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SEDIMENTARY DEPOSITS OF EAST, MIDDLE AND WEST FISH LAKES IN MONTMORENCY COUNTY, MICHIGAN

by

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Introduction

Three weeks (June 13 to July 5, 1941) were spent by the writer and his two assistants, Robert Wilson and John Thompson, Jr., in a study of the sedimentary deposits of East, Middle, and West Fish Lakes which lie in the southern part of Montmorency County, Michigan, near the Hunt Creek Experiment Station. Study of much of the material and data, final drafting of the maps and preparation of the report were accomplished by the writer and his assistants after their return to Heidelberg College. Living quarters were furnished by the Hunt Creek Fisheries Experiment Station and considerable help was given by the staff at that station in moving equipment from one lake to another, supplying boats and other facilities.

The principal object of the work was to determine the quantity and distribution of the sediment in each lake and to compute the percentage of filling of the original basins that has taken place. In addition, a rough determination of the nature of the sediment was attained as well as a comparison of the original basins with the present ones in respect to the maximum and mean depths, areas, volumes, lengths of shorelines, slopes and several other criteria that indicate the nature of the changes in the forms of the lake basins that have taken place during their existence.

Complete cores of sediment were taken from the centers of each of the lakes and a series of complete cores from the middle to the original shoreline at approximately 75-foot intervals on one side of Middle Fish Lake. Samples at foot intervals of these cores have been sent to Dr. J. E. Potzger of Butler University for the analyses of the pollen which they contain. When completed, this work will show the complete history of the vegetation of the region since glacial times. From this vegetational history the major changes in climate since the retreat of the glacier can be inferred. Chemical analyses of foot increments of the cores, when they are completed in the writer's laboratory, will be of considerable scientific interest and will give a good idea not only of the possible value of the deposits as a source of fertilizer but, also, as soil for the vegetation that grows in the lake. In some cases, marl deposits are of value as a source of material for the manufacture of cement.

Methods

The general procedure used in carrying out the work done in the field in this investigation was to make borings through the sediment along definite lines across the lakes (Figs. 4, 8, and 12) at frequent enough intervals to enable cross section profile diagrams of the basins showing both the original and present bottoms to be constructed (Figs. 5, 6, 9, 10, and 13). From these profile diagrams, contour maps of the original basins (Figs. 7, 11, and 14) were developed. These contour maps were, in turn, the basis for the determination by standard formulae of the volumes of the original basins as well as of several other morphometrical criteria. Maps in the files of the Institute for Fisheries Research of the present basins of the lakes were used in computing similar morphometrical criteria in the cases of the present basins. The volume of sediment in each case was determined by subtracting the volume of the present basin from that of the corresponding original basin. In determining the percentage of the original basin filled with sediment, the volume of the original basin, which is assumed to have been 5 feet higher than the present water level (Fig. 3), was used as a basis in one case (total) while the present water level (0-contour extended to the original basin) was used in another (labeled "exclusive of frustrum 1" in Table 1). The first method of expression is probably more accurate but the latter of more interest since it is the present water level and the status of the lake in respect to it about which one is most apt to be concerned. Figure 3 is a conventionalized drawing showing the relationships of the original and present basins to each other.

Complete description of the apparatus used has been given elsewhere by the writer (Wilson, 1941). Briefly, it consists of a float (Fig. 1, A) on which is a boom-pole that affords a convenient support for long lengths of pipe, pulleys, and hoisting apparatus.

From the float a 1 1/4-inch sampler (Fig. 2) attached to a ½-inch pipe is let down to the surface of the sediment. To secure a sample of surface sediment, the sampler is then jabbed into the sediment a distance of one foot, rotated clockwise to close the diaphragm at the bottom of the sampler, and then brought to the surface where the entrapped sediment can be examined. In securing samples below this level the sampler and ½-inch pipe mentioned above are attached at the top to a force pump by a hose (Fig. 1, B). As the pump is worked a jet of water is expelled from the bottom of the sampler. This washes away the sediment immediately below the sampler as it is lowered and cleanses it at the same time. When the desired level for securing a sample is reached, the pump is stopped, the hose detached and the sampler jabbed into the sediment and the sample retrieved as described before. When a great depth of sediment is penetrated, it is more convenient to put down a casing and work inside it. In this case a smaller sampler (3/4-inch) is used since a 1 1/4-inch casing is about all that can be handled easily on an ordinary float.

Description of the Lakes and the Sediment

The three lakes under consideration (East, Middle and West Fish Lakes) are in the headwaters of a small tributary of Hunt Creek (Fuller Creek), West Fish Lake being at the highest level. Although West Fish Lake is connected by a channel to Middle Fish Lake, it is doubtful whether any water flows in it except at the height of the rainy season. Somewhat the same situation obtains between Middle and East Fish Lakes except that there is some doubt whether water ever flows directly from one lake to the other, although it evidently did at some time in the remote past. An appreciable stream flows from East Fish Lake to Hunt Creek, most of the water coming from springs and seepage from a sphagnum bog that lies along the southern and western edges of the lake. The drainage basin of the three lakes combined is approximately one-half square mile.

The lakes are located in depressions in the main moraine of the Port Huron morainic system. This is land deposited moraine but there is considerable sandy drift in the region. All of the lakes are of the kettle hole type, i.e., the basins were formed when detached blocks of ice left behind by the retreating Wisconsin ice sheet that once covered the region melted. Considerable depths of sand underlie the more characteristic lake deposits of marl and organic matter, indicating that a great deal of wind-blown sand entered the basin in the early life of the lakes. Where the surface of this sand makes contact with the marl was counted as marking the "original bottom" in the profile diagrams and contour maps. This was necessary because the underlying sand could not always be penetrated to its full extent, i.e., to gravel which is ordinarily taken as indicating the original bottom. When this drift was completely penetrated, alternating layers of sand and gravel were found indicating it to be glacial outwash. The lakes lie at an elevation of approximately 1,000 feet above sea level. Hills rise up around all the lakes--approximately 200 feet in the case of West Fish Lake.

In the low ground immediately surrounding the lakes the timber consists of tamarack, white cedar, white spruce and balsam fir. The timber on the high ground surrounding the lake is mostly second growth and consists of black oak, quaking aspen, large toothed aspen, hard maple, red maple, silver maple, Norway pine, white pine, a few hemlock, balm of Gilead, tag alder and dogwood. The white pine was apparently the dominant species in the virgin forest (Dr. J. W. Leonard, personal communication). It is likely that a study of the pollen in the sediment will show that the original pine forest was preceded by the dominance of other species--probably spruce and fir.

Of the three lakes, East Fish is the largest. When a beaver dam raises its water level, as occurred recently, it has an area of 13.5 acres. When the dam is removed as at present, its area is slightly less (12.2 acres). Records for July 28, 1939, on file at the Institute for Fisheries Research show the lake to have a well developed thermocline between the 12- and 24-foot levels. There was an abundance of oxygen at all depths: 7.5 p.p.m. (parts per million) at the surface, 9.2 at the 21-foot level and 9.5 at the 40-foot level (just above the bottom). There was no CO_2 at the surface, 2 p.p.m. at the 21-foot level and 4 at the 40-foot level. The pH was 8.0 at the surface, 7.8 at all other levels to the bottom. Methyl orange alkalinity expressed as p.p.m. of CO_2 was 190.0 at the surface, 200 at the 21-foot level and 201 at the bottom (40-foot level). A Secchi disc could be seen to the 20-foot level. These data indicate a clear, alkaline lake with very little stagnation in the hypolimnion. This type of lake would be expected to favor the formation, deposition and preservation of a highly mineralized sediment, because the mineral portion of the sediment (especially in the hypolimnion) would be re-dissolved to only a slight extent due to the lack of acid production and most of the organic matter settling in the deeper parts as well as in the shallow zones would be destroyed by aerobic bacteria. Evidence that this has been the case is furnished by the very rich marl deposits that form a broad, exposed flat along the north and east shoreline, and by the entire deposit within the lake (Figs. 5 and 6). The sphagnum bog along the south and west part of the shore has deposited a great bed of peat. This has encroached on the underlying marl to some extent, i.e., the acid formed in the bog has dissolved the marl, thus giving the point of contact between the peat and marl a peculiar slant (Figs. 5 and 6)--this condition is just the opposite to what otherwise might be expected (A. S. Hazzard, personal suggestion).

Middle Fish is the smallest of the three lakes, the present area being only 2.49 acres. Its basin is nearly filled with sediment; the water remaining has a maximum depth of only 6 feet. There is a bog mat completely surrounding the lake that is well grounded near its outer border but is floating near the water's edge. The rapid encroachment of the mat from the edges of the lake, together with the rapid filling that is taking place on the bottom in the open water region, indicate that Middle Fish Lake is doomed to early extinction.

So shallow a body of water as Middle Fish Lake, of course, has no permanent stratification. Consequently its temperature is uniform from the surface to the bottom at most times. The Institute for Fisheries Research records show for July 27, 1939, a pH of 7.9, 3 p.p.m. of free CO_2, 7.9 p.p.m. of O_2 and a methyl orange alkalinity of 153 p.p.m. expressed as CO_2. This indicates an alkaline, hard-water, well aerated body of water. The surface sediment is relatively free from obnoxious odors. The gelatinous nature of most of its 50 feet of sediment (Figs. 9 and 10) together with the absence of minerals, especially carbonates, in nearly all of the rest of the deposit indicates that there was great stagnation and anaerobic bacterial activity in the bottom waters (hypolimnion) during a considerable part of the life of the lake. However, marl on the bottom reaches of sediment indicates a short period free from stagnation when this lake was young.

West Fish Lake, although larger and deeper (9.7 acres and 11 feet, respectively) than Middle Fish is like it in that it is nearly completely filled with a gelatinous, organic sediment (Fig. 13). West Fish Lake differs from Middle Fish in that it does not have a mat around the edges, although there are 4 small "islands" produced by well grounded, mat-like deposits in the lake various distances from shore. Several acres of bog, formerly a bay, exist at the southwest end of the lake. Like Middle Fish Lake, West Fish also has approximately uniform temperature from top to bottom. Institute for Fisheries Research records give the following additional data for July 26, 1939: pH of 8.4 at the surface and 8.1 at the

9-foot level; Secchi disc reading of 5 feet; 6.56 p.p.m. O_2 at the surface and 7.37 at the 9-foot level; 0.0 CO_2 at both levels; and methyl orange alkalinity of 105 at the surface and 128 p.p.m. at the 9-foot level expressed as p.p.m. of CO_2. The data indicates water of high alkalinity, considerable hardness, well aerated but of great turbidity. There is very little anaerobic bacterial action at the present time in the bottom sediment but as in the case of Middle Fish Lake the gelatinous organic nature of the 40 feet of deposit indicates great anaerobic bacterial activity in the past. The presence of amorphous marl over most of the immediate original bottom (below the gelatinous pulpy peat) in both Middle and West Fish Lakes suggests a condition existed, when it was laid down, similar to conditions as they now exist in East Fish Lake. This lake, also, would seem to be doomed to early extinction mostly by bottom filling--only slightly from the edges.

Comparisons of Morphometrical Features of the Original and Present Basins

Table 1 shows the morphometrical data for the three lakes arranged in a manner to facilitate comparisons between the three lakes and between the original and present basins of each lake separately; percentages of changes (increases or reductions) are included for each feature for all the lakes so that comparisons between the amount of the changes in the 3 lakes can be made. The significance of the various changes is not clear in all cases but where it is not, the data are included anyway in the hope that it may become so when a larger series of lakes has been similarly studied.

The reduction in area in East Fish Lake is 54.90 per cent (from 1,181,396 square feet to 532,783 square feet). The corresponding figures for Middle Fish Lake are 74.38 per cent (from 410,665 square feet to 105,206 square feet) and for West Fish Lake 45.18 per cent (from 748,700 square feet to 410,464 square feet). It is evident that, although East and West Fish Lakes have suffered considerable reduction in area, the amount in both cases is relatively small compared to that of Middle Fish Lake. This difference is due almost entirely to the presence in Middle Fish Lake of the floating mat that is rapidly encroaching on the lake from the edges. Apparently, when a lake has the right conditions for this development, its area is reduced much more rapidly than where the conditions are otherwise.

The very slight reduction in the mean depth (volume divided by area) of East Fish Lake (2.59 per cent) indicates that it is filling about as rapidly in the middle as from the edges. This is in marked contrast to the situation in both the other lakes--Middle Fish Lake has a reduction of 82.29 per cent and West Fish Lake 75.32 per cent in mean depth. This shows that, in the two latter cases, filling is going on relatively faster in the centers of the lakes than around the edges (even in the case of Middle Fish Lake). This is, no doubt, due to the fact that in both Middle and West Fish Lakes conditions were right for the formation of gelatinous sediment which contains approximately twice as much water per unit of dry weight as does an amorphous sediment such as is found in East Fish Lake.

The percentage of change in maximum depth in Middle and West Fish Lakes is approximately the same as their respective changes in mean depth (88.00 per cent and 82.29 per cent, respectively, in Middle and 75.00 per cent and 75.32 per cent, respectively, in West Fish Lake) but the percentage of change in maximum depth in East Fish (37.88 per cent) is very much greater than that of the mean depth (2.59 per cent). In the latter case this comparison emphasizes the fact shown previously by the writer for Winona and Tippecanoe Lakes located in Indiana (Wilson, 1936, 1938; Wilson and Opdyke, 1941) that depressions fill with sediment more rapidly than any other part of a basin. This phenomenon causes the shape of the bottom to become rounded rather rapidly subsequent to which sediment is more evenly distributed.

The tremendous increase in the ratio of mean to maximum depth from the original to the present basins in the case of East Fish (56.85 per cent) and Middle Fish (47.60 per cent) Lakes as contrasted to West Fish Lake (decrease of 1.48 per cent) is corelated to some extent with the considerably less percentage of reduction in area of the latter (45.18 per cent) as compared to the first two (54.90 per cent and 74.38 per cent, respectively).

As would be expected, there has been considerable reduction in the length of shoreline with the decrease of area in all the lakes. However, shoreline development (length of shoreline divided by the perimeter of a circle of equal area) shows an increase in East Fish (1.15 per cent) and West Fish (9.55 per cent) Lakes and decrease (6.99 per cent) in Middle Fish. In other words, Middle Fish Lake has become more nearly round as it has filled while East and West Fish Lakes have become less so. No doubt the encroaching shore mat on Middle Fish Lake has been responsible for the more rounded condition found there.

The mean slopes of both Middle and West Fish Lakes have decreased greatly due to the relatively faster filling in the middle (82.29 per cent and 75.32 per cent, respectively) as compared to the rate of filling at the edges (74.38 per cent and 45.18 per cent, respectively). In East Fish Lake there has been a considerable increase in slope (20.19 per cent and the mean depth has decreased only 2.59 per cent compared to a reduction in area of 54.90 per cent. This has been due partly to the lowering of the water level by the cutting down of the outlet until nearly all of the littoral zone of the lake is exposed leaving nothing submerged except the "pothole" depression. This is probably unfortunate because evidence (Scott, Hile and Spieth, 1938) indicates that a lake with a gentle slope is more productive than one with a much steeper one.

The present basins of Middle and West Fish Lakes are only remnants of their former selves, Middle being reduced in volume by 95.46 per cent and West Fish by 86.36 per cent. In fact, they have so little water that their capacity for storing nutrients and gases for the periods of peak growth of various organisms must be so limited that their productivity is severely curtailed. It would be expected that their oxygen supply might be so reduced during long, hot, dry spells or during severe winters, that few fish could survive except possibly carp and catfish. East Fish Lake, although reduced in volume by 55.98 per cent, has still the characteristics of a normal temperate zone lake with plenty of capacity for storing nutrients and gases.

Volume development (volume of lake divided by the volume of a cone of the same basal area as the area of the lake and a height equal to the maximum depth of the lake) in both East and Middle Fish Lakes increased markedly, 57.25 per cent and 47.62 per cent, respectively, but decreased slightly in West Fish Lake (1.55 per cent). Although, in the first two cases, the lakes were above 1 originally and, therefore, had concave basins their basins, at present, are much more concave. In the case of West Fish Lake, the basin was originally concave in shape but is slightly less so at present. Filling in from the edges at a relatively faster rate than from the center would produce greater concavity while filling in the center at a relatively faster rate than from the edges would produce less concavity. The percentage of change in the ratio of mean to maximum depth from the original to present basins expresses these changes and are nicely correlated with the percentages of changes in volume development (Table 1).

The absolute amount of sediment present in the various basins is of interest as the Institute for Fisheries Research has considered that the basin of Middle Fish and possibly West Fish Lake might be adapted to an experiment in pumping out the deposits and thereby rejuvenating the lakes. A knowledge of the nature of the sediment and the volume of each component is of great value in estimating the cost and practicability of such a procedure. A comparison of the average depths of sediment is also of considerable interest. It will be noted that the average depths are about the same--12.58 feet in East, 13.57 feet in Middle, and 14.08 feet in West Fish Lakes. These data together with that for Winona Lake with 14.92 feet and Tippecanoe Lake with 13.96 feet (both located in north central Indiana) strongly suggest that all lakes in the central states produce approximately the same amount of sediment per square foot of area. Since the Fish Lakes are considerably farther north (250 miles) than Tippecanoe and Winona Lakes, they have considerably less sunshine and a lower average annual temperature and would be expected to have correspondingly less biological activity which is responsible for nearly all of the sediment in the lakes concerned. Therefore, it remains obscure as to the reasons for the great similarity in the average depths of sediment. Comparisons of the quantities of sediment on a dry weight will probably show differences not apparent in the comparison on a wet basis used here.

The similarities of the mean depths of sediment in all the Fish Lakes and Winona and Tippecanoe Lakes in Indiana suggests that the percentages of their various original basins that are filled with sediment might be inversely proportional to the mean depth of the original basins. This was found to be true for various portions of the basin in Tippecanoe Lake (Wilson, 1938) and is well illustrated in the Fish Lakes. For example, on the basis of the present water level, i.e., exclusive of frustrum 1, East Fish Lake is 48.00 per cent filled and the original basin had an average depth of 28.94 feet, West Fish Lake is 82.47 per cent filled and had an original mean depth of 20.79 feet, while Middle Fish is 93.76 per cent filled and had a mean depth originally of 17.50 feet. The corresponding figures for Winona Lake are 43.66 per cent filled with a mean original depth of 34.20 feet, and for Tippecanoe Lake 31.90 per cent filled and original average depth 43.70 feet.

Distribution of the Sediment

Tables 2, 3, and 4 give the quantities of sediment by frustra (the lake is thought of as an inverted cone divided into frustra by the contour lines, Fig. 3). The distribution of the sediment can be inferred by noting and comparing between the various original basins the levels above and below which approximately 50 per cent (any other percentage can be used) of the sediment lies. It is the 30-foot level in East Fish Lake (Table 2). This is about one-half the maximum depth (66 feet) and nearly the same as the mean depth (28.94 feet). In Middle Fish Lake approximately 50 per cent of the sediment lies above the 10-foot contour which is one-fifth the maximum and slightly less than two-thirds the mean depth. In West Fish Lake it is at approximately the 8-foot contour which is between one-fifth and one-sixth of the maximum and between one-third and one-fourth the mean depth. The high levels at which 50 per cent of the sediment lies in Middle and West Fish Lakes as contrasted to East Fish is due to the nearly complete filling of the first two basins.

Stratification of the Sediment

Two kinds of stratification altogether were noted in the sediment of the three Fish Lakes, namely, an alternation of broad bands of peaty sediment with narrower (usually) bands of marl or sand (Figs. 9, 10, and 13) and very thin strata or laminations of sediment that probably represent annual increments of deposition. The first type was best developed in Middle Fish Lake (Fig. 10, section C-C) and the second in East Fish.

It will be seen when section C-C of Middle Fish Lake is examined (Fig. 10) that lying immediately above the sand and gravel of the "original bottom" is a layer of marl, above this a thick layer of sand, above it another layer of marl, then a thick layer of gelatinous pulpy peat and above this three alternating layers of marl and peat. This makes a total of 5 layers of marl. They represent periods of deposition in the life of the lake when probably relatively unstagnated conditions prevailed in the deep water, whereas the periods of peaty deposition probably represent times when the bottom waters were stagnant and the resulting acids dissolved the carbonates that settled out. Variations in climate that influenced the amount of incoming water and dissolved salts, the vigor of water circulation in the lake and the quantity of dissolved gases probably account for the reversals in the nature of the deposits. East and West Fish Lakes lack these numerous alternating bands (there is one band of marl beside the deposit on the original bottom in Middle Fish Lake (Fig. 13, section A-A). This is due probably to their greater size and consequently lesser sensitivity to climatic changes.

Some 1-inch increment counts were made of the "annual" laminations in East Fish Lake between the 46- and 53-foot levels. They varied from 10 to 20 per inch. If the laminations were discernable from the top to the bottom of a deposit, one should be able to determine the length of life of the lake. Since the laminations do not fulfill this condition, one is forced to speculate. If we take as an average annual increment one-fifteenth of an inch, approximately in this case, then multiply this by the number of inches in the core where the count was made (boring 9), namely, 228, we get a total of 3,420 lamina and presumably 3,420 years as the life of the lake--assuming that each lamina represents a year. This estimate is ridiculously low compared to previous estimates and should be considered only tentative until further and more extensive work can be done.

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INSTITUTE FOR FISHERIES RESEARCH

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Table 1
Morphometrical data of the original and present basins of East, Middle and West Fish Lakes and the percentage increase or reduction in each item. (The volume and average depth of sediment is given for each lake as well as the portion of the basins filled with sediment.)

		East Fish Lake	Middle Fish Lake	West Fish Lake
Area	Original basin	1,181,396 sq. ft.	410,665 sq. ft.	748,700 sq. ft.
	Present basin	532,783 sq. ft.	105,206 sq. ft.	410,464 sq. ft.
	Reduction	54.90 per cent	74.38 per cent	45.18 per cent
Maximum depth	Original basin	66 ft.	50 ft.	44 ft.
	Present basin	41 ft.	6 ft.	11 ft.
	Reduction	37.88 per cent	88.00 per cent	75.00 per cent
Mean depth	Original basin	28.94 ft.	17.50 ft.	20.79 ft.
	Present basin	28.19 ft.	3.10 ft.	5.12 ft.
	Reduction	2.59 per cent	82.29 per cent	75.32 per cent
Ratio of mean to maximum depth	Original basin	0.438	0.350	0.472
	Present basin	0.687	0.517	0.465
	Change	+56.85 per cent	+47.60 per cent	-1.48 per cent
Length of shoreline	Original basin	4,036 ft.	2,592 ft.	3,209 ft.
	Present basin	2,740 ft.	1,226 ft.	2,599 ft.
	Reduction	22.11 per cent	48.86 per cent	18.99 per cent
Shoreline development	Original basin	1.046	1.145	1.047
	Present basin	1.056	1.065	1.147
	Change	+1.15 per cent	-6.99 per cent	+9.55 per cent
Mean slope	Original basin	12.63 per cent	15.29 per cent	14.84 per cent
	Present basin	15.18 per cent	2.54 per cent	2.93 per cent
	Change	+20.19 per cent	-83.39 per cent	-80.26 per cent
Volume of basin	Original basin	34,188,377 cu. ft.	7,188,053 cu. ft.	15,564,236 cu. ft.
	Present basin	15,048,990 cu. ft.	326,177 cu. ft.	2,121,909 cu. ft.
	Reduction	55.98 per cent	95.46 per cent	86.36 per cent
Volume development	Original basin	1.31	1.05	1.417
	Present basin	2.06	1.55	1.395
	Change	+57.25 per cent	+47.62 per cent	-1.55 per cent

(Continued)

Table 1
Morphometrical data of the original and present basins of East, Middle and West Fish Lakes and the percentage increase or reduction in each item. (The volume and average depth of sediment is given for each lake as well as the portion of the basins filled with sediment.)
(Continued)

		East Fish Lake	Middle Fish Lake	West Fish Lake
Volume of sediment		14,853,940 cu. ft.	5,472,199 cu. ft.	10,544,438 cu. ft.
Average depth of sediment		12.58 ft.	13.57 ft.	14.08 ft.
Portion of basin filled with sediment	On basis of original water level	43.44 per cent	77.53 per cent	67.74 per cent
	On basis of present water level (Exclusive of Frustrum 1)	48.00 per cent	93.76 per cent	82.47 per cent

Table 2

Volumes of basins and of sediment by frustra of East Fish Lake.*

Number of frustra	Contour	Volume of original basin	Volume of present basin	Volume of sediment	Total to level	Per cent of total to level
1	-5-0	5,247,450	4,285,447	962,003	962,003	6.48
2	0-5	4,219,985	2,519,926	1,700,059	2,662,062	17.92
3	5-10	3,621,838	2,356,526	1,265,312	3,927,374	26.44
4	10-15	3,272,155	2,214,459	1,057,696	4,985,070	33.56
5	15-20	3,055,586	2,060,370	995,216	5,980,286	40.26
6	20-25	2,838,492	1,916,895	921,597	6,901,883	46.46
7	25-30	2,594,329	1,713,055	881,274	7,783,157	52.40
8	30-35	2,290,459	1,381,624	908,835	8,691,992	58.52
9	35-40	2,020,970	850,824	1,170,146	9,862,138	66.39
10	40-45	1,726,657	35,311	1,691,346	11,553,484	77.78
11	45-50	1,414,352	...	1,414,352	12,967,836	87.30
12	50-55	1,058,440	...	1,058,440	14,026,276	94.43
13	55-60	611,179	...	611,179	14,637,455	98.54
14	60-65	212,355	...	212,355	14,849,810	99.97
15	65-66	4,130	...	4,130	14,853,940	100.00
TOTALS		34,188,377	19,334,437	14,853,940		

* To get the real (exclusive of frustrum 1) volume of the present basin, subtract the volume of frustrum 1 (4,285,447 cu. ft.) from the recorded total (19,334,437 cu. ft.). This gives as the real volume of the present basin 15,048,990 cu. ft. The inclusion of the volume of frustrum 1 in the total was necessary to compute the total volume of sediment.

Per cent of original basin filled----- 43.44

Per cent of the original basin filled based on the present water level, i.e., exclusive of the frustrum 1-------------------- 48.00

Volume development
- Present basin-- 2.06
- Original basin--- 1.31

Length of shoreline
- Present basin-- 2,740 ft.
- Original basin--- 4,036 ft.

Shore development
- Present basin-- 1.058
- Original basin--- 1.046

Mean slope
- Present basin-- 15.18 per cent
- Original basin--- 12.63 per cent

Reduction in size of basin-- 54.90 per cent

Average depth of sediment--- 12.58 ft.

Mean depth
- Present basin-- 28.19 ft.
- Original basin--- 28.94 ft.

Ratio of mean to maximum depth
- Present basin-- 0.687
- Original basin--- 0.438

Table 3

Volumes of basins and of sediment by frustra of Middle Fish Lake.*

Numbers of frustra	Contours	Volume of original basin	Volume of present basin	Volume of sediment	Total to level	Per cent of total to level
1	-5-0	1,854,694	1,289,677	565,017	565,017	10.14
2	0-5	1,392,102	318,746	1,073,356	1,638,373	29.40
3	5-10	1,023,770	7,431	1,016,339	2,654,712	47.63
4	10-15	841,498	...	841,498	3,496,210	62.74
5	15-20	698,752	...	698,752	4,194,692	75.28
6	20-25	557,414	...	557,414	4,752,376	85.39
7	25-30	408,627	...	408,627	5,161,003	92.70
8	30-35	250,266	...	250,266	5,411,269	97.11
9	35-40	114,432	...	114,432	5,525,701	99.01
10	40-45	40,832	...	40,832	5,566,533	99.89
11	45-50	5,666	...	5,666	5,572,199	100.00
TOTALS		7,188,053	1,615,854	5,572,199		

*To get the real volume of the present basin, subtract the volume of frustrum 1 (1,289,677 cu. ft.) from the total (1,615,854 cu. ft.). This leaves a total of 326,177 cubic feet as the real volume of the present basin. Frustrum 1 was included in the total in order to compute the volume of sediment.

Per cent of the original basin filled----------------------77.53

Per cent of the original basin filled based on the present water level, i. e., exclusive of frustrum 1--93.76

Table 4

Volumes of the basins and of sediment by frustra of West Fish Lake.*✓

Numbers of frustra	Contours (feet)	Volume of original basin	Volume of present basin	Volume of sediment	Total to level	Per cent of total to level
1	-5-0	3,460,099	2,897,909	562,190	562,190	5.33
2	0-5	2,955,007	1,473,556	1,481,451	2,043,641	19.37
3	5-10	2,563,175	624,711	1,938,464	3,982,105	37.74
4	10-15	2,211,111	23,642	2,187,469	6,169,574	58.47
5	15-20	1,649,281	...	1,649,281	7,818,855	74.11
6	20-25	1,120,607	...	1,120,607	8,939,462	84.73
7	25-30	782,287	...	782,287	9,721,749	92.15
8	30-35	550,051	...	550,051	10,271,800	97.36
9	35-40	266,046	...	266,046	10,537,846	99.88
10	40-44	6,592	...	6,592	10,544,438	100.00
TOTALS		15,564,256	5,019,818	10,544,438		

*✓ To get the real volume of the present basin, subtract the volume of frustrum 1 (2,897,909 cu. ft.) from the total volume given (5,019,818 cu. ft.); this leaves 2,121,909 cu. ft. Frustrum 1 was included in the total so that the volume of sediment could be computed.

Per cent of original basin filled--------------------------67.74

Per cent of the original basin filled based on the present water level, i.e., exclusive of the frustrum 1-------------------------82.47

Figure 1

A. The float from which the borings were made on the three Fish Lakes. It consists of a platform lying across two boats, four oil drums, some small poles for reinforcement, and a boom pole held by guy ropes near the center which supports a pulley (through which the hose runs) and the 20-foot lengths of pipe used in the drilling operations. The boring takes place through a hole in the center of the float.

B. The force pump used to wash out the casing and sampler. This type of pump stalls whenever the outlet gets stopped up, thus making it certain that when it works the sampler is being washed clean.

C. The pump is forcing water through the tubing (small pipe) to wash out the drbris in the casing preliminary to taking a sample; the washings are returning to the surface between the casing (larger pipe) and tubing and are overflowing.

D. A segment of a core of sediment after extrusion from the sampler; the right end has been split open.

A

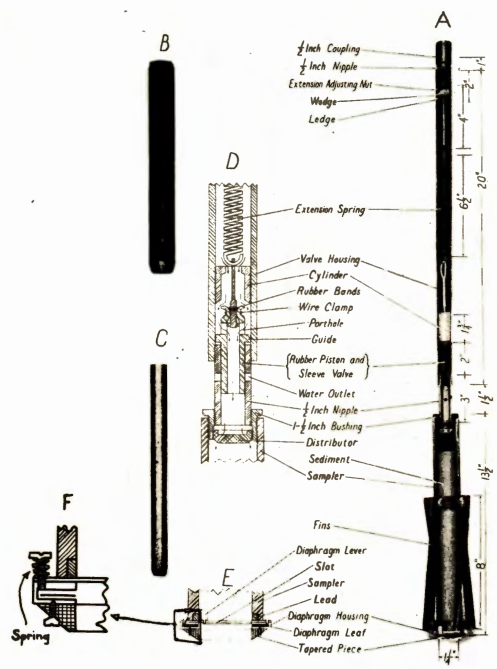
B

C

D

Figure 2

A. The sampling device cut out to show the details of construction. The upper part is referred to in the text as the valve enclosed in a housing; the bottom part is the sampler with an iris diaphragm and diaphragm closer (fins) used in the very soft sediment without a casing. B. The same sized sampler as shown in A except that there is no diaphragm or diaphragm closer. This sampler is used without casing in sediment that is solid enough to stock in the sampler without aid. C. This is the 3/4-inch sampler used when working inside a 1 1/4-inch casing. D. Drawing showing the sleeve valve and piston when water is being pumped through it. E. Drawing showing the details of the relationship of the diaphragm to the bottom of the sampler. F. Detailed drawing showing a small spring under the screw that fastens the upper and lower parts of the diaphragm housing together. This spring makes it possible to use the diaphragm in sand; the parts of the housing merely separating to accommodate any sand that gets in, thus preventing its getting "frozen."



A
1/2 Inch Coupling
1/2 Inch Nipple
Extension Adjusting Nut
Wedge
Ledge
Extension Spring
Valve Housing
Cylinder
Rubber Bands
Wire Clamp
Porthole
Guide
Rubber Piston and Sleeve Valve
Water Outlet
1/2 Inch Nipple
1-1/2 Inch Bushing
Distributor
Sediment
Sampler
Fins
Diaphragm Lever
Slot
Sampler
Lead
Diaphragm Housing
Diaphragm Leaf
Tapered Piece
B
C
D
E
F
Spring

Figure 3

Conventionalized profile diagram of a lake indicating the manner in which a lake is considered in figuring out the morphometrical criteria.

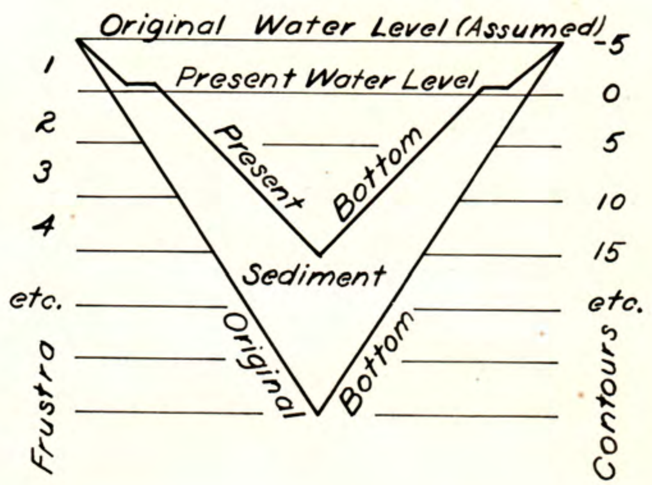
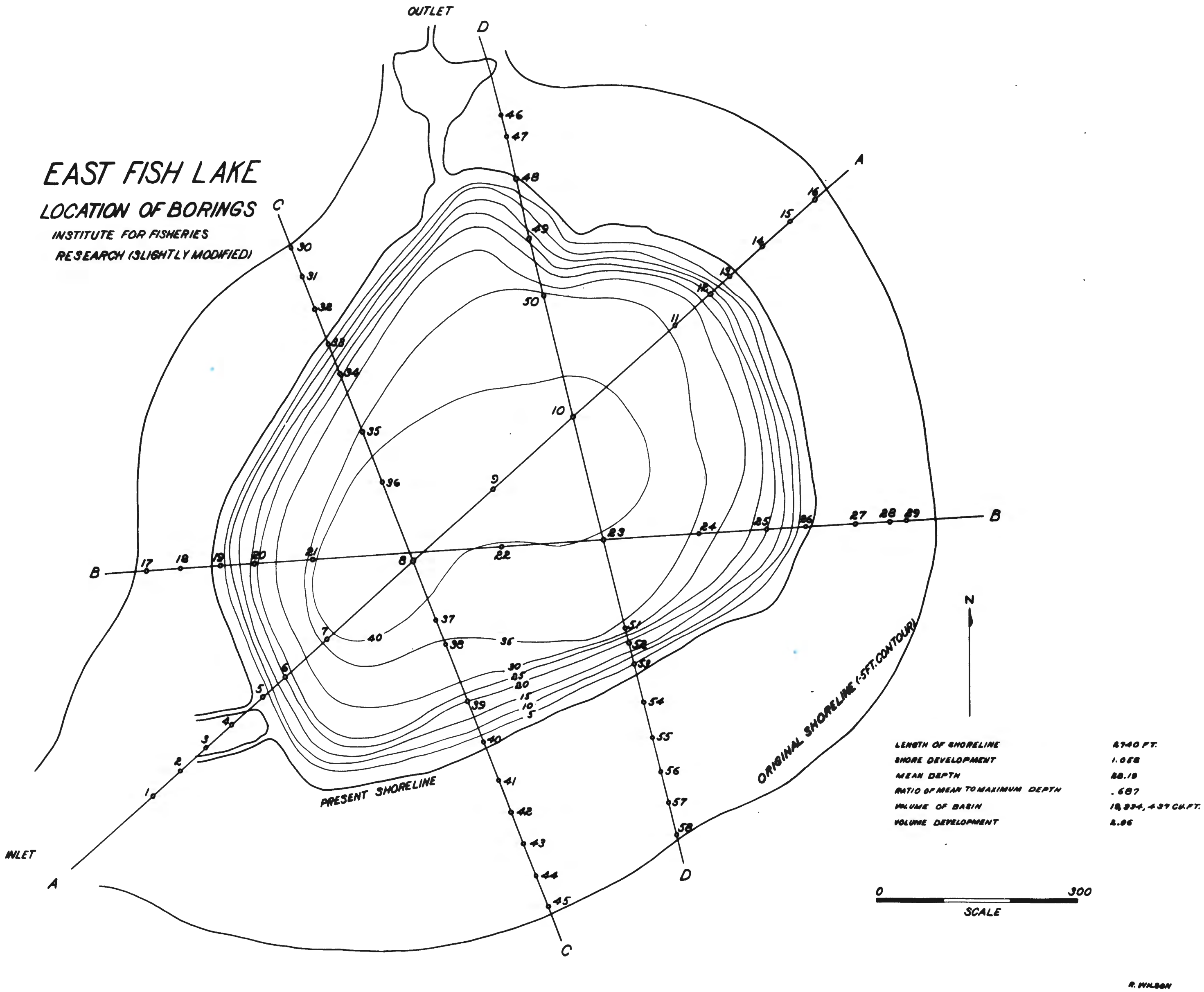

Original Water Level (Assumed)
Present Water Level
Present Bottom
Sediment
Original Bottom
1
2
3
4
etc.
Frustra
-5
0
5
10
15
etc.
Contours

Figure 4

Contour map of East Fish Lake showing the lines along which the borings (indicated by numbers) were made that furnished the data on which the profile diagrams (Figures 5 and 6) and the contour map of the original basin (Figure 7) are based.

Figure 4



EAST FISH LAKE
LOCATION OF BORINGS
INSTITUTE FOR FISHERIES
RESEARCH (SLIGHTLY MODIFIED)
OUTLET
INLET
PRESENT SHORELINE
ORIGINAL SHORELINE (-5FT. CONTOUR)
A
B
C
D
N
0
300
SCALE
LENGTH OF SHORELINE 2740 FT.
SHORE DEVELOPMENT 1.058
MEAN DEPTH 28.19
RATIO OF MEAN TO MAXIMUM DEPTH .687
VOLUME OF BASIN 19,334,437 CU.FT.
VOLUME DEVELOPMENT 2.06
R. WILSON

Figures 5, 6, 6A, and 6B

Profile diagrams across East Fish Lake at locations indicated on Figure 4. The numbers of the borings in Figure 4 correspond to those in these figures. Note the peculiar manner in which the peat (of the sphagnum bog) makes contact with the marl of the lake deposit.

Figure 5

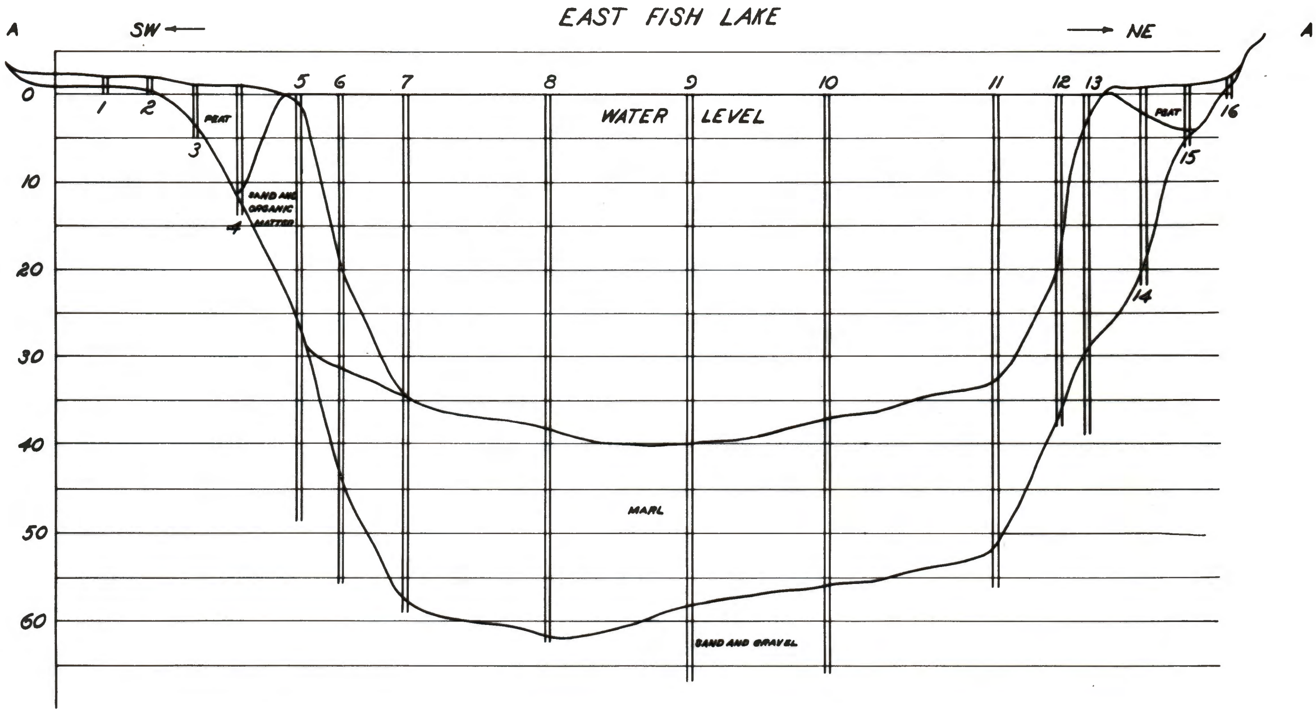


Figure 6

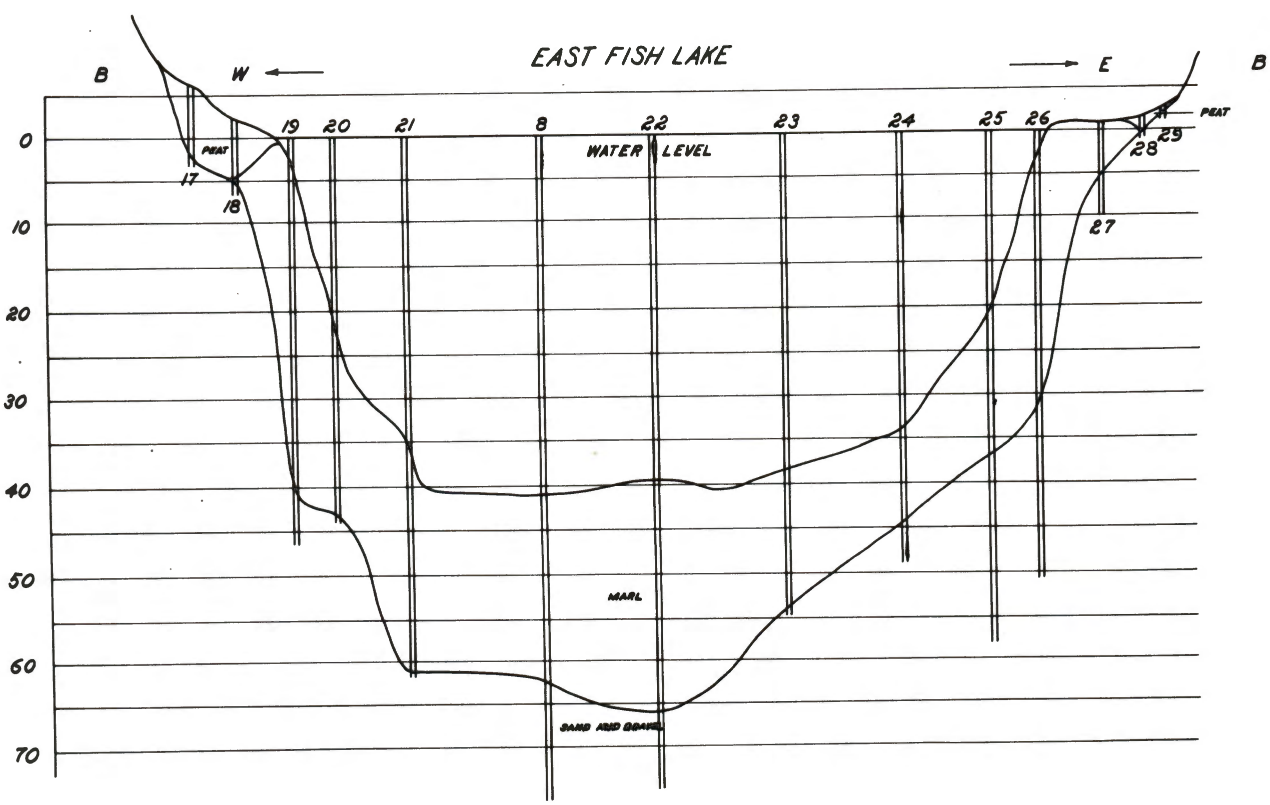


Figure 6A

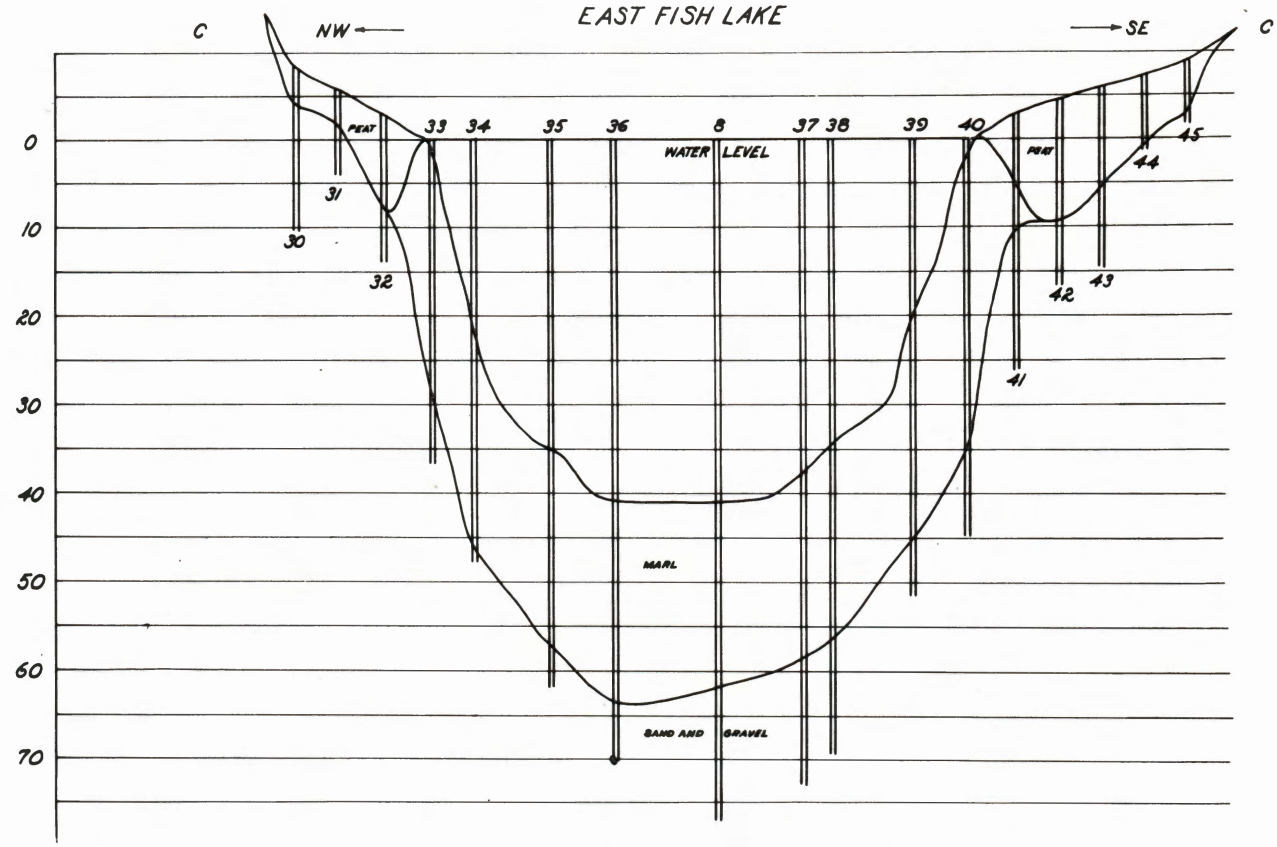


Figure 6B

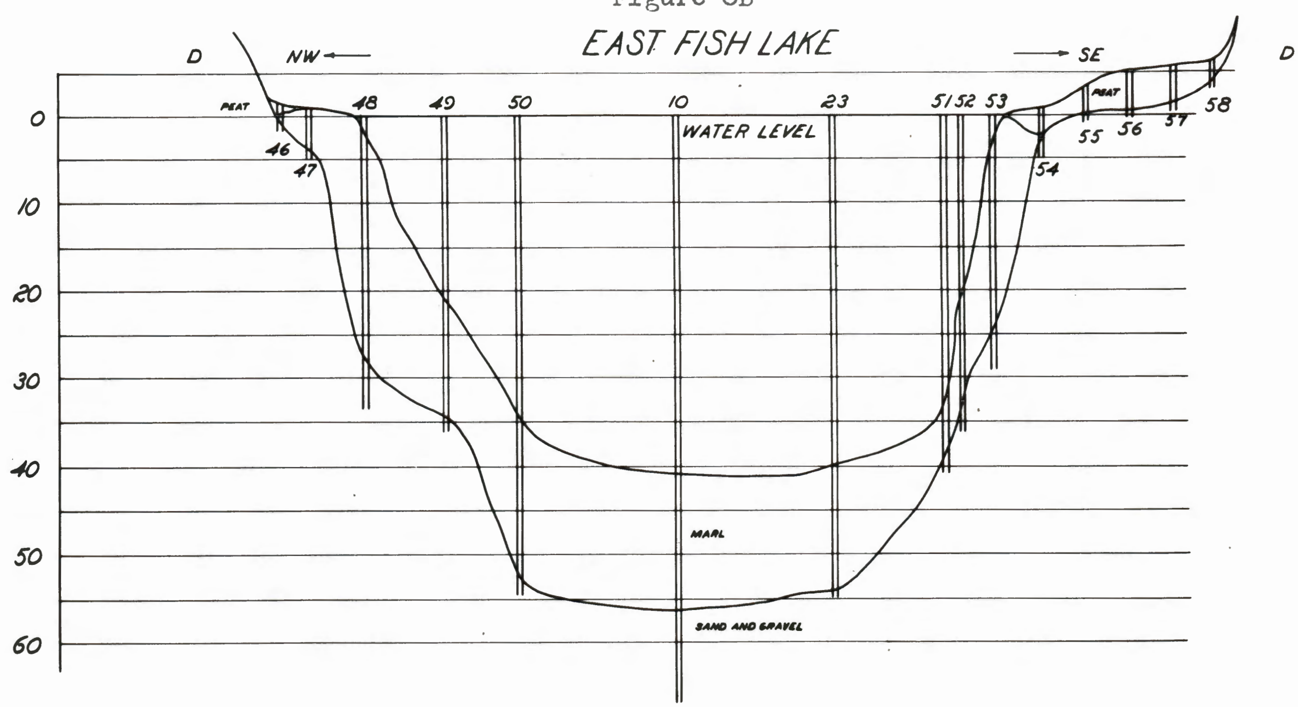
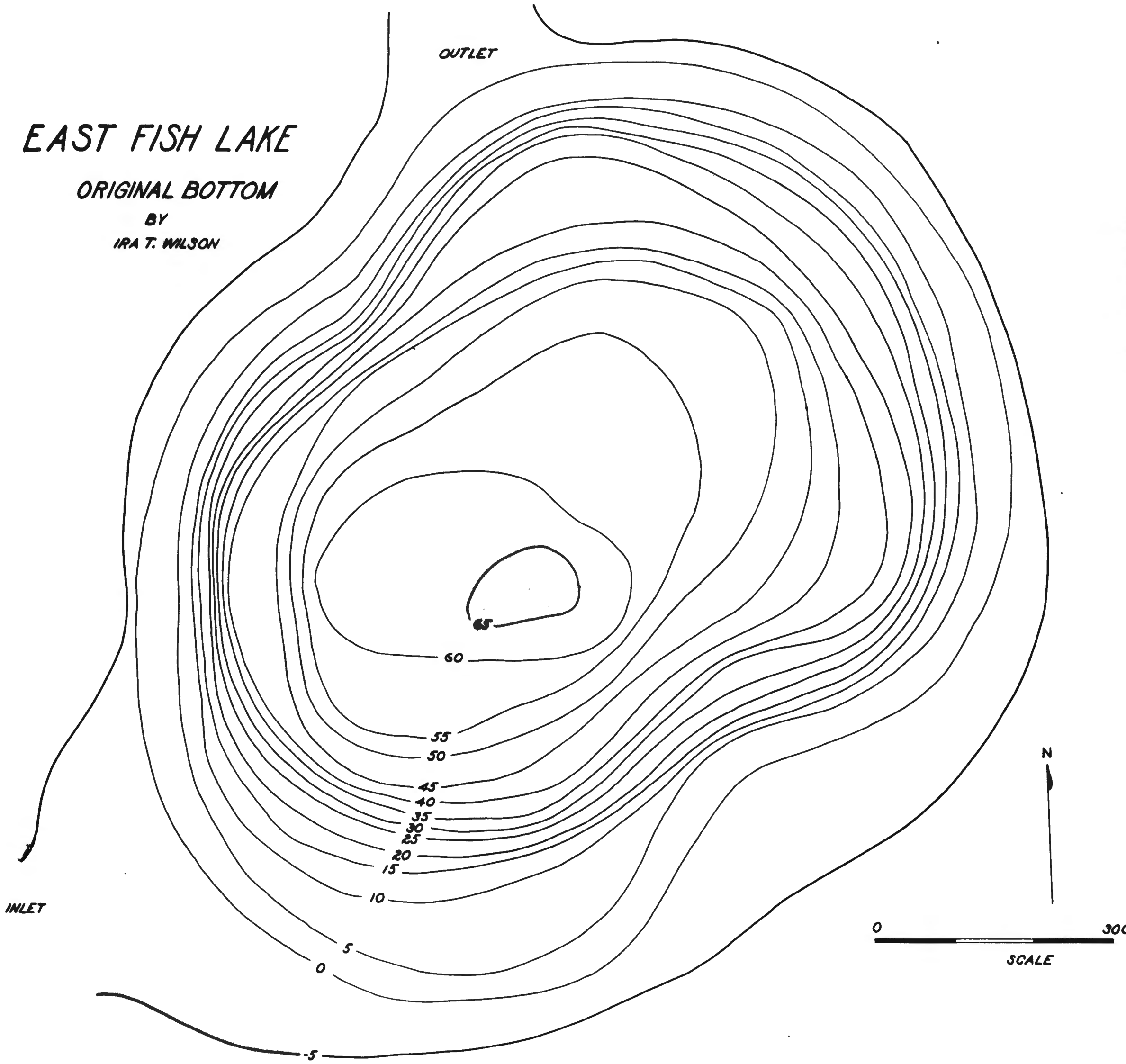


Figure 7

Contour map of the original basin of East Fish Lake assuming the bottom of the marl to mark the original floor of the lake. No doubt considerable sand had drifted into the lake basin before the marl began to form.

Figure 7

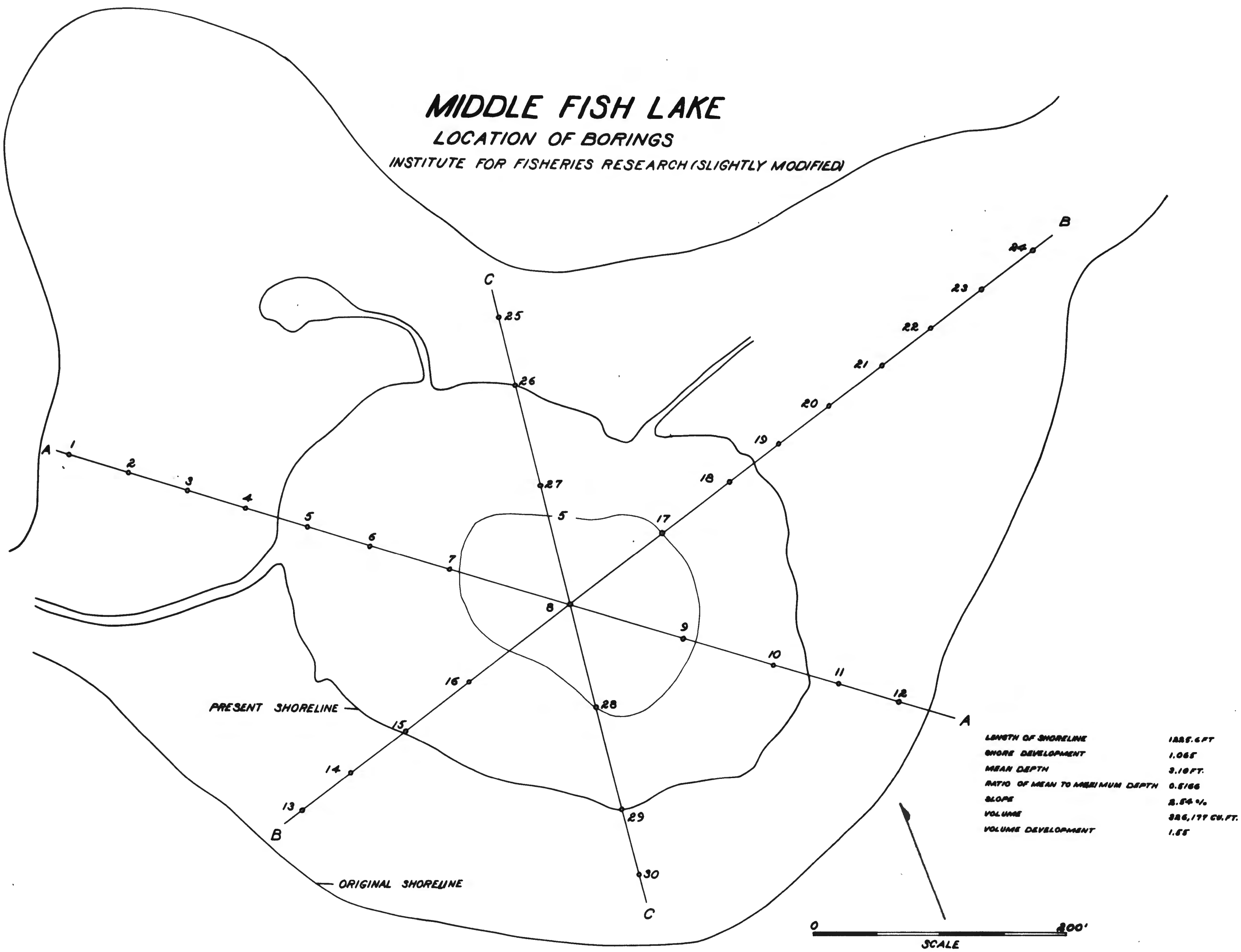


LENGTH OF SHORELINE	4036 FEET
SHORE DEVELOPMENT	1.046
MEAN DEPTH	28.34
RATIO OF MEAN TO MAXIMUM DEPTH	.438
SLOPE	18.63%
VOLUME	34,188,377 CU. FT.
VOLUME DEVELOPMENT	1.31
REDUCTION IN AREA	54.90%
VOLUME OF SEDIMENT	14,853,840 CU. FT.
PORTION OF BASIN FILLED WITH SEDIMENT	
TOTAL	43.45%
EXCLUSIVE OF FRUSTRUM I	46.66%

Figure 8

Contour map of Middle Fish Lake showing the lines along which the borings (indicated by numbers) were made that furnished the data on which the profile diagrams (Figures 9 and 10) and the contour map of the original basin (Figure 11) are based.

Figure 8



MIDDLE FISH LAKE
LOCATION OF BORINGS
INSTITUTE FOR FISHERIES RESEARCH (SLIGHTLY MODIFIED)
PRESENT SHORELINE
ORIGINAL SHORELINE
LENGTH OF SHORELINE 1225.6 FT
SHORE DEVELOPMENT 1.065
MEAN DEPTH 3.10 FT.
RATIO OF MEAN TO MAXIMUM DEPTH 0.5166
SLOPE 2.54 %
VOLUME 326,177 CU. FT.
VOLUME DEVELOPMENT 1.55
0 200'
SCALE

Figures 9, 10, and 10A

Profile diagrams across Middle Fish Lake at the locations indicated on Figure 8. The numbers of borings in Figure 8 correspond to those in these figures. Note that the lake deposited marl 4 different times, the layers of which alternate with sand and peat. Also, note that the lower layers of peat and in some cases the marl is in the form of a jelly.

Figure 9

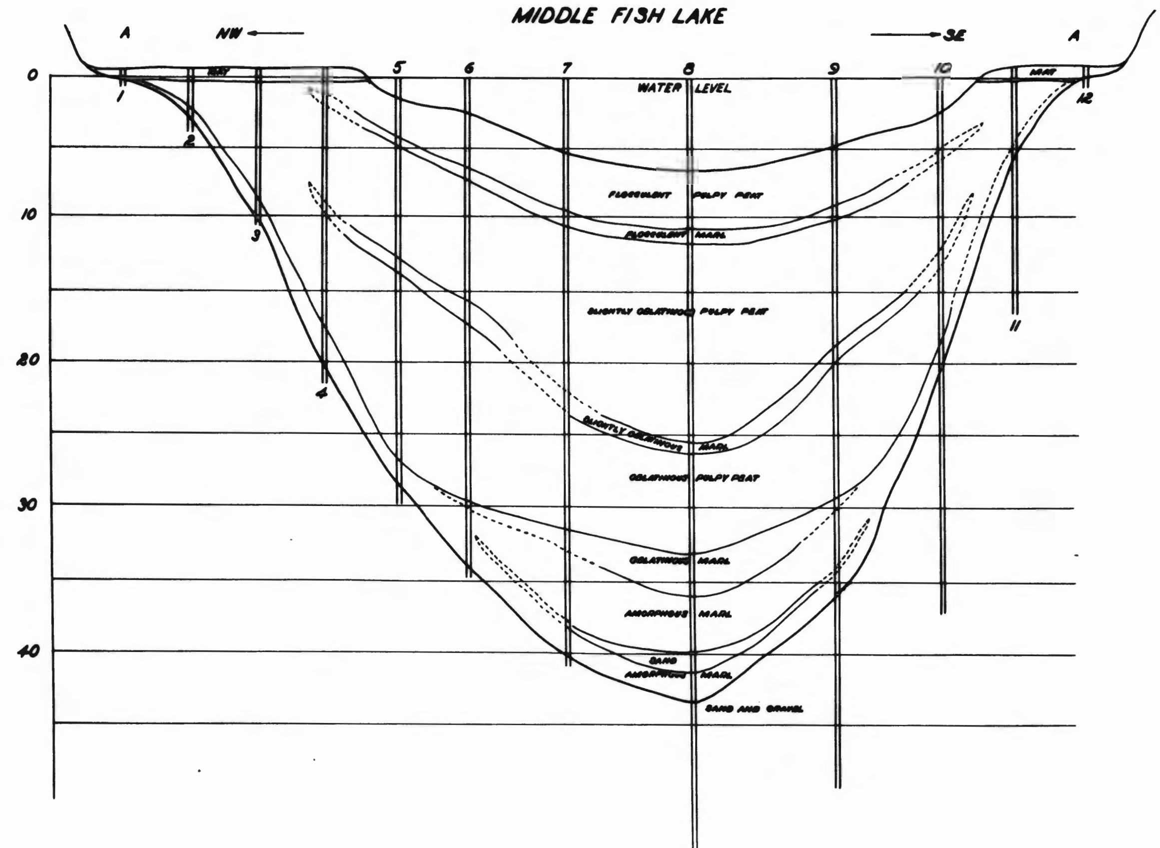


Figure 10

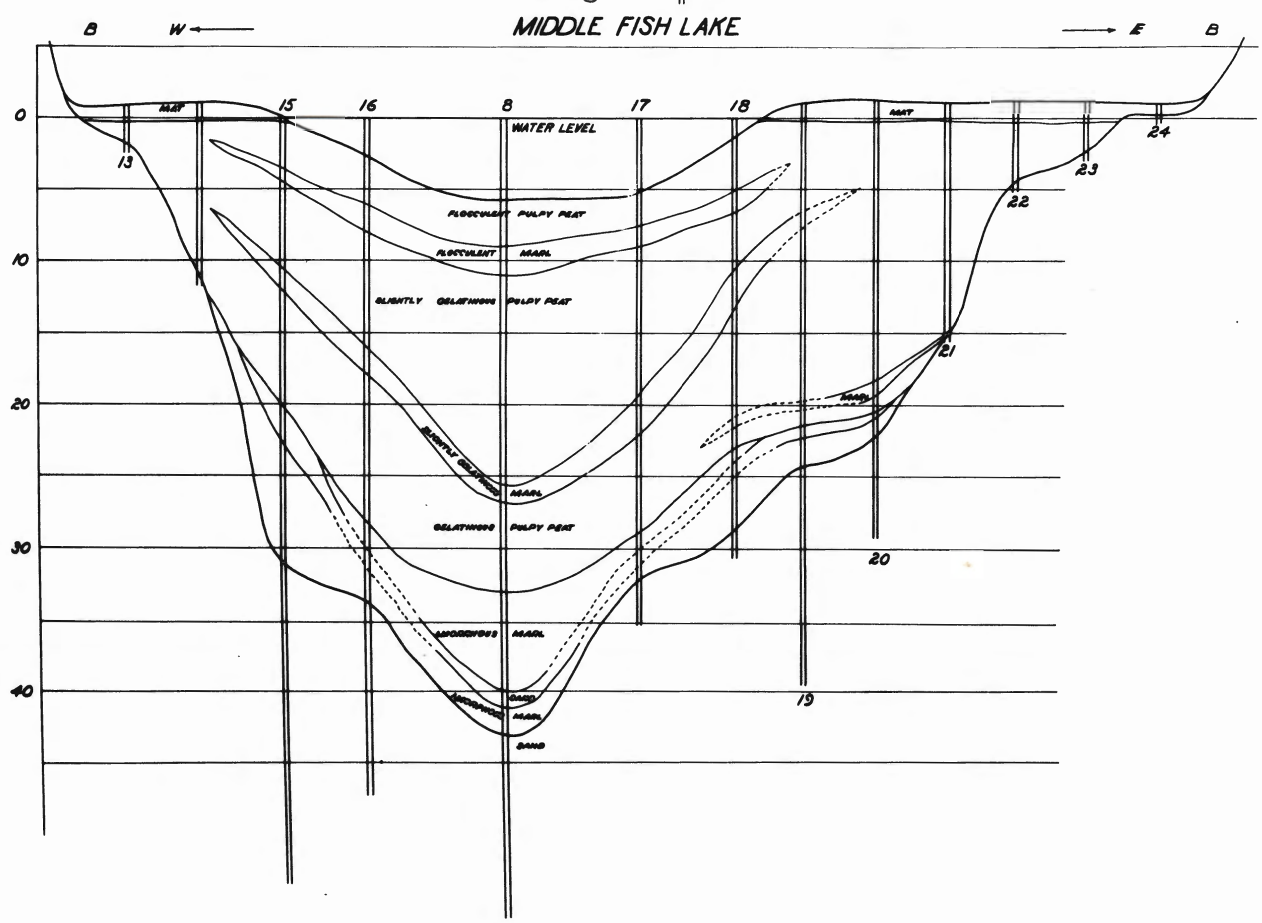


Figure 10A

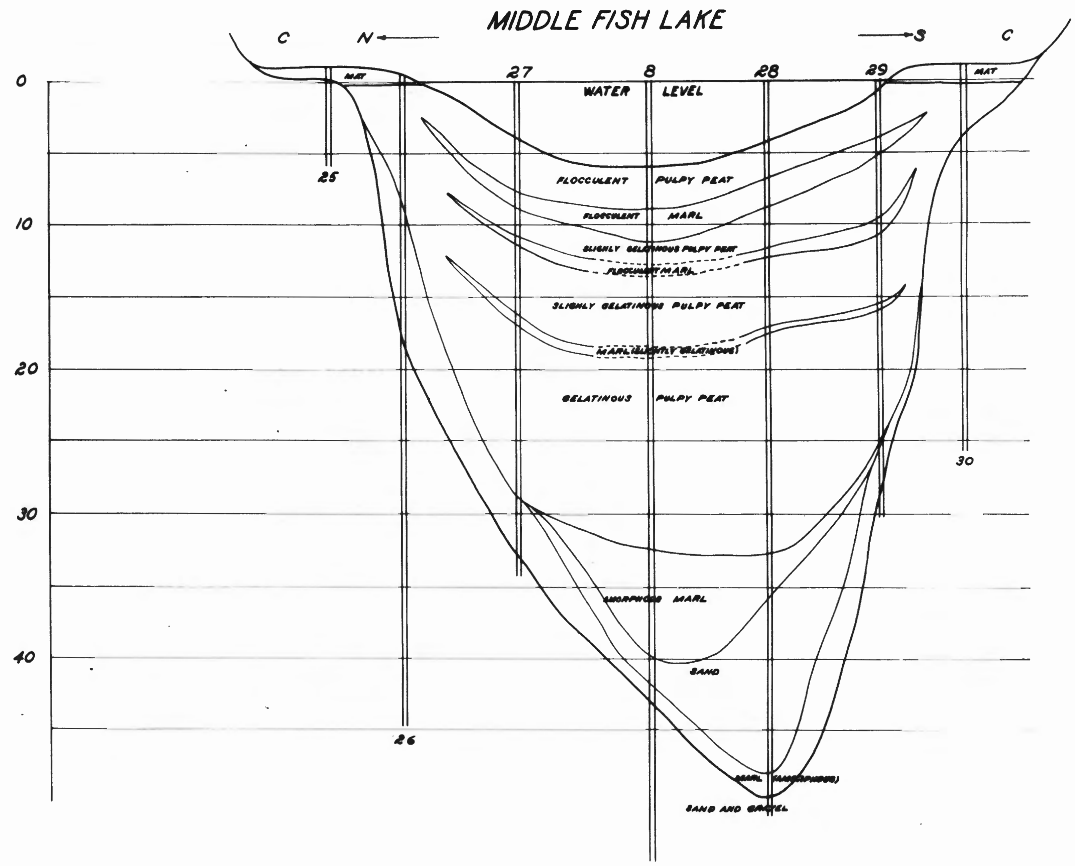
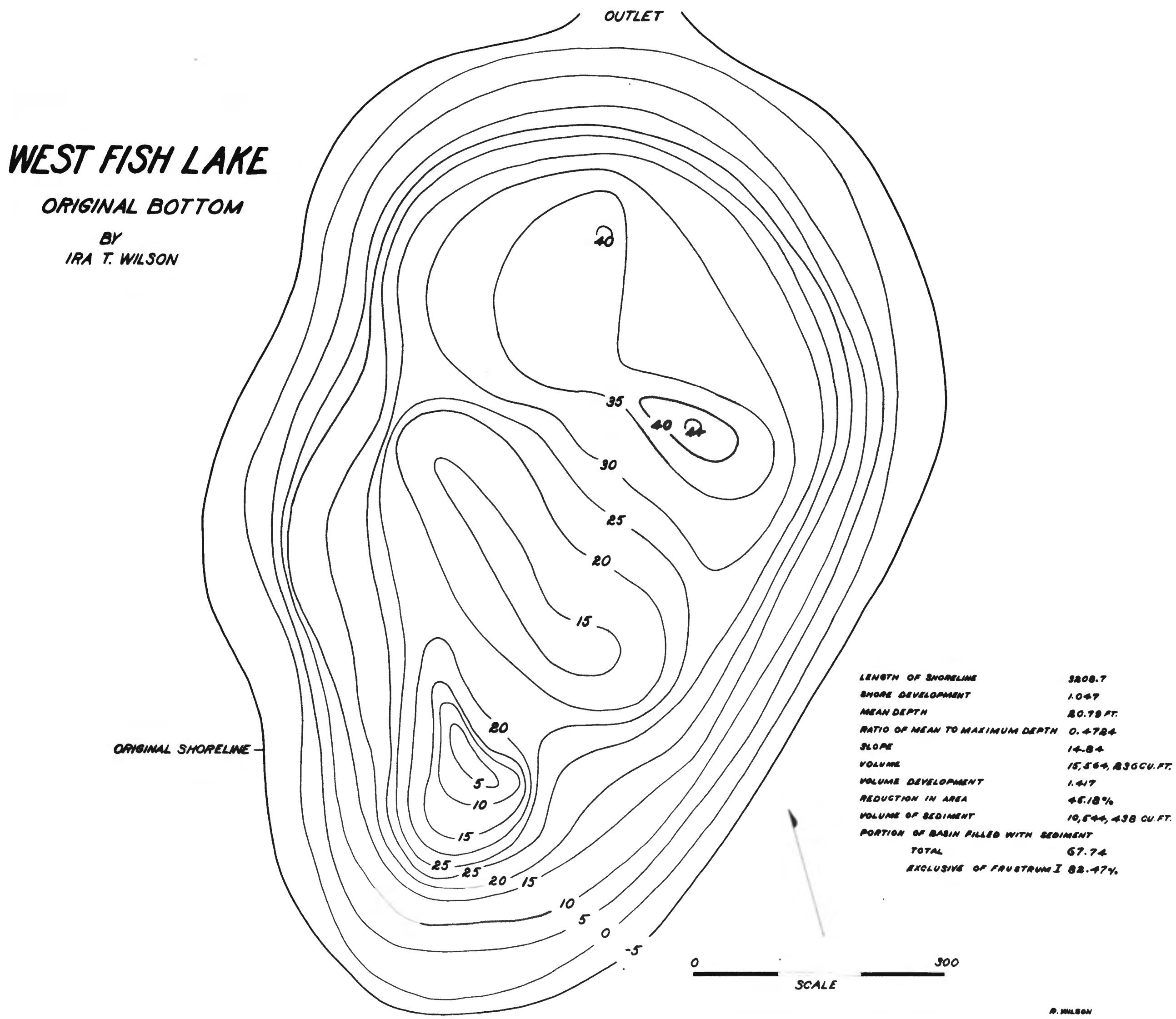

MIDDLE FISH LAKE
C
N
S
C
0
10
20
30
40
25
26
27
8
28
29
30
MAT
MAT
WATER LEVEL
FLOCCULENT PULPY PEAT
FLOCCULENT MARL
GELATINOUS PULPY PEAT
SAND

Figure 11

Contour map of the original basin of Middle Fish Lake assuming that the bottom of the lowest marl layer marks the original bottom of the lake. Undoubtedly considerable sand had drifted into the original basin before the beginning of marl deposition.

Figure 11



WEST FISH LAKE
ORIGINAL BOTTOM
BY
IRA T. WILSON
OUTLET
ORIGINAL SHORELINE
40
35
40
44
30
25
20
15
20
5
10
15
25
25
20
15
10
5
0
-5
LENGTH OF SHORELINE 3208.7
SHORE DEVELOPMENT 1.047
MEAN DEPTH 20.79 FT.
RATIO OF MEAN TO MAXIMUM DEPTH 0.4784
SLOPE 14.84
VOLUME 15,564,836 CU. FT.
VOLUME DEVELOPMENT 1.417
REDUCTION IN AREA 45.18%
VOLUME OF SEDIMENT 10,544,438 CU. FT.
PORTION OF BASIN FILLED WITH SEDIMENT
TOTAL 67.74
EXCLUSIVE OF FRUSTRUM I 82.47%
0
300
SCALE
R. WILSON

Figure 12

Contour map of West Fish Lake showing the lines along which the borings (indicated by numbers) were made that furnished the data on which the profile diagrams (Figure 13) and the contour map of the original basin (Figure 14) are based.

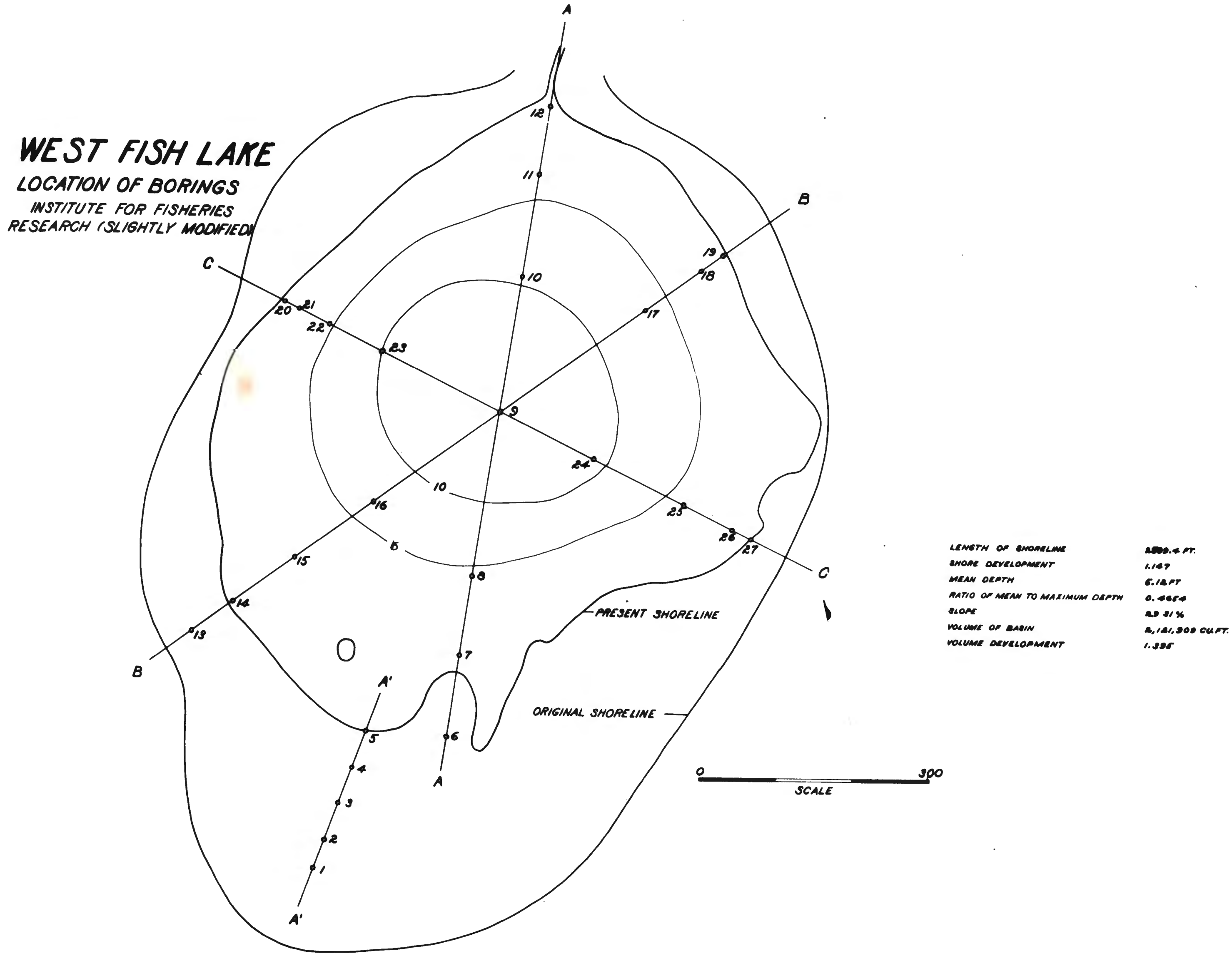

WEST FISH LAKE
LOCATION OF BORINGS
INSTITUTE FOR FISHERIES
RESEARCH (SLIGHTLY MODIFIED)
A
B
C
A'
PRESENT SHORELINE
ORIGINAL SHORELINE
0
300
SCALE
LENGTH OF SHORELINE
SHORE DEVELOPMENT 1.147
MEAN DEPTH
RATIO OF MEAN TO MAXIMUM DEPTH 0.4654
SLOPE
VOLUME OF BASIN
VOLUME DEVELOPMENT

Figure 13

Profile diagrams across West Fish Lake at locations indicated on Figure 12. The numbers of the borings in Figure 12 correspond to those in these figures. Note that most of the sediment is composed of gelatinous peat and that this reaches all the way to the original bottom (sand) in the deepest part of the original basin (B-B and C-C) but is underlaid by marl in the shallower parts of the basin.

Figure 13

WEST FISH LAKE

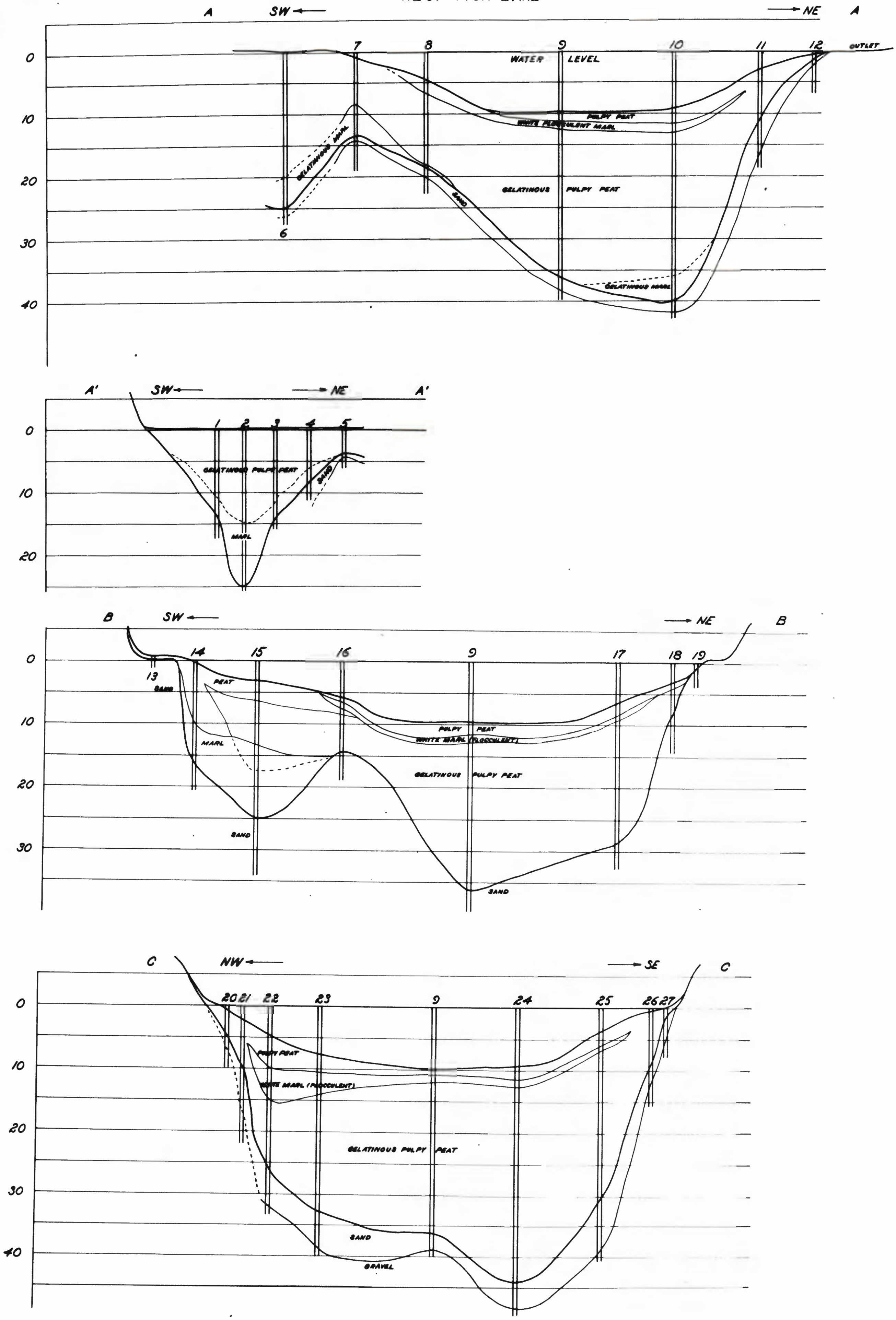
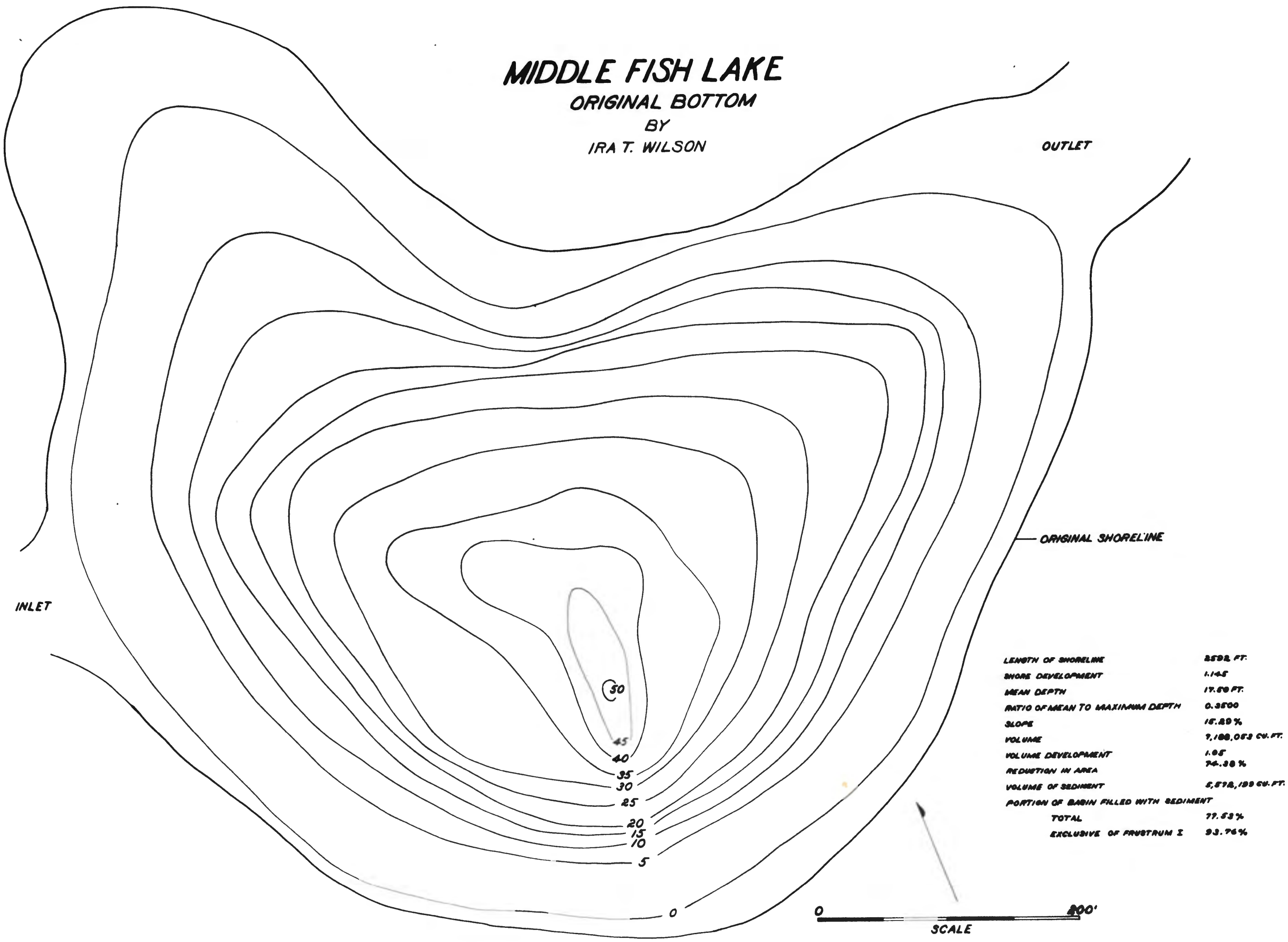


Figure 14

Contour map of the original basin of West Fish Lake assuming the bottom of the marl and peat to mark the original floor of the lake. No doubt considerable sand had drifted into the lake basin before the marl or peat began to form.

Figure 14


MIDDLE FISH LAKE
ORIGINAL BOTTOM
BY
IRA T. WILSON
OUTLET
INLET
ORIGINAL SHORELINE
50
45
40
35
30
25
20
15
10
5
0
LENGTH OF SHORELINE 2592 FT.
SHORE DEVELOPMENT 1.145
MEAN DEPTH 17.50 FT.
RATIO OF MEAN TO MAXIMUM DEPTH 0.3500
SLOPE 15.29 %
VOLUME 7,188,053 CU. FT.
VOLUME DEVELOPMENT 1.05
REDUCTION IN AREA 74.38 %
VOLUME OF SEDIMENT 5,572,199 CU. FT.
PORTION OF BASIN FILLED WITH SEDIMENT
TOTAL 77.53 %
EXCLUSIVE OF FRUSTRUM I 93.76 %
0
200'
SCALE