Limnological Survey of Lake Erie
1959 and 1960.

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LIMNOLOGICAL SURVEY OF LAKE ERIE

1959 AND 1960

by

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GREAT LAKES FISHERY COMMISSION
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ABSTRACT

Federal, provincial, state, and university organizations participated in cooperative limnological surveys of Lake Erie in September 1959 and August 1960 to determine the extent and severity of the low dissolved-oxygen content of the hypolimnetic waters. Observations were restricted to the central basin in 1959, but were lake-wide in 1960. Approximately 70 percent of the bottom waters of the central basin had a serious oxygen deficiency during both years. Data were obtained also on the distribution of temperature, transparency, specific conductance, pH, and phenolphthalein and total alkalinity. The distributions of the chemical values are discussed in terms of their relationships to each other, and to thermal stratification, river outflow, lake morphometry, and lake currents.

Introduction

Fishery biologists studying Lake Erie have become increasingly concerned over the accumulating evidence of accelerated eutrophication of this highly productive lake. The benthos has changed substantially in the western basin, and increases have taken place in mean annual water temperatures, in coliform bacteria, and in the concentrations of the major chemical constituents of the water. Changes in the fish population, such as the collapse of the cisco (Coregonus *artedi)* fishery ca. 1925 (Van Oosten 1930), the decline in the abundance of sauger *(Stizostedion canadense),* the recent near-disappearance of the blue pike *(Stizostedion vitreum glaucum),* and the long-term upward trend of the walleye *(Stizostedion vitreum vitreum)* from the early 1930's to the middle 1950's, are well documented in the published statistics or in special reports. Increases in gizzard shad *(Dorosoma cepedianum),* alewife *(Alosa pseudoharengus),* and smelt *(Osmerus mordax)* have been large, but quantitative information on abundance is limited because these species have not been exploited commercially, except for the smelt, within recent years (Beeton 1960).

The various agencies working on the lake increased their limnological sampling as a consequence of their concern over environmental conditions, and in August 1959 the Ohio Division of Wildlife found very low dissolved-oxygen concentrations near the bottom at several stations in central Lake Erie. Several other agencies were informed of this condition and a cooperative synoptic survey was organized to obtain information on the extent of the area affected. The results of this survey brought out the need for more detailed information; a lake-wide survey was made in August 1960.

Low concentrations of dissolved oxygen in central Lake Erie have been reported previously. The severity of oxygen depletion may, however, be greater at present than in the past. A larger area probably is involved and the period during which low concentrations occur may be longer now than in the past. A low of 0.8 ppm of dissolved oxygen was observed off Marblehead in August 1930 (Wright 1955) and concentrations of 4. 4 and 4.8 ppm were found in mid-August during the 1929 survey of the central basin (Fish 1960). The Fisheries Research Laboratory, University of Western Ontario, reported low dissolved-oxygen concentrations of 3.1, 2.4, 3.8, and 2.1 ppm in 1948, 1949, 1950, and 1951 (Powers et al. 1960). The Bureau of Commercial Fisheries found dissolved-oxygen concentrations ranging from 2.8 to 1.0 ppm in July and August 1958. These scattered observations provide little information on the extent both in time and area of these low concentrations and offer a poor basis for comparison with earlier findings (Carr 1962). Consequently, the recent occurrences of water with low dissolved-oxygen content may not be indicative of a great change in the central basin. On the other hand, the average percentage saturation of dissolved oxygen, over comparable periods, was lower in 1958, 63.3 percent, than in 1929, 83.3 percent (Beeton 1960).

Dissolved oxygen is usually around 80-percent saturation in the bottom waters of the western basin, except during periods of prolonged calm and accompanying thermal stratification such as occurred in 1953 (Britt 1955). The western basin is shallow enough to permit mixing to the bottom throughout most of the year. The average percentage saturation for bottom waters in 1928-30 ranged from about 83 to 91 and was 80 in 1958 (Beeton 1960).

Only a few observations have been made of the dissolved-oxygen content of the deeper waters of the eastern basin. The available data, however, indicate that the percentage saturation in the bottom waters averages around 60 to 70, although much lower saturations may be found during the same period in the shallower central basin.

The Ohio Division of Wildlife, Ontario Department of Lands and Forests, and the U.S. Bureau of Commercial Fisheries co-operated in the 1959 survey of the island area of the western basin and the western two-thirds of the central basin. Fifty stations were established during the survey on September 4-5 (Figure 1) . These stations were visited as follows:

George *L.*	U.S. Bureau of Commercial Fisheries	10-12, 14, 16-21, 23
Keenosay	Ontario Department of Lands and Forests	24, 26-29, 31, 32, 41, 42, 44-48
SP2	Ohio Division of Wildlife	49-57, 66-73, 49A, 49B, 67A
SP1	Ohio Division of Wildlife	59, 61-65, 58A-65A[1]

The Great Lakes Institute of the University of Toronto, Ohio State University, Ohio Division of Shore Erosion, and Pennsylvania Fish Commission joined the 3 original agencies in the lake-wide synoptic survey of August 30-31, 1960. Most of the 1959 stations were revisited and sampling was carried out at 168 stations (Figure 2). The 78 stations established by the *Porte Dauphine* are listed separately, since sampling was conducted underway and it was convenient to tabulate these observations in a special table. Provision was made for sampling for 30 hours at Stations 35, 37, 69, and 85. The *Alvera* and *SE1* completed their sampling at Stations 35 and 37, but 2 small boats from the Great Lakes Institute could not occupy Stations 69 and 85 because of a heavy swell in the eastern end of the lake.

Vessels from 7 agencies sampled at the following stations:

Porte Dauphine	Great Lakes Institute	1D-78D[2]
George L.	Bureau of Commercial Fisheries (Biological Research)	1-9, 1A, 2A
BioLab	Ohio State University	10-23
Keenosay	Ontario Department of Lands and Forests	24-34, 36, 38-40

[1] Engine trouble aboard the *SP1* delayed sampling at 7 stations until September 7.

[2] Stations occupied by the *Porte Dauphine* are not shown in Figure 2 but their positions are given in Table 7.

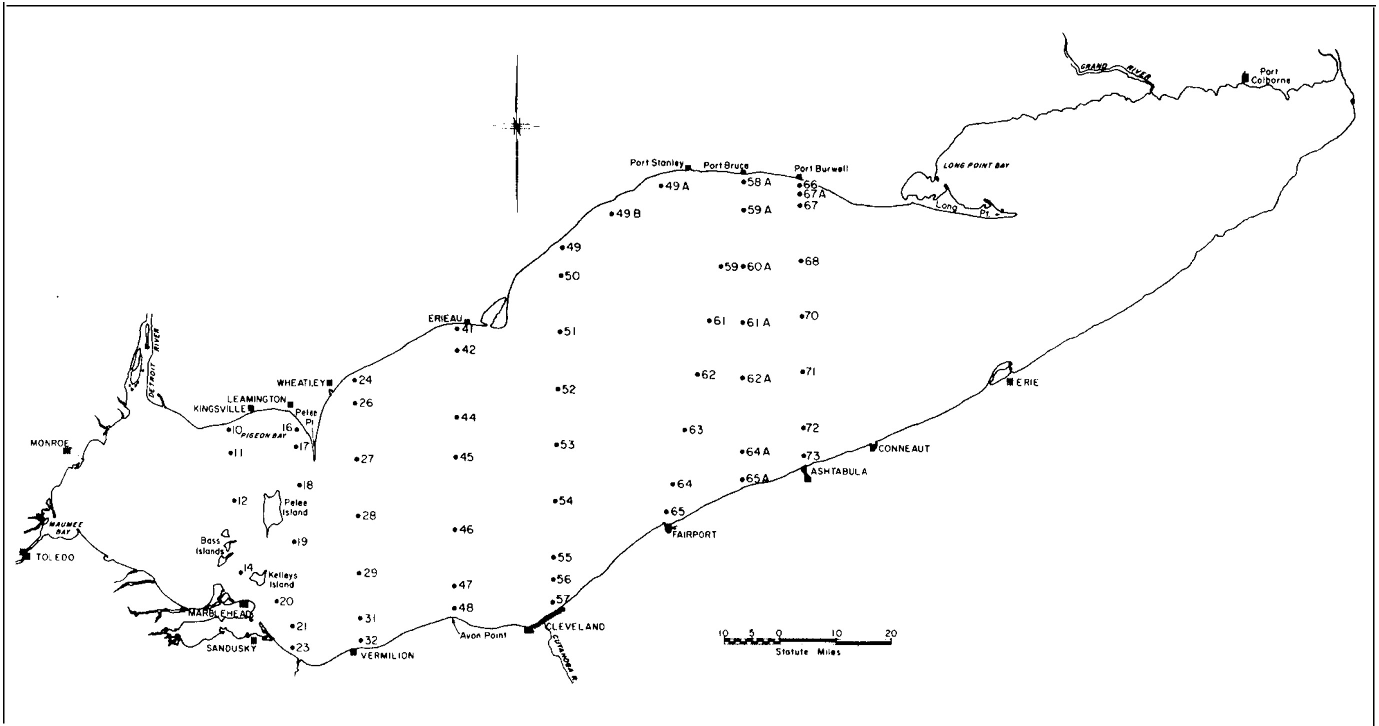

Figure 1. 1959 Stations

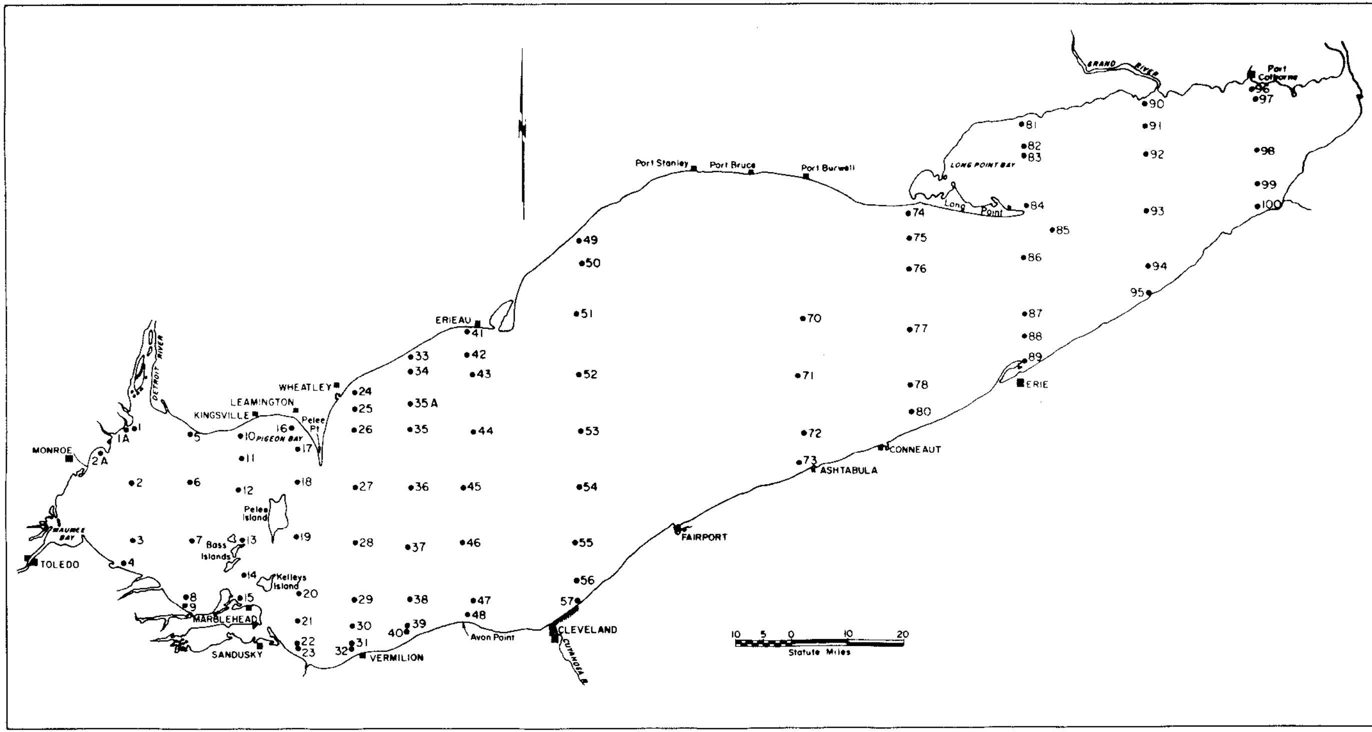

Figure 2. 1960 Stations

Alvera	Ontario Department of Lands and Forests	35
SE1	Ohio Division of Shore Erosion	37
SP3	Ohio Division of Wildlife	41-57
SP4	Ohio Division of Wildlife	70-73[3]
Perca	Pennsylvania Fish Commission	74-89
Active	Bureau of Commercial Fisheries (Exploratory Fishing)	90-100, 96A

Acknowledgments

The following investigators were primarily responsible for organizing and carrying out the 1959 and 1960 surveys; those designated by an asterisk participated only in the 1960 survey:

Merryll Bailey, Ohio Division of Wildlife
*Alfred M. Beeton, Bureau of Commercial Fisheries (Biological Research)
*N. Wilson Britt, Ohio State University
*Ira A. Carr, Bureau of Commercial Fisheries (Exploratory Fishing)
*R. E. Deane, Great Lakes Institute, University of Toronto
Robert Ferguson, Ontario Department of Lands and Forests
John Parsons, Bureau of Commercial Fisheries (Biological Research)
Charles Selden, Ohio Division of Wildlife
Nelson Thomas, Ohio Division of Wildlife
Harry Van Meter, Bureau of Commercial Fisheries (Biological Research)
*James Verber, Ohio Division of Shore Erosion

Field Procedures and Methods

Transects were laid out so the vessels traveled approximately due south or north. Two transects were assigned to each vessel. A vessel crossed the lake on one transect the first day of the survey and returned on the other transect the second day.

[3] Only 4 of the 17 stations designated for sampling by the SP4 were visited because of engine trouble.

Water samples were taken immediately above and below the thermocline and near the bottom in 1959. If the water was homothermous, samples were taken near the surface and near the bottom. Determinations were made for dissolved oxygen by means of the unmodified Winkler method. Temperatures and transparency were determined aboard each vessel with bathythermographs and Secchi discs.

Water samples were taken at the surface, immediately below the thermocline, and near the bottom in 1960 by all vessels except the *Porte Dauphine* which took only surface samples. Bathythermographs were lowered from all vessels except aboard the *Perca* where a Foxboro resistance thermometer was used. Transparency was measured with Secchi discs on all vessels except the *Porte Dauphine*. Only limited meteorological observations, such as cloudiness, visibility, and wind direction and approximate velocity, were made aboard most of the vessels. Complete records were kept aboard the *Porte Dauphine* of the above conditions as well as barometric pressure, sea state, and wet- and dry-bulb temperatures. The dissolved-oxygen content of the water samples was determined on board all vessels by the sodium azide modification of the Winkler method (Am. Publ. Health Assoc. 1955). Percentage saturation of dissolved oxygen was determined from a nomograph prepared by Mortimer (1956). Phenolphthalein and total alkalinities (methyl orange) were determined aboard the *SE1*, *Perca*, *BioLab*, *SP3*, *SP4*, and *George L.* Some water samples were preserved with 2 to 5 percent formalin for plankton; others were left unpreserved for determination of specific conductance. Resistance measurements were made in the Ann Arbor Biological Laboratory of the Bureau of Commercial Fisheries with an Industrial Instruments Type RC-1613-1 conductivity bridge. Resistance was converted to specific conductance in μmhos/cm^3 at 18^{o}C.

A few drift bottles (84) were released, but the small number recovered and the length of time before recovery made these data of little value; they have not been included in this report. Of the 31 bottles recovered, 5 to 61 days after release, only 2 were recovered within 2 weeks of release.

Some of the data as originally submitted by the agencies participating in the 1960 synoptic surveys were incomplete or had certain obvious inaccuracies. A subcommittee composed of A.M. Beeton, Bureau of Commercial Fisheries; N. Wilson Britt, Ohio State University; and Nelson Thomas, Ohio Division of Wildlife, was appointed by the Lake Erie Fish Management Committee to review procedures and results critically. Information on equipment used, records of accuracy of instruments, and standardization of the sodium thiosulfate were obtained, and appropriate corrections were made in the data included in this report. Certain data collected were obviously incorrect and have not been included.

Survey of 1959

Meteorological observations. -The following information was obtained from the U.S. Weather Bureau records for Cleveland, Ohio, since extensive meteorological observations were not made aboard the vessels participating in the survey. Winds averaging about 7 to 9 mph were out of the south-southeast, September 4-6. The sky was clear during most of this time. The relative humidity averaged around 65 percent in the morning, decreased to about 25 to 30 percent at noon, and increased again in late afternoon. During the 7 days prior to the survey the winds averaged 5 to 10 mph; consequently, only slight mixing of the waters could have occurred.

Transparency. -The transparency, as measured by Secchi disc, ranged from 4 to 6 feet around the islands in the western basin (Tables 1 and 2). The maximum disc depth in this area was 9 feet just east of Pelee Island. The range in transparency was much greater in the central basin where disc depths ranged from 4 to 33 feet. In general the lower values of 4 to 15 feet occurred in shoal areas near shore, although isolated masses of low-transparency water were found in the open lake. Water with high transparency, 20 to 33 feet, lay in an extensive area of the open lake between Avon Point and Ashtabula. The transparency decreased in the western part of the central basin and toward the north and south shores. A few Secchi-disc measurements of from 17 to 19 feet were made north of Ashtabula in the eastern part of the central basin.

Surface temperatures.-The surface temperatures averaged about 2° F. higher in the west end than in the central basin. Temperatures ranged from 77° to 81° F. in the island area and from 74° to 80° F. in the central basin (Tables 1 and 2).

Two cooler masses of surface water (74° to 76° F.) extended from the north shore of the central basin-a small one immediately east of Pelee Point and a larger mass, about 25 miles wide, from the vicinity of Port Stanley almost to Fairport. Warmer surface waters (78° to 80° F.) occurred along the southern shore between Marblehead and Ashtabula.

Subsurface temperatures .-In general the subsurface temperatures in the west end were the same as the surface temperatures,

Table 1. - Physical and chemical data for Lake Erie, September 4, 1959

[Bottom refers to immediately above the bottom.]

Station Number	Latitude	Longitude	Depth at station (feet)	Thermocline depth (feet)	Temperature (° F.)		Dissolved oxygen[1] (ppm)			Secchi-disc depth (feet)
					Surface	Bottom	Above thermocline	Below thermocline	Bottom	
23	41°25'40"	82°34'30"	26	None	11	71	1.3	1.0	8.1	4.0
21	41 29 00	82 34 30	39	34[2]	11	70	1.2	6.9	0.0	12.0
19	41 41 50	82 34 30	41	36[2]	18	12	1.6	6.8	1.3	9.0
18	41 50 40	82 34 30	30	None	11	77	8.4	1.1	6.7	6.0
17	41 56 20	82 34 30	38	34[2]	18	68	7.0	6.8	7.0	6.0
16	41 59 00	82 34 30	30	None	78	77	8.1	7.0	1.1	4.0
10	41 58 40	62 48 50	25	None	76	75	6.9	4.7	2.4	6.0
11	41 55 20	62 48 20	35	None	19	78	8.6	...	6.1	4.5
12	41 46 00	82 47 20	31	None	79	78	8.9	. .	1.3	6.0
14	41 36 50	82 45 30	31	None	80	78	9.3	...	6.4	4.5
20	41 32 40	82 31 50	39	34[2]	81	71	9.1	...	0.5	7.5
24	42 06 50	82 22 30	30	20-22	14.5	62.0	6.7	1.8	2.0	6.5
26	42 03 20	82 22 20	48	20-22	16.0	53.0	1.8	3.2	1.3	6.5
21	41 54 40	82 21 40	55	25-30	14.9	50.0	1.4	...	.	10.0
28	41 46 10	82 21 00	52	40-41	76.0	55.0	1.3	0.4	0.9	8.0
29	41 31 20	82 20 40	48	38-42	17.0	62.0	1.1	8.0	0.9	14.5
31	41 30 30	82 20 10	44	40-43	18.0	64.8	...	1.1	0.1	16.5
32	41 21 00	82 20 00	31	...	78.5	69.0	7.1	...	1.6	14.5
65	41 47 20	81 16 50	40	None	11.0	74.0	1.1	6.9	6.7	...
64	41 51 30	81 15 20	68	56-60	16.0	53.0	1.2	3.3	1.0	20.0
63	42 00 00	81 12 40	80	65-70	76.0	52.5	1.0	7.0	1.0	24.0
62	42 08 20	81 10 20	85	60-65	16.0	55.0	1.1	3.1	2.5	20.0
61	42 16 40	81 01 40	a3	55-60	16.0	54.0	1.5	5.4	2.8	19.0
59	42 25 20	81 05 20	78	54-56	16.0	51.0	1.4	2.5	1.8	...
73	41 56 00	80 48 00	40	None	18.0	18.0	6.6	.	8.8	8.0
72	4.2 00 20	80 48 00	63	503	18.0	52.0	0.9	6.0	4.6	19.0
11	42 00 00	80 48 20	12	503	11.0	50.0	1.1	6.4	6.3	19.0
IO	42 17 30	80 48 30	69	52[3]	11.0	51.5	6.8	8.3	5.9	11.0
68	42 26 00	80 48 40	68	48[3]	11.0	53.0	6.9	6.9	6.8	16.0
61	42 34 30	80 49 00	60	453	75.0	57.0	6.9	5.2	4.6	15.0
67A	42 36 20	80 49 00	57	453	76.0	58.0	1.2	8.3	6.2	16.0
66	42 31 40	80 49 00	40	None	11.0	71.0	6.9	1.0	6.2	6.0

1 In the absence of a thermocline samples were taken near the surface and midway between the surface and bottom.

2 Upper limits of thermocline.

3 Lower limits of thermocline.

Table 2. - Physical and chemical data for Lake Erie, September 5, 1950

[Bottom refers to immediately above the bottom.]

Station Number	Latitude	Longitude	Depth at station (feet)	Thermocline depth (feet)	Temperature (° F.)		Dissolved oxygen [1] (ppm)			Secchi-disc depth (feet)
					Surface	Bottom	Above thermocline	Below thermocline	Bottom	
48	41°32'20"	82°00'20"	48	35-40	11.5	61.0	1.1	0.6	0.0	...
41	41 35 30	82 00 20	56	50-52	71.5	61.0	7.8	1.8	...	19.5
46	41 44 20	82 00 20	69	60-62	17.5	56.3	1.1	1.0	1.3	26.0
45	41 55 20	82 00 30	12	60-63	71.2	55.2	1.8	2.3	1.2	33.0
44	42 01 30	82 00 40	11	57-60	11.1	53.8	1.8	1.0	1.6	19.5
42	42 11 40	62 00 40	51	40-43	76.2	55.8	7.4	1.6	1.1	23.0
41	42 15 00	82 00 40	35	...	16.0	63.0	1.1	2.1	2.6	11.5
58A	42 38 20	81 00 40	39	None	75.0	15.0	7.2	...	6.9	6.0
59A	42 33 50	61 00 40	55	40-48	14.0	51.0	1.1	5.0	2.8	12.0
60A	42 25 20	81 00 40	62	50-56	11.0	56.0	1.1	3.6	3.1	13.0
61A	42 16 30	81 00 40	10	40-45	76.0	53.0	1.2	3.6	4.0	12.0
62A	42 08 00	81 00 40	72	45-50	78.0	51.0	7.3	5.3	5.3	13.0
64A	41 56 40	81 00 40	64	48-55	19.5	52.0	7.2	4.3	4.2	21.0
65A	41 52 20	61 00 40	26	None	60.0	75.0	1.1	6.9	6.0	13.0
49A	42 31 20	81 18 50	40	10-25	16.0	61.0	5.6	2.5	2.3	8.0
49B	42 33 00	81 28 30	41	25-35	16.0	61.0	7.5	1.0	0.1	13.0
49	42 27 40	81 38 40	31	15-25	18.0	65.0	1.8	3.1	2.1	13.0
50	42 23 30	81 38 40	50	35-45	15.0	54.0	1.4	2.1	2.2	13.0
51	42 14 40	81 38 50	75	15-45	77.0	52.0	7.8	2.0	1.7	8.0
52	42 06 00	81 39 00	10	53-19	18.0	55.0	7.1	1.7	2.2	24.0
53	41 57 30	81 39 20	19	55-70	76.0	52.0	1.3	1.0	1.5	10.0
54	41 48 40	81 39 30	18	58-68	16.0	55.0	7.6	2.0	1.7	20.0
55	41 40 10	81 39 40	67	57-59	18.0	51.0	1.3	1.3	0.6	20.0
56	41 36 40	81 39 40	55	42-45	18.0	61.0	1.1	1.2	0.5	13.0
51	41 33 20	81 30 40	40	None	19.0	16.5	8.4	...	5.1	10.0

[1] In the absence of a thermocline samples were taken near the surface and midway between the surface and bottom.

since the water was homothermous at most of the stations. Thermal stratification was found at Station 17, however, just west of Pelee Point.

Temperatures were low in the deeper water of the central basin, although the coldest waters did not occur at maximum depth. The lowest temperatures (50° to 52° F.) were in areas with depths of 55 to 79 feet, whereas temperatures ranged from 52° to 55° F. at the maximum depths of '79 to 85 feet.

Thermal stratification was not well defined at most of the stations near the southern shore. The depths ranged from 26 to 30 feet at these stations. Thermal stratification occurred near the northern shore, however, between Pelee Point and Port Stanley (Tables 1 and 2).

The depth of the thermocline varied considerablyfrom area to area. The upper limits of the thermocline were 50 to 65 feet below the surface in the middle of the central basin. A north-south gradient was apparent in the western part of the central basin. The thermocline started 20 feet below the surface near the north shore and deepened to 40 feet toward the south shore. The depth of water apparently had some influence on the upper limits of the thermocline. At stations with water depths 50 feet and greater the average depth of the upper limit of the thermocline was about 49 feet below the surface. The thermocline started at an average depth of about 28 feet when water depths were less than 50 feet.

Dissolved oxygen.-The concentrations of dissolved oxygen in the western and central basins differed substantially. The waters in the upper strata in the western basin were super-saturated with dissolved oxygen (103 percent) at an average concentration of 8.1 ppm and a surface temperature of 78.7° F. The percentage saturation was somewhat less (76.5 percent) in the water near the bottom where the average dissolved-oxygen content was 6.1 ppm and water temperature was 75.7° F. The difference between the water in the upper strata and bottom, although slight, was significant, since the relatively shallow waters were essentially homothermous. The lowest dissolved-oxygen concentration (2.4 ppm) was at Station 10, 1 mile off-shore 5 miles west of Kingsville (Figure 3). Dissolved-oxygen concentrations in the bottom waters in the vicinity of the islands ranged from 6 to 7 ppm.

The dissolved-oxygen content in most of the central basin was less at all depths than in the west end. Despite the slightly cooler waters in the epilimnion (average temperature 76.80 F.) the dissolved oxygen averaged 7.3 ppm-a percentage saturation of 92 percent. The water near the bottom had a percentage

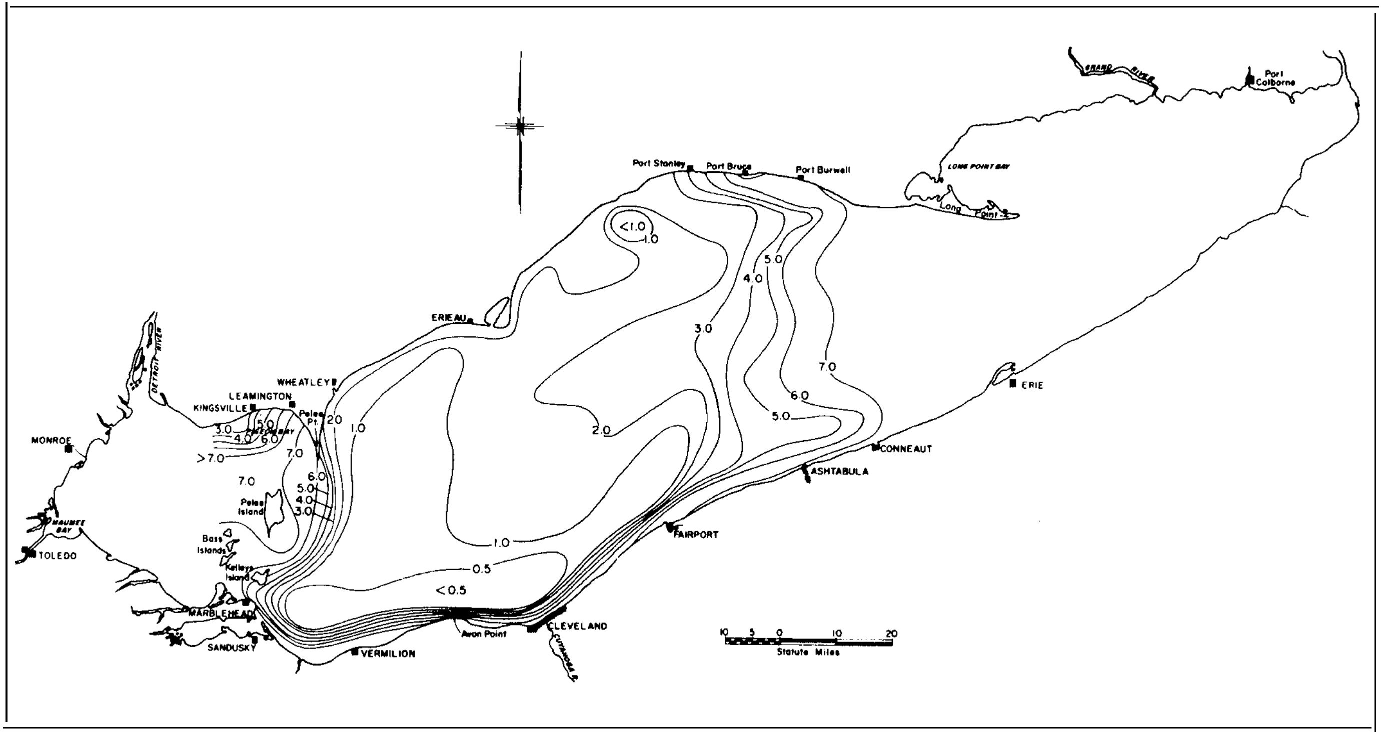

Figure 3.--Distribution of dissolved oxygen in the bottom waters of Lake Erie, 1959. [The eastern and extreme western areas were not sampled.]

saturation of 35 percent, an average dissolved-oxygen concentration of 3.3 ppm, and an average temperature of 60.0° F. A number of stations in the western part of the central basin gave dissolved-oxygen concentrations of less than 1 ppm. The contoured distribution of this oxygen-deficient water indicated that it extended in a band about 10 miles wide from the vicinity of Marblehead to northeast of Fairport (Figure 3). A broad tongue of this same mass extended north almost to the shore near Erieau. If the waters with a dissolved-oxygen content of 3 ppm or less are considered, it appears that about 70 percent of the bottom waters of the central basin had a serious oxygen deficiency. Sampling at 5 stations between Marblehead and Cleveland indicated that the dissolved-oxygen content of the bottom waters was 0.5 ppm or less; no oxygen could be detected at 2 of these stations (21, 48). An isolated instance of very low dissolved-oxygen concentrations occurred near the north shore southwest of Port Stanley. Toward the east from a line between Port Stanley and F-airport the dissolved-oxygen content of the bottom waters gradually increased to about 7 ppm.

Low dissolved-oxygen concentrations were accompanied by pronounced thermal stratification (Tables 1 and 2). In the shallower areas closer to shore where the waters were mostly homothermous, the dissolved-oxygen content was several parts per million greater than at adjacent deeper stations *where the* water was thermally stratified.

Survey of 1960

Meteorological observations.-During the first day of the survey, winds of 5 to 12 mph from the northwest produced a gentle sea with waves less than 1 foot high. Visibility was good-from 10 to 15 miles over most of the lake--although a light fog lay near the north shore in early morning. The sky was about three-quarters overcast throughout the day. Relative humidity on the lake decreased throughout the day from a high of 89 percent in the morning to a low of 81 percent in mid-afternoon.

Meteorological conditions had changed only slightly the second day of the survey. Calm seas prevailed throughout the lake. Winds of 1 to 5 mph were out of the northeast. The sky was clear to completely overcast. The relative humidity ranged from a high of 76 percent to a low of 66 percent.

The U.S. Weather Bureau records from Cleveland, Ohio, show that for the 7 days prior to the survey the winds averaged about 6 to 11 mph, mostly out of the southwest. Some winds reached velocities up to 28 mph on August 29. These winds did not last long and probably had little influence on conditions in the lake.

Transparency.-The transparency of the water in the western basin was low; Secchi-disc measurements were 2 to 4 feet. Secchi-disc depths were mostly 20 feet and more in the central basin and the maximum reading was 30 feet. Values were lower towards the island region where the transparency decreased from 20 to 6 feet. Most of the Secchi-disc measurements were around 24 feet in the eastern basin. Transparency was lower in the shallower areas near shore throughout the lake.

Surface temperatures.-Surface temperatures ranged from 71° F. (Station 94) in the eastern basin to 79° F. (Station 27) southeast of Pelee Point (Table 4). Water was warm (78° F.) in the shallows off Vermilion and in an extensive area extending from Monroe to Marblehead including Maumee Bay. Surface waters were cooler near the north shore of the central basin (74° F.) and along both the north and south shores of the eastern basin (71° to 72° F.).

Detroit River water extended from the river mouth almost to the Bass Islands as a forked tongue of cooler water (74°-75° F.). The major mass extended southward almost to Marblehead while a smaller mass protruded into Pigeon Bay.

Temperatures in the western half of the central basin were mostly around 75° F. (Tables 3, 4, and 7). Warmer water (77°-79° F.) extended southeast from Pelee Point. A large mass of surface water with temperatures around 73° F. extended from the east end of the lake into the eastern half of the central basin. Surface temperatures were higher (75°-76° F.) in the shallower areas inside of Long Point. Observations made over 30 hours at Stations 35A and 37 (Figure *2,* Tables 5 and 6) show diurnal changes in surface water temperatures of about *2.50* F. On August 30 at Station 35A, temperatures increased from 75.2° F. in the morning to 77.0° F. in the late afternoon, decreased to 74.3° F. by 1400 EST. Temperature changes were similar at Station 37, increasing from 72.50 to 75.0° F. on August 30 and decreasing again to 73.00 F. the morning of August 31. These changes probably reflect the usual daily fluctuations in summer during calm weather. A marked increase in surface temperature from 73.0° to 80.0° F. occurred between 0700 and 1500 EST at Station 37 (Table 5). This increase was probably due to a movement of a warmwater mass into the area from the northeast where temperatures had been 78° and 79° F. earlier that morning at Stations 28 and 27 (Table 4).

Subsurface temperatures.-The water was essentially homothermous in the western basin, although temperatures of the bottom waters were about 1° to 3° F. cooler than those at the surface. The distribution of the subsurface temperatures did not, however, reflect the distribution of surface temperatures. A large mass of 73° F. water occupied the entire western half of the basin. Temperatures were 1° to 2° F. higher among the islands, in Pigeon Bay, and along shore east of Maumee Bay (Tables 3 and 4).

Temperatures were much lower in the central basin where they ranged from 48° to 53° F. in the deeper areas (Tables 3, 4, and 7). A large mass of cool water (49.50 to 52° F.) lay near the bottom in an area which included Stations 35, 37, 52, and 53 (Figure 2). Temperatures gradually increased eastward of this area to a high of 53.5° F. at Station 70, although the depth remained the same, and decreased again farther eastward to a low of 48° F. at Station 76 (Table 4, Figure 2). The low value probably indicates the protrusion, into the central basin, of a mass of colder water from the eastern basin. The lower temperatures in the central basin were in areas with depths of at least 50 feet. The water depth increases just east of the islands to around 42 to 48 feet. Nevertheless, almost the entire area 10 miles east of the islands had water temperatures of about 72° F. Subsurface temperatures were higher along the south shore (75° to 76° F.) than at comparable depths along the north shore (72° to 73° F.) .

The temperatures were lowest in the deep waters of the eastern basin. Temperatures were less than 48° F. at stations where depths were greater than 90 feet. A low temperature of 40.80 F. was recorded at Station 93 (Table 4). Temperatures ran higher in the shallower areas; the highest was 74° F. where homothermous conditions existed at Station 89 just east of Erie.

Thermal stratification was limited to water depths of 50 feet or greater except for one shallow station in Long Point Bay (Table 3, Station 81). The depth of the thermocline was around 50 to 60 feet in most areas of the open lake and somewhat closer to the surface in shallower areas near shore. The lower limits of the thermocline extended 20 to 30 feet deeper in the deepest areas of the eastern basin. The hypolimnion existed as a narrow layer extending only 1 to 5 feet above the bottom except in the deepest areas in the central basin and in the eastern basin. The upper limits of the hypolimnion averaged 10.8 feet above the bottom in the central basin. The lower limits of the thermocline ended at the lake bottom at a number of stations; a true hypolimnion did not exist at these stations.

Table 3. - Physical and chemical data for Lake Erie. August 30. 1960

[Bottom refers to immediately above the bottom.]

Station number	Latitude	Longitude	Time (EST)	Depth at station (feet)	Thermocline depth (feet)	Temperature (°F.)		Dissolved oxygen (ppm)			Phenolphthalein alkalinity (ppm $CaCO_3$)			Total alkalinity (ppm $CaCO_3$)			pH			Secchi disc depth (feet)	Specific conductance ($K_{18} \times 10^6$)	
						Surface	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom		Surface	Bottom
9	41°32'20"	82°58'00"	0750	13	None	75.0	75.0	4.2	...	4.5	2	...	3	100	...	103	...	...	...	2.5	238	241
8	41°33'40"	82°58'00"	0830	18	None	75.0	74.5	5.2	...	5.0	4	...	3	102	...	103	...	...	...	3.0	236	238
7	41°42'20"	82°58'00"	1000	32	None	74.0	73.0	4.8	...	4.1	0	...	0	73	...	78	...	...	...	4.5	241	239
6	41°51'10"	82°58'00"	1200	35	None	74.0	72.5	6.9	...	6.5	4	...	0	99	...	97	...	...	...	7.0	213	218
5	41°58'40"	82°58'00"	1400	27	None	75.5	73.0	5.9	...	4.2	3	...	2	103	...	100	...	...	...	6.0	233	241
1A	41°59'20"	83°09'20"	1500	20	None	75.5	73.0	6.2	...	5.9	1	...	2	95	...	96	...	...	...	4.5	...	...
2A	41°55'30"	83°16'20"	1620	22	None	78.0	73.0	5.8	...	4.5	11	...	1	114	...	109	...	...	...	3.0	...	...
23	41°56'10"	82°34'40"	0750	35	None	75.0	73.4	5.7	...	6.2	8	...	10	102	...	107	...	...	...	7.5	247	253
22	41°56'50"	82°34'40"	0810	39	None	75.0	73.4	6.0	...	5.6	0	...	0	72	...	77	...	...	...	6.0	243	249
21	41°30'30"	82°34'40"	0900	39	None	75.0	73.4	6.0	...	3.6	8	...	0	98	...	104	...	...	...	6.0	248	231
20	41°34'30"	82°34'30"	1000	43	None	75.0	73.0	7.2	...	6.4	4	...	8	96	...	98	...	...	...	6.0	225	230
19	41°43'20"	82°35'00"	1100	43	None	75.5	72.5	7.6	...	6.4	9	...	0	96	...	84	...	...	...	8.0	230	226
18	41°51'30"	82°35'00"	1300	31	None	76.5	75.0	7.4	...	6.6	9	...	0	96	...	84	...	...	...	6.5	225	222
17	41°56'40"	82°35'00"	1400	34	None	77.0	74.0	7.4	...	6.6	11	...	6	98	...	92	...	...	...	5.0	225	222
16	42°00'00"	82°36'20"	1500	32	None	78.0	73.5	7.4	...	7.0	11	...	6	98	...	93	...	...	...	5.0	229	257
33	42°11'00"	82°12'00"	0750	40	None	74.0	70.8	7.3	6.0	4.0	...	...	...	...	...	...	...	...	...	8.0	...	...
34	42°08'40"	82°12'00"	0821	60	43-52	74.5	58.0	8.4	...	1.8	...	...	...	...	...	...	...	...	...	18.0	...	...
35	42°00'00"	82°12'00"	0918	67	48-52	74.8	49.5	9.5	8.1	3.3	...	...	...	...	...	...	...	...	...	15.0	...	...
36	41°50'40"	82°12'00"	1024	65	35-42	74.8	49.4	8.1	3.5	3.5	...	...	...	...	...	...	...	...	...	11.5	...	...
38	41°34'00"	82°12'00"	1233	51	47-51	75.0	63.0	8.5	...	7.7	...	...	...	...	...	...	...	...	...	10.0	...	...
39	41°30'00"	82°12'00"	1319	41	None	77.0	74.5	8.9	8.5	5.8	...	...	...	...	...	...	...	...	...	6.5	...	...
40	41°29'00"	82°12'00"	1459	34	None	77.8	76.0	9.3	8.9	8.7	...	...	...	...	...	...	...	...	...	5.0	...	...
57	41°34'00"	81°37'00"	0750	38	None	76.0	75.5	8.3	8.4	8.8	0	4	5	90	92	90	7.6	8.8	8.8	7.5	305	275
56	41°37'10"	81°37'00"	0830	50	None	75.0	73.0	8.3	7.5	7.3	5	4	5	95	90	95	8.8	8.8	8.8	18.0	262	264
55	41°42'40"	81°37'00"	0900	65	50-55	75.0	56.5	8.8	0.3	0.0	7	0	0	96	93	95	8.8	7.6	7.6	25.0	272	264
54	41°51'10"	81°37'00"	1000	75	55-70	75.5	54.5	8.8	1.2	0.5	6	4	6	95	98	99	8.8	...	...	20.0	269	274
53	42°00'00"	81°37'00"	1100	80	60-65	75.0	52.0	8.8	1.6	1.1	...	0	0	...	93	93	...	7.6	7.6	30.0	259	261
52	42°08'30"	81°37'00"	1200	80	60-70	75.0	51.5	8.8	3.6	1.9	0	0	0	89	87	95	8.8	7.8	7.6	30.0	260	260
51	42°17'40"	81°37'00"	1300	75	60-65	75.0	53.5	8.8	3.5	1.1	0	0	0	90	91	91	8.2	7.8	7.6	25.0	263	261

(Continued)

Table 3. --(Continued)

Station number	Latitude	Longitude	Time (EST)	Depth at station (feet)	Thermo-cline depth (feet)	Temperature (° F.)		Dissolved oxygen (ppm)			Phenolphthalein alka-linity (ppm $CaCO_3$)			Total alkalinity (ppm $CaCO_3$)			pH			Secchi-disc depth (feet)	Specific conductance ($K_{18} x 10^6$)	
						Surface	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom		Surface	Bottom
50	42°25'10"	81°37'00"	1400	65	50-60	75.0	59.5	8.2	4.4	2.5	0	...	0	89	...	90	8.2	...	7.6	20.0	251	254
49	42°28'20"	81°37'00"	1500	35	None	74.0	73.0	8.1	8.0	7.7	4	3	3	93	92	93	8.4	8.2	8.2	20.0	255	252
73	41°55'00"	80°51'00"	0750	40	None	74.0	74.0	7.6	...	7.6	0	0	6	92	93	98	7.6	7.6	...	18.0	256	255
72	42°00'00"	80°51'00"	0815	68	55-63	74.0	55.0	7.5	6.0	1.3	7	0	0	93	94	95	...	7.5	7.5	19.0	256	256
71	42°08'20"	80°51'00"	0935	72	54-60	73.0	54.0	7.4	1.4	1.4	0	...	0	85	...	82	7.6	7.5	7.6	19.0	247	257
70	42°17'00"	80°51'00"	1030	70	53-58	73.0	53.5	7.4	1.8	1.8	8	0	0	96	96	95	...	7.6	7.6	22.0	247	252
89	42°10'20"	87°03'00"	0700	30	None	74.0	74.0	8.2	...	8.2	0	...	5	96	...	105	7.7	...	...	11.0	261	262
88	42°14'10"	87°03'00"	0756	66	54-60	73.0	60.0	...	...	3.1	...	...	...	...	...	...	7.6	...	7.3	22.0	258	260
87	42°17'20"	87°03'00"	0836	67	54-67	72.0	52.0	9.6	...	4.4	...	...	...	...	...	...	7.6	...	7.3	25.0	258	263
86	42°26'10"	87°03'00"	1017	130	60-90	73.0	44.0	...	...	8.8	...	...	...	...	...	...	7.5	...	7.6	24.0	261	262
84	42°34'00"	87°03'00"	1222	173	66-108	74.0	42.5	8.8	...	8.2	...	...	...	...	...	...	7.7	...	7.5	24.0	257	259
83	42°41'40"	87°03'00"	1355	96	48-66	75.0	48.0	...	...	8.6	...	...	...	...	...	...	8.1	...	7.7	24.5	261	264
82	42°43'10"	87°03'00"	1430	73	54-72	76.0	51.5	...	...	...	...	...	...	...	...	...	8.5	...	7.7	24.5	257	270
81	42°46'30"	87°03'00"	1516	38	30-38	75.0	65.0	...	...	...	...	...	...	...	...	...	8.5	...	8.2	19.0	256	262
100	42°33'20"	79°14'00"	0810	64	None	72.5	71.6	8.4	...	8.4	...	...	...	...	...	...	...	...	...	26.0	266	266
99	42°36'40"	79°14'00"	0903	85	60	72.1	51.8	8.5	7.7	6.0	...	...	...	...	...	...	...	...	...	24.0	270	265
98	42°42'00"	79°14'00"	1028	76	65	72.7	53.6	8.4	...	5.3	...	...	...	...	...	...	...	...	...	29.0	267	265
97	42°49'40"	79°14'00"	1150	60	50	72.7	58.1	8.2	...	1.9	...	...	...	...	...	...	...	...	...	28.0	267	274
96	42°51'20"	79°14'00"	1225	25	None	73.4	71.1	8.4	8.4	8.0	...	...	...	...	...	...	...	...	...	18.0	272	268
96A	42°50'00"	79°24'30"	1355	60	45	72.9	62.1	...	...	7.9	...	...	...	...	...	...	...	...	...	22.0	...	...

Table 4. --Physical and chemical data for Lake Erie, August 31, 1960

[Bottom refers to immediately above the bottom.]

Station number	Latitude	Longitude	Time (EST)	Depth at station (feet)	Thermo-cline depth (feet)	Temperature (° F.)		Dissolved oxygen (ppm)			Phenolphthalein alkalinity (ppm $CaCO_3$)			Total alkalinity (ppm $CaCO_3$)			pH			Secchi-disc depth (feet)	Specific conductance ($K_{18}x10^6$)	
						Surface	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom		Surface	Bottom
1	41°59'30"	83°10'00"	0750	16	None	75.0	73.0	4.8	...	4.3	0	...	0	95	...	96	...	...	...	...	288	264
2	41°51'00"	83°10'00"	0905	30	None	76.5	73.5	7.3	...	3.9	7	...	0	103	...	94	...	...	...	...	245	241
3	41°42'00"	83°10'00"	1100	25	None	77.5	73.0	6.5	...	3.1	10	...	0	107	...	98	...	...	...	...	244	245
4	41°38'30"	83°10'00"	1200	13	None	78.5	75.0	6.2	...	6.2	8	...	4	108	...	101	...	...	...	...	242	249
10	41°58'40"	82°47'00"	0750	35	None	76.0	74.0	7.4	...	6.4	14	...	12	98	...	97	...	...	...	6.0	223	221
11	41°55'20"	82°47'00"	0830	36	None	75.0	74.0	7.6	...	6.8	8	...	3	92	...	92	...	...	...	4.5	219	223
12	41°50'20"	82°47'00"	1000	36	None	76.0	73.5	7.6	...	4.4	3	...	0	87	...	92	...	...	...	4.8	225	229
13	41°42'20"	82°46'20"	1200	35	None	78.0	74.0	6.6	...	6.0	12	...	6	95	...	94	...	...	...	4.8	227	228
14	41°37'20"	82°46'00"	1255	33	None	78.0	75.0	7.6	...	5.8	14	...	6	91	...	94	...	...	...	6.2	233	225
15	41°33'40"	82°47'00"	1355	16	None	78.0	75.0	6.6	...	5.0	11	...	6	93	...	93	...	...	...	4.0	237	233
32	41°26'20"	82°23'00"	0744	30	None	76.0	75.2	7.9	...	6.7	...	...	...	...	...	...	...	...	...	8.0	...	...
31	41°27'10"	82°23'00"	0758	42	None	76.0	74.0	8.8	...	5.8	...	...	...	...	...	...	...	...	...	6.5	...	...
30	41°29'40"	82°23'00"	0821	48	None	76.0	73.5	8.0	...	3.1	...	...	...	...	...	...	...	...	...	8.0	...	...
29	41°33'40"	82°23'00"	0859	48	None	75.8	70.8	9.4	...	4.0	...	...	...	...	...	...	...	...	...	6.5	...	...
28	41°42'20"	82°23'00"	1045	45	None	78.0	71.5	8.5	7.3	4.1	...	...	...	...	...	...	...	...	...	10.0	...	...
27	41°50'40"	82°23'00"	1245	40	None	79.0	72.5	9.0	...	8.2	...	...	...	...	...	...	...	...	...	10.0	...	...
26	41°59'40"	82°23'00"	1445	47	None	77.0	72.0	9.2	...	8.2	...	...	...	...	...	...	...	...	...	15.0	...	...
25	42°03'00"	82°23'00"	1512	41	None	77.0	72.0	8.8	...	7.3	...	...	...	...	...	...	...	...	...	11.5	...	...
24	42°05'20"	82°23'00"	1541	30	None	76.5	71.0	9.2	...	7.0	...	...	...	...	...	...	...	...	...	11.5	...	...
41	42°15'00"	82°00'00"	0750	35	None	76.0	73.0	8.6	8.0	7.7	4	4	2	90	91	92	8.4	8.4	8.4	...	256	253
42	42°11'20"	82°00'00"	0830	57	35-55	76.0	62.0	8.7	7.8	7.8	2	0	0	90	88	89	8.4	7.6	7.6	...	261	258
43	42°08'20"	82°00'00"	0900	65	50-55	75.0	54.5	8.4	3.9	2.4	5	0	0	95	95	95	8.4	7.6	7.6	...	256	260
44	42°00'00"	82°00'00"	1000	75	50-60	75.0	50.5	7.7	1.8	1.2	6	0	0	92	93	95	8.4	7.6	7.6	...	263	260
45	41°51'00"	82°00'00"	1100	75	35-60	76.0	49.5	7.9	7.0	2.8	8	0	0	98	95	95	8.4	7.8	7.6	...	262	259
46	41°42'30"	82°00'00"	1200	74	50-55	76.5	51.0	7.1	5.5	2.0	7	0	0	97	95	94	8.4	7.6	7.6	...	259	261
47	41°33'40"	82°00'00"	1300	53	45-53	76.0	53.0	8.1	0.6	0.7	6	0	0	96	93	92	8.4	7.6	7.6	...	248	261
48	41°32'00"	82°00'00"	1445	30	None	77.0	76.0	8.9	7.6	7.8	6	7	6	96	97	94	8.4	8.4	8.4	...	255	264

(Continued)

Table 4. --(Continued)

Station number	Latitude	Longitude	Time (EST)	Depth at station (feet)	Thermo-cline depth (feet)	Temperature (°F.)		Dissolved oxygen (ppm)			Phenolphthalein alkalinity (ppm $CaCO_3$)			Total alkalinity (ppm $CaCO_3$)			pH			Secchi-disc depth (feet)	Specific conductance ($K_{18} x 10^6$)	
						Surface	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom		Surface	Bottom
74	42°33'00"	80°26'00"	0915	39	None	73.5	72.0	...	...	...	...	...	...	...	...	...	8.4	...	8.2	10.0	255	254
75	42°29'20"	80°26'00"	1000	50	48-50	74.0	66.0	...	...	...	...	...	...	...	...	...	8.6	...	8.5	19.5	254	253
76	42°24'30"	80°26'00"	1030	77	66-77	74.0	48.0	...	...	5.3	...	...	...	...	...	...	8.5	...	7.9	21.0	255	259
77	42°15'20"	80°26'00"	1148	66	48-66	73.0	60.0	9.7	...	8.5	...	...	...	...	...	...	8.5	...	8.5	21.0	257	261
78	42°07'00"	80°26'00"	1245	45	None	73.0	67.0	8.8	...	9.5	...	...	...	...	...	...	8.3	...	8.6	21.5	255	254
80	42°02'40"	80°26'00"	1330	40	None	73.5	71.0	...	...	...	...	...	...	...	...	...	8.3	...	8.2	...	260	257
90	42°49'30"	79°37' 00"	0720	35	None	72.5	72.5	8.0	...	8.0	...	...	...	...	...	...	...	...	...	22.0	275	265
91	42°46'00"	79°37'00"	0819	85	68	72.7	48.9	8.2	4.7	5.2	...	...	...	...	...	...	...	...	...	27.0	267	272
92	42°41'30"	79°37'00"	0920	103	65	72.7	46.9	8.5	7.2	3.4	...	...	...	...	...	...	...	...	...	28.0	246	268
93	42°33'00"	79°37'00"	1100	166	65	73.8	40.8	8.4	6.6	8.9	...	...	...	...	...	...	...	...	...	30.0	270	271
94	42°24'30"	79°37'00"	1244	122	60	71.1	43.0	8.4	7.2	7.7	...	...	...	...	...	...	...	...	...	29.0	265	265
95	42°20'30"	79°37'00"	...	30	...	...	...	8.0	...	8.2	...	...	...	...	...	...	...	...	...	22.0	279	265

Table 5.--Physical and chemical data from Station 37 in Lake Erie, 1960

[Latitude 41°42'00"N, Longitude 82°12'00"W. Depth at station, 60 feet. Bottom refers to immediately above the bottom.]

Date and time (EST)	Thermocline depth (feet)	Temperature (°F.)		Dissolved oxygen (ppm)		Phenolphthalein alkalinity (ppm $CaCO_3$)			Total alkalinity (ppm $CaCO_3$)			pH			Secchi-disc depth (feet)	Specific conductance ($K_{18} x 10^6$)	
		Surface	Bottom	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom	Surface	Below thermocline	Bottom		Surface	Bottom
August 30																	
0750	40-45	72.5	50.1	0.7	1.0	10	0	0	99	93	85	8.4	7.0	7.0	12	...	...
0810	41-45	72.5	50.2	0.6	0.6	6	0	0	88	98	100	8.4	7.0	7.0	12	...	...
0830	39-45	72.5	50.1	0.7	0.7	5	0	0	100	100	95	8.4	7.0	7.0	13	...	...
0900	39-44	72.5	50.2	0.8	2.0	6	0	0	98	103	100	8.4	7.0	7.0	13	...	...
1000	39-42	73.0	50.2	1.3	2.4	5	0	0	98	100	98	8.4	7.0	7.0	13	...	...
1100	39-45	73.0	50.1	1.5	1.8	6	0	0	100	101	102	8.4	7.0	7.0	13	...	...
1200	39-43	73.8	50.1	1.9	2.0	3	0	0	102	99	109	8.4	7.0	7.0	13	253	247
1300	39-45	73.8	50.2	4.0	1.5	5	0	0	104	103	103	8.4	7.2	7.0	13	...	...
1400	40-45	74.3	50.6	3.2	2.0	5	0	0	100	106	104	8.4	7.2	7.0	12	...	...
1500	39-44	74.2	50.2	3.2	2.9	8	0	0	102	105	95	8.4	7.2	7.0	12	...	...
1600	39-42	74.2	50.5	2.6	2.9	2	0	0	94	101	100	8.4	7.2	7.0	13	244	255
1700	35-43	75.0	50.6	3.2	2.0	2	0	0	94	95	98	8.4	7.2	7.0	12	...	...
1800	41-45	74.2	51.0	1.7	1.2	1	0	0	91	95	101	8.4	7.0	7.0	...	...	...
1900	40-44	74.0	51.0	0.9	0.8	4	0	0	94	78	77	...	...	...	...	...	...
2000	41-44	74.0	50.9	0.9	0.9	1	0	0	88	102	94	8.4	7.2	7.2	...	247	251
2100	40-44	74.0	50.8	2.7	1.0	4	0	0	103	100	100	...	...	...	...	...	...
2200	40-45	73.8	51.1	0.5	0.9	8	0	0	99	105	100	...	...	...	...	...	...
2300	41-47	73.6	51.1	0.9	0.9	2	0	0	92	80	86	8.4	7.2	7.2	...	...	...
August 31																	
0000	44-46	73.5	51.1	2.6	1.1	5	0	0	100	105	106	8.4	7.4	7.2	...	253	250
0100	42-45	73.3	51.0	4.7	1.1	8	0	0	101	105	107	8.9	7.4	7.2	...	...	...
0200	42-46	73.2	50.8	1.9	1.4	4	0	0	107	100	103	...	...	...	...	...	...
0300	42-46	73.1	51.1	3.0	1.2	5	0	0	105	105	107	8.6	7.3	7.1	...	...	...
0400	41-44	73.3	51.0	3.6	0.7	5	0	0	109	107	104	...	...	...	...	243	254
0500	44-46	73.1	51.0	0.8	1.1	4	0	0	106	98	97	8.5	7.2	7.1	...	...	...

(Continued)

Table 5.--(Continued)

Date and time (EST)	Thermocline depth (feet)	Temperature (°F.) Surface	Temperature (°F.) Bottom	Dissolved oxygen (ppm) Below thermocline	Dissolved oxygen (ppm) Bottom	Phenolphthalein alkalinity (ppm $CaCO_3$) Surface	Phenolphthalein alkalinity (ppm $CaCO_3$) Below thermocline	Phenolphthalein alkalinity (ppm $CaCO_3$) Bottom	Total alkalinity (ppm $CaCO_3$) Surface	Total alkalinity (ppm $CaCO_3$) Below thermocline	Total alkalinity (ppm $CaCO_3$) Bottom	pH Surface	pH Below thermocline	pH Bottom	Secchi disc depth (feet)	Specific conductance ($K_{18}x10^6$) Surface	Specific conductance ($K_{18}x10^6$) Bottom
0600	41-46	73.1	51.0	0.8	1.1	5	0	0	105	97	95	...	...	...	...	...	...
0700	42-50	73.0	51.0	3.2	0.7	5	0	0	99	99	98	8.4	7.4	7.0	...	...	...
0750	40-51	73.2	51.3	4.7	0.8	1	0	0	94	95	92	8.4	7.2	7.1	12	245	253
0810	40-46	73.1	51.0	1.0	0.8	11	0	0	101	103	101	...	...	...	14	...	...
0830	42-45	73.1	51.0	1.0	0.6	5	0	0	100	103	100	8.6	...	...	14	...	...
0900	40-46	73.2	51.0	0.6	0.5	9	0	0	102	102	100	8.6	...	...	14	...	...
1000	42-46	73.8	51.1	0.3	0.5	2	0	0	96	101	100	8.5	...	...	14	...	...
1100	42-45	74.5	51.0	2.2	0.4	3	0	0	96	99	98	...	...	...	13	...	...
1200	42-45	76.0	51.0	0.9	0.6	7	0	0	95	102	100	...	...	...	13	247	253
1300	42-45	78.0	51.4	0.4	0.3	3	0	0	96	101	98	...	...	...	12	...	...
1400	42-43	79.0	51.4	0.5	0.2	3	0	0	98	99	100	...	...	...	12	...	...
1500	43-45	80.0	51.5	0.4	0.3	4	0	0	95	99	100	...	...	...	14	242	250

Table 6. - Physical and chemical data from Station 35A in Lake Erie, 1960

[Latitude 42°04'00"N, longitude 82°12'00"W. Depth at station 62-65 feet. Bottom refers to immediately above the bottom.]

Date and time (EST)	Thermo-cline depth (feet)	Temperature (° F.)		Dissolved oxygen (ppm)			Secchi-disc depth (feet)
		Surface	Bottom	Surface	Below thermocline	Bottom	
August 30							
0750	50-56	75.2	50.6	7.8	1.0	0.7	24.5
0825	50-56	75.3	50.8	...	...	...	24.5
0900	50-56	75.2	51.5	6.5	1.0	0.6	23.0
1000	50-56	76.1	50.8	...	...	...	23.0
1100	50-56	75.2	50.3	...	...	...	23.0
1200	50-57	75.9	50.5	...	...	...	23.0
1300	50-56	77.0	50.8	7.9	0.9	0.8	21.0
1400	50-55	77.0	50.5	...	...	...	21.0
1500	50-57	77.0	51.0	...	...	...	21.0
1600	50-58	77.0	51.0	...	...	...	21.0
1700	50-56	77.0	50.6	8.1	1.0	0.6	19.5
1800	50-56	77.0	50.8	...	...	...	19.5
1900	50-56	76.1	51.0	...	...	...	...
2000	50-56	75.9	50.6	...	...	...	...
2100	49-57	74.8	51.0	8.4	1.1	0.9	...
2200	50-57	74.3	51.0	...	...	...	...
2300	50-57	74.3	51.0	...	...	...	...
August 31							
0000	50-57	74.3	51.0	...	...	...	...
0100	50-58	72.3	51.3	a.2	1.0	...	...
0200	50-57	75.2	51.0	...	...	...	...
0300	50-58	75.2	51.0	...	...	...	...
0400	50-57	75.2	51.0	...	...	...	...
0500	51-58	73.4	51.0	8.1	0.8	0.4	...
0600	50-58	75.2	51.1	...	...	...	...
0700	50-57	74.3	51.0	...	...	...	...
0750	50-57	74.3	51.0	8.3	0.6	0.4	...
0810	50-57	74.3	51.2	...	...	...	...
0830	50-57	74.7	51.1	...	...	...	...
0900	50-57	74.9	51.0	...	...	...	...
1000	50-58	75.2	50.6	8.1	1.4	1.2	...
1100	50-56	76.8	50.0	...	...	...	...
1200	50-57	77.0	50.5	...	...	...	...
1300	50-58	77.0	51.3	...	...	...	...
1400	50-57	77.3	51.0	8.1	1.0	0.8	...
1500	50-56	77.3	51.0	...	...	...	...

Table 7. - Physical and chemical data collected in central Lake Erie by the C.M.S. Porte Dauphine, August 30-31, 1960

[Bottom refers to immediately above the bottom.]

Station number	Date and time (EST)	Latitude (North)	Longitude (west)	Depth at station (feet)	Thermocline depth (feet)	Temperature (° F.) Surface	Temperature (° F.) Bottom	Dissolved oxygen at surface (Ppm)
	August 30							
1D	0100	41°58'00"	81°53'00"	89	63-75	74.5	51.0	6.8
2D	0130	41 55 48	81 52 00	83	63-75	74.5	51.9	...
3D	0200	41 53 18	81 50 42	84	63-75	74.5	50.6	5.7
4D	0230	41 50 48	81 49 30	85	60-74	74.5	50.0	...
5D	0300	41 48 36	a1 48 30	85	60-70	74.5	49.5	6.9
6D	0330	41 46 18	81 46 30	83	58-65	74.5	51.5	...
7D	0400	41 43 42	81 45 42	82	56-65	74.3	51.3	7.1
8D	0430	41 41 30	81 44 00	78	56-75	74.0	53.0	...
9D	0500	41 38 42	81 42 00	68	55-60	74.0	56.0	7.0
10D	0530	41 37 18	81 41 30	59	50-59	74.0	60.1	...
11D	0600	41 34 30	81 40 30	55	40-47	74.3	72.3	6.7
12D	0630	41 34 36	81 37 42	50	...	74.0	73.8	...
13D	0700	41 37 42	81 33 48	40	...	74.0	74.0	7.1
14D	0730	41 40 48	81 27 18	50	...	74.0	74.0	...
15D	0800	41 43 30	81 23 00	40	...	75.0	75.0	7.6
16D	0830	41 46 54	81 17 18	62	...	75.0	74.0	...
17D	0900	41 49 06	81 12 42	54	40-54	74.3	65.0	7.1
18D	0930	41 51 12	a1 14 00	73	50-65	74.2	55.5	...
19D	1000	41 53 42	81 15 36	75	55-65	74.3	55.0	7.2
20D	1030	41 55 36	81 16 42	82	50-70	74.0	54.2	...
21D	1100	41 59 18	81 17 36	85	55-65	74.0	54.0	5.6
22D	1130	42 01 42	81 18 12	85	50-70	74.2	53.5	...
23D	1200	42 03 54	81 20 00	85	55-75	74.5	53.0	7.3
24D	1230	42 06 24	81 21 12	85	55-75	74.5	53.0	...
25D	1300	42 08 45	81 22 30	85	58-70	74.5	54.5	7.6
26D	1330	42 11 25	81 23 50	86	65-80	74.9	56.0	...
27D	1400	42 14 00	81 25 00	86	65-80	75.0	57.0	8.1
28D	1430	42 16 20	81 26 15	85	70-80	75.0	63.0	8.1
29D	1500	42 18 50	81 27 20	85	75-85	75.0	64.5	8.9
30D	1530	42 19 45	81 23 30	83	77-80	75.0	68.0	...
31D	1600	42 21 40	81 19 00	81	65-80	75.2	78.0	5.9
32D	1630	42 23 50	81 13 15	80	70-80	75.1	65.0	...
33D	1700	42 24 00	81 10 54	77	60-75	75.1	64.2	7.6
34D	1730	42 21 18	81 06 06	74	65-74	75.0	62.0	...
35D	1800	42 19 00	81 05 18	76	65-76	75.0	62.2	7.1
36D	1830	42 17 18	81 04 24	78	65-75	74.9	59.0	...
37D	1900	42 15 36	81 03 54	78	65-78	74.9	58.0	6.5
38D	1930	42 14 12	81 03 36	80	65-75	74.8	57.0	...
39D	2000	42 12 06	81 03 00	75	65-70	74.3	58.0	6.5
40D	2030	42 10 00	81 01 42	78	65-75	74.2	59.0	...
41D	2100	42 07 18	a1 01 00	78	63-70	74.2	57.0	7.5
42D	2130	42 05 12	80 59 48	78	65-75	74.2	56.0	...
43D	2200	42 03 36	80 58 54	78	65-75	74.2	55.0	7.5
44D	2230	42 01 06	80 57 48	78	65-72	74.2	54.2	...
45D	2300	41 58 36	80 57 00	75	56-70	74.2	52.0	7.1
46D	2330	41 56 42	80 56 48	67	52-67	74.2	55.5	...
	August 31							
47D	0000	41 54 12	80 55 18	64	...	74.5	70.5	6.7
48D	0030	41 55 35	80 51 50	58	50-56	74.1	66.0	...
49D	0100	41 46 45	80 49 25	62	50-58	74.4	59.5	7.8
50D	0130	41 59 05	80 49 30	73	60-70	74.0	54.9	...

(Continued)

Table 7. - (Continued)

Station Number	Date and time (EST)	Latitude (North)	Longitude (West)	Depth at Station (feet)	Thermo-cline depth (feet)	Temperature (° F.)		Dissolved oxygen at surface (ppm)
						Surface	Bottom	
51D	0200	42°01'05	80°51'00"	76	60-70	74.0	54.8	7.5
52D	0230	42 03 50	80 51 45	77	58-72	74.0	56.5	. .
53D	0300	42 06 30	80 52 30	80	60-75	73.9	54.0	7.9
54D	0330	42 OS 12	80 53 24	78	55-70	73.7	54.0	...
55D	0400	42 11 18	80 54 30	76	55-70	73.5	53.0	7.0
56D	0430	42 13 36	80 55 30	74	60-70	73.5	54.5	...
57D	0500	42 16 00	80 56 15	77	50-70	73.5	55.0	7.0
58D	0530	42 18 00	80 57 00	75	60-71	73.5	55.0	...
59D	0600	42 20 30	80 58 15	76	65-70	73.7	55.8	7.6
60D	0630	42 22 30	80 59 18	74	55-65	73.5	57.0	...
61D	0700	42 25 00	81 00 00	70	60-66	73.4	57.2	6.8
62D	0730	42 27 54	81 01 24	68	60-68	73.4	59.2	...
63D	0800	42 30 24	al 02 06	65	57-65	73.4	62.0	7.4
64D	0830	42 32 30	81 03 24	60	55-60	73.2	63.0	. .
65D	0900	42 35 06	al 04 06	54	48-54	73.4	63.0	7.1
66D	0930	42 37 12	al 05 00	40	35-40	73.6	68.6	. .
67D	1000	42 37 42	al 01 54	34	...	73.2	73.1	6.9
68D	1030	42 37 36	80 58 24	35	...	74.2	72.0	...
69D	1100	42 37 00	80 56 12	49	42-49	74.2	63.0	7.7
70D	1130	42 34 30	80 55 30	61	50-56	74.4	60.0	...
71D	1200	42 32 00	80 53 42	71	50-60	75.3	61.0	8.1
72D	1230	42 30 00	80 54 00	78	55-60	75.9	60.0	...
73D	1300	42 27 00	80 53 00	78	55-65	76.5	58.0	7.4
74D	1330	42 25 00	80 52 12	90	60-70	76.9	56.0	...
75D	1400	42 22 00	80 51 la	80	60-70	77.5	54.8	7.7
76D	1430	42 26 06	80 50 42	82	60-68	77.3	53.0	. .
77D	1500	42 30 30	80 49 30	80	55-60	76.3	62.0	7.1
78D	1600	42 32 30	80 49 06	60	55-57	76.0	61.2	7.8
78D	1700	42 32 30	80 49 06	65	51-57	76.0	61.0	6.9
78D	1800	42 32 30	80 49 06	60	49-56	76.7	60.8	7.9
78D	1900	42 32 30	80 49 06	59	50-55	75.5	60.5	7.0
78D	2000	42 32 30	80 49 06	60	50-55	75.1	60.1	8.2
78D	2100	42 32 30	80 49 06	60	52-55	75.1	60.8	7.9
78D	2200	42 32 30	80 49 06	60	50-55	75.0	60.5	6.9
78D	2300	12 32 30	80 49 06	60	50-56	74.6	61.0	7.7

The closeness of the thermocline to the bottom made it difficult to obtain water samples from the hypolimnion for dissolved-oxygen determinations.

Some slight changes were measured in water temperatures near the bottom at Stations 35A and 37 over 30 hours. No significance can be attached to these changes, however, since they were inconsistent and the depth of the thermocline remained stable at both stations throughout the observation period.

Specific conductance at the surface. - The specific conductance of the surface waters ranged from 213 to 305 μmhos. The values were lowest in the western basin. The higher values were at several stations near shore, especially off river mouths. The highest conductivity (305 μmhos) was at Station 57 (Figure 2) northeast of Cleveland; it probably reflects the outflow of the Cuyahoga River. Values were high also at Station 90 (275 μmhos) off the mouth of the Grand River, Station 96 (272 μmhos) off Port Colborne, and at Station 95 (Tables 3 and 4).

The lowest conductivity was in the main outflow of the Detroit River, i.e., the outflow from midchannel. This mass of low-conductivity water (about 220 μmhos) fanned out in a southeasterly direction from the river mouth and roughly followed the distribution of surface temperatures. Conductance probably was higher along both shores at the river mouth since the conductivities at Stations 1 and 5 were 288 and 233 μmhos (Tables 3 and 4).

Sampling in this area by the Bureau of Commercial Fisheries since the 1960 synoptic survey has shown that the waters in the shipping channel have much lower conductivity than waters along both shores. The International Joint Commission (1951) reported a similar distribution of chlorides during its 1946-48 survey.

The conductivity of surface waters among the islands averaged around 225 mhos. Thiswater probably extended southeast from the islands to Station 20 (Figure 2). Conductivity was higher (241-245 μmhos) in waters of the Maumee Bay area extending from the vicinity of Monroe to Station 7 (Figure 2).

The specific conductance of surface waters in most of central basin was around 250 μmhos, although a large mass of water with conductivity of 260 to 272 μmhos occupied the area between Cleveland and Erieau.

A low specific conductance of 246 μmhos at Station 92 in the eastern basin probably indicated the presence of a lens of low-conductivity water, since the conductivity increased in all directions from this station.

The distribution of surface temperatures and conductivity values did not coincide in the central and eastern basins.

Specific conductance of *subsurface waters.* -The distribution of the conductivity of the subsurface waters agreed in general with that described for surface waters. Such differences as did exist between the conductivity of surface and bottom waters usually were so slight as to be attributable to error in measurement. An average of all specific-conductance measurements made on subsurface water samples was 253 μmhos. An identical average was obtained for the surface waters.

The distribution of the conductivity of bottom waters differed from that of the surface waters in two ways. The highest conductivity values were not off rivers except for Station 57 near Cleveland (Table 3). The specific conductance of 275 μmhos at this station was the highest recorded for bottom waters, but nevertheless it was lower than the 305 μmhos at the surface. Evidently the river waters and their associatedhigher conductivity were warmer than the lake and flowed out into the surface layer. The distribution of subsurface water of higher conductivity in the eastern basin was different from that described for the surface waters. The highest values (268-271 μmhos) were in the deepest waters including the areas where values were low at the surface. It appears that a mass of high-conductivity water occupied most of the basin but had an isolated lens of lower conductivity surface water floating in its midst. The distribution of the high-conductivity water approximated the distribution of the cooler waters. A tongue of this water extended into the central basin to Station 77 north of Conneaut (Figure 2).

Total alkalinity at the surface. - All of the vessels did not make determinations for total alkalinity (ppm $CaCO_3$), and the accuracy of the method employing the methyl-orange indicator does not permit attaching any significance to differences of a few parts per million. Nevertheless, data for the western basin and most of the central basin (Tables 3, 4, and 5) appear to show some differences.

Values were low-95 ppm or less--in the Detroit River outflow extending into the island region. Values were higher, 100 ppm or greater, in the Maumee Bay area including Station 2A near Monroe which had a high of 114 ppm and extending almost to Marblehead to Stations 8 and 9 (Figure 2). In general the distribution of alkalinity agreed with that described for surface conductivity.

Most of the total alkalinity values in the central basin were around 95 ppm. An area with concentrations of around 90 ppm extended from the north shore near Erieau out to and including Stations 42 and 52 (Tables 3 and 4).

Total alkalinity of subsurface waters. -Total alkalinity concentrations in most of the western basin ranged from 92 ppm to 97 ppm. Values were slightly higher (98 ppm to 109 ppm) in the Maumee Bay area. A low value of 78 ppm occurred at Station 7 immediately west of the Bass Islands. Concentrations of 84 ppm were determined at Stations 18 and 19 just east of Pelee Island.

Total alkalinity ranged from 82 ppm to 107 ppm in the central basin, but most of the values were around 95 ppm. Concentrations were greater than 100 ppm off of Marblehead and Erie at Stations 21, 23, and 89 (Table 3).

Phenolphthalein alkalinity at *the surface.* -Phenolphthalein alkalinity (less than 4 ppm as calcium carbonate) was low in the main outflow of the Detroit River. These values generally were low where conductivity and temperature were low. Values were higher (8-11 ppm) off Monroe and east of Maumee Bay at Stations 2A, 3, and 4 (Tables 3 and 4, Figure 2). The highest values (12-14 ppm) were in the vicinity of the islands.

The distribution of specific conductance and phenolphthalein alkalinity in the central basin generally agreed. The highest concentrations were usually in water where the specific conductance was 260 μmhos or greater. Values ranged from 5 to 8 ppm along the southern shore and from 2 to 4 ppm near the northern shore. Isolated low values at several points on the southern shore (off Cleveland, Ashtabula, and Erie) seemed to occur in the outflow from rivers and harbors.

Phenolphthalein alkalinity in subsurface waters. - Phenolphthalein alkalinity was present in subsurface waters at only a few stations where the water was not stratified thermally. Phenolphthalein changes color at a pH of 8.3. The pH of most bottom-water samples from stratified areas was 8.0 or less. In general the pH was around 8.4 in the surface waters and decreased to 8.0 or less immediately below the thermocline (Tables 3 and 4). Evidently Detroit River water near the bottom in the western basin also had a pH less than 8.3, since the bottom waters extending from the mouth of the river and into the central basin did not have any phenolphthalein alkalinity. Phenolphthalein alkalinity of 6 ppm occurred at Stations 13-15 among the islands and in Pigeon Bay at Stations 16 and 17 (Figure 2, Tables 3 and 4). A high value of 12 ppm was recorded at Station 10 in Pigeon Bay off Kingsville, Ontario. Concentrations were 5 to 10 ppm along the southern shore at Stations 23, 46, 56, 57, and 73 (Tables 3 and 4).

Hydrogen-ion concentration.--The data on distribution of pH are incomplete, since all vessels did not make determinations.

Most of the pH measurements were on waters from the central basin. The accuracies of the various instruments used for the determinations were not the same, but nevertheless some general conclusions can be drawn.

The pH of the surface waters ranged from 7.5 to 8.8 and averaged *8.2*. The lowest values in the central basin were near shore, usually in homothermous water, off Ashtabula, Cleveland, and Erieau. Most of the surface waters in the central basin had a pH of 8.2 to 8.8.

The hypolimnetic waters had an average pH of about 7.6. The pH of the bottom waters at Stations 74-80 ranged from 7.9 to 8.6. These stations were all on or in the immediate vicinity of the shoal which extends from near Erie to about the middle of Long Point. The water depth above the shoal is 42 to 48 feet whereas the water depth on either side of the shoal is 66 to '78 feet. Consequently, the thermocline extended almost to or to the bottom at these stations and a true hypolimnion did not exist. Therefore, the pH of the bottom waters was almost the same as that measured at the surface (Table 4).

The pH of the surface waters (average 7.9) in the eastern basin was only slightly higher than that of the hypolimnetic waters (average 7.6).

Dissolved oxygen.-Several observations were made of dissolved-oxygen concentrations in the bottom waters prior to the 1960 synoptic survey. The Bureau of Commercial Fisheries found dissolved-oxygen concentrations of only 0.5 ppm in an area about 2 miles east of Marblehead on July 12. On June 14 the concentration had been 6.6 ppm. This area is where Wright (1955) found a low concentration of 0.8 ppm in 1930. The Ohio Division of Wildlife reported dissolved-oxygen concentrations of 2 ppm east of Kelleys Island on July 13. Concentrations of 1.1 ppm and 0.4 ppm occurred in water 50 feet deep off Vermilion July 27 and August 5 (personal communication). The decrease in the dissolved-oxygen content of the bottom waters apparently was less rapid near the north shore of the central basin. The Ontario Department of Lands and Forests established a station 10 miles from Wheatley, Ontario, on a course of 95°. The dissolved-oxygen concentration in the hypolimnion decreased from 8.1 ppm on July 7 to 6.8 ppm on July 21 to 5.7 ppm on August 5, and was 2.6 ppm on August 18 (personal communication).

The average dissolved-oxygen content of the waters in the island area of the western basin was similar to that in 1959. The percentage saturation of dissolved oxygen in the surface waters was 92 percent (dissolved oxygen at an average concentration of 7.3 ppm and a temperature of 77° F.). An average dissolved-oxygen content of 6.0 ppm at a temperature of 74.1° F. gave a saturation of 73 percent for the bottom waters at Stations 10-17 (Tables 3 and 4).

The shallow waters west of the islands had relatively low dissolved-oxygen content (Figure 4). The average concentration in the surface water was 5.8 ppm and 72 percent saturated at an average temperature of 75.9° F. Despite the lack of thermal stratification, the temperatures showed a gradual decrease from an average of 75.9° F. at the surface to an average of 73.5° F. at the bottom, the average dissolved-oxygen content of the bottom waters was only 4.7 ppm at Stations 1-9, 1A, and 2A (Tables 3 and 4). At 73.5° F. this gave a saturation of only 57 percent. Even the waters in or near the mouth of the Detroit River had dissolved-oxygen concentrations of only 4 to 5 ppm despite the considerable mixing characteristic of this area.

The surface waters of the central basin were supersaturated at 102 percent--average dissolved-oxygen content of 8.3 ppm and an average temperature of 75.3° F. Percentage saturation of dissolved oxygen ranged up to 117 percent at Stations 27, 35, 39, and 40 (Tables 3 and 4).

The average dissolved-oxygen concentration in the bottom waters at all the stations in the central basin was 4.8 ppm. At an average temperature of 64.80 F. this value represents a saturation of 54 percent. The average percentage saturation for those stations that were thermally stratified was 28 percent (average dissolved-oxygen concentration 2.8 ppm, temperature 54.7° F.). The oxygen minima was always near the bottom throughout the central basin.

The dissolved-oxygen conditions of the bottom waters in 1960 and of 1959 showed several differences. The size of the areas included by the 3 ppm contours was approximately the same in both years (Figures 3 and 4). The area of lowest concentration was farther to the east in 1960, however, than in 1959. The lowest dissolved-oxygen concentrations were near the southern shore between Avon Point and Ashtabula in 1960, whereas the lowest concentrations in 1959 were between Marblehead and Cleveland. Only Stations 54 and 55 (Table 3) had dissolved-oxygen concentration of 0.5 ppm or less in 1960, although nine stations had concentrations around 1.0 ppm (Tables 3-6). Consequently, a 0.5 ppm contour was not drawn for the 1960 data.

The area immediately east of Marblehead, where very low dissolved-oxygen concentrations have been found repeatedly (only 0.5 ppm was reported on July 12), had concentrations of 4 to 5 ppm. It is likely, however, that the distribution of the

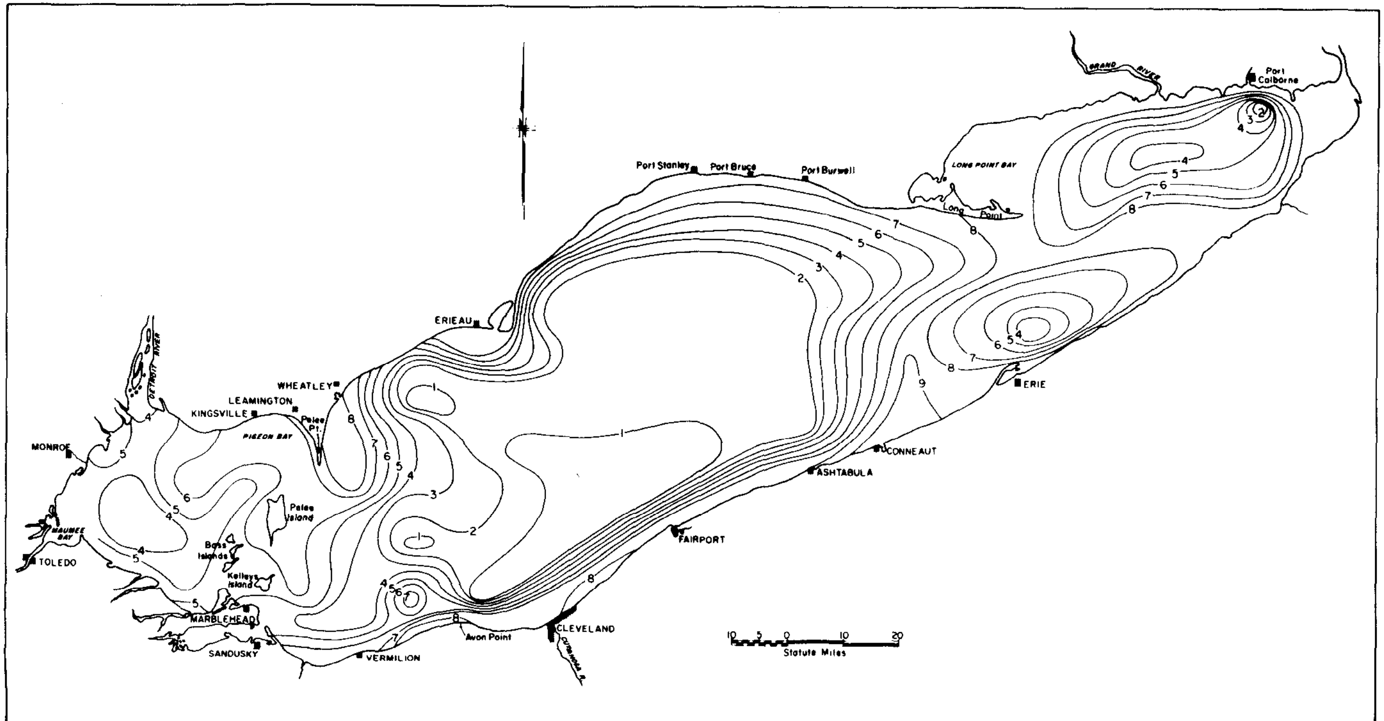

Figure 4. - Distribution of dissolved oxygen in the bottom waters of Lake Erie, 1960.

water with low dissolved-oxygen content does not necessarily indicate areas in which deoxygenation occurs. The oxygen-deficient water mass situated off of Cleveland and Fairport (Figure 4) may have originated farther west to be displaced by the inflowing river water and the seiches, which are especially pronounced in Lake Erie. The occurrence of dissolved-oxygen concentration of 1 ppm or less off Vermilion in late July and early August provides some evidence for this speculation.

Dissolved-oxygen concentrations in the surface waters of the eastern basin were closely similar to those of the central basin and averaged 8.4 ppm at an average temperature of 73.2° F. Consequently, the percentage saturation was 102 percent. The dissolved-oxygen content of the bottom waters of the eastern basin was greater, however, than in the central basin. The average oxygen content of the hypolimnetic waters was 6.1 ppm, giving a saturation of 59 percent at an average temperature of 51.9° F. (Tables 3 and 4). Dissolved-oxygen concentrations were less than 4 ppm only at Stations 88 and 97, off Port Colborne and Erie (Figure 4, Table 3).

The few determinations of the dissolved-oxygen content of waters immediately below the thermocline in the eastern basin at Stations 91, 93, and 94 offer evidence of a dissolved-oxygen minimum in this layer (Table 4). The depth of the thermocline ranged from 60 to 68 feet at these stations. These depths correspond to maximum depths at stations in the central basin where the lowest oxygen concentrations were near the bottom. It is likely that this occurrence of an oxygen minimum immediately below the thermocline represents a movement into this zone of bottom waters from the central basin. On the other hand, this minimum could have developed in situ due to respiration of various organisms and the oxidation of organic matter settled out from the epilimnion.

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