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A Preliminary Report on the Physical Features of Turkey Lake. By D. C. Ridgley.*

ACKNOWLEDGMENTS.

Most of the data on which this preliminary report is based were collected during the summer of 1895 at the Indiana University Biological Station at Vawter Park, Kosciusko County, Indiana, under the direction of Dr. Carl H. Eigenmann. I wish to acknowledge the aid of his valuable suggestions, both in the collection of the data and the preparation of the report. I wish to acknowledge also the

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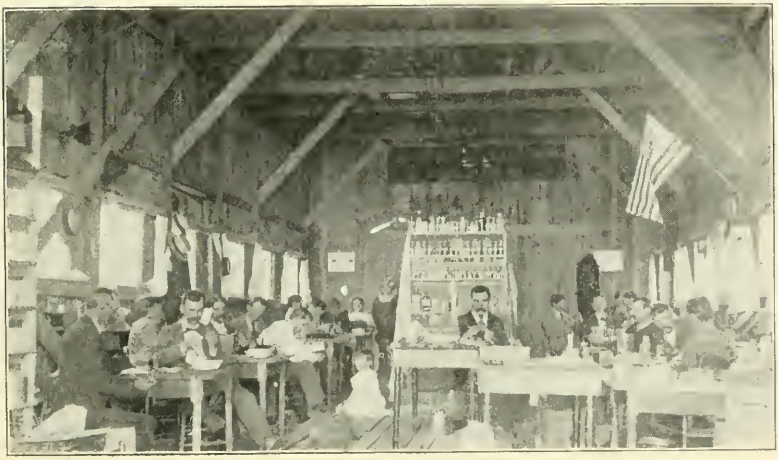
*Contributions from the Zoölogical Laboratory of the Indiana University, No. 15a.

PLATE I.

No. 1.

Indiana University Biological Station.

No. 2.



Interior of the Laboratory.

PLATE II.

No 3.

Vawter Park Hotel from the Laboratory.

No. 4.

Black Stump Point from the Laboratory. Plankton Boat.

PLATE III.

No. 5.

Looking Toward Ogden Point from the Laboratory. Plankton-Boat in Forewater.

No. 6.

Ogden Point from Near the Pottawatomie Club-House.

PLATE IV.

No. 7.

Students' Camp in Vawter Park.

PLATE V.

No. 8.

GENERAL VIEW FROM MORAINE AT HEAD OF TURKEY LAKE.

GANS' LAKE.
HOOPER'S LAKE.
HARTZELL'S LAKE, I.

OLD ISLAND.

TURKEY LAKE.
HARTZELL'S LAKE, II.
HARTZELL'S LAKE, III.

PLATE VI.

No 9.

West Beach of Morrison's Island.

No. 10.

Crow's Bay Showing Ice Beaches.

No. 11.

Cedar Point.

No. 12.

Beach West of Cedar Point.

No. 13.

In the Channel Between Turkey and Syracuse Lakes.

No. 14

At the Head of Syracuse Lake.

assistance of Mr. Chauncey Juday, Mr. Thomas Large and others in taking the soundings of the lake; of Mr. Juday, in making a survey of the shore and for copies of the accompanying map with which he has furnished me and from which the report on the topography of the bottom is largely drawn; of Mr. J. P. Dolan for records of daily observations of lake phenomena and for the history of the lake in years past; of the officials of the Baltimore & Ohio Railroad who furnished data with reference to elevations and whose generosity has made it possible for me to make frequent visits to the lake during the winter.

GENERAL FEATURES OF THE LAKE.

Turkey Lake is made up of two parts, connected by a channel. The channel is three-quarters of a mile in length and from one hundred feet to a half mile in width. Its depth varies from one to five feet. The part of the Lake north of the channel is known as Syracuse Lake. It includes an area of three-quarters of a square mile, which is approximately one-eighth of the area of the entire Lake. The larger part of the Lake, to the south and east of the channel, may be known as the main lake.

The general direction of the lake is from southeast to northwest. Its greatest length is five and a half miles, and its greatest width at a right angle to its length is one and a half miles. The entire shore line is between twenty and twenty-one miles in length, and the area of the lake is a little more than five and a half square miles. No very prominent irregularities occur around Syracuse Lake, while in the main lake a number of evident indentations are to be found. The east end of the main lake is made up of three bays. Johnson's Bay, extending to the north, is one mile long and three-eighths of a mile wide. Ogden Point lies to the west of the entrance of this bay and Cedar Point to the east. The east end of the main lake is Crow's Bay, with Cedar Point on its north and Morrison's Island on its south. Jarrett's Bay extends to the southeast, with Morrison's Island to the east of its entrance and Clark's Point to the west. In the west end of the main lake is Conkling Bay, circular in form and with the surrounding marsh a half mile in diameter. It lies south of Conkling Hill. These are the most prominent indentations. Between the channel and Ogden Point, which are two and a quarter miles apart, the shore line curves gently northward three-quarters of a mile, forming Sunset Bay. Between Clark's Point and Black Stump Point, one and three-quarters miles to the northwest, the shore line bends southward one-third of a mile.

The following places are located for convenience in referring to different parts of the shore line and lake: The town of Syracuse lies on the west side of Syracuse Lake near Turkey Creek, the outlet of the lake. Pickwick Park is on the north shore of the main lake a half mile east of the channel. Eppert's is 1,000 feet east of Pickwick Park, and nearly a half mile further east is Jones' Landing. Three-fourths of a mile east of Jones' Landing is Wawasee. Jarrett's Landing is at the middle of the southern extremity of Jarrett's Bay. Vawter Park is a half mile west of Clark's Point and directly south of Wawasee. The laboratory of the Indiana University Biological Station is located on the shore of the lake near the west end of Vawter Park.

TOPOGRAPHY OF THE BOTTOM.

The data from which the topography of the bottom has been determined consist of numerous soundings taken throughout the lake between June 29 and August 21, 1895. The water was very low during this period. For our purpose we may consider all soundings taken when the lake had the level of July 6, 1895. This level has been marked and is used for a bench line from which to read the fluctuations in level On August 21 the lake had receded 5 inches from this level. Soundings were taken along 28 lines in the main lake and 4 lines in Syracuse Lake. These soundings were taken about 300 feet apart along all lines. Where water deeper than 60 feet was found, numerous soundings were made to determine the extent of such areas. Below is given the number and location of each line along which soundings were taken, except No. 3 and No. 9 in the main lake, neither of which was used in drawing contour lines or in computing average depth.

IN MAIN LAKE.

No. of Line.	Location.
1	From Biological Station to Ogden Point, North 37° East.
2	From Ogden Point to east end of Crow's Bay, South 53° East.
4	From Biological Station to Wawasee, North.
5	From Wawasee to Black Stump Point, South 52° West.
6	From Biological Station to Cedar Point, North 64° East.
7	From Cedar Point to Morrison's Island, South.
8	From Morrison's Island to northeast corner of Crow's Bay, North 8° East.
10	From south end of Jarrett's Bay to mouth of Bay, North 7° West.
11	From east margin of Ogden Point to north end of Johnson's Bay, North 1° West.
12	From north end of Johnson's Bay to mouth of Bay, South 10° East.
13	From east side of Ogden Point across Johnson's Bay, North 60° East.
14	From middle of east side of Johnson's Bay, across the Bay, North 79° West.
15	From Clark's Point to Morrison's Island, East.
16	From mouth of Turkey Creek across Jarrett's Bay, West.
17	From a point $\frac{3}{4}$ of a mile west of Biological Station across the lake, North.
18	From Clark's Point to east side of Ogden Point, North $5\frac{1}{2}$° East.
19	From point a half mile east of Biological Station, North.
20	From Ogden Point to Black Stump Point, North 83° West.
21	From west side of Jarrett's Bay to Mineral Point, East.
22	From Clark's Point to east side of Johnson's Bay, North 30° East.
23	From north end of No. 22 to Ogden Point, South 85° West,
24	From point one-half mile west of Wawasee across lake, South.
25	From Black Stump Point, North.
26	From Eppert's South.
27	One-quarter of a mile west of No. 26 and parallel with it.
28	One-quarter of a mile west of No. 27 and parallel with it.

IN SYRACUSE LAKE.

No. of Line.	Location.
1	From middle of east end of Syracuse Lake, South 80° West.
2	From point 700 feet southeast of west extremity of Lake, North 70° East.
3	From a point on north shore one-half mile east of west extremity of lake, South 10° West.
4	From west extremity of lake, South 80° East.

In the accompanying map, constructed by Mr. Juday, the hypothetical contour lines of the bottom of the lake were drawn from the soundings along the above mentioned lines, and numerous other soundings taken to determine the extent of certain depths of water. The contour lines indicate intervals of ten feet

in depth. From the same data were constructed ten vertical sections of the bottom. In constructing the vertical sections a base line was drawn from Pickwick Park to Mineral Point, and seven of the vertical sections, from "A" to "G" inclusive, were made at right angles to this line at intervals varying from one-quarter of a mile to two-thirds of a mile. Vertical section "H" is a short distance east of No. 18, "I" is along No. 4, and "J" along No. 25 of the lines of soundings in the main lake. The remarks on the topography of the bottom are drawn largely from a study of these contour lines and vertical sections.

The average depth of the lake, found by taking the average for the soundings at regular intervals of 300 feet along the lines of soundings is 21 feet 6 inches in the main lake, 13 feet 6 inches in Syracuse Lake, and 20 feet 5 inches for the entire lake. By a different method, as explained in his report, Dr. Eigenmann has computed the average depth at a little more than 17 feet. The maximum depth found in the main lake is 68 feet 7 inches, one-quarter of a mile from the southern extremity of Jarrett's Bay; 1,000 feet northeast of the Biological Station a depth of 66 feet 5 inches was found; three-quarters of a mile north and one-quarter of a mile west of the Station the water is 60 feet deep; and a half mile northwest of Black Stump Point it is 63 feet 3 inches deep. The deepest water found by us in Syracuse Lake is 28 feet 10 inches. A depth of 35 feet is recorded for this lake in the State Geologist's Report for 1875.

An examination of the contour lines of the map shows that if we consider water having a depth of 30 feet or more as deep water, we have in the main lake four areas of deep water varying greatly in size, and connected with each other by channels.

In Crow's Bay the greatest depth found was 49 feet 9 inches. These waters enter the main body of the lake through a channel deeper than 30 feet, and 200 feet wide at its narrowest point. This channel flows across the mouth of Johnson's Bay, meeting a short arm deeper than 30 feet from that bay, and comes within 600 feet of the southeast extremity of Ogden Point. This channel continues less than 400 feet wide to a point two-thirds of a mile west of Ogden Point where it joins the channel deeper than 30 feet from Jarrett's Bay. The deepest water in Jarrett's Bay is 68 feet 7 inches, and the area deeper than 30 feet is one-fourth of a mile wide, extending north beyond the mouth of the bay and to within 700 feet of its southern shore. This 30-foot depth joins the main body of the lake a half mile north of Clark's Point where the channel 30 feet deep is only 100 feet wide. Turning to the west, 1,000 feet northeast of the Biological Station this channel deepens to 66 feet 5 inches, and widens to a half mile directly north of the Station. Here it meets the narrow channel 30 feet deep from Crow's Bay.

The two channels merge into one and form an area of water from 30 feet to 66 feet in depth, one mile in length and with a maximum width of three-quarters of a mile. This area of deep water lies nearer the south shore, its center being one-third the distance from the south shore to the north shore. Near Black Stump Point the deep water narrows abruptly from the north, and 500 feet out from Black Stump Point its width is bnt 200 feet. West of Black Stump Point the deep water widens abruptly to the north to a width of one-quarter of a mile and deepens to 63 feet 3 inches. West of this the area of deep water narrows again and the water having a depth of 30 feet ends one-quarter of a mile southeast of the entrance to the channel between the main lake and Syracuse Lake.

Between the deep channels from Crow's Bay and Jarrett's Bay the area having a depth less than 30 feet is one and one-quarter miles long, 1,300 feet wide, and contains an area one mile long and 500 feet wide over which the water is less than 10 feet deep.

If the level of the lake were lowered 30 feet there would remain four bodies of water connected by channels from 100 feet to 200 feet wide and less than 10 feet deep. These four bodies of water would be: (1) a small area in Crow's Bay with a maximum depth of 19 feet; (2) about one-half of Jarrett's Bay with a maximum depth of 38 feet; (3) the main body of the lake, its width decreased almost one-half, and its maximum depth being 36 feet; (4) a small area northwest of Black Stump Point with a maximum depth of 33 feet. Lower the level of the lake 10 feet more, that is, 40 feet below its present level and these four bodies of water would remain as separate lakes, the connecting channels now being dry.

Great changes in the shore line will take place if the level of the lake be lowered to a much less extent. By observing the map it will be seen that a lowering of the level of the lake to the amount of 10 feet would move the shore line to the first contour line. This would leave one-half the bottom of Johnson's Bay dry land; it would move the shore line along Crow's and Jarrett's Bays from 400 feet to 1,000 feet into the lake. Clark's Point would extend 2,000 feet further north, and the distance between Clark's Point and Ogden Point would be reduced from 4,000 feet to 1,800 feet. The south shore line from Clark's to Conkling Bay would be moved northward distances varying from 250 feet at Iron Spring Point to 1,000 feet along the shore west of Black Stump Point. The north shore line from Ogden Point to the Channel would be moved southward from 900 feet to 2,000 feet, and at one place—between Jones' Landing and Black Stump Point—4,000 feet, reducing the width of the lake at this place from 1 mile to 500 feet. The Channel between the main lake and Syracuse Lake would be drained, and the greater part of Syracuse Lake would become dry land.

Judging from the contour of the land, the level of the lake has probably never been more than 5 feet below its present level.

TOPOGRAPHY OF THE SHORE.

The shore of 20 miles is about equally divided between dry shores and marshy shores. The shores of Syracuse Lake and of the west end of the main lake were not carefully surveyed, but accurate measurements and notes were taken of the shore line of the east end of the main lake from a point on the north shore three-eighths of a mile to the northwest of Wawasee, around the east end of the lake to a point directly south of the starting-point. These data were used in mapping a ten-foot elevation line around this part of the lake. For this reason the shores of the east end of the lake are treated more in detail than the others.

The dry shores are composed of sand and gravel. Some are less than 5 feet high, but more often they are abrupt bluffs from 10 to 30 feet high, or hills which ascend rapidly to a height of 40 feet. The west, north and northeast shores of Syracuse Lake are bluffs or hills. The east shore is marshy. The shore south of Turkey Creek, the outlet, is also marshy, and these marshes extend along both sides of the Channel between Syracuse Lake and the main lake. Pickwick Park is located on a gravelly shore less than 10 feet above the level of the lake. Between Pickwick Park and Eppert's is the Gordoniere Marsh extending northwest to the Channel. Pickwick Park and the land to the west of it is surrounded by the main lake, the Channel and the Gordoniere Marsh and is known as British Island. The shore between Eppert's and Jones' is mainly marsh. From Jones' one-quarter of a mile east the shore is a bluff from 10 feet to 15 feet high. From this point almost to Wawasee the land near the shore is at present a dry marsh. The bluff at Wawasee is 15 feet high and extends along the shore 1,700 feet. This bluff extends back from shore 500 feet where it joins the marsh which stretches along the shore to Ogden Island, and also to the east to Johnson's Bay. Ogden Island, which is surrounded by the lake only on the southwest side and on all other sides by marshes, extends a half mile to the northwest of Ogden Point and is from 300 feet to 1,000 feet wide. Its greater part is from 3 feet to 6 feet above the level of the lake. About one-half of that part of the island which touches the lake is a bluff from 10 feet to 18 feet high. The area higher than 10 feet is 1,100 feet long and from 175 feet to 400 feet wide. The marsh around Johnson's Bay is known as the Johnson Marsh. It skirts the southeast and east sides of Ogden Island, surrounds a piece of timbered land 700 feet in diameter

north of Ogden Island known as Oak Island, borders the bay on the north, sending off a broad marsh across the country to the northeast, and continuing along the east side of the bay with a width of a half mile, joins a narrow marsh extending to the southeast. On the east side of Johnson's Bay are two bluffs, one reaching a height of 23 feet and extending from Cedar Point northwest one-quarter of a mile along the shore and having 500 feet for its greatest width; the other is 1,000 feet further to the northwest, and is between 10 feet and 15 feet high, 700 feet long and 150 feet wide. Lying to the northeast of these bluffs and extending between them is an arm of the Johnson Marsh from 50 feet to 800 feet in width, which joins Crow's Bay just east of Cedar Point. From the northeast corner of Crow's Bay the bluffs extend south along the east end of the lake for a half mile. They are from 10 feet to 27 feet in height. The 10-foot elevation line then leaves the shore and extends almost south to Turkey Creek, leaving an area of well timbered dry land along the lake with an elevation of from 3 feet to 10 feet and attaining a width of 1,000 feet.

The land on both sides of Turkey Creek, the inlet of the lake, is marshy. Lying to the north of the mouth of the creek this marsh is 400 feet wide and extends one-quarter of a mile north along the lake. This marsh is separated from the marsh along the east margin of Morrison's Island by a shallow channel of water. The west side of Morrison's Island is a bluff reaching a height of 21 feet. From Turkey Creek to Buttermilk Point the shore is skirted with marsh from 200 feet to 400 feet wide. Mineral Point is 200 feet from the lake and ascends abruptly from the marsh to a height of 25 feet. A half mile south of Turkey Creek the lake is entered by Jarrett's Creek which is the outlet of a chain of small lakes lying southeast of Jarrett's Bay. This stream flows through a marsh 400 feet wide, and all the small lakes are bordered by marsh land. The marsh along the lake ends at Buttermilk Point, and for a quarter of a mile the shore is dry and sandy. The land along this shore is not a perpendicular bluff, but rises rapidly from the lake to the south and reaches a height of 40 feet at a distance of 400 feet from the shore. The west side of Jarrett's Bay is skirted by a marsh from 150 feet to 1,000 feet wide. West of the marsh is a bluff from 10 feet to 15 feet high continuous with the land south of the bluffs of Vawter Park. West from Clark's the south shore of the lake is a perpendicular bluff reaching a height of 29 feet in Vawter Park and extending west beyond the point where our survey of the summer ended. This bluff is cut by a ravine 50 feet wide at the Biological Laboratory and by a small stream entering the lake a quarter of a mile west of Vawter Park. The shore extending west to and around Black Stump Point is from 5 feet to 15 feet above the level of the lake. The high bluffs from Clark's Point to Black

Stump Point is by far the longest stretch of highland along the shore, being nearly two miles in length. Conkling Bay during the summer months contained an area of water about 300 feet in diameter and 20 feet deep, bordered by wide stretches of marsh containing a few small pools of very shallow water. To the north of Conkling Bay, Conkling Hill ascends rapidly to a height of 40 feet or more. This hill is conical in shape and slopes to the water on the south and east, and to marsh and lowland on the north and west.

It will be noticed that the perpendicular bluffs of the main lake face to the south at Jones' Landing; to the southwest at Wawasee, Ogden Island and Cedar Point; to the west along Crow's Bay and Morrison's Island; and to the north along Vawter Park. The high hills at Jarrett's and Conkling's are without precipitous shores. All of these bluffs are bordered by wide areas of shallow water, and it will be noticed that the 10-foot contour line of the bottom does not approach the shore much nearer than 400 feet, and is usually much further from shore. As a rule, the bluffs facing to the south and southwest have a much wider margin of shallow water than those facing to the west or north.

Wherever there is a long stretch of shore, bordered by marsh, there is no beach formed, but the muddy bottom of the lake merges into the mud of the marsh along the shore line. Along all the dry shores, and along the marshes of small extent lying between bluffs, the beach is composed of gravel and sand. This gives a gravelly or sandy beach around Syracuse Lake, except on the east and southwest; along the north shore of the main lake, from the Channel to Ogden Point; along the east shore of Johnson's Bay, from Cedar Point northwest to the extremity of the dry shores; from the northeast corner of Crow's Bay to a point east of the north end of Morrison's Island; along the south end of Jarrett's Bay; from Clark's Point along the south shore for a short distance beyond Black Stump Point. These beaches along the bluffs are formed by erosion and deposit along the base of the bluffs. The sandy and gravelly beaches along marshes are found where the adjoining bottom of the lake is composed of sand and gravel. These beaches have most probably been formed by the action of ice.

Around the main lake a number of beach formations of this kind are found. From Wawasee a half mile west the beach is composed of sand and gravel. It is about three feet above the water's level, and is higher than the land back of it. From the east end of the bluffs of Wawasee to the dry land of Ogden Island is a distance of a half mile, and the marsh along the shore is very little, if any, higher than the level of the lake. Between the marsh and lake is a beach composed of sand and gravel. This beach is two feet or more above the level of the water, and 30 feet wide. The beach along the bluff of Ogden Island is of the

usual formation, but this beach continues along the shore for one-fourth of a mile beyond the bluff as a very sandy beach a foot or more above the water's level and 50 feet wide; then the beach grows narrower and is on the level of the water, the sand becomes less plentiful, and the beach is composed of a small amount of coarse gravel and then merges into the marsh, where the shore line of Ogden Point turns north. The same formation is found running a short distance north of the bluffs on the east side of Johnson's Bay.

Between the two bluffs on the east side of Johnson's Bay is a beach 1,000 feet in length, with the lake on one side and a marsh containing pond lilies on the other. This beach is from 20 feet to 80 feet wide, 3 feet above the water's level, and composed of sand and coarse gravel. The margin of the beach further from the lake is the higher, and is covered with a growth of willows, cedar and other small trees. Along the lowlands of Crow's Bay is a broad beach composed of coarse gravel about three feet high and on a level with the land back of it. Along the south end of the west side of Morrison's Island, which is lowland, the beach is from 15 feet to 25 feet wide, three feet high, and composed of coarse gravel. The beaches along marshes and lowland are broader and higher, and contain much more material than those along bluffs.

The action of the ice is an important factor in the formation of these beaches. For the explanation of the action of ice on beaches as well as the formation of ice cracks, I am indebted to I. C. Russell's excellent book, "Lakes of North America." The lake freezes over and by expansion the ice is pushed up along the shore carrying sand, gravel and stones with it. Numerous ice cracks form during the winter and fill with water. This water freezes and pushes the ice still further up the shore carrying the beach forming material still higher. These ice cracks are very numerous and may be as much as three inches wide. The amount of lateral pressure brought to bear on the shores by this means is very great, and beach ridges are begun and added to each year. The action of the ice in forming beaches along marshes is very great, while along bluffs it is small. In the first case no great resistance is met with in expansion, and the material for building the beach will be carried up to the full extent of the expansion of the ice, while along the bluffs the ice crowds against the shore and is itself broken at every expansion. A recent ice formation is evident at the northwest end of the Gordoniere Marsh, between the marsh and the Channel. In 1891 this marsh was under water, but since that time the water of the lake has receded and left the marsh dry. Separating the marsh from the Channel is a ridge of earth more than one foot high running parallel with the water's edge. This ridge can be accounted

for by the action of the ice subsequent to the time when the marsh was left without water. Some of the most striking examples of ice action in the formation of beaches are found along the east side of Johnson's Bay; along Crow's Bay; at Morrison's Island, where two ice beaches, separated by a few feet, are now covered by trees; at Clark's Point, where an old beach extending as much as 200 feet from shore is found, and at Black Stump Point.

CHARACTER OF BOTTOM.

In the shallower parts of the lake the bottom is composed of sand, gravel, and small boulders, except along the low marshy shores, where it is composed of mud. At several places, both in Syracuse Lake and in the main lake, dredgings were taken at depths from 25 feet to 60 feet. Here the bottom was covered with a deposit of marl in which were found many diatoms and shells.

Further investigations will be carried on to determine more fully the character of bottom at different depths.

ICE.

For information concerning the freezing of the lake I am indebted to Mr. J. P. Dolan, who has given me the history of ice formations as he has observed them during years past, and he has furnished me with records of careful observations made since the first formation of ice in October, 1895. These observations, unless otherwise indicated, are for Syracuse Lake. Ice forms on the main lake at the same time, but it does not freeze entirely over so soon as Syracuse Lake.

The lake begins to freeze along the edge, except where strong springs enter near the margin. Information has been obtained concerning the influence of springs only at Crow's Bay and Vawter Park. Springs are numerous along Crow's Bay for a half mile and the water along the edge is kept open after the lake is frozen over, but I have not yet learned to what extent these springs influence the freezing of the edge of the lake in this locality. From Mr. Smith Vawter, who has observed the springs at Vawter Park for a number of years, I learned that the spring, which is near the margin of the lake and 200 feet east of the Biological Laboratory, keeps the edge of the lake open throughout the winter. If the weather is not severe, ice does not form for 25 feet along the shore, and from 12 feet to 15 feet from shore. In the severest weather the lake is kept open for 2 or 3 feet from the margin.

The ice spreads rapidly from the shore towards the center. The lake freezes over quite rapidly when the general temperature remains below 32° Fahrenheit

and there is no accompanying wind. All parts of the lake freeze, except where it is kept open by springs, but the last place to freeze is a narrow strip from 20 feet to 30 feet wide, extending from the north end of the Channel to Turkey Creek, the outlet of the lake. Ice sometimes forms to a thickness of 6 or 8 inches along the margins of this channel before it freezes over. This is due to a current along this narrow channel towards the outlet. The ice is always thinner here than elsewhere.

Accurate information could not be obtained concerning the exact date of freezing in 1894, but from Mr. Dolan's observations we can give an accurate account of ice-formation during the fall and winter of 1895.

The first ice of the season was observed on October 20. The temperature of the air at 7 A. M. was 28°. A thin layer of ice 4 or 5 feet wide had formed along the edge of the lake. It melted during the day. At 7 A. M. October 30, the temperature of the air was 26°, and about one-fourth of Syracuse Lake was frozen over. Not quite all the ice melted, but it all disappeared on the following day. At 7 A. M. November 2, the temperature of the air was 22°. The mill race was covered with ice three-eighths of an inch thick. Only the edge of the lake was frozen, as the wind blew during the night. On November 21, the temperature of the air at 7 A. M. was 13°, and ice had formed from shore to shore on Syracuse Lake; at 12 M. the ice was nearly all melted, and at 5 P. M. the lake was free of ice. This was the first date on which the ice extended entirely across the lake. On November 23, at 7 A. M., the temperature of the air was 30°. Ice had formed on the mill race, but no ice formed on the lake, owing to a slight wind. On November 27, the temperature of the air at 7 A. M. was 16°, and a wide belt of ice had formed around the lake, but it disappeared on the following day. On December 2, the night was clear and calm. There was no ice at 4 P. M., but at 7:30 P. M. a thin sheet of ice had formed and extended apparently from shore to shore. On December 3, Syracuse Lake was completely covered with ice. The temperature of the air during the day was 6° at 7 A. M., 16° at 12 M. and 12° at 5 P. M. On December 5, the ice was 2 inches thick near shore. On December 7, the ice near shore was $3\frac{3}{4}$ inches thick, and 500 feet out from shore $1\frac{1}{4}$ inches thick. I visited the main lake on December 7, and the ice appeared to extend over the entire lake. Warren Colwell had skated over the lake during the forenoon as far east as Ogden Point. The only place where he found the lake open was a space about 20 feet square, half way between Ogden Point and Black Stump Point. Three dozen ducks and mud-hens had congregated in this open space.

The increase and decrease in the thickness of the ice from December 9, to December 20, are shown in the following table. The measurements were taken 50 feet or more from shore.

Day of Month.	Thickness of Ice in Inches.	Temperature of Air at 5 p. m.	Condition of Weather.
9	4	18°	North wind; cloudy.
10	4½	26°	Wind, southwest to south.
11	5	36°	Snow and rain.
12	5¼	20°	Clear.
13	5½	24°	East wind; clear.
14	6¼	36°	Wind, south to southwest.
15	6¼	26°	Clear.
16	5½	39°	East wind.
17	5	46°	Southwest wind; rain.
18	4¼	52°	South wind; rain.
19	2¼	54°	South wind; rain.
20	0	52°	South wind.

On December 13, ice cutting for commercial purposes was begun, with the ice 5½ inches thick. Last winter no ice was cut until January 1, 1895, when the ice had reached a thickness of 6 inches. On December 15, the ice had reached a thickness of 6¼ inches, after which it grew thinner, owing to the rise in temperature and the heavy rains. By December 20, the ice had melted so that only slush ice remained. On the morning of December 21, this ice had drifted to the north and northeast parts of the lake and at 5 p. m. of the same day the ice had all melted.

Mr. Dolan has given me accurate information concerning the ice on the lake from January 1, 1895, to March 25, when the ice left the lake. On January 1 the ice was 6 inches thick and kept increasing in thickness for more than a month. The maximum thickness, observed by persons engaged in fishing through the ice, was noted in the early part of February and found to be from 24 inches to 28 inches. The greatest thickness is found where the ice has been kept clear of snow by the wind. In January and February the snow lay about nine inches on the level, but it was drifted in many places on the lake while other areas were without snow.

In the spring the ice sometimes wears into holes out in the open lake, and breaks up in the center of the lake first, the last ice to break being along the shores. This is the case when the ice goes off in cloudy weather and with heavy rains. Usually the ice begins to melt along the shore, with some holes further out. A heavy wind then breaks the ice and carries it ashore. For the past ten years the

ice has gone off with a west or southwest wind and has been piled up on the east or northeast shores.

In the spring of 1895, the ice went off the lake in an unusually short time. The lake had remained completely frozen over until March 24. During this day the ice began to melt along the shores. On the morning of March 25, the ice had melted to a distance of 20 feet from shore. At noon the ice had receded 400 feet from shore. A heavy west wind was blowing all day, and the cracking of the ice could be heard. At 3 p. m. the noise caused by the crushing of the ice became very loud and could be heard for a quarter of a mile. The ice was broken into huge cakes. The wind now began to lift the ice and drive it eastward. At 4 P. M. all the ice was piled along the east shore. The height to which the ice is piled depends on the character of the shore and the strength of the wind. The piles are not so high along a low marshy shore as along an inclined or abrupt shore. Occasionally a great sheet of ice is pushed up a smooth inclined surface 6 or 7 feet without breaking the ice to any great extent. An instance of this kind was observed by Mr. Dolan on the northeast shore of Syracuse Lake last March. No ice formed on the lake after March 25.

Ice cracks are very numerous from the time the ice forms entirely across the lake and has attained sufficient stability. They form before the ice has reached the thickness of one inch. When the first cracks formed in December the ice was so thin that it sagged slightly along the crack. The water came through the crack and spread over the surface of the ice sufficiently to melt the small amount of snow covering the ice, to a distance of 5 or 6 feet on each side of the crack.

The explanation of ice cracks as quoted from Gilbert by Russell in his "Lakes of North America" is so applicable to the case in hand that I reproduce the quotation here:

"The ice on the surface of a lake expands while forming, so as to crowd its edge against the shore. A further lowering of the temperature produces contraction, and this ordinarily results in the opening of vertical fissures. These admit the water from below, and, by the freezing of that water, are filled, so that when expansion follows a subsequent rise of temperature the ice can not assume its original position. It consequently increases its total area, and exerts a second thrust upon the shore. When the shore is abrupt, the ice itself yields, either by crushing at the margin or by the formation of anticlinals (upward folds) elsewhere; but if the shore is gently shelving, the margin of the ice is forced up the acclivity and carries with it any boulders or other loose material about which it may have frozen. A second lowering of temperature does not withdraw the protruded ice margin, but initiates other cracks and leads to a repetition of the

shoreward thrust. The process is repeated from time to time during the winter, but ceases with the melting of the ice in the spring."

The formation of these cracks is accompanied with noise, and, when the ice has reached the thickness of four or five inches, the noise resembles the distant booming of cannon. These cracks may be mere seams in the ice, or they may be several inches wide. On December 7, I measured a crack three-eighths of an inch wide in ice one and three-fourths inches thick. On December 9, Mr. Dolan measured one two and three-fourths inches wide in ice four inches thick. On the same day he counted eleven loud reports caused by the formation of ice cracks in five minutes. They form during all parts of the day and night. They cross the lake in every direction, and, while the cracks are slightly zig-zag, their general courses are in straight lines.

The ice is very clear and pure, especially out from the shore, where there is no vegetation near the surface. Is is used very largely for commercial purposes, the ice being cut from about one-fourth of the surface of Syracuse Lake each year.

INLET.

The only stream flowing into the lake and containing water throughout the year is Upper Turkey Creek, which enters the lake on the east side of Jarrett's Bay. During the summer months it was filled with an abundant growth of water vegetation, and was without any perceptible current. When the water is high the chain of small lakes lying to the southeast is drained into the large lake through Jarrett's Creek, entering Jarrett's Bay a half mile south of Turkey Creek. During the past summer no water entered the lake from this source. A small stream one-fourth of a mile west of Vawter Park, and another from the east side of Johnson's Bay, contribute water to the lake when the water is high, but not during the dry summer months. There are no springs around Syracuse Lake, but springs are found along the margin of the main lake wherever the shore rises fifteen feet or more and extends across the country as elevated territory. These springs usually enter the lake near high water mark. This gives springs along Crow's Bay, Mineral Point, the south and west sides of Jarrett's Bay, and along the south shore from Vawter Park one mile west. No springs are found along the bluffs at Jones', Wawasee, Cedar Point, Morrison's Island, or Conkling Hill, but in each case these highlands are narrow and surrounded by marsh or lowland. For a half mile along Crow's Bay the bluff is more than twenty feet high. All along the foo of the bluff the water percolates from the gravel, and at places it flows from quite strong springs. At Mineral Point there are a number

of strong springs. At Buttermilk Point and along the base of the bluffs west of Jarrett's Bay are a number of springs. The margin of the lake from Vawter Park one mile west is very springy, but the flow of water is not so strong as along Crow's Bay. The waters from all these springs show traces of iron more or less strongly.

OUTLET.

The waters of the lake flow into Lower Turkey Creek through which they enter the Elkhart River near Goshen, Indiana; then through the Elkhart and St. Joseph rivers they reach Lake Michigan.

Near the outlet of the lake the creek, during the summer, was about 20 feet wide and had an average depth of less than 6 inches. The volume of water discharged through the outlet was computed from measurements taken in the creek and the overflow of the mill race July 18, 1895. The outflow through the creek was 103 cubic feet, or 772½ gallons, per minute; through the mill race, 41 cubic feet, or 307½ gallons, per minute, making a total of 144 cubic feet, or 1,080 gallons, per minute. At the same time the volume of the creek a half mile below was computed at 137½ cubic feet, or 1,031 gallons, per minute.

By taking the outflow of the lake at 144 cubic feet per minute, finding the amount discharged in twenty-four hours, and computing the amount the level of the lake, with an area of 5½ square miles, would be lowered by such an outflow with no inflow, we find it to be .016 of an inch. At this rate it would require 62½ days to lower the lake one inch. In one year of 365 days, at the same rate, the level would be lowered 5.84 inches. The inflow, during the summer months, is almost entirely due to springs, and probably equals the outflow. The lowering of the level of the lake, during the summer months, seems to be due almost entirely to evaporation.

ELEVATION.

The elevation of the lake above the sea and above Lake Michigan is shown in the following list of stations and their respective elevations. The list of stations with their respective elevations above mean tide at Sandy Hook, New York, was furnished by the General Superintendent of the Baltimore & Ohio Railroad. The elevation of each station above Lake Michigan was found by subtracting 582 feet, the elevation of the surface of Lake Michigan above the sea, from the elevation of the station above the sea:

ELEVATIONS OF STATIONS ON BALTIMORE & OHIO RAILROAD FROM SOUTH CHICAGO, ILL., TO PATTON SIDING, IND., THE MOST EASTERN STATION IN INDIANA.

NAME OF STATION.	No. Miles from Grand Central Station, Chicago.	Elevat'n Above Mean Tide at Sandy Hook, New York, in Feet.	Elevat'n Above Lake Michigan, in Feet.
STATIONS IN ILLINOIS.			
South Chicago	19	593.0	11.0
Rock Island Junction	.....	593.5	11.5
STATIONS IN INDIANA.			
Whitings	.....	598.5	16.5
Edgemoor	.....	596.5	14.5
Wilsons	.....	604.5	22.5
Millers	37	617.0	35.0
Dock Siding	.....	621.5	39.5
Willow Creek	.....	640.3	58.3
McCools	.....	640.5	58.5
Babcock	.....	652.0	70.0
Woodville	.....	687.8	105.8
Suman	.....	748.6	166.6
Coburg	.....	786.0	204.0
Alida	57	788.8	206.8
Wellsboro	64	760.0	178.0
Union Centre	71	718.5	136.5
Walkerton	79	716.0	134.0
Teegarden	85	800.7	218.7
La Paz	.....	859.0	277.0
La Paz Junction	88	856.0	274.0
Bremen	96	819.0	237.0
Berlinton	.....	853.0	271.0
Napanee	104	880.0	298.0
Milford Junction	112	840.2	258.2
Syracuse	116	869.2	287.2
Wawasee	120	882.2	300.2
Cromwell	125	935.2	353.2
Kimmell	.....	923.2	341.2
York	.....	901.6	319.6
Albion	135	926.2	344.2
Ripley	.....	970.2	388.2
Avilla	145	961.2	379.2
Garrett	150	890.0	308.0
Auburn Junction	153	871.7	289.7
Inverness	.....	864.2	282.2
St. Joe	163	812.2	230.2
Patton Siding	.....	849.7	267.7

Syracuse is the station having most nearly the elevation of the surface of Turkey Lake. The mean level of the lake is about 5 feet below the station at Syracuse. This gives the lake an elevation of 864 feet above the sea, and 282 feet above the surface of Lake Michigan.

CHANGES IN LEVEL.

Changes in the level of the lake have been due to three causes: erosion, the dam which is built across Turkey Creek just below the outlet of the lake, and climatic conditions.

Old beach formations give evidence that the level of the lake was formerly 5 or 6 feet higher than at present. By erosion the channel at the outlet was cut 10 feet below this ancient level, and the dam has raised the level of the lake 5 feet to its present level.

The history of the dam as given by an old settler is as follows:

A small dam was built in 1828, to which additions were made in 1831. This dam washed out in 1833, and the present dam and mill race were begun in the same year. This raised the level of the lake so that timber stood in water 5 feet deep. Much of this timber remained uncut in 1840, and some was still standing as late as 1865.

The vertical distance between the level of the water in the creek below the dam and the top of the waste gate, December 7, 1895, was five feet. This would be the amount the dam, when in working order, would raise the level of the lake. The dam is not in use at present and a small portion has been removed, which allows the water to pass into the creek at a level 16 inches below the top of the waste gate. This present condition of the dam holds the water of the lake 3 feet 8 inches above the level of the water in the creek below.

The submerged stumps in many parts of the margin of the lake is the best evidence that the dam had the effect of increasing the area of the lake. These stumps stand at present in water from a few inches to two feet or three feet deep. Along the margin of Syracuse Lake the stumps are most abundant at the point of the lake extending furthest west, and on the east shore along the edge of the marsh. Turkey Creek, from the lake to the dam, is sixty feet wide, and only twenty feet along the middle is clear of stumps. This was the channel of the creek before the dam was built, and the stumps now standing in water are the remains of the timber which grew along the banks of the creek. On the north and south sides of Buck Island, at the south end of Syracuse Lake, areas of submerged stumps indicate that this island was formerly one hundred feet wider in

each direction. On the east side of the entrance of the main lake to the channel are many submerged stumps. Along Johnson's Bay much timber stood in water, especially on the east side of Ogden Point and on the east side of the bay just north of the bluffs. In these localities the stumps are very numerous, and among the largest in the lake. There are a few stumps along the marsh just east of Cedar Point. Others are found in the vicinity of Morrison's Island and go to indicate that this island, before the building of the dam, was a part of the mainland. It is so represented in the government survey of 1838. On the west side of Jarrett's Bay submerged stumps are numerous, especially along the southeast corner, where much small timber is still lying in the marsh at the margin of the lake, and at Clark's Point where many large stumps are found in the water. Submerged stumps are also found west of Black Stump Point. The elevation of the lake by the dam, not only increased its area but must have rendered much of the low level land in the vicinity of the lake marshy, which would have been tillable. It is claimed by persons living in the vicinity of the lake that the dam rendered four thousand acres of land untillable.

The fluctuations in the level of the lake are caused by climatic conditions, and vary with the inflow and outflow, rainfall and evaporation. In Mr. J. P. Dolan's report will be found the record of changes of level as observed during the past few months. Annual fluctuations are estimated to be about two and one-half feet. The level of the lake is usually highest about May 1, after the heavy spring rains, and lowest in August, although this year it kept lowering until November 2, owing to the very light rains up to that time. It was then ten and one-half inches lower than on July 6. The lake was lower on November 2, than at any time since 1871, when the marshes around the lake were drier than in 1895. Since November 2, the lake has been rising until, on December 25, it was fifteen and three-quarters inches higher than on November 2.

In May, 1891, the lake was higher than at any time during the past twenty years. The difference between well-remembered high water marks of that time and the level of November 2, 1895, is four and one-half feet, which is the maximum fluctuation during recent years. Each spring since 1891, has found the level of the lake lower than during the preceding spring. This gradual lowering of the level of the lake has decreased its area and has shown marked changes in the marsh land along the margin of the lake. Four years ago the water in Conkling Bay covered an area a half-mile in diameter, now it is reduced to three hundred feet in diameter; a small shallow lake just west of Conkling Bay contained water throughout the year, now it is dry and growing good crops; fields lying west of the channel were almost marsh land, the crops being greatly damaged by

water, but during the past two years no difficulty has been experienced in filling them; two or three feet of water flowed over the Gordoniere Marsh, which is now dry with beach lines forming along its margin; and boats were rowed over all parts of the Johnson Marsh, while at present hardly any of its surface is submerged.

Consult Hydrographic Map Next to Front Cover.

Temperature of Turkey Lake. By J. P. Dolan.*

In making these observations a Charles Wilder standard, protected, thermometer was employed. They were begun the 13th of July, during which month four soundings were taken in the deepest parts of the lake from the surface to the bottom at every five feet. Then on October 5 two records were made at about the same points, and again on November 2.

September 17 a rain guage was set up and from that day to the present a regular record of temperature, precipitation, direction of wind and rise and fall of lake has been kept, but the observations have been confined to the northwest part of the lake; properly, Syracuse Lake.

1. TEMPERATURES OF TURKEY LAKE, 1895.

	July.				Oct. 5.		Nov. 2.	Dec. 14.	Dec. 24.
	Indiana University Biological Station.				I. U. Bio. Stat'n.	Jarrett's Bay.	I. U. Bio. Stat'n.	Black Stump Point.	
	13th, 10 A.M.	16th, 8:45 A.M.	17th, 9:30 A.M.	23d, 8:45 A.M.	11 A.M.	1:45 P.M.	11:10 A.M.	10 A.M.	
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	
Air	81½	83½	78½	72	65	.....	50	28	.....
Surface	74	75	75	76½	60½	61½	43	34½	.....
5 feet	.....	.....	.....	.....	60	60¼	.....	34½	.....
10 "	73	74	75	71	60	59	45	24½	.....
15 "	72½	74	74½	70	59	59	.....	.....	.....
20 "	71	71	73½	67½	58½	58½	43	.....	.....
25 "	68	65	68½	61½	58½	58½	43½	35	.....
30 "	65	63	68½	.....	58½	58½	.....	.....	.....
35 "	60	62	.....	58½	58½	58½	.....	35½	.....
40 "	60	60	.....	.....	58½	58	.....	.....	.....
45 "	59	57	.....	58	58½	58	.....	35½	.....
50 "	59	.....	.....	58	58½	58	.....	.....	.....
55 "	58	.....	.....	.....	58½	58	.....	.....	.....
60 "	58	.....	.....	58	58¼	57½	.....	.....	.....
65 "	58	.....	.....	58	58	56¼	.....	.....	.....
67½ "	.....	.....	.....	.....	.....	53¼	.....	.....	.....

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 15.