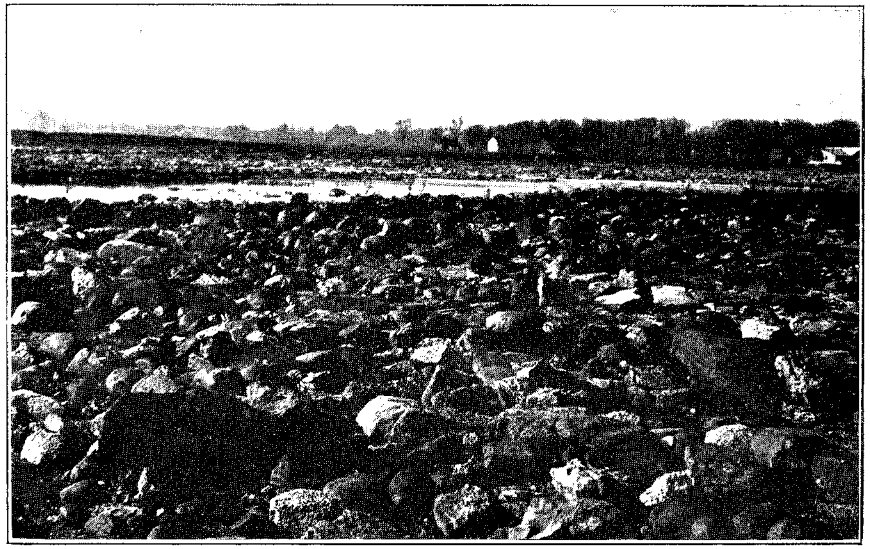
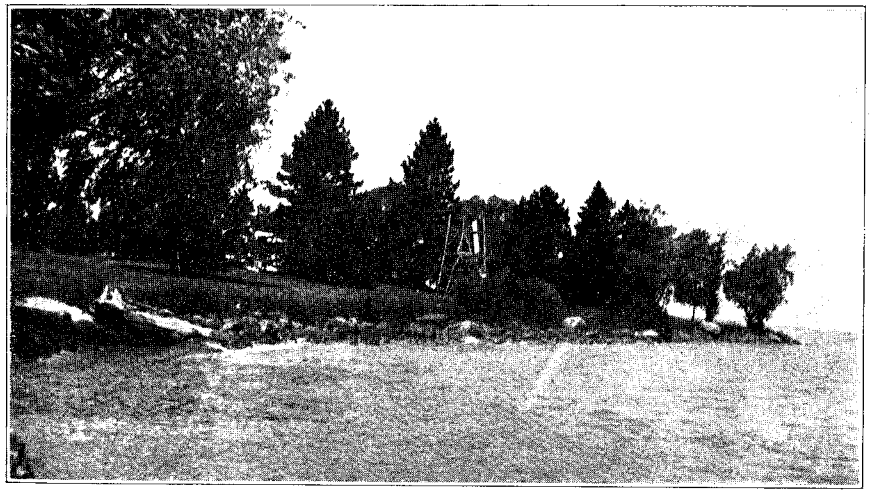


A. BOULDERS OF GROSSE ISLE MORAINE CONCENTRATED UPON DETROIT RIVER BED AND EXPOSED DURING THE CONSTRUCTION OF THE LIVINGSTONE CHANNEL.



B. MILK RIVER POINT, LAKE ST. CLAIR. BOULDERS OF MORAINE CONCENTRATED BY WAVE ACTION AND FURNISHING A NATURAL PROTECTION FOR THE BANK.

After pursuing a rather tortuous course in Augusta township, Washtenaw County, the Warren (Forest) beach enters Wayne County in sec. 7, Sumpter township, as a somewhat faint sand and gravel ridge. The broad delta of the old Huron has deflected the ridge eastward by some seven miles. It passes northward through Van Buren, intercepted by the Huron and showing very indistinctly for the next couple of miles. From sec. 10, it assumes definiteness and becomes more gravelly northward, furnishing a small gravel-pit in SE. 1/4 SW 1/4 sec. 34, of Canton township. Following due north, the beach shows as a rather distinct low ridge at the village of Canton, furnishing the site for the church and continuing just east of the central meridian of the township, to about the middle, where it disappears for a couple of miles. In the northern portions of secs. 11 and 12, separated sand strips seem to mark the location of the beach, curving into sec. 1. The elevation of the crest throughout is about 682 feet above sea level, the beach following closely the 680 foot contour of the topographic map. This contour enters sec. 6, Nankin township, and, although the slope to the eastward is unusually rapid for this region, falling 24 feet in a half mile, there is but slight trace of the beach. Just north, however, in sec. 31, Livonia, it takes form as a low sand crest, passes through the village of Nankin, following the road north and near the middle of the township breaking up into separate ridges or bars. In secs. 9 and 10, it is well developed again and leaves the county in the NE. 1/4 sec. 3. What appears to be a very well defined bar, having an elevation of 660 to 665 feet, appears in sec. 33, striking a little east of north through secs. 28 and 21, breaking up in sec. 15, but still showing traces in 10 and 3. Most of this region was marked upon the Higgins' map as "oak plains" and "oak openings", owing to the sparse timber growth.

The Wayne beach, the next in the series as we move eastward, is the most sandy of any thus far described and located, being throughout its course quite similar to the northern portion of the Warren beach. The real shore line is often disguised by dunes and bars making it difficult to locate the beach and to decide upon its approximate height. Most of the sand associated with the Wayne shore line lies between 650 and 660 feet elevation and the average height of the beach crests may be taken as about 654 or 655 feet. It enters Wayne County from London township, Monroe County, at the extreme SW. corner (sec. 31, Sumpter township), and passes northeastward across the center of the township. Sand was distributed to the westward for a mile or two, suggesting that the prevailing winds, or perhaps only the strongest winds, were from the east, instead of from the west as at present. The water in front of the beach was shallow and numerous bars were formed by wave action. In the SW. part of Romulus township, there is an unusually heavy development of sand, striking northward through the village of Romulus; north-northeastward through the western half of the township; across Nankin township, through the village of Wayne, and just west of the central meridian. The profile of the electric railway at Wayne shows a very broad, flat crest, 3,400 feet across and 5 feet above the general level, reaching an elevation of about 655. In Livonia township, the Wayne beach is not well defined, being represented by disconnected scraps of sand ridges. This is apparently due to the fact that the Detroit moraine formed a broad, rounded peninsula, projecting southward into Wayne County to a distance of three to four miles, giving rise to an embayment in northeastern Livonia and northwestern Redford and thus protecting the region from wave action. Upon the lakeward side of this peninsula and about its southern extremity, a well defined succession of sand ridges occur in the north central portion of Greenfield township. Just west of Palmer Park, the ridges become much complicated and in the park seem to mingle with dune ridges of the Grassmere stage (see Pl. X). Taylor has recently found evidence that this beach was submerged for a time just as in the case of the Arkona and Lower Maumee, an advance of the ice closing up the outlet of Lake Wayne and forcing the water to a higher level.

In its general characteristics and mode of development, the Grassmere (Lundy) beach is very similar to the Wayne just described and, through the bars of the latter and dunes of the former, the two are often very intimately associated, as in Greenfield, Romulus and Sumpter townships. The approximate elevation may be given as 635 feet above tide, but ridges, apparently the result of easterly wind action, rise 12 to 18 feet higher. It enters Sumpter township from Exeter township, Monroe County, with a complicated set of disconnected sand ridges amongst which it is difficult to pick out any particular beach ridge. Cutting across southeastern Sumpter and northwestern Huron townships, the system of sand ridges passes New Boston into Romulus where they become more crowded and prominent, especially in secs. 33, 28 and 21 and have a NW.-SE. trend. At the village of Romulus, the beach and the ridges swing around to the northeastward and then

northward, cutting through Nankin township just east of the central meridian, showing some strong ridges in secs. 1 and 2. In Livonia, a long, well defined ridge assumes shape in the NE. 1/4 sec. 27, branching in the SE. 1/4 sec. 22, one branch passing northward for a mile, the other curving abruptly eastward for two miles through the lower half of secs. 23 and 24. Numerous N-S ridges occur in the NW. 1/4 of Redford, with bars to the south at a somewhat lower level. At Sand Hill, just north of the center of the township, two prominent sand ridges are found rising to 640 and 660 above sea level, evidently due to wind action. In passing around the peninsula formed by the Detroit moraine the same phenomena are noted as for the Wayne beach. Sand ridges, with more or less gravel, occur both north and south of Grand River Avenue, Greenfield township, in secs. 28, 29 and 30. The eastern half of the township is spotted with beach and bar ridges in Palmer Park, about Highland Park and continuing into Hamtramck township as shown in Pl. X.

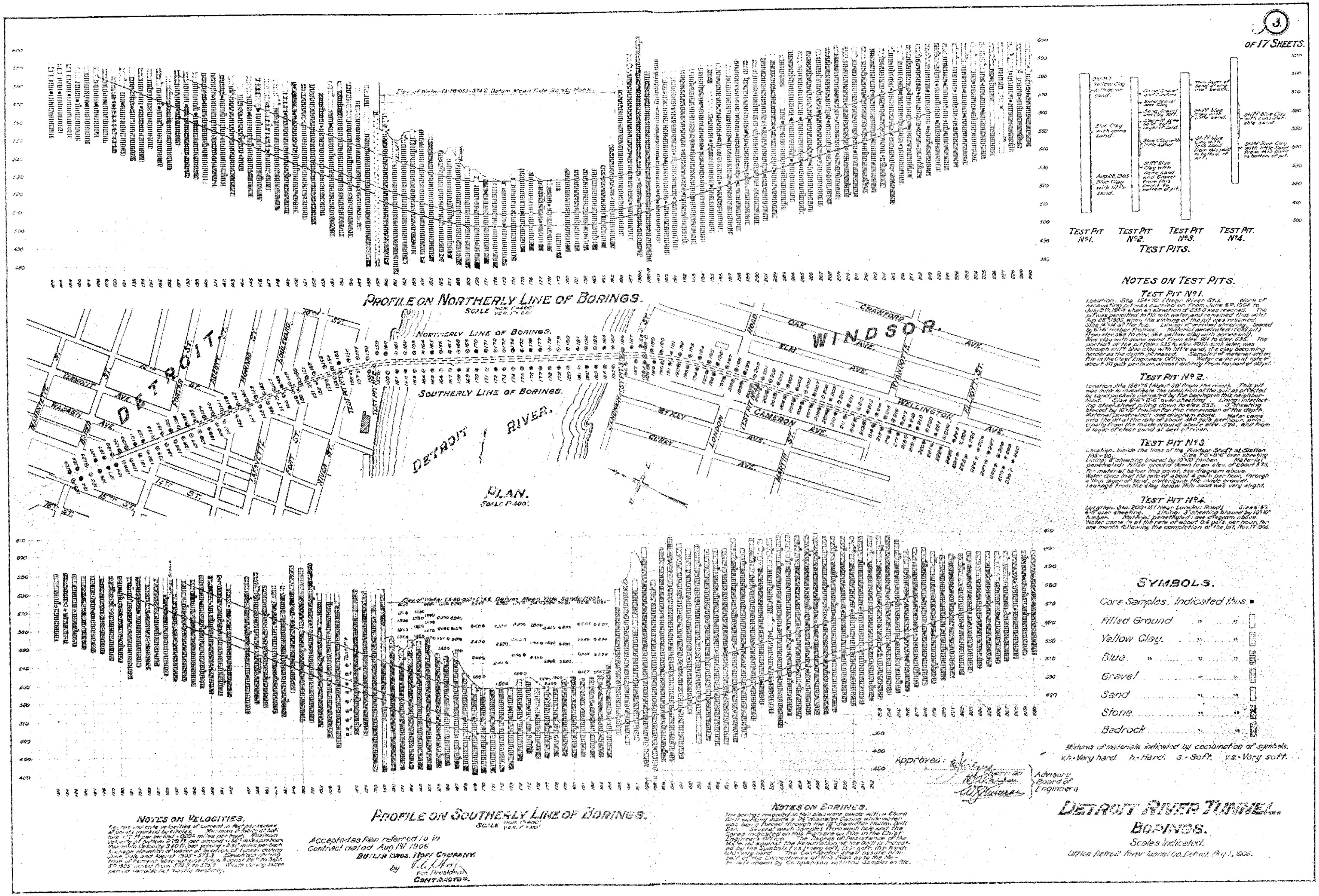
Near Willow and Waltz in southwestern Huron township some conspicuous NW. to SE. sand ridges are found whose elevation is too low for the Grassmere and somewhat high for the next lower beach of the series:—the Elkton. These rise to heights of 620 to 625 feet above sea level and are apparently the result of wind action. The eastern half of Huron township is more or less sandy but shows little suggestion of ridging. This condition of the soil and surface extends into northwestern Brownstown where ridging becomes noticeable in secs. 9 and 16, with elevations ranging from 606 to 612 feet. This belt of sand ridges passes northward through Taylor township, entering Dearborn township in sec. 33, not well defined at first but becoming more so toward the village of Dearborn. The profile of the electric railway here shows a crest 600 feet broad, reaching an elevation of 617 feet, with an abrupt slope on the eastern side and a much less one to the west. Northward from Dearborn, there is a belt of sand about two miles broad, with short, discontinuous ridges passing through secs. 21, 16, 9 and 4, becoming more and more indistinct as the old water line passed up behind the Detroit moraine. A gravel-sand ridge starts in the NE. corner of sec. 1 and continues into the eastern half of sec. 36, Redford township, rising to 621 feet. Turned eastward by the moraine, a nearly continuous ridge may be traced through the lower strip of sections of Greenfield township, crossing northeastern Springwells and entering the city of Detroit. It crosses

Warren Avenue southeastward and disappears as a ridge between Buchanan and Poplar streets, at about 17th Street, but with patches of sand still showing to the southeastward for a mile further toward Grand Circus Park. In passing around the point of the Detroit moraine, there was too much wave action for the formation of a beach ridge and there remains now only a cut shelf in the till slope, with the elevation of 605 to 615 feet, best seen on Joseph Campau Avenue, between Campau Park and Monroe Street, but also on the other neighboring streets looking northward from Monroe. Upon the eastern side of the moraine, the sand appears again to the northward and northeastward from Elmwood Cemetery, for the most part scattered but in places ridged. Parallel with Gratiot Avenue, but one to two miles to the eastward, the beach may be traced northeastward across Gratiot township leaving the county in sec. 6.

The next stage in the general recession of the lake waters is marked by a rather poorly defined beach line, the correlative of one of the Algonquin beaches, but at a lower level. The most northerly strip is to be designated the First St. Clair beach by Taylor in his forthcoming monograph and was formed about the margin of a lake which was the ancestor of our present Lake St. Clair. This lake received the drainage from Lake Algonquin during a considerable portion of the life of the latter and drained southward, as at present, into Early Lake Erie. The old water level is indicated in the northeastern corner of Gratiot township as a slight cut of one to two feet in the surface clay, entering the county just east of the 600-foot contour, passing southward and curving to the west before reaching Mack Avenue. As it approaches Connor's Creek, in the southern part of Gratiot, it shows some sand, apparently contributed by the creek itself during this stage. In the village of St. Clair Heights, some sand ridges mark the level, running southwestward towards the river just west of the Waterworks, crossing Jefferson Avenue and continuing parallel with it on the river side as a rather steep bluff entirely around the Detroit moraine, and causing the abrupt descent to the river.

In the east central part of Grosse Point township the Emmet moraine had its crest above the water level at this stage, forming a small island and having a gravelly beach formed upon its lakeward side. This moraine seems to have protected the shore line to the west from wave action and explains the weak character of the beach there formed.

Before reaching the present Michigan Central depot, foot of



PROFILE OF BORINGS FOR DETROIT RIVER TUNNEL, SHOWING THE STRUCTURE OF THE WISCONSIN TILL.

Third Street, the cut bluff crosses Jefferson Avenue to the northwest at about Wayne Street, curves to the north of the Union depot and continues westward on the north side of Fort Street. This cut bluff along the Detroit River front suggests rather vigorous current action as the waters entered Lake Rouge and marks the early banks of the then very short Detroit River, or perhaps more appropriately the Detroit Strait. Near the Boulevard, running back from the river, sand again makes its appearance between West Detroit and Ft. Wayne and numerous well defined ridges appear with a general east-west trend. These furnish the site for Woodmere Cemetery and a prominent sand-gravel ridge, one-half to one-eighth of a mile wide and some 15 to 16 feet above the river, which determined the location of Ft. Wayne and gave it command of the water. West of Rouge River some of this sand continues into Springwells township and much of it is found upon the Ontario side opposite, extending back two to three miles from the river, supplied mainly, Taylor thinks, by the distributaries breaking through the Detroit moraine and sweeping along the sand and gravel into the more quiet waters of Lake Rouge. This beach is the correlative of the First St. Clair; that is, it was formed simultaneously with it, as well as with the Algonquin further north, and will be named by Taylor the First Rouge beach. The shore line of this lake curves to the south through the western part of Ecorse township, turning eastward in sec. 31, because of the moraine there encountered, and continuing southward to the west of Trenton. The moraine upon which this village stands is high enough to have received the beach but may have been simply wave cut, either during the life of Lake Rouge or subsequently. In Monguagon township, sandy streaks occur at the right elevation in secs. 11, 14, 23, 26 and 35 and further west in and about Flat Rock on the Huron. Sand, probably of the nature of delta sand carried by the river during this stage, was deposited along the valley down to its present mouth. Grosse Isle was also an island at this stage, although more completely submerged and received a low gravel ridge about the northern end where the waves of the lake were strongest.

The last beach, before the present water level was reached, lies only some 6 to 7 feet above the present level (elevation about 582 feet), so near that it might readily be regarded as belonging to the modern series. It is more or less scrappy in character so that it can not be followed continuously, in some places represented by a cut bench, in others by a low sand or gravel ridge, usually quite near the present water margin, but where the land is low, more distant. Upon the Nellist map, the beach is marked as a "transition beach", is now regarded by Taylor as marking the level of the waters in this region during the life of Lakes Nipissing and will be known as the Second St. Clair and Second Rouge respectively. Formed in the bodies of water into which these lakes drained, this beach has been from the first at a lower level and can not with propriety be termed the "Nipissing," but it is its correlative. Although there has been considerable recent cutting along the western shore of Lake St. Clair, portions of this beach are preserved here and there between the lake and the main highway in Grossepoint township. At Milk River Point, just over the north county line, the northern end of the Emmet moraine shows a very pretty cut bluff referable to this stage of Lake St. Clair (see Pl. XVI, B) its preservation being due, apparently to the concentration of boulders along the shore by wave action (Pl. XI, B).

Southward from Grossepoint Farms, it leaves the river and swings to the southwestward about a mile back from the river in passing Windmill Point, continuing as a sand ridge through Cottage Grove and Fairview. The portion representing the bank of the river during this stage has been destroyed, either by its subsequent work, or by the grading and artificial structures along the river front. The Second Rouge beach, however, appears in the western part of the city, best seen at Ft. Wayne as a cut bluff and in Delray and on Brady Island as a ridge. It follows along the highway across Ecorse township, now on one side and now on the other, as a pretty well defined and rather continuous sand ridge which seriously obstructs the drainage of the region. In Monguagon township, the moraine throws the beach close to the river where the most of it has been destroyed. Upon the islands in the river, where protected from recent wave and current action, traces of this stage of the water level may be here and there detected. It shows as a cut bluff along the southwestern corner of Grosse Isle and as a gravel ridge on the mainland opposite in the NW. 1/4 NW. 1/4 sec. 1, Brownstown township.

Deltas. During the various lacustrine stages just described, the streams were at work bringing detritus from the higher portions of their basins and, upon the checking of their velocity, depositing it in the more quiet lake waters. Especially active during the stages of flood, year after year deposits were formed about the mouths of these streams, of the same age as the correlative beach, changing the topography and soil and furnishing a rough measure of the time involved in the lake stage itself.

So far as we may judge from the map of the Coast and Geodetic Survey, Huron River at the present stage has not formed a delta

over two square miles in area, while the same stream during the Lake Arkona stage formed a delta some twenty times as large. Climatic conditions, were of course, sufficiently different to vitiate any definite conclusions that we might draw from these facts. During the Maumee stages, only the Middle Branch of River Rouge was in existence and it emptied into this series of lakes just north of Plymouth, but deposited only a relatively small amount of sand and gravel, owing partly to the small size of the stream and the relatively short duration of the lakes. During the life of lakes Whittlesey and Arkona, much more work was accomplished by this stream, but, owing to the rise of water from the latter to the former, the work during each stage can not be distinguished. Gravelly sand extends from the northeastern corner of Canton and the northwestern corner of Nankin townships, northward across Plymouth and Livonia, to the county line, apparently distributed shoreward by waves and currents. This deposit extends southeastward for some five miles into Livonia and covers an area of some 28 to 30 miles, supplying the materials for the beach ridges and bars of this region. The surface elevation of this great fan-like deposit ranges from 730 feet, just in front of the Whittlesey beach to about 660 feet above sea level and an inspection of the topographic map shows how these contours have been deflected eastward as they cross this deposit. The well records of the region indicate that the beds of sand and gravel reach a depth of 12 to 15 feet, before the clay is struck, thinning towards the margins of the area.

Southward a very similar, but still larger, delta was formed during the same stages of the glacial lake waters by Huron River of that time. This delta covers the western and southern portions of Van Buren township and the northern two-thirds of Sumpter, comprising a gravelly-sand area of 42 to 43 square miles within the limits of Wayne County, and attaining a maximum thickness of some 20 feet. In a NE.-SW. direction, it extends from Denton to West Sumpter and eastward as far as French Landing. The more or less well defined character of the Arkona beaches which rest upon the Rouge and Huron deltas, indicates that these deposits were formed mainly during the life of the Arkona series of lakes, otherwise they would have been deeply buried in the deposits of Whittlesey time. During the latter stage, the Huron emptied into the lake with an estuary-like mouth and much of its delta gravel and sand was deposited before actually reaching the lake. The result of this is that the delta is continued up the present valley of the Huron as a well defined terrace. Very little in the way of delta deposit seems to have taken place during the subsequent lake stages, the material having been mainly sand and this was largely worked over into bar and beach ridges and subsequently into dunes by the wind. Were these deposits removed we should undoubtedly find a dressing of sand remaining to mark the location of the mouths of the various streams entering the lakes.

Distributaries. A very interesting series of "distributary channels" has been described by Taylor in the forthcoming monograph previously noted. When the waters were dropping from the First St. Clair stage, during the life of Early Lake Algonquin, the Detroit moraine is conceived to have served as a very temporary dam, over which the waters cut their way at several points simultaneously, digging channels and depositing the sand and gravel in Lake Rouge. Taylor recognizes two such channels in Detroit and others were probably formed and destroyed in the present bed of the river, since the permanent flow would probably be in the direction of the larger. Congress Street lies in the axis of one of these channels, east of Woodward, and Baker and Labrosse streets to the west of Grand Circus Park. The great quantity of sand and gravel between West Detroit and Ft. Wayne and between the Boulevard and the River Rouge (see Pl. X), with an elevation of 585 to 595 feet, is believed to have been so deposited and only a minor portion of it by the present Rouge (see Pl. XVII, A). Near Trenton, Grosse Isle (Pl. XVII, B) and Amherstburg a much more complicated system of such distributaries has been mapped by Taylor and are being described by him. Their course in this region seems to the writer to have been determined very largely by the morainic ridges of the Grosse Isle moraine, hence there was comparatively little erosive work done and little or no deposition about their mouths. The water found and occupied the depressions between these morainic ridges in the lower Detroit River region instead of carving them entirely from the till plain. According to Taylor's interpretation the till ridges are *destructional* features, while the writer is compelled to believe that they are really *constructional,* and modified more or less by current action.

Lake deposits. Aside from the gravel and sand deposits just described, the waters of the glacial lakes deposited comparatively little sediment over their floors. In many places, the glacial till comes quite to the surface and boulders and even cobbles are found resting upon the surface without cover. Theoretically there must have been some deposit throughout but it seems to have been so scanty in amount over much of county that it has either been removed by surface erosion, or incorporated into the few inches of surface soil. Just west of the Detroit moraine, however, in Springwells township, a considerable deposit was put down in the former depression, reaching a maximum thickness of some 40 feet, but thinning rapidly from this as a center. This gave rise to a finely laminated clay, the laminae being sometimes as thin as .5 millimeter, generally free from pebbles or boulders, and utilized for many years in the manufacture of brick. The pebbles and boulders that do occur have probably been transported on floating ice, while the clay represents the fine sediment, originally of glacial origin, that was slowly transported to the deeper water before settling to the bottom. Freshets and exceptionally heavy wind storms, by which wave action about the shore lines would be increased, would contribute unusual supplies of sediment to the deeper and more quiet water and successive layers would be deposited in very regular, horizontal laminae. Small irregular concretions, of lime carbonate, iron and clay, known locally as "clay dogs", occur in some of the beds. These have formed where they are now found by the segregation of the ingredients, probably while the deposit was fresh and moist. They are not abundant enough to seriously interfere with the utilization of the clay in the manufacture of brick and tile. The surface elevation of this lake clay deposit is about 585 to 590 feet above sea level and the workable portion of it covers four to five square miles, gradually thinning in all directions and merging into the glacial clay. When wet it is decidedly plastic and sticky and in the spring gives rise to roads that are well nigh impassable for teams and automobiles.

In the deeper pits from which brick clay is being taken (as at Haggerty's, Daniel's and Clippert's), three quite distinct beds may be noted, distinguished by their color and rather sharply separated. Beneath from 6 to 12 inches of surface soil, there occurs a yellowish-brown layer from 2 feet to 4½ feet in thickness. Beneath this occurs a layer in which the iron ingredient has assumed a slight reddish tinge, ranging in thickness from 3 to 5 feet, giving out to the eastward, or becoming indistinguishable from the upper. Below this lies a bluish bed, extending apparently to the bottom of the deposit. It is conceivable that these three beds were formed under slightly varying conditions during the lifetime of a single glacial lake, or that they represent the deposits of three successive lakes such as the Lundy, Warren and Wayne. Somewhat confirmatory of this latter view is the fact that there is an average increase in the amount of sand towards the top as though the water was becoming shallower during deposition and the shore line had drawn nearer to the region. The following analyses of these clays were made for this report in 1902 by Elmer E. Ware, under the direction of Prof. E. D. Campbell of the University of Michigan.

TABLE IX.—ANALYSES OF WAYNE COUNTY LAKE CLAYS.

Chemical ingredients of clays.	General description of samples.														
	Blue or deepest bed.			Red or middle bed.			Upper or yellow-brown bed.								
	Daniels & Bros. 14½ ft. from surface.	Clippert & Bros. 14 ft. from surface.	Haggerty & Son. 12½ ft. from surface.	Daniels & Bros. 7 ft. from surface.	Clippert & Bros. 7 ft. from surface.	Haggerty & Son. 5½ ft. from surface.	Lonyo Brick Co. 5 ft. from surface.	Proctor Bros. 5 ft. from surface.	M. Downey. 5 ft. from surface.	Daniels & Bros. 2½ ft. from surface.	Clippert & Bros. 2½ ft. from surface.	Haggerty & Son. 2 ft. from surface.	Lonyo Brick Co. 2½ ft. from surface.	Proctor Bros. 2½ ft. from surface.	M. Downey. 2½ ft. from surface.
Number of samples	3	6	9	2	5	8	10	12	14	1	4	7	11	13	15
Silica (SiO_2)	57.55	57.58	55.53	57.18	55.86	57.75	66.19	65.75	69.50	71.32	56.16	74.77	67.06	58.42	59.46
Alumina (Al_2O_3)	13.42	13.63	10.89	16.04	15.24	14.75	12.78	15.04	14.84	12.73	10.95	8.32	16.78	13.44	14.88
Ferric oxide (Fe_2O_3)	3.92	3.62	4.30	5.26	4.50	3.70	5.18	5.26	4.92	4.88	3.32	3.02	4.30	4.70	4.40
Calcium oxide (CaO)	7.40	6.94	9.23	6.46	7.10	5.92	3.37	3.10	1.92	1.70	10.24	3.04	1.70	5.86	5.18
Magnesium oxide (MgO)	5.96	4.68	5.36	4.60	5.05	4.68	3.58	3.05	2.09	2.19	4.86	2.52	2.30	4.46	5.01
Loss on ignition*	11.43	11.18	12.51	10.07	12.23	9.90	4.67	6.85	4.42	4.67	13.95	5.07	4.98	10.08	9.38
Sulphuric anhydride (SO_3)	.64	.65	.80	.01	.06	.06	.13	.06	.16	.13	.04	.05	.06	.01	.11
Sodium oxide (Na_2O)	......	......	......	......	......	......	......	2.45	......	......	......	1.85	2.69	......	......
Potassium oxide (K_2O)	......	......	......	......	......	......	......	.74	......	......	......	1.54	.87	......	......
Difference	−.32	+1.72	+1.38	+.38	−.04	+3.24	+4.10	−2.30	+2.15	+2.38	+.48	−.18	−.74	+3.00	+1.58
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*This includes combined and hydroscopic water, organic matter, carbon dioxide, alkaline chlorides, etc.

Of the various brick plants from which the samples were taken that of L. D. Haggerty and Son is the most westerly, being located just north of Michigan Avenue, in Springwells township, at the Pere Marquette crossing. George H. Clippert and Brother and Jacob Daniels and Brother, come next in order to the south of Michigan Avenue, ¼ and ½ miles respectively. The other three have their brick manufactories near the avenue; Lonyo-Brick Company 1 mile east of the Pere Marquette, Proctor Brothers 1½ miles east and M. Downey 2 miles. Aside from the composition of these economically important clays the above table shows several things of interest. The average amount of silica present in the 15 samples analyzed is 62.01% and of the alumina 12.60%. The two lower, and hence oldest beds, have an average of 56.91%. The ferric oxide in the entire series averages 4.35% and shows no marked differences in the samples selected from various depths, owing to the fact that this compound is insoluble in ordinary water. The case is quite different, however, when we examine the varying percentages of calcium and magnesium oxide and the sulphuric anhydride. These oxides listed are present in the clays as carbonates mainly and the anhydride is very probably combined with a relatively small amount of calcium oxide to form the calcium sulphate. These are all moderately soluble in ordinary water and appear to have been partially leached from the uppermost bed, since it gives an average of 4.01% of calcium oxide, 3.34% of magnesium oxide and .09% of sulphuric anhydride, as compared with 7.17%, 5.05% and .37% respectively in the middle and lower beds. The application of the dilute acid test in the field shows also a marked difference in the reaction, in harmony with the above conclusions. Since the carbonates of sodium and potassium are so readily soluble and are reported only from the upper beds, it seems likely that these akaline elements are in the form of silicates. Their absence in 12 of the samples would seem to indicate that they had not been determined in the analyses.

In Grosse Point township and within the city limits of Detroit, other less extensive deposits of similar lake clays are encountered, lying to the eastward of the Detroit moraine. In tunneling beneath the river from the Waterworks towards the head of Belle Isle in 1902, a cat tail bog, evidently of rather recent origin, was penetrated to a depth of 15 feet. Beneath this lay a bed of brownish lake clay carrying shells and occasionally glaciated, crystalline boulders. When visited by the writer in March, 1902, this bed had been penetrated to a depth of 25 feet below the river level. Excavations upon the grounds to the north showed that the deposit was of limited extent. In the Ecorse salt shaft, there was encountered 4 feet of muck, 2 feet of mucky clay and 4 feet of mottled (brown, yellow, blue) clay with shells. At the Woodmere salt shaft, there was blue glacial clay from the surface soil to bedrock.

A shallow deposit of lake clay is found in the vicinity of Leesville, on Gratiot Avenue, that was at one time extensively used in the manufacture of brick. The deposit averages only 3 to 4 feet in thickness, consisting of blue and yellow clay, free from stones, and extends for a distance of a couple of miles along the avenue. The area is rather difficult to trace from its surface exposure but appears rather narrow and much more local than the Springwells deposit.

CHAPTER IV.

PHYSICAL GEOGRAPHY (Continued).

SURFACE DRAINAGE.

Stream development. Within the limits of Wayne County, the present surface streams had their origin and began their development only after the waters of Lake Maumee had receded to the level of Lake Arkona, where they appear to have halted for a relatively long period. This recession of the water was practically the same as a general uplift of the lake bottom and there came into existence a large number of short, straight, approximately parallel, stream courses, devoid of tributaries, flowing down the eastern slope of the Defiance moraine and across the narrow strip of bared lake bed. Such streams are known in the physiographic language of today as "consequent streams", their course being in *consequence* of the surface slope at the time of their development. The surface topography of the region in question was due in large part to the ice sheet itself; to a less extent to the work of the lake waters both in their destructive and constructive action. A good example in miniature of the character of streams above referred to is shown in the accompanying Pl. XVIII, A, which represents an unusually heavy deposit of wind-blown sand exposed for the first time to a heavy shower.

Irregularities in the hardness of the material being cut into by the streams would cause lateral deflection here and there and the streams would begin to meander. Occasionally, the divide between two neighboring streams would be destroyed at some point by the more active and it would thus draw off the upper flow of the weaker neighbor, "capturing" or "beheading" it. Similar results would also be accomplished with the help of small tributaries developed along the side, or about the head of the more vigorous streams and there would be developed gradually a smaller number of drainage systems, nature favoring the more aggressive. Deep gullies were cut in the till in the upper, steeper part of their courses and the material so derived was deposited as bars and flood plains in the more gentle courses, eventually landing in the more quiet lake waters to assist in the formation there of deltas, beaches and bars.

The advance of the water-level from the Arkona up to the Whittlesey stage, some 35 to 40 feet, submerged to this depth the lower courses of the streams then in existence, causing less "fall" and bringing about a sluggish condition known as "drowning". It was as though the entire region had been depressed this amount, so far as the streams themselves were concerned. Something of a similar nature but on a smaller scale had occurred when the water rose from the lowest, or third stage of Lake Maumee up to the second stage. The chief streams of this region to be so affected were the Middle Branch of the Rouge and the Huron. The latter had entered Wayne County during the Arkona stage at Rawsonville but when the rise of water came had its mouth pushed westward into Washtenaw County, some two miles, forming an estuary in which the deposits of Whittlesey time found lodgment. When the level of the glacial waters finally dropped to that of Lake Wayne, the streams were revived, "rejuvenated" as it is termed, flowing to a lower level, with quickened velocity and increased cutting power. The normal direction of increase in the length of a stream is headward, as it works its way farther and farther back towards its limiting divide, thus enlarging its basin and increasing its drainage area. The streams of Wayne County have made but little headward growth but, relatively speaking, have greatly extended themselves mouthward, giving rise to a type of stream somewhat difficult to classify satisfactorily. Since most of the streams are still engaged in deepening their beds throughout a considerable portion of the year, we should look upon them as "youthful" and still they show well developed flood plains and mature meander loops.

The rise of the water from the Wayne to the Warren stage, some 25 feet, again brought about the same drowned condition of the lower courses of the streams, to be presently followed by a series of rejuvenated stages as the waters dropped successively to the lower levels. Not until the close of Lake Lundy did the three branches of the Rouge unite into a single stream, thus bringing these three systems into a single one. As the waters subsided, the Huron received very little additional surface drainage, but considerable seepage along its banks from the extensive sand and gravel deposits contiguous in Van Buren, Romulus, Sumpter and Huron townships. Only during the life of Lakes Nipissing and of the present system have the streams along the eastern margin of the county been in existence and that they are perceptibly younger is indicated by their direct courses and general absence of tributaries. Owing to their youth, lack of fall and limited drainage

areas, they have not reached the level of ground water throughout much of their courses and hence are only "intermittent streams" in these portions.

During the stage of Lake Algonquin, when the St. Clair outlet was not in commission, the streams of the county were all flowing to much lower levels than at present and were permitted to cut channels much deeper than would now be possible with the sluggish condition of the water about their mouths. When the drainage into the St. Clair was again established the level of the water rose, entering the river channels, submerging the banks and bringing about the present drowned condition of the modern streams.

Drainage systems. If one attempts to classify the present drainage systems of the county, the most natural basis of such classification would be the body of water into which the drainage is conducted; as Lake St. Clair, Detroit River and Lake Erie. Upon such a basis, only the short and relatively unimportant Milk River would constitute the first division; the Huron and Swan Creek would make up the Lake Erie, or third division, while the remaining streams would be included in the second, or Detroit River division. Instead of describing the various drainage systems of the county in this order it will be found more interesting to the general reader to take them up in the order of their appearance and subsequent development. In the first to be presented, we may then look for the evidences of relative age and contrast its stage of development with the youthful members of the series, our basis of classification then being relative age. The rather anomalous condition will then appear that these streams are all *older* than the bodies of water into which they now empty.

The oldest and largest drainage system to be developed within the county is that of the Rouge,[1] with its Eastern, Middle and Lower branches which unite into a single trunk stream just east of Dearborn. The area drained by this stream and its branches constitutes its *basin* and this comprises approximately one-half of the county. When the ice withdrew from the Defiance moraine and allowed the waters of the glacial Lake Maumee to work their way northeastward between this moraine on the west and the retreating ice-wall on the east, a series of gullies was started upon the eastern slope of the moraine; which, although separate and independent at first, eventually gave rise to the three branches of the Rouge in Oakland, Wayne and Washtenaw counties. The drainage from the *western* slope of this moraine in Northville and Ply-

1. This name presumably alludes to the color of the sediment with which the stream is generally charged. Instead of being *red* however, the color more frequently seen is yellowish-brown.

mouth townships, combined with that from portions of the Northville and Ft. Wayne moraines, which drainage had been to the southwestward while the ice front stood at the Defiance moraine, was now reversed, because of its finding a break in this moraine just south of Northville, and this gave the Middle Branch from the start an advantage of many square miles of drainage area over the other two branches. This advantage has been retained to the present day, accounting for its greater activity in the way of delta formation in the past and its greater importance today as a source of water-power.

This Middle Branch of the Rouge takes its origin in the swampy areas lying in the northern half of Salem township, Washtenaw County, the crest of the Ft. Wayne moraine serving as the divide between it and the upper Huron basin. Its general course across Salem township is southeastward, entering Plymouth in sec. 19 and thence following the course of the old drainage channel noted, but in reversed direction, for five miles to the northeast, cutting through the Defiance moraine and receiving from the region to the north the drainage from Ingersoll Creek and its tributaries, lying between the Defiance and Northville moraines. From Northville, the general course of the stream is southeastward, following the general surface slope, but turning eastward in the NE. ¼ of Nankin and NW. ¼ of Dearborn townships. Small tributaries, more or less intermittent in character, are received along the way. At Pikes Peak, it receives its largest tributary, Tonquish Creek, which starts with three branches heading along the eastern slope of the Defiance moraine, draining southern Plymouth, northern Canton and northwestern Nankin townships. In the latter township, this creek is deflected to the northeastward by the heavy sand deposits associated with the Wayne beach, otherwise it would have drained to the Lower Branch of the Rouge. Within the limits of the county, the average fall in the Middle Rouge is about 11 feet to the mile, measured along the valley, and not with the stream, as far as the junction with the other branches. Water-powers are utilized at Northville, between Plymouth and Waterford and at Pikes Peak. During times of flood from heavy rainfall, or rapid melting of snow, the stream becomes a torrent, deepening its bed and broadening its valley here and there by lateral cutting. Successive deposits at such times upon either side of the main current have built flood plains of river silt to a height of several feet above the ordinary stage of the water. As the stream swings from side to side these valley deposits are successively destroyed in one direction and slowly restored upon the other, so that the flood plain in any cross-section of the valley is not uniform in height. During times of flood, a deposit often takes place upon either side of the main channel just where the current is suddenly checked by the more sluggish water covering the valley flat. There may thus be built up a low ridge of sand, or silt, higher than the general level, upon either side of the main channel and roughly parallel with it, to which the term "natural levee" is applied. The flood plains are narrower and generally higher above the water in the upper portions of the valley and broader and lower as one descends the stream. At Plymouth, the Pere Marquette Railway crosses the Middle Rouge at right angles and the profile shows the valley there to be 1300 feet in breadth and that the banks have an elevation of 722 feet above sea level. The general level of the flood plain is 693 feet, making the banks above this plain about 29 feet, or some 35 feet above the water. One mile north a similar profile gives the same breadth to the valley, with 40-foot banks and a flood plain 5 feet above the bottom of the bed.

The Northern Branch of the Rouge is essentially similar to that just described although shorter and with smaller drainage area. It takes its origin in the NW. ¼ Southfield township, Oakland County, pursues a generally southern course across Redford township, owing to the Detroit moraine, uniting with the Middle Branch in the SE. ¼ sec. 10, Dearborn; just after the close of the first stage of Lake Lundy. In Southfield township, it is deflected to the southwestward for a few miles by the extension of the Birmingham moraine and at the village of Southfield furnishes water-power. From the Whittlesey beach the average fall to Dearborn is about eight feet to the mile, and that of the Middle and Lower branches from the same point of reference, flowing farther but with less total fall, average the same. Within the limits of the county, however, the fall in the North Branch is much less, only about 2½ feet to the mile, it having succeeded in cutting most of its bed below the 600-foot contour. In these measurements, the length of the valley itself was taken; with the actual length of the stream, the fall would average considerably less. The Pere Marquette profile furnishes a cross-section of this branch at Oak, in southern Redford township, showing the valley to be 1500 feet across, with banks 35 to 36 feet in height. Towards the north county line the banks become less in height, reaching 18 feet, and also southward in Dearborn township, where they are 25 to 30 feet. Small, more or less intermittent, tributaries are received, mainly from the eastern portions of Southfield and Redford townships. One larger double tributary is received from the west, just south of Bell Branch, which drains western Redford and the greater portion of Livonia. In his studies upon the lateral erosion of Michigan rivers, Jefferson included the three branches of the Rouge and notes the general inactivity of this North Branch when compared with the other two, so far as lateral cutting and deepening of the bed are concerned.[2] The former flood plain, some 10 to 15 feet above the water, has become a terrace, through the deepening of the bed and is no longer within reach of freshet waters.

The general course of the Lower Rouge is rather direct and easterly, turning in the last seven miles to the north of east, apparently deflected by the heavy sand deposits of the Wayne and Grassmere beaches. Its natural course was southeasterly across Romulus and Taylor townships to the Ecorse basin. It originates upon the eastern slope of the Defiance moraine, in the NE. ¼ of Superior township, Washtenaw County, is deflected to the southwestward by the Whittlesey beach near Cherry Hill, Canton township, receiving a succession of short tributaries from the moraine. In its course, it crosses southern Canton, Nankin and Dearborn townships, receiving a few simple tributaries. Throughout the main part of its course, it shows a well defined flood plain which receives deposits once or twice a year, at the times of overflow. The Pere Marquette profile, one-half mile west of Wayne, gives a breadth to the valley of 900 feet, with banks 27 feet above the bed and a flood plain 7 to 9 feet above. During ordinary stages of the stream the amount of water is slight but at flood it fills its valley from bank to bank, a muddy torrent (Pl. XVIII, B). The relative amount of cutting upon each of its banks was made the subject of study by Jefferson and his assistants in 1906 (*loc. cit.*, pp. 337 and 338). The stream was carefully studied for a distance of 13.3 miles and the amount of recent cutting of the banks determined by pacing. It was thus found that this cutting, having a tendency to widen the valley, amounted to 3182 paces upon the right, or southern bank, as compared with 1225 paces upon the opposite bank. These bare strips of bank were designated by the Scottish term "scaur" (pronounced *score*) and were found to equal about 10% of the total length of bank. The Middle Branch was similarly studied for a distance of 16½ miles, giving 1008 paces for the right bank and 299 paces for the left, the amount of scaur being but 2%. This effect may be assumed to be due to the direction of rotation of the earth upon its axis, which would theoretically tend to force the right bank against the stream, or to the tilting of the crust of the earth in this region which would tend to deflect the water of these particular streams against the right bank.

2. Lateral Erosion on Some Michigan Rivers: Bulletin of the Geological Society of America, Vol. XVIII, 1907, p. 341.

These three branches of the Rouge remained distinct until Lake Lundy dropped from its first to its second stage which allowed the North and Middle branches to unite into a short trunk stream. This seems to have delivered more or less sand to the lake which was worked into beaches, bars and dunes about Dearborn. The fall of the waters from the second stage (Elkton) to that of Lake Rouge allowed the Lower Branch to join the other two just east of Dearborn and the formation of the main stream was effected. The valley here is 3,000 feet across, with broad flood plain 6 to 10 feet above the water and banks about 20 feet above the plain. The stream itself is 40 to 50 feet across and some 8 to 10 feet deep, sluggish and generally more or less clouded with sediment. The fall is only about four feet in 7½ miles, or but slightly over six inches to the mile upon an average. The last four or five miles, however, are almost without current, except as the surface water is moved by the wind. The banks have grown lower with each mile and finally become submerged owing to the drowned condition of this section of the stream. (As types of drowned streams see Pl. XIX, A and B). At Oakwood, there is received from the north a small tributary known as Campbell Creek, draining the western slope of the Detroit moraine, except the small portion in the northeastern corner of Redford township which drains into the North Branch. This stream was known in an early day and still later as the East Branch of the Rouge, the short tributary at Woodmere being called Knaggs' Creek. The *drowning* continues for about a mile and one-half up this stream also. Near the mouth of the main Rouge, the stream curves to the north and east going about a mile out of its way to reach the river. An artificial canal about one-half mile long was constructed direct to the river, cutting off a marshy tract nearly one-half a square mile in area known as Brady Island. According to information secured from Pres. J. D. Hawks of the Detroit and Mackinaw Railway, this canal was built in 1888 by the River Rouge Improvement Company, 2887 feet in length. It was originally intended to be 60 feet in width by 12 feet in depth, but was not fully completed after it was discovered that there was sufficient current to continue the excavation, the water entering from Detroit River through the old mouth and passing out through the canal. A surprising feature of the lower portion of the main stream is the depth in mid-channel which is out of all proportion to the present amount of current and to be accounted for only on the theory that the stream at one time flowed to a lower level. The lake survey chart shows soundings four miles back from the mouth, ranging from 12 to 21 feet and averaging (30 readings) 15.8 feet. It is interesting and significant that the older maps show ship yards located at Woodmere, not only on the main stream but also the tributary, some four miles up from the mouth, at which lake going vessels were formerly constructed and repaired. In an official letter to the British Government in 1800, allusion is made to these yards as a menace, in that they furnished a sheltered site for the building and arming of lake vessels.[3] In 1812 the Brig Adams, of 14 guns, was here for repairs.[4] Such is the intimate relation between geological history and political and economic affairs. This submerged condition of the river banks is occasionally responsible for a tragedy, since boys wading along the banks may suddenly find themselves beyond their depth.

Although Huron River, in its upper course, considerably antedates the Rouge and its various branches, it did not enter the county permanently until after the fall of Lake Whittlesey. It takes its origin in the southern part of Springfield township, Oakland County, in Big Lake (elevation 1017 feet). A small pond with an elevation of 1020 feet lies some two miles to the southwest and is connected by marsh with Big Lake. It is quite probable that at times more or less flow would take place and that this pond is probably to be regarded as the true starting point of the Huron. The Huron River has a length of some 80 miles measured along the valley (probably three times this following the bends of the river) and, according to the estimate of the Hydrographic Bureau of the United States Geological Survey, has a drainage basin of about 1060 square miles, only a small portion of which lies in Wayne County. Its general direction of flow is southwestward, through a series of lakes in Washtenaw County, as far as Hudson Mills where it turns to the southeast, entering Wayne at Rawsonville on an easterly course as far as French Landing, apparently deflected from its natural course by the delta deposits in Lake Arkona which lie mainly southward. At this place, the stream turns southward and then southeastward across Huron township to Flat Rock, from which place it forms the boundary between Wayne and Monroe counties to its mouth in Lake Erie. In the vicinity of Flat Rock and Rockwood, the river has shifted its channel slightly in its meandering over the old lake bed. From Base Line Lake, the last in the series, there is a fall of 279 feet to Lake Erie, or an average of 5⅙ feet to the mile, causing an active flow, numerous

3. Michigan Pioneer and Historical Collections, Vol. XV, 1889, p. 14.
4. *Ibid*, p. 64. See also Lossing's Pictorial Field Book of the War of 1812, 1869, p. 265.

rapids and a gradual deepening of the bed throughout much of this course. From Rawsonville down, the fall is 2½ feet to the mile, upon an average, lessening towards Rockwood and becoming very sluggish toward the lake as in the case of the Rouge. The lake chart shows depths in mid-stream of 12, 10, 16, 11, 11, and 13 feet (average 12 feet) and still greater depths towards Rockwood were reported by residents. A small delta, covering about two square miles, is indicated in the lake opposite the mouth. Were the level of Lake Erie to be lowered, the stream now revived would cut through this delta deposit and leave it at a higher level as a delta terrace, exactly as in the case of the Arkona and Whittlesey deltas.

The average flow of the Huron at Flat Rock, some 7 valley-miles from the mouth, was estimated by the miller there in 1902, as 200 cu. ft. per second and the estimated minimum flow is placed as 109 cu. ft. per second by Lyman E. Cooley, who made a survey for the Washtenaw Light and Power Company. The estimated minimum flow at Rawsonville is placed by Cooley at 100 cu. ft. per second. Since the year 1903, the Hydrographic Division of the United States Geological Survey has maintained guaging stations at various points along the Huron, in order to discover its maximum, minimum and mean flow and these results have been published in the Water-Supply papers of the Survey (Nos. 129, 170, 206, 244 and 264). From these data, knowing the amount of fall in the stream, it is possible to figure the approximate power that could be utilized. Only temporary guages were maintained at Dover and French Landing, but, at Dexter, Geddes and Flat Rock, observations were made from 1905 to 1910. The data for the station at Flat Rock, are shown in the annexed table and are regarded as accurate and reliable. The gauge was placed upon the downstream side of the left-hand bridge abutment, just below the Metler dam, and was read twice daily by Mr. C. L. Metler. The discharge is given in feet per second, based upon the known size of the cross-section of the stream and the observed height of the water, as read from the gauge. Assuming the size of the drainage basin above Flat Rock to be 1000 square miles, there has been figured the monthly and annual "run off" for the years 1905 to 1910 inclusive. The average for these six years is 8.94 inches, which represents, if we assume an average precipitation over the entire basin of 33 inches, a run-off of 27%. The mean discharge per square mile over the drainage area may be obtained from the table by dividing the monthly, or annual mean, by 1000, the assumed size of the Huron basin.

TABLE X.—DISCHARGE MEASUREMENTS OF THE HURON RIVER, FLAT ROCK.

(Hydrographic Division, U. S. Geological Survey.)

Year and month.	Discharge in second-feet.			
	Maximum.	Minimum.	Mean.	Run off in inches on drainage area.
1904.				
August 6-31	335	89	209	.20
September	580	232	320	.36
October	447	282	351	.40
November	346	262	292	.33
December	543	242	313	.36
1905.				
January	593	346	463	.53
February	644	447	515	.54
March	2,354	580	1,149	1.33
April	1,513	531	957	1.07
May	1,832	495	846	.98
June	2,521	401	1,340	1.50
July	928	357	548	.63
August	814	335	434	.50
September	568	252	389	.43
October	842	324	513	.59
November	1,439	447	612	.68
December	1,476	507	753	.87
The year	2,521	252	710	9.65
1906.				
January (20-31)	2,030	696	1,450	.65
February	1,620	618	967	1.01
March	1,300	390	758	.87
April	1,370	593	938	1.05
May	1,100	447	617	.71
June	898	262	462	.52
July	483	204	277	.32
August	401	204	263	.30
September	242	141	180	.20
October	401	213	259	.30
November	722	282	419	.47
December	1,490	401	859	.99
The year	2,030	141	621	7.39
1907.				
January	2,180	....	1,490	1.72
February	....	....	700	.73
March	1,990	....	1,290	1.49
April	1,360	556	903	1.01
May	1,560	611	909	1.05
June	943	334	610	.68
July	490	220	357	.41
August	403	148	253	.29
September	583	166	306	.34
October	742	368	475	.55
November	654	403	517	.58
December	2,300	270	689	.79
The year	2,300	148	708	9.64

TABLE X.—Concluded.

Year and month.	Discharge in second-feet.			
	Maximum.	Minimum.	Mean.	Run off in inches on drainage area.
1908.				
January	2,060	....	1,030	1.19
February	....	....	1,490	1.61
March	....	....	2,860	3.30
April	2,040	802	1,340	1.50
May	1,570	654	1,000	1.15
June	1,040	240	550	.61
July	345	140	231	.27
August	503	132	309	.36
September	312	116	207	.23
October	452	140	227	.26
November	323	220	258	.29
December	440	250	336	.39
The year	....	116	820	11.16
1909.				
January	668	....	406	.47
February	2,420	....	995	1.04
March	2,030	802	1,240	1.43
April	1,680	625	747	.83
May	2,640	668	1,440	1.66
June	959	368	609	.68
July	312	166	234	.27
August	291	124	208	.24
September	240	148	196	.22
October	280	183	227	.26
November	1,010	240	449	.50
December	1,210	....	588	.68
The year	2,640	124	612	8.28
1910.				
January	1,160	529	719	.83
February	1,480	583	745	.78
March	2,780	757	1,580	1.82
April	1,480	403	688	.77
May	2,280	529	1,080	1.24
June	880	202	509	.57
July	220	140	179	.21
August	230	140	167	.19
September	260	148	209	.22
October	240	202	222	.26
November	312	202	240	.27
December	415	240	293	.34
The year	2,780	140	551	7.50

An excellent water-power at Rawsonville has not been utilized for a number of years, since the destruction of the dam, the only powers now used in Wayne County being at Belleville, New Boston, and Flat Rock. A series of 10 dams, 21 feet in height, is contemplated between Rawsonville and Dexter, to more completely utilize the power in this section of the river, and a storage reservoir of the lake region is being considered, intended to regulate the flow throughout the year. In this way, the damage from floods would be largely obviated and the entire annual flow much more fully utilized. The fall from Rawsonville to the lake is about 71 feet, so that much more power in the county could be procured than is at present utilized.

Upon entering the county at Rawsonville, the banks are 55 to 60 feet high and nearly a mile apart, rising higher toward Ypsilanti and dropping gradually toward the mouth. A series of terraces, marking former flood plain levels, occurs in which the river has incised its bed so deeply that only the lowest is now reached by high water. Across this series of terraces, the river meanders, cutting on the convex side of its loop and filling in upon the concave, but doing comparatively little in the way of broadening its valley. From a study of the breadth of the meander belts of certain rivers, Jefferson finds that the average width is about 18 times that of the stream itself.[5] When the loops become mature "cut-offs" occur, straightening the stream and giving rise to "oxbow lakes" upon the flood plain. At Belleville, 2½ miles from Rawsonville by the valley, a series of terraces occurs, related to the ancient river history. The village itself is located upon one such terrace, some 43 to 44 feet above the river, portions of which also show upon the north side. A section shows 4 to 5 feet of yellow loam and gravel resting on a bed of till. The banks of the river when this terrace was formed are now one to two miles distant and 10 to 12 feet higher. The stream itself at Belleville is 85 to 90 feet broad, with a flood plain 4 to 6 feet above the present water level. Between this and the upper terrace there occurs also an intermediate one about 10 feet above the present flood plain. At French Landing, the main terrace is about 38 feet above the flood plain and the old bank is some 54 feet above the water, the stream being here about 95 feet broad (Pl. XX, A). The elevation of this higher terrace near Belleville is about 678 to 680 feet above sea level and at French Landing, nearly three miles eastward, has dropped to about 665. It was evidently formed during the Lake Warren stage of the glacial lakes and left high and

5. Limiting Width of Meander Belts: National Geographic Magazine, Oct., 1902, p. 380.

dry when the stream was rejuvenated by the waters dropping to the Lake Lundy level.

Near New Boston, the Pere Marquette Railway furnishes a cross-section of the valley, which is seen to be 1800 feet across, the banks being 34 feet above the bed of the stream, which is 602 feet above sea level. The flood plain is 11 to 14 feet above this bed, with traces upon the south side of a terrace 7 to 9 feet higher, or at an elevation of about 625 to 630 feet, and probably representing the remains of a delta formed by the stream during the early stage of Lake Lundy. A section of the terrace shows 4 feet of yellow, gravelly loam, reposing on blue till. At Flat Rock, we have another railway section of the valley, 1500 to 1600 feet across, the stream 130 to 140 feet wide, and banks 20 to 22 feet above the bed. At South Rockwood, the valley is 1400 feet wide, the stream 100 feet broad and 7 feet deep, and the ordinary elevation of the water practically the same as that of Lake Erie. The banks are here 14 feet above the water and the flood plain 7 feet. Upon the northern side of the river, apparently resting upon the flood plain, there is seen a knoll nearly a half mile long, the crest of which is at the same level as the surrounding country. Although the up stream portion carries sand, the body of the knoll is found to be glacial clay and investigation shows that it marks an island in the bed of the river during the Lower Rouge stage, one relatively small channel passing to the north.

From 1823 and for a number of years subsequently, flat boats, of 20 tons burden, came up the river from Detroit as far as the "landing" at Rawsonville, then known as Michigan City. In the fall of 1833, the *Enterprise* was built in Ypsilanti and during the season of 1834 made several trips from Detroit to Ypsilanti, carrying a burden of 150 barrels and propelled by "setting poles". The experiment proved unprofitable and ended with the wrecking of the vessel in December, 1834.[6] The field notes of Hubbard[7] show that he made a detailed survey of the Huron from Ypsilanti to its mouth in August, 1838, mapping the various meanders, noting the soil, banks, timber, breadth and depth of the stream. So far as known, these notes were never published in detail.

Although interesting from the geological and scenic standpoint because of what the Huron is today, as well as because of its economic possibilities, chief interest centers in its development through its various historical stages, briefly alluded to in the

6. History of Washtenaw County, Michigan, 1881, p. 117.
7. These, along with much meteorological material, have recently come into possession of the writer through the courtesy of his daughter Mrs. Frederic Towle, of Detroit.

preceding pages. Very largely through the researches of Leverett, we are able to construct the main outline of this history. While the great Huron-Erie and Saginaw ice lobes were coalescent over the "thumb" and region to the south, (Interlobate moraine) a glacial stream, destined to become the Huron, emerged from between the two lobes near the present site of Hamburg, Washtenaw County, and flowed to the westward, past the present sites of Eaton Rapids, Charlotte and Kalamazoo into a slender glacial lake in front of the Michigan ice lobe known as Lake Dowagiac. From this, the drainage was into the Kankakee River, at South Bend, Indiana; thence into the Illinois and Mississippi.[8] When the ice had receded to a position just west of Ann Arbor (Ft. Wayne moraine) and had uncovered the head waters of the Huron the stream was increased in length as a result and the course of drainage from Eaton Rapids was shifted to the northward, down Grand River nearly to Lansing. Turning westward to Thornapple River and following this valley to the bend near Middleville, the old glacial stream turned southwestward to Kalamazoo and Paw Paw rivers and at Hartford entered the early stage of Lake Chicago. When the ice had withdrawn to about the position of the inner border of the Defiance moraine the discharge to the westward was abandoned, and the Huron was deflected to the present site of Ann Arbor, where it turned southwestward, received a strong tributary moving parallel with the ice margin along the present valley of the Middle Rouge and Fleming Creek, and utilizing a portion of the Saline River valley, received the Raisin and emptied into Lake Maumee while its drainage was by Ft. Wayne into the Wabash. When the ice withdrew from the Defiance moraine sufficiently to allow the water of this stage of Lake Maumee to reach Ann Arbor, the Huron was shortened by this amount, emptying at this place and forming a well defined delta in the northern part of the city at an elevation of 812 feet. With the fall of Lake Maumee to its third, or lowest stage, the Huron reached the lake at Ypsilanti and formed an extensive delta in the eastern part of the city. The rise of the water to the middle stage of Lake Maumee led to a drowning and shortening of the Huron and the formation of a third delta in the northeastern part of the city of Ann Arbor. These deltas all represent important sources of sand and gravel for the cities of Ann Arbor and Ypsilanti.

When the glacial lake waters had receded to the levels of Lake Arkona, the Huron, for the first time, entered Wayne County, with its mouth just east of Rawsonville and formed there the extensive delta described previously in this report. Then came again a slight shortening and drowning when the waters rose to the Whittlesey level and the formation of an extensive delta in the estuary carved by the Huron during the Arkona stages. This delta constitutes the terrace upon which the main part of the city of Ypsilanti is now built (elevation 730 to 740 feet) and may be traced along the valley as far as the Whittlesey beach, about half way between Ypsilanti and Rawsonville, where was located the real mouth of the Huron at this stage. This same peculiar history was repeated a third time, in this game of give-and-take between river and lake, as the water level dropped to that of Lake Wayne, extending the Huron as far as the southeastern corner of Van Buren township, then crowding it back to the site of Belleville and there forming the terrace described. During the early stage of Lake Lundy, the Huron mouth was at New Boston and at about the middle of Huron township during the late (Elkton) stage. It had advanced southeastward upon the fall of Lake Lundy, stood near Flat Rock during the early stage of Lake Rouge, the contemporary of Lake Algonquin, and near Rockwood during the later stage, or the correlative of Lakes Nipissing.

8. Geological Atlas of the United States, Ann Arbor folio, No. 155, 1908, p. 10, Fig. 6.

From this history, it is seen that the mouth end of the Huron is the youngest by many thousands of years, the meander loops from Belleville down becoming perceptably less mature. The evidence of lateral cutting by the stream, indicated by the breadth of the valley, shows less age for the lower portion. No deltas were formed at all comparable with those of the Maumee, Arkona, Whittlesey and Warren stages of the glacial lake series, although the river had grown longer and increased its drainage area. It is in its tributaries, however, that the relative youthfulness of the lower Huron is most apparent, especially when they are contrasted with those of the Rouge branches. These are short, very simply branched or not at all, and are largely *intermittent,* showing that they have only very partially cut their beds to the level of ground water. Near where they join the main stream, deep V-shaped gullies occur, but of the type known as *youthful* and requiring only a short time for their development. The main tributary of the Huron in Wayne County is Smith Creek, with its still longer tributary Silver Creek, draining northeastern Huron and southern Brownstown townships. This takes its origin within a half mile of the Huron, flows parallel with it but at a higher level for nearly eight miles and always less than a mile distant, reaching the Huron only when within a half mile of Lake Erie. Measured in terms of river history, only a short time would be required to develop lateral gullies from the Huron which would tap the bed of Smith Creek and divert the upper course more directly to the main stream. In the section of the river between Belleville and Rawsonville, there is considerably more evidence of age shown by the tributaries. Just north of the latter place (NW. 1/4 sec. 19, Van Buren) Bowman has described an interesting case of stream capture.[9] in which the Huron widened its valley and cut into the bed of Oak Run, a tributary of Willow Run, which is in turn a tributary of the Huron. In this way several hundred yards of the head waters of Oak Run were diverted directly to the Huron and the Run, shortened by this amount, "beheaded". About one-half mile east, the Huron started to remove the divide between its valley and that of Willow Run, as noted by Jefferson, by which the Run would have been shortened nearly a mile. A pronounced notch was cut but before the capture was completed the Huron began to swing in the opposite direction and the work is temporarily abandoned so far as the Huron is concerned.

The same peculiarity of youthful drainage described above is shown still more strikingly by Swan Creek, which drains nearly the whole of Sumpter and the southwestern portion of Huron townships. The northern branch starts two miles north of Willis, in Augusta township, Washtenaw County, and pursues a south-easterly course parallel with the Huron and at a considerably higher level for about 23 miles to Lake Erie. Throughout the greater part of its course, it is distant from the Huron but two to four miles and at one place (one mile west of Willow) the divide is less than a quarter mile in width. The development of a short gully, tributary to the Huron at this critical point, with the assistance of a flood, or ice jam in Swan Creek would shift the upper drainage of the latter to the former and another tragedy in stream life would be enacted. This creek came into existence with the fall of Lake Whittlesey and had a history practically identical with that given for the Huron from that stage of lake development.

An entire series of streams of this same type is found along the eastern margin of the county, all of them originating subsequent to the fall of early Lake Lundy; short, straight, with very few simple tributaries and in their upper courses largely intermittent. The fall is slight, the amount of lateral and vertical cutting small in amount, with low banks, expanded, estuary-like mouths (from the *drowning*), surrounded by marsh and at ordinary stages of

9. A Typical Case of Stream Capture in Michigan: Journal of Geology, vol. xii, 1904, p. 326.

the water with but slight current. Starting northward from the Huron, we first encounter Brownstown Creek, which with its tributaries drains the northern part of Brownstown and Huron, Monguagon, and the southern portions of Romulus, Taylor and Ecorse townships. The upper portions of several of the tributaries have been converted into drains and their courses thus brought under control and straightened. The natural course of these streams is southeastward, direct to the river, but the Grosse Isle moraine deflects them to the southward, many of them taking the old distributary channels, uniting them into a single system and bringing about an appearance of age not in harmony with their real state of development. Monguagon Creek, lies chiefly in the northeastern corner of Monguagon township, east of the Grosse Isle moraine, consisting mainly of an intermittent and a drowned portion (Pl. XIX, A), the latter in size entirely out of proportion with the former. Frenchman's Creek, upon Grosse Isle, is another similar stream lying in a distributary at the southwestern corner of the island.

Ecorse River furnishes another case similar to that of Brownstown Creek, in that two of the three branches are deflected, one to the north, the other to the south, by the beach deposits of the Second Rouge beach. The middle branch is short and aborted, its upper drainage basin having been invaded by the tributaries of the other two branches and its natural supply of water thus reduced. The three branches drain central Ecorse, northern Taylor, northeastern Romulus, southeastern Nankin and southern Dearborn townships. From the mouth of the trunk stream, the drowned condition extends for a distance of nearly two miles up the three branches, evidenced by low banks, broad channel, sluggish current and abnormal depth (Pl. XIX, B). Just opposite the mouth in Detroit River, the lake chart shows a depth of 27 feet. Savoy Creek, obliterated by grading and sewers, formerly crossed the central portion of the city of Detroit, near the river front, flowing southwestward in the depression just north of Jefferson Avenue and emptying into the river near the present site of the Michigan central portion of the city of Detroit, near the river front, flowing of the city was formerly drained by Bloody Run, much of which has also been diverted and obscured, but with a little changed portion in Elmwood Cemetery and vicinity. The region east of the Detroit moraine, northeastern corner of Wayne County, is drained by Connors Creek, Fox Creek and Milk River. The largest of the three is Connors, which starts in the southern part of Warren township, Macomb County; flows southeastward, draining northeastern Greenfield, Hamtramck and western Gratiot townships, reaching the river about one mile east of the Detroit Waterworks. The fall in the stream within the county is 45 feet, or at an average rate of six feet to the mile, giving banks in the middle course 12 to 18 feet high. The natural tributaries are few, short and simple but numerous drains utilize the creek as an outlet. Passing through Mt. Olivet Cemetery and through a thickly populated district of heavily manured truck farms this stream has been a menace to the city of Detroit, since it empties its waters above the intake pipe of the city system. Fox Creek is a much smaller stream draining the eastern part of Gratiot and the western parts of Grosse Point townships. The Emmet moraine has given this stream a southwesterly direction for all except the last mile of its course, where it has broken through and empties into the river at Windmill Point. Much of the creek has been ditched and it receives also the flow from numerous artificial drains in this depressed area. The stream is almost completely enclosed by the 580-foot contour (Detroit River being but 575 feet here) so that it has but little fall. A very insignificant creek is "Milk River", draining the extreme northern portion of Grosse Point township to the northeastward behind the Emmet moraine. It is all intermittent except for the last mile of its course, which is drowned.

Unless one has carefully followed the course of events narrated in the preceding pages, it will come as a surprise to the reader to learn that Detroit River, one of the most magnificent in the country, as well as most commercially important, should be amongst the youngest in the Wayne County series. Gazing upon its great expanse of blue, sweeping rapidly by, with its constant procession of vessels laden with freight and passengers, and then glancing at the relatively insignificant tributaries that enter it from the west, such discrepancy in age seems almost unbelievable. Detroit River, however, more of the nature of a *strait* (which the name means in French) than at present, did not make its appearance until Lake Rouge, the correlative of lakes Algonquin and Nippissing had been formed. Streams as small and young as Brownstown, Campbell and Connors Creek had already made their start in their upper courses. The course of the Detroit appears to have been determined in large part by the series of depressions formed across the back of the Detroit moraine by the ice front at the time of the formation of the Emmet and Grosse Isle moraines. Although submerged at the time, and long subsequently, when the level of the water fell sufficiently, the dominant depression, or depressions, determined the direction of flow. During the life of Lake Algonquin, when the discharge was entirely by the Kirkfield, or Chicago outlet, and while Lakes Nippissing were draining through the Mattawa-Ottawa channel, the discharge from the upper lakes was temporarily withdrawn, the Lake Erie level was reduced and the Detroit carried only the limited drainage collected southward from Port Huron. It was during these stages that the tributary streams cut their channels to such a depth below the present level of the river.

Measured along the channel, the river has a length of 28 miles, opposite the city of Detroit a breadth of 2200 feet, broadening to 4 miles at the mouth. The greatest depth observed is 45 feet opposite Woodward Avenue and ranges from 25 to 40 feet along the main channels.[10] The least depth and, indeed, the *sill* of the Great Lakes is at the Lime Kiln Crossing where the ordinary depth is 18 feet and this depth has been secured and maintained only by dredging. Where the Grosse Isle moraine crosses the river, as in the vicinity of Trenton and Detroit, the river contains numerous islands, the largest of which are Grosse Isle and Belle Isle. These islands, as well as a number of the others, carry morainic ridges, roughly parallel with those upon the mainland, and seem to represent fragments of the moraines, the backs of which are above the present water plane. From the head of Fighting Island to Belle Isle, a distance of over 9 miles, the river lies to the west of the moraine, has cut a deep channel in the soft deposits and contains no islands. The surface elevation of the river and its current varies with the level of Lake St. Clair, from which it starts and that of Lake Erie into which it empties. These levels are subject to much variation owing to the season, special climatic conditions, the force, direction and duration of the wind, etc. The ordinary level of Lake St. Clair is given as 576.17 feet above sea level and that of Erie as 573.11 feet, giving a fall of 3.06 feet for the river surface, or an average of about .11 foot to the mile. Opposite Detroit, the average surface velocity is about two miles an hour as determined by Clarence W. Hubbell, Engineer for the Detroit Water Board. In the preliminary work for the Detroit River tunnel, numerous determinations were made opposite 10th street, at varying depths. The greatest velocity observed was 2.32 miles per hour (3.40 feet per second) at a depth of 15 feet and nearly three quarters of the distance across the river from the Detroit side (see Pl. XII). The maximum surface velocity was just over

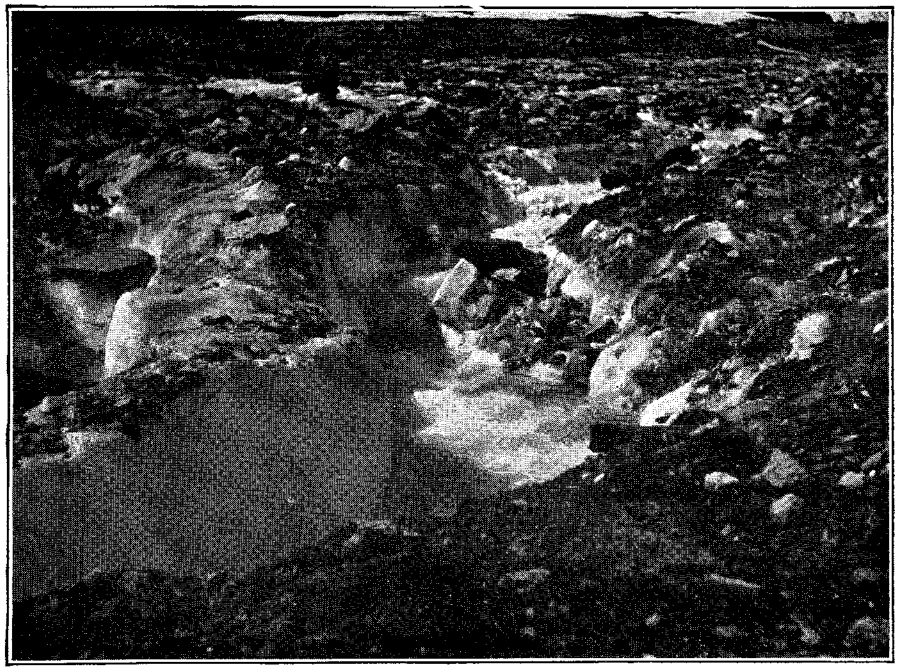
10. Through the work of the corps of engineers, U. S. Army, a careful survey has been made of the river and is the subject of continuous study and observation. Their charts of the river may be obtained from the Detroit office, Moffat Building, Griswold street.

this point and was found to be 2.18 miles per hour, or 3.20 feet per second, diminishing to 1.91 feet per second towards the Detroit side. Near the bottom, the maximum velocity noted was 1.56 miles per hour (2.29 feet per second) and the minimum .80 miles per hour, or 1.17 feet per second, at places beneath the points of maximum and minimum surface velocity respectively.

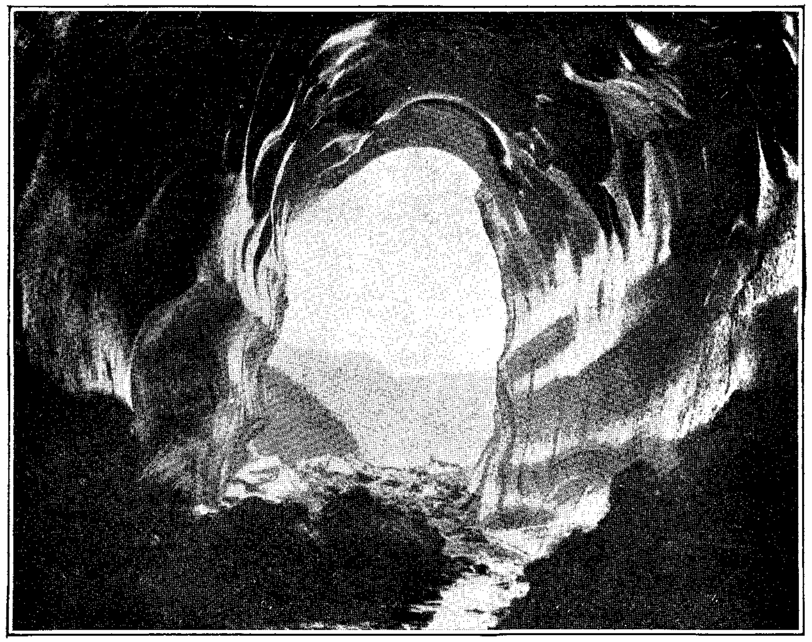
Although the main channel followed by the lake shipping lies upon the Canadian side of the river, between Bois Blanc Island and the mainland, the work of keeping this section of the river open has devolved entirely upon the U. S. Government. With a heavy blow from the west of any considerable duration, the water of Lake Erie is lowered about the mouth of the river and the depth of water in the neighborhood of Ballard's Reef and the Lime Kiln Crossing is so reduced that heavily laden boats are often detained. To obviate this difficulty as well as provide an American channel, the so-called Livingstone Channel[11] has just been constructed for the general government, by the contractors Grant Smith and Company and Locker. This channel consists of four sections, stretching from Ballard's Reef, just north of Stony Island, to deep water in Lake Erie, or a distance of about 11.9 miles. The material removed has consisted of dolomitic bedrock, boulders, till, silt, sand and gravel. From the geological standpoint the most interesting section of the channel is that opposite Stony Island, where about 150 acres of the river bed were laid bare by means of a coffer-dam (Pl. XX, B) and a 20-foot cut, 5750 feet long by 450 feet broad, made into the Monroe dolomites which overlie the Sylvania sandstone. Work was begun April 14, 1908, upon the dam, approximately 1,500,000 cubic yards of rock being removed, and has now been filled and put into commission. To bare the rock, it was estimated that 400,000,000 gallons must be removed and this was accomplished in 10 days by driving the water through 8 inch tubes by means of compressed air (see Pl. XXI, A).

Lakes, ponds, swamps and drains. With the neighboring counties of Washtenaw and Oakland so exceptionally well supplied with lakes, it seems rather strange that Wayne should have almost none whatever, except St. Clair and Erie upon her eastern border. Aside from the ox-bow lakes, or "bayous," along the Huron and Rouge valleys there is but one natural body of water in the county that can be called a lake (Pl. XXVI). This lake is small, only about 840 by 1170 feet, elliptical in outline and situated about

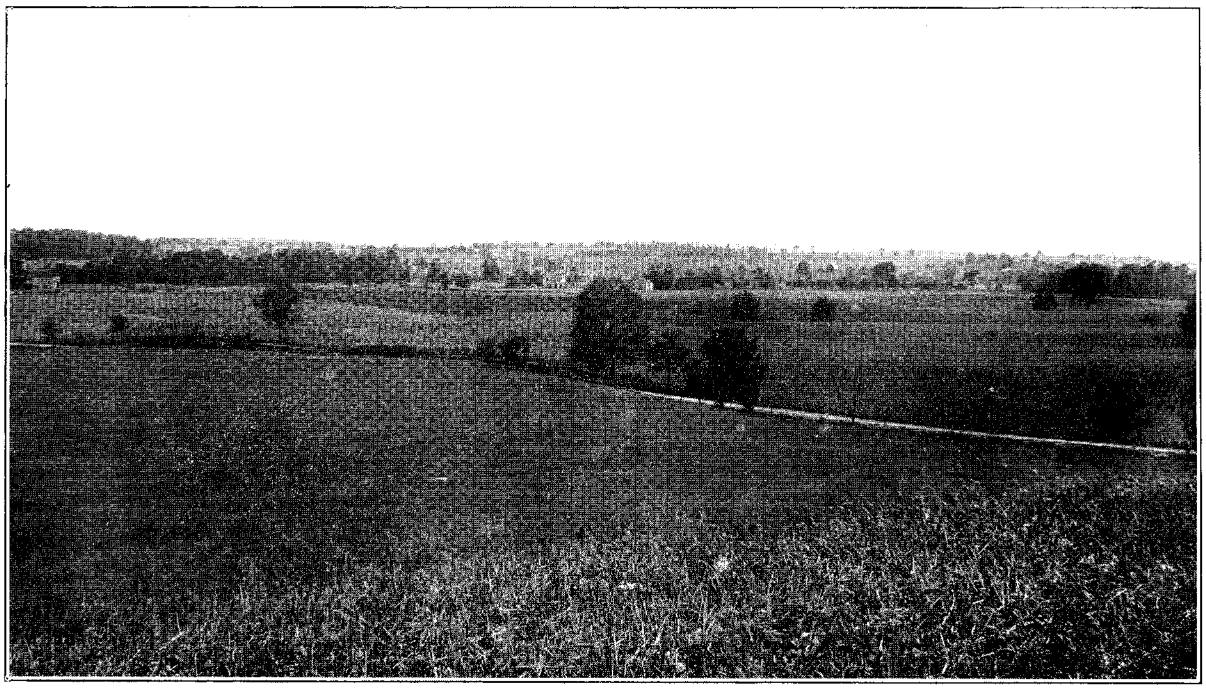
11. Named in honor of William Livingstone, president of the Lake Carriers' Association.



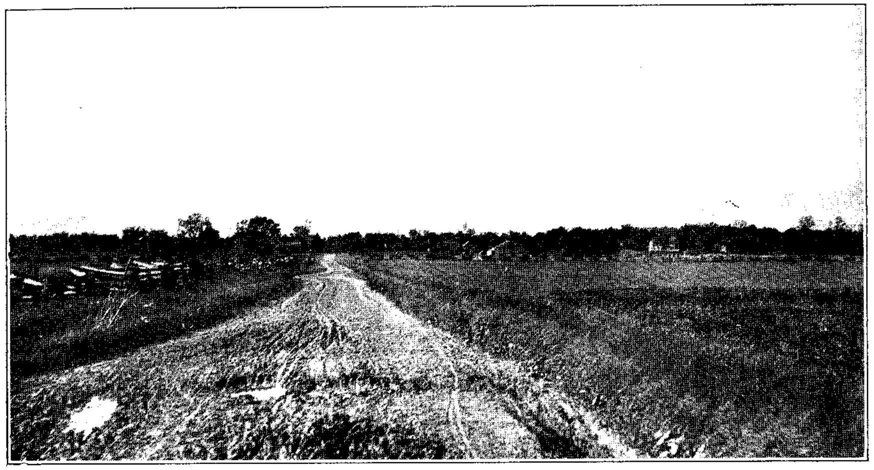
A. SURFACE STREAM VICTORIA GLACIER, CANADIAN ROCKIES.



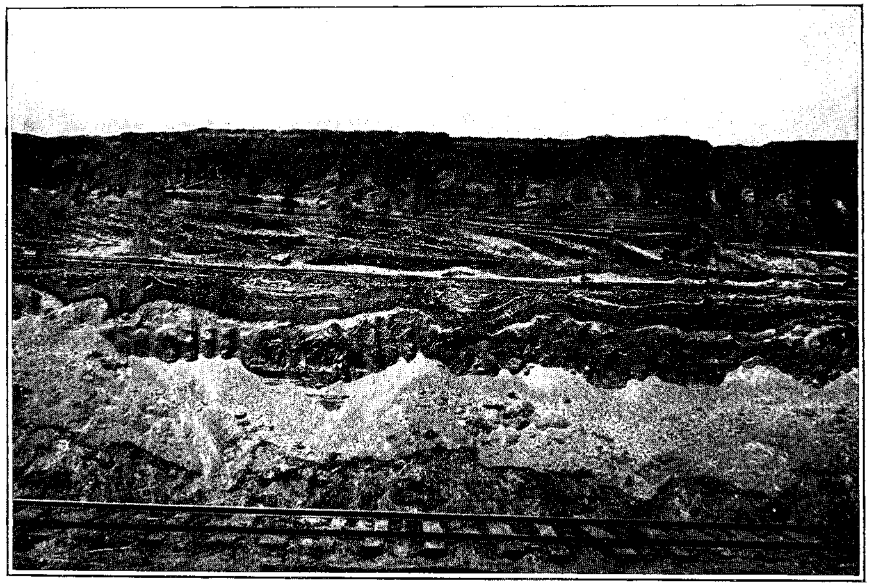
B. MOUTH OF SUBGLACIAL TUNNEL, VICTORIA GLACIER.
(PLATE XIII A & B COURTESY SMITHSONIAN INSTITUTION.)



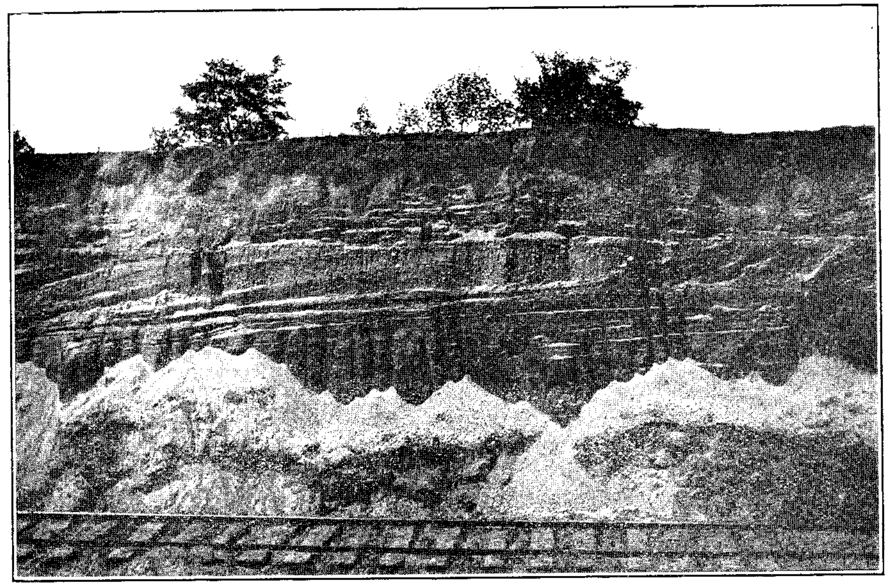
ANCIENT DRAINAGE CHANNEL, DEFIANCE STAGE OF ICE. LOOKING SOUTHEASTWARD FROM WESTERN BANK.



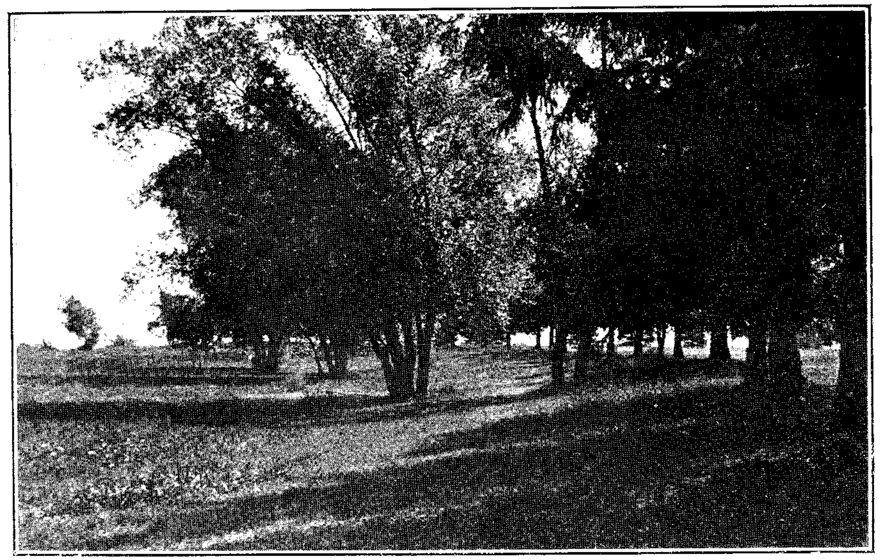
A. DISTANT VIEW OF WHITTLESEY BEACH, UTILIZED AS DWELLING SITE. LOOKING SHOREWARD FROM FORMER LAKE BED.



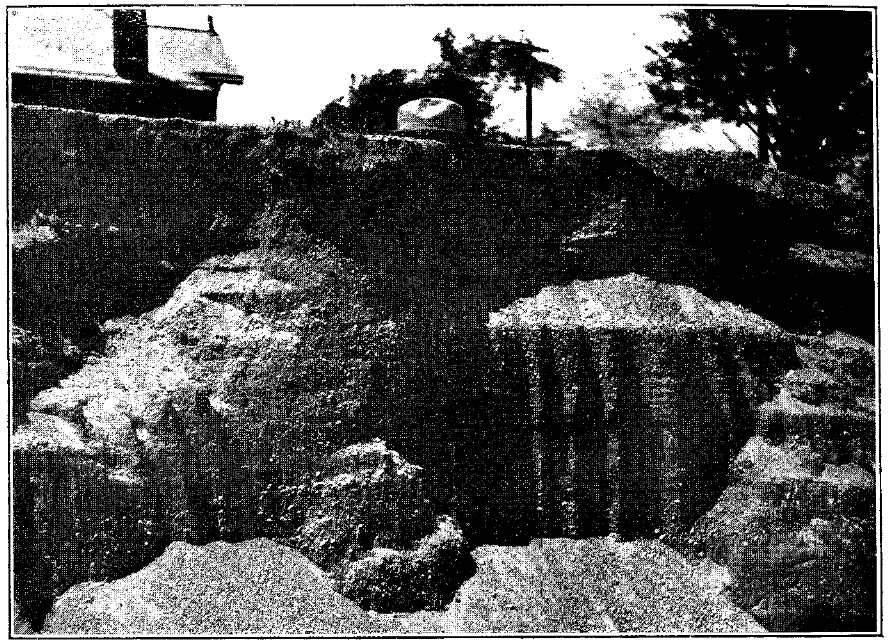
B. SECTION OF DELTA GRAVELS, LAKE WHITTLESEY STAGE. PERE MARQUETTE GRAVEL PIT, NEAR PLYMOUTH.



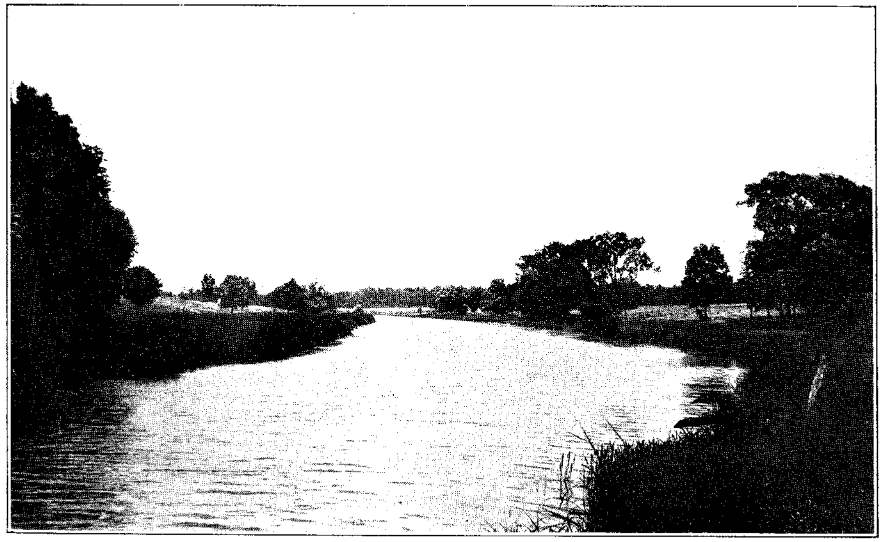
A. SECTION OF DELTA GRAVELS, LAKE WHITTLESEY STAGE. PERE MARQUETTE GRAVEL PIT, NEAR PLYMOUTH.



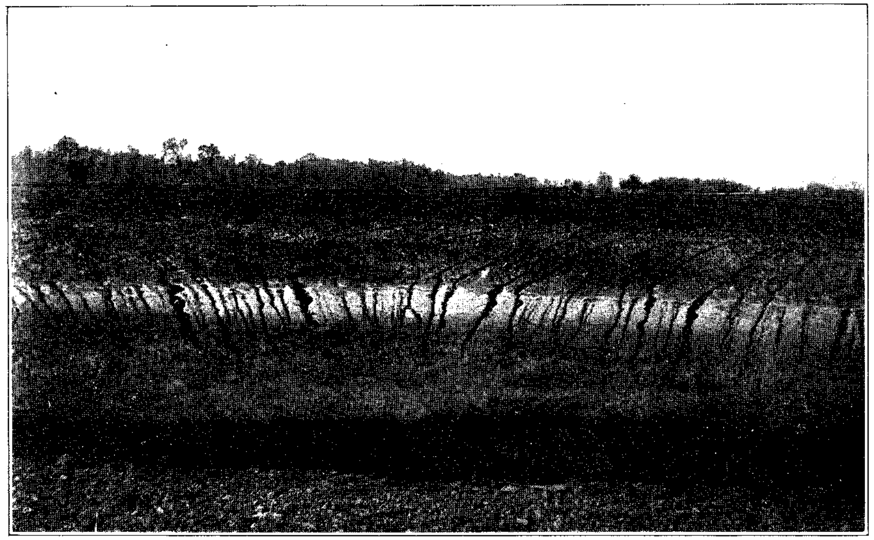
B. CUT BEACH, SECOND ST. CLAIR STAGE, MILK RIVER POINT.



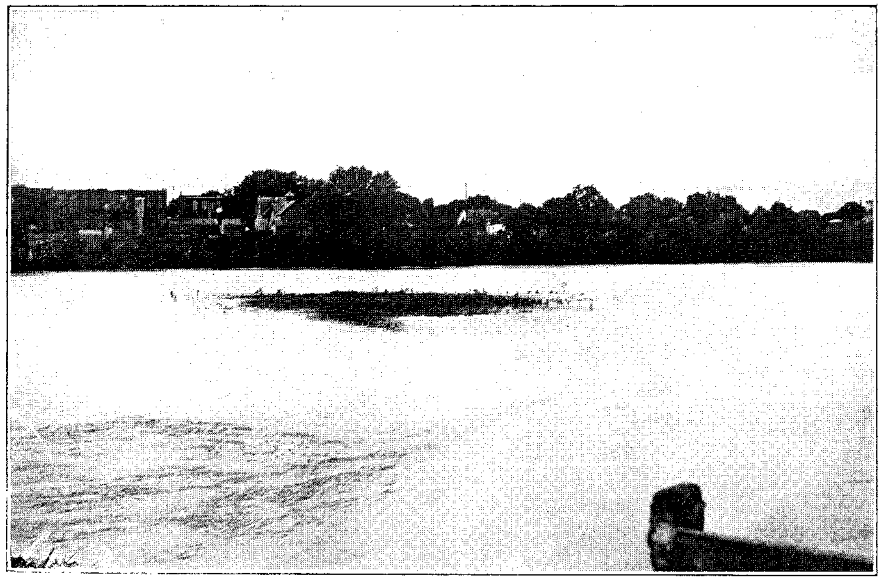
A. DELTA GRAVELS, FIRST STAGE OF LAKE ROUGE.



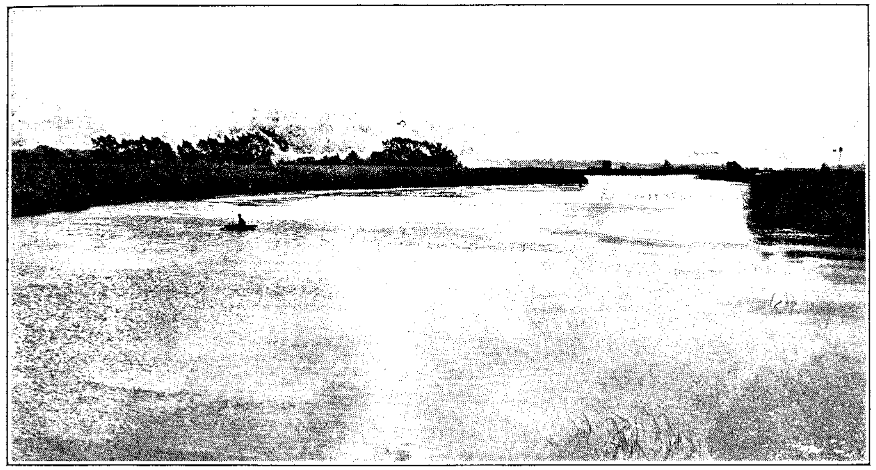
B. "THOROUGHFARE", GROSSE ISLE, A DISTRIBUTARY CHANNEL.



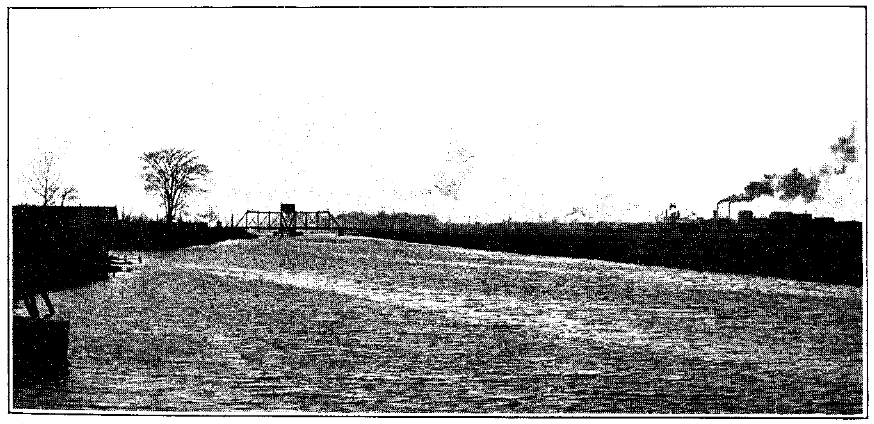
A. SYSTEM OF VERY YOUNG CONSEQUENT STREAMS OVER WIND BLOWN SAND DEPOSIT.



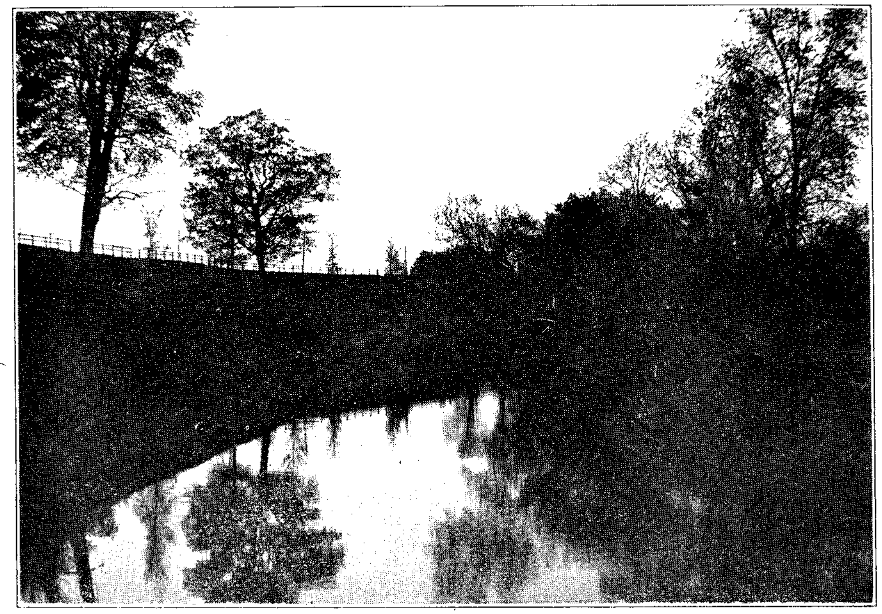
B. LOWER ROUGE AT FLOOD, WAYNE.



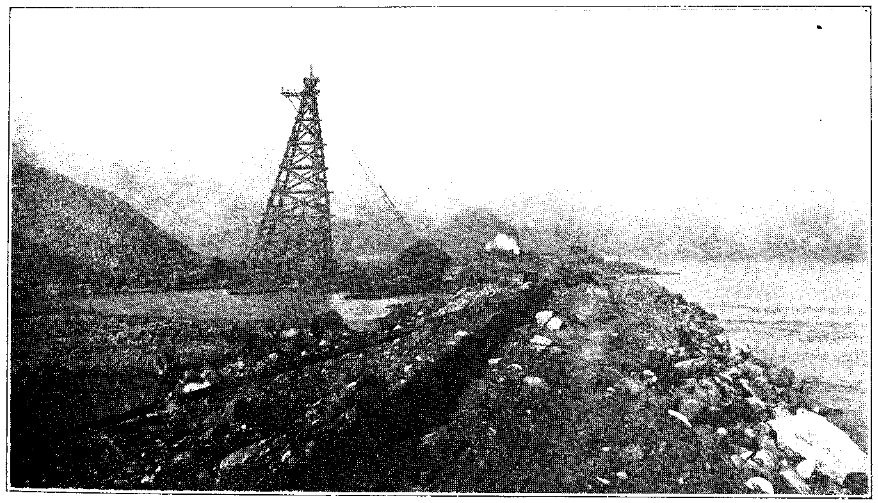
A. MONGUAGON CREEK, A DROWNED STREAM. FORMER BANKS ARE NOW SUBMERGED AND THE STREAM BORDERED ONLY BY MARSH.



B. ECORSE RIVER, NEAR MOUTH, SHOWING DROWNING.



A. HURON RIVER AND TERRACE AT FRENCH LANDING.



B. COFFER DAM, LIVINGSTONE CHANNEL, DETROIT RIVER, BY MEANS OF WHICH THE BED WAS BARED AND THIS PORTION CONSTRUCTED "IN THE DRY."

one mile east of the village of Northville (SW. 1/4 NE. 1/4 sec. 2). The average depth of the lake is given by the present owner (Mr. S. W. Curtiss) as 28 feet, with a maximum of 39 feet, and is fed by springs. It is surrounded by some swamp and drains southwestward into the Middle Rouge at higher levels, but is now without outlet. It was considered as a source of water supply for the village of Northville but is not high enough (somewhat under 800 feet) to give the necessary gravity pressure. It is well stocked with fish; bass, pike, perch, blue gills, and "bull heads".

Where the streams are dammed for milling purposes, artificial ponds occur as expansions of these streams, as at Northville, near Plymouth, at Pikes Peak on the Middle Rouge and at Belleville, New Boston and Flat Rock on the Huron. The dam serves to broaden and deepen the stream, checking the current and giving rise to marshy conditions about the margin. The largest of these ponds is found at Belleville. More or less standing water occurs in the clay pits at Dearborn, West Detroit and Leesville, seeping in through the clay, or collecting from rainfall and drainage, and in the abandoned quarries on Grosse Isle, Stony Island and near Gibraltar. Small ponds, fed by springs, supply the village of Plymouth and the U. S. Fish Hatchery at Northville (Pl. XXVIII, B).

Owing to the generally flat topography and the presence of moraines and beach deposits, portions of Wayne County are but poorly drained and there are still some extensive marshes. Along the margin of Detroit River, about the islands and about the Erie shore there are patches of marsh, the most extensive of which is found in southeastern Brownstown and between the Ecorse and Rouge. The drowned condition of the mouths of the streams and the flooding of the distributaries is responsible for the landward extension of these swamps, sometimes to a distance of two to three miles. Before being brought under cultivation as thoroughly as at present, these patches were much more extensive, being reduced, or entirely obliterated by artificial drainage, clearing of the forests and the cultivation of the soil. It was these marshes that rendered travel so slow and laborious in the early days, led to the selection of the beach ridges for roads and trails, furnished breeding places for the mosquito, which, in turn, gave rise to malaria and helped to establish the thoroughly bad name that the state possessed in an early day as a place of residence. The Higgins' map of the county shows the location of these originally poorly drained areas. A "tamarack marsh" is indicated in northeastern Redford and northwestern Greenfield covering about four square miles. Most of this has disappeared, although some still remains in secs. 4 and 5 of Greenfield, directly upon the crest of the Detroit moraine. "Open marsh" is also indicated for secs. 9, 10 and 15, which has been practically gotten rid of by a system of drains eastward into Connors Creek and southward into Campbell Creek. A marsh in sec. 10, Redford, has been similarly drained. Portions of secs. 1 and 12 in northeastern Greenfield and adjacent secs. 5, 6, 7, northwestern Hamtramck; also portions of secs. 3, 16 and 17 show swamp, being hemmed in between the Detroit and Grosse Isle moraines. This is the portion of the county in which artificial drainage has been most extensively practiced and with results that have fully justified the expense. A long strip of marsh extending along Fox Creek in the western part of Grosse Point was labeled "wet prairie and marsh". Secs. 17, 18, 19 and 20 of Nankin contained a patch of marsh originally which has not yet been entirely drained, although considerably reduced in size. The middle sections of Canton township, and portions of secs. 9, 19, 31 and 32 of Van Buren were found by Higgins to be wet. In the latter township, this condition still exists to a greater or less extent in secs. 7, 8, 17, 18, 19, 20, 29 and 30. "Big Bear swamp" was located in the northeastern corner of Van Buren (secs. 1 and 12) and the northwestern corner of Romulus townships (secs. 6 and 7), now drained into tributaries of the Lower Rouge. Eastern Romulus and Taylor (formerly Ecorse) are marked "wet prairie", also the southern half of Sumpter, the northeastern corner of Huron and the northwestern corner of Brownstown townships. In secs. 5, 8 and 9, of northern Brownstown, some 400 acres of undrained swamp still remain, drainage being somewhat difficult in this region owing to the flat topography and the Grosse Isle moraine to the east. The drainage here, as well as to the north and south, is into Brownstown Creek. The marshes along the river and lake front were, and still are, utilized by the French inhabitants as hunting grounds for wild fowl and muskrats. The highest marsh in the county (about 840 feet above sea level) is located in the old drainage channel (see Pl. X) that crosses the northwestern corner, where it is hemmed in by moraine and lies on the divide along this channel in secs. 19 and 30 of Plymouth township.

SOILS AND SUBSOILS.

General characteristics. The soils and subsoils of the county of Wayne may be simply classified under five heads; four of them being derived either directly or indirectly from the glacial deposit known as till. This material was produced by the grinding action of the great ice sheets upon the surface layers of bedrock to the northeastward and with it were mixed more or less preglacial soil, wind and water borne material. The soils, then, with which we are concerned in this report are referred genetically to those of the *transported* class; as distinguished from the so-called sedentary, or residual soils, which are formed *in situ* from bedrock.[12] Of the varieties to be briefly described below, the differences are due in large part to the texture, or degree of fineness, of the constituent granules and to a somewhat less extent to the actual mineral composition. No sharp lines can be drawn between the different varieties, one often shading into the other by imperceptible gradations.

By *soil* is usually meant the eight to twelve inches of the loose, finely divided debris that mantles the bedrock; that which is within reach of the ordinary processes of cultivation. Beneath this lies the *subsoil*, not sharply separated from the soil layer and extending from it to the bedrock, often many feet down. Owing to the action of plant roots, burrowing life forms and frost, the soil is loose and porous. When compared with the subsoil, it is often darker from the presence of organic matter or, when this is lacking, more highly colored from the rusting of the iron ingredient. In this climate, for reasons not yet fully comprehended, the subsoil shows less fertility when first brought under cultivation, as shown in the "dead-furrow", produced in plowing by throwing the soil in opposite directions and thus exposing the subsoil. In arid regions, it is said that no such difference in fertility exists.[13] Iron and calcium carbonate are not infrequently dissolved from the soil by percolating water, especially when charged with carbon-dioxide gas, and deposited in the subsoil, sometimes as a crust, more often as a filmy deposit in the interstices of the subsoil. As a result, there is sometimes seen in the section of a bank a more deeply rusted streak of iron stain than exists in the soil itself. When tested with the dilute acid the soil often shows slight reaction (due to leaching of the carbonates), the subsoil immediately beneath vigorous effervescence (due to secondary enrichment) and the deeper layers of subsoil moderate effervescence, due to the carbonates originally present.

Clay soils. The clay soils of Wayne County fall naturally under

12. A discussion of the soils that originate thus from the bedrock found in southeastern Michigan will be found in the writer's report upon Monroe County: Geological Survey of Michigan, vol. VII, part I, 1900, p. 149.
13. King, Physics of Agriculture, 1907, p. 50.

two heads, those derived directly from the till by long exposure to the soil making agencies and those which have been extracted from the till by water held in suspension, transported and redeposited under quiet conditions. The former we may characterize as the glacial clay, the latter as the lake, or river clays. They are alike in that they consist of a great variety of very finely divided mineral particles, under the microscope appearing quite fresh and angular in outline. Owing to this fine texture they are readily converted into good soil and, owing to the variety of minerals represented, they furnish an abundance of plant food suitable for the heavy cereals. Their fine texture greatly enhances their value for agricultural purposes since this fineness increases the total granular surface available for the retention of moisture. A cubic foot of solid rock, such as granite, has 864 square inches of surface, but if sawed into eight equal cubes, six inches upon a side, it now possesses 1728 square inches of surface. If cut into one inch cubes the total surface would be increased to 10,368 square inches (1728 x 6), or twelve times as great as the original surface of the cube. If this subdivision continues until we have to each single gram of soil many million individual particles, the combined surface of these is enormously increased.[14] When too finely divided, however, the soil becomes so damp that it is "cold" and the passage of air through it, necessary for the proper aeration of roots, is prevented. The clays are alike in being sticky and plastic when wet, in that they harden, shrink and crack upon drying and that they possess enough iron to burn red. The glacial clays are very compact, unstratified, generally more or less pebbly, with occasional coarse boulders, either resting upon the surface or embedded. The deeper layers are generally of a bluish color, the upper few feet being rusted to a drab, brown, yellow or red. The uppermost 6 to 12 inches are darker in color, looser in texture and more or less leached of their readily soluble ingredients. Produced as they were, it is obvious that they may differ greatly in composition within short distances, consisting essentially of varying quantities of silica and alumina, with carbonates, iron oxide, etc. The soils of Wayne County have not yet been subjected to analytical study by any interested bureau but those essentially similar, lying just north in Oakland County, have been so studied by the U. S. Department of Agriculture and reported upon in a

14. King has shown that with granules all the same size and of spherical form the number in a single gram of soil would be astonishingly great; for instance with a diameter of .01 mm. the number would equal 720,000,000 and for .0001 mm. would equal 720,000,000,000,000 (Physics of Agriculture, p. 117). In the latter case the combined surface of these granules would be equal to 226,415 square centimeters, or approximately 244 square feet.

bulletin procurable from Washington.[15] The glacial clays here described are referred to as "Miami clay loam" and three typical soil samples, with the corresponding samples of subsoil, from depths of 10 to 36 inches, were subjected to mechanical analysis, with the results given below. In these and the following analyses taken from the report varying proportions of organic matter, fine gravel, sand, silt and clay are indicated, throwing light upon the physical characteristics of the respective samples and furnishing inferences relative to chemical composition. The method of analysis consists in first passing the sample to be employed through a two millimeter sieve, so that in the tables given nothing coarser appears and no data are furnished as to the amount of such material thus removed. For detailed description of the method employed see "The Centrifugal Method of Mechanical Soil Analysis", Bulletin No. 24, 1904, U. S. Department of Agriculture.

15. Soil survey of the Pontiac Area, Michigan, 1904.

TABLE XI.—MECHANICAL ANALYSES OF GLACIAL CLAY, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 mm. to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9596	Sec. 5, Troy tp.	Clay loam, 0 to 12 inches	2.21	1.16	4.06	5.70	17.24	12.20	40.22	19.42
9597	Subsoil of 9596	Clay loam, 12 to 36 inches	.10	.70	2.60	3.60	12.74	15.20	34.36	30.68
9598	Sec. 17, Pontiac tp.	Heavy loam, 0 to 10 inches	.75	1.98	4.76	5.48	19.06	16.34	28.38	23.88
9599	Subsoil of 9598	Clay loam, 10 to 36 inches	Tr.	1.04	3.20	4.04	13.68	14.18	32.40	31.06
9600	Sec. 30, Farmington tp.	Heavy clay loam, 0 to 8 inches	1.80	.78	3.96	5.06	14.80	12.36	34.22	28.78
9601	Subsoil of 9600	Stiff clay loam, 8 to 36 inches	.34	1.04	2.16	2.36	8.10	9.50	31.02	45.72

No. 9599 contained 10.58 per cent of calcium carbonate and No. 9601 contained 6.96 per cent.

TABLE XII.—MECHANICAL ANALYSES OF LAKE CLAY SOIL AND SUBSOIL, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9604	Sec. 26, Troy tp.	Black clay loam, 0 to 10 inches	3.59	1.46	3.54	4.62	16.34	15.20	33.74	25.04
9605	Subsoil of 9604	Drab clay loam, 10 to 36 inches	1.45	.50	2.76	3.52	12.74	16.70	34.74	28.90

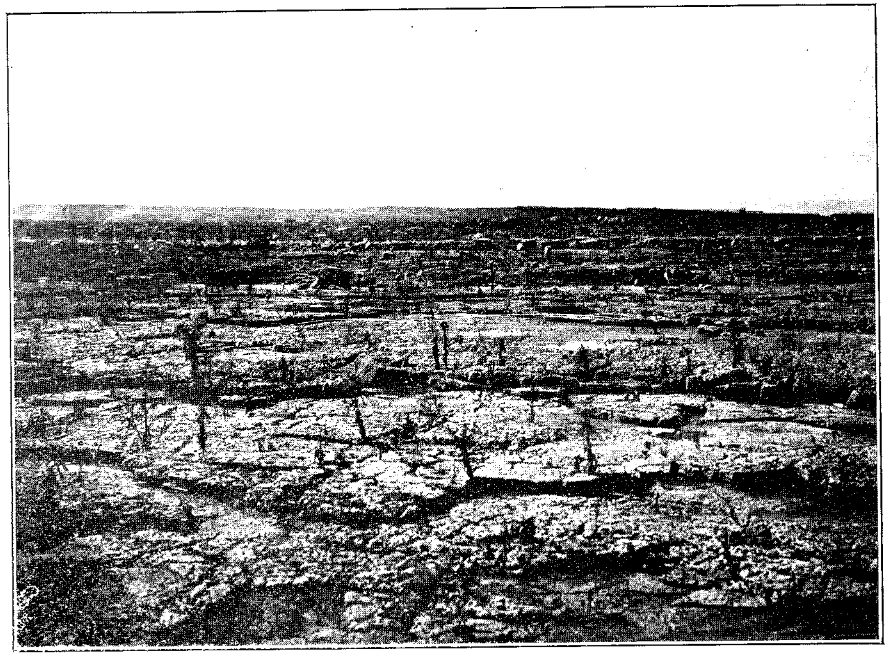
From this table, it is seen that the bulk of the material of each sample consisted of what is listed as silt and clay, with a considerable quantity of fine sand. This type of soil is difficult to work, when too dry, being stiff and hard and, when too wet, forming clods which are exceedingly difficult to reduce. It can be worked to advantage between certain moisture conditions only and very much needs thorough drainage. The original forest growth was black walnut, hickory, maple, beech, ash and several species of oak. By proper culture, good crops of wheat, oats, rye, corn and hay may be grown upon these soils. The Department of Agriculture suggests dairying wherever there exists a good market for dairy products; otherwise stock raising. In Wayne County, these soils cover the morainic knolls and ridges in the northwestern corner and eastern portions of the county and are found on the till plain between, where it has not been covered with lake clay, sand or gravel.

The lake clays are much more limited in extent, having been deposited mainly in the vicinity of Detroit as described previously. Their average texture is finer and much more uniform than that of the glacial clays; pebbles and boulders are very rare. They are often very regularly and delicately laminated, the laminae being separated by a very thin layer of minute sand particles. Owing to this structure these clays are much more permeable to water and surface changes, similar to those already described, may readily occur. Originally deposited in depressions they were naturally poorly drained, furnished favorable conditions for the growth of certain plants and are dark at the surface from the presence of this decaying organic matter. A series of chemical analyses of these subsoils has already been given in table IX of this report. What appears to be the same type of soil, judging from its occurrence, is referred to in the Pontiac bulletin (page 19) as the "Miami black clay loam" and the following mechanical analysis given. The small amount of very fine gravel may be due to overwash from adjacent higher land.

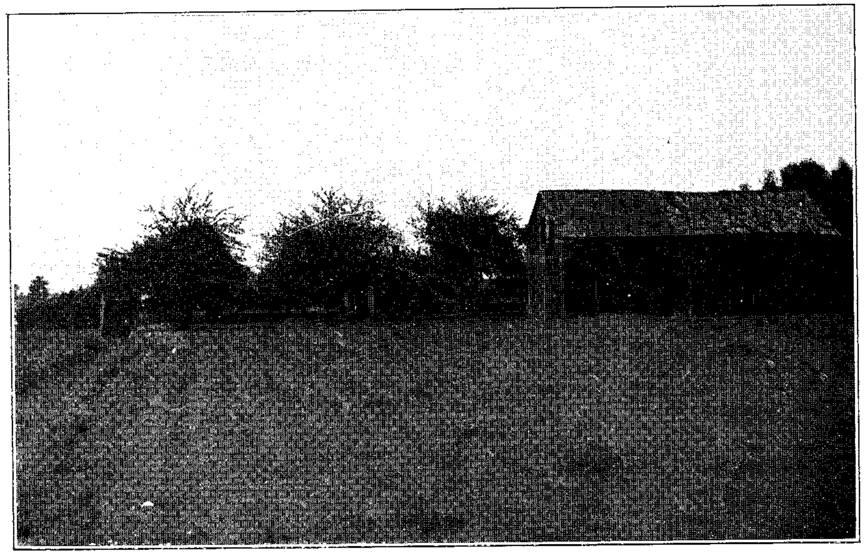
When wet, these clays are excessively sticky and were responsible for the wretched roads leading out from Detroit; those to the westward being practically impassable for teams at certain seasons. This fact has necessitated heavy county expenditures for macadamized and concrete roads. Naturally low and requiring drainage these deposits have also forced the owners to provide extensive systems of drains in order to carry on their agriculture with any degree of success. Owing to the slight fall procurable in these drains they are often expensive to keep open and a source of annoyance. In the early spring considerable areas are often flooded from the heavy rains and melting snows, causing damage to the wheat and delaying the spring tillage. When properly drained, wheat, corn, oats and hay furnish a good yield. In Oakland County, this soil is preferred for sugar beets giving an average yield of 10 to 12 tons to the acre. In the vicinity of Detroit the soil is extensively and very successfully utilized in truck farming. The original timber upon this land was largely elm, soft maple, basswood, and black ash, with some beech, oak, hard maple and whitewood on the higher and better drained portions.

Sand and gravel soils. Although typical sand and gravel soils are essentially different in appearance and agricultural importance, they may merge into one another at the limits and have had a similar origin and history. Their derivation from the till by stream, or wave action, has been described on previous pages. In the bed of the old glacial drainage channel, both sand and gravel were removed from the till while it was still covered with the ice and deposited between the two morainic ridges (Ft. Wayne and Northville) which diagonally cross northwestern Northville and Plymouth townships. Subsequently, during the lake stages the streams were active during flood, cutting both vertically and horizontally into the glacial clay, taking the finer materials into suspension, rolling along the bottom some of the coarser and depositing them in such a manner as to secure imperfect assortment. The deltas and delta terraces received alternating deposits of sand and gravel, as the currents fluctuated, while the finer silt and clay particles that reached the lakes remained in suspension longer and settled in the more quiet waters. Along the shore line, during times of maximum wave action, a similar mechanical separation of the till deposits occurred, the sand and gravel being thrown up to form a beach, while the finer sediment slowly worked its way lakeward. Upon drying, the sand was here and there gathered by the winds into knolls and ridges (dunes), or spread as a surface dressing over the clay. These strips, representing the approximate shore lines, have been previously located and will be again given in the summary by townships (Chapter IX).

The pebbles are sub-angular to rounded in form and of great variety of composition, having been derived from the glacial till. From one-third to one-half of them are dolomites and limestones and about one-fifth are crystallines and the same proportion are quartzites. The sand grains under the microscope show the effects of abrasion and appear somewhat rounded, but only to a light extent when compared with those subjected to long continued cur-



A. BARED MONROE STRATA, BED DETROIT RIVER, SHOWING DISSOLVING ACTION OF WATER UPON DOLOMITIC LAYERS.



B. AN EXHAUSTED FARM, READY FOR REFORESTATION.

rent, or wave action. The material represented is very largely quartz; the softer, decomposable and cleavable minerals having largely disappeared. This means that the sandy soils possess relatively little available plant food, a relatively small granular surface and consequent inability to retain moisture. They have the advantage of being light, easily tilled and readily drained. When ordinary crops are grown upon them the returns are generally meager and what little fertility was originally present is soon exhausted (see Pl. XXI, B). These soils are best adapted to rye, beans, potatoes, truck crops and small fruits. With intensive methods of farming and careful management good crops of corn, rye and hay may be grown upon soil once exhausted. The natural forest growth was scrub oak, with some chestnut and butternut. In the Pontiac area, these sands were classified as "Miami sand" and three mechanical analyses given, with those of the corresponding subsoils.

TABLE XIII.—MECHANICAL ANALYSES OF SANDY SOILS OF LAKE ORIGIN, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9614	Cen. Sec. 36, Farmington tp.	Fine sand, 0 to 8 inches	2.21	1.62	5.86	13.30	44.46	20.30	7.96	6.12
9615	Subsoil of 9614	Fine sand, 8 to 36 inches	.50	.26	.98	2.90	46.82	40.66	5.22	3.00
9616	NE. cor. Sec. 22, Royal Oak tp.	Medium sand, 0 to 10 inches	1.63	3.10	18.10	29.24	28.24	5.30	9.72	6.30
9617	Subsoil of 9616	Sand, 10 to 36 inches	.53	3.54	19.46	32.42	27.66	5.02	7.04	4.84
9618	Sec. 10, Waterford tp.	Sand, 0 to 8 inches	.64	.96	8.30	23.50	48.80	6.70	7.32	4.20
9619	Subsoil of 9618	Sand, 8 to 36 inches	.16	1.40	8.16	19.42	53.48	7.52	6.36	3.24

Loam. This term is applied to an admixture of sand and clay, which partakes of the nature of both to an extent, combining their good characteristics, agriculturally speaking, and eliminating those of an objectionable nature. It has resulted from the mechanical mixing of the two chief ingredients along the strip, sometimes of considerable breadth, separating the belts of sand from the areas of clay. This result may have been secured in a variety of ways; as when the lake sands and lake clays were being simultaneously deposited; by having a thin layer of sand spread over one of clay, or vice versa, as a lake deposit; the same result was secured by overwash from higher land, or by wind borne sand or dust. The work of earthworms, ants, crayfish, along with larger burrowing forms, root action, frost, etc., has, in the course of time, combined the two ingredents into a single type of soil. This is not so sticky when wet as the clay, does not harden and crack upon drying and hence can be worked with greater ease. It is sufficiently open and porous to permit of aeration and drainage and at the same time contains sufficient fine material to supply plant food and moisture. It is often dark colored from the presence of partially decayed organic matter; which serves a double purpose in supplying first, plant food and second, in enabling the soil to absorb so much additional heat because of this color.

When the clay ingredient predominates, the soil is referred to as a clay loam and when the sand is plainly in evidence, as a sandy loam, which may, with the introduction of pebbles, pass into a gravelly loam. No line of demarcation can be drawn between these different varieties, nor between loam and clay, or loam and sand. The most valuable lands in the county, from a purely agricultural standpoint, are these loams and they are adapted to the growing of all crops that may be raised upon either the clay or sand separately. When well drained, they produced also the greatest variety of natural forest growth.

A type of clay loam, in which the body of the soil is a glacial clay, has been mapped and described in the Pontiac area as "Oakland sandy loam". The same type of soil may be recognized in limited patches in Northville and Plymouth townships. The following mechanical analyses were made from the Oakland County samples.

TABLE XIV.—MECHANICAL ANALYSES OF GLACIAL CLAY LOAM, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9624	Sec. 27, Waterford tp.	Sandy loam, 0 to 10 inches	1.77	1.86	6.92	11.02	28.22	13.84	26.80	10.92
9625	Subsoil of 9624	Clay loam, 10 to 36 inches	.62	2.00	6.52	7.00	19.54	11.74	28.44	24.32
9626	Sec. 10, Bloomfield tp.	Sand loam, 0 to 15 inches	1.73	1.58	5.12	7.78	25.38	15.24	32.26	12.40
9627	Subsoil of 9626	Clay loam, 15 to 36 inches	.94	1.72	4.22	7.30	24.72	12.92	30.88	18.16
9628	Sec. 27, Pontiac tp.	Heavy sandy loam, 0 to 10 inches	2.54	1.06	3.96	8.16	25.02	12.62	34.42	14.74
9629	Subsoil of 9628	Clay loam, 10 to 36 inches	1.17	1.12	2.88	4.10	13.80	9.24	35.24	33.20

TABLE XV.—MECHANICAL ANALYSES OF LACUSTRINE SANDY LOAM, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9606	Sec. 21, Avon tp.	Loamy sand, 0 to 16 inches	2.06	3.42	11.78	15.00	33.22	14.72	14.42	7.26
9607	Subsoil of 9606	Sand, 16 to 36 inches	1.69	5.22	13.82	15.92	30.08	15.28	13.04	6.56
9608	Sec. 16, Bloomfield tp.	Medium sandy loam, 0 to 12 inches	1.10	1.88	7.44	11.26	25.06	20.36	25.16	8.60
9609	Subsoil of 9608	Medium sand, 12 to 36 inches	.20	2.20	8.62	11.60	25.80	20.94	22.64	8.20
9610	N. Sec. 22, Southfield tp.	Sandy loam, 0 to 10 inches	.79	2.16	8.04	15.86	37.80	14.70	13.08	8.34
9611	Subsoil of 9610	Sand, 10 to 36 inches	.71	1.40	6.36	14.28	42.12	16.30	12.28	6.70

A somewhat different variety of loam, formed along the margins of the glacial lakes Maumee, Whittlesey and Arkona, was described in the Pontiac survey as "Miami sandy loam" and the following mechanical analyses given (table XV). The typical areas figured from which the samples were selected are simply an extension of the soil belt found in Livonia township.

Silt. Another type of soil closely related to the preceding, but of more limited extent, it is convenient to recognize under the head of silt. It is confined mainly to the flood plains of the streams, is more or less distinctly stratified, dark from organic matter, loose in texture and often contains shells of both land and water forms. The material is more coarsely textured than clay and less so than sand, in the mechanical analyses above given being assigned the range of .050 mm. to .005 mm. (.002 inch to .0002 inch). Hilgard gives a range of .072 mm. to .016 mm. and Merrill .01 mm. to .005 mm. for this class of material. It may readily pass into sand upon one hand and clay upon the other, which may be conveniently termed alluvial sand, or alluvial clay, respectively, while the silt itself is often referred to as alluvial loam. The composition is often rendered variable from the deposition over it of material washed from the adjacent banks. Favorable conditions for plant growth often lead to the introduction of much organic matter. So far as known, no analyses of this type of soil have been made in Wayne County, nor in the Pontiac area, but in 1893 Prof. R. C. Kedzie published the chemical analyses of two samples of soil from the River Raisin bottoms,[16] which may be assumed to be essentially like that found along the Huron and Rouge rivers, when it is considered that the materials were all derived from the same type of till deposit.

No. 1. River Rasin bottoms, Deerfield, Lenawee County.
Selected by Geo. H. Kedzie.
Forest growth: ash, basswood, hickory, black walnut, oak, etc.
Soil cultivated forty years, without manure.

Sand and silicates	58.17
Alumina	6.48
Oxide of iron	7.62
Lime	1.98
Magnesia	1.43
Potash	1.84
Soda	1.20
Sulphuric acid	.32
Phosphoric acid	.40
Organic matter containing .42 nitrogen	10.97
Water	9.45

Capillary capacity for water, 65.60.

16. Michigan Soils: Bulletin 99, Michigan State Agricultural College, 1893, p. 6.

No. 2. River Rasin bottoms, Deerfield, Lenawee County.
Selected by Geo. H. Kedzie.
Virgin soil.
Timber: ash, basswood, black walnut, oak, etc.

Sand and silicates	62.42
Alumina	10.64
Oxide of iron	3.46
Lime	2.10
Magnesia	1.59
Potash	2.05
Soda	1.19
Sulphuric acid	.24
Phosphoric acid	.41
Organic matter containing .37 nitrogen	9.39
Water	6.08

Capillary capacity for water, 61.20.

When properly drained and protected from floods by dykes this soil has all the advantages of loam previously noted, but owing to the danger from overflow these flats are generally allowed to grow up with grass and are used for pasturage. In the Pontiac area they are all classed and mapped as "meadow." So far as timber was originally able to get a foothold upon these areas, it consisted in the main of elm, bass, sycamore, cottonwood and willow. But in addition, there occurred black walnut, butternut, ash, oak and maple.

Muck. One characteristic of a glaciated region, especially the morainic portions of it, is the presence of undrained portions in which spring and surface water may accumulate. In connection with the beaches, where the surface cover of sand over the clay is thin, patches of poorly drained areas occur of a similar nature. With an abundance of moisture and rich soil, a variety of plants get a foothold which in time gradually fill up the depression and displace any open water present. When conditions were favorable for the growth of *Chara* for a sufficient length of time, the lime carbonate which it secretes and deposits over its stems, accumulated upon the bottom faster than it could be dissolved by the water and a bed of white, chalky material was formed known as marl. More or less clay, sand, or gravel were often brought into the area of marl accumulation and incorporated into it, along with the shells of numerous water mollusks.[17] With the shallowing of the water thus produced other plants, of a higher order, obtained a foothold such as the rushes, sedges, cat-tails, reed-grasses, arrow-heads, pond-lilies, etc. Their remains, immersed in water and thus allowed to but partially decay, often completed the process of filling up the pond, or lakelet, and the shallow, swamp plant societies gave way to the bog and wet meadow varieties, such as *Carex* and *Sphagnum,* varieties of sedges and moss respectively. These forms, dying beneath and growing above were often able to raise the surface of the bog several feet above the original water level and thus contribute additional organic matter to that already deposited in the swamp. The researches of Davis have shown that floating mats of *Carex* and other plants may extend lakeward from the shore, over deep water, and partially decaying assist in the formation of deposits many feet in thickness.[18] Such partially decayed organic matter, however formed, slightly compacted from pressure gave rise to *peat.* When freshly cut it contains 60 to 90% of water and upon drying shrinks to two-thirds, or one-half, its original bulk. If now examined, it is found to be light in weight, light brown to black in color, porous to compact in structure and it absorbs water readily. The composition and uses of peat will be treated in another connection under the head of economic products (Chapter VIII).

Considering the method of its formation it is evident that the organic matter composing the peat is very liable to have mixed with it more or less marl, sand, silt and clay. These materials may have been introduced at the time the peat was in process of formation, as the result of stream, wave or wind action, or may have been derived from the decay of plant and animal forms. They may have been introduced subsequently by stream or wind action or by the various plant and animal agencies whereby soils and subsoils may become mechanically mixed. The result would be the formation of a type of soil known as *muck* and characterized by its deep black color, high content of organic matter, loose texture and light weight. Different varieties may be recognized depending upon the nature and amount of the material combined with the original organic matter. None of the mucks can be utilized for

17. For further discussion of marl turn to later page of this report.
18. Ann Arbor Folio, No. 155, 1908, page 8.
Report of the State Board of Geological Survey of Michigan for 1906, p. 92. Also for 1908, p. 205.

agricultural purposes until properly drained and very often they are rendered "sour" by the large amount of humic acid present. When these two things are suitably attended to, the soil, the heavier varieties especially, are well adapted to root crops, with the exception of the sugar beet which is found to be of inferior quality. Excellent crops of onions, celery and peppermint are produced upon this type of soil, while the undrained bogs, when not sour, furnish the conditions required for the cranberry. The natural timber upon such areas was the tamarack, white cedar and spruce. With a subsoil of clay within reach of their roots, black ash and elm were also able to grow.

No analyses of muck soils from southeastern Michigan have yet been made but there may be appended here three analyses of similar Michigan soils, well known from the quality of celery produced upon them. These analyses show that about 1/5 to 1/4 of these soils consist of sand, that but very little clay (alumina) is present and that they are nearly 2/3 organic matter. They may be termed sandy muck and with an increase in the percentage of sand at the expense of organic matter would pass into black sand ("Clyde sand" of the Pontiac area). With clay present, instead of the sand, the muck may be characterized as a clayey muck and may pass into black clay. Within the county of Wayne, the areas of mucky soil are found in the immediate neighborhood of existing, or former swamps (see Pl. X) and scattered over the flood plains of the rivers.

TABLE XVI.—ANALYSES OF MICHIGAN CELERY SOILS.[19]

	Grand Haven.	Newberry.	Kalamazoo.
Sand and silicates	24.09	24.56	19.16
Alumina	1.71	2.21	1.40
Oxide of iron	3.52	1.30	3.94
Lime	5.02	4.18	6.09
Magnesia	.62	.75	.81
Potash	.20	.42	.34
Soda	.33	.40	.38
Sulphuric acid	1.04	.67	1.31
Phosphoric acid	.69	.46	.88
Carbonic Acid	1.05	1.10	1.95
Organic matter	61.73	63.75	63.76
Water	10.85	7.31	6.51

19. Kedzie, Michigan Soils: Bulletin 99, Michigan State Agricultural College, 1893, p. 12.

Amelioration of soils. The maintenance of soil fertility, combined with an actual increase in the same, are matters of much importance, primarily to the farmer and indirectly to the entire community. This is one phase of the great question of conservation now before the public. Until the unwelcome truth has been forced upon him by gradually diminishing returns for his labor, the farmer has looked upon his land as an inexhaustible source of wealth, requiring only so much toil, rain and sunshine to yield returns. We have all learned by sad experience that bank accounts are sooner or later exhausted, if we continue writing checks and make no deposits. However rich the soil at the start, every load of grain harvested and every animal fattened upon it has reduced its resources by a certain calculable amount. The return of the straw and manure will greatly reduce the loss, but can not quite compensate. It is the height of folly to take from the soil as quickly as possible every dollar that it is capable of yielding and leaving it impoverished and temporarily worthless. A heritage in the shape of a patch of rich soil is a more valuable asset than a fat bank account, since banks occasionally fail and riches in the form of money oft "take wings."

Under the influence of natural agencies alone, in such humid climates as our own, soil is gradually brought to a state of fertility. The rain gathers annually from the atmosphere very appreciable quantities of ammonia and nitric acid which are brought to the soil and are subject to utilization by plants. Observations in Europe extending over a number of years indicate that the average annual amount of these two nitrogen bearing compounds is about 10.23 pounds to the acre, with a range of 1.86 to 20.91 pounds. This is estimated by King to be sufficient to supply the nitrogen for two bushels of wheat, were it all utilized. The observations of Failyer at Manhatten, Kansas, for the years 1887 to 1890, show a very appreciable but smaller amount.[20] Similar observations show that, for a rainfall equal to that of Wayne County, the amount of sulphuric acid brought to each acre is about 2¼ pounds. Small quantities of solid impurities are also washed from the atmosphere by rain and snow and contributed to the soil. Still larger quantities of dust and fine sand are swept across the country from the roadways and fields bare of vegetation. Clouds of such material may often be seen in the spring soon after the plowing. Rainwash from higher ground may also be spread over the adjacent land and add to its fertility. In some or all of these ways, fine material is gradually mixed in with the sands, giving them more body, supplying the variety of plant food needed and diminishing the average texture of the granules. Through the action of frost

20. Ammonia and Nitric Acid in Atmospheric Waters: Second Annual Report of the Kansas Experiment Station.

in disrupting the rock and mineral particles, the chemical action of the gases of the atmosphere, as well as that of the acids brought down in the rainfall, or produced in the soil itself, the soil particles are reduced in size and altered in character. Through this decay of the crystalline rocks there are added to the soil silica, alumina, carbonates of several kinds and varying quantities of soda and potash. The beneficial effects of the bare fallow upon most types of soil are thus accounted for.

Plant and animal agencies are also at work in bringing about a gradual improvement in the soil by loosening, mixing and the addition of organic matter. Plant roots often extend many feet into the ground and upon their decay leave the soil and subsoil more permeable to surface water and atmospheric gases, thus facilitating and extending downward the chemical changes required for a good soil. When plants are not removed from the soil in which they have grown, their decay returns to the soil all the mineral matter (ash) which they extracted from it and in addition certain substances derived from the atmosphere. Chief of these is carbon which but partially decays, as a rule, and helps to form the thin layer of surface mold. Certain plants, such as clover, beans, peas, etc., have the ability to extract from the air the free nitrogen and fix it into compounds not originally in the soil. This is done through the agency of the bacteria contained in the so-called "tubercles" upon their roots. This organic matter not only thus contributes to the soil food for future generations of plants, but renders the lighter soils more retentive of moisture and by giving them a darker color enables them to absorb more of the sun's heat in the spring when this is much needed for germination and early growth. Even dark colored heavy soils are also improved by the introduction of such organic matter, since they are rendered looser, more easily drained and more permeable to atmospheric gases. In its decay, this organic matter slowly liberates heat, by which the soil is slightly warmed, and in such decay organic acids are formed which assist greatly in rendering the minerals of the soil available as plant food. Animal substances introduced here and there would have the same result as that just given for plants. But while still alive, they are active agents in soil improvement. Darwin many years ago called attention to the great work done along this line by the common earthworm.[21] These creatures are often present in enormous numbers and in passing the earth through their long alimentary tracts, it is triturated, softened,

21. On the Formation of Mould: Transactions of the Geological Society of London, vol. V, 1840, p. 505
The Formation of Vegetable Mould through the Action of Worms, 1881. Latest edition, 1907.

chemically changed by the digestive juices, and finally ejected upon the surface. Since they are known to penetrate to depths of nine feet it is readily seen that they must have much to do in mixing soil and subsoil, furnishing means for the admission of surface water and atmospheric gases to considerable depths and in thus deepening the layer of true soil. They have the habit further, of drawing into their burrows at night quantities of leaves and seeds which may there partially decay. Darwin estimated that in ordinary English soil, every five years, the equivalent of one inch of soil is thus worked over by these creatures (page 171), and, when continued through a series of years, their importance can scarcely be over estimated. They, however, are most active in a moist soil already rich which needs them the least. In drier, poorer soils we find the ants active, penetrating also to considerable depths, bringing subsoil to the surface and opening up channels beneath. Shaler has found the soils of certain fields in Massachusetts completely altered through their agency and estimates that annually one-fifth of an inch of soil is thus brought to the surface and exposed.[22] The larvae of numerous insects also burrow in the soil and bring about a similar result. Among the higher animals, there may be mentioned also the mice, gophers, woodchucks, ground squirrels, moles, muskrats, pigs, some birds, etc. The crayfish often constructs long, subterranean passages, terminating at the surface in a chimney-like structure made of subsoil materials. A prominent farmer of Summerfield township, Monroe County, informed the writer than one of his sandy fields had been very materially helped through their influence. Their passages also assist in securing better drainage for the soil, thereby contributing to its fertility.

Nature thus offers to the intelligent farmer many suggestions for the improvement of his soil, as well as for the simple maintenance of its original fertility. In very many instances, the subsoil may be brought nearer the surface by deep plowing to the great advantage of the soil. Clay may thus often be incorporated into a sand or mucky soil. In some instances, the necessary food materials of the plant have been leached from the soil proper and deposited in the upper layers of subsoil. Where clay or sand knolls occur their materials may often be gradually distributed to the advantage of the adjacent soils. The importance of adding manure to the soil is universally recognized by farmers today but the use of commercial fertilizers is not fully appreciated.

22. Origin and Nature of Soils: Twelfth Annual Report, U. S. Geological Survey, part I, 1891, p. 278.

Our State Agricultural College stands ready to offer expert advice along these lines and will gladly furnish bulletins to those interested in the scientific use of such material and in the rotation of crops. The occasional plowing under of a green crop, such as clover, is of great advantage to certain soils. In case a soil is too barren to produce clover in quantity, it is recommended that a commercial fertilizer be first used until a good "catch" can be secured. In this way, the fertility of an impoverished soil may be eventually restored. Lime, ground limestone, marl, gypsum ("plaster") and wood ashes often supply the ingredients lacking in a certain type of soil or act beneficially upon it, and a most interesting and profitable line of experiments may be carried on about every rural home in discovering what crops can be most advantageously grown and of just what assistance the soil stands in need.

The importance of free drainage in the case of soils naturally wet and cold is very generally recognized and this applies to all types of soils. This is especially true for the mucky soils that are liable to be "sour" from the presence of the free acids resulting from the decay of the organic matter. Such soils have a sour odor and when applied to blue litmus paper[23] in moist condition give a reddish coloration. Barren patches in mucky areas, sometimes not even producing weeds, are generally due to this cause. The condition may be remedied by the application of sufficient lime, wood ashes, or marl, the latter being often found underlying the muck itself and hence readily available. When the soil runs into a pure peat it has little value for agricultural purposes, but when underlain by clay or loam, it may be burned after complete drainage and a good soil thus obtained. An illustration of such improvement is shown in the northwestern corner of Romulus township where the peat occasionally catches fire and burns to a depth of 5 to 8 feet. This practice is, however, wasteful of valuable material which may be utilized in a variety of ways noted upon a subsequent page.

23. This may be obtained from almost any drug store.

CHAPTER V.

PHYSICAL GEOGRAPHY (Continued).

CLIMATE OF WAYNE COUNTY.

Data available. The climate of Detroit has been made the subject of systematic study for three-quarters of a century and the records thus obtained furnish data for satisfactory generalizations. Future records will probably not materially disturb the averages already obtained until the climate itself has had time to become essentially different. For years, the U. S. Weather Bureau has maintained a station at Detroit with trained and salaried observers devoting their time entirely to the collecting, recording and study of meteorological data. For some 35 years previous to the establishment of this government station, Bela Hubbard, at great personal sacrifice that can be understood and appreciated by those only who have systematically tried it, collected very complete data relative to precipitation, temperature, winds and general climatic conditions. Based largely upon these observations, he read a paper in 1874 before the Detroit Scientific Association entitled "Climate of Detroit and the Lake Region,"[1] in which his summaries were presented and comparisons made with other sections of the state and country. From all the data now available, it seems that he had been able to discover the main climatological facts for this section of the state. A few years previous, Alexander Winchell had compiled all the meteorological data then available for the region of the Great Lakes and, with the help of a series of charts, showed how markedly these great bodies of water influence the temperature upon both sides of the state, making them warmer in winter and cooler in summer. These conclusions were published between 1866 and 1873, in a variety of places and attracted attention to this interesting feature of the climate of the region.[2] Based largely upon Winchell's studies, as well as upon some additional data then available, Dr. Henry T. Lyster, of the Michigan State Board of Health in 1878 prepared "A Study of the Climate and Topography of the Lower Peninsula of the State of Michigan.[3] Hubbard's observations and generalizations were finally brought together in a most readable volume entitled "Memorials of a Half-Century" (1888), in which 162 pages are devoted to the climatology of southeastern Michigan.[4]

1. Detroit Free Press, October 11, 1874. Published also in Michigan Pioneer Collections, vol. III, 1881, pp. 67 to 83. Memorials of a Half-Century, 1888, pp. 419 to 449.
2. The Fruit-bearing Belt of Michigan: Proceedings of the American Association for the Advancement of Science, Buffalo, 1866, p. 84. See also Proceedings of the Troy meeting 1870, p. 106.
State Geological Survey of Michigan, Report of Progress to November 22, 1870, 1871, p. 53.
Climate of the Lake Region, Harper's New Monthly Magazine, vol. XLIII, 1871, p. 275.
Climate. Atlas of the State of Michigan, 1873, p. 44. Also "Michigan," 1873, p. 89, and the Grand Traverse Region, 1866, p. 20.

The work of another voluntary observer should be also here mentioned, that of Rev. George Duffield, D. D., who kept a record of the Detroit climate from 1840 to 1857. The precipitation records, month by month, were published in the Report of the Board of Water Commissioners for the year 1858, page 16. Through the kindness of his son, Samuel P. Duffield, M. D., now of Detroit, the writer has learned that these data were collected at the northwest corner of what are now High Street and Woodward Avenue, just one mile back from the river (ground elevation 605 feet above sea level) and with a rain gauge manufactured by B. Pike and Son, of Philadelphia. The gauge was located in the garden and Dr. Duffield thinks may have been somewhat affected by "whirls" from the house in the case of certain heavy storms. The funnel of the gauge, five inches in diameter, he still retains but the glass graduate, which accompanied it, has been broken. The observations of Hubbard were made at the home still standing on Vinewood Avenue, between Lafayette and Howard streets, about one-half mile from the river, where the elevation is some 595 feet above sea level. The distance in a straight line from the Duffield home is about 2¼ miles. These details are mentioned in order to discover some possible explanation for the marked discrepancy in the two sets of precipitation data, those of Rev. Duffield being about 50% greater than those of Hubbard for the 17 years, 1840 to 1856, inclusive. It is known that gauges set at different levels and at no great distances show marked differences in their readings. Data of this nature were collected in New Orleans between 1895 and 1904 and reported in the Monthly Weather Review for May, 1905, page 204. Gauges were placed at different points in the city, the greatest distance between them being six miles. The means for the 10 years were respectively 52.80, 52.00, 49.85, 47.65 and 52.33 inches; but for single years variations of 10 to 12 inches were observed.[5]

3. Sixth Annual Report of the Michigan State Board of Health for the year 1878, pp. 169 to 210.
4. Through the kindness of Mr. Hubbard's daughter and her husband, Mr. Frederic Towle, of Detroit, the writer has secured possession of most of the original meteorological data and field notes of this distinguished pioneer geologist and meteorologist. It is expected that these will be eventually turned over to the library of the University of Michigan for preservation.
5. Jefferson, *loc. cit.*, below.

Besides the data collected at the Detroit station, the U. S. Weather Bureau has secured less complete observations from volunteer observers at numerous stations in southeastern Michigan, which data, along with those supplied by the Canadian Meteorological Service, have been made the basis from time to time of meteorological maps covering the Great Lake region. Director C. A. Schneider of the Michigan State Service, prepared such a rainfall map of Michigan in 1900 and two years later Prof. A. J. Henry issued the latest precipitation map of the United States,[6] based upon records from 1871 to 1901, inclusive. Prof. Mark Jefferson has made, more recently, a careful study of the precipitation of the Great Lake region and constructed a map of Michigan and the territory adjacent, based upon the records for a period of 25 years.[7] The averages for stations at which the records were incomplete were "corrected" by comparing them with the averages of the corresponding years at nearby stations where the records were complete.[8] Although still but approximations, such corrected averages must represent more nearly the normal mean for such stations. A still later summary has just been issued by the U. S. Weather Bureau covering the precipitation and temperature at selected stations in the eastern half of the Lower Peninsula, those stations being selected which furnished the longer records.[9] The summaries here given include the year 1908.

Owing to the more or less intimate connection between precipitation and lake and Detroit River levels, records of their extreme stages throw light upon the cycles of precipitation during the 50 years that preceded the taking of definite meteorological observations, thus extending our record through a period of some 125 years. These early data, however, are fragmentary and more or less legendary and unreliable. The extremely high water of 1838 called attention strongly to the lake and river fluctuations and three observers were especially active in gathering all the data at that time available and in recording subsequent levels. Charles Whittlesey published his full data in 1859 under the title "On

6. Monthly Weather Review, April, 1902, p. 207.
7. Rainfall of the Lake Country for the Last 25 Years: Eighth Annual Report of the Michigan Academy of Science, 1906, p. 78. See also Material for Geography of Michigan, Normal College News, vol. III, No. 18, 1906, p. 159.
8. This correction is made by finding first the average for the full period at the reference station selected; next the average also for the identical years during which observations were made at the station which is to have its average corrected. Dividing the average for the full period by that for the limited period at the reference station gives a ratio by which the average at the second is to be multiplied in order to get the corrected result. The assumption is that the ratio between the average for the actual years of observation and the full series, could it have been made at the second station, is the same as that of the corresponding ratio at the reference station, where the complete series was actually made.
9. Summary of the Climatological Data for the United States, by Sections. Section 63, 1910.

Fluctuations of Level in the North American Lakes"[10] and Bela Hubbard in his "Memorials of a Half-Century," 1888, page 461. A manuscript chart prepared by the latter is in the writer's possession showing lake and river levels from 1787 to 1894, with curves of rainfall and sun-spots for comparison. In his Second Annual Report, dated Feb. 4, 1839, Douglass Houghton devotes six of the thirty pages to the discussion of "Changes of Elevation in the Waters of the Great Lakes",[11] with the help of the "oldest inhabitants" going back to 1800. Based upon the scientific data supplied by the Smithsonian Institution, the War Department and the U. S. Lake Survey, Mr. Charles Crosman published in 1888 a complete chart of the five Great Lakes, with an explanatory booklet (Swain and Tate, printers, Milwaukee, Wis.). The chart shows the mean monthly and annual fluctuations of the surface levels and the rainfall curve for one or more adjacent stations, along with other interesting data, extending over the years 1859 to 1887. A similar chart but showing only the lake levels, was issued by the U. S. Lake Survey covering the years 1860 to 1904, inclusive. Since the year 1853, daily records of the level of the river have been taken for the Detroit Water Board. In their Forty-Ninth Report, published in 1901, a table is given showing the monthly high, low and mean levels for the years 1854 to 1900, inclusive. Partial data are also given extending back to the year 1819. It has been recognized by all observers that there is a direct connection between these lake and river levels and the general precipitation of the drainage basins into these lakes, the extreme stages of the levels lagging somewhat behind the corresponding precipitation stages. It has also been pointed out by Prof. Henry that the amount of evaporation from the surfaces of the lakes may have an important bearing upon their elevations and that a more or less complex relation may exist between their levels and precipitation, evaporation, strength and direction of winds and lake discharge.[12]

Precipitation. In the form of rain and snow, Detroit receives an average annual precipitation of 32.13 inches, as indicated by the 40 years' observations of the U. S. Weather Bureau (1871 to 1910). For the same period of time (1835 to 1874), but overlapping the former record by four years, Hubbard's average is 30.3 inches. This is as close agreement as we could expect in the case of records

10. Smithsonian Contributions to Knowledge, vol. XII, 1859, pp. 4 and 5. See also Second Annual Report of the Geological Survey of the State of Ohio, 1838, p. 51. Foster and Whitney's Report on the Geology of the Lake Superior Land District, pt. II, 1851, p. 319.
11. Senate Document No. 12, 1839, pp. 278 to 284.
12. Variations in Lake Levels and Atmospheric Precipitation: U. S. Department of Agriculture, Weather Bureau No. 203, 1899, p. 7.

obtained from separated and differently exposed gauges, for even the same series of years, and is a testimonial of the care and fidelity with which these early observations must have been taken and recorded. The total monthly and annual precipitation, with the averages for the entire period of 40 years, 1871 to 1910, is shown in table XVII.[13] about 33% of the precipitation occurs in May, June and July, just when it can be of the greatest service to the growing crops. The least monthly precipitation takes place in January, and mostly then in the form of snow. During the remaining eight months the precipitation is rather evenly distributed, as far as may be judged from the averages, ranging from 2.30 to 2.73 inches. The combined total for the winter and summer seasons is but slightly in excess of that for the spring and fall. The greatest precipitation for any single year since 1835 was 47.69 inches and occurred in 1880, due to abnormally heavy rainfall from April to September, inclusive. This represented an increase of 48.4% above the normal. The least annual precipitation for the entire period of 75 years was 21.06 inches in 1889, or only 65.5% of the normal, all months being deficient except May and December. During August of this year less than one-fifth of an inch fell, while, rather curiously, the previous August witnessed the heaviest 24 hour precipitation of the entire 40 year period, amounting to 4.42 inches.

13. The full data for this and the following tables is kindly supplied by Sgt. N. B. Conger and Observer C. D. C. Thompson, of the Detroit office of the Weather Bureau.

TABLE XVII.—MONTHLY PRECIPITATION DATA; U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU, DETROIT, MICHIGAN.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1871	2.01	2.42	2.62	1.55	2.34	3.88	1.94	1.21	1.43	.69	2.76	2.57	25.42
1872	.37	.69	1.22	2.15	5.64	2.85	2.63	2.60	3.84	1.60	.67	.69	24.95
1873	3.20	.32	1.79	4.94	3.50	5.18	3.43	.33	3.28	2.60	1.03	4.72	34.32
1874	4.96	2.00	1.55	1.39	1.93	4.53	3.65	2.11	.67	.78	2.26	.60	26.43
1875	.97	1.82	3.00	.70	5.83	3.25	3.73	6.04	2.10	3.35	1.72	3.20	35.71
1876	2.00	5.59	5.50	1.80	5.62	1.51	5.94	2.46	2.81	2.89	2.32	1.96	40.40
1877	1.23	.04	5.43	3.27	.90	4.80	1.57	7.29	.39	4.72	4.10	1.49	35.23
1878	3.04	2.58	3.35	2.06	2.77	3.36	8.76	2.92	3.74	2.89	3.10	4.83	43.40
1879	1.11	2.64	1.72	1.56	2.64	3.85	6.22	1.31	6.24	.83	4.71	4.62	37.45
1880	2.81	1.51	2.75	6.17	4.86	4.38	5.74	5.51	4.26	5.45	3.02	1.23	47.69
1881	2.39	6.41	3.36	2.37	2.45	5.90	3.33	1.32	2.86	6.52	4.36	4.17	45.44
1882	1.97	1.92	3.34	1.13	4.82	3.70	1.65	4.43	1.77	2.43	1.66	1.50	30.32
1883	1.69	3.22	1.55	1.53	5.11	4.32	5.29	.90	1.50	2.55	2.24	2.67	32.57
1884	2.08	3.39	2.10	1.54	2.38	1.92	3.76	1.55	2.70	1.96	1.74	3.05	28.17
1885	1.89	1.26	.66	1.74	3.65	3.36	2.83	5.05	1.54	1.68	2.19	2.30	28.15
1886	1.92	1.30	1.70	3.30	2.33	2.07	2.45	2.02	4.20	1.04	2.17	2.21	26.71
1887	1.31	4.16	1.44	1.19	2.11	4.19	1.31	2.30	4.41	1.49	2.72	2.34	28.97
1888	1.58	1.58	2.76	1.44	1.94	3.41	3.48	5.27	1.26	2.09	3.05	1.16	29.02
1889	1.51	.76	1.17	1.14	4.41	3.28	1.54	.19	.56	1.05	2.36	3.09	21.06
1890	2.70	2.01	1.32	2.74	3.94	4.28	1.69	4.46	2.31	5.67	2.64	1.23	34.99
1891	.92	3.07	2.23	2.72	1.68	2.28	2.90	2.86	1.33	1.93	5.30	1.61	28.83
1892	1.45	2.57	2.03	1.78	7.84	8.31	2.39	2.21	3.66	.30	3.10	1.47	37.11
1893	1.77	4.05	1.36	3.61	1.50	4.66	2.50	1.78	1.37	4.77	3.68	3.13	34.18
1894	.94	2.57	1.39	2.54	4.90	2.63	2.06	.16	2.47	3.37	1.15	1.56	25.74
1895	2.76	.22	1.69	1.31	2.61	.55	3.30	1.97	1.15	.56	4.19	4.73	25.04
1896	1.17	1.60	2.28	3.61	2.05	6.97	5.39	4.60	4.23	1.65	1.72	.93	36.20
1897	1.65	1.14	3.70	2.09	4.03	3.52	1.70	3.10	1.02	1.31	5.13	1.95	30.34
1898	3.32	3.27	3.11	1.51	1.65	5.15	2.03	1.84	3.30	3.49	2.92	2.75	34.34
1899	1.75	2.12	4.36	.53	3.38	1.82	2.95	.62	2.18	2.35	2.05	2.30	26.41
1900	1.14	4.30	3.26	1.64	3.08	3.99	3.71	2.08	1.88	2.85	3.10	.42	31.45
1901	1.52	1.64	1.80	2.07	2.76	2.08	3.50	3.20	1.65	1.90	1.00	3.66	28.78
1902	.57	.72	2.66	.60	3.52	6.97	7.55	.60	6.50	1.54	1.57	2.73	35.53
1903	1.63	3.19	1.36	5.51	1.55	6.32	4.59	4.27	2.78	1.67	1.18	1.83	35.88
1904	3.34	2.55	4.09	1.65	2.36	1.08	2.94	3.20	4.23	.86	.19	1.83	28.32
1905	1.93	1.50	1.02	2.20	4.31	4.44	3.52	4.18	3.27	1.15	2.76	1.72	32.00

TABLE XVII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	1.90	.87	2.03	1.92	2.12	5.24	4.24	3.25	1.85	4.20	2.28	3.77	33.67
1907	3.87	.61	2.20	2.33	2.64	3.60	2.71	.62	4.10	1.86	1.46	4.62	30.62
1908	2.84	4.95	2.46	2.44	3.57	1.85	1.83	4.49	.56	1.49	.73	1.38	28.59
1909	2.51	4.26	1.71	4.25	3.78	4.95	5.94	3.75	.75	1.46	4.70	2.59	40.65
1910	3.14	1.84	.38	4.73	3.65	1.47	1.48	1.11	2.02	1.07	2.04	2.05	24.98
Average or "Normal"	2.04	2.32	2.34	2.41	3.30	3.80	3.50	2.73	2.55	2.30	2.53	2.42	32.13

In table XVIII, there has been compiled the snowfall, expressed in inches, for the years 1871 to 1910, inclusive, which may prove to be of interest for purposes of reference. From this, it is seen that the heaviest snowfall for any single year occurred in 1900, amounting to 73.3 inches, or over six feet. The great bulk of this fell in February and March, that for January and December being especially deficient. The least snowfall recorded was but 13.4 inches, for the year 1872. Upon an average, January contributes the most snow, February next in amount and March and December about the same. Scarcely an April passes without some snowfall, the average amount for the period covered by the Weather Bureau being 1.78 inches. In 1886, however, the amount recorded was 25.7 inches for this month. Only exceptionally is there any snowfall in May, but this occurred in 1875, 1883, 1892, 1900, 1902, and for the last seven years to 1912, with the exception of 1911. Snow in October is not so rare as in May, and November furnishes somewhat more than does April. The heaviest monthly snowfall recorded was for February, 1908, amounting to 38.4 inches, or 3.2 feet. In the last column of table XVIII, there is given the total fall for the continuous autumn, winter and spring seasons, instead of the total fall for any single year, which is shown in the column headed *annual.* That there exists a periodicity in the amount of snowfall, corresponding to that of the precipitation, will be pointed out in a subsequent paragraph, restoring again the "old fashioned winter", about which there centers many a winter tale.

Although the climate of Detroit may be considered as representing fairly the entire county, still owing to its altitude, location in the eastern part of the county and proximity to the lakes, minor variations appear when we study the data secured from the contiguous territory. The only other stations within the county are located at Plymouth and at Eloise, the site of the Wayne County Home, which is nearer the geographic center of the county and would presumably furnish better average climatic conditions than does Detroit. Unfortunately, however, the record at the latter place is short and incomplete. In the counties adjacent to Wayne, volunteer stations have been maintained, similar to those at Plymouth and Eloise, and, in table XIX, there is given the summaries for those stations which are most likely to throw light upon the climatic conditions that exist in the contiguous portions of Wayne.

TABLE XVIII.—TABLE OF SNOWFALL BY INCHES FOR DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual.	Seasons total.*
1871	...	...	...	...	...	...	...	...	...	...	2.5	1.2	...	...
1872	2.7	1.8	1.1	.4	...	...	...	...	...	...	1.5	5.9	13.4	9.7
1873	9.9	.9	3.2	...	...	...	...	...	...	1.4	4.2	2.1	21.7	21.4
1874	22.8	6.0	...	...	...	...	...	...	...	...	9.6	.7	39.1	36.5
1875	5.9	13.2	8.8	T	T	...	...	...	...	...	...	...	27.9	38.2
1876	20.0	18.6	...	T	...	...	...	...	...	...	...	...	38.6	38.6
1877	11.9	.4	...	...	...	...	...	...	...	...	...	...	?	...
1878	30.4	11.1	...	...	...	...	...	...	...	...	...	...	?	...
1879	6.9	18.8	3.1	1.1	...	...	...	...	...	T	5.4	8.8	44.1	...
1880	.8	8.1	5.4	1.8	...	...	...	...	...	.4	6.9	6.2	29.6	30.3
1881	21.4	20.4	16.0	2.4	...	...	...	...	...	...	...	2.9	63.1	73.7
1882	1.5	1.9	4.1	T	...	...	...	...	...	...	3.5	8.2	19.2	10.4
1883	10.0	7.4	14.5	2.2	.1	...	...	...	...	...	.5	10.9	45.6	45.9
1884	20.8	2.8	1.4	.8	...	...	...	...	...	T	3.4	10.5	39.7	37.2
1885	6.0	2.1	2.4	6.2	...	...	...	...	...	...	.3	11.9	28.9	30.6
1886	8.4	5.3	8.6	25.7	...	...	...	...	...	...	.8	13.9	62.7	60.2
1887	11.4	4.6	4.2	.8	...	...	...	...	...	...	.3	4.3	25.6	35.7
1888	16.6	5.7	10.1	...	...	...	...	...	...	T	.9	1.2	34.5	37.0
1889	9.8	5.3	4.1	3.0	...	...	...	...	...	...	1.0	...	23.2	24.3
1890	1.6	4.0	9.1	...	...	...	...	...	...	...	3.2	11.9	29.8	15.7
1891	1.5	2.6	7.9	.6	...	...	...	...	...	...	6.8	5.4	24.8	27.7
1892	17.2	5.4	4.6	T	T	...	...	...	...	...	6.4	8.0	41.6	39.4
1893	23.1	18.0	1.5	2.7	...	...	...	...	...	T	2.7	16.6	64.6	59.7
1894	1.4	14.6	4.2	6.0	...	...	...	...	...	...	6.9	.4	33.5	45.5
1895	21.5	1.5	13.2	.1	...	...	...	...	...	.1	4.5	22.5	63.4	43.6
1896	2.6	6.5	10.5	.1	...	...	...	...	...	T	T	7.4	27.1	46.8
1897	8.7	8.2	10.4	T	...	...	...	...	...	...	.4	9.1	36.8	34.7
1898	11.4	19.6	2.5	.8	...	...	...	...	...	T	8.9	16.0	59.2	43.8
1899	4.2	6.5	24.1	.5	...	...	...	...	...	...	T	4.0	39.3	60.2
1900	5.4	28.0	30.2	1.5	T	...	...	...	...	...	6.2	2.0	73.3	69.1
1901	12.6	16.4	4.5	T	...	...	...	...	...	T	T	12.9	46.4	41.7
1902	5.4	5.4	1.2	.8	.5	...	...	...	...	...	5.1	13.8	32.2	26.2
1903	12.7	14.7	.1	4.9	...	...	...	...	...	T	2 3	12.3	47.0	51.3
1904	20.1	5.8	14.7	1.8	...	...	...	...	...	...	.8	7.5	50.7	57.0
1905	13.5	15.1	.2	.3	...	...	...	...	...	...	.3	4.8	34.2	37.4

TABLE XVIII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual.	Seasons total.*
1906	7.3	1.6	2.5	1.0	T	...	...	...	...	T	1.2	7.1	32.6	17.5
1907	12.7	5.8	3.2	.8	.2	...	...	...	...	T	2.5	13.0	38.2	31.0
1908	12.2	38.4	1.8	.1	T	...	...	...	...	...	.3	6.9	59.7	68.0
1909	11.4	14.3	5.0	3.0	.4	...	...	...	...	.4	.3	14.7	49.5	41.3
1910	22.2	9.1	.1	T	T	...	...	...	...	T	2.3	20.1	53.8	46.8
Averages	11.4	9.6	6 6	1.8	...	...	...	...	...	...	2.5	8.2	41.9	39.8

*This column combines the snowfall for the consecutive fall, winter and spring.

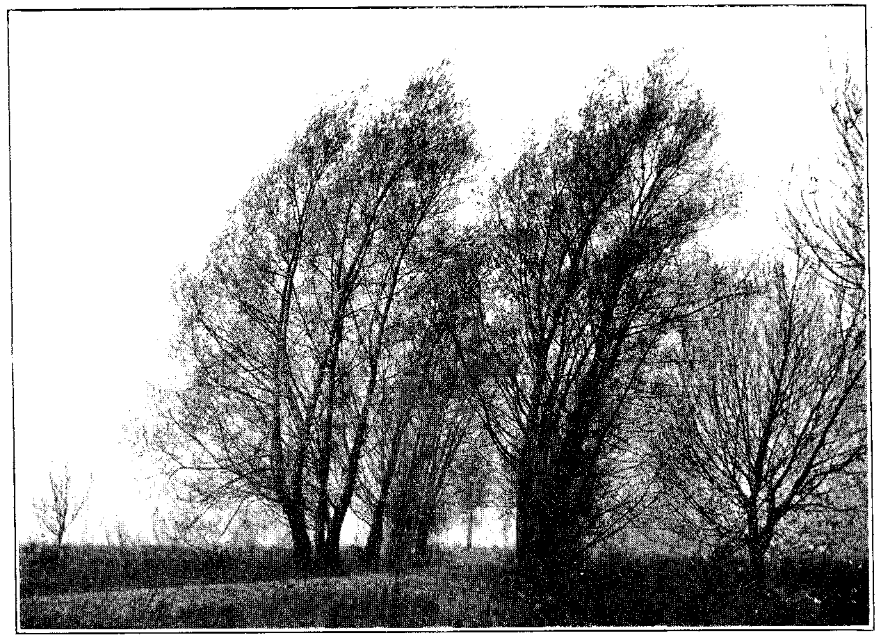
TABLE XIX.—METEOROLOGICAL SUMMARIES FOR WAYNE COUNTY AND VICINITY.

(Data supplied by the Michigan, United States and Ontario Weather Bureaus.)

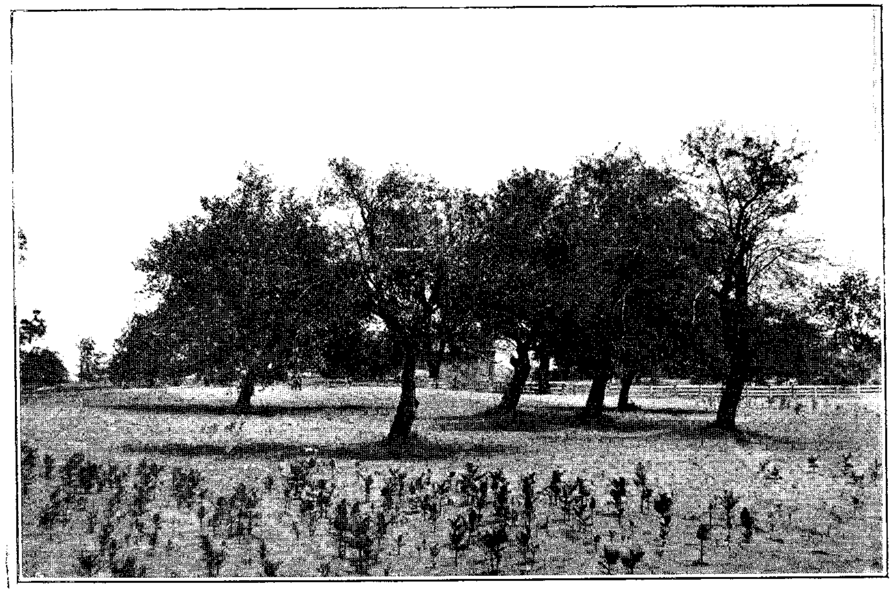
Station.	County.	Elevation above sea level.	Years of record.	Mean annual temperature. Degrees.	Mean annual precipitation. Inches.	"Corrected" with Detroit.	Average annual snowfall. Inches.	Prevailing wind.
Detroit	Wayne	730	40	48.2	32.13	32.13	41.9	SW.
Eloise	Wayne	640	14	48.9	29.45	30.02	35.9	SW.
Plymouth	Wayne	725	14	47.8	28.04	28.60	31.7	W.
Pontiac	Oakland	935	11	47.6	30.75	31.06	33.6	NW.
Ball Mountain	Oakland	983	20	46.0	32.14	32.78	42.6	SW.
Ypsilanti	Washtenaw	736	27	47.2	34.42	36.14	39.8	SW.
Ann Arbor	Washtenaw	930	31	47.0	31.77	32.09	38.5	SW.
Grape	Monroe	625	21	48.6	29.78	30.38	35.2	SW.
Windsor	Essex	626	34	47.7	30.80	30.65	37.9	SW.

An inspection of the preceding table shows that the Eloise and Plymouth records are for but 14 years, while that of Detroit runs continuously through 40 years. If the amount of precipitation maintained its average pretty closely, deficiencies or excesses of one year being promptly compensated for, the averages for Eloise, Plymouth and Detroit could be at once compared and conclusions drawn. However, an examination of the Detroit record shows that the average for the last 14 years is 31.54 inches, instead of 32.13 inches, that for the entire period. To reduce the 14 year average to that for the 40 years it is necessary to multiply it by the ratio $\frac{32.13}{31.54}$ or 1.02, and we may assume the same thing should be done for each of the other two stations. When the actual averages at the various stations are thus "corrected" with the Detroit record, it is found that they should all be slightly increased, for purposes of comparison, except the long Windsor record which is slightly reduced. This corrected column thus becomes necessary because of the fact, now of world-wide observation, that precipitation is in cycles. Although the actual range in precipitation is no greater than that which might occur within the limits of a single large city, still since these results represent *averages*, extending over a fairly long period, there are certain generalizations that seem justified. Some five years ago the writer pointed out that the precipitation over a belt of territory extending northeast and southwest across Monroe, Wayne and Oakland counties is somewhat less than that to the east and west.[14] These new figures, bringing the data to the close of the year 1910, show that this same condition still exists, the stations of Grape, Plymouth, and Eloise showing from 5 to 11% less precipitation than Detroit, and from 9 to 15% less than the average of the stations Ypsilanti, Ann Arbor and Ball Mountain, located in the high morainic section to the west. This slight reduction in precipitation might be assumed to be connected with the broad belt of sandy soil of this region were it not for the fact that the deficiency shows itself in the winter season as well as in the summer. The average annual snowfall at Grape, Eloise, Plymouth and Pontiac is less than that for Detroit, Ball Mountain, Ypsilanti and Ann Arbor, by a few inches. The phenomenon may be the climatic effect of the relatively high morainic belt that crosses Washtenaw and Oakland counties. For

14. Water Supplies of Wayne County: Water Supply and Irrigation Paper, No. 182, U. S. Geological Survey, 1906, p. 49.

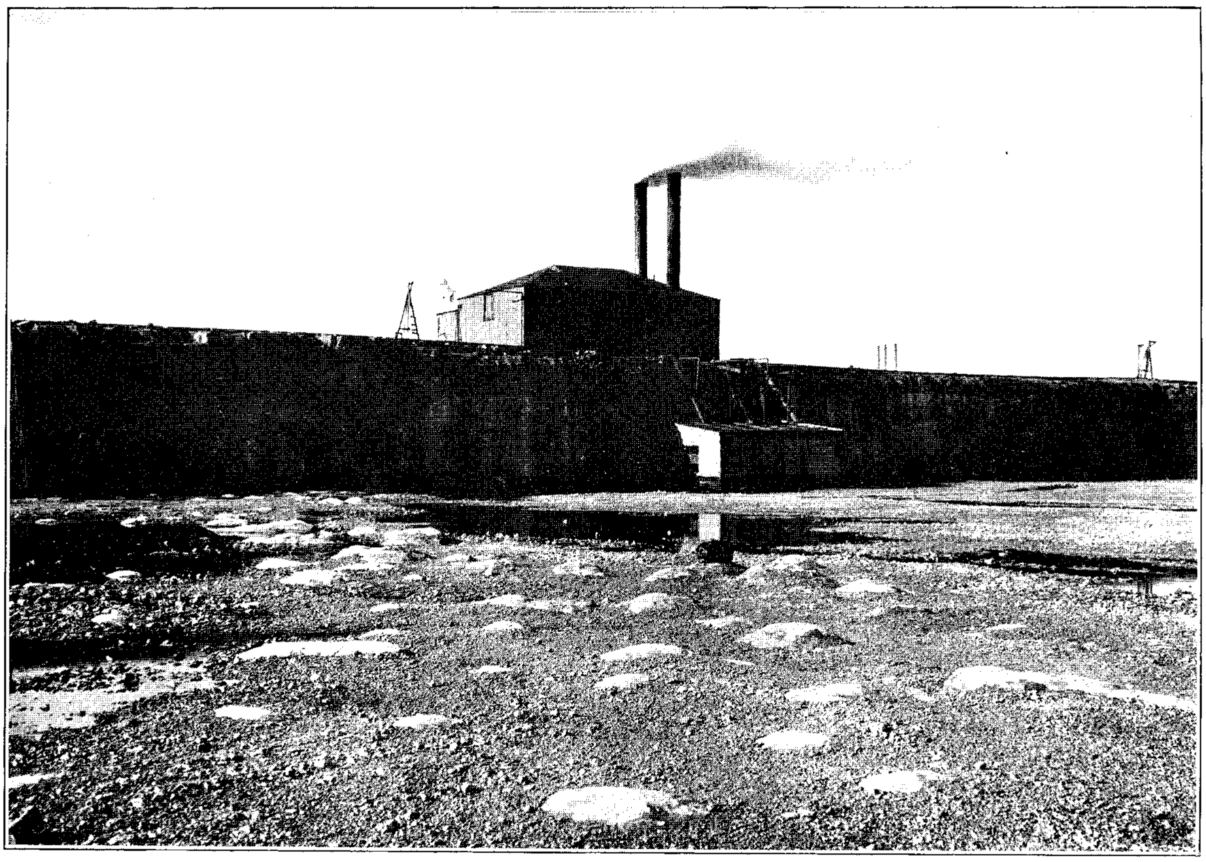


A. EFFECT OF PREVAILING WINDS UPON WILLOWS.

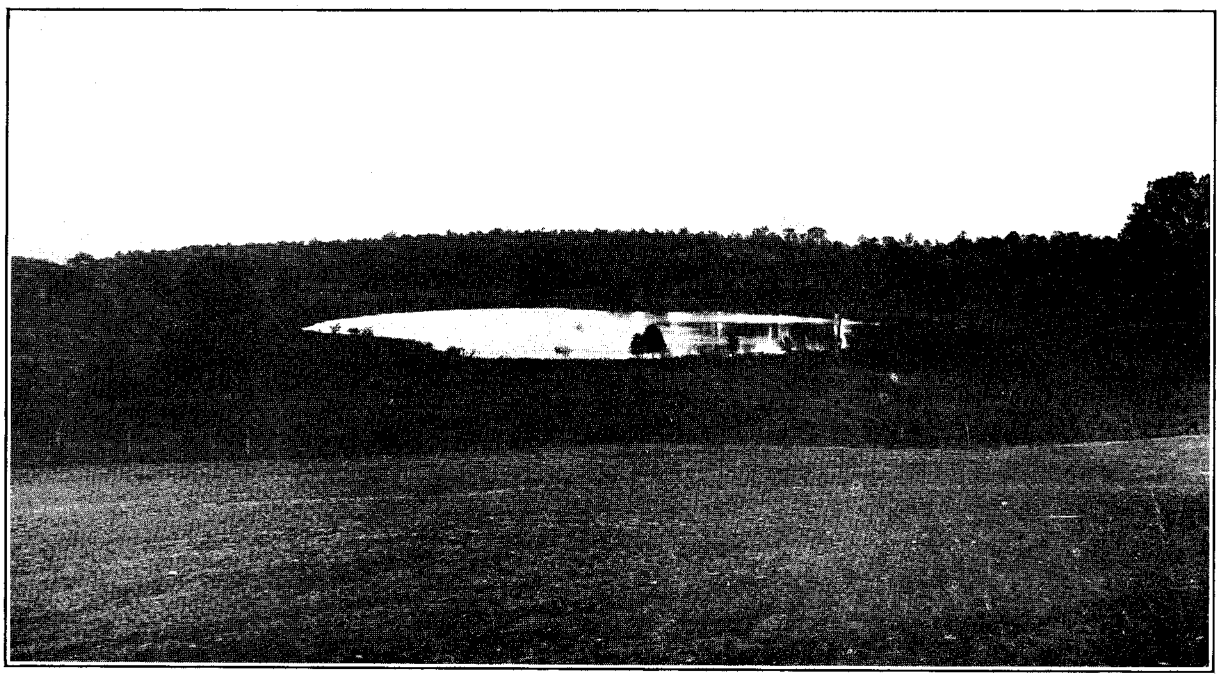


B. EFFECT OF PREVAILING WINDS UPON APPLE TREES.

ANDERDON STRATA, SIBLEY QUARRY. LOWER LAYERS ARE HIGHLY FOSSILIFEROUS.



UPPER MONROE STRATA, LIVINGSTONE CHANNEL, SHOWING THE LARGE CONCRETIONARY MASSES WHICH CHARACTERIZE SOME OF THE BEDS.



VIEW OF YERKES LAKE, NEAR NORTHVILLE, THE ONLY NATURAL LAKE WITHIN THE LIMITS OF WAYNE COUNTY.

the entire county of Wayne, the average annual precipitation of the nine stations listed in the table would more nearly represent that for the county, the average at Detroit being too high and that at Eloise too low. The general average for the vicinity is 31½ inches, of which the equivalent of 3.75 inches, or 11.9%, falls as snow. This snowfall represents an average fall of 37½ inches, as ordinarily measured, ten inches of snow being regarded as the equivalent of one of rain.

The prevailing direction of the wind for the entire county is southwest, although at Plymouth, for the 14-year period it appears as west and as northwest at Pontiac. The average mean annual temperature for the nine stations is 47.7°F., the more elevated stations of Ann Arbor, Ypsilanti, Ball Mountain, and Pontiac being lower. For convenience of holding in mind, the climatic data for Wayne County may be summarized as follows:—mean annual temperature 48°; average annual precipitation 31 inches; average annual snowfall 3 feet; prevailing direction of wind southwest.

Temperature. The monthly and annual mean temperatures as determined by the Detroit station of the Weather Bureau (Fahrenheit scale) are given in table XX, from 1871 to 1910, inclusive.[15] The average of annual means is 48.2°F. for the 40 years of observation. Hubbard's average for the 40 years 1835 to 1874 was 47°, which was gradually raised to 47.9° by subsequent observations (see Memorials, page 450). The range in the mean annuals is from 43.2° to 52°, the highest being reached in 1881 and 1882 and the lowest in 1835. The highest average monthly mean is found in July (70.1°) and the lowest in January (24.5°). The highest monthly mean for any single year was 77° (July, 1901) and the lowest 12° (February, 1875). In tables XXI and XXII we have presented the extremes of temperature, maximum and minimum, for each separate month of the 40-year period, as indicated upon self-registering standard instruments. The highest such temperature was in July, 1887, reaching 101°, and the lowest—24°, December, 1872, giving an extreme range in 75 years of 125°. Hubbard noted an interesting relation between the temperature means for the various seasons, which relation is still as true as it was 25 years ago. When the mean of the three summer months (69.2°) is averaged with that of the winter (26.0°) we have a close approxi-

15. The monthly means represent the average of the daily means, obtained by adding the daily maximum and minimum readings of the thermometer and dividing by two. The mean annual for any year is obtained by taking the average of its monthly means. The writer can find no statement as to how Hubbard's daily means were obtained.

mation (47.6°) to the annual mean (48.2°). Similarly the spring mean (45.6°) when averaged with that of the autumn (51.3°), gives a still closer approximation (48.6°) to the annual. If the twelve months are arranged in three groups, by selecting one and skipping two, the average of their means again gives the same approximate result. The average of the mean for January, April, July and October is 48.1°; that of February, May, August and November is 47.7°; of March, June, September and December is 48.2°, showing a pretty even balance in the average distribution of the annual temperature.

TABLE XX.—MONTHLY AND ANNUAL MEAN TEMPERATURES AT DETROIT STATION OF U. S. WEATHER BUREAU.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1871	26	26	39	45	58	66	69	70	58	54	33	23	47.2
1872	23	24	26	47	56	68	73	72	63	49	33	19	46.1
1873	20	23	31	42	56	69	72	71	61	48	32	33	46.5
1874	29	27	34	38	59	69	71	69	66	51	38	27	48.2
1875	15	12	28	40	57	66	70	67	60	46	34	33	44.0
1876	32	28	30	44	57	69	73	72	59	46	39	18	47.2
1877	19	34	26	45	56	66	72	71	64	54	39	38	48.7
1878	27	29	41	53	55	64	74	71	64	52	39	23	49.3
1879	21	22	34	45	59	65	73	69	59	60	38	29	47.9
1880	37	32	33	46	64	68	71	69	62	49	30	22	48.6
1881	17	26	34	45	64	64	75	74	72	56	44	41	51.0
1882	31	40	40	46	53	67	70	71	64	58	42	30	51.0
1883	22	25	30	46	54	68	71	67	59	51	44	33	47.5
1884	20	31	35	46	59	70	70	69	68	56	40	30	49.5
1885	23	17	26	45	57	66	74	67	63	51	42	33	47.0
1886	24	28	36	51	59	67	72	71	65	55	39	24	49.2
1887	23	28	30	46	63	68	76	69	60	48	38	29	48.2
1888	18	24	29	43	54	66	71	69	60	47	41	31	46.1
1889	30	19	37	46	57	64	71	70	63	47	40	39	48.6
1890	34	32	30	46	55	72	72	67	60	52	41	27	49.0
1891	29	31	31	48	56	68	67	70	68	51	36	36	49.2
1892	21	29	31	45	56	70	72	71	63	52	36	27	47.8
1893	15	22	33	44	55	70	73	70	62	53	38	28	46.9
1894	30	24	40	48	56	71	74	69	66	52	35	32	49.8
1895	20	18	28	49	60	71	70	71	67	45	38	30	47.2
1896	25	25	29	51	65	68	71	70	60	48	40	30	48.5
1897	23	27	35	45	55	65	75	68	66	56	39	28	48.5
1898	28	26	40	45	59	70	73	72	67	53	37	27	49.8
1899	24	20	29	50	60	69	72	72	60	56	43	29	48.7
1900	28	21	26	48	60	67	72	76	67	60	39	29	49.4
1901	25	16	33	48	57	69	77	72	65	53	36	25	48.0
1902	25	23	39	47	58	64	73	68	62	52	47	27	48.8
1903	24	26	41	47	61	63	73	67	64	53	36	22	48.1
1904	18	16	33	41	59	67	71	68	64	50	40	26	46.1
1905	20	18	38	44	57	67	71	71	65	52	38	32	47.8

TABLE XX.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1906	34	26	28	49	58	68	71	74	68	51	40	29	49.7
1907	26	21	39	39	51	64	71	68	63	47	38	30	46.4
1908	26	22	36	45	59	68	73	70	69	54	40	30	49.3
1909	29	29	33	43	56	67	71	72	61	47	45	23	48.0
1910	25	22	44	49	54	66	74	71	63	55	36	23	48.5
Averages	24.6	24.7	33.4	45.7	57.6	67.3	70.3	70.1	63.5	51.7	38.6	28.6	48.2

TABLE XXI.—MAXIMUM TEMPERATURES AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1871	57	59	64	80	87	90	88	95	85	81	50	54
1872	46	49	54	77	84	91	91	90	91	80	50	38
1873	54	52	53	64	83	90	94	90	86	78	56	57
1874	58	51	67	73	89	93	97	93	97	75	68	52
1875	41	51	75	75	86	90	86	84	88	75	59	65
1876	65	54	62	69	85	88	90	87	77	72	68	42
1877	48	58	50	75	86	85	90	88	83	84	57	58
1878	50	52	68	77	78	92	100	90	85	79	53	42
1879	44	42	67	76	87	91	94	93	82	85	69	59
1880	57	60	53	75	85	91	93	88	87	75	59	46
1881	37	54	53	78	90	88	95	99	94	75	66	60
1882	56	58	64	71	70	86	88	86	84	77	69	50
1883	50	58	58	78	77	87	91	89	81	78	67	58
1884	52	64	62	70	81	90	89	90	89	85	62	60
1885	53	50	55	77	80	87	90	86	81	72	67	55
1886	55	54	61	82	83	89	92	89	85	77	65	52
1887	54	54	52	72	87	88	101	93	90	75	64	55
1888	42	46	65	82	79	94	91	91	84	72	70	55
1889	49	49	65	76	88	86	91	90	85	76	64	65
1890	66	63	57	74	84	94	96	92	85	74	66	48
1891	50	53	52	79	81	88	89	96	93	85	64	58
1892	53	50	55	71	82	91	96	92	86	77	62	58
1893	46	42	66	76	85	89	93	92	87	81	62	60
1894	50	54	72	78	83	94	96	92	91	76	64	55
1895	49	52	62	80	95	96	93	92	94	70	68	59
1896	42	58	63	85	90	86	91	95	84	74	65	56
1897	58	44	57	73	79	89	94	84	93	88	59	54
1898	57	56	69	66	77	93	94	97	95	85	64	49
1899	50	55	58	84	84	90	90	92	95	79	58	59
1900	49	62	46	80	86	87	92	94	92	84	68	52
1901	50	34	66	83	85	90	94	88	88	78	63	58
1902	40	54	64	81	87	84	91	86	83	75	69	46
1903	53	50	73	79	87	86	92	84	88	75	71	39
1904	42	45	62	73	88	87	96	85	86	77	68	56
1905	47	36	77	72	80	89	94	90	87	81	61	48

TABLE XXI.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906	65	60	54	76	87	94	91	91	90	74	59	50
1907	60	47	75	72	81	87	86	86	83	76	54	53
1908	45	49	74	78	85	90	94	95	91	78	64	50
1909	61	52	53	74	81	87	90	92	87	75	70	59
1910	43	46	81	75	76	95	96	91	84	82	61	38

TABLE XXII.—MINIMUM TEMPERATURES AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1871	5	3	24	35	40	52	54	54	37	33	13	−10
1872	−5	Zero.	−7	25	36	51	60	52	42	33	5	−24
1873	−12	−7	1	30	39	55	50	55	37	22	7	12
1874	Zero.	8	12	9	30	44	54	49	41	27	4	6
1875	−15	−20	Zero.	8	29	38	52	45	35	24	7	5
1876	9	4	7	25	30	50	53	46	39	24	16	−9
1877	−5	16	−2	20	32	42	54	56	43	34	11	18
1878	Zero.	7	16	31	33	42	56	51	39	24	24	−4
1879	−15	−3	14	16	30	39	54	48	34	26	12	−2
1880	19	11	11	24	33	49	52	48	35	30	Zero.	−11
1881	−2	−5	15	16	36	44	54	53	50	37	19	24
1882	8	20	23	24	33	46	53	50	42	37	20	2
1883	−8	6	3	18	32	46	50	49	30	34	14	11
1884	−6	−6	3	30	36	48	51	46	45	28	14	−6
1885	−7	−12	−2	30	30	44	54	48	41	28	29	1
1886	−4	−3	6	23	40	49	54	52	43	36	19	2
1887	−3	1	7	18	45	50	54	49	34	22	16	7
1888	−3	−7	2	23	30	45	50	46	35	30	22	13
1889	7	−8	17	22	34	42	53	52	36	25	16	19
1890	5	12	4	25	32	45	52	46	39	29	21	10
1891	14	2	6	21	29	42	49	48	47	28	10	17
1892	−3	4	10	22	35	52	50	52	45	30	16	−1
1893	−10	−6	9	26	37	51	55	52	34	26	16	6
1894	−3	−11	12	24	34	38	48	47	39	29	17	−3
1895	−4	−8	2	25	33	46	48	51	36	23	11	7
1896	−6	−3	4	18	43	45	52	49	33	30	13	2
1897	−16	4	13	20	36	41	57	49	39	37	18	−2
1898	2	−4	16	18	37	49	49	51	47	30	14	4
1899	−4	−13	11	22	39	49	56	53	30	32	29	Zero.
1900	−2	−2	−2	26	35	48	51	60	41	40	18	11
1901	1	−1	2	29	36	42	56	56	40	28	16	−6
1902	Zero.	−4	10	28	34	46	49	51	40	31	22	8
1903	−5	−4	19	22	28	47	50	47	41	28	13	1
1904	−6	−9	13	22	38	50	51	49	40	29	16	12
1905	Zero.	−15	15	27	30	47	53	55	45	28	15	16

TABLE XXII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906	12	−2	8	26	31	42	52	56	45	25	21	8
1907	−2	−5	14	19	30	44	52	49	38	29	21	15
1908	2	−2	17	22	31	44	50	50	41	31	18	11
1909	4	Zero.	15	21	30	48	54	50	39	26	24	−1
1910	2	3	17	31	34	39	54	48	48	26	26	7

As pointed out by Winchell and Hubbard, the influence of the great bodies of water upon the climate of the lake region is clearly perceptible, when comparisons are made with those localities to the east or west, or even in the interior of the lower peninsula. This influence is shown by the modification of the extremes of temperature, the summer maximum being lower and the winter minimum higher than for places to the east or west upon the same parallels. The monthly means are also similarly modified and the spring and autumn seasons are prolonged, giving a more gradual passage from winter into summer and from summer into winter. This is indicated in the dates of last killing frosts in the spring and the first in the autumn, these being given in table XXIII. The averages of these two dates are May 1st and October 12th, and the latest and earliest were May 31st (1897) and September 21st (1871).

TABLE XXIII.—DATES OF KILLING FROSTS AT DETROIT, MICHIGAN.

Year.	Last in spring.	Year.	First in autumn.
1871	No record.	1871	September 21.
1872	No record.	1872	October 24.
1873	No record.	1873	October 7.
1874	May 7.	1874	October 13.
1875	May 6.	1875	October 12.
1876	May 1.	1876	October 9.
1877	May 2.	1877	October 5.
1878	May 15.	1878	October 19.
1879	May 2.	1879	September 25.
1880	May 14.	1880	September 30.
1881	April 9.	1881	October 21.
1882	May 2.	1882	October 20.
1883	April 29.	1883	September 26.
1884	May 29.	1884	October 15.
1885	April 9.	1885	October 21.
1886	May 8.	1886	October 2.
1887	April 19.	1887	October 22.
1888	May 18.	1888	September 29.
1889	May 28.	1889	September 27.
1890	May 11.	1890	October 21.
1891	May 17.	1891	October 13.
1892	April 26.	1892	October 5.
1893	April 21.	1893	September 26.
1894	April 9.	1894	September 25.
1895	May 21	1895	September 30.
1896	April 8.	1896	September 23.
1897	May 31.	1897	November 3.
1898	April 6.	1898	October 27.
1899	April 9.	1899	September 30.
1900	April 14.	1900	November 8.
1901	April 21.	1901	October 18.
1902	April 5.	1902	October 21.
1903	May 1.	1903	October 24.
1904	April 22.	1904	October 7.
1905	May 1.	1905	October 25.
1906	May 10.	1906	October 10.
1907	May 11.	1907	October 14.
1908	May 2.	1908	October 9.
1909	April 26.	1909	October 14.
1910	April 13.	1910	October 28.

Average date of last killing frost in spring, May 1.
Average date of first killing frost in autumn, October 12.

Winds. The passage of the weather *spells* across the country from west to east, as is so generally the case for the Lake region, accompanied by changes in the pressure of the air, influences greatly the direction of the wind. The direction of wind, thus determined, exerts a very marked effect upon temperature and precipitation. In a very strict sense then, the climate of Wayne County is largely determined by the number, intensity, direction, course, and velocity of these weather spells, which move in from the Pacific, as a rule, cross the country and pass off into the Atlantic. Any variation in these factors would lead to a corresponding alteration of climate. Without any such movement of these weather breeding areas, southeastern Michigan would have some kind of a climate, of course, but it would be a very different one from that which we are called upon to describe. In table XXV we have the prevailing direction of the wind given for each month of the Weather Bureau series, with also the average of each and the prevailing direction for each particular year. Perhaps it should be stated that by "prevailing direction" is meant the quarter from which the wind blew more frequently than from any other, regardless of whether or not this number constituted a majority of the entire monthly, or annual series. In case of "tie" both directions have been inserted, either for the month (March, 1871), or for the year (1875). An inspection of the table shows the great prevalence of westerly winds, ranging from southwest, through west to northwest; the prevailing direction for ten months of the year being southwest.

In March, the direction is slightly in favor of west, with northwest and southwest following in order. In April alone does the wind prevail from an easterly quarter, being then northeast, but with southwest next in order. Of the entire 40-year series only once did a southeast wind prevail for an entire month, this being in August, 1885, which month was characterized by 5.05 inches of rainfall, or 85% above the normal for this month. The full data for this month, along with others furnishing still heavier precipitation, are shown in the following table for ready comparison, from which it will appear that this extra rainfall is not to be attributed to the direction of the wind. In March, 1871, the "prevailing direction" was evenly divided between southeast and northwest, with only a small excess of precipitation beyond the normal (12%). North and south winds do not often prevail; the former being found most frequently in spring (April) and the latter in autumn (October). Taken by years, the southwest wind has greatly prevailed over all others combined, represented by 30 of the 40 years of observations. Rather curiously for three years (1881, 1884, 1885) a south wind prevailed, but with no very marked effect upon the mean annual temperature. In 1881, the south wind prevailed through September, October, November and December and for these four months alone the precipitation was 56% of the entire annual. In the other two years, however, the precipitation was below normal, both for the totals and for the months during which the south winds prevailed, so no generalizing is permissible.

TABLE XXIV.—YEARS OF HEAVY AUGUST RAINFALL, DETROIT.

Year.	Rainfall.	Percentage of normal.	Mean temperature.	Percentage of normal.	Prevailing wind.
1875.......	6.04 in.	221%	67°	96%	SW.
1877.......	7.29 in.	267%	71°	100%	SW.
1880.......	5.51 in.	202%	69°	98%	SW.
1885.......	5.05 in.	185%	67°	96%	SE.
1888.......	5.27 in.	190%	69°	98%	SW.

The direction of prevailing winds has given a set to the trees of most orchards (Pl. XXII, A) and to many of the native trees, apple and willow (Pl. XXII, B) being especially susceptible and are often found inclining strongly to eastward. In planting new orchards, it is advisable to give them a slight slant to westward in order to counteract this effect of the wind. Where the trunks of the less yielding native trees are not actually inclined, the tips of the twigs and smaller branches will be found bent toward the east and the head unsymmetrically developed, the greater bulk lying on the eastern, or leeward side.[16] The long continued falls of rain and snow are generally ushered in with a southeast wind; while the lighter falls and sudden storms are preceded by winds in the southwest. The continued heavy blows, so destructive to shipping, are often from the northwest. Winds of tornadic violence are very infrequent in occurrence, Hubbard during the entire 50 years of his recorded observations noting but one such (Memorials, pages 541 and 544). Upon the afternoon of Sunday, June 27, 1875, a writhing, funnel-shaped cloud, of inky blackness, struck the northwestern portion of the city a few minutes before six, destroying some twenty-one cottages, killing two people outright and injuring a score of others. The path of the tornado was from southwest to northeast, crossing Grand River Avenue nearly at right angles, between 12th and 18th Streets.[17] At the time of the

16. This wind effect has been especially described by Prof. M. S. W. Jefferson: Journal of Geography, vol. III, No. 1, 1904, p. 3.
17. The Detroit Post, June 28 and 29, 1875.

TABLE XXV.—PREVAILING DIRECTION OF WIND AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1871	S	W	SE NW	NE	SW	NW	SW	SW	SW	SW	NW	W	SW
1872	SW	NE	W	E	W	SW	SW	SW	SW	SW	W	W	SW
1873	SW	NW	NW	E	E	E	W	NE	SW	W	W	W	W
1874	SW	E	NW	NE	SW	E	SW	E	SW	SW	W	SW	SW
1875	W	W	NE	W	W	SW	SW	SW	SW	W	N	SW	W SW
1876	W	W	NW	W	E	SW	SW	SW	E	SW	W	SW	SW
1877	SW	SW	NW	NE	SW	SW	SW	SW	SW	SW	W	SW	SW
1878	W	SW	SW	NE	W	SW	SW	SW	SW	SW	W	W	SW
1879	SW	W	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1880	SW	SW	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1881	SW	E	W	NW	E	E	W	N E	S	S	S	S	S
1882	W	W	W NW	W	NE	E	SW	E	E	S	W	W	W
1883	SW	W	W	N	N	SW	W	W	NE	NW	W	SW	W
1884	SW	N	N	N	S	E	W	S	S	S	SW	S	S
1885	S	SW	S	NE	S	S	S	SE	SW	S	SW	W	S
1886	W	SW	E	E	SW	N	NE	SW	SW	SW	W	W	SW
1887	W	NW	N	W	E	W	W	E	NE	SW	SW	W	W
1888	W	SW	W	NW	W	S SW	NE	SW	SW	SW	NW	S	SW
1889	SW	W	NW	NW	SW	SW	SW	SW	SW	NW	SW	SW	SW
1890	SW	NW	NW	N	W	SW	SW	NW	W	NW	SW	SW	SW
1891	SW	SW	NE	NW	NE	SW	SW	SW	SW	SW	SW	SW	SW
1892	SW	NE	NE	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1893	SW	SW	SW	SW	SW	SW	SW	NE	NW	SW	SW	SW	SW
1894	SW	SW	SW	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1895	SW	NW	NE	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1896	SW	SW	NW	SW	SW	NE	SW	SW	SW	SW	SW	SW	SW
1897	SW	SW	NE	SW	SW	SW	NE	SW	SW	NE	W	W	SW
1898	W	SW	W	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1899	SW	SW	W	W	SW	SW	SW	NE	SW	NE	SW	SW	SW
1900	SW	W	NE	NE	SW	NE	SW	SW	SW	SW	SW	SW	SW
1901	W	W	SW	N	NE	SW	SW	NE	SW	SW	NW	SW	SW
1902	W	W	SW	W	NE	W	SW	NE	SW	SW	SW	SW	SW
1903	W	SW	SW	NE	NE	NE	W	NE	SW	SW	SW	SW	SW
1904	SW	NE	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1905	SW	SW	SW	W	SW	SW	W	SW	SW	SW	SW	SW	SW

TABLE XXV.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	SW	SW	W	W	W	SW	NE	SW	SW	SW	W	SW	SW
1907	W	W	W	NW	SW	S	W	W	W	NW	W	SW	W
1908	SW	W	SW	SW	E	S	E	S	S	S	SW	W	SW
1909	SW	SW	NW	E	E	SW	S	E	N	SW	S	W	W
1910	NW	SW	E	E	N	E	S	E	E	W	NW	NW	NW
Average	SW	SW	W	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW

Ypsilanti tornado, April 12, 1893, an extreme wind velocity of 120 miles per hour was noted in Detroit for five minutes but no particular damage occurred in the county as the result. An unusually heavy wind storm, of much greater extent and of essentially different character from the tornado ("cyclone" of the papers) swept across southeastern Michigan on the evening of June 4, 1911. Thousands of trees were uprooted, or snapped off by the wind; old orchards, shade trees and open woodlots suffering especially, the trees being thrown in the main to the S. SE. Some damage, considerable in the aggregate, was done to roofs and chimneys and an occasional building was entirely demolished by the direct force of the wind.

Weather cycles. The careful studies of Hubbard based upon accurate data covering some 50 years (1835 to 1888), led him to discover the cyclic character of both rainfall and temperature and that high annual temperatures were associated with minimum precipitation and low temperatures with maximum precipitation (Memorials, 1888, page 470). He endeavored to connect these cycles with those maximum and minimum periods of sun-spots, which have been found to average 12.3 years since 1769. In summarizing, he says, "The periods of maximum and minimum sun-spots, temperature and rainfall have an intimate relation to each other, and that this relation appears in the respective periodicities, which differ but little, while the means are nearly identical" (page 479). From charts and tables he showed an apparent relation between maximum numbers of sun-spots and low water stages of Lake Erie, diminished precipitation and high temperature, with the reverse of these conditions accompanying the stage of minimum spots. He then sagely adds, "It may be that all these cycles are but members of a grander whole, whose circles reach beyond our present ken" (page 480).

The work of connecting sun-spots with terrestrial climate, such as precipitation, temperature and atmospheric disturbances, had been previously undertaken by numerous writers (Baxendell, Blanford, Stewart, Smyth, Stone, Köppen, Meldrum, Poëy, Lockyer, Hunter, Dawson, etc.) and an intimate relation shown. A similar relation had been demonstrated between sun-spots and terrestrial magnetic phenomena (See reference to Lockyer and Hunter's paper noted in foot note 20).

In studying the long-period oscillations of the level of the Caspian Sea, Brückner reached the conclusion that there was indicated a 35-year cycle, which seemed to be connected with the stages of

water of the rivers emptying into it and hence with the precipitation of the entire basin.[18] Fuller studies of the fluctuations of other lakes and rivers of the world, in connection with precipitation and temperature, led this author to conclude that there exists a 35-year climatic cycle, made up of a cold, damp phase, followed by a warm, dry one.

Other investigators have collected data which tend to confirm the conclusions of Brückner,[19] relating to numerous phenomena, more or less closely associated with variations in precipitation and temperature. These are the advance and retreat of the extremities of glaciers, the dates of the opening and closing of rivers of Europe, the dates of the vintage in central Europe, and, in Norway, the years of harvest and those in which the crops failed to ripen. It was shown by Brückner that the price of grain in Europe during the wettest and coldest lustrum of the cycle averaged 13% higher than during the driest portion. In regions of lower latitude where the reduction of temperature is of less importance and the success or failure of the crop depends upon the amount of precipitation during the growing season, the wet phase of the cycle brings prosperity to the farmer; the dry phase may bring failure and possibly starvation. Lockyer and Hunter as early as 1877, in a paper entitled "Sun-spots and Famines", endeavored to connect the precipitation cycles with the famines in India.[20] Ward has shown that the rural depression in the central states, west of the Mississippi, appeared with the coming on of a dry phase of Brückner's cycle.[21]

In the year 1905, Prof. E. E. Bogue, of our Michigan Agricultural College, showed that a connection probably exists between the amount of precipitation and the thickness of the rings of growth in trees.[22] Four years later Prof. A. E. Douglass, of Tucson, Arizona, published the results of a very detailed study of the rings of growth of the pines growing near Flagstaff, some of them over 500 years of age.[23] In this study Prof. Douglass found evidences of cycles of growth recorded in the tree sections, the longer of which averaged 32.8 years, and which he believed to be connected with the precipitation cycles.

18. Klimaschwankungen seit 1700, nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit, 1890. Zur Frage der 35-jährigen Klimaschwankungen: Petermanns Geogr. Mitteilungen, Heft VIII, 1902, p. 1.

19. Hann, Ueber die Schwankungen der Niederschlagsmengen in grösseren Zeiträumen: Sitzungsberichte der kaiserlichen Akademie der Wissenschaften (Wien), CXI, 2a, 1902, p. 1.

Oyen, Klima—und Gletscherschwankungen in Norwegen: Zeitschrift für Gletscherkunde, I Band, 1906, p. 46.

Richter, Geschichte der Schwankungen der Alpengletscher: Zeitschr. deutsch. österr. Alpenver. (Vienna), 1891, p. 1.

20. Nineteenth Century, II, 1877, pp. 594 to 602.

21. Is our Climate Changing: Chicago Record Herald, March 25, 1906.

22. Monthly Weather Review, June, 1905, p. 250.

23. *Idem*, June, 1909, p. 225.

In order to show to what extent the climatic data of southeastern Michigan are in harmony with the theory above outlined, the two following tables are presented. Table XXVI is based upon European data, where alone sufficient observations are available for the construction of such a long series table. Still less reliable data carry the record as far back as the year 961. Table XXVII gives the annual precipitation and mean annual temperature for the Detroit station, with the excess, or deficiency, of each when compared with the average for a long series of years. From 1835 to 1870, inclusive, the averages of Hubbard were used (30.7 inches and 47.6°, respectively), and from 1871 to 1910 those of the U. S. Weather Bureau (32.13 inches and 48.2°). An inspection of the column of precipitation departures shows clearly that there are series of years in which the excess and deficiency are very marked. By taking the algebraic sum of these departures we obtain the *accumulated* excess, or deficiency, for the period and this is indicated in the table. When thus grouped it is most evident that for 75 years the precipitation of this region has been in cycles, each made up of a dry and a wet phase, and that these phases have a more or less close correspondence with those of other parts of the world (see table XXVII). The grouping of the years of the Detroit record was made, however, without any reference to others and could be made to correspond more nearly by transferring a few of the years near the margins of the series, about which there must necessarily be uncertainty as to which group they properly belong. From 1884 to 1901 in this region, there was marked deficiency, amounting to 48.85 inches, or the equivalent of a full year and a half of normal precipitation. During this phase, many wells went dry and had to be deepened, flowing wells lost head and were much reduced in volume. Well drillers were in demand and statistics would probably show a wave of prosperity in this line of business and in well supplies in general. It was of interest to note that the wells that actually failed to yield water during this phase were usually those that had been made during the preceding wet phase of the cycle, that is, from 1875 to 1884. Those that dated from the preceding dry phase could generally still be relied upon for a diminished yield. The records for the years 1902 and 1903 made it appear that the dry phase had closed, and a new, damp phase entered upon; but the marked deficiencies of 1904, 8, 10 leave the matter somewhat in doubt. However, since 1901 there is still an accumulated excess of 1.07 inches (to the close of 1910) for these nine years and data from other stations are needed to decide whether or not we have actually entered upon a wet phase. In the 65 years from 1837 to 1901, inclusive, there have been 2½ complete cycles, or an average of but 26 years to the cycle. The two years, 1835 and 1836, seem to represent the closing of a damp phase which was responsible for the long remembered and much talked of "high water of 1838". It seems not improbable that the averages of a longer series of years will give a longer cycle. The data referred to at the opening of this chapter enable us to extend the series backward nearly 50 years farther, if we conceded that stages of level of the lakes and Detroit river indicate abnormal precipitation in the years immediately preceding. Hubbard states it as admitted (Memorials, page 464) that the water was higher in 1838 than at any known period. Very high water is also traditionally reported in 1814-15, 1800-02, and again in 1788. The lowest level known to the old Frenchmen at Detroit occurred in the year 1819, but was also reported as very low in 1796. These records indicate fluctuations within the Brückner cycles and enabled Hubbard to connect so successfully the lake levels with sun-spot frequency. From the exceptionally low water of 1819, the water gradually rose and culminated in the high stage of 1838, lagging some two years behind the phase of excessive precipitation. This low water stage of 1819 appears as the culmination of the preceding dry phase, but does not harmonize with the European phase shown in table XXVI, indicating that there are other factors besides quantity of precipitation to be reckoned with in the matter of the lake levels of this region. Lake Huron is reported to have been lower in 1810-11 than in 1819, and although this date is more nearly in harmony with the phase of precipitation in other portions of the world, it still represents considerable retardation.[24]

24. See Lane, Geological Report on Huron County: Geological Survey of Michigan, vol VII, 1900, part II, p. 44.

TABLE XXVI.—CLIMATIC OSCILLATIONS AND EFFECTS.

Based upon European data.

Precipitation.		Temperature.		Lake Levels.		Glaciers.	
Damp.	Dry.	Cool.	Warm.	High.	Low.	Advancing.	Retreating.
1591-1600	....	1591-1600	1601-1610	....	....	1595-1610	....
1611-1635	....	1611-1635	1635-1645	....	....	1630	....
1646-1665	....	1645-1665	1665-1690	....	....	1677-1681	....
1691-1715	....	1691-1705	1706-1735	....	1720	1710-1716	....
1736-1755	1716-1735	1731-1745	1746-1755	1740	1760	1735	1750-1767
1771-1780	1756-1770	1756-1790	1791-1805	1777-1780	1798-1800	1760-1786	1800-1812
1806-1825	1781-1805	1806-1820	1821-1835	1820	1835	1811-1822	1822-1844
1841-1855	1826-1840	1836-1850	1851-1870	1850	1865	1840-1855	1855-1875
1871-1885	1856-1870	1871-1885	....	1880	1892-	1875-1893	1894-
....	1886-	1886-	....	....		....	

When table XXVII is inspected for evidence of a similar and corresponding temperature cycle, there is little to attract attention, the plus and minus departures following along as they might be expected to do if Nature was bent upon rendering hasty compensation. During the dry phase 1884 to 1901, the accumulated excess of temperature, to be sure, was 3.8°, or about 8% of the normal, but this seems slight in amount. Since 1901 (to 1910) the accumulated deficiency is but 1.1°. During the wet phase 1875 to 1883, with an excess of rainfall amounting to nearly two full years, instead of a corresponding deficiency in heat received, there was a slight excess, indicated by 1.4°. A similar, but even more pronounced reversal occurred during the wet phase of 1848 to 1863, and during the dry phase 1837 to 1847 there was a temperature *deficiency*. When examined year by year it is seen that years of especially heavy rainfall, such as 1880 and 1881, had also a mean annual temperature slightly above, instead of below the normal. A recent writer upon the subject has called attention to the fact that the relation of sun-spot frequency to terrestrial temperature is most clearly shown when only the temperature of the coldest month is considered, or the average is taken of the two coldest months.[25] When this is done, however, for the Detroit temperature monthly records, no more satisfactory results are obtained than when the yearly means are used. Based upon the Detroit data alone, there is little

25. Uber elfjährige Temperaturperioden, Dr. A. Magelssen, Christiania, Norway: Meteorologische Zeitschrift, Band 28, September, 1911, Beilage, p. 5.

TABLE XXVII.—CLIMATIC CYCLES AT DETROIT.[26]

Year.	Precipitation in inches.	Departure from normal.		Temperature, Fahrenheit.	Departure from normal.	
1835	32.2	+1.5	+11.10	43.2°	−4.4°	−7.7°.
1836	40.3	+9.6		44.3	−3.3	
1837	27.2	−3.5	Accumulated deficiency 26.40 in.	44.4	−3.2	Accumulated deficiency 3.2°.
1838	28.0	−2.7		46.0	−1.6	
1839	24.8	−5.9		48.4	+0.8	
1840	29.3	−1.4		47.2	−0.4	
1841	27.2	−3.5		46.3	−1.3	
1842	31.8	+1.1		48.8	+1.2	
1843	27.5	−3.2		45.7	−1.9	
1844	32.9	+2.2		48.8	+1.2	
1845	22.3	−8.4		48.6	+1.0	
1846	29.7	−1.0		49.8	+2.2	
1847	30.6	−0.1		46.4	−1.2	
1848	31.7	+1.0	Accumulated excess 27.10 in.	48.5	+0.9	Accumulated excess 6.4°.
1849	33.8	+3.1		49.0	+1.4	
1850	25.8	−4.9		49.6	+2.0	
1851	32.0	+1.3		46.5	−1.1	
1852	33.7	+3.0		47.3	−0.3	
1853	29.0	−1.7		49.5	+1.9	
1854	34.7	+4.0		48.9	+1.3	
1855	43.0	+12.3		48.3	+0.7	
1856	28.8	−1.9		45.0	−2.6	
1857	32.0	+1.3		43.3	−4.3	
1858	35.7	+5.0		49.9	+2.3	
1859	29.0	−1.7		48.3	+0.7	
1860	27.8	−2.9		48.4	+0.8	
1861	38.7	+8.0		48.6	+1.0	
1862	31.8	+1.1		48.8	+1.2	
1863	30.8	+0.1		48.1	+0.5	
1864	26.0	−4.7	Accumulated deficiency 28.40 in.	48.1	+0.5	Accumulated excess 1.1°.
1865	22.3	−8.4		45.2	−2.4	
1866	31.7	+1.0		46.3	−1.3	
1867	27.0	−3.7		48.0	+0.4	
1868	37.0	+6.3		51.3	+3.7	
1869	30.6	−0.1		51.7	+4.1	
1870	29.3	−1.4		48.5	+0.9	
1871	25.42	−6.71		47.2	−1.0	
1872	24.95	−7.18		46.1	−2.1	
1873	34.32	+2.19		46.5	−1.7	
1874	26.43	−5.70		48.2	0.0	
1875	35.71	+3.58	Accumulated excess 59.04 in.	44.0	−4.2	Accumulated excess 1.4°.
1876	40.40	+8.27		47.2	−1.0	
1877	35.23	+3.10		48.7	+0.5	
1878	43.40	+11.27		49.3	+1.1	
1879	37.45	+5.32		47.9	−0.3	
1880	47.69	+15.56		48.6	+0.4	
1881	45.44	+13.31		51.0	+2.8	
1882	30.32	−1.81		51.0	+2.8	
1883	32.57	+0.44		47.5	−0.7	
1884	28.17	−3.96	Accumulated deficiency 48.85 in.	49.5	+1.3	Accumulated excess 3.8°.
1885	28.15	−3.98		47.0	−1.2	
1886	26.71	−5.42		49.2	+1.0	
1887	28.97	−3.16		48.2	0.0	
1888	29.02	−3.11		46.1	−2.1	
1889	21.06	−11.07		48.6	+0.4	
1890	34.99	+2.86		49.0	+0.8	
1891	28.83	−3.30		49.2	+1.0	
1892	37.11	+4.98		47.8	−0.4	
1893	34.18	+2.05		46.9	−1.3	
1894	25.74	−6.39		49.8	+1.6	
1895	25.04	−7.09		47.2	−1.0	
1896	36.20	+4.07		48.5	+0.3	
1897	30.34	−1.79		48.5	+0.3	
1898	34.34	+2.21		49.8	+1.6	
1899	26.41	−5.72		48.7	+0.5	
1900	31.45	−0.68		49.4	+1.2	
1901	28.78	−3.35		48.0	−0.2	

26. Based upon the observations of the U. S. Weather Bureau for the years following 1870 and for the previous years upon the work of Hubbard, as deduced from his published tables; the actual figures for each year not being found amongst his papers.