

THE RELATION OF LAKES TO FLOODS, WITH SPECIAL REFERENCE TO CERTAIN LAKES AND STREAMS OF INDIANA.

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The problem of flood prevention is a part of a larger problem which we have considered either in a fragmentary way or not at all. This larger problem is the development of the waters of our state as a natural resource. To regard a river as a menace because its higher stages, under present conditions, are destructive; or to consider a lake to be a waste area because it can not be plowed, indicates a very limited insight or selfish motives. Some of the factors that must be considered in the development of this resource are power sites, building sites, water supply for cities, water for irrigation, places for recreation, avenues for transportation, and fish production.

It may be regarded as self-evident, that a whole drainage system must be treated as a unit. It is impossible to develop one power site, without affecting another; floods prevented in the upper course of a stream will make them less destructive in its lower course, etc.

The thing that affects most fundamentally these elements of value in a stream is its rate of discharge. The work of Tucker ('11) has shown that not nearly all of the power sites in Indiana are developed; and that those that are developed are limited in value because of the low minimum discharge. High banks along streams are worth much more for building sites than for farm land. The more constant the stream level is, the more these sites are worth. And so with all of the values that attach to a stream; the more regular the discharge, the greater these values are.

The attention of every one is attracted to the great losses that are caused by floods; but few recognize the decreases in value that are occasioned by the low stages of streams. The losses by floods are sudden and dramatic. They are more or less irregular in their occurrence, while the losses caused by low stages are constant and inconspicuous. The losses



North Side. Former Fish Breeding Ground, Now a Rocky and Unproductive Waste.



Plate I. Lingle Lake. Marsh in the Foreground and Middle Distance. A Fish Feeding Ground Spoiled by Lowering the Lake.

of the first class represent developed resources; while those of the second class represent resources that are for the most part undeveloped. This accounts for the difference in the attention that each receives. The problem is not the prevention of floods but the production of regular discharge in our streams. The rainfall is irregular, and if it is allowed to run off as it falls an irregular discharge must result. Each drainage system presents a different set of conditions that must be met in solving this problem. The solution of the problem in northern Indiana is intimately associated with the development of our lakes.

This paper is limited to a discussion of some lakes of Kosciusko County and their relation to the Tippecanoe drainage system of which they form a part.

That the Tippecanoe River has a more regular flow than the Wabash is due to the fact that the Tippecanoe has many more lakes and swamps in its headwaters. (The closer proximity of the Wabash to bed-rock probably has some influence on the irregularity of its flow.)

Some of the facts concerning the Wabash at and above Logansport, and the Tippecanoe River at and above Delphi are as follows:

	DRAINAGE AREA, Sq. Miles.	DISCHARGE, 1904.		SEC. FT. PER SQ. MILE.	
		Maximum. Sec. Ft.	Minimum. Sec. Ft.	Maximum.	Minimum.
Tippecanoe at Delphi	1,890	15,430	269	8.164	.142
Wabash at Lo- gansport . . .	3,163	48,080	260	15.02	.081

That is, the minimum discharge per square mile of drainage basin in the Wabash is 57.7 per cent of that of a square mile in the Tippecanoe, while the maximum discharge per square mile of basin is 183 per cent of that of the Tippecanoe. This indicates roughly the value of lakes under natural conditions.

The most important factor in the economy of lakes is the treatment of the outlet. This may be left in a natural condition, it may be dredged, or it may be dammed. I wish to describe the effect of these three conditions on the drainage systems below the lake and upon the lake itself.

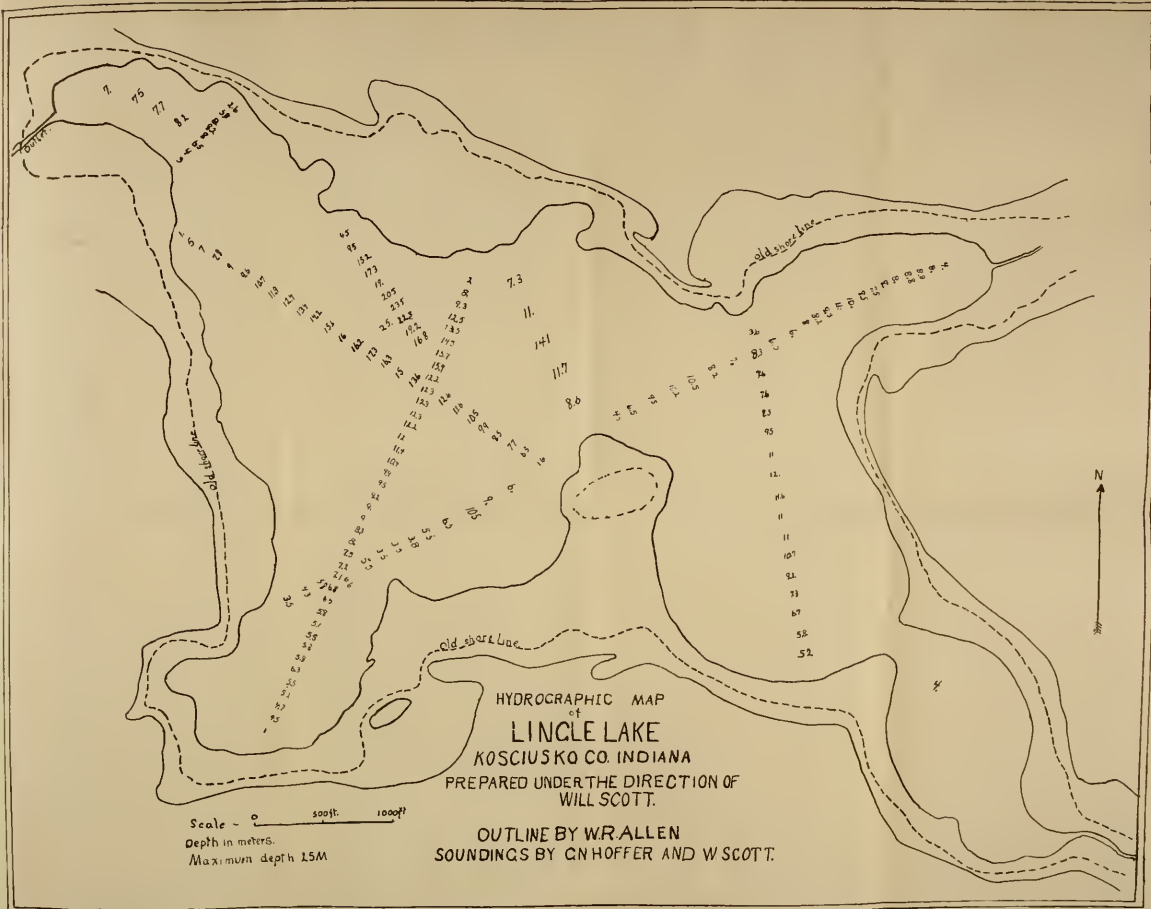
A lake with a natural outlet usually impounds water early in the year. With the first warm months their outlets become obstructed with



Spillway and Dam.



Plate II. Webster Lake. Fish Feeding Ground Formed by Damming the Lake.



plants* growing in them so that the excess of water is discharged gradually during the months that follow.

To leave the outlet of a lake undisturbed has many advantages to the lake. First of all, it insures a shore line of considerable age. On the windward side there is usually a wave-cut terrace, which forms the natural breeding ground for most of our lake fish. On the lee side there are usually plants which furnish protection and feeding ground for fish.

If the outlet is dredged the capacity of the lake as an impounding basin is decreased. The plants which obstruct the outlet are destroyed, so that the excess of water is rapidly discharged. For example Lingle Lake was lowered four feet by dredging. Caving of the banks and the obstruction of the outlet by waves has raised the water to within approximately two feet of its original level. This has decreased its area 10,152,800 square feet, and its capacity 40,107,600 cubic feet. See accompanying map.

The present area of Lingle Lake is .537 square miles. This reduction in level has exposed a large area of wave-cut terrace on the north and east shores, and thus destroyed the best nesting places for fish (especially sun-fish and bass). None of this land is used and apparently cannot be used. On the south and west extensive marl deposits were exposed on which sedges grow, forming an inferior pasture. The possibilities of aquiculture have been limited, while the available area for agriculture has been increased to a much less degree.

To illustrate the effect of damming lakes, I shall discuss five lakes, whose area is accurately known, and with whose environs I am familiar. These are Eagle Lake (Winona Lake), Little Eagle Lake (Chapman Lake), Webster Lake, Tippecanoe Lake, and Palestine Lake. If dams were constructed so that the level of these lakes could be fluctuated respectively 2, 3, 3, 5, 3 feet they would store and control 27.289 sec. feet per annum, distributed as follows: Eagle 2.02, Little Eagle 4.359, Webster 3.039, Tippecanoe 12.99, Palestine 4.509.

If this excess were discharged during the driest three months it would produce 109.156 sec. feet for that period. The minimum discharge for the Tippecanoe River at Delphi during 1904 was 269 sec. feet. If the excess just cited had been available during that period it would have increased the minimum discharge 40.5 per cent.

* This stream obstruction by plants may be excessive. It accounts for part, if not all, of the discrepancy between rainfall and discharge noted by Tucker ('11, p. 507).



Mill and Race. (See Text.)



Plate III. Webster Lake. Head of Race and Mill.

It is a well-established fact that the value of a power site is largely determined by the minimum rate of discharge. This means that the value of the water power along the Tippecanoe would be increased more than 40 per cent. by treating five lakes as I have suggested. Not only would this value be enhanced; but it would afford a better avenue of transportation, a more delightful place for recreation, and its yield of fish would be increased. By properly controlling all of the lakes in this basin, it is probable that the minimum rate of flow could be more than doubled. (The exact data for the remaining lakes in this system we hope to collect during the present year.)

The effect upon flood conditions is evident. The increase of the minimum discharge decreases the maximum discharge. Since it is the top of the flood that does the damage, it will be possible to practically eliminate excessive destruction along this stream. This will improve conditions in some degree along the streams to which the Tippecanoe is tributary.

It is very evident that handling lakes as I have indicated will make the streams that drain them more valuable and less destructive. It remains to determine, as accurately as the available data will permit, the effect upon the lakes themselves and their environs. Raising the level of any lake will of course inundate some land. The value of this land must be considered in determining the advisability of manipulating lake levels. These lakes are all intramorainal and are surrounded by moraines, rising rather abruptly from the water; or by marshes, which in most cases have been formerly a part of the lake.

Where the shore rises abruptly a narrow strip would be submerged by raising the level of the water. In many cases these slopes are used for the sites of summer homes, and it is only a question of time until all of them will be so utilized. The raising of the water along these sites would make boat landing less difficult and would not injure the facilities for bathing.

It is on the wave-cut terraces, which are formed along these moraines that most of the fish of the lake breed. This breeding ground would be narrowed at first, on account of the increased depth of the outer margin; but in a short time it would be more extensive than ever because of the increased width of the terrace.

The marsh land on the margin of lakes is often worthless and never valuable. It is sometimes used for pasture and occasionally it is mowed



The West Side, a Marsh.



Plate IV. Chapman Lake. The East Side, a Barren Slope. This Lake Has Recently Been Lowered Three Feet.

for marsh hay. The products in each case are coarse and of little worth. When these marshes are flooded they produce excellent feeding grounds for fish.

The damming of a lake would be sufficient, in many instances, for the development of water power. This could be used at the site of the dam or it could be converted into electricity and delivered to the property owners whose holdings abut the lake. The power thus produced would be sufficient in most lakes to offset the damage caused by the overflow of marshes, provided a just appraisalment could be secured. The owners of the high ground around the lake would very generally favor the change, because of the value added to the cottage sites.

THE EFFECT UPON THE PARTICULAR LAKES UNDER CONSIDERATION.

Webster Lake.—Webster lake has an area of 1.5 square miles. It has already received the treatment that I have outlined. I have been unable to determine the date of the first dam. The present dam was constructed in 1905. It gives a head of nine feet when the water is flowing over the spillway. The power is used to run a flouring mill owned by Mr. John Strombeck. One large turbine and two smaller ones are used. The large wheel delivers sixty horse-power at a nine-foot head and forty horse-power at a six-foot head. The ratings of the smaller wheels were not available. The dam is an earthen one except the spillway with its apron and wings, which are of concrete.

With the dam out the present lake would be cut into a number of smaller ones, connected by marshes. This former marsh land now furnishes excellent feeding ground for fish. As a direct result of this, Webster Lake has become one of the finest lakes in the state for bluegill fishing. I have counted forty fishing boats in view at once; and from fifty to eighty fish are counted a good string for a half day's fishing.

The present level makes it possible to use the surrounding moraines for the building of summer homes and resorts. One large hotel and several cottages have already been erected on the south shore. The town of North Webster has easy access to the lake. Many good building sites remain to be developed.

It is difficult to estimate the value of the power, the increased value of the adjoining real estate, and the augmented fish production; but this certainly would exceed the value of the marsh land that would be exposed if there were no dam. For map see Large ('96).



A Shallow Lake Which Produces Enormous Amounts of Fish Foods.



Plate V. Palestine Lake. Note the Close Proximity of Cultivated Land to the Water. No Waste Area as in Partially Drained Lakes.

Tippecanoe Lake.—Tippecanoe has an area at present of 1.71 square miles. If the level were raised five feet the area would be increased to 2.93 square miles. Its maximum depth is 121 feet, which is probably the greatest depth in any Indiana lake. The lake is bordered along most of its shoreline by moraines that rise rather abruptly to considerable height. The rest of the shore is bordered by marshes. Raising the level five feet would submerge most of the marsh land and a very narrow strip along the steeper shores. One building would be affected, but \$600 would easily replace it. The bathing beaches would be narrowed, but the action of the waves would soon broaden them. These are the items of loss.

By overflowing the marshes the shore line would be brought to other good building sites. This would increase its value from that of ordinary farm land to that of water-front building site. The value of the former is about \$100 per acre, while that of the latter is at present between \$500 and \$1,000 per acre.

The great depth of Tippecanoe Lake and the steep slope of much of its bottom make the area available for fish breeding and feeding very limited. The fish production could probably be doubled by utilizing the marsh land for feeding grounds and the wider wave-cut terraces as breeding ground.

The basin that discharges through the outlet of Tippecanoe Lake has an area of 136 square miles. One inch run-off from this basin would produce 10 sec. feet for one year. Twelve or fifteen inches run-off could be expected which would produce, respectively, 120 and 150 sec. feet for one year. The five-foot fall that would be produced by the dam could be increased two or three feet by building a race a quarter of a mile in length. For map see Large ('96).

Eagle Lake.—Eagle Lake has an area of .87 square miles. The swamp land that surrounds it covers about one-half square mile. A part of this swamp land has been filled by Winona Assembly and now forms very valuable real estate. This would make it rather impracticable to raise the lake more than two feet above its present level. But little of the remaining low land is used. About twenty acres are mowed for marsh hay and a similar amount is used for pasture, of which it produces a very inferior grade.

The outlet has been dredged so that the land below the lake could be drained. A dam has been built across this ditch, making a difference in level of six feet. By raising the dam two feet a fall of eight feet would be secured. The catchment basin discharging through the outlet of this lake contains forty square miles.



The Dam From Above.



Plate VI. Palestine Lake. General View of the Dam and Mill.

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HYDROGRAPHIC MAP OF LITTLE EAGLE LAKE

KOSCIUSKO CO. INDIANA

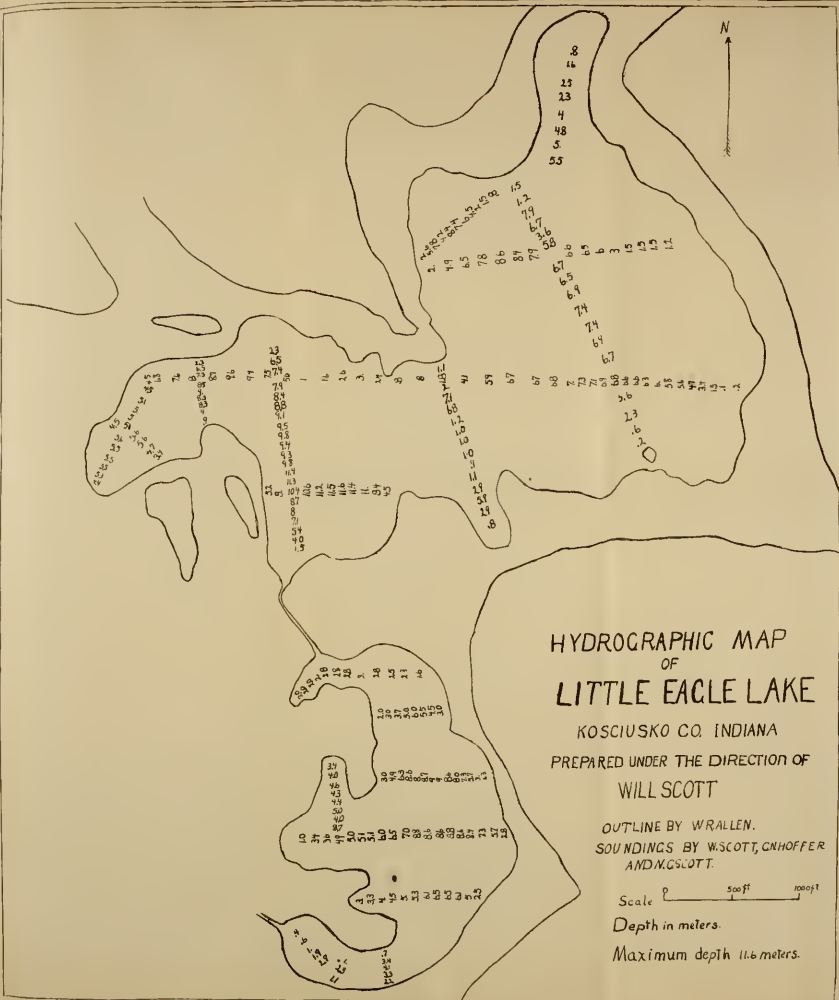
PREPARED UNDER THE DIRECTION OF
WILL SCOTT

OUTLINE BY WRALLEN.
SOUNDINGS BY W. SCOTT, CHOFFER
AND MCCLUTT.

Scale 0 500 ft 1000 ft

Depth in meters.

Maximum depth 11.6 meters.



The changes produced in Eagle Lake by raising the dam two feet would not be very great. Fishing would be improved and some power could be developed with an almost negligible loss of property.

Little Eagle Lake.—Little Eagle Lake (Chapman Lake) has an area of .822 square miles. It has a maximum depth of 38 feet. Along most of its shore line the bottom slopes rather gently, so that a slight change in level makes a marked change in area.

In recent years the outlet of this lake has been dredged, in an effort to reclaim some marsh land on the south and west of the lake. Some onions have been raised on this land, but most of it is not productive, for all of the lowland lying west of the lake is composed of marl.

This dredging of the outlet has exposed many acres of fine fish breeding ground on the east side and it has reduced the feeding ground on the west side. The east side has many good building sites, some of which are developed. The lowering of the lake has reduced the value of these properties by making the landing with boats more difficult and by making the shore line more distant.

The changes proposed for this lake would just about restore the original conditions. See accompanying map.

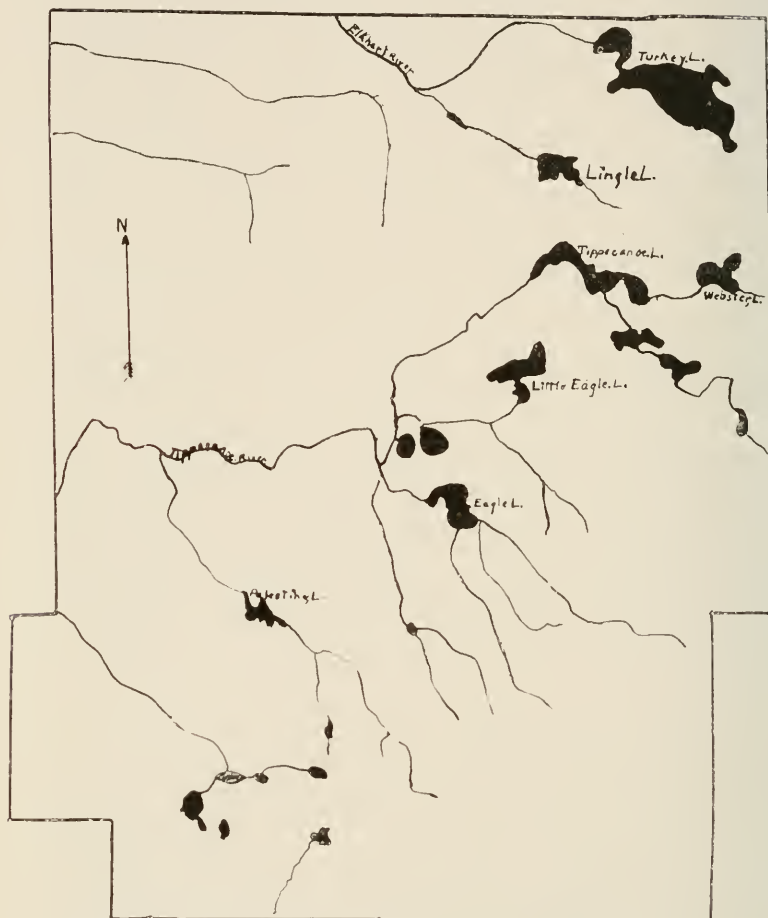
Palestine Lake.—Palestine Lake is said to contain 1,100 acres or 1.71 square miles. There are two small depressions whose maximum depth is 30 feet, but the most of the lake is less than ten feet deep. All shallow parts of the lake, comprising about five-sixths of it, are filled with an almost continuous mass of water plants. These shallows evidently formed an old flood plain or marsh that has been covered with water by damming the outlet.

The water from the dam is used to run a flouring mill. The turbine delivers forty-seven horse-power at a seven-foot head.

We have not completed the sounding and mapping of this lake and until this is finished it is impossible to say with certainty just what would be the best treatment for this lake to receive. It is certainly a valuable impounding basin as it is; and it seems that a small amount of land would be submerged by raising the water above its present level; thus increasing its efficiency as an impounding basin, and the amount of power developed.

On the other hand, this is one of the few lakes in which the lowering of the outlet would expose a relatively large amount of land. Because of this exceptional condition, it is necessary to collect all of the data before

MAP OF KOSCIUSKO COUNTY, INDIANA. SHOWING THE LOCATION OF THE
LAKES DISCUSSED IN THIS PAPER.



a just estimate of the various values can be made. It may be more economical in this case to remove the dam, in order to secure land for farming; but the evidence at present indicates that the dam should be raised rather than lowered.

CONCLUSION.

From the data presented, it is evident that the storage capacity of lakes can be increased by damming, and that by properly manipulating these dams the excess accumulated can be discharged during periods of minimum rainfall. This will benefit the streams to which the lakes are tributary (1) by decreasing the maximum discharge, thus preventing floods, and (2) by increasing the minimum discharge, which will add to all the elements that have been enumerated in stream valuation.

By analyzing the conditions carefully in each lake these changes can be made so that the value of the lakes and the property adjoining, when considered as a whole, will be increased.

Many details are yet to be worked out, but the advisability of this procedure is already apparent.

REFERENCES.

Large, Thomas: Map of Webster Lake. Proc. Ind. Acad. Sci. '96.
Map of Tippecanoe Lake. *Ibid.* '96.

Norris, A. A.: Map of Winona, Pike and Center Lakes. Proc. Ind. Acad. Sci. '01, p. 117.

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