	M. E. Friedman	585	98	3	496	589	.4	49	....do....	Made in 1897; cost $50; decreased.
13	Wenona Salt and Lumber Co.	585	870	4	285	.....	.....	.....	....do....	Much H_2S; chlorides, medium; salt well; flows from upper beds; rock at 100 feet.
14	A. Grenney	588	87	2	501	594	1	49	Soft	Some CO_2 present.
15	F. Marzinski, sr	589	85	2	504	.....	.5	49	....do....	Trace of sulphates.
16	G. L. Cornville	590	100	2	490	595	.9	49	Hard	Some chlorides; trace of sulphates; domestic use.
17	M. Patterson	590	100	2	490	.....	.5	50	Soft	
18	Henry Funk	590	90	2	500	.....	1	49	Hard	Domestic use.
19	Mike McGarry	592	90	2	502	.....	0	49	....	
20	F. Marzinski, jr	595	104	2	491	.....	.5	50	....	
21	Lutheran Church (Rev. Emmel).	596	90	2	506	.....	1.5	49	....	Drinking.
22	T. Davidson	585	80	2	505	.....	1	49	Hard sulphates.	Sand, 10 feet; clay, 50 feet; hardpan, 10 feet; gravel, 10 feet; water from gravel.
23	J. Hamilton	587	84	2	503	.....	6	48	Hard	Muddy before storms.
24	Heuston House	590	85	2	505	590	0	48	....	Water just at surface.
25	O. Grice	590	95	2	495	.....	6	48	....	
26	Wm. Phelan	590	105	2	485	.....	8	48	Soft	Made in 1890; slight decrease; hard water at 70-foot vein.
27	Dr. MacIntosh	590	90	2	500	.....	3	48	....	No rock; clay, 40 feet; hardpan, 50 feet; gravel, 6 feet; 96 feet to flow.
28	E. B. Van Horn	594	104	2	490	604	4	49	....	
29	G. A. Prescott	598	90	2	508	610	8	47	....	See section (p. 277).
30	J. Nesbit (farm)	600	114	2	486	.....	5	48	....	
31	City well	590	85	2	505	.....	1	47	Hard	Weak flow; supplies 4 houses.
32	Dr. Conant	589	95	1¾	494	.....	4	48	....do....	Water considered slightly cathartic; some chlorides present; sulphates strong.
33	F. Gauthier	590	70	2	520	.....	3.5	49	....	Supplies 2 families; trace of sulphates.
34	Blust estate	588	60	3	528	598	19.3	48	....do....	Sulphates present.
35	W. D. Graham	589	84	2	505	.....	0	48	....do....	Sand, 12 feet; clay, 50 feet; sand and gravel, 20 feet.
36	J. M. Walker	590	59	2	531	.....	8	47	....do....	Sulphates strong.
37	Rev. J. Pierson	588	85	2	503	.....	7	48	....do....	Affected by No. 13; when casing was pulled well stopped flowing.
38	W. D. Wingrove	587	85	2	502	.....	4	47	Hard	Sulphates present.
39	G. H. Redhead	591	78	2	513	606	8	48	....do....	Flow checked; much iron carbonate; not good for laundry purposes; sulphates strong.
40	City public school	594	76	3	518	.....	9	48	Soft	Drinking; flow decreased; trace of sulphates.
41	Lutheran school (Rev. Wuggazer).	592	90	2	502	602	9	48	....do....	See analysis above.
42	F. Ballotman	589	112	2	477	.....	3	49	....do....	Sand, 25 feet; gravel clay, 50 feet; sand and gravel, little water, 10 feet; hard clay, 20 feet; coarse gravel, 7 feet.
43	Chas. Zurek	588	90	2	498	596	1.5	48	....do....	
44	F. W. Schlecht	585	73	2	512	.....	3	47	Hard	Domestic use for 2 families.
45	Joseph Minor	586	75	2	511	.....	.....	.....	....	Decreased; no flow at present.
46	Steve Klish	587	87	2	500	597	3	48	Soft	Made in 1897; no decrease.
47	Mr. Bolt	588	104	2	484	.....	2	48	....do....	Domestic use.

Wells at Tawas—Continued.

No. on fig. 56.	Owner.	Elevation.	Depth.	Diameter.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*In.*	*Feet.*	*Feet.*	*Gals*	*° F.*		
48	Mr. Malone (east of town).	590	68	2	522	.....	1	47	Hard.....	Sand, 14 feet; clay, 40 feet; hardpan, 5 feet; gravel and sand, 9 feet.
49	M. Murphy.......	588	101	2	487	.....	3	49	Soft......	Saloon.
50	Mr. Halleck (west of town).	.....	65	2	.....	.....	2	47	Hard.....	High in sulphates.

Wells in region north of Tawas.

Letter on Pl. IV.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Quality.	Depth to rock.	Remarks.
		Feet.	*Ins.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*		*Feet.*	
A	Andrew Arnold...	660	2	111	449	670	0.8	Hard..	108	Stock well; made in 1900.
B	Milo Stevens.....	663	2	157	505	667	.5	...do..	......	Water bed at 155 feet.
C	C. Kruger........	648	1½	40	608	......	......	....	......	Pump well.
D	George Bennett..	650	2	39	611	640	......	....	......	Do.
E	August Letze.....	660	2	50	610	......	......	....	......	Do.
F	Chas. Green.....	653	2	59	594	......	......	....	......	Do.
G	August Colger....	648	2	40	608	......	......	....	......	Do.
H	E. T. Dowell.....	633	3	58	575	644	1.8	Hard..	57	
I	John McMullin...	665	2½	60	605	685	2.5	....	62	All clay; made in 1903.
J	George Simms....	670	2	83	587	......	2	....	78	Water at 50 and 60 feet.
K	J. Miller..........	630	2	60	570	......	......	....	......	Pump well.
L	John Schrieber....	665	2	82	583	675	3	....	82	Made in 1903.
M	Andrew Franks...	655	2	35	620	......	......	....	......	Pump well.
N	Philip Land Co...	615	2	90	525	......	......	....	......	Pump well; mostly sand.
O	Henry Goodale...	650	2	79	571	......	[a] 2	....	70	Water at 45 and 60 feet.
P	Mr. Sullivan......	670	2	291	379	......	1.5	Salt..	......	Clay 52 feet; cased 70 feet.
Q	Mr. Pierson......	690	2	78	612	......	[a] 1.9	....	40	
R	School house.....	702	2	110	692	712	1	....	91	
S	W. Ames.........	703	2	115	588	......	1.2	....	96	
T	Mr. Gray.........	700	2	68	632	......	1	....	......	Pump well; domestic use.
U	Mr. Robinson....	695	2	69	626	......	1.3	....	59	
V	John Grant......	658	2	160	498	......	......	....	......	Through clay; no water.
W	Mr. Black (Tawas beach).	583	2	145	438	......	......	....	83	Water just to surface.
X	Salt well.........	......	......	......	......				......	
Y	Chas. Conklin....	615	2	104	501	......	......	....	84	No flow.

[a] Flow estimated by driller.

MISCELLANEOUS WELLS.

Scattered wells (mainly flowing) on the northwest border of Saginaw Bay.[a]

Number on Pl. IV.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*° F.*		
1	E. Sack...........	615	......	......	605	......	....	Hard...	Pump well.
2	Bradley farm......	590	105	485	608	1.9	49	....	Rock at 30 feet.
3	E. Butler..........	592	60	532	......	.9	48½	Hard...	Domestic and stock.
4	Primary school, Standish.	626	50	576	......	......	....	....	Just flows; high in sulphates.
5	High school, Standish.	626	230	396	632	1	48	....	Not flowing now.
6	Court-house, Standish.	626	258	368	......	......	48	....	Flowed in 1893; not flowing now.

[a] The diameter of all the wells is 2 inches except the following: Omer village, 1½ inches; August Badour, 3 inches; James Daley, 1½ inches; N. Knight, 1 inch.

Scattered wells (mainly flowing) on the northwest border of Saginaw Bay.—Continued.

Number on Pl. IV.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
7	A. Forsythe	628	85	543		1	48		Barn use; rock at 40 feet.
8	M. M. Milling Co	625	78	547	631	1.1	48		Near boilers.
9	James Norn's mill	626	1,900	1,276		12	50		Water has salt and H_2S.
10	J. Larch	591	101	490		.9	48	Salt	Rock at 8 feet.
11	F. Menzer	610	148	462	609				Rock at 29 feet; no flow.
12	Omer village	611	350	261	618	1.9	49	Hard	Rock at 21 feet; supplies 2 hotels.
13	H. Ullman	604	342	262	624	10			Rock at 22 feet.
14	W. Mackin	608	16	592					Dug well in rock.
15	J. Ryland	601	200	401	631	3	49	Hard	Rock at 12 to 18 feet.
16	Mr. Bradley	586	65	521	566			do	Pump well; rock at 30 feet.
17	August Badour	586	301	285	611	3.5	48	do	Formerly bath house.
18	E. C. Cole's store	587	126	461		2			Rock at 30 feet; supplies store and house.
19	F. D. Noggle	587	29	558	587				Just flows; decreased.
20	Geo. Grimore	590	108	482		2.5	48		Rock at 28 feet.
21	E. C. Cole	595	322	273	611	8.2	48	Hard	Rock at 60 feet; piped to house.
22	Wm. French	600	315	285		3.2			Rock at 20 feet.
23	Harmon salt well	587			587			Bitter	Just flows.
24	Mrs. Peggel	608	146	462		2.1		Hard	Rock at 44 feet.
25	Ed Mosher	622	83	539		.8		do	Rock at 8 feet.
26	J. Pollock	624	57	567	629	2.1	48	do	Rock at 7 feet.
27	J. McCready	622	83	539		.8		do	Rock at 10 feet.
28	J. Pollock (barn)	625	65	560		1.2	48	do	Do.
29	Mr. Swartz	650	240	410	665	12	49	Medium.	Rock at 27 feet; stopped flowing in 1904.
30	Mr. Reade	630	39	591	625			Hard	Rock at 5 feet; pump well.
31	Mr. Campbell	631	17	614				Bitter; hard.	Rock at 14 feet; pump well.
32	J. Barr	638	28	610	631				Unfit for use; rock at 8 feet.
33	W. Aigens	650	25	625				Hard	Pump well; rock at 14 feet.
34	H. Newman	640	140	500	655	2.5	49	do	
35	Mr. Eymer	638	105	533		1.1		do	Rock at 40 feet.
36	Public school, Turner	642	130	512	652	1.8	49	do	
37	S. Churchill	638	10	628				Bitter	Rock at bottom; pump well.
38	J. Clukey	625	300	325		3	50	Hard	Rock at 30 feet.
39	Village well, Turner	635	300	335	640	12	50		See cut; rock at 40 feet.
40	Young Bros	630	53	577				Hard	Pump well; stock and domestic.
41	Philip Rosenthall	640	105	535	653	2.3	48	do	Rock at 26 feet; stock and domestic.
42	Sam. Rosenthall	640	104	536	658	2.5	49	do	Rock at 21 feet; stock and domestic.
43	M. Siebeck	640	40	600					Pump well; drift, gypsum in clay.
44	S. B. Dryer	670	19	651	660			Hard	Pump well; dug.
45	T. Applin	630	250	280	645	15	50	Medium.	Rock at 20 feet; salty.
46	J. Henry	650	115	435				Salt	Just to rock.
47	H. McGrady	629	350	279		2.5		Hard	Rock at 115 feet.
48	N. Johnson	640	139	501					Rock at 115 feet; no flow.
49	Emery Junction Hotel.	677	40	637	647				No rock; little water.
50	J. Curtiss	770	180	590					Rock at 40 feet; 2-inch casing; no flow; little water.
51	George Koyl	730	40	690	642	2.8	48	Medium.	All clay.
52	James Daley	738	100	658				Hard	Brown clay 20 feet; blue clay 40 feet; sand 10 feet; hardpan 30 feet. Pump well.
53	Chas. Jones	810	60	750					Hard clay 14 feet; sand with water 10 feet; clay 35 feet; sand and gravel 1 foot. Pump well.
54	N. Knight	740	149	591					Clay 14 feet; remainder sand. Pump well.
55	Jas. Thompson	795	165	630					Clay 40 feet; sand and gravel 20 feet; clay 30 feet; sand and gravel 75 feet. Pump well.
56	Robert Garner	618	78	540				Soft	Rock at 14 feet; no flow.
57	Old coal shaft	760	106	654					Flow from top of sandstone; Sand 20 feet; clay 10 feet; rock at 30 feet.
58	Black's test well	595	135	460					Rock at 57 feet; no flow.

MISCELLANEOUS VILLAGE SUPPLIES.

The tabulated data on wells and villages and near country post-offices, presented below, were obtained chiefly by correspondence:

Village supplies on northwest border of Saginaw Bay.

Town.	Source.	Depth to rock.	Depth of wells. From—	To—	Common.	Depth to water bed.	Head.	Springs.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Alger	Driven wells	......	15	100	20	80	......	Small.
Arenac	....do	......	8	50	14	14	− 5	Do.
Augres	Dug and drilled wells	16	12	220	16	180	+15	None.
Maple Ridge	Open and driven wells	......	12	45	35	35	......	Small.
Melita	Driven wells	......	18	50	14	14	− 5	
Moores Junction	....do	......	15	50	35	45	−15	Do.
Omer	....do	20	15	104	40	40	+ 2	Do.
Pine River	....do	28	12	138	30	138	+10	Do.
Saganing	....do	70	6	70	20	20	− 8	Do.
Standish	Driven wells, and creek	40	12	350	......	50	+ 8	None.
Sterling	Driven wells	......	14	48	24	......	−14	Small.
Au Sable	Lake Huron by waterworks	......	......	......	......	......	......	
East Tawas	....do	......	......	......	......	......	......	
Hale	Dug and driven wells	......	10	80	40	40	−35	Do.
Oscoda	Lake Huron by waterworks	......	......	......	......	......	......	
Siloam	Dug and driven wells	......	12	33	33	33	−25	Do.
Whittemore	Driven wells	60	20	60	40	60	−20	Do.

WATER SUPPLIES OF OGEMAW COUNTY.

By W. M. Gregory.

GENERAL STATEMENT.[a]

Ogemaw County, of which West Branch is the county seat, lies east of Roscommon County. The elevated moraine which crosses the southeast part of Roscommon County continues northeastward, passing a little east of the center of Ogemaw County, leaving the county at its northeast corner. There is an elevated gravel plain on the northwestern face of this moraine, which at one time was occupied by settlers, but has been abandoned because of the failure of crops in dry seasons. The distance to water on this gravel plain ranges from 10 to 15 feet near the Roscommon County line to about 100 feet in the vicinity of the moraine from Beaver Lake northeastward. On the moraine there are very few residents, and the water table appears to lie at great depth, for the drift is very loose textured.

Southeast of this large moraine are the flowing-well districts of Rose City and West Branch, which stand in recesses in the moraine. There is a broad gravel plain leading from near Rose City and Lupton southward along Rifle River, where the water table lies only a few feet below the surface, but in which there are few settlers.

[a] By Frank Leverett.

In the eastern range of townships is a fertile till tract with gently undulating surface which has as yet but few settlers. Wells are obtained at depths from 20 to 75 feet.

There are exposures of rock along Rifle River in the southern part of the county, but the wells, both flowing and non-flowing, usually obtain their supplies from the drift. One well at Rose City entered the rock and got only a weak flow. Others at West Branch may have reached the rock, and two deep borings near Edwards Lake entered rock.

MISCELLANEOUS VILLAGE SUPPLIES.

At Prescott there are wells ranging in depth from 18 to 75 feet, in which the water stands 12 to 20 feet below the surface, coming from sand beds in the clay. Both open and bored wells are in use.

At Lupton, which stands in the valley of Rifle River, the wells are 20 to 50 feet in depth, and are largely through gravel and sand.

At South Branch, in the eastern part of the county, on the inner border of the large moraine, wells are driven to depths of 20 to 30 feet and obtain abundance of water.

At Edwards post-office, in the southwestern part of the county, the wells are from 6 to 50 feet in depth, the largest supplies being from 35 to 50 feet. Dr. A. C. Lane reports several test borings for coal. One at the south side of Edwards Lake in sec. 29 struck sandstone at 205 feet, and penetrated rock of various kinds for 33 feet. Another near Chapman Lake struck sandstone at 190 feet and continued to a depth of 400 feet. A fresh, soft water was struck at 202 feet, which had a head of 8 feet. A third well, 214 feet in depth, on the east side of George Lake, did not reach rock, but found a flow of fresh, soft water yielding a barrel a minute.

Plans have been made to install a waterworks plant at West Branch in 1906, the supply being taken from flowing wells northwest of the village. These wells discharge into a reservoir from which water will flow by gravity to the village, a distance of about 2 miles.

FLOWING WELLS.

WEST BRANCH AREA.

Location.—The flowing-well area of which West Branch is the center (fig. 57) embraces $2\frac{1}{2}$ square miles on the headwaters of the West Branch of Rifle River. This district is located in a recess along the eastern side of one of the stronger moraines of the Saginaw ice lobe. The actual extent of the area, outside of the above city limits, has not been determined, but it has been traced north and south along the eastern slope of the moraine, and may connect with the well-developed area at Rose City. An almost continuous belt of springs occurs at the edge of the high hills between West Branch and Ogemaw

Springs station, at which place the principal spring flows about 13 gallons a minute. Part of this water comes from loose drift on top of the clay, while the larger share is from beneath a clay bed which has been opened by small creeks working back into the hills. This condition of abundant springs is present about the western edge of the entire area and the flow of water is in proportion to the extent that the creeks have worked back their heads.

Wells.—At present (August, 1904) the number of wells in the general district is 119, of which 106 have fair flows. Of these, 102 flows are within the village limits of West Branch. The wells are all 2 inches in diameter except Nos. 12, 17, and 27, which are 1½ inches. Few wells are pumped and the flowing wells are utilized very generally for stock farms, creamery, domestic use, laundry purposes, a few for steaming, and one in a brewery.

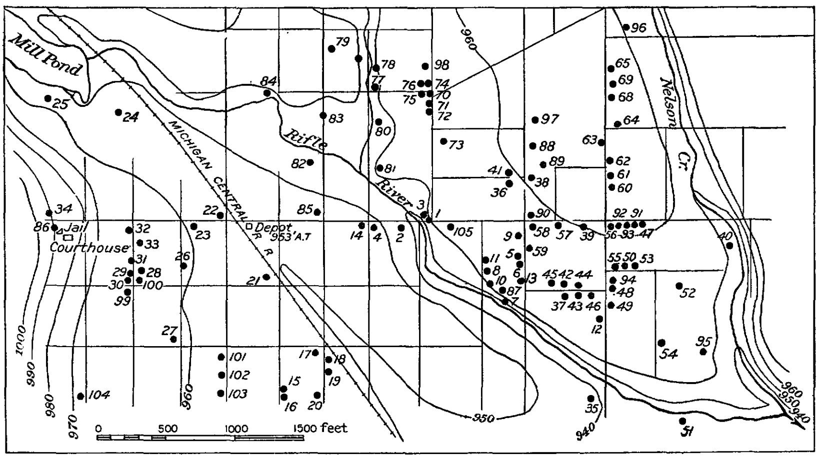


FIG. 57.—Map of West Branch, Ogemaw County, showing flowing wells.

The pioneer well was made by E. V. Goodell in 1880 by driving a 2-inch pipe to the first water bed at 30 feet and later to the 80-foot bed; the supply has decreased since drilling. The number of wells has increased rapidly, and with the increase some of the shallow wells have ceased flowing entirely. The pressure of the water is sufficient in a few cases to warrant piping to the second floor of a dwelling, and hydraulic rams are used in several cases to force water into kitchens.

The cost of the wells is somewhat less than in other regions, ranging from $40 to $80, the low price being due to the slight depth of the water bed and to the use of casing in the deeper wells only. That the supply is valued the large number of wells show, but only in a few instances are check valves used, the large majority of the wells being allowed to flow full capacity throughout the entire year.

This wasteful practise is believed to be the cause of the decrease of the flow shown in the past two years.

Flow.—The total flow from 106 wells is about 610 gallons a minute, of which 540 gallons are from wells within the limits of West Branch. The strongest flow is 60 gallons a minute, on the property of C. J. Blakeley (No. 22), and another large flow is at the West Branch brewery of Mr. A. M. Schieke (No. 40), where the combined flow of three connected wells is 156 gallons a minute. Many of the flows from the upper water beds have been decreasing for the last three years, this decrease being noted in many wells that the writer saw in 1903 and 1904. In some cases the decrease has been due to sand filling the pipe, in some to deposits of iron carbonates or other incrustations, and in some to the overdrawing of the supply by the drilling of recent wells. If wells were checked and controlled the supply might be available longer.

Water beds.—The water beds in this locality have been thoroughly exploited, especially the upper ones. The well drillers find that they are not as uniform as at Rose City. Their thickness is often 20 to 30 feet, consisting of gravel or coarse sand interbedded with clay. The coarser material is generally at the bottom, while at the center quicksand has been so abundant as to cause some delay in drilling and to prevent the use of the common form of jetting drill which is usually employed in drift wells. The thickness and extent of the first water bed is shown by well No. 22, at the livery barn of C. J. Blakeley, which was 65 feet at first, when it drew the water level down on all wells in the upper bed, some of these especially affected being Nos. 23, 32, 31, 30, 100, 33, 101, and 102. Doctor Newman's well, No. 23, did not flow after No. 22 reached 65 feet, but when the latter was cased to 108 feet and drilled to 165 feet the former regained a small flow. Later it was drilled to 130 feet, the level of the third water bed.

The first water bed in West Branch is about 40 feet from the general surface and some 25 feet thick. Its elevation above tide is about 920 to 945 feet. In the eastern part of the village the upper bed is somewhat lower and supplies the brewery well (No. 40), which has partly drained wells Nos. 47, 92, and 93. The group of wells directly south of the depot seems to reach a second water bed at a lower elevation, the drillers there finding a hard clay, varying from 20 to 30 feet in thickness, beneath which is obtained the supplies for wells Nos. 7, 91, 97, and 105. At the present time the second water bed is the source of a better supply than is obtained in the upper beds. The third bed, with a general elevation of 430 feet, is the source of the strongest supply of the area. From it comes the supply for the wells of Stephen Weigers (No. 14), Ogemaw Bank (No. 85), C. J. Blakeley (No. 22), and Gale Lumber Company (No.

24). In several of the wells in this bed drift coal is found, coming from the coal series of the Michigan formation, which outcrops to the south and east. The greater supply and pressure of the water from the lower bed is due to the presence of the Michigan formation to the east. At the West Branch Bridge over Rifle River, due southeast of this area, outcrops of the early Carboniferous limestone and sandstone occur at an altitude of 785 feet above tide, and as the lower water beds are 790 feet above tide this seems a case where the rock cuts off an escape of the water at lower levels.

Catchment area.—The catchment area for the West Branch wells is in the loose drift material which constitutes the land to the north and west, having an elevation of 1,200 to 1,300 feet above tide. The presence of springs and lakes on the drift plains where the clay comes to the surface is due to the large amount of ground water in the porous material and the small run-off. A part of the supply at Ogemaw Springs can readily be traced to the water following clay through the drift down to lower elevation, while the larger supply is from between clay beds at greater depths.

Temperature.—The temperature of the wells averages nearly 48°, or 5.5° higher than the mean annual temperature of West Branch. The temperature of the Gale Lumber Company's wells (Nos. 24 and 25) is the same, although there is a difference of 89 feet in their depths. The shallow well has 25 feet of pipe exposed, while the deeper one has none. The exposure of 15 feet of pipe may account for a temperature higher than normal in the wells of Joseph Merrik (No. 1) and at the village park (No. 3), while representative temperatures for that depth are in adjacent wells of Frank Smith (No. 2) and the Episcopal Church (No. 105). The difference between the air and soil temperatures (5.5°) is larger than in some experiments and observations elsewhere, but may be due to the blanketing effect of the heavy winter snow. The temperature of the springs at Ogemaw Springs station, on the Michigan Central Railroad, north of West Branch, in July, 1904, was 47°, which agrees with similar springs at Rose City.

Data.—The table on the next page gives data of wells at and near West Branch.

Wells in West Branch area.

WELLS AT WEST BRANCH.

No. on fig. 57.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—[a]	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	°*F*			
1	Joseph Merrik	950	34	916			49		$22	Flowed 6 gallons a minute in 1903; drained by No. 105 in 1904.
2	Frank Smith	948	34	914		2	47½		25	Store and blacksmith.
3	Village park [b]	950	34	916		3	49			Water trough.
4	A. C. Irons [c]	952	35	917		3		Soft		At store.
5	A. C. Irons	955	52	903		7		do		Domestic use.
6	A. L. Shirgley	955	90	865		18	49	do		
7	James Barker	940	90	850		15		do	72	Barn and house.
8	Mrs. McKenna	952	80	872		1				Water has small amount of iron carbonate.
9	Mr. Banasso	956	50?	906		2	47	Soft	60	Domestic use.
10	F. Smith	950	81	869		.3	47½			Do.
11	Mr. Birdsall	953	82	871		1.7			60	Water has CO_2; corrodes pipe and tin dishes.
12	E. V. Goodell	953	80	873						Made in 1888; 1.5-inch; weak flow.
13	Chas. Raymour	952	92	860						Not flowing.
14	Steven Weigers [d]	953	160	793		25.7	49½		375	Carefully piped and controlled.
15	Mrs. T. L. Lowenzo.	965	45	920		1.2	48½		40	Not flowing in 1903, but after sand pumping in 1904 good flow.
16	C. E. Camp	965	75	890		7	48			Reduced to 1 inch.
17	C. W. Longwell	960	85	875		1.2	49			Well 1.5-inch; much algæ in water.
18	L. Walters	958	86	872		10.5		Soft	70	Fountain and fish pond.
19	Geo. Alexander	958	85	873		12	47½	do		Domestic use.
20	Alex. Brigham	964	90	874		1	47½	do		Decreased by No. 16; much iron carbonate on pipe.
21	McCannond Wood	953	151	802		3			150	Fountain and livery barn.
22	C. J. Blakeley [e]	953	165	898	963	60	47½	Soft	180	Drift coal in well.
23	Doctor Newman	958	130	828		3.7	48	Salt		Original flow at 60 feet; lowered by No. 22.
24	Gale Lumber Co. [f]	953	165	888	978	12.7	46½	Soft	100	Drinking.
25	Gale Lumber Co.	955	76	889	977	6	46½		50	Drinking and steaming.
26	D. McCannon	960	125	835		1.5	47	Soft		Livery.
27	H. Buckle	963	100	863		1	49	do	82	Domestic use; well 1.5-inch.
28	I. Unger	965	170	795		2	48	do	105	Domestic and stock.
29	John Gauf	966	45	921		4	47			Flow decreased since 1903.
30	Chas. Ross	966	45	921		3				Weak flow in 1903; no flow in 1904.
31	Chas. Wilson	967	45	922						Weak flow.
32	Ira Mitchell	968	45	923		1			40	
33	U. V. Guilford	967	80	887		1.2	49			Decreased since 1903.
34	Catholic Church [g]	990	30	960		1.8		Hard	100	Not suitable for laundry.

[a] All wells flow unless otherwise indicated, but the head can not be measured in those with goosenecks.

[b] This well was made in eight hours by hand with a clay auger and driving pipe in 1899. The following is the record:

	Thickness (feet).
Sand and gravel	4
Solid blue clay	47
Water gravel	1

[c] Wells No. 1 and No. 3 have 15 feet of pipe exposed above the surface. This accounts for high temperature.

[d] Supplies butcher shop and grocery store with a large butter room in basement; also piped to living room on second floor; made in 1899.

[e] Made in 1900 and is cased 108 feet. Is said to flow 2,000 barrels in twenty-four hours (probably an overestimate). First water at 65 feet; for a time supply was drawn from a 95-foot vein; later well drilled to 165 feet. This well is No. 164 in Water-Supply Paper No. 102, United States Geological Survey.

[f] The following is the record of this well:

	Thickness (feet).
Clay	10
Sand	15
Clay	50
Sand and gravel	5
Clay	20
Sand, small pieces of coal	5
Hard blue clay	50
Gravel, coal fragments	10

Water at 80 and 160 feet.

[g] Drilled to 130 feet; no flow; pipe pulled back to vein at 30 feet.

Wells in West Branch area—Continued.

WELLS AT WEST BRANCH—Continued.

No. on fig. 57.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	°*F.*			
35	Catholic Cemetery	940	110	830		3			$92	Small fountain.
36	Peter Lambert	958	14	944						Weak.
37	A. B. Dembar	955	42	913		2.5	47½			Decreased by No. 42.
38	Mike Cullen	961	15	946	961	.5			10	Weak flow; much CO_2.
39	A. M. Schieke	960	53	907		.8	47½			House; piped to barn.
40	A. M. Schieke [a]	950	44	906		156	47½		100	3 wells connected and fountain.
41	May Brow	960	45	915		.9			35	Decreased since 1903.
42	Silva Kenney	955	45	910		3	47½		35	Domestic use.
43	Albert Schugley	954	45	909		1.8	47	Soft	35	Do.
44	Wm. Colligan	955	30	925						Flowed in 1903; not in 1904.
45	Joseph Neffler	955	35	920						Do.
46	James Hutton	953	50	903						Ceased to flow.
47	A. Clark	960	50	910		8.5	49			Domestic use.
48	John Hook	956	50	906			48	Soft		Weak flow.
49	Geo. Reminder [b]	953	48	905		12.2	47¼			Domestic and stock.
50	Lawrence Sams	957	40	917		1	48			
51	A. M. Guilford	938	50	888		3			42	Large stock farm.
52	G. French	953	60	893		12				Stock.
53	James Trigis	957	90	867		12	48		70	Do.
54	J. L. Jones	952	95	857		3.5				
55	T. Pillsbury	958	50	908		1.5	47	Soft	40	Domestic use.
56	W. Kennedy	962	50	869		2		do	40	House and fountain.
57	Milton Whitman	959	90	869		3				Domestic use.
58	T. McGregor	958	100	858			48	Soft		Pumped.
59	Joseph Penard	955								Do.
60	J. B. Howe	963	50	913		1.5				Domestic use.
61	James Horton	962	30	932		7.5	48	Hard	22	Good drinking water; unfit for laundry purposes.
62	W. W. English	961	60	901		3	47¼		80	House and fountain; flow decreasing.
63	Robert Miller	962	60	902		1.6	47¼			Domestic use.
64	Mr. Dutchler	963	45	928		3	47¼			
65	Wm. Prey	964	45	919						Pumped.
66	J. Grengagor [c]		60							1 mile south of village post-office; pumped.
67	John Tolfry		185			39	47		75	Stock farm south of village.
68	Angus Bowen	953	30	923		8		Hard		Water has much iron carbonate.
69	Mr. Talse (?)	952	50	902			48			Domestic use; weak flow.
70	Cedus Hakes	953	45	908		31		Soft		Do.
71	A. Perrin	953	90	863	943					Pump well.
72	Mr. Palmer	953	75	878			48	Soft		Weak flow.
73	Mr. Hyslop	952	80	872						Well clogged with sand.
74	E. J. Goodell	953	75	878		.5	49	Soft		Weak flow.
75	Mr. Gauf	952	45	917		1.5	47½	do		Flow decreased since 1903.
76	Frank Smith	952	90	862		1.2	48			House and barn.
77	T. S. Haig	949	60	889		1.5	48	Hard		Domestic; not suitable for laundry use.
78	W. H. Gard	950	60	890		1	47½	do		Decreased by No. 77.
79	K. Weeks	953	90	863						No flow; pump well.
80	C. Graves	943	80	863		1.8	48	Soft		Domestic use.
81	Chas. Woods	951	75	876		1.5	48	do		Supplies house and barn.
82	Doctor Witter	948	40	908		3	47½	do		Supplies barn; much CO_2.
83	Judge Sharp	946	58	888		1.8	48	do		Ram used to raise water to house.
84	W. R. Turner	949	60	889		2				Weak flow; medium soft.
85	Ogemaw Bank	954	175	779		8				Strong flow; piped to second floor.
86	County jail	992	182	810						
87	Cheese factory	950	40	910		5				Butter room and for steaming.
88	Mrs. Fenton	962	30	932		2				2 wells same depth; medium hard.

[a] Water used in brewery satisfactorily. There are three wells 20 feet apart, which lowered head in wells 47, 91, and 93. The owner, A. W. Schieke, states that water contains magnesia and plenty of CO_2. The latter corrodes iron pipes and tinware rapidly. No decrease in supply has been noted.

[b] Sunk 50 feet to first water and continued through water-bearing sand to 108 feet without increase in amount.

[c] One mile south of court-house; penetrates following beds:

	Thickness (feet).
Clay	30
Sand	8
Clay hardpan	22

Wells in West Branch area—Continued.

WELLS AT WEST BRANCH—Continued.

No. on fig. 57.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Gals.*	° *F.*			
89	G. Day	962								
90	E. Evans	958	30	928		6.5?		Hard		Much sediment in water.
91	J. Bitters	961	51	910		1.5	48			Decreased since 1903.
92	Mr. Tartman	962	50	912		1.5	48			Supplies house and barn.
93	E. Clark	961	52	909		1.1	48½	Soft		Domestic use.
94	E. Shrively	955	60	895		.1				Decreased since 1903.
95	Lumber Co	951	60	891		.5	48			Stock.
96	T. Wilder	961?	72	889						Pumped.
97	Mr. MacKinson	963	90	903	951					Pump well.
98	E. Blundell	955	45							Flowed in 1903; pumped in 1904.
99	Joe Reminder	968	80	888		4	48			Made in 1904; domestic use.
100	F. Hutton	966	72	894		2				Decreased by No. 22.
101	Mrs. Gray	958	73							Decreased by No. 22; no flow.
102	D. E. Marsh	958	116	842		2		Soft		Not good for drinking; muddy.
103	Jas. Lambert	958	70	888		.5		do		Decreased since 1903.
104	Joe Walters	969	65	894		4	48	do		Made in 1904.
105	Episcopal Church	950	40	910		3	47½	Medium.		Drained by well No. 1.

WELLS NORTH OF WEST BRANCH.

Township N.	Range E.	Section.	Owner.	Elevation.	Depth.	Flow per minute.	Temperature.	Quality.	Remarks.
				Feet.	*Feet.*	*Gals.*	° *F.*		
22	2	18	W. Tallman	1,043	45	1	48½	Soft	Stock and domestic use.
22	2	7	do	1,045	50	10	48	do	Domestic use.
22	2	17	Wm. Moss	1,030	62	1.5	48	do	All clay.
22	1	24	A. Ford	953	34	3	47	do	Quicksand and clay on top.
22	2	8	Jas. Moss	1,040	80	4	47		Stock and house use.
22	2	7	D. Webster	1,042	60	3			
22	2	18	L. Carr	1,000	60	1	48	Soft	Dairy and house use.
22	2	7	School	1,100	50	3	49	do	Drinking fountain.

WELLS SOUTH OF WEST BRANCH.

Township N.	Range E.	Section.	Owner.	Elevation.	Depth.	Flow per minute.	Temperature.	Quality.	Remarks.
22	2	31	O. B. Stevenson		{20 30}	10	47½	Soft	Two flows; water rises 2 feet above surface.
22	2	31	Mrs. Place		75	5	48	do	Sand 28 feet; remainder clay; water rises 1 foot above surface.
22	2	32	Chas. Perry		55	6	48		Sand 30 feet; clay to water bed.
22	2	30	P. Mark		38	8	47½	Hard	Water rises 12 feet above surface.
22	2	32	Mr. Cook		26	5			All clay.
22	2	31	Mr. Rice		48	7			

ROSE CITY AREA.

Location.—The flowing wells of the Rose City region are distributed over an area of 3 square miles (fig. 58), which lies to the east of a Saginaw Bay moraine, here 1,200 to 1,500 feet above sea level. The eastern slope of this moraine forms the catchment basin for the headwaters of Rifle River, and the sand plains north and west belong to the catchment basin of Au Sable River.

The flowing-well district, of which that at Rose City is a part, extends west of north, following the trend of the neighboring portion of the moraine, and good flows have been obtained for 3 miles in that direction. Three miles north of the town the morainal ridges turn to the northeast, and along this southern slope a few wells have been found, and there is a strong probability that 2 miles north of the villages of Lupton and Maltby flows could be obtained near the base of these ridges. South of Rose City, on the eastern slope of the morainal country, many strong springs occur, but no flowing wells as yet. Unsuccessful attempts have been made at Campbells Corners on a prominent point, which not only seems too high for a flow, but is liable to have its water table lowered by creek-valley drainage on either side.

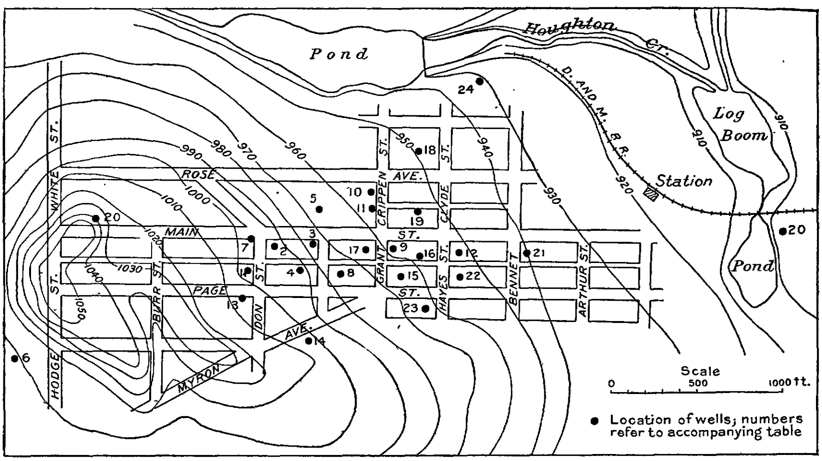


FIG. 58.—Map of Rose City, showing location of flowing wells.

Wells.—There are at present 25 flowing wells within the limits of the village of Rose City and 8 outside of the village. The first of these in Rose City was drilled in 1894, on the property of H. Hodge, in the western part of town. The 25 wells furnish an abundant supply of good water for domestic purposes to the 300 inhabitants. Some of the stronger flows, as that belonging to Professor Karcher, are piped to supply several families, a small rental being paid to the owner for the privilege.

The shallow wells are made by driving a 2-inch galvanized iron pipe, without point or screen, down to the waterbed. These wells are made by the job, and $30 to $40 is the average price for the well complete, including pipe and the labor. The stronger flows, which are from the deeper of the two beds discussed below, are made by price per foot, which is usually 50 cents, exclusive of piping, making the average

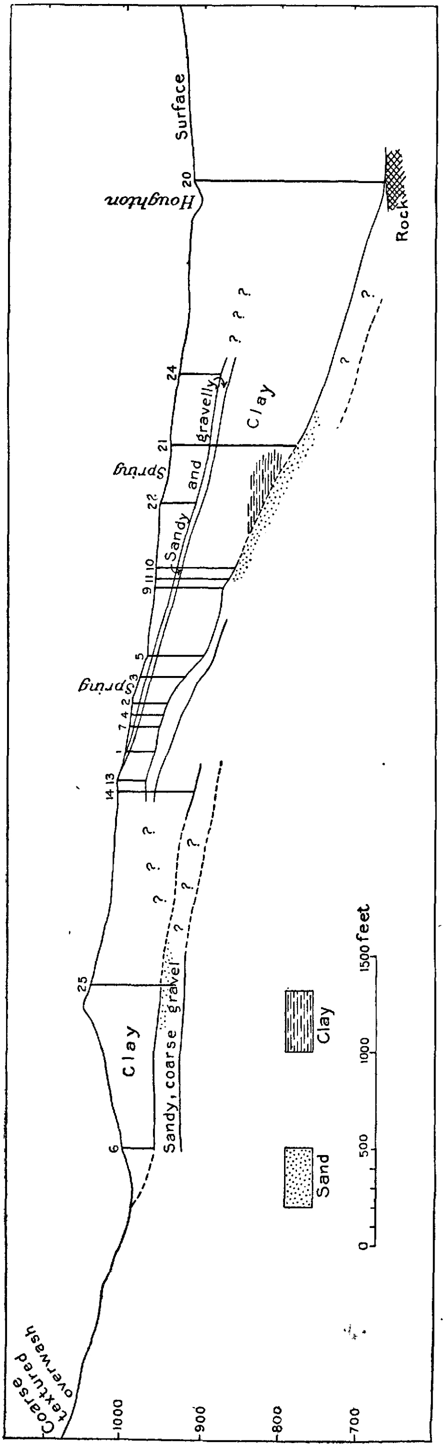


FIG. 59.—Ideal section showing distribution of water beds.

cost of each well from $70 to $80. The wells require very little repairing, but must be sand pumped as often as once in three years. This costs about $10. The average cost of these wells is so low and the quality of the water so good that such a supply is one of the valuable resources of the town and ought to be carefully guarded from unnecessary depletion or waste.

Flow.—The total flow of the Rose City wells amounts to about 2,290 gallons a minute from 20 of the 25 wells which could be measured, which gives over 10,000 gallons daily per capita, or far above the maximum amount used in any city in the State. The individual flow of the wells appears in the table on page 293. With a few exceptions the wells are allowed to flow freely, a practise which, as already suggested, tends to decrease the head. As yet no failure to obtain a flow has resulted where the trial has been made on ground which stands below 990 feet above sea level, and none of the wells have shown a marked decrease in flow since they were first made, except in cases where they have become sand clogged; but in such cases sand pumping restores the original flow. A case in point is that of Doctor Kiehle's well, which had a flow in 1902 of 108 gallons a minute, and some time later was stopped with sand and ceased to flow for several months, but on being sand-pumped early in 1904 resumed the same flow as at the time of the first measurement.

Water beds.—Two water horizons are usually found in driving these wells. One from a bed of sand quite near the surface, and the other from a gravel bed somewhat irregular in its dip, yet always containing an abundant supply of water under considerable head. The first or upper bed has been found in nearly all of the wells that have reached the lower stronger flow. The relations are set forth in the accompanying diagram (fig. 59), where it will be seen that the thickness of the upper bed is from 8 to 10 feet. The supply of water in this upper bed may come, to some extent, from the upward rise of water from the lower bed, since its outcrop or intake is but a narrow strip not large enough to supply the amount of water yielded by some of the wells that terminate in this upper bed. Where the upper bed is cut into by Houghton Creek, above the mill pond, many large boiling springs occur, and at the time the writer was in this region in 1904 the pond and the creek had a gray color from the breaking out of several new springs that the creek had opened by its recent active cutting on its southern bank.

The lower water bed, which supplies the stronger flows, contains coarse gravel. Some sand occurs in the western part of the town and forms the larger part of the bed in the eastern part. The fact that several of the wells of the eastern part, although of lower altitude than those of the western, have less velocity of flowage may be due to the finer texture of the material. This stronger bed appears at an altitude of 960 feet in the well of Mr. Hodge (No. 6) in the western part of the town and dips only slightly to the east until the public-school well is reached. This well apparently passed the main bed, as Mrs. Slater has a well only a few feet below it giving a good flow and rising nearly 14 feet above the surface, suggesting that the schoolhouse well may have been carelessly drilled. From the Slater well the deeper water bed dips rapidly to the east, being found at 940 feet above sea level in the Cooley well, 870 feet in Professor Karcher's well, and 780 feet in the Houghton House well.

The porosity of this lower water bed in the western part of the village is well shown when the W. Rose well is shut off, for in twenty minutes afterward there is an increase in the flow of the Cooley well 200 feet to the southwest. This continues to increase for several hours, until the well has regained its original flow. The lower water bed is the principal source of supply for the larger wells of the village, and the limit of flow apparently has not been approached, as none of the wells show any indications of decrease.

Quality of water.—Examination of the quality of the water by field methods shows an entire absence of sulphates and chlorides. The shallow wells contain a larger amount of carbonates than the deeper ones. The degree of hardness in some of the deeper ones is so low that no softening preparation is used for washing or for laundry purposes. None of the wells have notable deposits of the iron precipitate and the pipes do not corrode rapidly.

Temperature.—The temperature of the wells averages a little below 49° F., which is very suitable for water used for cooling and drinking. The mean annual temperature of Rose City is 6° lower than the average well temperature; but the soil in northern latitudes, where snow prevents radiation for several months of the year, has a greater mean temperature than the air. This probably accounts for much of the difference here between the mean temperature of the air and of the soil. (See pp. 15–20.) The well on the property of the Rose City stave mill shows how the well temperatures are affected by outside heat. This well ought to have a temperature of about 50°, and its temperature of 56° was first noted by Dr. A. C. Lane, and the boilers of the engines given as the cause of the increase.[a]

Catchment area.—Attention was called above to the high morainal ridges west and north of Rose City, which form the boundary of the flowing-well district in those directions. These in all probability constitute a catchment area for much of the water within the flowing-well district. In the portion of the district from which the village obtains its supply a catchment area appears to be found close at hand. The contour map (fig. 58) shows a culminating point in the western part of the town, standing 150 feet above Houghton Creek, a stream which rises in the heavy springs along the eastern slope of the morainal country to the west and which in the eastern part of the town is a small stream of about 50 second-feet volume. West of this high tract in the west part of the village and outside the town is a lower belt of loose-textured material one-eighth mile wide, which lies between the high point in the village and the high land to the west, and which rises in morainal ridges until the crest is reached at an elevation of about 1,500 feet on Cooks Knob, 3 miles west of Rose City. This belt of loose-textured material runs parallel with the large ridges to the west, having the same general north-south trend, and seems a probable catchment area intimately related to the Rose City wells. The loose-textured material apparently dips beneath the ridge in the west part of town and is covered by several layers of clay, which are impervious enough to retain the water and give it considerable head in places of lower elevation. This catchment area is probably itself fed by the high ridges to the west of it, just as Houghton Creek is fed from a portion of the ridges farther north.

[a] Water-Sup. and Irr. Paper No. 30, U. S. Geol. Survey, 1899, p. 57.

Wells at Rose City.

No. on fig. 58.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*	*Galls.*	*° F.*			
1	Mrs. Slater	998	2	43	960	1,012	109	48	Medium.	$30	House use.
2	Dr. Kiehle	990	2	46	944	....	108	48	Soft	.....	Do.
3	W. Rose	978	2	60	918	996	221.7	49	....do...	67	House well; interferes with No. 4.
4	J. Cooley	990	2	45	945	....	30+	48	....do....	50	Supplies 5 families; total flowage not measured.
5	H. Rose	968	2	76	960 905	988	28	48	....do...	35	House use.
6	H. Hodge	1,000	2	40	962	....	110	48	....do...	50	Pioneer well, made in 1894.
7	O. Morrison	994	2	41	953	....	42	48	....do...	38	House use.
8	E. Atherton	976	2	100	.....	....	150	49	....do...	78	Supplies 4 families.
9	Wm. Tulloch	958	2	90	868	987	225	49	....do...	75	Supplies 5 families.
10	A. S. Rose	957	2	100	860	969	272	49	....do...	80	Supplies 10 families
11	Prof. Karcher	957	2	95	865	969	270	48½	....do...	75	Supplies 15 families.
12	M. Lansbury	953	1½	100	.....	....	....	....	....	.....	
13	E. Rennier	1,006	1½	35	972	1,007	5	....	Medium.	.....	House use.
14	Public school	1,007	2	100	974 907	....	....	....	....	125	No flow.
15	C. Clearmont	965	2	60	.....	....	15	....	....	.....	Clogged with sand.
16	D. Warner	958	1½	120	.....	....	....	49	....	80	House use.
17	H. Beach	964	2	100	.....	....	120	....	Soft	.....	Do.
18	A. Rose	950	2	120	.....	....	60	49	....do...	84	
19	J. Machny	954	2	107	.....	....	135	....	....	.....	Do.
20	Stave mill	910	1½	241	677	915	1	56	Hard.	.....	Soft sandstone at 233 feet.
21	Houghton Hotel.	940	2	160	780	980+	150	50	Soft.	90	Used in hotel laundry.
22	Wm. Tulloch	952	2	42	910	....	100	48	....	.....	House use.
23	.....do	962	2	138	.....	....	140	49	Soft	110	Supplies 8 families.
24	A. Rose (mill)	930	2	50	.....	....	28	48½	....do...	28	Used in boiler.
25	A. Cary	1,040	2	120	960 920	990	00	....	....	.....	On brow of hill.

WATER SUPPLIES OF MANISTEE COUNTY.

By FRANK LEVERETT.

GENERAL STATEMENT.

Manistee County fronts on Lake Michigan in the western part of the Southern Peninsula, the city of Manistee being the county seat. Manistee River traverses the southern part of the county, and with its tributaries drains all of the county except a narrow strip on the northern and western borders. The district south of Manistee River is largely a sandy plain, and has few settlers except at the village of Dublin, outside the city of Manistee and its suburbs. North and west of Manistee River in the east is a prominent morainic system, a large part of which has become settled. The wells on it range in depth from 50 feet or less up to fully 200 feet. West of this morainic system there is a broad, sandy plain traversed by Bear Creek, a tributary of the Manistee, in which a strong flowing well has been obtained. The northwestern part of the county west of Bear Creek and north of Manistee River is largely morainic, but has recesses extending in from Lake Michigan in which flowing wells have been obtained. One important district on the borders of Portage Lake, in and near the village of Onekama, is discussed by Mr. Gregory (pp. 297–301). There is a smaller district near Arcadia, concerning which a few data are presented below. The wells on the moraines in the northwestern portion of the county are often driven to depths of 75 to 100 feet, though as a rule the hills are avoided and wells are sunk in depressions, where water is found at convenient depths.

The salt wells at Manistee penetrate about to sea level before striking rock, but at Onekama rock is reached at a level 100 feet or more above tide. It is not known whether the altitude of the rock surface continues low to the eastward across this county, for no other borings have been driven to the rock. The highest points in the eastern part of the county have an altitude of more than 1,000 feet above sea level. If, therefore, the rock surface does not rise in that part of the county, there would be about 1,000 feet of drift. Borings at Manistee and Onekama, as well as the shallower ones elsewhere in the county, show the drift to be largely gravel and sand, which is filled with water below the level of the streams, but which is liable to be dry at points much higher than the drainage lines.

WATERWORKS.

MANISTEE CITY.

The city of Manistee, with a population of about 14,000, stands on the shore of Lake Michigan at the mouth of Manistee River. It is supplied from a system of wells sunk on a terrace a short distance from the lake, on the south bank of Manistee River. There is a large excavated well, 30 feet in diameter and 40 feet deep, with which are connected three 8-inch wells which extend 60 feet below the level of the bottom of the large well and about 75 feet below the river and Lake Michigan level. The large well was excavated in sand, though there was a bowldery bed at 23 feet and an occasional streak of gravel. The tubular wells are through sand, except for 10 feet of brick clay near the bottom. The water stands 23 feet below the surface, or at about Lake Michigan level. The following analysis of water was made by Ricketts & Banks, of New York City, July 25, 1899, just before the purchase of the waterworks by the city:

Analysis of waterworks water, Manistee.

	Parts per million.
Chlorine (Cl)	5.33
Sodium (Na)	3.47
Nitrogen in nitrites	.02
Nitrogen in nitrates	5
Free ammonia	.08
Albuminoid ammonia	.07
Calcium (Ca)	74.84
Carbonic acid (CO_3)	112.06
Loss on ignition	35

Analysis of waterworks water, Manistee—Continued.

	Parts per million.
Mineral matter, nonvolatile	157
Total solids (by evaporation)	192
Iron (Fe)	None.
Lime	72
Magnesium (Mg)	14.50

Appearance, clear; color, none; odor, none.

The works were acquired by the city October 1, 1899, from a private water company, the price paid being $125,155.81. The extensions made since purchasing the works have brought the cost up to $160,394.10, as shown by the annual report for the year ending February 28, 1905. The length of mains is now 21.33 miles. There are 137 fire hydrants, 1,540 service taps, and 98 meters. The ordinary pressure carried is 63 pounds, and fire pressure 100 to 120 pounds. The water is pumped direct to the mains.

The average daily consumption of water is 819,344 gallons. This is a lower rate than prevailed when the works were acquired by the city, although the number of consumers has increased 25 per cent. A tendency to guard against waste is therefore developing in the community. Superintendent Stephen Cahill, who furnished the data concerning this waterworks system, estimates that about 60 per cent of the population, or 8,500 people, are now using the city supply. The remainder depend on private wells, which range in depth from 15 to 90 feet.

MISCELLANEOUS VILLAGE SUPPLIES.

At Arcadia the supply is from driven wells 20 to 25 feet deep, which strike water at about the level of Lake Michigan.

At Chief the wells are commonly about 50 feet, but wells in the country around reach depths of 150 feet, and when on high points have only 10 to 20 feet of water.

At Onekama the flowing wells, ranging in depth from 40 to 300 feet, are in general use and have a pressure equal to a head of about 70 feet and a discharge as high as 168 gallons a minute from a 2-inch pipe. These wells are discussed in some detail by Mr. Gregory (pp. 297–301). There are a few pump wells on the hill back of the village ranging from 10 to 100 feet in depth. Springs in the vicinity of the village are strong and yield as high as 50 gallons a minute.

At Pierport, on the shore of Lake Michigan, wells are from 10 to 125 feet in depth, though they are commonly less than 60 feet.

At Tanner, in the valley of Bear Creek, wells are commonly about 18 feet deep, though tubular wells reach a depth of 80 feet.

At Brethren, on the plain east of Bear Creek, and also at Kaleva, wells are driven to depths of 20 to 30 feet and find abundance of water.

At Copemish the wells are but 15 to 30 feet in depth, though in the higher country immediately east they are much deeper.

At Harlan, in the northeastern part of the county, there are a few shallow open wells, but the driven wells in that vicinity are usually 100 feet or more in depth.

At Dublin, in the southeastern part of the county, the wells are 70 to 75 feet in depth and have very little head, but at Wellston siding, 3 miles north, an abundance of water is found at 16 feet.

FLOWING WELLS.

ARCADIA.

There are two flowing wells east of the village of Arcadia, in northern Manistee County, on a low plain bordering Lake Michigan—one on the farm of Luther Finch, the other at a German cemetery. The Finch well, in sec. 11, T. 24 N., R. 16 W., is about 1 mile from the lake and 40 feet above it. It was made in April, 1903. The cemetery well is a mile farther east, on somewhat higher ground, and has been running for about four years. (See Pl. V, *B*.) The Finch well is 187 feet deep and flows a half-inch stream from a 3-inch pipe. It has the following section, as reported by the owner:

Record of Finch well, east of Arcadia.

	Thickness.	Total.
	Feet.	*Feet.*
Red sand, lake deposit	4	4
Red glacial clay (till)	80	84
Water vein with head of −2 feet		
White sand	80	164
Light-colored clay	10	174
Clay and gravel	3	177
Water gravel with head of 14 feet	10	187

The cemetery well is 143 feet deep and flows a 1-inch stream, which has shown no perceptible diminution in the four years it has been flowing.

The catchment area for these wells is likely to be in the bordering morainic hills which sweep around the plain on which they occur on the north, east, and south. It is probable that other wells may be obtained on this plain if sunk to levels as low as those already obtained. In most cases wells are shallow and afford sufficient supplies by pumping. There are numerous springs along the base of the morainic tracts bordering this plain, which are utilized by the residents.

VICINITY OF KALEVA.

Andrew Kullgren has a flowing well on the bank of Bear Creek, about 4 miles northwest of Kaleva, with a depth of 130 feet. At about 30 feet he reached the bottom of the surface deposit of gravel and sand and penetrated clay to the water-bearing gravel at bottom.

Joseph Gilson has a flowing well in a recess of a moraine about 4 miles east of Kaleva, in sec. 20, Marilla Township, with a depth of 75 feet and a head of 2 feet. Water was struck at 65 feet, with a temperature of 45° F.

Joel Gilson has a well in the same region, made in March, 1903; depth 75 feet, diameter 2 inches, with a head of 2 feet. Water was struck at 70 feet and is soft. The well is located in a stream bed.[a]

BEAR LAKE.

A newspaper report concerning a flowing well at Bear Lake appeared in the Jackson (Mich.) Press October 26, 1904, as follows:

Manistee, Mich., October 26.—A farmer living near Bear Lake has an artesian well on his farm which spouts both water and gas. The well in 419 feet deep and the pipe is forked at the surface and one part, which is considerably higher than the other, emits gas, while water flows from the lower one. The farmer intends storing the gas in a tank and will use it to light his home this winter.

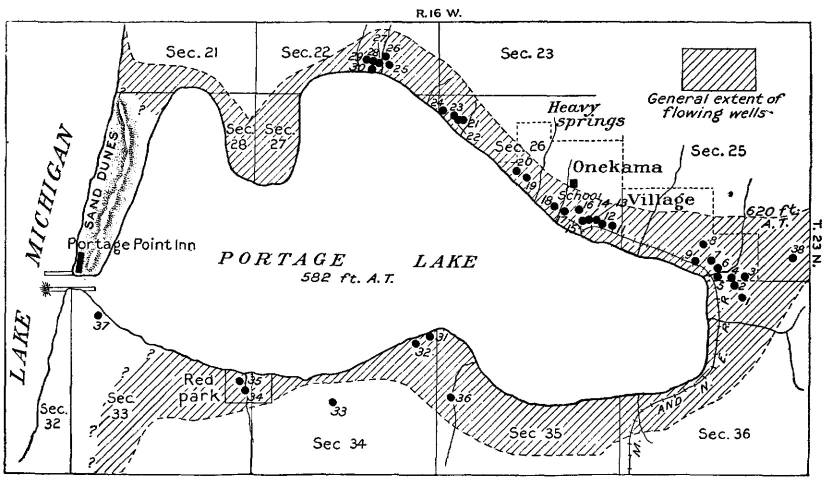


FIG. 60.—Flowing wells in and near Onekama, Manistee County.

ONEKAMA.[b]

The Onekama district is a narrow strip of land about Portage Lake, in Manistee County, having an elevation of 582 to 620 feet above tide. The lake is surrounded by high hills of porous drift deposited in part by a small local ice lobe. At the west end of Portage Lake currents in Lake Michigan have built a bar and piled the sand in dunes, so that the once wide mouth of this basin is nearly closed. The Lake Michigan shore north of this region has a 40-foot cliff of clay capped with varying depths of sand and gravel.

[a] Data by A. L. Gleason, driller.

[b] By W. M. Gregory.

The high hills of 200 to 300 feet above the lake average a mile back from the shore of Portage Lake.

The Onekama district has at present 40 wells, 36 of which are good flows and the remainder either failures or very weak (fig. 60). The wells are all drilled, nine being driven, as the clay is compact and the sand is often consolidated. The tubular-well machine with a water jet is generally used for sinking wells in this region. In the shallow wells and in drift which is less compact and tenacious an outfit of similar construction is utilized. The wells are generally made by contract, varying from 75 cents to $1 a foot in the deeper wells, and by the job for a flow in shallow wells. Some few of the wells require a screen, but generally the supply is from a rather coarse gravel water bed. The wells are in general use throughout the district for domestic purposes, dairy and stock use, and water has been occasionally shipped from Mr. Canfield's well to outside markets.

The waters are soft enough for all domestic purposes and are preferred by some to the lake water for laundry purposes. The field analyses show that the hardness is above the average of the drift water, while the carbonates are low, and the chlorides are above the normal water.

The combined flow of the 36 wells is 2,197 gallons a minute, or 61 gallons a well, which is a high rate. Changes in flowage of several wells occurred when Mr. C. J. Canfield's well (No. 23) was made. This well has an estimated flowage of 250 gallons a minute.

The deposits of this region consist of alternate clay and sand layers, and the latter form many water beds which give flows of varying strength, depending on the coarseness of the material. The alternating character of these beds is shown in the record of John Neitzke's well (No. 3), where a small flow was found under each clay bed. At the western end of the lake no flows are obtained, a few trials showing this to be a sand bar built across the mouth of the lake. At the fish hatchery the most productive bed is the third one, at 43 feet, though porous gravel beds have been found at 19 feet and at 25 to 35 feet, while a small flow comes from the Antrim shale, which is reached at 425 feet. At Mr. Canfield's, one-half mile east of the fish hatchery, there is a coarse gravel water bed, at 160 to 170 feet, which yields a heavy flow. This bed apparently rises to the east. In Mr. W. W. Davis's well (No. 14) it is found at 160 feet; at A. E. Solomon's (No. 12), at 157 feet; and at the cheese factory (No. 5), at 138 feet. Below this bed there are several others ranging from 224 feet in the well of W. W. Davis (No. 14) to 300 feet in A. L. Showalter's (No. 6).

The deposits on the south side of the lake are more sandy than those to the north, and the wells have not been so successfully developed. A fairly good supply is obtained at less than 100 feet by

P. Noud (No. 34), Joe Frisbe (No. 35), and H. Hanson (No. 36). Several of the wells which have been drilled to the Antrim shale at 472 feet yield no water. Mr. August Lipkowski (No. 33) obtains gas enough for two burners from a well in this shale.

The catchment area of wells about Portage Lake is in the highlands of Glacial drift which reach an elevation of over 900 feet above tide about the border of the lake. Well drillers find it difficult to obtain water on the high hills, for wells have much loose, porous material and few seams of clay. The general absence of creeks north and south of this area is the result of the porous character of the drift. When the clay comes to the surface at lower elevations lakes or springs are the result. The upper limit of strong springs along Portage Lake is at 650 feet above tide, and some are well developed at 620 feet. Some springs in the western part of Onekama village have recently burst out in new places. The supply for the fish hatchery well (No. 27) is evidently drawn from the water bed that supplies the small creek which heads in several springs at an altitude of 625 feet above tide.

The area affords some good data concerning the well pressure which it has not been possible to obtain from other regions. Mr. W. W. Davis, a competent well driller, has taken much interest in the pressure of the different wells, and has arranged to measure it in each by means of a small steam boiler fitted with a gage. The pressures have all been carefully recorded in the accompanying table. The greatest pressure is 35 pounds to the square inch, which is reported by Mr. Davis from wells No. 21, 22, and 23, and seems rather large. The writer saw Mr. Davis test well No. 25 with the apparatus which has been used on the other wells of the region. The pressure gage registered 20 pounds to the square inch; or 5 pounds less than when the well was first made. Mr. Davis asserts that this decrease is due to sand in the pipe.

Wells at Onekama.

No. on fig. 60.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Gage pressure.[a]	Remarks.
		Ft.	*In.*	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*° F.*			*Lbs.*	
1	J. E. Carleton[b]	607	2	185	422	656	75	$49\frac{1}{2}$	Soft	$75	30	Domestic use
2	J. E. Carleton	602	2	132	471	647	75	....	....	....	20	Barn and pasture.
3	John Neitzke[b c]	610	2	290	320	667	150	....	Medium	....	25	Domestic use.
4	Henry Smith	602	2	129	473	659	102	49	Soft	....	25	House and barn.
5	Cheese factory	597	2	138	359	....	50	....	....	....	10	Cooling room.
6	A. T. Showalter	597	2	300	297	642	150	....	Medium	208	20	Domestic use.
7	H. Hanson	597	2	101	496	633	125	49	Soft	....	15	Do.
8	O. Peterson	597	2	85	512	633	125	49	....	....	15	Do.
9	J. J. Kenny	594	2	291	303	....	100	49	Soft	....	10	
10	R. F. Wendell[b]	592	2	83	509	....	100	....	....	83	10	
11	A. F. Richmond	594	2	126	468	649	140	49	Soft	....	20	
12	A. E. Solomon[d]	602	2	157	445	....	100	$49\frac{1}{2}$	....	150	8	Hotel.
13	J. E. Erickson	607	2	159	448	....	100	....	....	....	8	
14	W. W Davis[e]	607	2	244	363	....	150	$49\frac{1}{2}$	....	....	25	First flow at 160 feet.
15	Wm. Hoglin[b]	607	$1\frac{1}{4}$	40	567	622	40	....	....	....	6	Domestic use.
16	Fred Brown	612	2	134	778	....	160	49	Soft	....	32	House and barn.
17	Chas. Tomlin	597	2	157	420	....	125	49	do	....	15	Piped to second story.
18	F. Hall	597	2	40	557	....	75	$49\frac{1}{2}$	do	....	8	All clay; flow in gravel.
19	Mr. Miniter[b]	607	2	85	522	....	125	....	....	....	20	Piped to second story.
20	Ramsell & Marsh	604	2	67	547	....	75	$48\frac{1}{2}$	Soft	....	11	
21	C. J. Canfield	607	2	162	445	....	168	49	....	160	35	Water from gravel.
22	do	607	2	168	439	....	168	....	....	....	35	
23	C. J. Canfield[f]	607	$3\frac{1}{2}$	162	435	....	250	....	Soft	....	35	Occasionally sold for drinking.
24	C. J. Canfield	607	2	126	481	....	74	....	....	120	....	
25	Fish hatchery	602	2	43	559	....	75	$48\frac{1}{2}$	....	....	....	
26	Fish hatchery[g]	602	2	425	177	....	10	....	Hard	....	....	Rock at 300 feet.
27	Fish hatchery	602	$1\frac{1}{2}$	19	583	....	30	....	....	....	....	
28	do	602	2	25	577	....	30	....	....	....	....	
29	do	602	2	35	567	....	35	....	....	....	....	
30	do	602	2	304	298	....	....	....	....	....	....	No water.
31	E. L. Reeves[h]	592	....	304	288	....	100	....	Hard	....	25	Water from gravel.

[a] W. W. Davis, a well driller of Onekama, is authority for the pressures, which were obtained by connecting well to boiler with steam gage attached.

[b] Screen used only in Nos. 1, 3, 10, 15, 19, and 38.

[c] The following is the record of this well:

	Thickness.	Total.
	Feet.	*Feet.*
Sand	18	18
Clay	99	117
Sand	12	129
Clay	24	153
Sand	32	185
Clay	24	209
Sand	23	232
Clay	45	277
Gravel and sand; water bed	23	300

[d] A field analysis of the hotel well is as follows:

	Parts per million.
Hardness	187.6
Carbonates	24
Chlorides	15
Iron	0

[e] A field analysis of water from the Davis well is as follows:

	Parts per million.
Hardness	175.5
Carbonates	29
Chlorides	15

Wood was found in this well at 110 feet.

[f] When well No. 23 was drilled, 100 feet west of No. 21, the pressure in the latter was decreased from 35 to 28 pounds. Wells Nos. 22 and 23 are connected, and the total flow is used to operate a water turbine which gives power for a small electric-light plant.

[g] Strong pressure of gas, which rapidly decreased.

[h] Beneath 96 feet of surface sand and 16 feet of marl and clay are alternating beds of clay and sandy gravel, the clay predominating.

Wells at Onekama—Continued.

No. on fig. 60.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Gage pressure.	Remarks.
		Ft.	*In*	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*° F.*			*Lbs.*	
32	Wm. Nuttall [a]	592	....	225	367	....	100	....	....	175	15	
33	Aug. Lipkowski [b]	642	2	418	224	646	....	....	Hard	....	....	
34	Pat. Noud	....	....	83	....	+11	20	....	Soft	....	....	Stock and domestic use.
35	Joe Fiske	....	2	65	....	+17	75	....	....	50	....	Passed 6 water beds.
36	Hans Hanson	612	2	63	549	....	20	....	....	....	10	
37	A. Clark estate [c]	592	2	472	120	....	....	....	Hard	....	....	No water.
38	Ed. Kinney [d]	594	$1\frac{1}{4}$	43	551	....	25	....	....	....	5	Some gas at intervals.
39	Mr. Klein	....	2	225	....	+32	5	....	Soft	150	....	Sand 13 feet; remainder tough clay.
40	Public school	624	2	40	....	616	....	....	....	....	....	

[a] Sand 103 feet; remainder soft clay, with some sand and gravel.
[b] Gas enough to supply two burners in one house for the past year.
[c] Record of well, with 100 feet unaccounted for:

	Thickness.	Total depth.
	Feet.	*Feet.*
Sand	128	128
Clay	14	142
Sand	20	162
Clay	30	192
Reddish shale (?)	123	315
Black shale	57	372

[d] Screen used only in Nos. 1, 3, 10, 15, 19, and 38.

WATER SUPPLIES OF WEXFORD COUNTY.

By Frank Leverett.

Wexford County, of which Cadillac is the county seat, is immediately east of Manistee County, in the western part of the southern peninsula. Its southeast corner is between the Lake Michigan and Saginaw lobes, on a prominent interlobate moraine, the highest point of which rises to a little above 1,500 feet and the greater part of which is above 1,300 feet. In this moraine wells have in several cases reached depths of over 200 feet before striking water, though the high hills are generally avoided and water is reached at 100 feet or less. This moraine extends but little north of Cadillac. Along its northwest border is a sandy plain several miles wide in which the Clam lakes are situated, from one of which the waterworks supply of Cadillac is drawn. North and west of this plain is a prominent moraine, with a crest 1,400 to 1,500 feet above tide. The village of Boone is near its eastern border, and Harrietta is in a recess on its western border, while Sherman and Manton are also near the inner border. It is a tract in which the few wells made are ordinarily deep, but much of it is still unsettled. West and north of this moraine is a broad plain through which Manistee River flows. It is largely covered with sand, but portions of it between Manton and Sherman have till at surface. The part north of the river is an outwash from a moraine that runs through eastern Manistee and southern Grand Traverse County. On this plain water is usually found at depths of 20 to 50 feet, or in harmony with the streams flowing into Manistee River. The county is tributary to Manistee River except a few square miles in the southeastern part that drain eastward through Clam River to the Muskegon.

Throughout the county the drift is so loose textured that water is nearly all absorbed, and there seems to be a general water table in harmony with the streams. Wells on high points and elevated plains generally go about to the level of the neighboring streams to strike water, and this in the highest ridges is about 200 feet. So far as known there are no flowing wells in this county. The only places where they seem likely to be found are in recesses in the moraine south of Manistee River, or along the low bottoms of the river or its tributaries.

No borings have been carried to sufficient depth in this county to reach rock, and it is probable that the rock lies several hundred feet below the surface.

The city of Cadillac and the village of Manton have waterworks plants using surface water. That of Cadillac is from Little Clam Lake which lies west of the city. The Manton supply is from a small stream running through the village. Wells are in common use for drinking at both towns. In Cadillac wells which the public utilize have been drilled along some of the streets in the business section. Analyses of water from the lake and from private wells at Cadillac were made by Mr. Lewis, who found that some carelessness is displayed in selecting the sites for wells. The porous character of the soil in this region is such that it will readily receive whatever surface contamination there may be.

In the accompanying table are given the results of a number of partial analyses made by S. J. Lewis in the vicinity of Cadillac. The lake water is soft and satisfactory. The Platt and Leeson wells are both supplied from sand beds in the drift. The Leeson water shows the normal composition, but the high percentage of chlorine in the Platt water indicates that it may be polluted by seepage from the near-by barns of the owner. The data are furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of well and lake waters at Cadillac.

[Parts per million.]

	1.	2.	3.
Color	46	65	37
Iron (Fe)	Strong trace.	.5	1
Chlorine (Cl)	21.7	51	24.25
Carbon dioxide (CO_2)	20.05	78.09	80.14
Sulphur trioxide (SO_3)	0	36	0
Hardness (as $CaCO_3$)	90.6	139+	139+

S. J. Lewis, analyst. 1. Lake. 2. J. H. Platt; depth, 36 feet. 3. Dr. J. Leeson; depth, 113 feet.

The data on village supplies given below were largely obtained by correspondence:

Village supplies in Wexford County.

Town.	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Benson post-office	1,300±	Springs and driven wells	16	200	40	150	−20	Small.
Boone	1,387	Driven wells	104	246	104	104		
Cadillac	1,280 / 1,400	Driven wells, and waterworks supply from lake.	30	150	50	50		Do.
Gilbert	1,250±	Driven wells	15	135	50	50		None.
Harrietta	1,115	do	35		35			Large.
Hobart	1,300	do	50	200				Small.
Manton	1,132	Spring brook for waterworks and wells.	12	30		30	−12	Large.
Sherman	920	Open and driven wells	10	90	25	25		Small.
Wexford	1,000±	Driven wells	35	185	50	60	−40	
Yuma	982	do	15	150	20	20	−15	

WATER SUPPLIES OF MISSAUKEE COUNTY.

By Frank Leverett.

TOPOGRAPHY.

Missaukee County is situated east of Wexford County, and is crossed by the same morainic systems as the latter, the interlobate moraine being in the southwest corner and the strong moraine north of it running through the center in a course south of east. There is a large amount of till plain between the two moraines in the south and also a till plain in the east. On these till plains the water table is generally near the surface, portions of them being swampy; but the moraines are of gravelly constitution and the water table is near the level of their bases or but little higher than in the till plains. The moraines have reliefs of 50 to 100 feet or more and the wells along them are of corresponding depths. In the northeast there is considerable swamp underlain with sand; this is unsettled, but there are settlements on its northwestern border at Stratford and Moorestown. North of this swamp, along the border of Kalkaska County, is a morainic belt which crosses to the north side of Manistee River near the northwest corner of the county. This morainic belt also is largely unsettled.

The greater part of the county drains southeastward into Muskegon River, but the northwestern part is tributary to Manistee River. In the western part, near Jennings and Lake City, there is a group of lakes, one of which is drawn on for the water supplies of those towns.

FLOWING WELLS.

In this district are three flowing wells, one at and two near Dolph post-office, in the Muskegon Valley, in the eastern part of the county.

DOLPH DISTRICT.

The well at Dolph is owned by F. L. Witherell, and has a depth of 62 feet. It stands on ground about 8 feet above Muskegon River, and has a head of 8 feet and a flow of about 9 gallons a minute. It penetrated blue clay and "putty sand" to the flow at 36 feet. The well was continued to greater depth in order to strike gravel, but found only fine sand in the lower portion.

A short distance north of Dolph, in sec. 34, Butterfield Township, also in the Muskegon Valley, is the flowing well of Elisha Clifford, about 40 feet in depth.

Another flowing well was made by a Mr. Bowman on a tributary of Muskegon River northeast of Dolph, in the edge of Roscommon County, but this was not visited.

McBAIN DISTRICT.

East of McBain, in sec. 21, Riverside Township, is the flowing well of John Gates, 34 feet in depth, with a head of at least 2 feet. It struck water at 4 feet and found it all the way down. The well cost $12.

There is a flowing well at D. G. Spreksell's, 1½ miles east and 1 mile south of McBain, about 25 feet in depth.

William De Zwaan has a flowing well about 40 feet deep located 3 miles east and one-half mile north of McBain.

There is also reported to be a flow, made by some hunters or campers, in an unsettled tract near the edge of Osceola County, southeast of McBain.

The extent of this district and the number of flows can probably be greatly increased, for the high moraine to the west forms a good catchment area. The flows near Dolph also lie east of a strong moraine, and it is probable that this district may be extended along Muskegon River and its tributaries. Much of that country is unsettled, so there has been no demand for wells.

WATERWORKS.

LAKE CITY.

The waterworks plant at Lake City is owned by a private company, and water is pumped from Lake Missaukee. It is largely used for drinking as well as for fire and sprinkling. It is soft enough for laundry use and in boilers. Some residents consider this supply less satisfactory for drinking than wells.

JENNINGS.

The waterworks at Jennings are operated by a private company, and the supply is drawn from Lake Missaukee. The water is soft enough for boiler and laundry use. Wells are in common use for drinking, as there is some distrust of the safety of the lake waters. The wells are usually 60 to 80 feet deep.

MISCELLANEOUS VILLAGE SUPPLIES.

Village Supplies in Missaukee County.

Town.	Population.	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Butterfield			Driven wells	14	116	14–35	27	−22	Large.
Jennings	900±	1,275±	Driven wells, lake	20	80	60	60		Small.
Lake City	816	1,260±	Driven wells, Missaukee Lake.	15	60	30	60		Do.
Lucas	200±	1,299	Driven wells	25	40	40	40	−30	None.
McBain	709	1,232	do	43	185	80	80	−20	Small.
Pioneer			Open and driven wells.	20	190	50	50	−20 −40	Do.
Stittsville			do	16	100	25	100		Do.
Stratford			Driven wells	25		25		−18	Do.

WATER SUPPLIES OF ROSCOMMON COUNTY.

By Frank Leverett.

General statement.—Roscommon County is situated east of Missaukee County, and embraces a high table-land in which Muskegon River and south branch of Au Sable River have their sources. The head of the Muskegon is in Higgins Lake, which lies at an altitude of about 1,150 feet and embraces an area of several square miles, bordered on the north by a moraine which rises above 1,200 feet. The outlet leads into Houghton Lake, a body of water about 10 miles long and 4 miles wide, whose altitude is about 1,125 feet. In the southeastern part of the county is a prominent moraine of the Saginaw lobe whose highest points are fully 1,400 feet above tide. On the borders of Houghton Lake and eastward across the county to Lake St. Helen are extensive swamps, underlain in large part by clay. Between this swampy tract and the high moraine in the southeast are extensive sand plains, parts of which are being developed as a forest reserve. On these sand plains the distance to water is but a few feet, and basins in them are occupied by swamps and small lakes. There are several small groups of hills scattered over the county, which, being composed largely of gravel and sand, probably have a water table at considerable depths. The water table also is at considerable depth in the high moraine in the southeast.

The county is very sparsely settled, the population in 1900 being but 1,787, of whom 465 were in Roscommon village. Most of the farming is done in Richfield and Markey townships.

Flowing wells.—At the west end of Houghton Lake there is a well about 30 feet deep, which flows at a level 8 feet above Muskegon River, on the bank of which it stands. It is largely through blue till.

Another flowing well, noted in the Missaukee County discussion (p. 304), is a few miles southwest of Houghton Lake, on the farm of Mr. Bowman.

So far as known these are the only flowing wells in the county, but it is probable that others might be had from Houghton Lake southwestward into Missaukee County in the swamp traversed by Muskegon River. Whether flowing wells could be obtained on Au Sable River has not been determined. The stream, however, follows the base of a prominent ridge near Roscommon, which may furnish head for flows.

In the vicinity of Houghton Lake, on the Hall farm and at King's store, wells on ground 25 feet above the lake have been sunk to depths of 50 to 75 feet. At Prudenville, a little farther east, the wells are only 12 to 24 feet in depth, and at St. Helen, on the border of Lake St. Helen, they are only 8 to 10 feet. At Nolan lumber camp, on the south side of the prominent moraine in the southeastern part of the county, wells are 8 to 30 feet in depth, and in the vicinity there are large springs. The wells in the neighborhood of Herbert post-office are 14 to 40 feet in depth.

Waterworks.—The village of Roscommon has a small waterworks system in which a windmill pumps water from a spring brook to an elevated tank about 16 by 22 feet, from which water is distributed through about 2 miles of mains to all parts of the village.

WATER SUPPLIES OF ALCONA COUNTY.

By Frank Leverett.

General statement.—Alcona County fronts on Lake Huron north of Saginaw Bay, Harrisville being the county seat. It is more elevated than counties to the north and south, there being a belt of high country fronting on the lake above Harrisville, which extends westward across the northern part. The highest points in the northwestern part reach about 1,200 feet above tide, and there are probably 40 square miles in the western part that stand above 1,000 feet. About three-fourths of the county stands between 700 and 900 feet above the sea. The lowland bordering the lake is limited to a strip about 5 miles wide at the south border and 3 miles at the north border, which is narrowed to less than 1 mile in the middle part of the county.

The drainage is nearly equally divided between the Thunder Bay River and Au Sable River systems, the north half being drained northward to Thunder Bay River and the south half southward and eastward to Au Sable River. A narrow strip on the border of Lake Huron is drained by Black River and other small direct tributaries to the lake. Au Sable River crosses the southwest corner of the county in a deep and broad valley, but receives no important tributaries in that part of its course. Pine River, with its numerous tributaries, drains six townships in the southeast and enters the Au Sable in Iosco County. The principal tributaries of Thunder Bay River in Alcona County are Hubbard Lake, with its main affluents, Sucker Creek, and Hubbard Creek in the northeastern part, and Wolf, McGinn, Silver, and Wildcat creeks in the northwestern part. Hubbard Lake is a body of water 7 miles in length and nearly 2 miles in average width, bordered on all sides by ranges of hills. There are numerous other lakes scattered over the county.

It is only in the eastern portion of the county that wells are sufficiently numerous to test the supply of underground water, and even there only to slight depths. In the thinly settled central and western portions springs and surface water are generally adequate to the needs of the residents, and the few wells made are usually between 15 and 30 feet in depth. In the eastern portion wells that are sunk beyond the surface water veins vary greatly in depth and in strength, because of the differences in texture of the drift. They indicate that a widespread bed of sand occurs under the surface clay in the eastern part of the county, which is often dry for a few feet but is charged with water farther down. In such wells there is little rise of the water above the level at which it is struck.

Flowing wells.—It is probable that flowing wells may be obtained in several localities within the county by sinking to a depth of 100 to 150 feet or less, for the situation is very similar to that in the flowing-well districts to the southwest at Rose City and West Branch, in Ogemaw County. One favorable belt is on the eastern slope of a moraine leading from Lott northward across tps. 25, 26, and 27 N., R. 6 E. Flows may perhaps be obtained in the southeastern part of T. 27 N., R. 5 E., and northwestward past McCollum Lake. If the ice sheet pushed up into that region from the northeast, as seems probable, the waters that soak in along the elevated moraine that constitutes the divide between Au Sable and Thunder Bay rivers are likely to be working down the slopes in the direction of surface drainage, and may have sufficient head to overflow in the comparatively low tracts near the head of Wolf, Silver, and McGinn creeks, and possibly for some distance down these streams.

In the eastern part of the county flowing-well prospects seem good along the lake shore, and flows may also be struck in low ground at the headwaters of tributaries of Hubbard Lake and of the east and west branches of Pine River. One flowing well has already been obtained near a branch of Pine River in sec. 11, T. 26 N., R. 8 E., at the moderate depth of 65 feet, which is at least an encouragement to prospect for others in similar situations along each side of this divide. The well referred to is on the land of Frank Blong, 2 miles southwest of Lincoln. It penetrated clay 18 feet, gravel (with weak water vein) 8 inches, clay with hard crust at about 30 to 35 feet from the surface and softer clay below at 44 feet, and terminated in gravel which yielded a flow of water. The altitude is about 120 feet above Lake Huron, or 700 feet above tide.

Springs.—Large springs abound along the lake front from near Greenbush northward past Springport and Harrisville, which supply the needs of residents to such an extent that but few wells have been made. Springs also abound along the headwaters of the several branches of Pine River and on nearly every stream tributary to Thunder Bay River. The water seeps out in such abundance that most of the streams are bordered by marshy tracts.

Miscellaneous village supplies.—At Harrisville springs issuing along the border of the lake have furnished most of the residents with water. In the winter of 1903 and 1904 a boring was made to test for oil and gas and flowing water. It was, however, located on the court-house grounds at an altitude 60 feet above the lake and a flow was not obtained. Before reaching a depth of 40 feet the well struck two strong veins of water, estimated to supply 150,000 gallons a day from an 8-inch pipe. Another supply was found at 100 to 130 feet in sand below hardpan, and still another was found in the Berea sandstone at 230 to 260 feet. The boring was carried to a depth of 506 feet and has the following section, furnished by J. H. Killmaster, of Harrisville:

Record of Harrisville well.

	Thickness.	Total.
	Feet.	*Feet.*
Yellow loamy soil	12.5	12.5
Quicksand, full of fresh water	14	26.5
Red clay	6.5	33
Coarse gravel, full of fresh water	6	39
Bowldery till	60	99
Sand with signs of oil and fair yield of water	30	129
Red clayey hardpan, with some sand and gravel	59	188
Red clay	4	192
Blue hardpan, with fragments of Berea sandstone	38	230
Berea sandstone, of light color, fine grained	30	260
Light-gray shale	149	409
Brown and black shale	97	506

At Black River village water is hauled from the lake and delivered in barrels to the residents, the lake water being of better quality than that obtained in shallow wells.

At Greenbush wells 25 to 30 feet deep furnish a good quality of water and are largely through sand and gravel.

At Lincoln lakes are used to a great extent for watering stock, but the houses are supplied by wells 30 to 40 feet in depth.

In and near Mikado wells are about 30 feet in depth, largely through clay. Farm wells in the vicinity of the village have been sunk to depths of 60 or 70 feet.

At Killmaster there is abundance of water at various depths, as shown by three deep borings made in prospecting for oil. Fresh water overflows from the base of the drift at depths of about 240 feet, and salt water, accompanied by inflammable gas, is struck in the Berea sandstone at 570 to 610 feet. In one of the borings gas had worked up into the base of the drift. No water was found below the Berea sandstone, although one of the borings was carried to a depth of 1,530 feet. These wells are discussed by Doctor Lane in the Annual Report of the State geologist for 1901.

At Vaughn wells ordinarily obtain a good supply of water at about 30 feet, and they are of similar depth in the vicinity of Lott.

At Spruce, in the north part of the county, wells are obtained at depths of 20 to 25 feet or less, but several farm wells in that vicinity have been sunk to depths of 80 to 100 feet.

Village supplies in Alcona County.

Town.	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Alcona	590	Lake Huron, springs, shallow wells.	10	30	20	20	....	Large.
Bamfield	870	Au Sable River, springs, shallow wells.	40	40	40	40	−35	Strong.
Black River	590	Lake Huron, shallow wells	8	40	8	8	− 4	Do.
Bryant	850	Shallow wells	20	30	25	25	....	Weak.
Greenbush	640	do	25	30	25	25	−20	Strong.
Gustin	693	do	30	50	35	35	−30	Weak.
Harrisville	600 640	Springs, shallow wells	10	40	30	....	....	Large.
Killmaster	700	Wells	20	240	30	30	+20	Weak.
Lincoln	770 810	Lake, shallow wells	30	40	35	35	−30	Do.
Mikado	634	Wells	30	70	30	30	−20	Do.
Springport	600 640	Mainly springs	30	40	30	....	....	Large.
Spruce	750	Shallow wells	15	30	25	20	−10	Weak.
Vaughn	1,000 1,025	Lakes, wells	20	80	30	30	−25	Do.

WATER SUPPLIES OF OSCODA COUNTY.

By FRANK LEVERETT.

Oscoda County is situated west of Alcona County, with Mio as its county seat. About half its surface is occupied by sandy plains unsuited for settlement, and much of the remainder is in sharp morainic ridges of gravelly or sandy constitution not calculated for successful farming. There are, however, fertile tracts to the northeast near Fairview, to the northwest toward Redoak, and to the southwest between Mio and Luzerne. The entire population of the county in 1900 was only 1,468; Mentor Township, including the village of Mio, is credited with a population of 119. Au Sable River runs through the county nearly centrally from west to east in a valley 50 to 100 feet below the bordering sand plains, draining, with its tributaries, all of the county except a narrow strip on the north edge, which discharges northward to Thunder Bay River.

The drift is probably several hundred feet in thickness, but no wells have yet reached rock. Several in the vicinity of Fairview are over 200 feet in depth, and are largely through sand. At Mio the dug wells are 50 feet, and bored wells in that vicinity are 100 to 150 feet. There are few places in the county where wells can be obtained at less than 50 feet, except in the valleys.

The village of Mio has a public water supply, built in 1889, in which water is pumped from a spring brook to an elevated tank. It is credited by the Manual of American Waterworks with 0.6 mile of mains, four hydrants, and 18 taps, all of which are reported to have cost $2,844. This yields an annual income of $1,000 paid by the village for fire protection and about $100 from other sources.

Village supplies of Oscoda County.

Town or post-office.	Population.	Elevation.	Source.	Depth of wells.			Springs.
				From—	To—	Common.	
		Feet.		*Feet.*	*Feet.*	*Feet.*	
Comins	7	1,150	Springs and driven wells	28	100	40	Large.
Fairview		1,250±	Lakes, springs, wells	20	220	65	Do.
Mio	100±	1,000±	Waterworks, wells	50	102	95	Small.
Luzerne	50±	1,100±	Wells	50	70	50	Do.
McKinley		900	do	12	15		Large.
Redoak			Driven wells	16	30	20	Do.

WATER SUPPLIES OF CRAWFORD COUNTY.

By FRANK LEVERETT.

Crawford County is situated on the high table-land in the northern end of the Southern Peninsula about midway between Lake Huron and Lake Michigan, Grayling being the county seat. Its western side drains westward to Lake Michigan through Manistee River, but the major part of the county drains eastward through Au Sable River. Its glacial drainage, however, was westward past Portage Lake to Manistee River. This county, like Oscoda, is very largely occupied by sandy plains or by moraines of loose-textured drift. The principal part of the farming is in Maple Forest Township, in the northern part of the county, and three towns in that part of the county, Judge, Frederick, and Deward, are largely devoted to lumbering. There are several good farms in the southern end of the county a few miles northeast of Higgins Lake. The township in which Grayling is situated had a population of 1,716 in 1900, a large part of which are within the village limits.

The wells throughout the county appear to be to a water table in harmony with the inland lakes and streams, and the drift so far as penetrated by them is mainly sand and gravel.

In Grayling, which is on a plain but little above Au Sable River, the wells are 20 feet in depth, and water stands within 13 feet of the surface.

At Judge the conditions are very similar to those at Grayling, wells being commonly from 16 to 20 feet deep, or about to the level of the north fork of Au Sable River. On moraines near Judge a depth of 135 feet is reached by the deepest wells.

At Frederick, wells are about 40 feet in depth with the water level perhaps 25 feet below the surface. On the moraine east of Frederick, in Maple Forest Township, wells are usually nearly 100 feet and in some cases about 200 feet in depth, with but a few feet of water in the bottom.

At Deward, in the valley of Manistee River, wells need to be driven only 10 to 20 feet.

In the southern part of the county near Wellington the wells range from 30 to 200 feet in depth, the deepest being on morainic ridges, and the shallowest in valleys. On most farms, however, wells are obtained at 50 to 100 feet.

The distance to rock, as determined by a boring at Grayling, is 365 feet, making the rock surface 775 feet above tide at that point. The drift here is largely sand and filled with water. This boring, which reached a depth of 2,750 feet, is discussed by Doctor Lane in the report of the State geologist for 1901. The highest points in the county are nearly 1,400 feet and the drift beneath them is liable to be over 600 feet, if we may judge by the altitude of the rock at the Grayling well.

At Roscommon, just south of the county line, a boring was made many years ago which is thought to have reached rock at about the same level as that at Grayling, but no accurate record is now to be obtained.

WATER SUPPLIES OF KALKASKA COUNTY.

By Frank Leverett.

General statement.—Kalkaska County lies west of Crawford County, on the western slope of the high tract in the northern part of the peninsula. Its eastern and southern parts are drained by Manistee River and its northwestern parts by Boardman and Rapid rivers. The part south of Manistee River has a small settlement around Fletcher, in the southeastern township, where there are a few square miles of good farming land, but the remainder has scarcely any settlers. The eastern townships north of the river have only lumber camps. The principal farming district in the county is on a morainic belt lying east of the Grand Rapids and Indiana Railway and running entirely across the county from its north border to its southwest corner. The railway runs through a sandy plain several miles wide that is largely unsettled. In the northwestern part of the county is another morainic belt which is nearly all settled. The northwest corner is on a low sandy plain bordering Torch and Round lakes.

Wells.—The only flowing wells noted in this county are in the southwestern part near Fife Lake. Walton Blue has a well in a valley near the center of sec. 7, Springfield Township, 22 feet in depth, which flows a weak stream. About a mile southeast, at an old sawmill site, in the western part of sec. 17, is a flowing well 63 feet deep, which discharges a 1-inch stream.

It is probable that flowing wells may be obtained in the vicinity of Rapid City and Barker Creek at the foot of the moraine in the northwest part of the county, for they have been obtained in similar situations a few miles to the west at Williamsburg and Traverse City. (See pp. 315–324.)

The wells in the Fletcher settlement go down 60 to 70 feet to water and have very little head.

In the moraine east of the Grand Rapids and Indiana Railway wells run from 40 to over 100 feet, the ground-water table being generally about on a level with the inland lakes and streams. The moraine is loose textured and largely gravel and sand below a few feet of surface till.

In the sand plain along the railway wells are also sunk to a general water-table in harmony with the streams and lakes, and range in depth from 10 feet near Kalkaska to about 80 feet in the northern part of the county. The moraine in the northwestern part has wells of various depths from 25 to 200 feet, there being no general water table. The deep wells, however, go to a level about as low as the sandy plain in the northwest corner. On that plain water is only a few feet below the surface, or in harmony with Torch and Round lakes.

So far as ascertained no wells have reached rock, and it is probable that the rock surface lies at a depth of several hundred feet throughout the county.

Miscellaneous village supplies.—Barker Creek is on the slope of the moraine south of Round Lake, in the southwestern part, at a level about 40 feet above the lake, or 630 feet above tide. Wells obtain water at 16 feet, and there are large springs in the vicinity which supply part of the residents.

Rapid City is on the sand plain near Torch Lake, and has wells 16 to 20 feet deep.

Kalkaska, the county seat, is on Boardman River, and wells are obtained at 10 to 24 feet. There is a waterworks plant, which pumps its supply from the river, and is mainly used for fire protection and street sprinkling. The water, both in wells and river, is soft enough for laundry and boiler use. In wells 10 to 16 feet deep it is softer than in the deeper ones, probably because of more thorough leaching of the upper part of the sand.

Below are given two partial analyses,—one of a shallow-well water and one of a river water at Kalkaska. There has been much typhoid in the town, and the shallow waters must be regarded as unsafe. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of well and river water at Kalkaska.

[Parts per million.]

	1.	2.
Color	107	10
Iron (Fe)	2.5	(a)
Chlorine (Cl)	9	9
Carbon dioxide (CO_2)	66.17	60.55
Sulphur trioxide (SO_3)	0	0
Hardness (as Ca CO_3)	139+	132.1

[a] Very slight trace.

S. J. Lewis, analyst. 1. Pere Marquette Railroad; depth, 28 feet. 2. Boardman River.

Leetsville, though in the same sand plain as Kalkaska, is 50 feet higher, and has wells correspondingly deeper, the usual depth being 65 feet.

At Westwood, which is north of Leetsville on the sand plain, wells are 50 to 60 feet deep.

At South Boardman wells are 18 to 40 feet, the town being on the uneven slope of the moraine that lies east of the Grand Rapids and Indiana Railway.

At Spencer and Sharon wells are only 12 to 20 feet deep, for they are on low tracts bordering Manistee River.

WATER SUPPLIES OF GRAND TRAVERSE COUNTY.

By Frank Leverett.

GENERAL STATEMENT.

Grand Traverse County is situated at the south end of Grand Traverse Bay, with Traverse City as the county seat. The south end of the county is occupied by an elevated moraine, with a southern outwash apron extending into Wexford County. North of this is a broad gravel plain traversed by Boardman River to the meridian of Traverse City, and continued westward, past a group of lakes near Interlochen, into Benzie County. This gravel plain is an outwash apron from a morainic belt that sweeps around the head of Grand Traverse Bay in the northern part of the county. Traverse City stands in a recess on the inner border of this moraine, and its numerous flowing wells are fed from the water absorbed by the moraine. The peninsula which runs northward between the arms of Grand Traverse Bay is occupied by a rather porous drift beneath the surface coating of till, so that underground drainage is very efficient.

Throughout much of the county the water table appears to be nearly as low beneath the moraines and elevated gravel plains as the surface of the neighboring streams and lakes, and wells ordinarily go to depths corresponding to the relief of the well mouths above the nearest stream or lake. On the gravel plain in the south part of the county, and the moraine of which it is the outwash, wells are ordinarily from 75 to 190 feet in depth, those near the crest of the moraine being deeper than on the plain to the south. Several wells around Summit City are over 100 feet in depth, but the common depth is 35 to 50 feet.

At Fife Lake and Walton, which stand but little above the drainage lines, wells are obtained at about 30 feet.

West of Traverse City is a prominent moraine in which the depth to water is in some places very great. Henry Sochleben has a well near the center of sec. 6, T. 27 N., R. 11 W., which is 293 feet in depth and was entirely through sand after penetrating about 5 feet of surface clay; water rises in it only 15 feet from the bottom. R. Wiedoft, on the west side of the same section, at a level perhaps 75 feet lower, has a well 220 feet deep, with but a few feet of water in the bottom. L. Ruthart, in the northwest part of sec. 5, has a well 230 feet deep which penetrated considerable blue clay and has 20 feet of water.

On the peninsula records of wells near the highest points show that water is struck at about the level of Grand Traverse Bay. Joseph Eiman has one 180 feet and William Ayers one 197 feet in depth in the northwestern part of sec. 10, T. 29 N., R. 10 W., both of which strike water in gravel practically at the level of Grand Traverse Bay. There are, however, wells on this peninsula which obtain a fair amount of water at moderate depths, this probably being due to the presence of a nucleus of clay beneath the looser textured drift, which prevents the water from sinking down to the level of the bay.

The flowing wells of Traverse City and of Williamsburg, a village 12 miles east, are discussed below by Mr. Gregory. These, so far as known, are the only flowing wells in the county. It is probable, however, that flowing wells may be obtained along the north shore of the high moraine in the south, for the situation is similar to that at Traverse City and Williamsburg, and it is a region of strong springs. They may also be obtained some distance up Boardman River from Traverse City, and around Fife Lake, as they have already been found in the neighboring part of Kalkaska County.

MISCELLANEOUS VILLAGE SUPPLIES.

At Interlochen wells are driven to depths of 12 to 22 feet to a water table in harmony with neighboring lakes.

At Karlin the wells are about 40 feet and have very little head.

At Mayfield the depth ranges from 12 to 30 feet.

At Old Mission the wells are 20 to 50 feet deep.

At Summit City the common depth is 35 to 50, but the range in depth is from 14 to 112 feet.

At Monroe Center the wells are from 25 to 30 feet in depth.

At Cedar Run, in the northwest corner of the county, is a very strong spring, which supplies most of the inhabitants. The wells in that vicinity range from 8 feet to 150 feet, the deep ones being on the elevated land.

FLOWING WELLS.[a]

WILLIAMSBURG AREA.

The Williamsburg area, less than three-fourths of a square mile in extent (see fig. 61), is located on the banks of a small creek of eastern Grand Traverse County. With a general elevation of 690 feet this area is bordered by moraines and outwash plains having an elevation of 800 feet. The precise limits of the district have not been outlined, as few trials for flows have been made along the border of the area, which appears to be confined almost to the village itself.

Out of 23 wells in this region 20 flow, furnishing an abundant supply of water for domestic and stock purposes.

The first well was drilled in 1892, on the property of Mr. J. H. Bissell (No. 4), and is still flowing, with no perceptible decrease. The temperature, quality, and abundance of the water are such that it has been utilized by Mr. Bissell for a State fish hatchery. It is valuable for keeping in equable and natural condition the young fry. This use

[a] By W. M. Gregory.

of water could be profitably extended to some of the other flowing-well districts in the northern part of the State.

The wells are all driven; a few have screens and points, but the large number have simply galvanized pipes driven to the water beds. The average cost of the wells, with 2-inch pipe, is $1 a foot, though some cost less when made by the owners. The average cost here is somewhat higher than in other areas, owing to the fact that wells drive harder here and some trouble has been experienced with bowlders.

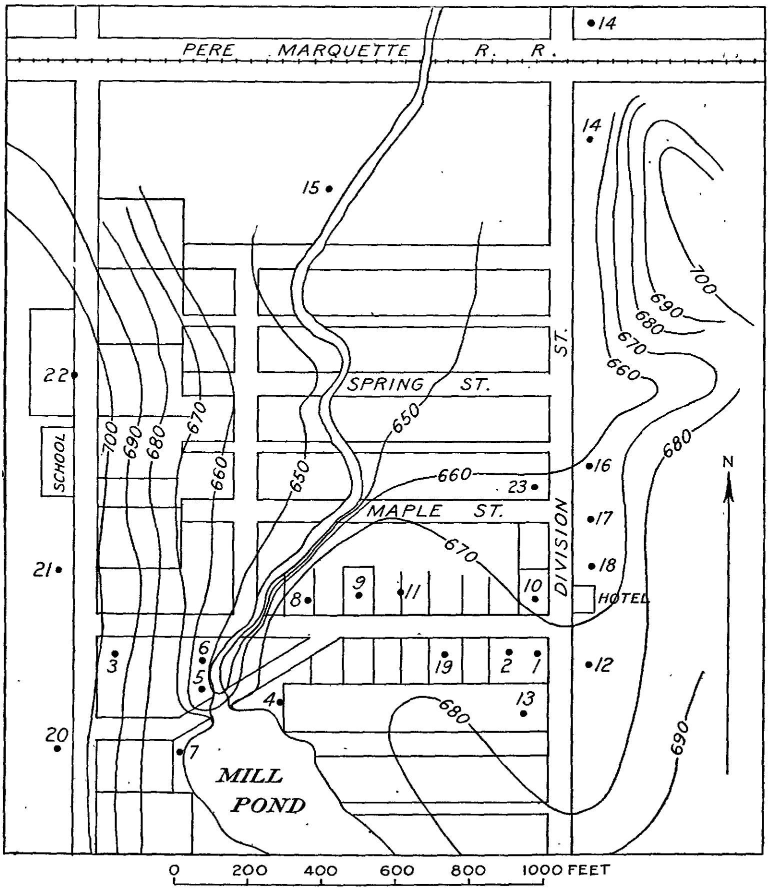


FIG. 61.—Contour map of Williamsburg flowing-well district.

The combined flow of the 20 wells is 448.5 gallons a minute, the largest flow (130 gallons a minute) being at the fish-hatchery well (No. 6). Several cases have been observed of decrease in head, due to drainage of one well by a near neighbor tapping the same water bed, but no general change in flow has occurred.

The water beds which supply the wells at Williamsburg are two, the upper supplying the majority of the wells, for the lower has not been exploited enough to reveal its extent. The upper water bed is of gravel and sand, covered by a few feet of hardpan, 35 feet of clay with small sandy seams, and 10 feet of sandy soil at surface. The general relations of a water bed along an east-west section are shown in fig. 62. The wells, with the exception of the fish-hatchery well (No. 6), are dependent for their supply on this bed of coarse gravel and sand. A section (fig. 63) north from Mr. B. Johnson's well (No. 12) brings out clearly the distinct dip which the water bed has to the north, but the 50-foot wells at the Williamsburg creamery indicate that this dip is not continued to the north as regularly as the profile indicates. An attempt was made at the creamery to secure a stronger flow by drilling deeper than 50 feet, but the drillers reported mostly hard clay from 50 to 310 feet with no water. Several attempts about the edge of this basin have been made to penetrate the water beds. At Mr. Lidell's farm a well (No. 20) 400 feet deep failed to secure water, which seems to be due to the fact that the water beds are near the surface and are easily overlooked in drilling, as has happened in other locations.

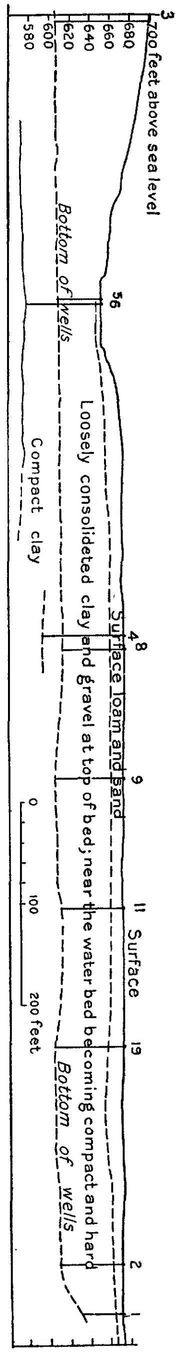


Fig. 62.—East-west section through Williamsburg district.

The location of Williamsburg is on the northern lakeward side of high plains of morainal outwash, which reach an elevation of 800 feet just outside the limits of the village. The small creek of the village is the product of the numerous springs which are so abundant along the edge of the drift at an elevation of 740 to 760 feet above sea level. To the south there is abundant chance for a catchment area in the loose porous drift, which has clay at bottom, as is indicated by some of the small lakes which exist there.

The water is used throughout the village for laundry and domestic purposes, and is not considered hard, lathering freely with ordinary soap. Analysis shows its hardness to be near that of the average drift water. Sulphates and iron seem to be absent, and the two field analyses of samples from wells No. 16 and 2 show how water from the same bed is apt to differ in carbonates. The water is very free from surface contamination, and is an excellent potable water. Its temperature, purity, and freedom from silt are of special value in this region for the fish-hatchery business.

Analysis of water from well at Williamsburg.[a]

	Parts per million.
Silica (SiO_2)	8.40
Sulphate radicle (SO_4)	7.32
Carbonate radicle (CO_3)	90.44
Chlorine (Cl)	2.67
Sodium (Na)	1.80
Potassium (K)	.31
Calcium (Ca)	46.85
Iron (Fe)	5.95
Aluminum (Al)	2.86
Magnesium (Mg)	9.93
Lithium	Trace.
Organic matter	Trace.
	176.53

Analyst, John E. Clark, M. D., Detroit College of Medicine.

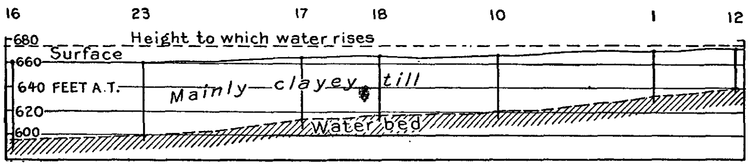


FIG. 63.—North-south section through Williamsburg district.

Analysis of Weesh-Ko-Wong flowing well water, Williamsburg.[b]

	Parts per million.
Silica (SiO_2)	8.40
Aluminum (Al)	2.78
Iron (Fe)	6.00
Calcium (Ca)	46.77
Magnesium (Mg)	9.96
Sodium (Na)	1.78
Potassium (K)	.34
Sulphate radicle acid (SO_4)	7.42
Chlorine (Cl)	2.67
Carbonate radicle acid (CO_3)	90.33
	176.45

Analyst, John E. Clark, M. D., Detroit College of Medicine, March 6, 1893.

Field analyses of water from wells at Williamsburg.

[Parts per million.]

	1.	2
Hardness	148	178
Carbonates	110	160
Chlorides	5	10
Sulphates	0	0
Iron	0	0

1. Charles Wills (No. 16). 2. Dr. Prentice (No. 2).

[a] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.
[b] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Wells at Williamsburg.

No. on fig. 61.	Owner.	Elevation.	Diameter	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Ft.	In.	Ft.	Ft.	Ft.	Gls.	°F			
1	D. E. Rolf [a]	673	1½	40	633	.....	30	48¼	Soft...	$12	Made in 12 hours.
2	Dr. Prentice	673	1	60	613	.....	28	48	....	60	See analysis (p. 318).
3	Dr. C. A. Clark	700	1½	96	604	701	25	49	Soft...	90	Flow decreased by No. 6.
4	J. H. Bissell	673	1½	82	591	683	10	48	....	82	See analysis of Weesh-Ko-Wong well (p. 318).
5	Fish hatchery [b]	655	2½	45	610	.....	12	....	....	45	Water flowed around pipe.
6	Fish hatchery [c]	655	4	87	568	680	130	48	....	200	
7	J. Abbott	672	1½	42	630	.....	10	....	....	130	
8	Ralph White	675	1½	60	615	680	13	48	Soft...	60	Head said to be decreased by No. 6.
9	James Ernest	674	2	65	609	.....	13	....	....	.....	
10	F. E. White	669	2	55	614	673	10	48	....	.....	
11	S. J. Seeley	673	2	60	613	.....	12	....	....	55	Sand 10 feet at top; remainder sand and clay.
12	B. Johnson	672	2	35	637	676	6	....	Soft...	35	
13	Methodist Episcopal parsonage.	675	1½	43	632	.....	25	49	...do..	40	
14	Williamsburg creamery. [d]	658	....	45	613	.....	.....	....	....	.....	Flow not estimated.
15	A. Devries	650	2	60	590	.....	6	....	....	.....	
16	Chas. Wills [e]	660	2	64	596	674	30	48	....	30	Head, 14 feet; see analysis.
17	W. Herald [f]	664?	2	55	609	.....	46	48	....	25	
18	H. Hobbs [g]	665	....	50	615	674	15	50	....	25	
19	Dr. Van Stickle	672	....	60	612	.....	12½	48	....	30	Decreased by Nos. 5 and 6.
20	Lidell farm	705	2	400?	305	.....	.....	....	....	.....	No water; said to be mostly clay from near surface.
21	Bissell farm	703	....	100	603	.....	.....	....	....	.....	No flow.
22	J. Lidell	705	....	116	589	.....	.....	....	....	.....	Do.
23	T. J. Conklin [h]	660	2	62	598	.....	15	49	....	50	Made in 1903.

[a] Water rose 18 feet at time of drilling; has decreased to 3 feet now. Beds penetrated as follows: Dark loam and sand, 10 feet; sand and clay, 30, and water in gravel bed, 40 feet. Well driven in 15 hours; throws sand.

[b] Two wells at fish hatchery have some sand at top, and the remainder is clay, with sheets of sand, which contain no water, but are a hindrance in drilling. Water from bed of gravel with some sand; Below water bed is a compact clay bed 20 to 30 feet thick.

[c] Water broke out about pipes, and has required many cubic yards of filling, making the cost high. Temperature said to be 43° November 1, 1903.

[d] Three wells, 45, 49, and 50 feet deep. Attempt was made here for deep water supply; went 310 feet, all clay, no water.

[e] Head 14 feet; affects other wells in near vicinity.

[f] Lowered by No. 16.

[g] Actual depth not known.

[h] Sand 10 feet; clay, with sandy sea ns, 40 feet; hard, compact clay 8 feet; gravel water bed.

TRAVERSE CITY.

The flowing wells of Traverse City are confined to a small area of 4 square miles in Farfield Township at the head of West Grand Traverse Bay. This region is a depression in the drift which was filled by an ice tongue of the Michigan lobe and was later covered by Glacial lake deposits of considerable thickness, as revealed by deep wells in Traverse City. Flows are obtained at from 50 to 400 feet in depth, and at present are 19 in number, yielding abundant and excellent water. These wells are in drift material, and casing is necessary, as much sand is encountered and causes considerable annoyance. The wells vary from 3 to 8 inches in diameter and cost on the average about $1 a foot, the work being done by contract for a flow.

The total flow from these wells is 1,092 gallons a minute, the figures being based on measurements made by well drillers at the time of completion of the various wells and by the writer where the wells were freely flowing. In a special report of the water-supply committee of the Traverse City council, Mr. G. W. Rafter, the consulting engineer, expressed doubt as to the ability of flowing wells to furnish a sufficient quantity for a city supply, but a flow of 1,092 gallons a minute would be ample. A few of the wells have decreased considerably. The Park Place Hotel well, for instance, now yields only half its former flow, according to Mr. Fairbanks, a well driller of Traverse City. The first well in this city was made on the grounds of the Northern Michigan Asylum in August, 1897, and flowed 600,000 gallons a day from a depth of 93 feet. In April, 1890, this flowage suddenly ceased; investigation showed that the pipe was filled with clay; by driving to 190 feet a good supply was reached. This well, with another recently made, 100 feet deep, now supplies the institution with 400,000 gallons a day, much more than is needed. In the well on the asylum ground the pressure is 8.75 pounds at the well head, which is 70.25 feet above the engine room of the institution, where the pressure is said to be 40 pounds to the square inch. The total cost of the well and pipe line was $1,500 and was made by contract. The wells are 135 feet above Lake Michigan, on the slope west of the asylum buildings, and were discovered by workmen in making an excavation for a standpipe. The well on the Lion saloon property is carefully piped, and supplies a bottling factory, several stores, a saloon, and a large fountain. Water rises 8 feet from the end of a 1-inch nozzle on 20 feet of hose attached to the main pipe at the saloon, and at time of drilling the well spouted a 2-inch stream 32 feet above its mouth. More use would be made of the artesian water in Traverse City if it were not for a city ordinance prohibiting pipes from crossing alleys and streets.

Several analyses and a number of careful field tests have been made of the waters. Mr. George Rafter considered the water rather hard for boiler use, and the amount of iron rendered it rather undesirable for laundry purposes. The water from the Park Place Hotel has the following composition:

Analysis of water from Park Place Hotel well, Traverse City.[a]

	Parts per million.
Silica (SiO_2)	6
Calcium (Ca)	48.55
Magnesium (Mg)	9.88
Iron (Fe)	1.53
Sodium (Na)	2.25
Chlorine (Cl)	3.45
Sulphate radicle (SO_4)	1.20
Carbonate radicle (CO_3)	106.54
	179.40
Free ammonia	.15
Albuminoid ammonia	.08

Hardened by soap test, 12; permanent hardness, 6; temporary hardness, 6.
Doctor Kedzie, analyst.

The analysis shows nitrites entirely absent and nitrates present only as a trace.

The field tests on samples from the Park Place Hotel well show carbonates to be 170 parts per million, no reaction for sulphates, 170.8 parts of hardness, and chlorides 5.2 parts per million. An analysis by the Northern Michigan Insane Asylum of the water when it came from the 93-foot well is as follows:

Analysis of water from well of Northern Michigan Insane Asylum, Traverse City.[b]

	Parts per million.
Silica	34
Oxide of iron and aluminum	5.10
Carbonate of lime	168.75
Carbonate of magnesia	68.47
Sulphate of lime	27.04
Sodium and potassium chlorides	Trace.
Sodium and potassium carbonates	10.27
	313.63

The Lion saloon well had a total hardness of 178.8; carbonates 200, chlorides 25.4, and iron 2 parts per million. For the comparison the analysis of water from a spring on the land of Hannah Lay & Co., south of the asylum, is given:

Analysis of spring water near Traverse City.

	Parts per million.
Sulphate radicle (SO_4)	2.12
Carbonate radicle (CO_3)	82.14
Magnesium (Mg)	.17
Sodium (Na)	.39

[a] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

[b] Expressed by analyst in grains per gallon; recomputed to parts per million at United States Geological Survey.

	Parts per million.
Chlorine (Cl)	.61
Calcium (Ca)	56.17
Silica (SiO_2)	3
Free ammonia	2
Albuminoid ammonia	1.5

The two water beds which have been utilized to supply the present wells are at depths of 450 to 350 feet and at 200 feet, respectively, above tide. The upper of the two beds furnishes the greater supply and the best pressure. The following wells are supplied from this bed: Traverse City high school, Jackson's fish house, William Brothers, P. Hannah, Park Place Hotel, Lion saloon, and the old well at the Grand Rapids and Indiana depot. At the high school the following order of drift material was found:

Record of high school well, Traverse City.[a]

	Thickness (feet).
Sand	30
Clay	40
Sand and gravel	60
Marl	5
Gravel and first flow at	238
Stronger flow at	270

In drilling wells down to this first bed the usual order is 100 feet of sand with small streaks of clay, succeeded by 200 feet of gravel, sand, and clay, which becomes hard and compact 250 feet below the surface. In drilling the new well at the depot the drillers found a good flow at 316 feet and a fair one at 417 feet, both beds being utilized for the flow in this well. The two wells of E. S. Pratt, which are situated on hills west of the city, are believed to tap heavy springs such as were found in the early exploration for water on the State asylum ground. A number of wells have been made on a lower level to a depth of 75 feet, east of E. S. Pratt's place, but the water stands 20 to 30 feet below the surface. The wells which have been drilled below the 300-foot bed do not furnish a very satisfactory supply. The well at the county jail is 400 feet deep, but never rose more than to the surface; in drilling it the following drift was found:

Record of well at county jail, Traverse City.

	Depth (feet.)
Sand and some marl	200
Clay	200–232
Sand and clay alternately	252–340
Gravel	340
Sand and water	390–400

[a] For analysis see Water-Supply and Irrigation Paper No. 31, U. S. Geol. Survey, 1899, p. 30.

The well at the Boardman Avenue school is said to be nearly all sand, with a little clay at the bottom. The well recently made for the Grand Rapids and Indiana Railway is 417 feet deep and has a good flow, but the larger part of it is evidently from the upper bed. Many attempts have been made to get water at the Oak Park school, in the eastern part of the city, one well being drilled to 400 feet, and at present having a very small flow. In this well the following material was penetrated:

Record of Oak Park school well.

	Depth (feet.)
Sand (thickness)	30
Clay (thickness)	60
Water in sand (depth)	220
Red clay (depth)	363–383
Gravel and small flow (depth)	383–400

The well on the property of Ellis Ramsell was drilled through the following material:

Record of Ellis Ramsell well.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	60	60
Gravel	60	120
Clay	40	160
Sand and gravel	20	180
Hardpan	50	230
Clay, water under clay	60	290

At the State asylum Mr. Fairbanks helped to drill the 93-foot well and found nearly 35 feet of sand and gravel, the remainder being hard clay, under which was the water. At 75 feet a log 3 feet in diameter was encountered.

In seeking for flows in this area the wells should not be deeper than 350 feet, and the lower the elevation of the well mouth the greater will be the pressure.

No rock has been reached in any of the Traverse City wells, but in the Provement well at Fountain Point, some 12 miles northwest of Traverse City, it is nearly 312 feet to rock, and at Elk Rapids some 15 miles northeast it is 450 feet.

The catchment area for the Traverse City wells is found on the surrounding moraines and associated plains of porous overwash material, which reaches an elevation of 800 to 1,000 feet in the region west and south. In the immediate vicinity the material exposed on some of the hills is porous enough to absorb the necessary water to supply the strong flows.

Wells at Traverse City.

Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.[a]	Remarks.
	Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*	
Lion saloon	605	6	307	248	670	210	49½	Flow from gravel.
Grand Rapids and Indiana depot (new).	605	......	417	187	640	54	51	Steaming and drinking.
Park Place Hotel	605	3	357	248	630	25	50	Drinking fountain.
P. Hannah	......	4	350	......	......	63	......	Domestic use.
County jail	605	......	400	205	605	......	......	Small flow.
E. S. Pratt	659	8	50	609	665	80	......	Domestic use.
Williams Bros	625	......	367	258	645	112	......	Flow from gravel.
State Insane Asylum	715	......	290	527	735	277	......	Drinking.
Oak Park school	615	4	400	215	615	2	......	Do.
Jackson fish house	605	4	300	305	635	50	49	Fishing, packing.
E. R. Ransom	......	......	486	......	......	......	......	
Boardman school	620	......	235	390	628	5	......	12 feet in block shale.
Grand Rapids and Indiana (old well).	605	6	311	284	630	45	49½	
Carter's mill	585	......	180	405	585	1	......	Small flow.
Mr. Broadhagen	635	3	330	305	655	90	......	At house on Washington street.
High school	612	4	271	341	656	......	......	Pressure of 17 pounds.
Wilhelm Bartok Co	592	......	280	......	603	15	......	
Ellis Ramsell	......	......	......	280	......	......	......	

[a] The only satisfactory temperature observation was at the Grand Rapids and Indiana depot well (new). The others are affected by buildings, etc.

WATER SUPPLIES OF BENZIE COUNTY.

By Frank Leverett.

GENERAL STATEMENT.

Benzie County, of which Frankfort is the county seat, fronts on Lake Michigan in the northwestern part of the peninsula. The lake shore presents a succession of headlands 200 to 300 feet high, between which are low embayments extending back several miles inland and terminating in a strong morainic belt of which the headlands are small interlobate spurs. The interior and eastern part of the county is a somewhat elevated plain with numerous lakes and basins interrupted by groups of knolls. The altitude of the plain is between 200 and 300 feet above Lake Michigan, and the lakes on it usually stand 30 to 50 feet below its general surface. The water table on the plain and also on the knolls appears to be in harmony with the neighboring lakes and drainage lines, for there is but little clay in them above the level of the lakes. The water table also is at a low level throughout much of the morainic region of the western part of the county. This is well shown at Benzonia, which stands on a moraine south of Crystal Lake at a level 200 feet above the lake, and has a water level at least 125 feet below the surface. There are, however, a few places in the morainic tracts where there is enough clay present to prevent the downward passage of the water, and thus permit wells to be obtained at shallow depths.

The principal streams are Betsy and Platte rivers, the former draining the southern and the latter much of the northern part of the county. Between their mouths and near the shore of Lake Michigan stands Crystal Lake, a body of water 9 miles long and 2 miles wide, connecting with Betsy River through a narrow gap in the morainic hills that encircle the lake. Platte River discharges through Platte Lake, a body of water covering several square miles, just before entering Lake Michigan. These lakes apparently occupy basins of considerable depth which were left by the ice sheet. The lakes of the interior of the county are all small and are usually in basins in the gravel plains.

The drift in this county is shown by borings at Frankfort to extend down nearly to sea level, being 570 feet in one boring and 527 in another. The rock surface seems to be about as low to the east at Traverse City, and may hold a low level beneath the high tracts which lie between Frankfort and Traverse City, in which case the drift would have a thickness of about 1,000 feet on the highest points.

FLOWING WELLS.

The embayments along the shore in the recesses of the moraine furnish favorable places for obtaining flowing wells, and such wells have already been made at Frankfort on Betsie River, at Beulah on Crystal Lake, and at Honor on Platte River, while others may be found near the Herring lakes in a recess a few miles south of Frankfort. There is also a single flowing well at Thompsonville in the southeastern part of the county, in the valley of a small stream. The wells at Frankfort and Beulah were examined by Mr. Gregory and are discussed on pages 327–330. The well at Thompsonville was reported by Mr. W. F. Cooper; those at Honor were examined by the writer.

THOMPSONVILLE.

The Thompsonville flowing well was made by John Irwin and has a depth of 150 feet, with a head of 5 feet.

HONOR.

The village of Honor stands at the foot of the north bluff of Platte River in northern Benzie county. Several flowing wells have been made in the eastern part of the village, all very near the bluff on ground a few feet above the broad valley bottom. It is probable that flows could be obtained on this lower ground.

George Weaver has a well 70 feet deep on ground about 9 feet above the railroad station, or 620 feet above tide. It has a head of more than 4 feet. It now escapes around the pipe, and this has reduced the flow through the pipe to a very weak stream—about 10 quarts an hour. It did flow a half-inch stream. The water is hard and has considerable iron. The temperature is 47.3° F.

South of this well about 50 yards is the flowing well of Ira Gordon, 38 feet deep. It flows a very weak stream—about 15 quarts an hour at a level 3 feet above the surface or 622 feet above tide. The water is said to be rather soft. The well struck a hard clay under the surface gravel at about 20 feet and obtained the water from a seep in the clay. The well has never been much stronger. The temperature is 48° F.

At a dwelling occupied by W. M. O'Brien on the south side of Main street is a flowing well only 21 feet deep which yields about 30 quarts an hour through a small escape pipe one-third of an inch in diameter. The altitude of the well is 618 feet above tide. The temperature was 48.5° F. in October, 1904. Possibly the effect of the summer heat would be felt in a well so shallow as this and give it a temperature higher than that of deeper wells or higher than it presents at the cold part of the year.

At another dwelling on the south side of Main street, occupied by Frank Weaver, is a flowing well that yields about 3 quarts a minute, and has a temperature of 47.8° F. This is the oldest flow in the village and has been in operation about eight years. The water contains iron in notable amount and is so hard that it needs softening for laundry use. The well is at an altitude of 617 feet.

On the north side of Main street, about 100 yards east of the well just noted, is a weak flow at the dwelling of Joseph DeWitt now yielding about 30 quarts an hour—about as much as it ever did. It is very shallow—15 feet—and had a higher temperature than the deeper wells, it being 49° F. The water carries iron, but is not very hard. The well has been in operation about 7 years. The altitude is 618 feet.

Across the street from the DeWitt well and on ground 3 feet lower, at a dwelling occupied by V. Pierce but owned by P. Reynolds, is a flowing well 21 feet deep. A pump is now attached because the head is very slight. The well was made in 1903.

A similar well, only 13 feet deep, with water rising barely to the surface, was made by J. C. Van Blaricom about 200 feet west of the Pierce well. It passed through a bed of clay at 6 to 13 feet and entered gravel at bottom. The water is rather hard.

Mr. Van Blaricom has another well at the post-office, with pump attached, but with a head of about 2 feet. This well is 23 feet deep. Its temperature, when pumped vigorously, could not be carried below 48° F. The altitude is 622 feet at the post-office. West from the post-office the dwellings are mainly on ground a little too high to admit of a flow.

BEULAH AND BENZONIA.[a]

In Beulah, Benzie County, in a narrow belt along the eastern shore of Crystal Lake, is a small area with seven flowing wells (fig. 64). The wells have a total flow of 56 gallons a minute and no indications of any decrease in head have been observed. The best head of water is obtained in wells nearest the lake. The irregular flow of a well at Small's livery barn is due to the presence of gas which, at the time of the writer's visit in July, 1904, was forcing small quantities of water out of the well at frequent intervals. The water supplied by these wells is hard and unsatisfactory for laundry use, but excellent for

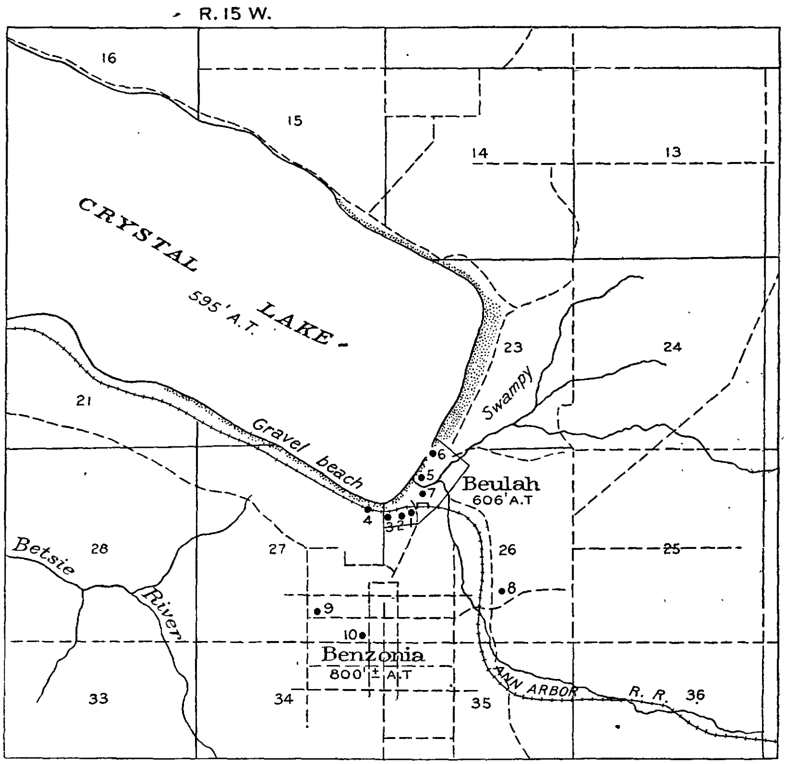


FIG. 64.—Map of southeast end of Crystal Lake, Benzie County.

drinking. The best supply in Beulah comes from the beds 100 to 150 feet below the level of Crystal Lake, the depth varying in different wells.

The field analyses of samples collected show that the waters are high in carbonates, reaching 300 parts a million in one case (the well of H. A. Bailey, No. 5), but this is higher than the average. Sulphates are absent from all the water tested, and chlorides are present in varying quantity, 34 parts per million from a well belonging to

[a] By W. M. Gregory.

Mr. Gibbs being the highest found. In several of the wells much CO_2 was present, especially in the Gibbs well. The water is somewhat harder than water at Oden, Indian River, and Williamsburg, varying from 136 parts per million in H. A. Bailey's well to 361 parts in J. Gibbs's well. It is easily sofened for laundry purposes by any of the various washing compounds, otherwise much soap is required. Water from the well of H. S. Bozy (No. 6) requires one-half more soap for laundry purposes than water from Crystal Lake. The flowing well water is excellent for drinking and in the well of Mr. H. Smith (No. 4) the water has mild cathartic properties.

Field analyses of water from wells at Beulah.

[Parts per million.]

	1.	2.	3.
Hardness	136	361.8	227.8
Carbonates	300	240	120
Chlorides	4	34	8.9
Sulphates	0	0	0
Iron	....	0	0

1. H. A. Bailey (No. 5). 2. J. Gibbs (No. 1). 3. H. Smith (No. 4).

In the houses where the water is used small tanks have been constructed so that full advantage may be taken of its temperature for cooling purposes. The temperatures vary slightly in the wells because of the difference in the length of pipe exposed, but the average is 49°.

Two beds seem to be present in Beulah which yield flows. The extent and thickness are unknown, for the well records are few and lack detail. According to Mr. N. Benson, a well driller of Beulah, the first bed of sand and gravel is 90 to 100 feet below the surface; the second bed ranges between 150 and 200 feet. The well of Mr. H. Smith (No. 4) is 97 feet deep, 94 feet to water, and has the following drift layers:

Record of H. Smith well, Beulah.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	3	3
Gravel	6	9
Yellow clay	20	29
Gravelly hardpan	25	54
Blue clay	40	94
Black clay and gravel	2	96
Gravel	1	97

In the well on the property of Mr. Small (No. 7) small flows are found at 150 and 200 feet. The well was drilled to 250 feet and was believed to be nearly to rock. The present flow of this well comes from 200 feet, but enough gas is present to cause an irregular flow.

The shallow pump wells of the town have never yielded a good supply of water, being deficient in quantity, and having a "swampy" taste. In drilling a well on the property of Fred Bailey (No. 3) the following drift was penetrated:

Record of Fred Bailey well, Beulah.

	Thickness.	Total.
	Feet.	*Feet.*
Gravel and sand	27	27
Muck shells and cedar wood	5	32
Yellow clay	20	52
Blue clay	50	102
Gravel	8	110

Mr. Benson, a well driller, thinks that good flows can be obtained along a large part of Crystal Lake at points less than 20 feet above the lake.

In the town of Benzonia, which is half a mile south and 180 feet higher than Beulah, the water bed is from 100 to 150 feet below the porous surface material, water being obtained at considerable expense.

Mr. T. B. Pettit's well, in Benzonia, 176 feet above Beulah, is driven 190 feet, and the water stands 175 feet below the surface; the entire cost was $230. Mr. Pettit has another well in sec. 27, near Benzonia, which is 85 feet deep and in which the water stands 75 feet below the surface. The soil here is largely sand and gravel with one clay bed of 19 feet near the surface. The village well of Benzonia is 213 feet deep, the lower 150 feet of which is fine clay and yields a scant supply of water.

The hills about Crystal Lake consist of loosely consolidated drift with irregular beds of clay. In a cut 100 feet above the Ann Arbor Railroad depot, on the steep hill road from Beulah to Benzonia the clay layers are thin, small, and irregular, but at lower elevations the clay is present in thicker layers, and seems to have been plastered upon the overwash material at places. A section on the hill road has the following layers exposed:

Section in road near Benzonia.

	Thickness (feet).
Sand	3
Pebbles	1
Clay and sand	10
Sand	5
Smooth clay, large, rough, rounded pebbles	8

Wells at Beulah and Benzonia.

No. on fig. 64.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Cost.	Remarks.
		Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*	*Gals.*	*°F.*		
1	J. Gibbs	609	2	150	459	613	8	47½		Drilled in 1900; screen; see analysis (p. 328).
2	J. Thompson	607	2	100	507		5			
3	Fred Bailey	608	2	110	498		2	49		Flow varies.
4	H. Smith	609	2	97	512	628	12	49		See analysis.
5	H. A. Bailey	607	2	166	441	627	10	50	$125	Drilled in 1901; water at 160 feet.
6	H. S. Bozy	600	2	180	420	619	19	50		Water hard.
7	F. S. Small	605	2	222	383					Flowage irregular.
8	E. J. C. Ellis		2	213						91 feet to water; pump.
9	T. B. Pettit		2	190					230	175 feet to water; pump and windmill.
10	Benzonia village			213						Lower 150 feet solid clay; weak well.

FRANKFORT AREA.[a]

The city of Frankfort, in Benzonia County, is situated at the mouth of Betsie River, on Lake Michigan. Only a few flows are found here in the drift, which is about 550 feet deep, the best water beds being 150 to 200 feet below the surface. There are only four of these drift wells, two at the Frankfort City waterworks, each 150 feet deep, one at the Ann Arbor Railroad grain elevator, 100 feet deep, and one at the Ann Arbor Railroad depot, 200 feet deep; the combined flowage is 7.5 gallons a minute. A sample of the water from the elevator showed 278 parts per million of hardness, no sulphates, 260 parts of carbonates, and 15.5 parts of chlorides.

Frankfort has two deep wells from the rock, both belonging to D. B. Butler. The deeper one is 2,200 feet, with a temperature of 58°, and flows 480 gallons a minute from a 6-inch pipe. It contains H_2S gas.

Wells at Frankfort.

Owner.	Diameter.	Depth.	Flow per minute.	Temperature.	Remarks.
	Inches.	*Feet.*	*Gallons.*	*°F.*	
D. B. Butler	4	1,800			Mineral water.
Ann Arbor Railroad depot	2	200	1.5	50.5	Drinking fountain.
D. B. Butler[a]	6	2,200	480.0	58.0	Mineral water.
Ann Arbor Railroad elevator	2	100	1.0	48	Drinking and boiler use.

[a] For analysis of water see Water-Sup. and Irr. Paper No. 31, U. S. Geol. Survey, 1899, p. 72.

WATERWORKS.

FRANKFORT.

The waterworks supply is from driven wells about 90 feet deep which only lack a few feet of flowing. The water is pumped to a tank on a hill north of the town.

[a] By W. M. Gregory.

THOMPSONVILLE.

The village of Thompsonville has a public supply reported to be from driven wells, about 60 feet deep, in which water rises to 10 feet below the surface. Water is pumped direct to mains.

MISCELLANEOUS VILLAGE SUPPLIES.

Village supplies of Benzie County.

Town.	Population.	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to main supply.	Head.	Springs.
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Benzonia	500	800	Driven wells	125	250	200	225	{ −100 −150 }	Large.
Beulah		{ 600 615 }	Driven wells, some flowing.	20	150	{ 100 150 }	100	Flow	Do.
Frankfort	1,465	595	Driven wells	45	2,200	{ 90 150 }	200	{ −5 +10 }	Small.
Homestead		805	do	8	100	50			
Honor	550	611	Driven wells, stream	12	40	30	30	+8	Do.
Lake Ann	241	816	Lake wells, springs	20	90	30	30	−15	Large.
Nessen City	±100	885	Driven wells	10	30	18	30		Small.
Platte		700	do	10	+200	75		−10	Do.
South Frankfort	639	600	do	30	90	30	30	−10	Do.
Thompsonville	893	791	do	16	150	40		{ −10 +5 }	Do.

WATER SUPPLIES OF LEELANAU COUNTY.

By Frank Leverett.

General statement.—Leelanau County comprises the point of land that extends northward between Grand Traverse Bay and Lake Michigan and also the Manitou Islands which lie a few miles off shore. Like Benzie County, it presents bold headlands along the shore, between which are low tracts extending back several miles and heading in a moraine of which the headlands are considered spurs. This moraine comes up from the southwest and curves around in the southern part of Leelanau County and then passes southeast to the head of Grand Traverse Bay. An elevated gravel plain about 300 feet above Lake Michigan lies on the south border of the moraine. The highest points on the moraine are about 400 feet above Lake Michigan, and at Sleeping Bear Point there is a bold bluff of nearly that height. In the recesses between the headlands are lakes, conspicuous among which are Glen Lake, which lies east of Sleeping Bear Point and has an area of about 6 square miles, and Carp Lake, which leads south from Leland and is about 15 miles long. Between these is a chain of lakes extending back nearly to Maple City. On the east side are small projections of Grand Traverse Bay, known as Northport Bay and Sutton Bay. The latter is similar to the recesses on the Lake Michigan shore in having headlands on each side.

The county has no rivers nor creeks but simply small runs leading down to the lakes from the moraines.

On the elevated morainic tracts and also on the gravel plain in the southern part of the county wells are usually deep, ranging from 80 feet on the gravel plain to 240 feet on the crest of the moraine. They reach about to the level of the neighboring lakes, and have little or no rise of water. There are wells 80 to 150 feet deep along the ridges that run from the moraine out toward the lake and bay. These ridges, however, contain clayey drift, and in places shallow wells are obtained on them. In the lowlands or recesses water in wells generally rises nearly to the surface, and in places will flow. It is probable that flows might be obtained at many points if borings were made in the lowest lands near the high ridges.

In one boring in the county, made in 1853 near Provement in sec. 36, T. 30 N., R. 12 W., rock was found at a depth of 312 feet, or 292 feet below the level of Lake Michigan and 288 feet above sea level.[a] It is reported that limestone rock outcrops at the northeast end of the county in the bed of Grand Traverse Bay at 20 to 25 feet below the water surface, and shale rises to considerable height in the east bluff of the bay opposite this point.

Flowing wells.—The well near Provement, noted above, which is now the property of Mrs. Florence Whitfield, of Ann Arbor, is about 780 feet deep, and flows with a reported head of 40 feet, or about 60 feet above Lake Michigan. It discharges with such force as to form an umbrella-shaped sheet, and to run a small brook, estimated at several barrels a minute. It is strong in sulphates with a considerable amount of H_2S gas and also CO_2.

It is reported that the flow of water was struck in the upper part of the rock, but no definite data in addition to those published by Winchell could be obtained. There was a deposit of sand, gravel, and bowlders for 146 feet from the surface, beneath which was laminated clay for 135 feet, and beds of sand and clay for 25 feet. The water here came in and kept increasing until the rock was entered at about 312 feet.

Whether flowing wells could be obtained in this valley along Carp Lake at less depths has not been determined. The topographic situation in a valley between prominent drift ridges seems favorable for obtaining flows.

The Empire Lumber Company has a flowing well 54 feet in depth at its mill on the shore of Lake Michigan in Empire. The water comes from gravel under sand and possibly under clay. The water rises only about 8 feet above the lake.

Miscellaneous village supplies.—The villages are all situated on low ground and consequently have shallow wells. No town has a com-

[a] Record by A. Winchell, Proc. Am. Assoc. Adv. Sci., 1875, p. 31.

plete waterworks system, but at Suttons Bay N. S. Johnson has provided for a partial supply by damming a spring brook. A larger dam and complete waterworks are contemplated.

Village supplies in Leelanau County.

Town.	Population.	Elevation.	Source.	Depth of well.			Depth to water bed.	Head.	Springs.
				From—	To—	Common.			
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Empire	609	586 / 620	Driven wells, Lake Michigan.	25	75	35	....	+4	Large.
Leland	±300	600	....do	18	18	18	18	−20	Do.
Maple City	±200	±700	Wells and springs	16	90	......	80	−28	Do.
Northport	545	610	Wells, springs, bay	12	100	25	100	a−5	Do.
Omena	±300	610 / 700	Wells and bay	20	200	100	100	−25	Small.
Solon	....	625	Driven wells, springs	15	235	15	....	−10	Do
Suttons Bay.	398	600	Pond by waterworks, wells, and springs.	17	70	30	....	−20	

a The postmaster at Northport has a well 90 feet deep that flows at 5 feet below cellar floor.

WATER SUPPLIES OF ANTRIM AND CHARLEVOIX COUNTIES.

By Frank Leverett.

GENERAL STATEMENT.

These two counties, which stand east of Grand Traverse Bay, are treated together, since they are so much alike. The part of Emmet County south of Little Traverse Bay is also included in the same description.

This district between Grand Traverse and Little Traverse bays contains a radiating system of finger lakes separated by prominent ridges, upon which drumlins have been developed. The lakes apparently lie, in part at least, in deep pre-Glacial valleys whose bottoms are 200 feet or more below the level of Lake Michigan. The ridges between have limestone exposed along the borders of Lake Michigan and Little Traverse Bay in Charlevoix and southern Emmet counties. Upon passing back to the southeast, Devonian shale sets in, which, in places, reaches an altitude of 120 feet or more above Lake Michigan, or fully 700 feet above sea level. The shale formation has a very uneven surface, and the ridges have been padded out with clay deposits. These were derived from the shale in large part, probably through the abrasion by the ice sheet, and yet they are often laminated as if deposited in water and are nearly free from stones such as appear in till. They are therefore considered lacustral rather than glacial deposits. They are overlain by till, and thus shown to be inter-Glacial. The lake clays are built up on some ridges to a height of nearly 300 feet above Lake Michigan, or much higher than the top of the shale ridges. The lake clays when not too thickly covered by till deposits have been shaped into drumlin form. Throughout much of the district, however, the drumlins are composed wholly of till. This drumlin district and the finger lakes associated with it finds its southeastern border in a prominent moraine running from northeast to southwest across the southeastern part of Charlevoix and central part of Antrim counties. On the outer or southeastern border of this moraine is a gravel plain forming a well-defined line of glacial drainage utilized because of its smoothness by the Grand Rapids and Indiana Railway from Elmira southwestward to Kalkaska. East of this gravel plain is an abrupt rise of about 150 feet to another moraine and this has a gravel plain on its outer or southeastern face that covers the southeast part of Antrim County and embraces the source of Manistee River.

Striking differences in water supplies are found which are determined by the texture of the deposits and the topographic relations just outlined. In the gravel plains and also to a great extent in the moraines that lie southeast of the drumlin district the water table is found at a level as low as the neighboring lakes and streams, for there appears to be little or no clay above this level to prevent the water passing down.

On the high moraine east of the Grand Rapids and Indiana Railway, wells are accordingly sunk to a depth of about 200 feet, or to the level of lakes in the gravel plain along the railway. Wells are 50 to 75 feet or more in this gravel plain. In the moraine west of the railway some wells have been found at depths of 30 to 50 feet, but the best supply is generally found by sinking to depths of 150 feet or more to a level in accord with streams on the inner face of the moraine.

Upon entering the drumlin area the conditions become more complex, for there no general water table is struck either near the surface or at great depths. The lake clay as well as the till carries water only along certain favored courses where there are sandy partings or veins, and the position of these can not be predetermined. Neighboring wells may, therefore, differ very greatly in depth, one obtaining water at 20 feet or less and its neighbor going to depths of 100 or even 200 feet. Instances were found where wells on the crest of drumlins, standing nearly 100 feet above the bordering sags, have struck water at only 30 to 50 feet, while neighboring wells nearer the level of the sags have gone far below the level of the lowest ground in the vicinity before obtaining a good supply.

Along the borders of the system of finger lakes several small flowing-well districts have been developed as indicated below, but the wells seldom have such head as the great reliefs would lead one to expect, and the districts in which flows are obtainable seems to be restricted, like the supplies in the drumlin areas to favored localities.

The valleys in which these lakes lie seem to be underlain by a looser textured material than the lake clay. This is commonly termed quicksand, but in the absence of samples it can not well be compared with the lake clay exposed in the ridges. There is generally a coarse sand covering the valley bottoms, derived in part from hillside wash, whose full extent and relations are undetermined. Many wells in the valleys are very shallow and obtain their supply from the coarse sand.

The rock formations furnish but a limited part of this district with water, the only points noted being a narrow strip along the border of Lake Michigan from near Norwood to Petoskey and thence eastward along the south side of Crooked Lake to Burt Lake.

FLOWING WELLS.

Flowing wells have been obtained from the rock near Norwood, and at Charlevoix, Petoskey, and Bay View, and possibly farther east in southern Emmet County, as indicated in the report by Mr. Gregory (pp. 365–378). The flowing-well districts of Charlevoix and Antrim counties have received only a hasty inspection by the writer in connection with other lines of investigation.

ALDEN.

Alden, a village on the east shore of Torch Lake, in Antrim County, has shallow wells on the shore of the lake with sufficient head to flow, but pumps are attached.

One well, made by L. Armstrong at a feed mill, is only 12 feet deep, and another, owned by Mr. Terrell, is of similar depth.

Benjamin Armstrong has a well about 100 feet deep on higher ground in the eastern part of the village, the water in which stands just at the surface.

A deep boring was made north of the station in Alden by E. F. Foster, which struck water veins at 57, 68, and 86 feet depth. The water from the 68-foot vein rose to the surface at an altitude 10 feet above Torch Lake, but from the other veins it fell short a few feet. The boring was carried to a depth of 278 feet without reaching rock. It was largely through sand, with thin beds of hard clayey material, to a depth of 86 feet. The remainder of the section was nearly all clay, though some beds of fine quicksand 2 to 8 feet thick were passed through. The lower 27 feet was a hard blue clay, and the boring stopped in this deposit.

INTERMEDIATE LAKE DISTRICT.

GENERAL RELATIONS.

Along the border of Intermediate Lake, from Central Lake village southward past Bellaire, the county seat of Antrim County, flowing wells are obtained at several points. Some are very shallow and penetrate little but muck and marl. Others go to considerable depth through clay before striking a flow. The wells are all on low ground bordering the lake or its outlet. Those at Central Lake are at an altitude of 609 feet above tide, or 2 to 7 feet above the lake, and those between Central Lake and Bellaire are at similar altitudes, with the exception of a well at a schoolhouse in the northeast corner of sec. 7, T. 30 N., R. 7 W., which is on ground about 640 feet above tide, or 33 feet above the lake. The waterworks wells in Bellaire are along the outlet of Intermediate Lake below the dam at an altitude of only 600 feet, and a well south of Bellaire, on the border of Goose Lake, is at similar altitude. On each side of Intermediate Lake a rapid rise is made to uplands standing 200 feet or more above the lake. The head in the wells is only a few feet above the surface, or less than might be expected from the height of the bordering uplands. The uplands have a large amount of inter-Glacial lake clay capped by only a few feet of glacial deposits. This clay is very slowly pervious to water and may not therefore contribute much water to increase the head in the wells along the lake.

BELLAIRE.

An examination of the several flowing wells of Bellaire was made by Hon. Roswell Leavitt, of that city, prior to the writer's visit, and the data here presented were mostly collected by him.

There are two flowing wells at the Bellaire waterworks, one being a large excavated well 60 feet in depth, the other a tubular well 6 inches in diameter and 55 feet in depth. The temperature of water from the tubular well is 47.8° F. The large well furnishes the main supply for the village, and water is pumped from it to a reservoir, which gives 72 pounds pressure at the level of the railroad station, 614 feet above tide. When the flowing wells prove inadequate, water is pumped from the mill race. This is at times very unsatisfactory, and many citizens depend upon private wells, in which water is obtained at depths of 14 to 35 feet. It is thought that a supply from Cedar River, which comes into the village from an elevated district on the east, would be preferable to the water from the mill race, now turned into the public supply, which carries much refuse from a mill that stands above the intake.

A flowing well was obtained on the property of G. J. Noteware on the site of an old sawmill, about 1½ miles south of Bellaire, at the east edge of Goose Lake, in the central part of sec. 31, T. 30 N., R. 7 W. The well had ceased flowing in 1904. The depth is about 28 feet, and it was made about 1890.

The schoolhouse well, in the northeast corner of sec. 7, T. 30 N., R. 7 W., was not flowing in October, 1904, but is reported to discharge a small stream from the pump spout in wet seasons. The depth is 47 feet, and it was made about 1901.

On an island in Intermediate Lake in the southwestern part of sec. 7, T. 30 N., R. 7 W. is a flowing well 28 feet deep made by S. Brodeway, which is used by summer visitors. No record was obtained, but it is reported to have passed through marl.

Fisk Brothers have a camp and flowing well in sec. 1, T. 30 N., R. 8 W. near the bank of Intermediate Lake and about 4 feet above water level. It was driven to a depth of 67 feet through sand and gravel and a bed of clay. Water barely comes to the surface. It was made about 1902.

CENTRAL LAKE.

The strongest flow in the group in and near the village of Central Lake is from the well of the Cameron Lumber Company, made in 1902, which discharges 4 gallons a minute from an escape pipe three-fourths of an inch in diameter, at an altitude of 10 feet above Intermediate Lake. The temperature was found to be 48° F., at a time when the air was 60° F. and the lake 64° F. The temperature is said to be very uniform throughout the year and the flow steady. The well penetrated the following deposits: Sand, 2 feet; marl, 20 feet; yellow clay, 200 feet; sand and gravel, 7 feet. Another flowing well one-half mile south of the Cameron well at a camp of Fisk Brothers is only 21 feet deep. The well passed through a few feet of marl and then clay before striking water. Analyses of these two wells and of one other follow, the data being furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of waters near Central Lake.

[Parts per million.]

	1.	2.	3.
Color	5	29	24
Iron (Fe)	Strong trace.	3	Strong trace.
Chlorine (Cl)	11.5	4	9.1
Carbon dioxide (CO_2)	67.14	76.77	86.97
Sulphur trioxide (SO_3)	5	5	8
Hardness (as $CaCO_3$)	139+	139+	139+

S. J. Lewis, analyst. 1. Public supply (spring). 2. Cameron mill; depth 222 feet. 3. F. M. Fisk; depth, 36 feet.

Just north of Bridge street in Central Lake, on the west bank of the lake, are four shallow flowing wells, which have been in operation for several years. Charles Briggs's well, made in 1897, is 27 feet deep, has 1¼-inch pipe, and flows 3 quarts a minute at a level 3½ feet above ground, or 614 feet above tide. The water will rise to 616 feet. The temperature is 50° F., or somewhat above that usual in this latitude.

The well passed through considerable bog line but started and ended in sand.

About 50 yards north of the Briggs well is the well of S. Frost, 37 feet in depth with 1½-inch pipe and 1-inch escape. It flows 6 quarts a minute from a pipe 18 inches above the ground, or 610 feet above tide. The well has been running ten years.

Across the road from the Briggs well, on south side of Maple street, is the flowing well of Will Acker on ground 613 feet above tide. The well is 25 feet deep, and flows 5 quarts a minute from a pipe 15 inches above the surface. It flowed more rapidly when first made in 1896, and flows a little faster for two months in the spring. The well is 1¼ inches, but the escape pipe is three-fourths inch. The water will rise 3 feet above the top of the pipe or to 617 feet. Considerable yellow sand was penetrated, but there is some clay and some marl or bog lime. The temperature is 48° F. The water is hard, but does not show much iron.

South of the Acker well near Bridge street is Mrs. Hastings's flowing well, 20 feet in depth, on ground 611 feet above tide. The water issues from the pipe 3 feet above the surface at the rate of 4.5 quarts a minute and has a temperature of 50° F. The water is hard. This well was driven in 1902. There was one a few feet west of this from which the pipe has been drawn because the screen was worn out.

At the old stave-mill site in the north part of Central Lake was a flowing well 66 feet deep that used to flow from a vein 33 feet below surface. This was not visited as no use is now made of the water.

SUMMARY.

Wells of Intermediate Lake district.

Owner and location.	When made.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.
		Feet.	Feet.	Feet.	Feet.	Gals.	°F.	
Bellaire waterworks (2 wells)	....	600	{ 60 55	540 545	}	......	47.8	
G.J.Noteware, sec. 31, T.30 N., R.7 W.	1890	600	28	572	......	......	......	
Schoolhouse, sec. 7, T. 30 N., R. 7 W.	1901	640	47	593	643	......	......	
Fisk camp, sec. 7, T. 30 N., R. 8 W.	1902	611	67	534	612	......	......	
S. Brodeway, sec. 7, T. 30 N., R. 7 W.	....	609	28	581	612	......	......	
Cameron Lumber Co., Central Lake.	1902	612	223	389	+617	16	48	See analysis (p. 337).
Fisk camp, south of Central Lake.	....	612	21	591	615	......	......	Do.
C. Briggs, Central Lake	1897	611	21	584	616	3	50	Hard.
S. Forest, Central Lake	1894	608	37	572	(?)	6	48	Do.
Will Acker, Central Lake	1896	613	25	588	616	5	48	Do.
Mrs. Hastings, Central Lake	1902	611	20	591	616	4.5	50	Do.

NORWOOD.

A flowing well 33 feet deep was made in 1866 at a mill in Norwood, at the edge of Lake Michigan, which is still flowing 13 feet above Lake Michigan. The water is from gravel.

Another flowing well was obtained in rock in 1904, in a test boring 1½ miles south of Norwood. It struck the flow under shale at a depth of 150 feet and it is reported to discharge a full 4-inch stream.[a]

The conditions seem favorable for obtaining flows at other points along the shore, if on ground less than 15 feet above the lake. There are numerous springs in the vicinity of Norwood, but they appear to seep from the hillside rather than boil up from the bed of gravel that yields a flow.

EAST JORDAN-SOUTH ARM DISTRICT.

East Jordan stands at the head of the south arm of Pine Lake in southern Charlevoix County. The valley in which the lake lies is about a mile wide. On each side is a rapid rise to uplands standing 200 feet or more above the lake. The wells are on low ground bordering the lake, some of them being in a marsh underlain by marl that is probably a filled portion of the lake.

There are nine flowing wells at the East Jordan waterworks, ranging in depth from 75 to 105 feet and having a diameter of 3 inches. They are all at an altitude of 585 feet and are confined to a space of 3 or 4 square rods, or not more than one-fortieth of an acre. They have a slight head and a total discharge of 56,000 gallons a day. (See p. 346.)

At a shingle mill of the East Jordan Lumber Company, one-fourth mile south from the waterworks, is a flowing well 50 feet deep, and there are two others at dwellings near by on the mill property. The altitude is about 585 feet. The well at the mill flows 15 quarts a minute through a 1-inch escape pipe, and has a temperature of 46° F. A well at one of the residences has a flow of 7 quarts a minute, and a temperature of 46° F. The rate of flow of the third well could not be ascertained, as it escaped from a box. The mill well has been running about thirteen years, but those at the dwellings are more recent, one being made in 1902.

On the north side of State street, at the drug store of L. C. Mattison, there was a flowing well which became clogged and was abandoned. Another well was then sunk to a depth of 70 feet that has a head of 1 foot, but the pipe was not brought to a level low enough to allow it to flow. This well passed through 30 feet of bog lime or marl and then through fine sand, no clay being present.

A boring near the corner of State and Second streets, made by W. L. French, was carried to a depth of 280 feet entirely through fine sand

[a] Data by William Harris, of Norwood.

with only an occasional fine pebble. The boring was abandoned without getting water, because of some difficulty in preventing sand from rising in the pipe. This boring serves to demonstrate the presence of a deep pre-Glacial valley under the lake, for it was driven to about 300 feet above tide without reaching rock.

George Japson has a well at the east end of the bridge that crosses the south end of the lake, which has a head 4 feet above the surface, but which is prevented from flowing by having the pump pipe carried up to a level above the head of the water. The well is about 45 feet in depth, with 1½-inch pipe, and was made in 1897.

J. H. Lamway, in the village of South Arm, across the lake from East Jordan, has a flowing well 48 feet deep and 1¼ inches in diameter. It stands at the edge of the lake and has a head 18 inches above lake level. The rate of flow is 10 quarts a minute. It seems to be very largely through muck and bog lime, but as the pipe was driven with a sledge there is very little knowledge of the material penetrated. The well was made in 1890 to a depth of 44 feet. It became clogged in 1898 and was then driven to 48 feet. The temperature is 48° F., or 2° higher than the East Jordan flows. An analysis of the water was made by Mr. Lewis. Mr. Lamway has two other wells, one at his barn and one at his store, each about 46 feet deep, that have a similar head to the flowing well by the lake, but being on higher ground they lack a few inches of reaching the surface. Other wells in the village when carried to depths of 40 feet or more show a rise nearly to the surface.

In the following table are given a number of partial analyses of water from Bellaire, South Arm, and East Jordan, including one from mill race leading from the river. The public supply at Bellaire is from a 60-foot flowing well; that of East Jordan from nine connected wells. The data were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of waters from Bellaire, South Arm, and East Jordan.

[Parts per million.]

	1.	2.	3.	4.	5.
Color	24	19	19	5	5
Iron (Fe)	Strong trace.	Very slight trace.	Very slight trace.	0	Very minute trace.
Chlorine (Cl)	19.2	4	11.6	19.2	19.2
Carbon dioxide (CO_2)	72.99	65.96	66.2	66.18	71.23
Sulphur trioxide (SO_3)	0	5	5	0	0
Hardness (as $CaCO_3$)	139+	139+	139+	139+	139+

S. J. Lewis, analyst. 1. H. Richards, Bellaire; depth, 100 feet. 2. River (mill race), Bellaire. 3. Public supply (well), Bellaire; depth, 60 feet. 4. J. H. Lamway, South Arm; depth, 47 feet. 5. Public supply, East Jordan; depth, 75 feet.

IRONTON.

This village stands on the west shore of the south arm of Pine Lake, about 6 miles southeast of Charlevoix. The land rises rapidly westward from the lake to a drumlin area whose highest points are about

200 feet above lake level. On the slope wells have strong head when sunk to depths of 50 feet or more, but the shallow wells, 14 to 16 feet in depth, have but little head. There is a flowing well at Sequetata, a resort about a mile north of Ironton, at an altitude of 634 feet, or 54 feet above Pine Lake. It is 120 feet deep and passed through considerable red clay, probably inter-Glacial lake clay, before striking water. The water discharges at the rate of 2.4 quarts a minute at a level 2.5 feet above the surface. The temperature is 48.5° F. and the diameter of pipe 2 inches. The well was made in August, 1903.

About one-eighth mile west of this resort, on ground 31 feet higher, or 665 feet above tide, is a well at the residence of H. Coblentz, 50 feet in depth, in which water stands 1 foot below the surface. The diameter of the well is 3¼ inches. The water is very hard and has a temperature of 48.5° F.

There was a flowing well at Ironton, on the grounds of the Pine Lake Iron Company, which flowed a 1-inch stream for several years. It was made about twenty years ago, and is at an altitude of 605 feet above tide. The water now stands in the pipe about 1 foot above the level of the ground, but flowed over the top of the pipe 2 feet above the ground until 1903. When first made it would discharge from a pipe 4 feet above the surface. The depth is 130 feet, and water was found in sand below clay.

BOYNE.

This town stands at the east end of Pine Lake, an arm of Lake Michigan, which opens into the main lake at Charlevoix. Several flowing wells have been obtained at the shore of the lake about 5 feet above water level, and others up the valley of Boyne Creek. They are not from a single water bed, but strike water at various depths. The shallowest ones only pass through marl or bog lime that fills marshes along Boyne Creek valley, but the majority go through clay and find water in sand.

The strongest flow is one recently made (September, 1904) at the Elm Cooperage Company mill, in the eastern edge of town, nearly one-half mile from Pine Lake, but on the bank of Boyne Creek. The depth is 91 feet and the level of the discharge pipe 16 feet above Pine Lake, or 596 feet above sea level. It discharges a gallon in seven seconds from a ¾-inch nozzle, or at the rate of 7.5 gallons a minute. The discharge from the 2-inch pipe was much greater. The water will rise to 605 feet, or 25 feet above the lake level. The well passed through marl and sand for 40 feet, then through a stiff clay to the water-bearing gravel at about 90 feet. The temperature of the water is 46.5°, somewhat lower than that in wells of shallower depth and weaker flow tested on the same day. The water shows less iron than is commonly found in flowing wells, but is rather hard for boiler use.

The cost of drilling this well was 45 cents a foot (driller, Willis Wilson).

There are several flowing wells at Van Platen's mill, on the shore of Pine Lake, with a depth of 63 to 65 feet. Only one is permitted to flow at present, and this discharges nearly 4 gallons a minute from a 1-inch pipe at 4 feet above the surface, or about 8 feet above the lake. The wells are 1½ inches in diameter. These wells are near the engine, and the water seems to be affected by the heat, for it showed a temperature of 50° F.

Across the street the engineer of this mill, James Smith, has a flowing well 78 feet in depth, with a temperature of 48° F. It flows only half a gallon a minute, and the water carries considerable iron as well as lime.

White's machine shop has a weak flowing well near the bank of Pine Lake, now clogged and out of use. It flows 3 quarts a minute and has a temperature of 49.5° F.

John Sudman has a flowing well on north side of Boyne Creek, about one-fourth mile from the lake, made in 1904, which obtained a flow from 47 feet depth. The water will rise 12 feet above the surface, or to 597 feet above tide, and discharges 1.5 gallons a minute from a 1½-inch pipe; temperature of water, 47.5° F.

There are two shallow wells across the creek from the cooperage mill, which strike flows under a bog-lime deposit at about 12 to 16 feet. Wm. Ormsley's well is 12 feet, has a head of 4 feet, and flows a gallon a minute. Its altitude is about 590 feet; temperature of water, 50.5° F. It has a slight taste of sulphur. Mr. Curtis has one 16 feet deep that brought up "snail shells" from the bottom.

Wells driven in the business part of Boyne to depths of 30 to 35 feet have a head very nearly level with the surface, which is 5 to 10 feet above the lake.

The two partial analyses from drift wells at Boyne are given below. The determinations, which were made by S. J. Lewis, were furnished by M. O. Leighton, of the United States Geological Survey.

Partial analyses of well waters at Boyne.

[Parts per million.]

	1.	2.
Color	19	19
Iron (Fe)	Strong trace.	0
Chlorine (Cl)	14	4
Carbon dioxide (CO_2)	81.43	71.67
Sulphur trioxide (SO_3)	5	10
Hardness (as $CaCO_3$)	139+	139+

1. Cooperage mill; depth, 91 feet. 2. City; depth, 26 feet.

SPRINGWATER SIDING.

A single flowing well at Springwater siding on the Grand Rapids and Indiana Railroad just south of the Charlevoix and Antrim county line gives the name "Springwater" to the siding. The well was dug many years ago by L. Meaker, of Boyne Falls, who reports that for 24 feet there was loose gravelly material, beneath which he found a blue clay, and after penetrating it a few feet struck the flow. It pours out over the top of the well and runs away as a small brook. The temperature is 46.5° F. The well is in a deep valley with bordering hills fully 200 feet higher near by on the east, which may easily serve as a catchment area and give the head.

The valley leading from this siding down to Boyne Falls has springs along its borders and bottom, which are probably fed from the water absorbed by the bordering hills. On the Robbins's farm, about midway between Springwater siding and Boyne Falls, two wells 36 and 48 feet in depth have water only 10 to 15 feet below the surface. They penetrated no clay, but are in sand and gravel from top to bottom.

BOYNE FALLS.

The village of Boyne Falls is in a valley bordered closely on the east by high land, the situation being similar to that at Springwater siding, but no flows have been obtained. A test boring was made about 1900 to a depth of nearly 300 feet on the McMahon property, one block north of the railroad station. There was some water at about 30 feet and at various lower depths, but the greatest head obtained was 30 feet below the surface. There is a large amount of inter-Glacial lake clay in the highlands near this village which will not absorb water readily, and this may account for the failure to get flowing wells. Other tests, however, may result more successfully.

About 2½ miles northeast of Boyne Falls, on the farm of John Harmon, is a well which when first made did not flow. But after the pump was attached the water burst in with greater head, causing the well to discharge through the pump spout a stream about one-half inch in diameter. This well was not visited, but was reported by L. Meaker to be in a depression among hills.

WALLOON LAKE DISTRICT.

A well is reported to flow on the Rokopf farm on the west arm of Walloon Lake, but was not visited.

At the outlet of Walloon Lake a well 175 feet deep is reported to have flowed until it became clogged because of imperfect casing. This well is thought to have entered a gray shale at about 100 feet.

There was a flowing well at the tie mill by Bear Creek at Clarion, but it has been out of use for some years, and appears to have stopped flowing, though the writer did not visit the spot to ascertain the present condition.

These wells are all located in valleys bordered by prominent drift ridges and are of value in showing the promising prospects for development of a flowing-well district in the valleys.

WATERWORKS.

ANTRIM COUNTY.

Waterworks plants are in operation at Bellaire, Central Lake, Elk Rapids, and Mancelona, all of which use surface water except Mancelona, though Bellaire is supplied in part by flowing wells (see pp. 336, 345).

CENTRAL LAKE.

The public supply for Central Lake village is obtained from springs that issue on the slope west of the village at an altitude about 100 feet above the main part of town, as estimated by the reservoir pressure of 45 pounds. The springs yield 2,000 gallons an hour. The water runs from the reservoir through a pipe only 3 inches in diameter, but this is adequate to carry the water needed by the village for domestic use. The character of the water is shown by the analysis made by S. J. Lewis (p. 337). The waterworks plant is owned by private individuals, but the village is arranging for its purchase at an early date.

The springs do not boil up from deep strata like the flowing wells, but issue at the outcrop of nearly horizontal beds of sand which occur between beds of inter-Glacial lake clay.

ELK RAPIDS.

The waterworks are in the hands of a private company. The supply is derived from Elk Lake, being pumped direct to mains with an ordinary pressure of 45 pounds and a fire pressure of 100 pounds. Water power is used to run the pumps. The plant was installed in 1892.[a]

Private wells, which are in common use, are driven to the bottom of the sand at 20 to 25 feet. A boring 526 feet deep made by William H. Davis obtained a flow of water which is not utilized. The drift here is 475 feet, largely of blue clay said to be free from grit or pebbles.

MANCELONA.

The wells at Mancelona are sunk in the bottom of a natural basin about 40 feet below the general level of the town, and thus save the pipe necessary to reach water. The deposits penetrated are gravelly and the wells are cased to the water bed. Water is pumped direct to the mains.

[a] Manual of American Waterworks.

MISCELLANEOUS SUPPLIES.

The principal data on village supplies of all sorts are embraced in the following table:

Village supplies in Antrim County.

Town.	Population (1900).	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to main supply.	Head.	Springs.
		Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Alba	600±	1,171	Driven wells	75	125	100	100	− 70 − 90	Strong west of Alba.
Alden	500±	603	Driven wells, Torch Lake.	10	278	15	15	+ 2 − 8	Small.
Antrim		1,115	Tubular wells	70	300	70	70	− 65	Weak.
Atwood		825	do	65	150	Variable.	Variable.	− 60 −135	Do.
Bellaire	1,157	600 614	Driven wells, and stream by waterworks.	16	115	16–35	100	+ 3	Strong.
Central Lake	1,301	610 680	Springs by waterworks, flowing wells, lake.	12	230			− 6 + 3	Very strong, supplying waterworks.
Chestonia		650	Driven wells	10	20	20	20	− 10	Strong.
Eastport		600	Driven wells, Torch Lake.	15	25	20	20	− 10	Weak.
Echo		620	Stream and lake, flowing wells.						Strong.
Ellsworth	350±	610 650	Driven wells, springs, lake.	15	60	45	45		Small.
Elk Rapids	2,200	595	Elk Lake by waterworks, driven wells.	8	[a]526 186	20	20	− 16	None.
Elmira	300±	1,233	Driven wells	75	75	75	75	− 50	Weak.
Finkton		750	do	50	100	50	50	− 30	Do.
Mancelona	1,226	1,117	Tubular wells by waterworks, driven wells.	40	125	65	65	− 32 − 50	None.
Simons	300	1,197	Driven wells	100	100	100	100	+ 4? − 96	Small.
Torch Lake		600	Driven wells, Torch Lake.	15	30	20	20	− 10	Do.

[a] Test well.

CHARLEVOIX COUNTY.

Waterworks have been installed in Bay Shore, Boyne, Charlevoix, and East Jordan.

BAY SHORE.

The supply at Bay Shore is pumped from Lake Michigan to an elevated tank. It serves mainly for fire protection, private wells being the main domestic supply.

BOYNE.

The public supply is from springs that issue at the base of prominent hills on the south border of the town. The springs are in a marl bed under a foot or two of peat. The water, as may be expected, is hard and contains iron. It is collected under a shed which protects it from leaves and floating refuse matter, and flows by gravity to a reservoir 67 feet above the level of Pine Lake, giving it all the pressure available at present.

CHARLEVOIX.

At Charlevoix water is obtained from Lake Michigan, a filtration gallery being used. This village sunk three deep wells some years ago for the purpose of obtaining a supply, but this proved unsatisfactory and the present supply was recently adopted. Water is pumped direct to the mains, with an ordinary pressure of 50 pounds and fire pressure of 100 pounds or more.

EAST JORDAN.

The supply at East Jordan is from nine flowing wells, as indicated on pages 339–340. The flow of these wells, amounting to 56,000 gallons a day, is not enough to meet the demands of the town, and pumps have been installed which draw about 300,000 gallons a day in the dry portion of the summer. The water is pumped to an elevated tank 20 by 20 by 24 feet, standing on a tower at sufficient height to give 80 pounds pressure at lake level. It has a temperature of 46° as it flows from the wells. The first wells were made in 1897, but some are as recent as 1901. An analysis is given in the table on page 340.

MISCELLANEOUS SUPPLIES.

The principal data on village supplies are embraced in the following table:

Village supplies in Charlevoix County.

Town.	Population (1900).	Elevation.	Source.	Depth to rock.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
		Feet.		*Feet.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Feet.*	
Advance	100±	600	Wells, lake and springs.	40	6	40	10	30	− 5	Large.
Bay Shore	350±	625	Lake Michigan by waterworks, open and driven wells.	15	20	100	40	40	......	Small.
Boyne	a2,453	590	Springs by waterworks, driven wells, some flowing.	.....	10	90	20	20	+ 5	Large.
Boyne Falls	431	711	Driven wells	......	14	120	25	25	−20	Small.
Charlevoix	2,079	590 620	Lake Michigan by waterworks, driven wells.	15 230	25	482	50	50	+ 5 −30	Do.
Clarion	200±	685	Wells and springs	......	10	30	25	25	......	Do.
East Jordan	1,205	590 600	Flowing wells by waterworks, wells and springs.	280+	25	280	25	75	+ 5	Large.
Horton Bay	....	600	Wells and springs	......	17	17	....	....	−15	Do.
Ironton	....	600	Wells and Pine Lake	......	14	60	....	....	+ 1	Do.
Norwood	150±	595 660	Wells and Lake Michigan.	.....	20	175	60	60	+ 5 −30	Do.
Phelps	....	700±	Open wells	......	8	30	10	10	− 4	Small.
St. James (on Beaver Island).	500±	600	Driven wells, Lake Michigan.	......	12	35	25	25	......	
Springvale	....	950	Driven wells	......	65	100	65	....	−30	None.
Thumb Lake	....	1,100±	Driven wells, lake	......	37	70	65	65	−40	Large.

a In 1904.

WATER SUPPLIES OF OTSEGO COUNTY.

By Frank Leverett.

General statement.—Otsego County, of which Gaylord is the county seat, is one of the most elevated counties in the north end of the Southern Peninsula and contains the headwaters of Au Sable, Manistee, and Cheboygan rivers. Its western edge was covered by the Lake Michigan lobe, but the remainder of the county by ice pushing southwestward from the north end of Lake Huron. There is an interlobate moraine in the southern part of the county, with Otsego Lake lying in the midst. The portion of the moraine west of the lake is the product of the Lake Michigan ice lobe, while that on the east was formed by ice from the Lake Huron basin. To the north and west of this interlobate tract is an extensive gravel plain standing in the reentrant angle between the two ice lobes. Its altitude at the northern edge is 1,350 to 1,400 feet above the sea, or nearly as high as the crest of the moraines which sweep around it on the east, north, and west. The city of Gaylord stands on this gravel plain. The portion of the county northeast of Gaylord is all morainic, but among the moraines there are numerous channels apparently formed by glacial waters as the ice was shrinking down the slope toward Lake Huron. This part of the county is drained northward to Cheboygan River through Pigeon and Sturgeon rivers. The southern part is drained to the Au Sable, which flows eastward to Lake Huron, while the western edge is drained by the Manistee, which leads westward into Lake Michigan.

The drift is probably several hundred feet in thickness except, perhaps, in the northeastern part. Rock in this part of the State is not known to occur at an altitude greater than 900 feet, and the surface of this county would average about 1,200 feet.

Wells.—Wells on the elevated tracts 1,350 to 1,450 feet above tide are 100 to 325 feet in depth, the deepest well reported being in Dover Township, a few miles northeast of Gaylord. Two wells on the moraine southeast of Otsego Lake, at an altitude of 1,375 to 1,400 feet, are each 175 feet deep and have only a few feet of water in the bottom. Wells on the high moraine east and south of Elmira are from 130 to 250 feet in depth. On the high moraine west of Vanderbilt, John Warner has a well 275 feet in depth, on ground about 1,350 feet above tide, in which there is only 30 feet of water; after penetrating 20 feet of surface till, this well was mainly in dry gravel and sand to the water bed at about 270 feet. On the gravel plain in the reentrant angle between the Lake Michigan and Lake Huron moraines, northwest of Gaylord, several wells are 160 to 175 feet in depth, the altitude being about 1,380 feet. South from these wells, on ground about 1,325 feet above tide, are wells 100 to 120 feet in depth which have scarcely 20 feet of water. At Gaylord, at an altitude of about 1,340 feet, the usual depth of wells is 80 feet, and wells are 80 to 120 feet from Gaylord eastward past Johannesburg. Around Otsego Lake the wells are much shallower, the range being from 18 to 45 feet, but the altitude there is a little less than 1,300 feet. Wells are also obtained at depths of 40 to 50 feet in a belt running northwest from Otsego Lake to the edge of Elmira Township. Around Vanderbilt the wells are only 40 feet and strike water at 30 feet; but this town is on a gravel plain much lower than that at Gaylord, the railroad station being 1,090 feet. On the moraine north of Vanderbilt, near the line of Otsego and Cheboygan counties, at an altitude of 1,175 feet, several wells are about 180 feet in depth.

The following communication from Mr. J. B. F. Gocha, an experienced well driller at Gaylord, gives the results of a season's drilling in 1901 in that region, and notes concerning the deepest well yet reported. All are tubular wells except one in Livingston Township, which was driven.

Wells in Otsego County and vicinity.

Township.	County.	Diameter.	Depth.
		Inches.	*Feet*
Hayes	Otsego	2	112
Star	Antrim	2	159
Bagley	Otsego	2	82
Do	do	2	59
Gaylord	do	2	100
Do	do	2	98
Bagley	do	2	91
Corwith	do	2	92
Hayes	do	2	75
Livingston	do	1¼	30
Do	do	2	117
Gaylord	do	2	106
Hudson	Charlevoix	2	73
Wilson	do	2	132
Charlton	Otsego	2	92
Dover	do	2	325
Bagley	do	2	89
Do	do	2	70
Hayes	do	2	211
Do	do	2	110

Mr. Gocha says:

The soil in these wells is mostly plaster sand, with some gravel and cobblestone and hardhead stone and some clay, but not much. These wells were all made with No. 60 gauze points or screens, with Eureka brass cylinders and Maud S. pumps. The water does not rise at all and you have to case every foot of it [the well]. In my 325-foot well in Dover Township I had to dig down 223 feet and put in a 4-inch casing 7 feet long to keep the sand and water from holding my 2-inch casing in about 7 feet of clay. There was 3 feet of water on the clay. The well is now in good running order, and I am going to put in a 10-foot Fairbanks windmill to pump the water. The water is hard. It is for farm use.

Springs.—Springs of considerable strength are found along the borders of the streams, but hillside springs are exceedingly rare, since the water table under the hills is nearly as low as in the surface of the streams.

Waterworks.—The public supply of Gaylord is from a well 80 feet deep, from which water is pumped to a standpipe. The well penetrated gravel for its entire depth and came into water near the bottom, the general level of the water table being nearly 80 feet below the surface. Many of the residents depend on private wells, though the public water supply is considered of good quality.

WATER SUPPLIES OF MONTMORENCY COUNTY.

By Frank Leverett.

Montmorency County lies east of Otsego County. The large morainic belt of northeastern Otsego runs southeastward across it, covering much of the central and southwestern parts. The southwest corner is on an elevated gravel plain. The northern and eastern parts of the county are largely sandy plains, in which there are small lakes and swampy areas, some being of considerable extent. These plains extend southwestward into the high moraine in recesses comparable to the finger-lake tracts of the Lake Michigan slope in Antrim and Charlevoix counties (pp. 333–334), but have only a small part covered with lakes. The prominences between them are morainic and not shaped into drumlin form, as they are in Antrim and Charlevoix counties. The entire drainage is tributary to Lake Huron, but drains in various directions. The northwestern part of the county is drained northward by Black River to the Cheboygan; the southwestern corner southward to the Au Sable, and the remainder and greater part eastward by various tributaries of Thunder Bay River to the lake at Alpena. Each stream is bordered by broad sandy tracts along much of its course. Most of the streams originate in springs, and there is a large amount of seepage into them from the bordering plains. A spring a few miles northeast of Atlanta is reported to discharge a large amount of inflammable gas, but it was not visited by the writer.

There are few settlers except in or near Vienna and Lewiston in the southwestern part, Atlanta (the county seat) in the central part, and Hillman in the eastern part of the county; the entire pouplation in 1900 was only 3,234. The main farming settlements are within a few miles north and south of Hillman, where the soil carries a considerable amount of clay both on the moraines and plains. There are also a number of good farms in the southwestern fourth of the county, chiefly on the elevated moraine and the gravel plain outside of it.

In this county, as in Otsego, wells generally need to penetrate to about the level of the base of the morainic ridges to find adequate supplies. At Lewiston, which is built on the borders of Twin Lakes, the wells are shallow, although the altitude is high. At Vienna, and east from there in the moraine, the wells usually reach depths of 100 feet or more. Atlanta is in a plain near Thunder Bay River and has shallow wells, and Hillman (also on this plain) has wells of moderate depth. The neighboring farming districts, also being largely on ground but little above the river, have shallow wells. Lewiston has waterworks used chiefly for fire protection and supplied from Twin Lakes. Hillman has a plant for fire protection supplied from Thunder Bay River. Atlanta is planning for a plant for fire protection supplied by Thunder Bay River.

The principal data on wells in and near the villages are included in the following table:

Village supplies in Montmorency County.

Town.	Elevation.	Source.	Depth of wells.			Depth to water bed.	Head.	Springs.
			From—	To—	Common.			
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Atlanta	900	Driven wells	14	24	22	22	−15	Large.
Big Rock	950	Driven wells, lakes	10	65	30	50	−30	Do.
Hillman	800	Thunder Bay River, by waterworks, open and driven wells.	25	150	50	75	−30	Small.
Lewiston	1,200	Lakes, by waterworks, driven wells.	22	36	30	25	−22	
Valentine Lake	950	Driven wells	30	217	45	45	....	Large.
Vienna	1,300	.....do	50	140	110	110	−50	Small.

WATER SUPPLIES OF ALPENA COUNTY.

By Frank Leverett.

Alpena County fronts on Lake Huron in the northeastern part of the Southern Peninsula, the county seat being the city of Alpena. It is all within the drainage basin of Thunder Bay River except a narrow strip next to Lake Huron. The southwestern part is elevated like the adjoining parts of Montmorency and Alcona counties, with ridges rising to nearly 1,200 feet, and has very few settlers. The remainder of the county is comparatively low, most of it being between 700 and 900 feet above tide. There are a few square miles of barren sand along the shore of Lake Huron west and south of Alpena and a swamp in the northwestern part of the county occupying several square miles. With these exceptions and counting out the elevated tracts in the southwest, the county is well adapted for farming and is already largely under cultivation. In the northern half, rock is near the surface, and in a limestone district which runs from Alpena northwestward the bed rock is often exposed in roadside ditches and forms a low cliff south of Long Lake. Sink holes abound from near Flanders, northward past Long Rapids, into Presque Isle County. The north branch of Thunder Bay River, when the country was first settled, had its entire low-water flow absorbed by a sink hole at the side of its valley near the line of Presque Isle and Alpena counties, but a dam has now been constructed which prevents it from entering.

In the limestone district in the northern part of the county the depth of wells varies greatly because of the different levels at which water is found in the rock. This seems to be completely filled with water only to a level a little above Lake Huron; but there are in places higher shale beds that prevent the water from going directly down to this low-water table, and in such places wells can usually be had at moderate depth, though even in these places they often reach depths of 50 to 100 feet. The water is usually of good quality for drinking, though very hard.

In the southern half of the county, where the wells draw their supply from the drift, the depth ranges from 20 feet to about 120 feet, the deepest wells being on the ridges.

At Alpena there are several deep wells which obtain a large supply of flowing water from 600 to 650 feet, some of the wells being carried to much greater depths. The water is reported to rise to about 40 feet above Lake Huron. It is sulphated and sulphureted, but is not very salt and can be drunk without much discomfort. The temperature of a well at the office of the Fletcher Paper Company was 53.5° on August 8, 1905. Analyses appear in Water-Supply Paper No. 31, pages 72 and 73.

Springs are not so conspicuous in this county as in the higher counties to the south and west, but there are weak ones along the water courses at numerous points.

The city of Alpena purchased in 1905 the old plant of a private water company installed in 1879, which, it is reported, has a considerable extent of wooden mains and is generally run down. It is proposed to use this only until a new plant can be installed. The supply is drawn from Thunder Bay and pumped direct to the mains.

The principal data concerning the supplies at the several villages and in vicinity of country post-offices are presented in the following table:

Village supplies in Alpena County.

Town.	Elevation.	Source.	Depth to rock.	Depth of wells.			Depth to main supply.
				From—	To—	Common.	
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Alpena	585-610	Thunder Bay, deep and shallow wells.	0-80	20	1,278	640	620
Bolton	730	Open and drilled wells	0-20	10	100	50	50-100
Cathro	725	do	5-20	8	100	75	50-100
Flanders	760-800	do	50-80	20	80	Variable	Variable.
Hubbard Lake	725	do		20	120	do	Do.
Long Rapids	725-825	do	0-20	20	60	60	60
Ossineke	604	Devil River, springs, no wells.					

WATER SUPPLIES OF PRESQUE ISLE COUNTY.

By Frank Leverett.

General statement.—Presque Isle County has an extensive frontage on Lake Huron above Alpena County, and its county seat, Rogers, stands on the lake shore. The greater part of the county has limestone at slight depth. The southwest corner, a morainic tract in Moltke Township west of Rogers, and another in the northwest part of the county, are the only districts in the county where the drift deposits are so thick as to supply wells and leave the distance to rock uncertain. A chain of sink holes in the southwest corner is thought to indicate that limestone immediately underlies the drift there, and if so the entire county has a limestone platform beneath the drift, except at the outcrops of the narrow strips of shale that occur between the limestones. Low escarpments face northeast near Ocqueoc and south of Rogers, continuing southeastward into Alpena County. Grand Lake and Long Lake in the eastern part of the county lie at the base of such limestone cliffs.

Part of the southern side of the county drains into the north fork of Thunder Bay River and thence southward. The southwest part drains northwestward, through Rainy and Black rivers, to Cheboygan River. A narrow belt along the lake front drains more directly to Lake Huron through several small streams.

Wells.—The best supplies of water in the limestone are found at levels nearly as low as the surface of Lake Huron. This is well shown at Onaway, where the largest supplies are from 250 feet, and also at numerous farm wells in the central and eastern parts of the county. In the villages the wells are usually of less depth, drawing on weak surface veins. No deep wells have been made in the region of heavy drift in the southwestern part of the county, where there are very few settlers. The belt of heavy drift in Moltke Township is thickly settled and has some deep wells, several being over 100 feet, and one, that of F. Sargenfrei, in sec. 23, being 260 feet. The Sargenfrei well is about 270 feet above the surface of Lake Huron, and is thought to have struck rock at bottom. The other wells are at about the same altitude and have not reached rock. At Rogers there is a gap in the limestone bluff filled in by drift to a level 50 to 80 feet below Lake Huron, and in this flowing wells may be obtained, as indicated below.

Flowing wells can probably be obtained only on low ground near the shore of Lake Huron. A flowing well has been obtained at a gristmill at Rogers by penetrating to a depth of about 100 feet. It struck water in gravel and has a head 15 feet above the surface and about 30 feet above Lake Huron. The well is 6 inches in diameter and flows 2 barrels a minute.[a]

[a] Reported by W. F. Cooper.

Waterworks.—The waterworks plant at Onaway in the western part of the county is supplied by two wells 190 and 235 feet deep, which enter rock near the surface and are largely through limestone. The water is pumped to a reservoir on a hill in the south part of town, standing nearly 100 feet above the railway station. The waterworks supply is in general use for domestic and manufacturing purposes, as well as for fire protection and sprinkling. The average daily consumption is about 60,000 gallons.[a]

Miscellaneous village supplies.—The principal data on supplies at villages and in the vicinity of country post-offices are presented in the following table:

Village supplies of Presque Isle County.

Town.	Elevation.	Source.	Depth to rock.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common—	Depth to water bed.	Head.	Springs.
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Grace	600	Lake Huron, wells			10	8			Small.
Hagensville	775	Wells	50	30	60	35	35	—25	Strong.
Hawks or Le Rocque.	815	Open and driven wells	15	8	38	20		— 5	Small.
Millersburg	785	Wells and stream		12	40	20	20	— 8	Do.
Metz	800	Open wells							
Onaway	830	Drilled wells	5	30	600	200	250		Do.
Posen	788	Drilled and open wells	38	15	38	38		—11	None.
Rogers	600	Open and driven wells, lake	60 to 100	17	165	22		+15	

WATER SUPPLIES OF CHEBOYGAN COUNTY.

By FRANK LEVERETT.

GENERAL STATEMENT.

Cheboygan County fronts on Lake Huron immediately east of the Straits of Mackinac. It is comparatively low along the lake shore, and its northern half has only a few square miles higher than 200 feet above lake level. Except for a few islands this part was once covered by Lake Algonquin. It contains four inland lakes—Douglas, Burt, Mullet, and Black—each with an area of several square miles, and several smaller lakes. Its southern half is largely morainic and reaches altitudes of 1,000 to 1,200 feet on the south border.

Each of the streams running northward through the southern half of the county flows through valleys or plains 1 to 3 miles wide, above which the moraines rise to heights of 200 feet or more. The eastern half of the county is largely unsettled except in a strip running southeastward from Cheboygan past Black Lake to Onaway, and much of the southeast quarter is still covered by hard-wood forests. The western half is largely cleared and much of it is settled.

[a] Data by W. Barker, superintendent of waterworks.

Limestone, with altitudes ranging from 350 feet below to 250 feet or more above Lake Huron, immediately underlies the drift of Cheboygan County and extends nearly to the southern end of the county. It is, however, covered thickly with drift in the southern townships and also from Mullet and Burt lakes southward, and is seldom reached by shallow wells in the north. At Cheboygan, the bed of a pre-Glacial valley 350 feet below the level of Lake Huron is reached by borings, and it is probable that this valley underlies Mullet Lake and comes in from the south past Wolverine along or near Sturgeon River Valley, for a boring at Wolverine about 300 feet deep did not reach rock.

In the settlements made on the moraines in the southwestern part of the county and in a rolling tract north and east of Douglas and Burt lakes, wells are generally sunk to the level of neighboring valleys or plains or to depths ranging from 50 to 250 feet or more In the valleys of the south, and in the bed of Lake Algonquin in the north part, wells are usually obtained at shallow depths unless flowing wells are desired. These are usually 100 feet or more in depth even when on ground but little above the inland lakes.

The conditions are favorable for obtaining flowing wells around the south end of Burt Lake, and along the western border of Mullets Lake, and to some distance southward along valleys that drain into these lakes. It is probable also that flowing wells could be obtained at moderate depths along Black River as far up as Black Lake, and perhaps along the part of the stream above the lake, as far as settlements have reached. But this valley has not as yet been tested sufficiently to determine the artesian prospects. There are also swampy tracts along the northern side of uplands southwest and west of Cheboygan, in which flows may be expected if borings are carried to moderate depths, for the wells on these uplands have a head somewhat above the swamps, beneath which the underground drainage is likely to pass on its way to Lake Huron. The principal development of flowing wells has been at Indian River and other points at the south end of Burt Lake, and along the west side of Mullet Lake.

SPRINGS.

At the south edge of a narrow ridge that lies between Douglas and Burt lakes is a spring that is thought to be the largest in the Southern Peninsula of Michigan. It emerges from the ridge as a torrent about 36 feet wide and 6 to 18 inches deep, which rushes down to Burt Lake with a fall of about 25 feet in a distance of perhaps one-half mile. The spring at its point of emergence is about 75 feet lower than Douglas Lake, and only one-half mile distant, and is thought to be fed by the waters of that lake. After leaving the field the writer learned that there is a whirlpool near an island in Douglas Lake which marks the probable intake of the lake water. The temperature of the spring on October 29, 1904, was found to be 50° F., which is about 4° higher than the temperature of flowing wells in that region, and in harmony with shallow wells supplied with surface water, and whose temperature at that time of the year is about at its maximum. Possibly a more careful investigation would fully settle the question of the relation of this spring to Douglas Lake. Easily recognized objects or substances if thrown into the whirlpool in the lake might be detected in the spring and perhaps the rate of flow from the lake to the spring determined.

WATERWORKS.

CHEBOYGAN.

The waterworks plant is supplied from drilled wells 408 feet in depth which would flow if permitted, but is provided with an air lift in order to increase the yield. The temperature is 51.8° F., or about 5° higher than from the shallow flowing wells of that region.[a]

The wells penetrated about 360 feet of drift of which the upper part to a depth of 150 feet is largely clay, but the remainder is nearly all sand. The wells terminate in dolomitic limestone, of the Monroe group. The record of a deep boring at Cheboygan (2,750 feet), made to test prospects for oil and gas, appears in the report of the State geologist for 1901, pages 230–231.

MISCELLANEOUS VILLAGE SUPPLIES.

At Freedom, on the shore of Lake Huron, wells are driven to depths of 30 to 50 feet, or about to the level of Lake Huron.

At Mullet Lake and Indian River the main supplies are from flowing wells, which are discussed below.

At Rondo, Wolverine, and Trowbridge, in the valley of Sturgeon River, water is usually found at depths of 25 to 75 feet and on the low bottom lands at less than 25 feet. An oil boring at Wolverine on ground 62 feet above the railway station, or 835 feet above tide, was abandoned at about 300 feet without reaching rock. It found a large amount of water, but the pressure was not sufficient for a flow.

FLOWING WELLS.[b]

MULLET LAKE.[c]

A flowing well some 2 or 3 miles back from Mullet Lake on the farm of George Long, sec. 1, T. 36 N., R. 2 W., suggests the possibility of a large extension of the flowing-well district to the west from the northern part of Mullet Lake, but this is at present the only well back from the immediate lake border. The Long well was visited

[a] Data from A. C. Lane. [b] By W. M. Gregory. [c] By Frank Leverett.

by the writer in October, 1904, and found to have an altitude about 60 feet above Mullet Lake, or 650 feet above tide, and to be bordered on the southwest by a range of hills 100 feet higher. Its depth is 97 feet, its head 26 feet, and its flow 2 gallons a minute through a 1-inch pipe. The temperature October 26, 1904, was 46° F. The well passed through 30 feet of hard clay just before striking the water-bearing gravel at bottom of well.

HAAKWOOD.[a]

At Haakwood station on the Michigan Central Railroad about 7 miles south of Indian River in the Sturgeon River Valley is a strong flowing well made by the Haak Lumber Company. The depth is 205 feet, diameter 3.5 inches, and flow about 9 gallons a minute. The well penetrated surface sand for 100 feet, then clay for 100 feet, and obtained water from gravel at bottom. The water will run from the top of a pipe extending 18 to 20 feet above the surface of the ground, but how much higher it will rise it has not been ascertained. The water is distributed as follows: One main about 300 feet long to barn; another about 1,200 feet long to the sawmill, and also 1,200 feet to some tenement houses. There are nine taps with nozzles that reduce the flow at each tap to a small stream that runs constantly.

The following analysis of this flowing-well water was made at Saginaw by H. and W. Heim, analytical chemists, September 11, 1900:

Analysis of water of Haakwood well.[b]

	Parts per million.
Total residue	297.5
Total mineral residue	227.5
Hardness	185.72
Permanent hardness	42.86
Silica (SiO_2)	5.50
Iron and alumina (Fe_2O_5, Al_2O_5)	37
Calcium (Ca)	60.01
Magnesium (Mg)	10.03
Sulphate radicle (SO_4)	12.35
Carbonate radicle (CO_3)	86.91
Chlorine (Cl)	Trace.
Nitrates and nitrites	None.
	211.80

No other wells have been drilled at this point to sufficient depth to reach this water bed. The valley is bordered by high morainic

[a] Data by Haak Lumber Company.

[b] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

hills on either side, which probably serve as a catchment area, and flows should be obtained in it wherever the water beds are confined by clay, as in this well.

CHEBOYGAN.

In the city of Cheboygan good flows were formerly obtained at depths of 20 to 100 feet in a strip of land bordering Cheboygan River. Mr. Spiller, a retired well driller, says that a number of wells drilled by him twenty to twenty-five years ago gave strong flows at that time, although at present the water in them stands at nearly the same level as in the river. Messrs. Robert Patterson, Harris Embry, Withnow, and Brenton, all neighbors of Mr. Spiller, have wells at 60, 30, 19, and 25 feet deep, respectively. These all formerly flowed, but now the water level is 15 to 20 feet below the surface. The cause of the decrease in head is thought to be due to dredging a 10-foot channel in the river. Mr. Spiller observed that during the blasting for the removal of some of the large bowlders all the wells of his neighborhood ceased to flow. At the tannery of the Northern Extract Company several flowing wells were used for a few years, but at the present time a flowing well 6 inches in diameter and 629 feet deep furnishes an abundant supply of a hard alkaline water. There are several other deep wells in Cheboygan. Three are owned by the Fletcher Paper Company and one by C. Moench Sons Company. The city waterworks are supplied by a flowing well 408 feet deep, which, according to Dr. A. C. Lane, has a temperature of 51.8° F.[a]

INDIAN RIVER AREA.

The artesian wells of Indian River are within an area of 2 square miles at the outlet of Burt Lake. The wells are on a low sand plain between higher tracts to the north and south of the village. The elevation of the well district varies from 600 to 640 feet above tide (see fig. 65, next page), while the catchment area to the south attains, within 8 or 10 miles, an altitude of more than 1,000 feet.

The wells of Indian River belong to a general belt which extends from Harbor Springs to Cheboygan, as outlined in the Harbor Springs discussion (pp. 366–370), and it is probable that flows may be obtained from Indian River all along the south and east shore of Burt Lake and the marsh that connects Crooked Lake with Burt Lake.

In the limits of the Indian River area 43 flowing wells have been made, and at the date of observation (August, 1904) 40 were in operation. In this village the first well was made in 1889 by George Patterson, and has been flowing with no apparent decrease in volume since drilling. The wells in the village are used entirely for domestic and laundry purposes, while at the summer resort of Columbus Beach

[a] Geol. Survey of Michigan, Ann. Rept. for 1901, pp. 230, 248, 249.

the purity and abundance of the water are attractions for summer homes. The summer population at Columbus Beach is supplied from 17 wells, the abundance and pressure of the water being such that some places have bathrooms on the second floor.

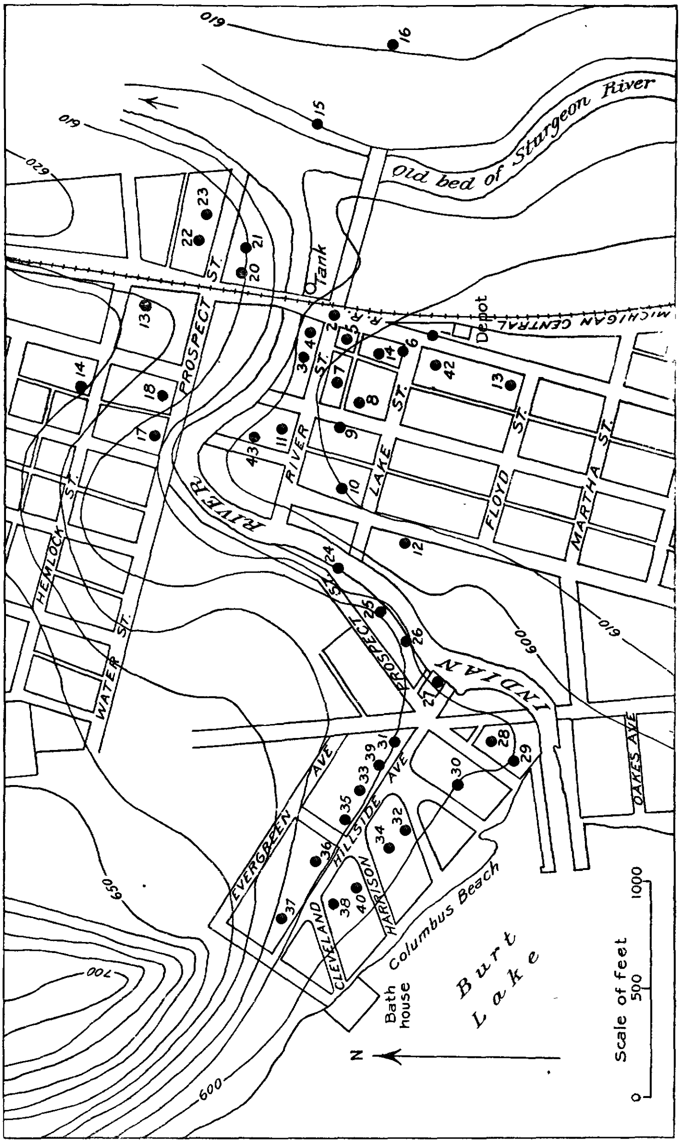


FIG. 65.—Contour map of Indian River flowing-well district.

The wells are drilled by contract, the price varying from $60 to $125, according to the depth. The toughness of the clay beds and the presence of bowlders in a few of the wells renders drilling rather slow north of the river, and four days is the usual time for completing a well, though some of the wells with plenty of sand have been completed in two days. No rock has been reached and casing has not been found necessary except in wells where the sand was troublesome.

In this area it is fortunate that the overlying beds are so impervious, otherwise much of the pressure would be lost and trouble would be experienced in leakage about the pipe, as is occasionally found in wells at Onekama and West Branch. In this region the wells are greatly appreciated, as is shown by the presence of a number of carefully piped wells with check valves, as the wells of Mr. Martin, W. H. Morgan, and others. At the summer resort of Columbus Beach the wells are carefully shut off for the winter.

Flow.—The total flow of wells in this district was determined by measuring wells flowing freely, and making estimates of those with check valves and of those piped to several houses. Such estimates have been starred in the tabulation of well data from this area. Mr. Morgan, a practical well driller, is the authority for the flow of a number of wells, which were measured at time of drilling. The total flow is 5,448 gallons a minute, which includes estimates on wells which are reduced or have check valves. This is an average of 136.2 gallons a minute for each well and is the highest average of any well area examined in this region. The well having the largest flow is that belonging to Mr. Mihan Green (No. 24 on table), which out of several tests has given 224 gallons a minute as the average. No trouble has been experienced with a decrease in the head and no records are at hand to indicate any failure to obtain a supply.

In drilling for water in this area only one bed has been found which yields a usable flow. This bed is irregular in depth in various parts of town and appears to dip slightly west to Burt Lake. It ranges in depth from 86 feet below the surface, as in the well of Mr. B. Field's (No. 21) in the eastern part of town, to 175 feet at the Columbus Beach Club house (No. 38).

The bed is about 10 feet thick and is of rather coarse gravel, with a slight admixture of sand, which flows out in a few days after the well is completed. The water bed may not be far above the rock, as at the Colonial Hotel, 4 miles northwest, rock is found at 140 feet, and 2 miles to the south rock ledges are present in hills which are 100 feet higher than the village.

The wells south of the river have sand beds at the surface from 30 to 50 feet thick, and the remainder is hard clay. The latter is varied in a few of the wells by having many sand and gravel layers which yield some water, but not enough for a flow. North of the river hardpan clay is on the surface and forms the larger part of the wells for about 40 feet, as at Mr. T. Dagwell's well (No. 17), which has a small surface layer of sand and the remainder clay, the upper part of which contains bowlders.

The wells at Columbus Beach have the finest beds of sand midway of the depth and small beds of light-colored clay below. No failure to reach the water bed was reported, but there are wells which do not flow. The well at the public school (No. 41) did not flow, the water being about 10 feet below the surface. By cutting off the pipe and carrying the water down the hill some 10 feet a weak flow was made.

Well drillers will not try for a flow when the surface is over 30 feet above the water level of the river, and on the map (fig. 65) it will be seen that flowing wells are below the 640-foot contour. In all parts of the village south of the river flows may be found, but to the north the area is limited.

The wells have the strongest force near the river, and some of the homes are fitted up with flush closets and bathrooms, using the water in the same manner as a city supply. Mr. W. H. Morgan (No. 7) has sinks, closets, and bathroom; none of the water is wasted, as it is controlled by check valves. Mr. F. E. Martin (No. 2) has coupled both his wells to a small hand fire engine, which gives plenty of water, and a good pressure in case of fire. A small plant for village fire protection could be installed at small expense by use of a gas engine and small distributing pipes, or a portable hand engine fitted for quick connection with several wells scattered about the village. The Alcove Hotel has sinks for kitchen use, flush closets in second story, and 4 stationary stands in a wash room, all supplied from one well. The water from this well rose 23 feet in a hose attached to it, and with the nozzle at the mouth of the well the water went vertically 12 feet into the air.

Several ornamental fountains are operated by wells. Medbury's well (No. 34) supplies several families and a fountain; in the latter water rises 15 feet through a quarter-inch aperture.

The Indian River area is in a valley or lowland plain at the outlet of Burt Lake. To the south, about 685 feet above tide, is a sand plain, which is several miles wide and ends some 3 miles south of Indian River in morainal hills, which show rock outcrops up to 720 feet above tide, the drift surface being about 100 feet higher there and of much greater altitude farther south. There beds of loose-textured drift material, dipping to the north and covered by the later deposits of lake sand and clay, form the probable catchment area of the wells.

Clay, with a few bowlders, is present north of the village, but the highest hills in that direction scarcely reach an elevation of 850 feet. On the eastern side of Burt Lake the sand-capped clay is 40 feet above ake level, as shown by the abundance of springs. The porous overwash to the north may contribute somewhat to the flows of Indian

River, but the larger supply is believed to come from the beds to the south.

Quality of water.—Examination of water from several wells of Indian River shows that its hardness averages a little higher than that from Oden, Harbor Springs, or Conway. Complaints are frequent that the water is hard, requiring the use of softening compounds for laundry purposes, though it is excellent for drinking. Sulphates were absent from the waters examined, and chlorides were present in small amount. The hardness is easily remedied, and this is fortunate, for the chief use of the water in this district is for domestic purposes. The presence of iron was not indicated by tests or deposits of the carbonate about any of the wells. The results of testing wells by the field method are shown in the following analyses:

Field analyses of water from wells at Indian River.

[Parts per million.]

	1.	2.
Hardness	227	178
Carbonates	195	192
Chlorides	60	15
Sulphates	0	0
Iron	0	0

1. Alcove Hotel (No. 5). 2. T. C. Herrick (No. 26.)

The temperature of the wells averages slightly above 48° F., which is 6° higher than the mean annual temperature of Indian River. The large flowage of water of this temperature into Indian River may acccount for its open condition in winter, while Sturgeon River without such a supply, is frozen

The temperature of the water makes it especially useful in domestic needs, doing away with the use of ice. In the general store of Mr. F. E. Martin an excellent butter room has been constructed in the basement by using the flowing water, which gives a satisfactory temperature for keeping dairy and farm products for the market.

The average temperature of these wells is exactly what sanitary officials of the larger cities demand for the storage of butter and milk during the summer months. This not only makes a well of especial value, but is an attraction to the summer residents.

The growth of algæ in the water is seldom sufficient to be an objection to its use. Indeed the wells generally are remarkably free from organic growths such as are due to water standing too long in tanks exposed to the sun's rays.

Wells at Indian River.[a]

No. on fig. 65.	Owner.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	°*F.*			
1	Town property	611	118	493	651	100	48			Supplies large fountain and 2 drinking founts.
2	....do	605	112	493		100	48			
3	F. E. Martin[b]	603	108	495		[c] 190			$100	Made in 1895.
4	....do	603	108	495		190				
5	Alcove Hotel[d]	605	107	498	628	[c] 200	48	Hard	125	
6	Commercial Hotel	611	115	496		115	48			
7	W. H. Morgan	612	124	488	647	205	48	Medium.	70	Only a little softening compound needed.
8	E. Walkins	613	107	506		[c] 150				Supplies 2 families.
9	A. Clements	612	106	506		[c] 190	48½			Supplies 4 families.
10	J. Berry	610	122	488	627	150	48		50	
11	B. Clements	605	110	495		[c] 160	48½	Hard	65	Supplies 3 families; cased 100 feet; made in 1899.
12	D. Corwin	606	125	481	654	155	48½	....do	60	Throws much sand; pressure, 22 pounds.
13	Dr. J. W. Bell	614	135	479	641	150	49½	....do	55	
14	A. Bradley	611	108	503	631	150	49	....do	50	Made in 1898.
15	Geo. Patterson	600	102	498		128		....do		Made in 1889.
16	J. J. Donnely	610	120	490		130	49			
17	T. Dagwell	609	137	472					70	Not flowing in 1904; sand clogged.
18	H. B. Lauterman	612	142	470	637	100	49	Hard	115	Made in 1897.
19	Jos. Frye	620	126	494	645	125	48½	....do	60	Made in 1900; cased 120 feet.
20	J. Vermilya	610	108	502		120	49	Medium.		Cased 40 feet through sand.
21	G. Fields	610	86	524		65			65	
22	J. W. Peck	615	93	522	625	175		Hard		Some water at 33 feet.
23	F. E. Martin	616	107	509		60				
24	Mahan Green	598	130	468		[b] 224	48		85	
25	H. P. Gordon	610	155	455		90	48¼		80	
26	T. C. Herrick	610	165	445	650	130	47 1/7			Pressure, 22 pounds.
27	W. R. Kinnear	600				130	47¼			
28	Mrs. Hover	604	150	454		125	47½			
29	H. Burgess	600				100	48			
30	H. Barcus	600	175	425			48			Stopped by sand.
31	J. C. Brown	610	150	460		100				
32	T. L. McFee	604	170	434		108				
33	T. H. Dunn	612	130	482		[c] 180			85	Supplies 4 families.
34	Dr. Medbury	604	160	444	619	[c] 190	48		80	Supplies 5 families and fountains.
35	Mrs. J. B. Brown	611	155	456		[c] 105				Supplies 2 families.
36	J. McFee	610	170	440		[c] 150				Supplies 3 families.
37	W. F. Brums	615	168	447		[c] 100			125	
38	Columbus Beach Club House.	605	175	430	640	[c] 150	48			Supplies 2 families and club house.
39	....do	611	140	471		100				Pressure, 14 pounds.
40	J. Fieser	603	156	447		100	48	Soft		
41	Public school	630	175	455	624					No flow.
42	Joe Miller	613	113	500	647	110	48½	Hard	35	Cased 96 feet.
43	Crawley & Newman.	608	116	492		128	49	....do	70	Pressure, 20 pounds.

[a] So far as ascertained, the wells are 2 inches in diameter.
[b] In basement of F. E. Martin's store. The wells are connected and furnish water for 2 stores and a butter room and for 2 families over the store. One well is connected to a hand fire engine for fire protection.
[c] Wells controlled by faucets; flow estimated.
[d] By measurement at date of observation the water rises 23 feet, and when allowed to flow into the air rises 12 feet from the surface. It supplies the hotel and has sufficient pressure to operate the closets and wash basins on second floor.

MULLET AND BURT LAKES.

Wells at Burt Lake.

No. on fig. 67.	Owner or location.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	*°F.*			
1	Harry Sweet	599	105	494		38				House use.
2	Warren farm	601	70	531		7		Soft	$50	Said to flow from rock.
3	W. B. Thomas	603	108	495		20	48		80	Flow has decreased.
4	Mr. Humphrey	601	66	535		40			40	
5	Mr. Brown	605	55	450	625	50	46			Domestic use.
6	Mr. Parks	608	107	501		6				
7	J. M. Sager	599	88	511		8	48	Soft		Weak flows at 46 and 70 feet.
8	do	599	97	502	609	12	48	do	100	Hotel, laundry, and domestic use.
9	Mrs. Williamson	601	112	489		12				House use.
10	T. A. Parker	601	110	491	615	30			130	Do.
11	Pittsburg Landing.	626	180	446		15	46			Club-house use.
12	Colonial Hotel	605	464	141		4	51	Hard		Hotel, kitchen, laundry.
13	J. M. Sager	599	99	500		36	48	Soft		Do.

Wells at Mullet Lake.

Owner or location.	Elevation.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Remarks.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Galls.*	*°F.*		
H. H. Pike's Sons, Topinabee.[a]	604	119	485		40	48	Soft	Shipped and carbonated; well, 3-inch.
A. W. Starks	586	55	531	592	7	47½	do	Domestic use.
J. C. Rittenhouse	585	28	557		5	47	do	Do.
Geo. J. Dodge	589	121	468	590	2	48	do	House supply; some H_2S.
Do	589	100	489		3		do	House supply.
Abbott & Levington	590	60	530				do	Do.
F. Bennett, Topinabee	606	119	487	616	20		do	Domestic use; made in 1893.
Michigan Central station, Topinabee.		118						Made in 1903.
Schoolhouse, Topinabee		125						Do.

[a] Water shipped by H. H. Pike's Sons as "Sanitas Spring" water.

Analysis of Sanitas Spring water. [a]

	Parts per million.
Chlorine	14.5
Free ammonia	None.
Nitrogen in nitrates	23
Total hardness	20.2
Permanent hardness	17.1
Organic and volatile matter (by loss)	18.2

Color, none; odor, none; taste, perfect; reaction, neutral. I. V. S. Stanislaus, analyst.

Field analysis of Sanitas Spring water.

	Parts per million.
Hardness	153.2
Carbonates	180
Iron	.5
Chlorides	214

W. M. Gregory, analyst.

[a] See Wells of Lower Michigan: Water-Sup. and Irr. Paper No. 102, U. S. Geol. Survey, 1904, p. 500.

WATER SUPPLIES OF EMMET COUNTY.

By Frank Leverett.

GENERAL STATEMENT.

Emmet County fronts on Lake Michigan at the west end of the Straits of Mackinac and extends south to include Little Traverse Bay. The part south of this bay was described in connection with the discussion of Charlevoix and Antrim counties, it being in the region of drumlins and finger lakes. From Little Traverse Bay eastward is a lowland strip, which runs through to Lake Huron past Burt and Mullet lakes in Cheboygan County. North of this and north of Little Traverse Bay are very prominent uplands rising in places to an altitude of 400 to 500 feet above Lake Michigan. These high tracts are composed of loose-textured drift, into which the water table sinks to a great depth. A well dug by a farmer, C. Cobleman, on one of the highest points in the northeast part of T. 36 N., R. 5 W., found the water table 400 feet below the surface. The well is 404 feet and water is drawn from the bottom. It was at first drawn by horsepower, the horse being driven around a drum, on which the rope was wound, but is now fitted with a 12-foot windmill wheel. Its bottom is probably 100 feet above Lake Michigan.

Near the west side of the highlands are blowing wells, also of great depth. One in sec. 29, T. 37 N., R. 6 W., on the farm of J. Bradley, was dug 300 feet and cemented all the way down. Then a boring 65 feet deep was made in the bottom to reach water. The well under certain barometric conditions has a strong down draft and under other conditions a strong upward rush of air. A whistle has been attached to the well, and this, it is said, is blown with sufficient force at certain times to be heard a mile away. Notwithstanding the great depth to the water table this upland carried a heavy forest growth, and orchards planted on it are not affected by drought. A large part of the rainfall seems to be kept within reach of the roots.

The lowland leading east of Little Traverse Bay and also the north border of the bay furnish strong flowing wells, which have been studied by Mr. Gregory, and are discussed below. It is probable that flowing wells can be obtained at moderate depth at the north border of the highland tracts just mentioned and in recesses along the shore of Lake Michigan, but none have as yet been reported. In the map accompanying Mr. Gregory's report the prospective, as well as present, flowing-well districts are represented.

The portion of the county south of Little Traverse Bay and of the lowland running east of the bay has limestone up to a height of 100 to 150 feet above the level of the bay and extends about to the middle part of the lowland, though at an altitude but little above the bay.

North of the lowland the rock surface, as indicated by the deep borings on the uplands and by the deep flowing wells in the lowlands, is at a comparatively low altitude, and it may be largely below the level of Lake Michigan. At the north end of the county, however, it outcrops at heights of 75 to 100 feet above lake level and is penetrated at slight depth by nearly all the wells in Mackinaw City.

MISCELLANEOUS VILLAGE SUPPLIES.

The villages of Alanson, Oden, Conway, Wequetonsing, and Harbor Springs are supplied with flowing wells and but few others are in use (see pp. 365–378).

Data on the supplies of other villages and of the regions around country post-offices are presented in the following table:

Village supplies in Emmet County.[a]

Town.	Elevation.	Source.	Depth of wells. From—	Depth of wells. To—	Depth of wells. Common.	Depth to water bed.	Head.	Springs.
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Ayr	850±	Wells and creek	6	12	12	12	......	Small.
Bliss	800	Driven wells	......	......	35	......	......	Do.
Brutus	680	Open and driven wells	15	105	18	105	−2	Do.
Carp Lake	724	Driven wells	16	30	16	16	......	Do.
Cecil	......	Driven wells, stream	35	60	40	40	−3	Do.
Ely	725	Wells and streams	20	40	30	40	......	Large.
Epsilon	......	Open wells and streams	6	30	20	20	......	Do.
Goodhart	......	Open wells and lake	25	......	......	......	......	Do.
Levering	760	Open and driven wells	25	200	25	120	−20	Small.
Littlefield post-office.	......	Driven wells	10	230	50	50	......	Do.
Mackinaw	590	Open wells, lake	25	65	25	......	......	Do.
Pellston	690	Driven wells	16	24	24	24	−12	Large.
Pleasant View	750±	......do	22	25	25	25	−5	Do.

FLOWING WELLS.

PETOSKEY AND BAY VIEW.[b]

A well near the mouth of Bear Creek in the west part of Petoskey, about 10 feet above Lake Michigan, was sunk to a depth of 489½ feet and struck a strong flow of sulphur water at 295 feet beneath a thin bed of blue shale.

Another well at Bay View, near the east end of Little Traverse Bay, at an altitude about 5 feet above the bay, found under a very hard stratum of limestone, a flow estimated at 200 barrels an hour. In both wells limestone is near the surface, and the wells seem to belong in a different class from those across the bay at Harbor Springs (see pp. 366–370), being unlike them in quality as well as in geologic relations.

[a] Not including those with flowing wells.

[b] Data by A. W. Grabau.

HARBOR SPRINGS AND WEQUETONSING AREAS.

General relations.—This area is a narrow strip of land not more than one-half mile in width and 5 miles in length, along the north shore of Little Traverse Bay (fig. 66). It is at the west end of an almost continuous belt of flowing wells extending from Harbor Springs on the Lake Michigan shore to Cheboygan on the Lake Huron shore. In fact, the Harbor Springs area is separated only by a strip of sand dunes from the remainder of the belt. To the north of this narrow artesian belt is higher land with loose-textured drift which in places reaches an altitude of 400 feet or more above the flowing-well district, while to the south an even higher altitude is attained within a few miles. This entire artesian district embraces the flowing wells of Cheboygan, Mullet Lake, Topinabee, Indian River, Burt Lake, Alanson, Oden, and Conway, as well as those of Harbor Springs and Wequetonsing. It lies along what is known as the "inland lake route" between the resorts on Little Traverse Bay and the city of Cheboygan on Lake Huron.

Records from different sections show the drift to be loosely consolidated at the surface, and succeeded by alternate layers of clay and somewhat consolidated gravel and sand, porous enough to take in water. The amount of underground water that the drift absorbs must be great, as may be inferred by the relative scarcity of small creeks or lines of surface drainage. The scarcity is greater in the highlands north of this flowing-well district than south, and it is probable that the main catchment area is on the north.

Within the limits of the Harbor Springs and Wequetonsing area there were 72 flowing wells in August, 1904, of which 41 were at Harbor Springs and 31 at Wequetonsing. The first well was drilled in 1887 by Charles Ross, being discovered accidentally while driving piles for a dock. When a pipe was driven through the clay into the underlying bed of gravel and sand the water rose 10 feet above the lake level and is still flowing. It is well No. 48 on accompanying table. Flowing wells of this class supply a large number of homes with abundant water, while the waterworks, owned by E. Shay & Co., derive their supply for public consumption from nine flowing wells, ranging in depth from 64 to 320 feet, and flowing 3,000,000 gallons a day.

The shallow wells are made by driving a 2-inch pipe with a strong point and screen to the water bed. Such wells cost from $50 to $70, including pipe and labor. The deeper wells are drilled and some are cased to shut off water from the upper bed, and cost from 75 cents to $1.30 a foot.

Flows from the upper water bed require frequent sand pumping to maintain a good flow. At present only a few are checked. No decrease in head has resulted from this practice, although some of the citizens

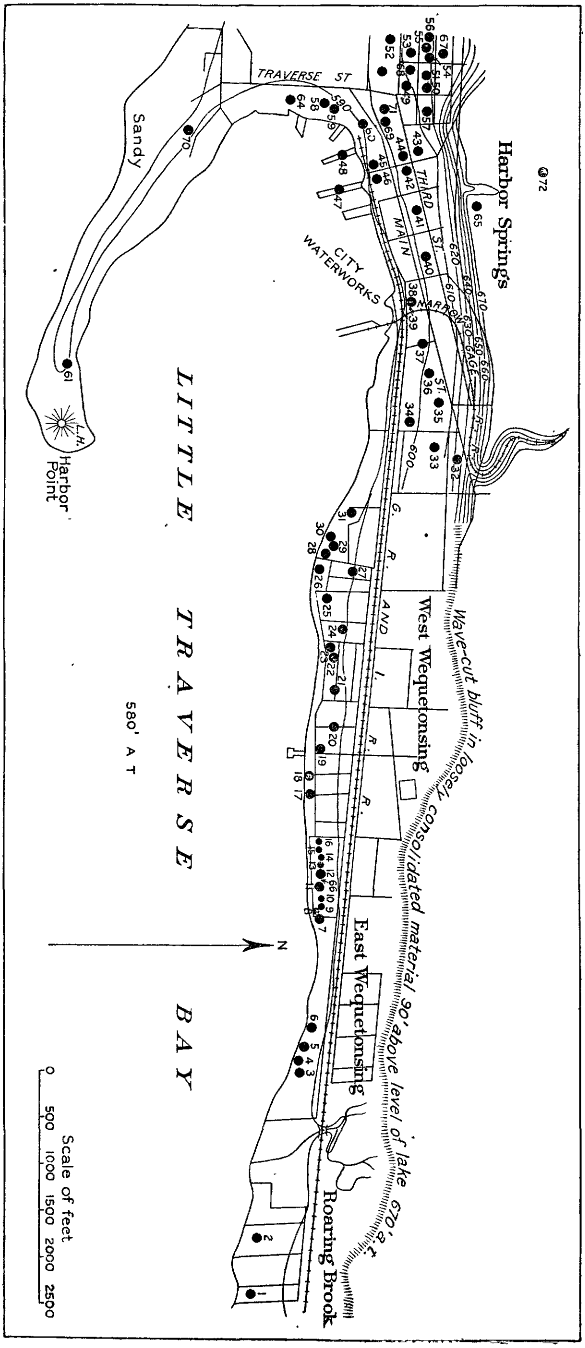


Fig. 66.—Contour map of Harbor Springs flowing-well district.

have agitated the question of having all the wells controlled. Some of the numerous fountains at Wequetonsing might be cut down with no inconvenience.

Flow.—The total flow of the Harbor Springs and Wequetonsing wells amounts to 430.9 gallons a minute, not including about 275 gallons a minute from the nine wells at the city waterworks. Aside from these the greatest flow is 33 gallons a minute from the well of Homer Clark (No. 55), which draws from the upper water bed. The well of Doctor Barr (No. 7) and Hughston (No. 6) have large flows, and are also from a shallow water bed. Mr. E. Shay, of Harbor Springs, has observed the wells since they were drilled, and states that the nine wells at the city waterworks have their flow increased as much as 10 per cent after a rainy season. Some of the well drillers claim that the flow from wells is greater during the spring than in the late autumn, but none of these statements are as yet supported by precise data.

At the Wequetonsing resort three water beds are developed. The upper is the stronger; it varies in depth from 30 to 40 feet in the eastern to 50 feet in the central part of the resort; on the western edge only a few wells draw their supply from it. The second bed is quite uniform in depth, being 60 to 70 feet down in the eastern and central and reappearing in a few wells in the western section. The third bed is the only one between wells Nos. 19 and 22 which gives a sufficient flow for water supply, although well drillers have found water at other depths. The wells are restricted to the bay shore below the terrace that passes through the north edge of Wequetonsing. The various beds at Harbor Springs have been penetrated at the city waterworks wells (No. 39), of which five are from 66 to 88 feet, three are 100 feet, and one (a 6-inch well) 320 feet deep. The following record of the material penetrated in the waterworks wells was obtained from Mr. E. Shay:

Record of waterworks wells, Harbor Springs.

	Thickness.	Total.
	Feet.	*Feet.*
Sand	10	
Clay and sand	22	
Clay, some bowlders	30	
Hardpan	4	66
Gravel and sand (first water bed)	12	
Hard clay, no water	10	88
Sand and gravel (second water bed)	5	
Clay, no water, some bowlders	7	100
Sand and gravel (third water bed)	15	
Clay, blue and tough	50	165
Some gravel and sand in alternate layers (fourth water bed)		260
Clay from 260 to 320 feet, which is near limestone rock		320
Flow (fifth water bed).		

The records of wells nearer the snore than those of the city waterworks indicate that the beds dip toward the lake. At Harbor Point, at the light-house (No. 61), a depth of 291 feet, and at Harbor Springs

Park (No. 70), one of 300 feet, was reached without striking rock, the wells being entirely in sand. At the higher elevations in the town the water bed is penetrated at lesser depths than in the wells along the shore, as the wells of M. Losinger (No. 57), B. Barbour (No. 49), and George Wheeler (No. 67).

Quality of water.—The field analyses indicate that the sulphates are absent, while the carbonates are medium, the hardness about 160 parts per million, and the chlorides from 50 to 100 parts per million. The following analyses are representative of the water from this region:

Field analyses of water from wells at Harbor Springs.

[Parts per million.]

	1.	2.
Hardness	141	160.8
Chlorides	95.9	51
Carbonates	165	140
Sulphates	....	0

1. Atkinson & Abbott (No. 46). 2. P. Pfister (No. 56).

Well data.—The following table gives the data of the wells of the region:

Wells at Harbor Springs and Wequetonsing.

No. on fig. 66.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Flow per minute.	Temperature.	Cost.	Remarks.
		Feet.	*In.*	*Feet.*	*Feet.*	*Galls.*	° *F.*		
1	Doctor Barr	588	1	151	437	5.3	46¼	$125	
2	H. R. Pattengill	587	1	154	433	5.2	46	......	Domestic use.
3	T. West	584	.5	74	510	.7	46¾	50	Do.
4	.....do	584	1.5	26	558	7.5	46¼	......	Fountain.
5	Mrs. Scott	586	1.25	44	542	15	45¾	......	Domestic use.
6	Mr. Hughston	587	2	40	547	30	46½	......	Fountain and domestic use.
7	Doctor Barr[a]	588	1	53	535	30	46½	50	Fountain and fish pond.
8	D. B. Little	587	1.5	73	514	4.5	46	......	Fountain and domestic use.
9	Mr. Ferguson	586	1.25	80	506	12.5	46¼	......	Domestic use.
10	S. C. Edgar	587	1.5	78	509	7.9	46½	......	Head lowered by No. 8.
11	Mrs. Maxwell	585	1.5	73	512	4.6	46	50	Fountain and house use.
12	F. Eaton	588	1.5	79	508	6	46¼	50	Fountain.
13	Mr. Garrett	587	1.5	80	507	5.7	45	50	Fountain and house use.
14	Mr. Clark	588	1.5	64	524	4.8	46½	......	Piped into house.
15	R. M. Bishop	588	1.5	80	508	2	46½	......	Domestic use.
16	Mr. Smith	588	1.5	120	468	7.9	46	......	Small fountain and house use.
17	Mr. McClure	584	3	74	510	6.8	47	......	Fountain and house use.
18	.....do	584	1.5	73	511	3.3	46	50	
19	Mr. Brubaker (hotel)	587	1	144	433	3.3	46	100	Hotel lavatory, flush closets, and kitchen.
20	Mr. Pratt	589	1	191	398	1.7	46	......	Small flow at 50 feet.
21	Mr. Brown	589	1.5	157	432	7.9	45	......	House use.
22	A. C. Clifford	589	1	172	417	2.1	47	......	Do.
23	C. Conklin	587	......	178	509	......	......	......	Small flows at 30 and 75 feet.
24	Mr. Roland	590	1	122	468	1.4	46	......	Domestic use.
25	Mr. Reber	586	.75	131	455	1.5	46	......	Do.

[a] The following is the record of Doctor Barr's well:

	Thickness (feet).
Sand	11
Hard clay	90
White sand and first water	10
Clay	30
Gravel and flow	10

Wells at Harbor Springs and Wequetonsing—Continued.

No. on fig. 66.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Flow per minute.	Temperature.	Cost.	Remarks.
		Feet.	*In.*	*Feet.*	*Feet.*	*Galls.*	*° F.*		
26	F. Wyman	583	1	132	451	2.7	46	......	Fountain and house use.
27	Mr. Eaton	590	1	144	446	3	46	......	Domestic use.
28	Doctor Breed	586	1.5	52	534	8.3	46¾	......	Piped to house.
29	Mr. Ferguson	586	1	63	523	4.5	46¾	......	Domestic use.
30	Mr. Kennedy	584	1	54	530	3.5	46	......	Do.
31	Mr. Strutt [a]	588	.75	185	403	1.4	46¾	......	Do.
32	Mr. Johnson (saw-mill).	620	......	41	579	......	......	$25	Used for steaming, softened by boiler compound.
33	Village electric-light plant	603	......	40 72	533	......	......	......	Deeper well drained shallow one.
34	Mr. McIntosh	595	1.5	144	451	1.9	47	......	Garden and house use.
35	Mr. Tanner	605	1	63	542	2.1	47	......	House use.
36	E. Parameter	601	1.25	141	460	8.3	46	140	Head 607 feet; used for large gardens.
37	Mr. Rockwell	599	1.25	100	499	7.8	46	70	House use.
38	Eight waterworks wells	595	1	66 150	548 445	......	......	......	City supply; head 605 feet.
39	Deep waterworks well	595	......	330	265	......	......	......	City supply.
40	J. L. Thompson	601	.75	144	457	12	47	......	Domestic use.
41	N. Moore	603	1	164	439	3.6	46½	......	Water hard; supplies house and several stores.
42	F. R. Ferguson	604	2	112	492	10	46½	......	Used at livery stable.
43	Mr. O'Conner	605	1	112	493	3.7	......	......	Public fountain.
44	.....do	605	1	112	493	1.8	......	......	House use.
45	Thos. Lay	592	.75	102	490	6	46½	......	Fountain and house use.
46	Atkinson & Abbott	592	2	48	546	10	46	48	
47	Northwestern Steamship Co.	589	2	63	526	10	47½	......	Public drinking fountain on dock.
48	Rose Dock [b]	589	1.75	92	509	10	46½	......	Head 599 feet; pioneer well; fountain on dock.
49	B. Barber	609	1.25	55	454	14	45.2	......	Domestic use.
50	M. Juilleret	619	1.25	38	581	6.2	46	......	Do.
51	F. R. Ferguson	619	1	35	574	1.3	46	......	Water hard; flow has decreased somewhat.
52	R. R. Ransom	608	.5	56	542	1.2	45¾	......	Flow decreased by sand in pipe.
53	H. Gillette	612	1	49	563	.5	48	......	
54	W. Loundy	619	1	31	588	1.9	46	......	House use.
55	Homer Clark	619	2	48	571	33.3	46	......	
56	J. Pfister [c]	619	2	42	577	10	45.5	......	Water soft; well reduced to 1.5-inch.
57	M. Losinger	619	2	39	580	10.5	46¼	......	
58	J. L. Thompson [d]	589	2	100	489	20	......	......	Drinking, laundry, and cooking.
59	L. B. Densmore	590	......	153	437	10	......	......	Domestic use.
60	Mrs. Crystler	590	2	120	470	18	46	......	Do.
61	Light-house, Harbor Point.	591	2	281	300	......	......	......	No flow; mostly sand, little clay.
62	Emmet Beach	......	......	112	......	......	......	......	West of Harbor Springs; not shown on city plat.
63	S. Olds	......	......	113	......	......	......	......	Do.
64	Grain elevator	588	2	160 80	428 508	......	......	......	Two wells.
65	Schoolhouse	675	2	80	595	......	......	......	Well on bluff; no flow.
66	Mr. Housler	588	2	164	424	......	......	......	Domestic use.
67	Geo. Wheeler [e]	625	2	47	578	.4	45¾	20	Drilled in 1903; water soft.
68	M. J. Barnes [f]	612	2	85	527	.2	......	......	Domestic use; water soft.
69	Catholic school	601	2	145	456	......	......	......	Pump well; water soft.
70	Harbor Springs Park	595	......	300	295	......	......	......	Small flow; all sand.
71	Catholic school	601	2	56	......	......	......	......	No flow; pumped in tanks; water soft.
72	J. S. Sharpstein	683	......	80	......	......	......	......	No flow; all clay; some gas.

[a] Small flows in gravel under clay at 40 and 60 feet.

[b] Pioneer well, made in 1887. Water at 45 and 92 feet. Water bed discovered while driving piles for dock. Present well cased to lower water bed.

[c] Water excellent for laundry purposes. Water bed under hardpan. Weak flow at 36 feet.

[d] Ram is used for forcing water into upper floor of house. The ram cost $13, and the complete outfit and labor, including well, pipe, cooling room, bathroom, flush closet, and plumbing, $250. The ram will pump about 420 gallons in ten hours.

[e] Weak flow at 15 and 35 feet from small gravel beds between clay. Made in two days.

[f] Does not overflow, but flows into underground cistern.

CROOKED LAKE AREA.

General relations.—The Crooked Lake area is part of the flowing-well district east of Harbor Springs and around Crooked Lake. (See fig. 67.) The flowing wells of the region are located in the depression discussed under Harbor Springs (pp. 366–368), and range in altitude from 600 to 630 feet, which is their general elevation throughout the Harbor Springs-Cheboygan region. The wells in the Crooked Lake area are located below a sandy terrace underlain with clay, which stands between the lake and the high morainic hills, and is well devel-

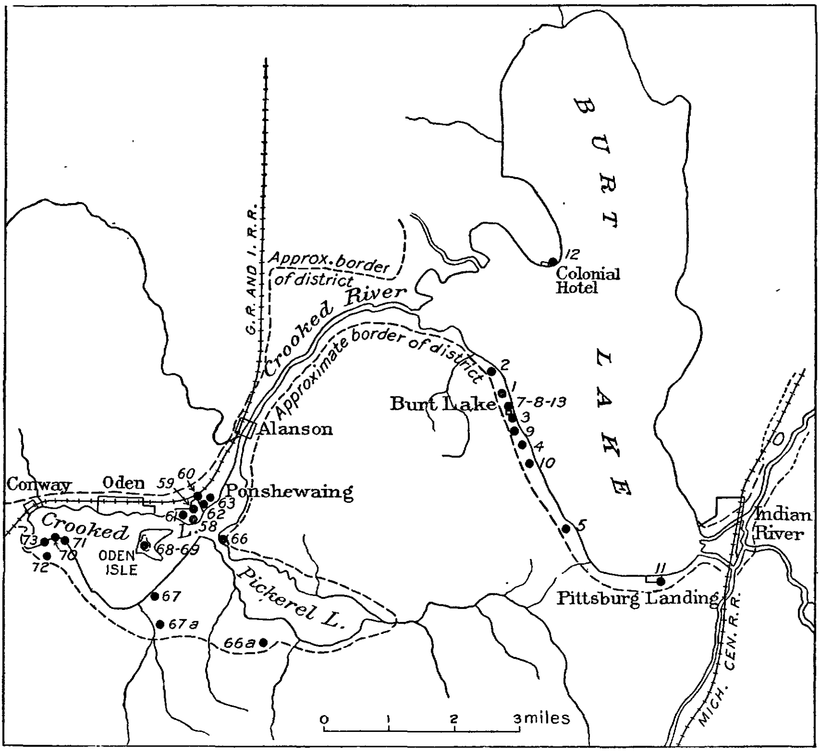


FIG. 67.—Sketch map of flowing-well region between Conway and Indian River.

oped from Harbor Springs to Alanson (altitude 640 to 650 feet). The edge of this terrace is 500 feet north of the Grand Rapids and Indiana depot at Oden (see fig. 68); it is just west of the depot at Alanson, and one-half mile north of the depot at Conway. The higher hills of loose-textured drift reach an altitude of 940 feet above tide within three-fourths mile north of Oden. This higher tract is an eastward continuation of that north of Harbor Springs, and reaches in places an elevation of about 1,000 feet (Leverett). On the south side of Crooked Lake limestone appears near the surface in the low country, but there is a rapid rise southward into a district with drumlinoidal hills. Elevations of 300 feet above Crooked Lake are reached within 2 miles to the south.

The wells are best developed and strongest on the north side of the lake, chiefly at Oden, a few at Conway, Alanson, and Ponshewaing, while on the south side of the lake they are difficult to obtain and only a few exist. The part of the flowing-well area extending from Conway to Alanson is some 4 miles in length and varies from three-fourths to 1 mile in width. South of Crooked Lake its extent is not clearly defined, but it appears to be only a very narrow irregular strip not extending over a mile back from the edge of the lake. The wells about Crooked Lake number 100, 65 of which are at Oden, 14 at Conway, 8 at Alanson, and several on the south side of the lake.

The first effort to get a flowing well was made in 1884 at Oden in a search for suitable water for boiler use in the engines of the Grand Rapids and Indiana Railway. An excellent flow resulted, though the water was found to be too hard for use in boilers. The rapid increase of summer residents has made many demands for a water supply of

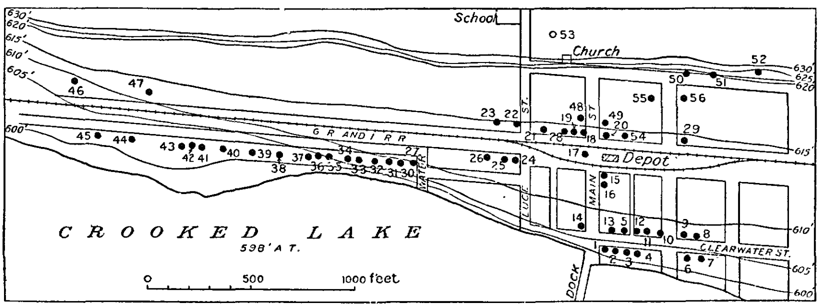


FIG. 68.—Contour map of Oden and vicinity.

this character and the number of wells has increased rapidly. The wells are drilled by contract, averaging from $40 to $60 complete. The depth of the water bed is so well known to the drillers that the time and labor as well as the cost of the material can be estimated very accurately.

Flow.—The total flow in this area is about 2,000 gallons a minute, of which the wells at Oden yield 1,362 gallons, at Conway 353, Alanson 147, Ponshewaing 145, Burt Lake 279, and Mullet Lake 77 gallons a minute. The strongest flow is that of the Grand Rapids and Indiana Railway well (No. 17) at Oden, which yields 80 gallons a minute. The wells on the south side of the lake have the smallest flow, and all attempts to secure better wells there have been failures. The water at Oden is allowed to flow freely and poor drainage of this surplus water is the cause of many swampy spots. In this growing summer resort such a supply of water is one of the valuable features, and where so many wells are being drilled it would be well to consider the future conditions. There is some objection to using check valves, for when the water is checked the sand settles and fills the pipe, often completely choking the flow. The amount of sand that some of the wells bring to the surface renders the water unfit for domestic use and a settling tank on the roof or second floor of the dwelling has to be used. A large well screen with a small mesh would be a means of checking the sand. Small screens are used in a few wells, but have been discarded by owners because of a tendency to decrease the head.

In Oden three or more water beds are present, the lowest bed being the one in which the strongest flows are found. The majority of the wells are not drilled but are driven, and but little accurate data are available concerning the character of the beds. The writer's information has been furnished by the Pope brothers, who have had considerable experience in well drilling in this region. The Oden beds dip gently to the shore of Crooked Lake, with an additional dip from west to east, the stronger flows being found at 130 to 140 feet in the rail-

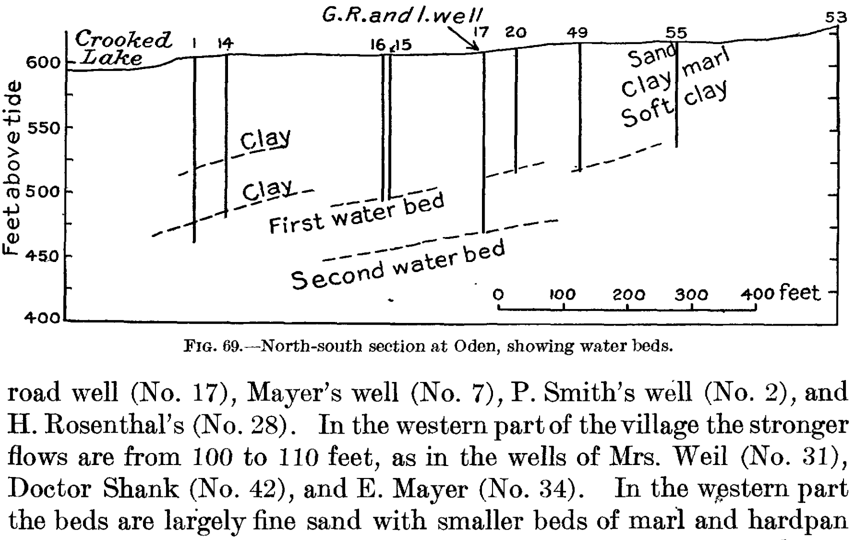


FIG. 69.—North-south section at Oden, showing water beds.

road well (No. 17), Mayer's well (No. 7), P. Smith's well (No. 2), and H. Rosenthal's (No. 28). In the western part of the village the stronger flows are from 100 to 110 feet, as in the wells of Mrs. Weil (No. 31), Doctor Shank (No. 42), and E. Mayer (No. 34). In the western part the beds are largely fine sand with smaller beds of marl and hardpan clay. The general relations in Oden are shown in fig. 69, which is a profile of water beds on a line drawn north and south from the Grand Rapids and Indiana Railway depot. The two beds which have been exploited for the majority of flows are under clay layers 5 to 6 feet in thickness. The water beds are usually fine sand with only a small amount of gravel. The depth of the upper bed averages from 75 to 95 feet, while that of the strongest flow averages 120 to 140 feet. Below this water is not abundant. For this reason the pipe in the railroad well (No. 17) after being put down to 180 feet was drawn back to the 140-foot flow. In the western part of Oden the upper bed is used for flows, as it is stronger there than to the east, and it is in this part of the village that sand in the water causes considerable trouble, requiring settling tanks to get rid of it.

Bed rock is not reached in any of the Oden wells, but is penetrated 150 feet in the wells of the Dart & Dart Company on Oden Isle, in Crooked Lake, three-fourths of a mile southeast of the Grand Rapids and Indiana Railway station in Oden. This continuous belt of the Traverse limestone to the south, as shown in the outcrops of Bay View, may aid in preventing the escape of the water and thus keep the head up in the region around Crooked Lake.

The contour map of Oden (fig. 68) will serve as a local guide in selecting well sites. By locating the prospective well on the map and referring to the accompanying table of data for the records of the surrounding wells a fair estimate of the cost and character of the flow can be obtained. The 630-foot contour lines limit the field to the north. Below this contour from Oden west to Conway and east to Ponshewaing flows are to be obtained. On the large map of the region (fig. 67) the area in which flows are possible is indicated between the dotted line and the lakes.

The water beds at Conway have not been explored by drillers as fully as those at Oden. There are two distinct water beds present and possibly more. The well of F. Stallman (No. 10), 88 feet deep, is from the upper bed, which ranges from 88 to 115 feet from the surface. The sand bed supplies the strong flows of C. Lyon (No. 12), W. Van Avery (No. 6), and the depot (No. 4). The well of E. E. Blackmar (No. 14) penetrated the following materials: Sand, 35 feet; clay, 47 feet; gravel, 12 feet; clay, 13 feet.

The wells on the south side of Crooked Lake are nearly all in rock, and very few flows have been obtained. Mr. Jewell's well on the beach west of Hastings Point is a small flow from the rock. The Cincinnati Club at Hastings Point has a well 140 feet into rock, which yields a small flow. On Hastings Heights at the hotel, which is 628 feet above tide, several attempts for flows have been made. Limestone is reached at 18 feet below the surface and water at 252, but no flow, and the water is so scarce that the well has been abandoned. Several other attempts have been made along the beach to obtain flows, and, while some have been successful, at present they all require pumping to raise the water. There are two flows farther east on the south side of the lake which were not visited. One is at an old lumber camp. In the region to the southeast of Crooked Lake few deep wells have been made. Mr. George Benham drilled 150 feet, largely through bed rock, and found a small flow.

At Ponshewaing two water-bearing beds are present, the upper one being the stronger, as at Conway. The "Resort" well (No. 58) is from a bed of rather coarse gravel under 8 feet of sand, 15 feet of marl, and 48 feet of clay. The drillers find water from 100 to 150 feet. Near the surface the beds are sandy and below are thin beds of clay and gravel, no rock being found in the 200-foot well at the Pon-shewaing Hotel (No. 60) nor in Mr. L. Schwab's well (No. 63), which is 225 feet deep.

The high morainic region, a short distance north of the Crooked Lake flowing-well belt, contains unconsolidated drift material well suited as a catchment area for the flowing wells along its south border. Springs are very frequent along the edge of the higher land. The wells of Alanson, Pohshewaing, Oden, Conway, and Harbor Springs are all believed to be supplied from this catchment area.

Quality of water.—The water in the district north of the lake is reported soft, as it requires no special softening compound, and is in general use for laundry and domestic purposes. At the Hotel Rawdon, in Oden, a glycerine soap for use with this water has given best satisfaction. The Grand Rapids and Indiana Railroad have found the water unsuitable for boiler use, the deposit of scale being too great. Dr. A. B. Prescott, Ann Arbor, Mich., said of the water taken from the railroad well (No. 17):

This water contains a moderate amount of lime, a good part of which is held in solution as a carbonate. Sulphates are present in very small proportions and chlorides are not present in any proportions that would affect uses. Iron salts are not present in more than traces. The hardness by Clark's scale is 11°, corresponding in effect to the presence of 11 grains of carbonate of lime in a United States gallon of water. In respect to the presence of organic matter the tests show a good degree of purity in this water.

The hardness in waters tested varies from 201 parts per million in E. Mayer's well (No. 34) to 186 parts in the Rawdon Hotel well (No. 1). Carbonates average 156 parts per million. The rock well of the Cincinnati Club at Hastings Point has a hardness of 314, carbonates 320, and some sulphates.

Field analyses of water from wells at Oden and Conway.

[Parts per million.]

	1.	2.	3.	4.
Hardness	201	120.6	186.9	314
Carbonates	160	160	166	320
Chlorides	1	5	5	150
Sulphates	None.	None.	None.	33
Iron	None.	None.	....	....

1. E. Mayer (No. 34), Oden. 2. Rawdon Hotel (No. 1), Oden. 3. Depot (No. 17), Oden. 4. Cincinnati Club (No. 71), Conway.

Well data.—The following tables give the data of the wells of the region:

Wells of Crooked Lake area.

WELLS AT ODEN.

No. on fig. 68.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
		Feet.	*In.*	*Feet.*	*Feet.*	*Feet.*	*Gals*	*°F.*			*Feet.*	
1	Hotel Rawdon [a]	604	2	140	464	618	32	46		$140		
2	P. W. Smith	604	2	138	462		60	46				Domestic use.
3	E. Morrow	604	2	114	490							First clay at 90 feet.
4	Grand Rapids and Indiana Rwy. park.	603	1½				10	46				First flow, made in 1884, still flowing.
5	....do	605	2	102								Park and bathhouse.
6	J. A. Andrews	603	2	105	498		30	46				2 wells connected; fountain, fish pond.
7	Mr. Mayers [b]	603	2	130	473	613	65	46				Domestic use.
8	Club house	606	2	100	506		60	46	Hard	54		Domestic and laundry use.
9	A. Saunders	606	2	93	513	618	63	46				Sand 80 feet, clay 12 feet, gravel and sand 4 feet.
10	H. Gordon	605	2	96	509	617	40	46	Soft	60		Domestic use.
11	H. Tugar	606	2	96	510		50	46				House and barn.
12	J. Havlin	606	2	96	510		65	46				Domestic use.
13	R. B. Allison	606	2	106	500		50	46		59		
14	Oden House	607	1½–2	127	480		65	46		150		4 wells connected.
15	R. L. Marvin	609	2	114	485	614	32			30		Domestic and store use.
16	H. Pope	608	2	113	485		25	46	Soft	15		Domestic use.
17	Grand Rapids and Indiana Rwy. depot. [c]	611	8	140	471	629	80	46				Drinking water.
18	V. Powell	614	2	130	484				Soft	30		
19	J. C. Carpenter	613	1½	140	473		50					Said to be nearly all quicksand. Hardpan at 95–100 feet and at 120 feet.
20	P. Tile	612	2	100	512		7	46	Soft	15		Butter cooler and domestic use.
21	C. Rush	613	2	114	499		29	46				Well driven in 10 hours.
22	G. Woodruff	615	2	113	502		32					Domestic use.
23	W. L. Murphy	615	1¼	112	503		30					House use.
24	Mrs. Ruggles	611	2	140	471		20	46				Domestic use.
25	J. Carpenter	611	2	123	488		25	46				Supplies 2 families.
26	Mrs. W. Smith	611	2	81	530		5	46	Soft			Domestic use.
27	E. Stricher	610	2	78	532				...do			No flow, sand clogged.
28	H. Rosenthall [d]	616	2	140	476		25	46				Supplies 2 families.
29	G. Engle	614	2	90	524		50	46	Soft			Domestic use.
30	G. Williamson	609	2	65	544		8	45¼		75		
31	Mrs. Weil [e]	609	2	110	501		35					3 wells connected, 110 to 115 feet deep.
32	M. Market	609	2	78	531	629	60	46	Soft			Settling tank used.
33	S. Johnson [f]	608	2	90	418	630	42	46	...do			Domestic use.
34	E. Mayer	607	2	118	489		40	46		105		Settling tank; see analysis of water.
35	A. Fisher	605		73	532		10	46				House use.
36	P. Soldern	605	2	78	527	629	15	46				Domestic use.
37	I. Carus	604	2	77	527		10	45½	Soft			Do.
38	C. Daley	603	2	80	523		12		...do			Supplies 2 families.
39	Mr. Forrester	603		70	533	629	15					

[a] Used in hotel for kitchen, laundry, drinking, and washing. A glycerine soap is found to be best for the wash room. A small water ram forces the water to the second floor. The first clay is at 80 feet, the second at 120 feet. The rest is sand.

[b] Three wells, 127, 133, and 130 feet, respectively. The two deeper ones are connected and feed a large fountain.

[c] Drilled for water supply for engines, but is not suitable. It is used for drinking on the Grand Rapids and Indiana Railway. At the time of drilling the water rose 18 feet above the surface. It was drilled 180 feet, but the supply being poor the pipe was drawn back to 140 feet. See analysis (p. 375).

[d] Flows were found at 60, 80, and 140 feet; the lowest is the strongest. Said to be decreasing.

[e] Supplies 3 families and a fountain.

[f] The water is carried to a large tank on the roof of the dwelling, where the finer sand settles; without this the water is not suitable for use. This form of settling tank has to be used with several of the wells.

Wells of Crooked Lake area—Continued.

WELLS AT ODEN—Continued.

No. on fig. 68.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
		Ft.	*In.*	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*°F.*			*Ft.*	
40	E. Thorpe	604	....	60, 175	544	....	15	46	....	$75	....	2 wells, 175 and 60 feet.
41	P. Baumgarten	604	2	55	549	....	12	45¼	....	....	....	Hard, compact sand; no clay.
42	Doctor Shank	604	....	101	....	....	10	45¼	....	....	....	
43	J. Hendrick	604	2	75	529	....	8	45¾	....	....	....	Domestic use.
44	J. Stenbeck	603	....	85	518	....	5	46	....	....	....	
45	Mr. Bell	602	2	70	532	....	....	....	....	25	....	Trouble with sand.
46	A. Hewey	610	....	65	545	....	10	45½	Medium.	35	....	Well hand driven.
47	J. Holmes	611	2	55	556	....	....	....	....	....	....	Not flowing in 1904.
48	G. Hughes	616	....	96	520	....	5	46	Soft	....	....	Made in 8 hours; hard clay at bottom.
49	Mrs. Beard	616	2	99	517	....	6	46	....	....	....	
50	W. Pope	624	....	75	549	....	10	46	Soft	....	....	Sand 10 feet, white clay 15 feet, hard clay 50 feet, small flow at 60 feet.
51	N. Fordman	625	2	73	542	....	10	46	....	....	....	House use.
52	Mr. Duncan	628	2	86	532	....	2	....	....	....	....	Small flow at 33 feet.
53	James Hart	631	....	83	548	....	....	....	....	....	....	No flow.
54	Mrs. Shaw	615	2	110	515	....	11	46½	Soft	60	....	Domestic use.
55	G. Wrens	618	2	85	533	620	1½	....	Hard	....	....	Throws sand at intervals.
56	M. Haey	618	2	76	542	....	7½	46	....	....	....	House use.
57	Chas. Engle	....	....	82	....	....	....	....	Soft	....	....	

WELLS AT PONSHEWAING.[a]

No. on fig. 67.	Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
		Ft.	*In.*	Ft.	Ft.	Ft.	*Gals.*	°F.			*Ft.*	
58	N. M. Kellam[b]	600	2	70	530	620	50	45	Soft	$20	70	Fountain.
59	N. M. Kellam[c]	610	2	180	430	....	25	....	....	100	140	Hotel and laundry.
60	N. M. Kellam	615	2	200	415	621	20	46½	Medium.	100	140	Log found at 50 feet.
61	R. L. Myers	619	2	175	444	....	15	....	....	100	140	
62	F. M Cappoc	610	2	225	385	615	10	46	Medium.	125	200	Domestic use.
63	Louis Schwab	612	2	225	387	....	8	46	....do	125	200	
64	Sawmill	600	2	82	518	....	17	45½	....	....	....	Steaming.

WELLS ON SOUTH SIDE OF CROOKED LAKE.

66	Warren Keelers	....	1½	100	....	....	2	....	....	....	....	Flows pipe quarter full.
67	Geo. Benham[d]	610	1½	150	....	....	2	....	....	....	....	All clay. Said to reach rock.
68	Dart & Dart Co	600	2	84	....	....	3	....	....	....	....	On Oden Isle; small flow.
69	....do	603	2	152	....	....	....	....	....	....	....	Said to stop in rock.
70	John Hastings	615	2	63	....	....	1	47	....	....	....	30 feet to rock.
71	Cincinnati Club	628	1¾	140	....	....	1	48	....	....	....	See analysis (p. 375); 14 feet to rock.
72	Hotel Hastings	728	1½	260	....	....	....	....	....	....	....	Mostly in rock.
73	J. Jewell	605	2	40	....	....	3	....	....	....	....	Flow from top of rock.

[a] The pipes in all the Ponshewaing wells, except No. 58, are without screens.

[b] The following is the record of Kellam well, No. 58:

	Thickness (feet).
Sand	8
Marl	15
Blue and yellowish clay	48
Gravel and sand with water	1

[c] When well No. 59 is checked, well No. 60 flows one-third more.

[d] Mr. Benham is reported to have another flowing well at an old lumber camp in the NW. ¼ sec. 32 T. 35 N., R. 4 W., which flows about 10 gallons a minute. This was not visited.

Wells of Crooked Lake area—Continued.

WELLS AT CONWAY.

Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
	Ft.	*In.*	*Ft.*	*Ft.*	*Ft.*	*Gals.*	*°F.*			*Ft.*	
W. Day		2	172			10					Domestic use.
N. Blackmar	606	2	165	441		15	46	Soft			Clay 125 feet; rest sand.
N. McFarlane cottage (2 wells)	606	1½	160 161	446		30					
Grand Rapids and Indiana Rwy. (depot).	605	2	115	490	625	30	46	Soft			
Mr. Mathews		2	116			15	46				House use.
W. Van Avery	603	2	100	503		50	46	Soft			House and store use.
V. Powell	604	2	103	501		18		do			Carefully piped.
J. McFarlane mill	604	2	120	484		19					Drinking.
W. Rice	604	2	100								Not flowing.
F. Stallman	601	2	88	513	616	35	46	Soft			House use
A. Blackmar		2	100			15					Small hotel.
C. Lyon	605	2	110	585		64	46	Soft			House use.
J. Cook	604	1½	100	504		20					Do.
E. E. Blackmar	603	1½	107	505	638	32		Soft			Made in 1885.

WELLS AT ALANSON.

Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
E. R. White	609	2	82	527		10	45				Domestic use.
G. W. Rotten	607		72	535		8			$60		Do.
Colby Hinckly Co.	608	2	80	528	618	18					Do.
F. Keiger	614	2	96	518	634	50	45		100		House and barn.
H. McPhee	610	2	122	488		16	45½		100		Drilled in 1898.
J. McPhee	608	1½	90	518		15			65		Store.
W. McDonald	605		65	540		20					House use.
H. Fairbanks	603	2	70	533		10	46		75		Drinking.

WELLS NEAR BRUTUS (SEC. 34, T. 36 N., R. 4 W.).

Owner.	Elevation.	Diameter.	Depth.	Elevation of water bed.	Water rises to—	Flow per minute.	Temperature.	Quality.	Cost.	Depth of casing.	Remarks.
Joseph Morris[a]	625	2	65	570	647	20±		Soft			Fish pond and stock.
Do.	625	2	55	570	647	20±		do			Do.

[a] Two wells in a valley near the Grand Rapids and Indiana Railway, about 30 feet below the bordering plain, flow a full 2-inch pipe. Reported by owner; not visited.

INDEX.

I.

R.

S.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 183.]

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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian-well prospects in the Atlantic coastal plain region, by N. H. Darton, Bulletin No. 138.

Correspondence should be addrest to

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Geology and Ground-Water Resources of the Douglas Basin Arizona

By D. R. COATES *and* R. L. CUSHMAN

With a section on

CHEMICAL QUALITY OF THE GROUND WATER

By J. L. HATCHETT

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1354

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By D. R. Coates and R. L. Cushman

ABSTRACT

The Douglas basin is part of a large northwest-trending intermontane valley, known as the Sulphur Spring Valley, which lies in southeastern Arizona, and extends into northeastern Sonora, Mexico. Maturely dissected mountains rise abruptly from long alluvial slopes and culminate in peaks 3,000 to 4,000 feet above the valley floor. Bedrock in the mountain areas confines drainage on the east and west, and an arc of low hills to the north separates the basin from the Willcox basin of the Sulphur Spring Valley. Drainage of the 1,200 square miles in the Douglas basin is southward into Mexico through Whitewater Draw.

The mountains include igneous, metamorphic, and sedimentary rocks ranging in age from pre-Cambrian to Tertiary, including Paleozoic and Mesozoic sedimentary rocks that total about 10,000 feet in thickness. The older rocks have been metamorphosed, and all the bedrock has been affected by igneous intrusion, largely in Mesozoic time, and by structural movements, largely in Cenozoic time and extending into the Quaternary period. By the early part of Cenozoic time the major structural features were formed, and mountain ranges had been uplifted above the valley trough along northwest-trending fault zones. Since that time the physiographic features have resulted through erosion of the mountain blocks and the deposition, in places, of more than 2,800 feet of unconsolidated rock debris in the valley.

Ground-water supplies of the Douglas basin are developed largely in the saturated zone of the valley-fill sediments. The ground water in the valley fill occurs in thin lenses and strata of sand and gravel, which are interbedded with large thicknesses of silt and clay. Scattered gypsum beds and extensive caliche deposits appear at the surface and occur within the valley fill at various depths. Although the valley-fill sediments are as much as 2,800 feet thick, the uppermost 300 feet or so are the most permeable.

Ground water originates as precipitation in the mountain areas. The water collects in streams that lose much of their flow into the coarse sediments that fringe the mountains. Part of the water ultimately percolates into the zone of saturation. High evaporation rates, vegetative use, and the presence of caliche and clay at shallow depth in the interstream areas of the valley floor prevent important recharge of the ground-water reservoir from direct rainfall or seepage of water applied for irrigation. The total recharge into the ground-water reservoir of the Douglas basin was about 20,000 acre-feet in 1951.

Ground water is discharged from the basin by evapotranspiration, by effluent seepage into Whitewater Draw and underflow out of the basin, and by pumping. In 1951, the total amount of ground water discharged was about 50,000 acre-feet, of which more than 41,000 acre-feet was pumped from wells. Ground water used in excess of recharge is withdrawn from storage, causing a decline in the water table. Maximum declines have occurred in the heavily pumped Elfrida area, where a decline of more than 11 feet occurred in the 5-year period 1947–51, inclusive.

Most irrigation wells in the Douglas basin are less than 200 feet in depth and usually produce less than 400 gpm (gallons per minute). The average specific capacity of the wells is about 12 gpm per foot of drawdown. Although water in some parts of the basin is artesian, all irrigation wells must be pumped.

Ground water in the basin is generally of excellent to good quality for irrigation use. In small areas along the southern part of Whitewater Draw and east of Douglas the ground water is high in dissolved-solids content. Although most of the water is hard, it is generally satisfactory for domestic use. In many areas the fluoride content is more than 1.5 ppm (parts per million).

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The need for factual information concerning the ground-water resources of Arizona is becoming increasingly urgent. Ground-water studies in Arizona by the Geological Survey began about the turn of the century. A district office was established at Tucson in July 1939, under an arrangement of financial cooperation with the State of Arizona. This report is one of a series prepared under a cooperative agreement with the Arizona State Land Department. The report includes discussion of the geology, ground-water resources, and quality of ground water in the Douglas basin, Cochise County.

The report represents the combined work of many of the personnel of the Ground Water Branch of the Geological Survey, from the beginning of the investigation in January 1946 to the completion of field work in March 1952. Others who contributed substantially in collecting data on which this report is based, or in preparation of the report, include H. M. Babcock, M. B. Booher, S. C. Brown, O. B. Coulson, J. H. Feth, R. S. Jones, A. E. Robinson, and J. I. Webster.

The study was under the general supervision of O. E. Meinzer and A. N. Sayre, successive chiefs of the Ground Water Branch of the Geological Survey, and under the immediate supervision of S. F. Turner and L. C. Halpenny, successive district engineers. The quality-of-water phase of the work was under the general supervision of S. K. Love, chief of the Quality of Water Branch of the Geological Survey, and under the immediate supervision of J. D. Hem, district chemist.

ACKNOWLEDGMENTS

Appreciation is expressed to all coworkers who helped in the collection of data and in the preparation of this report. Organi-

zations that have been especially helpful in supplying needed information from their files include the Arizona Edison Co., the City of Douglas Water Works, the U. S. Department of Agriculture, the Phelps Dodge Corp., the Rural Electrification Administration, and the University of Arizona. Thanks are given also to the many well drillers who willingly supplied copies of their drilling logs. Many residents of the Douglas basin have provided invaluable assistance and information.

LOCATION AND EXTENT OF THE AREA

The Douglas basin is in Cochise County in southeastern Arizona (fig. 1). The basin is part of the Sulphur Spring Valley, a large

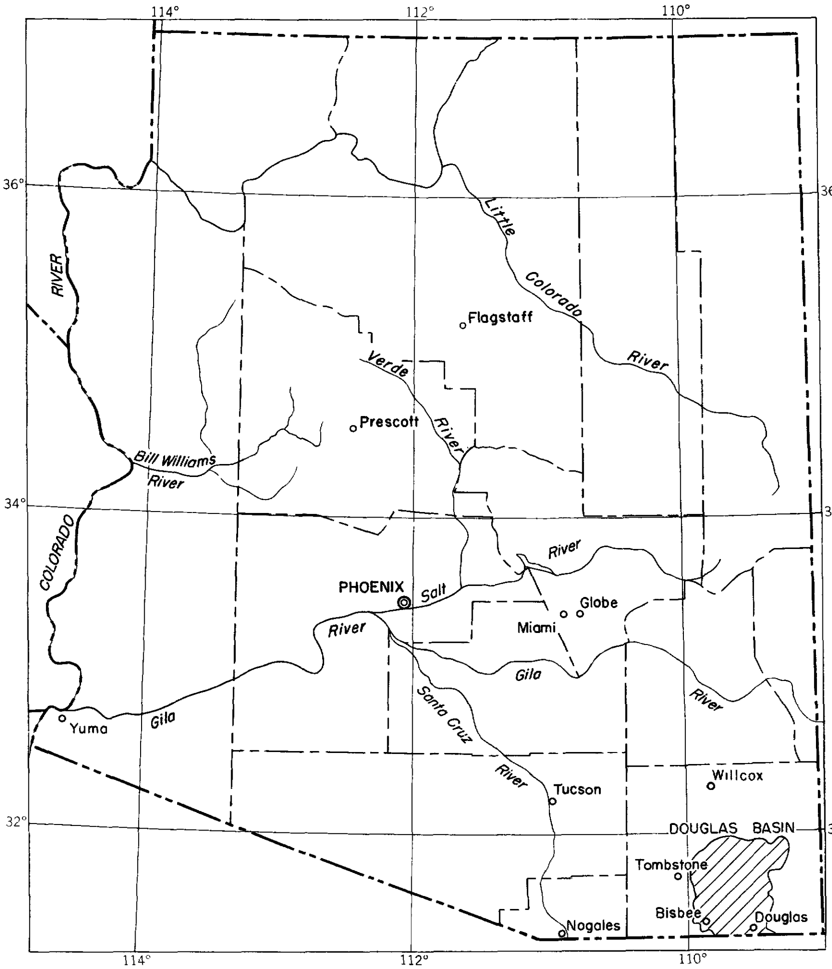

Figure 1.—Map of Arizona showing location of Douglas basin.

northwest-trending intermontane trough which extends into northeastern Sonora, Mexico. For this report the Douglas basin is considered to be that portion of the drainage basin of Whitewater Draw north of the international boundary, although the basin extends south into Mexico. Highland areas that form the drainage divides of the basin are the Chiricahua, Pedregosa, and Perilla Mountains in the east; the Dragoon and Mule Mountains in the west; and in the north, a series of ridges and buttes, the most prominent of which are Six Mile Hill, Township Butte, the Pearce Hills, and Turkey Creek Ridge. The basin averages about 40 miles in length and 30 miles in width and has an area of about 1,200 square miles.

CLIMATE

The Douglas basin has a semiarid climate similar to that of other parts of southern Arizona (Smith, 1945). The climate in the valley portion of the basin is characterized by low precipitation, high evaporation, and large daily fluctuations in temperature. The hot summer days are tempered by breezes and low humidity, and the nights are cool. Winter temperatures are mild, although the night temperatures occasionally go below freezing. These generalizations for the valley are in sharp contrast to the climate of the mountains, which constitute about one-third of the total area of the basin. Climatic conditions in the mountains are more rigorous, and snow is common at higher altitudes during the winter.

The United States Weather Bureau maintains temperature and rainfall stations at Douglas and Bisbee (table 1). Rainfall stations are also maintained at Leslie and Rucker Canyons. Climatic conditions in the vicinity of the Douglas station, altitude 3,973 feet, are considered representative for most of the valley. The mean annual rainfall there is 12.74 inches, of which about 8 inches occurs in the summer months during brief, intense thunderstorms. April, May, and June are the driest months, and the average total precipitation in this period is about 1 inch. The mean annual temperature is 62.5°F. The wind blows mostly from the southwest at an average velocity of 7.1 miles per hour. The growing season averages 212 days at Douglas; the last killing frost of the spring usually occurs in early April and the first killing frost of fall early in November. Douglas receives an average of 3,800 hours of sunshine a year. Conditions of low humidity in the region are indicated by evaporation measurements made at Willcox, 24 miles north of Pearce. The annual evaporation at Willcox averages 84.59 inches, about seven times the annual precipitation there.

The Bisbee station, altitude 5,350 feet, is considered to represent typical climatic conditions in the lower parts of the mountain areas. At Bisbee the mean annual rainfall is 19.15 inches and the mean annual temperature is 61.3°F.

HISTORY OF DEVELOPMENT

A full account of early development in the Douglas basin is given by Meinzer and Kelton (1913). The basin is included in the area acquired from Mexico by the Gadsden Purchase of 1853. It remained largely an Indian reservation until 1876 when the Chiricahua Apaches were moved to the San Carlos Reservation and the Sulphur Spring Valley was returned to the public domain.

Development of ranches began about 1872 when Fort Grant was moved to the northern part of the Sulphur Spring Valley, but extensive settlement of the Douglas basin did not begin until the building of the railroad from Bisbee to the copper smelters at the newly developed townsite of Douglas in 1902. The principal industries in the basin up to 1910 were mining and cattle raising. Farming started after 1910 when the first irrigation wells were drilled. The farming economy of the Douglas basin is dependent on the availability of ground water. Agricultural acreage has expanded rapidly in recent years, from about 3,000 acres in 1940 to more than 14,000 acres in 1951. About 75 percent of the 1951 acreage was devoted to cotton.

PREVIOUS INVESTIGATIONS

The earliest study of the Douglas basin that is referred to in this report is that of Ransome (1904), who described the geology of the Bisbee area. The most comprehensive study of the basin was made by Meinzer and Kelton (1913). Many of the conclusions reached as a result of this early work are applicable at present and, whenever possible, unnecessary duplication is avoided in this report. The U. S. Bureau of Agricultural Economics (1940) prepared a report on the water supply of the Douglas basin. Other works that have been used include those of Darton (1925), Wilson (1927), Gilluly, Cooper, and Williams (1955), and Cederstrom (1946), and the geologic map of the State of Arizona (Darton, 1924). A Geological Survey report on the ground-water resources of the Gila River basin and adjacent areas[1] contains a resume of the data presented here.

[1]Halpenny, L. C., and others, 1952, Ground water in the Gila River basin and adjacent areas, Arizona—a summary: U. S. Geol. Survey Open-File Report.

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METHODS OF INVESTIGATION

The section on geology of the Douglas basin includes data from previous investigations in addition to the results of reconnaissance geologic mapping by geologists of the Ground Water Branch in areas where mapping was incomplete. The geology was recorded on topographic maps and aerial photographs and was later transferred to the base map (pl. 1). Geologic mapping in the mountain areas was on a reconnaissance scale, as there was no need to map in detail the various rock units.

Records have been collected for 475 of the more than 500 wells of all types that exist in the Douglas basin. Records of representative wells are shown in table 2. Included in the well-record file of the district office at Tucson are more than 200 well logs, which indicate the type of rock material encountered at various depths. Table 3 is a compilation of characteristic well logs. To determine changes in the position of the water table, the Survey makes water-level measurements in 23 observation wells four times a year and in 21 observation wells once a year. All water-level measurements are made with a steel tape from fixed measuring points. The observation-well measurements, in addition to hundreds of others made during the last 5 years, give an accurate record of depth to water in the basin. These data were used in compiling a depth-to-water map (pl. 1), a water-table contour map (pl. 2), and a map showing the decline of the water table (pl. 3). Data for the water-table contour map were obtained by determining the altitude above sea level of the land surface at more than 200 wells by spirit leveling and correlating that information with water-level measurements. A pumpage inventory for the Douglas basin is compiled annually from records of power consumption by pumps and from measurements of well discharges. Chemical analyses were made of 129 samples of water collected from various wells, springs, and streams. Table 4 includes 40 of the analyses.

WELL-NUMBERING SYSTEM

In this report, wells are numbered in accordance with the General Land Office subdivision system, and the well numbers show the locations by township, range, and section. A graphic illustration of the well-numbering system is shown in figure 2. The capital letter indicates the position of the area with respect to the Gila and Salt River base line and meridian. The first numeral of the well number indicates the township, the second the range, and the third the section in which the well is located. The lowercase letters following the section number indicate the position of

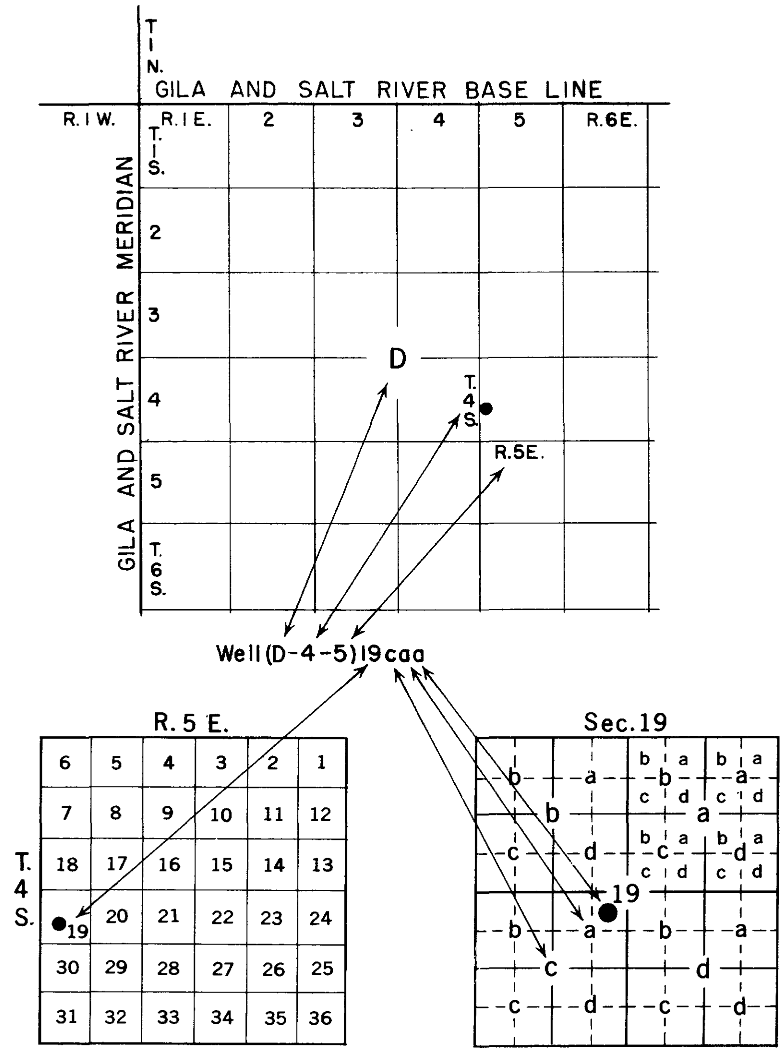


Figure 2. —Sketch showing well-numbering system in Arizona.

the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). All letters are assigned in a counterclockwise direction, beginning in the northeast quarter.

GEOLOGY AND ITS RELATION TO GROUND WATER

GEOMORPHOLOGY

The Douglas basin is part of the Mexican Highland section of the Basin and Range physiographic province (Fenneman, 1931). The section is an area characterized by isolated and dissected fault-block mountains separated by debris-filled desert valleys. The valley and mountain areas provide a convenient division for description of the Douglas basin. The central area consists of a relatively flat valley floor about 35 miles long and 15 miles wide whose axis trends northwest. This part of the basin is hereafter referred to as "the valley." The valley slopes are gentle and concave upward from the axis to the sharply defined mountain fronts. The valley trough slopes southward about 10 feet per mile from an altitude of about 4, 300 feet at the north end of the basin to 3, 900 feet at the Mexican border. The Chiricahua, Swisshelm, Dragoon, Mule, Perilla, and Pedregosa Mountains are built of bedrock and project above the valley floor. These bedrock areas lie above altitudes of 4, 700 feet and comprise about 360 square miles or about 30 percent of the total area of the basin. The mountains are maturely dissected and have steep, well-drained forested slopes. The highest and most rugged are the Chiricahua Mountains, culminating in Chiricahua Peak whose altitude is 9,795 feet. In the other ranges the highest altitudes are 7, 185 feet in the Swisshelm Mountains, 7,150 feet in the Dragoon Mountains, 7,400 feet in the Mule Mountains, 6, 385 feet in the Perilla Mountains, and 6, 510 feet in the Pedregosa Mountains.

Whitewater Draw, which derives its name from the white caliche deposits along the bank, drains the Douglas basin. The headwaters of Whitewater Draw are in Rucker Canyon in the Chiricahua Mountains. The uppermost channel is V-shaped, is geologically youthful, and has a steep profile. The slope downstream flattens appreciably into that of a mature stream in Rucker Canyon, after passing from volcanic rocks to sedimentary rocks. A continuous channel is maintained from the source, around the northern end of the Swisshelm Mountains, and to the cultivated lands northeast of Elfrida where the channel loses its identity. The channel again becomes well defined at a point about 2 miles southwest of Elfrida. From this point Whitewater Draw continues southward into Mexico where it is tributary to the Yaqui River, which flows into the Gulf of California. In the southern part of the Douglas basin the channel of Whitewater draw has been offset to the east because a greater load of sediments has entered the valley from the Mule Mountains to the west than has come from the Perilla Mountains to the east. Perennial flow in Whitewater Draw occurs in only two places in the basin: in the upper 3 miles of Rucker Canyon; and in the 2-mile reach immediately north of the international border.

Tributary streams in the basin are ephemeral, and most of the stream channels disappear before reaching the central part of the valley floor. Many of the larger washes, such as Leslie Creek and Mud Springs Draw, do not have continuous channels from their sources to their confluence with Whitewater Draw. However, in the vicinity of Douglas and for a few miles north of Douglas, several streams issuing from the mountains have been able to establish a junction with Whitewater Draw. These channels have steep banks and are cut about 15 feet below the general level of the valley floor. Whitewater Draw is incised to a maximum depth of about 25 feet northwest of Douglas.

Maximum runoff occurs during the thunderstorm season in the summer, but generally each period of runoff after a storm is short. Other streamflow occurs in the spring with the melting of mountain snow. Streamflow from the mountains generally is dissipated in distributaries and as sheet runoff on alluvial fans and pediments, or infiltrates into the coarse sand and gravel near the mountain front.

Coalescing alluvial fans occur along some of the mountain fronts, and are most prominent on the east front of the Mule Mountains. Gently sloping bedrock surfaces, called rock pediments, are exposed along the west base of the Perilla Mountains (pl. 1) and probably occur, concealed by alluvium, along the Swisshelm Mountains. The terraces that are common and characteristic of many other southern Arizona basins are lacking in the Douglas basin. In general, the long alluvial slopes continue smoothly to the central valley floor, except for local development of small, indeterminate benches a few feet in height. The continuity of the slope is broken by buttes and outliers. These hills are particularly concentrated along the drainage divide that extends from the northern tip of the Swisshelm Mountains to the Pearce area. The outliers are erosional remnants of an older topography now partly buried by valley fill.

Many Indian artifacts have been found along Whitewater Draw. The oldest finds have been determined to be more than 10,000 years old (Sayles and Antevs, 1941, p. 55). If there had been a period of great erosion in post-Pleistocene time, it probably would have obliterated many of the Indian relics and would have cut terraces. In the Recent epoch, therefore, there is strong suggestion that it has been characterized by interrupted aggradation until the 19th century when widespread gullying began.

During Quaternary time, erosion has been the dominant activity in the upland areas and deposition has been dominant in the valley. The upper slopes of the valley have been created in part by the erosive retreat of the mountain fronts. The intermittent streams in the basin are now eroding the land and the Douglas basin is expanding slowly northward at the expense of the aggrading, interior-draining Willcox basin.

The decade 1880-90 saw the beginning of important changes in the valley of the Douglas basin, as well as in many other parts of the Southwest. Gregory (1917, p. 130), Bryan (1925, p. 339), and Thornthwaite and others (1942, p. 102-104) fix the period of the 1880's as the beginning of the gullying that is currently occurring in the Southwest. William Cowan, a pioneer rancher in the Sulphur Spring Valley, dates the beginning of channel cutting in Whitewater Draw after 1884 (Meinzer and Kelton, 1913, p. 28). Other oldtime residents of the valley also date the cutting before 1900. Causal relationships for the recent cycle of arroyo cutting are imperfectly known and controversial. The two theories most widely advanced to explain the beginning of the recent gullying are overgrazing and climatic variations.

In 1884 there were 300,000 cattle in the Territory of Arizona, and by 1893 this number had increased to 800,000 (Thornber, 1910, p. 338). The possibility exists that, with the increase in cattle in the 1880's, much of the range grass was destroyed and the range soil was disturbed by the animals' hoofs (Sauer, 1930, p. 387) thus reducing the resistance of the land to erosion (Thornthwaite and others, 1942, p. 123). It is known that the character of the vegetation in the valley of the Douglas basin has changed since it was first described in writing. Parry and Schott (1857, p. 17) reported patchy growth of coarse grass in the valley and hackberry and walnut trees in a side wash, but made no mention of the mesquite groves which had become extensive by the time of the investigation by Meinzer (Meinzer and Kelton, 1913, p. 89). These groves occupied about the same area in 1910 as now, except where they have been cleared for cultivation. Oldtime residents in the valley agree that mesquite did not get a foothold until about 1900. Changes in erosion and sedimentation may have resulted from such an upsetting of the delicate balance of nature by overgrazing and change in vegetal cover.

The effects of climatic variations upon the erosion cycle are difficult to evaluate. Fragmentary records from some U. S. Weather Bureau stations (Trask and others, 1950, p. 420) indicate that the rainfall was much greater during the first 4 years of the 1880-90 decade than it was during the whole period of record. Statistical analysis by Leopold (1951, p. 351) has shown for some areas in the Southwest prior to 1900 "a relatively high frequency of large rains." Thus, the increased precipitation in the early 1880's with a higher frequency of storms of great intensity, falling on impoverished rangelands of poor cover and broken sod may have combined to trigger a new cycle of gullying.

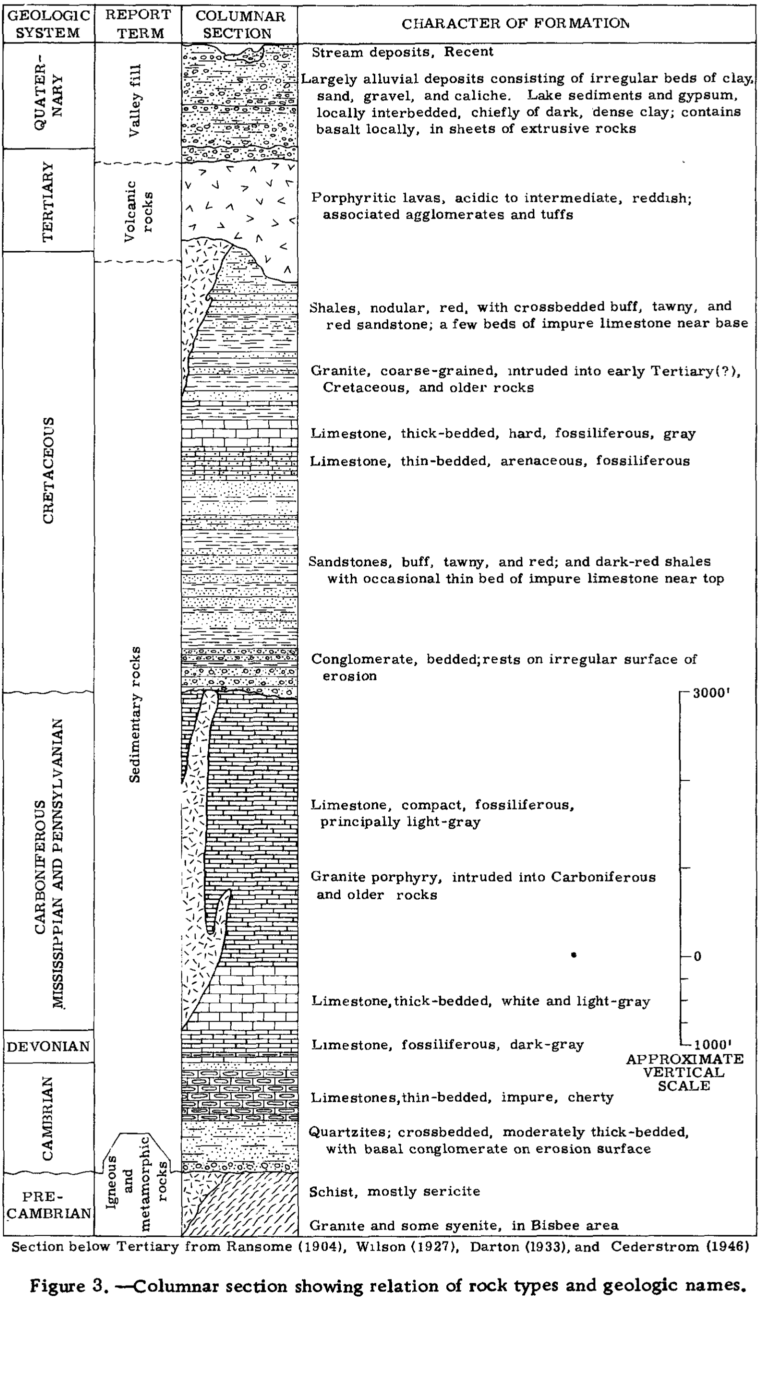
It has been suggested that differential uplift of mountain areas offers at least a partial explanation for gullying (see Gregory, H. E., in Knechtel, 1938, p. 189). Earthquake and faulting activity is known to have occurred on May 3, 1887, throughout much of the Southwest. Earthquake tremors were felt in a large region from El Paso, Tex., west of Centerville, Calif., and from Globe, Ariz., south to Guaymas, Mexico. The Tombstone Epitaph newspaper on May 4 and 8, 1887, carried vivid accounts of earthquake activity throughout the Sulphur Spring Valley. It was reported that "hundreds of water veins opened in the earth with a sufficient quantity to supply 100,000 cattle." In the Dragoon Mountains there was a severe shock and great noise, and "huge boulders were thrown down the mountain." Artesian conditions were reported "to have been disrupted at Soldier's Hole." In spite of these reports the writer believes that such activity has had no far-reaching effects in the Douglas basin.

HISTORY AND WATER-BEARING CHARACTERISTICS OF ROCK UNITS

The sequence of rock units in the Douglas basin is shown in the geologic column (fig. 3). The following paragraphs briefly discuss these units according to the groups by which they were mapped (pl. 1), the oldest being presented first. The geologic column shows more subdivisions than are considered in the following discussion. The units were combined for the present report into groups, the members of which have relatively uniform water-bearing characteristics.

SCHIST

During pre-Cambrian time thousands of feet of sediments, mostly silt and sand, were deposited in southern Arizona. After consolidation into rock, these strata were severely distorted by igneous intrusions, folding, and faulting, and were metamorphosed into schists. The pre-Cambrian schists are well exposed in several areas in the Dragoon Mountains and at Bisbee in the Mule Mountains. The schist in the Douglas basin has been correlated with the Pinal schist in other parts of Arizona (Ransome, 1904, p. 2).



Section below Tertiary from Ransome (1904), Wilson (1927), Darton (1933), and Cederstrom (1946)

Figure 3. —Columnar section showing relation of rock types and geologic names.

Schists in this region rarely yield much water and, owing to the limited area of outcrop in the Douglas basin, they are of little or no significance as a source of ground water.

At the close of pre-Cambrian time a long interval of erosion started. Highland areas were eroded to a surface of low relief, setting the stage for the advance of the first seas of the Paleozoic era.

SEDIMENTARY ROCKS

In the Paleozoic era shallow seas, alternately advancing and retreating, left sediments of several kinds in the Douglas basin area. The early sediments were gravel and sand, and the later deposits were predominantly limestone, indicating progressively deeper and warmer conditions. After the deposition of more than 5,000 feet of conglomerate, quartzite, sandstone, shale, and limestone, the area was uplifted and the seas retreated, ending the era. Erosion continued during the first two periods of the Mesozoic era (Triassic and Jurassic periods) and ended with subsidence and the advance of marine water in Cretaceous time.

In Cretaceous time about 4,500 feet of fragmental sedimentary rocks and lesser thicknesses of limestone were deposited. These deposits represent the last marine transgression into the area.

The Paleozoic and Cretaceous sedimentary rocks yield water in quantity sufficient only for domestic and stock use. They do not supply any of the water used for irrigation. Along the slopes of the Mule and Perilla Mountains there are stock and domestic wells that penetrate the sedimentary rocks and have yields of several gallons of water a minute. In the mine workings at Bisbee, where the rocks are cavernous and have been broken by faults or joints, and where collection areas are large, some of the limestone formations yield millions of gallons of water daily. The Waddell-Duncan oil test (D-22-27)5b (see log, table 3) is the only well in the valley that has penetrated the entire thickness of valley fill. It encountered sedimentary rocks at a depth of 1,605 feet. The well yielded water under artesian pressure after passing through limestone of Mississippian age at a depth of 2,270 feet and flowed an estimated 100 gpm at a temperature of 129°F.

GRANITE

The nonvolcanic igneous rocks in the Douglas basin have all been shown as "granite" on the geologic map (pl. 1). Although several different types of intrusive rocks crop out in the area, precision in individual classification was unnecessary for description of the ground-water resources. In the larger granitic areas the rocks are thought to be of Cretaceous age (Cederstrom, 1946, p. 601), but it is reported that intrusive igneous rocks were formed during various geologic intervals (Wilson, 1927, p. 22-23; Darton, 1933, sheet 21; Ransome, 1904, areal geologic map).

In areas where granitic and associated intrusive rocks have been greatly fractured and deeply weathered, sufficient water may be obtained to supply small amounts to domestic and stock wells. The communities of Courtland and Gleeson were formerly supplied with water from areas where deep weathering had created local basins of loose granitic sand. According to Meinzer and Kelton (1913, p. 114-115), at Courtland more than 15,000 gpd (gallons per day) was pumped from such a source and as much as 3,200 gallons per hour after the summer rains. The water yield of the intrusive rocks of the area is insufficient for irrigation or other large-scale uses.

VOLCANIC ROCKS

Volcanic rocks of Cretaceous(?) and Tertiary(?) age in the Douglas basin occupy an area second in extent only to the valley fill. Volcanic rocks compose most of the mountain area on the east side of the basin, most of the hills along the northern drainage divide, and part of the rocks in the Dragoon Mountains. The volcanic sequence in the Chiricahua Mountains aggregates several thousand feet in thickness. These rocks consist of a wide variety of explosively erupted (pyroclastic) and lava-flow materials, mostly of acidic composition. Thin strata of sandstone are present, locally interbedded with the volcanic rocks, suggesting that volcanic activity was occasionally interrupted long enough to permit fluviatile deposition. A conspicuous landmark in the Pedregosa Mountains is Castle Dome, a volcanic plug which rises 805 feet above the surrounding land surface.

Water is present in small amounts where the lavas are well fractured, and in the pyroclastic materials where they are not cemented. Some springs in the mountain areas issue from volcanic rocks. In the concealed pediment areas on the east side of the basin, the only ground water that is known to be present occurs in small quantities in the volcanic rocks. Many test wells in this area did not yield water, and only a few wells obtain sufficient water even for domestic or stock use. If wells can be dug or drilled in areas where the rocks have been shattered or deeply weathered, the chances of obtaining a water supply are improved, as ground water commonly occupies such zones. There is no indication that the volcanic rocks in the basin contain ground water in quantities sufficient for irrigation or other large-scale uses.

VALLEY FILL

The valley fill constitutes about 70 percent of the area of the Douglas basin. Although the basalt (malpais) and gypsum are contemporaneous with parts of the valley fill they were mapped separately because of their possible local effect on ground-water conditions.

Events that caused the Cenozoic cycle of deposition were the post-Cretaceous disturbances which raised the mountains relative to the central trough. The partial filling of the trough has resulted from the accumulation of mountain debris, locally more than 2,800 feet thick. It is believed that some of the deeper strata filling the trough are of Tertiary age. The upper fill materials are predominantly of Quaternary age and some of the beds adjacent to washes and arroyos have been deposited during the Recent epoch. These deposits may be equivalent to beds described by Gilbert (1875, p. 540–541) as the Gila conglomerate, a term that covers a wide range in age and lithologic character.

The valley fill consists mostly of a large variety of sediments derived by erosion from rocks in the adjacent mountain areas (fig. 4). The beds are generally unconsolidated to poorly consolidated clay, silt, sand, gravel, and occasional boulders. The materials were carried downslope by streams and sheet runoff, the larger fragments being deposited near the mountain source and the smaller fragments farther away as the carrying power of the transporting water diminished. Ideally, there is a grain-size gradation of the valley fill, from coarse at the mountain front to fine in the center of the basin. Conditions of transportation and deposition of the fragments vary, however, with the carrying capacity of the streams, and this in turn varies in each stream with the intensity of the storm causing the runoff. As a result, an area covered during one flood with gravel may, after another storm, receive a deposit of silt or clay. Furthermore, the stream channels constantly shift but tend to be occupied by coarser grained materials than are found in adjacent interstream areas. The end result of such widely fluctuating conditions is deposition of lens-shaped and fingerlike strata which change markedly in texture and character both horizontally and vertically (fig. 4). Well logs throughout the valley reflect these conditions, and correlation of individual beds from well to well is usually impossible.

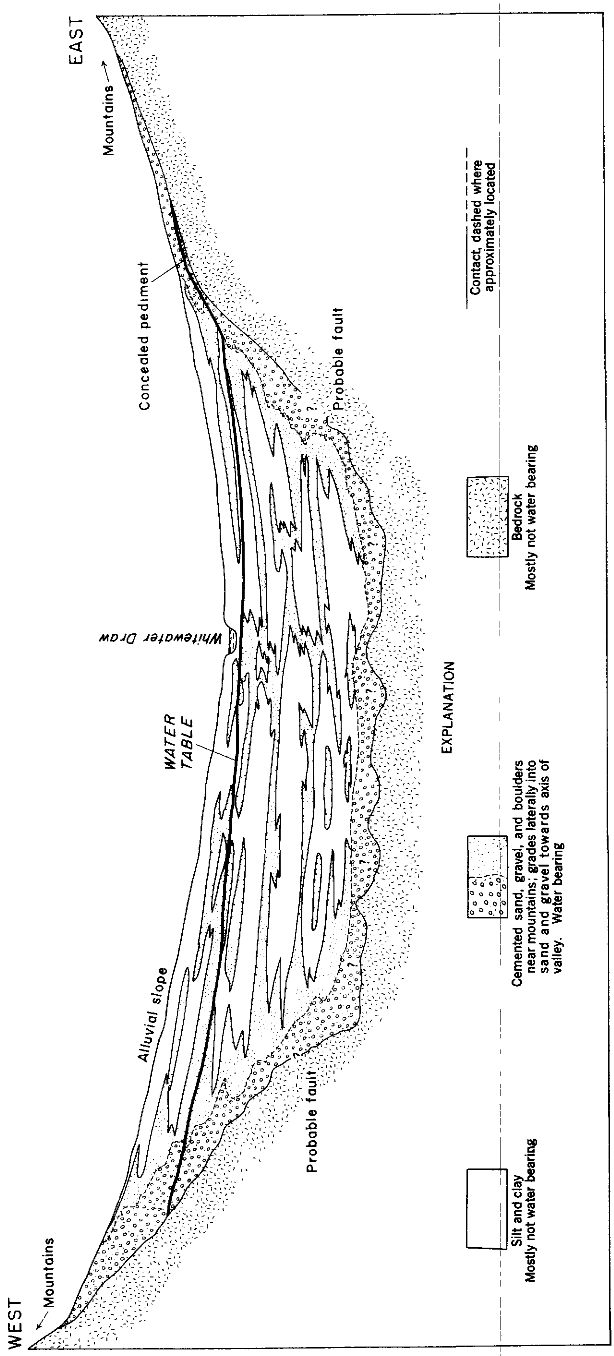


Figure 4.—Diagrammatic cross section of representative valley-fill conditions in Douglas basin.

There is a preponderance of clay throughout the alluvial fill in the Douglas basin, and statistical analyses of logs of many wells in the central part of the valley indicate that clay and silt may make up about 80 percent of the fill. Fine-grained deposits are especially abundant in the southern half of the Douglas basin and extend to depths of at least 1,000 feet. A lake of considerable size existed in the Willcox basin during the Pleistocene epoch. In the Douglas basin the gypsum and marl deposits east of Douglas, and the laminated clays now exposed in the banks of Whitewater Draw near Double Adobe (Sayles and Antevs, 1941, p. 34), indicate that standing water existed at least locally in that basin as well.

Caliche is present throughout most of the alluvium in the Douglas basin. Although it does not occur as a large, continuous blanket in the valley, it can be seen along most road cuts and stream channels, and it is mentioned in most of the driller's logs. The caliche tends to impede the downward movement of percolating water and thus to reduce recharge to the water-bearing beds.

Unconsolidated gravel and sand sediments in the valley fill of Tertiary and Quaternary age are the principal source of ground water in the Douglas basin and are the only beds that yield ground water in quantities sufficient for irrigation or other large-scale uses. The Recent alluvium along present stream channels is relatively thin and hence is capable of supplying only a small quantity of water sufficient for domestic or stock use in or near the mountain washes.

BASALT

Basaltic lava flows of Quaternary age crop out in a few small areas along the eastern margin of the valley. Basaltic lavas are known to occur also at depth, interbedded with the valley fill in an area of a few square miles in the vicinity of the city of Douglas. Thus, there were at least two periods of basaltic extrusion. The log of well (D–24–27)15bad is typical of the wells that penetrate the basalt. Basalt interbedded with valley fill has been reported in driller's logs in the city of Douglas area most commonly between 300 and 350 feet below the surface.

The areas of basalt are so small that they do not affect the general occurrence of ground water. On a restricted scale the basalt may influence ground-water conditions and cause, in part, minor ground-water anomalies such as are present in the Douglas area. Basalt is unimportant as an aquifer in Douglas basin but some of the interbedded sediments are water bearing, and in local areas the lava is sufficiently fractured to permit ground-water movement.

GYPSUM

Four small areas of gypsum have been mapped separately (pl. 1) because of the local effect of the gypsum on quality of the ground water. The gypsum deposits east of Douglas are of lacustrine origin and are interbedded with lake marls and sandy clays. The largest deposit, in sec. 11, T. 24 S., R. 28 E., is spoon-shaped, with strata that are 25 feet thick in the center and taper to feather edges. The gypsum is white and earthy and is characterized by an almost complete lack of grit and crystals. These deposits have been worked intermittently for many years. Small mining operations were in progress in the spring of 1952.

Fossil snails collected from the beds east of Douglas indicate (Teng-Chien Yen, personal communication, 1950) that the gypsum was deposited in a lake that existed in Douglas basin during middle or late Pleistocene time.

The gypsum deposits in Turkey Creek Ridge are different from those east of Douglas; at Turkey Creek Ridge the gypsum occurs largely in crystalline and fibrous forms. The deposits are crudely bedded and contain many veinlets of fibrous gypsum. The thickest measured section of gypsum was 6½ feet. The gypsum is white to brownish red, very gritty and rocky, and nonfossiliferous.

Gypsum is encountered at depth in wells at several places in the Douglas basin, and the chemical composition of the ground water in the vicinity is generally affected by such occurrence. The gypsum deposits do not themselves yield ground water in quantity but by solution they affect water in nearby aquifers. (See analysis (D-24-28)11bca, table 4.)

STRUCTURAL GEOLOGY

Structurally the Douglas basin is typical of the tectonic basins of the Basin and Range province. The alinement of the northwesterly trending mountain and valley areas has resulted from major movements along faults, which tilted the mountain blocks northeastward. A reflection of this structure is found in the Mule, Dragoon, Swisshelm, and Perilla Mountains, where the rock strata dip almost exclusively northeast.

The depth to which the rock floor of the valley has been downfaulted in relation to the mountain blocks can be inferred from previous studies and recent deep drilling. On the western side of the Douglas basin Ransome (1904, p. 9) records faults of 3,000-foot displacement. These faults were dated as pre-Cretaceous.

In the Bisbee district the mountain block has been tilted northeast about 15°. East of Bisbee parts of the sedimentary sequences of Paleozoic age were thrust at a later geologic time approximately 2 miles over strata of Cretaceous age. An oil test hole, (D-21-25) 25ad, was reported to have been drilled through a total valley-fill thickness of 2,835 feet and to have encountered rocks of Cretaceous age at that depth. A well, (D-22-26)27bbd, was drilled to a total depth of 1,604 feet, all in valley fill. Another oil test hole, (D-22-27)5b, penetrated the full thickness of valley fill at a depth of 1,605 feet and entered rocks of Pennsylvanian(?) age. These strata are structurally more than 2,000 feet lower than matching beds in the adjacent mountains to the east. Thus, the rock floor of the Douglas basin has probably been downfaulted at least 2,000 feet on the east and west sides of the structural trough; the trough is possibly asymmetrical and tilted westward; and the bedrock floor is locally more than 2,800 feet below the surface of the valley.

A separate downfaulted block lies between the Swisshelm and Chiricahua Mountains. In that small basin well (D-21-28)3baa encountered bedrock beneath 1,020 feet of valley fill. Other wells on the flanks of that basin passed through the valley fill at depths ranging from 870 to 1,100 feet. These relations are strongly suggestive of major faulting along the western slopes of the Chiricahua Mountains.

Displacement of Tertiary volcanic rocks by faulting, along both northwest and northeast lines, indicates that much of the major structural movement in the basin occurred in late Tertiary or early Quaternary time. Along the eastern border of the valley are a few basaltic dikes of Quaternary age having predominantly northeast strikes. It is probable that these dikes follow preexisting fault zones.

The northwest-trending arc of hills that extends from the Swisshelm Mountains to the vicinity of Pearce is partly related in origin to the northwest-trending fault pattern. These hills, which represent the remnants of the older landscape now largely buried by valley fill, are believed to represent a northwest extension of the structural block forming the Swisshelm Mountains.

The northwest-trending major faults have been emphasized in this report. There is also a pattern of minor fault structures striking northeast. Some faults have broken the continuity of the mountain blocks, creating a locally rugged topography and, in part, governing the location of some of the major canyons.

Folding of the sedimentary strata is less pronounced and is not as important as faulting in the structural history of the basin. The rocks of Paleozoic age in the Bisbee area were folded before or during the Mesozoic era. A later period of mountain building is indicated by the fact that Cretaceous rocks in the Bisbee area and in the Perilla and Swisshelm Mountains have been folded and faulted.

Bedrock structures are effective in controlling ground-water movement. The impervious mountain areas in the eastern and western parts of the Douglas basin prevent both leakage away from the basin and inflow from other basins. There is probably some ground-water movement southward among the hills that extend northwest from the Swisshelm Mountains, as discussed in the following section on ground-water resources.

GROUND-WATER RESOURCES

OCCURRENCE

The ground-water supplies that have been tapped in the Douglas basin are in the valley fill, in local areas of the hard-rock exposures, and in some of the hard rocks underlying the valley fill. These ground waters occur under unconfined (water table) conditions and under confined (artesian) conditions. The search for and the development of ground water in the basin indicates that the unconfined waters are easier to obtain and develop, especially in the large quantities that are needed for irrigation use.

UNCONFINED WATER

The valley fill is the source of supply for most of the water withdrawn from wells in the Douglas basin and contains the largest proven supply of unconfined water in the basin.

WATER IN VALLEY FILL

The main body of water as well as local areas of perched water are unconfined in the valley fill. The upper surface of the main body of unconfined water is the main water table. The depth to the main water table below land surface is the depth to water in all the irrigation wells and most of the domestic and stock wells in the fill. All of the valley-fill materials below the water table contain water, but the various materials comprising the valley fill have considerable differences in their water-storage, water-transmitting, and water-drainage capabilities.

The water-bearing characteristics of the materials depend on the grain size, the degree of sorting or lack of sorting of component particles, and the degree of consolidation by compaction or by cementation. The more permeable zones in the valley fill are those that are coarse grained, fairly well sorted, and unconsolidated. Consolidation of the materials generally increases with depth with a consequent decrease in permeability. There are local exceptions to this, but in general, the valley-fill materials below depths of 300 to 400 feet have not yielded water to wells in sufficient quantities to justify the cost of the drilling below those depths.

Ground water occurs below the water table in all the various combinations of gravel, sand, silt, and clay described earlier in the report. The more permeable valley-fill materials are the unconsolidated or poorly consolidated deposits of sand and gravel. These more permeable deposits are interconnected, as shown by the presence of a single main water table, but the connections may not be direct and may be by way of less permeable materials. These permeable sand and gravel deposits release their stored water readily to wells and, therefore, are recognized as being "zones" from which water is developed. Such zones are commonly reported in drillers' logs as "water strata." The "water strata" are discontinuous laterally because of the nature of the deposition of the valley fill, and therefore the water strata in nearby wells cannot be correlated with certainty either by altitude or depth below the surface.

In addition to storing water for ready release, these more permeable members, after they have been partially unwatered, collect water draining from the surrounding less permeable materials.

Form of the water table.—The form of the main water table in the Douglas basin resembles the form of the valley slopes, but has fewer irregularities and gentler gradients (fig. 4). The water table descends southward at a gradient of about 9 feet per mile from an altitude of about 4,200 feet in the vicinity of the buttes and ridges in the northern part of the basin to about 3,870 feet at the international boundary. (See plate 2.) The water table slopes downward from the east and west sides of the valley toward the axis at gradients ranging generally between 15 and 30 feet per mile. The gradient of the water table closely approximates the gradient of the valley floor along the axis of the valley, and there is but a relatively slight decrease southward in the depth to water (pl. 1). The upward slope of the water table from the axis toward the east or west sides of the valley is much less than the slope of the land surface, resulting in an increase in depth to water outward from the axis of the valley of about 30 feet per mile.

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Depth to water.— The depth to the main water table in the Douglas basin is least along the axis of the valley, ranging from several inches below the land surface near Whitewater Draw at the international boundary, to about 100 feet in the vicinity of the buttes and ridges in the northern part of the basin. (See plate 1.) Data about depth to water near the mountains were difficult to collect—there were few wells and many of them were sealed so that the water level could not be measured. In the central and southern parts of the basin, the depth to water near the mountain fronts is generally less on the east side than on the west side. On the east side of the valley the maximum depth to water is about 225 feet, generally about 2 miles valleyward from the hardrock-alluvium contact. Between this line and the mountain front the depth to water abruptly decreases, ranging from 50 to 100 feet below land surface. The cause of this sharp break is attributed to a pediment surface that is buried under a cover of valley fill. On the west side of the basin the depth to the water table becomes progressively greater toward the mountain front, reaching a depth of as much as 280 feet. The greatest measured depth to water in the Douglas basin in 1951 was 474 feet in well (D–18–28)22cba; however, a depth to water of as much as 800 feet has been reported in well (D–21–28) 3baa, which lies in the small valley between the Swisshelm and Chiricahua Mountains.

Perched water.—In local areas, small bodies of unconfined water are held in temporary storage above and separate from the main water table by relatively impervious zones of caliche, clay, or lava. Ground water occurring in this manner is called "perched water" and its upper surface is called a "perched water table." Perched waters are not uniformly distributed throughout the valley, but occur in small isolated areas near the mountain fronts, principally along major washes immediately downstream from the hard rock-alluvium contact. Wells deriving water from perched supplies are subject to rapid water-level fluctuations and, because of the limited storage capacity, are apt to go dry during periods of drought. Some of the larger areas of perched water are along Whitewater Draw between the Swisshelm and Chiricahua Mountains, and along Leslie Creek in T. 21 S., R. 28 E.

WATER IN HARD ROCKS

Ground water in the hard-rock areas of the Douglas basin occurs principally in weathered zones where the fractures and crevices act as minute conduits or for storage of water. The storage capacity and water-yielding characteristics of the rocks depend on the degree to which the conduits have been closed by the deposition of lime or silica cement. In general, where the hard rock is water bearing and is in contact with the valley fill, the water table extends from the valley fill into the weathered hard rock without an appreciable interruption. Some of the water percolating downward through the hard rocks encounters relatively impermeable zones, and moves laterally until it reaches the mountain slope and discharges as a seep or spring. There are several springs and seeps in the mountain areas of the Douglas basin, and probably there are many areas where water discharges from the hard-rock areas into the valley fill below the land surface.

CONFINED WATER

Any ground water under sufficient pressure to cause it to rise in a tightly cased well to a level appreciably above the water table in that vicinity is termed confined or artesian water. Contrary to popular belief, artesian conditions can exist although the pressure is insufficient to raise the water to or above the land surface and cause the well to flow. In general, the following conditions are necessary for the occurrence of artesian water: A confining bed or layer of relatively lower permeability must overlie a bed or layer having a much higher permeability than the confining bed; the confining bed must extend, uninterrupted by fractures or other breaks, to the area in which water is recharged to the underlying permeable stratum; the lower surface of the confining bed must slope downward away from the recharge area; the permeable stratum must be saturated with water from its lowest point to the vicinity of the recharge area.

Water in valley fill.— Unlike basins adjacent to the Douglas basin, deep drilling in the valley fill has not disclosed the presence of a competent confining bed in a large area or areas of the basin under which water can accumulate under pressure, and thus create an extensive artesian system. Although much of the valley-fill material in the Douglas basin is of low permeability, there are numerous permeable avenues throughout the fill that prevent an accumulation of water under considerable pressure. Water under pressure has been reported in deep wells in the basin, principally from T. 20 S., southward to the international boundary; however, there is little or no correlation of pressure, so that local rather than general artesian conditions are indicated. Water was encountered under artesian pressure in sand and gravel beds between 472 and 1,012 feet below the land surface in well (D–21–25) 1dd (table 3). At the time the well was drilled, in 1935, the artesian pressure was sufficient to cause the water to rise to the land surface and overflow the top of the casing, about 60 feet above the water table in that vicinity. Well (D–24–27)15baa penetrated permeable material at a depth of 833 feet, and the water rose in the well bore to within 40 feet of the land surface, or about 20 feet above the water table. Artesian conditions were encountered also at depths ranging from about 300 to about 500 feet in a group of wells drilled prior to 1910 in the SW¼ sec. 14, T. 24 S., R. 27 E. Pressure heads in these wells ranged from slightly above the land surface to about 5 feet below the land surface. Flows were reported to range from 25 to 500 gpm.

Although artesian conditions exist in parts of the Douglas basin, it is likely that in most of the basin artesian pressure is lacking or is insufficient to raise water above the land surface.

SPRINGS

Springs occur principally in the Mule and Dragoon Mountains and in the saddle between them, and on the western slopes of the Swisshelm, Pedregosa, and Chiricahua Mountains. There were perhaps 35 permanent springs in the Douglas basin in 1951, as well as a number of wet-weather seeps and cienagas (swampy areas).

The geology of the springs in Douglas basin is not complex. Springs result from:

1. Obstruction of underflow by a rock barrier. The Leslie Creek spring, (D–21–28)21bc, and Antelope Spring, (D–20–24)21ca, are examples.

2. Incisement of stream channels below the water table. Springs can form where a stream channel has cut below the water table, a perched water table, or an aquifer confined between permeable beds. Springs of this general classification are Sycamore Spring, (D–19–29)14ad, spring (D–18–24)28cd, and spring (D–19–29)10dd.

3. Faults. In places the rock materials in a faulted zone are sufficiently fractured to act as an avenue for the escape of ground water under artesian pressure. Two examples of fault springs are, respectively, spring (D–20–28)13bd and spring (D–22–24)29bc.

The spring waters are of normal temperature (66° to 81°F) rather than thermal or hot. Yields range from less than 1 to 60 gpm.

ORIGIN

The origin of ground water in the Douglas basin is precipitation in the mountain areas and on the valley floor.

Annual precipitation is about 15 inches in most of the Dragoon, Perilla, and Pedregosa Mountains; about 19 inches in the Mule and Swisshelm Mountains; and a maximum of more than 26 inches in the higher parts of the Chiricahua Mountains. Most of the water is absorbed by the soil in the mountains and is either lost to the atmosphere by evaporation or is transpired by vegetation. The remainder of the water is channelized into small gullies and rills, then into progressively larger streams, and finally passes out of hard-rock areas of the mountains. At the mountain front there is a sharp reduction in the gradient of the channels, and the runoff quickly loses velocity. In some places the streamflow progresses several miles out into the valley, but in other localities much of the flow is lost in alluvial fans and is spread or dissipated in distributary channels. Thus, much of the recharge to the ground-water reservoir of the valley fill occurs near the mountains, where water percolates rapidly through permeable materials and reaches a sufficient depth below the zone of capillarity and root growth to eliminate losses by evaporation and transpiration.

Most of the recharge into the ground-water reservoir occurs in washes in a narrow zone along the mountain fronts. Seepage from streams into the coarse materials underlying the washes unites with water infiltrated from precipitation upon the alluvial fans and ultimately reaches the water table. Studies show that of the total amount of precipitation falling within the drainage area of the hard rocks, only a small percentage leaves the mountains as runoff. The factors that bear on this percentage are complex, as shown in studies such as those of Peterson (1945), Schwalen (1942), and Sonderegger (1929). Important physical features of the drainage areas include: (1) Altitude, (2) surface gradients, (3) size of area, (4) character of soil and subsoil, (5) seasonal changes in infiltration capacity of the soil, (6) quantity and type of vegetation, and (7) type and structure of bedrock. Meteorological and other conditions that affect the quantity of runoff are: (1) Amount, intensity, and distribution of precipitation, (2) temperature, and (3) evapotranspiration. Runoff in the drainage basins of Parker and Workman Creeks in central Arizona (Rich, 1951, p. 11), and in the drainage basin of Salt River above Roosevelt Dam (Cooperrider and Sykes, 1938, p. 45), was 13 and 14.5 percent, respectively, of the precipitation.

Runoff figures are available for the Rucker Canyon drainage area (U. S. Geol. Survey, 1948, p. 475–476). This area is in the

Chiricahua Mountains, where the altitude ranges from about 5,400 feet at the gaging station to about 9,800 feet on the crest. The mean annual rainfall is about 22 inches in this area (Smith, 1945, p. 90). Rucker Canyon has a drainage area of 40 square miles. Using these data, about 47,000 acre-feet of precipitation occurs annually, of which about 4,500 acre-feet, or about 10 percent, leaves the area as runoff. On the basis of these data, runoff percentages of 10 to 15 percent were chosen for the different mountain areas for computations in this report.

Most rain that falls on the valley fill is used by vegetation or is held in the soil until it is evaporated. Rainfall-penetration studies in desert plains by Shreve (1934, p. 150–51), Lee (see Sonderegger, 1929, p. 1310), and Turner[2] indicate that practically none of the rainfall on the valley floor reaches the water table. Factors that prevent recharge from direct precipitation in Douglas basin are rapid evaporation, vegetative use, and strata and lenses of impermeable clay and caliche near the land surface. Of the precipitation that falls upon the valley floor, only that part passing over the coarse-grained materials along the washes is believed to be a source of recharge to the ground-water reservoir.[3]

Part of the water applied to the land for irrigation is returned to the ground-water reservoir by seepage. Although this seepage constitutes only recirculation of part of the ground water, it must be considered in evaluating the available ground-water supply. In some basins in southern Arizona, estimates of recharge from irrigation water run as high as 25 percent of the total amount of water applied to crops.[4] Some of the tests upon which these estimates are based, however, were conducted in areas having conditions considerably more favorable for recharge than those in Douglas basin. It is believed that the same conditions that limit recharge from direct precipitation also limit recharge from irrigation in the Douglas basin.

The only avenue of known movement of ground water into the basin occurs in the vicinity of Turkey Creek, at the surface-water divide that separates the Douglas and Willcox basins (pl. 2). In a strip about a mile or so wide infiltration of surface water into the alluvium of Turkey Creek eventually moves as ground water into Douglas basin. The hard-rock barriers that separate the Douglas basin from other basins on the east and on the west effectively prevent movement of ground water between basins.

[2] Turner, S. F., and others, 1943, Ground-water resources of the Santa Cruz basin, Arizona: U. S. Geol. Survey Open-File Report, p. 35.

[3] Turner, 1943, op. cit., p. 45, 54.

[4] Turner, S. F., and others, 1946, Ground-water resources and problems of Safford basin, Arizona: U. S. Geol. Survey Open-File Report, p. 7.

MOVEMENT

The general movement of ground water in the Douglas basin is shown by the water-table contour map (pl. 2). The direction of movement is downslope and at right angles to the contours. The contours indicate that recharge occurs at the mountain fronts and that ground water moves toward the central part of the valley at a slight angle to the south. On reaching the axis of the valley the ground water moves southward, toward Mexico.

The rate of ground-water movement depends upon the gradient of the water table and upon the type of sediments the water moves through. In general the gradient of the water table is greatest near the mountains and becomes progressively less toward the valley (fig. 4). The close spacing of water-table contours may be indicative of abundant recharge, presence of extremely fine-grained materials, or thin, though permeable aquifers with low rates of transmissibility (ability to transmit water). Studies of the rate of ground-water movement (Slichter, 1905a, b; Smith, 1910, p. 126–154) indicate that the rate of flow is extremely variable and may range from a few inches to several feet per day. On the basis of these and other studies, the rate of ground-water movement in Douglas basin probably does not exceed a few feet per day and, in the central part of the valley where silt and clay materials comprise up to about 80 percent of the valley fill in many areas, the rate of movement is likely to be much slower.

The average slope of the water table is about 9 feet per mile in the central portion of the valley. Steeper gradients are present in the northern part of the basin and near the mountain areas (pl. 2). The direction of the water-table contours between Turkey Creek Ridge and Ash Creek Ridge indicates that ground water is reaching the main part of Douglas basin from recharge along Turkey Creek. The water-table contour map (pl. 2) also indicates that the northern limit of the ground-water reservoir cuts diagonally across the surface-water divide. Therefore, in this area some ground-water movement occurs both into and out of the Douglas basin. The closely spaced contours in the vicinity of the buttes and ridges are believed to be a reflection of local areas of low transmissibility, and the total amount of ground water moving between these bedrock areas is believed to be small.

The correlation of water-level data from the wells in the vicinity of the city of Douglas is difficult because many of the deeper wells exhibit artesian pressure, and the distinction between those wells and wells that reflect water-table conditions is not always clear cut. At the time of the Meinzer and Kelton report (1913) water-table contours in this area were uniform and conformable with those in the upper parts of the valley. However, by 1952 the water-table contours (pl. 2) in this vicinity were closely spaced, indicating a steepening of the water-table gradient, particularly on the west side of Whitewater Draw. This change in gradient is attributed primarily to the heavy municipal and industrial pumpage in this small area.

RECHARGE

The sources of recharge to the ground-water reservoir of Douglas basin have been described in the section entitled "Origin." The following paragraphs provide quantitative estimates that were made to evaluate the approximate amount of annual recharge from precipitation in mountain areas, precipitation on valley floor, and seepage from irrigation. Underground leakage is not considered as a separate topic, but is included in the section on "Precipitation in mountain areas."

PRECIPITATION IN MOUNTAIN AREAS

An estimate of the average annual quantity of recharge from precipitation in the mountain areas was made on the basis of partial data on precipitation in the mountains, an estimate of the portion that reaches the mountain fronts as runoff, and an estimate of the proportion of runoff that infiltrates to the ground-water reservoir.

The total average precipitation was computed as about 375,000 acre-feet per year on a hard-rock area of 360 square miles. To approximate the runoff, estimates of 10 to 15 percent were applied to the individual mountain ranges according to the factors listed on page 25. The sum of the estimates indicated that about 40,000 acre-feet of runoff enters the valley from the mountain areas in an average year. This includes recharge occurring between the surface-water divide and the ground-water divide in the northern part of the basin.

Only part of the runoff infiltrates into the coarse-grained sediments at the mountain front and percolates to the ground-water zone. Studies by Smith (1910, p. 118–119), U. S. Bureau of Agricultural Economics (1940, p. 42) and Babcock and Cushing (1942, p. 56) indicate that only about half the total runoff recharges the ground-water zone. The recharge from this source in Douglas basin was estimated as about 50 percent of the total runoff from the mountain areas, or about 20,000 acre-feet per year.

PRECIPITATION ON VALLEY FLOOR

It is estimated that about 2,000 acre-feet of water may reach the ground-water zone annually from precipitation on the valley floor. Nearly all the recharge from this source occurs along washes.

SEEPAGE FROM IRRIGATION

Tests in the Douglas basin by the Soil Conservation Service, U. S. Department of Agriculture (personal communication, 1951), indicated a complete lack of moisture penetration below a depth of 5 feet, even after heavy irrigation. Therefore, the quantity of water recharged to the ground-water reservoir from irrigation is believed to be negligible. The low recharge is a result of the tightness of the soil and the general fine-grained character of the alluvium, as indicated by the tests of the Soil Conservation Service.

DISCHARGE

Ground water is discharged from the valley fill of Douglas basin by evapotranspiration, flow out of the basin, and pumping from wells.

EVAPOTRANSPIRATION

The amount of evaporation of ground water in Douglas basin is believed to be negligible. The only area where the water table is near enough to the surface to permit evaporation is a narrow fringe on either side of the lower 2 miles of Whitewater Draw.

In western United States many plants grow where the depth to ground water is shallow. By sending roots below the water table the plants obtain a perennial supply of water. Plants that depend upon ground water for growth are termed "phreatophytes" (Meinzer, 1923, p. 55). The amount of ground water that may be utilized by vegetation is conditioned by the species of plant, the depth to which it can extend its roots, the density of plant growth, the length of the growing season, the depth to the water table, and the availability of surface water and soil moisture. The plants considered as potential phreatophytes in the basin are mesquite, salt bush, and some grasses. Of these plants mesquite is probably the only one capable of sending roots from 30 to more than 50 feet below the land surface. In order to determine the amount of ground water available for such vegetation, the mesquite areas were mapped and separated into areas where the water table was less than 30 feet below the land surface and areas where depth to water ranged from 30 to 50 feet. The characteristics of the individual trees and groves were noted, such as areal density and height, and frondage density.

In general, the mesquite in Douglas basin averages 4 to 5 feet in height, and less than 15 feet in diameter of crown area. In the zone where the depth to water is less than 30 feet below the land surface mesquite occupy an area of about 7 square miles and have an average areal density of about 40 percent. Where the water table is 30 to 50 feet below land surface the mesquite occupy an area of about 47 square miles and average about 30 percent areal density. Mesquite of 100-percent volume density in Safford Valley, where depth to water was about 10 feet, used a total of more than 3 acre-feet of water per acre in 1943–44 (Gatewood and others, 1950, p. 203). Owing to the greater depth to water in Douglas basin the use of ground water by mesquite of 100-percent density is assumed to be 1 acre-foot or less per acre per year. Another indication that ground-water use by mesquite in the Douglas basin is small is the noticeable uniformity in the size of mesquite under varying ground-water conditions. There is no apparent change or diminution in mesquite growth in areas where the depth to water exceeds 50 feet. It is probable, therefore, that much of the water used by mesquite in Douglas basin is derived from rainfall and from surface runoff. Total ground-water use by phreatophytes in Douglas basin was estimated to be between 8,000 and 13,000 acre-feet in 1951.

FLOW OUT OF BASIN

Discharge records for Whitewater Draw at the gaging station on U. S. Highway 80, west of the city of Douglas, are available for the years 1912–19, 1930–33, 1935–46, and 1948–51. The mean surface flow for all years of record is 8,740 acre-feet per year. The mean surface flow for the period 1947–51, is 6,100 acre-feet per year. Of this total flow, a study of the records indicates that less than 300 acre-feet per year constitutes seepage of ground water into the stream and remainder is flood-water runoff.

The main avenue of ground-water leakage from Douglas basin is southward into Mexico. It is believed that ground-water loss to adjacent basins is negligible because of the extensive hard-rock barriers. The determination of the quantity of ground water moving into Mexico annually can only be approximated from the data available. This computation is made difficult by complicating factors that include the heterogeneous character of the valley fill, the existence of buried lava flows near the border, and relatively heavy pumping by city of Douglas and Phelps Dodge Corp. wells in a small area. As a result, several unusual conditions exist locally: (1) the water level in shallow wells is shallower than in adjacent wells; (2) Whitewater Draw changes from an intermittent to a perennial stream at a point about 2 miles north of the international boundary; (3) the water surface in the draw corresponds in elevation to that in adjacent shallow wells, but is at a higher elevation than in nearby deep wells; and (4) the apparent direction of ground-water movement in the area west of Whitewater Draw and near the boundary is partially reversed with respect to the general pattern of ground-water movement in the basin.

The equation for underflow out of the basin is as follows: Underflow (in gallons per day) = transmissibility (in gallons per day per foot) x gradient (in feet per mile) x width of ground-water movement (in miles). Near the international boundary the following conditions are assumed: Coefficient of transmissibility of 40,000 gpd per foot; a gradient of 20 feet per mile; and a width of ground-water movement of $1\frac{1}{2}$ miles. Thus, the underflow leaving Douglas basin would be about 3 to 4 acre-feet per day, or about 1,400 acre-feet per year.

PUMPING FROM WELLS

Most of the ground water discharged from the Douglas basin is by pumping from irrigation wells. Locally, relatively large amounts of ground water are also pumped from the wells of the city of Douglas and the Phelps Dodge Corp. smelter. Minor ground-water withdrawals are made for stock and domestic use throughout the valley.

Ground water has been pumped in the basin for irrigation since 1910, but prior to 1939 pumpage for irrigation probably did not exceed 5,000 acre-feet annually. After 1945 pumpage for irrigation began to increase sharply. During the 5 years 1947–51, inclusive, ground-water pumpage in the basin more than doubled, as shown in the following table.[5] In 1951, a total of 14,300 acres was irrigated

Year	*Ground Water (acre-feet)*	*Year*	*Ground Water (acre-feet)*
1947	17,000	1950	35,000
1948	22,000	1951	38,000
1949	30,000		

[5]Halpenny, L. C., and Cushman, R. L., 1952, Pumpage and ground-water levels in Arizona in 1951: U. S. Geol. Survey Open-File Report, p. 3.

with about 38,000 acre-feet of ground water from about 270 wells (pl. 4). Irrigation wells in the basin range in diameter from 6 to 20 inches and in depth from 50 to more than 600 feet. The average diameter is 12 inches and the average depth is 160 feet. The average discharge of irrigation wells in the Douglas basin, based on 95 well-discharge measurements made throughout the valley, was about 380 gpm in 1951. Some wells yield as little as 80 gpm, and the maximum measured discharge was 1,500 gpm. The irrigation wells yield from 3 to 100 gpm per foot of drawdown, the average specific capacity in 65 representative wells being 12 gpm per foot of drawdown. Pumping lifts range from 50 feet near Whitewater Draw to more than 165 feet in wells 6 miles west of Douglas and in other wells east of McNeal. The nonpumping depth to water in irrigation wells ranges from 26 to 115 feet and averages 55 feet. Most of the pumps are powered with electricity but a few are powered by various petroleum-type units.

Figures supplied by the City of Douglas Water Department and by Phelps Dodge Corp. officials show a total withdrawal of 3,000 acre-feet in 1951 from the city and smelter wells. During the period 1947–51, the water requirements for the smelter remained nearly constant but pumpage for municipal use increased slightly.

Total ground water pumped from domestic and stock wells is about 500 acre-feet per year, calculated from an estimated average discharge of 2 gpm from about 300 wells that operate about half the time.

The total quantity of ground water withdrawn from wells in Douglas basin in 1951 was, therefore, about 41,000 acre-feet.

SPRINGS

The discharge of springs in the basin ranges from a negligible amount to as much as 60 gpm. The flow of the average spring is from 1 to 2 gpm. It is estimated that the total amount of water discharged by springs is less than 200 acre-feet per year. However, most of the water discharged flows only a few feet before percolating below the land surface, so that evaporation and transpiration losses are small.

Oldtime residents of the Douglas basin agreed that springs are now fewer in number and yield less water than in former years. Many of the springs shown on the topographic maps were dry in 1951. In some localities, windmills are used to withdraw water by pumping where springs had formerly existed. Examples are: Gadwell Spring, SE¼ sec. 31, T. 21 S., R. 24 E.; Mud Spring, NE¼ sec. 16, T. 22 S., R. 28 E.; and Outlaw Spring, center sec. 24, T. 20 S., R. 24 E. T. M. Watson (personal communication, 1952) reported that, in the early 1900's, Mud Spring discharged sufficient water to take care of all the cattle in a radius of many miles. It is now dry. It is generally concluded that the drought starting in 1941 is an important factor in the decline of spring discharge (Searles, 1951, p. 19–28).

SUMMATION OF RECHARGE AND DISCHARGE

In recent years there has been a general increase in irrigated acreage in the Douglas basin, and a corollary increase in the amount of ground water pumped. This pumping removes water from underground storage, a portion of which is replenished by annual recharge from precipitation and runoff. The fact that in recent years the amount of discharge has exceeded the amount of recharge is shown by the decline of water levels in wells. Any attempt to arrive at an estimate of the amount of ground water withdrawn from storage is limited by the availability of certain basic quantitative data. Although all the component items of recharge and discharge discussed in the text are estimates or approximations, they are believed to be of the proper order of magnitude.

On their basis, the amount of annual recharge from all sources in the Douglas basin is estimated to be about 20,000 acre-feet per year. The total amount of discharge, occurring by evapotranspiration, effluent seepage, underground flow out of the basin, and pumping, is believed to have been about 30,000 acre-feet in 1947 and about 50,000 acre-feet in 1951. During the past few years the increase in pumping has resulted in a greater annual discharge, whereas the amount of recharge has remained relatively constant. The difference between the amount of discharge and the amount of recharge represents approximately the amount of ground water removed from storage.

FLUCTUATIONS OF THE WATER TABLE

Under natural conditions a balance exists between water that is recharged to a ground-water basin and water that is discharged from the basin. Abnormal climatic conditions may cause an adjustment of the level of the water table to meet a changed situation, but the trend in years under natural conditions is for the establishment of equilibrium between ground-water gains and losses. When the natural state is radically disturbed by manmade conditions, however, the water table may fluctuate widely in local areas in response to the changes. When the total discharge is more than the recharge, depletion of storage in the ground-water reservoir occurs and the water table declines. Persistent pumping of water from storage is termed "ground-water mining." This practice has been followed in the Douglas basin at least since 1945. In 1951 the total ground-water use was more than double the estimated rate of recharge.

For the period 1947–51, the average decline of the water table was 6 feet in the heavily irrigated areas (pl. 3). Throughout the basin the decline ranged from about a foot near the mountains to a maximum of more than 11 feet northeast of Elfrida. Noticeable declines in the water table are also present in the area south and east of McNeal. The maximum decline of the water table since 1910 (Meinzer and Kelton, 1913, pl. 2) is 38 feet, east of Douglas. Declines in specific wells in the past decade are shown on the hydrographs (fig. 5).

From the water-table decline map (pl. 3) it was calculated that a total of 1,120,000 acre-feet of sediments had been dewatered in the period 1947–51. The coefficient of drainage of sediments in the Douglas basin may be about 8 percent, on the basis of data from other parts of Arizona[6] and from Piper (1939, p. 121). Accordingly, a coefficient of 8 percent was assumed for the area unwatered, although the average for the entire body of valley fill is likely to be much less. The total amount of ground water withdrawn from storage in the last 5 years was computed to be about 90,000 acre-feet, or an average of 18,000 acre-feet per year. This computed quantity is in the order of magnitude of the annual overdraft as indicated by the ground-water inventory.

With increased pumpage in recent years, more water has been withdrawn from storage each year. According to the tabulation summarizing recharge and discharge, the average annual overdraft—excess of discharge over recharge—during the period 1947–51 was more than 20,000 acre-feet, and was about 28,000 acre-feet in 1951. Less water has been available for use by phreatophytes each year, because of the declining water table. Another result of a declining water table is that less water will leave the basin as effluent seepage into Whitewater Draw and, eventually, as underflow.

The decline of the water table in the Douglas basin is believed to be due almost entirely to pumping from wells. Although rainfall since 1941 has generally been below normal, the drought is believed not to have been sufficiently intense to cause a large reduction in recharge. Some of the recharge that was received during

[6] Halpenny and others, 1952, op. cit., table 3.

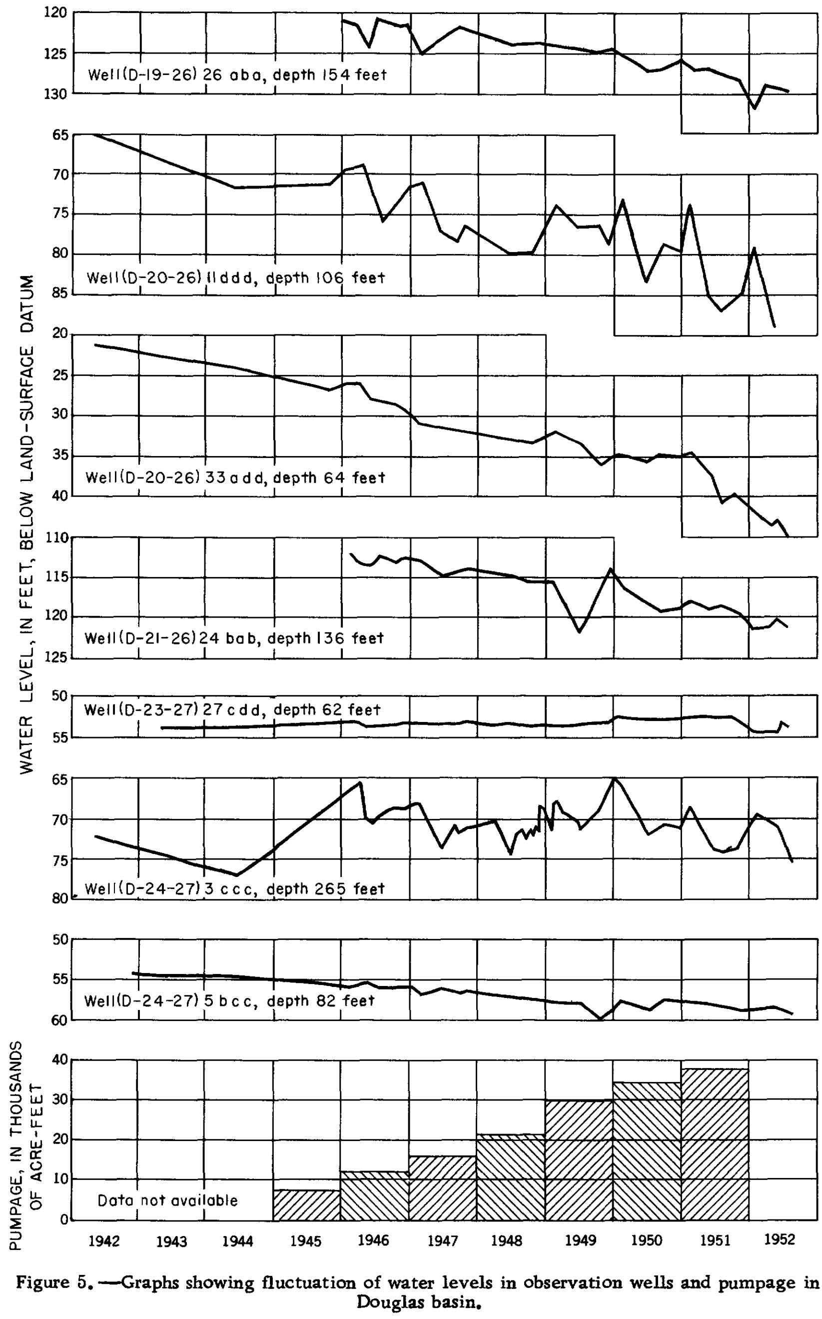

Figure 5.—Graphs showing fluctuation of water levels in observation wells and pumpage in Douglas basin.

the past 10 years probably has not yet reached the areas of heavy pumpage because of the slow rate of ground-water movement, so that the downward trend of water levels is mostly a result of localized conditions. Water levels in wells at some distance from the heavily pumped areas have remained nearly static for the past few years.

Well interference.—During the pumping of a well, ground water is withdrawn from the area immediately around the well. As pumping continues, more ground water is withdrawn from storage in the vicinity of the well, until the gradient of the water table from all directions is sufficiently steep to supply the pump without further local drawdown. The unwatered zone surrounding a pumping well is called a "cone of depression." The water-level decline is greatest near the well and gradually tapers off in all directions. The cone expands as more ground water is withdrawn from the pumped area. When a cone of depression merges with another cone from a nearby pumping well, interference occurs and a ground-water divide is created. The size of the cones of depression and the amount of well interference is dependent upon several factors, including the rate and quantity of water withdrawn and the permeability of the water-bearing sediments (Theis, 1938, p. 889–902).

The effects of well interference and the spread of cones of depression in the Douglas basin are well demonstrated by water-level data. Fluctuations of water level in wells that are not pumped reflect the extent of well interference resulting from seasonal withdrawal of ground water for irrigation. Well (D–20–26) 11ddd, with fluctuations of 12 feet (fig. 5), illustrates seasonal changes in water levels caused by pumping in nearby wells. Abandoned wells in the center of some heavily irrigated areas also show seasonal and yearly changes in water levels. There is a lack of rapid spread of cones of depression, during short-time pumping of some wells and this may be partly attributable to the clay which predominates in much of the valley fill. In February 1952, a pumping test was made on well (D–23–26)1ada which has a static water level of 65 feet. During a 32-hour period the well was continuously pumped at an average rate of 145 gpm, and a drawdown of 44 feet resulted in the pumped well. The water level in an abandoned well 700 feet north, however, did not change noticeably during the test.

QUALITY OF WATER

By J. L. Hatchett

CHEMICAL CHARACTER OF THE GROUND WATER

WELLS

Analytical data for water from 112 wells were used in preparing this section on the quality of water in the Douglas basin. Most of the sampled wells are in the valley fill of the central part of the valley (pl. 5). Table 4 lists 32 analyses of water from selected wells.

Water from 98 of the wells sampled contains 100 to 500 ppm of dissolved solids. The dissolved solids consist mostly of calcium, sodium, and bicarbonate. Water from the remaining 14 well samples had a dissolved-solids content of more than 500 ppm. The water from the wells along Whitewater Draw in this group contained mainly sodium, chloride, and sulfate, whereas the water from wells east of Douglas contained mainly calcium and sulfate. A deep well drilled as an oil test on the east side of the Douglas basin (D–22–27)5b is reported to yield water from limestone of Mississippian age. The dissolved solids in this water consist mostly of sodium, bicarbonate, and sulfate. As water from limestone ordinarily contains much more calcium than is present in this water, it is possible that the water in the well may have been more closely related to other aquifers.

SPRINGS

Water samples from 15 springs in the Douglas basin were analyzed. These waters contained from 100 to 500 ppm of dissolved solids, mostly calcium and bicarbonate. The formations from which the springs issue include sandstone, shale, limestone, volcanic rocks, and granite. Table 4 lists the analyses of water from six of these springs.

The streamflow in Whitewater Draw near the international boundary was sampled in sec. 28, T. 23 S., R. 27 E., and in sec. 10, T. 24 S., R. 27 E. (table 4; pl. 5). At the times of sampling, the flow was entirely effluent ground-water seepage. Both of the water samples contained over 500 ppm of dissolved solids. The water sample from sec. 28 contained mostly sodium and sulfate. The water sample from sec. 10 contained considerably more sodium and chloride than other dissolved constituents.

DISSOLVED-SOLIDS CONTENT OF THE GROUND WATER

The dissolved-solids content of the ground water in the Douglas basin is shown graphically on plate 5. This map was prepared by drawing a circle at the location of each well and spring for which a chemical analysis was available. The dissolved-solids content of the water is indicated by the amount of shading in the circle. If only the specific conductance of the water was determined for a particular well or spring, the approximate dissolved-solids content was calculated by multiplying the specific conductance (micromhos at 25°C) by 0.6.

SOURCE OF DISSOLVED SOLIDS

The source of most of the dissolved solids contained in the ground water of the basin is the minerals of the rock material that comprise the valley fill. The longer the ground water is in contact with these minerals the greater is the opportunity to dissolve them. If time were the only factor, the dissolved-solids content would be expected to increase uniformly with depth and distance from the recharge areas. However, such uniform changes are rare because the rocks of the valley fill are erosional products of many formations and are not homogeneous. Therefore, the composition and solubility of the minerals that are available for solution are also factors that affect the amounts of dissolved solids in the ground water.

Flow from mountain springs and runoff are lesser sources of dissolved solids in ground water of the valley fill. Evapotranspiration returns almost pure water to the atmosphere and thereby concentrates the dissolved solids in the remaining water or in the soil. The process does not increase or reduce the total quantity of soluble material in the basin.

The locally high dissolved-solids content of the ground water in the valley fill possibly is related to the presence of beds of evaporites. These beds were formed by evaporation of impounded water in basins that existed temporarily during the deposition of the valley fill, examples of which are the gypsum beds described on page 18. It is conceivable that in some areas highly mineralized water entered the basin during the periods of volcanic activity. These waters or deposits resulting from them would affect the quality of ground waters in the basin.

DISCHARGE OF DISSOLVED SOLIDS

It has been stated previously in this report that ground water leaves the Douglas basin by movement southward into Mexico. Although the quantity of ground water thus discharged is known to be relatively small, data available are insufficient to determine the amount of dissolved solids thus discharged.

COMPARISON OF RECENT ANALYSES WITH THOSE OF EARLIER YEARS

Few of the wells listed by Meinzer and Kelton (1913, p. 157–159) were sampled during the current investigation, as most of the old wells had been destroyed or could not be located. Comparison of data for the two periods is possible, however, at two places along the former El Paso & Southwestern Railroad. At Kelton junction the railroad well was sampled in 1910 and again, as well (D–19–25) 25ac, in 1946. At McNeal station the well that was sampled in 1910 was about one mile from well (D–21–26)24bab, which was sampled in 1946. The analyses, as shown in the following tabulation, indicate practically no difference in the constituents that were determined in the water samples in 1910 and in 1946.

Well	Date of collection	Parts per million		
		Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)
Kelton Junction	10-29-10	180	12	7
(D-19-25)25ac	5- 1-46	182	------	7
McNeal Station	11-17-10	221	7	10
(D-21-26)24bab	3-27-46	222	12	9

Well (D–23–27)19dad was sampled in 1946, 1951, and 1952. The analyses show a considerable increase in dissolved-solids content of the water during these years. The well is close to a heavily pumped irrigation well. The heavy pumping may have caused movement of ground water toward the pumped well from a local area of highly mineralized water.

RELATION OF QUALITY OF WATER TO USE

IRRIGATION

Water being used for irrigation in most of the Douglas basin is "excellent to good" in quality as evaluated according to standards suggested by the U. S. Department of Agriculture (Wilcox, 1948, p. 26). Some of the water used for irrigation in the area along

Whitewater Draw, from T. 22 S. to the international boundary is in the "good to permissible" division. Two wells in this area yield water that is classified as "permissible to doubtful," and one well yields water classified as "doubtful to unsuitable."

Water having a boron content as much as 1 ppm is classified by Wilcox (1948, p. 27–28) as "permissible" to use in irrigating boron-sensitive crops, which include most fruit trees. This classification considers only the boron content but not other dissolved solids in the water. Only a few samples were analyzed for boron, all of which had less than 1 ppm boron.

DOMESTIC

Analyses made by the Geological Survey do not indicate the sanitary condition of the water analyzed. On the basis of the dissolved mineral content the water used in the basin for domestic purposes is generally of good quality. The ground water in the valley fill apparently increases in dissolved solids concentration as it moves southward toward the international boundary. Most of the water used for domestic purposes in the basin has less than 1,000 ppm of dissolved solids. This is the maximum amount considered acceptable for use as a municipal water supply and for drinking water to be used on interstate carriers (U. S. Public Health Service, 1946, p. 13). Water from a few wells along Whitewater Draw, about 6 miles north of Douglas, has more than 1,000 ppm of dissolved solids. Waters containing somewhat more than the suggested limits of dissolved mineral constituents have been used by many persons for long periods without apparent ill effects, although such waters might have a noticeable taste to one unaccustomed to them.

In most of the Douglas basin the ground water is fairly hard. The available analyses show that water from wells in most of the basin has a hardness of 100 ppm or more. The city of Douglas is supplied with water that is rather high in dissolved solids, but the water is unusually soft for the area, as it has less than 30 ppm of hardness as calcium carbonate. It would be expected that the water pumped from the city wells, which are west of Douglas near the international boundary, would be at least as hard as the water to the north. It is possible that the water has been softened by contact with cation-exchange minerals in the valleyfill as it moves southward. Use of hard water for household purposes results in excessive consumption of soap. Detergents make it easier to wash dishes and clothes in hard water, or the water can be softened before use by various types of softeners. If hard water is used in hot-water tanks and boilers, objectionable scale is formed.

According to the U. S. Public Health Service standards (1946, p. 12) a satisfactory drinking water should not contain more than 1.5 ppm of fluoride. Medical authorities agree that waters containing excessive amounts of fluoride can cause mottling of the tooth enamel of children who drink the water during the time their permanent teeth are forming. However, recent studies have shown that a small amount (about 1 ppm) of fluoride in drinking water may cause teeth to become more resistant to decay. Ground water containing more than 1.5 ppm of fluoride is common in Douglas basin, as indicated by the available analyses. Therefore, it would be desirable to detêrmine the fluoride content of drinking water to be used by families with young children.

Most of the nitrate present in ground waters of the Douglas basin probably is derived from sources other than contamination by human and animal wastes, although the presence of nitrate is sometimes an indication of such contamination. Waters containing more than about 45 ppm of nitrate are considered by some authorities (Maxcy, 1950) to be inadvisable for use in feeding infants, as the presence of a high nitrate concentration for such use has been associated with cases of methemoglobinemia, a "blue-baby disease." Only one of the samples analyzed (table 4) indicated a nitrate concentration in excess of 45 ppm.

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Table 1.—*Climatological data, Douglas basin*

[Data from Smith, 1945, p. 34, 36, 51, 53, 87, 88]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Douglas—altitude 3,973 feet													
Precipitation .... in.	0.62	0.77	0.45	0.26	0.22	0.54	3.19	2.86	1.31	0.77	0.81	0.94	12.74
Mean maximum temperature[1] .... °F	61.4	65.8	71.9	79.0	86.7	95.8	93.8	91.4	89.0	81.3	69.7	61.4	78.9
Mean minimum temperature[1] .... °F	29.2	33.0	37.3	42.7	49.6	59.2	65.8	64.4	59.2	46.8	35.7	30.2	46.1
Mean temperature[1] .... °F	45.3	49.4	54.6	60.8	68.2	77.5	79.8	77.9	74.1	64.0	52.7	45.8	62.5
Extreme maximum temperature .... °F	82	89	94	97	106	110	111	107	101	95	92	81	111
Extreme minimum temperature .... °F	-7	12	17	26	30	42	41	50	37	23	14	6	-7
Bisbee—altitude 5,350 feet													
Precipitation .... in.	1.15	1.37	0.95	0.45	0.25	0.61	4.17	4.63	2.10	1.08	1.01	1.38	19.15
Mean maximum temperature[2] .... °F	57.8	60.9	66.4	73.6	81.2	90.2	88.6	86.1	83.3	76.1	65.6	57.8	74.0
Mean minimum temperature[2] .... °F	34.6	36.7	40.7	46.0	53.7	62.2	64.1	62.4	58.9	50.1	40.9	35.4	48.8
Mean temperature[2] .... °F	46.0	48.5	53.3	59.8	67.2	76.1	76.3	74.1	71.3	63.0	53.1	46.5	61.3
Extreme maximum temperature .... °F	85	85	88	95	101	106	104	101	100	98	90	78	106
Extreme minimum temperature .... °F	8	11	23	28	32	38	53	47	41	28	16	13	8

[1] Means are for 50 years of record ending Dec. 31, 1940.
[2] Means are for 44 years of record ending Dec. 31, 1940.

Table 2.—*Records of representative wells and springs in Douglas basin*

Type of lift: C, cylinder; T, turbine; W, windmill; E, electric; G, gas; Dl, diesel.
Use of water: I, irrigation; D, domestic; S, stock; Ind, industrial; M, municipal; N, not used.
Remarks: H, see hydrograph, fig. 4; O, observation well; Ca, see chemical analysis, table 4; L, see log, table 3; Dm, discharge measured in gallons per minute; De, discharge estimated; Dr, discharge reported; Tt, transmissibility test in gallons per day per foot.

WELLS

Well no.	Owner	Depth of well (feet)	Diameter of well (inches)	Water level		Altitude of land surface at well (feet)	Type of lift	Use of water	Remarks
				Depth to water below land surface datum (feet)	Date measured				
(D-18-26)									
11bab	Mrs. Pressey	100	6	81.94	8-24-51	4,318	C, W	S	Ca.
15bcb	D. M. Ingle	110	6	89.30	6-28-51	4,292	C, W	D, S	Ca.
18bbb	—Stark	100	6	74.65	5-28-46	------	C, W	S	Ca.
21ddd	Frank Jeans	89	6	73.85	1-13-52	4,268	C, W	S	
22cba	------	------	6	474.00	9- 9-51	4,898	C, W	S	
(D-19-25)									
25acc	Lewis C. Grizzle	650	12	------	------	------	T, G	I, D	Ca, Dm585.
(D-19-26)									
1aaa	Frank Geer	------	6	124.03	8-14-51	4,324	C, W	D, S	Ca.
26aba	—	154	6	131.55	1-16-52	4,280	C, W	S	H.
29bab-2	George Berry	60	16	43.36	1-13-52	4,196	T, E	I	O.
30aab	John Morris	------	------	[1]90	------	------	T, E	I	Ca, Dm250.
(D-20-26)									
6abb-1	J. M. Peevey	72	12	49.60	1-17-52	------	T, E	I	Ca, Dm670.
11ddd	W. P. Cheek	106	10	49.10	1-14-52	4,298	C, W	D, S	H.
12bba	W. H. Seaver	150	10	94.62	12-31-51	4,232	T, E	D, S	Ca, O.
16daa	D. C. Sherman	133	16	48.28	1-18-52	4,150	T, E	I	L, Dm520.
33add-1	F. O. Mackey	64	16	38.78	1-14-52	4,124	T, E	I	H.
(D-20-27)									
18daa-2	L. I. Kennedy	600	14	81.90	1-29-52	------	T, E	I	L, Dm280.
(D-21-25)									
1ddb	Ralph Cowan	1,012	12	3.77	3- 7-52	4,121	C, W	S	L, artesian.
23aab	Clarence Davis	------	6	88.35	1-14-52	------	C, W	D, S	Ca.
25aaa	Webb Schoolhouse	------	8	67.75	1- 1-52	4,117	C, W	D	

(D-21-26)									
1bdc	Ames and Brockman	200	12				T, E	I	Ca, Dm260.
17ccc	Mrs. Yard	118	14	27.17	12-19-51	4,079	T, G	I	Dm550.
21dda	J. W. Franklin	154	12	60.90	12-27-51	4,101	T, E	I	Dm90.
23ab	L. C. Pinkard	505	20	95.94	1-25-52	4,161	T, E	I	L, De600.
24aab	McNeal Cemetery	136	8	121.43	1-14-52	4,196	C, W	I	Ca, H.
26dcd	J. K. Shearman	364	16	112.75	12-27-51	4,159	T, E	I, D	L, Dm330.
28ddc	Howard E. Ames	250	12	57.85	12-27-51	4,089	T, E	I	L, Dm280.
29dda	S. Pinedo	111	12				T, E	I	Ca, Dm390.
(D-21-27)									
13cdd	Jesse Eades	122	12	62.25	12-18-51	4,487		N	Ca.
28ccc	Ralph Cowan	300	6	222.79	12-20-51	4,293	C, W	S	L.
(D-21-28)									
3baa	S. S. Shattuck	1,517		[1]800					L.
(D-22-25)									
24da	—			[1]70			C, W	S	Ca.
(D-22-26)									
4daa	—Holman	250	12	67.68	12-10-51	4,094	T, G	I	L, Dm170.
5dda	E. M. Downs	100	12	42.39	1-14-52		T, E	I	Dm130.
28baa	J. E. Brophy	500	12	26.40	2- 5-46		T, E	I	Ca, De200.
27bca	W. W. Harsha	210	14				T, E	I	Ca.
34ada	Homer McBride	145	12	61.79	2- 2-52		T, E	I	Dm340, Tt9,000
(D-22-27)									
5b	Waddell-Duncan Oil Co.	4,210	11	0	8-31-51			S	Ca, L. Oil test, artesian flow, De100.
34cd	Douglas Airport	420	13					Ind.	L, Dr55.
(D-23-26)									
1aad	D. C. McDaniels	256	12	66.60	1-14-52		T, E	I	L, Dm145, Tt5,100.
3aab	H. P. Jacoby	75	10				T, E	I, D	Ca, Dm170.
12bbb	Dan C. Cravey	100	12				T, E	I	Ca, Dm150.
(D-23-27)									
19dad	W. E. Mason	39	Dug	29.97	12-11-46			N	Ca.
19dbc	Fred M. Schukraft	150	12				T, E	I	Ca.
24cbb	Harry Watson	197	6	179.30	12-28-51	4,091			
27cdd	—McGintry	62	Dug	54.15	1- 9-52	3,947			H.
(D-23-28)									
15ac	—Bloomquist	175	6	115.52	8-18-47		C, W	S	Ca.
30cc	Chap Howard	230	6	193.18	12-28-51	4,077	C, W	D, S	
(D-24-26)									
1bbd	—Clarkson	321	16				T, E	I	L.
1ccb	Walter Holland	110	6	111.65	1- 9-52	4,073	C, W	D, S	
6acc	J. C. Mulhern	210	6	184.63	1-31-52	4,217	C, W	D	O.

Table 2.—*Records of representative wells and springs in Douglas basin*—Continued

WELLS—Continued

Well no.	Owner	Depth of well (feet)	Diameter of well (inches)	Water level: Depth to water below land surface datum (feet)	Water level: Date measured	Altitude of land surface at well (feet)	Type of lift	Use of water	Remarks
(D-24-27)									
3ccc	Cochise Co. Hospital	265	6	69.70	1- 9-52	3,948	------	N	H.
3cdd	—	27	Dug	22.44	2-28-52	3,931	C, W	D, S	Ca.
4ccb	Leonard Burns	300	16	----------	----------	----------	T, D	I	Dm360.
5b.c	L. L. Keith	82	Dug	58.37	1-14-52	4,000	C, W	D, S	Ca, H.
8bcc	George Hanigan	460	14	68.02	1- 9-52	4,009	T, E	I	Dm280, Tt9,500.
10dbb	City of Douglas	350	12	61.00	2-20-52	3,923	T, E	M	Ca, Dr1,000.
10dca	Ariz. State Highway Dept.	24	1	13.27	6-17-48	----------	------	------	Ca, O.
13bbd	Southern Pacific RR.	250	13	101.05	1-15-52	3,970	T, E	Ind, D	L, Dr150.
15baa	Phelps-Dodge Corp.	950	12	62.90	2-20-52	3,933	T, E	Ind.	L, Dr950.
17aaa	R. M. Johnston	65	6	51.80	1- 9-52	3,979	C, W	D	O.
(D-24-28)									
7abc	Richard Mealins	335	12	151.83	2-20-52	4,026	T, E	I	L.
11bca	George Rogers	190	6	86.23	3-13-52	----------	C, W	S	Ca.
14cda	George Rogers	-------	6	62.10	2-11-52	----------	C, W	D, S	Ca.
(D-24-29)									
18bcd	George Rogers	160	6	154.61	2-11-52	----------	C, W	S	Ca.

SPRINGS

Spring no.	Owner	Flow (gpm)	Geologic source	Temperature (°F)	Improved	Use	Date investigated	Remarks
(D-18-24)								
28cd	—Stearns	½	Volcanic rocks	----------	Yes	S	9-18-51	
34cc-1	—Stearns	2	Sandstone and tuff (?)	75	Yes	S	9-18-51	Ca, Walnut Spring.
(D-19-29)								
10dd	Sid Vail	15	Volcanic rocks	61	----------	------	10- 4-51	Ca, In John Long Canyon.
14ad	Mrs. Dana	2	do	----------	Yes	S	10- 2-51	Sycamore Spring.
21dc	—Ryers	2	do	69	Yes	D	10- 4-51	Ca, Tributary of Rucker Canyon.

(D-20-24) 21ca	J. Harmon	$\frac{1}{4}$	do	76	Yes	S	9-19-51	Ca, Antelope Spring.
(D-20-28) 31bd	Jesse Eades	2	Limestone and shale	69	Yes	D, S	10- 5-51	
(D-21-28) 21bc	—Kimble	60	Alluvium	73	Yes	S	10- 3-51	Ca, Leslie Spring.
(D-22-24) 29bc	A. C. Stevenson	$4\frac{1}{2}$	Schist, sandstone contact	72	----	----	9-20-51	Ca.

EFFLUENT SEEPAGE ENTERING WHITEWATER DRAW

Surface water location no.	Flow (gpm)	Geologic source	Date investigated	Remarks
(D-23-27) 28cab	7	Alluvium	3-14-52	Ca.
(D-24-27) 10db	25	do	2-12-52	Ca.

[1] Water level reported.

Table 3.—*Logs of representative wells in Douglas basin*

	Thickness (feet)	Depth (feet)
(D-20-26)16daa		
Soil and clay	31	31
Sand, water	1	32
Clay	12	44
Sand, water	6	50
Clay	12	62
Sand, water	3	65
Clay	11	76
Sand, water	3	79
Clay	10	89
Sand and gravel	3	92
Clay	20	112
Sand and gravel	2	114
Clay	6	120
Clay and gravel	13	133
(D-20-27)18daa		
Sand, clay, and boulders	86	86
Sand	2	88
Clay	434	522
Granite	18	540
Gravel	8	548
Granite or blue quartz	22	570
Gravel	6	576
Granite	14	590
Sand and gravel with gold-bearing quartz	10	600
(D-21-25)1dd		
Adobe	56	56
Fine sand, first water	4	60
Hard clay	34	94
Sand, slight showing of water	2	96
Hard clay	94	190
Gravel	4	194
Sticky clay	86	280
Clay fault, fairly strong showing of water	5	285
Sandy clay	65	350
Clay, very sandy	10	360
Water, gravel, slight increase in water, hard clay	6	366
Hard clay	12	378
Clay and gravel mixed	96	472
Strong water strata, water raised within 5' of surface	12	484
Red clay, very sticky	16	500
Sand, gravel, and clay mixed	42	542
Light-gray clay, very hard	3	545
Sand and gravel, water raised within 3'6" of surface	17	562
Yellow clay, very sticky	66	628
Hard sand	2	630
Water, gravel and sand, water raised within 2'6" of surface	25	655
Red clay	6	661
Hard sand	12	673
(D-21-25)1dd—Con.		
Yellow sticky clay	29	702
Red sticky clay	28	730
Dark-red clay with gravel embedded	95	825
Water gravel	9	834
Very hard clay with streaks of hard sand about one-inch thick	156	990
Gypsum with fine sand showing increase in water; the well started to run over at this depth	22	1,012
(D-21-26)23abb		
Top soil	5	5
Caliche and clay	10	15
Clay	77	92
Sand, gravel, and water	2	94
Clay	14	108
Gravel and water	3	111
Clay	49	160
Sand	2	162
Clay	39	201
Sand	3	204
Clay	96	300
Clay, tough and gravelly	30	330
Clay, sticky	16	346
Gravel	4	350
Clay	20	370
Clay	63	433
Gravel	4	437
Clay	9	446
Gravel	3	449
Clay	11	460
Gravel	16	476
Clay	6	482
Gravel	5	487
Clay	5	492
Gravel	9	501
Clay	4	505
(D-21-26)26dcd		
Top soil, black	4	4
Rocks, gray clay, and conglomerate	16	20
Clay, red and hard	50	70
Clay, soft and sandy	16	86
Sand and gravel, dry	6	92
Conglomerate, light-red and hard	17	109
Water	6	115
Clay, red and soft, and conglomerate	41	156
Water	2	158
Clay, gray, with hard and soft streaks	28	186
Conglomerate, light-red and soft	31	217
Clay, gray and soft	3	220
Conglomerate, light-brown and hard	35	255
Water	2	257

Table 3.—*Logs of representative wells in Douglas basin*—Continued

	Thickness (feet)	Depth (feet)
(D-21-26)26dcd—Con.		
Clay and conglomerate gray and hard	22	279
Clay, hard and in streaks, water rose 2 feet	1	280
Clay and conglomerate, gray and in streaks	58	338
Water	2	340
Clay and hard conglomerate, gray and in streaks	24	364
(D-21-26)28dcd		
Top soil	4	4
Clay, small amount of water at 54 feet	50	54
Clay	12	66
Clay	20	86
Sand and gravel with water	1	87
Clay	99	186
Clay, jointed	2	188
Clay, sandy with water	12	200
Clay	50	250
(D-21-27)28ccc		
Sand and gravel	18	18
Yellow clay, gravel imbedded	216	234
Gravel and clay (about 550 gal. water in 24 hours)	6	240
Tight clay	29	269
Sand and gravel (water rose to 225')	12	281
Hard brown clay	19	300
(D-21-28)3baa		
Fill	1,020	1,020
Limestone; water would bail out at 1,165 feet	180	1,200
Porphyry	65	1,265
Limestone	252	1,517
(D-22-26)4dad		
Soil, sandy	15	15
Clay, red	22	37
Clay and boulders	5	42
Sand and gravel	4	46
Clay and small rocks	19	65
Sand and gravel with water	2	67
Clay and small rocks	4	71
Clay, red	18	89
Sand and gravel with water	4	93
Clay and small rocks	23	116
Clay	19	135
Caliche	10	145
Clay and rocks	5	150
Caliche	16	166
Clay, red, with rocks	66	232
Sand and gravel with water	11	243
Clay, red	7	250

	Thickness (feet)	Depth (feet)
(D-22-27)5b		
Clay and silty sand	110	110
Red and gray pebbly sand	280	390
Red, silty sand	110	500
Red, coarse sand	120	620
Red and gray coarse sand	640	1,260
Gray and red sand	345	1,605
Interbedded limestone and quartzite	660	2,265
Pink quartzite and limestone	60	2,325
Limestone and shale	430	2,755
Red sandstone	130	2,885
Alternating beds sandstone and dolomite	210	3,095
Red-brown and gray dolomite	130	3,225
Various colored dolomite	70	3,295
Gray limestone	145	3,440
Gray sandstone	245	3,685
Various colored quartzite	120	3,805
Quartzite and sandstone	80	3,885
Arkosic quartzite	35	3,920
Granite	75	3,995
Granite	215	4,210
(D-22-27)34cd		
Soil	5	5
Red clay	25	30
Gray clay	35	65
Red clay	32	97
Conglomerate (clay, sand, gravel)	46	143
Hard pan (sandy clay)	50	193
Water gravel	2	195
Hard pan (sandy clay)	5	200
Clay	6	206
Sand and gravel, water	2	208
Hard pan (sandy clay)	3	211
Red clay	9	220
Water gravel	$1\frac{1}{2}$	$221\frac{1}{2}$
Clay, gravel and rock mixed	$15\frac{1}{2}$	237
Concrete light sandy clay	86	323
Hard pan and rocks (sand clay, rocks)	47	370
Several small water strata (clay and sand mixed)	38	408
Red clay	12	420
(D-23-26)1aa		
Soil and clay	60	60
Clay and sand with water	30	90
Gravel with water	20	110
Clay strata and sand strata with water	40	150
Clay, red	36	186
(D-24-26)1bbd		
Top soil	6	6
Gravel	24	30

Table 3.—*Logs of representative wells in Douglas basin*—Continued

	Thickness (feet)	Depth (feet)
(D-24-26)1bbd		
Gray clay	4	34
Gravel	4	38
Gray clay	21	59
Gravel	2	61
Gray clay	7	68
Gravel	7	75
Red clay	31	106
Gray clay	8	114
Water gravel	1	115
Gray clay	15	130
Red clay	4	134
Gray clay	21	155
Conglomerate	3	158
Gray clay	16	174
Red clay	1	175
Chalk	2	177
Red clay	4	181
Water gravel	3	184
Conglomerate	3	187
Gravel	10	197
Red clay	14	211
Water sand	5	216
Red clay	6	222
Sandstone	7	229
Red clay	12	241
Conglomerate	3	244
Water sand and gravel	9	253
Sandstone	2	255
Sand	3	258
Red clay	7	265
Water gravel	4	269
Conglomerate	5	274
Gray clay	2	276
Gravel	2	278
Gray clay	2	280
Conglomerate	17	297
Red clay	4	301
Gray clay	15	316
Sand	1	317
Red clay	4	321
(D-24-27)13bbd		
Soil	6	6
Gravely clay	6	12
Clay	24	36
Shale	6	42
Clay and gumbo	25	67
Shell rock and water	2	69
Clay	47	116
Shale	5	121
Water sand and gravel	3	124
Gravel and gumbo	18	142
Clay	11	153
Shale	7	160
Water sand and gravel	4	164
Gravely gumbo	16	180
Clay	7	187
Gravely gumbo	3	190
Clay	6	196
Water-bearing strata	6	202
Gravely gumbo	23	225
Water gravel and boulders	12	237
Gravely gumbo	13	250
(D-24-27)15baa		
Top soil	3	3
Sand soil—surface water	30	33
Gravel	27	60
Fine sand	8	68
Gypsum	2	70
Red, sticky clay	144	214
Light-brown clay	127	341
Malpais and clay	5	346
Malpais—surface water disappeared	18	364
Conglomerate	14	378
Malpais	17	395
Sand	3	398
Red clay	32	430
Brown clay	25	455
Sand	2	457
Finer sand	33	490
Light-brown clay	55	545
Hard sand	10	555
Coarse sand and gravel	4	559
Light-brown clay	6	565
Sand	35	600
Hard clay	14	614
Sand	12	626
Coarse sand and gravel	4	630
Hard clay	8	638
Hard sand	4	642
Coarse sand	5	647
Sticky clay	27	674
Hard sand and gravel	4	678
Sticky clay	12	690
Fine sand	4	694
Sticky clay	9	703
Hard sand	5	708
Sticky clay	2	710
Hard sand	6	716
Hard clay	15	731
Hard sand	16	747
Sticky clay	14	761
Hard sand	20	781
Very sticky clay	52	833
Struck water	-------	833
Sand and gravel, water	23	856
Clay	32	888
Sand	47	935
Hard clay	15	950
(D-24-28)7abc		
Top soil	2	2
Caliche	3	5
Boulders and clay	29	34
Clay, red	9	43
Conglomerate	106	149
Gravel, water	3	152
Conglomerate	28	180
Gravel, water	6	186
Conglomerate	29	215
Gravel, water	2	217
Malpais (i. e., basalt)	105	322
Water	10	332
Clay, red	3	335

Table 4.—*Analyses of water from selected wells and springs in Douglas basin*

[Data in parts per million except specific conductance and percent sodium]

Location no.	Date of collection	Temperature (° F.)	Specific conductance (micromhos at 25° C.)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium
WELLS															
(D-18-26)															
11baa	5-30-46	67	196	----	20	5.1	16	107	7.6	4	0.8	3.3	110	71	33
15bbc	5-28-46	70	286	----	30	5.2	26	141	18	6	3.0	3.0	161	96	37
18bbb	5-28-46	70	500	----	33	14	61	236	23	23	1.2	25	296	140	49
(D-19-25)															
25acc	5- 1-46	78	347	----	----	----	----	182	----	7	4.4	----	----	----	----
(D-19-26)															
1aaa	5-28-46	75	347	----	----	----	----	161	----	17	4.4	----	----	----	----
30aab	2-12-52	69	261	37	34	7.0	10	129	10	8	2.0	3.8	176	114	16
(D-20-26)															
6aba	6-14-46	68	339	----	----	----	----	[1]158	----	20	2.4	----	----	----	----
12bba	2-27-46	70	237	----	29	1.6	25	136	12	5	.8	.8	141	79	41
(D-21-25)															
23ab	2-12-52	69	613	30	36	7.6	86	202	42	59	2.8	11	374	121	61
(D-21-26)															
1bdc	5-29-46	70	516	----	56	18	30	250	39	20	1.6	2.3	290	214	24
24bab	3-27-46	73	383	----	38	13	30	222	11	9	1.6	5.8	218	148	31
29dda	6-15-46	68	686	----	64	27	43	[1]249	37	79	1.2	7.8	382	270	26
(D-21-27)															
13cdd	8-15-47	----	563	31	69	12	39	254	50	21	.4	20	368	222	28
(D-22-25)															
24da	2-12-52	69	410	27	66	7.9	11	245	7.8	6	.0	4.5	251	197	11
(D-22-26)															
21ca	2- 5-46	----	1,050	32	55	16	152	255	123	131	3.1	3.8	[2]642	203	62
27bca	6-17-46	68	500	----	53	13	35	201	40	36	.8	4.0	281	186	29
(D-22-27)															
5b	3- 7-51	129	1,420	8.5	30	10	290	[3]413	322	40	6.0	.1	910	116	84
(D-23-26)															
3aab	5-31-46	68	923	----	66	16	109	237	106	112	.7	2.7	529	230	51
12bbb	5-31-46	66	1,690	----	200	25	150	187	537	150	.1	5.9	1,160	602	35
(D-23-27)															
19dad	2- 5-46	----	3,340	----	180	93	429	261	484	740	.6	.4	[2]2,060	832	53

Table 4.—*Analyses of water from selected wells and springs in Douglas basin*—Continued

Location no.	Date of collection	Temperature (°F.)	Specific conductance (micromhos at 25°C.)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium
WELLS—Continued															
(D-23-27)—Con.															
19dad	10-16-51	-------	4,630	----	-------	-------	---------	270	------	1,060	0.8	------	-------	-------	-------
19dad	5-28-52	80	7,130	26	380	212	966	249	1,140	1,790	1.0	4.2	4,640	1,820	54
19dbc	10-16-51	-------	2,500	----	-------	-------	---------	208	------	575	.7	------	-------	-------	-------
(D-23-28)															
15acc	8-18-47	80	634	----	63	34	31	368	35	14	.8	5.7	365	297	18
(D-24-26)															
1cb	2- 5-46	-------	623	----	62	17	51	264	49	44	.8	3.9	358	224	33
(D-24-27)															
3cdd	5-28-52	78	988	19	4.5	1.1	209	176	96	153	2.6	2.5	575	16	97
5bcc	2- 5-46	-------	623	----	-------	-------	---------	254	34	53	------	------	-------	-------	-------
10dbb	9-12-51	76	1,600	21	6.2	2.4	326	[4]172	183	288	3.2	1.8	[5]919	25	96
10dca	6-16-48	68	3,600	31	68	57	661	[6]291	774	550	1.6	21	2,310	404	78
(D-24-28)															
11bca	3-13-52	67	2,950	28	556	154	54	207	1,810	48	1.2	16	2,770	2,020	5
14cda	2-11-52	68	1,170	32	149	56	20	286	265	46	.8	85	795	602	7
(D-24-29)															
18bcd	3-13-52	78	779	31	85	41	27	269	200	6	.7	.2	524	380	15
SPRINGS															
(D-18-24)															
34cc	9-18-51	75	585	18	96	14	14	326	46	6	.2	4.8	236	297	9
(D-19-29															
10dd	10- 4-51	61	176	31	22	4.0	8.5	70	26	3	.4	.4	129	79	21
21dc	10- 4-51	69	373	51	53	6.6	21	235	2.3	5	.9	.9	257	159	22
(D-20-24)															
21ca	9-19-51	76	618	45	71	15	47	332	42	14	.9	3.8	403	238	30
(D-21-28)															
21bc	10- 3-51	73	577	33	96	11	16	293	36	5	.4	42	383	284	11
(D-22-24)															
29bc	9-20-51	72	223	20	30	5.7	7.8	108	20	3	.6	.6	141	98	15

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(D-23-27) 28cab	3-14-52	50	950	9.5	50	16	137	194	239	55	.6	1.3	604	191	61
(D-24-27) 10db	2-12-52	47	2,090	5.1	76	46	299	181	295	404	.9	1.7	1,220	378	63

[1] Includes equivalent of 8 ppm CO_3.
[2] 0.1 ppm boron present.
[3] Includes equivalent of 12 ppm CO_3.
[4] Includes equivalent of 21 ppm CO_3.
[5] 0.28 ppm Fe.
[6] Includes equivalent of 20 ppm CO_3.

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