the surface. The temperature averages about 51° F., with a range of about 3° on either side." In this territory the flows are situated between Denton and Plymouth. There is another district at higher altitude near Northville, 775-800 feet. In Oakland county I believe this basin is continued in the southern and southeastern part, where flows are found at Farmington, where the head is 700-730 feet; at Franklin, head about 760 feet; at Birmingham and Rochester where the head is 750 feet. Thence in the same direction in Macomb county at Washington, 710 to 740, Armada is about 760 feet, and Memphis 760 feet more or less. Mr Lane adds the following note: "In general on the lakeward side of the till ridge in the lowlands, or close to a well marked drop in the topography, flowing wells are liable to occur." Prospectively then we would expect to obtain flowing wells in the territory above mentioned, the distance varying in the lowlands between the moraines, but hardly exceeding 6 miles in width.

It will be observed that this belt is approximately parallel to the one previously described, but extends father north, the ice having retreated toward Lake Huron basin in the meantime, thus forming a greater extension of the basin in which flows would be produced. At Plymouth in August, 1892, Dr. M. V. B. Saunders drilled a well with medical properties, the flow being struck at a depth of 97 feet. John E. Clark, professor of chemistry and physics in the Detroit College of Medicine, made the following analysis.

Analysis of Plymouth well water.	Grains to the U. S. gallon.
Chloride of sodium	14.384
Sulphate of sodium	.372
Bi-carbonate of sodium	5.276
Bi-carbonate of potassium	1.730
Bi-carbonate of calcium	5.471
Carbonate of magnesium	2.906
Alumina and ferric carbonate	1.736
Silica	.500
Organic and volatile	1.298
Total solids	33.673

Carbonate of lithium, present, amount not estimated
Carbonic acid gas, not estimated.

The remedy has proven efficacious in stomach, kidney and bladder troubles.

Birmingham which is situated in T. 2 N., R. 11 E. has obtained numerous flows in sand and gravel varying in depth from 60 to 150 feet. The amount of flow varies from 3 to 150 gallons per minute, being somewhat inversely greater according to the depth of the well. The temperature is 50°. Imlay City is situated between morainic ridges, and so are Attica and Lapeer, and flows are obtained at each of these places. From Lapeer a flowing well tract leads southwestward past Farmer's Creek to Ortonville in the northern part of Oakland county. Concerning the flowing wells at Ortonville, Mr. Leverett sends the following note, based on statements made by R. E. Cassedy, well driller: "There are about 100 flowing wells at and near Ortonville 35 to 70 feet deep from sand under a bed of

blue clay. The strongest well flows 40 gallons a minute from 1¼-inch pipe, but these strong flows are found only in the ravines along Kersley creek, and the head there is 18 feet above the surface. On the plain each side of the ravine, the head is only 1 to 4 feet above the surface and flows are weak." "The deepest well in Ortonville is at Mrs. Storms Arnold's, the depth being 149 feet. No rock was struck." "Northwest of Ortonville, in the western part of Atlas township, T. 6 N., R. 8 E., Chas. Cheney has a well 111 feet deep in which some coal was found at about 105-108 feet. First rock at 98 feet. Water flows two feet above surface and is a hard water well, 3.5-inch with casing."

West of Ortonville in section 5 of Groveland township, T. 5 N., R. 8 E., Jas. Algoe has a flowing well 118 feet deep, that did not reach rock. The head is 10 feet above the surface. Altitude of well about 900 feet A. T. It fills 1¼-inch pipe full at a height of 4 feet above the surface." At Thornville southeast of Lapeer flows are also found in a drainage valley off the moraine. At Lapeer the city water works has from 5 to 8 wells, and pump from 300,000 to 500,000 gallons every 24 hours, with a very little lowering. The water was found at a depth of 280 feet in the drift. An analysis of this water has already been given in Water Supply paper No. 31.

In Washtenaw county flows are found at Ann Arbor, Fredonia, Sylvan and Manchester, from gravel beds in the drift. At Brooklyn in the southwestern part of Jackson county there are flows from the rock, and at Trumbulls west of Jackson artesian wells have been drilled. At Marengo and Albion in the eastern part of Calhoun county there are also flows which are used for a city water supply in the latter place. Parma which is situated between Albion and Trumbulls has no flowing wells. The basin is probably quite localized. In the well put down for the Albion water works in 1902, the depth of the well was 175 feet, and the flow, which was obtained from the Marshall sandstone, amounted to 300 gallons per minute. This formation is famous as a good water producer in the greater part of its basin in lower Michigan. In a later part of this report will be found 13 analyses made by Prof. Delos Fall from wells in Albion. They originally appeared in a supplement to the Albion Recorder.

The flowing wells at Brooklyn are also from the eastern side of the Marshall sandstone area and occur at a depth of 40 feet in the rock, which is said to outcrop on the farm of Geo. Knowles.

The Ann Arbor Water Company has kindly furnished me with the log of a well situated in the city limits, being section 29 of T. 2 S., R. 6 E.

Boring for Ann Arbor Water Co.	Feet.
Surface	12
Quicksand	33
Dry gravel	3
Dry gravel and stones	12
Clay, hardpan, and layer of sand and cobble stone	25
Quicksand	5
Blue clay	5
Hardpan	12
Fine water gravel	7
Clay hardpan, gravel and streaks of water sand	9
Total	123

Geographically there is an area which extends in a southeasterly direction through the eastern part of Allegan, and through Barry county as far as the northwestern part of Calhoun county. From the last named place flowing wells are found in a northeasterly direction through Eaton, Ingham, Clinton, Livingston and Genesee counties. This territory does not form, that is it is not one geological basin in either the Pleistocene formation or the underlying sedimentary rocks. Flowing wells may, however, be found in the low ground in the territory above named, (but that is quite prospective). Flows have, however, been found in Allegan county at Burnip's Corners, Moline, Wayland, Hopkins and Otsego; in Barry county at Hastings, Pritchardville, Prairieville, Hickory Corners and Assyria, as well as at Bedford in the northwestern part of Calhoun county. In Eaton county at Bellevue, Olivet, section 8 of T. 2 N., R. 5 W., Petreville, Potterville, Windsor and Millett artesian basin or basins have been tapped. In Ingham county there are flowing wells at Stockbridge, Leslie, Eden, Mason, Leadley's, Dimondale, Lansing, Okemos, Meridian and Webberville; in Clinton county in the basin of the Lookingglass river at Wacousta, DeWitt and Bath; in Shiawassee county at Shaftsburg, Morrice, Byron, Burns, Durand, Vernon and Owosso; in the northern part of Livingston county at Oak Grove and Madison; while in Genesee county, Flushing, Flint, Atlas and Davison are represented. As thus defined we have a broad segment of a circle swinging three-fourths across the lower peninsula, and doubtless including several local basins.

At Burnip's Corners it is 5 miles to the nearest flowing well; one or two deep wells drilled without obtaining water; the usual depth of water being from 15 to 45 feet deep, being in coarse gravel.

At Wayland flowing wells are 30 to 60 or 20 to 200 feet deep, all under strata of clay, except one which is through into the Marshall sandstone.

Hastings with a population of 3,000 has such a supply that the pumps cannot lower it. At or near Petreville there is a flowing well with medicinal qualities, 165 feet deep. The flow rises 19 feet above the surface. Near Potterville there are two wells, 40 and 150 feet deep with an ample flow, the water being hard and alkaline.

The flows at Dimondale and Millett are in a tributary of the Grand river.

At Leslie, Mr. Arthur J. Tuttle has kindly sent me a record of the strata passed through in his two wells, which is as follows:

Tuttle Wells at Leslie.	Feet.
Drift	30-40
Slate	60-70
Sandstone	10

A softer bed of sandstone was penetrated by the drill at this depth which caused the water to flow just to the surface. Below this a flint rock (probably $FeCO_3$) 2-4 inches, and then sandstone to 160 feet underlaid by a honey comb rock filled with water which rose 10 feet above the surface. This well was drilled by Frank Dodge in 1899, while an earlier well which flows was made by Sanford Bros. of Jackson, Mich., about 1868. The wells flow about 3 barrels per minute. The temperature of the water is about 54° and is slightly mineralized with iron and sulphur. An analysis has been given by Mr. Lane in Water Supply paper No. 31. The beds of coal measure sandstone in which these wells

are found are more or less local in deposition and while almost always water-bearing would not furnish flowing wells where the top of the drift accumulation is higher than the head of the water in local synclines. Mr. Lane in his report on coal,[1] has represented a continuous bed of sandstone running from Leslie to Lansing along the Michigan Central R. R., which would probably furnish flowing wells in the lower reaches of the Grand river basin, including here more particularly Sycamore creek and its tributaries.

At Mason a number of wells have been put down for the city water supply, of which the following will serve as an example:

Well at Mason, Mich	Thickness.	Feet.
Surface	3	3
Gravel	2	5
Water gravel	1	6
Gravel and sand	14	20
Hardpan	8	28
Hardpan and shale	4	32
Fire clay	2	34
Black slate or shale	10	44
Lighter shale	10	54
Hard rocks	2	56
Sand and water	31	87
Sand rock	16	108
Slate	12	112
Sand rock	6	118
Light shale	6	124
Light sand rock	5	129
Shale	2	131

This is in the coal formation, underlying the central portion of the lower peninsula of Michigan.

The mineral well at Lansing is from the Marshall formation. Mr. Lane has given an analysis in his Water Supply paper No. 31. At Flint, Mr. C. B. Berry, medical director of the Oak Grove Sanitarium, has given a section of the beds passed through.

	Feet.	Inches.
Clay and gravel	33	
Sand rock	85	
Flint rock		8
Black slate		10
Coal		10
Slate	2	
Hard sand rock	15	
White slate	5	6
Flint rock	0	8
White slate	9	6
Sulphur rock	0	7
Blue slate	16	
White slate	0	6
Blue rock	28	
Sand rock	67	6
Total	265	

[1] Mich. Geol. Surv., Vol. VIII, Pt. 2.

The water is obtained in the basal bed of [Marshal. L.] sand rock passed through. The flow is 9 gallons per minute.

Along the first correction line of the U. S. Government Linear Survey there is a broad belt where flows have been struck at numerous places. In Tuscola county there are flowing wells at Cass City, Novesta, Wilmont, Mayville, Caro, Akron, Wisner, Fairgrove and Gilford. At Caro a well having a capacity of 400,000 gallons per day was struck at a depth of 274 feet. The water at this depth is pronounced excellent for drinking or other purposes, and its temperature 47°. I believe that Mr. Lane recommended that Saginaw obtain its water supply from this vicinity. Such wells as this might prove a solution of the problem if the supply is permanent.

Prof. C. A. Davis, who is engaged in the preparation of a report on the geology of Tuscola, has kindly sent me the following notes:

"(1) Beginning with the Bay shore and working inland is a region from 4-6 miles wide, in which most of the wells which go into the rock are salt or at best strongly brackish. The district is flat and clayey (clay till or lake clays) to the rock surface, with here and there low sandy tracts or ridges scattered over the surface. From some localities boulders and thin layers of gravel are reported on top of the rock and this overlaid by compact clay or hardpan. The hardpan is generally reported, whether the boulders are or not. This belt runs from a point about a mile north of Unionville where there is a brackish well, southwest through Akron township, includes practically all of Wisner, the northwest corner of Fairgrove and about all the northwest half of Gilford, with the deeper wells salty or brackish, less so to the east, however, along the south line of the township, clear across the township to the east. In Denmark township, brackish water is found along the north border from the northeast corner of section 3 westward, and southeast half of 2, thence westward in deeper wells though some of the shallower areas are not brackish. South of this are no brackish wells until the southwest ¼ of section 16 is reached. There are brackish wells also on the west side of 21 and on the south side of 30, but none east that I found, and the brackish water is practically out of the county in the southwest corner of section 31 of Denmark township, although a deep well at Vassar of more than 400 feet depth is decidedly brackish.

"Throughout this belt there are numerous flowing wells, but many others do not flow and never have, while some used to flow and have stopped, as the number of wells put down has increased. It seems possible that these brackish waters came from the coal measures and from the shales and finer sandstones or even from coal strata as is sometimes reported. The flows from these wells where they flow at all are seldom large and often are very small and feeble, and there is frequent testimony that the head has lowered perceptibly, all, of course, showing that the basin from which they come is not of large extent or is poorly supplied with water, the latter being most probable from the character of the rock, which is not porous. Near the edge of this formation where it overlies the sandstones below, it sometimes happens that the sandstone is reached and then large flows result, which although salty or brackish, are sometimes manifestly getting the salt from the overlying strata since the owners report that before they pulled the casing out the water was much fresher, or entirely fresh. In some cases I advised casing down through the rock to near the bottom of the hole to shut off all water except that from the sandstone, and the quality of the water was improved by this means in two wells under my observation.

"(2) East of this salty belt and sharply distinct from it in the character of the water, is another tract elongated to the south west and extending nearly parallel with the border of the bay, in which the water is very fresh and free from both lime and iron salts, only traces of any mineral water being found in it. The water comes from sandstone in these wells, and because of the abundant supply of good water easily obtained there is a great development of drilled wells in the west side of Columbia township and in the east half of Akron and southward through Fairgrove. Here the rock is from 70 to 100 feet below the surface with local valleys and depressions in the rock surface which makes some greater depths. Most of the well records show some coal or black shale and it is fair to infer that the sandstone is, in part at least, Carboniferous, but to the eastward it seems possible that this runs without any marked division into the sub-carboniferous sandstones which crop out in the Cass river valley. There are some local faultings in these rocks which may complicate matters geologically, but there is no evidence that such faults affect the water supply, that I have been able to discover. The flows in some of the wells from this belt are large and strong but there is no great head and 3-4 or possibly 6 feet would be the average maximum height above the surface to which the water would rise when I visited the wells, though an occasional well, usually in a depressed place would be reported as rising 10 or 15 feet when piped up that far. On the other hand it was a common occurrence to have the report that the well formerly flowed but stopped when another one was put down near by. It seems probable that the sandstone is more or less discontinuous in this area since some holes have been put down which gave no water at all and the beds of sandstones were interbedded with shale in many of the records. It is certain that in some wells greater depth is reached than in others but whether this means that the water always came from the greatest depth reached by the drill, of course we have no means of knowing. This belt extends northeast into Elmwood township and southwest into Fairgrove and Gilford and Denmark, but on account of the occurrence of morainal and beach ridges to the east it is frequently true that the land surface is so far above the rock, and the head, that while the water rises some distance in the well tube it does not flow. A high morainal ridge runs down from Gagetown to Vassar and along the foot of it to the west and strong beach lines which of course act as reservoirs and give abundance of water in the form of springs so that the deeper wells are not needed. On the moraines the wells are mainly shallow since the till is gravelly and water-bearing gravels are common and productive enough for domestic uses. In Cass valley there are great deposits of gravel and sand, in which good water is abundant and here also no deep wells are put down until Vassar is reached. Here there are a group of wells in the river valley 40-60 feet deep all in the sandstone, from which the city supply is taken. There are also some private wells in the lower part of the town. The flows are all on the river terraces, and the water is free from salt and mineral matter. Near the P. M. R. R. station, or rather the junction of the M. C. and P. M. R. R., is a deep well, which flows a large steady stream, but I was unable to get a record of it as the former owner was dead and the record lost. It was said to be 400-600 feet deep, probably

to the Marshall sandstone. This is drinkable but salty and unpleasantly full of other minerals.

"Southwest of Vassar, at and near Tuscola village, is another group of flowing wells in the river valley. These are shallow and from the Carboniferous sandstone. They are from 40 to 70 feet deep. South of Vassar about 7 miles are a few flowing wells along the foot of the water laid moraine, that comes down from Millington and across Arbela township from about the middle of section 13 to 31. These do not reach the rock but the flow is from gravel below the till on the north side of the foot of the moraine. There are only two or three such wells that I could learn of. Most of the rest of the county is either too high to have flowing wells, or too sandy to need them, the water supply coming almost exclusively from dug wells, throughout the township south and east of the Cass valley, and where these are not sufficient as on the moraine in the southeast corner of the county the elevation is too great to secure a flow, and there are very few drilled wells in that entire district."

Since the report on Huron county was printed seven wells have been drilled by the Coryell Drilling Co. at Bad Axe, which are said to be able to produce about 4 million gallons of water every 24 hours, the Marshall sandstone being the source of the supply. These flow at times.

In Saginaw county flowing wells are obtained in almost any locality, except that in the southern part of the county they are rather restricted to the river valleys. At Chesaning an abundant supply is obtained from the Coal Measure sandstone which is utilized for the village water supply. Also at Fergus, St. Charles, Swan Creek, Merrill, Burt, Birch Run, Blackmar, Frankenmuth, Bridgeport, and at numerous other places flows have been obtained either from the drift or the underlying sedimentary strata.

In Bay county artesian water is found in sections 1, 2, 3 and 12, Williams township, T. 14 N., R. 3 E., in sections 7 and 18 of Monitor township, T. 14 N., R. 4 E., while recently Mr. Theodore Archambeau while drilling for coal in the valley of the south fork of the Kawkawlin river tapped a flowing well near the line of sections 3 and 10. Also in Kawkawlin township there are flowing wells at the corner of sections 29, 30, 31 and 32, which is the remnant of a larger basin which opened out to the east, extending as far as the north fork of the Kawkawlin river. In Beaver township, T. 15 N., R. 3. E., this area embraces parts of sections 33, 35, 26, 28, 21, 23, 14, 15, 11, 12, 2 and 3, the greater part of the basin being adjacent to the south fork of the Kawkawlin river. Also in Kawkawlin township there is an area between the State road which follows the Algonquin beach line and Saginaw bay, where flows are obtained as far south as section 23, T. 15 N., R. 4 E. On the west side of the State road this area is extended into sections 3-5 of the same township. Fraser township T. 16 N., R. 4 E. is abundantly supplied with flowing wells in the area adjacent to Saginaw bay and east of the State road, the same area being extended up Michie creek and into sections 4-6, 8-10. This latter area extends northward into Pinconning township, T. 17 N., R. 4 E. the greater part of the basin being in or adjacent to sections 33, 28, 22 and 15, thence swinging southeast through sections 14 and 23, where the Saginaw bay area is met, an angle with the State road and passing into the bay in section 7, T. 17 N., R. 5 E. To the south of the union of these basins the area adjacent to the bay extends down into Frazer township. An isolated area is in the southeastern part of section 10, T. 17 N., R. 3 E. Most of these wells are in the drift, and are found in gravel or a sandy

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gravel overlying the rock. The following section taken from a test hole record for coal will serve to illustrate the stratigraphy of the deposits; the record being in the N. E. ¼ of the S. E. ¼ of section 24, T. 15 N., R. 4 E.

		Total.
Sand	25	25
Clay	35	60
Sand	4	64
Gray shale	15	79

Mr. Floyd D. Owen has given the results of analysis of Bay county waters in the report of the State Board of Geological Survey of Michigan for the year 1902.

In the deep well at the plant of the North American Chemical Co. at South Bay City, a flowing brine was struck in the Berea grit at a depth of 2,170 feet, the flow amounting to 1.25 gallons every 3½ minutes. An analysis has been given in Water Supply paper No. 31.

In Arenac county the Bay county basin is continued with interruptions flows being found at Standish, Omer, Twining, Turner and AuGres. The prospects for obtaining flows adjacent to the bay and east of the place above named is fair. Furthermore in Iosco Co. at Whittemore, Alabaster, East Tawas and AuSable, flows have been obtained both in bed rock and the Pleistocene; while in Alcona county at Killmaster and Alcona, and at Alpena, there are flowing wells, the greater part of the flows being adjacent to the shore of Lake Huron.

At West Branch, Rose City, and thence north to Indian River there are flowing wells with a great abundance of flow. These lie in basins between high moraines, which have been described by Mr. Lane in Water Supply report No. 30.

Returning again to the south we find in the basin of the Maple river artesian wells at Ashley, Hubbardston, Pewamo and Muir, situated at its junction with the Grand river, with Ionia and Lowell farther down stream. At Ashley the flow is found 260-278 feet with 3 feet head, temperature 52° F. Again at Hubbardston a flow was struck in a sand and gravel bed of the Pleistocene at a depth of 210 feet, where the water rose 20 feet above the surface. The flow at Pewamo is ample and occurs at a depth of 35 feet, while at Muir 5 miles west J. Hale and Sons obtained flows at a depth of 240 feet and another at 300 feet, showing the great variability of the Pleistocene from which these waters were obtained. At Ionia, Mr. H. R. Welker writes me that he struck flows at 27 feet, in the drift and at 313 feet in the bed rock, the flow increasing to a depth of 320 feet.

In the basin of the Pine river at Alma, Breckenridge and Pleasant Valley there is a bunch of flowing wells. "At Alma in 1897, the entire number of flowing wells in the town was 76, of which 9 had a depth of less than 50 feet, while 7 were over 100 feet deep, the greatest being at the Sanitarium engine room, which is 144. The depth of 13 is unknown, while 37 range in depth from 55 to 80 feet. The greatest flows occur at a depth of less than 100 feet as the following table will show:"

	Feet deep.	Barrels per day.
Brainard's	49	634
Strubele's	71	532
Fullerton's	62	450
Pringle's	85	450
Hutchinson's	55	270

In this connection I cannot do better than quote an article which appeared in the Alma Record, Friday, Sept. 10, 1897, prepared by a student of Alma College, under the direction of Prof. C. A. Davis, regarding the wastefulness of the drinking water supply. "Allowing each individual in Alma and Ithaca three pints of water per day, the little well near Clubb's shop would be sufficient for both towns. Assuming that the 71 unmeasured flows are as strong as the ones just referred to, the whole amount of water that issues from the earth within our narrow limits is 222 times what we use, and would slake the thirst of Detroit, Grand Rapids and Toledo. What a waste of water! Eventually the underlying fountains will be drained down to the level of their lowest outlet, and we shall have to scrape acquaintance with the pump handle." In such cases nature exacts her own remedy. For when the flow falls below the surface the basin has an opportunity to become refilled. However, as suggested in the article, it is better to introduce the stop-cock or the simple round plug with a small hole.

At Pleasant Valley in the southwestern part of Midland county the flows occur in interstratified beds of gravel and are found at depths varying from 26 to 60 feet. This portion of Michigan is all deeply covered with the drift.

North of Pleasant Valley there is another artesian area around Alamando and Coleman, in the northwestern part of Midland county, and in the basin of Salt river tributary to the Tittabawassee. In Gladwin county north of there, numerous flows are found at Beavertown, Gladwin, Wheatley, McClure, section 6 of T. 19 N., R. 2 W., and at Butman. The probability of finding flows in Range 2 west of Gladwin county is excellent, as well as in R. 1. W, township 19 and 20 north. At Gladwin water was found in sandstone at a depth of 350 feet, the flow amounting to 100 gallons per minute. Mr. Geo. Shaley, engineer of the Gladwin water works, informs me that small flows are also found there in the drift at a depth of 100 feet.

In Isabella county at Loomis and at Clare just across the line in Clare county, flows have been obtained. Also at Mt. Pleasant, Jordan, Leaton, Rosebush, Brinton, and Sherman City in Isabella county the same water supply is obtained, as well as at Barryton, a short distance west of Sherman City, in the northeastern part of Mecosta county. At Mt. Pleasant water is found in gravel at a depth of 205 feet. Mr. Leverett informs me that much of the northern part of Isabella county is high moraine, flows being obtained only at the localities mentioned above, or on lowland tracts.

In a sand and gravel area extending southeast from Mecosta county into the southwestern corner of Isabella county, and thence south through Stanton as far as Belding in the northwestern part of Ionia, there are a number of flows where land is low among the moraine ridges. This area affords a good opportunity for further prospecting. At Mecosta, Remus, Millbrook, Blanchard, Edmore, Cedar Lake, Vestaburg, Stanton, and Belding, artesian basins are tapped. At these localities the depth of water varies, being 35 feet at Millbrook, 30 feet at Blanchard, 40 feet at Stanton, where it is used for fire and domestic purposes, and 130 feet at Belding, where the water is found in sand. It will be noticed that the depth increases to to the south as far as our records show.

In the southern part of Newaygo county, in the basin of the Muskegon river, there are several artesian wells. At Fremont, section 5, T. 12 N., R. 14 W., Brunswick, Sitka, and Newaygo, there are flows, as well as a separate basin on the south side of the moraine at Grant, Bailey, Plumville, Grove and thence west and south along a tributary of the Grand river as far south as the latitude of Kent City. At Fremont water bearing beds are found at 18, 100 and 200 feet in the drift, the flow being about 15 feet above the surface for the deeper wells and 15 inches for the most shallow. The temperature is 51°. In the deepest wells the flow is given at 1,800 gallons per hour. The water is hard except in the well 18 feet deep. In Newaygo the depth to water varies from 30 to 44 feet. The wells both here and at Fremont are in the drift.

In the basin of the Muskegon river there are several flowing wells in the southern part of Osceola county at Reed City, Hersey, Evart, Sears, at Marion in the northeastern part of the county, and at McBain in the southwestern part of Missaukee. It is not impossible that flows would be obtained between these places, as well as in the environment of the places last mentioned. At Reed City flowing wells are found in interstratified beds of sand and gravel at a depth of 300 feet. Three miles southwest of the city the depth is only 100 feet. In the deeper wells the water is hard, becoming softer in the more shallow wells. At Marion there are only a few flowing wells out of a number of records that I have received. The depth at that place varies from 30 to 60 feet. McBain situated northwest of Marion has a flowing well at 30 feet, while another well having a depth of 140 feet rose to within 15 or 30 feet of the top.

In the highlands north and east of McBain I have not obtained the records of any flowing wells. In this region water is found at a depth of from 25 to 175 feet at Morley in Missaukee county; from 20 to 70 feet at Fletcher in the southeastern part of Kalkaska, at a depth of 200 feet at Grayling, 176 feet at Frederic, and 90 feet at Gaylord. Flowing wells will probably be found all the way down the AuSable river.

At Indian River there are numerous flowing wells, the basin extending along the south and west side of Burt Lake, north along the Sturgeon river past Topinabee, Mullets Lake, and thence to Cheboygan. West from Burt Lake flows have occasionally been found, and there are numerous wells at Harbor Springs, which is almost due west of Indian River. Mr. Daniel Foreman, a driller residing at Harbor Springs, informs me that flowing wells have been found for a distance of 26 miles east of that place.

At Indian River the depth to water varies from 93 to 189 feet. In two wells 108 and 142 feet deep, the head forces the water 20 feet above the surface, while another well 110 feet deep rises 35 feet above the ground, which is the greatest elevation given. Again in the well record having a depth of 175 feet, the water rises 30 feet above the surface. Not having the elevation of the wells it is impossible to arrive at any satisfactory conclusion relative to depth and head. In all the wells the water is hard and impregnated with iron. The temperature is given at 48° F. in four wells varying from 108 to 142 feet deep, and as 44° F. in one well

110 feet deep. The flow is given as 100 gallons per minute at 142 feet, 180 at 110 feet, and 200 at 112 feet; while in another lot the flow would average four barrels per minute in three wells having an average depth of 106, and three barrels per minute in four wells with an average depth of 135. Not until the elevation above tide is determined for some of the different wells, and the amount of flow actually gaged as given in Schlichter's paper can any reliable conclusions be arrived at concerning the relation of depth and head. Mr. G. P. Cowley has sent me the following record of strata passed through in one well there:—

Well at Indian River.	Feet.
Sand	40
Hardpan	7
Sand	12
Gravel	5
Sand	25
Clay	15
Gravel	5

In three other wells the amount of surface sand varies from 40 to 45 feet, with from 53 to 60 feet of clay overlying the gravel in which the water is found. At Topinabee there are two wells with a depth of 119 feet, the flow being in the drift. In one well the water will rise 11 feet above the surface, in another from six to eight feet. The temperature in the Sanitas deep well belonging to H. H. Pike's Sons is 48°. To Mr. Horace L. Pike I am indebted for an analysis of the water from this well, which was made by Prof. I. V. S. Stanislaus of Notre Dame University.

Physical examination showed:—

Color	none
Odor	none
Taste	perfect
Reaction	neutral

Chemical examination in parts per 1000.

Chlorine	.0145
Free ammonia	none
Nitrogen in nitrates	.0023
Total hardness	.0202
Permanent hardness	.0171
Organic and volatile matters (by loss)	.0182
Total solids	.1146

The inorganic constituents proved potassium, sodium, and magnesium bi-carbonates and chlorides, with sodium phosphate and calcium.

At Harbor Springs flows are found from 45 to 320 feet in depth as at Mr. E. Shay & Son's well. All the wells are said to be in the drift. In Mr. Shay's well the flow amounts to 100 gallons per minute, the temperature being 45° F. Mr. Lane has given an analysis of this well in Water Supply paper No. 31. Mrs. Chas. Roe writes me that flowing wells were first discovered there by driving piling 200 feet from shore for Roe & Co.'s steamboat dock. The flow was struck at a depth of 45 feet, and was of sufficient strength to lift heavy piles after being driven down.

Along the latitude of Harbor Springs and Indian River, artesian water has been struck at Rogers City on the shore of Lake Huron. Mr. F. C. Larke, president of the village council has sent me the following section of beds passed through:—

Well at Rogers City.	Feet.
Coarse gravel	10
Hardpan with streak of gravel	80
Limestone	21

In the basin contiguous to Lake Michigan and south of Harbor Springs, there are artesian basins all the way down to the Indiana state line. Adjacent to Grand Traverse bay and Pine Lake flows are found both at Boyne and Boyne Falls; near Bellaire, Williamsburg, South Boardman and Traverse City. In the little finger of the lower peninsula, forming Leelanaw county, there is a flowing well near Provement, and farther down the coast at Empire, Frankfort, Beulah, Thompsonville and Onekama. East of Onekama, in the basin of the Manistee river, there is an artesian basin at Yates and another around Fife Lake. However, just west of Fife Lake and around Summit City, water is found at a depth of 94 feet, gradually increasing to the south, until on the north side of the Manistee in section 4 of T. 24 N., R 10 W., water is found at a depth of 135 feet. In these wells water does not reach the surface. Likewise east of Yates at Wexford, it is 47 feet to water, near Farnsworth 127 feet, while in Antioch township, T. 23 N., R. 11 W., the depth varies from 60 to 128 feet. The area of non-flowing wells is continued on to the southeast where at Cadillac the depth varies from 125 to 225 feet to water.

Around Ludington flows are again struck. In Oceana county there are several separate areas of flowing wells near Hart, Elbridge, section 24 of T. 15 N., R. 17 W., Shelby, section 18 of T. 14 N., R. 17 W., Marshallville and Holstein.

Muskegon and Fruitport both have artesian wells, and in the valley of the Grand river we find flows at Eastmanville, Lamont, and Georgetown, 19 miles east of the shore of Lake Michigan.

Again adjacent to the lake at West Olive, Gibson, Hamilton on the Rabbit river, and at Ganges there are flowing wells, while at Casco, seven miles south of Ganges, it is 160 feet to water which does not reach the surface.

In Van Buren, Cass and Berrien counties, the civil divisions correspond to an enlarged artesian area. This region is rather heavily belted with moraines running parallel with Lake Michigan, and flowing wells are only found in the lower areas. In this territory flows have been obtained near South Haven, Lacota, Grand Junction, Geneva, Breedsville and Bangor in the basin of the Black river; around Watervliet, Hartford, Lake Cora, Paw Paw, and Keller in Van Buren county, in the basin of the Paw Paw; in Cass county there are a few flows near Marcellus, Penn, Pokagon and Dowagiac; while farther west in Berrien county there are artesian wells at Niles, Berrien Springs, Buchanan and New Troy.

Throughout this considerable extent of the lower peninsula, the depth to artesian water varies. At Boyne the depth to water-bearing gravel is 70 feet, the temperature being 50°. At Bellaire the water is also found in the drift at the depth of 100 feet. The capacity is 4,000 gallons per day, and is used in the city water supply.

At Williamsburg, Mr. John H. Russell of Detroit, obtained flows at 45, 82½, and 87 feet, the water coming from interstratified gravel beds in the till. Most of the flows there occur at a depth of from 58 to 65 feet, the average depth being 61 feet. The water rises from 10 to 20 feet above the surface, the average elevation for six wells being 14 feet. Mr. Russell gives the temperature as 43° for one well 87 feet deep, and 45.5° for another well 82½ feet deep. In two other wells 58 and 60 feet deep the temperature is given as 42°, while another well 64 feet deep is 45°. Mr. Emery Rose has sent me the following section of beds passed through there:—

Emery Rose well at Williamsburg.	Feet.
Sand	15
Blue clay	20
Sand	2
Blue clay	22
	60

I am also indebted to Mr. Russell for an analysis of the water from his well 45 feet deep which was made by John E. Clark:—

	Grains per U. S. gallon.
Sodium chloride	.2571
Sodium sulphate	.0085
Potassium sulphate	.0431
Magnesium sulphate	.5051
Magnesium carbonate	1.6671
Calcic carbonate	6.8410
Ferric oxide	.5004
Aluminic oxide	.3169
Silicic acid	.4907
Lithia carbonate (present but not estimated.)	
Organic matter	trace
	10.6299

Detroit College of Medicine, March 6th, 1893.

At Provemont there is an artesian well 780 feet down which was drilled about 1853. The flow amounts to one barrel per minute. I am obliged to Mrs. Florence M. Whitfield for an analysis of this water, which is as follows:—

Analysis of Whitfield well at Provemont.	Grains per U. S. gallon.
Sulphate magnesia	14.295
Sulphate alumina	4.172
Sulphate lime	6.005
Chloride sodium	1.240
Carbonate silica	1.96
Hydroxide of iron	.269
Total	27.941

	Cubic inches.
Sulphuretted hydrogen	10.09
Carbonic acid gas	29.14
Total	39.23

At Empire the flow is found in gravel at a depth of 60 feet.

East of Frankfort there are several flowing wells at Beulah, near the head of Crystal lake. The depth of water varies from 97 to 163 feet, the amount of flow in one well is stated to be 270 barrels per day, in another 300 barrels, the deeper wells having the greater head. Mr. H. T. Smith has sent me the following section of his well:—

	Feet.
Gravel and sand	10
Blue clay	20
Sand, solid clay and gravel	67

At Onekama, the shore of Portage lake is surrounded by a flat 20 to 40 rods broad, on which a flow may be obtained by driving a pipe, beginning at 15 to 20 feet with a one-half inch stream, and increasing in volume, in head, for greater depth. Mr. Davis' wells at 60 to 100 feet have a very strong flow, throwing a stream horizontally 10 to 20 feet.

At Hart the depth of water is 173 feet with head sufficient to throw the water 20 feet above the surface. Mr. Lane has obtained the following section of beds passed through at the Potato Starch factory situated there:—

Hart Potato starch factory well.	Feet.
Clay till	43
Water gravel	1
Plastic clay	129
Cavity	1
Total	174

The temperature of the water as determined by Mr. Lane with a standard self-registering thermometer was 49.5°, August 23, 1902.

Elbridge, situated 6½ miles east of Hart has a flow at a depth of 93 feet, the water rising 20 feet above the ground.

Mr. Isaac Timmons sends me the following sections of beds passed through there:—

Elbridge.	Feet
Sandy soil	30
Clay, into water-bearing gravel	63
	93

Southeast of Elbridge in section 25 of T. 15 N., R. 17 W., Mr. Amos Rellinger has the following log:—

	Feet.
Sand	24
Gravel	2
Clay, water-bearing sand	89
	115

In Muskegon county, according to C. D. McClouth, flowing wells are quite common along the shore, ranging in depth from 35 feet at Montague to some 250 feet at the south line of the county. Around Fruitport wells have a head of about 30 feet above the lake, or six feet above the ground.

In the southwestern portion of the lower peninsula, the variation in conditions producing flowing wells are very considerable. Six and one-half miles southeast of South Haven an artesian well has a depth of 228 feet, with the following section:—

Well near South Haven.	Feet.
Sand	20
Clay	170
Soft rock (Coldwater shale)	38
	228

Near Watervliet there are two wells with a depth of 45 and 50 feet, the flow being in sand and gravel, while another well in the drift is 89 feet in depth. In all these wells the flow is 10 feet above the surface. In the wells 50 and 89 feet deep the temperature is given as 50°. The water is hard, in common with the most of the wells in the Pleistocene. Near Hartford I have the records of two wells in the drift which are 44 and 58 feet deep, the water rising seven and ten feet above the surface. At Paw Paw flows are found in the lower levels of the Paw Paw valley at depths variously given as from 40 to 100 feet.

For artesian conditions in Cass county the reader is referred to the special report on that territory.

CHAPTER II.

SPRINGS AND NON-FLOWING WELLS.

At numerous localities in the lower peninsula of Michigan water horizons reach the surface. A large number come from gravel beds in the drift. In other cases where beaches have been left during the later stages of the Pleistocene or lacustrine epoch, small surface springs flow from the base of the beach. I suspect that in rare cases springs will be found to indicate interglacial deposits. The valley of the AuSable and the high cliffs around Frankfort and Newaygo may expose such formations. Where the margin of overwash sand and gravel beds lie above the till, fine springs are frequently found. When these areas have been indicated it will be possible to locate springs with quite a reasonable degree of certainty. Bed rock is so infrequently exposed in the lower peninsula as to make it a small factor in water supplies of this character. However, in

the Traverse formation near Alpena, I have seen quasi springs in sink holes where the subsurface drainage has eroded away the overlying limestone. Again as at Barron lake the water is derived from springs which serve as a water supply for Niles. In this connection it might be well to gage streams issuing from inland lakes, with a view to utilizing such water for city and town use. The water supply of Adrian, which is a source of serious consideration, might be obtained from lakes in the northwestern part of Lenawee county, but I doubt if the supply would be in the least adequate. In most cases our inland lakes are either drying up, or are represented by beds of muck. In this chapter it is intended to give all the information obtained relating to the geographical distribution of springs, but it is not presumed that the information is complete. Analyses of 12 springs have been obtained. Part of these have already been given in Mr. Alfred C. Lane's Water Supply report No. 31. The rest will be given at the end of this chapter.

In the valley of the Huron river above Ann Arbor there are a number of fine springs near Delhi in the same area. In the valley of the Paw Paw there is a spring southeast of Benton Harbor and another near Hartford in Van Buren county. In Jackson county there are a number of springs in Springport township, T. 1 S., R. 3 W., in the drainage basin of the Grand river. This area is indicated as covered with interlobate sand and gravel in plate 2 of Water Supply paper No. 30. In the same county springs have also been found near Brooklyn and Napoleon in the southeastern part of the county.

In Wayne county there is a spring at Plymouth in the northwestern part of the county. At Dorr and Moline in the basin of the Rabbit river springs are found in a region covered with sand and gravel. This is also true of Anderson in the southwestern part of Livingston county. In the eastern part of Oakland county there are springs near Thomas, Pontiac, and Troy, as well as in Macomb county near Mt. Clemens, and at Fraser in the southern part of the county.

In the basin of the Grand River there are similar water supplies at Spring Lake, Nunica, Crockery, Eastmanville, Grand Rapids, Bowen, Ionia and Lansing. This region is mostly covered with sand and gravel. Farther east in about the same latitude they are found at Owosso and St. Clair adjacent to the St. Clair river. In the northern part of Gratiot county, in the basin of the Pine river, there are springs in section 23 of T. 12 N., R. 4 W., near Elwell, Alma, St. Louis, and at Midland, where the Pine unites with the Tittabawassee river. In Oceana county there is a spring at Hesperia in the valley of the White river. Thence east at Big Rapids in the valley of the Muskegon we obtain similar flows. In Bay county springs are often found at the foot of beaches which were deposited in lake basins during the glacial retreat. The flow is quite limited. In the basin of the Muskegon river in Osceola county there are numerous springs in LeRoy township, T. 19 N., R. 10 W.; and near Marion in the northeastern part of the county. Also at Tustin, near the headwaters of the Manistee, springs are found. In Hatton township, T. 18 N., R. 4 W., there are similar flows along the headwaters of the Tobacco river. Likewise in the valley of the Tittabawassee near Highwood, springs are abundant. In the valley of the Manistee there are similar water supplies at Manistee, in Springville township, T. 23 N., R. 12 W., east of Beulah three miles, Manton in the northeastern part of the same county,

and at Cadillac. In section 18, T. 21 N., R. 1 W., and near Butman in the northwestern part of Gladwin county springs also occur.

At Frankfort and around the shores of Crystal lake there are springs at rather numerous locations. In Oscoda county there are springs at Luzerne and Mio in the valley of the AuSable river.

In the area adjacent to Grand Traverse bay and Lake Michigan, similar water supplies have been located on the eastern shore of Torch lake in T. 30 N., R. 8 W., near Norwood, in Jordan township, T. 31 N., R. 6. W., as well as at Levering. At Topinabee there is a spring of which an analysis will be given further on. At the headwaters of the Sturgeon river there are also a number northeast of Gaylord. In the basin of the Thunder Bay river, springs are also found at Big Rock, Atlanta and Alpena. While this list is not in any way complete it will serve to give some idea of the very general distribution of this source of water supply in the lower peninsula of Michigan.

Analyses of Springs.

Benton Harbor.

Four of these analyses have already been printed in Water Supply No. 31. The additional records here given were made by Prof. E. G. Smith of Beloit College, Wisconsin. They belong to the same group as the Eastman springs.

"Bimini" Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.052
Sodium sulphate	0.524
Sodium chloride	0.104
Sodium phosphate	0.017
Sodium borate	trace
Sodium bi-carbonate	0.262
Magnesium bi-carbonate	3.557
Calcium bi-carbonate	7.484
Iron bi-carbonate	0.075
Alumina	0.034
Silica	0.542
Total	12.651

"Winans," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.104
Sodium sulphate	0.314
Sodium chloride	0.093
Sodium phosphate	0.023
Magnesium sulphate	0.419
Magnesium bi-carbonate	3.126
Calcium bi-carbonate	5.564
Iron bi-carbonate	0.039
Alumina	0.058
Silica	0.402
Total	10.142

"Golden Fountain," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.116
Sodium sulphate	0.262
Sodium phosphate	0.040
Sodium chloride	0.093
Magnesium sulphate	0.180
Magnesium bi-carbonate	3.213
Calcium bi-carbonate	8.206
Iron bi-carbonate	0.384
Manganese bi-carbonate	trace
Alumina	0.017
Silica	0.408
Total	12.919

"Psyche," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.104
Sodium sulphate	0.507
Sodium chloride	0.016
Sodium phosphate	0.017
Magnesium bi-carbonate	2.257
Calcium bi-carbonate	6.604
Iron bi-carbonate	0.025
Alumina	0.058
Silica	0.513
Total	10.101

Analysis of water from a surface spring at Spring Lake, Ottawa county, Michigan. The color is clear; taste, saline; temperature, about 60° F. It is the property of E. C. Dyer of Chicago, but I obtained my information from Geo. H. Hammond of Spring Lake village.

Spring Lake.	Grains per gallon.
Potassium chloride	4.2880
Sodium chloride	405.5330
Calcium chloride	113.4200
Magnesium chloride	36.2000
Sodium bi-carbonate	0.9537
Calcium bi-carbonate	0.1808
Iron bi-carbonate	0.0060
Magnesium bi-carbonate	0.0640
Manganese bi-carbonate	0.0647
Magnesium bromide	2.1700
Sodium sulphate	46.7000
Silica	0.5030
Alumina	traces
Total fixed residue	629.3684

C. Gilbert Wheeler, Professor of Chemistry, University of Chicago.

Prof. I. V. S. Stanislaus of the University of Notre Dame has made an analysis of a spring belonging to H. H. Pike's Sons of Topinabee.

Topinabee Hill Springs. Physical examination showed:—

Color	none
Odor	none
Taste	soft
Reaction	neutral

Chemical examination:—

	Parts per 1,000.
Chlorine	.0155
Nitrogen and nitrates	.0037
Total hardness	.0210
Permanent hardness	.0180
Organic and volatile matters (by loss)	.0190
Total solids	.2410

The inorganic constituents contained potassium, sodium, calcium, magnesium bi-carbonates and chlorides, in small quantities.

NON-FLOWING WELLS.

In this report it is not intended to give any detailed account of ground waters which do not reach the surface. For those who are interested in geological work in the lower peninsula, however, it has been thought well to print all the sections which have not yet been published, inasmuch as they either fill in gaps of territory not heretofore covered or correlate sections already printed. Primarily these sections are intended for reference to those engaged in geological work in the lower peninsula or adjacent states.

To Mr. T. B. Pettit of Benzonia, Mich., I am indebted for the following log, which is in section 27, T. 26 N., R. 15 W.:—

Benzonia well.	Feet.
Sandy loam	4
Clay	19
Sand and gravel	50
Total	73

Mr. F. R. Deckrow, in a well put down for Chas. Richardson on section 16 of T. 25 N., R. 2 W., went through 90 feet of blue clay, the water being found in a gravel bed underneath. The water rises within 22 feet of the surface. In another well 186 feet deep, for Jacob Karner, T. 28 N., R. 4 W., the first 10 feet was of clay loam, the balance being sand. A third well made by the same driller for Mr. A. House in section 17, T. 28 N., R. 3 W., has a depth of 200 feet. The first 10 feet was sandy loam, the balance being sand and gravel. The water raised 10 feet.

At Highwood water is found at a depth of from 8 to 20 feet in gravel below the clay, the water in some wells rising to within 18 inches of the surface. To Mr. W. G. Hay of West Saginaw, Michigan, I am indebted

for the record of the following holes which were put down by Mr. A. J. Utter while prospecting for coal in the vicinity of Highwood, Gladwin county. In no case was bed rock reached. In well No. 3 the water rose within 18 inches of the surface.

Report on Wells at Highwood.

Well No. 1.

N. E. ¼ of S. E. ¼, Section 26, Town 18 N., R. 1 East.

1 ft.	Surface.
2 ft.	Sand.
37 ft.	Putty clay.
13 ft.	Hardpan.
2 ft.	Shell rock.
27 ft.	Sand; coarse river sand, indicating a wash out, or where the bed rock dips down to a great depth.
82 ft.	

Well No. 2.

S. E. ¼ of S. E. ¼, Section 27, T. 18 N., R. 1 East.

1 ft.	Muck.
3 ft.	Sand.
35 ft.	Putty clay.
16 ft.	Hardpan.
12 ft.	Putty clay.
5 ft.	Hardpan.
20 ft.	Putty clay.
8 ft.	Hardpan.
16 ft.	Putty clay.
5 ft.	Hardpan.
25 ft.	Red marl.
31 ft.	Sand (wash out).
176 ft.	Total.

Well No. 3.

N. W. ¼ of N. E. ¼, Section 3, Town 17 N., R. 1 East.

32 ft.	Clay.
9 ft.	Hardpan.
12 ft.	Putty clay.
2 ft.	Hardpan.
39 ft.	Quicksand (not through sand).
94 ft.	Water to within 18 inches of the surface.

Well No. 4.

S. E. ¼ of N. E. ¼, Section 34, Town 18 N., R. 1 East.

1 ft.	Muck.
2 ft.	Quicksand.
37 ft.	Putty clay.
10 ft.	Hardpan.
16 ft.	Hard black gravel clay.
14 ft.	Hard black gravel clay.
32 ft.	Hard black gravel clay.
14 ft.	Hardpan.
35 ft.	Red marl, streaked with gray.
1 ft.	Sand.
162 ft.	

Well No. 5.

S. E. ¼ of S. E. ¼ of Section 13, T. 18 N., R. 1 W.

1 ft.	Muck.
1 ft.	Sand.
1½ ft.	Marl.
2 ft.	Sand.
12 ft.	Putty clay.
5 ft.	Hardpan.
15 ft.	Putty clay.
8 ft.	Hardpan.
11 ft.	Putty clay.
10 ft.	Hardpan.
22 ft.	Putty clay.
4 ft.	Sand and gravel—good vein of water in this gravel.
9 ft.	Hardpan.
40 ft.	Gravelly clay.
20 ft.	Putty clay.
33 ft.	Hardpan.
38 ft.	Quicksand.
232½ ft.	(Still 12 ft. of sand.)

Mr. John Sisson of Imlay City has sent the following log of his well. It is situated in Section 33 of T. 8 N., R. 12 E.

Well near Imlay City.	Feet.
Clay	4
Fine water sand	50
Quicksand	6
Coarse gravel	1
Blue putty clay	19
Shale rock? (Coldwater)	73
	153

The Antrim Iron Co. at Mancelona has a well from 250 to 300 feet deep, the depth to principal source of water being 65 to 70 feet. Sand and gravel formed the greater part of the strata passed through. A bed of clay 10 to 20 feet thick was struck at 160 to 215 feet from the surface.

This well apparently did not reach the rock. To the Antrim Iron Co. I am indebted for the following analysis:—

Mancelona. Antrim Iron Co.	Grains per U. S. gallons.
Silica	.5240
Oxides iron and alumina	.1458
Carbonate of lime	7.4646
Carbonate of magnesia	2.4493
Sulphate of lime	.5248
Sodium and potassium chlorides	trace
Sodium and potassium carbonate	.3218
Total solids	11.4303

The Michigan Sulphate Fibre Co. of Port Huron has very obligingly sent me through their manager, Mr. O. L. E. Weber, the following sections, analysis and data. I quote from Mr. Weber's letter and report:—

"Well No. 1 was drilled in the spring of 1898, our object being a search for either gas or oil for fuel purposes. Six-inch and eight-inch pipe was used to the slate and smaller pipe continued down. At a depth of 266 to 267 feet from the surface we encountered quite a strong flow of gas, pressure of which ran up to over 75 lbs. gauge, and the entire pressure was blown off in about two days through a seven-inch pipe and has not recovered since. Analysis of the same you will find as the last item in the description of these wells. At 575 feet we began to get traces of salt and the well was discontinued at 600 feet. The following is the data of the material passed through as given by Mr. A. Morrison, the well driller.

Wells 2, 3, 4, and 5 were drilled in the fall of the year 1900, our object this time being a search for a supply of water for our mill. The following is a description of the four wells:—

Data of material gone through in well No. 1, Port Huron.

	Feet.
From surface to 78 feet, drift sand	78
From 78 feet to 102 feet, blue clay	24
From 102 feet to 107 feet, gravel drift clay with pebbles	5
From 107 feet to 187 feet, slate	80
From 187 feet to 215 feet, top lime rock	28
From 215 feet to 266 feet, soap stone	51
From 266 feet to 311 feet, lime rock	45
From (266 feet to 267 feet), gas	
From 311 feet to 319 feet, soap stone	8
From 319 feet to 321 feet, lime rock	2
From (319 feet to 321 feet), gas	
From 321 feet to 415 feet, soap stone	94
From 415 feet to 417 feet, middle lime	2
From 417 feet to 482 feet, lower soap	65
From 482 feet to 600 feet, lower lime	118
	600

Well No. 2, Port Huron.

From surface to 48 feet, sand and drift.
From 48 feet to 64 feet, blue clay.
From 64 feet to 72 feet, coarse gravel.

Well No. 3, Port Huron.

From surface to 46 feet, sand or drift.
From 46 feet to 62 feet, blue clay.
From 62 feet to 70 feet, gravel.
From 70 feet to 101 feet, blue clay and 1 foot of black sand.
From 101 feet to 391 feet, black shale.
From 391 feet to 491 feet, soap stone.
From 491 feet to 521 feet, lime rock with strong flow of gas.
From 521 feet to 651 feet, soap stone.
From 651 feet to 728 feet, lime rock with indications of petroleum.
This well showed very little water on top of bed rock. Well was cased with 46 feet of wooden conductor, 10 inches diameter on the inside. One hundred and four feet of eight-inch pipe to bed rock.

Well No. 4, Port Huron.

From surface to 48 feet, sand or drift.
From 48 feet to 65 feet, blue clay.
From 65 feet to 74 feet, gravel with large supply of water.

Well No. 5, Port Huron.

From surface to 48 feet, sand or drift.
From 48 feet to 65 feet, blue clay.
From 65 feet to 76 feet, gravel.

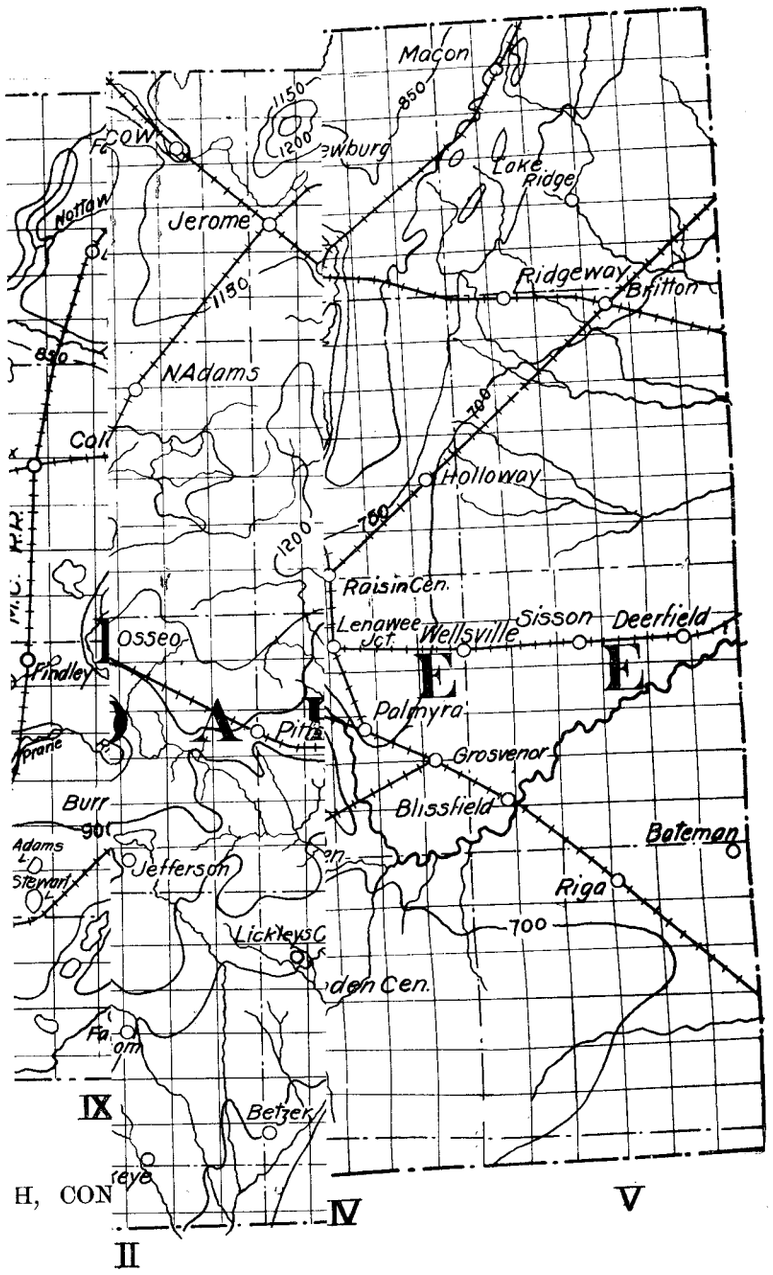
Wells 2, 4 and 5 are cased with a wooden conductor 46 feet deep, 10 inches inside diameter and continued with 10-inch iron pipe to the depth of the well excepting No. 5 which has a 12-inch instead of a 10-inch pipe.

The wells are stopped at the bottom with wooden plugs, each with about 400 ½-inch holes extending up from the bottom of the pipe about seven feet.

Water in the wells rose to within about 19 feet of the surface and at the time observations were taken this was about one foot below the surface of Black river. The wells were pumped 10 hours a day for about two weeks with the idea of freeing the water from the iron held in suspension, but it did not free it to any appreciable extent. The following is an analysis of the water:—

Suspended matter 66.00 parts per million, mostly clay carrying iron. The filtrate analyzed as follows:—

	Parts per million.
Silica ($Si O_2$)	27.40
Iron and alumina (Fe_2O_3 Al_2O_3)	1.15
Lime (Ca O)	128.80
Magnesia (Mg O)	33.85



The following is an analysis of gas from well No. 1:—

Marsh gas (Methane)	88.64%
Hydrogen	2.27%
Carbon monoxide	0.20%
Nitrogen	8.89%
Total	100.00%

CHAPTER III.

TOPOGRAPHY AND WATER POWER OF LENAWEE, HILLSDALE, BRANCH, ST. JOSEPH AND CASS COUNTIES.

In the descriptive portion which pertains to this chapter, the elevations are given above tide. By this is meant the elevation above the average sea level height of New York bay. This is the zero which has been adopted by the U. S. Government, and all topographic elevations are stated as so many feet or fractional parts of a foot above this datum or zero. In the contour lines which are represented on the maps forming part of this report, each line is intended to represent the same constant elevation above sea level, or above tide as it is usually stated. This is generally abbreviated A. T. In this connection I cannot do better than quote Mr. Alfred C. Lane as to the proper significance of contours.[1] "As we have said, in 1896, Lake Huron had been retreating. Imagine the process suddenly reversed, and the lake suddenly raised 10 feet and the new shore line marked upon the map. Suppose the lake raised 10 feet more, and the resulting shore line marked upon the county. Such lines would be called contour lines and all points of a given contour line are obviously at the same level above the lake." In the maps presented in this report the contour lines are represented at intervals of 50 feet of vertical elevation, and are only approximately located, but one line of elevations having been taken through each township. In the map of Lenawee county it will be observed that the lowest line is marked 700 A. T. This means that if Lake Erie were to rise 130 feet from its present elevation of about 570 feet above tide the shore line of the lake would wash the hills and plains and form inlets up the valleys as approximately indicated by the 700-foot line A. T. The same would be true of each successive line of greater elevation. In the different intervals islands would appear. These imaginary islands are represented by contour lines which entirely enclose a certain amount of land. Such areas will be observed northeast of Tecumseh and at Prospect Hill in the northwestern part of Lenawee county. It will be readily observed that there is a great advantage in having a common base as a reference plane from which to estimate all points of elevation, and in this report it may be understood that sea level in New York harbor furnishes such a base. High water of 1838 in the great lakes is supposed to be 584.34 feet above it (i. e., 584.34 A. T.).

[1] Michigan Geological Survey, Vol. VII, part 2, P. 42.

Highest Elevations.

Within this area the highest elevation is at Bunday hill, situated in section 8 of Somerset township, Hillsdale county, T. 5 S., R. 1 W., the altitude being 1,284 feet above tide as given in the report of the U. S. Lake Survey. At another station in the northwest quarter of section 29, T. 6 S., R. 1 W., the elevation is 1,247 A. T. In the intervening area about the lowest elevation is near Jerome Station where the surface drops to 1,105 A. T. This axis of elevation runs north and south, very nearly one mile east of the line between ranges 1 and 2 west. The northern limit is Bunday hills, while southward the elevation at Pittsford geodetic station is 1,149 A. T., the depot at Pittsford being 1,087 A. T. These elevations form part of a morainal accumulation which was deposited by the Huron-Erie glacier lobe. This area of greatest elevation forms the divide between the waters of Lake Erie and Lake Michigan and is approximately one-third of the distance across the state going west.

Lenawee County Moraine.

On the east side of the Hillsdale watershed the elevation falls quite rapidly to the east, in Lenawee county. The highest elevation within this county is Prospect hill, which is about 100 feet lower than Bunday hill, or 1,184 feet A. T. Where the Raisin river enters Monroe county the altitude is less than 650 A. T., making the extremes of elevation 634 feet. Prospect hill is located in section 13 of T. 5 S., R. 1 E. The Huron-Erie glacier lobe deposited in its retreat a great amount of morainal accumulation in the northwestern part of this county including the Prospect hill area, the principal moraine leading from Hudson northeast in an irregular line to the northeastern corner of section 5, T. 5 S., R. 3 E.

Inside of this area the greater part of the lakes in Lenawee county may be found. Posey lake, northeast of Hudson, is 933 A. T. This has an outlet into the Tiffin river. Devil's lake is 1,051 feet A. T. Pickerel lake in the northeast quarter of section 14, T. 5 S., R. 1 E., is 971 feet A. T., being very nearly on the same elevation as Deep lake, which is on the other side of Prospect hill. Lake Dody and Lake Washington, situated southeast of Cambridge in T. 5 S., R. 2 E., both have an elevation of 996 A. T. Goose lake, southeast of Woodstock, is about 1.005 A. T.

Later Huron-Erie Moraines.

East of this principal moraine last described, there are three small inlying moraines, deposited by the same Huron-Erie glacier lobe. As will be seen on the map, they trend southwest, ending at the north, west of Tecumseh, and at the south, northwest of Adrian. For the most part they are in townships 5 and 6 S., and R. 3 E. The elevation of the most westerly one reaches a height of 860 A. T. The extension of this moraine to the south causes Wolf creek to form a loop in the same direction, before emptying into the Raisin river at Adrian.

Moraine West of Hillsdale.

West of Hillsdale there is another very considerable area of glacial accumulation which has a northwesterly trend, the northern limit being near the road from Jonesville to Quincy, the southeastern end is about

three miles west of Pittsford. On both flanks there is a chain of lakes and ponds which either form areas due to the unequal amount of glacial accumulation, the melting of buried or surface ice masses, or glacial drainage valleys which have become filled up by glacial or post-glacial erosion, the lakes representing glacial mill ponds, as it were. Within this area the highest elevation of which I have any knowledge of, is the station of the U. S. Lake Survey. This is situated in the west half of section 27 just southwest of Hillsdale. The elevation is 1,238 feet A. T. The elevation of the Lake Shore depot at Hillsdale is 1,085 A. T. On the road leading south from Hillsdale and two miles west of the range line, the highest elevation is 1,219 feet A. T. This is four-tenths of a mile north of the east quarter post of section 10. Thence south the elevation drops to 1,042 at Cubb lake in section 34, T. 7 S., R. 3 W. This forms the southern extremity of the same chain of which Sand lake is the northern link. Cubb lake is near the headwaters of one of the feeders to St. Joseph of the Maumee. Camden, which is situated on another tributary of the same stream, is in the southwestern part of the county and is approximately 988 feet A. T. The main branch of the St. Joseph of the Maumee is in the southeastern part of Hillsdale county. Near the northeast corner of section 28, T. 7 S., R. 1 W., the elevation is 926 A. T. A feeder which starts about one-half mile south of Pittsford has an elevation of 1,025 A. T. Laird creek, another branch of the same stream, has an elevation of 985 A. T., just north of the east quarter post of section 16, T. 8 S., R. 2 W. Burt creek, another feeder, is 905 feet A. T., a few feet east of the northeast corner of section 23, T. 8 S., R. 2 W. Where this creek heads in Bird lake the elevation is 1,040 A. T.

Moraine at Reading.

Another deposit of morainal accumulations is west of the Hillsdale moraine. The main trend is north and south of Reading. At the Lake Survey station in the northwest quarter of section 24, T. 7 S., R. 4 W., the elevation is 1,208 A. T. Four and one-half miles south the elevation at Camden is 988 A. T. as already given. To the north the elevation drops to 1,081 A. T. within six miles.

Moraine North of Hillsdale.

North of Hillsdale there is a knoll of morainic material which accumulated on the southern border of the Saginaw shoulder. In the southeastern quarter of section 29, T. 5 S., R. 3 W., the elevation is 1,150 A. T. The area is quite circumscribed.

Moraine in Western Branch County.

On the western side of the Hillsdale watershed in Branch county, there are several irregular areas of morainic deposition. The ice retreating to the northwest deposited in the western part of Branch county a moraine which leads northeast, west of Bronson, within two miles west of Union City. From there the course southwest is about parallel with the St. Joseph river. At the station of the U. S. Lake Survey in the southwest quarter of section 16, T. 7 S., R. 8 W., the elevation is 997 A. T.; at the northeast corner of section 33, T. 5 S., R. 7 W., the altitude has fallen to

975 feet. Matteson lake, situated within this area, has an elevation of 889 feet. The drainage is all westward into the St. Joseph river.

Lakes in Central Branch County.

After the deposition of this moraine there was a period of recession, during which time the drainage was parallel with that of the moraine last deposited, and in front of the retreating ice mass. This may account for the chain of lakes which extends northeast of Bronson towards Girard. The lakes appear to be formed of ice drainage outlets which were locally dammed up by either glacial or post-glacial material.

To the south and east of Coldwater there are several lakes within the limits of the Huron-Erie lobe. The Huron-Erie glacial lobe entered Michigan in the southeastern part of Branch county, forming a scattered, irregular moraine south of Quincy. North of Quincy the deposits are to be referred to as the Saginaw shoulder, which extends as far west as Coldwater, thence east to Jonesville and northeast to Mosherville in Hillsdale county.

Lakes in Southeastern Branch County.

Marble lake, situated between the Saginaw shoulder and Huron-Erie glacier, has an elevation of about 1,000 A. T. Coldwater lake is 950 feet above tide. California P. O., which is situated on the Huron-Erie lobe, is about 1,031 feet A. T. The highest elevation which has been determined on the Saginaw shoulder in the northeast part of Branch county, is in the southwest quarter of section 8, T. 6 S., R. 5 W. The station of the Lake Survey situated there has an elevation of 1,060 A. T.

Glacial Drainage.

Mr. Leverett informs me that as the great ice mass retreated north from Branch county the united drainage from the Michigan lobe on the west, the Saginaw shoulder which had not yet reached the form of a lobe, in the center, and the Huron-Erie lobe on the east, poured their united drainage down what is now the valley of the St. Joseph river. At that time it must have presented the appearance of a great glacial Amazon, the united waters laden with sediment, forming a stream many times greater in volume than the present river.

Sturgis Moraine.

St. Joseph county has a fine, well marked moraine in the southern portion, which Mr. Leverett has designated the Sturgis moraine. On the west it almost reaches the road which runs southwest from Centerville to Constantine reaching into section 16, T. 7 S., R. 11 W. From there the main axis of the moraine trends east and south of Burr Oak. Near the east quarter post of section 18, T. 7 S., R. 10 W., and just south of the northeast corner of section 19, in the same township and range, the elevation is 942 feet A. T. North and south from here the elevation falls rapidly. To the north, the east quarter post of section 30, T. 6 S., R. 10 W., is 830 A. T. South the descent is even more abrupt. In the creek which crosses the line, four-tenths of a mile north of the east quarter

post of section 31, T. 7 S., R. 10 W., the elevation is 823 feet A. T. This creek runs in a valley 61 feet high on the south side and 70 feet high going north, draining into Klinger's lake, and thence on into the Fawn river. Where the U. S. Lake Survey Station was situated in the northeast quarter of section 22, T. 7 S., R. 10 W., the elevation is 1,037 feet A. T. This is the highest point that I know of either on this moraine or in St. Joseph county. East of here, where the moraine is crossed by the G. R. & I. R. R., the greatest surface elevation is 960 feet A. T. This is 2¾ miles north of Sturgis. Sweet lake, on the south side of the moraine, and east of Sturgis, is 895 feet A. T.

Topography in St. Joseph County.

West of Sturgis the country is a plain, gently sloping to the west. In the valley of the St. Joseph river the country is level going from Nottawa to Mendon, Leonidas and Colon, the same topography being found between Three Rivers, Moorepark and Parkville. South of the St. Joseph river on the road leading from Parkville to Centerville, the land is rolling with undrained hollows. The east side of the St. Joseph river valley is level as far as White Pigeon and two miles east of there.

Interlobate Moraine.

In the western part of St. Joseph county and the eastern part of Cass there is a pronounced interlobate moraine. Going south from Vandalia the crest of this moraine is a well marked ridge trending east and west and having an extreme elevation of 977 feet A. T. This is one-tenth of a mile north of the east quarter post of section 28, T. 7 S., R. 14 W. One mile north from here the descent is 100 feet. To the south the elevation drops 117 feet in 1½ miles. Where the U. S. Lake Survey station was situated in the northeast quarter of section 27, T. 7 S., R. 14 W., the elevation is 1,010 feet A. T. In the southeastern part of T. 8 S., R. 13 W., the top of the moraine leads southeast, being 903 feet high in the southeast quarter of section 33, T. 7 S., R. 13 W.

In the semi-morainic area of this interlobate moraine the main trend is towards the northeast. At Jones the elevation is 921 feet A. T., the great mass of the moraine increasing in elevation northward. Northwest of Jones, Bald hill is 1,070 feet A. T. Another hill situated about three-tenths of a mile south and one-half mile west of the east quarter post of section 16, T 6 S., R. 13 W., has an elevation of 1,115 feet, which is probably the highest elevation in Cass county. This pronounced interlobate moraine is continued northeast into St. Joseph county. In the north half of section 33, T. 6 S., R. 12 W., there is a knoll having an elevation of 1,011 feet. North from here the descent into the drainage valley of Rock creek is quite rapid. Fabius, situated on the southern side of this interlobate area, has an altitude of 896 feet. Going north from Fabius the topography is hilly, many lakes being imprisoned in the moraine. Forming a pronounced ridge on top of this elevated moranic area is a hill range trending southwest through sections 6, 5 and 4, of T. 6 S., R. 12 W., and sections 33, 34 and 26 of T. 5 S., R. 12 W. Within this area the elevation is above the 950 foot contour line, culminating at a height of 1,011 feet A. T. The topography has much of the appearance of one moraine being built on top of another. This may be due to a readvance of the ice.

Rock creek, which bounds this interlobate moraine area on the north has an elevation of 825 feet at Howardsville and 839 feet on the road leading south from Marcellus. This creek meanders through a rolling country, and may have drained the front of the ice during its subsequent retreat.

Lakes of the Interlobate Moraine.

There are numerous lakes in the area of this interlobate moraine. Lake Baldwin and Long lake are situated in front of the morainic deposit in the southeastern part of Cass county, and are long, crooked lakes which have the appearance of drainage channels from off the ice, which were later obstructed by glacial or post-glacial drainage. In sections 21, 22, 23, 24, and 13, T. 7 S., R. 14 W., there is a chain of lakes draining into Christian creek. The most important of these are Curtis, Day, Sharps, and Clear lakes. The lakes are within the moraine and may have originated by the melting of ice masses forming the so-called "kettle-holes," by obstructed glacial drainage, or by the unequal deposition or settling of glacial debris. On the line between sections 21 and 22 the stream channel connecting these lakes has an elevation of about 838 feet A. T. In the less sharply morainic area southwest of Jones, Bear lake is without any outlet and is of morainic origin. The elevation is 883 feet A. T. Skyhawk lake on the road from Marcellus to Jones is on the northern edge of this moraine and drains into Rock creek. The elevation is 847 feet A. T. In the area west of Three Rivers in St. Joseph county there are numerous lakes imprisoned in the moraine area. Pleasant lake, in section 9, T. 6 S., R. 12 W., has an elevation of 58 feet above the Michigan Central depot at Three Rivers, the respective elevations being 795 and 853 A. T. The region is heavily covered with sand and gravel and may represent a cusp dumping ground.

Lake Michigan Glacier Lobe.

The eastern border of the Lake Michigan glacier lobe enters the lower peninsula a few miles east of the southwest corner of Cass county. From here there is a well defined morainal area leading to Cassopolis, varying in width from one to three miles. At Cassopolis the moraine is somewhat interrupted by glacial drainage from Stone lake which empties into Pokagon creek. Northeast from Cassopolis the east side of the moraine is west of and approximately parallel to the Grand Trunk R. R., leaving Cass county near the northeast corner of section 2, T. 5 S., R. 13 W. There is also a pronounced morainal ridge running northwest through section 3, T. 5 S., R. 15 W., north through section 22, T. 5 S., R. 15 W., and on up to Kalamazoo.

The elevation of this moraine is quite considerable. At the U. S. Lake Survey station in the southeast quarter of section 4, T. 8 S., R. 16 W., the altitude is 896 feet above sea level. On the road from Barron lake to Edwardsburg the moraine rises from an elevation of 774 to 859 feet A. T., on the west side, the greatest elevation being 894 A. T., in the east half of section 36. Going on towards Edwardsburg the drop is from 862 to 823 feet A. T. Just west of Cassopolis the greatest elevation is 931 above sea level. The west front of the moraine has an altitude of 889 feet on the same road. West from there the drop is quite rapid, the elevation of the old glacial channel on the north line of section 33 being 826 feet or

32 feet lower than the same drainage outlet between the east side of the moraine and the city of Cassopolis. On the road leading north from Penn the foot of the moraine has an elevation of 896 A. T., at the east quarter post of section 9, T. 6 S., R. 14 W. Just north the crest rises 48 feet. One mile north the elevation has increased to 968 A. T. at the east quarter post of section 4. The greatest elevation that I obtained within this tract is one-tenth of a mile west of the northeast corner of section 27, T. 5 S., R. 13 W., where the altitude is 982 feet A. T. On the western side of the moraine and east of Dowagiac, the west crest of the morainal accumulations are marked by a fine hill range well adapted for fruit culture. The elevation here is 943 feet A. T., and is four-tenths of a mile east of the northwest corner of section 3, T. 6 S., R. 15 W., the elevation of the corner being 840 A. T. The moraine falls off rapidly towards La Grange and is recessed by a creek valley, which heads in northeast of Volinia. On the quarter line road in section 22, T. 5 S., R. 15 W., the greatest elevation that I obtained was 895 A. T., which was one-tenth of a mile west of the east quarter post. Seven-tenths of a mile west the west front of the moraine is 891 feet above sea level. Mr. Leverett makes the elevation through here 930 feet A. T., and it is in deference to him that the 900 foot contour line is run. Very nearly one mile west the Michigan Central profile has an altitude of 842 feet A. T. To the west Dowagiac creek served as the cusp drainage for the west side of this lobe.

Lakes in Western Cass County.

Within this general area the elevations of several lakes were obtained. Barron lake, which serves as a water supply for Niles, is 754 A. T., or 75 feet above the Michigan Central depot there. Eagle lake, near Edwardsburg is 823 feet above sea level. Stone lake, which supplies Cassopolis with water, has an elevation of 857 feet A. T. The lake at La Grange, which is really a great mill pond, is 810 A. T.

Intermorainic Area.

In the area between the Michigan moraine and the interlobate area, the country is rolling, the present surface drainage being into the St. Joseph river. Christian creek is the largest stream in this territory. Most of the intermorainal area is contiguous to the Grand Trunk R. R., and that furnished data for the altitudes. At Edwardsburg, the elevation is 829 A. T., increasing to 891 feet A. T., at Cassopolis and 888 at Marcellus.

ELEVATION OF STREAMS.

During the course of this work considerable information was obtained relative to the elevation of streams. Given the amount of fall and the quantity of flow in the stream channel, we have two of the principal factors which determine its utility for water power. While the stream elevations here given are not always accurate, I believe that the amount of error is less than five feet. The gaging of streams does not fall within the province of this report. In Michigan, Mr. Robert E. Horton has had the establishment of water gage stations, over 60 stations being recently set. The results are published annually in the Water Supply and Irrigation Papers (49, 65, 75, 83), issued by the Division of Hydrography of

the U. S. Geological Survey. In this connection it should be mentioned that Mr. Horton has published some results of his work on water power in Water Supply paper No. 30, p. 22, et sequor, and in the Proceedings of the Michigan Engineering Society for 1901. In Water Supply and Irrigation paper No. 83, p. 265, the results of gage readings at Mendon are given.

In the report of the tenth census there is considerable information relative to dam locations in the southeastern part of the state.

Naming of Streams.

At the outset it was found that the nomenclature for streams is not very uniform or consistent. In the map of Branch county in Volume V of the Michigan Geological Survey report, Coldwater river is indicated as flowing into Hog creek, in the northern part of Branch county. Also in Rand-McNally's sectional map of Michigan there are two Bear creeks in St. Joseph county, while the Tiffin river in the western part of Lenawee county is formed by the union of another Bear creek and Hillsdale creek, the two streams uniting above Hudson. In the blue print maps which were used in the field, the St. Joseph river is called Nottawa creek, in its course in St. Joseph county above Three Rivers, being properly designated in its upper reaches in Branch and Hillsdale counties. In Rand-McNally's sectional map of Michigan Nottawa creek is represented as rising in the southern part of Kalamazoo county. From there the course is approximately parallel with the St. Joseph river, the outlet of the stream being three miles east of Mendon.

I believe that Mr. John F. Nellist's blue print maps which were used in field work are largely based on county atlases. In the same blue print maps Prairie river in the southern part of Branch county is indicated as emptying into another Hog creek, which otherwise is known as Spring creek, in its course through Centerville, and on to the St. Joseph river. The Pokagon creek on our blue print maps is called Putnam creek in the Rand-McNally map. I have used the former name as preferable. In Hillsdale county there are three St. Joseph rivers. One which has already been mentioned in the northwestern part of the county, passing through Jonesville and Litchfield. The other two are tributary to the drainage into Indiana, one flowing southeast through Camden. The third, which runs southwest in the same territory has a handle, being designated as St. Joseph of the Maumee, which is at least specific, if somewhat cumbersome.

I have not presumed to establish the nomenclature in all these cases. In the case of Nottawa creek the error is obvious and the name should be used as designated on Rand-McNally's map. The name Prairie river I have used instead of Spring creek, the duplicate name of Hog creek being only used for the stream in the northern part of Branch county. This is in accordance with common usage. The other streams are relatively unimportant. It is obvious, however, that there should be established some clear and consistent nomenclature.

Elevation of Streams and Dams.

In the list of improvements only the location of such dams and the elevation of stream courses are given as were obtained incidental to the main question of water supply. What I have endeavored to do is to determine wherever possible, and with as much accuracy as possible, the elevation of the different streams which will give some idea of their utility for water power when properly gaged, the elevation of the streams being obtained below the dams unless otherwise mentioned.

The River Raisin, according to Mr. Leverett, has an elevation of about 645 feet A. T. at Deerfield; of 664 feet above the dam at Blissfield; of 686 A. T. at Palmyra. Mr. Leverett makes the elevation at the R. R. crossing in section 21, Raisin township, 703; four-tenths of a mile east of Sutton of 715 A. T. At Tecumseh the altitude of the stream below the dam is 744 feet as determined by the U. S. Topographic Survey. The dam at this point is 18 feet high. The altitude below the dam at Clinton as determined by the Topographic Survey is 799 feet; at the Lenawee-Washtenaw county line of 808 feet A. T. Near Somerset Center the elevation is about 1026 feet A. T. Dams have been put in at Deerfield, Blissfield, Palmyra, Tecumseh, Clinton, River Raisin, and various other points as far up as Somerset Center. That at Palmyra is 5 feet high, but washed out this year, and at Somerset Center 11 feet. The mill at Somerset Center is situated not far from the head waters of the stream, which is fed by a large spring.

South Branch of Raisin River.

The south branch of the River Raisin is 731 feet above tide at Adrian and 831 feet high on the line between sections 2 and 3, T. 7 S., R. 2 E. Wolf creek is 935 A. T. high at Springville in T. 5 S., R. 2 E. and about 730 feet A. T. where it empties into the south branch of the River Raisin near Adrian.

Black Creek.

Black creek heads northeast of Hudson, emptying into the River Raisin about three miles west of Blissfield. On the section line 3 and 4, T. 8 S., R. 4 E. the elevation is 686 A. T.; ½ mile south of Jasper the height is 723 A. T.; near the northeast corner of section 15, T. 8 S., R. 2 E. the elevation is 783 A. T.; at the northeast corner of section 9, T. 8 S., R. 2 E. of 793 A. T.

Tiffin River.

Where the Tiffin river is crossed by the Lake Shore and Michigan Southern R. R. in section 24 of T. 8 S., R. 1 E. the elevation of the track as given by Mr. Leverett is 794 feet and of the stream about 775 feet A. T. One-tenth of a mile south of the northeast corner of section 36, T. 7 S., R. 1 W. the height is 869 feet A. T., the elevation increasing to 887 feet three-tenths of a mile south of the northeast corner of section 25 in the same township and range. At Hudson the stream is 898 feet above sea level. There are dams in the river in section 36 and at Tiffin.

In Cass county there are several small powers. Christian creek formerly had a dam at Vandalia. The elevation of the stream there is 861 A. T.

One-half mile south of the northeast corner of section 9, T. 7 S., R. 14 W. the elevation is approximately 847 feet A. T.

Pokagon creek is 730 feet high at Pokagon falling 55 feet where the stream crosses the road, six-tenths of a mile west of the northeast corner of section 31, T. 6 S., R. 15 W. This makes the fall very nearly 9 feet per mile. If the same rate is continued down stream to where the creek empties into Dowagiac creek, two miles west of Pokagon, the elevation would be approximately 712 A. T. for both streams. Mr. Leverett gives the elevation of Dowagiac creek on the north line of section 16, T. 6 S., R. 16 W. as 720 A. T. In the northeast quarter of section 27, T. 5 S., R. 16 W. the elevation of the north fork is about 723 A. T. increasing to 728 feet near the northeast corner of section 24, T. 5 S., R. 16 W. The south fork of this stream is 800 feet A. T. below the 10 foot dam at La Grange. The millpond here floods over several fractional sections of land. Near the corner of sections 1, 2, 11, and 12, T. 6 S., R. 15 W. there is another power utilized by a farmer for a feed mill. Between the two forks of Dowagiac creek is situated what is known as the Marguerite mill. This is on the quarter line of section 13, T. 5 S., R. 16 W. The creek there is tributary to the north fork of Dowagiac creek and is 738 feet A. T. The dam is 8 feet high. There are probably a number of small powers along Dowagiac creek and its tributaries which could be utilized for local milling purposes or village electric light plants.

St. Joseph River.

The St. Joseph river of lower Michigan and northern Indiana rises north of Hillsdale and empties into Lake Michigan at St. Joseph. In St. Joseph county at Constantine the stream has an elevation of 762 feet A. T. Mr. James E. Bunn, city clerk of Three Rivers informs me that "the water in the St. Joseph river below the dam at the St. Joseph cement bridge is 14.5 feet below the top of the rail of the Michigan Central R. R. track at their depot."

"The water in the race adjacent to the M. C. depot is 8 feet below the top of the rail at that point."

"The water in the St. Joseph river below the dam at the St. Joseph cement bridge is 11.2 feet below the top of the rail of the L. S. & M. S. R. R. tracks at their depot."

"These measurements were taken in August, 1902, when the water was at an ordinary stage—neither low nor high. At the present time (Nov. 10, 1903) there would be considerable difference, owing to the low stage of the water."

The elevation of the Michigan Central tracks at their depot is 795 feet A. T., which would make the elevation of the river 780 feet A. T.

In the east half of section 10, T. 6 S., R. 11 W. the river is approximately 795 feet A. T. under the bridge. One-tenth of a mile south of the east quarter post of section 27, T. 5 S., R. 10 W. in the village of Mendon, I made the elevation 826 feet A. T. There is a gage located here. Where the stream is crossed by a bridge in the northeast quarter of section 3, T. 6 S., R. 9 W. the altitude is approximately 835 feet A. T.

In Hillsdale county the river has an elevation of 991 A. T. at Litchfield, and of 1085 feet at Jonesville. There are dams at both places, the one at Jonesville being an overflow dam between 6 and 7 feet high.

Fawn River.

This empties into the St. Joseph river in Constantine, where as we have seen, the elevation of the main stream is 762 feet above tide. Where this tributary river is bridged in the northwest quarter of section 28, T. 7 S., R. 11 W. the height is 797 feet. At the intersection of the G. R. & I. R. R. one mile south of the Michigan state line the elevation has increased to 855 A. T. This stream drains the region south of the Sturgis moraine, and a small part of northern Indiana.

Prairie River.

This water course, which is otherwise known as Hog creek or Spring creek in its lower reaches, has two forks in the south central part of Branch county, one rising in Pleasant lake, the other in Cook lake. Westward the river passes near Burr Oak, through Centerville, emptying into the St. Joseph river not far south of Three Rivers. The following elevations were obtained: Just south of the Michigan Central R. R. at Centerville the height is 803 A. T. Where the stream is crossed by the G. R. & I. R. R. less than one-half mile east of Nottawa the elevation of the stream is 825 feet above sea level. Just north of the northeast corner of section 22, T. 7 S., R. 9 W. the altitude has increased to 859 feet A. T.

In Branch county one-tenth of a mile south of the northeast corner of section 26, T. 7 S., R. 8 W. the height is 911 A. T., increasing to 930 feet, two-tenths of a mile north of the southeast corner of section 32, T. 7 S., R. 7 W.

Portage River.

This stream unites with the St. Joseph river at Three Rivers, where as we have seen, the elevation is 780 feet A. T. Three-tenths of a mile south of the northeast corner of section 27, T. 5 S., R. 11 W. the height is about 820 A. T. Where the stream is crossed by the G. R. & I. R. R. in section 22, T. 5 S., R. 10 W. the elevation is 835 feet A. T. This stream rises in the eastern part of Kalamazoo county running southwest.

Bear Creek.

This water course runs across the southeastern part of Kalamazoo county, emptying into Nottawa creek west of Leonidas. Where the two streams unite two-tenths of a mile west of the east quarter post of section 20, T. 5 S., R. 9 W. the elevation 838 feet A. T.; dam 4 feet high.

Hog Creek.

This water course runs northwest from the west central part of Hillsdale county to its junction with the St. Joseph river at Union City in the northern part of Branch county. At the north quarter post of section 23, T. 5 S., R. 6 W. the elevation of the stream is 945 feet above sea level, increasing to 967 feet A. T. at the northeast corner of section 29, T. 5 S., R. 5 W.

The elevation of numerous small water courses were obtained, but it is believed that the elevation of all the streams that can have any economic development is given.

CHAPTER IV.

WATER SUPPLY OF LENAWEE, HILLSDALE, BRANCH, ST. JOSEPH, AND CASS COUNTIES.

LENAWEE COUNTY.

Flowing Wells.

Within the limits of this county there are two principal areas in the lower parts of which flows have been obtained. In the eastern part of the county there are several flowing wells east of the Belmore beach, which follows approximately the road running northeast and southwest through Ridgeway, and west of the line 700 feet A. T. This area leads northeast of Lenawee Junction. I have not obtained the records of any flowing wells west or south of the River Raisin.

Within this area beginning at the northeast flows have been obtained at Britton, southeast of Ridgeway, Holloway, at the northeast of Raisin Center, in the east half of section 32, T. 6 S., R. 4 E., and at Lenawee Junction. At Britton the depth of wells varies from 25 to 50 feet deep, the elevation being about 698 to 700 feet A. T. In the east half of section 32 the flow is found in gravel at a depth of 186 feet; surface elevation 725 A. T. At Lenawee Junction the water is also found in gravel in the drift at a depth of 135 feet, the elevation A. T. being 714 feet. Most of the flows through here are small. It is quite noticeable that the depth increases to the south, which will have to be taken into account in prospective drilling.

Tipton-Rollin Artesian Area.

Another belt trending southwest from Tipton is described by Mr. Wm. Beebe of that place as being from ½ to 2 miles wide and extending northeast and southwest of Tipton for a distance of over 40 miles, the wells varying from 12 to 150 feet in depth, but mostly from 50 to 70 feet in depth. At Tipton the head is 900 A. T., the wells being 25 to 75 feet deep. In the valley of Wolf creek artesian wells are found at the southeast corner of section 1, T. 6 S., R. 2 E., at a depth of 81 feet. One mile south two flows were found at a depth of 94 and 76 feet the greater flow coming from the more shallow well. In section 10, T. 6 S., R. 2. E., at an elevation of 966 feet A. T., a fairly strong flowing well throwing water 10 feet above the surface was obtained at a depth of 58 feet. The water is slightly chalybeate both here and at Tipton. South from Rome Center and three-tenths of a mile east of the northeast corner of section 28, T. 6 S., R. 2 E. there is a strong flowing well at an elevation of 900 feet A. T. This is in the basin of the south fork of the river Raisin. The most westerly flow that I obtained any information of in this area, is the southwest quarter of section 27, where a flowing well is found at an elevation of 982 feet A. T.

The flowing wells in this tract are all found in the area between the 900 and 1,000 foot A. T. contour lines. In the low areas the probabilities for obtaining flows are fair, especially east of the morainal tract running south from Stoddard.

Addison and Woodstock.

In the northwestern part of the county flows are occasionally found at Addison and Woodstock at a depth of 25 feet. This is west of the Huron-Erie moraine.

Ground Waters.

In reviewing the water supply data for the rest of this county I have begun at the southeastern part of the county and worked by townships north and west, after the manner of the original linear survey. The advantage of this plan, however, is that some approximation is made to the altitude of the land, the difference of elevation affecting to a greater or less extent the depth at which water can be obtained. But this is mostly within circumscribed areas where the elevation is abrupt.

In the territory between Sisson, Blissfield and Riga the land is a plain varying in elevation from 665 to 700 feet A. T. The depth of wells is from 82 to 95 feet, water generally being obtained in beds of gravel. In one well in section 5, T. 8 S., R. 5 E. the rock was struck at a depth of 602 A. T. or 88 feet below the surface and the water is soft. In two wells in section 16, T. 7 S., R. 5 E. salty water is found at a depth of 82 to 95 feet. Water in bed rock will probably be salt?

In T. 6 S., R. 5 E., which includes the civil townships of Ridgeway and part of Deerfield the topography is level through the central portion. The elevation increases from 675 feet A. T. in the southern portion to 740 A. T. at Ridgeway. The depth to water is variously stated as from 13 to 100 feet. Wells having a depth of 13 feet are doubtless surface waters. Not only are they liable to contamination but the supply is generally insufficient in summer. Such sources of water supply should be deepened. Water is found in the drift and is generally hard. In two of the wells having the greatest depth of 87 and 100 feet the water is brackish. In general it would seem that a fair supply of water could be obtained at a depth of less than 30 feet. In a well 200 feet in depth situated in section 33, T. 6 S., R. 5 E. no water was found.

Macon Township.

The township of Macon corresponds to the government township of T. 5 S., R. 5 E. The elevation increases over 100 feet from the eastern border of the county to the divide east of the Raisin river. A fair amount of water is obtained at a depth of 20 feet or less, the water being hard. One well situated in section 27 entered rock at a depth of 120 feet, or 622 feet A. T. Mr. Frank Leverett is engaged in the preparation of a report on this, and the adjoining township to the west, in connection with his work on the Ann Arbor Quadrangle. The results are to be published by the U. S. Geological Survey.

Ogden Township.

In Ogden township, T. 8 S., R. 4 E. the well records showed a depth of from 60 to 115 feet. The township is a plain going north and east from the center, the elevation within that area being from 709 to 714 feet A. T. outside of Black creek, which is about 15 feet below the level of the surface, in the north central part. The water is found in gravel beds in the drift. In three wells having a depth of from 80 to 115 feet the water is impregnated with salt and sulphur. Around Ogden Center the average depth of wells is 100 feet.

Palmyra and Raisin Townships.

These occupy townships 6 and 7 S., R. 4 E. In this area all the wells of which I obtained information are found in gravel beds in the Pleistocene. The wells vary in depth from 37 to 186 feet, the water being generally hard, except in the well 37 feet deep. There are no wells mentioned in which salt or sulphur occurs. It is in a portion of this area that flowing wells are found. As has been mentioned Mr. Leverett is reporting on Clinton township to the north.

Fairfield and Madison Townships.

These lay south and west of Adrian in R. 3 E. South of Adrian the country is hilly for three or four miles, being rolling south of Fairfield and west of Jasper. Most of the wells are shallow, water being obtained at a depth of from 14 to 47 feet, the elevation increasing somewhat to the north. Water is obtained in sand and gravel beds in the drift, being generally hard. The supply is abundant.

Adrian and Franklin Townships.

These are townships 5 and 6 S., R. 3 E. and contain the flowing wells found at Tipton, and southwest from there. Like the wells south from here the water is hard. In Adrian township water is generally found at a depth of less than 40 feet in the drift, increasing somewhat in depth northward. Two miles south of Tipton water is obtained at a depth of 62 feet, which is the average depth for wells at Tipton.

Seneca and Dover Townships.

These are the government townships of 7 and 8 S., R. 2 E. East and north of Seneca P. O., which has been renamed Ennis, the country is rolling. Water is obtained from the drift in wells varying in depth from 10 to 110 feet. The water is generally hard. In two wells having a depth of 42 and 65 feet, in the southern part of Dover township the water contains iron. In several of the wells having a depth of less than 40 feet the supply is limited or decreasing. In a well 110 feet deep the capacity is 50 barrels per day. It would probably be well to go to a depth of over 50 feet for water supply. Mr. Chas. Middleton, section 27, T. 7 S., R. 2 E., states that the first 20 feet was red clay, changing to blue, with occasional beds of gravel. Under that 48 feet of sand in which the water was obtained.

Rome and Cambridge Townships.

These are townships 5 and 6 S., R. 2 E. The Huron-Erie moraine runs along the western part of Rome township and east northeast through Springville in Cambridge township. Dr. E. J. Ross of Rome P. O. writes that the east half and the southwest quarter of Rome township is rolling being composed of a heavy clay. The northwest quarter is "hilly and sandy." On the road from Tipton to Cambridge and south of Cambridge to Onstead the country within the moraine is hilly, with overwash beds of sand and gravel.

The average depth for wells around Rome center is 75 feet, the depth varying from 45 to 145. In two wells dug there the depth is 85 and 91 feet. The water rises 75 feet. Water is obtained in the drift from beds of sand or gravel. It is either hard or contains iron. In Rome township the supply is abundant, and as we have seen, the water head frequently reaches the surface producing flowing wells. To the north in Cambridge township the depth of wells varies from 16 to 48 feet, water in some cases being obtained about on a level with adjacent lakes. Where the supply has lowered, the causes seem to be local. The remedy probably lies in either having the wells sandpumped or increasing the depth. Wells are found in the drift.

Medina, Hudson, Rollin and Woodstock.

In this tier of townships, forming the western part of Lenawee county, the water is generally found in the drift. In one well in section 21, T. 6 S., R. 1 E., having a depth of 265 feet, the well entered rock at about that depth. This is 806 A. T. At the Hudson water works the city is supplied with 8 wells 6 inches in diameter, which are capable of supplying 300,875 gallons per day. In general throughout this region the supply is abundant at depths varying from 25 to 100 feet. Mention has already been made of the artesian wells in the northwestern part of the county.

HILLSDALE COUNTY.

Wright and Pittsford Townships.

These townships are located in the southeastern part of Hillsdale county, constituting townships 7 and 8 S., R. 1 W. Water is found in gravel beds at a depth of from 10 to 245 feet as at Pittsford. The supply is ample. Water is generally hard except in a well 71 feet deep which is reported soft. The depth at which water is usually obtained is from 35 to 95 feet. In the deep well at Pittsford the supply was obtained from water bearing gravel at a depth of 245 feet, the water rising 145 feet. This is situated on a heavy morainal deposit.

Wheatland and Somerset Townships.

These are townships 5 and 6 S., R. 1 W. Mr. A. C. Lane has represented the greater portion of this area as underlaid by the Marshall sandstone. In Wheatland, T. 6 S., R. 1 W., I did not obtain the record of any wells into the rock. But they would probably yield water as the Marshall sand-

stone is a good source of supply. In Somerset township, section 8, rock was struck at an elevation of 1,163 feet A. T., dropping in section 23 to 1,037 A. T. A flowing well was obtained in section 1 of Wheatland, and near Somerset. There is also a very fine flowing well in section 16, T. 6 S., R. 1 W. This is found in a narrow valley and is isolated. The amount of flow is 23.37 gallons per minute. Flows are also obtained at Jerome at a depth of 30 feet. Throughout the central part of these townships there is an abundant supply of hard water. Springs are abundant near Jerome.

Ransom and Jefferson Townships.

In these civil divisions constituting townships 7 and 8 S., R. 2 W., the depth to water in Ransom township varies from 20 to 90 feet, throughout the central portion the average depth being 53 feet. The land is rolling. In Jefferson township to the north the depth varies from 14 to 79 feet, the average depth around Osseo being given as 50 feet. There are no flows throughout here that I obtained information of. The water is hard and occasionally contains iron. Water is from gravel beds in the drift. Osseo is near the edge of a moraine which follows approximately the course of the Marshall sandstone. The drift accumulation is probably considerable, but an abundant supply of water is obtainable if the supply from the drift should fail. In Jefferson township the depth to water varies as much as the surface.

Adams and Moscow Townships.

These are townships 5 and 6 S., R. 2 W. Almost the entire area is represented as underlain by the Marshall sandstone in Mr. Lane's most recent geological map of Michigan. The depth to water varies from 18 feet near Lake Adams, where the surface elevation of the well is 1,136 A. T., the water being found at 1,118 and the elevation of the lake is 1,117. North from here in section 21, T. 5 S., R. 2 W., water is found in the Marshall sandrock at a depth of 95 feet at an elevation of 1,164 A. T., rock found at 50 feet. In a well in section 3, T. 5 S., R. 2 W., sandrock is said to have been struck at a depth of 14 feet; surface elevation 1,104 A. T. A well in section 21, T. 6 S., R. 2 W., entered rock at 70 feet; the well top is 1,160 A. T. The elevation of the rock surface, therefore, is from 1,090 to 1,115 in the central portion of Adams and Moscow, the average amount of drift being 50 feet more or less. Throughout this area there is an abundant supply of hard water both in the sandrock and the drift.

Woodbridge and Cambria Townships.

These form townships 7 and 8 S., R. 3 W. of the linear survey. In this valley of a tributary to Cubb lake there are two flowing wells found in sections 22 and 26, T. 7 S., R. 3 W. The region is very hilly. Areas in which flows are likely to be obtained are constricted in area. The depth to water varies somewhat according to the elevation of the land. Thus we have a well 32 feet deep at a height of 1,048 A. T. in section 11, T. 8 S., R. 3 W., the greatest depth increasing to 96 feet at an elevation of 1,089 A. T. in section 34, T. 7 S., R. 3 W. Where relatively high elevations of

land cover a considerable area the catchment basin generally increases with the surface. The reverse is true where the elevation approaches a knob formation.

Fayette and Scipio Townships.

These are townships 5 and 6 S., R. 3 W. Around Jonesville the depth to water is from 20 to 100 feet, at Hillsdale 35 feet, and at Mosherville 24 feet. In all three places an ample supply of hard water is obtained. The greater part of this area is underlain by the Marshall sandrock, forming a continuation of the region to the east. The greater part of the water supply comes from the bed rock. A spring on the farm of Arthur Merchant, in section 29, T. 5 S., R. 3 W. is said to flow from this sandrock. This is in the valley of the St. Joseph river.

Camden and Reading Townships.

Artesian wells have been obtained at Reading and in sections 18 and 19, T. 7 S., R. 4 W., the depth to water varying from 70 to 90 feet. This depressed area runs north and south, west of the elevation around Reading, and may furnish flowing wells at other localities. At Reading the Coldwater shale was struck at about 55 feet. In section 2, T. 7 S., R. 4 W. the Marshall ? sandstone was found under 22 feet of drift at 1,115 A. T. Again in section 22 of Reading township rock (Marshall?) was struck at 1,117 A. T. with an abundant supply of water. All the northeastern part of this township is probably underlain by the Marshall, which is a good bearer of water. The rest of this area is underlain by the blue Coldwater shales, with occasional thin beds of limestone. This is a poor water carrier, and wells will be sunk to best advantage in the overlying drift or soil formation. In Camden, T. 8 S., R. 4 W. the drift is 112 feet thick in section 15 and furnishes a steady supply of hard water.

Allen and Litchfield Townships.

These are townships 5 and 6 S., R. 4 W. Water is hard but there is an abundance of supply at depths variously ranging from 25 to 60 feet. The elevation of wells varies from 1,011 to 1,113 A. T. in the central portion of this area while the level reached by wells is from 997 to 1,098 A. T. This makes the extremes of the surface and water elevation very nearly the same. Marshall sandrock was struck at a depth of 15 feet in section 34, T. 6 S., R. 4 W., elevation 1,098 A. T.; in section 28, T. 5 S., R. 4 W., at about 28 feet or 997 A. T.; in section 13, T. 5 S., R. 4 W. at 40 feet or 1,027 A. T. The probabilities are that the eastern half of both of these townships are underlain by this water bearing sandstone, as well as the north and east half of Litchfield township.

BRANCH COUNTY.

This county is underlain almost entirely by the Coldwater shale, which as we have seen, is a poor water producer. Therefore throughout the county water is found in the drift formation at a depth of less than 100 feet. The water is almost uniformly hard, and occasionally contains iron. In lake regions wells are generally shallow, the depth to water being the same as the elevation of the lake surface.

Algansee and Quincy Townships.

In the central portion of these townships the depth to water is from 15 to 38 feet, the elevation of the water horizon rising and falling with the elevation of the surface. The supply is abundant, the wells at the Quincy water works having a capacity of 20,000 gallons per hour. The supply is generally sufficient for all needs.

Kinderhook and Ovid Townships.

These are townships 8 and 7 S., R. 6 W. In the former township the average depth is from 18 to 40 feet, the average depth around Kinderhook being 25 feet. In the township north, the depth varies somewhat in the hilly region. Thus in a well in section 21, the depth to water is 12 feet, the well being 856 A. T. North in section 16 the depth has increased to 90 feet, the surface elevation increasing 106 feet and the water horizon 28 feet. These elevations are more or less local. In section 18, T. 7 S., R. 6 W. the depth to water is 65 feet.

Coldwater and Girard Townships.

These are the government townships of 6 and 5 S., R. 6 W. In these two civil divisions the average depth to water is approximately 30 feet. The supply is abundant. In section 33, T. 6 S., R. 6 W. rock was struck at a depth of 36 feet elevation A. T. 960 feet. The water horizon varies from 900 to 1,000 feet A. T., oscillating more or less with the elevation of the surface.

Gilead and Bethel Townships.

These are respectively townships 8 and 7 S., R. 7 W. Around Gilead depth to water varies from 30 to 90 feet, the average depth being given as 30 feet. The supply is ample. The water horizon varies with the inequalities of the surface, maintaining throughout this area an average depth of approximately 25 feet in the central portion north and south. The supply comes from sand and gravel, and is abundant.

Batavia and Union Townships.

These constitute townships 6 and 5 S., R. 7 W. The average depth to water is very nearly the same as south of here or from 30 to 40 feet. Around Batavia the depth varies from 15 to 30 feet, increasing northward to 40 feet around Union City. The supply is ample except in the elevated morainal region north of Ensleys lake, where wells have been sunk to a depth of 50 feet, only obtaining a limited supply. I believe that a sufficient supply could be obtained within that area which is embraced approximately by the 950 foot contour line, by increasing the depth to 75 feet. The highest elevation that I determined within that tract is near the east quarter post of section 4, T. 6 S., R. 7 W. This is 990 A. T. At Union City a dry well 250 feet deep was sunk.

Bronson, Mattison and Sherwood Townships.

These townships are in the western part of the county and form townships 7, 6 and 5 S., R. 8 W. At Sherwood drilled wells are from 75 to 110 feet deep. On the moraine southeast of there the elevation increases 80 feet on the side of Mattison lake. In that neighborhood, however, wells sometimes strike water at an elevation of the lake surface, which is approximately 889 feet A. T. Through Mattison township the depth to water averages 45 feet, the elevation of the water horizon being 20 feet above the wells at Sherwood.

ST. JOSEPH COUNTY.

This county is also underlain by the Coldwater shale formation. Throughout the county water is generally found in sand and gravel beds in the drift or soil formation, properly known as the Pleistocene. I have not obtained any information relative to flowing wells in this territory, though there are numerous flowing wells at Klingers Lake and a few elsewhere in the county. The supply is generally ample. Like most of the wells from the drift the water is generally hard, and sometimes impregnated with iron.

Fawn River and Burr Oak Townships.

These form townships 8 and 7 S., R. 9 W. A fair average for wells in this locality would be 45 feet. On the south side of the Sturgis moraine, however, in section 5, T. 8 S., R. 9 W. the water horizon is at the same elevation as in Burr Oak township, the elevation increasing so that the distance to water, on an average, is 100 feet.

Colon and Leonidas Townships.

These are townships 6 and 5 S., R. 9 W. In this area the elevation of Sturgis lake is 835 feet A. T.; of Palmer lake 840 A. T. In the records of all the wells that I obtained between Leonidas, Colon, and thence on the road to Burr Oak, the elevation of the water horizon is within the elevation of these lakes. The maximum elevation obtained in this district is on the line of sections 2 and 3, T. 7 S., R. 9 W.; 909 A. T. The depth there to water would be about 69 feet, decreasing to 40 feet at Leonidas, where the elevation is 860 A. T., and to 25 feet in section 15, T. 6 S., R. 9 W., which is 866 A. T.

Sturgis and Sherman Townships.

In the Linear Survey these are townships 8 and 7 S., R. 10 W. Sturgis township lies south of the Sturgis moraine, or at least in its most pronounced development. On the road from Sturgis to White Pigeon the land is rolling for the most part, the fall amounting to 50 and 60 feet. The average depth to water in Sturgis township is the same as around Leonidas, amounting to 40 feet. The supply of water is abundant. At the Sturgis water works the capacity of the wells is 125,000 gallons per day. Mr. E. B. Gray, Supt. of the Sturgis water works, has very obligingly given an analysis of the water from the two wells there.

Sturgis Water Works.	Grains per U. S. gallon. Open well.	Driven well.
Sodium carbonate	none	none
Lime carbonate	15.42	16.5
Magnesia carbonate	5.52	6.10
Lime sulphate	2.66	2.63
Magnesia sulphate	none	none
Sodium chloride	2.63	2.63
Free acid	none	none
Iron oxide and silica	0.20	0.23
Volatile organic matter	4.07	6.16
Total solids	30.50	33.80

It will be observed that the Sturgis moraine occupies the greater part of Sherman township to the north, the contour lines showing an elevation of 1,000 feet. Within this tract water in sufficient quantities is generally difficult to obtain, at depths of less than 100 feet.

Nottawa and Mendon Townships.

Going north these constitute townships 6 and 5 S., R. 10 W. Throughout this area the depth to water varies from 18 to 70 feet, the average around Mendon being variously given as from 20 to 70 feet in depth. The supply of water is generally ample.

Florence, Lockport and Park Townships.

These are townships 7, 6 and 5 S., R. 11 W. In these townships the water-bearing conditions seem quite fairly identical where I obtained records between Moorepark, Parkville, Centerville and thence southwest and west to White Pigeon. The average depth to water is 25 feet, wells varying in depth from 16 feet as in Sec. 3, T. 7 S., R. 11 W., to 40 feet in section 26, T. 5 S., R. 11 W. At Parkville the average depth is given as 14 feet the depth increasing to 27 feet at Flowerfield in the northwest portion of Park township. At the Three Rivers waterworks, and section 14 of the same township, flowing wells have been obtained in the valley of the St. Joseph river. The supply is ample.

Mottville, Constantine, Fabius and Flowerfield Townships.

In the Government Linear Survey these are respectively townships 8, 7, 6, and 5 S., R. 12 W. In Mottville township the average depth to water is very nearly the same as in the area last discussed. At White Pigeon the average depth is from 26 to 28 feet, decreasing to 20 feet at Mottville, which is in the valley of the St. Joseph river. At Constantine the topography is quite irregular as will be seen by referring to the contour map. Water is obtained there at depths variously ranging from 15 to 60 feet. Going north on the interlobate moraine a well in section 10, T. 7 S., R. 12 W. obtained an ample supply of water at a depth of 50 feet. The elevation of the well is 63 feet above the depot at Constantine. On the same moraine in the lower part of Fabius township water is generally found at a depth of 90 feet, increasing in depth northward, until in section 28, T. 5 S., R. 12 W., it is over 100 feet to water, which is found in the drift. In the valley of Rock creek, at a much lower elevation, there are springs at Howardsville.

CASS COUNTY.

Throughout this county the water supply is either obtained from the drift or from lakes or running streams. The county is underlain by shale rock, which is almost invariably a poor water producer. Flowing wells have been found in several localities, but apparently on low ground, with restricted areas. Most of the artesian wells are in the northern tier of townships. Northwest of Marcellus, at Fish lake, there is such a well 90 feet deep belonging to Dr. Davis. Two miles east of Wakelee there is another flow north of the interlobate moraine. Thence west in the township of Wayne, T. 5 S., R. 15 W., there are flowing wells at Glenwood, and at Dowagiac flows are obtained at 100 feet, which are utilized in the city water supply. West of Glenwood at Long lake there is another artesian well. In section 35, T. 5 S., R. 16 W., a flowing well 152 feet deep in the drift flows 1 barrel a minute. South of these localities a flowing well was obtained at a depth of 33 feet in section 19, T. 6 S., R. 14 W. There are also a few flows at Summerville in the valley of Dowagiac creek, the water being obtained from 30 to 100 feet.

Porter Township.

This civil division includes the government townships of 8 and 7 S., R. 13 W. Within this area there are generally 2 or 3 water horizons. In T. 8 S., R. 13 W., water is obtained at depths varying from 20 to 100 feet, but the elevation at which the water is found apparently varies more than the surface. In this area fine springs are sometimes found at the foot of the moraine. Going north the elevation increases after the crest of the moraine on the south side has been reached. Water through here is obtained at depths varying from 55 to 160 feet, the records showing that water was found at from 55 to 60 feet deep; at 120 to 125 feet; and from 160 to 165 feet in depth, the elevations of the water horizons A. T. respectively on an average of 835, 766, and 735 feet. The water is hard and is from beds of sand or gravel. In section 27, T. 7 S., R. 13 W., the following section was obtained:—

	Feet.
Surface soil and clay	3
Sand	53
Blue clay	2.5
Water bearing sand	23
Total	81.5

Newberg and Marcellus Townships.

These occupy townships 6 and 5 S., R. 13 W. In section 10, T. 6 S., R. 13 W., springs are found in great abundance. On the interlobate moraine in sections 9 and 16, T. 6 S., R. 13 W., the depth of water is from 100 to 130 feet, decreasing to 25 feet north towards Marcellus. In section 21 a

well was sunk 199 feet without getting through the drift. The average depth to wells in Newberg township is 97 feet. At Marcellus the drift is over 208 feet thick. Drove wells there are from 12 to 25 feet deep, tubular from 60 to 100 feet. The average depth for wells in Marcellus township is about 45 feet.

Calvin, Penn and Volinia Townships.

These are townships 7, 6 and 5 S., R. 14 W. In the heavy morainic region in Calvin township, and adjacent thereto the depth to water varies from 50 to 90 feet, the average depth being about 65 feet. Northward in Penn, T. 6 S., R. 14 W., the average elevation is approximately the same, going north and south through the township. The water horizon, however, rises over 30 feet, making the depth to water 20 to 40 feet. At Penn wells are from 20 to 70 feet in depth; at Wakelee in the neighborhood of 50 feet, but occasionally 200 feet in depth. Around Vandalia the depth varies from 10 to 120 feet, those at 10 feet being surface water. Going north into Volinia the depth increases somewhat with the elevation, water being obtained from 60 to 115 feet, or on an average of 83 feet, more or less. Throughout these three townships there is generally an abundant supply of hard water.

Ontwa and Jefferson Townships.

These constitute townships 8 and 7 S., R. 15 W. Around Edwardsburg the depth to water is about 26 feet. The water is said to rise and fall in the wells, according to similar variations in the lake near Edwardsburg, but I am unable to find any very close agreement in the elevation of the water horizon and that of the lake surface which is over 10 feet higher.

In section 14 of Jefferson there are a number of springs. Going through this township on the road from Edwardsburg to Milton, the depth to water varies from 35 to 50 feet, the average of several wells giving 40 feet. In the hilly morainic region in the western part of this township the depth quite probably increases to 80 feet in places. At least this is true of the extension of this same hill region between Edwardsburg and Barron lake in Howard township.

La Grange and Wayne Townships.

In the Linear Survey these are townships 6 and 5 S., R. 15 W. The city of Cassopolis obtains a supply of soft water from Stone lake, which is supplemented by water from wells. Between Cassopolis and La Grange the depth to water varies with the surface, the water horizons in sections 22 and 26 being 35 feet below Stone lake. An abundant supply is obtained at a depth of 70 feet north of Cassopolis becoming less towards La Grange.

On top of the moraine which crosses the town line in section 4, T. 6 S., R. 15 W., the depth to water is 140 feet, as at Mr. Henry Springsteens. From here the elevation decreases to 30 feet in section 10, T. 5 S., R. 15 W. There are at least two water-bearing gravel beds in Wayne township, the lower water horizon in the morainal region probably outcropping in the springs at Glenwood, which are at very nearly the same elevation above tide.

Howard, Pokagon and Silver Creek Townships.

These are townships 7, 6 and 5 S., R. 16 W. Around Barron lake the depth to water is 20 feet increasing to 40 feet or over in section 4, T. 7 S., R. 16 W. On the road from Barron lake station to Edwardsburg, water is obtained on the moraine at 80 feet, at very nearly the top of the moraine or hill range. Between Pokagon and Dowagiac the land is rolling somewhat, the extremes of elevation being very nearly 50 feet. In this region water can be obtained at from 15 to 35 feet in depth. Around Pokagon the average is given as 25 feet with an ample supply of water. At Summerville there are a great many springs in the valley of the Dowagiac creek. The 11 flowing wells at Dowagiac which furnish part of the city water supply are 100 feet deep and have a capacity of 600 gallons per minute. The two dug wells 47 feet in depth, which are part of the same plant have a capacity of 400 gallons during the same time. The water is hard and contains iron. I am indebted to Mr. Mann for a record there.

Dowagiac City Well.	Feet.
Black muck and fine sand	2
Sand and small stones	3
Fine sand	2
Stones and gravel	15
Sand and gravel	10
Water-bearing gravel	15
Total	47

ACKNOWLEDGMENTS.

General acknowledgment is due to a large number of persons who have rendered assistance, mainly by replies to schedules. I am particularly indebted to Alfred C. Lane for the free use of data accumulated in the office both before and since the publication of his water supply papers in 1899, and for criticisms and suggestions in this article. Mr. Frank Leverett has also greatly added to the completeness of this report. Thanks are due to him for the history of the glacial retreat as given in Chapter III and for several locations and names of the several moraines. Also for information and criticism relative to artesian wells, and the elevation of the River Raisin. For the altitudes in this report, however, I am almost entirely responsible. In obtaining these data, each line of aneroid elevations began and ended at the railroad station for nearly every day's work, and generally I was able to make a railroad depot at noon time, obtaining a check above tide on the barometer before and after dinner. In addition to this a self recording barometer was left at a railroad base, which gave the variation in feet per hour. Several railroad profiles have been obtained by Mr. Lane, and these were used to obtain independent elevations above sea level.

Finally, I wish to express my indebtedness to Prof. C. A. Davis of the University of Michigan for his notes on the water supply of Tuscola county. Prof. W. H. Sherzer who is engaged in the preparation of a report on the geology of Wayne county has also materially added to the completeness of this paper by his information on artesian wells there.

Lansing, Michigan, November 24, 1903.

ANALYSES OF LOWER PENINSULA WATERS.

In connection with Mr. Cooper's paper it seems well to give a number of analyses of waters that have been collected since the issue of Water Supply Paper No. 31, as such analyses are of interest to manufacturers and makers of boiler compounds, when the waters are liable to be used in boilers, and are also of interest medically and to cities. We divide them into three classes. (1) Surface waters; (2) shallow wells; (3) deep wells.

1. Surface waters.

Detroit river waters are illustrated by the following analyses for the Water Works Commissioners, all in grams per metric ton (parts per million).

DETROIT RIVER ANALYSES.

	1.	2.	3.	4.	5.
Calcium carbonate	33.00	5.10	57.49	28.2	70.2
Magnesium carbonate	.....	.73	20.73	Mg Cl_2 3.50	1.53 1.14
Ferrous carbonate	8.14	21.60	trace.	8.9	.67
Sulphate of lime	.....	2.54	17.89	43.3	1.20
Sulphate of soda	7.50	7.50	$Na_2 CO_3$ 5.75	.....	$Na_2 CO_3$ 5.5
Sulphate of potash	2.83	2.83	trace.	K Cl 2.47	.....
Phosphate of lime	31.10	51.92	.....	(of Al) 0.58	.....
Alumina	10.50	10.50	4.13	10.18	.....
Silica	5.00	5.83	5.24	4.5	4.8
Chloride of sodium	trace.	trace.	3.93	.61	4.13
H_2S	.....	trace.	.....	.....	.....
Oxygen with permanganate	1.11	1.42	.....	.....	.....
Total	98.07	108.39	115.16	103.7	108.0

1. S. H. Douglass, Feb. 11, 1854. Iron pipes, evidently imperfect. Note date.
2. S. H. Douglass, Feb. 11, 1854. Log pipes, evidently imperfect.
3. Frederick Stearns, (A. B. Lyons), inorganic constituents, Sept. 10, 1879, hydrant, quite unlikely to be so much sodium carbonate, better sulphate.
4. S. P. Duffield, 1861.
5. M. C. Fluke, 1877.

These analyses should be compared with analyses 4 to 8 and 5a, 6a and 7a of Water Supply Paper No. 31. The variation is more one of analytical combination and error, than in the quality of the water probably. No. 1 here is the same as No. 5 there, but is repeated for the sake of its companion No. 2. The total solids are 100—115 parts per million, and of these about 75 parts are calcium magnesium carbonates, more or less replaced by sulphates, of which there may be about 10 parts additional. There are about 5 parts silicia, 10 parts alumina, chlorine varies according to the purity of the water probably, but there is not less than 4 parts

of chlorides, about half of which may be combined with potash. The hardness is accordingly about 5°. The presence of carbonate or sulphates of soda may account for the water being less hard than say Lake Michigan or Detroit river or most of the Michigan rivers. Probably the waters from Georgian Bay also are less hard.

The analyses below show the water of Pine river at Alma.

PINE RIVER.

A. N. Clark, Analyst.

	Parts per thousand.	Parts per thousand.
Total solids	.26940[1]	.34148[2]
Inorganic matter	.22188	.26444
Organic matter	.04752	.09504
	.53880	.70096
Free ammonia	.00020	.00060
Insoluble in HCl	.01050	.01200
$(Al_2 Fe_2) O_3$	.00300	.00730
Ca O	.07249	.07562
Mg O	.03098	.03084
$S O_3$	.02229	.03018
Cl	.00300	.00500
	.14246	.16154

To Mr. W. M. Courtis we owe a number of water tests, which though incomplete are of interest. They were mainly made for a special purpose,—to test the water for beet sugar or boiler purposes. The following two are of (1) Clinton lake and (2) Clinton river:—

1 Above dam-7:10 A. M., September 16, 1902.
2 465-ft. below mouth of factory sewer-8:30 A. M., September 16, 1902.

CLINTON RIVER.

Character.	Both neutral carbonates.	
	1.	2.
Temporary hardness in parts per 1,000,000	105.3	.....
Permanent hardness in parts per 1,000,000	34.0	.....
Total	139.31	116.
Compared with Detroit river	2.7	2.2
Suspended matter	3.71	.....
Solid salts	280.	.....
Lime as carbonate	119.40	114.84
Magnesia carbonate	55.82	50.43
Soda and potash	1.65	.....
Silica	2.24	288.
Alumina (with ferric oxide)	.29	14.73
Organic matter with crystallization water	100.60	108.
CO_2	present	in both.
Cl	traces	in both.
Phosphoric acid	.....	trace.
Molassegenic salts (harmful in making sugar) very small	.....	.....

The following tests are of Calumet river, which is a neutral carbonated water, a good deal like Clinton river, with the salts mainly carbonate of lime and magnesia, with traces of sulphuric acid and chlorine. For boiler water there should be 76% allowance.

CALUMET RIVER.

	Parts per million Ca CO_3
Temporary hardness equal to	134
Permanent hardness equal to	191
Total (19° or)	325
Solid salts	460

Compared with Detroit river, 4½ times harder.

The character of the following Oxford water is unknown,—it may be a shallow well, but I think probably not. It is also a neutral carbonated water. I have made some emendations.

OXFORD.

	Parts per million gals. Ca CO_3.
Temporary hardness equal to	140.6
Permanent hardness equal to	55.4
Total (11.4 or)	196.0
(Clarke's scale, Courtis 6.2.)	
Solid salts	233.38
Organic matter	58.8
Sulphuric acid	0.26
(For boiler water 9.81.)	

It is probably an ordinary hard (calcium carbonate) water. The following tests of a water from Pinconning were to test its fitness as a boiler water. It compares most closely with Owen's test of a surface water at Kawkawlin river, among his Bay county analyses (Annual Report for 1902). It is also neutral carbonated. The hardness is equal to 236 parts (per million Ca CO_3).

PINCONNING.

Clarke's scale 3 to 4.	
Compared with Detroit river it is 2.14 times as hard.	
Suspended matter	350.
Solid salts	600

(It must undoubtedly be salty as so many of the Bay county waters are.)

Lime, magnesia, ferric oxide, organic matter, carbonic and sulphuric acids, and chlorine present.

2. *Shallow wells and springs.*

The following is an analysis of the Owosso mineral water, which comes out of the side of a moraine just north of town, flow—11 barrels per minute with a temperature of 50° F. This is practically the same as No. 227 of the Water Supply Paper No. 31. The analysis is by Prof. S. P. Duffield and reduced from grains per imperial gallon by dividing by 70 while the analysis there is the same but the gallon was assumed to be the U. S. gallon, which it proves not to be.

OWOSSO.

		Carbonate.
Calcium bi-carbonate	366.7	227
Magnesia bi-carbonate	272.8	157
Iron bi-carbonate	227.4	148
Sodium (and potassium) chloride	30.0	30
Silica and alumina	8.8	9
Total	905.7 904.9	571

The water is rather unusually strong in carbonates, and the salts must (see page 212 of part 3, of Vol. VIII) be in the form of bi-carbonates.

But of course on evaporation this would be lost and the total solids left would approach the second set of figures.

On page 60 is given a partial test of the water of the Sanitas Spring, Topinabee, by Prof. J. V. Stanislaus. The water is from a well driven or drilled 130 feet through drift. The spring itself on August 17, was so piped that the temperature did not fall below 50°. It was a hot day. But near by a similar well at the railroad station had a temperature of only 48.8°, while near by at Indian River flowing wells ranging from 90 feet to 189 feet deep through 40 to 60 feet of sand and 20 feet of smooth clay had temperatures ranging from 47.6° up to 53° according to the amount of pipe and strength of flow.

These two are almost[1] at the extremes as regards hardness. I imagine the cause of this difference may lie in the fact that the Owosso spring draws from a comparatively narrow vein through the till, extracting all the lime it can from the highly calcareous till, while the Topinabee well taps a sand or gravel bed laid down in and full of water of an old glacial lake, which was relatively soft as melting ice generally is.

We have an interesting series of analyses near Durand. According to W. J. Richards, bed rock does not occur there until 180 to 210 feet down, so that the well record in Volume VIII, part 2, p. 199 must be corrected accordingly. The brown shale is then probably merely a pink or brown stratified clay. He says the springs south of town, analysis (4), are in lime beds. In putting down a well by the railroad he used water from the ditch but it was too salt. There is he says, 24 grains to the gallon, analysis (4), in a 200 foot well in the gravel. He has recently put down a well only 60 feet from the former Durand well 206 feet deep, with 51 feet of gravel. He thinks it would have been 210 feet to bed rock. Half way up West Main street there is a trough where the water has 6 feet head.

DURAND.

	4.	1.	3.	2.	5.
Depth	178 ft.	178 ft.	Spring.	91 ft.	Spring.
Calcium carbonate	87.1	46.0	205.	68.5	121.6
Magnesium carbonate	66.5	42.0	92.1	54.7	101.6
Sodium potassium sulphate	44.6	35.6	16.	14.8	8.9
Sodium potassium chloride	414.0	253.	17.2	57.3	28.6
Sodium potassium carbonate	34.3	158.2	36.0	93.0	23.0
Silica	16.3	4.0	2.2	8.2	4.5
Iron and Alumina	trace.	1.3	2.0	3.7	2.5
Total	661.5	540.1	375.5	300.2	290.7

We have arranged these analyses in order of decreasing amount of salts. Analysis (6) by Prof. Kedzie is stated in a slightly different form, but is not essentially different from 5 though only 50 feet deep. Nos. 5 and 6 represent the second water there and 4 and 1 the third, which is quite brackish. No. 6, the city water well, is about 6 to 10 rods from the

[1]Mrs. W. Peterson, West Olive, according to the U. S. experiment station at the Michigan Agricultural College has still softer water.

plant, and goes through 10—18 feet of blue clay, then sand and a little gravel and hardpan, striking the water-bearing gravel from 50 to 55 feet down, i. e., the second water.

No. 6. Depth 50 to 58 feet.	Parts per million.
Calcium carbonate	66
Magnesium carbonate	73
Calcium sulphate	23
Sodium chloride	46
Silica	10
Alumina and iron	13
Organic (volatile at red heat)	66
Total	297
Temporary hardness (removed by boiling)	6
Permanent hardness	8
Total	14

In total solids this closely resembles Nos. 2 and 5.

As to boiler use:

1. Gives little scale, will give corrosion, pitting, perhaps foaming.
2. Gives some scale, medium hard, slight foaming.
3. Fair water, twice as hard as No. 2, but not as hard as usual, considering total solids.
4. Gives some scale but more corrosion.
5. Average feed water, with considerable scale of medium hardness but not corrosive.

The deepest well is about three feet above the crossing. Rigg's and Sherman's map varies from 80 at the north to 103 feet above their datum, the crossing being 93. The deepest well was put down by J. Coryell.

Other wells around here at Byron, etc., are salty, and we must imagine that the Durand wells barely escape striking the Michigan series and do get some of the salty waters thereof. In fact if it is really as deep to bed rock there must be a valley in the rock surface here into which these brackish waters might easily collect.

In Volume VIII, part 2, is also found an analysis of Goose lake near Cement City, showing the character of the water in one of the marl lakes, the main constituent out of 282 parts per million solids is 262 parts per million calcium magnesium carbonate.

The following analysis by W. M. Courtis labelled Detroit Water, is certainly not a surface water, but probably of a shallow well:

Character	salt
Suspended matter	18.94 per gal
Solid salts	235.667
Lime as carbonate	22.649
Magnesia	with the lime
Soda and potassa, as chlorides	213.018
Silica and ferric oxide	with lime
Carb. acid	present
Sulphuric acid	present
Chlorine	present

EATON RAPIDS.

Analysis of Eaton Rapids water made by F. W. Robinson for Prof. W. C. Eslow.

Total solids	1.550000
Loss on ignition	.270000
Free ammonia	.000360
Albumenoid ammonia	.000100
N_2O_3 Nitrates and nitrites	absent
Cl	trace
SO_3	.0683800
SiO_2	.0019000
Fe_2O_3 (etc.)	.00054
CaO	.0638000
MgO	trace only
CO_2	considerable—not estimated

Quantities are in parts per thousand. Well cased 35 feet only; 185 feet deep.

Passing now to the wells into bed rock, but not very deep and with so little mineral matter as to be palatable drinking waters, we have to compare with Nos. 243 to 247 from Eaton Rapids the following, which is like the other wells in this group, high in sulphates and iron, low in chlorides, a typical coal series water.

Ashley, Chesaning, and Maple Rapids have waters unusually strong in sulphates relative to chlorides. The analysis at Ashley is as follows:—

ASHLEY.

	Per million.
Calcium carbonate	40
Calcium sulphate	693
Magnesium carbonate	146
Sodium chloride	666.8
Silica	8.8
	1554.6

Albion is another place where the various wells have been carefully studied, where also there are flowing wells. In the set of 13 analyses by Prof. Fall given below, we note that Nos. 1, 2, 3, and 4 penetrate into bed rock, entering the Marshall sandstone. The depth of the other wells is not known but they are not deep. No. 1, artesian flowing, possibly the National Bank well, which is now descended to by steps from the sidewalk. It used to flow above the street level and with force enough to

ANALYSES OF ALBION WATER.
BY DELOS FALL.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Total solids	386.	309.	305.	232.	580.	600.	.....	500.	238.	614.	.....	428.5	571.
Chlorine	36.88	4.5	4.5	5.6	37.89	28.6	40.	74.3	7.14	32.8	32.8	51.4	42.8
Free ammonia	.228	.114	.082	.088	.096	.022	.08	.12	.046	.08	.07	.08	.066
Albumenoid ammonia	.048	.042	.052	.054	.062	.12	.26	.42	.024	.32	.14	.25	.40
Temporary hardness	.....	.....	.....	.....	.....	.....	100.	.....	28.5	14.3	.....	5	107
Permanent hardness	.....	.....	.....	.....	.....	.....	100.	.....	114.3	71.4	.....	80.7	.93
Total hardness	307.	293.	293.	243.	279.	164.3	200.	.....	142.8	85.7	157.1	85.7	200.
Nitrates	0.	.3	0.	.75	.15	.....	.....	.....	.....	.....	.....	.....	.....
Nitrites	Minute trace.	0.	0.	0.	0.	.....	.....	.....	.....	.....	.....	.....	.....

spatter out of the cup, but now has lowered until there is not much head and it stops in dry weather. It is 200 feet deep, but the water is mainly at 100 feet, and yet the extra amount of chloride over 2 and 3 is doubtless from the greater depth.

No. 2. The Warner Spring, flowing, the city water is the same as this and the following practically. The city supply comes from 4 6-inch wells and 4 8-inch wells from 110 to 114 feet deep, which used to flow with 8 to 10 feet head. They are close to the river bank. In July they are rather short of water. A partial analysis of this is given in Water Supply Paper No. 31, analysis No. 69.

No. 3. Parmenter well, 100 feet deep, similar to No. 2. These three first wells agree very closely, and the amount of ammonia and chlorine found are no sign of contamination. The hardness is considerably greater than in the 30-foot shallow well No. 9, and may point to nearly complete saturation with bi-carbonate in the absence of free CO_2.

No. 4 is from the Albion Manufacturing Co.

No. 7 was slightly turbid, yellowish, and had bad odor on standing.

No. 8 was considerably turbid, slightly green, and had hardly any odor on standing.

No. 9 was from a well 30 feet in the rock, clear, colorless, and odorless.

No. 10. Slightly turbid, colorless, odorless.

No. 11. Clear, bluish, odorless.

No. 12. Clear, slightly yellow, odorless.

No. 13. Clear, colorless, odorless.

In Lansing we have an analysis of the well of the Piatt Bros. which is a more or less mixed water. The analysis made at the M. A. C. gave, in grams per ton:—

SiO_2	22.6	
Fe_2O_3	7	
Ca O	147.6	
Mg O	58.6	
Na_2O (48.6 Na)	65.5	
Cl	107.21	
SO_3	32.4	
CO_2	138.1	
		579
Total solids	680	
Loss on ignition (organic)	130	
		550
Inorganic matter present.		
Difference (O of Na_2O and Fe_2O_3)		29

This may be combined in various ways, for instance as:—

Calcium sulphate	54.9
Calcium carbonate	223.6
Magnesium carbonate	52.3
Sodium chloride	78.2
Sodium silicate	45.7
Magnesium chloride	78.6
	546.

This well is in the coal measures, and the presence of sulphates is significant, but the water is peculiar and has a peculiar history. It is 62 feet to bed rock and 115 feet deep. But it is only 125 feet from the Downey House well which was put down 740 feet in hope of a flow. None was obtained, but it grew salty. So it was plugged at 72 feet. When the Piatt well is not pumping the Downey well[1] stands about 22 feet below the ground level, but when the Piatt well began to pump it dropped. The first of the year the Piatt well was not salt, but lately it has been so, as they are using it hard. It can give 17,000 gallons an hour, and they have used as much as 6,000 pounds. Evidently the Piatts are drawing from the Downey well below the plug.

A well at 1316 Washington avenue south, gave Prof. Kedzie:—

	Grams per litre.
Total solids	565.6
Organic	96
Inorganic	469.6
Chlorine	37.2
Sodium chloride	61.5

This was only between 30 and 100 feet deep.

[1] Proc. A. A. A. S. 1875.

The Kennicott Water Softener Co. have sent us the following analyses, obviously of rather shallow waters, though we do not know the exact source. Those at Midland and Benton Harbor are nearly saturated with incrusting solids.

Analysis of Water from Midland.

	Parts per million.
Calcium carbonate	126
Calcium sulphate	32
Calcium chloride	2
Magnesium carbonate	43
Magnesium sulphate	9
Magnesium chloride	9
Sodium sulphate	0
Sodium chloride	17
Sodium carbonate	0
Oxides of iron and alumina	3
Carbonic acid	78
Silica	62
Alkalinity	160
Suspended matter	29
Incrusting solids	237
Non-incrusting solids	17

Analysis of Benton Harbor Water.

Kennicott Water Softener Co., 1363, March 11, 1902.

	Parts per million.
Calcium carbonate	101
Calcium sulphate	18
Calcium chloride	trace
Magnesium carbonate	19
Magnesium sulphate	41
Magnesium chloride	0
Sodium sulphate	0
Sodium chloride	10
Sodium carbonate	0
Oxides of iron and alumina	2
Carbonic acid	8
Silica	6
Alkalinity	140
Suspended matter	37
Incrusting solids	224
Non-incrusting solids	10

Analysis of Niles Water.

Kennicott Co. 1396. Apr. 19.

		Parts per million.
$Ca\ CO_3$	4.02	69
$Ca\ Cl_2$	.....	.....
$Ca\ SO_4$	0.50	10
$Fe_2\ O_3$	0.05	1
$Mg\ CO_3$	1.57	27
$Mg\ Cl_2$	.....	.....
SO_3	0.47	8
$Na_2\ CO_3$	1.91	33
$Si\ O_2$	0.13	2
Na Cl	trace	.....
Na	0	.....
CO_2	1.28	2
Alk.	8.16	140
Sulp.	0	.....
Incrust.	6.74	116
Non-incrusting solids	1.91	33

A report (Omaha Bee, Sept. 8, 1901) that there was a large amount of lithia found in a stream flowing into Little Traverse Bay by Prof. Kedzie was a mistake.

The following analysis by Prof. R. C. Kedzie of Carrier creek near Grand Rapids is also a typical hard water, but little more than saturated. There must be free carbonic acid and calcium sulphate in excess.

Calcium carbonate	160
Calcium sulphate	35
Magnesium carbonate	91
Soluble $Si\ O_2$	29
Sodium (and potassium) chloride	28
	315
Organic or loss	14
Total	329

Hardness 16°.

S. O. Hickok at Allen, Hillsdale county, Michigan, has a well which yields:—

	Grams per gallon.
Sodium chloride	277.04
Calcium sulphate	33.04

In Saginaw recently[1] a well was put down in "middle ground," a former island in Saginaw river, to test the probabilities as a water supply.[2] The longer it was pumped the saltier it got as appears from the following tests, and it is apparent that the shallower wells in Saginaw are likely to have more or less admixture of salt from the abandoned salt wells whose casings have rusted.

[1] Saginaw Courier Herald 2:26:1903, 3:25:1903, 8:26:1903, 8:27:1903.

[2] It passed through lumber mill waste and salt, and at 12 feet river sand and then clay, then at 42 feet into fine gravel and then from 44 to 53 feet coarse gravel.

The following analyses were made by Heim Bros., reduced to parts per million.

June.	10	11	15	16	17	19	20
(Sodium) chloride	1,370	1,399	1,285	1,285	1,287	1,329	1,343
Total solids	2,630	2,809					
Hardness[1]			77°	77°	84°	87°	80.5°

It may be worth while to include a few typical analyses of deeper waters, which may be classed as mineral waters or brines. I have spent some time in studying analyses of a large series of brines of the Napoleon series, analyzed by Hahn, but these have already been published, though in German. An analysis as yet unpublished, is the following, of the brine at St Charles, at a depth from 700 to 810 feet.

The statement is worked up by me from figures by A. N. Clark.

		Parts per thousand, grams per kilogram.
$Ca\ Cl_2$		48.100
$+2\ H_2O$	14.68	
$Ca\ SO_4$		.884
$+2\ H_2O$	.232	
$Mg\ Cl_2$		7.620
$Mg\ Br_2$		.200
FeO		.259
$Fe_2\ O_3$		.196
Balance chlorine as NaCl		222.460
		279.719
Water of crystallization		14.912
Solids by summation		294.631
Solids by evaporation		295
Specific gravity		1.183

This is a typical Marshall water, high in earthy chlorides, and low in sulphates. The North American Chemical Co. brine runs 40.3 $Ca\ Cl_2$ and 16 $Mg\ Cl_2$ with only .874 $Ca\ SO_4$.

The next important brine below, that of the Berea, is different, being very much freer from calcium magnesium chloride. This may be connected with its being isolated in a greater series of shales fairly free from lime and magnesia. The strata are also quite salt even close to their outcrop. For instance Mr. Cobb made the following determinations on a brine from Jason & Shumway's test well for oil:—

Sp Gr = 1.1426

Cl = 11.54

As sodium chloride 19.18% NaCl which would imply Sp. wt. 1.1441. Dow reports Sp. Gr. 1.139 and Br = .033 or $Mg\ Br_2$ = .0395.

[1] The hardness is probably largely sulphates as well as carbonates.

Microscopic examinations of an evaporated drop shows no Ca SO_4 nor (Ca Mg) Cl_2, and there is no excess of specific weight over that of pure Na Cl solution which there would be the (Ca Mg) Cl_2 admixture appreciable. The refractive index is five times farther from that of water than that of saturated brine. This well is recorded below.

The next brine in order is that of the Dundee or Corniferous.

The following is an analysis of a sample from this horizon at Assyria:—

Sp. Gr. ..... 1.1955=25.26% salt if all salt.

	Per cent.
Br	0.11
CaO	4.4
MgO	1.076
Cl	14.65

Whence

	Parts per thousand.
Ca Cl_2	87.02
Mg Cl_2	24.67
Mg Br_2	1.27
NaCl	119.66
	237.62

Laboratory of Prof. E. D. Campbell, E. E. Ware, Analyst.

Spectroscopic examination revealed strontium, bromine and lithium, and faintly perhaps barium. The presence of barium and strontium accounts for the absence of sulphates. No H_2S was noticeable, but the sample[1] also contained 1.044 grams of undissolved matter, chiefly calcium carbonate and clay, as the sample was taken while work was going on.

From the Company we have the following analysis of the Dundee or Corniferous water at Port Huron.

This is a new well 750 feet deep and said to be 100 feet in solid rock, i. e., Dundee. Compare Grand Trunk well on p. 277, Report for 1901.

Port Huron, Mich., July 8th, 1902.

From the analyses of Dr. E. Ristenpart, analytic chemist, of Patterson, N. J., and Prof. Kedzie of the Michigan Agricultural College, we obtain the following as the constituents of the Deep-spring Mineral Water:—

[1]40cc.

DEEP SPRING MINERAL WATER, PORT HURON.

	Parts per 1000.
Chloride sodium	66.6832
Chloride potassium	2.8181
Chloride ammonium	0.1431
Chloride calcium	5.2492
Chloride magnesium	6.7846
Bromide magnesium	0.0488
Iodide magnesium	0.0003
Bicarbonate calcium	1.7600
Bicarbonate iron	0.0140
Sulphate calcium	3.7721
Hyposulphite sodium	0.0177
Hydrosulphate sodium	0.0136
Carbonate sodium	.....
Lithium chloride	.....
Alumina	0.0033
Silica	0.0085
Sulphuretted hydrogen gas	0.3146
Carbonic acid gas	0.7147