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LAKE SUPERIOR BATHYTHERMOGRAPH DATA: 1973-79

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FIGURES

TABLES

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Temperature surveys were made across an east-west transect of Lake Superior during the 1973, 1974, 1975, and 1976 winter seasons and the 1976, 1977, 1978, and 1979 autumn seasons. A portable bathythermograph recorder measured water temperatures along the transect to a maximum depth of 200 m. There were 46 temperature surveys made, with an average of 24 temperature profile measurements per survey. This report presents tabulations of 39 of the 46 temperature surveys, along with isothermal contour charts portraying the thermal structure of the lake and station position charts showing the location of each temperature profile for all 46 surveys. Temperature tabulations from the 1973 and 1974 winters were published in a previous report.

1. INTRODUCTION

This report presents water temperature survey data collected across Lake Superior over portions of four winter and four autumn seasons. The data were collected by the Great Lakes Environmental Research Laboratory (GLERL) as part of the Congressionally funded Demonstration Program to Extend the Navigation Season on the Great Lakes and St. Lawrence Seaway (1972-79).

A portable bathythermograph recording system using expendable bathythermograph probes was used aboard U.S. Steel Corporation ore carriers to obtain water temperature profile measurements along an east-west transect of the lake. Included here are tabulations of water temperature profiles for the 1975 and 1976 winter seasons and for the 1976, 1977, 1978, and 1979 autumn seasons. Water temperature survey data for the 1973 and 1974 winter seasons can be found in an earlier report (Leshkevich, 1975).

In addition to the tabular data, charts showing the number and locations of temperature profile stations and isothermal contour charts illustrating the thermal structure of the lake are also presented. These tabular data and charts are given in microfiche appendices located in the back of this report. One example of the data in each of the three appendices is given in the report.

2. DATA COLLECTION

Temperature surveys were made across Lake Superior at 2-week to 1-month intervals. Twenty-one surveys were made during the four winters of 1973 through 1976, and 25 surveys during the four autumns of 1976 through 1979. The objective of the winter surveys was to document water temperature decline from the end of the fall overturn period to as late in the winter or early

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spring as possible. Winter surveys were started the last half of December and continued to the end of March in 1975 and to the end of April in 1976. During the 1973 and 1974 winters, surveys were discontinued in January and by the first of February, respectively.

The autumn temperature surveys were made to document the water temperature decline from late summer, when the surface water temperature was at its maximum, to the end of the fall overturn period, when the entire water column was isothermal at approximately 4°C. Autumn surveys were initiated in August and completed in December, with the exception of 1977 when a shipping strike and equipment problems delayed the first temperature survey until October of that year.

Temperature surveys were usually made along regular commercial shipping routes between Sault Ste. Marie, Mich., at the east end of the lake and Duluth or Two Harbors, Minn., at the west end. (See fig. 1.) In bad weather, ships would alter these routes and follow the lee shore of the lake. Scientists conducting the surveys usually boarded commercial vessels at Sault Ste. Marie for a round trip across the lake. The temperature survey normally took 2-4 days to complete. During some surveys, temperature measurements were completed in the east-to-west crossing of the lake, while on other surveys half the lake was covered in the westward crossing and the other half of the lake in the eastward (return) crossing. In a few cases, complete surveys were made on both transits across the lake. A temperature profile measurement was usually made once an hour, with an average of 24 profile measurements per survey. The average distance between profiles was 25.5 km. Table 1 summarizes the dates of temperature surveys, the number of temperature profile measurements, and the average distance between profile measurements.

A Sippican model MK2A-1 portable bathythermograph recorder, modified for shallow water (200 m), and a hand-held launcher and Sippican T-10 expendable temperature probes were used to measure and record the water temperature profile at each measurement location. The temperature accuracy of this system is ± 0.2°C and the depth accuracy is ± 2 percent of the depth or 4.57 m, whichever is greater.

3. DATA REDUCTION AND PRESENTATION

Analog strip charts of water temperature profile traces were tabulated during each survey. These data were later keypunched, and a computer disk file was created for each survey across Lake Superior. Temperature files consist of water temperature to the nearest 0.1°C for every meter of depth from the surface to lake bottom or 200 m, whichever is least.

The ship's course was plotted on a navigation chart from information given in the ship's log. The positions of temperature profiles (obtained from the average velocity between landmarks and times the ship was abeam of given landmarks) were plotted on the ship course and their geographic coordinates abstracted from the navigation chart.

Lake-bottom depth was obtained from the temperature analog strip chart trace. Most strip chart traces had a characteristic discontinuity marking

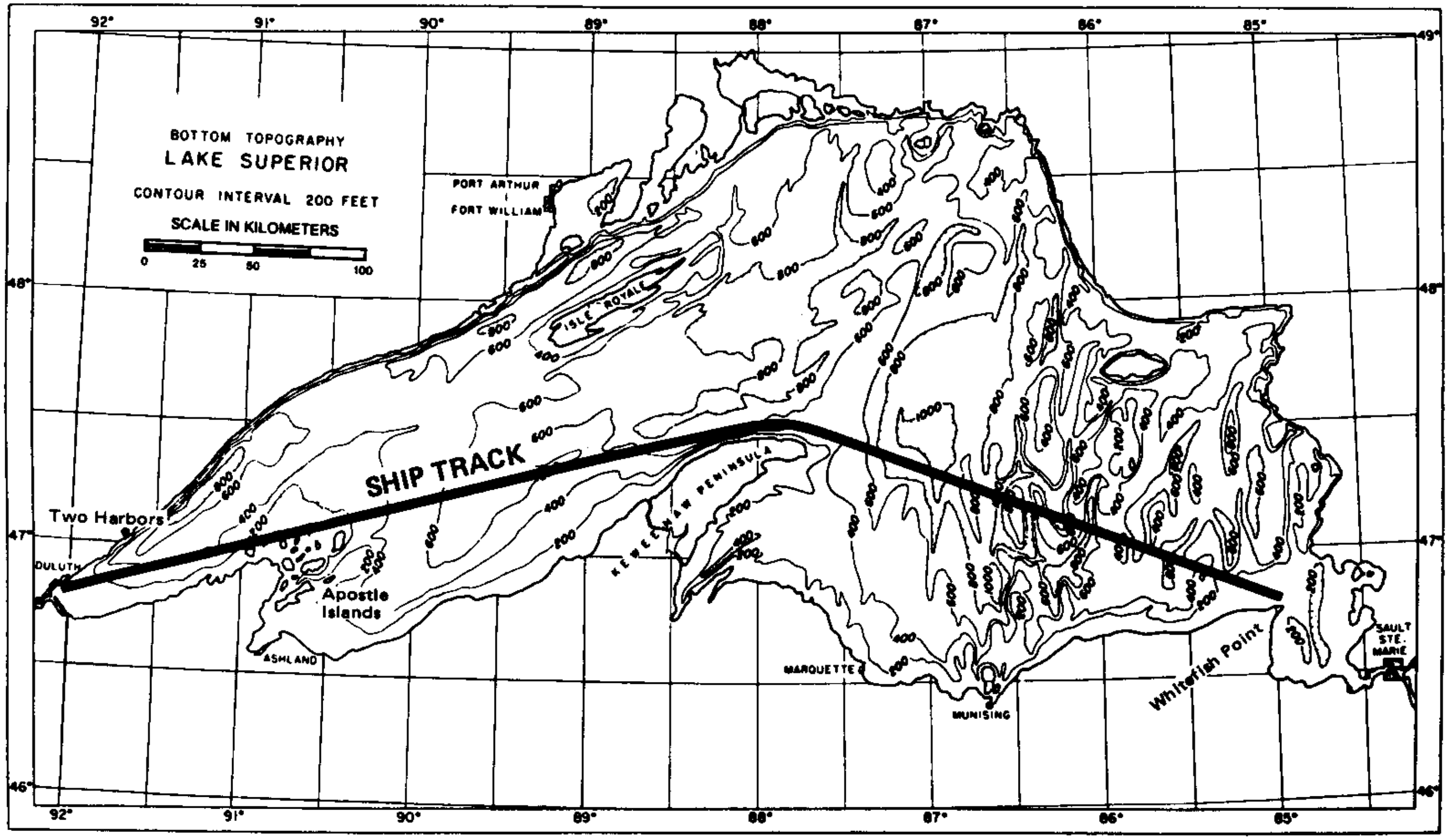

FIGURE 1.--*Lake Superior bathymetry and usual ship track between east and west ends of the lake.*

TABLE 1.—*Temperature surveys across Lake Superior: winter 1973, 1974, 1975, and 1976, and autumn 1976, 1977, 1978, and 1979*

Winter survey dates	Number of stations	Average distance between stations (km)	Autumn survey dates	Number of stations	Average distance between stations (km)
1973			1976		
Dec. 20-21, 1972	43	13.7	Aug. 18-20, 1976	24	24.0
Dec. 27-28, 1972	43	13.2	Sept. 7-9, 1976	24	22.8
Jan. 15-16, 1973	30	18.0	Sept. 28-29, 1976	24	23.1
Jan. 31-Feb. 1, 1973	28	19.3	Oct. 20-22, 1976	24	23.9
			Nov. 14-16, 1976	24	23.4
1974			Dec. 5-7, 1976	24	22.9
Dec. 19-20, 1973	27	20.6	1977		
Jan. 10-12, 1974	31	17.5			
Jan. 22-23, 1974	24	25.1	Oct. 30-31, 1977	27	20.8
			Nov. 1-2, 1977	28	20.5
1975			Nov. 17-22, 1977	31	22.6
			Dec. 16-17, 1977	25	22.2
Dec. 19, 1974	22	25.3	Dec. 19-20, 1977	16	31.1
Dec. 27-28, 1974	33	17.3			
Jan. 7-8, 1975	32	17.7	1978		
Jan. 21-24, 1975	38	16.8			
Feb. 5-7, 1975	25	21.0	Aug. 22-23, 1978	19	26.1
Feb. 18-20, 1975	27	19.5	Sept. 11, 1978	21	26.9
Mar. 11-12, 1975	26	19.9	Sept. 28-29, 1978	21	26.9
			Oct. 17-18, 1978	27	19.0
1976			Nov. 16-17, 1978	26	20.4
			Nov. 30-Dec. 1, 1978	31	18.3
Dec. 17-19, 1975	22	31.5	Dec. 15-17, 1978	29	20.5
Jan. 6-8, 1976	16	41.6			
Jan. 8-9, 1976	9	56.1	1979		
Jan. 27-29, 1976	24	34.9			
Feb. 21-22, 1976	22	23.7	Aug. 23-24, 1979	23	23.0
Mar. 25-27, 1976	16	30.8	Sept. 11, 1979	24	23.7
Apr. 27-29, 1976	22	24.6	Sept. 25-26, 1979	26	21.0
			Oct. 16-18, 1979	26	21.4
			Oct. 30-31, 1979	22	25.8
			Nov. 16-18, 1979	26	21.6
			Dec. 13-15, 1979	23	22.8

the depth at which the expendable bathythermograph probe struck the lake bottom. If this characteristic discontinuity was not observed on the strip chart, lake depth was estimated from the bathymetry given on the navigation chart. Comparisons were made between profile lake depths and lake depths given by Schwab and Sellers (1980). As a result of these comparisons, the geographic coordinates or lake-bottom depth, for depths of 200 m or greater, of approximately 23 percent of the temperature profiles were adjusted to provide closer agreement with the depth and associated latitude and longitude values given by Schwab and Sellers.

Appendix A is a summary of the temperature profiles for each cruise. Table 2 is an example of the data in appendix A. In table 2 the depth and temperature coordinate for each temperature change in a profile is tabulated, and each temperature profile is annotated with the latitude, longitude, lake-bottom depth, date, and profile station number. A code of 99 indicates missing temperature data. Temperature profiles are arranged in ascending station number going from the east- to the west-end of the lake.

Appendix B illustrates the position of each temperature profile station for a given survey. Figure 2 is an example of the data in this appendix. Station numbers given in figure 2 correspond to the temperature survey station numbers given in table 2. The primary use of appendix B is to illustrate differences in temperature survey routes for the 46 surveys. It is also useful in visualizing and comparing the geographic location of individual temperature profiles with other temperature profiles.

The thermal structure of the lake along the survey route for temperature surveys is illustrated by isothermal contour charts in appendix C. Figure 3 contains examples of these data. The temperature profile data in table 2 was smoothed by vertically averaging the temperature for 10-m layers at each profile station. Lake-bottom depths were rounded to the nearest 10 m for this calculation. The smoothed temperature data were used for an objective isothermal contour analysis of the temperature field for each of the surveys. The station numbers in figure 2 and table 2 are also shown at the top of the contour charts in figure 3 to facilitate comparisons of lake thermal structure, survey route, and associated lake bathymetry. For clarity, only every other temperature profile station is labeled on figure 3.

4. DISCUSSION

There are discontinuities in the survey routes, i.e., irregular spacing between stations and areas where there are overlaps (appendix B). These are due primarily to the deletion of some stations with questionable data and to the fact that some surveys included two transits of the lake with an area of overlap in the middle. In addition, the survey routes for December 17-19, 1975; January 6-8, 1976; January 8-9, 1976; and January 27-29, 1976, were along the lee of the lake because of bad weather. These discontinuities have introduced some distortion in the isothermal contour analysis in appendix C, and the four surveys noted above may not be representative of lake thermal structure along the normal shipping route between the east and west ends of the lake.

TABLE 2.—*Lake Superior temperature profiles, August 18-20, 1976***

STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP
1	20/ 8/76	84 88	46 75	86	0 18.1 26 16.3 37 13.7 47 9.0 57 6.0 84 4.8	1 18.0 27 16.0 38 13.5 48 8.7 58 5.9 86 4.8	2 17.6 28 15.7 39 13.0 49 8.5 59 5.8	3 17.5 29 15.5 40 12.5 50 8.0 61 5.6	9 17.4 30 15.0 41 12.3 51 7.5 62 5.5	16 17.0 31 14.5 42 11.7 52 7.3 63 5.3	17 16.8 32 14.3 43 11.0 53 7.0 66 5.2	18 16.7 34 14.2 44 10.0 54 6.7 67 5.1	19 16.6 35 14.1 45 9.7 55 6.5 73 5.0	22 16.5 36 14.0 48 9.3 56 8.3 77 4.9
2	20/ 8/76	85 15	46 86	18	0 17.0	2 16.7	3 16.5	4 16.4	11 16.3	14 16.2	15 16.1	17 16.0	18 15.8	
3	20/ 8/76	85 44	46 93	100	0 15.1 15 9.7 25 6.2 41 5.0	2 15.0 16 9.0 26 6.0 42 4.9	3 14.9 17 8.5 27 5.8 44 4.8	8 14.8 18 8.0 28 5.7 47 4.7	9 14.7 19 7.5 29 5.6 51 4.6	10 14.5 20 7.2 31 5.5 57 4.5	11 14.0 21 7.0 32 5.4 58 4.4	12 13.0 22 6.9 33 5.3 71 4.3	13 12.0 23 6.7 35 5.2 75 4.2	14 11.0 24 6.5 39 5.1 100 4.2
4	20/ 8/76	85 72	47 03	105	0 13.4 17 8.5 27 5.5 49 4.5	2 13.3 18 7.5 28 5.4 50 4.4	9 13.1 19 7.0 30 5.3 60 4.3	10 12.9 20 6.7 33 5.2 70 4.2	11 12.7 21 6.5 34 5.1 105 4.1	12 12.5 22 6.3 36 5.0	13 12.0 23 6.0 37 4.9	14 11.0 24 5.8 40 4.8	15 10.0 25 5.7 44 4.7	16 9.0 26 5.6 45 4.6
5	20/ 8/76	86 08	47 10	243	0 13.7 21 12.0 31 6.9 42 5.4 76 4.3	3 13.6 22 11.5 32 6.7 43 5.3 77 4.2	10 13.5 23 11.0 33 6.6 44 5.1 104 4.1	13 13.4 24 10.0 34 6.5 45 5.0 121 99.0	15 13.3 25 9.0 35 6.2 46 4.9 200 99.0	16 13.2 26 8.0 36 6.1 50 4.8	17 13.0 27 7.7 37 6.0 51 4.7	18 12.7 28 7.5 38 5.8 56 4.6	19 12.4 29 7.3 40 5.6 64 4.5	20 12.3 30 7.0 41 5.5 65 4.4
6	19/ 8/76	86 38	47 19	170	0 13.1 19 10.0 29 5.5 39 4.4	4 13.0 20 9.0 30 5.4 47 4.3	9 12.9 21 8.5 31 5.3 48 4.2	12 12.8 22. 8.0 32 5.2 61 4.1	13 12.7 23 7.5 33 5.1 70 4.0	14 12.6 24 7.0 34 5.0 148 3.9	15 12.5 25 6.5 35 4.8 170 3.9	16 12.0 26 6.3 36 4.7	17 11.5 27 6.0 37 4.6	18 10.5 28 5.7 38 4.5
7	19/ 8/76	86 68	47 28	256	0 12.4 16 8.0 26 5.0 125 4.0	4 12.3 17 7.5 27 4.9 200 4.0	8 12.2 18 7.0 28 4.8	9 12.0 19 6.5 29 4.7	10 11.7 20 6.0 31 4.6	11 11.5 21 5.8 34 4.5	12 11.0 22 5.6 35 4.4	13 10.5 23 5.4 51 4.3	14 9.5 24 5.3 55 4.2	15 8.5 25 5.1 95 4.1
8	19/ 8/76	86 99	47 36	276	0 12.7 13 9.0 23 5.7 50 4.2	1 12.6 14 8.5 24 5.5 99 4.1	4 12.4 15 8.1 25 5.0 105 4.0	6 12.0 16 8.0 26 4.9 200 4.0	7 11.5 17 7.5 27 4.8	8 11.3 18 7.0 28 4.7	9 11.0 19 6.7 31 4.6	10 10.5 20 6.5 32 4.5	11 10.0 21 6.3 33 4.4	12 9.5 22 6.0 40 4.3
STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP

** DEPTH (M) AND TEMPERATURE (C) COORDINATES (DEP/TEMP) FOR TEMPERATURE CHANGES IN EACH PROFILE FROM THE SURFACE TO 200 METERS OR TO THE STATION DEPTH (*SDP) WHICH EVER IS SMALLER

99.0 = MISSING DATA

TABLE 2.--*Lake Superior temperature profiles, August 18-20, 1976 (cont.)***

STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP
9	19/ 8/76	87 30	47 45	225	0 15.6 10 12.4 20 8.4 30 6.5 43 4.9 131 3.9	1 15.5 11 12.2 21 8.3 31 6.4 44 4.8 200 3.9	2 15.0 12 12.1 22 8.2 32 6.0 45 4.7	3 14.5 13 12.0 23 8.1 33 5.8 47 4.6	4 14.4 14 11.5 24 8.0 34 5.6 50 4.5	5 14.3 15 11.0 25 7.6 35 5.5 51 4.4	6 14.0 16 10.5 26 7.5 36 5.4 57 4.3	7 13.5 17 10.0 27 7.3 37 5.3 60 4.2	8 13.0 18 9.0 28 6.8 39 5.1 75 4.1	9 12.5 19 8.6 29 6.6 40 5.0 76 4.0
10	18/ 8/76	87 56	47 47	111	0 15.0 13 12.4 24 8.5 35 6.5 49 4.8 111 3.9	1 14.9 14 12.3 25 8.0 36 6.3 51 4.7	2 14.8 16 12.1 26 7.9 37 6.0 53 4.6	3 14.7 17 11.9 27 7.6 38 5.7 56 4.5	6 14.6 18 11.5 28 7.4 39 5.6 57 4.4	7 14.0 19 10.1 30 7.3 41 5.5 61 4.3	8 13.3 20 10.0 31 7.2 43 5.3 68 4.2	9 13.0 21 9.7 32 7.1 44 5.1 69 4.1	11 12.9 22 9.3 33 7.0 46 5.0 75 4.0	12 12.5 23 9.0 34 6.8 47 4.9 79 3.9
11	19/ 8/76	87 60	47 53	157	0 16.3 13 14.3 23 9.5 35 6.4 49 5.3 88 4.2	2 16.2 14 14.0 24 8.5 36 6.3 51 5.2 111 4.1	3 16.0 15 13.9 25 8.0 38 6.2 52 5.1 115 4.0	4 15.8 16 13.7 26 7.5 39 6.1 56 5.0 157 4.0	6 15.7 17 13.0 27 7.3 40 6.0 57 4.9	8 15.5 18 12.5 28 7.1 41 5.9 60 4.8	9 15.2 19 12.0 31 7.0 42 5.7 63 4.7	10 15.0 20 11.5 32 6.9 43 5.6 67 4.6	11 14.8 21 11.0 33 6.7 45 5.5 74 4.4	12 14.5 22 10.0 34 6.5 46 5.4 87 4.3
12	18/ 8/76	87 91	47 52	153	0 15.0 12 13.7 22 6.7 35 5.1 70 4.0	1 14.9 13 13.0 23 6.5 37 5.0 77 3.9	2 14.8 14 12.0 24 6.4 38 4.9 153 3.9	3 14.7 15 11.0 25 6.0 39 4.7	4 14.5 16 10.0 26 5.7 40 4.6	5 14.4 17 9.0 29 5.6 42 4.5	6 14.3 18 8.5 30 5.5 43 4.4	7 14.2 19 8.0 32 5.4 45 4.3	8 14.0 20 7.5 33 5.3 50 4.2	11 13.9 21 7.0 34 5.2 54 4.1
13	18/ 8/76	88 25	47 50	223	0 16.0 15 10.5 25 7.3 35 5.4 49 4.1	1 15.5 16 9.5 26 7.2 36 5.3 66 4.0	3 15.4 17 9.0 27 7.0 37 5.1 90 3.9	5 15.3 18 8.7 28 6.8 38 5.0 192 3.8	7 15.2 19 8.5 29 6.5 39 4.7 200 3.8	9 15.0 20 8.3 30 6.3 40 4.6	11 14.5 21 8.0 31 6.0 41 4.5	12 13.5 22 7.8 32 5.8 42 4.4	13 12.5 23 7.5 33 5.6 43 4.3	14 11.5 24 7.4 34 5.5 48 4.2
14	18/ 8/76	88 58	47 48	210	0 15.0 10 13.0 20 7.3 30 5.1 46 4.1	1 14.8 11 12.9 21 7.0 31 5.0 66 4.0	2 14.5 12 12.8 22 6.8 34 4.9 90 3.9	3 14.3 13 12.0 23 6.5 36 4.8 136 4.0	4 14.2 14 11.0 24 6.0 38 4.7 189 4.1	5 14.0 15 10.0 25 5.6 39 4.6 193 4.2	6 13.8 16 9.0 26 5.5 40 4.5 200 4.2	7 13.5 17 8.5 27 5.4 41 4.4	8 13.3 18 8.0 28 5.3 42 4.3	9 13.1 19 7.5 29 5.2 45 4.2
15	18/ 8/76	88 94	47 43	158	0 16.5 15 14.7 25 7.5 35 4.9 158 4.0	1 16.0 16 13.0 26 7.3 36 4.8	2 15.9 17 11.5 27 7.0 37 4.7	3 15.7 18 10.5 28 6.5 38 4.6	9 15.6 19 9.5 29 6.1 40 4.5	10 15.5 20 9.0 30 5.9 43 4.4	11 15.4 21 8.5 31 5.6 50 4.3	12 15.3 22 8.3 32 5.4 54 4.2	13 15.2 23 8.0 33 5.3 68 4.1	14 15.0 24 7.8 34 5.0 69 4.0
STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP

** DEPTH (M) AND TEMPERATURE (C) COORDINATES (DEP/TEMP) FOR TEMPERATURE CHANGES IN EACH PROFILE FROM THE SURFACE TO 200 METERS OR TO THE STATION DEPTH (*SDP) WHICH EVER IS SMALLER

99 0 - MISSING DATA

TABLE 2.--*Lake Superior temperature profiles, August 18-20, 1976 (cont.)***

STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP
16	18/ 8/76	89 31	47 38	191	0 18.0 13 16.3 23 11.5 33 5.6 53 4.3	1 17.5 14 16.2 24 10.5 34 5.2 54 4.2	2 17.3 15 16.1 25 9.5 36 5.1 80 4.1	3 17.2 16 16.0 28 9.0 37 5.0 90 4.0	4 17.1 17 15.8 27 8.7 38 4.9 191 4.0	5 17.0 18 15.7 28 8.5 39 4.8	6 16.9 19 15.3 29 8.1 41 4.7	7 16.8 20 15.0 30 7.9 42 4.6	11 16.7 21 14.5 31 7.0 43 4.5	12 18.5 22 13.0 32 6.5 44 4.4
17	18/ 8/76	89 65	47 32	198	0 17.0 13 15.2 23 6.5 34 4.5	2 16.9 14 15.0 24 6.0 35 4.4	3 16.5 15 14.0 25 5.5 39 4.3	4 16.3 16 12.0 26 5.3 40 4.2	6 16.2 17 10.0 27 5.2 51 4.1	7 16.1 18 9.0 28 5.0 52 4.0	8 16.0 19 8.0 29 4.9 167 3.9	9 15.6 20 7.5 31 4.8 198 3.9	11 15.5 21 7.0 32 4.7	12 15.3 22 6.7 33 4.6
18	18/ 8/76	90 02	47 27	148	0 18.5 17 11.0 27 5.4 66 4.1	1 18.3 18 10.0 28 5.2 75 4.0	2 18.0 19 9.0 29 5.0 148 4.0	3 17.8 20 8.0 30 4.8	5 17.7 21 7.5 31 4.7	9 17.6 22 7.0 32 4.6	13 17.5 23 6.5 33 4.5	14 17.0 24 6.0 34 4.4	15 16.0 25 5.7 43 4.3	16 14.0 26 5.5 44 4.2
19	18/ 8/76	90 37	47 21	86	0 20.4 13 17.1 24 8.0 34 5.4 60 4.4	1 19.0 14 17.0 25 7.0 37 5.3 65 4.3	2 18.5 16 16.9 26 6.5 40 5.2 66 4.2	3 18.3 17 14.0 27 6.3 41 5.1 86 4.2	5 18.2 18 12.0 28 6.0 45 5.0	8 18.1 19 11.0 29 5.9 46 4.9	9 18.0 20 10.0 30 5.8 50 4.8	10 17.8 21 9.5 31 5.7 51 4.7	11 17.5 22 9.0 32 5.6 54 4.6	12 17.3 23 8.5 33 5.5 59 4.5
20	18/ 8/76	90 71	47 14	46	0 20.0 10 13.0 20 6.7 30 4.8	1 18.5 11 12.0 21 6.5 32 4.7	2 18.0 12 11.0 22 6.3 34 4.6	3 17.0 13 10.0 23 6.0 46 4.6	4 16.0 14 9.5 24 5.7	5 15.4 15 8.5 25 5.5	6 15.0 16 8.0 26 5.2	7 14.5 17 7.7 27 5.1	8 14.0 18 7.3 28 5.0	9 13.5 19 7.0 29 4.9
21	18/ 8/76	91 05	47 06	126	0 14.9 10 8.5 22 5.0 55 4.0	1 14.8 11 8.0 23 4.9 105 3.9	2 14.7 12 7.0 25 4.8 126 3.9	3 14.0 13 6.5 30 4.7	4 13.7 14 6.0 31 4.6	5 13.5 15 5.8 35 4.5	6 13.4 17 5.5 37 4.4	7 13.0 18 5.3 44 4.3	8 11.0 19 5.2 45 4.2	9 9.0 20 5.1 54 4.1
22	18/ 8/76	91 38	46 98	149	0 12.3 10 8.5 20 5.7 48 4.4	1 12.2 11 8.4 21 5.5 60 4.3	2 12.0 12 8.3 22 5.3 61 4.2	3 11.5 13 8.0 23 5.2 74 4.1	4 11.0 14 7.7 24 5.1 75 4.0	5 10.3 15 7.4 25 5.0 149 4.0	6 10.0 16 7.0 27 4.9	7 9.7 17 6.7 28 4.7	8 9.3 18 6.3 37 4.6	9 9.0 19 6.0 47 4.5
23	18/ 8/76	91 72	46 88	93	0 19.3 15 12.0 25 5.8 42 4.8	4 18.7 16 11.0 26 5.7 44 4.7	5 18.6 17 10.0 27 5.6 45 4.6	6 18.5 18 8.7 28 5.5 49 4.5	8 18.4 19 8.0 29 5.4 50 4.4	9 18.3 20 7.0 30 5.3 60 4.3	11 18.0 21 6.5 33 5.2 73 4.2	12 17.0 22 6.3 34 5.1 74 4.1	13 14.0 23 6.0 36 5.0 93 4.1	14 13.0 24 5.9 38 4.0
24	18/ 8/76	92.04	46.79	20	0 20.7 20 18.5	1 20.0	2 19.5	3 19.4	4 19.3	5 19.0	7 18.8	9 18.7	10 18.6	17 18.5
STA	DA/MO/YR	LON W	LAT N	SDP*	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP	DEP/TEMP

** DEPTH (M) AND TEMPERATURE (C) COORDINATES (DEP/TEMP) FOR TEMPERATURE CHANGES IN EACH PROFILE FROM THE SURFACE TO 200 METERS OR TO THE STATION DEPTH (*SDP) WHICH EVER IS SMALLER

99 0 - MISSING DATA

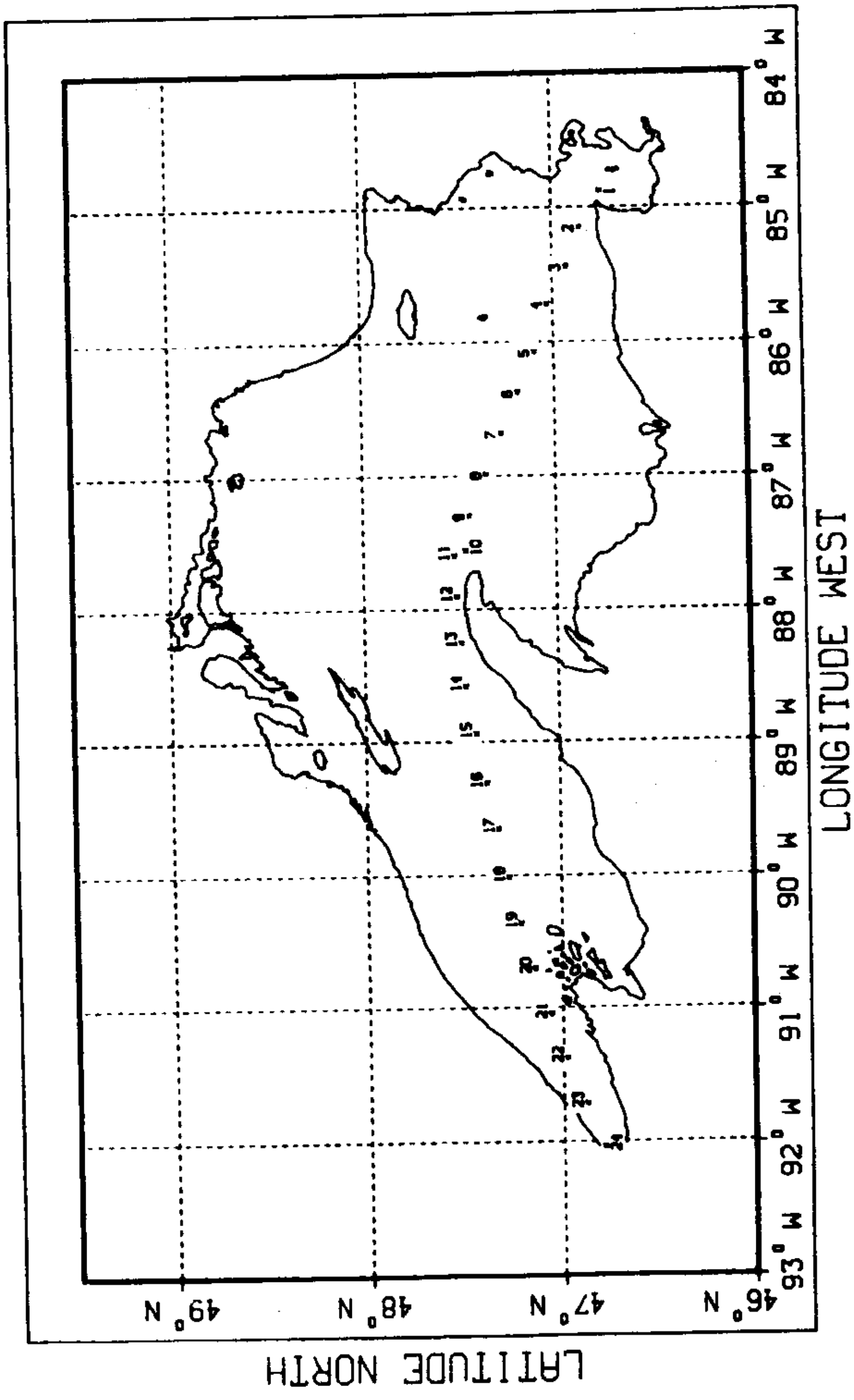

FIGURE 2.--*Lake Superior temperature profile stations, August 18-20, 1976.*

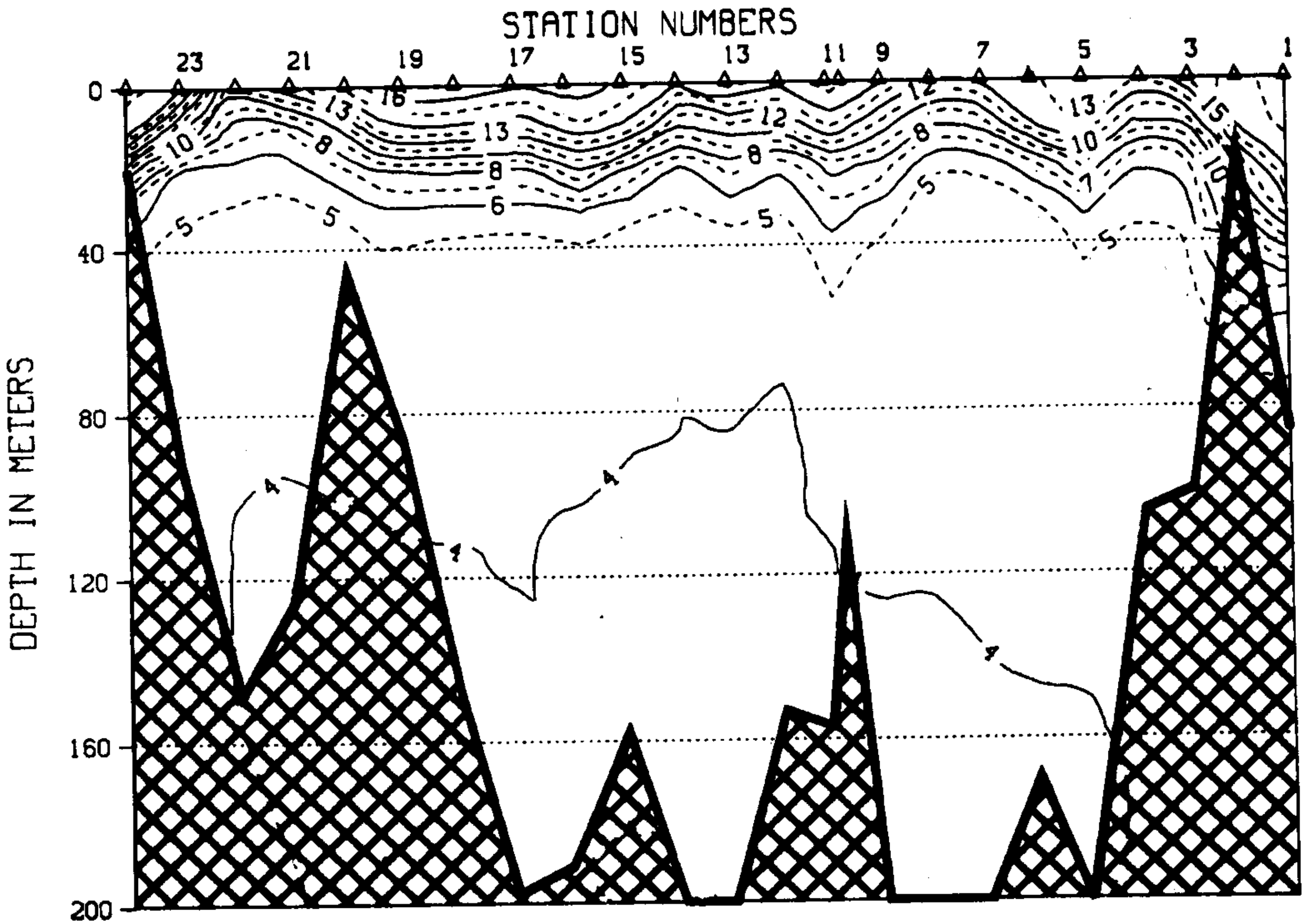

FIGURE 3a.--*Isothermal contour analysis, August 18-20, 1976.*

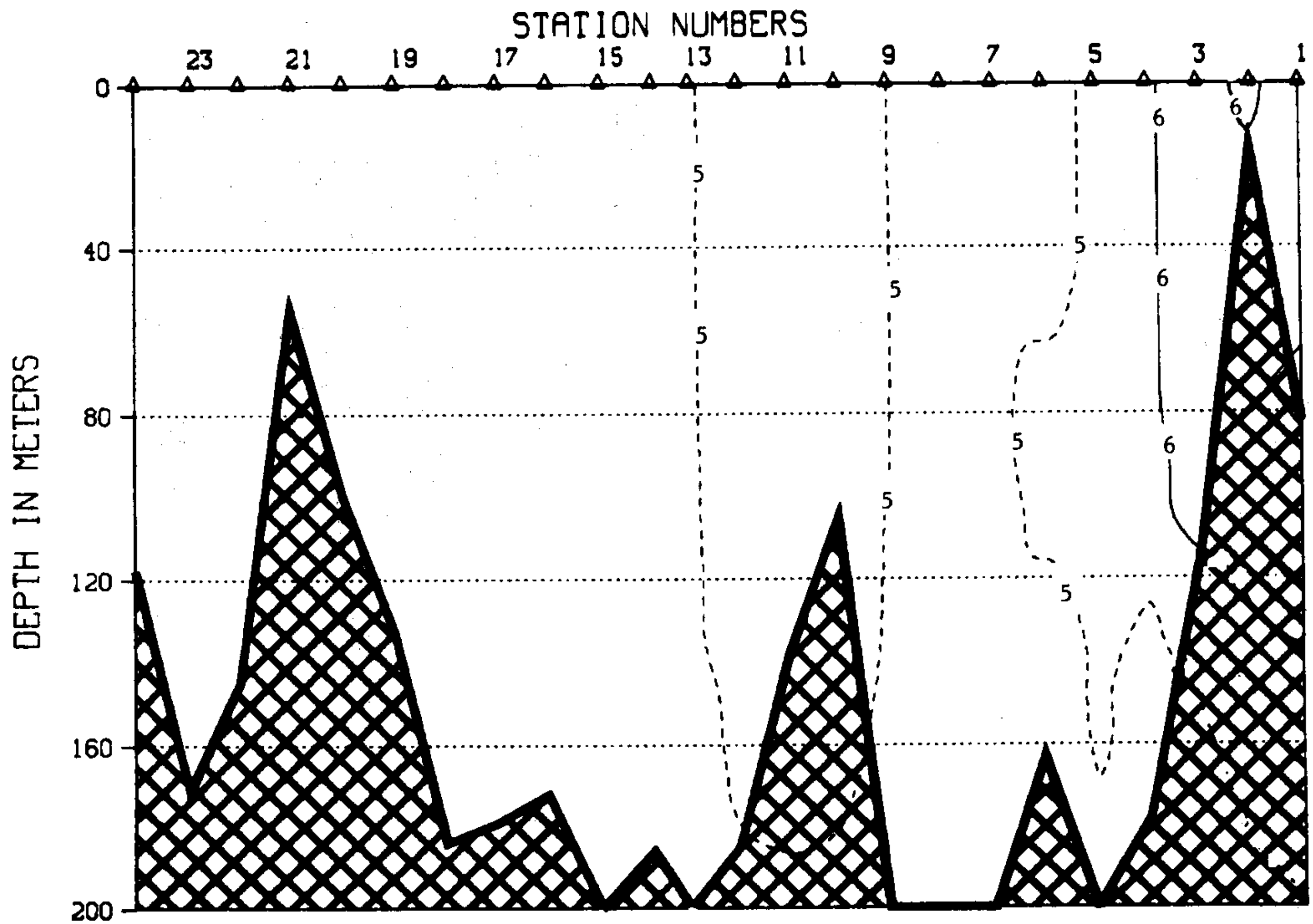

FIGURE 3b.--*Isothermal contour analysis, November 14-16, 1976.*

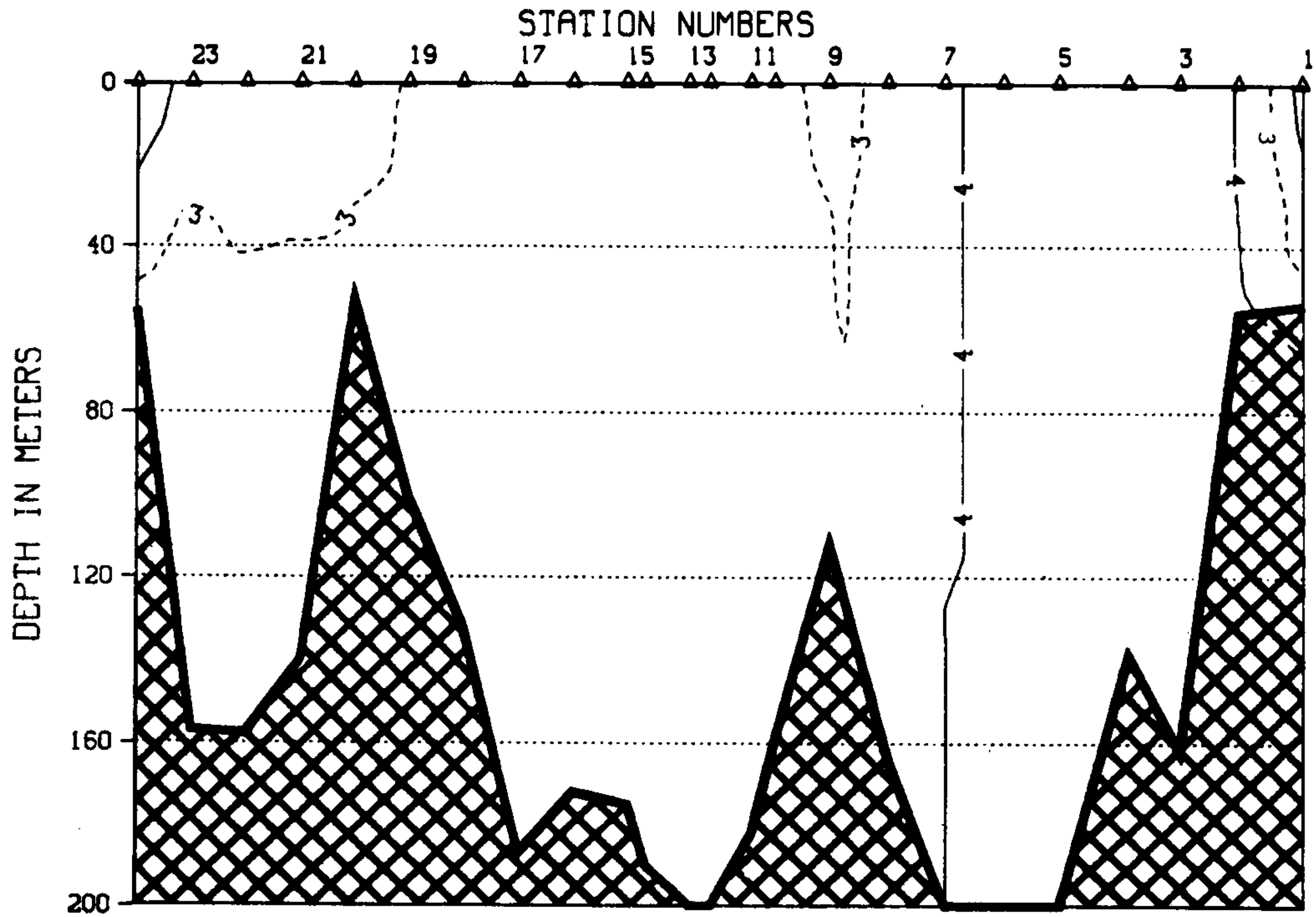

FIGURE 3c.--*Isothermal contour analysis, December 5-7, 1976.*

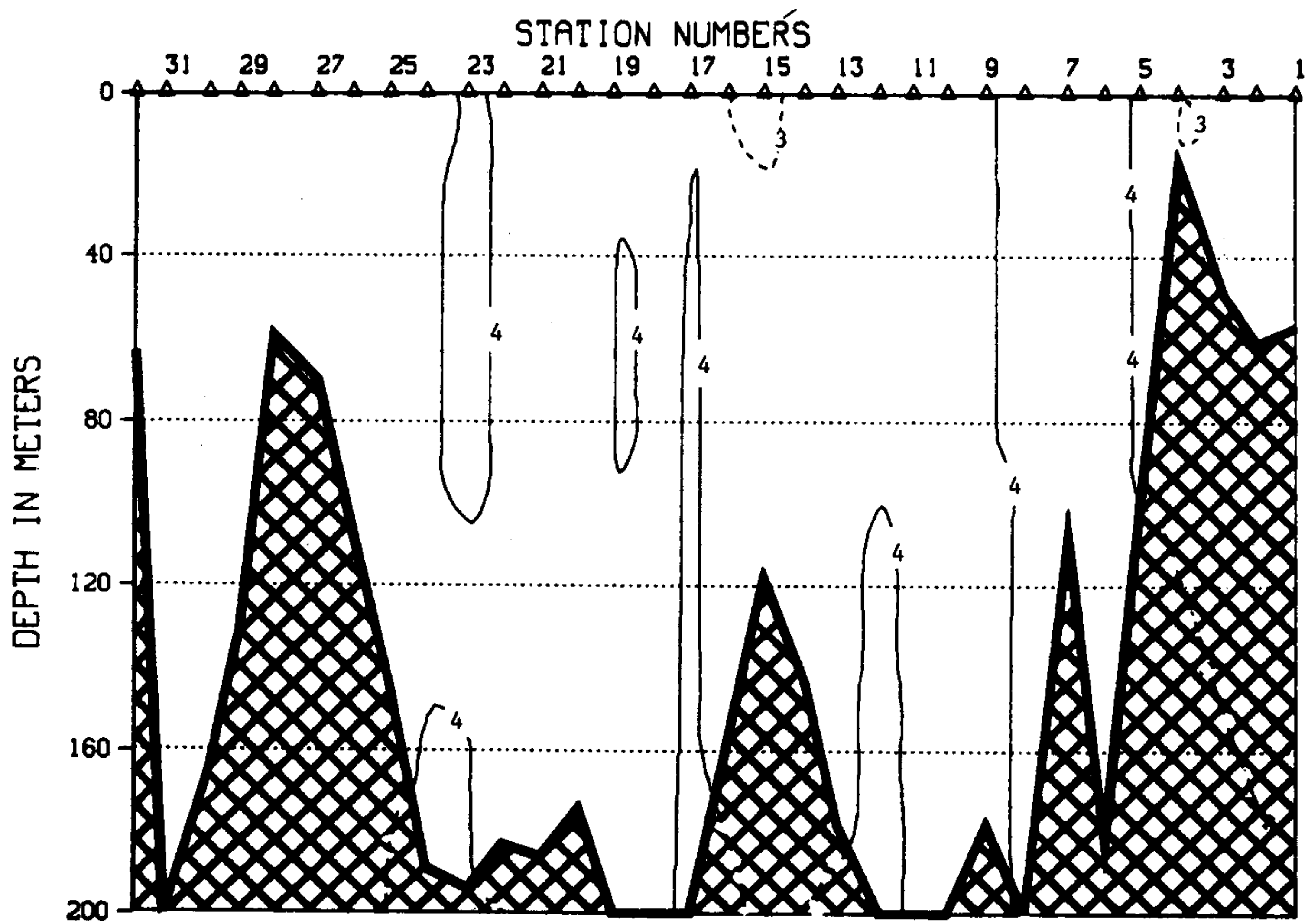

FIGURE 3d.--*Isothermal contour analysis, January 7-8, 1975.*

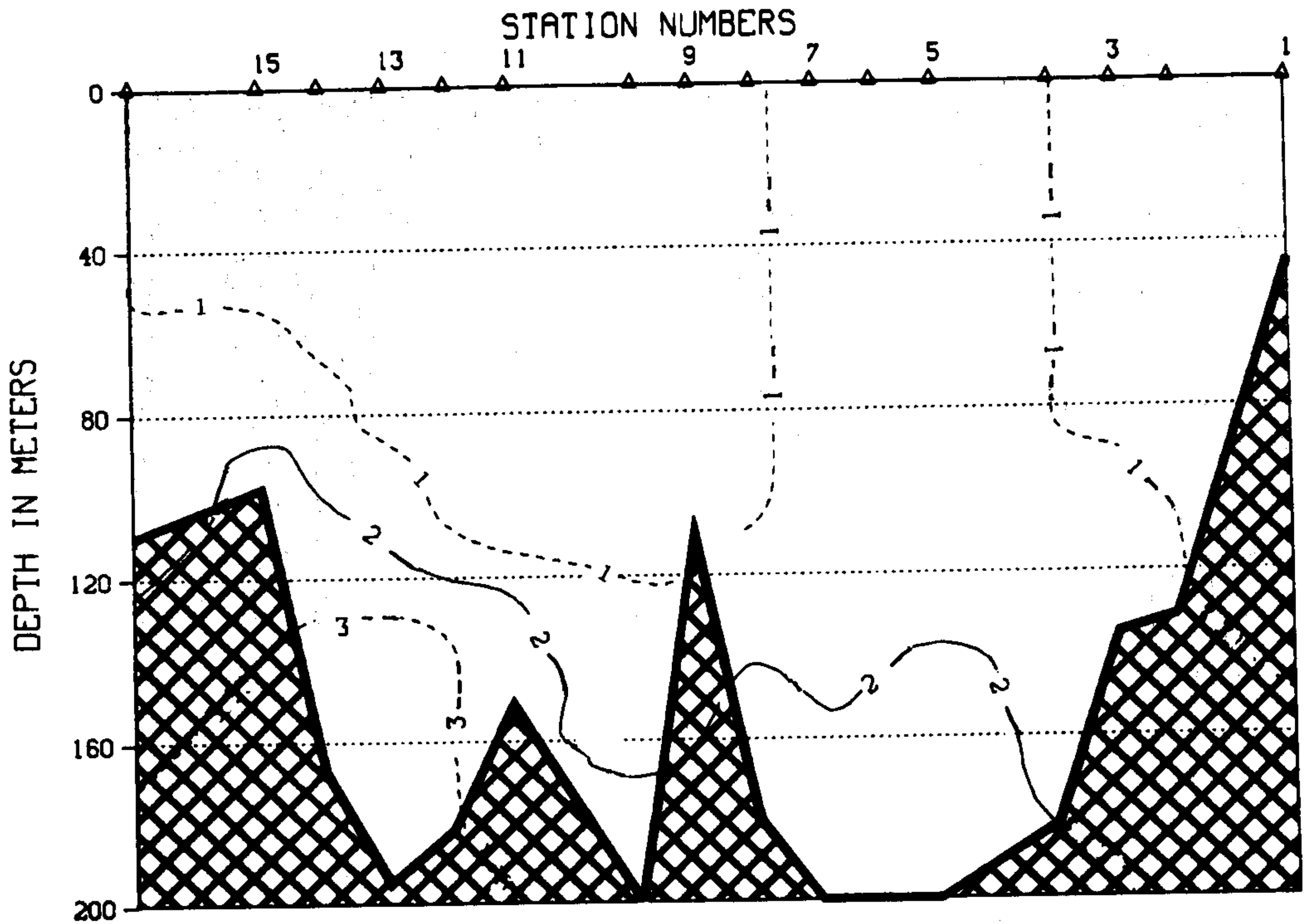

FIGURE 3e.--*Isothermal contour analysis, March 25-27, 1976.*

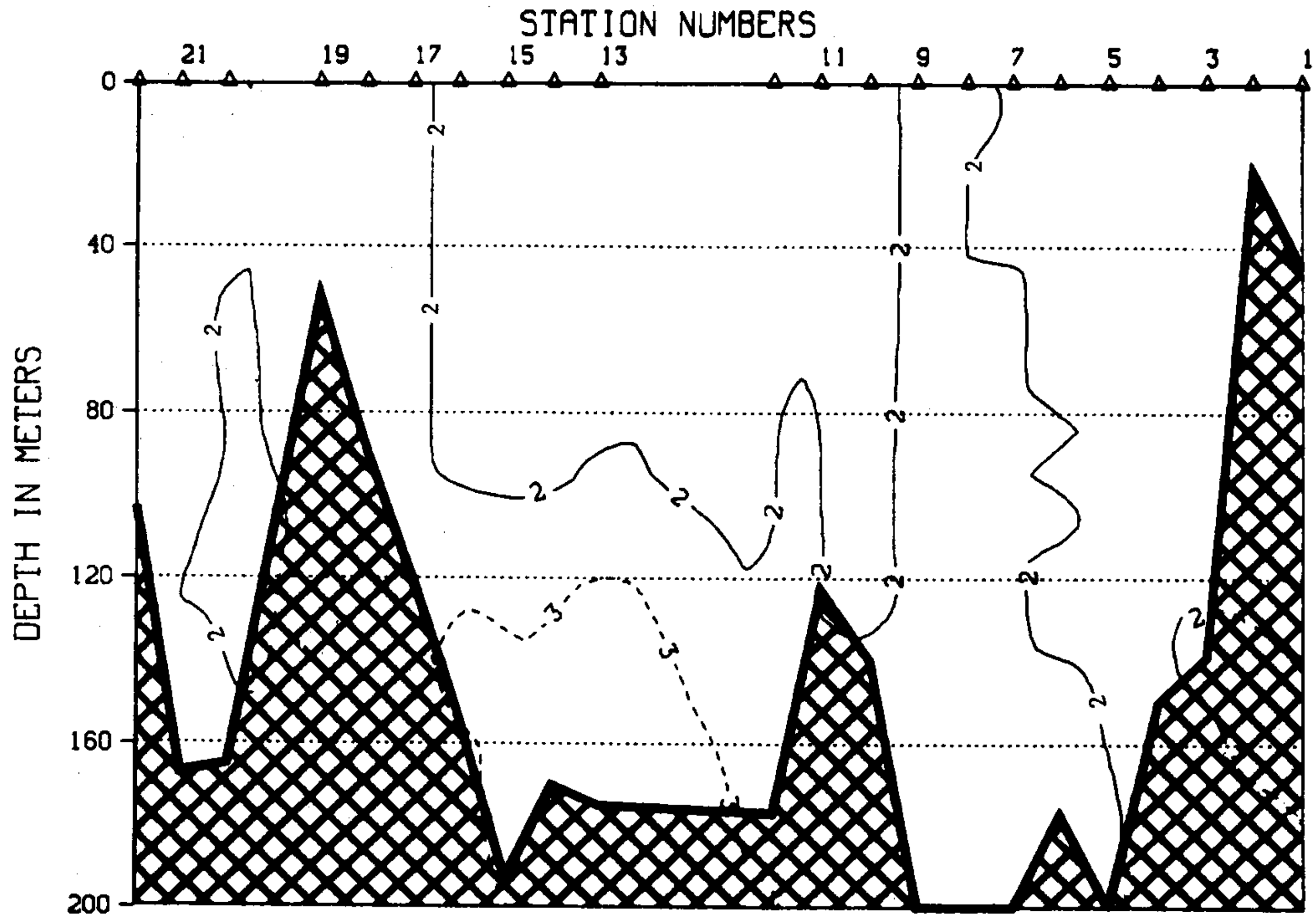

FIGURE 3f.--*Isothermal contour analysis, April 27-29, 1976.*

Given these limitations on the interpretation of the contour analysis, seasonal trends in the lake's thermal structure can be identified and related to lake bathymetry. Figure 4 portrays an idealized depth profile along the normal survey route shown in figure 1. This profile shows that the west end of the survey route to the Apostle Islands, the tip of the Keeweenaw Peninsula, and the east end of the survey route are all shallow areas. The west lake basin and eastern half of the east lake basin are next in increasing depth, and the western half of the east lake basin is the deepest area of the survey route.

In late summer, August 15 to September 15, heating of the surface waters produces a large vertical temperature gradient in approximately the upper 30 m of the water mass (fig. 3a). Heat storage in the epilimnion is near its maximum value during this time. During the last half of September through approximately the middle of November, surface cooling produces an unstable density gradient in the upper portion of the water mass that results in mechanical mixing to increasingly greater depths.

The water column eventually becomes virtually isothermal at a temperature above the temperature of maximum density (fig. 3b). Then the entire water column cools to the temperature of maximum density, approximately 4°C, marking the end of the fall overturn period. This is usually completed in shallow areas by or before mid-December (fig. 3c). In the deeper areas of Lake Superior and during years with mild air temperatures in December, fall overturn may not be complete until late December to early January (fig. 3d).

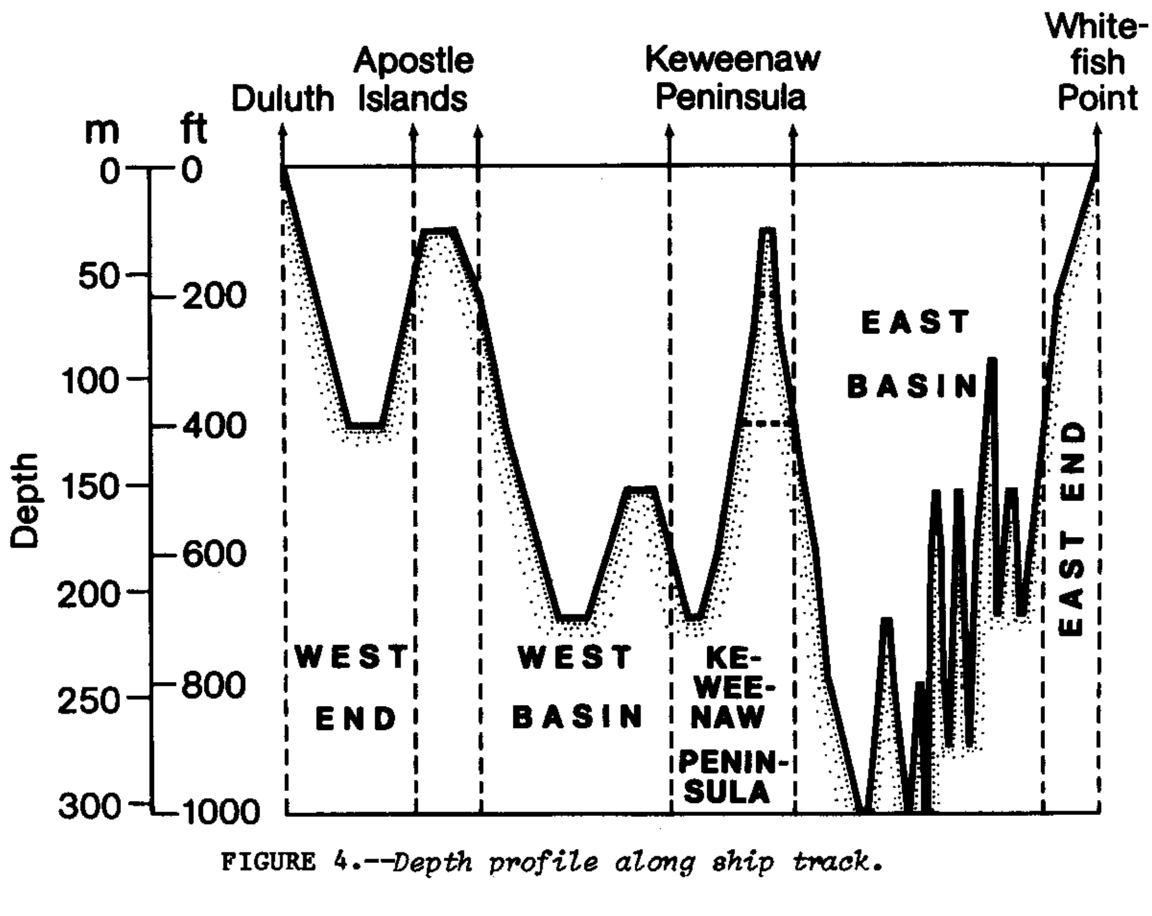

FIGURE 4.--*Depth profile along ship track.*

During winter, a weak reverse thermocline is formed, particularly in the west half of the ship track (fig. 3e). This structure showed signs of deterioration by the end of April 1976 (fig. 3f), indicating that heat storage in Lake Superior was likely to have been at a minimum in March or early April that year.

This report presented temperature data collected across Lake Superior during portions of the 1975 and 1976 winter seasons and portions of the 1976, 1977, 1978, and 1979 autumn seasons. The end of the fall overturn period was discussed in relation to lake bathymetry, and the general characteristics of the seasonal decline in temperatures and heat storage were summarized. Future research using these data will include an analysis of the autumn and winter temperature decline characteristics of discrete areas of the lake.

5. ACKNOWLEDGMENTS

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