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Edw. A. BIRGE, Director **Wm. O. HOTCHKISS, State Geologist**

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THE INLAND LAKES OF WISCONSIN

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THE HYDROGRAPHY AND MORPHOMETRY OF THE LAKES

BY
CHANCEY JUDAY

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PREFACE

The following report deals with the physiography, hydrography, and morphometry of the inland lakes of Wisconsin. Its purpose is to present in a convenient and readily accessible form the main facts pertaining to any or all of these subjects, which have been ascertained about the various lakes up to the present time. So far complete and detailed information of this character has been obtained for only fifty-four lakes. In addition to such data, however, enough soundings have been made on one hundred eighty-five other lakes to determine approximately their maximum depths, but detailed studies have not been made on them yet. In spite of the large number of lakes which have been studied more or less in detail a very large number remains still untouched.

The hydrographic survey of the lakes of southeastern Wisconsin, made by the Geological and Natural History Survey, was begun in the winter of 1897–98 and was continued more or less regularly for about five years. Since that time only one additional lake has been sounded, namely, Rock lake, in the summer of 1912. Most of the soundings were made, however, during the winter of 1897–98 and in the following summer. In a number of lakes the main lines of soundings were run in the former season and additional soundings were made in the summer of 1898 in order to trace out the shoal areas more carefully and to check some of the previous results. Also during the summer visit to many of the lakes, an accurate survey of their outlines was made for the purpose of making such corrections on previous maps as were found necessary. One group of lakes, namely the Chain O' Lakes at Waupaca, was surveyed entirely during the summer of 1898. The locations of the various lakes and lake districts of the southeastern quarter of the state, are shown in Fig. 3, p. 8.

The positions of the soundings which were made through the ice in winter were carefully determined by means of chain and transit, and the general plan was to run a line of soundings through the middle of the lake along its main axis. At certain intervals along this line, other lines of soundings were run out to the shore on either side. Whenever necessary, also, additional soundings were made for the purpose of ascertaining the size and shape of offshore shoals or of the deeper basins. In summer the locations of the soundings were determined either by means of stadia observations or by the use of two transits.

The total number of soundings made during this survey amounts to about 11,500. Mendota and Monona lakes were more thoroughly sounded than any of the others, the average number of soundings in them being about 115 per square kilometer (300 per sq. mi.) of surface. In the other lakes, the number of soundings varied from 23 to 30 per square kilometer (60 to 78 per sq. mi.) in the larger bodies such as Green and Geneva lakes to as many as 72 to 122 per square kilometer (190 to 315 per sq. mi.) in such small bodies as Otter and Beasley lakes.

The results of this work on all except three lakes were embodied in ten hydrographic maps which have been published within the past fifteen years. Some of these maps show the hydrography of but a single lake, while others include the lakes of an entire district. The hydrographic maps of Kegonsa, Waubesa, and Rock lakes have not been published hitherto. With one exception, the hydrographic work done by the Wisconsin Survey has been in charge of Professor L. S. Smith of the College of Engineering of the University of Wisconsin. The surveying and mapping of Green lake were in charge of Dr. C. Dwight Marsh.

The hydrographic maps of two of the lakes shown in this report, are based on data which were not obtained by the Wisconsin Survey. These are Devils lake and lake Winnebago. (Maps VIII and XXVI.) Mr F. T. Thwaites, together with three assistants, surveyed Devils lake and prepared a hydrographic map of it in 1908. Lake Winnebago was sounded by the U. S. War Department and the results were embodied in a chart which was published by that department in 1908.

The six maps showing topographic features (I, VI, IX, XVI, XX, and XXII) are reproductions of maps which have been issued by the United States Geological Survey.

The maps showing the northeastern and northwestern lake districts of the state (maps XXVIII and XXIX) are based chiefly on county maps. For the northeastern district, however, data were also obtained from individuals residing in this section and from maps which were published by the Chicago, Milwaukee, & St. Paul railroad and by the Chicago & Northwestern railway. A special acknowledgment is due the

Chicago, Milwaukee, & St. Paul railroad for furnishing a blue print map showing the latest extensions of that line in the district.

The Milwaukee Light, Heat & Traction Company kindly furnished a map showing the location of the trolley line which it has recently constructed through the Oconomowoc-Waukesha lake district.

The physiographic portion of this bulletin is based chiefly upon Professor N. M. Fenneman's report on the physical geography of the lakes of southeastern Wisconsin, and to this the reader is referred if he desires a more detailed discussion of this phase of the subject. The first edition of this report was published in 1902 and a second edition, revised and enlarged, appeared in 1910, (Bull. No. VIII, Wis. Geol. and Nat. Hist. Survey). The geography of the Devils lake region is fully discussed by Salisbury and Atwood in Bulletin No. V of the Wisconsin Survey, which appeared in 1900, but is now out of print.

During the summers of 1907, 1908, and 1909, more than one hundred twenty lakes, situated in northeastern and northwestern Wisconsin, were visited for the purpose of making investigations with respect to the gases dissolved in their waters. In the prosecution of these studies many soundings were made in the various lakes, enough, in fact, to determine approximately the maximum depth of each lake, and the greatest depths that were found are shown in appended tables. (Tables 3 and 4, pp. 126 and 130.)

Soundings have also been made in a number of unsurveyed lakes in southeastern Wisconsin for the purpose of determining approximately their maximum depths and the results obtained are shown in table 2, p. 124. Most of this work was done by Mr. L. G. Steck during the summer of 1912. The lakes listed from Waushara county were sounded by Mr. N. Fasten in the summer of 1912.

Such, in brief, is the history of the material upon which this bulletin is based. It will be noted that a large portion of the data has already been published, but these publications have appeared separately and at various times, the whole covering a period of at least a dozen years. So it has seemed desirable to present in a single volume the greater portion of this published material and to add to that, the data which have not been published hitherto. The latter consists of (a) three hydrographic maps, (b) all morphometrical data, and (c) data relating to the depths of many lakes in southeastern, northeastern, and northwestern Wisconsin. (Tables 2, 3, and 4.)

INTRODUCTION

Over about three-quarters of the area of Wisconsin, inland bodies of water are numerous enough to constitute an important element of the landscape. (See fig. 1.) The total number of such bodies probably reaches well into the thousands. They vary in size from small ponds and lakelets to lakes as large as Mendota, Poygan, and Winnebago, whose areas are respectively 39 sq. km. (15 sq. mi.), 44 sq. km. (17 sq. mi.) and 557 sq. km. (215 sq. mi.), the latter being by far the largest inland lake of the state. For the most part, however, the lakes are comparatively small, less than 10 per cent. of those given in the tables having an area equal to or greater than 10 sq. km. (3.8 sq. mi.), but 62 per cent. of them have an area of 1 sq. km. or more.

The land surface of the state is given as 143,113 sq. km. (55,256 sq. mi.) and the water surface as 2,098 sq. km. (810 sq. mi.)[1] which makes the ratio of the former to the latter about 68 to 1. This estimate is undoubtedly considerably below the actual amount of water surface within the state since it includes the meandered streams as well as the lakes. The area of the lakes considered in this report, which is only a comparatively small portion of the total number, approximates 1,400 sq. km. (540 sq. mi.). In view of this fact, it seems probable that twice the amount of water surface given by the United States Geological Survey would be more nearly correct.

These lakes are glacial in origin and are not very deep, since the maximum depth of the deepest one, Green lake, is only 73 m. (237 ft.). Only a very few of them exceed 30 m. (100 ft.) in depth. Very few of them possess comparatively large affluents, while by far the greater portion of them are fed either by ground water or by relatively small affluents, or by both.

The inland lakes of Wisconsin lie between 87° and 93° west longitude and between 42° 30′ and 47° north latitude. Speaking roughly they may be regarded as belonging to three of the four quarters of the state,

[1] U. S. G. S. Bull. 302, 1906, Series F, Geography 53, p. 8.

viz., the southeastern, the northeastern and the northwestern, but it must be borne in mind that these rather arbitrary divisions are made chiefly for the sake of convenience in the discussion of the various groups. The southwestern quarter of the state possesses no lakes, since it comprises the driftless area. (See fig. 1, p. 2, and fig. 2, p. 4.)

Since not only the lake basins but also the more superficial topographic features of those portions of the state in which lakes are found, are of glacial origin, it may be well to give a brief account of the glacial history of Wisconsin in so far as it is known at the present time.

During the Pleistocene or Glacial period, the greater portion of Wisconsin was covered with a thick mantle of ice which moved southward from certain accumulation centers in northern Canada. These ice invasions were repeated at intervals and they were separated by long intervals of mild climate, so that the whole of the glacial age extended over a considerable period of time. While the ice, during some of the invasions at least, extended far beyond the southern boundary of Wisconsin as well as beyond the western boundary, yet the southwestern quarter of the state was not invaded; as a result it does not contain any lakes or other features that are characteristic of a glaciated region. The great majority of the lakes, as well as the greater part of the other features of glacial origin in the other three quarters of the state, date their existence from the close of the last or Late Wisconsin ice period. But some of the lakes in northwestern Wisconsin, more especially some of those in Barron and St. Croix counties, were probably formed before the Wisconsin glacial epoch. It may be suggested here also that some of the deeper lakes, such as Geneva and Green lakes, may have been formed before the Late Wisconsin period and may have had their basins preserved during this invasion without very great modification.

It seems very probable that the ice which invaded the state during the last or Late Wisconsin glacial epoch constituted a portion of the great Labrador ice sheet. The position of the terminal moraine in this region indicates that the direction of ice movement was governed largely by the basins of lakes Michigan and Superior, the ice being deflected into them and then flowing out over the adjacent regions. As a result of these deflections the portion of the last ice sheet which invaded Wisconsin was deeply and distinctly separated into several lobes. (See fig. 2, p. 4.) The larger lobes occupied the basins of lakes Michigan and Superior, while smaller ones between these two were deflected through Green bay and the large bays of lake Superior. The most easterly lobe which touched the state was that which occupied the basin of lake

Michigan, known as the Michigan glacier. To the west of this lay the Green Bay lobe which advanced through the valley now occupied by Green bay and lake Winnebago and moved far down toward the southern boundary of the state. Next in order were two small lobes, the Langlade and the Wisconsin Valley, which did not advance very far into the state. To the west of these was the Chippewa glacier which advanced about a third of the way across the state and covered a fairly large area in northern Wisconsin. Beyond this was the Superior glacier which covered a comparatively small portion at the northwestern corner of the state.

These lobes were in more or less intimate contact along their lateral margins, but each possessed the features of a distinct glacier in that the ice moved outward from their centers at all points. As a result drift accumulated at both sides along the common margins of the various lobes, forming rugged ridges which are known as kettle moraines. These kettle moraines are simply the combined terminal moraines of two glaciers. They consist largely of kame gravel because the zone of accumulating drift between the lobes formed the only drainage outlet for the large amount of water derived from the adjacent glaciers. Hence the deposit was pretty thoroughly worked over by the escaping water. The longest moraine of this character within the state was formed along the adjacent margins of the Michigan and Green Bay glaciers. (See fig. 2, p. 4.) It has a length of about 240 km. (150 mi.), reaching from the place at which the lobes became distinct on the Green bay peninsula to a point south of the city of Whitewater. The broken and irregular character of this long kettle moraine makes it a favorable region for lakes and lakelets and they are found in varying numbers throughout its whole extent. They are most numerous in or adjacent to this moraine toward its southern end. The irregular character of terminal moraines also makes them favorable places for such bodies of water.

The deposition of drift was not confined to the margins of the various glaciers and glacial lobes, but it also took place beneath the ice, thus forming the characteristic ground moraine. This ground moraine is substantially coextensive in area with the glaciated portion of Wisconsin and it varies in thickness from only a few meters in some plases to a maximum of 100 m. or 130 m. (328 ft. or 425 ft.) in other localities. In general, the surface of the ground moraine is not as broken and irregular as those of the terminal and kettle moraines, so that, relatively, it does not possess as many undrained depressions; taken as a whole, however, the ground moraine area possesses a very considerable number of lakes.

The inland lakes of Wisconsin constitute one of the most important and most valuable elements of the state's water resources and their importance as an asset of the state will undoubtedly be enormously enhanced by future development. So far comparatively little has been done to develop their latent resources but it is only a question of time when they will be made to contribute their full share to the material, cultural, and scientific phases of the state's progress.

Many of these lakes are now used as storage reservoirs, but hundreds more have such possibilities still undeveloped. The storing of surplus waters not only helps to prevent destructive floods by regulating stream flow, but the stored water also serves as an important source of power.

The great diversity of character possessed by the various lakes and the variety of their surroundings add greatly to the scenic features of the different sections in which they are situated. Thousands of summer residents and visitors seek their shores each season, where bathing, boating, fishing, and out-door life may be enjoyed to the fullest extent, thus making them important centers of recreation. This feature is of great importance, not only from the standpoint of the conservation of health, but also from an economic point of view, because a very large amount of money is brought into the state each season by summer residents and visitors from other states. This source of income is large enough to give it a high rank with some of the great industries of the state.

Our lakes possess still another economic possibility of no small importance, viz., the production of good, wholesome food, more especially the various food fishes that thrive in such waters. While the great majority of them do not now rank very high as producers of food fishes, yet this does not mean that they are not capable of producing many times the present amount under proper care and management. We know almost nothing of the science of aquiculture and until this practically unknown realm is much more thoroughly explored, we can scarcely hope to add greatly to the present production of our lakes. But it seems probable that if aquiculture received its due share of attention and were placed upon a scientific basis, similar to the one that agriculture has now attained, the lakes would show gains in food production entirely comparable to those shown by the land.

But the scientific aspect of our lakes is no less interesting and important than the others. In fact, the development of some of their latent assets is entirely dependent upon an exhausive study of the many physical, chemical, and biological problems which they present and about which we now know so little. Likewise their geologic, physiographic, and hydrographic features, with which this report is concerned, are equally as interesting and important; in fact, a knowledge of them is prerequisite to the consideration of some of the other limnological problems.

THE INLAND LAKES OF WISCONSIN

CHAPTER I.

ORIGIN, EXTINCTION, AND SHORE MODIFICATIONS OF LAKES.[1]

Origin. In general, the basins occupied by the various inland lakes of Wisconsin were formed in four different ways. 1. Some of them are pits formed by the melting of blocks of ice which became embedded in the glacial débris. These blocks of ice may have been stranded icebergs where the front of the glacier was bordered by a lake, or masses of ice buried in a terminal moraine. More often perhaps, they were portions of the lower zone of the glacier, which carries the débris. Since the upper zone of the glacier carries little or no detritus, it might retreat rapidly and leave a mass of the lower ice embedded in drift. The slopes of the basins belonging to this group are generally very steep. All but one of the Oconomowoc-Waukesha lakes belong to this class. 2. Some basins were formed by the damming of preglacial erosion valleys. While such valleys were subject to partial or entire obliteration by the drift, yet some of those which were more favorably situated with respect to the direction of the ice movement escaped filling and were dammed by local deposits, thus forming basins which were subsequently occupied by water. Green lake and lake Mendota are good examples of this class. 3. In a few localities, the material composing the terminal moraines was deposited in a series of parallel ridges with more or less prominent valleys between them. Some of these intervening valleys were blocked with drift at either end and became lake basins. The best example of this group is Big Cedar lake whose basin was formed not entirely but mainly in this manner. 4. The fourth class of basins owe their existence to the inequalities in the ground moraine. Just what

[1] Fenneman, Bull. VIII, Wis. Survey, pp. 4 and 13, 1910.

caused these inequalities is not definitely known. Such lakes are comparatively shallow and the slopes of their shores are usually gentle. Both of these characteristics are due to the fact that the curves of the ground moraine are gentle when no other conditions are prominent.

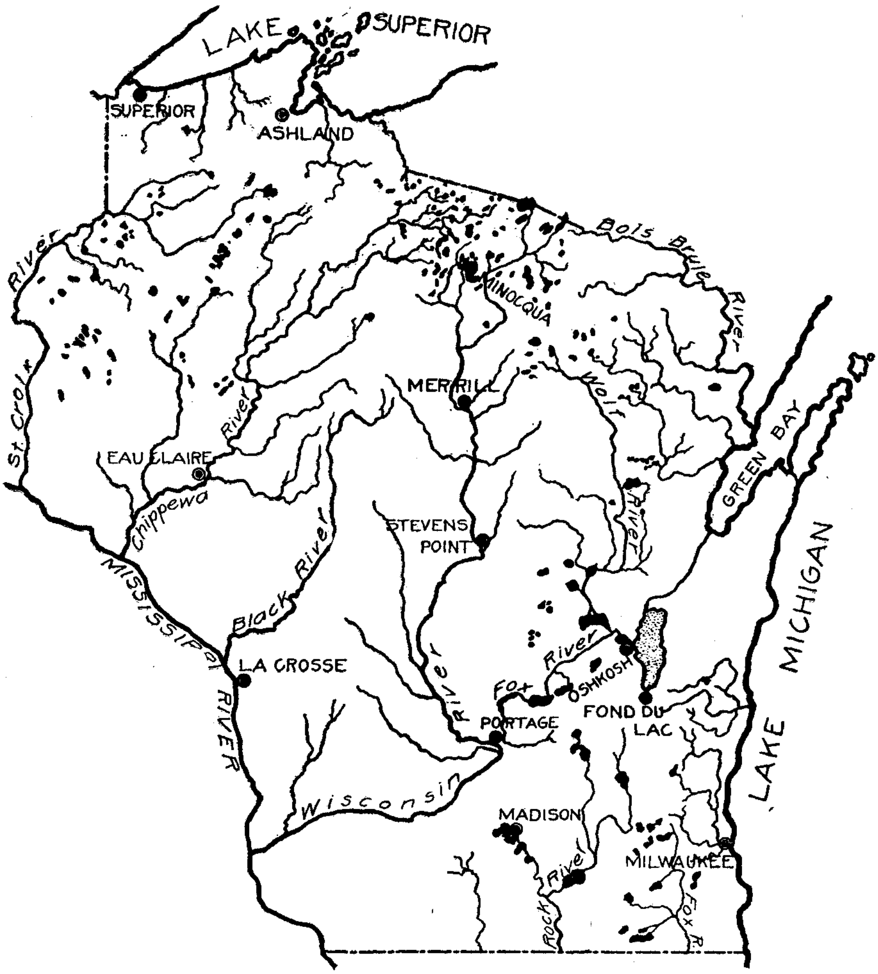


Fig. 1. Sketch map of Wisconsin showing principal lakes and lake districts. Approximate scale, 1 mm. = 4.5 km., or 1 in. = 70 mi.

Extinction.—Even the larger and deeper lakes are but fleeting features of the landscape from a geological point of view, because they are all doomed to extinction sooner or later. Many examples of basins which were once occupied by water, but which have been filled in and converted into swamps or grassy meadows, are now found in the various lake districts of the state. The smaller and shallower basins were the first to be obliterated. Three factors are involved in the extinction of lakes: (1) The down-cutting or deepening of the outlet when such bodies of water possess a stream outlet, (2) filling by detritus derived from the shore or brought in by affluents, and (3) the accumulation of vegetable or animal remains.

The relative effectiveness of each of these factors varies greatly. When the outlet stream flows through loose drift, it may cut down into this material very rapidly and thus lower the surface of the lake with corresponding rapidity; but if the outlet flows over bed rock, the down-cutting will be much slower. It has been estimated that previous to the construction of dams, the outlets of lakes Geneva and Mendota through downcutting had lowered their surfaces enough to decrease the original volumes of the former one-eleventh, and of the latter one-seventh. Dams, however, have restored the greater part of this loss in both instances.

In most of the Wisconsin lakes, the detritus brought in by affluents is not very important, relatively speaking. This is due to the comparative newness of the land surface, and hence to the small amount of dissection by streams. The shores contribute a much larger proportion of the detritus. They are generally composed of loose drift material which is easily eroded and the youth of the shoreline is such that a very large proportion of them is still in the cutting stage.

In many lakes, the accumulation of vegetable material is a very important factor in the process of filling. It is most vigorous in the shallow bodies of water and the deeper lakes with wide, shallow margins stand next in order. In the deepest lakes the larger aquatic plants are confined to the shallow regions around their margins, but even in such cases they contribute their quota of material to the deposits in deep water because these plants become detached and are carried out to deep water by currents. As the lake passes into the more advanced stages of its existence, the vegetable accumulation is accelerated, so that a "dead" lake presents the appearance of a grassy meadow, with peat taking the place of the water. This peat is often several meters deep and is usually underlain with marl or clay. Thus the peat represents the final or closing stage in the life of a part or the whole of a lake. The marl and clay represent depositions in much earlier stages of the process of filling. Sometimes, however, the final extinction is due to drainage or sedimentation.

Some lakes contain large marl deposits, a large percentage of which consists of the calcareous shells of animals. In such instances these animal accumulations are no small factor in the process of extinction.

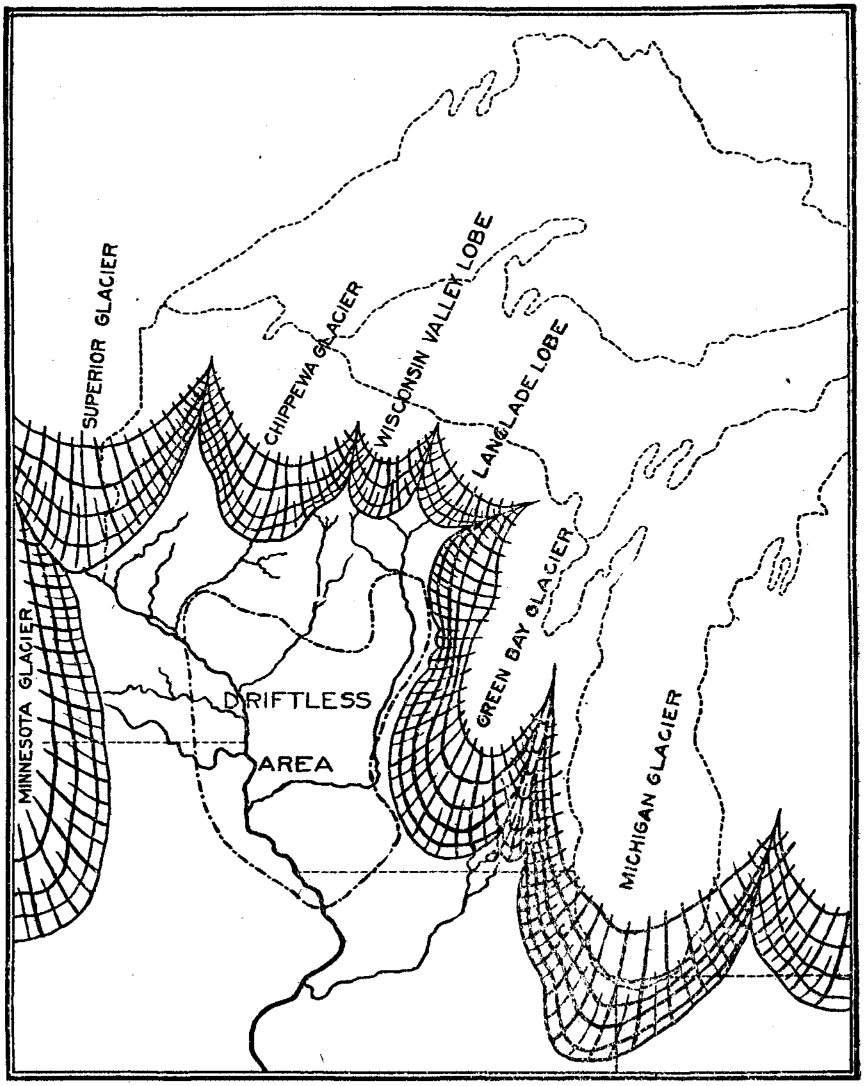


Fig. 2. Sketch map showing the lobation of the Wisconsin ice sheet. (After Weidman.)

Shore modifications. In the first stage of their existence these lakes possessed shorelines which were more irregular in outline than at present, those belonging to the pitted plain class generally having the maximum shore development. Many of these irregularities were ill adapted to the movements of the water and a process of simplification was instituted which has continued down to the present time. Those sinuosities which offered most resistance to the free movement of the water, such as the boldest headlands and the sharpest reentrants, were attacked first. Two factors are involved in this process of simplification, viz., waves and currents, both of which are caused by the wind. These lake waves belong to two general types which are known respectively as waves of oscillation and waves of translation. The simple waves that are found on deep water belong to the former class and in them the particles suffer no transfer; they simply rotate in circular orbits and come to rest again in their original positions after the wave has passed. In waves of translation, however, there is an actual transfer of water. The particles are carried forward in semi-elliptical paths and do not return to their former positions.

The waves of oscillation are subject to various modifications. The wind which causes them may also set up currents, thereby causing a transfer of the water particles. In such instances, the particles rotate in a spiral orbit rather than in a circular one. Strong winds tend to form waves whose crests are steeper than the surface water can assume; but even before the limit of theoretical steepness is reached, the crests are blown over by the wind, thus forming the familiar whitecaps. The most radical change, however, takes place in the shoal waters along the shore. When the depth of the water is so small that the wave agitation reaches the bottom, the lower part of the wave is retarded and the water particles, even at the surface, no longer move in circular orbits but in ovals resembling ellipses.

As the wave advances into pregressively shallower water its form changes. (1) It increases in height because the motion is transferred continually to a smaller quantity of water; (2) owing to friction on the bottom, the wave-length is diminished; (3) the crest becomes steeper and shorter in comparison with the trough; (4) the front of the wave becomes steeper than the back, thus making it asymmetrical. As a result of these changes the crest finally breaks and the wave becomes the familiar "breaker." The distance from shore at which breakers form depends upon the size of the wave and the slope of the bottom along the shore. In its final stage the wave makes a plunge on the shore but there is no true wave motion beyond the point at which the plunge begins, merely an outrush and an inrush of the water. When no current is present and where the bottom near the shore has a gentle slope, the oscillatory wave may be transformed into almost a pure translatory wave at the point where it breaks and it continues as such thence to the shore.

The shoreward movement of waves is accompanied by an outward movement of water along the bottom. The latter is known as the undertow and it is produced mainly in three different ways. (1) The incoming breakers are frequently accompanied by an onshore surface current, thus making a return undercurrent necessary. (2) The waves may be of the translatory type thus necessitating a compensatory return of the water carried shoreward by them. (3) Even common oscillatory waves on a shallow bottom carry more water forward under their crests than backward under their troughs because the motion of the crests is less interfered with by friction on the bottom. The volume of the undertow is greater some distance out than near the water's edge because some of the water turns back before reaching the extreme limit.

In addition to causing waves a wind blowing from a given direction for a few hours produces currents in the waters of a lake. The surface water drifts across the lake with the wind, but when it reaches the lee side, it is forced to return. Some of it turns to one side or the other and returns along the sides of the lake; some turns down and returns below the surface as an undercurrent. The exact depth of the returning undercurrent depends upon the temperature of the water. In spring and autumn, for example, during the periods of complete circulation, it may return along the bottom even in very deep lakes. But in summer, when the lake is thermally stratified, this return current is confined to the epilimnion, or the region above the thermocline.

The simplification of the shoreline is brought about by two processes, viz., cutting and building, and the agents concerned are the waves and the currents. Waves are chiefly responsible for the shore-cutting process, but they also possess a building function. In its final plunge, a wave makes an attack upon the shore, a large part of its energy being expended above the usual water line. The vigor of this assault depends upon the offshore slope of the bottom and the size of the wave. If the bottom slope is very gentle, the wave will break some distance from shore and lose much of its energy before reaching the water's edge; when the offshore slope is steep, the wave suffers little loss of energy before reaching the shore. The size of the wave is largely a function of the area of the lake and the strength of the wind. Likewise the effect of the assault is conditioned by the vigor of the attack and the character of the shore. When the shore is composed of fairly resistant bed rock, it will require a long period of time for the waves to effect much of a change in the shoreline. But, when it is composed of uncompacted drift material, such as constitutes by far the greater portion of the shores of the Wisconsin lakes, erosion proceeds with much greater rapidity. In spite of this more rapid erosion, however, the coastlines of many of these lakes are still in a comparatively youthful stage.

On a shore which is composed of glacial drift the final plunge of the wave loosens some detritus and the retreating water carries more or less of it into the lake where it is disposed of according to the transporting power of the undertow and the currents. If the shore drift is unassorted and its particles range in size from fine silt to fairly large boulders, it will now undergo a sorting process and be laid down in fairly regular sequence. The heaviest portion, such as the boulders, remains at or near the water's edge. If the material contains enough boulders, they may accumulate in such large numbers at the edge of the water as to form a formidable barrier to further erosion. The smaller rocks, such as cobblestones, are dragged a little further into the lake so that they form a belt just beyond the boulder line. Still further out comes the belt of coarse gravel, then finer gravel, and finally the sand. These elements taken together constitute the subaqueous marginal shelf or terrace. Beyond this the sand gradually passes into the fine mud of which the bottom is composed in the deeper water. Since the silt is capable of remaining in suspension for some time, it is carried away by the currents and gradually settles to the bottom in various parts of the lake. The actual cutting of the shore is limited to a comparatively narrow horizon which reaches little, if any, higher than the crests of the waves. But the removal of the material in this horizon, called undercutting, leaves the material above unsupported and it falls, thus forming a steep face which is called a cliff.

If the cutting cliff is composed of unfractured rock, the erosion takes place very slowly. When some fragments of rock have accumulated at the foot of the cliff, however, they become an important aid to the waves in their assaults, since they may be hurled against the cliff with considerable force. The rate at which any cliff is worn away depends upon the character of the material of which it is composed, the power of the waves, the capacity of the currents which remove the waste, and the height of the cliff. If the cliff is high, a small amount of undercutting will cause a large amount of material to fall which will require a proportionately long time for its removal by waves and currents.

Not all of the work done by the waves on the shore of a lake are de-

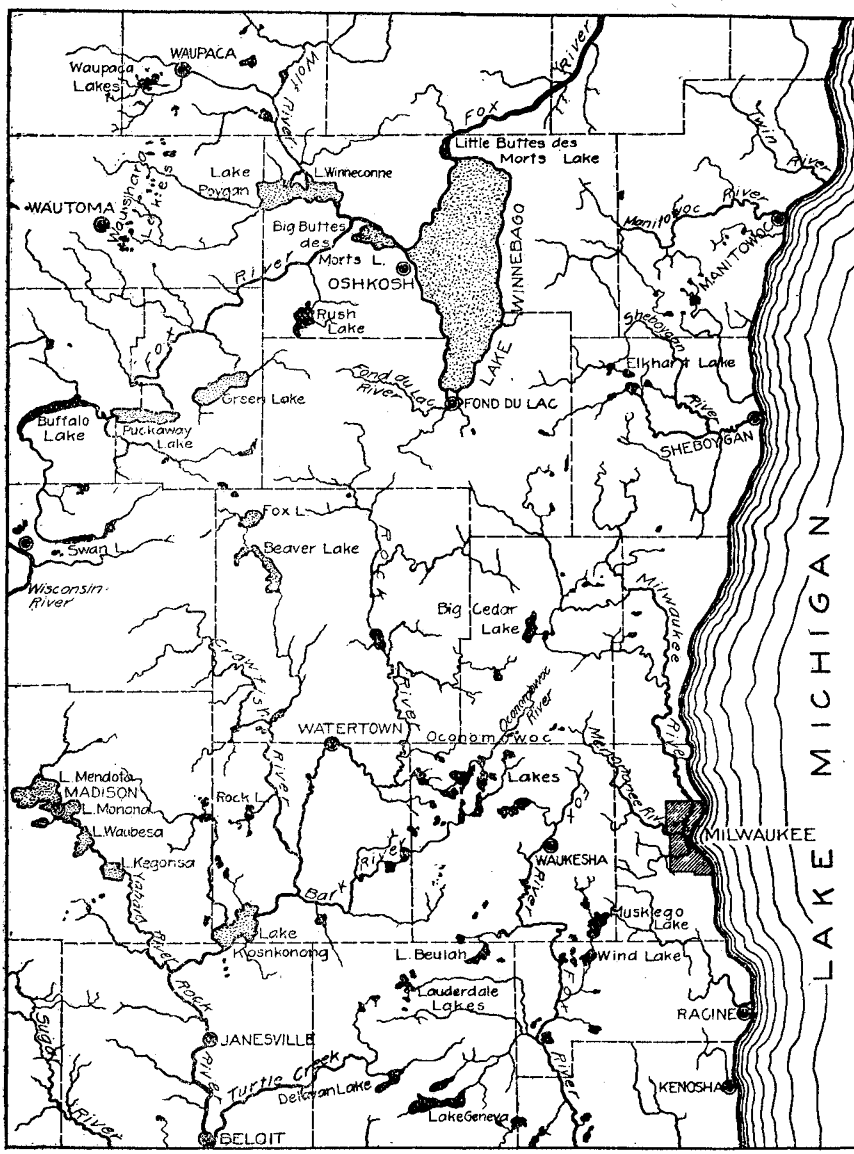


Fig. 3. Sketch map of the southeastern portion of Wisconsin, showing the principal lakes and lake districts in this quarter of the state. Approximate scale, 1 cm. = 13.8 km., or 1 in. = 22 mi.

structive in nature. Where conditions are favorable they are the active agents in the construction of the familiar beach ridges along the shore. But currents are more active transporting and building agents. Some of the material which is obtained from the cliffs by the waves is carried away by the currents and deposited in structures for which they are responsible. Where the shoreline is too sinuous for the currents to follow, the most common mode of deviation is for them to leap from headland to headland, cutting across bays, thus running tangent to the shore on one or both sides. In such instances, some of the material which is carried by the currents is dropped along this path and eventually enough accumulates to form a subaqueous embankment. Such a structure is composed of sand and gravel. When this ridge rises high enough, waves begin to break over it and the dashing water piles some of the gravel into a still higher ridge. Vegetation soon takes hold and helps to maintain the structure. The subaqueous embankment thus becomes a spit which assumes all the functions of a beach. This structure may be gradually extended across the mouth of the bay and finally span it, thus forming a bar. This leaves a body of water behind the ridge which is eventually filled with débris and converted into dry land. In bays which are large enough to permit a fairly free circulation of the water, only the head of the bay is subject to this cutting-off process.

The wearing away of small headlands, the filling of small bays, and the smoothing of the inequalities of the marginal bottom constitute the main simplifications along the shore. The net result of the process is to make a path for the shore currents along which they may travel with the minimum waste of energy. The infancy of the shoreline is characterized by irregularity and by lack of adjustment to the movement of the water. As the various shore processes progress the irregularities are gradually eliminated until finally there comes a time when no more cut-offs can be made. The shore may still be subject to adjustment, but these changes are neither sudden nor radical.

Effect of ice on the shore. These lakes are generally covered with a thick coat of ice each winter and the expansion of this ice under the influence of rapidly warming weather exerts an enormous pressure on the shore. Sometimes the ice itself is upheaved in long ridges, but sometimes the shore against which the ice is braced yields to the pressure and its materials are pushed up into an irregular ridge called a rampart. These ice ramparts may be recognized by their irregularity and by the character of the material of which they are composed, that is, unassorted shore material.

As the result of successive pushings of the ice, the shore may have a line of boulders just above the edge of the water. Also many lakes in the kame gravels have a characteristic gravel shelf at the foot of their steep banks. These are formed by the ice pushing up successive ridges of gravel to substantially the same height. They are called ice-push terraces.

CHAPTER II.

LAKES OF THE YAHARA BASIN.

In the upper half of its course, the Yahara river traverses a chain of four lakes, and this region is sometimes called the Four Lake district. (See map I.) These lakes have a northwest-southeast trend, the general course of the river being southeast and they are but local enlargements of the Yahara valley. Named in order beginning with the one nearest the headwaters of the stream, these bodies of water are known as Mendota, Monona, Waubesa, and Kegonsa. A small body of water between lakes Waubesa and Kegonsa is known as Mud lake but it is so small and shallow that it has not been considered in the following discussion. A fifth lake lies within this district but it does not form a part of the chain. This body of water is known as lake Wingra, and is situated a short distance west of lake Monona.

Geology.—The different rock formations found in the vicinity of the lakes are four in number. The lowest is the Potsdam sandstone and above it in order come Mendota limestone, Madison sandstone, and the Lower Magnesian limestone. The last is found only in the higher hills several kilometers away from the lakes, and still further away there are patches of St. Peters sandstone and remnants of Trenton limestone. Potsdam sandstone is the general bed rock of the lake basins. It appears at the foot of the various rock cliffs of lake Mendota, such as those at Maple bluff and at the foot of Eagle heights.

A calcareous zone in the upper part of the Potsdam sandstone is known as Mendota limestone and exposures of it lying 10 m. or more above the water level are found on the shores of lake Mendota. This stratum dips slightly to the south. It appears that the water's edge on the shores of lake Monona, and at Colladay point on lake Kegonsa. The Madison sandstone does not show conspicuous outcrops in the cliffs. It is softer and less resistant than the Mendota limestone below or the Lower Magnesian limestone above; as a result its area of outcrop is usually a gentle slope between the more obtrusive outcrops of the two limestones.

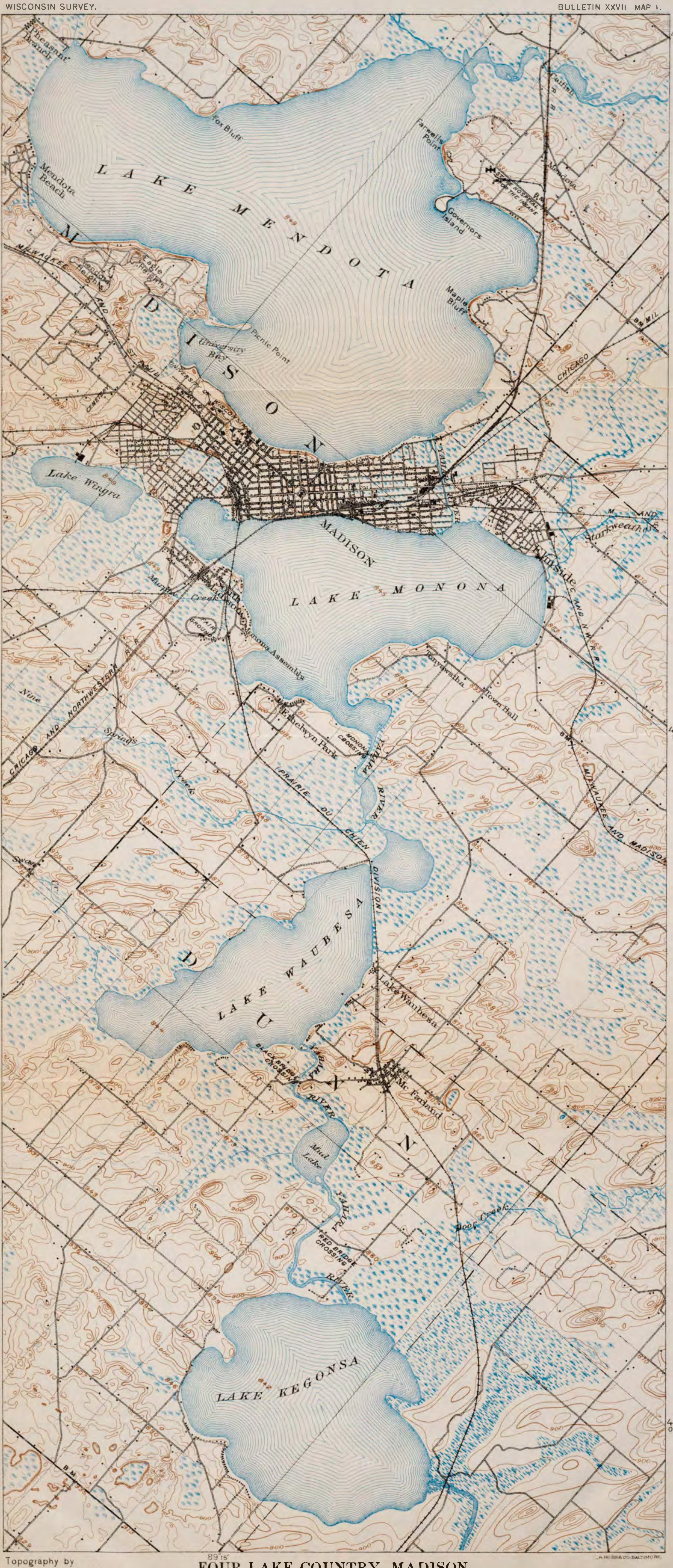
Origin of the basins.—These lakes owe their existence to two factors, viz., (a) to the erosion of the stream which produced the preglacial Yahara valley, and (b) to the subsequent modification of this valley by the glaciers. The preglacial topography of this region is shown on a map which was compiled by Mr. Frederik T. Thwaites and which was published in Bulletin No. VIII, second edition, of the Wisconsin Survey (1910). This map shows the general course of the preglacial stream that produced the valley in which these lakes are now situated. Just what effect the ice had on the depth of the basins is not clearly evident. The long axis of lakes Mendota and Monona lie in the direction of the ice movement and, at the west and southwest ends of their basins respectively, there are deposits of sand having a terminal aspect. These facts suggest that the basins may have been deepened by the erosive action of the ice, but on the other hand, data obtained from wells seem to indicate that the channel of the preglacial valley was probably 30 m. (100 ft.) or more, deeper than the present lake basins. Another point in favor of this view is found in the very small basin in which lake Mendota reaches its maximum depth. (See map II.) If these depressions were deepened in any way by glacial erosion, such an action was most probably confined to the sides of the original valley, the channel being filled rather than worn deeper. But the most imporant work of the ice was the formation of the dams of glacial débris which now impound the waters of the lakes.

These lakes lie in the Mississippi basin since the Yahara river which drains them, is a tributary of the Rock river which, in turn, is a tributary of the Mississippi river. (See fig. 3, p. 8.)

Lake Mendota.

The shores of lake Mendota for about three-quarters of their length are high and, for the most part, have a steep slope. (Map I.) They rise rather rapidly to heights of 10 m. to 15 m. or more above the water. They reach a maximum height of about 45 m. at Eagle heights and to the southwest of them lie Mendota heights, with an altitude of more than 50 m. (170 ft.). The most extensive areas of low, swampy shores are located at the head of University bay, at the west end of the lake where Pheasant Branch creek enters, on the north side in the vicinity of the mouths of the Yahara river and Six Mile creek, and at the head of Northeast bay.

The form and area of the lake (see map II) are such that the wind produces waves and currents of considerable strength and eroding



Topography by U. S. Geological Survey

FOUR LAKE COUNTRY, MADISON

power, the wave base extending to a depth of 4.5 m. to 6 m. (15 ft. to 20 ft.). As a result of the action of these agents, the banks are being cut away more or less rapidly along about two-thirds of the shoreline. Much of the cutting is being done in boulder clay and along such shores the work is proceeding fairly rapidly.

The more active cutting of the shores of lake Mendota is due in the main to the fact that a dam 1.2 m. (4 ft.) high was placed in the outlet a number of years ago. The rise of the water raised the horizon of action of waves and currents above the old beach which in time had become adapted to resist attack, and set these agents to work on a new shoreline which was not protected from erosion. As the beach features become more fully developed, shore cutting becomes less and less vigorous.

Cutting shores.—Cliff cutting in boulder clay characterizes many kilometers of the shores of lake Mendota. That on the northwest side of Picnic point is particularly active. (Map II.) This cliff is nearly bare of vegetation and trees standing at the top have been undercut several meters. The total amount that this shore has already retreated amounts to probably 100 m. (328 ft.) or more and the point will eventually be destroyed unless this process is stopped by artificial barriers. Cutting is much less active on the southeast shore of the point because this side is not exposed to such heavy storms. There is also a marked difference in the marginal shelf on the two sides. That on the northwest side is covered with heavy residual boulders, while that on the southeast side is covered with sand and mud, supporting a dense growth of vegetation.

A short distance east of Second point the boulder clay cliffs are characterized by deep gullying, and the same is true of the cliff just north of Mendota beach. This gullying is formed in each case by a long back slope yielding a large run-off during rains and by an absence of forest.

A fine rock cliff extends westward from the vicinity of Eagle heights for a distance of more than a kilometer. A comparatively narrow shelf is found at its base, indicating that the recession of the cliff has not been great. Rock cliffs are also found just east of the mouth of Pheasant Branch creek, at West point, Farwells point, Governors island, and Maple bluff. The one at Maple bluff is wearing away more rapidly than that at Eagle heights, due most probably to the longer fetch of the waves raised by the heavier storms from the west.

A long cliff cut in boulder clay extends from a point a little west of Foxs bluff to the marsh south of the mouth of Six Mile creek. It has a distinct terrace at its base which descends gradually to a depth of

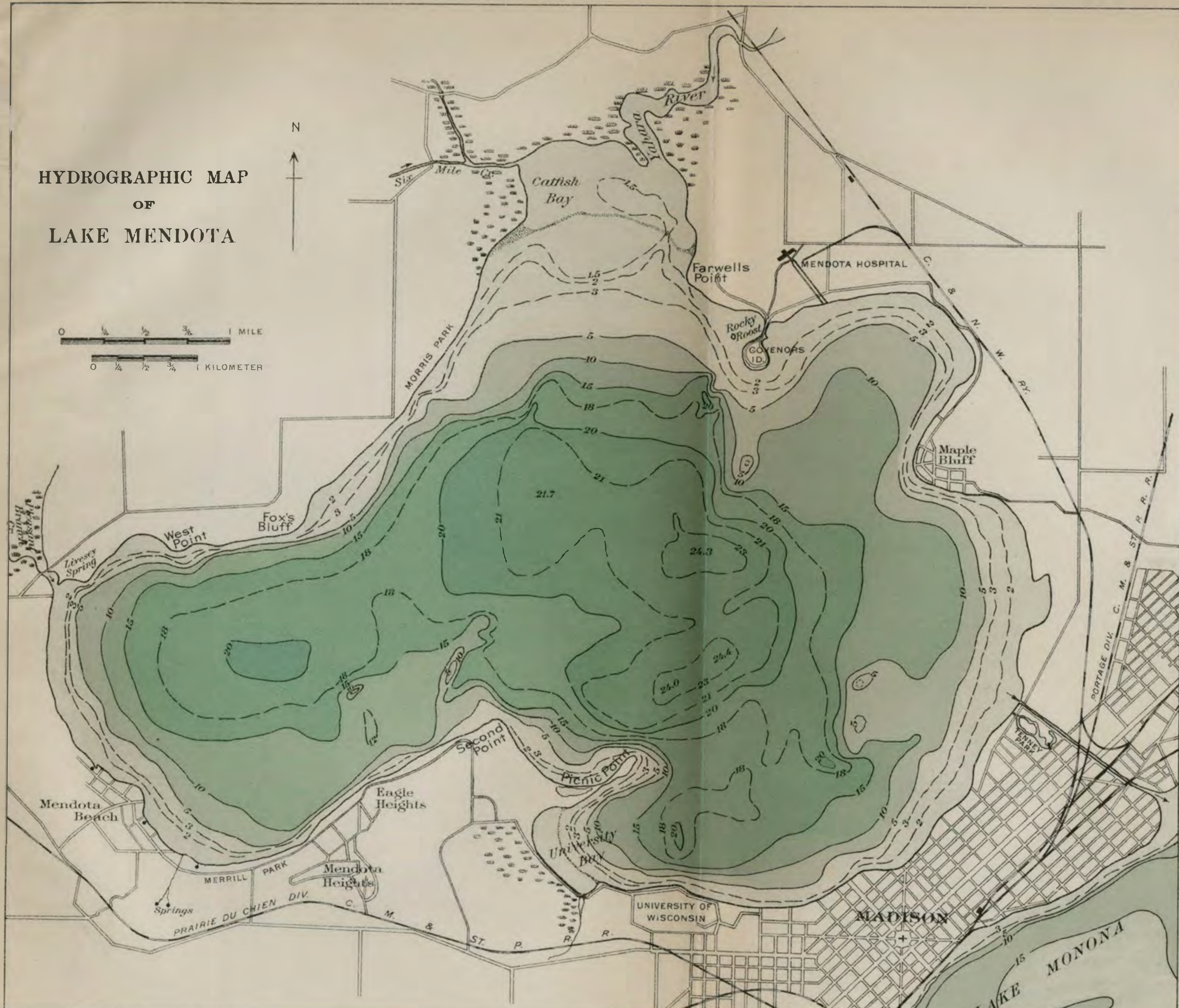
4.5 m. (15 ft.), beyond which there is a steep and sudden descent to deep water. It belongs to the cut-and-built type of terrace, probably in large part built rather than cut. Toward the north end this terrace partakes more and more of the built type and broadens into the extensive shallow area situated in and in front of Catfish bay.

Beginning just a little southwest of the outlet, a long cliff extends thence to University bay. But cutting along this shore is comparatively slow because the waves and currents are interfered with by many piers and other obstructions. Also along the University campus the cliff is protected by the trees and the shrubs which cover it.

Beach structures.—The beach structures which have been built by the waters of lake Mendota are fully as significant as the cliffs which have been cut. The latter are the quarries from which material has been obtained for the built structures. Much of this material has been used in building the subaqueous terraces. Though hidden from view these terraces have a very important function. They are so disposed as to make the paths of the currents smooth and regular and it is only by the perfection of these pathways that the lake is enabled to build the more impressive features which appear above water. These terraces are composed of the coarser material of the cliffs; the clay, for example, is so easily held in suspension that there is no limit to its distribution.

The youngest bit of coast is found on the west side of Maple bluff. There is not only no beach, but, in places, there is no shelf to provoke breakers and support stones within their grasp to be hurled against the cliff. In other words, the cliff is perpendicular, or in places even overhanging. The waves strike this vertical face and most of their force is spent in producing a choppy sea, rather than in doing injury to the cliff. More rapid erosion takes place in the jointing cracks thus forming triangular recesses which will hold detritus. These are known as bay head beaches and they are the earliest form of beach accumulation. With the development of the coast, these bay heads are extended laterally and united across the headlands between them to form a shelf for the accumulation of material which may be used by the larger waves in an assault on the cliff. With the exception of Devils lake, no other lake in southern Wisconsin possesses a stretch of shore line in so young a stage. The south side of Maple bluff and all of the other rock cliffs mentioned above show slightly more advanced stages of the same features.

A more advanced stage of shore development is seen in the bars which have not yet been raised above water. Two good examples of such structures are now found in the lake; one spans the large bay on the


HYDROGRAPHIC MAP
OF
LAKE MENDOTA
N
0 ¼ ½ ¾ 1 MILE
0 ¼ ½ ¾ 1 KILOMETER
Six Mile Cr.
Catfish Bay
Yahara River
Farwells Point
MENDOTA HOSPITAL
Rocky Roost
GOVENORS ID.
C. & N. W. RY.
MORRIS PARK
Maple Bluff
Fox's Bluff
West Point
Livesey Spring
Second Point
Picnic Point
University Bay
Eagle Heights
Mendota Beach
Mendota Heights
MERRILL PARK
Springs
PRAIRIE DU CHIEN DIV. C. M. & ST. P. R. R.
PORTAGE DIV. C. M. & ST. P. R. R.
TENNEY PARK
UNIVERSITY OF WISCONSIN
MADISON
LAKE MONONA
21.7
24.3
24.4
24.0

north side known as Catfish bay and the other spans University bay. The bar in Catfish bay is more than a kilometer and a half in length and is covered by about half a meter of water when the lake is at its usual level. Its height varies somewhat, probably due to the fact that it has been subject to ice pushing in some places. The material of which it is composed was derived from cliffs in the vicinity of Farwells point and from the long cliff which extends from the west end of the bar to the southwest beyond Foxs bluff. The greater part of the detritus came from the latter cliff apparently, although some material obtained from the bluff at Farwells point, which is easily recognized by its color, has been found west of the middle of the bar. But the bar is broken by a channel over four meters deep not far from its eastern end which indicates a greater building vigor from the west. This channel owes its existence to the lakeward current of water from the bay behind the bar, which receives the waters of Six Mile creek and the Yahara river. It is almost due south of the latter stream.

The more vigorous currents are deflected by the bar and pass along its outer face. But some of the weaker ones pass over it and enter the bay. These and the pushing of the ice have built some poor ridges of sand, especially along the west side of the bay. On the east side for some distance north of the bar, the waves are still actively cutting a cliff in very sandy drift.

The area of the bay behind the bar was once much larger than at present. This is shown by the old abandoned cliffs which are now some distance from the water's edge. It is only a question of time, in fact, when the whole bay will be converted first into a swamp and later into solid land. It is now filled with dense growths of vegetation and the swamp is advancing upon the bay with considerable rapidity. The latter is in part a delta formation of the Yahara river but the upper layers are largely of vegetable origin.

The bar which spans University bay is now covered by only about 15 cm. (6 in.) of water; in fact, portions of it are above water when the lake falls a little below its normal level. The cliffs at both ends are actively contributing material for it. This is the second attempt to simplify the shore line at the head of University bay. In a more youthful stage of the lake, a bar was built along the line of the present driveway at the head of the bay, thus cutting off a large westward extension which once formed a part of the lake.

There are several other bar formations which are now in a much more advanced state of maturity than the submerged ones in Catfish and University bays. The best example of a bar which has been raised above water and converted into a beach ridge is found along the front of the swamp at the head of the bay just west of Picnic point. Its form is ideal in vertical cross section and the curve of its shore line is very symmetrical. It is about 10 m. (33 ft.) wide and stands over half a meter above high water. Another beach structure of this sort is found at the west end of the lake. A ridge extends south from the mouth of Pheasant Branch creek for a distance of more than a kilometer along the front of a swamp which was once a part of the lake. A similar beach ridge with a long and graceful curve borders the head of the bay north of Maple bluff.

To the east and south of Maple bluff there is a stretch of low cliff which is cutting rapidly in a ridge of nearly pure sand. A spit has been built southward from this cliff in front of a small bay which is situated about three-quarters of a kilometer north of the outlet. If not interfered with this spit would span the bay as a bar, but the exposure to the west winds is such that the point of the spit has been turned sharply into the bay, thus making a hook with an acute angle. These turnings have been made at different stages of the spit, so that there are now three hooks on the same trunk. A similar spit growing northward from the cliff lying south of the bay has been turned shoreward in a curve and united with the mainland, thus forming a loop which encloses a swamp. This shore line is probably the most advanced in its cycle of any around the lake. This is shown by the cutting away of these beach structures. When the cliffs from which they grew held their positions further west, these spits were built in continuation of the same line but the cliffs have receded so far that these built structures are now wasting away. This is especially marked on the one from the north which springs from a cliff of sand; trees which have grown upon this spit are now undercut and falling into the water. When the line of cliffs and beach ridges has been pushed back a little further, there will be no bay and no necessity for spits and bars. This is a good illustration of the transient charcter of such beach structures.

The pushing of the ice is also an important factor in the construction of beach features at some points. Picnic point is prominently exposed to such action and ice ramparts on its east side rise in places to a height of 3 m. (10 ft.) above the level of the lake. Conspicuous ice ridges are also found on the north side of the lake just east of Governors island and smaller structures of similar origin appear at various places for short distances. There are at least three ice ramparts which resemble spits in that they are intimately connected with cutting cliffs. In origin, however, they have nothing in common with spits, except that they indicate the paths of the currents. An ice rampart of this character extends southward from the outlet to a low cliff, cutting in the till, which is nearly half a kilometer away. A part of this distance the ridge originally stood between the lake and a small swamp which was below the lake level, but this swamp has since been converted into a park lagoon. The original rampart has been subject to considerable artificial modifications, now having an artificial portion at the north end and the entire ridge having been enlarged to serve as a dam. A similar ice rampart extends northward on the east side of Governors island and another heads westward across the mouth of Pheasant Branch creek.

Source of Water.—A drainage basin of perhaps 640 sq. km. (250 sq. mi.) discharges its water into lake Mendota. A part of this water enters as surface drainage, mainly by the Yahara river and Six Mile creek. Another part derived from the rainfall over the same catchment basin, enters the soil and reaches the lake as springs. These springs may also bring water from beyond the limits of the drainage basin, while ground water from a part of this basin may feed springs which issue beyond its limits. The springs are situated almost entirely at the west end of the lake, the largest ones being found in the vicinity of Merrill park.

The lower lakes of the Yahara basin receive all the water which overflows from lake Mendota and the drainage from an additional catchment basin about equal in size to that possessed by lake Mendota.

Lake basin.—The hydrographic map of lake Mendota (No. II), as well as those of all other lakes, shows by means of contour lines and blue tints the depth of the water and the general topography of the bottom. The contours are shown in meters, thus 3, 5, 10, and so on indicate the three, five, and ten meter contour lines or isobaths. Where these lines are close together the slope of the bottom is steep and where they are far apart the slope is correspondingly gradual. The depths, areas, and volumes of the various lakes are given in English as well as in metric units in table No. 1, p. 122–123.

The soundings in lake Mendota were all referred to a surface elevation of 258.8 m. (849 ft.) above sea level. This datum plane was established from a certain bench mark on Science Hall, University of Wisconsin, whose elevation, according to the United States Geological Survey, is 270.1 m. (886.3 ft.) above sea level. This bench mark consists of a cross chiseled on the upper surface of a projection on the third stone above the ground at the northeast corner of the tower portion of this building, that is, just to the right of the main entrance.

The hydrographic map shows that the basin occupied by lake Mendota has fairly steep sides with a large, comparatively flat area in the middle. The slope of the sides of the western half of the basin is steeper than that of the eastern; but in both parts the water descends to considerable depths rather rapidly so that a large portion of the lake has a depth of 18 m. (60 ft.) or more. The steepest slope of the bottom is found on the northeast side of the small basin which is situated a short distance southwest of Governors island. Here the depth of the water increases 21 m. (69 ft.) in a horizontal distance of about 100 m. (328 ft.), thus making the slope somewhat steeper than 1 to 5.

The maximum depth of the water for the lake is found in the above depression, in spite of the fact that it is very small and isolated from the main body of the deep water by water which is less than 18 m. (60 ft.) deep. The origin of this basin, therefore, is rather puzzling, but it seems most probable that it represents a portion of an unfilled or but partially filled valley of a preglacial stream. The regularity of the lake basin is broken by five detached shoals. Two of these shoals are located in the southeastern part of the lake, one lies just south of Governors island and two are situated north of Second point and Eagle heights.

Bottom. Dredgings show that the bottom consists of coarse material in the shallower water, such as boulders of various sizes, gravel, and sand, and fine mud or marl in the deeper water. This results from the action of the waves and currents on the shore and on the bottom in the shallower water. The materials are assorted according to the strength and carrying capacity of these agents; the material being coarsest at the edge of the lake and gradually becoming finer as deep water is approached. The transition from the coarser components, generally fine sand, to the fine mud takes place at very different depths in different parts of the lake owing to differences in the amount of exposure to the wind. In University bay, for example, which is pretty well sheltered, the bottom consists of mud in places where the water is only 5 m. to 6 m. (16 ft. to 20 ft.) deep; but along the more exposed portions of the coast the bottom is kept free of mud to a much greater depth. On the south side of Picnic point, pure mud is not found above a depth of 12 m.; while on the east and northeast sides of the point, which are boldly exposed to north and northwest winds, this depth is increased to 18 m. Also in the small basin southwest of Governors island, the bottom consists of gravel and sand where the water is 24 m. (79 ft.) deep, and a muddy sand at 25 m. (82 ft.), pure mud not being found for some distance southwest of the basin. It seems most probable that southerly, more especially southwesterly winds are responsible for the scarcity of mud on the bottom of this small depression. Such winds drive the surface water northward into Catfish bay and deflect the return currents to the east shore so that they pass southeastward along Governors island. During the vernal and autumnal periods of circulation when the whole mass of water is kept in rotation by the wind, return currents readily flow along the bottom and may thus remove the deposit of fine mud which is generally found in the deeper water. During the summer, however, when the lake is thermally stratified, the return currents would not reach the lower water, hence they would not affect the bottom beyond the depth of the thermocline. The descent of the thermocline on the leeward side of the lake appears to produce secondary currents in the hypolimnion but these currents move so slowly that they have little or no transporting power. It may be added, also, that the five shoals mentioned above are kept free of mud and their tops consist of coarse material, such as boulders and coarse gravel.

LAKE MENDOTA.

T. 7 and 8 N., R. IX E.		Mean depth	12.1 m.
Length	9.50 km.	Length of shoreline	32.4 km.
Breadth	7.40 km.	Shore development	1.47
Area	39.40 sq. km.	Mean slope of bottom ..	0° 43′
Maximum depth	25.6 m.	Number of soundings ..	4,500

Depth.	Area.		Length of contours	Stratum.	Area between contours	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilometers.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	39.4	100.0	32.4	0–3	7.4	106,922,000	22.4	0° 43′	1.2
3	32.0	81.2	28.9	3–5	3.0	61,004,000	12.8	1° 3′	1.8
5	29.0	73.9	27.5	5–10	5.0	131,987,000	27.6	1° 3′	1.8
10	24.0	61.0	26.8	10–15	7.2	101,165,000	21.1	0° 38′	1.1
15	16.8	42.6	22.8	15–20	10.2	63,843,000	13.3	0° 20′	0.6
20	6.6	16.8	13.5	20–25.6	6.6	13,449,000	2.8	0° 12′	0.3
					Total..	478,370,000			

LAKE MONONA.

Lake Monona is oblong in shape and fairly regular in outline, there being only two prominent extensions from the general body of the lake. (See map III.) These are the bay extending westward beyond the railroad tracks and that portion of the lake which extends southeast of a line connecting Turville point with Winnequah. The direction of the long axis of the lake is northeast and southwest. The deepest portion is situated toward the southwest end of the lake where there are two distinct basins. The south basin is much deeper than the north one and possesses the deepest water in the lake.

The regularity of the bottom topography is broken by only one shoal and this is located a short distance west of the place where the water reaches its maximum depth. The water over this small shallow area is a little less than 5 m. (16 ft.) deep but the shoal is surrounded by water which has a depth of 12 m. (40 ft.) or more. The bottom descends to deep water with a much more gentle slope at the ends of the lake than along the sides, the middle third of the northeast side showing the longest stretch of steep slope. The steepest gradient, about 1 to 18, is found a short distance off shore about half way between Oak Park and Winnequah.

Shores.—The shores of lake Monona are not as rugged as those of lake Mendota and a larger portion of them is low and formerly swampy. (See map I.) But the greater part of the swampy shore either has been filled in and converted into dry land or is now in the process of such transformation. The most rugged shores are situated along the city front of Madison, at Elmside, at Tonyawatha and south of it and at Ethelwyn and Monona parks. The maximum elevation is found at Ethelwyn park where the shore rises to a height of about 25 m. (82 ft.) above the surface of the lake within about 150 m. of the water's edge.

The present level of lake Monona has been maintained for a long period of time, consequently its beach formations are mature and well adapted to the protection of the shores against the action of waves and currents and the smaller size of this lake makes these agents less effective than in lake Mendota. In spite of such adverse conditions, however, cutting and building are proceeding more or less actively at various points along the shore of the lake.

Along the northwest side of the lake from the crossing of the railroads almost to the mouth of the Yahara river, the shore is high, rather steep, and composed of glacial drift. Though normally a cutting coast


HYDROGRAPHIC MAP
OF
LAKE MONONA
N
0 ¼ ½ ¾ 1 MILE
0 ¼ ½ ¾ 1 KILOMETER
LAKE MENDOTA
Yahara River
TENNEY PARK
ELMSIDE
Starkweather Cr.
MADISON
UNIVERSITY OF WISCONSIN
GREENBUSH
Tonyawatha Spring
OAK PARK
Winnequah
SOUTH MADISON
LAKE WINGRA
Murphy Creek
MONONA PARK
Turville Point
DANE COUNTY FAIR GROUNDS
C. M. & ST. P. R. R.
C. & N. W. RY.
LANCASTER DIV. C. & N. W. RY.
Yahara River

it is now so well protected by artificial barriers that active retreating has practically ceased. The marginal shelf at the foot of this stretch of shore may be classed as a cut terrace. This is shown by the fact that, out to a depth of 3 m. (10 ft.), the surface of this terrace carries stones that are too heavy to be transported by currents.

When the lake was new, the Yahara river entered a fairly large shallow bay which represented the present flats on both sides of the inlet. This bay was gradually filled up and converted into a swamp. Just recently these swamp areas have been filled in artificially and are now dry land. Beyond this there is a highland at Elmside which has suffered much wasting and cutting still continues active. The marginal shelf at the foot of the cliff shows no residual boulders, but they are concealed beneath a layer of sand, thus showing less active cutting. As the off-shore depth of this beach gradually decreases, the cliff will retreat with ever increasing slowness.

The shore along most of the northeast end of the lake is low and sandy. The lower course of Starkweather creek is bordered by a swampy flat whose lake front consists of a beach ridge. This swamp represents a former bay that was cut off by the ridge. The growth of the latter was so vigorous from the northwest that the mouth of Starkweather creek was carried some distance to the southeast. The creek now turns at right angles and flows parallel to the shore for a quarter of a kilometer before it succeeds in entering the lake.

The southern quarter of the shore of the northeast end is a cliff cut in glacial drift. Beyond this is a small bay whose shore is marked by an ice rampart in front of a low valley. The headland southeast of this bay is a rock cliff and the adjacent marginal shelf shows the features of a cut terrace, that is, a rocky bed out to a depth of about 2 m. (6.5 ft.).

At the head of the broad bay southwest of this headland is an area of lowland in front of which is a massive tree-covered beach ridge. The northeastern portion of this ridge is widest, having a maximum width of 30 m. (100 ft.) but the southwestern portion consists of only a single ice rampart of boulders.

From Tonyawatha to Winnequah the shore is one long cliff cut in till, but cutting is not progressing rapidly at present. This is an excellent example of a slowly wasting till cliff. It is nearly all forested. At its foot is the characteristic boulder line. The adjacent bottom which has been cut down to allow the waves to attack the shore, is strewn with boulders and cobblestones which could not be carried away.

The lowlands bordering the outlet bay are fronted by feeble ridges composed largely of muck. They have been built for the most part by the ice. On the south side of the bay, however, there is an old spit which has been converted into a beach ridge. From the outlet bay to Ethelwyn park the shore is a tall cliff. At the latter point there is a rock cliff of Mendota limestone. This limestone is thin bedded and easily broken up. It is being actively eroded, which is shown by the fragments covering the shelf at its foot.

The head of Turville bay, west of Ethelwyn park, is approaching a stage when vegetable filling will proceed rapidly. The shallow water is filled with dense growths of vegetation and swamp forms are now crowding in along the edges. The shore along the west side of Turville bay rises rather abruptly to a height of 1.5 m. to 2 m. (5 ft. to 6.5 ft.) above the level of the lake and at one place it rises higher, forming a cliff.

On the east side of Turville point, an old water line two-thirds of a meter above the present level is marked by a faint cliff and boulder line. On the northeast side of this point there is a massive ice rampart, an excellent example of this kind of formation. It has a height of almost 2 m. (6.5 ft.).

The shore along Monona park has a moderately steep slope and most of it is being cut. In places where the slope is gentle, ice ramparts appear. Beyond Murphy creek is another hill with a shore of similar character. The mouth of Murphy creek is bordered by a belt of low land which was covered with water, forming a bay, when the lake stood at the higher level indicated at Turville point and west of the outlet. This is shown by abandoned cliffs now above water level on both sides of this low land. The present beach ridge forms almost a straight line connecting these two cliffs. Behind this is a broad, low, curved ridge which formed the beach in an earlier stage of the lake's history.

The bay at the west end of Lake Monona is cut off from the active circulation of the lake by the railroad embankments. Until recently the shallow water was filled with a large amount of vegetation and the swamp along the shore was slowly advancing on the bay. But a few years ago the shallow portions were deepened by dredging and the shores were much improved by the filling of swamps, thus counteracting the natural processes tending toward the extinction of the bay.

Water supply.—Lake Monona receives the waters of the Yahara river on its notheast side and they leave the lake on the southeast side. It also receives the waters of Murphy and Starkweather creeks and of several springs located chiefly toward the northeastern end of the lake.

The portions of the Yahara river between lakes Monona and Waubesa have been dredged for canal purposes so that they are now navigable for motor boats.

LAKE MONONA.

T. 7 N., R. IX and X E.		Mean depth	8.4 m.
Length	6.70 km.	Length of shoreline	21.4 km.
Breadth	3.85 km.	Shore development	1.62
Area	14.10 sq. km.	Mean slope of bottom...	0° 43′
Maximum depth	22.5 m.	Number of soundings ..	1,600

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilo-meters.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	14.1	100.0	21.4	0–2	2.7	25,540,800	21.4	1° 2′	1.8
2	11.4	81.2	19.4	2–3	0.9	10,970,600	9.2	1° 15′	2.2
3	10.5	74.9	18.7	3–5	1.3	19,711,300	16.6	1° 24′	2.4
5	9.2	65.2	14.1	5–10	2.6	39,238,400	33.0	1° 22′	2.4
10	6.6	46.7	11.0	10–13	3.0	14,980,000	12.6	0° 32′	0.9
13	3.6	25.3	7.6	13–15	2.6	5,425,300	4.6	0° 33°	0.9
15[1]	1.0	7.0	4.2	15–18[1]	0.7	1,808,800	1.5	0° 48′	1.4
18	0.3	2.0	2.4	18–20	0.24	309,800	0.25	1° 4′	1.8
20	0.06	0.4	1.8	20–22.5	0.06	59,000	0.05	2° 7′	3.7
15[2]	0.9	6.7	3.8	15–16[2]	0.5	641,200	0.6	0° 20′	0.6
16	0.4	2.7	2.8	16–17	....	201,800	0.2	0° 23′	0.7
					Total..	118,887,000			

[1] South basin of lake. [2] North basin of lake.

Lake Waubesa.

Origin of basin. In the vicinity of lake Waubesa, the trend of the preglacial Yahara valley was most nearly north and south and here also, the movement of the glacial ice was almost due south so that the liability to drift filling was much less than if the glacier had crossed the valley at right angles. In spite of the favorable conditions for keeping the preglacial valley free of drift at this point, however, well borings show that it was filled to a depth of 30 m. (100 ft.) or more, leaving only a shallow basin for the lake. Just below lake Waubesa the preglacial valley was narrow and its course was transverse to the ice movement. As a consequence this narrow part received a deeper filling of drift which now constitutes the dam holding back the waters of the lake.

The long axis of the lake has a general north and south trend and the outline is fairly regular. (See map IV.) The basin is comparatively shallow and the general slope of the bottom is gentle, being steeper along the sides than at the ends. The steepest bottom slope is found at the east end of the shoal which lies to the east of Brams bay. The maximum gradient here is about 1 to 17. This shoal area constitutes the only break in the regularity of the bottom.

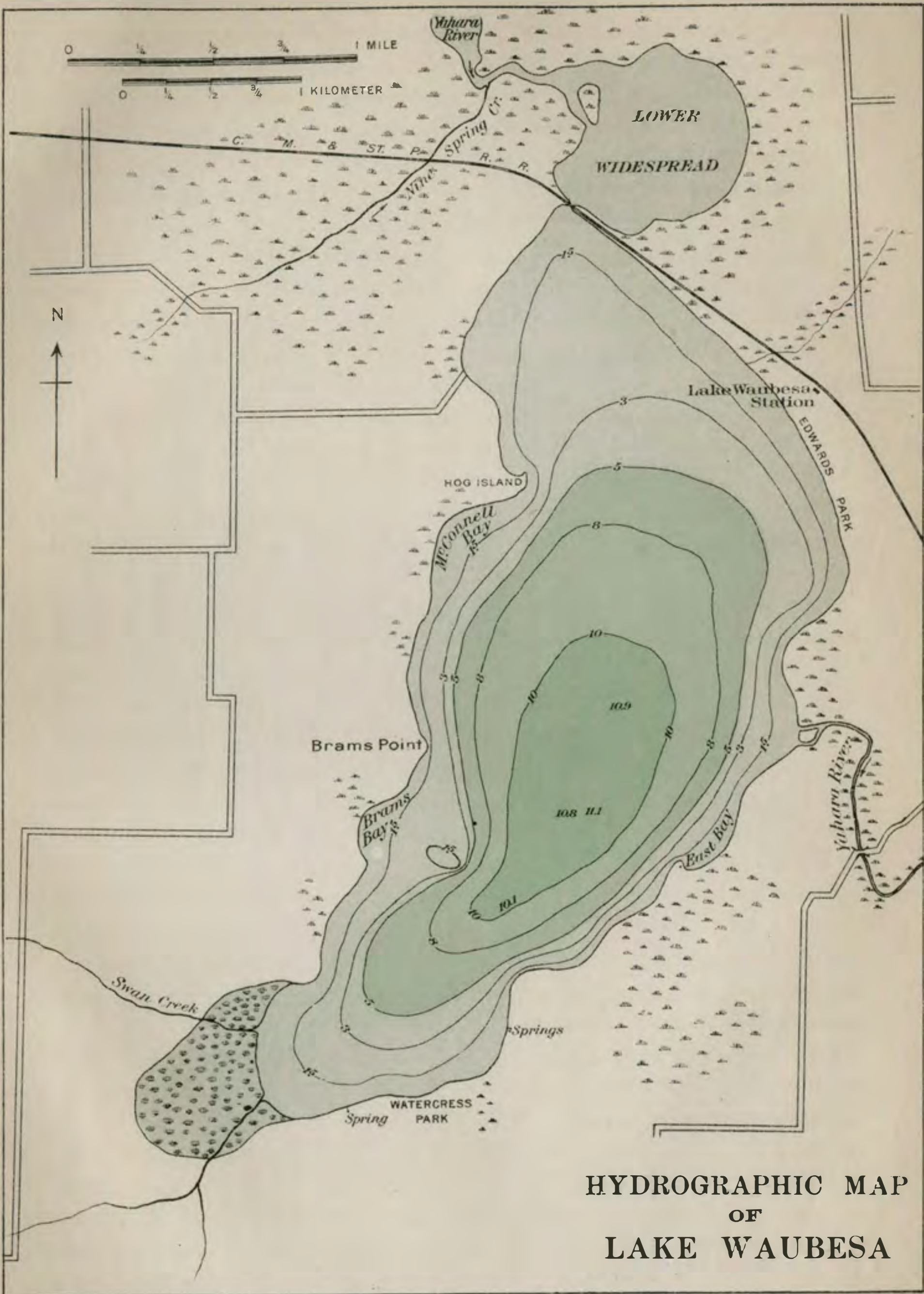
Shores. The shores are characterized by an alternation of drumlins and swamps; portions of the former have been worn away leaving cliffs and the latter are usually separated from the lake by low beach ridges which have been formed through the agencies of waves and currents in summer and ice in winter. (See map I.) The highest drumlin is situated on the east side of the lake toward the south end and it reaches an elevation of about 23 m. (75 ft.) above the surface of the lake.

The beach features of the lake are in an advanced stage of maturity so that little cutting and building are now in progress, and the amount will gradually decrease in the future unless the water level be raised artificially.

Along the east shore cutting is still in progress at Edwards park, on the drumlin south of the outlet, and on the headland just south of East bay. At the north end of Edwards park, the cliff consists of till but the southern portion is Madison sandstone, being the only rock cliff on the lake. The point south of East bay is the boldest headland on the lake and it is wasting rather rapidly. The drumlin of which it consists was once an island, but the channels north and south of it have been spanned by ramparts and the area between them has been converted into a swamp.

At the north end of the lake there is an extensive area of marsh which formed a part of the lake at one time; but through the action of waves and currents in summer and ice in winter, it has been cut off from the lake by beach ridges. Two small areas of water are now the only remnants of this former extension of the lake.

Very little cutting is now in progress along the west shore. Just north of the so-called Hog island is a high cliff of till but cutting at its base has practically ceased. Hog island is a swampy peninsula which has been built out from the base of the high drumlin by the combined action of water and ice. It protects the old cliff from further erosion. At Brams point and along the steep shore south of Brams bay, the old cliffs are now protected by a margin of abandoned beach. At the head of Brams bay, there is the usual beach ridge fronting a



HYDROGRAPHIC MAP
OF
LAKE WAUBESA

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swamp, but at one point this ridge is pierced by a small stream which carries so much sediment that it has built a triangular-shaped delta into the bay for a distance of about 30 m. (100 ft.). The apex of the delta points lakeward. South of Brams point the shore processes are greatly hindered by abundant growths of the larger aquatic plants in the shoal water. In fact, a fairly large amount of vegetation is found in the shallow water all along the edge of the lake but these growths are not so dense and continuous elsewhere as along the above shoreline.

LAKE WAUBESA.

T. 6 and 7 N., R. X E.		Mean depth	4.9 m.
Length	6.75 km.	Length of shoreline ...	13.9 km.
Breadth	2.25 km.	Shore development	1.36
Area	8.24 sq. km.	Mean slope of bottom..	0° 28′
Maximum depth	11.1 m.	Number of soundings ..	168

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilo-meters.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	8.24	100.0	13.9	0-3	3.47	19,277,000	47.90	0° 35′	1.01
3	4.77	57.9	9.7	3-5	1.11	8,404,300	20.87	0° 56′	1.62
5	3.66	44.4	8.4	5-8	1.24	9,054,800	22.50	1° 1′	1.77
8	2.42	27.2	6.3	8-10	1.41	3,330,400	8.27	0° 26′	0.75
10	1.01	12.3	4.2	10-11.1	1.01	185,500	0.46	0° 8′	0.23
					Total..	40,252,000			

At the southern end, there is a large marsh which was a part of the lake at an earlier stage of its history. It represents a part of the valley of the preglacial Waubesa creek. At Water Cress park, the beach consists of a broad, sandy rampart lying at the foot of the old cliff.

Ice ramparts are numerous along the shores of lake Waubesa. Some of them are now several meters higher than the level of the lake.

Water supply. The Yahara river flows into lake Waubesa at the north end and leaves again about the middle of the east side. The lake also receives the waters of several other affluents, viz., Swan creek, and another small stream at the south end, a small stream at the northeast corner, and several springs.

Lake Kegonsa.

The exact conditions attending the formation of the Kegonsa basin are not as well known as those of Waubesa, because the preglacial topography on its east side has not been determined in the same detail. It is, however, like Waubesa, a mere local enlargement of the old Yahara valley which was exceptionally broad at this place on account of two tributaries from the west. The basin is shallow, so that the bottom of the lake is scores of meters above the old Yahara channel.

Lake Kegonsa is larger and more nearly circular in outline than lake Waubesa, the east-west axis being but little longer than the north-south one. (See map V.) The symmetry of the bottom is broken by a long submerged ridge which extends out from one of the headlands, Colladay point. The slope of the bottom is more gentle than that of lake Waubesa. The maximum is only about 3.4 per cent. which is found just off of East point.

Shores. The higher lands bordering lake Kegonsa on the east, north, and west are preglacial in origin with only a veneering of drift, but the south side is bordered by a terminal moraine. It has fewer swamps than lake Waubesa, these being located chiefly on the north side of the lake. (See map I.) The highest and steepest shores are situated at the west end, where in one place a height of about 45 m. (148 ft.) above the lake is reached within three-quarters of a kilometer of the water's edge.

The lake is free from bays, and this fact permits a freer circulation of the water and tends to prevent the growth of vegetation in the shallow water. As a result of the regularity and simplicity of the outline, the shore processes are not very vigorous because there is little occasion for the simplification of the shore line.

The swampy shores are confined almost entirely to the north side of lake Kegonsa; in fact, there is but a small portion of this coast which is not low and swampy. With the exception of a small area at the southwestern corner of the lake, the remaining shores rise to an altitude of 5 m. to 15 m. (16 ft. to 50 ft.) or more above the surface of the water within a comparatively short distance of the lake.

The regularity of the coast line is broken by three prominent peninsulas known respectively as East, South, and Colladay points. East point is an outcrop of Lower Magnesian limestone and South point owes its existence to the form of the underlying rock. The third peninsula, known as Colladay point, lies on a ridge of Mendota limestone which

HYDROGRAPHIC MAP OF LAKE KEGONSA

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has a length of about 1.5 km. (0.9 mi.), including the outer shoal as shown on the hydrographic map. (No. V.)

A very interesting feature of the beach modifications is the shifting of the mouths of some of the affluents. The mouth of the Yahara river, which is the principal affluent, has been shifted eastward a considerable distance by the prevailing currents which have carried the sand and gravel in that direction. On the other hand, less than half a kilometer to the east of this point, the mouth of Door creek has been moved westward in a similar manner; the bar is continued beneath the streams, thus forming a kind of shallow sill over which the water escapes while preserving a much greater depth behind it. The mouth of the small stream northwest of the outlet has been shifted eastward by the formation of a bar out of material derived from a cliff which lies just west of it.

In front of Door marsh on the north side of the lake the waves have built a fine sandy beach ridge which rises nearly a meter above the water level. Two previous attempts to cut off the former northward extension of the lake at this point are now represented by long spurs parallel to the coast and lying in the marsh behind. Both of these structures are massive and the inner one heavily wooded. The old cliff at the eastern edge of Door marsh which was cut in the rock when the lake had its northern extension, is still well preserved. The low shores to the east of East point are fronted by ice ramparts and the higher shores are wasting slowly. Almost the whole of the south shore consists of a cliff which is cut chiefly in boulder clay, but in part also in stratified drift. Normally this cliff is being cut slowly if at all because it is protected by a natural boulder line. There are also some remnants of ice ramparts along the shore.

A creek from the west enters the lake through a small marsh at the southwest corner. The road along the shore at this place seems to follow a natural ridge made by waves and ice.

Upon the limestone ledge at Colladay point a ridge has been built by waves and ice. This ridge encloses a small lagoon. Just northwest of the point is a limestone cliff which is succeeded by a fine gravel beach fronting the lowland to the north of the cliff. Further along this type of shore gradually passes into a high till cliff which is overgrown with trees and shrubs. A lower cliff to the northeast gives way to the spit of coarse gravels whose eastward growth has shifted the Yahara inlet to the east. This spit concentrates the stream current at its end, thus causing the erosion of the bottom here and producing a small area which has the unusual depth of 1.5 m. to 2 m. (5 ft. to 6.5 ft.) depending upon the stage of the water.

Sources of water. Lake Kegonsa receives the overflow waters from the lakes above through the Yahara river which enters it on the north side and leaves again at the east end. It also receives the waters of four creeks, of which Door creek on the north is the largest.

LAKE KEGONSA.

T. 6 N., R. X and XI E.		Mean depth	4.6 m.
Length	4.83 km.	Length of shoreline ...	15.5 km.
Breadth	3.62 km.	Shore development	1.22
Area	12.73 sq. km.	Mean slope of bottom...	0° 20′
Maximum depth	9.6 m.	Number of soundings ..	252

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilo-meters.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	12.7	100.0	15.5	0–3	4.0	31,930,000	54.1	0° 37′	1.1
3	8.7	67.6	13.8	3–5	2.0	15,302,000	25.9	0° 32′	0.9
5	6.7	52.4	12.0	5–8	5.3	11,126,000	18.8	0° 18′	0.5
8	1.4	11.0	6.3	8–9.5	1.4	702,000	1.2	0° 12′	0.3
					Total..	59,060,000			

Lake Wingra.

Lake Wingra is a small, shallow body of water which lies a short distance west of lake Monona; its waters reach the latter through Murphy creek which has recently been dredged and made into a canal. (See map I.) The name Wingra is that which was applied to this lake by the Winnebago Indians who formerly occupied this portion of Wisconsin. The name signifies *dead* and locally this body of water is frequently called "Dead" lake. In reality, however, the lake is not dead yet but has reached an advanced stage in its life history, and this fact doubtless accounts for the application of this name to it. The maximum depth is only 4.25 m. (14 ft.) and by far the greatest portion does not exceed 3 m. in depth.

Shores. The immediate shores of the entire lake are swampy and marshy. This low margin varies in width from only a few meters in some places to a kilometer or more at other places. At two points on the south side and along practically all of the north side the swampy margin is not very wide and back of this zone the shores rise rather abruptly to a height of 8 m. to 10 m. (26 ft. to 33 ft.) above the level of the lake. At the western end the low margin is more extensive and the rise to the higher ground beyond is gradual. The most extensive marsh and swamp areas are located along the eastern and southeastern portions of the lake. The low shores support a luxuriant growth of vegetation and an abundant growth of the larger aquatic plants is also found in the shallow water along the margins of the lake.

At the northeastern corner of the lake a small, low island has been formed artificially by dredging and filling, and the low portion of the shore at this point has also been raised by artificial filling. Extensive modifications by dredging and filling have also been made along the southern shore.

There are large marl deposits both on the bottom of lake Wingra and along its margins. In some places these deposits reach a thickness of 8 m. to 9 m. (26 ft. to 30 ft.).

Sources of Water. Two small streams enter lake Wingra, one at the west end and the other on the south side; the chief source of water consists of springs which are situated along the margins of the lake. There are two large springs on the south side of the lake and one on the north side together with a number of small ones on these two sides as well as at the west end. The outlet emerges from the lake at the northeastern corner.

CHAPTER III.

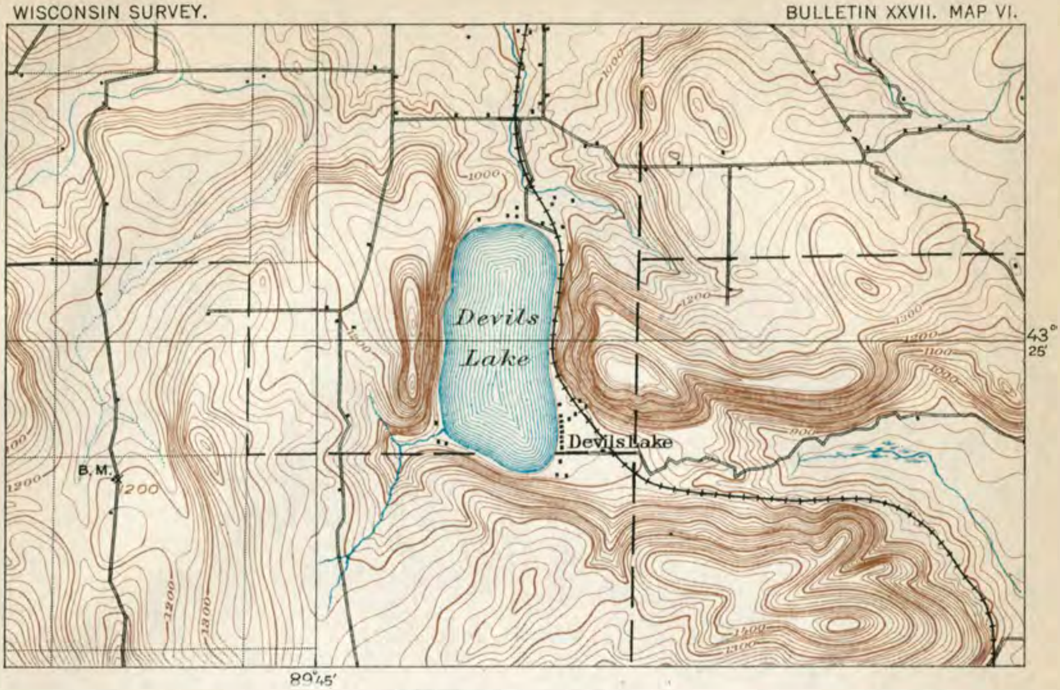
DEVILS AND ROCK LAKES.

DEVILS LAKE.

Devils lake is situated in Sauk county, Wisconsin, about 7 km. (4.5 mi.) south of the city of Baraboo. It lies in the midst of an area that is noted for the great beauty of its natural scenery and in order to preserve the attractive features of the lake and its immediate shores, a state park has been established here. With the exception of the north end and the southeast corner, the lake is surrounded by rugged quartzite bluffs which rise far above the surface of the water. The greater portion of the faces of these bluffs is more or less densely covered with trees and shrubs which add greatly to their beauty. The bluffs are especially gorgeous when the autumn colors are at their height. (See maps VI and VIII.)

Geology.[1] Devils lake lies in a deep, narrow gorge which cuts through the South or main Baraboo quartzite range. This range has a general east and west trend and the valley or gorge cuts through it from north to south, separating it into two parts. The long axis of the lake has a north and south trend, parallel to the gorge and at the south end of the lake the valley turns abruptly eastward. The existence of Potsdam sandstone at different levels in this gorge gives an important clue to its geological history. Following the subaqueous deposition of the thick beds of sand which now constitute the quartzite bluffs, this area was raised above the water, tilted to the north, and the sand was cemented into a quartzite by the seepage of water. As soon as this land appeared above the water, streams began work upon it, removing whatever may have overlain this formation, and cutting deep valleys into the hard quartzite. This erosion took place in pre-Cambrian times and the valley was formed chiefly during this period of erosion. Following the pre-Cambrian period came the submergence of this

[1] a. Salisbury and Atwood, Bull. V, Wis. Geol. & Nat. Hist. Survey, 1900.
b. Thwaites. The Madison Democrat, Feb. 18, 1908.



DEVILS LAKE

Topography by
U. S Geological Survey

ROCK LAKE

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region and the deposition of the thick paleozoic beds which filled the gorge and even buried the ridges on either side. This stage was followed by another uplift and a second period of erosion. During the latter the quartzite ridges were again exposed by the removal of the beds which overlay them and the gorge was again occupied by a stream.

As erosion progressed, the old gorge was cleaned out, enlarged, and finally deepened. This work was done by the Wisconsin river which, at that time, flowed southward through the present lower narrows of the Baraboo river, thence through the Devils lake gorge to its present course near Merrimac. The river continued in this course long enough to wear down the bottom of the Devils lake gorge to a level at least 107 m. (350 ft.) below the present lake surface.

While the ice edge was stationary in its position of maximum advance in glacial times, it extended along the north side of the main quartzite range, thus crossing the valley at the north end of the gorge where it deposited a rather high, well defined moraine. At this time also, the ice front at the other end of the gorge lay a short distance southeast of the present lake and a massive moraine was deposited across the valley here. These two moraines now constitute the dams which impound the waters of the lake. The original basin between these moraines was filled with glacial outwash to a depth of perhaps 90 m. (300 ft.), but a portion escaped filling. Since the ice retreated the bottom of this basin has been raised somewhat by wash from the small inflowing streams and by deposits of organic material derived from the vegetation growing in the lake. As a result of these filling processes, the present basin occupied by the waters of the lake is relatively small in comparison with the original basin which the impounding moraines formed.

Shores. The depression in which the lake lies separates the South range into two parts which are known respectively as the East and the West bluffs. About 6 km. (4 mi.) east of the lake the East bluff reaches a maximum elevation of about 490 m. (1600 ft.) above sea level or nearly 200 m. (650 ft.) above the surface of the lake. At the south end of the lake, the eastern extension of the West bluff, known locally as the Devils Nose, reaches a maximum height of about 170 m. (560 ft.) above the surface of the lake.

The greater portion of the east, west, and south shores consists of rugged bluffs which rise abruptly to a height of 125 m. (410 ft.) or more above the lake. The shoreline at the bases of these bluffs consists of quartzite boulders which are too large to be affected by waves and currents. The shore at the north end is composed of the morainal débris which forms the dam that prevents the waters of the lake from draining into the Baraboo river. The slope of this shore, as well as of the adjacent bottom, is gentle. The morainal dam at the southeast corner of the lake is low and has a gentle slope with a wide sandy beach.

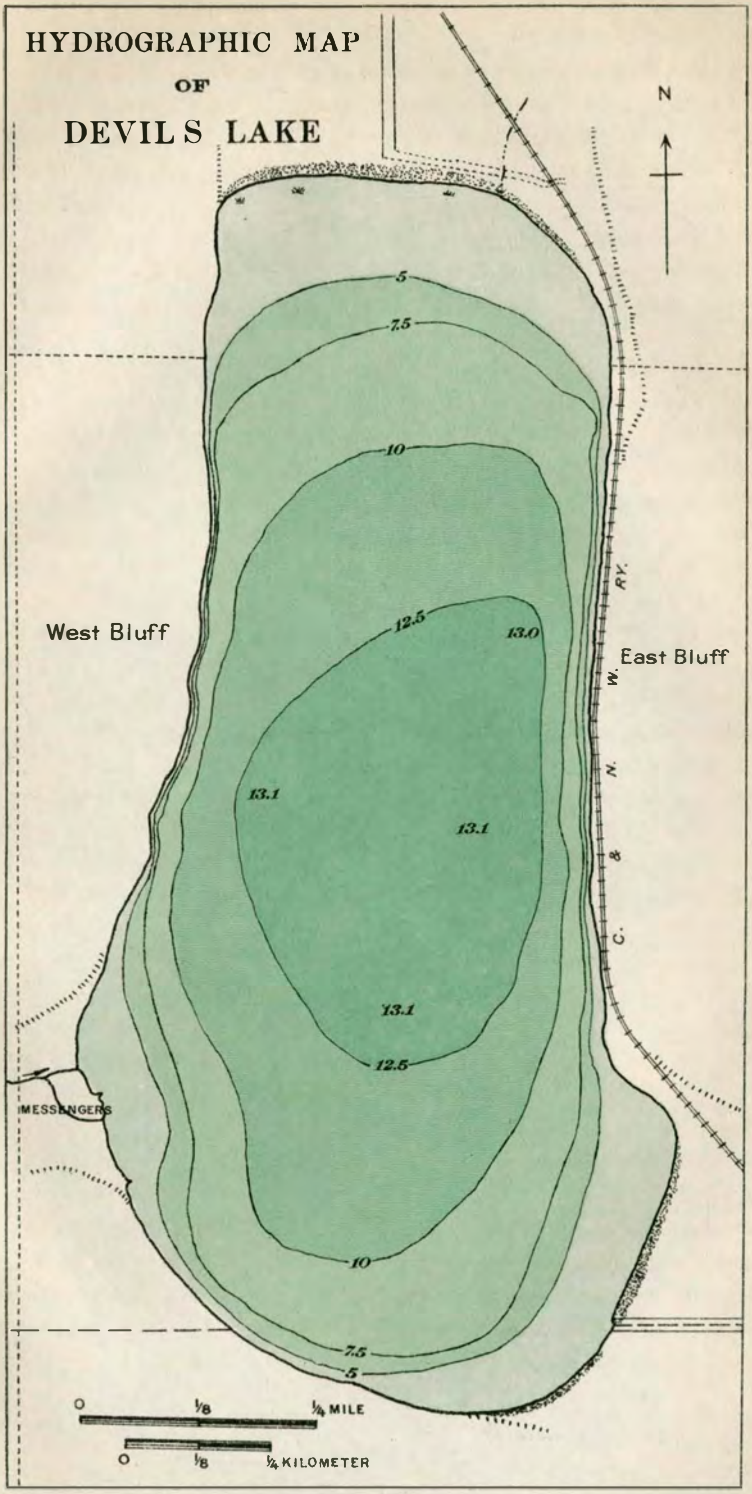
At the southwest corner of the lake there is a fair sized alluvial flat or grassy meadow which has been formed by a small, spring-fed stream. Very little work is being done on the shores by waves and currents owing to the small size of the lake, to the protection from wind afforded by the high shores, and to the character of the greater portion of the shore.

Shape and topography of bottom—Devils lake is an oblong body of water with its long axis lying in a north and south direction. The average width is about a third of the length. The hydrographic map (VIII) shows that the topography of the bottom is even and regular, with a large area in the center whose depth closely approaches the maximum. At both ends of the lake the slope of the bottom is gentle, while along the sides the water descends rather abruptly to a depth of 9 m. (30 ft.) beyond which the slope is more gradual. The steepest slope is found on the west side where it reaches a gradient of 1 to 4.7 between the shoreline and 9 m. (30 ft.).

Changes in level.—When the ice blocked the valley at both ends of the gorge during the glacial period, it formed a basin which was filled with water from the melting ice. This glacial lake was much deeper than the present body of water because the basin had not been filled to its present level, and also because the water stood at a much higher level when the ice reached its maximum height in the valley. The surface of this ancient lake rose at least 36 m. (120 ft.) above the present lake level. This is shown by the presence of drift boulders on the sides of the gorge at this height above the present water level. These boulders were transported to their present resting places by icebergs which broke loose from the glacier and floated out upon this old lake.

The variation in the present level probably does not exceed 1.5 m. (5 ft.). The water is highest during the vernal freshets and lowest in late summer or early autumn. It is said that, about forty years ago, the water was high enough to flow out over the morainal ridge at the north end of the lake.

Drainage basin. The lake receives the drainage from a small area of land, only about 14 sq. km. (5.5 sq. mi.) in all. A small intermittent stream enters the north end and a small spring-fed stream discharges its waters into the southwestern corner of the lake. There is no visible outlet, but some springs in the valley about 1.6 km. (1 mi.) southeast



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of the lake and about 30 m. (100 ft.) below the lake surface are probably fed very largely by seepage from the lake.

The lake water is soft since it holds only small amounts of calcium and magnesium in solution. This is due to the fact that it occupies a quartzite basin and receives only a relatively small amount of drainage from the surrounding glacial drift. The lake is situated in the Mississippi basin.

DEVILS LAKE.

T. 11 N., R. VI E.

Length	2.00 km.	Mean depth	8.9 m.
Breadth	1.00 km.	Length of shoreline	5.3 km.
Area	146.1 ha.	Shore development	1.23
Maximum depth	13.1 m.	Mean slope of bottom	1° 27′
		Number of soundings	115

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	146.1	100.0	5.3	0-5	25.8	6,624,000	50.9	5° 28′	9.6
5	120.3	82.5	4.6	5-7.5	16.9	2,784,000	21.4	3° 45′	6.5
7.5	103.4	70.8	4.3	7.5-10	31.6	2,179,000	16.7	1° 36′	2.8
10	71.8	48.5	3.4	10-12.5	40.8	1,276,000	9.8	0° 59′	1.7
12.5	31.0	21.2	2.1	12.5-13.1	31.0	152,000	1.2	0° 3.5′	0.1
					Total..	13,015,000			

ROCK LAKE.

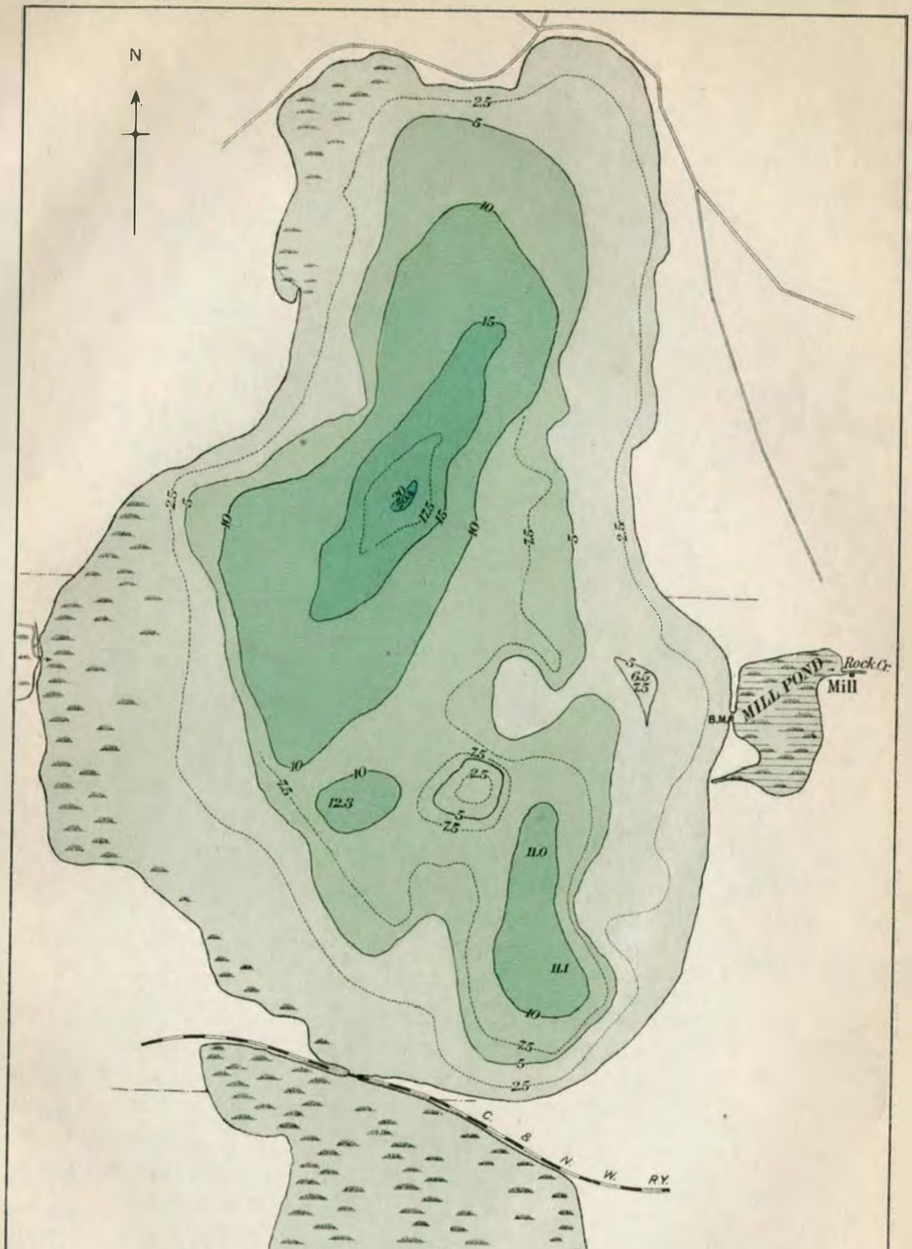
Rock lake is situated in Jefferson county and it lies about midway between the lakes of the Yahara basin and those of the Oconomowoc-Waukesha district. It occupies a depression in the ground moraine.

Map IV shows the topography of both the Devils lake and the Rock lake areas. It will be noted that there is a very marked contrast in the relief of the two regions. The topography of the former is characterized by its boldness, the quartzite bluffs rising to a very considerable height above the surrounding drift covered country and possessing many steep slopes, some of which are precipitous. Also by far the greater portion of the shores of Devils lake rises abruptly to a height of more than 100 m. (328 ft.) above the level of the water. On the other hand, Rock lake lies in a region whose relief was determined by glacial agencies so that in comparison, its topography is very gentle and quite like that of general ground moraine areas. While the shores are rather high at the northwest corner of the lake, yet they reach a maximum elevation of only about 30 m. (100 ft.) above the water and for the most part they do not exceed 10 m. to 20 m. (33 ft. to 65 ft.) in height.

There is a broad expanse of swamp at the south end; in fact, nearly all of that portion of the lake which lies south of the railroad is essentially a swamp at low stages of the water in summer. There is also a narrow belt of swampy shore on the west side, another at the north end, and still another south of the mill pond at the outlet.

The lake is fairly regular in outline and somewhat pear-shaped, the north end being the narrower. (See map VII.) The main axis lies in a north and south direction. A dam in the outlet, a short distance below the lake, raises the lake level about 2 m. (6.5 ft.). This increased height has added materially to the size of the lake. It is largely responsible for the portion south of the railroad, for the mill pond, and also for a rather large, shallow area along the west side. In summer these shallow areas support a dense growth of the larger aquatic plants.

The hydrographic map (VII) shows that the bottom of the lake is complex and irregular. The basin consists of four pits which are more or less distinctly separated by shallower water. The main or northwestern depression comprises about two-thirds of the area of the lake and is the deepest part. In the southeastern third, there are three depressions which vary in depth from 7.5 m. to 12.3 m. (25 ft. to 40 ft.). These pits are situated around the edge of a shoal area over which the water has a depth of less than 2.5 m. (8 ft.).



HYDROGRAPHIC MAP
OF
ROCK LAKE

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The lake receives the waters of two small streams. One enters the south end of the lake and it drains Mud lake and the large swamps lying south of Rock lake; another flows into the lake south of the middle of the west side. The outlet, Rock creek, leaves the lake a little south of the middle of the east side and flows northeastward to the Crawfish river. The latter stream is a tributary of Rock river whose waters flow into the Mississippi river.

ROCK LAKE.

T. 7 N., R. XIII E.

Length .... 3.20 km.
Breadth .... 2.00 km.
Area ....496.0 ha.
Maximum depth .... 20.4 m.
Mean depth .... 6.1 m.

Length of shoreline ... 9.7 km.
Shore development 1.23
Mean slope of bottom.. 1° 7′
Number of soundings .. 342
Area of mill pond ..... 10.6 ha.
Area south of railroad..115.8 ha.

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	496.0[1]	100.0	9.7	0-2.5	133.0	10,700,000	35.4	1° 1′	1.7
2.5	363.0	73.1	8.8	2.5-5	122.0	7,500,000	24.7	1° 7′	1.9
5	341.0	48.5	9.8	5-7.5	58.3	5,281,000	17.4	2° 20′	4.1
7.5	182.7	36.9	8.9	7.5-10	76.6	3,571,000	11.8	1° 29′	2.6
10	106.1	21.4	6.8	10-15	85.4	2,894,500	9.5	1° 34′	2.7
15	20.7	4.2	2.4	15-17.5	15.9	295,700	0.95	1° 35′	2.7
17.5	4.8	1.0	1.0	17.5-20	4.4	76,300	0.25	2° 9′	3.8
20	0.4	01	0.3	20-20.4	0.4	500	....	0° 50′	1.4
					Total..	30,319,000			

[1] Not including mill pond and area south of railroad.

CHAPTER IV.

THE OCONOMOWOC-WAUKESHA LAKE DISTRICT.

The Oconomowoc-Waukesha lake district comprises a rectangular area about 22.5 km. (14 mi.) long in an east-west direction by 14.5 km. (9 mi.) broad from north to south. Within this area there are about 45 bodies of water of various sizes. (See map IX.) The main axis of the chain has a northeast-southwest trend, extending from lake Five, near the northeastern corner of the area to Golden lake, near the southwestern corner. Twenty of the larger and deeper lakes have been sounded and hydrographic maps of them have been prepared. (See maps X to XV.) Those that have been surveyed vary in size from Pewaukee lake which has an area of 930.5 ha. (2,298 a.) to Garvin lake, whose area is only 8.75 ha. (21.6 a.). The maximum depth of these 20 lakes ranges from 4.8 m. (16 ft.) in Crooked lake to 28.8 m. (94.5 ft.) in Nagawicka lake.

Geology. This lake district lies in and adjacent to a sag or break in the large kettle moraine that has already been mentioned (p. 1). The existence of the gap or sag is emphasized by the fact that two parallel streams flow through or across the course of the moraine ridge. North of Beaver and North lakes the line of the moraine is marked by a distinct ridge several kilometers wide, whose trend is east of north. It rises more than 30 m. above the adjacent country and fully 60 m. above the level of the Oconomowoc-Waukesha lake district. The most prominent peak in this vicinity is Holy hill which reaches an altitude of 415 m. (1361 ft.) above sea level. South of Nagawicka lake the ridge appears again, trending west of south, but with less prominence than to the north of this lake district. The most prominent peak is Government hill which lies a short distance south of Nagawicka lake and has an elevation of 375.8 m. (1233 ft.).

Kames and pitted plains are unusually well developed in this region, as shown on the accompanying topographic map. (No. IX.) The pits and all of the lake basins, except that of Pewaukee, owe their existence to the burial of blocks of ice during the glacial period. The subse-

Topography by
U. S. Geological Survey

OCONOMOWOC-WAUKESHA LAKES

quent melting of these blocks produced basins which vary in size from mere kettle holes, only a few meters in diameter, to the largest lakes of the district. The bottoms of some of these kettle holes are above the level of the ground water so that they contain water only during the flood season; some have water in them permanently, while others have had water in them permanently in the past but have been filled in so that they are now occupied by swamps or grassy marshes.

Pewaukee lake differs in origin from the other lakes of this district. It is situated in an area of ground moraine and the basin it occupies resulted from the failure of the glacier, which moved westward down an ancient river valley, to fill this portion of the valley with morainic material; in fact, the basin may even have been deepened by the glacier.

In a general view the topography of this area exhibits a series of broad terraced plains with the highest ones on the east side. The levels of these terraces gradually decrease toward the west so that the general slope of the region is toward the west. The manner in which the terraces were formed is not known definitely but they probably resulted from a peculiarity in the drainage here at the time that the ice was retreating from this area. A preglacial depression here probably concentrated the drainage from the melting glaciers; the outflow passed along the line of the ice front but the current was not strong enough to carry away the heavier material and it was deposited; as the ice front retreated westward, the line of drainage also shifted westward from time to time, thus leaving a series of terraces after the ice had all disappeared.

In the vicinity of Pewaukee lake the drift is not very deep so that the underlying Niagara limestone appears at the surface in various places; it is found at the water's edge at one point on the lake. Over the kame and pitted plain area, that is, the remainder of the district, the stratum of drift is much thicker, having a depth of 30 m. (100 ft.) or more. It is coarse and gravelly, consisting of all sizes of stones up to small boulders. This seems to indicate that the material was pretty well washed by water at the time of deposition. The underlying rock of this portion consists of Galena limestone and Cincinnati shale.

Drainage. The surplus waters of this district finally reach the Mississippi river, but the immediate drainage system consists of four streams. (See map IX.) The waters of the southeastern corner, including Pewaukee lake, drain into the Fox[1] river whose waters reach

[1] Two different streams bearing the same name are mentioned in this report. (See sketch map, fig. 3, p. 8.) This one forms a part of the Mississippi river system. Its headwaters are situated a short distance north of the city of

the Mississippi river through the Illinois river. The northwestern corner is drained by the Ashippun river. This stream is a tributary of the Rock river whose waters join the Mississippi river. The middle portion of this district is drained by the Oconomowoc and the Bark rivers whose general courses run from northeast to southwest across this area. These two streams are also tributaries of the Rock river. Many of the smaller bodies of water in this district do not have outlets, but all of the lakes that do have outlets, except Pewaukee lake, are drained by these two rivers. The surplus waters of eight of the larger lakes reach the Oconomowoc river, while six are drained by the Bark river.

Bottom slopes. As might be expected from their mode of formation, the slopes of most of the lake basins of this district may be characterized as steep. Pewaukee lake, whose basin was formed in a different manner, is an exception and so are Lac la Belle and the shallower lakes. The typical slope consists of (a) a steep portion above the water line, generally a cliff formation, (b) a belt at the edge of the lake which has been worked over by the waves and currents and transformed into a beach and a subaqueous terrace, and below the latter (c) a steep descent to the deeper waters of the lake. In some instances the steep bottom slope begins even at the water's edge. At one point on the west side of Mouse lake, for example, the gradient from the shoreline down to a depth of 18 m. (60 ft.) is 1 to 3.4 and a similar descent is found on the east side of North lake, toward the south end. Just north of the outlet bay in Okauchee lake, there is a slope of 1 to 3.8 between the water's edge and a depth of 24 m. (79 ft.). On the west side of Pine lake, toward the north end, and on the east side of Nagawicka lake, toward the south end, are maximum slopes of 1 to 4.4 between the shoreline and a depth of 21 m. (69 ft.).

Beaver Lake.

Beaver lake lies at the head of a small drainage system whose surplus waters reach the Oconomowoc river during flood season through Pine lake and its outlet. (See maps IX and X.) The lake is fed chiefly by springs and during dry seasons there is no stream outflow. But during seasons of abundant rainfall the outflowing waters make a stream of considerable size. Apparently the outlet stream has cut down its chan-

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Waukesha. It flows southward into the state of Illinois where it joins the Illinois river. The other Fox river is situated in east central Wisconsin and flows into Green bay, thus lying within the lake Michigan basin. It is more fully considered in Chapter VIII, p. 99.

nel about a meter so that the level of the lake is now lower than it was originally.

The basin of this lake consists of two large pits which are nearly equal in area. A little above the present water level, there are several arms extending out from the main depression which give the basin a scalloped appearance. If the water were one or two meters higher, these arms would form bays and thus make the coast line very irregular. At present the immediate shores are about equally divided between steep, kame slopes and the low flat or gently sloping arms. At the heads of the latter, however, there are steep cliffs. Considerable cliff cutting has been done in the past, but at present, the cliffs are protected by ice ridges at their bases. The waves in summer are unable to remove all of the terraces formed by the ice in winter so that wave action is limited to the shore drift. This working over of the shore drift keeps a belt of clean cobble stones just under the edge of the water.

Fronting nearly all the low shores are fairly high ridges which have the graceful curves of bars. Some exceptionally fine examples, still unmodified, are found along the south shore; but at other points, more especially at the east end, the ridges have been unmodified by the ice. The irregular arrangement of material in some of the ridges indicates that they were built either largely or wholly by the ice.

BEAVER LAKE.

T. 8 N., R. XVIII E.		Mean depth	5.1 m.
Length	1.77 km.	Length of shoreline	5.4 km.
Breadth	0.70 km.	Shore development	1.38
Area	123.7 ha.	Mean slope of bottom	1° 44′
Maximum depth	15.0 m.	Number of soundings	79

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	123.7	100.0	5.4	0-3	62.0	2,726,800	43.2	1° 27′	2.5
3	61.7	50.0	5.0	3-5	15.1	1,079,400	17.1	3° 17′	5.7
5	46.6	37.8	3.7	5-10	14.2	1,765,000	28.0	0° 50′	1.4
10	32.4	26.2	2.8	10-14.5	28.4	734,000	11.6	1° 37′	2.8
14.5	4.0	3.2	0.7	14.5-15	4.0	6,800	0.1	0° 17′	0.5
					Total..	6,312,000			

Pine Lake.

The basin of Pine lake consists of a large pit with an elongated north-south axis. (See map X.) Some of the pits, which are so characteristic of the surrounding land, are connected with the main one, thus forming bays which contribute to the irregularity of the coast line. The regularity of the basin is broken by an island situated toward the east side and a little north of the center of the lake. Its area is about 0.8 ha. (2 a.).

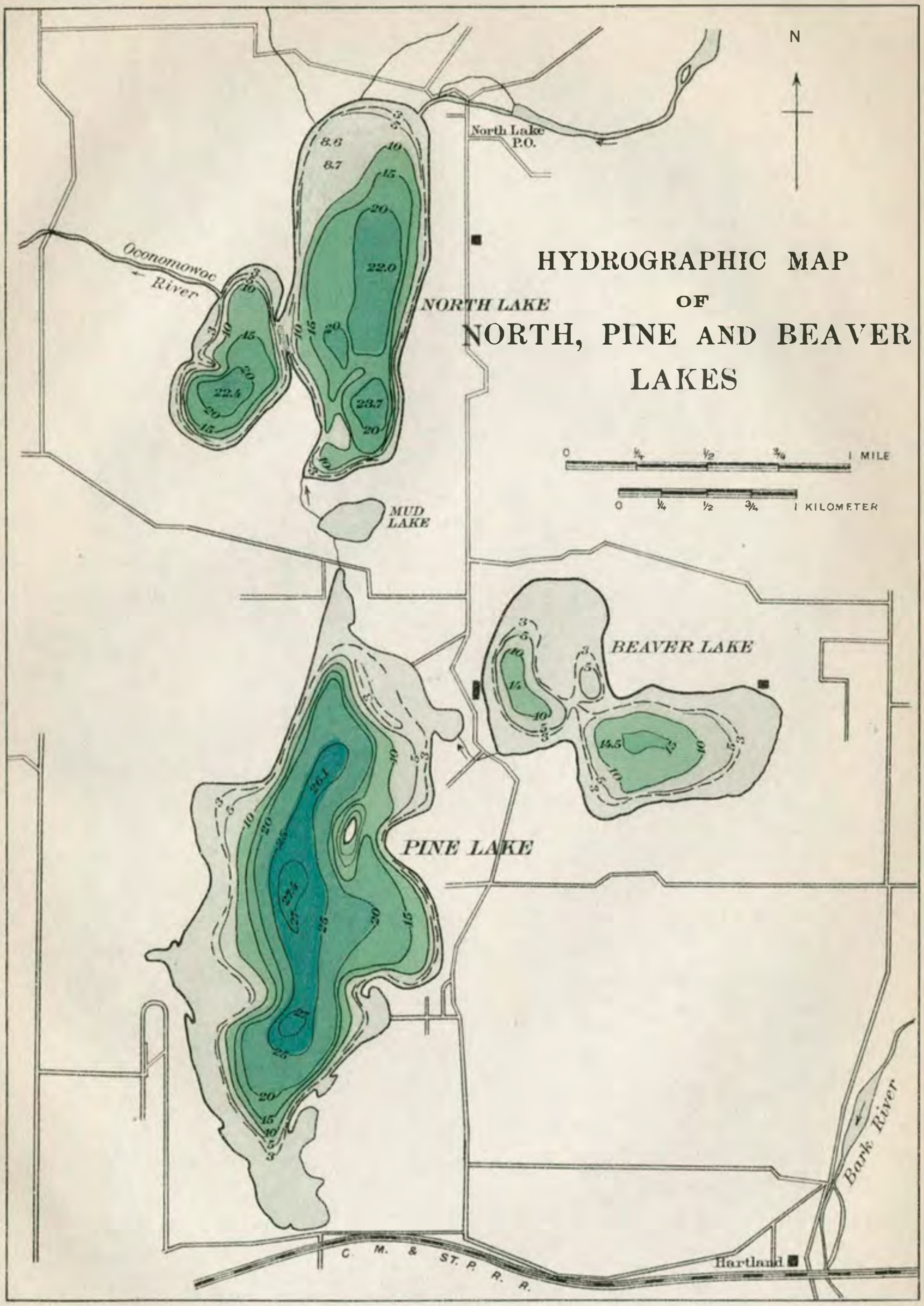
Shores. For the most part the shores have a gentle slope, gradually rising to a height of 8 m. to 10 m. (26 ft. to 33 ft.) above the lake; near the middle of the east side and toward the north end of the west side the banks are steeper, rising rather abruptly to a height of 25 m. (82 ft.) or more.

The water level seems to be falling gradually which is due apparently to a general sinking of the level of the ground water in the vicinity. The level of the water is generally below the point of overflowing and it is only in exceptionally wet seasons that there is any outflow. The lowering of the lake level protects the bases of the cliffs from the cutting action of the waves. In seasons with an average amount of precipitation, the water level is half a meter or more below the bases of the present cliffs so that a band of beach covered with gravel and cobble stones is found between the bases of the cliffs and the water's edge. When the lake stood at a higher level, the waves actively cut the cliffs; some of the headlands on the west side, for example, have been worn back several meters.

Another evidence of the activity of waves and currents is shown by some shoals which lie about 200 m. (655 ft.) off shore at Pine Lake park. They are covered with boulders and appear to be remnants of higher elevations which were cut down by the removal of all of the finer morainal material.

The amount of material used for beach structures is small in comparison with the quantity removed from the cliffs. This is due to the shape of the basin occupied by the water. The sides are so steep that a large amount of material has been used in constructing the marginal shelf. In spite of the large amount used for this purpose, enough has been worn from the cliffs to build bars entirely across some small bays, and others are now in the process of being spanned by bars or spits.

Also, the point of land on the east side toward the southern end of the lake has a long, submerged spit extending southward from it,



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and the island about the middle of the east side, has a similar structure at its north end.

Owing to the steepness of the sides of the basin, the lowering of the water level caused the renewal of cutting on the marginal shelf along a large portion of the east side and at the north end on the west side and the consequent formation of a new marginal shelf.

Where the shores have a comparatively gentle slope the beach is subject to modification by the action of ice and long stretches of ice-ramparts are found in such localities.

The water of the lake is derived chiefly from springs and from the seepage from Beaver lake. When the water rises high enough it overflows into North lake; but sometimes there is no overflow for a considerable period of time. The lake also loses some of its water by seepage toward the north and west.

PINE LAKE.

T. 8 N., R. XVIII E.

Length	3.70	km.
Breadth	1.70	km.
Area	305.9	ha.
Maximum depth	27.4	m.
Mean depth	12.1	m.
Length of shoreline	10.9	km.
Shore development	1.73	
Mean slope of bottom	2° 41′	
Number of soundings	143	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	305.9	100.0	10.9	0-3	84.9	7,869,000	21.2	1° 58′	3.4
3	221.0	72.2	7.5	3-5	27.0	4,151,600	11.2	3° 6′	5.4
5	194.0	63.3	7.0	5-10	31.3	8,915,000	24.1	6° 8′	10.7
10	162.7	53.2	6.4	10-15	36.9	7,191,800	19.4	4° 59′	8.7
15	125.8	41.2	6.4	15-20	35.2	5,386,500	14.5	4° 46′	8.3
20	90.6	29.6	5.2	20-25	56.6	3,002,600	8.2	1° 59′	3.5
25	34.0	11.1	4.0	25-27.4	34.0	498,500	1.4	1° 34′	2.7
					Total..	37,015,000			

North Lake.

It will be noted on the topographic map (IX) that the basins of North, Pine, and Nagawicka lakes are elongated in a north-south direction and that they form a chain which extends almost entirely across this lake district. There is intimate connection between North and Pine lakes, any overflow of water from the latter being discharged into the former; but Nagawicka lake is isolated from them, a morainal ridge which rises to a height of 5 m. to 10 m. (16 ft. to 33 ft.) above the lakes separating it from Pine lake. Nagawicka lake, in fact, belongs to an entirely different river system, that of the Bark river, while Pine and North lakes are drained by the Oconomowoc river. A similar, but smaller chain is formed by the Nashotah–Nemahbin lakes. (See p. 54).

The basins occupied by North lake represent two pits formed, apparently, by two separate blocks of ice. (Map X.) The two basins are unequal in size, the west one being very much smaller than the east one, and they are separated by a narrow ridge whose average height above the water is about half a meter, at ordinary summer levels. This ridge is pierced at only one point and that is where the stream flows from the east into the west basin.

More than half of the shore of North lake has a steep slope, rising rather abruptly to a height of 10 m. or 12 m. (33 ft. or 40 ft.) This applies particularly to the eastern basin where the shores are high along the east, south and southwest portions. The north end is bordered by an extensive swamp. Most of the immediate shore of the west basin is low, but a short distance back from the lake except at the north end, it rises to nearly or quite the height found along the east basin.

Practically all of the steep shores of the lake are being eroded, but this action is not progressing vigorously owing to the small size of the basins and to the fact that the water now stands at a slightly lower level than formerly. Ice-push terraces are a prominent feature of the beaches and they also aid in protecting the cliffs from cutting. Through the action of vegetation in summer and ice in the winter, the swamp at the north end of the east basin is gradually encroaching upon the lake. At one point the old shore line lies many meters behind the present one, with swamp between them. Marl is a conspicuous constituent of the beaches of the west basin. It is white in color and appears in the form of gravel passing into sand. On the southwest side of this basin there is a terrace several scores of meters in width which is composed of successive ridges of this material.

The two most prominent ice ridges at present are situated respectively at the northeast corner of the east basin and at the outlet, i. e. at the northwest corner of the west basin.

North lake receives the waters of the two branches of the Oconomowoc river and of Mason creek. These streams drain extensive tamarack swamps situated north of the lake and their waters have the usual brownish color which is characteristic of peat stained water. The waters of the lake possess this same color. There are some strong springs toward the south end of the east basin which doubtless represent chiefly the seepage from Beaver and Pine lakes. The west basin possesses no springs and the only water received by it is the overflow from the east basin. The Oconomowoc river leaves the west side near the north end.

NORTH LAKE, EAST PART.

T. 8 N., R. XVIII E.		Mean depth	12.7 m.
Length	2.16 km.	Length of shoreline ...	5.2 km.
Breadth	0.75 km.	Shore development	1.29
Area	133.2 ha.	Mean slope of bottom..	3° 34′
Maximum depth	23.7 m.	Number of soundings ..	112

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	133.2	100.0	5.2	0-3	14.7	3,775,000	22.2	5° 59′	10.5
3	118.5	88.9	5.0	3-5	7.0	2,300,000	13.5	8° 1′	14.1
5	111.5	83.7	4.8	5-10	29.7	4,832,000	28.4	4° 34′	8.0
10	81.8	61.4	4.6	10-15	21.0	3,565,000	21.0	5° 55′	10.4
15	60.8	45.6	4.0	15-20	34.8	2,170,000	12.7	3° 3′	5.3
20	26.0	19.5	3.4	20-23.7	26.0	378,000	2.2	1° 23′	2.4
					Total..	17,020,000			

NORTH LAKE, WEST PART.

T. 8 N., R. XVIII E.		
Length	1.07	km.
Breadth	0.57	km.
Area	46.7	ha.
Maximum depth	22.4	m.
Mean depth	11.4	m.
Length of shoreline	2.7	km.
Shore development	1.12	
Mean slope of bottom	4° 15′	
Number of soundings	53	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	46.7	100.0	2.7	0-3	8.1	1,279,200	24.0	5° 28′	9.6
3	38.6	82.6	2.44	3-5	3.6	736,000	13.8	7° 40′	13.5
5	35.0	74.9	2.4	5-10	7.4	1,565,700	29.4	8° 55′	15.7
10	27.6	59.1	2.2	10-15	11.1	1,103,300	20.7	4° 54′	8.6
15	16.5	35.3	1.6	15-20	10.2	569,500	10.7	3° 26′	6.0
20	6.3	13.4	0.8	20-22.4	6.3	75,300	1.4	0° 55′	1.6
					Total..	5,329,000			

Mouse Lake.

The pit occupied by Mouse lake is long, narrow, and deep; the lake has a maximum depth of 20.2 m. (66 ft.) and the shores rise abruptly to a height of 12 m. or 15 m. (40 ft. or 50 ft.) while further back from the lake on the east side the bluffs reach a height of nearly 30 m. (100 ft.). (See maps IX and XI.) Its shores are free from low swampy land and but little indented by bays. The south end is separated into two parts by a long promontory.

Owing to the small size of the lake and the high shores which protect it somewhat from wind, the waves are not powerful enough to cut the banks very vigorously or extensively. The cliffs show evidence of having been cut when the water stood a little more than half a meter above its present level. Owing to this fall in level, the greater part of the work now being done by the waves is upon the marginal bench formed when the water stood at the higher level. At some points, however, all of this bench material has been removed and the waves are now at work upon the cliffs.

Owing to the steep slope of the sides of the water filled basin, most of the material obtained from the cliffs is used in constructing the subaqueous marginal shelf. There is one good beach ridge, however, which spans a hollow at the north end of the lake.

The lake has no stream inlet and derives its water chiefly from springs on the east side. Pine lake, which lies 1.6 km. (1 mi.) east has its water level about 7.5 m. (25 ft.) higher than that of Mouse lake, so that much of the spring water entering this lake is probably derived from Pine lake. On the west, Mouse lake is separated from Okauchee lake by a ridge about 100 m. (330 ft.) wide and the water level in the former is about 1.5 m. (5 ft.) above that in the latter, so that the water of Mouse lake passes westward by seepage to Okauchee lake. As a result many springs discharge their waters into Okauchee lake along the western edge of this ridge.

At the southwest corner of Mouse lake, there is a sag in the ridge which separates it from Okauchee lake. This is the lowest point of the shore, so that, if Mouse lake ever had an outlet, it was probably through this depression. But the shore at this point rises about 3 m. to 5 m. (10 ft. to 16 ft.) above the present water level, and it is very doubtful whether the water ever stood so much above its present level. There are no evidences to show that it ever stood more than a little over half a meter above the present stage and, if the water ever were high enough to overflow, it did not remain at that level for a very long period of time.

MOUSE LAKE.

T. 8 N., R. XVIII E.		Mean depth	9.1 m.
Length	1.32 km.	Length of shoreline	3.9 km.
Breadth	0.33 km.	Shore development	1.84
Area	36.6 ha.	Mean slope of bottom	3° 58′
Maximum depth	20.2 m.	Number of soundings	47

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	36.6	100.0	3.9	0–5	16.2	1,404,700	45.6	5° 23′	9.4
5	20.4	55.6	2.1	5–10	5.0	891,500	28.8	11° 7′	19.6
10	15.4	42.0	1.8	10–15	7.3	577,300	18.6	5° 55′	10.3
15	8.1	22.2	1.2	15–19	5.4	207,500	6.7	3° 27′	6.0
19	2.7	7.5	0.4	19–20.2	2.7	11,000	0.3	0° 30′	0.9
					Total..	3,092,000			

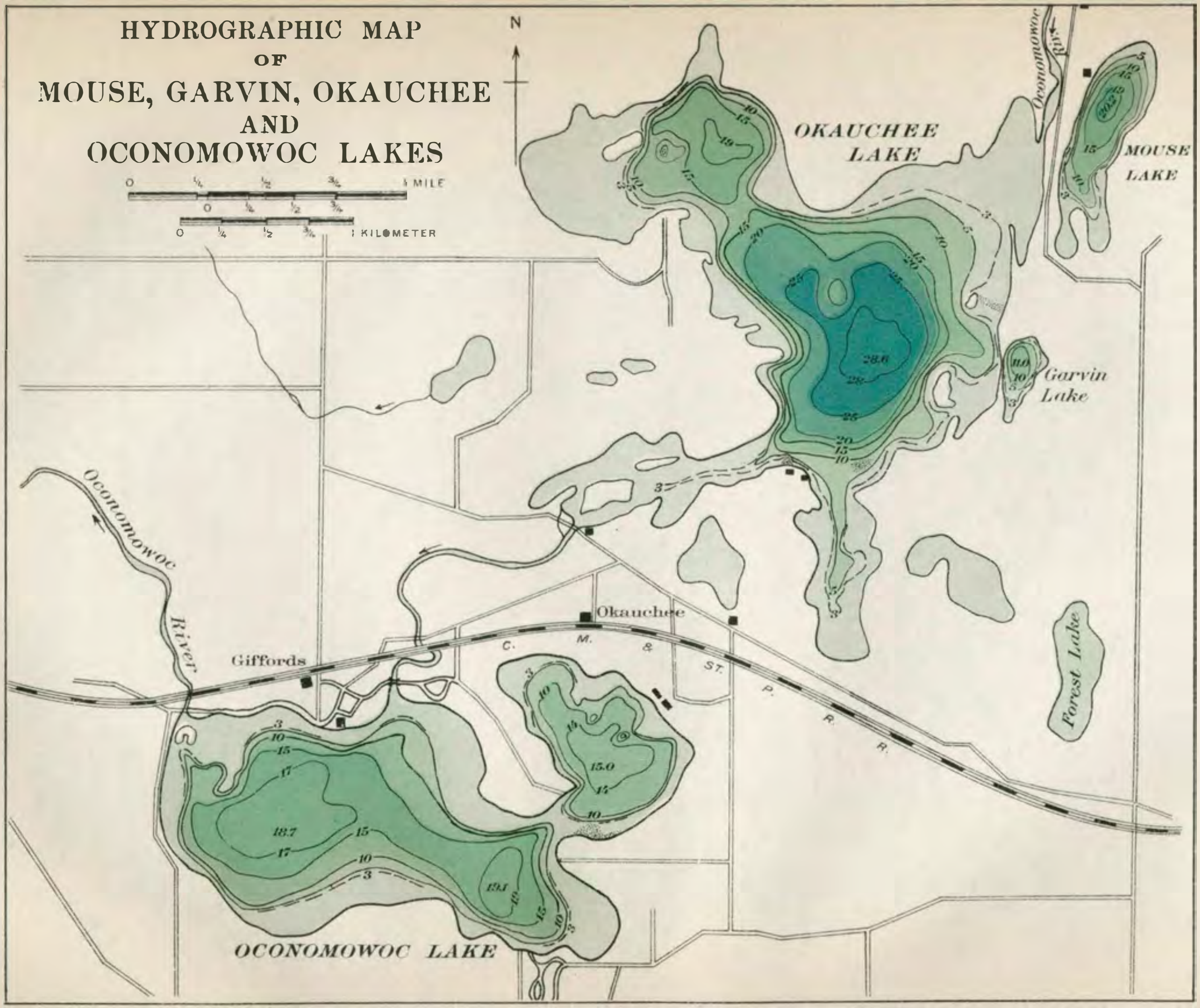
Okauchee Lake

The hydrographic map (XI) shows that the outline of Okauchee lake is very irregular, so irregular in fact that its basin can scarcely be attributed to the presence of but a single block of ice. There are two fairly distinct basins with a number of bays and arms extending out from these in various directions. The present shoreline is more regular even than former ones because the shore processes have rounded off many of the bolder curvatures. The main part of the lake contains three islands, and there are two in the southwest bay. The area of these five islands is 9.2 ha. (22.8 a.).

With the exception of a short stretch of low shore at the northwest corner of the lake, the shores are steep, rising abruptly to a height of 10 m. to 15 m. (33 ft. to 50 ft.) or more above the surface of the lake. (Map IX.)

The water is held about 3.3 m. (11 ft.) above its natural level by a dam in the Oconomowoc river at the outlet. The rise of the water has set it at work upon the shores at a new level and as a result, the present beaches are comparatively recent structures. The youthfulness of the shoreline is shown by the fact that the steep banks are being worn away so rapidly in many places that the resulting cliffs are quite free from vegetation. A long stretch of such shore is found along the east side; generally, however, there is an alternation of cutting headlands and small bays which are gradually being exterminated by the various processes going on. The youthfulness of the shoreline is also shown by the fact that very little bar building is now in progress because the waves and currents are still able to carry the material obtained from the cliffs out to the front of the marginal shelf. The numerous irregularities in the coastline will offer abundant opportunities, though, for the building of bars when the shelf becomes so wide that the currents are no longer able to transport detritus to its outer margin.

Several structures which were either completed, or were in process of construction at the time the water was raised by the dam, are still preserved in various parts of the lake. A spit was being built across the mouth of the long, narrow bay which extends southward from the lake; another was being extended across the bay which extends southwestward to the outlet; a bar had been completed between the south end of the island which lies to the west of Garvin lake and the adjacent headland; the small island to the north of this one was also connected with the mainland by a bar. There are other



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similar structures which are less conspicuous. Further construction work on those formations was stopped when the water was raised to a higher level; a few, in fact, are now being destroyed.

The only stream affluent received by Okauchee lake is the Oconomowoc river which enters the lake at its northeastern corner and leaves it again through an arm extending southwestward from the main body of water. Another supply of water is derived from a number of springs, most of which are situated at the northeast corner of the lake.

OKAUCHEE LAKE.

T. 8 N., R. XVII and XVIII E.		
Length	3.81	km.
Breadth	2.90	km.
Area	427.8	ha.
Maximum depth	28.6	m.
Mean depth	12.1	m.
Length of shoreline	17.9	km.
Shore development	2.44	
Mean slope of bottom	1° 43′	
Number of soundings	292	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	427.8	100.0	17.9	0–3	169.9	10,178,600	23.3	1° 28′	2.6
3	257.9	60.2	11.4	3–5	33.4	4,821,000	11.0	3° 36′	6.3
5	224.5	52.3	9.6	5–10	48.2	9,995,600	22.9	5° 2′	8.8
10[1]	137.9	32.1	5.1	10–15	26.7	7,878,700	18.0	5° 18′	9.2
15	111.2	26.1	4.5	15–20	23.8	4,953,600	11.35	5° 6′	8.9
20	87.4	20.4	4.0	20–25	44.8	3,183,000	7.3	2° 19′	4.0
25	42.6	9.9	3.2	25–28	29.6	791,000	1.8	1° 20′	2.3
28	13.0	3.1	1.4	28–28.6	13.0	25,900	0.06	0° 12′	0.3
10[2]	38.4	8.9	2.4	10–15	19.0	1,418,000	3.2	3° 24′	5.9
15	19.4	4.6	2.1	15–19	14.2	461,800	1.06	2° 25′	4.2
19	5.2	1.2	0.9	19–19.8	5.2	13,800	0.03	0° 24′	0.7
					Total..	43,721,000			

[1] Main basin of lake. [2] North basin of lake.

Garvin Lake.

Garvin lake (maps IX and XI) is situated near the middle of the eastern side of Okauchee lake and it is separated from the latter by a ridge which is only a few meters wide. Formerly it was entirely land locked but some years ago an artifical channel was dug through to Okauchee lake.

The shores of Garvin lake possess the typical kame steepness which characterizes those of Okauchee lake in the immediate vicinity. They rise 10 m. to 15 m. (33 ft. to 50 ft.) or more above the surface of the lake. The only break in the steep shores is found at the point where the artificial channel connects it with Okauchee lake. A small area of low land is found at the south end of the lake. The area of the lake is so small that comparatively little work is done on the shores by waves and currents. There is no stream affluent, but there are a few small springs along its eastern shore. Ever since it has been connected with Okauchee lake its water level has been controlled by that of the latter.

GARVIN LAKE.

T. 8 N., R. XVIII E.		Mean depth	5.0 m.
Length	0.50 km.	Length of shoreline	1.4 km.
Breadth	0.26 km.	Shore development	1.36
Area	8.8 ha.	Mean slope of bottom	2° 47′
Maximum depth	11.0 m.	Number of soundings	35

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	8.8	100.0	1.4	0-3	2.7	222,300	51.0	7° 30′	13.1
3	6.1	70.2	0.9	3-5	2.9	92,300	21.2	3° 20′	5.8
5	3.2	38.0	0.8	5-11	3.2	121,200	27.8	12° 28′	22.1
					Total..	435,800			

OCONOMOWOC LAKE.

The basin occupied by Oconomowoc lake consists of two large pits which were formed by two separate blocks of ice. (See map XI.) These pits are connected by a short, narrow strait of water which averages about 1 m. (3 ft. to 4 ft.) in depth. Scarcely more than half the shoreline is characterized by the steepness of the typical pit and the highest portions scarcely exceed 10 m. to 12. m. (33 ft. to 40 ft.) in height. The north and east shores are the steepest; along the south shore kame ridges and swamps are found alternately; the west shore has a fairly graduual slope which is hummocky. In spite of the adjacent low ground and of the existence of considerable shallow water along the shores, the marginal waters are comparatively free from aquatic vegetation, so that the shore currents are unimpeded except by friction on the bottom.

The beaches are being modified by waves and currents along the greater part of the shoreline, but in only a few instances is this work proceeding vigorously. Parts of the cliffs which face to the west or southwest are being worn away rapidly enough to keep them free from vegetation. Evidences of former extensive beach modifications are most conspicuous along the south shore. Here the swamps have been separated from the lake by long ridges which were built as bars and were subsequently raised to a greater height by the action of the ice. These ridges imply a large amount of cliff cutting to furnish material for them. Similar ridges are found at the northeast and the northwest corners of the lake. Icc ramparts are found along most of the west side.

This lake receives the waters of Oconomowoc river which enters about the middle of the north side and leaves again at the northwestern corner of the lake. Springs enter the lake only along the east shore. They are largest and most numerous in the vicinity of Spring Bank. These probably represent the seepage from Okauchee lake which is only about 1 km. away and has a water level about 3.3 m. (11 ft.) higher than that of Oconomowoc lake.

OCONOMOWOC LAKE.

T. 7 N., R. XVII E.

Number of soundings 191

Main basin.

Length .... 2.82 km.
Breadth .... 1.37 km.
Area ....255.6 ha.

Maximum depth ..... 19.1 m.
Mean depth .... 9.5 m.
Length of shoreline .. 7.5 km.
Shore development ... 1.32
Mean slope of bottom 1° 50′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	255.6	100.0	7.5	0-3	83.0	6,382,000	26.3	1° 29′	2.6
3	172.6	67.5	6.8	3-5	10.1	3,352,000	13.8	3° 43′	6.5
5	162.5	63.6	6.6	5-10	26.0	7,465,000	30.7	0° 45′	1.3
10	136.5	53.4	6.4	10-15	47.5	5,591,000	23.0	3° 52′	6.7
15	89.0	34.8	2.0	15-19.1	89.0	1,513,000	6.2	0° 43′	1.2
					Total..	24,303,000			

Northeast basin.

Length .... 1.20 km.
Breadth .... 0.80 km.
Area .... 72.8 ha.
Maximum depth ..... 15.0 m.

Mean depth .... 7.9 m.
Length of shoreline .. 3.7 km.
Shore development ... 1.23
Mean slope of bottom 3° 12′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	72.8	100.0	3.7	0-5	27.0	2,940,400	51.2	3° 34′	6.2
5	45.8	63.1	3.0	5-10	12.6	1,966,000	34.1	6° 34′	11.5
10	33 2	45.4	2.8	10-14	23.5	811,300	14.1	2° 9′	3.8
14	9.7	13.4	1.6	14-15	9.7	32,300	0.6	0° 28′	0.8
					Total..	5,750,000			

FOWLER LAKE.

Lying to the northwest of Oconomowoc lake there is a chain of four pits which form the basins of two lakes. (See maps IX and XII.) These pits are elongated in a northwest-southeast direction. The first of them is occupied by Fowler lake and the other three constitute the basin of Lac la Belle.

The shores of Fowler lake are low but not marshy and active cutting of them by waves and currents is prevented in many places by artificial walls of stone and piles. But much of the shore would be subject to cutting if it were not for these barriers. In some places these walls are washed vigorously, while in other places gravel beaches are being built outside them.

This lake receives the waters of the Oconomowoc river and its overflow is discharged into Lac la Belle. A dam in the outlet raises the water to a height of about 2 m. (7 ft.) above the surface of Lac la Belle.

FOWLER LAKE.

T. 8 N., R. XVII E.

Length	1.60 km.	Mean depth	4.4 m.
Breadth	0.70 km.	Length of shoreline	3.2 km.
Area	33.8 ha.	Shore development	1.57
Maximum depth	15.2 m.	Mean slope of bottom	3° 0′
		Number of soundings	71

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	33.8	100.0	3.2	0-2	12.8	543,700	36.8	2° 21′	4.1
2	21.0	62.3	2.0	2-3	9.7	159,500	10.7	1° 1′	1.7
3	11.3	33.5	1.4	3-5	2.3	203,500	13.8	6° 34′	11.5
5	9.0	26.8	1.2	5-10	2.4	390,800	26.5	11° 40′	20.6
10	6.6	19.6	0.8	10-15.2	6.6	181,000	12.2	2° 35′	4.5
					Total..	1,478,500			

Lac La Belle.

Lac la Belle is somewhat irregular in outline and the basin is made up of three fairly distinct pits. (See map XII.) The two southeast pits are connected by water which is more than 6 m. (20 ft.) deep but the water connecting these with the northwestern pit is less than 2 m. (6.5 ft.) deep. The lake possesses two small islands known respectively as Islandale and Round island. The area of the former is 3 ha. (7.5 a.) and of the latter 1.3 ha. (3.2 a.).

The south and west shores of the lake have a gentle slope and have none of the characteristics of a plain. They show clearly the topography of ground moraine. On the north side of the lake there are some kames and where these border the lake the shores have the usual kame steepness. There are also two prominent areas of low land along the north shore of the lake.

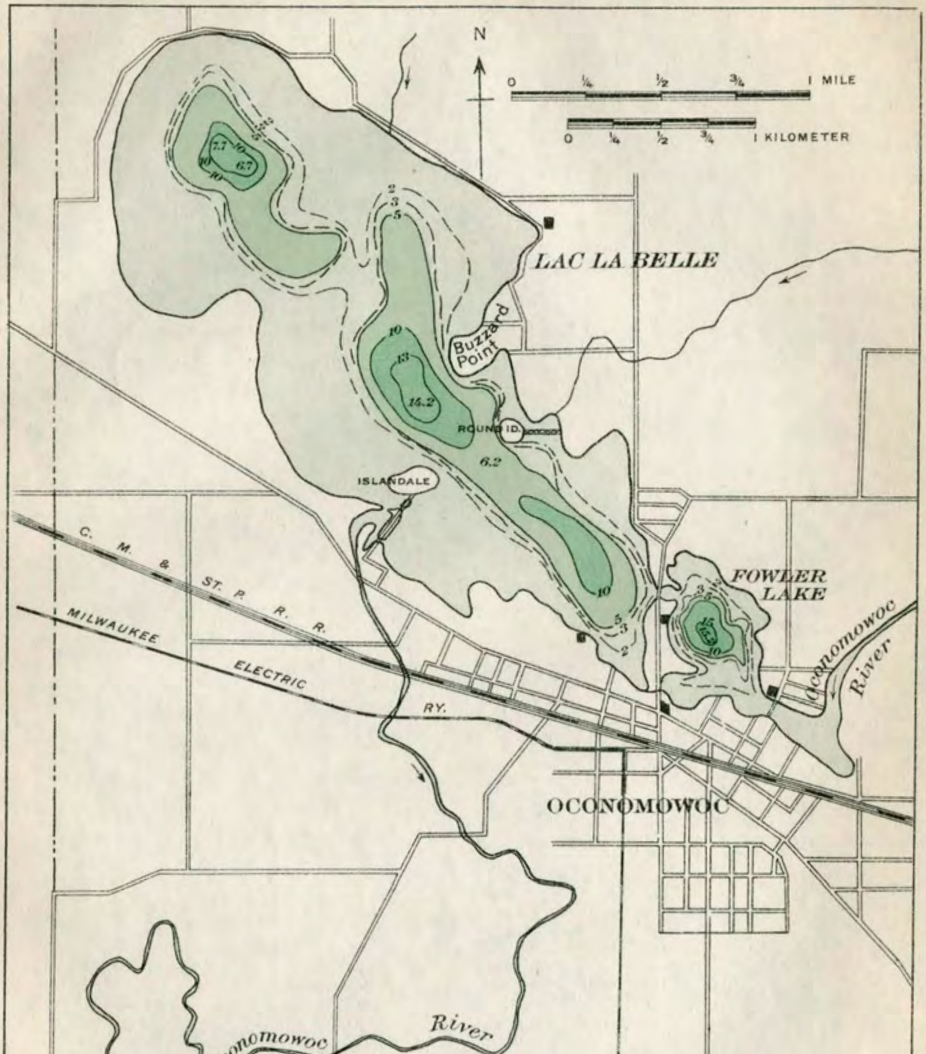
The more prominent peninsulas are being worn away by the waves, but very few of them are retreating rapidly enough to prevent the growth of vegetation on the faces of the cliffs. The most rugged cliff is found on the peninsula situated on the south side of the lake toward the west end. The face of this headland is almost vertical. The material derived from it has been transferred along the shore both to the south and to the west where it has been built into beach ridges. These ridges have been subjected to much pushing by the ice and their position has been shifted as a result of the continued cutting of the headland.

At the head of the bay west of the peninsula, there is an abandoned cliff which is now covered with grass. Not only has the cutting been stopped at this point, but various forms of the larger aquatic plants are now advancing into the lake.

There are prominent beach ridges fronting the lowlands which border the bay north of Buzzard point.

Typical ice ramparts are found along the west and northwest shores of the lake. Many of the beach ridges have been modified by the pushing of the ice.

The waters of the Oconomowoc river enter Lac la Belle at the east end and leave near the middle of the south side. The lake also receives two small affluents on the north side.



HYDROGRAPHIC MAP
OF
LAC LA BELLE AND FOWLER LAKE

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LAC LA BELLE.

T. 8 N., R. XVII E.		Mean depth	3.3 m.
Length	4.44 km.	Length of shoreline	12.5 km.
Breadth	1.80 km.	Shore development	1.64
Area	460.5 ha.	Mean slope of bottom..	0° 53′
Maximum depth	14.2 m.	Number of soundings ..	102

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	460.5	100.0	12.5	0–2	259.9	6,435,500	42.4	0° 30′	0.8
2	200.6	43.3	9.9	2–3	53.0	1,734,300	11.4	1° 4′	1.8
3	147.6	32.0	9.7	3–5	27.6	2,671,000	17.6	3° 46′	6.6
5	120.0	26.0	8.5	5–10	65.6	3,681,900	24.3	2° 14′	3.9
10[1]	35.6	7.7	1.7	[1]10–12.2	35.6	261,000	1.7	0° 45′	1.3
10[2]	18.8	4.1	2.0	[2]10–13	12.7	356,700	2.4	1° 49′	3.2
13	6.1	1.4	1.0	13–14.2	6.1	24,600	0.2	0° 54′	1.5
					Total..	15,165,000			

[1] East basin of lake. [2] Middle basin of lake.

SILVER LAKE.

Formerly the water of this lake stood nearly a meter above its present level and at that time, the overflow was discharged through a small stream into the Oconomowoc river. But the lake is now below the overflow stage. (See maps IX and XIV.)

The shores of the eastern half of Silver lake are steep and kame-like as this portion of the lake lies in the area of kames and pitted plains; the western half, however, lies within the ground moraine area and its shores have a gentle slope, being low and swampy in places.

The fall in level has left the former cliffs well above the water and the shore processes now in progress have to do with the former marginal shelves. An interesting feature which is characteristic of falling levels, is found along much of the north shore. Several meters off shore, there is a typical wave-built barrier which is separated from the former shore by lagoons. On the east and south sides the low portions of the shore or hollows are fronted by large gravel beach ridges. An especially good one is found on the west side of the prominent peninsula which indents the south side of the lake.

SILVER LAKE.

T. 7 N., R. XVI E.

Length	1.56 km.	Mean depth	4.8 m.
Breadth	0.90 km.	Length of shoreline	4.6 km.
Area	93.9 ha.	Shore development	1.35
Maximum depth	13.4 m.	Mean slope of bottom	1° 44′
		Number of soundings	117

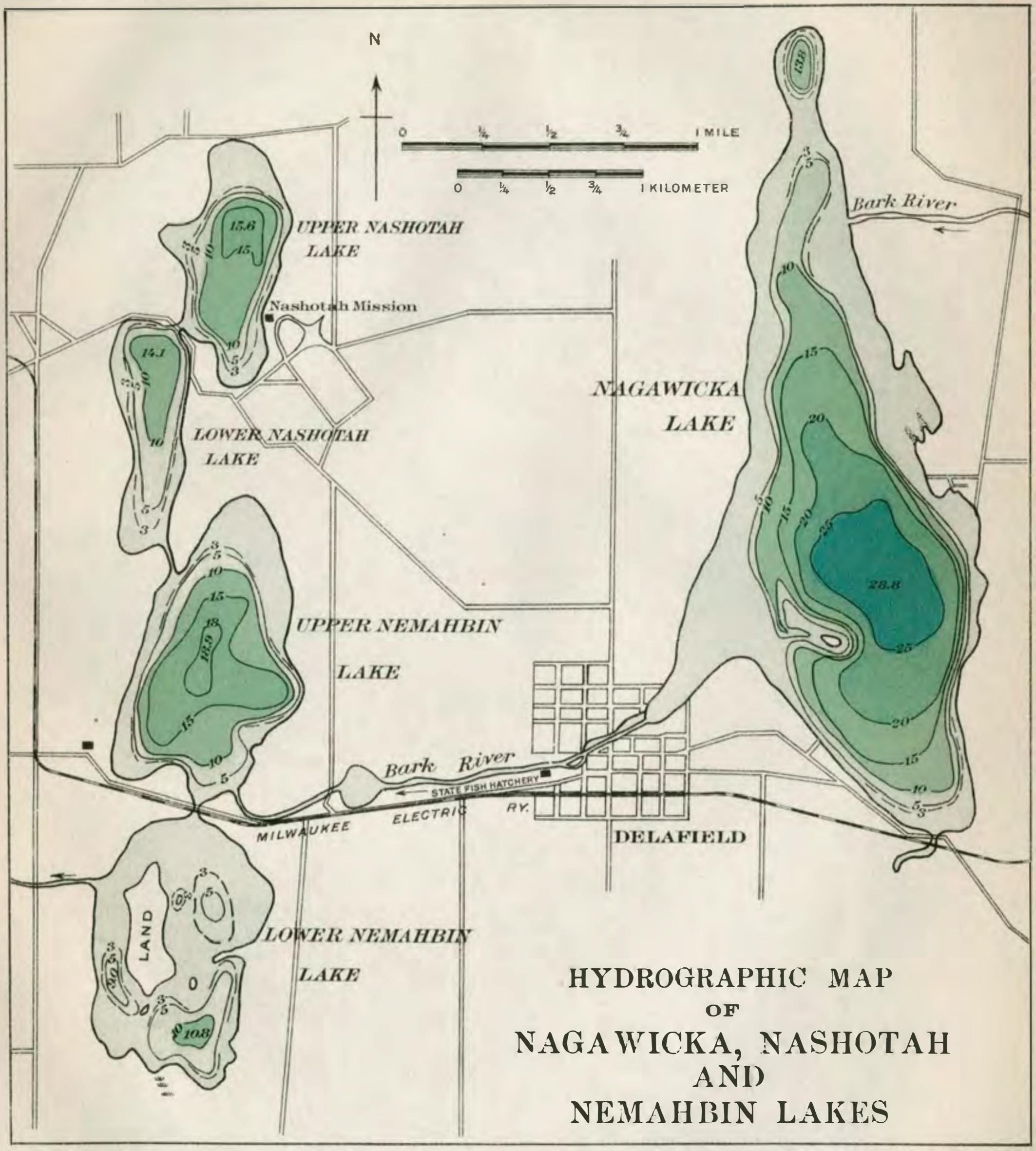
Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	93.9	100.0	4.6	0-3	46.3	2,083,200	46.3	1° 31′	2.6
3	47.6	50.6	3.5	3-5	10.4	846,200	18.8	3° 44′	6.5
5	37.2	39.6	3.2	5-10	20.2	1,323,900	29.4	3° 53′	6.8
10	17.0	18.1	2.3	10-12	11.2	218,500	4.9	1° 56′	3.3
12	5.8	6.2	1.4	12-13.4	5.8	27,200	0.6	1° 0′	1.6
					Total..	4,499,000			

Nashotah-Nemahbin Lakes.

The four lakes of this group have their main axis elongated in a north-south direction and together they form a chain with a maximum length of about 4.8 km. (3 mi.). (See map XIII.) The direction of the chain is parallel to that of the North-Nagawicka lake chain, and it is also parallel to the position of the front of the retreating Green Bay glacier.

The Bark river enters Upper Nemahbin lake at the southeast corner and leaves Lower Nemahbin on the southwest side. These two lakes and Lower Nashotah have the same level, but an obstruction in the outlet of Upper Nashotah, maintains its water more than half a meter higher. The two Nashotahs are fed by springs and the surplus water drains southward into Upper Nemahbin lake. The various lakes are connected by streams whose immediate banks are low and more less marshy.

For the most part the shores of these four lakes may be characterized as steep kame slopes, rising to a greater height on the east than on the west side of the chain. In only one place on the west side do the shores reach a greater height than 6 m. to 8 m. (20 ft. to 26 ft.) above the level of the water, but on the east side they reach an altitude of 10 m. (33 ft.) to more than 20 m. (65 ft.) in some places. Upper Nashotah



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and Upper Nemahbin lakes have a small amount of swampy shore, but the other two lakes are free from swamp.

Upper Nashotah. Along the shores of this lake slopes alternate with flats which consist of kettles that have been partially filled with vegetable débris. A comparatively small amount of erosion has taken place, the most conspicuous example being found on the north side of the prominent bay which is situated about the middle of the west side. The material obtained from this cliff has been used in constructing a beach ridge in the bay, the largest beach structure on the lake.

Lower Nashotah lake. The shores are more uniformly steep, especially along the northwest side. Most of the cliffs are now fronted by bands of gravelly strand indicating a falling level, and their bases lie about half a meter above the water. The largest amount of erosion has taken place at the north end of the east side.

Upper Nemahbin lake. Owing to the larger size of this lake, the shore processes are much more vigorous than in the Nashotah lakes. At the north end there is a rather broad, wave-built terrace with three successive ridges. These ridges have been disturbed somewhat by the pushing of ice. Similar ridges which have been built by the combined action of water and ice are found across the front of several hollows on the east side. Near the inlet is a prominent headland which was once an island. A large bar was built out to the north end of this island and was raised above the water. Then the decline in the water level and the accumulation of vegetable débris converted the onetime bay behind the ridge and island into a swamp. A strip of low land extends north from this lake to Upper Nashotah and it may represent a former direct connection between these two lakes.

Lower Nemahbin lake. The bluffs show evidences of former cutting but not much at the present time. There are some good beaches along the southeast and southwest shores. Much of this lake is shallow and filled with growths of the larger aquatic plants which interfere greatly with wave action. Its surface is broken by three islands, a large one and two small ones. The area of the former is about 12.7 ha. (31.5 a.) the combined area of the latter is 0.4 ha. (1 a.).

The ice has not formed any typical ramparts along the shore of any of these lakes, but it has modified some of the beach ridges and has also constructed narrow ice-push terraces at the bases of the cliffs. The best example of this kind of terrace is found at the northwest corner of Upper Nemahbin lake where there is a structure of this sort about half a kilometer long with almost a uniform height of three-quarters of a meter.

UPPER NASHOTAH LAKE.

T. 7 N., R. XVII E.

Length	1.30 km.	Mean depth	7.0 m.
Breadth	0.64 km.	Length of shoreline	3.5 km.
Area	55.4 ha.	Shore development	1.34
Maximum depth	15.6 m.	Mean slope of bottom..	2° 32′
		Number of soundings ..	44

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	55.4	100.0	3.5	0-3	19.9	1,330,400	34.3	2° 33′	4.4
3	35.5	64.1	2.4	3-5	6.0	648,200	16.7	4° 30′	7.9
5	29.5	53.2	2.3	5-10	7.8	1,271,600	32.7	7° 53′	13.8
10	21.7	39.2	2.0	10-15	16.5	624,500	16.0	2° 37′	4.6
15	5.2	9.4	1.0	15-15.6	5.2	10,300	0.3	0° 20′	0.6
					Total..	3,885,000			

LOWER NASHOTAH LAKE.

T. 7 N., R. XVII E.

Length	1.27 km.	Mean depth	6.1 m.
Breadth	0.40 km.	Length of shoreline	3.0 km.
Area	40.6 ha.	Shore development	1.35
Maximum depth	14.1 m.	Mean slope of bottom..	3° 4′
		Number of soundings ..	35

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	40.6	100.0	3.0	0-3	11.5	1,041,600	41.7	4° 12′	7.4
3	29.1	71.6	2.6	3-5	7.9	501,000	20.0	3° 29′	6.0
5	21.2	52.3	2.2	5-10	9.9	800,500	32.1	5° 18′	9.3
10	11.3	27.9	1.4	10-14.1	11.8	155,000	6.2	1° 50′	2.6
					Total..	2,498,000			

UPPER NEMAHBIN LAKE.

T. 7 N., R. XVII E.		Mean depth	9.0 m.
Length	1.69 km.	Length of shoreline	4.5 km.
Breadth	0.90 km.	Shore development	1.21
Area	109.7 ha.	Mean slope of bottom..	2° 14′
Maximum depth	18.9 m.	Number of soundings ..	81

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	109.7	100.0	4.5	0-3	33.6	2,771,600	27.8	2° 5′	3.6
3	76.1	69.5	3.6	3-5	6.0	1,462,500	14.7	6° 42′	11.7
5	70.1	64.0	3.4	5-10	14.6	3,133,000	31.4	3° 55′	6.8
10	55.5	50.6	3.0	10-15	24.8	2,126,700	21.4	3° 17′	5.7
15	30.7	28.0	2.6	15-18	25.9	318,600	3.2	1° 12′	2.1
18	4.8	4.4	1.0	18-18.9	4.8	145,600	1.5	0° 30′	0.9
					Total..	9,958,000			

LOWER NEMAHBIN LAKE.

T. 7 N., R. XVII E.		Mean depth	2.5 m.
Length	1.49 km.	Length of shoreline ...	4.1 km.
Breadth	0.96 km.	Shore development	1.12
Area	107.5 ha.	Mean slope of botton..	1° 3′
Maximum depth	10.8 m.	Number of soundings ..	48

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	107.5	100.0	4.1	0-3	82.3	1,848,400	69.3	0° 49′	1.4
3	25.2	23.5	3.7	3-5	9.5	403,600	15.1	3° 53′	6.8
5	15.7	14.6	2.8	5-10	13.1	411,000	15.35	2° 52′	5.0
10	2.6	2.4	0.6	10-10.8	2.6	7,000	0.25	0° 32′	0.9
					Total..	2,670,000			

Crooked, Otis and Genesee Lakes.

Crooked lake. This is a small, irregular body of water which is shallow. (See maps IX and XIV.) There are two small islands in the northern part whose combined areas are 0.5 ha. (1.3 a.). The waters of Bark river pass through the lake, both inlet and outlet being situated on the east side near the south end.

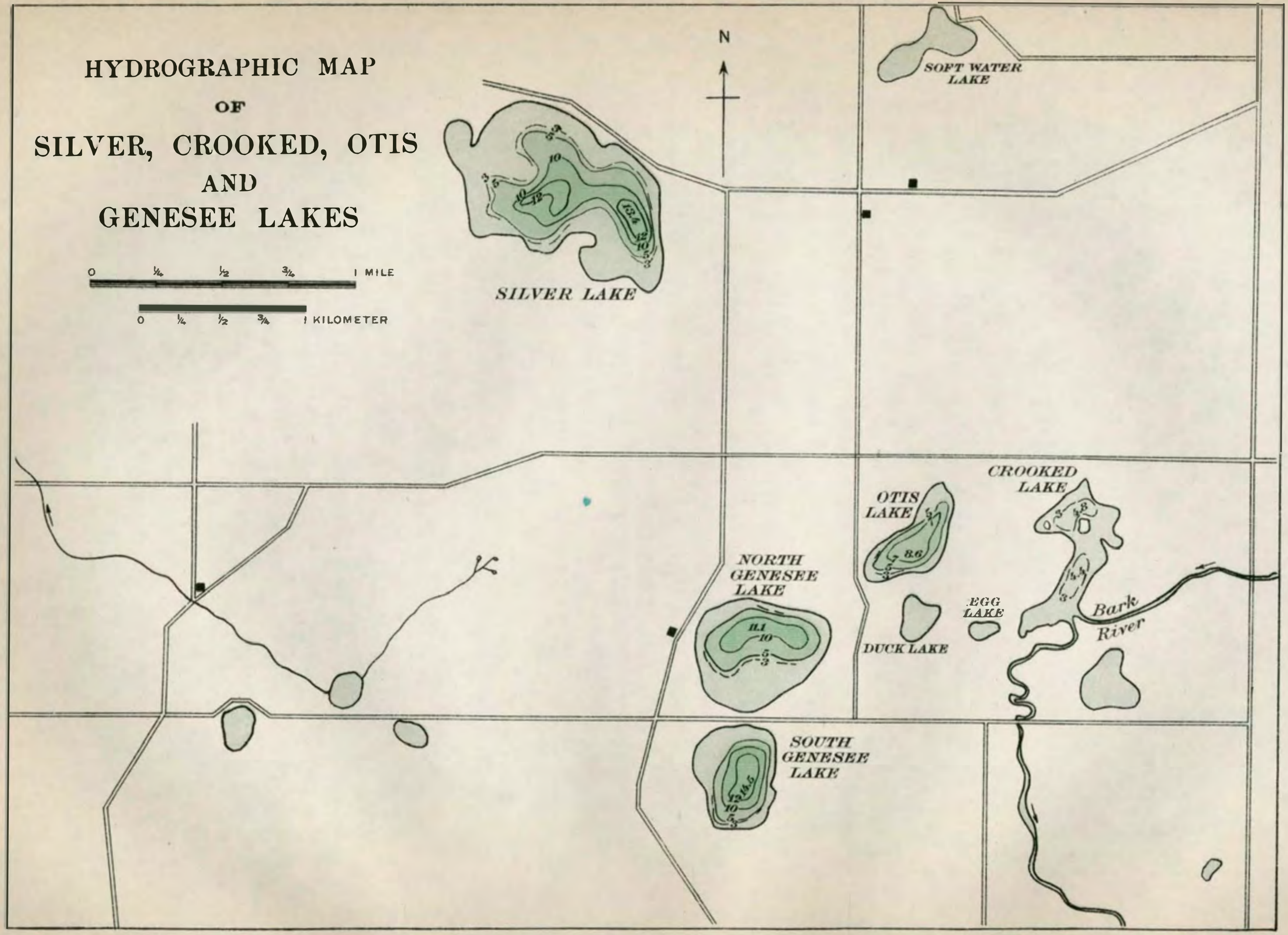
The shores are low and rather swampy. They do not rise to a height of 5 m. (16 ft.) above the water for some distance away from the lake.

Otis and Genesee lakes.—These lakes are situated within the basin of the Bark river, but they have neither stream inlet nor outlet. (See maps IX and XIV.)

The shores of Otis lake are fairly low with swampy areas at the north end and also at the southwest end.

The shores of the Genesee lakes also are low with swampy areas on the west side and at the south end of South Genesee lake. These two lakes occupy simple ice pits and are separated by a ridge composed of sand and gravel. Their waters have been subject to rather wide variations in level and as a result the beach features have been unusually well developed for such small bodies of water. A corresponding wide marginal zone has also been subject to the beach processes. The chief beach structures lie well above the present level, thus indicating a higher stage of water during their formation. The most prominent beach ridges are situated at the east end of the ridge which separates the two lakes. They are continuous with the ridge, are composed of the same material, and have the same height. On the west side of the lakes also, there are beach ridges which have been modified somewhat by the pushing of ice. There is a sand dune about 6 m. (20 ft.) high and from 100 m. (328 ft.) to nearly 200 m. wide, situated on the east side of the south lake.

The level of the water in the north lake is about a third of a meter above that of the south lake. The waters of both probably escape southward by percolation.



A HOEN & CO BALTIMORE

CROOKED LAKE.

T. 7 N., R. XVII E.

Length	1.08 km.	Mean depth	1.9 m.
Breadth	0.50 km.	Length of shoreline	2.9 km.
Area	22.2 ha.	Shore development	1.75
Maximum depth	4.8 m.	Mean slope of bottom..	1° 7′
		Number of soundings ..	53

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	22.2	100.0	2.9	0–3	16.4	394,000	92.5	2° 12′	3.8
3	5.8	26.3	1.2	3–4.8	5.8	31,000	7.5	1° 6′	1.9
					Total..	425,000			

OTIS LAKE.

T. 7 N., R. XVII E.

Length	0.70 km.	Mean depth	4.9 m.
Breadth	0.60 km.	Length of shoreline ...	1.9 km.
Area	16.2 ha.	Shore development	1.30
Maximum depth	8.6 m.	Mean slope of bottom..	2° 57′
		Number of soundings ..	45

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	16.2	100.0	1.9	0–3	5.7	397,600	50.3	5° 3′	8.8
3	10.5	65.2	1.5	3–5	1.3	197,400	25.1	12° 26′	2.2
5	9.2	57.1	1.4	5–8	5.5	188,000	23.9	3° 38′	6.3
8	3.7	23.1	1.0	8–8.6	3.7	6,000	0.7	0° 37′	1.0
					Total..	789,000			

SOUTH GENESEE LAKE.

T. 7 N., R. XVII E.

Length	0.64 km.	Mean depth	6.75 m.
Breadth	0.48 km.	Length of shoreline	1.9 km.
Area	25.4 ha.	Shore development	1.05
Maximum depth	14.5 m.	Mean slope of bottom	3° 30′
		Number of soundings	19

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	25.4	100.0	1.9	0–5	10.8	987,000	57.6	4° 18′	7.5
5	14.6	57.2	1.4	5–10	5.7	581,000	33.8	6° 11′	10.8
10	8.9	28.6	1.1	10–12	5.4	120,500	7.0	2° 2′	3.5
12	3.5	14.0	0.8	12–14.5	3.5	28,500	1.6	1° 37′	2.8
					Total..	1,717,000			

NORTH GENESEE LAKE.

T. 7 N., R. XVII E.

Length	0.82 km.	Mean depth	4.5 m.
Breadth	0.67 km.	Length of shoreline	2.4 km.
Area	41.3 ha.	Shore development	1.06
Maximum depth	11.1 m.	Mean slope of bottom	1° 56′
		Number of soundings	23

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	41.3	100.0	2.4	0–3	19.8	926,000	49.6	1° 52′	3.2
3	21.5	52.1	1.9	3–5	5.3	376,000	20.2	3° 58′	6.9
5	16.2	39.2	1.8	5–10	10.0	538,500	28.9	4° 26′	7.7
10	6.2	15.0	1.4	10–11.1	6.2	24,500	1.3	0° 47′	1.3
					Total..	1,865,000			

NAGAWICKA LAKE.

The long axis of Nagawicka lake extends in a north-south direction and the basin consists of two parts. (See maps IX and XIII.) The small northern basin has a maximum depth of 14.7 m. (45 ft.) and is connected with the main part of the lake by a narrow, shallow thoroughfare. This channel owes its existence to the dam in the outlet of the main basin which maintains the water about 1.8 m. (6 ft.) above its former level. The larger, southern portion has a maximum depth of 28.8 m. (94.5 ft.). This is the greatest depth found in the lakes of this district, but Okauchee and Pine lakes are close rivals. The regularity of the main basin is broken by an island which is situated in the southwestern part and which has an area of about 1.2 ha. (3 a.). The deepest water lies a short distance northeast of this island.

The rise in the water level caused by the dam in the outlet flooded rather wide terraces at the inlet, at the outlet, along the west side, and at the north end. These shallow margins are now covered with rather dense growths of the larger aquatic plants which give the borders a marshy appearance. Part of the valley of a small affluent at the south end has been flooded also, and now forms a similar marshy area.

Shores. About half the coast line of the lake is bordered by shores which have the usual kame steepness. Back of the submerged terrace on the west side the shores rise rather abruptly to a height of 10 m. to 12 m. (33 ft. to 40 ft.) or more above the lake. On the east side the banks rise rapidly to a height of 20 m. (65 ft.) toward the north end, and to nearly double this height towards the south end. There is a long stretch of low shore on this side which extends southward from the inlet where the adjacent plain rises only a very few meters above the surface of the lake.

The west shore of the lake is protected against the action of waves by the vegetation which thrives in the shoal water. But waves and currents are actively at work along practically all of the east side of the lake. The rise of the water has set these agents at work at a new horizon and the present shore has a very youthful appearance. Along the south half of the east side the shore is being cut rather rapidly, producing steep cliffs which are bare of vegetation in places. The material derived from the cliffs is used in building a new marginal terrace over the old one. As yet this terrace is not very wide because the water descends rather rapidly so that a great amount of material is required for the shelf. A portion of the old terrace is still found beyond the edge of the new shelf.

The bay lying north of the peninsula which indents the middle of the east side is being spanned by a spit which extends northward from the outer edge of this peninsula. To the east of this spit is another which was built when the lake was young and had about the same level as at present, but work has not been renewed upon it since the dam has restored the former water level.

The bay lying southeast of this peninsula is also being spanned by a spit. The shallow area which connects the island in the southwestern part of the lake with the mainland, is an original feature of the bottom and was not produced by the agency of the water.

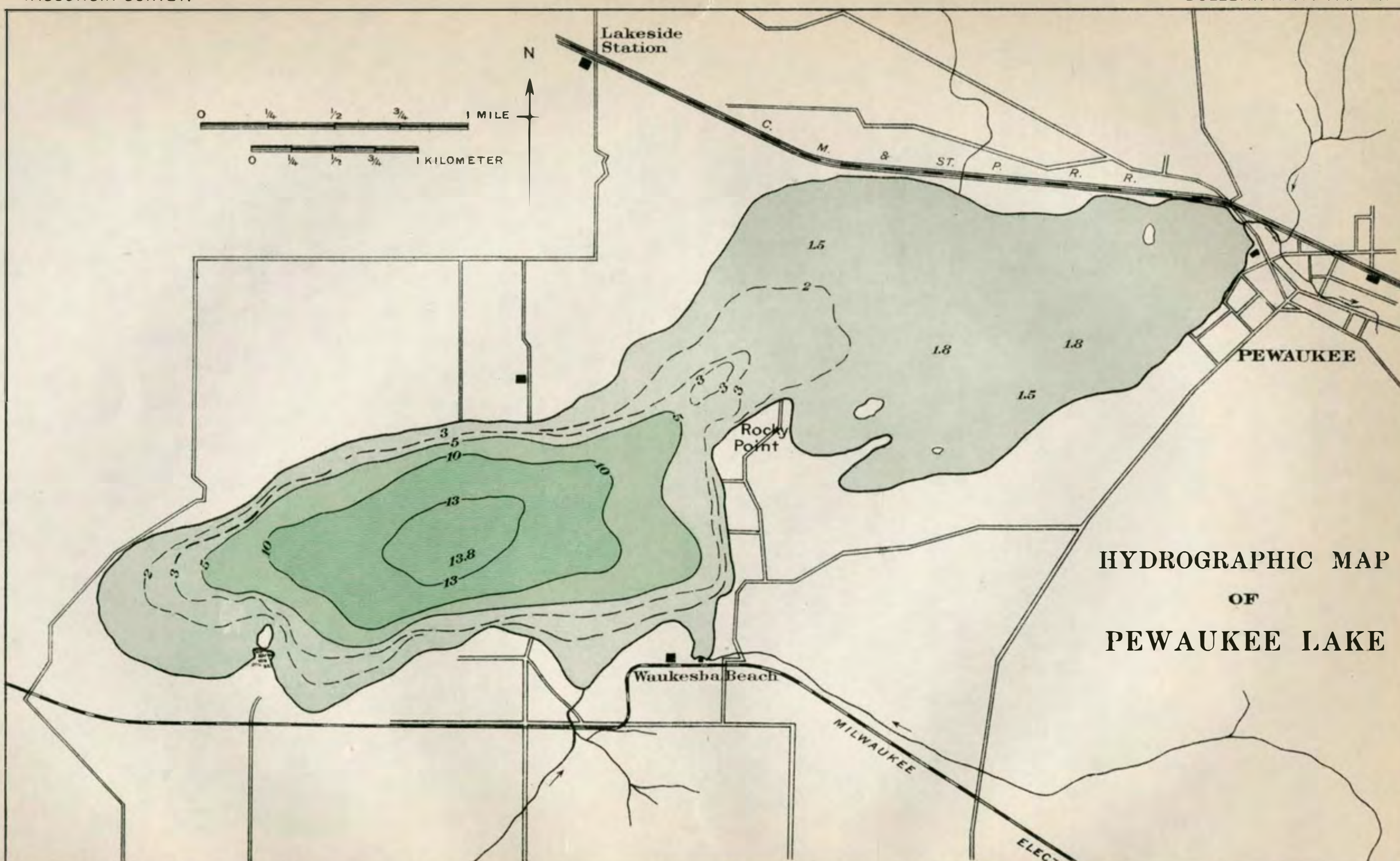
Some ice ramparts are found along the low shore extending southward from the outlet, but they have been partly cut away in the improvement of private grounds.

Nagawicka lake lies in the course of the Bark river which enters it on the east side near the north end and leaves on the west side toward the south end. Also a small stream flows into the southern end of the lake.

NAGAWICKA LAKE.
T. 7 N., R. XVIII E.

Length	4.42	km.
Breadth	1.80	km.
Area	371.5	ha.
Maximum depth	28.8	m.
Mean depth	11.0	m.
Length of shoreline	11.3	km.
Shore development	1.65	
Mean slipe of bottom	2° 25′	
Number of soundings	223	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	371.5	100.0	11.3	0–3	131.9	9,094,000	22.2	1° 18′	2.3
3	239.6	64.5	9.3	3–5	13.0	4,664,000	11.4	7° 51′	13.8
5	226.6	61.2	9.1	5–10	40.4	10,313,000	25.2	6° 28′	11.3
10	186.2	50.2	7.8	10–15	53.5	7,935,000	19.4	3° 32′	6.2
15	132.7	35.7	5.5	15–20	42.5	5,539,000	13.5	3° 12′	5.6
20	90.2	24.3	4.1	20–25	56.4	2,987,000	7.3	1° 38′	2.8
25	33.8	9.1	2.3	25–28.8	33.8	429,000	1.0	0° 46′	1.3
					Total..	40,961,000			



HYDROGRAPHIC MAP OF PEWAUKEE LAKE

A. HOEN & CO. BALTIMORE.

Pewaukee Lake.

The basin of this lake consists, in the main, of a preglacial erosion valley, down which the Lake Michigan glacier moved westward, and which was blocked at its west end by the stratified drift associated with the kettle moraine. (See maps IX and XV.)

Shores. In harmony with the fact that Pewaukee lake is stituated in an area of ground moraine, the shores do not possess the steepness of the banks of kame lakes, though they are fairly high in some places. The western half of the north shore rises to a height of 40 m. (130 ft.) or more above the water but this altitude is not reached for nearly a kilometer from the lake. The south shore also rises to a height of 30 m. (100 ft.) or more, but here, too, the slope is quite gradual. The eastern part of the north shore is low and swampy in three places; the same is true of a small area at the west end and of the valleys of two affluents on the south side.

A dam in the outlet maintains the water about 2.1 m. (7 ft.) above its natural level and it is responsible for about half the area of the lake. That is, the depth of the water in the eastern half scarcely exceeds the height of the dam so that this portion was a swamp before the dam was built. This shallow eastern half supports an abundant growth of the larger aquatic plants; these growths produce bogs which may rest loosely on the bottom, or which may rise to the surface and become floating bogs. Shallow water vegetation is rather scarce in the western half of the lake. The three small islands in the eastern half of the lake have a total area of about 2 ha. (5 a.).

The vegetation of the eastern half protects its shores against the action of waves and currents. The comparatively recent raising of the water level has exposed the cliffs of the western half to erosion at a new level and active cutting is now in evidence at several points. Nearly all of the north coast of the west half is eroding more or less, the most active cutting being found at the eastern end where the cliffs are raw and steep. Part of the material derived from the cliffs at this point, is being used for the construction of two spits. The beach at the northwest corner of the lake is sandy as is commonly the case with beaches near the ends of small, elongated lakes.

Most of the south side as far east as Rocky point is faintly cutting. Owing to the youth of the shoreline in its present cycle, this cutting now extends well into the bays. When the salient curves become more rounded, cutting will cease in these bays and bars or beach terraces will be built there.

The waters of Pewaukee lake are derived in part from three small affluents and in part from springs which are found chiefly along the north shore. The outlet, Pewaukee creek, leaves the lake at the eastern end and flows southeastward to the Fox river.

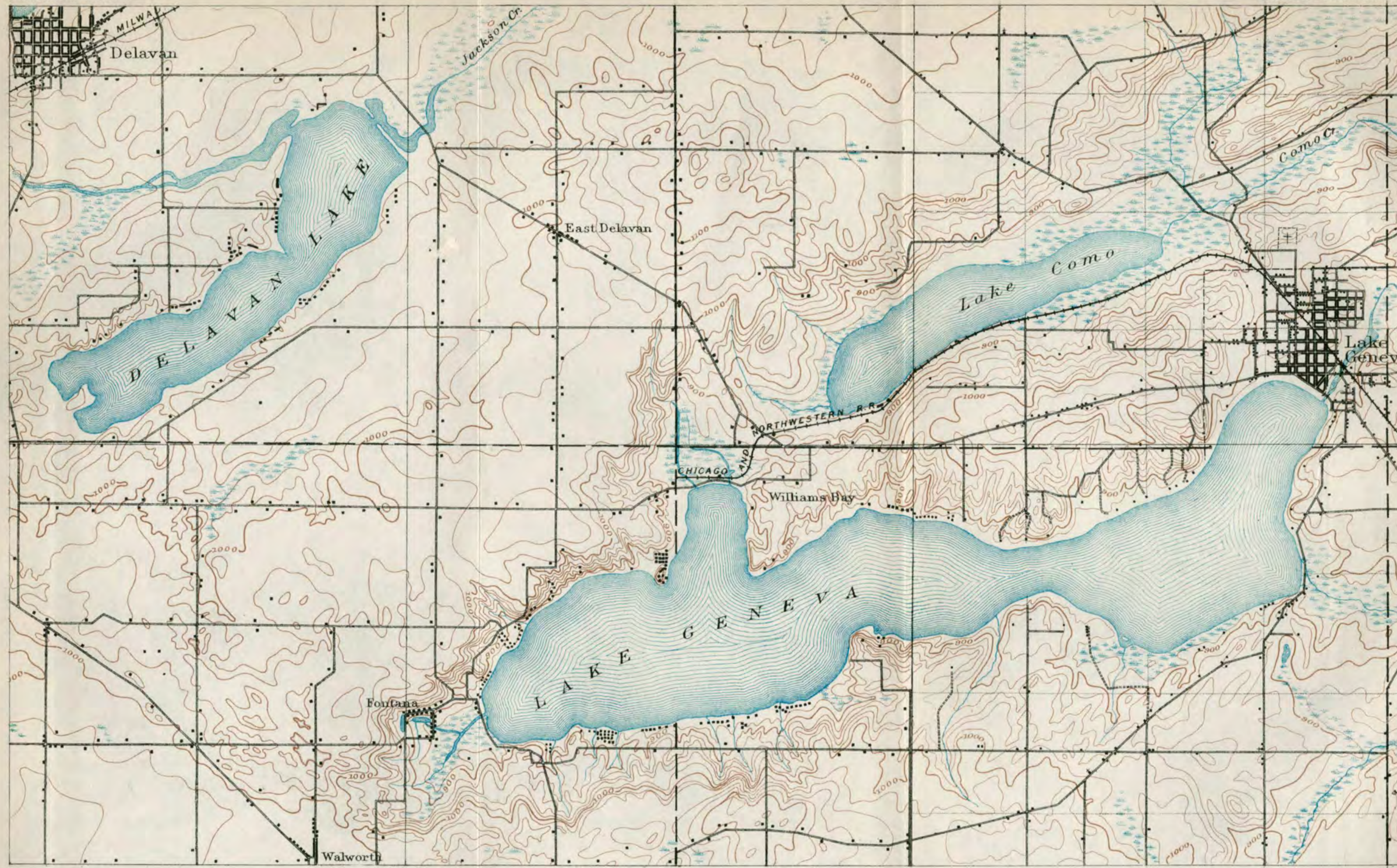
PEWAUKEE LAKE.

T. 7 N., R. XVIII and XIX E.		Mean depth	3.9 m.
Length	7.25 km.	Length of shoreline	19.5 km.
Breadth	1.93 km.	Shore development	1.79
Area	930.3 ha.	Mean slope of bottom	0° 32′
Maximum depth	13.8 m.	Number of soundings	383

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	930.3	100.0	19.5	0-2	506.8	14,823,000	40.4	0° 15′	0.4
2	423.5	38.3	11.0	2-3	97.2	3,734,000	10.2	0° 44′	1.3
3	326.3	33.9	9.0	3-5	72.1	5,790,000	15.8	[illegible]° 18′	2.3
5	254.2	23.0	7.4	5-10	109.3	9,849,000	26.8	1° 39′	2.9
10	144.9	13.1	5.2	10-13	114.5	2,417,000	6.6	0° 34′	1.0
13	30.4	2.7	2.2	13-13.8	30.4	81,000	0.2	0° 9′	0.3
					Total..	36,694,000			

UNSURVEYED LAKES.

A complete survey of three of the larger lakes of the district has not been made. They are lakes Five and Keesus in the northeastern corner of this area and Golden lake in the southwestern portion. (See map IX.) Enough soundings have been made in each, however, to determine approximately the maximum depth. (See table 2, p. 124.) Lake Five is the smallest of the three and possesses neither a stream inlet nor outlet. It is the highest lake in the district, having an altitude of about 296 m. (971 ft.). The surplus waters of both Golden and Keesus lakes reach the Oconomowoc river.



Topography by
U. S. Geological Survey

LAKE GENEVA

CHAPTER V.

GENEVA, COMO AND DELAVAN LAKES.

LAKE GENEVA.

Geology.—A small portion of the western end of lake Geneva and the neighboring shore are underlain by Hudson River shales; but the remainder of the basin, as well as the adjacent shores on the north, south, and east is underlain with Niagara limestone. Well borings show that the bed rock is deeply covered with glacial drift; it is buried so deep, in fact, that it is rarely reached even in deep wells. In the vicinity of the Narrows, the drift reaches a little more than 30 m. (100 ft.) below the lake level and this increases to about 45 m. (150 ft.) at the eastern end of the lake. At various points the drift appears in the form of firmly consolidated sandstone or conglomerate. Typical examples are found in the cliff at Camp Collie and at the water's edge on the south shore just west of the Narrows. (See maps XVI and XVII.)

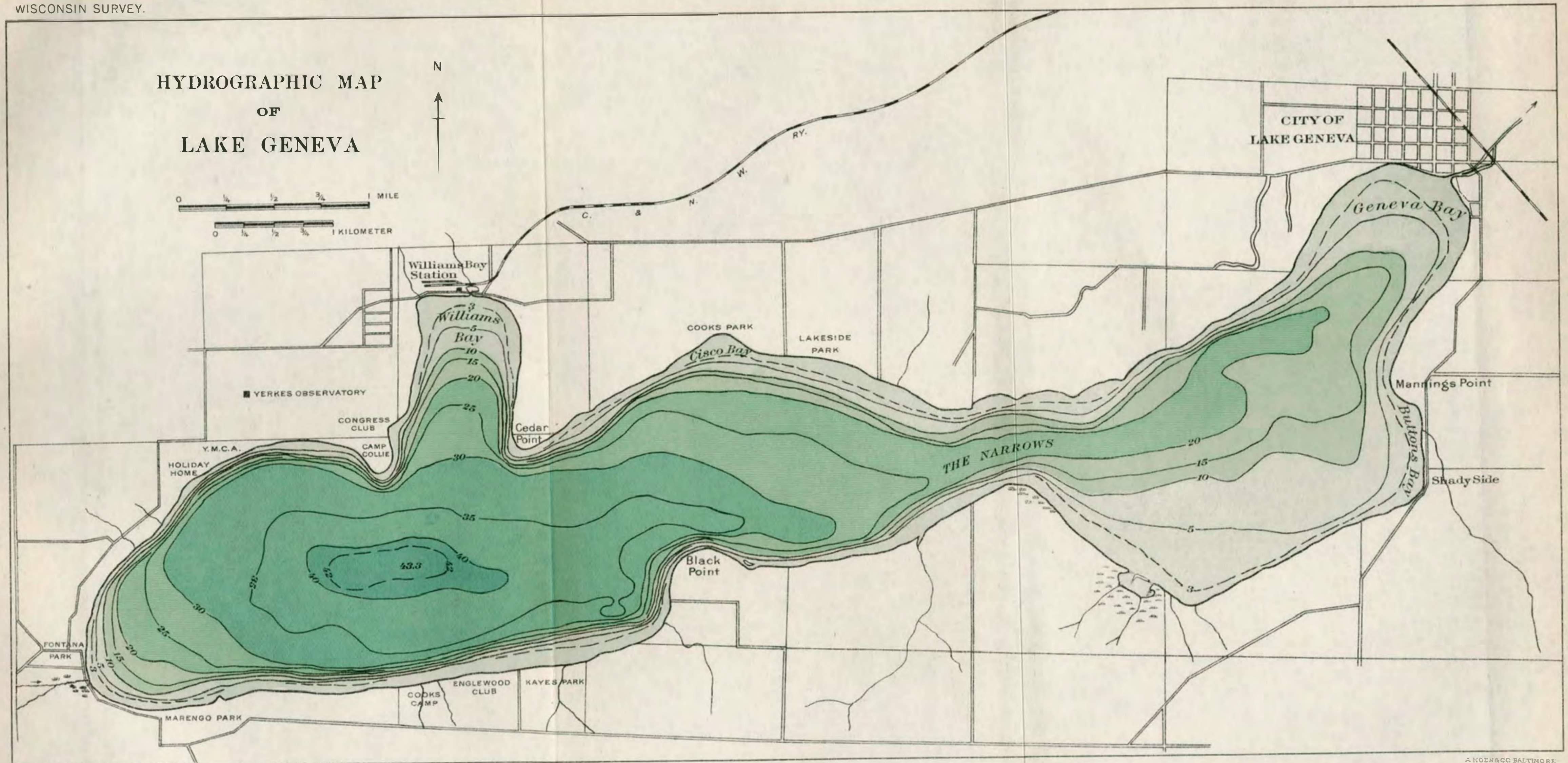
Origin of basin. The basin of the lake seems to owe its existence to three factors, stream erosion and the work done during two separate glacial epochs. A preglacial Geneva valley was formed by a stream which apparently flowed westward at this point. The ice of the earlier Wisconsin epoch moved down this valley, forming a ridge of terminal moraine at the western end of the present lake. During the next ice invasion, a small lobe, known as the Delavan lobe, lying between the Green Bay and Michigan glaciers, reached this region and in the vicinity of lake Geneva the ice moved almost south. This lobe built the high terminal moraine (the Darien moraine) which borders the lake on the south side and curves northward toward the ends. Then the ice front retreated northward from 6 km. to 10 km. (4 mi. to 6 mi.) where another ridge, the Elkhorn terminal moraine, was formed, leaving the basin of lake Geneva unfilled. In just what manner the basin escaped being filled either during or subsequent to the retreat of the ice front is not clearly evident. With the exception of the gravel terrace on which the city of Lake Geneva stands, the topography of the shores does not show the characteristics of a basin preserved by a block of ice.

Shape. The lake is long and narrow, the narrowest part being located about one-third of the length of the lake from the east end. The outline is fairly regular; Williams bay, situated on the north side toward the west end, is the only prominent extension from the main body of water. In most places along the western two-thirds of the lake, the water descends rapidly to a depth of 30 m. (100 ft.) or more. Along a great portion of the northern shore of the eastern third, the offshore slope is steep also. The gentlest bottom slopes are found at the head of Williams bay and at the two ends of the lake. The steepest slope is situated off Black point where it is about 1 to 3.5, or nearly 30 per cent. between the surface and 35 m.

Shores. The shores of lake Geneva are characterized by their steepness and by the very small area of swamp and marsh. (See map XVI.) With the exception of two or three relatively narrow stretches they rise rather rapidly to a height of 30 m. to 40 m. (100 ft. to 130 ft.) or more above the lake, forming an almost complete rim of high wooded slopes. Previous to 1836 the outlet had cut down through the dam of drift at the east end to a depth of 2 m. and lowered the level of the lake by this amount; but an artificial dam was erected in that year which raised the level to its original height and it is still maintained at this point by a dam. The shores do not show any evidences that the water level was ever any higher than the present high water mark.

The raising of the water level, the size of the lake, and the general steepness of the shores and the character of the drift composing them, are the chief factors responsible for the vigorous shore processes now in progress; but these processes are not proceeding with as great rapidity at present as in the past. The predominance of high, steep shores over low ones results in a large predominance of cutting shores over those that are being built. The cliffs vary greatly in freshness; some are steep and so fresh that they are free from vegetation, while others are gentle grassy or wooded slopes with very little erosion at their bases.

The points on either side of the mouth of Williams bay are boldly exposed to the erosive action of the water so that the cliffs here are steep and bare. During the past few years, however, the cutting of the cliff at Camp Collie, the point on the western side of the bay, has been stopped by artificial barriers and vegetation is now getting a foothold. A few cliffs on the south side of the lake are also bare, one just west of the Narrows being especially so.


HYDROGRAPHIC MAP
OF
LAKE GENEVA
N
0 ¼ ½ ¾ 1 MILE
0 ¼ ½ ¾ 1 KILOMETER
C. & N. W. RY.
CITY OF
LAKE GENEVA
Geneva Bay
Williams Bay
Station
Williams Bay
YERKES OBSERVATORY
CONGRESS CLUB
Y.M.C.A.
CAMP COLLIE
HOLIDAY HOME
Cedar Point
COOKS PARK
Cisco Bay
LAKESIDE PARK
THE NARROWS
Mannings Point
Buttons Bay
Shady Side
Black Point
43.3
FONTANA PARK
MARENGO PARK
COOKS CAMP
ENGLEWOOD CLUB
KAYES PARK
A. HOEN & CO. BALTIMORE

There are several good examples of steep cliffs which have been abandoned; the bases of these cliffs now lie from only a few meters to 100 m. (328 ft.) or more back of the water's edge. A few small examples are found between Camp Collie and the west end of the lake, but the best examples are situated on the south side of the lake, one about half a kilometer east of the mouth of Fontana creek and another just southeast of the Narrows.

The built beaches have nearly all reached an advanced stage of maturity. All of the large bars have been raised above the water and the bays which they cut off from the lake have advanced to the stage of swamp or marshy meadow. Only four such features are found along the shores of lake Geneva. These are located respectively at the west end of the lake, at the head of Williams bay, at the head of Buttons bay, and on the south side just southeast of the Narrows. About a kilometer southeast of the Narrows, there is a more youthful beach structure. At this point a small bay is being spanned by a bar, but the lagoon behind the bar is still connected with the lake by two passages which are kept open, apparently, by the flood waters of small streams flowing into the lagoon. The bar is narrow and the northwestern ends of the segments formed by the passages are turned at right angles into the lagoon, thus forming hooks.

Attention should also be called to the cuspate form of the shoreline on the north side of the Narrows. The four outstanding points are built structures whose form and position have been determined by waves and currents which pass through the Narrows during the prevalence of westerly winds. This is the best example of rhythmically arranged cusps which has yet been noted on the lakes of Wisconsin.

Ice ramparts are found in many places but all of them are short because there are no long stretches of shore which are favorable for the formation of such structures.

Sources of water. Lake Geneva receives its supply of water from a a large number of springs located on its shores and from several small, spring-fed streams. The village of Fontana at the west end of the lake derives its name from the numerous springs found in this locality. The volume of water derived from one small group of these springs is sufficient to furnish 15 horse power to a mill. The water supply of the village is derived from another group of springs. The waters of these and many other springs unite to form the small stream which enters the western end of the lake. White river is the outlet of lake Geneva. It emerges from Geneva bay and flows northeastward to join the Fox river of the Mississippi system.

LAKE GENEVA.

T. 1 and 2 N., R. XVI and XVII E.		Mean depth	19.7 m.
Length	12.10 km.	Length of shoreline ...	32.4 km.
Breadth	3.22 km.	Shore development	1.94
Area	22.10 sq. km.	Mean slope of bottom..	1° 58′
Maximum depth	43.3 m.	Number of soundings ..	656

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Km.	Per cent of total.	Kilo-meters.	Meters.	Km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	22.1	100.0	32.4	0–3	2.6	62,380,000	14.4	2° 6′	3.7
3	19.5	88.2	30.4	3–5	1.8	37,240,000	8.5	1° 53′	3.3
5	17.7	80.0	29.1	5–10	2.6	82,000,000	18.8	3° 8′	5.5
10	15.1	68.5	27.4	10–15	1.6	71,466,000	16.5	4° 40′	8.1
15	13.5	61.0	26.0	15–20	2.3	61,734,000	14.2	3° 15′	5.7
20	11.2	50.7	24.8	20–25	2.6	49,541,000	11.4	2° 12′	3.8
25	8.6	39.0	15.7	25–30	2.1	37,558,000	8.6	1° 54′	3.3
30	6.5	29.3	12.9	30–35	3.4	23,470,000	5.4	0° 59′	1.7
35	3.1	14.1	10.2	35–40	2.5	8,528,000	2.0	1° 20′	2.3
40	0.6	2.7	3.8	40–43.3	0.6	856,000	0.2	1° 2′	1.8
					Total..	434,773,000			

Lake Como.

Lake Como lies about 3 km. (about 2 mi.) north of lake Geneva and it occupies a shallow basin in a longitudinal trough in the Elkhorn moraine. The floor of lake Como is level and the maximum depth of the water is about 2 m. (6.5 ft.). It is filled with a dense growth of the larger aquatic plants in summer. (See map XVI, and table No. 2, p. 124.) Its surplus waters are discharged into the White river.

Delavan Lake.

Delavan lake is long and fairly narrow, its longest axis has a northeast-southwest trend. (See maps XVI and XVIII.) Its basin lies wholly within a narrow belt that is underlain with Hudson River shales, but these shales are deeply covered with drift material. The symmetry of the bottom is not broken by any shoal areas and the maximum depth of water is found near the middle of the lake. At both ends the bottom has a gentle slope but the descent on both sides of the middle third of the lake is much steeper. At one point near the middle of the south side there is a maximum slope of 1 to 2.6, or 38.4 per cent. between 3 m. (10 ft.) and 12 m. (40 ft.). The southwestern end is separated into two parts by a prominent peninsula.

Shores. The shores are not as high as those of lake Geneva. At the northeast end they do not reach a height of 10 m. (33 ft.) above the water for a considerable distance away from the lake, but they are somewhat steeper toward the southwestern end, rising to a height of about 15 m. (50 ft.) within a relatively short distance of the lake. The shore features have reached a more mature stage than those of lake Geneva, because the banks are composed of gravelly material and have a more moderate slope. But cutting is still a very prominent feature of the shore processes in spite of this maturity. There are several abandoned cliffs, however, at whose bases building is now taking place instead of cutting.

More or less active cutting prevails along about the middle two-thirds of both sides of the lake. In a few places, the cliffs are steep and free from vegetation, but for the most part, the erosion is slow enough to permit the growth of plants. In many places, also, the shore is protected by artificial walls that have been erected along private grounds.

The more important building processes are found toward the ends of the lake. At the northeastern end the shore currents have built a long bar across what was formerly the mouth of the principal affluent, Jackson creek, causing this stream to flow northwestward for a considerable distance parallel to the shore before it enters the lake. A shorter bar has been built out from the northern shore toward the southeast to meet the long bar and the two are now separated only by the channel through which the stream enters the lake. At the northwest corner of the lake similar bars are being built out from both sides of the bay at the outlet. The one on the north side of the bay is being extended in a southwesterly direction toward the point where the outlet stream emerges. But the bar on the south side is being built northward, directly across the bay.

Cedar point is an excellent example of a V-shaped bar which at first enclosed a lagoon, but this lagoon has been converted into marsh and swamp. It has been built at a point where the shore of the lake makes a rather abrupt change in its direction from almost east to north. The material of which the bar is composed seems to have been derived chiefly from cliffs to the west of the point where cutting is active. Very little cutting is in progress along the shore north of the point.

At one time active cutting was in progress on both sides of the peninsula at the southwest end of the lake; but modifications in the shoreline caused the cliffs to be abandoned and building processes are now taking place along their fronts. On the north side of the peninsula a spit is being built across the bay and it now covers about half the distance. A large portion of this spit is now above the low water level. On the south side the conditions are such that a large flat about 100 m. (328 ft.) wide has been built instead of a spit. A portion of the bay on the north side of the peninsula is being cut off by a long spit which is being extended from the mainland in a southwesterly direction.

On the south side of the lake, toward the southwest end, two small spits have been built out obliquely from the shore in front of a small bay. This bay receives the waters of a small stream and the oblique position of the spits is doubtless due to the interaction of the current of the stream and the shore currents of the lake.

Aquatic vegetation plays a very important rôle in shore building in Delavan lake. The shallower, protected portions of the lake support luxuriant growths of the large plants and the débris resulting from these growths is a very important factor in converting such areas into swamp. The best examples of such encroachments are found in the bay at the outlet and in the two bays at the southwestern end of the lake.

Jackson creek is the principal affluent of Delavan lake and Turtle creek is the outlet. Both of these streams are located at the northeast end of the lake. Turtle creek is a tributary of the Rock river.

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DELAVAN LAKE.

T. 2 N., R. XVI E.

Length .... 6.00 km.
Breadth .... 1.80 km.
Area ....734.1 ha.
Maximum depth .... 17.2 m.

Mean depth .... 8.0 m.
Length of shoreline ... 19.7 km.
Shore development 2.05
Mean slope of bottom....1° 2′
Number of soundings .. 260

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	734.1	100.0	19.7	0–3	226.2	18,527,000	31.6	1° 15′	2.2
3	507.9	69.2	13.4	3–5	53.3	9,657,000	16.4	2° 47′	4.9
5	454.6	61.8	12.7	5–10	139.9	19,125,000	32.7	2° 21′	4.1
10	314.7	42.9	10.2	10–13	128.9	7,421,000	12.5	1° 12′	2.1
13	185.8	25.3	7.6	13–15	81.6	2,861,000	4.8	1° 15′	2.2
15	104.2	14.3	5.0	15–17	88.8	1,065,000	1.8	0° 51′	1.5
17	15.4	2.1	1.9	17–17.2	15.4	15,000	0.2	0° 12′	0.4
					Total..	58,671,000			

CHAPTER VI.

LAUDERDALE AND BEULAH LAKES.

Lauderdale and Beulah lakes are situated in the northern part of Walworth county. They lie on the eastern side of the kettle moraine near the edge of the Michigan glacier and also near the actual limit of the late Wisconsin ice sheet. In this locality several lines of kames extend northwestward in the direction from which the ice came and within this kame area, there are many lakes whose basins were formed by the burial of masses of ice and the subsequent melting of these remnants. Beulah and Phantom lakes mark the location of one line of these kames, the latter being near its northeastern extremity. (See map XX.) The Lauderdale group lies in a southwestern continuation of the same line, a few kilometers from the axis of the kettle moraine. The zone of kames and pitted plains associated with the interlobate kettle moraine is here much widened on the side toward the Lake Michigan lobe as it is in the Oconomowoc-Waukesha district on the side toward the Green Bay lobe. The plains here are also terraced, even more distinctly than in the latter district. (See chapter IV, p. 37.) The lower and later terraces in this area are toward its southern edge. Complete surveys have been made of only two of these bodies of water, viz. Lauderdale and Beulah lakes. A few soundings have been made in some of the other lakes, such as Pleasant, Potter, Phantom, and Eagle, but the survey was not complete enough for the preparation of hydrographic maps. (See figs. 4, 5 & 6.) The surplus waters of this area reach the Fox river of the Mississippi system. (See fig. 3, p. 8.)

LAUDERDALE LAKES.

The depression occupied by the Lauderdale lakes has an exceedingly irregular outline as if it had been formed by the burial of a number of very irregular masses of ice which left the imprint of their irregularities on the sides of the basin when they melted. The different parts of the depression have their axes elongated in a general northeast-southwest direction. The hydrographic map (XIX) shows that the water occupies three deep pits which are broadly connected by shallow areas. A dam, which is about 2 m. (6.5 ft.) high and which was erected a little before the middle of the nineteenth century, is responsible for the present broad connections between the three parts. Previous to that time they were distinctly separated, and each part was given a separate name, viz., Green, Middle and Mill lakes.

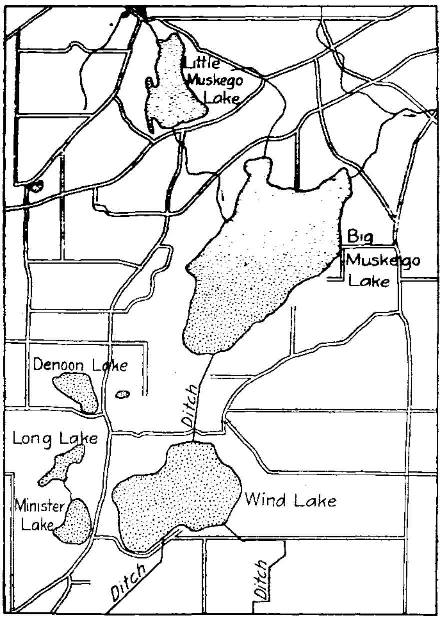


Fig. 4. Sketch map of Muskego lake district. Approximate scale, 1 cm. = 1.8 km.; or 1 in. = 2.9 mi. (From U. S. G. S. map.) See p. 83.

The rise in the water level increased the size of the lakes materially because there were large areas whose elevation above the previous level was less than the height of the dam. These flooded areas consisted of grassy meadows and wooded slopes. The latter are now marked by stumps of the trees killed by flooding. The bottoms of the former meadows, where they are not covered by a subsequent deposit of mire, are composed of the same tough mats of roots passing into peat which constitute the main body of the floating bogs. In the west half of Middle lake, where this is best illustrated, the bottom is marked by vertical walled holes similar to those which may be found among floating bogs, or in swamps which rest upon a semi-liquid foundation.

Thus the former bottom deposits covering these shallow areas indicate that they constituted a part of the lake originally.

The shallow areas are now in the process of being converted into swamps. They support abundant growths of the larger aquatic plants whose remains in successive years will eventually fill them up. The southern extension of Mill lake is a good example of the work of this vegetation. Over much of its area the apparent depth is only about half a meter, yet an oar may be thrust into the loose deposit on the bottom for a distance of a meter or a meter and a half before it meets with much resistance.

The bottoms of the shallow areas which owe their existence to the dam are very flat. The bottom slope of Mill lake is fairly gentle, but

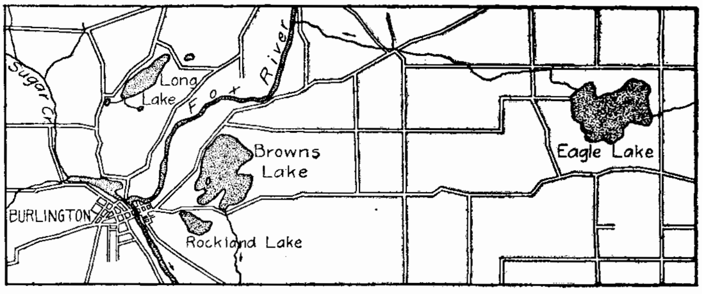


Fig. 5. Sketch map of Browns—Eagle lake district. Approximate scale, 1 cm. = 1.8 km., or 1 in. = 2.9 mi. (From U. S. G. S. map.) See p. 83.

it is much steeper in both Middle and Green lakes, especially between 3 m. (10 ft.) and 12 m. (40 ft.). At one point on the south side of the former lake the gradient between these depths is 1 to 2.6, or more than 38 per cent., while on the latter lake the maximum between these depths is 1 to 3.4, or about 33 per cent.

These lakes possess seven islands whose total area is 6 ha. (15 a.). The rise in the water level caused by the dam produced all of the islands.

Shores.

The shores of the Lauderdale lakes are fairly high and steep. They rise to a height of 8 m. to 20 m. (26 ft. to 65 ft.) above the surface, close to the edge of the lake and are entirely free of swampy or marshy areas.

Green lake.—The three basins are connected by broad channels but these passages are so shallow that there is only a slight circulation of the water through them. (See map XIX.) As a result each lake has its own independent system of shore currents. In comparison with the other two lakes, Green lake has a very small area of shallow water resulting from the artificial raising of the water level, so that practically the whole surface of the lake is involved in the production of waves and currents by the wind. As a consequence these agents are more active here than in the other two bodies of water and shore processes are being prosecuted with much greater vigor. Most of the shores are steep so that they are easily attacked by the waves. Both the northeast and the northwest sides show cliffs which have been eroded rapidly enough to keep them free from vegetation.

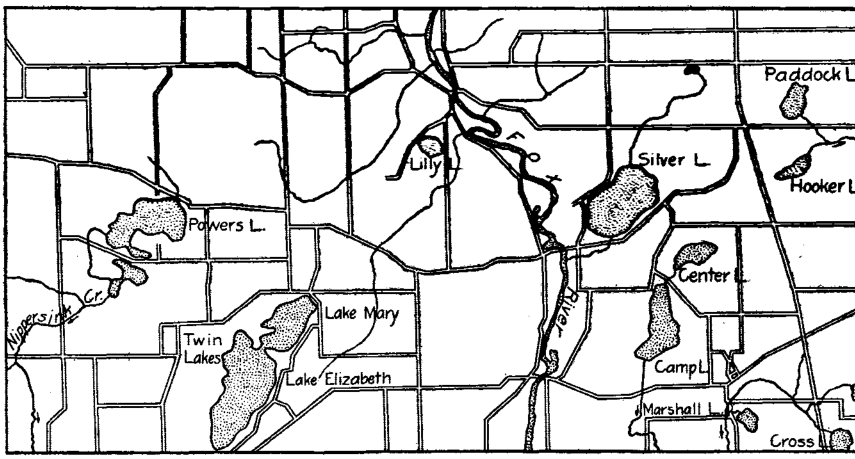


Fig. 6. Sketch map of Twin lakes district. Approximate scale, 1 cm. = 1.8 km., or 1 in. = 2.9 mi. (From U. S. G. S. map.) See p. 83.

Deposition is most active along the east shore. A spit extends south and eastward from Tratts point and the small bay just north of this point has been spanned by a bar. The material for both of these structures was obtained from a cliff just north of this small bay.

A small but clear example of deposition by currents at a salient angle is found on the west side near Ewings landing. A small headland here is too sharp to be turned by the shore currents without some dissipation and consequent loss of load. This has resulted in the construction of a terrace which gives the shoreline a curve instead of an abrupt angle. The passage west of Green island which connects this lake with Middle lake is spanned by a bar on the Green lake side.

Middle lake.—The large westward extension of Middle lake is so shallow and contains such large numbers of the larger aquatic plants, that it most probably contributes very little, if any, toward increasing the action of the waves and currents in the main lake. Omitting this portion, the remainder of the lake is small and the shore processes are correspondingly slight. The most active cutting now in progress is found along the south shore of Stewarts bay. The south side of Green island is being worn away slightly also.

Corresponding to the small amount of erosion, is a small amount of deposition. A poorly formed bar has been built across the narrow channel that once existed at the east end of Green island. Another bar spans this passage on the Green lake side, thus tying the island to the main land by two bars, and the one-time lagoon between them has now been converted into dry land.

Mill lake.—In this lake there are freshly cut banks on both sides of the outlet bay, at the point south of Dunhams bay, and at Wolfs point. Material derived from the first of these cliffs is being used to construct a bar across the outlet bay. Dunhams bay is spanned by a bar whose material was derived from the point to the south of it, and detritus obtained from this cliff and at Wolfs point is being used to extend a spit across the channel between Mill and Middle lakes. This spit extends northwestward from Wolfs point toward Pleasant island, and it now reaches about half way across the channel.

These lakes have no stream affluents, but they receive the waters of a number of springs which are situated chiefly along the western shores. The outlet is located on the east side of Mill lake and is known as Honey creek. It is a tributary of the White river which, in turn, is a tributary of the Fox river.

LAUDERDALE LAKES.

T. 4 N., R. XVI E.
Number of soundings .. 157
Green lake.
Length .... 1.75 km.
Breadth .... 1.06 km.
Area ....112.5 ha.

Maximum depth ..... 17.3 m.
Mean depth .... 7.5 m.
Length of shoreline .. 6.0 km.
Shore development .. 1.56
Mean slope of bottom 2° 11′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	112.5	100.0	6.0	0-3	43.7	2,693,000	31.9	1° 55′	3.3
3	68.8	61.0	3.7	3-5	12.1	1,252,600	14.9	3° 19′	5.8
5	56.7	50.2	3.3	5-10	12.1	2,527,600	30.1	7° 24′	13.0
10	45.0	39.8	2.9	10-15	11.7	1,755,300	20.8	3° 37′	6.3
15	25.6	22.6	2.0	15-17.3	25.6	195,500	2.3	0° 33′	0.9
					Total..	8,424,000			

HYDROGRAPHIC MAP
OF
LAUDERDALE LAKES

A. HOEN & CO. BALTIMORE

Middle Lake.

Length	2.57 km.	Mean depth	2.9 m.
Breadth	0.72 km.	Length of shoreline	8.7 km.
Area	115.0 ha.	Mean slope of bottom	1° 44′
Maximum depth	15.2 m.		

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	115.0	100.0	8.7	0–3	94.8	1,836,400	55.5	1° 0′	1.8
3	20.2	17.6	2.5	3–5	1.4	389,800	11.7	19° 18′	35.0
5	18.8	16.3	2.4	5–10	4.7	818,800	24.7	13° 46′	24.5
10	14.1	12.3	2.2	10–15.2	14.1	266,000	8.1	2° 19′	4.0
					Total..	3,311,000			

Mill lake.

Length	1.20 km.	Mean depth	2.5 m.
Breadth	0.79 km.	Length of shoreline	8.4 km.
Area	120.0 ha.	Shore development	2.26
Maximum depth	15.2 m.	Mean slope of bottom	1° 21′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	120.0	100.0	8.4	0–3	98.9	1,913,000	64.0	0° 55′	1.6
3	21.1	17.5	2.2	3–5	4.9	373,000	12.5	4° 37′	8.1
5	16.2	13.5	1.8	5–10	8.8	577,000	19.3	4° 46′	8.3
10	7.4	6.2	1.1	10–15.2	7.4	124,000	4.2	2° 8′	3.7
					Total..	2,987,000			

Beulah Lake.

Beulah lake is similar in origin and history to the Lauderdale group, and the topography in its vicinity is also characterized by kames and pitted plains. It occupies a series of five pits which have a general northeast-southwest trend (see hydrographic map, XXI) corresponding to the direction of ice movement. These pits are now connected by broad expanses of shallow water, the whole forming a single body. Mill lake occupies a separate (sixth) pit at the northeast end of the chain.

Previous to the changing of the outlet and the erection in it of a dam about 3 m. (10 ft.) high, the five pits of Beulah lake constituted three separate bodies of water corresponding to the portions now designated as Upper, Round, and Lower lakes. The last included three pits. There are several features which indicate that the present water-level maintained by the dam is not very different from that which existed when work was first begun on the shores. The area of Beulah lake was increased materially when the water was raised to its present height, since large areas of low, flat land, much of which was wooded, were flooded.

In the Beulah group, the steepest bottom slopes are found in Upper lake. On the east side of Wilmers point the maximum gradient between the water's edge and the 18 m. (60 ft.) contour is 1 to 2.9, or a little over 34 per cent. The maximum for Mill lake is 1 to 3.9 between the shoreline and the 12 m. (40 ft.) contour. The slope of the bottom in both Booth and East Troy lakes is very gentle.

The shoreline of Beulah lake is extremely irregular, the most irregular part being found on the south side of Lower lake, just west of Broad bay. This is a good illustration of the extremely sinuous shoreline which is produced when water rises upon an area of kames and pits.

The point of land between Lower and Mill lakes is separated from the mainland at its east end by the natural channel connecting these two bodies of water and at its west end, by an artificial channel or canal. This body of land is now called Beulah island. Three former islands have been tied to the mainland by bars which have been raised above the surface of the water, and there yet remain three small islands, two in Round and one in Lower lake, whose combined areas amount to 0.6 ha. (1.5 a.).

Shores. The shores are steep, rising rather abruptly to the plain above, which is 15 m. (50 ft.) or more above the surface of the lake. (See map XX.) Only a very small portion of them is swampy. The

Topography by
U. S. Geological Survey

LAKE BEULAH

A. HOEN & CO. BALTIMORE.

rise in the level has set the water at work on the shores with renewed vigor. The most vigorous cutting is found along the northeastern portion of Lower lake where the cliffs face the westerly and southwesterly winds and the largest expanse of water; it is so rapid on the southwestern side of Beulah island and at Lake View, that the cliffs are kept bare of vegetation. Good examples of breaker terraces are found at the foot of these cliffs, a characteristic accompaniment of fresh cutting in kame gravels. The east end of Twin islands is also being eroded rather rapidly.

Among the built structures is an old bar extending northwest from Wilmers point which was built previous to the erection of the dam. Work on this structure was stopped when the water was raised to its present stage because it now lies below the zone of activity of waves and currents. On the north side of Upper lake near its eastern end, there is a prominent peninsula which is made up of a former island tied to the mainland by a bar.

A spit is now being extended to the northwest from the east-facing cliff of Twin island; another is being built to the northwest from Beulah island across Brooks bay. Gaskells bay at the southeast corner of Lower lake is spanned by a bar.

Beulah lake receives the waters of a few small affluents and of a number of springs which are situated chiefly at the southwestern end. Its surplus waters pass into Mill lake whence they enter the outlet at the northwestern end of this lake. This stream is a tributary of the Mukwonago river, which constitutes a part of the Fox river system.

Mill lake.—The pit occupied by this lake is small and almost simple in form. The shores are steep and high, and are composed of uncompacted kame gravels. Owing to the small size of the lake and to its protection from wind by high, more or less wooded banks, the shores have not been vigorously attacked by the waves. But the ease with which erosion takes place, has enabled the small waves to wear away enough material from the cliffs to construct a new submerged marginal terrace several meters wide.

Booth lake.—This body of water lies southwest of Beulah lake. It is regular in outline and its surface is broken by a small island near the northeastern corner whose area is about 0.25 ha. (0. 6 a.). Its shores are composed of sand and gravel and they are comparatively free from swamps. It has neither a stream inlet nor outlet.

East Troy lake.—This lake is situated a little way east of the middle of Beulah lake. It is more irregular in outline than Booth lake, but its shores are very similar to those of the latter. It is shallow and has an island near its southern side. The area of this island is 0.5 ha. (1.2 a.). A small stream discharges the surplus waters of this lake into Beulah lake.

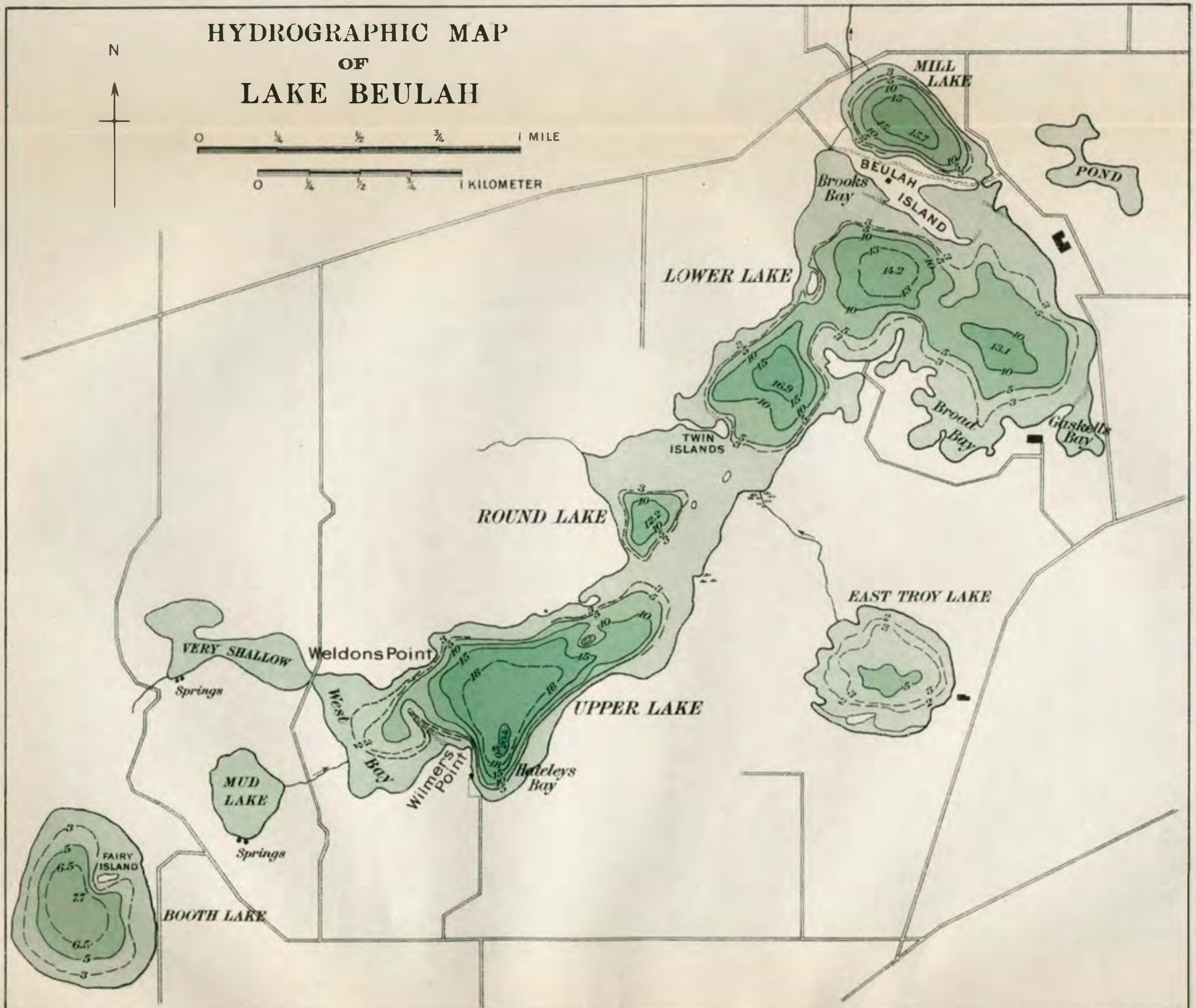
BEULAH LAKE.
T. 4 N., R. XVIII E.
Length .... 4.26 km.
Breadth .... 1.76 km.
Number of soundings .. 170

Upper lake.
Area ....102.4 ha.
Maximum depth ..... 20.4 m.
Mean depth .... 8.0 m.
Length of sholeline .. 8.0 km.
Shore development .. 2.25
Mean slope of bottom 3° 12′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	102.4	100.0	8.0	0-3	39.8	2,451,000	29.9	2° 41′	4.7
3	62.6	61.0	4.4	3-5	11.0	1,141,000	13.9	4° 23′	7.6
5	51.6	50.3	4.0	5-10	13.0	2,249,000	27.5	8° 3′	14.1
10	38.6	37.7	3.4	10-15	12.7	1,603,000	19.6	6° 18′	11.0
15	25.9	25.3	2.3	15-18	11.0	604,000	7.4	3° 2′	5.3
18	14.9	14.5	1.6	18-20.4	14.9	134,000	1.7	0° 43′	1.2
					Total..	8,182,000			

Round lake.
Area .... 39.4 ha.
Maximum depth ..... 12.2 m.
Mean depth .... 2.8 m.
Length of shoreline .. 2.5 km.
Shore development ... 1.11
Mean slope of bottom 1° 51′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	39.4	100.0	2.5	0-3	30.8	664,200	60.5	0° 59′	1.7
3	8.6	22.0	1.0	3-5	1.8	153,600	13.9	5° 24′	9.4
5	6.8	17.2	0.7	5-10	3.5	246,700	22.4	6° 47′	11.9
10	3.3	8.4	0.5	10-12.2	3.3	35,500	3.2	1° 52′	3.2
					Total..	1,100,000			



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BEULAH LAKE—Continued.

Lower lake.

Area	**178.6 ha.**	Length of shoreline ..	9.8 km.
Maximum depth	**16.9 m.**	Shore development ...	2.08
Mean depth	5.3 m.	Mean slope of bottom	1° 22′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	178.6	100.0	9.8	0-3	80.3	4,092,000	43.4	1° 42′	3.0
3	98.3	55.0	6.0	3-5	20.1	1,761,700	18.7	3° 24′	5.9
5	78.2	43.7	5.9	5-10	45.0	2,707,000	28.8	3° 13′	5.6
10[1]	33.2	18.6	1.7	10-15[1]	28.3	433,000	4.6	1° 16′	2.2
15	4.9	2.7	0.8	15-16.9	4.9	29,300	0.3	0° 51′	1.5
10[2]	14.5	8.1	1.4	10-13[2]	9.0	290,500	3.1	2° 14′	3.9
13	5.5	3.1	0.9	13-14.2	5.5	22,000	0.2	0° 32′	0.9
10[3]	5.5	3.1	1.0	10-13.1[3]	5.5	84,500	0.9	1° 36′	2.8
					Total..	9,420,000			

[1] South basin of lake. [2] North basin of lake. [3] East basin of lake.

Mill lake.

Area	23.2 ha.	Length of shoreline ..	2.0 km.
Maximum depth	15.7 m.	Shore development ...	1.18
Mean depth	9.0 m.	Number of soundings.	16
Mean slope of bottom	3° 45′		

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	23.2	100.0	2.0	0-3	4.4	663,000	31.6	5° 13′	9.1
3	18.8	81.0	1.8	3-5	2.8	311,700	14.9	8° 28′	14.9
5	16.0	69.5	1.5	5-10	3.8	702,800	33.5	8° 26′	14.8
10	12.2	52.6	1.3	10-15	7.5	408,500	19.5	4° 24′	7.7
15	4.7	20.6	0.9	15-15.7	4.7	11,000	0.5	0° 24′	0.7
					Total..	2,097,000			

BOOTH LAKE.

T. 4 N., R. XVII E.		Mean depth	3.7 m.
Length	0.93 km.	Length of shoreline	2.6 km.
Breadth	0.69 km.	Shore development	1.04
Area	49.6 ha.	Mean slope of bottom..	1° 6′
Maximum depth	7.7 m.	Number of soundings ..	19

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	49.6	100.0	2.6	0-3	20.5	1,167,300	63.3	2° 3′	3.6
3	29.1	58.7	2.3	3-5	12.1	455,800	24.7	1° 50′	3.2
5	17.0	34.2	1.6	5-6.5	8.4	188,600	10.2	1° 23′	2.4
6.5	8.6	17.4	1.0	6.5-7.7	8.6	31,300	1.8	0° 23′	0.7
					Total..	1,843,000			

EAST TROY LAKE.

T. 4 N., R. XVIII E.		Mean depth	2.9 m.
Length	0.80 km.	Length of shoreline	2.3 km.
Breadth	0.62 km.	Shore development	1.17
Area	31.6 ha.	Mean slope of bottom..	0° 58′
Maximum depth	5.0 m.	Number of soundings ..	15

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	31.6	100.0	2.3	0-2	12.3	505,400	56.5	1° 52′	3.2
2	19.3	61.1	1.7	2-3	6.1	161,600	18.1	1° 26′	2.5
3	13.2	41.6	1.4	3-5	13.2	228,000	25.4	1° 28′	2.6
					Total..	895,000			

LAKES EAST OF BEULAH AND GENEVA.

Lying east of lakes Beulah and Geneva is an area about 50 km. (30 mi.) long and half as wide which possesses a number of bodies of water. This region includes parts of Waukesha, Racine, Kenosha, and Walworth counties. The main axis of the district has a north and south trend, extending from Big and Little Muskego lakes on the north to Camp and Twin lakes on the south. The various bodies of water within this area range in size from mere ponds to lakes as large as Wind and Big Muskego, whose areas are 5.7 sq. km. (2.2 sq. mi.) and 11.0 sq. km. (4.2 sq. mi.) respectively. The larger and more important lakes of this region are shown in figures 4, 5 and 6, pp. 73–75.

All of the lakes that have outlets, with the exception of the Muskego lakes, drain into the Fox river whose waters reach the Mississippi through the Illinois river. The Fox river, in fact, takes its general course from north to south through this region. (See fig. 3.) Little Muskego lake drains into Big Muskego, and the natural outflow of the latter passes into the Root river, which flows into lake Michigan, thus throwing them in the St. Lawrence basin. But a large ditch now connects Big Muskego and Wind lakes and the latter is connected by a ditch with the Fox river. As a result of this artificial connection, the Muskego lakes are connected with both the St. Lawrence and the Mississippi systems.

These lakes and lakelets occupy basins in glacial drift and their shores have a general resemblance to those of the Lauderdale and Beulah lakes. Big Muskego and Wind lakes have unusually low and swampy shores, however, since they lie in the midst of a large area of low, marshy land. The other lakes are comparatively free of swamps and their shores vary in height and steepness from those of the Lauderdale to those of the Beulah group.

The location, area, and maximum depth of the larger lakes are shown in table 2, p. 124. The areas given in the table are to be regarded only as approximate, since they are based on planimeter measurements of county maps and not on detailed surveys.

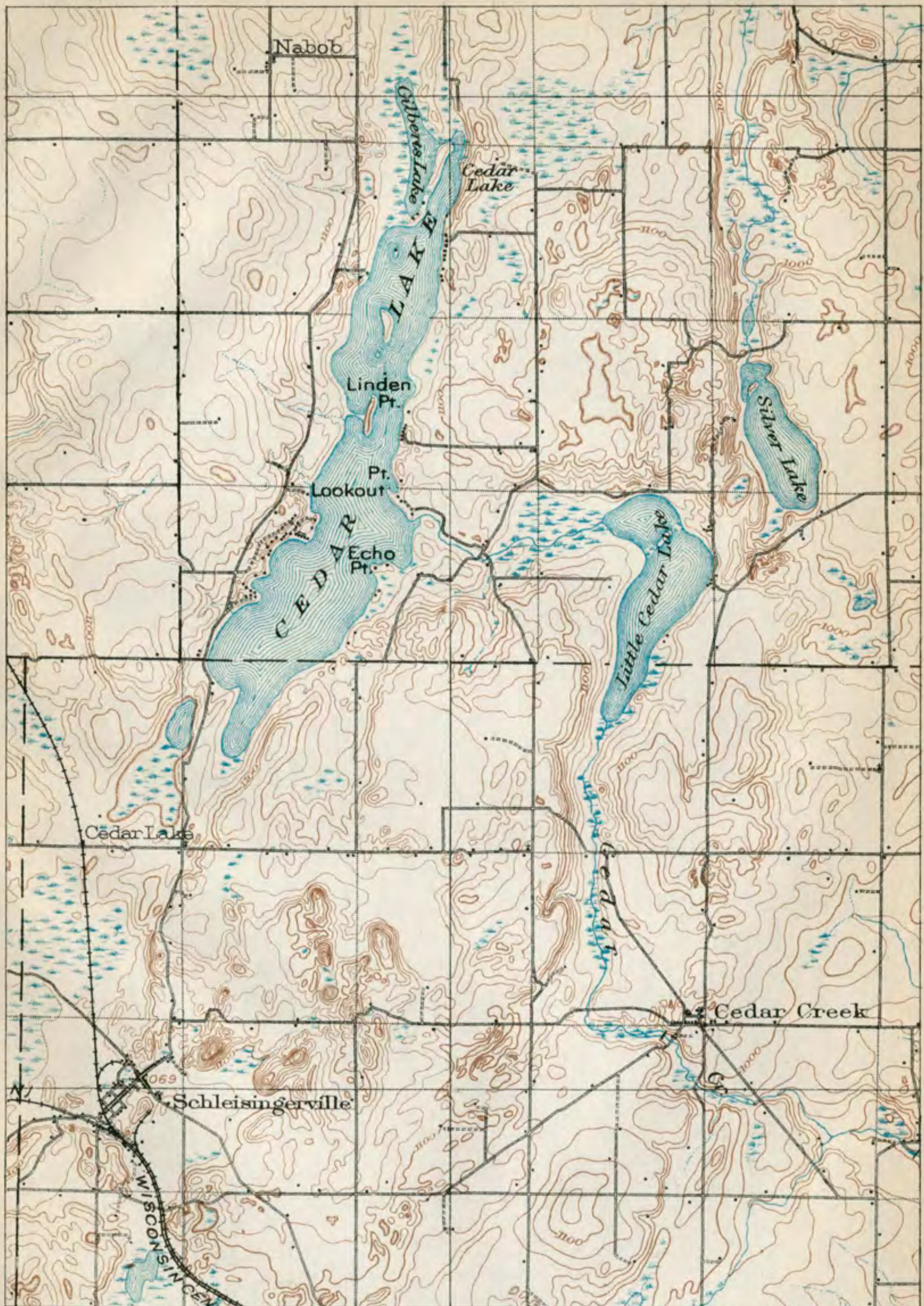
CHAPTER VII.

BIG CEDAR AND ELKHART LAKES.

Big Cedar Lake.

The lake district of Washington county contains three bodies of water which are large enough to be called lakes and several others to which the term pond or lakelet would be more appropriate. (See map XXII.) The district is situated in a kettle moraine area whose topography is characterized by a range of morainal ridges which vary in number from three to five. These ridges may be crudely parallel for long distances, but sometimes they meet and merge at low angles. These variations in the ridges and the accompanying discontinuities in the intervening valleys owe their existence to the fact that this kettle range is a continuation of the terminal moraines of two glaciers. In this vicinity the ice movement was from the east on the one hand and from the northwest on the other. Each ridge marks the position of the front of a glacier while the ridge was being formed. This front alternately advanced and retreated, but the ever changing sinuosities of its outline occasioned, upon each new advance, a pushing of the old ridge at some points and an interval between the old ridge and the ice at other points. Thus a new ridge would be formed which at places appeared as an independent feature.

While these ridges were forming, the drainage from the constantly melting ice was necessarily in courses along the ice fronts, that is, parallel with the ridges. As any one valley served as a drainage line only while the ice stood at one or both of its sides and there was thus a constant supply of morainic material upon its slopes, these valleys should not now be expected to present the features of well developed river basins. The latest of such drainage lines on the side of the Green Bay glacier was along the low strip bordering the western base of the moraine. It is now partly occupied by swamps and includes the basin of Pike lake. At the east base of the moraine, the last drainage line for the Michigan glacier is now occupied in part by Silver creek, the outlet of Silver lake, with the series of lakes and



Topography by U. S. Geological Survey

CEDAR LAKE

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swamps through which it flows. (See map XXII.) The depression along the same line is also well marked south of Silver lake.

The valley in which Big Cedar lake is situated lies between two prominent ridges whose general trend is the same as that of the long axis of the lake. The ridge on the western side is the higher, reaching an altitude of 40 m. (130 ft.) to almost 60 m. (200 ft.) above the level of the lake. The maximum height of the one on the east side is about 40 m. (130 ft.). The intervening valley was partially filled with kame gravels and the basin now occupied by the waters of the lake doubtless escaped filling by being occupied by a mass of ice. Very little is known of the preglacial topography in the immediate vicinity of the lake because the underlying rock has such a deep covering of drift. This mantle is so deep, in fact, that bed rock has not been reached in borings for wells.

About 10 km. (6 mi.) southwest of Big Cedar lake the Niagara limestone has only a thin covering of drift and on both sides of Little Cedar lake the same rock is found only 3 m. (10 ft.) below the level of the water or less than 10 m. (33 ft.) below the surface of Big Cedar lake. Thus the top of the bed rock under the valley occupied by Big Cedar lake is very much lower than on either side of this valley, but neither the nature nor the shape of this depression is definitely known.

Big Cedar lake is the largest body of water in this district and the only one of which a hydrographic survey has been made. It consists of two basins which are conected by water that is less than 1 m. deep. (See hydrographic map, XXIII.) The northern basin has a maximum depth of about 13 m. (43 ft.) and the southern 31.9 m. (104.7 ft.) In the latter basin there is a long, narrow shoal along the western edge of the deepest water. This ridge is about half a kilometer long and its crest is covered by less than 2 m. (6.5 ft.) of water. It is separated from the western shore by water which has a depth of 12 m. (40 ft.) or more.

For the most part the bottom slopes of the southern portion are very steep, those of the eastern side being most abrupt. About midway between Pebbly beach and the south end, the slope from the shoreline down to a depth of 30 m. (100 ft.) is 1 to 3.4, or nearly 30 per cent.; a little further south, the gradient from the water's edge to a depth of 24.5 m. (80 ft.) is 1 to 2.1, or nearly 50 per cent. The bottom slopes of the northern basin are gentle.

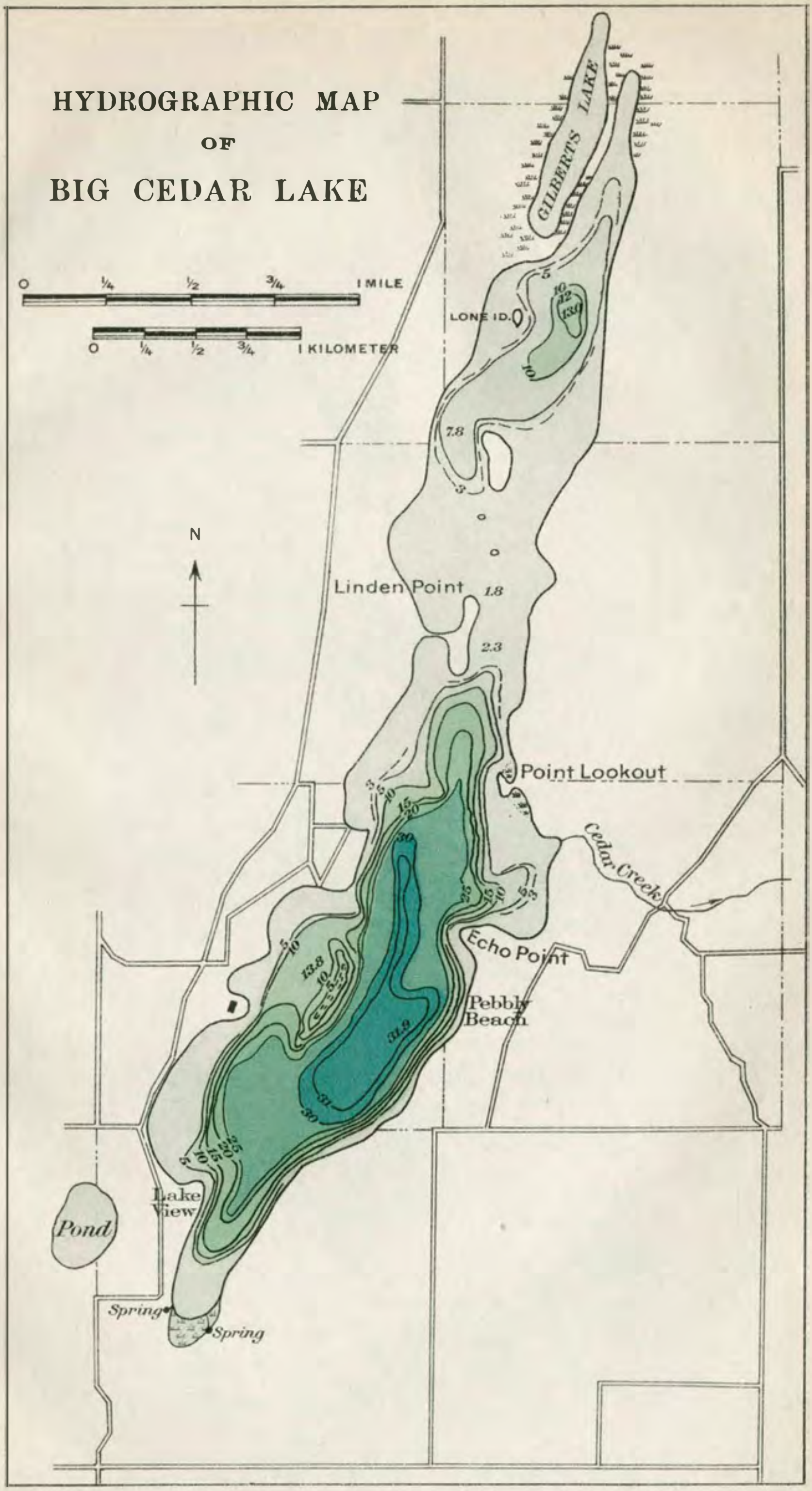
Shores—For the most part the shores are fairly high and have a steep slope. No portion is so fresh and steep, however, as to prevent the growth of vegetation. The lowest point in the elevated rim of the lake is found about the middle of the east side where the outlet, Cedar creek crosses the eastern ridge and discharges the outflowing water into Little Cedar lake. There is a small amount of swamp at both the north and the south ends.

Most of the shore features are in an advanced stage of maturity because the banks are composed of loose drift which is easily eroded. The most mature shore is found along the west side where the initial slope of the bottom was gradual so that a comparatively small amount of material was required for the completion of the marginal shelf. The least developed portion is on the east side between Pebbly beach and the south end. The steepness of the bottom slope here accounts for the poor development of beach features. Cliff-cutting in various places is now very much hindered by a zone of boulders at the water's edge. These boulders are too large to be removed by the water and the ice keeps pushing them landward, thus forming a barrier which is very effective.

Point Lookout is partly a wave-built structure and partly ice-built. Originally a small island was connected with the mainland by a long ridge formed mainly by ice. A hooked spit is now being built northward by the water. Linden point is an excellent illustration of an island tied to the mainland by a bar. At first the currents passed through the channel between the island and mainland but later they passed to the east of the island. Then a spit was built out from the mainland and another from the island. These two spits finally met and the resulting bar was raised above the water, thus tying the former island to the mainland by a ridge. There still remain four islands with a total area of 1.2 ha. (3 a.).

Gilbert lake, at the north end, was once a part of Big Cedar lake, but currents in the latter formed bars in the passages between two islands on the east side of the former lake and made a separate body of water out of it. All of Gilbert lake and a considerable area in the north end of Big Cedar are rapidly nearing extinction as a result of the growth of vegetation which not only furnishes its own débris but also retains the material brought in from the shores during rains.

Big Cedar lake is fed by springs which are found chiefly toward the south end. A dam in the outlet maintains the water of the lake about a meter above its natural level. The outlet, Cedar creek, leaves the lake near the middle of the eastern side and flows eastward to Little Cedar lake.



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BIG CEDAR LAKE.
T. 11 N., R. XIX E.

Length	5.90	km.
Breadth	1.00	km.
Area	387.3	ha.
Maximum depth	31.9	m.
Mean depth	11.1	m.
Length of shoreline	16.4	km.
Shore development	2.34	
Number of soundings	316	

North Part.

Area	133.0	ha.
Maximum depth	13.0	m.
Mean depth	3.3	m.
Mean slope of bottom	1° 8′	

South Part.

Area	254.3	ha.
Maximum depth	31.9	m.
Mean depth	14.7	m.
Mean slope of bottom	3° 50′	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0[1]	133.0	34.4	6.8	0–3	87.0	2,572,000	6.12	1° 8′	1.8
3	46.0	11.8	3.9	3–5	11.4	802,000	1.91	3° 37′	6.3
5	34.6	8.9	3.3	5–10	26.9	975,000	2.32	2° 19′	4.0
10	7.7	1.9	1.1	10–12	6.0	86,500	0.20	1° 28′	2.5
12	1.7	0.4	0.4	12–13	1.7	5,700	0.01	0° 47′	1.4
0[2]	254.3	65.6	9.6	0–3	77.4	6,431,800	15.33	1° 57′	3.4
3	176.9	45.6	8.3	3–5	6.6	3,471,500	8.26	14° 22′	25.6
5	170.3	43.9	8.6	5–10	20.5	7,997,000	19.04	10° 46′	19.0
10	149.8	38.6	7.0	10–15	30.6	6,711,000	16.00	6° 30′	11.4
15	119.2	30.7	7.0	15–20	21.6	5,485,500	13.05	8° 32′	15.0
20	97.6	25.1	6.0	20–25	15.9	4,476,000	10.65	10° 10′	17.9
25	81.7	21.1	5.4	25–30	51.1	2,707,000	6.44	2° 30′	4.3
30	30.6	7.9	3.5	30–31	14.4	230,000	0.55	1° 16′	2.2
31	16.2	4.1	3.0	31–31.9	16.2	54,000	0.12	0° 28′	0.8
					Total..	42,005,000			

[1] North part. The lake has been separated into two parts by a line runing directly east from the middle of Linden point.
[2] South part.

Little Cedar Lake.

The basin occupied by Little Cedar lake is similar to that of Big Cedar lake and had the same origin. Its bottom lies well below the level of bed rock in that vicinity and it consists of an undrained trough between two moranic ridges which were preserved by temporary fillings of ice. (See map XXII.) The main axis of this trough has the same general trend as that of Big Cedar lake. The topography of its shores was not controlled by outwash from the ice to any great extent and the slopes of the shores are those which are characteristic of ridges of terminal moraine. The slopes are somewhat steeper on the west side than on the east side of the lake. There is some swampy land where the stream from Big Cedar lake enters, and also at the south end of the lake.

It receives the outflowing waters of Big Cedar lake at its north end and its outlet, Cedar creek, emerges from the south end of the lake. This creek flows southward for a short distance, then eastward until it reaches the Milwaukee river, whose waters pass into lake Michigan.

Silver Lake.

Silver lake lies a short distance northeast of Little Cedar lake and is separated from the latter by a rather high ridge; in fact the main ridge on the east side of the valley occupied by Cedar lake passes between Little Cedar and Silver lakes. (See map XXII.) It occupies an elongated depression whose main axis has a general north and south trend. Its shores are high, those on the west side being higher and steeper than those on the east side. A small stretch of swampy shore is found at the south end.

Silver lake has no stream affluents and it is drained by Silver creek, which flows northward to the Milwaukee river. The outflowing waters of this lake reach the Milwaukee river about 50 km. (30 mi.) above where those from Big and Little Cedar lakes, its near neighbors, reach the same stream.

Elkhart Lake.

Elkhart lake is situated about midway between lake Michigan and the southern end of lake Winnebago. The dominant topographical feature in this vicinity is the elongated kettle moraine whose crest lies a short distance east of the lake. The height of this moraine above the general level of the country on both sides varies from 30 m. (100 ft.) to more than 100 m. (328 ft.). In spite of this conspicuous height, however, the moraine does not form a water-shed for any but the smallest streams. The drainage of the area is controlled by an older ridge consisting of an outcrop of Niagara limestone which is found along the east side of lake Winnebago. Elkhart lake lies in a preglacial valley on the eastern slope of this older ridge. Well borings in this vicinity show that this valley was filled with glacial drift to a depth of at least 27.5 m. (90 ft.) and in some places more, but the basin of the lake was preserved by masses of ice.

The lake consists of two basins (see map XXIV) which are separated by a fair sized, submerged island, over which the water has a depth of 1.5 m. (5 ft.) or even less. On the north side this shoal area is separated from the shore by water which reaches a maximum depth of a little more than 10 m. (33 ft.) and on the south side the maximum depth is about 8 m. (26 ft.). The smaller, western basin has a maximum depth of nearly 27 m. (88 ft.) and the larger, eastern portion, 34.5 m. (113 ft.).

The bottom slopes are fairly steep and regular. The steepest one is found near the middle of the east side where the gradient is 1 to 2.4, or more than 41 per cent., between 3 m. (10 ft.) and 15 m. (50 ft.). At one point on the south side the average slope from the shoreline down to a depth of 33 m. (108 ft.) is a little more than 1 to 6, or about 16.5 per cent.

Shores—The shores of Elkhart lake have the usual kame steepness. Those on the east and north sides rise rather abruptly to a height varying from 6 m. (20 ft.) to 10 m. (33 ft.) above the water; those on the south and west sides reach a height of 20 m. (65 ft.) or more in places while the kames back of them are 30 m. to 40 m. (100 ft. to 130 ft.) high. Cutting is very general along the shores so that their steepness is either preserved or increased. Erosion is proceeding slowly, however, because the high cliffs furnish a large amount of material for a small amount of cutting and because the eroding power of the waves is limited by the small size of the lake. As a result of the slow cutting the steep slopes are well wooded, which still further retards the wasting of the cliffs.

The youthful stage of the shoreline is shown by the prevalence of cutting, even in some of the bays which are not readily accessible to currents. The shore along the west side of Turtle bay, for example, is kept fresh by a small amount of cutting when one would naturally expect this bay to be spanned by a bar and the area behind this bar converted into a swamp at a very early stage of the lake's history. But no such bar has been formed, neither is one in the process of formation at the present time. It appears that the shore west of this bay does not form a sufficiently smooth path for currents to make bar-building possible at the mouth of the bay. The currents enter the bay in such a way that the sediment borne by them is spread out over a shoal instead of being concentrated into a bar.

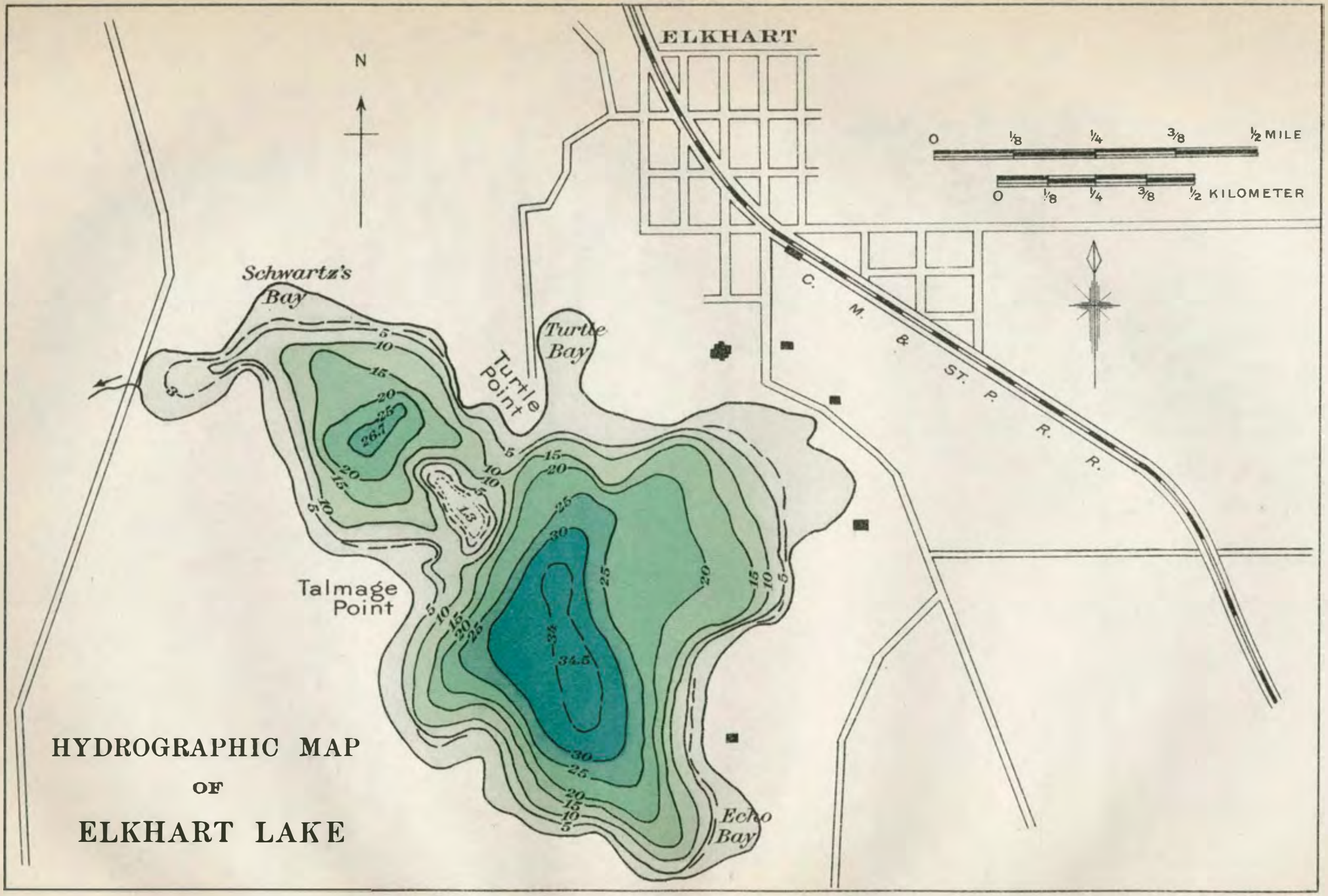
The largest amount of reconstructive work has been done in the northeast bay. Here are found rather extensive beach deposits and a wide expanse of subaqueous terrace. The marginal shelf along the east side, where the cliffs are exposed to the strongest wave action, is not very wide, rarely exceeding 25 m. (82 ft.) in width. There is a wave-built terrace above the water at the head of Echo bay which is now covered with trees and its area is constantly being increased by additions to the sandy beach.

The large bays between Echo bay and Talmage point still remain as they were in the infancy of the lake. So far only some deep kettles along this portion of coast, which formerly made scallops in its outline, have been cut off. The outlet bay at the western extremity of the lake has been narrowed by the development of beach structures.

Just north of Echo bay, there are typical ice-formed ramparts one of which rises to a height of 2 m. (6.5 ft.). One of these ramparts now has spruce trees at least half a meter in diameter growing between it and the water's edge. There is also a long ridge between Talmage point and the outlet bay which was formed by the combined action of beach processes and ice pushing.

Elkhart lake has no inlet stream but several springs are found along the shores. A small creek issues from the lake at its western extremity and discharges the outflowing water into the Sheboygan river a few kilometers from the lake. The waters of this stream finally reach lake Michigan. Further lowering of the level of the lake by the down cutting of the outlet is now prevented by an artificial obstruction.

Sheboygan marsh—Just west of Elkhart lake lies the Sheboygan marsh whose basin at one time was occupied by a large lake. The area of the present swamp is about 36 sq. km. (14 sq. mi.) but in its earliest stages the lake was probably somewhat larger. Beach ridges show that at one stage in its existence the eastern shore of this extinct lake was only about 200 m. (655 ft.) from the present outlet of Elkhart lake. At several places along the border of this swamp there are beach structures still in an excellent state of preservation. The lacustrine deposits show that this extinct lake had a depth of at least 14 m. (45 ft.) in some places.



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ELKHART LAKE.

T. 10 N., R. XXI E.		Mean depth	13.5 m.
Length	1.76 km.	Length of shoreline	6.6 km.
Breadth	1.26 km.	Shore development	1.70
Area 121.2	ha.	Mean slope of bottom..	5° 21′
Maximum depth 34.5	m.	Number of soundings ..	84

Depth.	Area		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Percent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	121.2	100.0	6.6	0-3	27.4	3,223,500	19.7	3° 43′	6.5
3	93.8	77.3	5.3	3-5	9.1	1,784,600	10.9	7° 8′	12.5
5	84.7	69.6	5.0	5-10	24.0	3,620,500	22.2	5° 55′	10.4
10	60.7	50.3	4.8	10-15	6.7	2,976,000	18.2	3° 18′	5.8
15	54.0	41.6	4.3	15-20	16.3	2,256,000	13.8	6° 29′	11.3
20	37.7	31.7	3.2	20-25	18.1	1,409,400	8.6	4° 42′	8.2
25	19.6	16.1	2.3	25-30	7.8	761,000	4.7	6° 44′	11.8
30	11.8	9.7	1.4	30-34.5	11.8	803,000	1.9	1° 30′	2.7
					Total..	16,334,000			

CRYSTAL OR CEDAR LAKE.

Less than 2 km. (1.25 mi.) south of Elkhart lake is another body of water somewhat less than half as large as Elkhart. This is known as Crystal or Cedar lake. Its origin was similar to that of the former lake and its shores are high and steep for the most part. The surface of this lake is said to be almost 6.7 m. (22 ft.) above that of Elkhart lake, but its water level seems to be slowly falling. This is shown by the fact that the main cliff cutting was done a meter or two above the present level and also by the fact that the lake is surrounded by a considerable strand of gravel and cobble stones. The lake contains two small islands which are isolated kames. These islands are connected with the mainland by submerged bars. Further data concerning the lake are contained in table 2, p. 124.

CHAPTER VIII.

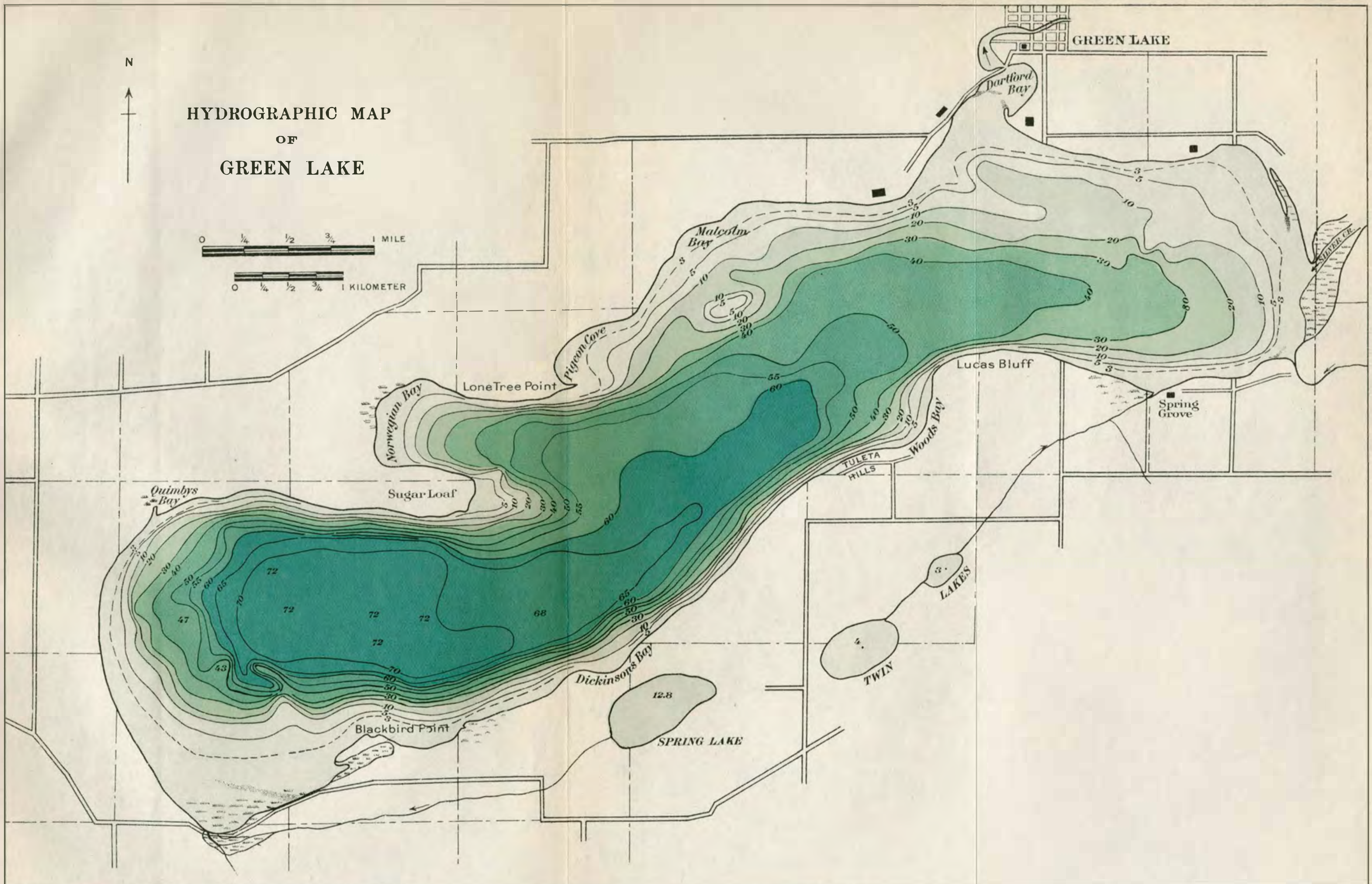
GREEN AND WINNEBAGO LAKES.

Green Lake.

Green lake is an unusually attractive body of water from a scenic standpoint. The shores present a diversity of characters, varying from low, sandy beaches, through more or less steep, wooded slopes, to perpendicular bluffs in which the bed rock is exposed. There is a relatively small amount of swamp. The topography of the adjacent country is characterized by a series of troughs and ridges which are roughly parallel; the ridges rise to a height of 30 m. to 60 m. (100 ft. to 200 ft.) above the lake and have broad, gently rolling tops. The larger features of the landscape had a preglacial origin, having been carved by streams before the ice came; in general the ridges are covered with only a thin layer of drift and there are many outcroppings of the bed rock. A large portion of the glacial drift consists of sand which was worn from the local sandstones. It is the deepest lake known to exist in the state; the water is clear and its color is suggestive of the name of the lake.

Rocks—The bed rock underlying Green lake consists of Potsdam sandstone; practically the entire basin, in fact, is scooped out of this rock. Above it comes the Mendota limestone which is exposed in several places along the shores; its lower level extends just a little below the level of the water. Above this stratum is a layer of Madison sandstone which is about 7.5 m. (25 ft.) thick in this vicinity; it is exposed for its entire depth on the west side of Lucas bluff. Next in order above is a stratum of Lower Magnesian limestone. This rock is very resistant to weathering and many of the long ridges owe their existence to caps of this material which shield them from the action of the water and ice. This limestone forms a typical monadnock at Sugar loaf; it appears also in the highland back of the cliff at Lucas bluff. (See map XXV.)

The next higher formation is the St. Peter sandstone, a soft, friable stratum which is responsible for Mitchell's glen, a beautiful



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gorge situated about 0.8 km. (0.5 mi.) southeast of the east end of Green lake. A stratum of this rock about 30 m. (100 ft.) thick is exposed in this glen. Overlying the St. Peter sandstone and some distance east of the lake is found the Trenton limestone.

Origin of basin. Green lake is situated in a valley which was eroded by a preglacial stream. This valley was modified by the ice during the glacial period, the sides being smoothed off and the smaller tributary valleys being filled with drift. It seems probable, also, that the lake basin was deepened by the action of the ice because the ice movement was about parallel with the axis of the valley and because the bottom of the preglacial valley consisted of the easily abraded Potsdam sandstone.

The final modification which resulted in the formation of the present basin was the building of a morainal dam across the ancient valley at the west end of Green lake and this structure now impounds its waters. The top of this morainal dam is 88 m. to 90 m. (289 ft. to 295 ft.) above the bottom of the deepest part of the lake.

Drainage. The lake receives the drainage from a rather large area, the largest stream being Silver creek which flows into the east end. Many springs, some of which are fairly large, contribute their quota of water to the lake, either directly or through streams. Puchyan river, the outlet, is a stream of considerable size. It leaves the lake near the end of Dartford bay and flows northwestward to the Fox river which lies in the lake Michigan basin. An artificial dam has been placed in the outlet a short distance below its origin and this structure maintains the water of the lake about 1.5 m. (5 ft.) above its natural level.

Shape and bottom features. The hydrographic map (XXV) shows that the lake has a fairly regular outline and that the deepest water is toward the western end. In the eastern third, the bottom slope is much more gentle than the other two-thirds of the lake. Along a large part of the south side and along Sugar loaf, the water descends rapidly to considerable depths within a short distance of the shore. At the latter point, the slope of the bottom at one place, from the shoreline down to a depth of 60 m. (200 ft.) is about 1 to 4.2, or 23.6 per cent. A maximum gradient of 1 to 3, or 33.3 per cent., is found at Lucas bluff. The bottom is usually free from irregularities; its regularity is broken by only two shoals, one off Malcolm bay and another at the eastern end of the lake.

Shores.

Cliff-cutting. Only a very small portion of the shore is low and swampy; small areas of swamp land are found at the east end, at the head of Norwegian bay, and at the southwest corner of the lake. The remainder of the shore shows a great variety in height and character; in some places the shore rises abruptly from the water's edge to a considerable height, as at Lucas bluff, while at other points the rise to the surrounding hills and ridges is very gentle.

The rise in the level of the lake which resulted from the erection of the dam in the outlet, set the water at work on the shore at a new horizon. As a consequence the beach features still show a considerable degree of immaturity. The most youthful beach structures are found at the points where bed rock appears at the water's edge. While some of the exposed rock is very friable, yet material for beach formation is not so readily obtained from it as from loose glacial drift. For this reason, the subaqueous shelf is not so fully developed as it is where drift material is more readily obtained and the shores are not being eroded so rapidly. The principal points at which bed rock is subject to the erosive action of the water, are Lucas bluff, the south side of Sugar loaf, east of Dickinsons bay, and west of Lone Tree point.

More mature beach profiles are found where the shores are composed of loose glacial material. At such places the most effective barriers to erosion are the boulders which are derived from the wasting cliffs. The pushing of the ice keeps these boulders at the water's edge where they form an important protection against the action of waves and currents. At the northwestern corner of the lake, for a distance of about a kilometer on either side of Quimbys bay, the shores consist of high cliffs which are composed of very sandy drift. Along these cliffs, cutting is still rapid enough to keep them steep and fairly free from vegetation. The sand beaches here have a perfect profile. Along the north shore for a distance of about 1.5 km. at Sherwood forest and from Oakwood to Pleasant point, steep cliffs are being actively worn away also, but they are composed of coarser material which is not so easily eroded. The subaqueous terraces adjacent to these cliffs are unusually broad and must be ascribed to the agencies which formed the basin rather than to the action of waves and currents.

Built structures. A large part of the material eroded from the cliffs has been used in constructing subaqueous terraces along the shores; another part has been used in building spits, bars, etc., while the silt which is easily transported, is carried to all parts of the lake.

Two spits now almost span the entrance to Dartford bay, only a narrow channel being left between them. (See map XXV.) The larger one has been built out from the western side and extends about two thirds of the distance across the mouth of the bay. It is composed of material which has been transported chiefly from the cliffs west and north of Sherwood forest. The smaller spit extends northwestward from the east side and its outer end is about 20 m. (65 ft.) south of the outer end of the one from the opposite side. Active building is still in progress on both spits and the landward ends of both are now above water.

At the eastern end of the lake a long spit extends southward from Terrace beach. It consists of material which was transported from the cliffs at Pleasant point and further west. This spit lies in front of a long marsh which extends back to the original shoreline at the foot of the steep, sandy bluff. This structure is still gradually growing southward. An old spit has crowded the mouth of Silver creek toward the south a short distance but its growth has ceased.

Beyond Silver creek, there are several pits, but they are small, ill-formed structures because much of the shore to the west consists of bed rock, especially limestone, which furnishes very little material for the construction of such features. Also much of the available material transported along this shore has been used in the formation of a bar across a bay which at one time existed just west of Spring grove. The bay is now represented by a swamp behind the bar.

The largest and finest beach ridges are found about the middle of the western shore of Green lake. In all there are three parallel ridges; the one furthest from the water's edge is the largest, having a width of about 60 m. (200 ft.) and a height of about 1.5 m. (5 ft.). The width of the ridge forming the present shoreline is about 30 m. (100 ft.). The material of which these ridges are composed was transported from the cliffs which lie to the north of them.

Lone Tree point is a small promontory on the north side of the lake, whose connection with the mainland presents the appearance of a wave-built bar. The edge of this isthmus, however, is marked by a line of boulders which the ice has pushed up; such a condition makes it doubtful whether this structure was formed by waves or not. It may represent an original ridge of morainic material or it may have been formed by ice pushes. Several beach ridges with lagoons between them have been formed between Lone Tree point and Pigeon cove.

Ice ramparts are not abundant; the largest and best examples are found about the middle of Malcolm bay. Some of these ridges are nearly 2 m. high. Smaller ramparts are found just east of Sherwood forest and along the more gentle slopes east of Lucas bluff.

GREEN LAKE.

T. 15 and 16 N., R. XII and XIII E.		Mean depth	33.1 m.
Length	11.90 km.	Length of shoreline	34.2 km.
Breadth	3.22 km.	Shore development	1.78
Area	29.72 sq. km.	Mean slope of bottom	2° 52′
Maximum depth	72.2 m.	Number of soundings	674

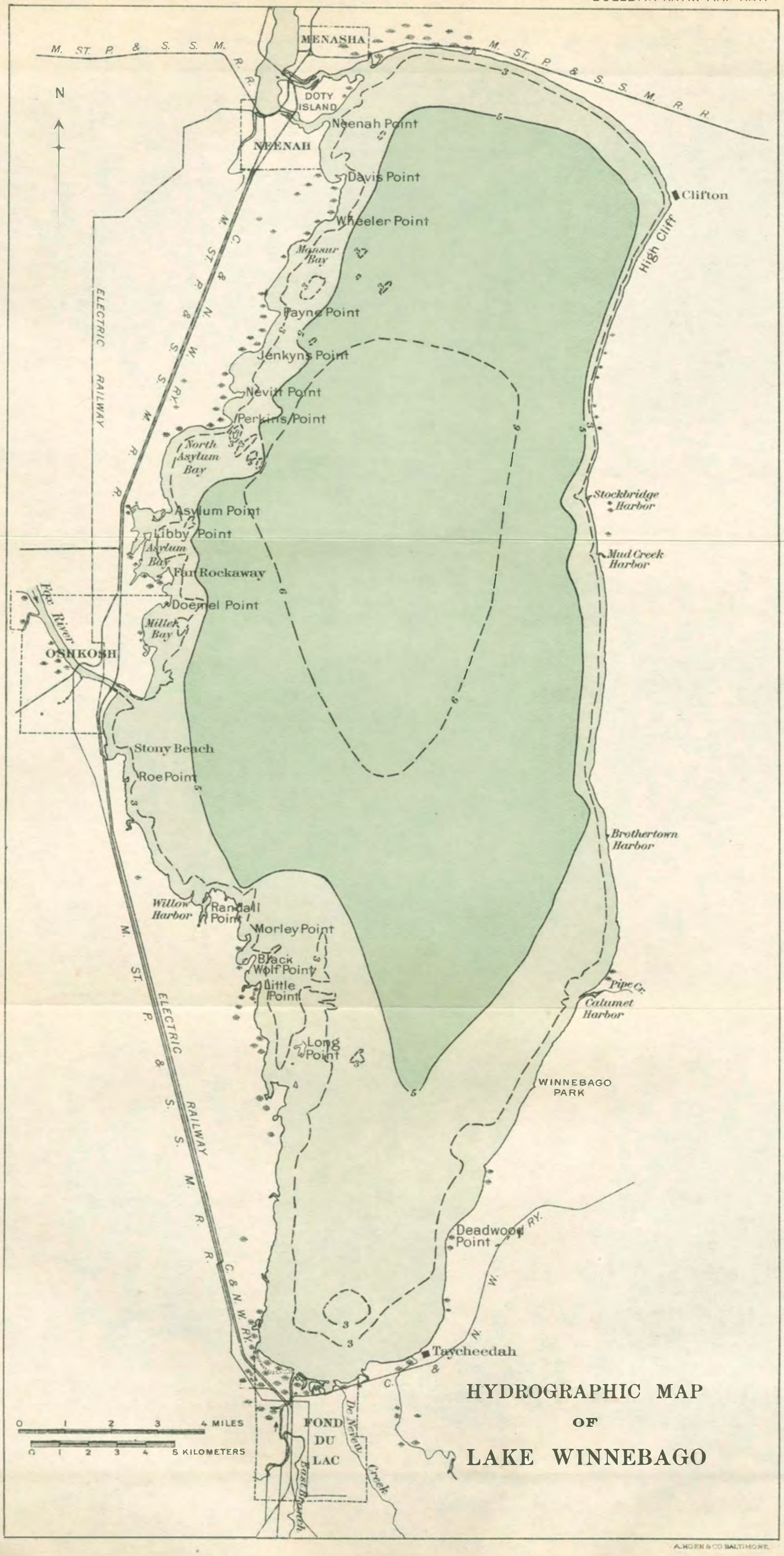
Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilometers.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	29.7	100.0	34.2	0–3	4.3	82,602,000	8.4	1° 17′	2.2
3	25.4	85.5	30.4	3–5	1.8	48,993,000	5.0	1° 56′	3.3
5	23.6	79.4	29.4	5–10	2.6	111,517,000	11.3	3° 16′	5.7
10	21.0	70.7	29.8	10–20	3.1	194,429,000	19.8	5° 15′	9.2
20	17.9	60.3	27.8	20–30	2.4	166,813,000	16.9	6° 20′	11.1
30	15.5	52.1	25.8	30–40	2.5	142,183,000	14.5	5° 31′	9.7
40	13.0	43.6	22.4	40–50	3.2	113,349,000	11.5	3° 42′	6.4
50	9.8	32.9	19.2	50–55	1.7	44,648,000	4.5	3° 10′	5.5
55	8.1	27.3	16.9	55–60	2.0	35,356,000	3.6	2° 14′	3.9
60	6.1	20.4	15.2	60–65	2.0	25,232,000	2.6	1° 50′	3.2
65	4.1	13.8	10.1	65–70	2.0	15,333,000	1.5	1° 15′	2.2
70	2.1	7.0	6.7	70–72.2	2.1	4,370,000	0.4	1° 24′	2.4
					Total..	984,825,000			

Lake Winnebago.

Lake Winnebago is a large, shallow body of water situated in eastern central Wisconsin, in the lower course of the Fox river. (See fig. 3, p. 8, and text, p. 99.) It is the largest body of water wholly within the boundaries of the state. The longest axis has a north-south trend and measures about 45 km. (28 mi.), while the greatest width is 16.6 km. (10.4 mi.). (See map XXVI.)

Origin of the basin.[1] In glacial times that portion of the Fox river

[1] Geol. of Wis., Vol. II, p. 137, 1877.


HYDROGRAPHIC MAP
OF
LAKE WINNEBAGO
MENASHA
DOTY ISLAND
NEENAH
Neenah Point
Davis Point
Wheeler Point
Mansur Bay
Payne Point
Jenkyns Point
Nevitt Point
Perkins Point
North Asylum Bay
Asylum Point
Libby Point
Asylum Bay
Far Rockaway
Doemel Point
Miller Bay
OSHKOSH
Fox River
Stony Beach
Roe Point
Willow Harbor
Randall Point
Morley Point
Black Wolf Point
Little Point
Long Point
Clifton
High Cliff
Stockbridge Harbor
Mud Creek Harbor
Brothertown Harbor
Pipe Cr.
Calumet Harbor
WINNEBAGO PARK
Deadwood Point
Taycheedah
FOND DU LAC
De Neveu Creek
East Branch
M. ST. P. & S. S. M. R. R.
M. C. & N. ST. P. & S. S. M. RY.
ELECTRIC RAILWAY
M. ST. P. & S. S. M. R. R.
C. & N. W. RY.
N
0 1 2 3 4 MILES
0 1 2 3 4 5 KILOMETERS
A. HOEN & CO. BALTIMORE.

valley in which lake Winnebago lies was modified in two ways by the ice. (1) It was greatly enlarged by the erosion of the Green Bay lobe of the glacier. (2) During its retreat, the ice deposited a dam of glacial débris which partially filled the valley and now impounds the waters of the lake. The preglacial channel of this valley lies further to the east, that is, nearer Clifton, than the present outlet of the lake. But this channel was blocked with drift material, thus forming the basin now occupied by the lake. This dam raised the water to such a height that a discharge took place over the low rock barrier at the northwestern corner, which separates the basins of lake Winnebago and Little Butte des Morts.

Shores. The eastern shore of lake Winnebago has a fairly regular outline, but it is steep and high for the most part and consists of an escarpment of Niagara limestone. The northern portion is especially steep and rugged. Here the cliffs rise abruptly to a height of 60 m. (200 ft.) or more above the surface of the lake. The other portions of the eastern shore do not possess such a steep slope and such a height is not reached for some distance away from the lake. The southern end of this shore possesses the widest belt of gently sloping land.

At the south end of the lake the shore is low and much of it is swampy. The Fond du Lac river enters here and the swamp is due in part to delta formations and in part to the encroachment of bog formations on the lake.

The western shoreline is very irregular owing to the large number of bays and points. This shore is low and has a very gradual slope. The height of this shore above the water rarely exceeds 3 m. to 5 m. (10 ft. to 16 ft.) within a kilometer of the water's edge. In several places there are small areas of marsh.

At the north end of the lake, the eastern half of the shore is fairly high and steep, but the western half is low, a large portion of it being marshy.

Bottom. The data for the accompanying hydrographic map (XXVI) were obtained from a chart published by the U. S. War Department in 1908. According to this chart the water descends rather rapidly along most of the shore to a depth of 3 m. to 4 m. (10 ft. to 13 ft.) the steepest descent being along the north end and the east side of the lake. At the south end and in some places along the west side the bottom slope is more gentle. Beyond this narrow belt of marginal slope, the bottom of the lake is an extensive plain, almost free from topographical irregularities, over which the depth of the water ranges between 4 m. (13 ft.) and a little over 6 m. (20 ft.).

There are a few offshore shoals along the west side but most of them are small. The most extensive one is known as Long Point reef.

On the government chart, the bottom of perhaps ninety per cent. of the lake is characterized as mud. A narrow zone along the shore is kept free of mud by the waves and currents, and the shoals which come within the range of these agents are recorded as composed of rock, gravel, and sand.

Four small islands are situated on the west side of the lake, and there is a larger one at the outlet.

Sources of water. Lake Winnebago receives the waters of a number of streams but most of them are small. The Fond du Lac and Fox rivers are the only important ones. The former enters the south end of the lake. The Fox river flows into the lake about the middle of the west side and emerges from the lake at the northwest corner in two nearly parallel channels which are a little more than a kilometer apart. About 3 km. (2 mi.) below the lake these branches join in Little Butte des Morts lake. Dams have been built in the two outlet channels of lake Winnebago for water power purposes and they have raised the water level high enough to increase the size of the lake about 5.5 per cent. over its original area. There is a government ship canal in the north outlet channel.

Among the European lakes, the one which most closely resembles lake Winnebago is lake Balaton or Plattensee in Hungary. The latter is nearly twice as long, but its width is only a little more than half as great, so that they do not differ so very widely in area, the latter being only about 90 sq. km. (35 sq. mi.) larger than the former. The maximum depth of lake Winnebago is 6.4 m. (21 ft.) while that of lake Balaton is almost 11 m. (36 ft.) but the mean depth of the former is 4.7 m. (15.4 ft.) while that of the latter is only about 3.0 m. (10 ft.). The shores of lake Balaton are more rugged, however. Along the north side the hills rise abruptly in many instances to heights of 100 m. to over 300 m. (328 ft. to 984 ft.) above the surface of the lake. But the south shore has a more gentle slope and in some places it does not rise to a height of more than 10 m. to 20 m. (33 ft. to 65 ft.) above the surface for a considerable distance from the water's edge. In fact, there are some rather large swamp areas along this shore. Both lakes are covered with ice for a rather long period in winter and the annual range of temperature is substantially the same, the minimum being just above 0° and the maximum 28° C.

LAKE WINNEBAGO.

T. 15–20 N., R. XVI–XVIII E.
Length .... 45.00 km.
Breadth .... 16.60 km.
Area ....557.52 sq. km.
Maximum depth .... 6.4 m.
Mean depth .... 4.7 m.
Length of shoreline ....148.0 km.
Shore development 1.76
Mean slope of bottom.. 0° 3′

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Sq. km.	Per cent of total.	Kilo-meters.	Meters.	Sq. km.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	557.52	100.0	148.0	0–3	65.52	1,576,323,000	59.9	0° 23′	0.66
3	494.00	88.6	131.1	3–5	151.00	832,422,000	31.7	0° 5′	0.14
5	343.00	61.5	86.1	5–6	244.79	208,258,000	7.9	0° 1′	0.02
6	98.21	17.6	88.6	6–6.4	98.22	13,095,000	0.5		
					Total..	2,630,098,000			

Lakes of the Fox and the Wolf Rivers.

The Fox river of the lake Michigan basin has its source northeast of the city of Portage. (See fig. 1, p. 2.) It flows westward for a distance and then turns abruptly northward in the vicinity of Portage; beyond this its general course is northwest toward Green bay into which its waters finally flow. Its chief tributary is the Wolf river which has its headwaters in the southeastern corner of the northeastern lake district. (See map XXVIII.) The general course of this stream is south and it joins the Fox river a few kilometers above lake Winnebago. The latter stream posseses some local expansions or lakes in its course. Going down stream, they are Buffalo, Puckaway, Big Butte des Morts, Winnebago, and Little Butte des Morts lakes. All of these bodies of water are fairly large, but they are shallow, the deepest being lake Winnebago. The depth of Buffalo and Puckaway lakes ranges from 2 m. to 3 m. (6.5 ft. to 10 ft.) while Big Butte des Morts lake is a little deeper, having a maximum depth of 4 m. to 5 m. (13 ft. to 16 ft.). (See table 2, p. 124.) In its lower course the Wolf river has two large expansions which are known as Poygan and Winneconne lakes whose maximum depth scarcely exceeds 3 m. (10 ft.). For the most part the shores of these five lakes are low and swampy. Little Butte des Morts lake lies just below lake Winnebago. It is also very shallow but its shores are higher than those of the lakes above lake Winnebago.

CHAPTER IX.

THE WAUPACA CHAIN O' LAKES.

This group of lakes is situated about 6 km. (4 mi.) southwest of the city of Waupaca. The main chain extends in a general northeast-southwest direction with Otter lake at the northeastern end and Long lake at the southwestern end. (See map XXVII.) It comprises nine lakes which vary in size from that of Beasley lake, which has an area of 5.4 ha. (13.5 a.) to that of Rainbow lake with an area of 55.6 ha. (137.5 a.). These nine lakes have approximately the same water level and are connected by channels which are wide enough and deep enough to permit the passage of row boats; with the exception of Otter lake, in fact, small launches pass from one end of the chain to the other.

The water flows from the northeast toward the southwest through the chain and the upper lakes are fed entirely by springs, there being no stream inlets. The supply is barely sufficient to maintain a feeble current from Round lake into Columbian. Otter, Hicks, and Round lakes receive by far the largest amount of spring water. Long lake receives the waters of some springs, those of Emmons creek, and the overflow of Beasley and Columbian lakes.

Six members of this chain, Otter, Beasley, and Long lakes being the exceptions, may be classed as marl lakes; marl deposits are more or less prominent in the shallow water and the bottom in the deeper water contains a large percentage of marl. Also, the color of the water is the same as that of typical marl lakes, being greenish blue in the shallow water and a darker green in the deep water. The bottom deposits of Otter, Beasley, and Long lakes contain a much larger percentage of organic material and have a dark color. Their waters have a correspondingly dark color.

To the north of Beasley lake lie two small, shallow bodies of water known as Bass and Youngs lakes. To the west of Beasley and Long lakes is a chain of four lakes which is connected with the main chain by Beasley brook. These four lakes, known respectively as Marl, Pope, Mud, and Knights lakes, receive a large amount of spring water either directly or through small streams; the outlet from them, Beasley brook, is a stream 2 m. or 3 m. (6.5 ft. to 10 ft.) wide and about 30 cm. (1 ft.) deep. Marl lake has considerable deposits of marl and its water has the color characteristic of such a lake. The bottoms of Pope and Mud lakes are dark in color, with a large amount of organic material, and their waters are consequently dark in color. Although Knights lake has large deposits of marl, yet its water has a very dark color.

To the east of Columbian lake are Dake and Miner lakes which are connected with each other by a channel but which are not connected with the other lakes of this group.

Arbor creek, the outlet of the entire group of lakes, has its origin at the south end of Long lake. It is a stream of considerable size, being large enough to furnish power for a small mill. It is a tributary of the South Fork of the Waupaca river and the latter stream is a tributary of the Wolf river. These lakes, therefore, lie within the lake Michigan drainage basin. (See fig. 3, p. 8.)

Origin of the basins. The underlying rock in this lake district is Potsdam sandstone but it is covered by a rather thick layer of glacial drift. The nearest known rock of any other age is at the city of Waupaca, about 6 km. (4 mi.) away, where the pre-Cambrian appears. The topography in the vicinity of the lakes is that of a pitted plain, such as was noted for the Oconomowoc-Waukesha district (see p. 36). Here, as in the latter district, the pits owe their existence to the burial of blocks of ice during the glacial epoch, and the subsequent melting of them. These pits vary in size from small ones which are only a few meters in diameter to that of the largest lake. Rising above the plain in this vicinity are a few isolated hills, some of which are 30 m. (100 ft.) or more in height and perhaps a kilometer in extent. These hills are now well covered with drift, often carrying great boulders, and their topography suggests that they are remnants of a former upland whose surface was at or above the present level of their tops.

The late Wisconsin ice sheet extended about 25 km. (15 mi.) west of the lakes where the limit of its advance is marked by a terminal moraine. It moved into this region from the northeast and its disappearance was not markd by uniform retreat. There were halts at certain points along the line at which smaller terminal or recessional moraines were formed. Such a halt was made in a north-south line along the east side of Rainbow and Hicks lakes. It remained in this position long enough to build a high ridge between Otter and Hicks lakes, Maple island, and the high shore along the east side of Rainbow lake. The drift in the vicinity of the lakes is extremely sandy and this is accounted for by the fact that the glacier for about 30 km. (18 mi.) to the eastward was gathering material from the friable Potsdam sandstone.

Shores. The shores of all the lakes possess the usual steepness of pitted-plain basins. Between the steep shores and the edge of the water in some of the lakes there are narrow belts of grass or tamarack swamp which serve as good illustrations of the encroachment of vegetation in lakes. Otter lake is an excellent example of this type of shore; such conditions are shown also by Beasley, Bass, and Youngs lakes, by a portion of the shore of Long lake, and by the four lakes at the head of Beasley brook. This abundant growth of vegetation along the shores contributes a great deal of organic material to the bottom mud, even in the deeper water. The difference in the appearance and character of the water together with the fact that some of the lakes are still surrounded by forest, which gives them an appearance of wildness, adds very much to the beauty and attractiveness of this group of lakes.

Beach features are unusually well developed for lakes of such small size. This is accounted for by the fact that the shores are composed largely of loose, sandy material which is readily cut by the waves, and which furnishes an abundance of material for transportation by currents. The subaqueous, marginal terrace is well developed, generally, and extends to a depth of about 1 m. (3.3 ft) in the smaller lakes and 1.5 m. (5 ft.) in the larger ones.

Bottom-slopes. With very few exceptions, the steepest descent of the bottom in all except the shallower lakes, begins just a little way beyond the marginal terrace, that is, at a depth of about 3 m. (10 ft.) and extends thence to a depth of 12 m. (40 ft.) or 15 m. (50 ft.) or perhaps more, depending upon the depth of the lake. In this belt, gradients ranging from 30 or 35 per cent. to as much as 45 per cent. are common in several of the lakes, such, for example, as Beasley, Long, MacCrossen, and Rainbow. With the water's edge as a starting point, the steepest slopes are found in MacCrossen and Otter lakes. At the west end of the former, near its connection with Round lake, there is a bottom slope of 1 to 2.1, or a little over 47 per cent., between the shoreline and the 15 m. (50 ft.) contour. Near the middle of the west side of Otter lake, the gradient between the water's edge and a depth of 12 m. (40 ft.) is 1 to 2.6., or more than 38 per cent.

Rainbow and Hicks lakes. These two bodies of water are so broadly connected that, in reality, they constitute only a single lake. (See map XXVII.) They contain two islands, Club and Juniper, and a third, Maple island, separates them from Taylor lake on the east. It will be noted that the bottom slope of Rainbow lake is very steep and the water reaches an unusual depth in proportion to the area of the lake. At no point along the shores of these lakes is the cutting of the cliffs rapid enough to keep their slopes free of vegetation. Cutting is proceeding most actively on the south side of Club and Juniper islands and on the west side of Maple island. The material obtained from the south side of Club island is used in extending the ends of the island northward, giving it a crescent form; that obtained from the south side of Juniper island is used in building a northward extension. The material obtained from the west side of Maple island has been used chiefly in forming a large subaqueous terrace which has a maximum width of about 100 m. (328 ft.). Three small bays in Hicks lake have been spanned by bars, one on the east side, one at the northwest corner and a third at the southwest corner of the lake.

The work of the ice is in evidence along almost the entire shoreline. Wherever the form of the shore is favorable, small ridges have been pushed up; where the shores are steep, boulders are pushed up in line along the bases of the cliffs. In some instances where shore material was not available, bottom material has been pushed up into a series of terraces.

The area of Juniper island is about 2 ha. (4.9 a.); of Club island 0.13 ha. (0.34 a.); and of Maple island 5.3 ha. (13.2 a.).

Taylor lake. The shores of this lake are lower than those of the the lakes to the west; throughout much of their extent they do not rise more than 1.5 m. (5 ft.) above the surface of the water and much of the north side is bordered by swamp. A broad marginal shelf extends almost entirely around the lake and in places this supports a dense growth of *Scirpus*. Beyond this margin the bottom descends rapidly to the deeper water.

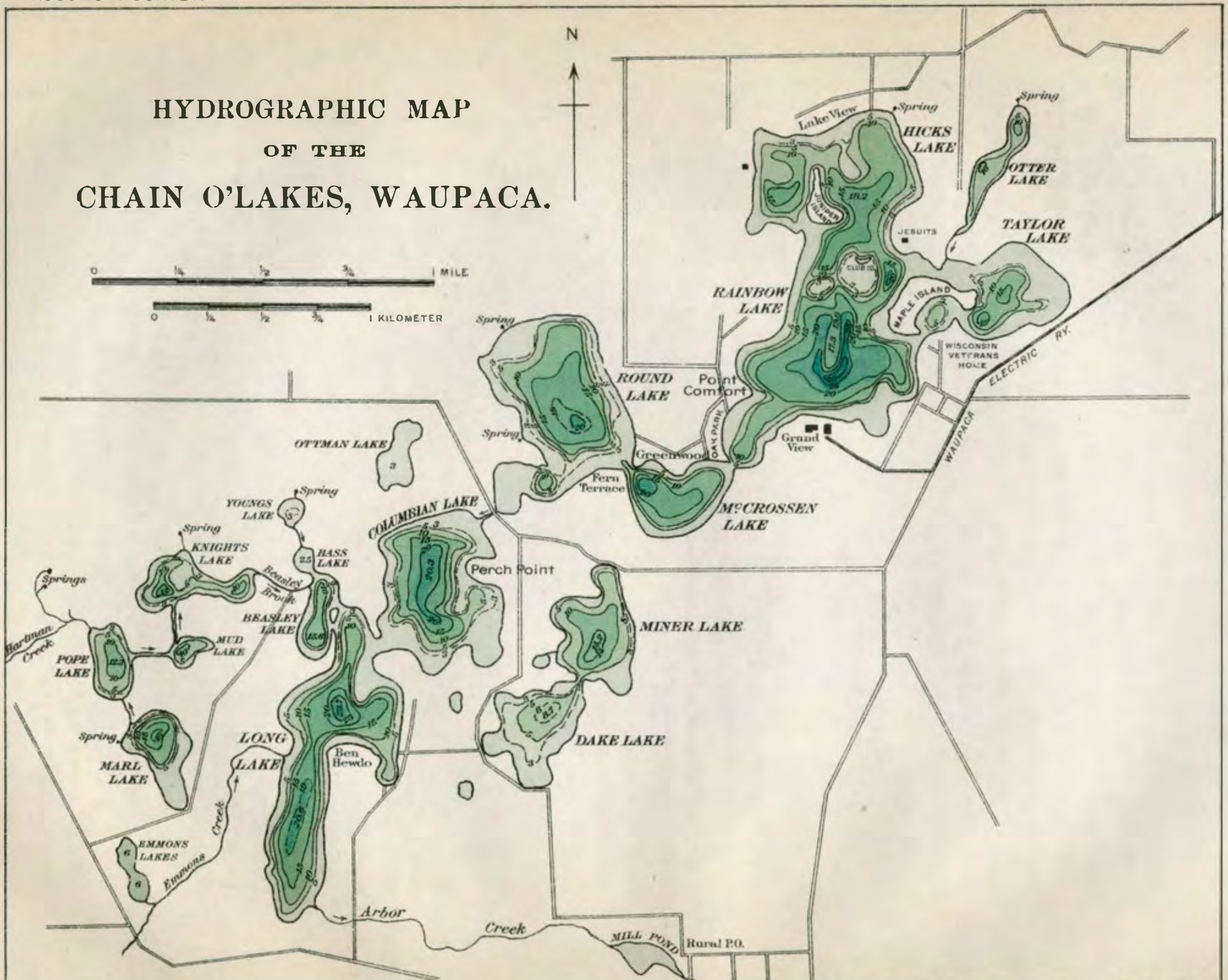
MacCrossen lake. The north shore of this lake is steep and fairly high, but the south shore is lower, rising only 2 m. to 3 m. above the surface of the water. The latter possesses an excellent beach ridge about 60 m. (200 ft.) long, 10 m. (33 ft.) wide, and over a meter high. The arrangement of the materials in this ridge indicates that it was built by water rather than by ice. The height of this ridge and a few smaller ones, suggests that the water once stood at a higher level. Even the largest waves now produced could not build such a structure so high above the present water level. There is no evidence however, to show that the water has ever been more than a meter above the present level since the glacial period.

The passages at both ends of MacCrossen lake are bordered by wave-built points which converge from opposite sides of the straits. At the western passage, the water between these points is rather deep, more than 6 m. (20 ft.), and the shoal bar separating this basin from that of Round lake is some distance inside the latter.

Round lake. Round lake is exceeded in size by only two other lakes in this group. Through the action of the waves and currents, it possesses a well marked marginal shelf which is broadest at the northwestern corner. The unusual form of the passage connecting Round and MacCrossen lakes is probably due in part to the original shape of these basins, and also in part to the more vigorous wave action in the former lake owing to its larger size and to the prevailing westerly winds. As a result of the wave action the points bordering this passage have been crowded into MacCrossen lake. The southwestern arm of Round lake contains a large deposit of marl. The small, deep basin in this arm is an excellent example of the many small pits that are found in the district, most of which are above the water level. (See map XXVII.)

Columbian lake. The greater part of the shore cutting on Columbian lake has been done at the northwestern corner and along the east side, in the vicinity of Perch point. Some of the material obtained from the cliffs at the northwest corner has been transported eastward and used in building the wide marginal shelf at the northeastern corner. Boulders are more numerous along the east shore of the lake than elsewhere, owing to the wasting of Perch point and of the shoal extending southward from it. Just north of Columbian lake is a fairly large body of water called Ottman lake. It is shallow, however, and is entirely filled with a dense growth of the larger aquatic plants in summer.

Long lake. The shores along Ben Hewdo and along the western side of Long lake are the highest; in fact no other shores of this group of lakes rise so high except the ridge between Otter and Hicks lakes and the western part of Maple island. Considerable of the shore, however, consists of tamarack swamp. Cutting is not very vigorous along any part of the shoreline, hence the marginal shelf is not so wide as in most of the other lakes belonging to the main chain. Long lake receives the surplus water from all of the other lakes so that a considerable amount of water flows through it.



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BEASLEY LAKE.

T. 21 N., R. XI E.		Mean depth	6.1 m.
Length	0.40 km.	Length of shoreline ...	1.0 km.
Breadth	0.16 km.	Shore development	1.22
Area	5.4 ha.	Mean slope of bottom..	7° 20′
Maximum depth	15.6 m.	Number of soundings ..	23

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	5.4	100.0	1.0	0-3	2.8	126,000	38.4	6° 54′	12.1
3	3.1	57.4	0.86	3-5	0.4	72,400	22.1	22° 34′	41.5
5	2.7	50.0	0.8	5-10	1.2	103,900	31.7	17° 48′	32.1
10	1.5	27.0	0.65	10-13	1.3	23,000	7.0	5° 56′	10.4
13	0.2	3.7	0.2	13-15.6	0.2	2,700	0.8	13° 53′	24.7
					Total..	328,000			

COLUMBIAN LAKE.

T. 21 and 22 N., R. XI E.		Mean depth	7.7 m.
Length	0.80 km.	Length of shoreline ...	2.8 km.
Breadth	0.54 km.	Shore development	1.39
Area	33.2 ha.	Mean slope of bottom..	4° 56′
Maximum depth	20.3 m.	Number of soundings ..	61

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	33.2	100.0	2.8	0-3	13.0	793,300	30.9	3° 27′	6.0
3	20.2	61.2	2.4	3-5	2.6	378,000	14.7	9° 36′	16.9
5	17.6	53.3	2.2	5-10	5.6	734,900	28.7	9° 40′	17.0
10	12.0	36.1	1.7	10-15	5.3	460,000	17.9	7° 54′	13.8
15	6.7	20.2	1.3	15-19	3.7	189,500	7.4	7° 6′	12.5
19	3.0	9.2	1.0	19-20.3	3.0	10,100	0.4	0° 55′	1.6
					Total..	2,565,800			

DAKE LAKE.

T. 21 N., R. XI E.

Length	0.60	km.
Breadth	0.50	km.
Area	14.8	ha.
Maximum depth	8.7	m.
Mean depth	3.26	m.
Length of shoreline	2.2	km.
Shore development	1.54	
Mean slope of bottom	2° 19′	
Number of soundings	30	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	14.8	100.0	2.2	0-3	7.8	319,800	66.0	3° 41′	6.4
3	7.0	46.8	1.2	3-5	3.5	103,500	21.3	3° 23′	5.9
5	3.5	23.4	0.8	5-8	2.7	59,900	12.4	3° 34′	6.2
8	0.8	5.2	0.35	8-8.7	0.8	1,800	0.3	0° 55′	1.6
					Total..	485,000			

HICKS LAKE.

T. 22 N., R. XI E.

Length	0.80	km.
Breadth	0.60	km.
Area	42.6	ha.
Maximum depth	18.2	m.
Mean depth	8.1	m.
Length of shoreline	3.6	km.
Shore development	1.57	
Mean slope of bottom	5° 48′	
Number of soundings	114	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	42.6	100.0	3.6	0-3	11.9	1,095,000	31.6	5° 4′	8.8
3	30.7	71.8	3.4	3-5	3.4	579,600	16.7	12° 14′	21.7
5	27.3	64.0	3.8	5-10	8.2	1,155,400	33.4	12° 38′	22.4
10	19.1	44.8	3.5	10-13	9.0	431,000	12.4	5° 42′	10.0
13	10.1	23.6	2.5	13-15	4.8	150,800	4.4	5° 2′	8.8
15	5.3	12.4	1.7	15-18.2	5.3	52,200	1.5	2° 55′	5.1
					Total..	3,464,000			

KNIGHTS LAKE.

T. 21 N., R. XI E.

Length	0.50 km.	Mean depth	4.4 m.
Breadth	0.20 km.	Length of shoreline	1.6 km.
Area	9.0 ha.	Shore development	1.53
Maximum depth	13.0 m.	Mean slope of bottom	6° 55′
		Number of soundings	42

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	9.0	100.0	1.6	0-3	4.0	207,500	51.9	6° 5′	10.6
3	5.0	55.5	1.3	3-5	1.7	82,000	20.5	9° 23′	16.5
5	3.3	36.6	1.4	5-10	2.4	99,000	24.8	12° 31′	22.2
10	0.9	10.0	0.6	10-13	0.9	11,500	2.8	7° 1′	12.3
					Total..	400,000			

LONG LAKE.

T. 21 N., R. XI E.

Length	1.50 km.	Mean depth	9.9 m.
Breadth	0.60 km.	Length of shoreline	4.2 km.
Area	43.9 ha.	Shore development	1.81
Maximum depth	23.7 m.	Mean slope of bottom	5° 45′
		Number of soundings	95

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	43.9	100.0	4.2	0-5	15.3	1,798,300	41.3	7° 45′	13.6
5	28.6	64.9	4.1	5-10	8.2	1,382,900	31.6	12° 54′	22.9
10	20.4	46.3	3.4	10-15	8.4	800,300	18.3	10° 11′	18.0
15	12.0	27.4	2.5	15-20	9.4	335,000	7.7	5° 15′	9.2
20	2.6	5.8	0.6	20-23	1.4	45,500	1.05	5° 50′	10.2
23	1.2	2.7	0.35	23-23.7	1.2	2,000	0.05	0° 35′	1.0
					Total..	4,364,000			

MacCROSSEN LAKE.

T. 22 N., R. XI E.		Mean depth	9.0 m.
Length	0.50 km.	Length of shoreline ...	1.6 km.
Breadth	0.30 km.	Shore development	1.21
Area	14.2 ha.	Mean slope of bottom..	6° 58′
Maximum depth	21.3 m.	Number of soundings ..	49

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	14.2	100.0	1.6	0-3	4.1	363,500	28.4	6° 10′	10.8
3	10.1	71.0	1.4	3-5	1.2	190,000	14.9	12° 25′	22.0
5	8.9	62.5	1.3	5-10	2.0	393,500	30.8	16° 48′	30.2
10	6.9	48.4	1.1	10-15	3.8	242,000	18.8	7° 27′	13.1
15	3.1	21.8	0.8	15-20	2.6	80,500	6.3	6° 7′	10.7
20	0.5	3.5	0.3	20-21.3	0.5	10,000	0.8	2° 14′	3.9
					Total..	1,279,500			

MARL LAKE.

T. 21 N., R. XI E.		Mean depth	6.2 m.
Length	0.50 km.	Length of shoreline	1.3 km.
Breadth	0.30 km.	Shore development	1.25
Area	8.6 ha.	Mean slope of bottom..	5° 50′
Maximum depth	18.4 m.	Number of coundings ..	17

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	8.6	100.0	1.3	0-3	4.6	193,000	35.9	3° 47′	6.6
3	4.0	46.5	0.73	3-5	0.5	101,000	18.8	15° 58′	28.6
5	3.5	40.8	0.7	5-10	1.1	146,000	27.1	15° 7′	27.0
10	2.4	27.4	0.5	10-15	1.4	81,700	15.2	9° 12′	16.2
15	1.0	11.7	0.4	15-17	0.5	14,700	2.7	7° 58′	14.0
17	0.5	5.6	0.3	17-18.4	0.5	1,600	0.3	2° 24′	4.2
					Total..	538,000			

MINER LAKE.

T. 21 N., R. XI E.

Length	0.54 km.	Mean depth	6.9 m.
Breadth	0.50 km.	Length of shoreline	1.9 km.
Area	15.6 ha.	Shore development	1.37
Maximum depth	14.2 m.	Mean slope of bottom..	4° 42′
		Number of soundings ..	43

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	15.6	100.0	1.9	0-3	4.3	402,000	37.4	6° 57′	12.2
3	11.3	72.3	1.6	3-5	1.7	209,000	19.4	11° 9′	19.7
5	9.6	61.6	1.4	5-10	4.9	385,300	35.8	7° 13′	12.6
10	4.7	30.3	1.0	10-13	3.8	76,700	7.1	3° 9′	5.5
13	0.9	5.7	0.4	13-14.2	0.9	3,000	0.3	1° 19′	2.3
					Total..	1,076,000			

MUD LAKE.

T. 21 N., R. XI E.

Length	0.20 km.	Mean depth	5.1 m.
Breadth	0.10 km.	Length of shoreline	0.6 km.
Area	1.7 ha.	Shore development	1.32
Maximum depth	9.7 m.	Mean slope of bottom..	7° 52′
		Number of soundings ..	12

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	1.7	100.0	0.6	0-5	0.8	63,700	73.1	16° 52′	30.3
5	0.9	53.0	0.4	5-8	0.4	20,300	23.3	14° 12′	25.3
8	0.5	29.4	0.3	8-9.7	0.5	3,200	3.6	3° 17′	5.7
					Total..	87,200			

OTTER LAKE.

T. 22 N., R. XI E.

Length	0.64 km.	Mean depth	4.7 m.
Breadth	0.12 km.	Length of shoreline	1.7 km.
Area	5.9 ha.	Shore development	2.00
Maximum depth	12.2 m.	Mean slope of bottom	8° 15′
		Number of soundings	39

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	5.9	100.0	1.7	0-3	1.9	147,800	52.5	14° 12′	25.3
3	4.0	67.8	1.3	3-5	1.3	67,200	23.9	10° 24′	18.3
5	2.7	45.7	1.1	5-10	2.4	64,500	22.9	7° 52′	13.8
10	0.3	5.0	0.2	10-12.2	0.3	2,000	0.7	4° 29′	7.9
					Total..	281,500			

POPE LAKE.

T. 21 N., R. XI E.

Length	0.35 km.	Mean depth	5.8 m.
Breadth	0.17 km.	Length of shoreline	1.0 km.
Area	6.6 ha.	Shore development	1.08
Maximum depth	12.3 m.	Mean slope of bottom	4° 32′
		Number of soundings	17

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	6.6	100.0	1.0	0-5	2.6	263,800	69.5	14° 15′	25.4
5	4.0	60.6	0.7	5-10	2.4	103,400	27.3	6° 57′	12.2
10	1.6	24.2	0.5	10-12.3	1.6	12,400	3.2	2° 3′	3.6
					Total..	379,600			

RAINBOW LAKE.

T. 22 N., R. XI E.

Length	1.00	km.
Breadth	0.75	km.
Area	55.7	ha.
Maximum depth	29.0	m.
Mean depth	11.2	m.
Length of shoreline	4.0	km.
Shore development	1.51	
Mean slope of bottom	6° 8′	
Number of soundings	151	

Depth.	Area.		Length of conto rs.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	55.7	100.0	4.0	0-3	16.0	1,424,000	22.7	4° 12′	7.3
3	39.7	71.4	3.8	3-5	2.5	769,200	12.3	17° 4′	30.7
5	37.2	67.1	3.7	5-10	5.2	1,728,300	27.6	19° 20′	35.1
10	32.0	57.5	3.6	10-13	6.8	855,700	13.7	8° 8′	14.3
13	25.2	45.4	2.8	13-15	5.5	448,000	7.2	5° 16′	9.2
15	19.7	35.5	2.3	15-20	10.1	718,600	11.5	6° 7′	10.7
20	9.6	17.3	2.0	20-23	5.0	208,400	3.3	5° 53′	10.3
23	4.6	8.2	1.4	23-25	2.5	64,600	1.0	5° 2′	8.8
25	2.1	3.7	0.8	25-28	1.3	41,500	0.66	7° 56′	13.9
28	0.8	1.4	0.3	28-29	0.8	2,700	0.04	1° 17′	2.2
					Total..	6,261,000			

ROUND LAKE.

T. 22 N., R. XI E.

Length	0.90	km.
Breadth	0.60	km.
Area	43.0	ha.
Maximum depth	20.3	m.
Mean depth	8.4	m.
Length of shoreline	3.2	km.
Shore development	1.35	
Mean slope of bottom	3° 15′	
Number of soundings	91	

Depth.	Area.		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilo-meters.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	43.0	100.0	3.2	0-5	18.0	1,681,600	46.2	4° 24′	7.7
5	25.0	58.2	2.4	5-10	6.8	1,077,000	29.6	7° 38′	13.4
10	18.2	42.0	1.8	10-15	8.8	678,000	18.4	5° 7′	8.9
15	9.4	21.7	1.3	15-17	4.3	142,800	3.9	2° 54′	5.0
17	5.1	11.8	0.8	17-19	4.1	55,900	1.5	1° 46′	3.1
19	1.0	2.3	0.4	19-20.3	1.0	1,700	0.4	0° 34′	1.0
					Total..	3,637,000			

TAYLOR LAKE.

T. 22 N., R. XI E.

Length	0.70 km.	Mean depth	4.4 m.
Breadth	0.50 km.	Length of shoreline	2.5 km.
Area	20.7 ha.	Shore development	1.57
Maximum depth	17.0 m.	Mean slope of bottom..	4° 2′
		Number of soundings ..	68

Depth.	Area		Length of contours.	Stratum.	Area between contours.	Volume.		Slope.	
Meters.	Ha.	Per cent of total.	Kilometers.	Meters.	Ha.	Cubic meters.	Per cent of total.	Degrees.	Per cent.
0	20.7	100.0	2.5	0-3	12.4	420,600	45.5	1° 41′	2.9
3	8.3	40.0	1.7	3-5	2.3	141,500	15.3	7° 42′	13.5
5	6.0	29.0	1.4	5-10	2.7	227,400	24.6	10° 57′	21.2
10	3.3	15.9	0.8	10-14	1.4	101,400	10.95	11° 39′	20.6
14	1.9	9.1	0.6	14-15	1.3	11,800	1.25	1° 57′	3.4
15	0.6	2.9	0.25	15-17	0.6	2,800	0.3	1° 28′	2.6
5[1]	0.6	2.9	0.25	5-9	0.6	20,000	2.1	20° 9′	36.7
					Total..	925,500			

[1] Basin south of Maple island.

CHAPTER X.

LAKES OF NORTHEASTERN AND NORTHWESTERN WISCONSIN.

THE NORTHEASTERN LAKE DISTRICT.

The lake district of northeastern Wisconsin is situated chiefly in Forest, Oneida, and Vilas counties. (See map XXVIII.) In general this region is covered with a thick mantle of glacial drift and much of it is fairly level. But there are hills and ridges which rise above the level of the surrounding country as much as 12 m. to 15 m. (40 ft. to 50 ft.), or in some instances, perhaps as much as 30 m. (100 ft.) or more. All of the lakes occupy typical morainal basins and have sandy or gravelly shores which show considerable variation in steepness and height. There is a very wide variation also in the outline of the different bodies of water; some are regular and almost circular in outline while others are very irregular. Generally in the elongated ones the main axes approximate a northeast-southwest trend, being parallel to the line of movement of the ice which was from the northeast to the southwest.

The elevation of the lakes of this district varies somewhat but the differences are not enough to affect the general biological conditions. The following lake elevations were furnished by Mr. A. A. Babcock, Manager of the Wisconsin Valley Improvement Company, and they are based upon the elevation of the lower Eagle River chain of lakes which is given as 492 m. (1,614 ft.) in Gannett's Dictionary of Altitudes.[1] A line of levels has been run across from these lakes to the Minocqua lake district and to several lakes lying south of this district. The datum in all of the tables is the mean tide level of the sea.

[1] U. S. G. S. Bull. 247, Series F, Geog. 47, 1906.

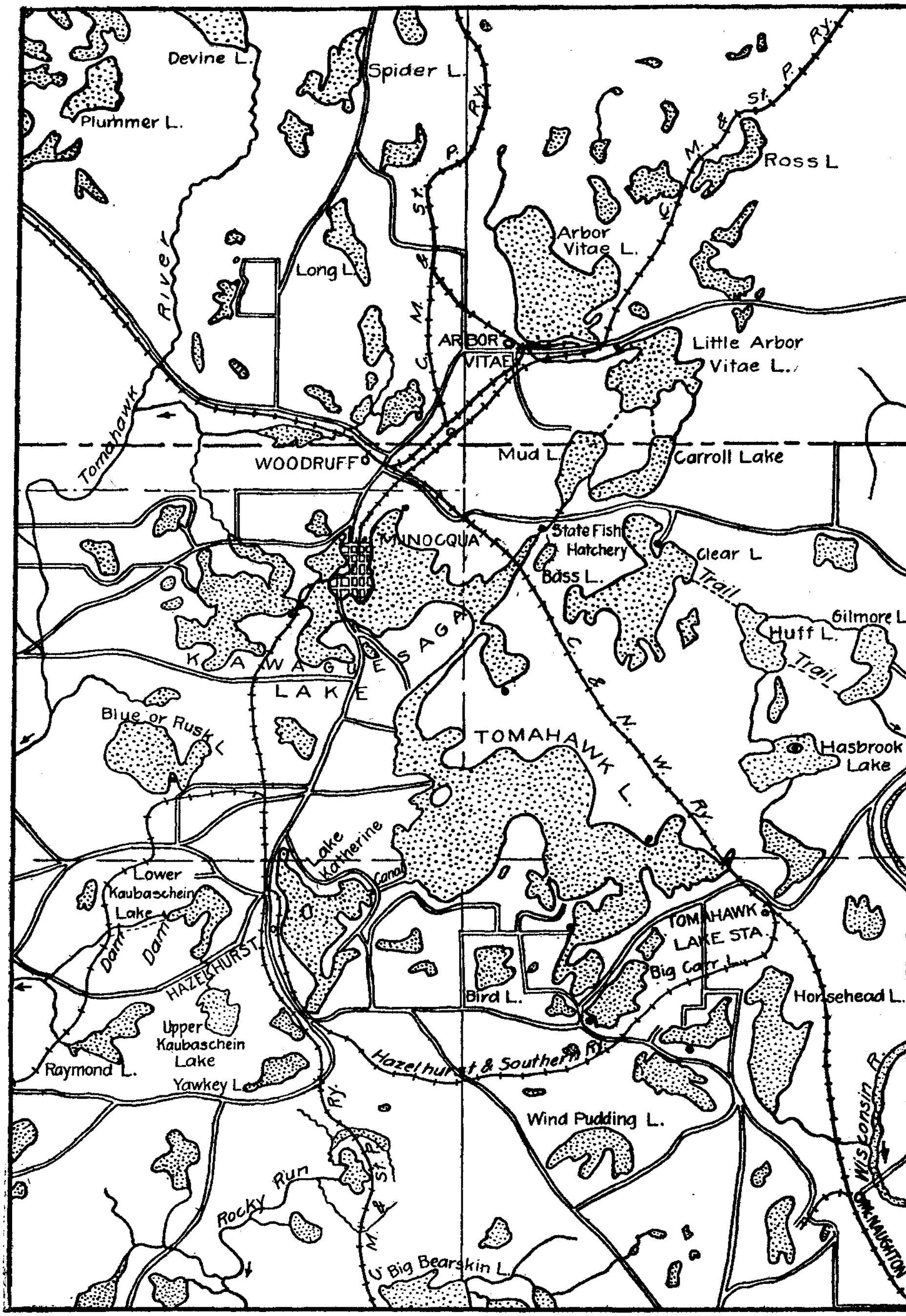


Fig. 7. Sketch map showing principal lakes in Minocqua region. Scale, 1 cm. = 1.6 km., or 1 in. = 2.5 mi. (See p. 116.)

	Elevation, Meters	Feet
Big Rice lake	446	1462
Dam lake	488	1603
Gilmore lake	482	1581
Kawaguesaga-Tomahawk chain of lakes	482	1582
Saint Germain, Big	485	1593
Saint Germain, Little	490	1609
Sand lake, T. 39 N., R. IX E.	488	1603
Squirrel lake	475	1560
Upper Eagle River chain of lakes (east of Three Lakes)	496	1626

In February, 1914, this line of levels was checked up at the Minocqua end. The surface of the ice in Kawaguesaga lake was found to be about 5 m. (nearly 17 ft.) below the railroad station for which an elevation of 488 m. (1,603 ft.) is given. This would make the altitude of the lake 483 m. (1,586 ft.) instead of 482 m. as given in the table. With respect to this difference, it may be said that both figures are based on railroad elvations and one is probably no more nearly correct than the other.

In Gannett's Dictionary of Altitudes, the elevation of the Lower Eagle River chain of lakes, which lies east of the city of Eagle River, is given as 492 m. (1614 ft.), while that of Pelican lake is 488 m. (1600 ft.). From data kindly furnished by the Chicago, Milwaukee and St. Paul railway, it has been found that the altitude of the surface of Trout lake is about 493 m. (1618 ft.). (See fig. 8).

Some idea of the altitude of the lakes in the different localities may be obtained from the following table of railroad elevations. In general the surfaces of the lakes in the vicinity of these places are not more than a few meters below the railroad stations for which the figures are given. A few of these elevations have been taken from Gannett's Dictionary of Altitudes, but thanks are due the Chicago, Milwaukee and St. Paul railway and the Chicago and Northwestern railway for the majority of them. Where lake Michigan was given as the datum plane, its surface has been regarded as 177.4 m. (582 ft.) above mean tide at New York.

	Elevation, Meters	Feet
Arbor Vitae	497	1630
Boulder Junction	505	1657
Conover	505	1656
Crandon	500	1640
Fosterville (now called Winegar)	501	1643
Hackley (now called Phelps)	515	1691
Hazelhurst	486	1595
Lac du Flambeau	498	1634
Mercer	487	1599
Papoose Junction	498	1633
Plum Lake	506	1659
Rhinelander	472	1550

Sayner	512	1679
Star Lake	512	1681
State Line	521	1711
Watersmeet	482	1581
Winchester	496	1626

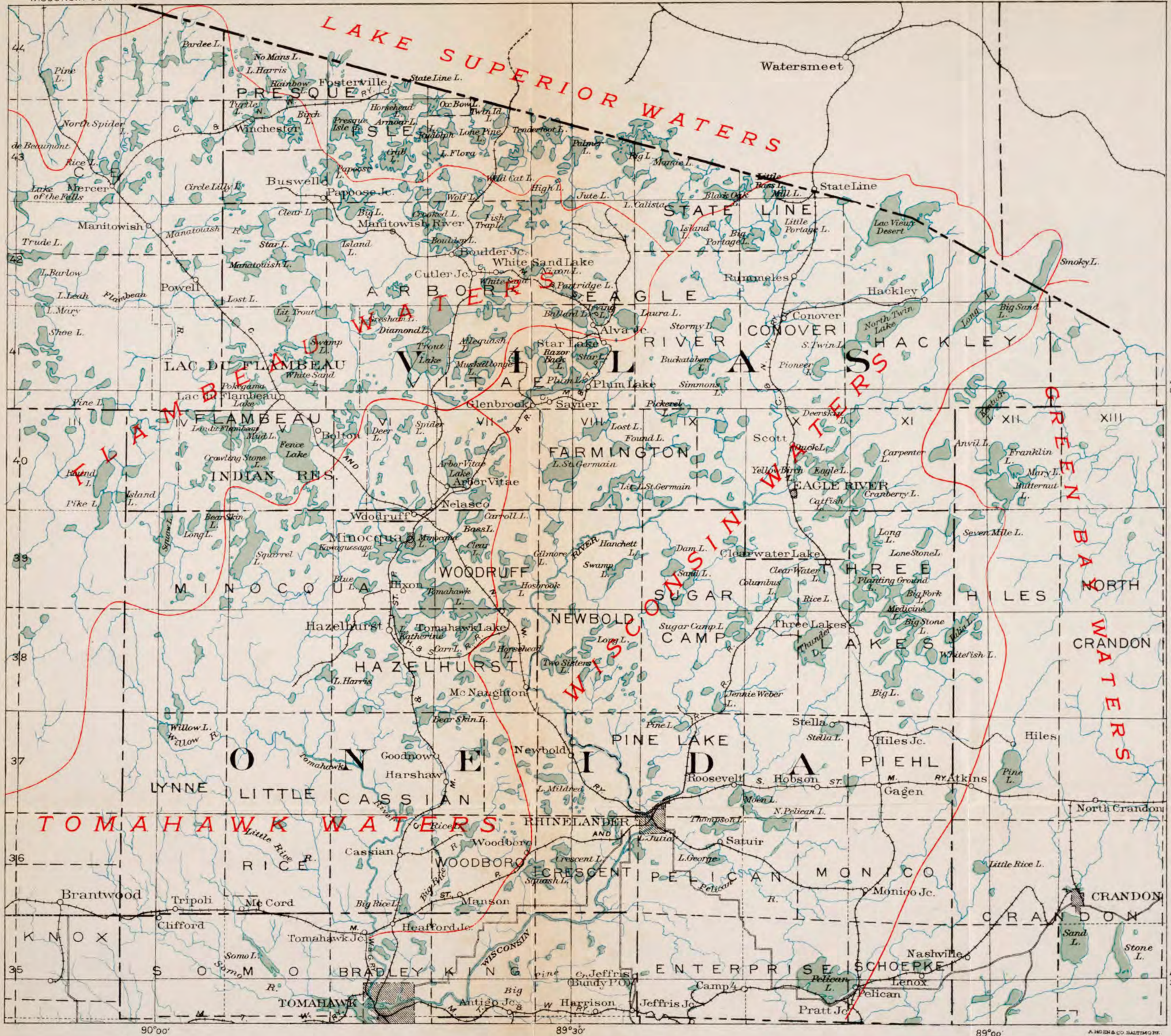
Taking the district as a whole, it will be noted that the maximum difference in the elevation of the various places given in the tables amounts to about 75 m. (249 ft.) which is not great enough to affect biological conditions.

It will be noted in Vilas county that the lakes comprise a very large percentage of the surface. The area of land surface in this county is about 2,350 sq. km. (907 sq. mi.) and of lake surface about 363 sq. km. (140 sq. mi.), making the ratio of the former to the latter about 6.5 to 1. The lake areas have been ascertained by planimeter measurements of the county map and consequently are only approximate. The total water surface, however, is undoubtedly larger than the amount given, since many of the smaller bodies of water are not shown on the map.

At one time the water area was even appreciably greater, for there are considerable expanses of swamp land which now represent extinct lakes. Many of the smaller lakes show various stages in the process of extinction; some are bordered by only a narrow margin of bog while others show only a small area of water in the midst of a wide area of bog.

In some instances several lakes are connected by streams or thoroughfares which are navigable for canoes and row-boats, while some are even navigable for small launches. In general, however, the deeper connections are the result of damming the outlet of a chain and raising the water level of the lower lakes high enough to affect that of the upper ones. The best illustrations of this are the Minocqua and Eagle River chain of lakes. Formerly Kawaguesaga and Minocqua lakes were two separate bodies of water, but a dam in the outlet of the former gives them such a broad connection that they really constitute but a single body now. This dam also raises the level of Kawaguesaga lake high enough to change the former stream connection between it and Tomahawk lake into a broad and deep thoroughfare. A more detailed map of this section is shown in fig. 7, p. 114. Trout lake is the deepest lake yet found in this district and it is also second in size, being exceeded only by Lac Vieux Desert. A more detailed map of the Trout lake region is shown in fig. 8, p. 118.

The general drainage areas are shown on map XXVIII. The central and larger portion of the district is drained by the Wisconsin river and its tributaries, chief among the latter being the Tomahawk



Scale $\frac{1}{380160}$ or 6 miles to an inch.

6 3 0 6 12

NORTHEASTERN LAKE DISTRICT

river. The more westerly portion drains into the Flambeau and its tributaries. These two streams belong to the Mississippi system so that the greater portion of the district lies within the Mississippi basin. The more northerly and the more easterly portions are in the Great Lakes basin. The former drains into lake Superior through the Presque Isle and Ontonagon rivers, while the latter drains into lake Michigan through the Bois Brule, the Peshtigo, and the Wolf rivers. Many of the lakes do not possess visible outlets.

Most of the lakes of this district have soft water; in some of them the water is unusually soft. The waters of many of the lakes have a brownish color as the result of being stained in passing through marshy or swampy areas.

The location, length, breadth, area, and maximum known depth of a number of these lakes are given in table No. 3, p. 126. For the purpose of ascertaining their value as reservoir sites, some of these lakes have been surveyed by Mr. C. B. Stewart, Consulting Engineer, and their areas have been carefully determined. In such cases the areas obtained by him have been incorporated in the table, and these lakes are indicated by an asterisk. With respect to the areas of the other lakes included in the table, it may be said that they were determined from county maps by means of a planimeter and are to be regarded only as approximate.

LAKES OF NORTHWESTERN WISCONSIN.

The lakes of northwestern Wisconsin are widely distributed through an area which is about 175 km. (110 mi.) long in a northeast-southwest direction and from 60 km. (37 mi.) to a little over 100 km. (62 mi.) wide in a northwest-southeast line. The district comprises some or all of the following counties: Barron, Bayfield, Burnett, Chippewa, Douglas, Polk, Rusk, Sawyer, and Washburn. (See map XXIX.) This area belongs to three drainage basins. The northern portion lies within the lake Superior basin, as shown on the map, and the remainder is about equally divided between the Chippewa and the St. Croix basins which are parts of the Mississippi basin.

The lakes of this area may be separated into three groups on geographical grounds[1]. One group consists of those which lie in the vicinity of the kettle range in Bayfield and Douglas counties. This range forms the height of land separating the Great Lakes and Mississippi basins. Many of these lakes are small and have neither a vis-

[1] Geology of Wisconsin, Vol. III, p. 374, 1880.

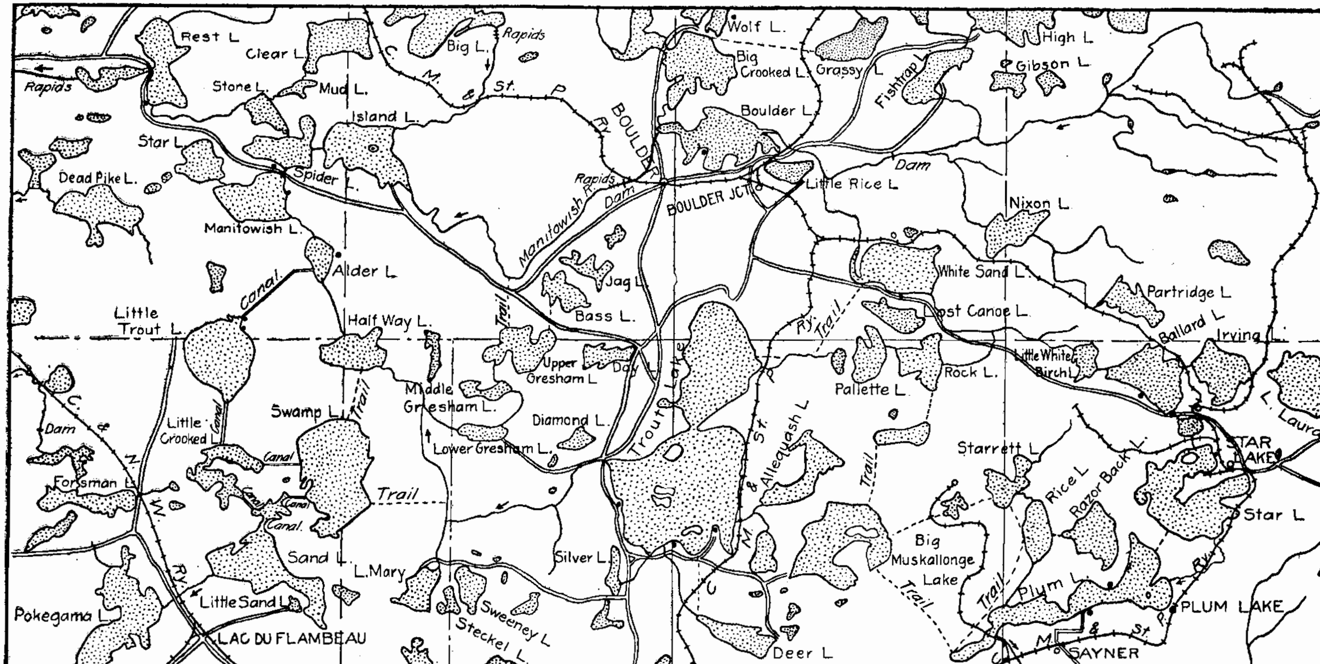


Fig. 8. Sketch map of Trout lake region. Scale, 1 cm. = 2.1 km., or 1 in. = 3.4 mi. (See p. 116.)

ible inlet nor outlet; while others are larger and are the sources of streams whose waters reach either lake Superior or the Missisisppi river.

The other two groups of lakes extend southwestward from the first group to the southern edge of the lake district. The one on the west side of this area lies in the basin of the St. Croix river. The northern lakes of this group are situated in sand and gravel plains which have been called the "barrens". The southern ones lie in or near a range of drift hills and ridges which form a part of the great kettle moraine.

The third group comprises the eastern division and its members lie chiefly in the basin of the Chippewa river. The waters of those at the extreme southwestern end reach the St. Croix river. The accompanying map (XXIX) shows that the second and third groups are separated by a long narrow belt of land which has very few or no lakes at all. This area shows no unusual elevation above the surrounding country but its eastern edge forms the watershed which separates the upper courses of the St. Croix and Chippewa rivers.

The lakes of this entire district belong to the morainal type; not a single one occupies a basin excavated in bed rock because the whole region is covered with a thick mantle of drift. During the late Wisconsin glacial epoch most of this region was covered by the Chippewa and Superior glaciers, consequently most of the lakes date their existence from this period. A small area in the vicinity of St. Croix was invaded by the Keewatin glacier.[1] Apparently some of the extreme southern portion of this district was not invaded by ice during the Wisconsin epochs, so that the lake basins in this section were formed in pre-Wisconsin times.

The basins which are now occupied by the waters of these lakes were formed by various agencies, chief among which were the burial of blocks of ice in the glacial débris and their subsequent melting, and the damming of valleys during the deposition of this thick mantle of drift. The shores are composed of morainal detritus, chiefly sand and gravel. Some of these lakes are situated in hilly country so that portions of their shores are steep and high; others occupy depressions in fairly level plains, and have comparatively low shores.

Some idea of the elevation of the various lakes of this district may be gained from the following table of railroad elevations. The altitude of the lakes in the vicinity of these places varies from 2 m. or 3 m. (6.5 ft. to 10 ft.) to perhaps 10 m. or 15 m. (33 ft. to 50 ft.) below the figures given in the table. Most of these elevations have been

[1] Jour. Geol., Vol. XIII, 1905, p. 238.

taken from Gannett's Dictionary of Altitudes, but a few of them have been kindly furnished by the Minneapolis, St. Paul and Sault Ste. Marie railway.

	Elevation, Meters	Feet
Amery	326	1070
Birchwood	381	1249
Cable	418	1370
Chetek	321	1053
Cumberland	378	1241
Drummond	395	1297
Frederic	369	1210
Hayward	361	1186
Iron River	334	1096
Lake Nebagamon	347	1137
Luck	370	1213
Minong	323	1061
Reserve	399	1309
Saint Croix Falls	281	921
Shell Lake	378	1241
Signor	396	1299
Solon Springs	330	1083
Stone Lake	399	1308
Turtle Lake	383	1258

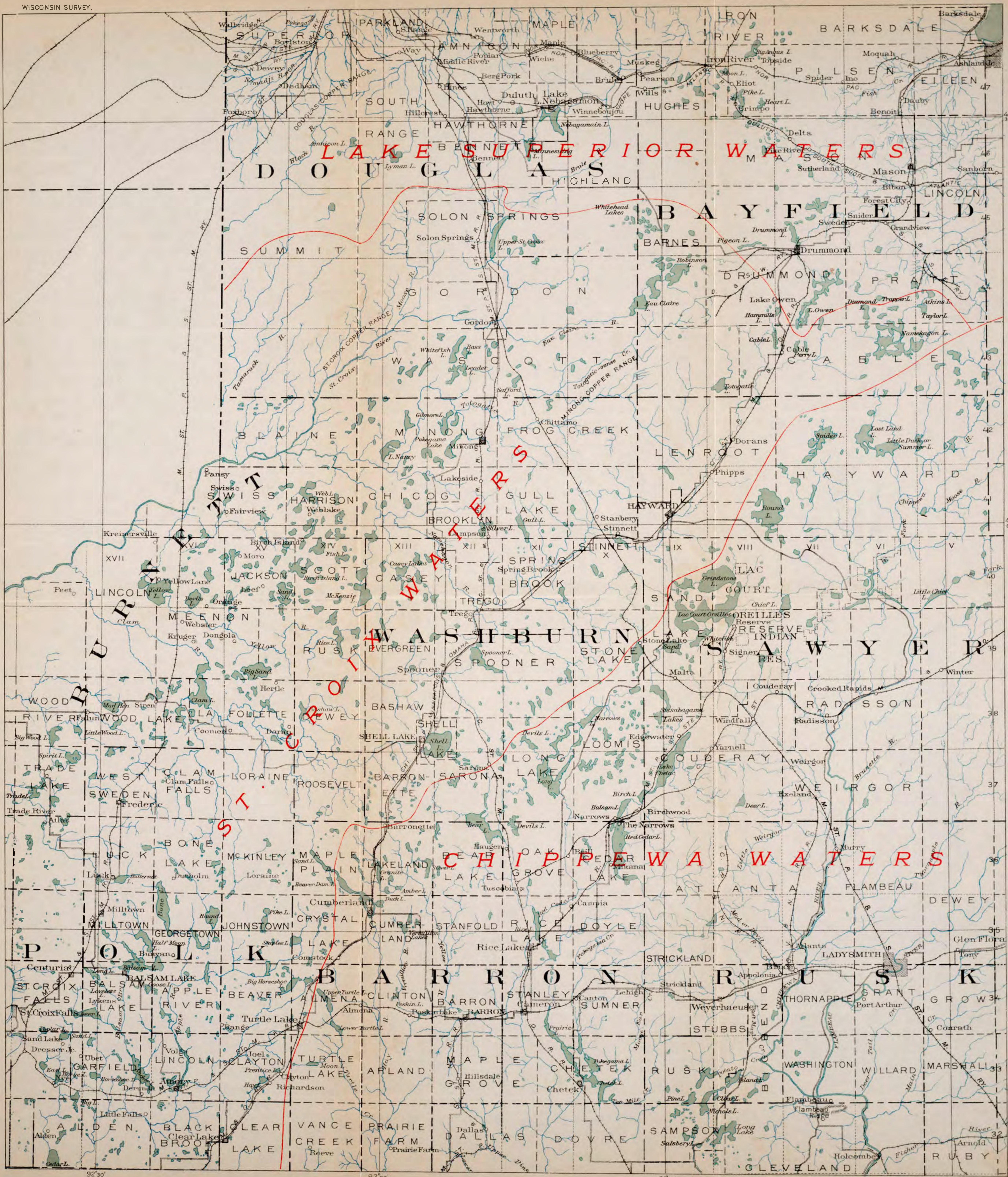
It will be noted that the general altitude of this district is distinctly lower than that of the northeastern district, and that the maximum range of elevation is somewhat greater, that is, about 100 m. (328 ft.).

Many of the smaller lakes have fairly regular outlines, but the larger ones are frequently very irregular, such as Owen and Namekagon lakes and Lac Court Oreilles. Many of the latter are very much elongated also, but their axes do not all trend in the same, or approximately the same direction, some of them even lying at right angles to others.

Most of the lakes of this district which have been tested possess waters of a medium hardness, but a few of them have unusually soft waters.[1]

Some data concerning those lakes of this district which have been visited for preliminary studies, are shown in table No. 4, p. 130. The areas must be regarded as approximate since they have been determined by planimeter measurements from county maps.

[1] Bull. XXII, Wis. Geol. and Nat. Hist. Survey, p. 77, 1911.



Scale 380160 or 6 miles to an inch.

6 3 0 6 12

NORTHWESTERN LAKE DISTRICT

CHAPTER XI.

STATISTICAL TABLES.

Morphometrical data for all of the Wisconsin lakes of which complete surveys have been made are given in connection with the discussion of the various lakes and lake districts. Table 1 contains a restatement of some of the more general facts concerning the same lakes, together with some additional data; and this table is followed by three others (tables 2, 3, and 4) which give data concerning the lakes that have been visited but of which detailed surveys have not yet been made. Four of the larger lakes that are shown on the sketch map of southeastern Wisconsin (fig. 3, p. 8) have not been considered in the text and they are not given in the tables. They are Beaver, Fox, Koshkonong, and Rush lakes. All are known to be shallow bodies of water, their maximum depths probably falling somewhere between 3 m. and 6 m. (10 ft. and 20 ft.).

LOCATIONS AND DIMENSIONS.

The location of the lakes is indicated by the town, the range, and the county. The length, the breadth, the depth, the length of the shoreline, and the elevation above the sea, are stated in both metric and English units. The length and the breadth are the maximum dimensions and have been measured substantially at right angles to each other. The area of each lake is given in square kilometers, in square miles, and in acres. The surface areas of the lakes, as well as the areas at different depths, were determined by planimeter measurements. The enlarged, original maps, which were prepared from county and other maps and from data obtained in the hydrographic survey, were used for these measurements. The large maps could be measured more accurately than the smaller, printed maps. The scales of the original maps are shown in the last column of the table.

The mean depth has been determined by dividing the volume of the lake by its surface area $\left(\frac{V}{A}\right)$. The relation of the mean depth to the maximum depth is found by dividing the former by the latter.

$$\left(\frac{Dm}{Dmx}\right)$$

The depths shown on the accompanying hydrographic maps are given only in meters.

The length of the shoreline as well as the length of the isobaths or bottom contour lines, was determined by means of a Universal Map Measurer. The term *shore development* means the ratio of the length of the shoreline to the length of the circumference of a circle whose area is equal to that of the lake. The simplest ratio is unity. Therefore when the ratio of the shoreline to the circumference of a circle of equal area approaches one, it indicates that the lake has a simple shoreline and that it is circular in form. On the other hand, a wide departure from unity indicates that the lake has a very irregular coastline. The maximum development of shoreline is shown by Cedar and Okauchee lakes and the minimum by Booth lake. (See table No. 1.)

VOLUME.

There are several formulas for calculating the cubic contents of hills or mountains and all apply equally as well to the determination of the volume of a body of water. Penck[1] and Halbfass[2] have shown that all of them give substantially the same results; the differences, at least, are well within the limits of error of the maps and of the measurements. The following formula[3] has been selected as the one which gives most closely, perhaps, the actual volume of a body of water and it has been used for all of the volumetric determinations.

$$V = \frac{h}{3}\left(s_1 + s_2 + \sqrt{s_1 s_2}\right)$$

In this formula s_1 is the area of the upper surface and s_2 the area of the lower surface of the stratum whose volume is to be determined; h is the vertical depth or thickness of this stratum. The volumes are given in million cubic meters and million cubic yards in the general

1 Morphometrie des Bodensees. Jahresber. d. Geograph. Gesellsch. in München, 1894, p. 119.

2 Morphometrie des Genfer Sees. Zeit. d. Gesellsch. f. Erdk. zu Berlin, Bd. XXXII, 1897, p. 219.

3 Penck. Morphologie der Erdoberfläche, Bd. I, p. 77, formula 37. Stuttgart, 1894.

TABLE I. SURVEYED LAKES IN SOUTHEASTERN WISCONSIN.

Lake.	Town. N.	Range. E.	County.	Length. Km.	Length. Mi.	Maximum breadth. Km.	Maximum breadth. Mi.	Area. Sq. Km	Area. Sq. Mi.	Area. Acres.	Depth. Maximum. Meters	Depth. Maximum. Feet.	Depth. Mean. Meters	Dm / Dmx	Volume. Million cu. m.	Volume. Million cu. yds	Development. Volume.	Development. Shore	Length of shoreline. Km.	Length of shoreline. Mi.	Mean slope of bottom. Degrees.	Mean slope of bottom. Per cent.	Elevation above sea. Meters	Elevation above sea. Feet.	Number of hydrographic map.	Scale of hydrographic map.	Scale of original map.
Beaver	8	XVIII	Waukesha	1.77	1.10	0.70	0.44	1.24	0.48	305.4	15.0	49.0	5.1	0.34	6.31	8.26	1.02	1.38	5.4	3.4	1° 44′	3.0	277.4	910	X	1:39,600	1:12,700
Beulah	4	XVIII	Walworth	4.26	2.65	1.76	1.10	3.42	1.32	848.6	......	......	......	......	20.80	27.22	......	3.18	20.9	13.0	......	......	246.9	810	XXI	1:33,300	1: 8,000
Upper	......	......	......	......	......	......	......	1.02	0.39	253.0	20.4	67.0	8.0	0.39	8.18	10.71	1.17	2.24	8.0	5.0	3° 12′	5.6	......	......	......	......	......
Round	......	......	......	......	......	......	......	0.39	0.15	97.2	12.2	40.0	2.8	0.23	1.10	1.44	0.69	1.11	2.5	1.5	1° 51′	3.2	......	......	......	......	......
Lower	......	......	......	......	......	......	......	1.78	0.69	441.2	16.9	55.5	5.3	0.31	9.42	12.34	0.93	2.08	9.8	6.0	1° 22′	2.4	......	......	......	......	......
Mill	......	......	......	......	......	......	......	0.23	0.09	57.2	15.7	51.5	9.0	0.58	2.10	2.73	1.74	1.18	2.0	1.2	3° 45′	6.5	......	......	......	......	......
Big Cedar	11	XIX	Washington	5.90	3.64	1.00	0.64	3.87	1.47	942.3	31.9	104.7	11.1	0.35	42.00	54.93	1.05	2.34	16.4	10.2	3° 50′	[1]6.7	314.0	1,030	XXIII	1:35,300	1:11,900
Booth	4	XVII	Walworth	0.93	0.58	0.69	0.43	0.49	0.19	122.4	7.7	25.4	3.7	0.49	1.84	2.41	1.47	1.04	2.6	1.6	1° 6′	1.9	247.5	812	XXI	1:33,300	1: 8,000
Crooked	7	XVII	Waukesha	1.08	0.67	0.50	0.31	0.22	0.08	54.8	4.9	16.0	1.9	0.40	0.42	0.55	1.20	1.75	2.9	1.8	1° 7′	1.9	264.6	868	XIV	1:40,000	1:12,700
Delavan	2	XVI	Walworth	6.00	3.75	1.80	1.10	7.34	2.83	1,813.2	17.2	56.7	8.0	0.46	58.67	76.77	1.38	2.05	19.7	12.2	1° 2′	1.8	283.5	930	XVIII	1:40,000	1:10,500
Devils	11	VI	Sauk	2.00	1.25	1.00	0.61	1.46	0.56	360.8	13.1	43.2	8.9	0.68	13.01	17.03	2.04	1.23	5.3	3.3	1° 27′	2.5	291.0	955	VIII	1:13,100	1: 6,000
East Troy	4	XVIII	Walworth	0.80	0.50	0.62	0.39	0.31	0.12	78.2	5.0	16.5	2.9	0.58	0.89	1.16	1.74	1.17	2.3	1.4	0° 58′	1.7	246.9	810	XXI	1:33,300	1: 8,000
Elkhart	16	XXI	Sheboygan	1.76	1.10	1.26	0.79	1.21	0.47	299.5	34.5	113.2	13.5	0.39	16.33	21.39	1.17	1.70	6.6	4.1	5° 21′	9.4	282.0	925	XXIV	1:17,500	1: 6,000
Fowler	8	XVII	Waukesha	1.60	0.94	0.70	0.44	0.34	0.13	83.5	15.2	50.0	4.4	0.29	1.48	1.92	0.87	1.57	3.2	2.0	3° 0′	5.2	262.4	861	XII	1:40,000	1:12,700
Garvin	8	XVIII	Waukesha	0.50	0.31	0.26	0.17	0.08	0.03	21.6	11.0	36.1	5.0	0.45	0.43	0.56	1.35	1.36	1.4	0.87	2° 47′	4.8	266.1	873	XI	1:39,600	1:12,700
Genesee, North	7	XVII	Waukesha	0.82	0.51	0.67	0.42	0.41	0.16	101.9	11.1	36.4	4.5	0.41	1.86	2.43	1.23	1.06	2.4	1.5	1° 56′	3.4	264.0	866	XIV	1:40,000	1:12,700
Genesee, South	7	XVII	Waukesha	0.64	0.40	0.48	0.30	0.25	0.09	62.7	14.5	47.6	6.7	0.46	1.71	2.24	1.38	1.05	1.9	1.2	3° 30′	6.1	263.6	865	XIV	1:40,000	1:12,700
Geneva	1	XVII	Walworth	12.10	7.50	3.22	2.00	22.10	8.76	5,451.3	43.3	142.0	19.7	0.47	434.77	569.54	1.41	1.94	32.4	20.1	1° 58′	3.4	263.3	864	XVII	1:43,500	1:15,800
Green	15 & 16	XII & XIII	Green Lake	11.90	7.40	3.22	2.00	29.72	11.47	7,342.4	72.2	237.0	33.1	0.46	984.82	1,290.20	1.38	1.78	34.2	21.2	2° 52′	5.0	278.0	912	XXV	1:42,300	1:15,800
Kegonsa	6	X & XI	Dane	4.83	3.00	3.62	2.25	12.73	4.91	3,145.2	9.6	31.4	4.6	0.49	59.06	77.25	1.47	1.22	15.5	9.6	0° 20′	0.6	256.6	842	V	1:41,400	1:11,800
Lac la Belle	8	XVII	Waukesha	4.44	2.70	1.80	1.12	4.60	1.77	1,137.5	14.2	46.6	3.3	0.23	15.16	19.85	0.69	1.64	12.5	7.8	0° 53′	1.5	260.3	854	XII	1:40,000	1:12,700
Lauderdale	4	XVI	Walworth	......	......	......	......	3.47	1.34	858.3	......	......	......	......	......	......	......	......	......	......	......	......	271.3	890	XIX	1:21,800	1:10,500
Green	......	......	......	1.75	1.09	1.06	0.66	1.12	0.43	277.9	17.3	56.8	7.5	0.43	8.42	11.03	1.29	1.56	6.0	3.7	2° 11′	3.8	......	......	......	......	......
Middle	......	......	......	2.57	1.60	0.72	0.45	1.15	0.44	284.0	15.2	50.0	2.9	0.19	3.31	4.33	0.57	2.27	8.7	5.4	1° 44′	3.0	......	......	......	......	......
Mill	......	......	......	1.20	0.75	0.79	0.49	1.20	0.46	296.4	15.2	50.0	2.5	0.16	2.98	3.90	0.48	2.26	8.4	5.2	1° 21′	2.4	......	......	......	......	......
Mendota	7 & 8	IX	Dane	9.50	5.90	7.40	4.60	39.40	15.20	9,729.8	25.6	84.0	12.1	0.47	478.37	626.66	1.41	1.47	32.4	20.1	0° 43′	1.3	258.8	849	II	1:45,400	1:10,500
Monona	7	X & X	Dane	6.70	4.16	3.85	2.40	14.10	5.44	3,482.7	22.5	74.0	8.4	0.37	118.88	155.73	1.11	1.62	21.4	13.3	0° 43′	1.3	257.5	845	III	1:35,000	1: 7,800
Mouse	8	XVIII	Waukesha	1.32	0.82	0.33	0.21	0.36	0.14	90.3	20.2	66.3	9.1	0.45	3.09	4.04	1.35	1.84	3.9	2.4	3° 58′	6.9	267.3	877	XI	1:39,600	1:12,700
Nagawicka	7	XVIII	Waukesha	4.42	2.75	1.80	1.12	3.71	1.43	917.6	28.8	94.5	11.0	0.38	40.96	53.65	1.14	1.65	11.3	7.0	2° 25′	4.2	271.3	890	XIII	1:40,000	1:12,700
Nashotah, Upper	7	XVII	Waukesha	1.30	0.81	0.64	0.40	0.55	0.21	136.7	15.6	51.2	7.0	0.45	3.88	5.08	1.35	1.34	3.5	2.2	2° 32′	4.4	265.8	872	XIII	1:40,000	1:12,700
Nashotah, Lower	7	XVII	Waukesha	1.27	0.79	0.40	0.25	0.40	0.15	100.3	14.1	46.2	6.1	0.43	2.49	3.26	1.29	1.35	3.0	1.9	3° 4′	5.3	265.5	871	XIII	1:40,000	1:12,700
Nemahbin, Upper	7	XVII	Waukesha	1.69	1.05	0.90	0.56	1.09	0.42	271.1	18.9	62.0	9.0	0.48	9.95	13.03	1.44	1.21	4.5	2.8	2° 14′	3.9	265.5	871	XIII	1:40,000	1:12,700
Nemahbin, Lower	7	XVII	Waukesha	1.49	0.93	0.96	0.60	1.07	0.41	265.5	10.8	35.2	2.5	0.23	2.67	3.49	0.69	1.12	4.1	2.5	1° 3′	1.8	265.2	870	XIII	1:40,000	1:12,700

[1] South part.

TABLE I.—Continued.

Lake.	Town. N.	Range. E.	County.	Length. Km.	Length. Mi.	Maximum breath. Km.	Maximum breath. Mi.	Area. Sq. Km	Area. Sq. Mi.	Area. Acres.	Depth. Maximum. Meters	Depth. Maximum. Feet.	Depth. Mean. Meters	Dm / Dmx	Volume. Million cu. m.	Volume. Million cu. yds	Development. Volume.	Development. Shore	Length of shoreline. Km.	Length of shoreline. Mi.	Mean slope of bottom. Degrees.	Mean slope of bottom. Per cent.	Elevation above sea. Meters	Elevation above sea. Feet.	Number of hydrographic map.	Scale of hydrographic map.	Scale of original map.
North, east part	8	XVIII	Waukesha	2.16	1.35	0.75	0.47	1.33	0.51	329.0	23.7	78.0	12.8	0.54	17.02	22.29	1.62	1.29	5.2	3.3	3° 34′	6.2	273.4	897	X	1:39,600	1:12,700
North, west part	8	XVIII	Waukesha	1.07	0.67	0.57	0.36	0.47	0.18	115.0	22.4	73.6	11.4	0.52	5.33	6.96	1.56	1.12	2.7	1.7	4° 15′	7.4	273.4	897	X	1:39,600	1:12,700
Oconomowoc, main basin	7	XVII	Waukesha	2.82	1.75	1.37	0.85	2.55	0.99	631.3	19.1	62.6	9.5	0.50	24.30	31.84	1.50	1.32	7.5	4.7	1° 50′	3.2	262.4	862	XI	1:39,600	1:12,700
Oconomowoc northeast basin	7	XVII	Waukesha	1.20	0.75	0.80	0.50	0.73	0.28	180.0	15.0	49.2	7.9	0.52	5.75	7.53	1.56	1.23	3.7	2.3	2° 12′	3.8	262.4	862	XI	1:39,600	1:12.700
Okauchee	8	XVII & XVIII	Waukesha	3.81	2.37	2.90	1.80	4.28	1.65	1,057.0	28.6	94.0	12.1	0.42	43.72	57.27	1.26	2.44	17.9	11.1	1° 43′	3.0	266.1	873	XI	1:39,600	1:12,700
Otis	7	XVII	Waukesha	0.70	0.43	0.60	0.37	0.16	0.06	40.0	8.6	28.3	4.9	0.57	0.79	1.02	1.71	1.30	1.9	1.1	2° 57′	5.1	264.0	866	XIV	1:40,000	1:12,700
Pewaukee	7	XVIII & XIX	Waukesha	7.24	4.50	1.93	1.20	9.30	3.59	2,298.0	13.8	45.3	3.9	0.28	36.69	48.06	0.84	1.79	19.5	12.1	0° 32′	0.9	259.7	852	XV	1:39,600	1:12,700
Pine	8	XVIII	Waukesha	3.70	2.30	1.70	1.05	3.06	1.18	755.7	27.4	90.0	12.1	0.44	37.01	48.48	1.32	1.73	10.9	6.8	2° 41′	4.7	275;2	903	X	1:39,600	1:12,700
Rock	7	XIII	Jefferson	3.20	2.00	2.00	1.25	4.96	1.91	1,225.0	20.4	67.0	6.1	0.30	30.32	39.66	0.90	1.23	9.7	6.1	1° 7′	1.9	252.1	827	VII	1:23,500	1: 4,800
Silver	7	XVI	Waukesha	1.56	0.97	0.90	0.56	0.94	0.36	231.9	13.4	44.0	4.8	0.36	4.50	5.88	1.08	1.35	4.6	2.9	1° 44′	3.0	263.3	864	XIV	1:40,000	1:12,700
Waubesa	6 & 7	X	Dane	6.75	4.20	2.25	1.40	8.24	3.18	2,034.4	11.1	36.6	4.9	0.44	40.25	52.64	1.32	1.36	13.9	8.7	0° 28′	0.8	257.2	844	IV	1:41,100	1:11,800
Waupaca Chain O' Lakes.	21 & 22	XI	Waupaca.						......	......	......	......	......	......	......	......	......	......	......	......	......	......	244.0	[2]800	XXVII	1:33,300	1: 8,000
Bass	......	......	......	0.09	0.06	0.09	0.06	0.01	0.003	2.5	2.7	9.0	1.3	0.48	0.013	0.017	1.44	1.09	0.3	0.2	......	......	......	......	......	......	......
Beasley	......	......	......	0.40	0.25	0.16	0.10	0.05	0.019	13.5	15.6	51.2	6.1	0.39	0.33	0.43	1.17	1.22	1.0	0.6	7° 20′	12.5	......	......	......	......	......
Columbian	......	......	......	0.80	0.50	0.54	0.34	0.33	0.13	82.0	20.3	66.6	7.7	0.38	2.56	3.35	1.14	1.39	2.8	1.7	4° 56′	8.6	......	......	......	......	......
Dake	......	......	......	0.60	0.35	0.50	0.30	0.15	0.06	36.7	8.7	28.5	3.2	0.37	0.48	0.62	1.11	1.54	2.2	1.3	2° 19′	4.0	......	......	......	......	......
Hicks	......	......	......	0.80	0.50	0.60	0.40	0.42	0.16	105.4	18.2	60.0	8.1	0.45	3.46	4.54	1.35	1.57	3.6	2.2	5° 48′	10.1	......	......	......	......	......
Knights	......	......	......	0.50	0.34	0.20	0.14	0.09	0.03	22.4	13.0	42.6	4.4	0.34	0.40	0.52	1.02	1.53	1.6	1.0	6° 55′	12.1	......	......	......	......	......
Long	......	......	......	1.50	0.94	0.60	0.36	0.44	0.17	108.4	23.7	77.7	9.9	0.42	4.36	5.71	1.26	1.81	4.2	2.6	5° 45′	10.0	......	......	......	......	......
MacCrossen	......	......	......	0.50	0.31	0.30	0.19	0.14	0.054	35.2	21.3	70.0	9.0	0.39	1.28	1.67	1.17	1.21	1.6	1.0	6° 58′	12.2	......	......	......	......	......
Marl	......	......	......	0.50	0.31	0.30	0.19	0.08	0.03	21.3	18.4	60.6	6.2	0.34	0.53	0.69	1.02	1.25	1.3	0.8	5° 50′	10.2	......	......	......	......	......
Miner	......	......	......	0.54	0.34	0.50	0.31	0.15	0.06	38.6	14.2	46.6	6.9	0.48	1.07	1.40	1.44	1.37	1.9	1.2	4° 42′	8.2	......	......	......	......	......
Mud	......	......	......	0.20	0.13	0.10	0.06	0.017	0.065	4.2	9.7	32.0	5.1	0.51	0.087	0.10	1.53	1.32	0.6	0.4	7° 52′	13.8	......	......	......	......	......
Otter	......	......	......	0.64	0.40	0.12	0.08	0.059	0.023	14.5	12.2	40.0	4.7	0.39	0.28	0.36	1.17	2.00	1.7	1.1	8° 15′	14.5	......	......	......	......	......
Pope	......	......	......	0.35	0.22	0.17	0.11	0.066	0.025	16.2	12.3	40.6	5.8	0.47	0.38	0.49	1.41	1.08	1.0	0.6	4° 32′	7.9	......	......	......	......	......
Rainbow	......	......	......	1.00	0.62	0.75	0.47	0.55	0.21	137.5	29.0	95.1	11.2	0.39	6.26	8.20	1.17	1.51	4.0	2.5	6° 8′	10.7	......	......	......	......	......
Round	......	......	......	0.90	0.55	0.60	0.35	0.43	0.16	106.2	20.3	66.6	8.4	0.41	3.63	4.75	1.23	1.35	3.2	2.0	3° 15′	5.6	......	......	......	......	......
Taylor	......	......	......	0.70	0.45	0.50	0.31	0.20	0.077	51.2	17.0	55,7	4,4	0.26	0.92	1.20	0.78	1.57	2.5	1.5	4° 2′	7.0	......	......	......	......	......
Youngs	......	......	......	0.13	0.08	0.11	0.07	0.012	0.004	3.0	3.5	11.6	1.9	0.54	0.023	0.03	1.62	1.11	0.4	0.25	2° 54′	5.0	......	......	......	......	......
Winnebago	15 to 20	XVII & XVIII	......	45.00	28.00	16.60	10.40	557.52	215.2	137,708.0	6.4	21.0	4.7	0.73	2,630.09	3,440.15	2.19	1.76	148.0	92.5	0° 3′	0.07	227.7	747	XXVI	1:185.000	1:62,500

[2] This elevation is only an estimate based on the elevation of the weather bureau in the city of Waupaca which is 261 m. (857 feet).

table, but they are stated in cubic meters only in the detailed statements for the various lakes.

The volume development shows the relation of the volume of the lake to that of a cone whose basal area is equal to the area of the lake and whose height is equal to the maximum depth. It is determined by the following formula: $3\left(\frac{Dm}{Dmx}\right)$. That is, it is three times the quotient obtained by dividing the mean depth by the maximum depth. When the result approaches unity, as in Beaver lake, it means that the basin occupied by the lake is cone shaped so that its volume is approximately that of a cone whose base equals the surface of the lake and whose height equals its maximum depth. When the lake bottom is concave toward the water, the result is greater than unity; that is, the volume is greater than that of the cone; when the bottom is convex toward the water so that the volume of the lake is less than that of a cone the result is less than unity, as in Fowler and Pewaukee lakes, for example. (See table No. 1.).

SLOPES.

The slope of the bottom is expressed in degrees and in per cents. For the calculation of the slope between two contour lines or isobaths the following formula[1] has been used:

$$S = \frac{I_1 + I_2}{2} \cdot \frac{h}{a} = \tan^{-1} \theta$$

I_1 and I_2 represent the lengths of the isobaths; h is the vertical distance or interval between the two isobaths; and a is the area included between the two isobaths. In calculating the mean slope of the bottom of a lake which has a number of isobaths, or contour lines, still another formula is employed. It is the following:

$$S = \left(\frac{\frac{1}{2} I_0 + I_1 + I_2 + \cdots + I_{n-1} + \frac{1}{2} I_n}{n}\right) \frac{H}{A}$$

In this formula I_0, I_1, I_2, etc. represent the lengths of the various isobaths, or contour lines, from surface to bottom, while H is the maximum depth and A is the area of the lake.

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[1] Penck. Morphologie der Erdoberfläche. Bd. I, p. 48, Stuttgart, 1894. See also Gravelius. Zeit. f. Gewässerk. Bd. IX, 1910, p. 267.

Table 2.—UNSURVEYED LAKES IN SOUTHEASTERN WISCONSIN.

Lake.	Town N.	Range E.	County.	Length. Km.	Length. Mi.	Direction of greatest length.	Maximum breadth. Km.	Maximum breadth. Mi.	Area. Sq. Km.	Area. Sq. Mi.	Area. Acres.	Maximum known depth. Meters.	Maximum known depth. Feet.
Bear	22 & 23	XIII	Waupaca	1.80	1.10	N-S	1.28	0.80	0.93	0.36	230.4	18.0	59.0
Browns	2 & 3	XIX	Racine	2.00	1.25	N-S	1.20	0.75	1.58	0.61	390.4	7.0	23.0
Butte des Morts (Big)	18 & 19	XV & XVI	Winnebago	7.40	4.60	NW-SE	4.18	2.60	18.23	7.04	4,505.0	3.4	11.2
Butte des Morts (Little)	19 & 20	XVII	Winnebago	4.80	3.00	NE-SW	1.30	0.80	5.28	2.04	1,305.6	3.6	12.0
Camp	1	XX	Kenosha	2.40	1.50	N-S	1.60	1.00	1.04	0.40	256.0	6.0	19.7
Como	2	XVII	Walworth	5.23	3.25	NE-SW	1.00	0.62	3.75	1.45	928.0	2.0	6.5
Crystal or Cedar	15 & 16	XXI	Sheboygan	1.16	0.72	E-W	0.64	0.40	0.57	0.22	140.8	19.6	64.3
De Neveu	15	XVIII	Fond du Lac	1.28	0.80	N-S	0.45	0.28	0.41	0.16	102.4	15.8	52.0
Denoon	5	XX	Waukesha	1.30	0.81	NW-SE	0.70	0.44	0.75	0.29	185.6	19.0	62.3
Eagle	3	XX	Racine	2.10	1.31	E-W	1.60	1.00	1.97	0.76	486.4	4.0	13.1
Eagle	5	XVII	Waukesha	1.40	0.87	NE-SW	0.90	0.56	0.85	0.33	211.2	1.5	4.9
Five	9	XIX	Waukesha	1.00	0.62	NW-SE	0.60	0.37	0.51	0.20	128.0	5.0	16.4
Gilbert	20	XI	Waushara	1.53	0.95	E-W	0.56	0.35	0.56	0.22	140.8	19.5	64.0
Golden	7	XVI & XVII	Jefferson and Waukesha	2.20	1.37	NW-SE	0.80	0.50	1.05	0.40	256.0	13.0	42.6
Hills	19	XI	Waushara	1.45	0.90	NE-SW	0.50	0.31	0.54	0.21	134.4	9.0	29.5
Hooker	1	XX	Kenosha	1.20	0.75	NE-SW	0.60	0.37	0.26	0.10	64.0	7.0	23.0
Keesus	8	XVIII	Waukesha	1.40	0.87	E-W	1.30	0.81	0.96	0.37	236.8	12.5	41.0
Little Cedar	10 & 11	XIX	Washington	2.15	1.34	NE-SW	0.64	0.40	1.06	0.41	262.4	11.3	37.0
Little Green	15	XIII	Green Lake	1.93	1.20	NE-SW	1.44	0.90	1.89	0.73	467.2	7.9	26.0
Long	14	XIX	Fond du Lac	3.70	2.30	N-S	0.64	0.40	2.05	0.79	505.6	13.8	45.5
Long	20	XI & XII	Waushara	2.57	1.60	NE-SW	0.80	0.50	1.09	0.42	268.8	23.0	75.5

Long	4	XX	Racine	1.60	1.00	NE-SW	0.40	0.25	0.54	0.21	134.4	6.0	19.7
Minister	4	XX	Racine	1.20	0.75	N-S	0.80	0.50	0.65	0.25	160.0	20.0	65.6
Muskego (Big)	5	XX	Waukesha	6.03	3.75	NE-SW	3.21	2.00	11.08	4.28	2,739.2	8.0	26.2
Muskego (Little)	5	XX	Waukesha	2.41	1.50	N-S	1.40	0.87	2.10	0.81	518.4	14.0	46.0
Paddock	1	XX	Kenosha	1.00	0.62	N-S	0.60	0.37	0.39	0.15	96.0	9.5	31.1
Phantom	5	XVIII	Waukesha	1.09	0.68	NE-SW	0.60	0.37	0.44	0.17	108.8	8.5	27.9
Pine	20	XI	Waushara	1.41	0.88	NE-SW	0.62	0.39	0.62	0.24	153.6	14.5	47.6
Pleasant	4	XVI	Walworth	1.20	0.75	NW-SE	0.80	0.50	0.57	0.22	140.8	7.0	23.0
Potter	4	XVIII	Walworth	1.20	0.75	E-W	0.70	0.44	0.65	0.25	160.0	5.0	16.4
Powers	1	XVIII & XIX	Kenosha and Walworth	1.80	1.12	E-W	1.00	0.62	1.68	0.65	416.0	10.0	32.8
Poygan	19 & 20	XIII & XIV	Waushara and Winnebago	12.39	7.70	E-W	5.63	3.50	44.50	17.18	10,992.2	3.3	10.8
Puckaway	15	XI & XII	Green Lake and Marquette	13.04	8.10	E-W	2.90	1.80	12.69	8.49	5,433.6	1.6	5.2
Rockland	2 & 3	XIX	Racine	0.80	0.50	NW-SE	0.40	0.25	0.21	0.08	51.2	8.0	26.2
Round	20	XI	Waushara	0.94	0.59	NW-SE	0.69	0.43	0.41	0.16	102.4	5.8	19.0
Silver	1	XX	Kenosha	2.00	1.25	NE-SW	1.40	0.87	2.36	0.91	582.4	13.0	42.6
Silver	11	XIX	Washington	1.51	0.94	NW-SE	0.53	0.33	0.39	0.15	96.0	10.5	34.4
Silver	20	XI	Waushara	0.95	0.59	E-W	0.27	0.17	0.21	0.08	51.2	14.5	47.6
Silver	18	XI	Waushara	2.60	1.62	NW-SE	0.90	0.56	1.58	0.61	390.4	13.3	43.6
Spring	15	XIII	Green Lake	1.04	0.65	NE-SW	0.48	0.30	0.44	0.17	108.8	12.8	42.0
Twin	1	XIX	Kenosha	....	....	....	....	....	4.35	1.68	1,075.2	....	....
Elizabeth	....	....	....	4.21	2.62	N-S	1.40	0.87	3.24	1.25	800.0	8.0	26.2
Mary	....	....	....	1.93	1.20	NE-SW	1.12	0.70	1.11	0.43	275.2	8.0	26.2
Wilson	20	XI	Waushara	0.82	0.51	E-W	0.62	0.39	0.31	0.12	76.8	4.8	15.7
Wind	4	XX	Racine	3.21	2.00	NE-SW	2.41	1.50	5.70	2.20	1,408.0	15.0	49.2
Winneconne	19 & 20	XV	Winnebago	5.15	3.20	NW-SE	3.21	2.00	13.21	5.10	3,264.0	3.0	9.8

TABLE 3.—LAKES OF NORTHEASTERN WISCONSIN.

Lake.	Town N.	Range E.	County.	Greatest length.		Direction of greatest length.	Greatest breadth.		Area.			Maximum known depth.	
				Km.	Mi.		Km.	Mi.	Sq. Km.	Sq. Mi.	Acres.	Meters.	Feet.
Adelaide	43	V	Vilas	0.75	0.47	N-S	0.51	0.32	0.18	0.07	45.0	21.0	68.9
Allequash	41	VII	Vilas	2.41	1.50	NE-SW	1.41	0.88	1.42	0.55	352.0	7.5	24.6
Anderson	43	IX	Vilas	0.88	0.55	N-S	0.40	0.25	0.21	0.08	53.1	19.5	64.0
Arbor Vitae	40	VII	Vilas	2.90	1.80	N-S	2.25	1.40	4.22	1.63	1,043.2	8.8	28.9
Armour	43	VI	Vilas	1.61	1.00	E-W	irreg	ular	1.24	0.48	307.2	14.3	46.9
Ballard	41	VIII	Vilas	2.41	1.50	E-W	1.30	0.81	2.17	*0.84	537.6	5.0	16.4
Bass	39	VII	Oneida	0.96	0.60	NE-SW	0.35	0.22	0.23	0.09	57.6	7.0	23.0
Bass	33	X	Langlade	2.30	1.43	E-W	1.40	0.87	0.80	0.31	198.4	6.0	19.7
Big Carr	38	VII	Oneida	2.41	1.50	NE-SW	0.96	0.60	1.29	0.50	320.0	22.8	74.8
Big Sand	41 & 42	XII	Vilas	4.83	3.00	NE-SW	2.01	1.25	6.99	2.70	1,728.0	9.5	31.2
Birch	36	XV	Forest	2.09	1.30	E-W	1.28	0.80	2.17	0.84	537.6	18.8	61.7
Bird	38	VII	Oneida	1.50	0.93	N-S	0.88	0.55	0.54	0.21	134.4	13.0	42.6
Black Oak	42 & 43	IX & X	Vilas	3.70	2.30	E-W	1.04	0.65	1.89	0.73	467.2	24.5	80.4
Blue or Rusk	39	VI	Oneida	2.17	1.35	E-W	1.61	1.00	2.20	0.85	544.0	13.5	44.3
Boulder	42	VI & VII	Vilas	3.62	2.25	E-W	1.93	1.20	2.48	*0.96	614.4	6.0	19.7
Carroll	39 & 40	VII	Vilas and Oneida	2.09	1.30	NE-SW	0.75	0.47	1.16	0.45	288.0	7.0	23.0
Catfish	39 & 40	X & XI	Vilas	4.62	2.87	NE-SW	irreg	ular	3.65	1.41	902.4	6.0	19.7
Clark	28 & 29	XXVII	Door	2.73	1.70	N-S	2.10	1.31	2.69	1.04	665.6	6.0	19.7

Clear	42	V & VI	Vilas	2.81	1.75	NE-SW	1.10	0.70	2.04	0.79	505.6	8.0	26.2
Clear	39	VII	Oneida	3.38	2.10	N-S	irreg	ular	3.73	1.44	921.6	25.0	82.0
Clear Crooked	42	VI & VII	Vilas	2.25	1.40	NE-SW	1.80	1.12	2.72	1.05	672.0	10.0	32.8
Clover Leaf	26	XV	Shawano						1.18	0.46	297.6		
Golden Rod				0.40	0.25	E-W	0.35	0.22	0.07	0.03	19.2	11.4	37.4
Grass				0.80	0.50	E-W	0.60	0.38	0.34	0.13	86.4	14.8	48.5
Pine or Shamrock				1.37	0.85	NW-SE	0.80	0.50	0.77	0.30	192.0	10.8	35.4
Crab	43	VI	Vilas	3.41	2.12	NE-SW	2.17	1.35	5.33	2.06	1,318.4	13.5	44.3
Cranberry	40	XI	Vilas	2.01	1.25	NE-SW	1.12	0.70	1.35	0.52	332.8	3.5	11.5
Crawling Stone	40	V	Vilas	3.86	2.40	NW-SE	2.65	1.65	6.47	*2.50	1,600.0	28.3	93.0
Diamond	41	VI	Vilas	1.12	0.70	NE-SW	0.64	0.40	0.31	0.12	76.8	9.0	29.5
Duck	40	X	Vilas	0.80	0.50	NE-SW	0.48	0.30	0.26	0.10	64.0	4.9	16.1
Eagle	40	X	Vilas	1.93	1.20	E-W	1.77	1.10	2.64	1.02	652.8	7.0	23.0
Fence	40	V	Vilas	5.23	3.25	N-S	3.37	2.10	13.73	*5.30	3,492.0	28.3	93.0
Fish Trap	42	VII	Vilas	2.41	1.50	NE-SW	1.00	0.62	1.32	*0.51	326.4	9.0	29.5
Flambeau	40	IV & V	Vilas	3.22	2.00	N-S	irreg	ular	5.18	*2.00	1,280.0	15.0	49.2
George	36	IX	Oneida	1.61	1.00	N-S	1.12	0.70	1.06	0.41	262.4	6.5	21.3
High	42 & 43	VII & VIII	Vilas	3.22	2.00	NE-SW	1.61	1.00	3.08	*1.19	761.6	9.5	31.2
Horsehead	43	VI	Vilas	2.41	1.50	E-W	1.28	0.80	1.66	*0.64	409.6	6.8	22.3
Island	42	V & VI	Vilas	3.22	2.00	NW-SE	1.61	1.00	3.52	*1.36	870.4	11.0	36.0
Kathrine	38	VI	Oneida	3.62	2.25	N-S	irreg	ular	2.46	0.95	608.0	8.5	27.9
Kawaguesaga	39	VI & VII	Oneida	6.84	4.25	E-W	irreg	ular	8.36	3.23	2,067.2	17.0	55.8
Laura	41	VIII & IX	Vilas	2.41	1.50	NW-SE	1.45	0.90	2.59	1.00	640.0	12.0	39.4
Little Muskallonge	40	VI	Vilas	1.04	0.65	N-S	0.48	0.30	0.31	0.12	76.8	6.5	21.3

TABLE 3. Continued. LAKES OF NORTHEASTERN WISCONSIN.

Lake.	Town N.	Range E.	County.	Greatest length.		Direction of greatest length.	Greatest breadth.		Area.			Maximum known depth.	
				Km.	Mi.		Km.	Mi.	Sq. Km.	Sq. Mi.	Acres.	Meters.	Feet.
Little Tomahawk....	38	VII	Oneida.......	0.96	0.60	N-S	0.56	0.35	0.54	0.21	134.4	13.7	44.9
Little Trout.........	41 & 42	V	Vilas.	2.81	1.75	N-S	2.01	1.25	3.88	*1.50	960.0	28.0	91.8
Long.................	40	V	Vilas........	2.25	1.40	N-S	0.96	0.60	1.81	*0.70	448.0	17.0	55.8
Long or Trump.......	35	XV	Forest.......	1.70	1.06	NE-SW	0.48	0.30	0.98	0.38	243.2	4.9	16.2
Lost Canoe...........	42	VII	Vilas........	2.01	1.25	NW-SE	0.61	0.38	0.83	0.32	204.8	12.5	41.0
Mamie	43	IX	Vilas........	1.61	1.00	N-S	1.37	0.85	1.55	0.60	384.0	4.5	14.8
Manitowish....	42	V	Vilas........	2.57	1.60	E-W	1.37	0.85	2.07	*0.80	512.0	15.0	49.2
Medicine.............	38 & 39	XI	Oneida... ...	2.25	1.40	NE-SW	0.96	0.60	2.07	0.80	512.0	4.0	13.1
Mud..................	38	VII	Oneida.......	0.55	0.34	NE-SW	0.40	0.25	0.163	0.063	40.3	8.3	27.2
North Long..........	41 & 42	XII	Vilas........	5.15	3.20	NE-SW	1.20	0.75	4.40	1.70	1,088.0	27.0	88.6
North Twin..........	41 & 42	XI	Vilas........	6.60	4.10	NE-SW	2.57	1.60	10.92	4.22	2,700.8	13.0	42.6
Otter................	40	X	Vilas........	1.40	0.87	N-S	0.80	0.50	0.80	0.31	198.4	8.9	29.2
Palmer...............	43	VIII	Vilas........	2.81	1.75	NE-SW	2.01	1.25	2.48	0.96	614.4	4.5	14.8
Pelican..............	35	X & XI	Oneida.......	5.79	3.60	E-W	3.38	2.10	14.24	5.50	3,520.0	12.3	40.3
Pokegama	40 & 41	V	Vilas........	5.23	3.25	N-S	1.9	1.20	4.92	*1.90	1,216.0	13.0	42.6
Plum....	41	VII & VIII	Vilas........	6.76	4.20	NE-SW	2.01	1.25	4.40	1.70	1,088.0	15.5	50.8
Presque Isle.........	43	VI	Vilas........	6.03	3.75	NW-SE	3.22	2.00	7.64	2.95	1,888.0	24.0	78.7
Razor Back..........	41	VIII	Vilas........	1.77	1.10	N-S	1.45	0.90	1.42	0.55	352.0	9.5	31.1

Sand	35 & 36	XIII	Forest,.......	4.83	3.00	N-S	2.09	1.30	8.08	3.12	1,996.8	14.8	48.5
Silver................	36	XIV	Forest........	1.61	1.00	E-W	1.20	0.75	1.35	0.52	332.8	6.0	19.7
Silver................	41	VI	Vilas.........	1.61	1.00	N-S	0.32	0.20	0.52	0.20	128.0	17.0	55.8
Spider................	40	VI	Vilas.........	2.17	1.35	NE-SW	irreg	ular	1.11	*0.43	275.2	8.0	26.2
Squirrel..............	39	V	Oneida.......	6.03	3.75	N-S	1.61	1.00	6.34	2.45	1,568.0	10.3	33.8
Star..................	41	VIII	Vilas.........	3.41	2.12	E-W	2.57	1.60	4.66	1.80	1,152.0	8.0	26.2
Star..................	42	V	Vilas...	1.61	1.00	E-W	1.04	0.65	1.08	*0.42	268.8	17.5	57.4
Stone..........	35	XIII	Forest........	5.63	3.50	N-S	1.12	0.70	3.42	1.32	844.8	23.3	76.4
Summit..............	33	X	Langlade.....	1.50	0.93	N-S	0.59	0.37	1.55	0.60	384.0	4.9	16.1
Tenderfoot...........	43	VIII	Vilas.........	2.57	1.60	E-W	2.41	1.50	2.61	1.01	646.4	8.5	27.9
Thousand Island.....	44	XXXXI W	Gogebic, Mich........	3.62	2.25	E-W	irreg	ular	3.34	1.29	825.6	21.5	70.5
Tomahawk...........	38 & 39	VI & VII	Oneida.......	7.24	4.50	E-W	irreg	ular	14.76	5.70	3,648.0	22.5	73.8
Trout.................	41 & 42	VI & VII	Vilas	7.24	4.50	N-S	3.86	2.40	16.83	*6.50	4,160.0	35.0	115.0
Turtle, North.........	43 & 44	V	Vilas.........	2.01	1.25	NE-SW	1.28	0.80	2.59	1.00	640.0	14.5	47.6
Turtle, South........	43	V	Vilas.........	3.62	2.25	N-S	1.01	0.63	3.21	1.24	793.6	13.1	43.0
Two Sisters...........	38	VIII	Oneida.......	3.05	1.90	E-W	1.80	1.12	3.68	1.42	908.8	19.5	64.0
Upper Gresham......	41 & 42	VI	Vilas........	2.01	1.25	E-W	1.28	0.80	1.45	0.56	358.4	8.0	26.2
Vieux Desert.........	42	XI	Vilas.........	7.53	4.68	NE-SW	3.92	2.44	19.34	7.47	4,780.8	6.0	19.7
White Sand...........	42	VII	Vilas.........	2.65	1.65	E-W	1.40	0.87	3.21	*1.24	793.6	20.5	67.2
Yellow Birch.........	40	X	Vilas.........	1.20	0.75	N-S	0.71	0.44	0.78	0.30	192.0	4.7	15.4

* The areas of the lakes marked with an asterisk were determined by Mr. C. B. Stewart, Consulting Engineer, Madison, Wis.

TABLE 4. LAKES OF NORTHWESTERN WISCONSIN.

Lake.	Town N.	Range W.	County.	Greatest length.		Direction of greatest length.	Greatest breadth.		Area.			Maximum known depth.	
				Km.	Mi.		Km.	Mi.	Sq. Km.	Sq. Mi.	Acres.	Meters.	Feet.
Atkins	44	V	Bayfield	2.17	1.35	E-W	1.45	0.9	2.12	0.82	524.8	18.0	59.0
Balsam	34 & 35	XVI	Polk	2.06	1.28	N-S	1.61	1.00	1.86	0.72	460.8	11.0	36.1
Balsam	37	X	Washburn...	3.06	1.90	NE-SW	0.64	0.40	1.55	0.60	384.0	13.0	42.6
Bardon or Whitefish	43	XII	Douglas......	4.18	2.60	NE-SW	1.20	0.75	3.11	1.20	768.0	31.0	101.7
Beaver Dam.........	35 & 36	XIII & XIV	Barron	6.12	3.80	NW-SE	1.20	0.75	5.13	1.98	1,267.2	28.0	91.9
Bennet................	37	IX	Sawyer.......	0.60	0.37	N-S	0.32	0.20	0.08	0.033	21.1	19.5	64.0
Big Angus............	47 & 48	VIII	Bayfield	1.93	1.20	NE-SW	0.88	0.55	1.10	0.426	272.6	9.5	31.2
Big Balsam...........	34 & 35	XVII	Polk..........	4.83	3.00	E-W	1.61	1.00	7.22	2.79	1,785.6	5.5	18.0
Big Butternut........	36	XVII	Polk..........	1.93	1.20	E-W	0.96	0.60	1.55	0.60	384.0	6.5	21.3
Big Horseshoe........	34	XIV & XV	Barron & Polk	4.02	2.50	N-S	1.61	1.00	3.24	1.25	800.0	18.0	59.0
Big Sand..............	36	XIV	Barron.......	3.62	2.25	NW-SE	0.56	0.35	1.42	0.55	352.0	17.0	55.8
Big Sissabagama.....	38	IX	Sawyer.......	3.94	2.45	NW-SE	1.20	0.75	3.75	1.45	928.0	14.5	47.6
Big Spider...........	42	VII	Sawyer	4.00	2.49	NE-SW	irreg	ular	7.20	2.78	1,779.2	14.5	47.6
Birch..................	37	X	Washburn ...	1.45	0.90	N-S	1.13	0.70	0.98	0.38	243.2	17.5	57.4
Bone	35 & 36	XVI	Polk..........	7.72	4.80	N-S	1.61	1.00	8.31	3.21	2,054.4	15.0	49.2
Bottomless	47	IX	Bayfield	1.13	0.70	N-S	0.56	0.35	0.44	0.17	108.8	10.0	32.8
Cable	43	VIII	Bayfield	2.90	1.80	N-S	0.85	0.53	1.50	0.58	371.2	10.0	32.8
Camp 20..............	46 & 47	VIII	Bayfield	0.40	0.25	N-S	0.18	0.12	0.06	0.024	15.4	11.0	36.1
Clear..................	33	IX	Rusk	1.09	0.68	N-S	0.40	0.25	0.28	0.11	70.4	19.5	64.0
Crow..................	47	VIII	Bayfield.....	1.61	1.00	NE-SW	0.72	0.45	0.70	0.27	172.8	18.0	59.0

Deer	34	XVII & XVIII	Polk	4.50	2.80	E-W	1.13	0.70	3.26	1.26	806.4	12.0	39.4
Diamond	44	VI	Bayfield	2.17	1.35	N-S	1.32	0.82	2.02	0.78	499.2	19.8	65.0
Eau Claire	44	IX	Bayfield	3.62	2.25	N-S	1.61	1.00	3.11	1.20	768.0	20.5	67.2
Gilmore	42	XII	Washburn	4.59	2.85	NE-SW	0.97	0.60	2.67	1.03	659.2	10.0	32.8
Grindstone	40	VIII & IX	Sawyer	5.47	3.40	NE-SW	3.38	2.10	14.01	5.41	3,462.4	14.5	47.6
Half Moon	47	VIII	Bayfield	1.13	0.70	E-W	0.64	0.40	0.40	0.154	98.5	7.0	23.0
Hammills	44	VII & VIII	Bayfield	1.61	1.00	NE-SW	0.88	0.55	0.90	0.35	224.0	15.0	49.2
Hawley	44	VII	Bayfield	....	....	....	....	....	....	....	....	8.5	27.9
Island	33	VIII	Rusk	2.82	1.75	NE-SW	1.05	0.65	1.76	0.68	435.2	14.5	47.6
Lac Court Oreilles	39 & 40	VIII & IX	Sawyer	9.10	5.65	NE-SW	3.06	1.90	21.24	8.20	5,248.0	20.5	67.2
Little Duck	42	VI	Sawyer	3.54	2.20	NE-SW	1.77	1.10	4.30	1.66	1,062.4	5.0	16.4
Little Sissabagama	38	IX	Sawyer	1,61	1.00	N-S	1.28	0.80	1.29	0.50	320.0	15.0	49.2
Little Spider	42	VII	Sawyer	1.61	1.00	NE-SW	1.05	0.65	0.93	0.36	220.4	6.0	19.7
Long	37 & 38	X & XI	Washburn	14.89	9.25	NE-SW	irregular		14.81	5,72	3,660.8	23.0	75.4
Long	34	XVII	Polk	2.73	1.70	NW-SE	0.88	0.55	1.55	0.60	384.0	7.5	24.6
Long	32	VIII & IX	Chippewa	4.83	3.00	NE-SW	1.37	0.85	4.32	1.67	1,068.8	23.5	77.1
Lost Land	42	VI	Sawyer	4.02	2.50	N-S	irregular		6.01	2.32	1,484.8	4.8	15.7
Loveless	34	XVII	Polk	1.61	1.00	NW-SE	0.51	0.32	0.62	0.24	153.6	6.5	21.3
Lower Bass	43	XII	Douglas	1.61	1.00	N-S	1.45	0.90	0.88	0.34	217.6	24.0	78.7
Minnesuing	46	XI	Douglas	3.22	2.00	N-S	1.13	0.70	2.07	0.80	512.0	7.0	23.0
Namekagon	43	VI	Bayfield	7.24	4.50	NE-SW	irregular		14.89	5.75	3,680.0	10.0	32.8
Nebagamain	46 & 47	XI	Douglas	4.50	2.80	NW-SE	3.54	2.20	4.14	1.60	1,024.0	14.0	45.9
Nichols, or Chain	32 & 33	IX	Chippewa and Rusk	3.70	2.30	NE-SW	0.74	0.46	0.75	0.29	185.6	20.0	65.6
Owen	43 & 44	VII	Bayfield	10.05	6.25	NE-SW	irregular		8.10	3.13	2,032.0	27.0	88.6
Perry	43	VII	Bayfield	1.07	0.66	N-S	0.40	0.25	0.28	0.11	70.4	5.0	16.4
Pike	47	VIII	Bayfield	3.22	2.00	N-S	1,93	1,20	2,19	0.845	540.8	15.0	49.2

TABLE 4.—Continued.—LAKES OF NORTHWESTERN WISCONSIN.

Lake.	Town N.	Range W.	County.	Greatest length.		Direction of greatest length.	Greatest breadth.		Area.			Maximum known depth.	
				Km.	Mi.		Km.	Mi.	Sq. Km.	Sq. Mi.	Acres.	Meters.	Feet.
Pine..................	32 & 33	IX	Chippewa and Rusk..	2.01	1.25	NE-SW	0.80	0.50	0.83	0.32	204.8	30.5	100.0
Pitcher..............	44	VII	Bayfield.....	0.82	0.51	NE-SW	0.40	0.25	0.14	0.054	34.5	4.0	13.1
Pokegama...........	42	XII	Washburn...	3.86	2.40	NE-SW	0.97	0.60	2.05	0.79	505.6	7.0	23.0
Red Cedar...........	36	X	Barron.......	7.24	4.50	N-S	2.25	1.40	9.37	3.62	2,316.8	15.0	49.2
Round...............	41	VII & VIII	Sawyer.......	7.64	4.75	N-S	4.67	2.90	14.50	5.60	3,584.0	18.0	59.0
Saint Croix..........	45	XI & XII	Douglas......	6.44	4.00	NE-SW	0.88	0.55	4.17	1.61	1,030.4	6.0	19.7
Salsbery.............	32	IX	Chippewa....	1.61	1.00	NE-SW	0.69	0.43	0.26	0.10	64.0	2.5	8.2
Shell.................	37 & 38	XII & XIII	Washburn...	5.23	3.25	NE-SW	4.02	2.50	12.95	5.00	3,200.0	15.0	49.2
Spirit................	37	XVIII	Burnett......	2.73	1.70	NE-SW	1.61	1.00	2.59	1.00	640.0	7.5	24.6
Sucker...............	33	XVII	Polk..........	5.63	3.50	NW-SE	1.93	1.20	5.88	2.27	1,452.8	8 5	27.9
Swenson.............	43	VII	Bayfield.....	2.01	1.25	NE-SW	0.56	0.35	0.80	0.31	198.4	5.3	17.4
Taylor...............	44	VI & VII	Bayfield.....	1.16	0.72	E-W	1.05	0.65	0.80	0.31	198.4	4.5	14.8
Trade................	37	XVIII	Burnett......	1.61	1.00	NE-SW	irreg	ular	2.07	0.80	512.0	6.0	19.7
Trapper.............	44	VI	Bayfield.....	2.01	1.25	NE-SW	0.88	0.55	1.10	0.426	272.6	9.0	29.5
Upper Turtle.........	34	XIV	Barron.......	3.70	2.30	NW-SE	0.64	0.40	1.94	0.75	480.0	7.0	23.0
Whitefish............	39	IX	Sawyer.......	4.18	2.60	NE-SW	1.05	0.65	3.63	1.40	896.0	22.5	73.8
Wild Goose..........	34	XVII	Polk..........	1.53	0.95	NW-SE	1.03	0.64	1.03	0.40	256.0	4.5	14.8

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