STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 74

WATER MASSES AND THEIR MOVEMENTS IN WESTERN LAKE ERIE

by

Charles E. Herdendorf

Columbus
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INTRODUCTION

A synoptic survey of several of the physical and chemical characteristics of the water in western Lake Erie was conducted on June 23, 1963, by the Ohio Department of Natural Resources. The main objective of the study was to determine the feasibility and value of a synoptic survey of water properties as a method of mapping water masses and of determining their origins and paths of movement. Western Lake Erie was selected as the area in which to conduct the survey for several reasons. West of the island chain between Marblehead and Pelee Point the lake forms a natural basin. This basin is the recipient of large influxes of water, each with its distinctive properties, from the Detroit and Maumee Rivers and from the central basin of Lake Erie. The area of western Lake Erie is also relatively small, slightly less than 1,300 square miles, making it possible to survey the entire basin within a single day. These features made this basin an ideal area in which to conduct a water property study.

The Ohio Division of Wildlife contributed three boats for the survey: *Explorer, Investigator,* and *Inspector.* The Ohio Division of Geological Survey provided its research vessel, *GS-1.* Sampling stations were established on a two-mile grid, resulting in a total of 300 stations (fig. 1). Stations were allotted to each vessel in a pattern such that all sampling could be accomplished within a period of eighteen hours.

At each station water samples were taken with Kemmerer water samplers at two depths: five feet below the surface and two feet above the bottom. At the time of sampling, water temperatures were measured to the nearest degree Fahrenheit. The samples were analyzed within three days of the survey for the following properties: (1) turbidity, (2) hydrogen-ion concentration (pH), and (3) specific conductance. Turbidity values were obtained with a Hellige turbidimeter. Hydrogen-ion concentrations were determined with a Beckman Zeromatic pH meter. Specific conductance (conductivity) was measured with an Industrial Instruments conductivity meter, model RC 16B2, and reduced to micromhos per cm at 25°C. Conductivity yields a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in the water and to water temperature. In general, the ratio of total dissolved solids to specific conductance for western Lake Erie is 0.59. In addition to these measurements, bathythermograph temperature recordings were made on a four-mile grid and were reported by Herdendorf (1967). Dissolved oxygen and alkalinity determinations were made at the time of sampling for those samples taken from the *Explorer* and were discussed in a report by Carr, Applegate, and Keller (1965). Water color observations were recorded from the *GS-1.*

The results of the field measurements and laboratory analyses were plotted on charts of western Lake Erie, using U.S. Lake Survey Chart 39 as a base. The values for each property were contoured in order to establish areal patterns of circulation, if such existed.

Preliminary results of this investigation were reported by Hartley, Herdendorf, and Keller (1966a, b). They concluded that conductivity and water temperatures below the zone of diurnal heating were the most reliable indicators of water masses. An attempt was also made to interpret the movement of these masses.

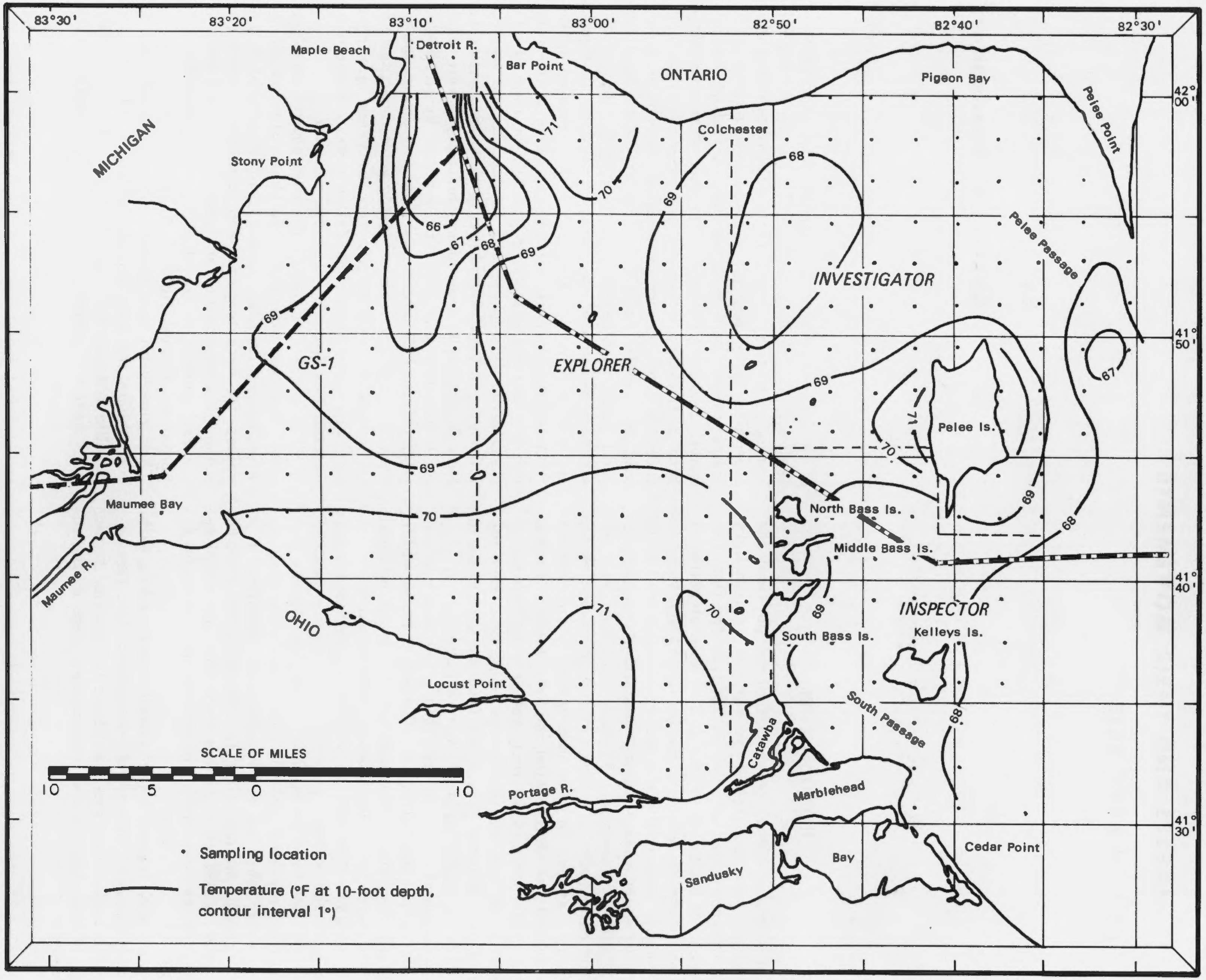

FIGURE 1.–Water temperatures at 10-foot depths in western Lake Erie on June 23, 1963; sampling stations shown by dots.

The following report is presented as a supplement to the earlier interpretations: movements of water masses in western Lake Erie are further discussed and a method for computing movement velocities is developed.

WATER MASSES AND MOVEMENTS

The water property survey of June 23, 1963, demonstrated that water masses can be mapped, particularly those created by major inflows. Emphasis must be placed on the fact that the following interpretations are based on the results of a one-day survey conducted in early summer during a period of calm weather when disturbing influences were at a minimum. It is likely that strong winds and pronounced seiche activity can significantly disrupt the pattern described in this report.

Subsurface temperatures obtained from bathythermograph recordings at the 10-foot depth, when plotted and contoured, showed a definite southward movement of relatively cold midchannel Detroit River water flanked by warmer water on both sides. The contours in figure 1 suggest that this warmer water was moving southwestward along the Michigan shoreline and eastward along the Ontario shoreline. The midchannel flow split about 10 miles south of the river mouth, with the bulk of the flow continuing in a southerly direction and a lesser branch moving eastward toward Pelee Passage. Temperature values also indicated an eastward movement of water along the Ohio shore from Maumee Bay and a northward flow of warm water west of the Bass Islands as well as an insurgence of cooler central Lake Erie water in the southern island area and in Pelee Passage.

Surface conductivity values showed definite patterns which appeared to be related to individual water masses (fig. 2). The water with the highest conductivity was found west of the Detroit River mouth and appeared to have been moving southward. The patterns indicate that this flow may have joined another water mass which also had high conductivity and had been moving southeastward from the Maumee River along and near the Ohio shore. Another mass of water with high conductivity was noted on the west side of the Bass Islands, but water with low conductivity was found in the southern island area and south of Pelee Point. This suggests that water from along the Ohio shore west of Catawba was moving northward on the west side of the islands, and that the southern island area and, to a lesser extent, Pelee Passage were receiving an influx of central Lake Erie water.

A band of water with relatively low conductivity extended southward from the midchannel of the Detroit River to the Ohio shore near Locust Point. This flow appeared to bifurcate about 10 miles southeast of the river mouth, with a substantial flow moving eastward along the Ontario shoreline to Pigeon Bay, thence southeastward toward Pelee Passage. The midchannel flow from the mouth of the Detroit River to the Ohio shore was characterized by four podlike masses of water with very low conductivity. These pods are labeled A through D on figure 2 and are of considerable importance in computing the velocity of this flow.

VELOCITIES OF WATER MASSES

Lake level fluctuations in western Lake Erie for six days preceding the survey are shown in figure 3. On each of the four days immediately before the survey, seiche activity caused the lake level to fall and rise noticeably. The low points of these fluctuations are labeled *A* through *D* on figure 3. This suggests that these times of low lake levels are related to the four pods of water with very low conductivity which are shown in figure 2. During the four low lake levels a larger volume of midchannel Detroit River water apparently entered the lake because of the increased surface gradient. The succeeding higher levels decreased the hydrostatic head and thereby lessened the rate of flow. The conductivity patterns reflect this phenomenon by showing a pod with low conductivity for each period of low lake level, the pods being separated by water with medium conductivity.

The matching of the four pods with the four periods of major low levels that preceded the survey appears to be justified because low water level *B* of June 20, 1963, is the lowest lake level recorded in the six days prior to the survey and low conductivity water mass B contains water with the lowest conductivity readings. Presumably the size of the pod is dependent upon the relative lowness of the lake level and the amount of dispersion which occurred after the mass entered the lake.

Once a pod has been correlated with its corresponding period of low lake level, its average velocity can easily be computed by dividing the distance it has traveled by the time that has elapsed since the related low level. The following table shows the relative movements of these pods:

Position of pods	Distance between pods (mi)	Time between low levels (hrs)	Velocity	
			mph	ft/sec
D to C	12	24	0.50	0.74
C to B	8	28	0.29	0.43
B to A	4	14	0.29	0.43

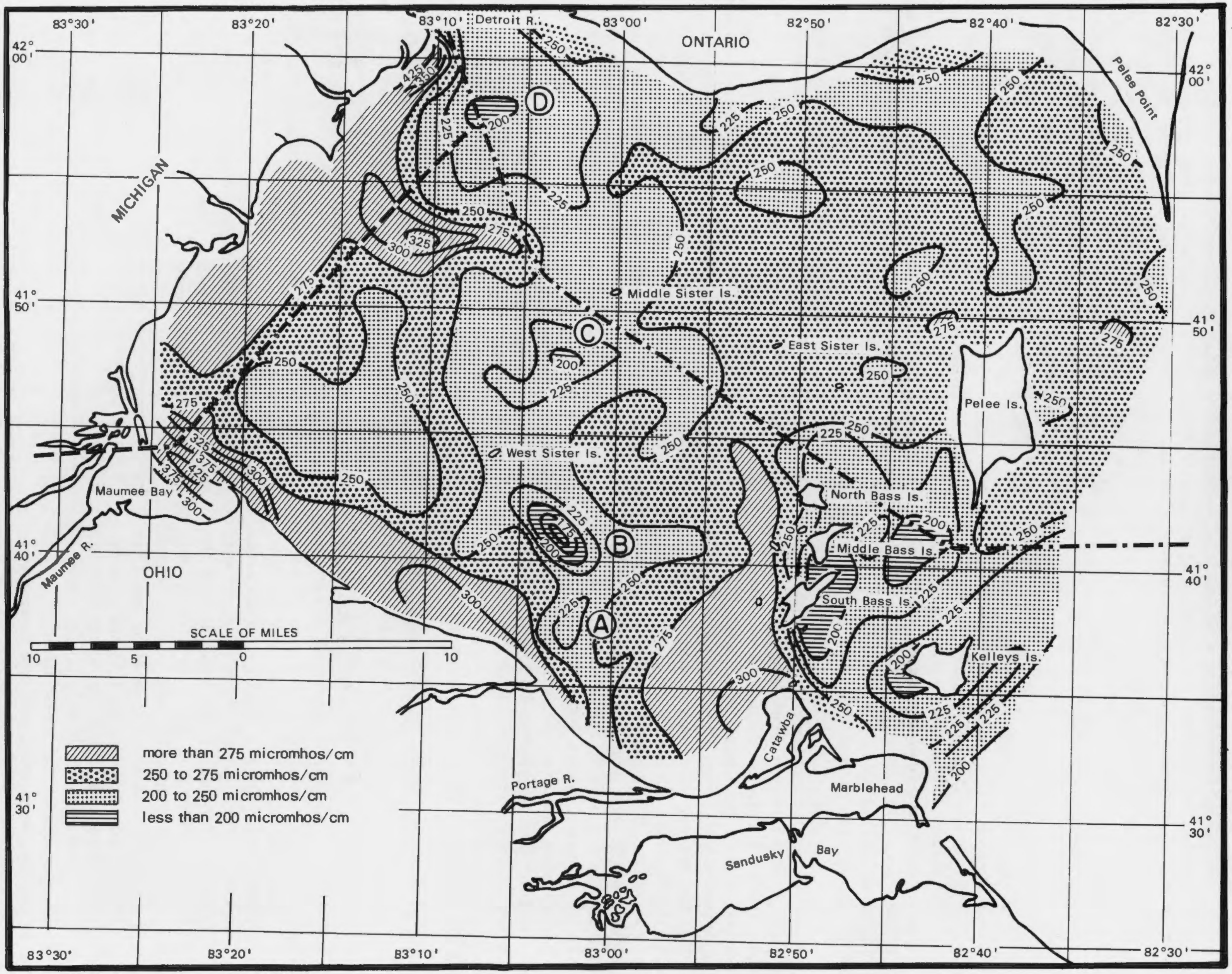

FIGURE 2.—Surface conductivity of western Lake Erie on June 23, 1963.

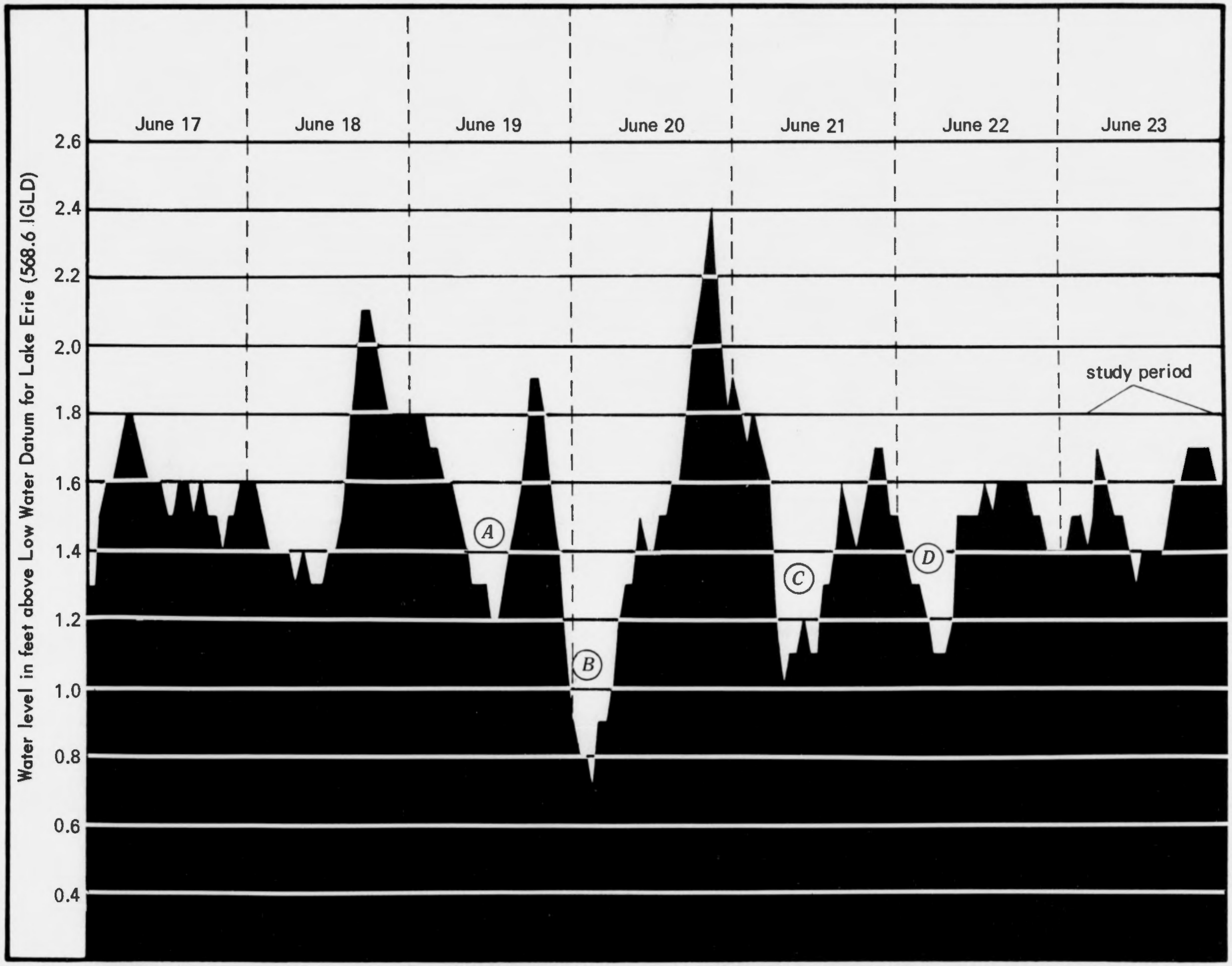

FIGURE 3.—Water level fluctuations in western Lake Erie as recorded at U.S. Army Corps of Engineers gauge in Toledo, Ohio, on June 17 through 23, 1963. Low water levels indicated by letters *A, B, C,* and *D* correspond with water masses A, B, C, and D.

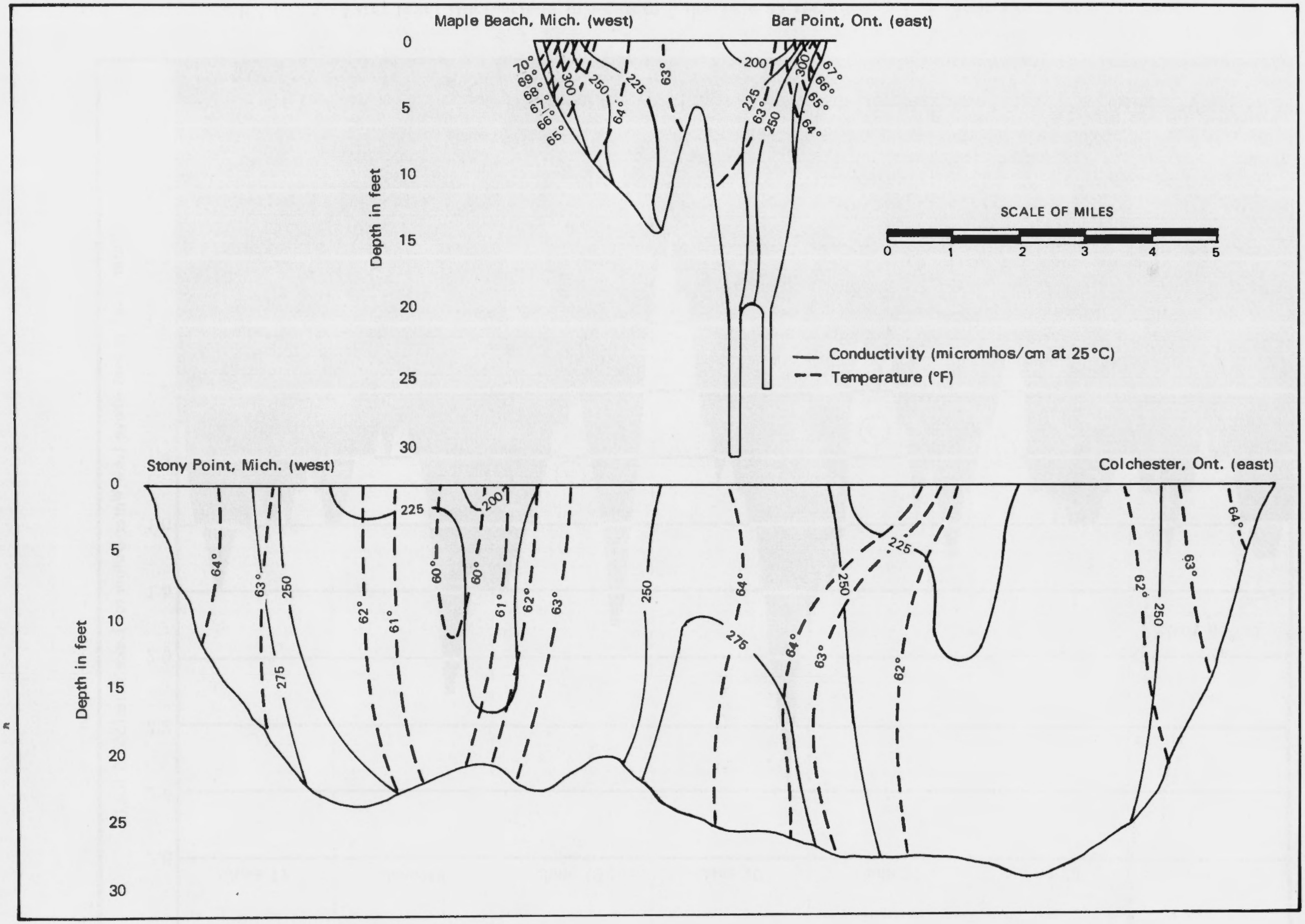

FIGURE 4.–Temperature and conductivity profiles near the mouth of the Detroit River on June 18, 1965.

The average velocity computed for water moving from the position of pod D to the position of pod A was found to be 0.36 mph or 0.53 ft/sec. This indicates that Detroit River water normally would reach the Ohio shore 110 hours, or approximately 4½ days, after it entered the lake at the river mouth.

The computed velocities of these pods are generally substantiated by direct measurements. Currents were measured with an Ekman meter at a station midway between Middle Sister and West Sister Islands on July 1 and July 8, 1964, for a total of 11 hours. These currents were found to be moving southerly at all depths. Velocities near the surface ranged from 0.2 to 0.5 ft/sec. Data collected from this station show the same directions as those interpreted from the temperature and conductivity patterns and the calculated velocities also agree reasonably well with the measured values.

Temperature and conductivity surveys near the mouth of the Detroit River on June 18, 1965, showed distinct water masses consistent with those found on June 23, 1963. Two profiles were made of Detroit River water, one at the river mouth along a line between Maple Beach, Michigan, and Bar Point, Ontario, and another about seven miles to the south in western Lake Erie between Stony Point, Michigan, and Colchester, Ontario. Temperature and conductivity were measured at five-foot depth intervals from surface to bottom: at quarter-mile intervals at the river mouth and at mile intervals in the lake. The river profile shows three distinct water masses (fig. 4). Water with higher temperature and greater conductivity occupied the shallower areas along the east and west shores; the midchannel flow was cooler and lower in conductivity. The lake profile indicates that five zones or water masses were present south of the river mouth: it appears that midchannel flow divided upon entering the lake and was separated by western basin water with higher conductivity. This profile correlates with the surface conductivity pattern of the June 23, 1963, study (fig. 2), which shows a split in the midchannel flow about 10 miles southeast of the river mouth, producing southerly and easterly flows.

SUMMARY

The synoptic water property study has demonstrated that a sampling and analysis program carried out in a short time and in a dense pattern can be valuable in determining the existence, shapes, movements, and velocities of water masses.

Temperature and conductivity values indicate a dominating southward movement of the Detroit River water, some of which reached the Ohio shore near Locust Point. Part of the midchannel main flow appears to split off and move eastward near the Ontario shore. Water along the sides of the Detroit River has higher temperature and conductivity values and produces sluggish flow that generally clings to the shoreline or forms eddy currents. Measurements indicate an eastward movement of water along the Ohio shore from Maumee Bay to the Bass Island area and thence northward along the west side of the islands. A northwestward flow of central Lake Erie water into the southern islands area and south of Pelee Point is also recognized. Most of the flow from western Lake Erie into the central basin appears to be through Pelee Passage.

Variations in water levels, when correlated with podlike masses of water which have entered the lake from the Detroit River, provide data for determining the velocity of their movements. The average velocity of Detroit River water flow in western Lake Erie is approximately 0.5 ft/sec.

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