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THESIS.

HYDROGRAPHIC SURVEY OF PINE LAKE.

SURVEYED AND MAPPED, SPRING TERM, 1908.

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HYDROGRAPHIC SURVEY OF PINE LAKE.

The purpose of this Thesis was to secure a complete hydrographic contour map of Pine Lake. This is a meandered lake situated in sections 2,3,10, and 11, of township of Meridian, county of Ingham, State of Michigan.

During the spring term of 1907, G.H. Ellis and Gar. Verran, senior students of Michigan State College, made as their Thesis, a topographical survey and map of the land surrounding the lake.

It was our intention to use the triangulation system of the above survey as a base for the hydrographic survey. With this in mind we examined carefully the entire Thesis of Ellis and Verran, making a copy of such notes as we thought necessary to locate the points of their triangulation system.

To systematize the arrangement of the subject matter of this Thesis we use the following order:

I. Method used in triangulation of lake.

(a) Reconnaissance, and location of base-line and triangulation points.

(b) Measurement of base-line.

(c) Reading angles of triangles.

II. Hydrographic Data.

(a) Crew and equipment.

(b) Methods of sounding and of tying in soundings.

(c) Datum Plane.

(d) Inlets and outlets.

(e) Character of shore line.

(f) Character of lake bottom.

III. Tying in triangulation system to government survey.

(a) Plotting triangulation points and shore line.

(b) Reduction of notes.

(c) Symbols used.

(d) Drawing contours.

(e) Area of lake.

Conclusions

I. Triangulation.

II. Obtaining hydrographic data.

III. Possibilities in improvement of lake.

I. Method used in triangulation of lake.

(a) Reconnaissance, and location of base-line and triangulation points.

With Ellis and Verran's notes as a guide we made a reconnaissance attempting to find the points of their base-line, and other points near the lake which would serve as stations from which to lay out lines across thelake. The base-line was easily found and will be taken up under the head of "Measurement of base-line". But because of the fact that some of the points had not been marked or referenced in any way, and the markings of others had been destroyed, we succeeded in finding but few of the points, and these were unfortunately for the most part not suitable for our use. We therefore established new points which we considered better adapted to our purpose, using only points Nos. 1, 2,29,31, and 18 of the old triangulation. Where the new points were located near the old ones we gave them the same numbering, except Nos. 16 and 44, which are discussed in notes on survey under dates of April 4th and 12th. Where we could find the old points we tied the new ones in to them, together with other witness marks. For points entirely different from the old, we continued the numbering as used by Ellis and Verran, making our first point No. 44. In our main triangulation we used fourteen stations numbered as follows; easterly around lake from base-line: 1,2,3,4,6,1[illegible], 44,16,18,31,29,2[illegible],37, and 2[illegible]. These were marked with gas-pipe and witnessed as recorded in the notes. In locating these points two men were used, one with a transit at No.3, a prominent point near the wind-mill on Hickory Island, while the other with field glasses went around to the different stations and set up standards with cross-arms at points which could be seen by the man at No. 3, and from which could be seen as many as possible of the other triangulation points. It was subsequently found necessary to further mark these standards with red rags to make them readily distinguishable across the lake.

(b) Measurement of base-line.

This was measured between stations 1 and 2, as located by Ellis and Verran on a straight-away between the double tracks of the Grand Trunk R.R. in the village of Haslett, and given by them as 2100 feet. By our measurement it is 2100.1 feet. The exact location with regard to the government survey will be given under that heading.

(c) Reading angles of triangles.

The form of notes for this work was taken from Ellis and Verran's note book and is as follows:

Transit at Sta.	Shot at Sta.	Angle.	Bearing	Remarks.
6	27	$212^\circ - 55'$	$S\ 75^\circ - 30'\ W$	

The method of procedure is as follows: the transit is set up at each station in turn and set at zero on one of the other stations, and the angles to all other stations in sight are turned off successively. Completing the revolution brings the sight on the first point, and the vernier again on zero, (if the lower plate remains stationary) thus in a measure checking the operation.

II. Hydrographic Data.

(a) Crew and Equipment.

The number of men in the crew was varied. When four men were available for sounding, two were used at instruments, one man rowed the boat and kept sounding notes, and the fourth dropped the lead. For shore line three men were required, two being transitmen and one a rodman.

Total equipment used in obtaining hydrographic data was as follows:

Two transits and accessories.	Targets and flags.
One flat-bottomed boat.	One lead and line.
Three transit note books.	Pair field glasses.
One steel tape and pins.	Flag-pole.
One sextant	Level-rod.
Pair of hip boots.	Axe.

The transits, sextant, tape, pins, level-rod, and flag-pole were obtained from the College equipment. The boat was hired from William McGivern. The transit note books accompany this Thesis. The boots were necessary in securing shore line data. The field glasses were indispensable to the boatman in observing the signals of the transit men. The sounding line is a sixty five foot length of common three strand hemp rope. In preparing the rope, it was first soaked in water, stretched between two posts and let dry, then rubbed with a rag soaked with linseed oil. When the oil was dry, the rope was marked off in one foot divisions. Every fifth foot was marked with a leather tag and intermediate points with cord tied through the strands. The ten foot leather tags were marked with notches, one for ten feet, two for twenty, etc.

The lead was moulded in the shape of a cone (eight inches high and two and one half inch base) around an iron bolt which had a loop at the apex of the cone for attaching the rope. A conical hollow in the bottom of the lead, in which tallow was placed, facilitated getting samples of the lake bottom. The bottom of the lead was made the zero of the line.

The signal flags used by the transit men were about 18" by 24", of white muslin, with a 5 by 5 inch red square of bunting sewed in the center. These flags were very satisfactory when placed on a 5 foot stick.

(b) Methods of sounding and tying in soundings.

A net work of lines of soundings was chosen that would give as accurate a map of the lake bottom as we could expect to get in the time at our disposal, not forgetting that the work might be continued in succeeding years.

The first method used for tying in soundings was by the

intersection of two sides of a triangle, two angles of which were measured simultaneously by transits on shore. A line determined by two known points on opposite sides of the lake was selected on which to take soundings, and a transit set on one of the points to line-in the boat. Another transit was placed at such a triangulation point that the resulting triangle between the boat and the two transits was as nearly equilateral as practicable. The line betwen the two transits was used as a base-line, from which each transit man turned off the angles to the boat.

The operation for taking soundings was as follows: The boatman having proceeded a distance in his judgment, equal to the desired sounding interval, and the leadsman's hand (holding the lead at the side of the boat) being in line as directed by the transitman, the lead is dropped. Simultaneously with the dropping of the lead a flag is waved by the leadsman, at which signal both instrument men sight on the leadsman's hand. The lower limbs of the transits having been clamped on the base-line of the triangle when the leadsman's signal is seen the upper limbs are clamped and the angle read and recorded. The boatman keeps the sounding notes (depths and bottom as called out by the leadsman), and each transit man his record of angles. The three note books are made to correspond for every sounding.

<u>Notes in Transit Book No. 1.</u>

Line	No. of Sounding	Angle.	Remarks.
(Δ 28 - 14)	2	8° - 3'	Base-line 48 - 28

Notes in Transit Book No. 3.

Line	No. of Sounding	Angle	Remarks.
(28 -14)	2	59°-46'	Base -line 48 - 28

Notes in Transit Book No. 2.

Line	No. of Sounding	Sounding	Remarks.
(28 -14)		4.6	Sand

We found that with some care, the transit man ranging in the boatman could get the leadsman on the line, and thus make the angle at his instrument constant. This reduced the labor of plotting the soundings by one half.

Another method used to tie in soundings when only two or three men were available was to range in a buoy about 300 feet from the triangulation point and require the boatman to range himself in line with the buoy and a flag set on the shore points; a transit being used at another triangulation point to read the angles determining the successive positions of the boat, as in the first method. Only two note books are required with this method and we think it practically as accurate as the first.

We secured much general information, but not accurate data, on depths of water by using two men in a boat taking soundings on lines not covered by the more accurate methods. This data was invaluable for plotting contours.

The character of the lake bottom was found by observing the material brought up by the lead. This data was placed in the note book under "Remarks".

The main difficulty we encountered was in getting the note books to correspond. We finally used a red flag as a boat signal at every fifth sounding and a white flag for intermediate soundings. This method worked well.

(c) <u>Datum Plane</u>.

The water surface was taken as the datum plane all depths being negative elevations. Changes in the elevation of the water surface were observed by stages marked on a small pile in the lake outlet. The stages were recorded in the note books with the date and were as follows:

April 4,08.	Water	surface	.9 ft.	below	B.M.
May 17,	"	"	.91 "	"	"
May 23,	"	"	.917"	"	"
May 27,	"	"	.91 "	"	"

Average distance of water surface below B.M. .909 ft. Maximum correction because of change of datum, to be applied to soundings as recorded, is .009 ft. We considered that to apply this correction would be inconsistent with the accuracy of taking soundings so no corrections for change of datum were made.

The B.M. in the outlet was compared by a line of levels to a previously established B.M. on the top of the pile supporting the S.E. corner of the Casino. The casino B.M. being the higher by 3.1425 ft.

Verran and Ellis gave the elevation of the Casino B.M. as 100,38 on April 27,1907.

We found the elevations of thewater surface for the following dates to be:

April 4,08,101.25 Average for spring 08,101.203

May 23,08, 101.22 April 27,07, 100.28

May 27,08 , 101.14 Difference in elevation .923

This increase in the elevations for the year is probably due to a dam across the outlet made after the Ellis and Vorran survey. We obtained heresay evidence thatthe water would drop one and a half feet during the summer.

The Casino B.M. at time of survey was 4.1 ft. above water level. The proper correction for depths of water as recorded on the map is the difference between the above value for B.M. and a valye for B.M. as measured at the time to be corrected for.

(d) Inlets and Outlets.

The inlets to thelake are numerous there being seven more or less clearly defined channels leading into it from the surrounding marshes. These inlets and marshy places are separated from one another by high knolls or stretches of high ground.

The only natural outlet known is a well defined channel through soft earth between high hills on the north west side of the lake. This has quite a substantial dam across it which raises the level of the lake about ten inches. The spillway in the dam is about three feet wide and six inches deep. The wings are somewhat lower than the main part of the dam, which allows the water to run around the sides during high water, or when the spillway is closed.

The Grand Trunk R.R. takes water from the lake ammounting to from 1,200,000 gallons per month in the summer, to 2,375,000 gallons during the winter months. This would not be noticable in the level of the lake as the water taken out per month in summer would lower it only .008? foot if there were no water flowing in.

(d) Character of shore line.

The greater part of the shore is solid and of a sandy or gravely nature, but on the north west side around the outlet there is quite an extent of marsh and the soil is boggy, the muck deep and extending out into the lake. Around O'Gara Bay just north of Hickory Island, and on the south and west sides of South Bay the shore is of a like nature. The piles which support the dock at the south end of the lake were driven by hand thirty feet into the mud. Along the north east shore though it is marshy, the soil is solid and sandy.

(e) Character of bottom of lake.

The soil on the bottom is varied. The ridges are sand, the side slopes clay and the hollows filled with black silt with either clay, sand, or marl produced by weeds, and in other places especially around the marshes the mud is deep and mucky.

Nearly the whole bottom bears more or less weeds. The sandy spots are grown with rushes, the marl with the weeds which produce it, and the mucky portions with spatter-dock and other weeds.

III. Tying in triangulation system to government survey.

Intersection of base-line and section line between 10 and 11, is 371.1 feet from the ¼ section corner between sections 10 and 11. The base-line lies N.E. and S.W. and makes an angle of 62°-16' with the section line. The intersection is 870.4 feet along the base-line from triangulation station No. 1.

IV. Mapping.

(a) Plotting triangulation points, shore line, and location of soundings.

We decided that with a protractor reading to minutes we could plot the triangulation as accurately as by latitudes and departures and with greater facility.

A Keuffel & Esser protractor having a complete 8 inch circle, a $6\frac{1}{2}$ inch arm, a horn center, and a vernier reading to minutes was used to plot all triangulation points, shore line, and soundings.

Two triangles which were as near equilateral as possible and which checked within one minute of arc, were used to locate each triangulation point. The two locations were made on the paper and checked. The shore line was plotted by laying off an angle from each end of a base line between two triangulation points. The intersection of the sides of the triangle is the point on shore.

The soundings were plotted by drawing the line on which the soundings were taken and intersecting it with lines laid off with a protractor from the base line between the transit points.

(b) Reduction of notes.

Although much care was exercised in preparing the sounding line, we found after some use that it had shrunk. It was measured at different times and correction factors determined for the soundings as recorded. The difference in the depth at a place recorded as 36 feet, as computed by the use of the extreme factors was .22 foot. This was so small that the average of the correction factors was used on all recorded soundings.

(c) Symbols used.

The corrected depths in feet were placed directly over the corresponding point on the map. Only such soundings whose location was accurately determined being thus designated. A △ was used to denote a primary triangulation point and a circle thus, ⊙ , was used to denote a secondary triangulation point. The solid shore line was put in with a heavy continuous line and at such places as were marshy the edge of clear water was shown by a dotted line.

(d) Drawing contours.

The soundings which were approximately located were of much assistance in drawing contours. But as we did not wish them to appear upon the original map, a tracing paper was used to record all true depths in their proper positions, and the contours drawn on the same paper. A contour interval of 5 feet was chosen, and the proper interpolation made from the corrected soundings to locate the contours. The final tracing of the located soundings and the contours, was made from the tracing paper and the tracing of the triangulation, shore line, title, etc. made from the original map. Zero contour is shown by full shore line; dotted shore line meaning an average of one foot of water along the marshes.

(e) Area of lake.

The plotted shore line was traced with an integrator, and the total area found to be 447.38 acres. The area in the respective sections being as follows:

Section 2, 232.65 acres.
" 3, 137.93 "
" 10, 12.76 "
" 11, 84.33 "

447.67 Acres

The difference is .29 acres or an error of one in fifteen hundred.

Conclusions.

I. Triangulation.

Many angles taken in our field work of triangulation were superfluous, as also was the bearing of each line. A much better method than that used, would be to choose good triangles and read their angles only, and by repetition. The following form of notes could be used:

Tri-angle	Angle read	Angle.	Three times 4	Average value	Remarks.
1-2-3	2-1-3	30°-43'	62°-8'	30°-43' - 40"	
"	2-3-1				
"	3-2-1				

The first two columns should be filled out before going into the field. This was the method used in checking up some of the angles of the triangulation although this form of notes was not put into the note book.

II. Obtaining hydrographic data.

In taking soundings we found that by having the boat man wave a red flag at every fifth sounding and a white flag

for intermediate soundings it avoided confusion of the transit men as to the proper number of any sounding.

We found also that the use of a buoy as described under "Hydrographic Data" reduced the number of the crew, transits and note books by one and gave as consistant and practical results as the use of a transit on the line.

When using the buoy method care should be taken to so place the one transit as to facilitate the changing of the buoy from one line to another.

Data for a more complete map could have been obtained by measuring the marshes and swamps surrounding the lake, on the actual shore line, or zero contour.

The loss of water through the outlet could be determined by constructing a wier and measuring the flow. The size and shape of the outlet stream is such that a wier could easily be constructed.

The loss of water by evaporation could be roughly computed and the three losses, by evaporation, outflow, and Grand Trunk pumps, would constitute the total loss of water from the lake.

III. Possibilities in improvement of lake.

The shore line has been much improved in some places by scraping back the marsh, thus raising the banks and making deeper water close to shore. Much more could be so improved. It is thought that the work could be facilitated by lowering the lake level temporarily and using teams and scrapers on the land thus left dry. The practicability of lowering the lake cheaply could be determined by running a line of levels down the outlet a short distance.

The shore line in West Bay, O'Gara Bay (north of Hickory Island) and South Bay could be little improved without great expense, as the bottom is mucky and the marsh area quite large.

The important triangulation points are marked by wrought iron pipe 2 inches below the surface and well witnessed as recorded in the note books, and B.M's. established so that data for the more accurate plotting of the contours can be obtained at any time.