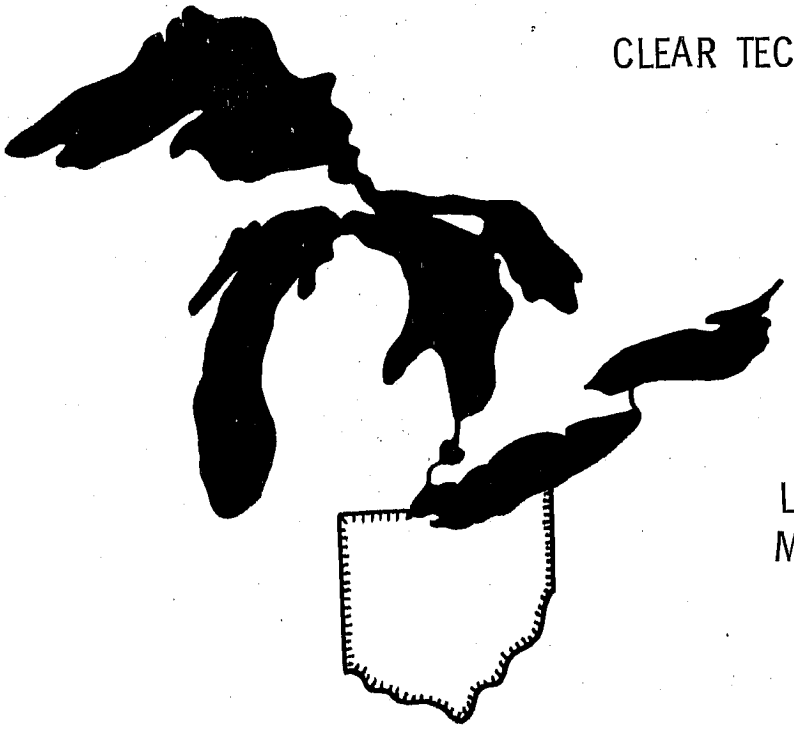

CLEAR TECHNICAL REPORT NO. 129

LAKE ERIE WATER QUALITY: MAIN LAKE STATUS FOR 1977 FINAL REPORT

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Errata for T. R. # 129

Lake Erie Water Quality : Main Lake Status for 1977. Final Report

Chlorophyll a in this report is actually SCOR/UNESCO chlorophyll a and not corrected chlorophyll a as it says in the text.

This makes the graphs misleading.

Corrected chlorophyll a results are lower than SCOR/UNESCO chlorophyll. A correction to the graph will be made.

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LAKE ERIE WATER QUALITY: MAIN LAKE STATUS FOR 1977

INTRODUCTION

Seven water quality monitoring cruises were conducted by the Center for Lake Erie Area Research (CLEAR) in Lake Erie between March and November 1977 under the sponsorship of the U.S. Environmental Protection Agency, Region V, Eastern District Office:

TABLE 1

LAKE ERIE CRUISE SCHEDULE FOR 1977

Cruise No.	Dates	Basin		
		Western	Central	Eastern
1	3/21-4/03	x	x	(ice)
2	4/28-5/08	N.S.	x	x
3	6/20-6/30	N.S.	x	x
4	7/12-7/31	N.S.	x	x
5	8/11-8/21	N.S.	x	x
6	9/10-10/09	x	x	x
7	11/07-11/20	x	x	x

N.S. - not scheduled

The stations monitored during these cruises are shown on Figure 1. Sampling methods, analytical techniques and volume-weighting procedures are described in ERL-DUL-R5 (Herdendorf, 1979). Water quality grids used for volume calculations are shown on Figure 2.

The following report of water quality in these three basins deals with six parameters: (1) temperature, (2) dissolved oxygen, (3) suspended solids, (4) conductivity, (5) phosphorus, and (6) chlorophyll. Results of all measurements made during these surveys have been entered in the STORET data storage system with the assistance of USEPA's Large Lake Research Station, Grosse Ile, Michigan.

WATER QUALITY ANALYSIS

Temperature

The Central and Eastern Basins of Lake Erie became thermally stratified during the period mid-May to mid June. Figure 3 shows that a well developed thermocline was present in both basins during Cruise No. 3 (June 20-30). The Central Basin remained stratified through Cruise Nos. 4 (Figure 4) and 5. (Figure 5) and finally overturned during Cruise No. 6 (Figure 6) as a result of a storm in late September. Cruise No. 7, in November, shows the water to be well-mixed in all three basins as indicated by fairly uniform temperatures. The period of stratification for the Central Basin in 1977 was approximately 120 days. The Eastern Basin hypolimnion persisted until late October, yielding a stratified period of about 150 days.

The thermal characteristics of the Central and Eastern Basin hypolimnions are presented in Table 2. The averaged temperatures of the hypolimnions varied less than 2°C, but the Central Basin was nearly twice as warm as the Eastern Basin throughout the stratified period.

Dissolved Oxygen

Figures 8-11 depict the dissolved oxygen (DO) concentrations in the bottom waters of Lake Erie during the stratified period. As early as June (Cruise No. 3) depressed oxygen concentrations ($<$1.0 ppm) were observed in the Sandusky sub-basin of the Central Basin. By mid-August (Cruise No. 5), approximately half of the hypolimnion of the Central Basin yielded DO concentrations less than 1.0 ppm. The most severe DO depression in the far eastern end of the Eastern Basin also occurred at this time with values below 4.0 ppm. The entrainment of oxygen-rich waters from the Eastern Basin into the Central Basin hypolimnion is evident in Figure 10. This phenomenon may have prevented a larger area of the Central Basin from becoming anoxic. By late September most of the Central Basin had "overturned", but a small anoxic area persisted in the northwestern part of the basin (Figure 11). In November (Cruise No. 7), the lake was well-mixed with uniform bottom oxygen concentrations throughout (Figure 12).

Figure 13 illustrates the areas of low dissolved oxygen concentrations in Lake Erie during 1977 and the maximum development of hypolimnions in all three basins. Critical areas of low DO are considered to be those with less than 1.0 ppm in water samples taken 1.0 m above the bottom, while anoxic areas are considered to be those areas with less than 0.5 ppm DO in similarly taken samples. Significant nutrient regeneration from sediments has been observed to correspond with later measured concentrations. Critical areas of low DO persisted over an area of approximately 8000 km^2 during 1977. This corresponds to 69% of the Central Basin hypolimnion or 58% of the entire basin. The anoxic area of this basin in 1977 was equal to 2870 km^2 (24.8% of the hypolimnion or 20.8% of the total basin).

A summary of the dissolved oxygen characteristics of the Central and Eastern Basin hypolimnions is presented in Table 2. The average DO concentration in the Central Basin dropped from 8.3 to 0.5 ppm in three months, whereas the Eastern Basin concentration fell from 10.8 to 6.5 during the same periods (Cruise Nos. 3-6). The oxygen depletion rates calculated from these data are given in Table 3. A comparison of the Central Basin hypolimnion characteristics from 1973 to 1977 (Herdendorf 1979) are presented in Table 4. With the exception of 1975 which was an unusual year meteorologically, the volumetric oxygen depletion rate for the Central Basin has been relatively stable. However, in the four decades prior to 1970 the areal and volumetric DO depletion rates showed dramatic increases (Table 5 and 6). The data in Table 5 indicate erratic depletion rates for the Eastern Basin. The complex thermal structure of this basin does not permit a routine calculation of rates. Because of these difficulties, it is also suspected that the depletion rates in the Eastern Basin have been relatively stable since at least 1970.

Suspended Solids

The total suspended solids in surface and bottom waters for Cruise Nos. 1-3 and for surface waters for Cruises Nos. 4-7 are depicted in Figures 14-23. In March (Cruise No. 1) large amounts of sediment were delivered to the Western Basin via the Maumee and Detroit Rivers. Concentrations of dissolved solids in Maumee Bay exceeded 100 mg/l during this period. Concentrations in the Central Basin ranged from less than 2 mg/l in the northern and central part of the basin to 10 mg/l along the southern shore. The Eastern Basin was ice-covered during Cruise No. 1.

By May (Cruise 2), suspended solids load had decreased by nearly 50% in the Central Basin surface water but the bottom showed less improvement. The highest concentrations of those stations sampled were found in the Sandusky sub-basin (up to 6 mg/l). The Eastern Basin ranged from less than 1 mg/l south of Long Point (surface) to slightly over 2 mg/l on the bottom near the north and south shore. The Western Basin was not scheduled for a cruise during the period May through August.

The June cruise (Cruise No. 3) showed continued improvement in the amount of material suspended in the water. Most of the surface waters and a large percentage of the bottom waters had less than 1 mg/l of suspended solids in both the Central and Eastern Basins. Nearshore concentration along the American shore continued at about 5 mg/l in the bottom waters. During the July cruise (Cruise 4), a continued decrease occurred in suspended solids with no measurements in excess of 3 mg/l in the Central and Eastern Basins. July was the least turbid period of the year observed during the study of those stations sampled.

In August, the Central and Eastern Basins remained relatively clear except for the Sandusky sub-basin and the American nearshore zone. The maximum concentrations did not exceed 6 mg/l. In late September and early October, increased turbidity occurred at the east and west extremities of the lake, with values in excess of 12 mg/l in the vicinity of the Maumee River mouth and Buffalo Harbor. Less than 2 mg/l of suspended solids occurred in almost all of the Central Basin and the western part of the Eastern Basin during this period. In November, after lake turnover, surface turbidity throughout the lake increased sharply (Figure 23).

Specific Conductance

The conductivity (μmhos/cm) of surface waters for Cruise Nos. 1 and 2, of surface, mid-water, and bottom waters for Cruise Nos. 3-6, and of surface waters for Cruise No. 7 are displayed on Figures 24-38. Conductivity is a good indicator of the amount of solids dissolved in the water. The International Joint Commission (1975) has proposed a factor of 0.65 to convert specific conductance in μmhos/cm to total dissolved solids in mg/l.

In March (Cruise No. 1) the influence of the Detroit River, with its low-conductance upper-lakes water (<220 μmhos/cm), is apparent in the Western Basin (Figure 24). The highest concentration of dissolved solids were observed in nearshore waters of the Western Basin from Maumee Bay to Catawba Island (>300 μmhos/cm). Relatively uniform concentrations occurred in the Central Basin beyond the Sandusky sub-basin. The Eastern Basin was ice-covered during this period. May conductivity values (Cruise No. 2) indicated about 10% higher nearshore dissolved solids concentration as compared to offshore areas. Conductivity decreased toward the eastern end of the Eastern Basin.

Surveys in June, July, August, and September (Cruise Nos. 3-6) showed relatively consistent conductivity values during the stratified period. Open lake values ranged from 270-300 μmhos for the Central and Eastern Basins. In November (Cruise No. 7) a pattern similar to that observed in the Western Basin in the spring was exhibited. The other basins also showed similar patterns as those described for earlier in the year. Fall turnover did not appear to substantially affect the concentration of dissolved solids in the lake (Table 7).

During the period March to November, 1977, a general, but small, increase in dissolved solids occurred in all three basins of approximately 5% (Figure 39). Table 7 shows that average total lake concentration rose from 177.4 mg/l to 188.6 mg/l for a mass increase of 87.3 million metric tons to 92.5 million metric tons. Figure 40 indicates that the epilimnion of the Central Basin consistently had a lower concentration of dissolved solids that the water below the upper knee of the thermocline (mesolimnion and hypolimnion). However, this difference averaged less than 10%.

Phosphorus

The 1977 concentrations and mass of total phosphorus (TP) in the Western, Central, and Eastern Basins are listed in Table 8 by stratum for each cruise and shown graphically on Figures 41-54. The highest concentrations in all three basins occurred in the fall after anoxic regeneration and sediment resuspension following overturn. In the Central Basin anoxic regeneration yielded a 1,939 metric ton increase in TP to the water column from the bottom sediments during August and September.

The concentrations and mass of TP in the Western Basin have only fluctuated slightly since 1970 (Herdendorf 1979) and appear to be relatively stable

in response to nearby uniform TP loading during this period (Figure 63). The Central Basin shows a similar stability with some indication toward a slightly rising quantity of TP during the past four years (Figure 64). The Eastern Basin data suggests a slight downward trend in TP concentrations since 1973 (Figure 65).

Soluble reactive phosphorus (SRP) concentrations and quantities for 1977 in the Western, Central and Eastern Basins of Lake Erie are listed in Table 9. The highest mean concentration in the Western Basin (8.35 µg/l) was found in September. During the same period in the Central Basin, the highest mean concentration was observed in the hypolimnion (34.58 µg/l) as a result of anoxic regeneration. However, the mean value for the entire Central Basin water column in September was only 7.41 µg/l. The Eastern Basin mean concentration of SRP for September was the lowest, at 5.15 µg/l. Sediment resuspension in the Central Basin in November appears to have resulted in the high value of 10.30 µg/l observed during Cruise No. 7.

Chlorophyll

Corrected chlorophyll a (CHL a) concentrations and mass for 1977 in the Western, Central, and Eastern Basins are listed in Table 10 and shown graphically on Figures 55-61. The highest concentration and quantities in each basin were observed in late summer (Cruise Nos. 5 and 6). The mean Western Basin concentration was 3.6 times as great as that of the Central Basin and 4.7 times the Eastern Basin mean concentration. The west to east decrease in CHL a is well illustrated by the surface concentrations observed during Cruise No. 6 (figure 60).

Chlorophyll a mean concentration for 1977 in the Western Basin shows a marked increase over the 1976 mean level (Figure 66). This rise may be the result of increased productivity due to warm water temperature and higher than average hours of sunshine. A reduced cruise schedule in this basin in 1977 may also have influenced the calculated mean concentration. The Central and Eastern Basin CHL a mean concentrations have been relatively stable for the past five years with a slight indication of a decrease over the past three years (Figures 67 and 68).

WATER QUALITY TRENDS

Dissolved oxygen, conductivity, phosphorus and chlorophyll have been the most useful parameters for indexing the trophic status of Lake Erie. Since 1970 similar analytical methods and calculation procedures have been used to provide information on these parameters in the three basins of the lake. Although some minor changes have been observed over the past eight years, such as the small but persistent decline in conductivity (Figure 62), each of these parameters appears to have been relatively stable over this period of time (Figures 62-68). This is not surprising considering the fact that nutrient loading to the lake has also been fairly uniform during this period.

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TABLES

TABLE 2

SUMMARY OF 1977 HYPOLIMNETIC SURVEYS OF LAKE ERIE

Central Basin

Cruise	Date	Area (km^2)	Volume (km^3)	Avg. Thickness (m)	Total Heat ($kcal \times 10^{12}$)	Avg. Temp (^oC)	Total O_2 ($kgO_2 \times 10^6$)	Avg. O_2 (ppm)	Avg. Temp Gradient ($^oCm^{-1}$)	Avg. O_2 Gradient (gO_2m^{-4})
3	6/20-6/30	13,245	89.9	6.8	965.75	10.74	745.85	8.30	2.64	1.96
4	7/12-7/31	12,876	59.8	4.6	659.72	11.03	304.6	5.09	4.11	2.13
5	8/11-8/21	11,705	35.4	3.0	422.89	11.93	74.91	2.11	12.54	9.31
6	9/22-9/30	1,891	3.9	2.1	43.47	11.17	2.14	0.49	4.92	8.86

Eastern Basin

Cruise	Date	Area (km^2)	Volume (km^3)	Avg. Thickness (m)	Total Heat ($kcal \times 10^{12}$)	Avg. Temp (^oC)	Total O_2 ($kgO_2 \times 10^6$)	Avg. O_2 (ppm)	Avg. Temp Gradient ($^oCm^{-1}$)	Avg. O_2 Gradient (gO_2m^{-4})
3	6/21-6/23	4,620	59.9	14.0	374.18	6.24	647.28	10.81	1.65	0.15
4	7/15-7/20	3,754	48.0	12.8	330.38	6.88	435.37	8.91	1.93	0.26
5	8/12-8/15	3,256	36.4	11.2	215.22	5.91	276.02	7.58	5.14	1.54
6	10/5-10/9	2,013	23.3	11.6	131.16	5.63	150.56	6.46	8.71	2.34

TABLE 3

LAKE ERIE HYPOLIMNETIC OXYGEN DEPLETION RATES FOR 1977

CENTRAL BASIN

Cruise Nos. Interval	Simple Calculation		Model Calculation (Burns, 1976)	
	Areal	Volumetric	Areal	Volumetric
3-4	1.57	0.27	1.00	0.17
4-5	0.59	0.15	0.46	0.12
5-6	0.28	0.06	0.27	0.09
Mean	0.81±0.33	0.16±0.05	0.58±0.19	0.13±0.02

EASTERN BASIN

Cruise Nos. Interval	Simple Calculation		Model Calculation (Burns, 1976)	
	Areal	Volumetric	Areal	Volumetric
3-4	1.93	0.15	0.93	0.07
4-5	1.62	0.13	0.71	0.06
5-6	1.05	0.09	0.40	0.04
Mean	1.53±0.22	0.12±0.02	0.68±0.13	0.06±0.01

Area Rate = $gO_2m^{-2}day^{-1}$

Volumetric Rate = $gO_2m^{-3}day^{-1}$

TABLE 4

COMPARISON OF 1973 - 1977
CHARACTERISTICS OF HYPOLIMNION IN CENTRAL LAKE ERIE

	1970 (Project Hypo)	1973	1974	1975	1976	1977
JUNE						
Thick (m)	-	-	6.2	7.7	6.6	6.8
DO (mg/l)	-	-	9.9	10.0	9.6	8.3
Temp (^{o}C)	-	-	8.8	6.5	9.4	10.4
JULY						
Thick (m)	-	5.0	4.6	6.7	-	4.6
DO (mg/l)	-	4.9	5.2	7.8	-	5.1
Temp (^{o}C)	-	10.3	11.8	7.7	-	11.0
AUGUST						
Thick (m)	-	4.4	4.3	6.8	3.0	3.0
DO (mg/l)	-	1.6	2.1	3.3	0.7	2.1
Temp (^{o}C)	-	11.9	13.5	10.2	13.7	11.9
SEPTEMBER						
Thick (m)	-	3.0	-	-	-	2.1
DO (mg/l)	-	1.1	-	-	-	0.5
Temp (^{o}C)	-	13.8	-	-	-	11.2
NET OXYGEN DEMAND						
loss/day (mgO_2/cm^2) rate per unit area	0.043	0.053	0.060	0.067	0.075	0.058
loss/day (mgO_2/l) rate per unit volume	0.13	0.12	0.13	0.10	0.13	0.13

TABLE 5

TRENDS IN NET OXYGEN DEMAND OF THE
CENTRAL AND EASTERN BASIN HYPOLIMNIONS
OF LAKE ERIE
1930-1977

Year	NET OXYGEN DEMAND			
	Rate Per Unit Area ($mg\ O_2\ cm^{-2}\ day^{-1}$)		Rate Per Unit Volume ($mg\ O_2\ l^{-1}\ day^{-1}$)	
	Central Basin	Eastern Basin	Central Basin	Eastern Basin
1930	0.008	-	0.054	-
1940	0.015	-	0.067	-
1950	0.025	-	0.070	-
1960	0.037	-	0.093	-
1970	0.043	0.087	0.13	0.057
1973	0.053	0.023	0.12	0.016
1974	0.060	0.057	0.13	0.026
1975	0.067	0.076	0.10	0.040
1976	0.075	-	0.13	0.032
1977	0.058	0.068	0.13	0.060

TABLE 6

ESTIMATED AREA OF THE ANOXIC HYPOLIMNION

OF THE CENTRAL BASIN OF LAKE ERIE 1930-1977

YEAR	AREA (km^2)	PERCENT OF CENTRAL BASIN	
		Hypolimnion	Total Basin
1930	300	3.0	1.9
1959	3,600	33.0	22.3
1960	1,660	15.0	10.3
1961	3,640	33.0	22.5
1964	5,870	53.0	36.3
1970	6,600	60.0	40.4
1972	7,970	72.5	49.3
1973	11,270	93.7	69.8
1974	10,250	87.0	63.4
1975	400	4.1	2.5
1976	7,300	63.0	53.0
1977	2,870	24.8	20.8

TABLE 7

TOTAL DISSOLVED SOLIDS BUDGET FOR LAKE ERIE IN 1977

Cruise No.	Date	WESTERN BASIN				CENTRAL BASIN				EASTERN BASIN				TOTAL LAKE				
		umhos/cm	mg/l or tons/$km^3 \times 10^3$	km^3	tons $\times 10^{-6}$	umhos/cm	mg/l or tons/$km^3 \times 10^3$	km^3	tons $\times 10^{-6}$	umhos/cm	mg/l or tons/$km^3 \times 10^3$	km^3	tons $\times 10^{-6}$	umhos/cm	mg/l or tons/$km^3 \times 10^3$	km^3	tons $\times 10^{-6}$	tons $\times 10^6$
1	3/21-4/3	252.4	164.06	22.16	3.636	278.0	180.7	302.20	54.604	266.6*	173.3	167.75	29.071	273.0	177.4	492.11	87.311	
2	4/28-5/8	262.6*	170.65	22.73	3.879	288.7	187.66	306.08	57.439	276.9	180.00	169.16	30.449	283.5	184.3	497.97	91.767	+4.456
3	Epi	258.5*	168.0	22.55	3.788	278.4	181.00	179.0	32.399	285.5	185.6	99.6	18.489	279.2	181.5	301.1	54.68	
6/20 to 6/30	Meso					282.2	183.40	35.2	6.456	292.0	189.8	13.3	2.524	284.8	185.2	48.5	8.98	
	Hypo					264.5	171.90	89.9	15.454	287.2	186.7	54.3	10.231	273.1	177.5	144.7	25.68	
	Total					274.8	(178.6)	304.1	54.309	286.5	(186.3)	167.7	31.240	278.1	180.7	494.3	89.337	-2.430
4	Epi	252.4*	164.1	22.57	3.704	262.3	170.6	219.2	37.396	282.6	183.7	84.5	15.523	267.2	173.7	326.27	56.62	
7/12 to 7/31	Meso					298.7	194.2	25.4	4.933	281.0	182.7	36.4	6.650	288.3	187.4	61.8	11.58	
	Hypo					282.8	183.8	59.8	10.991	284.9	185.2	48.0	8.890	283.7	184.4	107.8	19.88	
	Total					269.5	(175.2)	304.4	53.32	282.9	(183.9)	168.9	31.063	273.3	177.6	495.9	88.08	-1.257
5	Epi	250.0*	162.5	22.49	3.655	281.0	182.6	256.9	46.910	281.2	182.8	114.2	20.876	279.2	181.5	393.6	71.441	
8/11 to 8/21	Meso					305.7	198.7	11.6	2.305	294.7	191.5	18.2	3.485	298.9	194.3	29.8	5.790	
	Hypo					303.1	197.0	35.4	6.974	296.5	192.8	36.4	7.018	299.8	194.9	71.8	13.992	
	Total					284.8	(185.1)	303.5	56.189	286.0	(185.9)	168.8	31.379	283.4	184.2	495.2	91.223	+3.143
6	Epi	271.3	176.3	22.57	3.979	279.0	181.4	298.3	54.112	295.9	192.3	143.0	27.499	283.8	184.5	463.9	85.590	
9/10 to 10/9	Meso					291.0	189.1	2.3	0.435	299.8	194.8	2.4	0.468	295.6	192.1	4.7	0.903	
	Hypo					298.4	193.9	3.9	0.756	296.9	193.0	23.3	4.497	297.1	193.1	27.2	5.253	
	Total					279.4	(181.6)	304.5	55.303	296.0	(192.4)	168.7	32.464	284.7	185.0	495.8	91.746	+0.523
7	11/7-11/22	264.2	171.7	22.5	3.863	286.7	186.4	300.5	56.013	299.7	194.8	167.7	32.668	290.1	188.6	490.7	92.544	+0.798
Average		262.63				280.27				284.75				280.87				+5.233
Std. Dev.		12.71				6.89				11.17				6.33				

*Estimated

**0.65--factor to convert umhos/cm to mg/l total dissolved solids

TABLE 8

TOTAL PHOSPHORUS IN LAKE ERIE FOR 1977

CRUISE NO.	DATE	LIMNION	WESTERN BASIN			CENTRAL BASIN			EASTERN BASIN		
			VOLUME (km^3)	TP MASS (M-tons)	TP CONC. (mg/l)	VOLUME (km^3)	TP MASS (M-tons)	TP CONC. (mg/l)	VOLUME (km^3)	TP MASS (M-tons)	TP CONC. (mg/l)
1	3/21-4/3	TOTAL	22.16	773.25	34.89	302.20	3988.07	13.20			
2	4/28-5/8	TOTAL				306.08	3747.74	12.24	169.16	2192.82	12.96
3	6/20-6/30	EPI				178.79	5090.47	28.47	99.57	1888.26	18.96
		MESO				35.24	805.20	22.85	14.33	246.73	17.22
		HYPO				89.91	2433.06	27.06	54.76	950.42	17.36
		TOTAL				303.94	8828.73	27.40	168.66	3085.41	18.29
4	7/12-7/31	EPI				219.21	5759.03	26.27			
		MESO				25.45	591.74	23.25			
		HYPO				59.82	1792.85	29.97			
		TOTAL				304.48	8143.62	26.75			
5	8/11-8/21	EPI				256.94	7361.73	28.65			
		MESO				11.59	423.24	36.52			
		HYPO				35.44	1182.02	33.35			
		TOTAL				303.97	8966.99	29.50			
6	9/10-10/9	EPI				298.34	9509.76	31.88	142.97	2718.98	19.02
		MESO				2.25	184.36	81.94	2.43	48.56	19.98
		HYPO				3.89	388.66	99.91	23.29	456.85	19.62
		TOTAL	22.57	1203.53	53.32	304.48	10082.78	33.11	168.69	3224.39	19.11
7	11/7-11/20	TOTAL	22.48	762.36	33.91	300.45	7912.23	26.33	167.68	3844.70	22.93
ANNUAL MEAN				913.05	40.71		7310.02	24.08		3086.83	18.32

TABLE 9

SOLUBLE REACTIVE PHOSPHORUS IN LAKE ERIE FOR 1977

CRUISE NO.	DATE	LIMNION	WESTERN BASIN VOLUME (km^3)	WESTERN BASIN SRP MASS (M-tons)	WESTERN BASIN SRP CONC. (mg/l)	CENTRAL BASIN VOLUME (km^3)	CENTRAL BASIN SRP MASS (M-tons)	CENTRAL BASIN SRP CONC. (mg/l)	EASTERN BASIN VOLUME (km^3)	EASTERN BASIN SRP M-TONS (M-tons)	EASTERN BASIN SRP CONC. (mg/l)
1	3/21-4/3	TOTAL	22.16	141.67	6.39	302.20	294.63	0.97			
2	4/28-5/8	TOTAL				306.08	450.00	1.47	169.16	295.88	1.75
3	6/20-6/30	EPI				178.79	564.35	3.16	99.57	232.50	2.34
		MESO				35.24	84.34	2.39	14.33	27.02	1.89
		HYPO				89.91	272.15	3.03	54.76	149.75	2.73
		TOTAL				303.94	920.84	3.03	168.66	409.27	2.43
4	7/12-7/31	EPI				219.21	825.94	3.77			
		MESO				25.45	86.35	3.39			
		HYPO				59.82	196.77	3.29			
		TOTAL				304.48	1109.06	3.64			
5	8/11-8/21	EPI				256.94	741.38	2.89			
		MESO				11.59	55.40	4.78			
		HYPO				35.44	314.32	8.87			
		TOTAL				303.97	1111.10	3.66			
6	9/10-10/9	EPI				298.34	2069.55	6.94	142.97	661.72	4.63
		MESO				2.25	53.39	23.73	2.43	13.43	5.53
		HYPO				3.89	134.50	34.58	23.29	193.96	8.33
		TOTAL	22.57	188.53	8.35	304.48	2257.44	7.41	168.69	869.11	5.15
7	11/7-11/20	TOTAL	22.48	129.77	5.77	300.45	3094.88	10.30	167.68	873.80	5.21
ANNUAL MEAN				154.32	6.84		2746.84	4.35		612.02	3.64

TABLE 10

CHLOROPHYLL a IN LAKE ERIE FOR 1977

CRUISE NO.	DATE	LIMNION	WESTERN BASIN			CENTRAL BASIN			EASTERN BASIN		
			VOLUME (km^3)	CHLa MASS (M-tons)	CHLa CORR. (mg/l)	VOLUME (km^3)	CHLa MASS (M-tons)	CHLa CORR. (mg/l)	VOLUME (km^3)	CHLa MASS (M-tons)	CHLa CORR. (mg/l)
1	3/21-4/3	TOTAL	22.16	173.02	7.81	302.20	1071.68	3.55			
2	4/28-5/8	TOTAL				306.08	1102.48	3.60	169.16	122.63	2.50
3	6/20-6/30	EPI				178.99	544.14	3.03	99.57	294.56	2.96
		MESO				35.24	92.85	2.63	14.33	34.42	2.40
		HYPO				89.91	243.62	2.71	54.76	91.78	1.68
		TOTAL				304.14	880.61	2.89	168.66	420.63	2.49
4	7/12-7/31	EPI				219.21	829.35	3.78	84.50	259.99	3.08
		MESO				25.45	91.44	3.59	36.38	74.53	2.05
		HYPO				59.82	195.52	3.27	48.02	77.51	1.61
		TOTAL				304.48	1116.31	3.67	168.90	412.03	2.44
5	8/11-8/21	EPI				256.94	1765.87	6.87	114.20	621.98	5.45
		MESO				11.59	78.75	6.79	18.25	74.05	4.06
		HYPO				35.44	194.84	5.50	36.40	76.20	2.09
		TOTAL				303.97	2039.46	6.71	168.85	772.23	4.57
6	9/10-10/9	EPI				298.34	1994.92	6.69	142.97	761.46	5.33
		MESO				2.25	21.19	9.42	2.43	7.56	3.11
		HYPO				3.89	24.49	6.30	23.29	60.34	2.16
		TOTAL	22.57	540.25	23.94	304.48	2040.60	6.70	168.09	819.36	4.86
7	11/7-11/20	TOTAL	22.48	396.97	17.66	300.45	1461.93	4.86	167.68	681.11	4.06
ANNUAL MEAN				370.08	16.47		1387.58	4.57		588.00	3.49

FIGURES

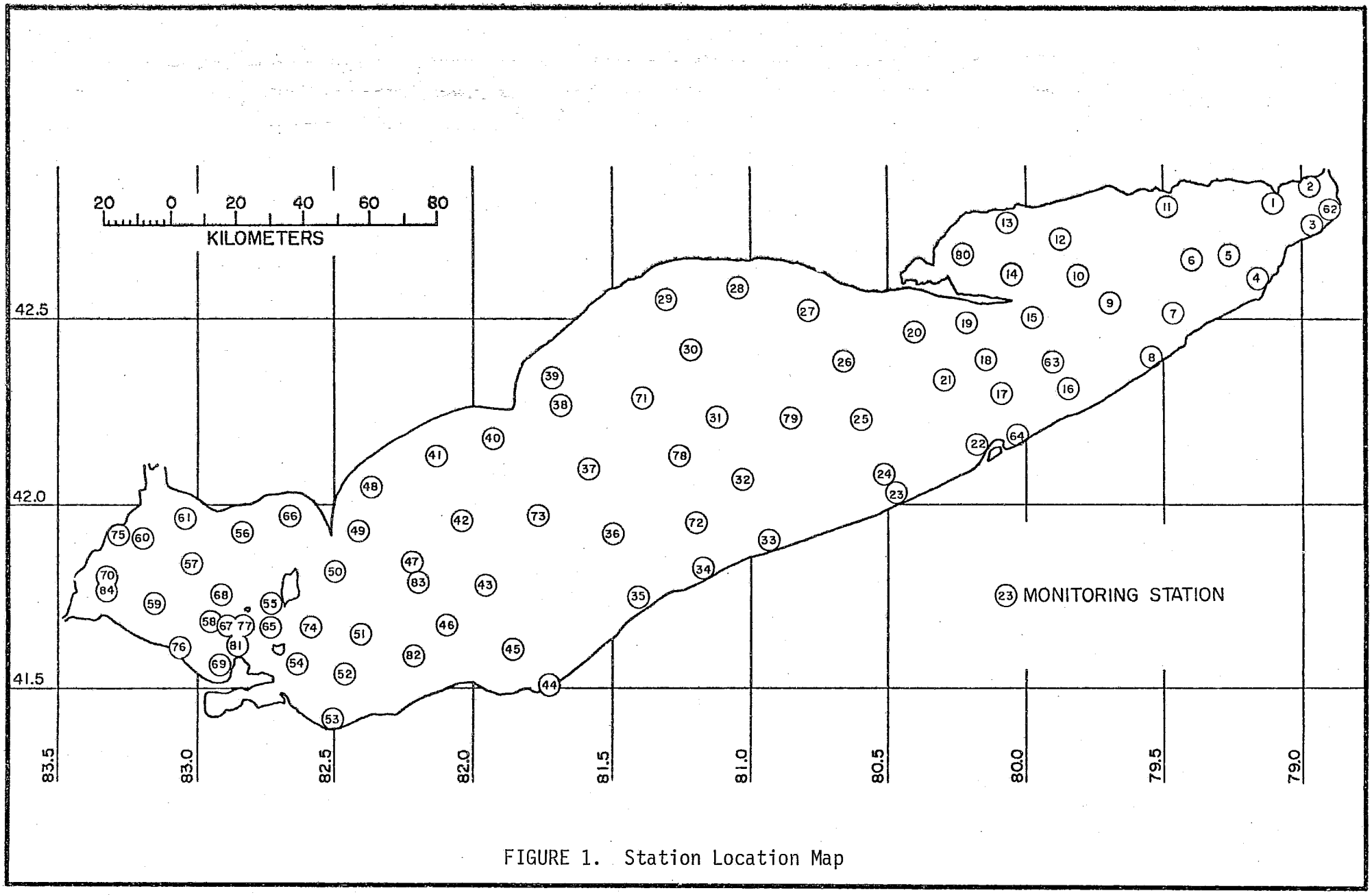


FIGURE 1. Station Location Map

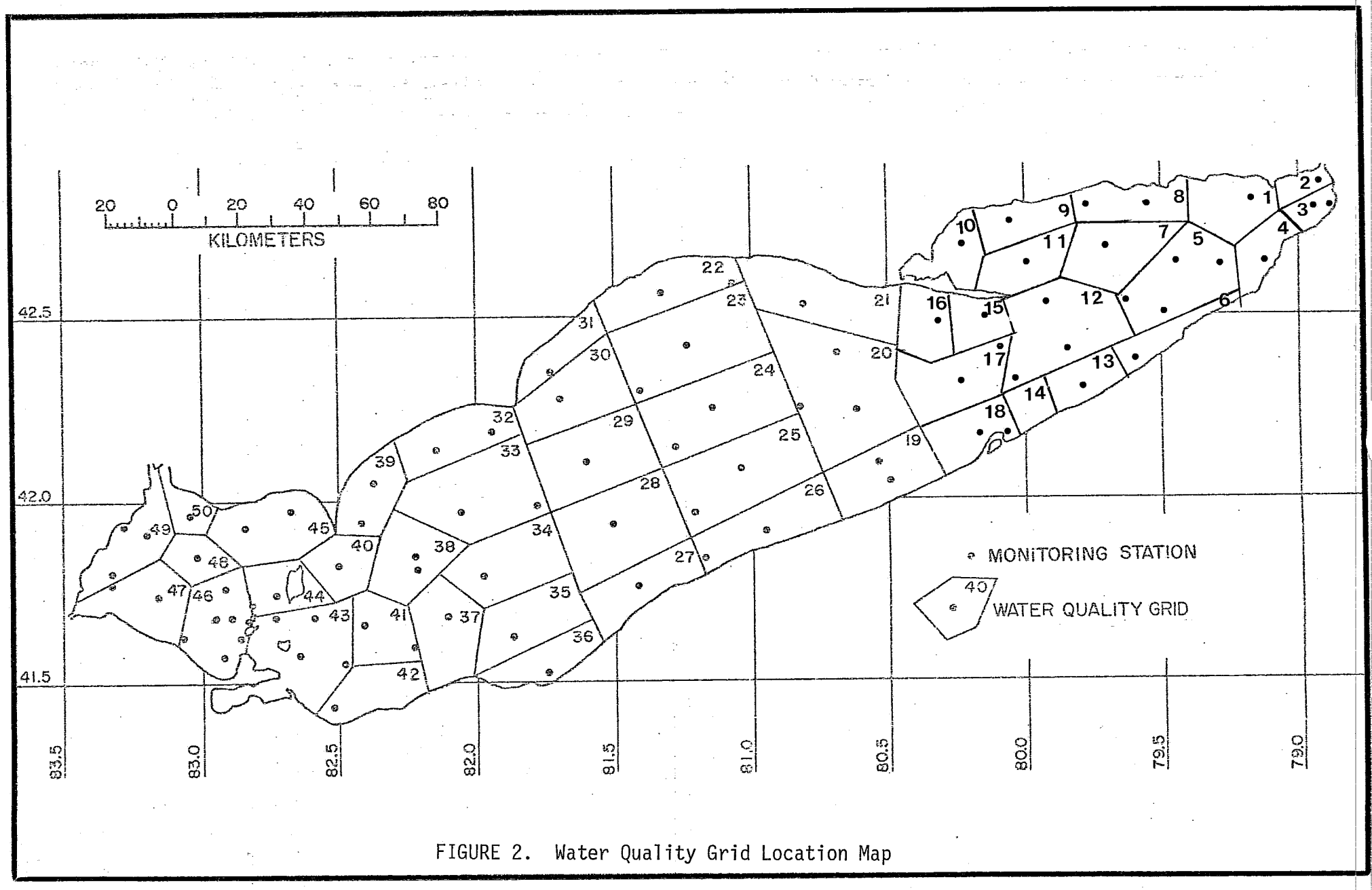


FIGURE 2. Water Quality Grid Location Map

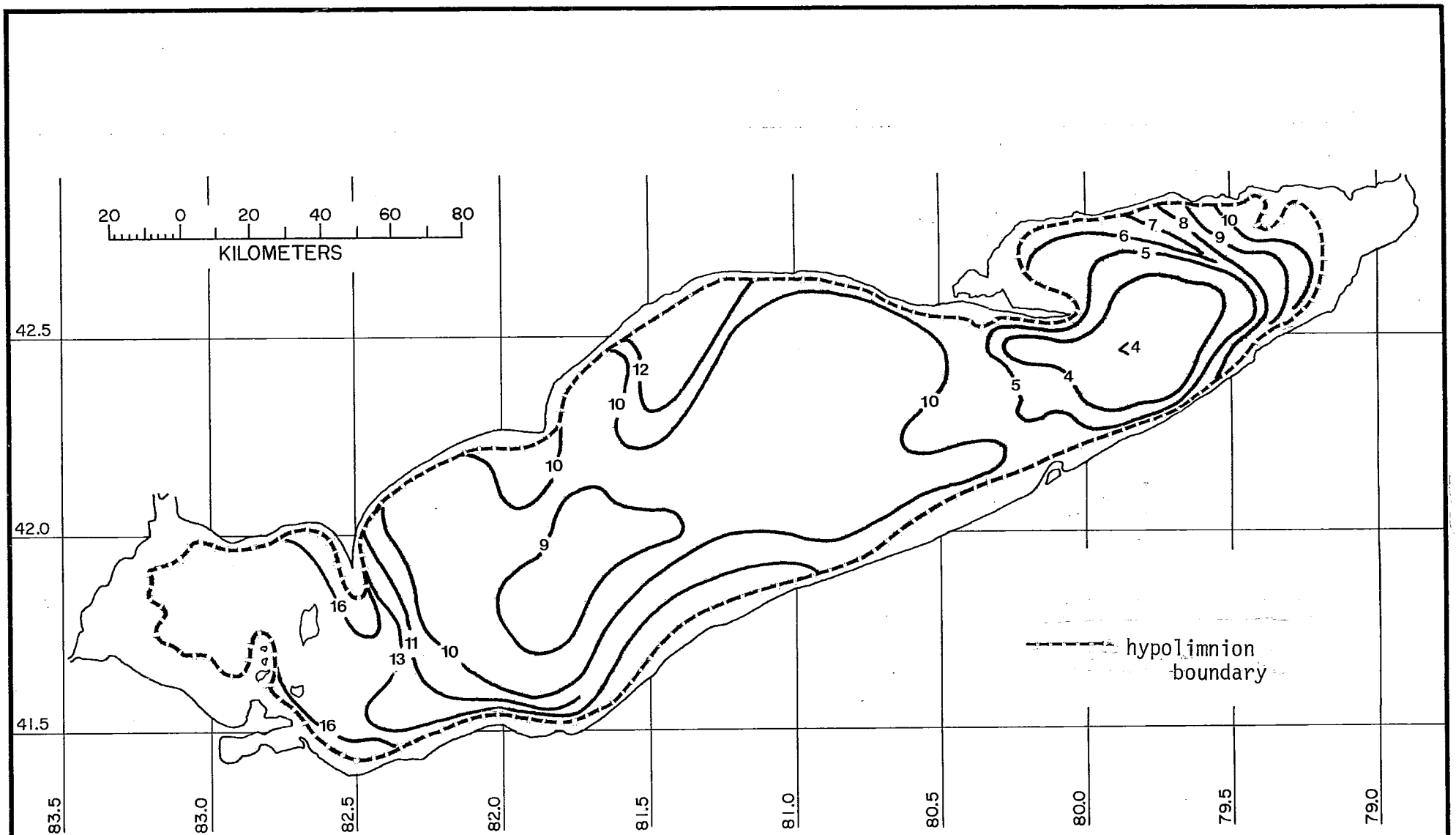


FIGURE 3. Bottom Temperature (^{o}C) for Cruise No. 3 (June 20-30, 1977).

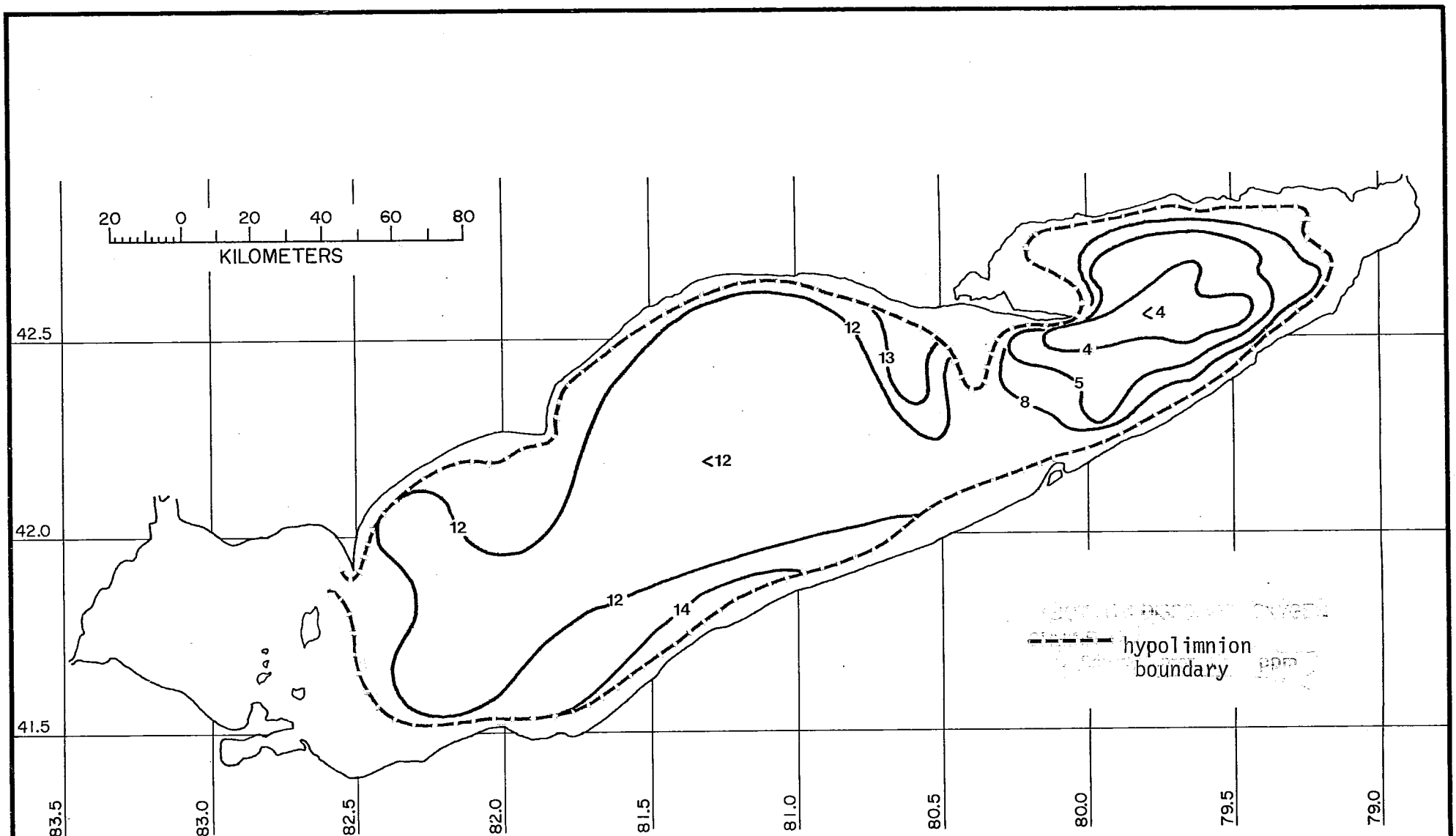


FIGURE 4. Bottom Temperature (^{o}C) for Cruise No. 4 (July 12-31, 1977).

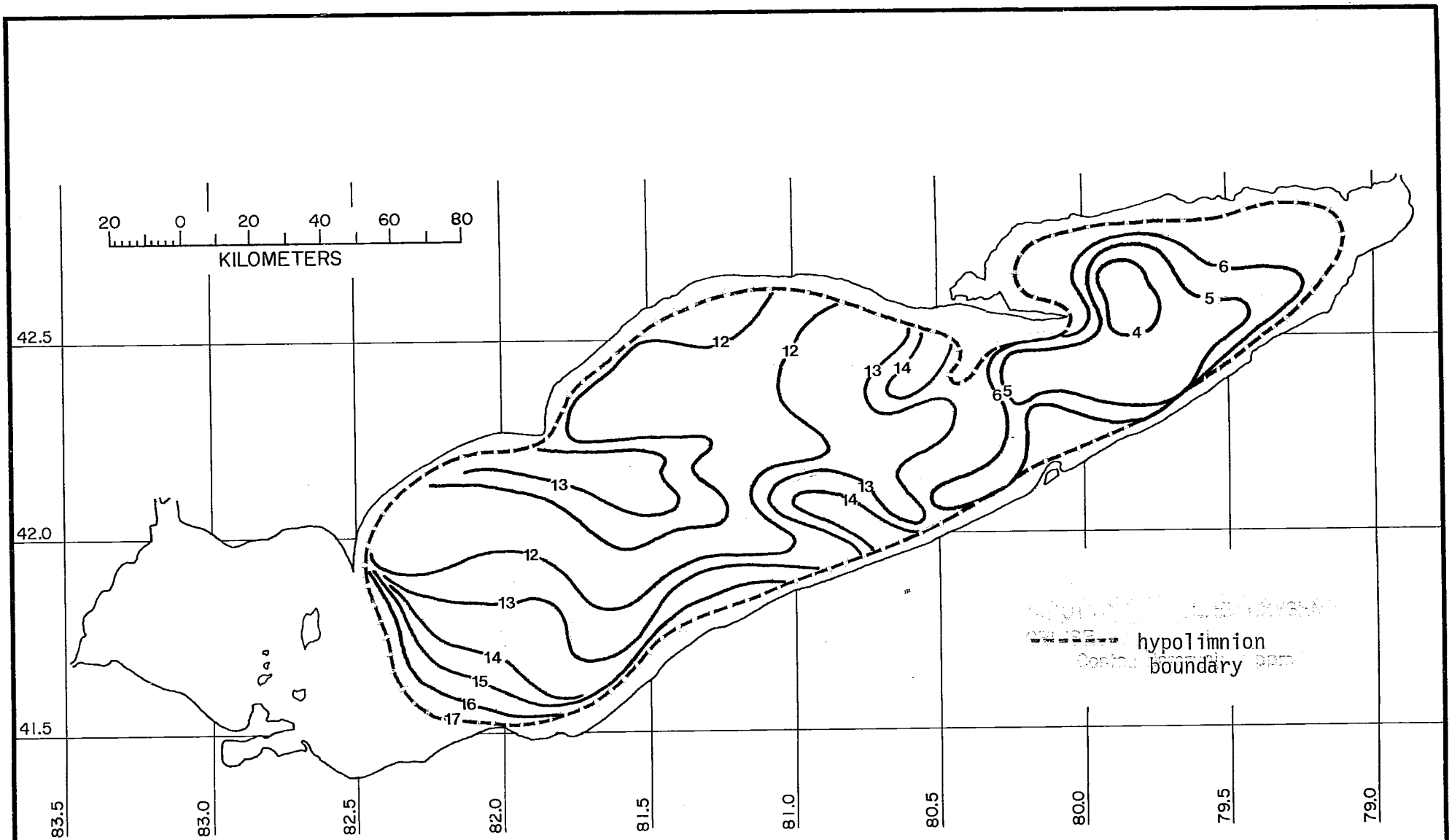


FIGURE 5. Bottom Temperature (°C) for Cruise No. 5 (August 11-12, 1977).

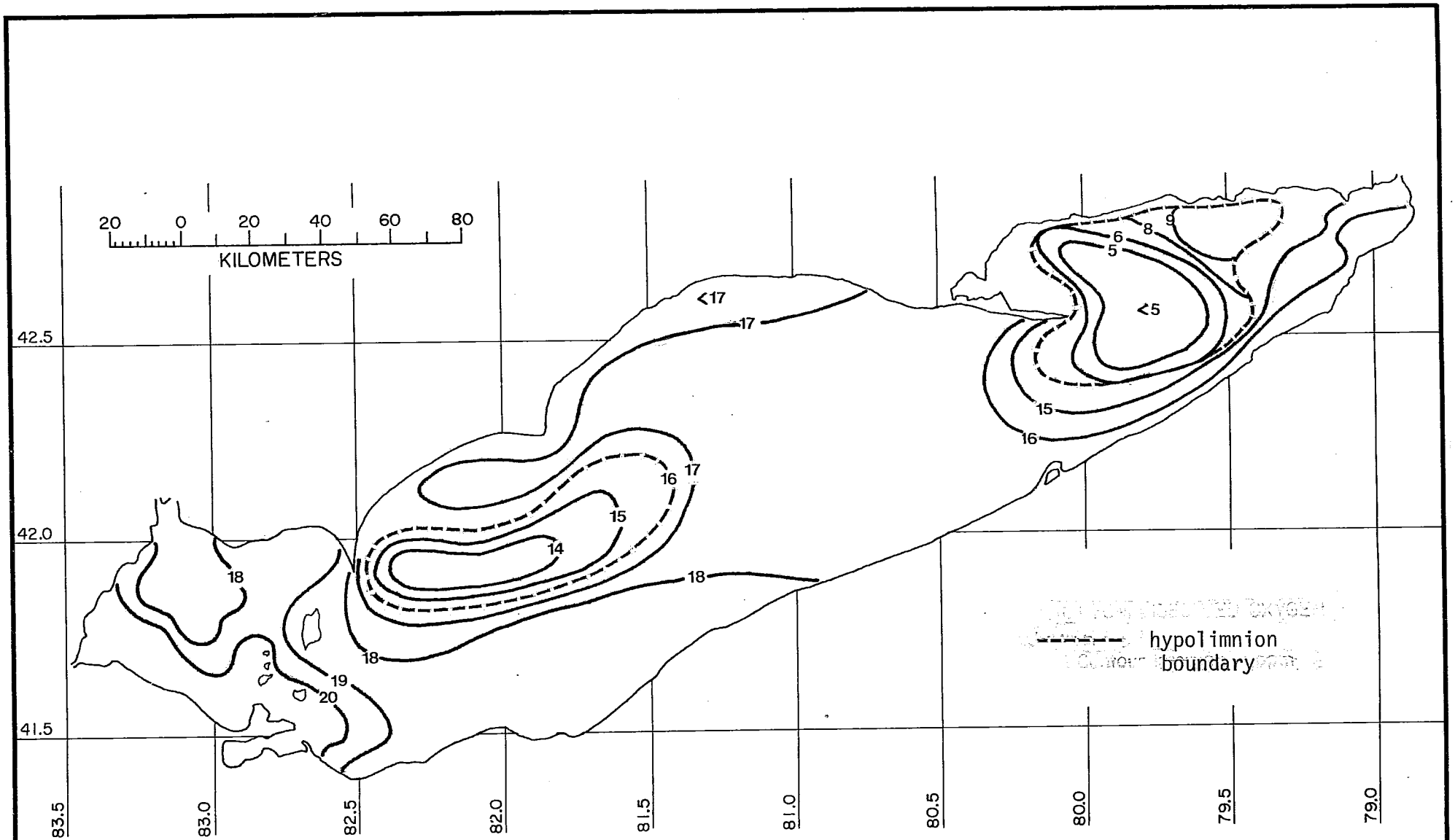


FIGURE 6. Bottom Temperature (°C) for Cruise No. 6 (September 10-October 9, 1977).

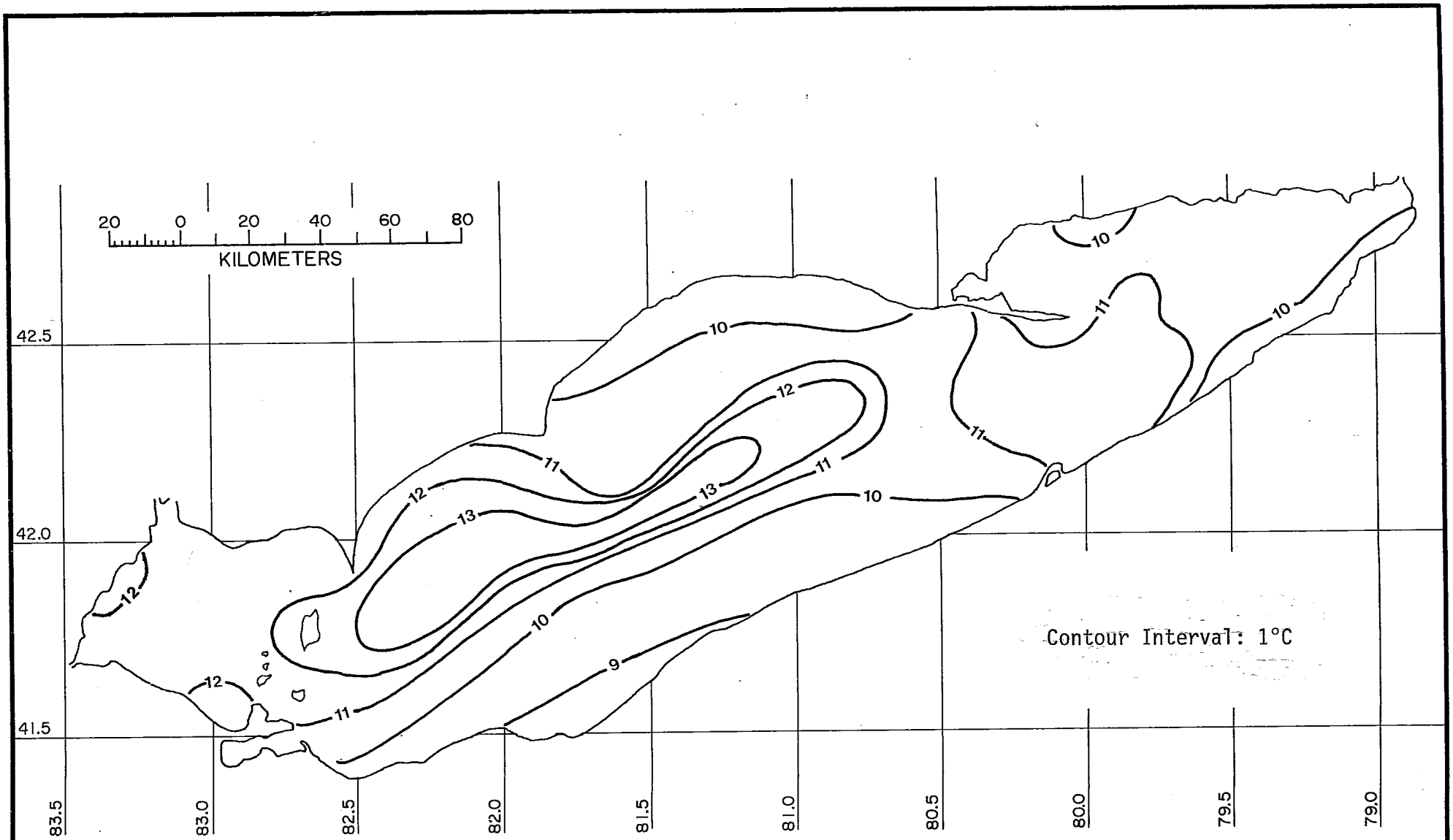


Figure 7. Bottom Temperature (°C) for Cruise No. 7 (November 7-20, 1977).

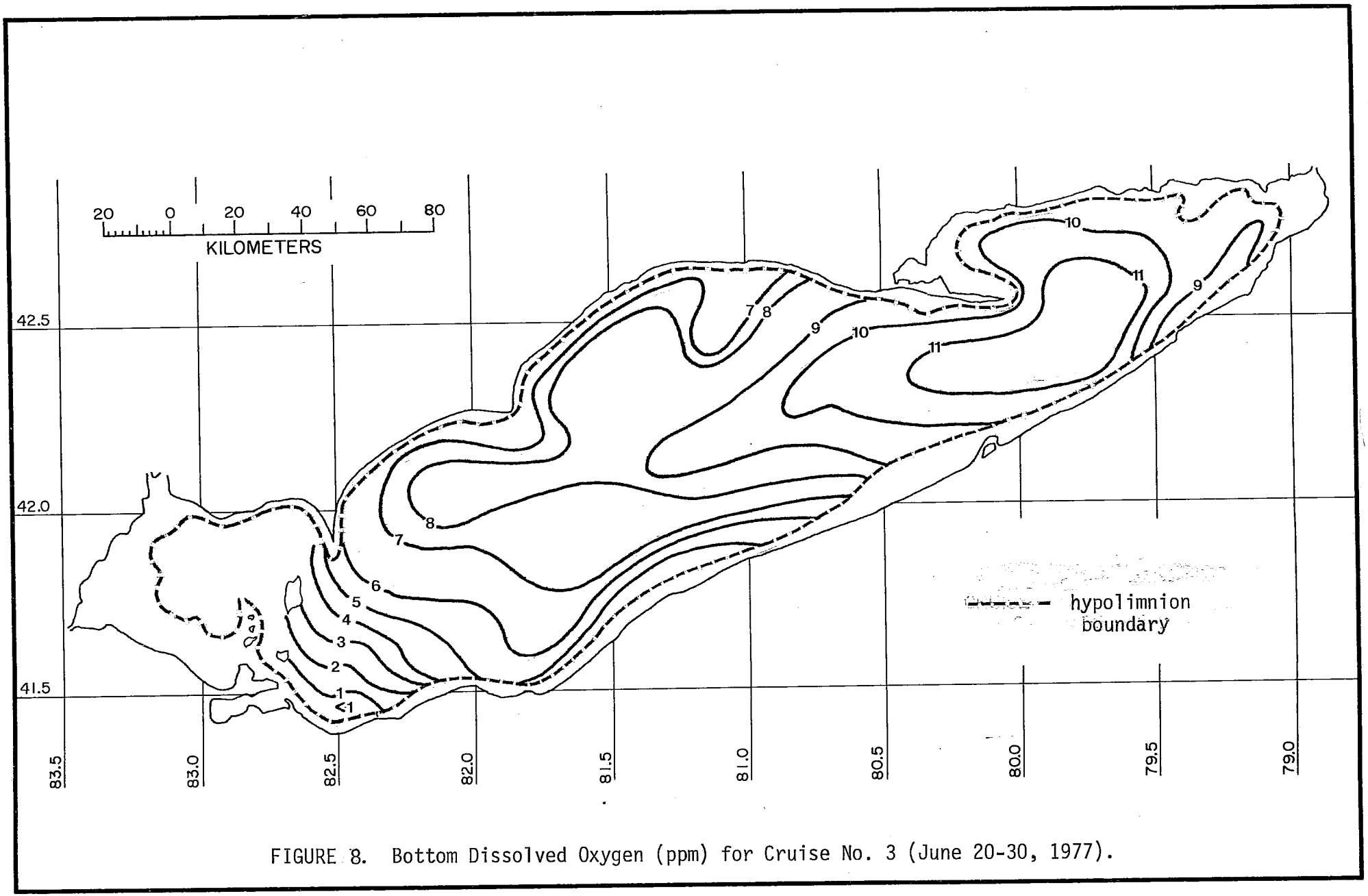


FIGURE 8. Bottom Dissolved Oxygen (ppm) for Cruise No. 3 (June 20-30, 1977).

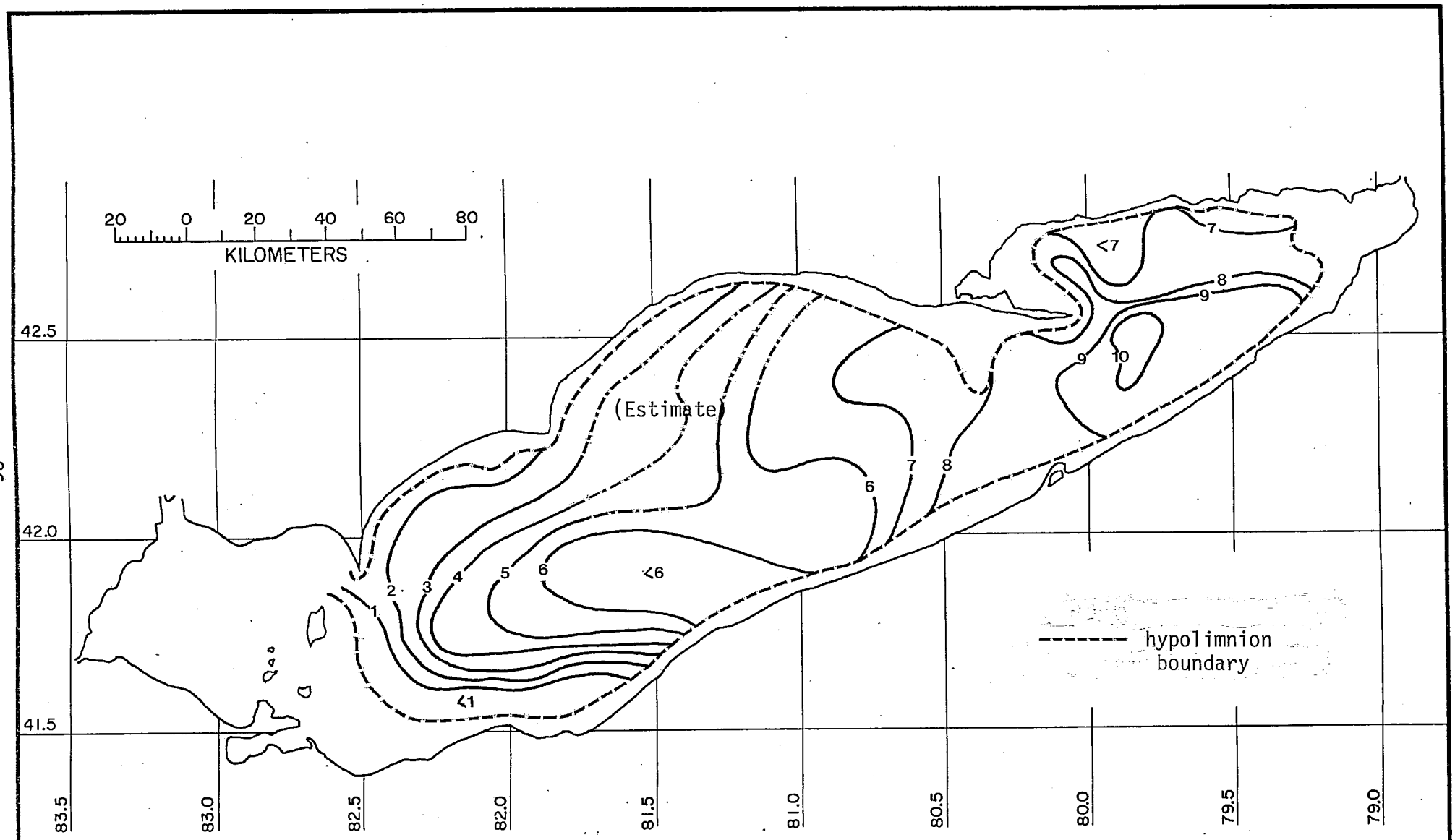


FIGURE 9. Bottom Dissolved Oxygen (ppm) for Cruise No. 4 (July 12-31, 1977).

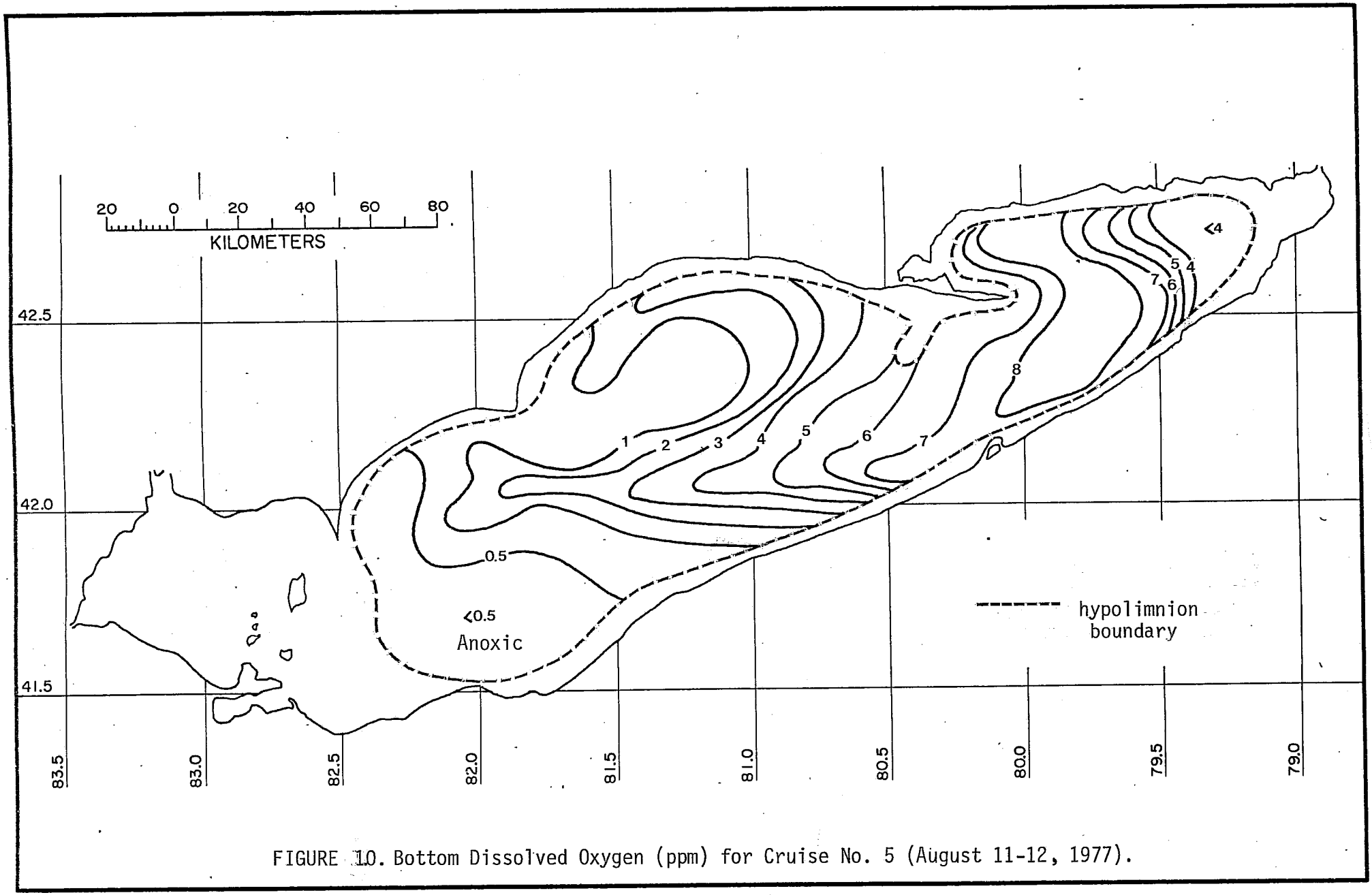


FIGURE 10. Bottom Dissolved Oxygen (ppm) for Cruise No. 5 (August 11-12, 1977).

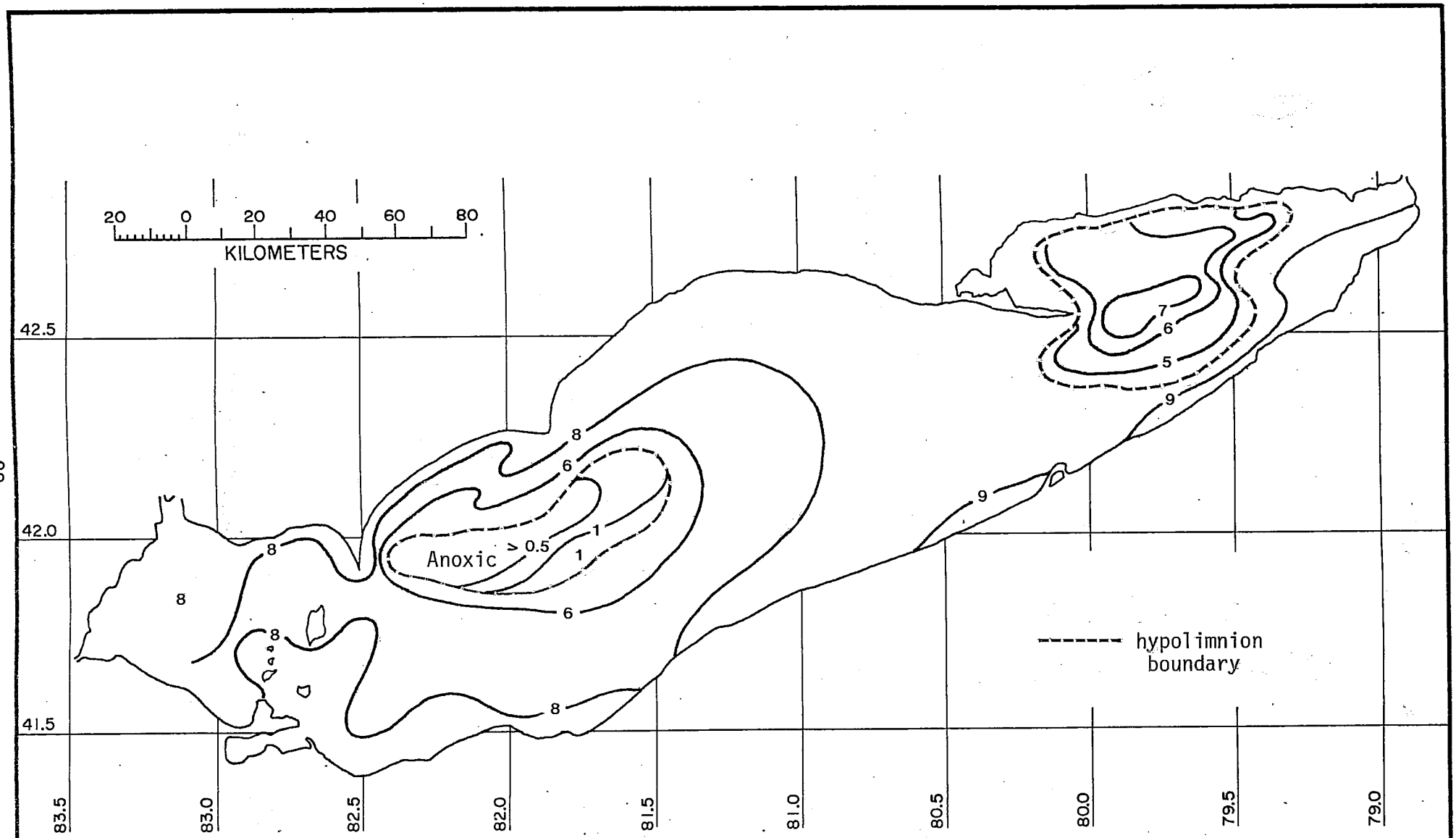


FIGURE 11. Bottom Dissolved Oxygen (ppm) for Cruise No. 6 (September 10-October 9, 1977).

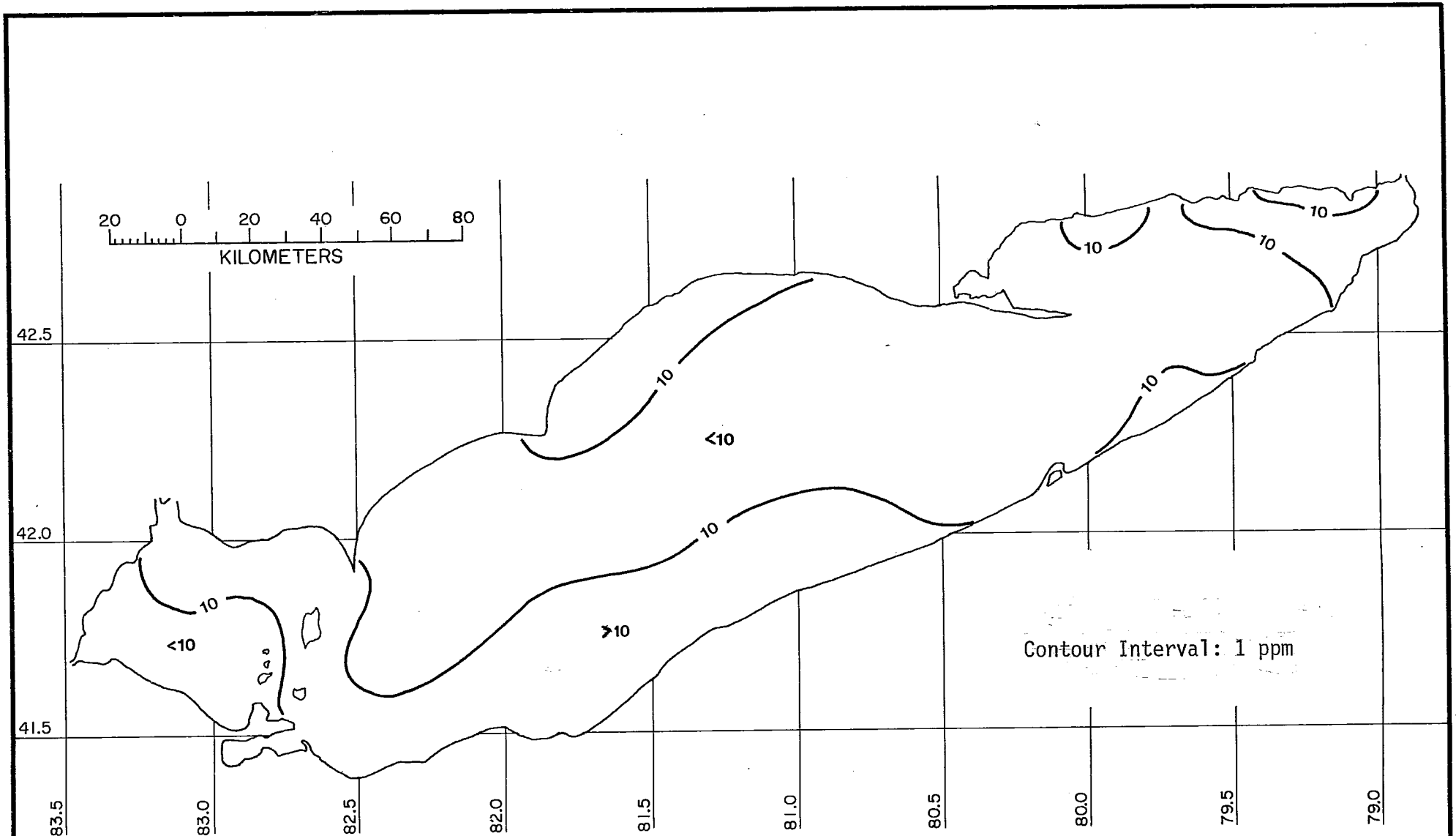


FIGURE 12. Bottom Dissolved Oxygen (ppm) for Cruise No. 7 (November 7-20, 1977).

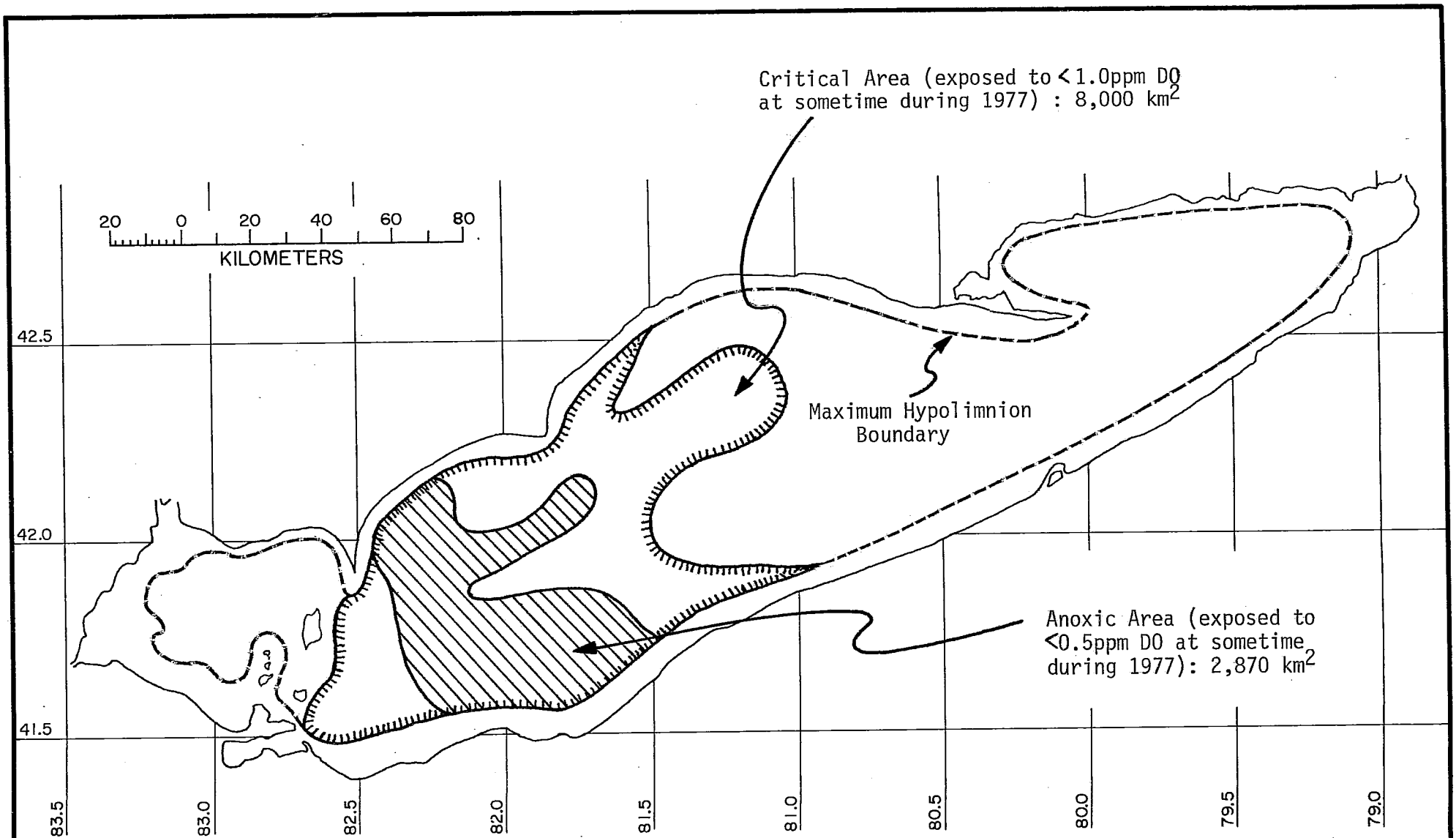


FIGURE 13. Low Bottom Dissolved Oxygen Areas for Cruise Nos. 3-6 (June-September 1977).

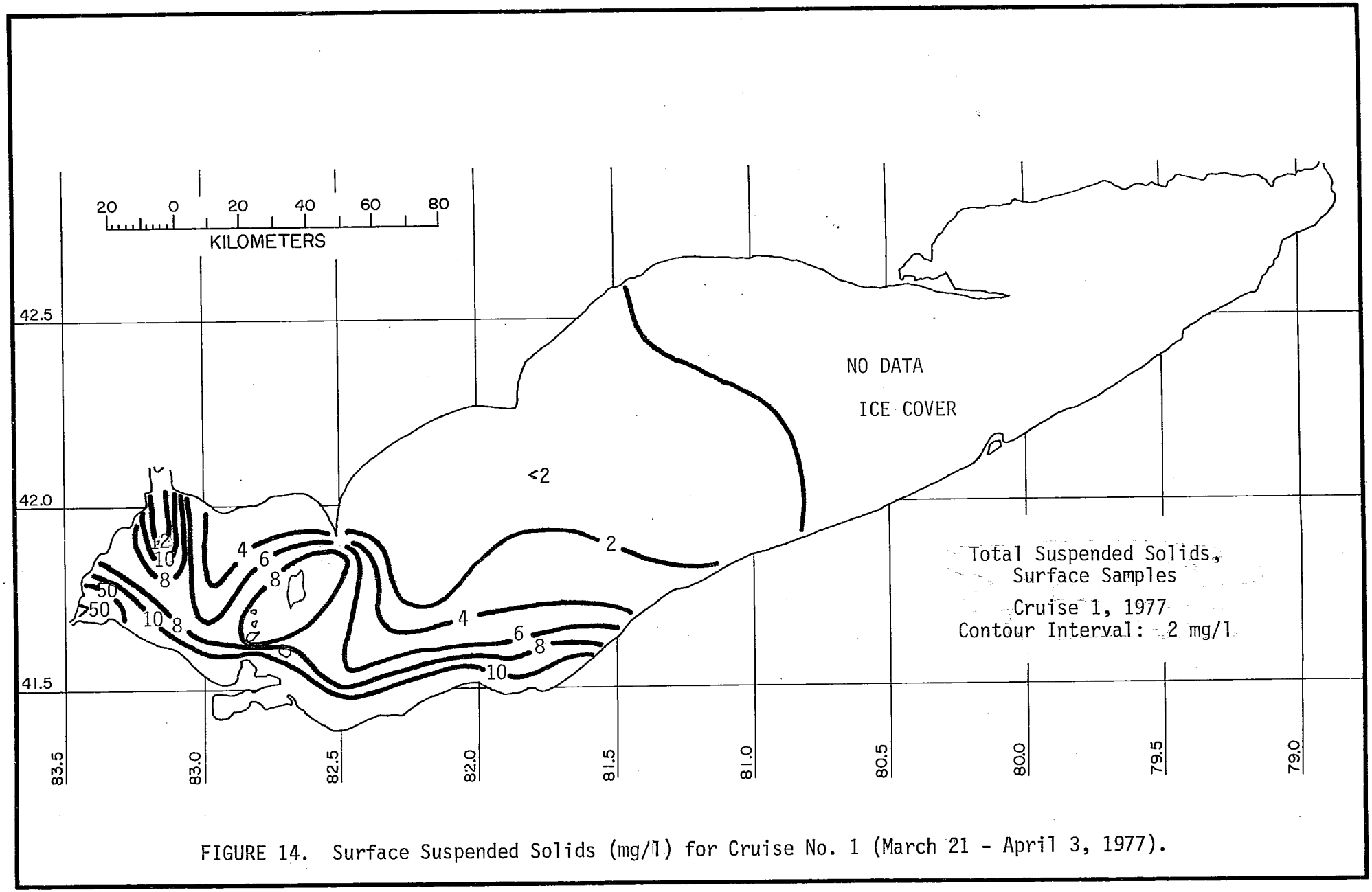


FIGURE 14. Surface Suspended Solids (mg/l) for Cruise No. 1 (March 21 - April 3, 1977).

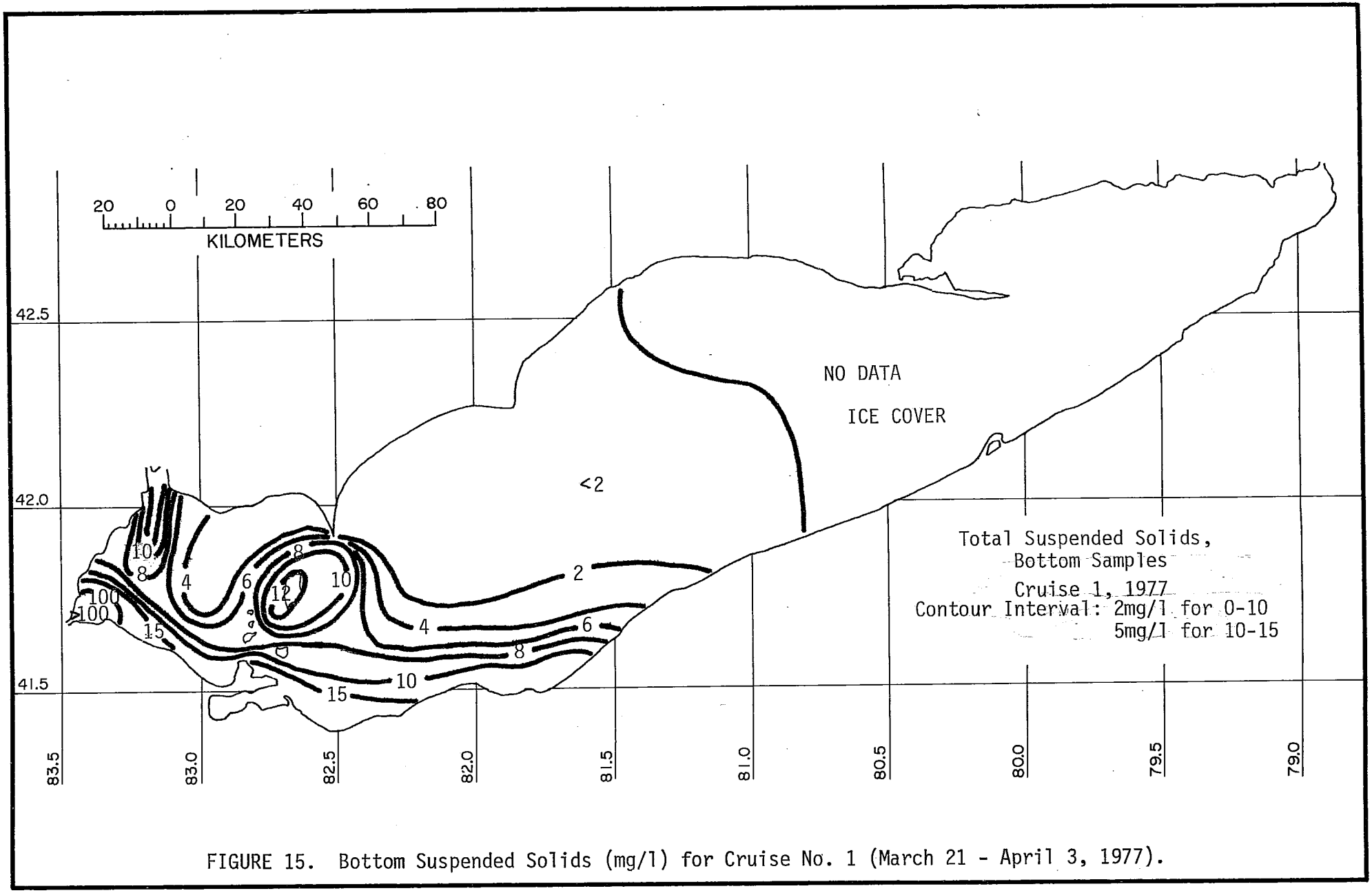


FIGURE 15. Bottom Suspended Solids (mg/l) for Cruise No. 1 (March 21 - April 3, 1977).

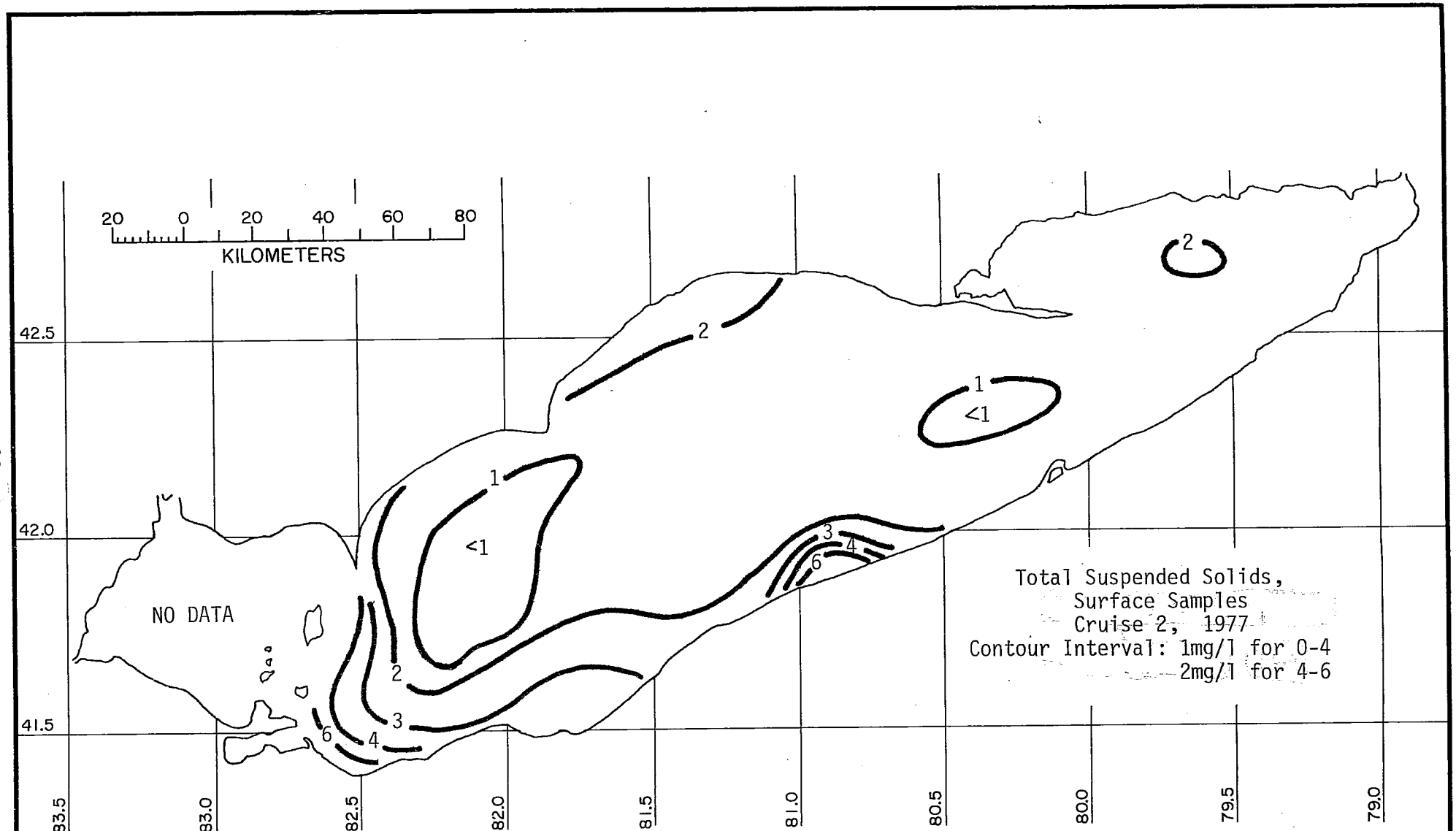


FIGURE 16. Surface Suspended Solids (mg/l) for Cruise No. 2 (April 28 - May 8, 1977).

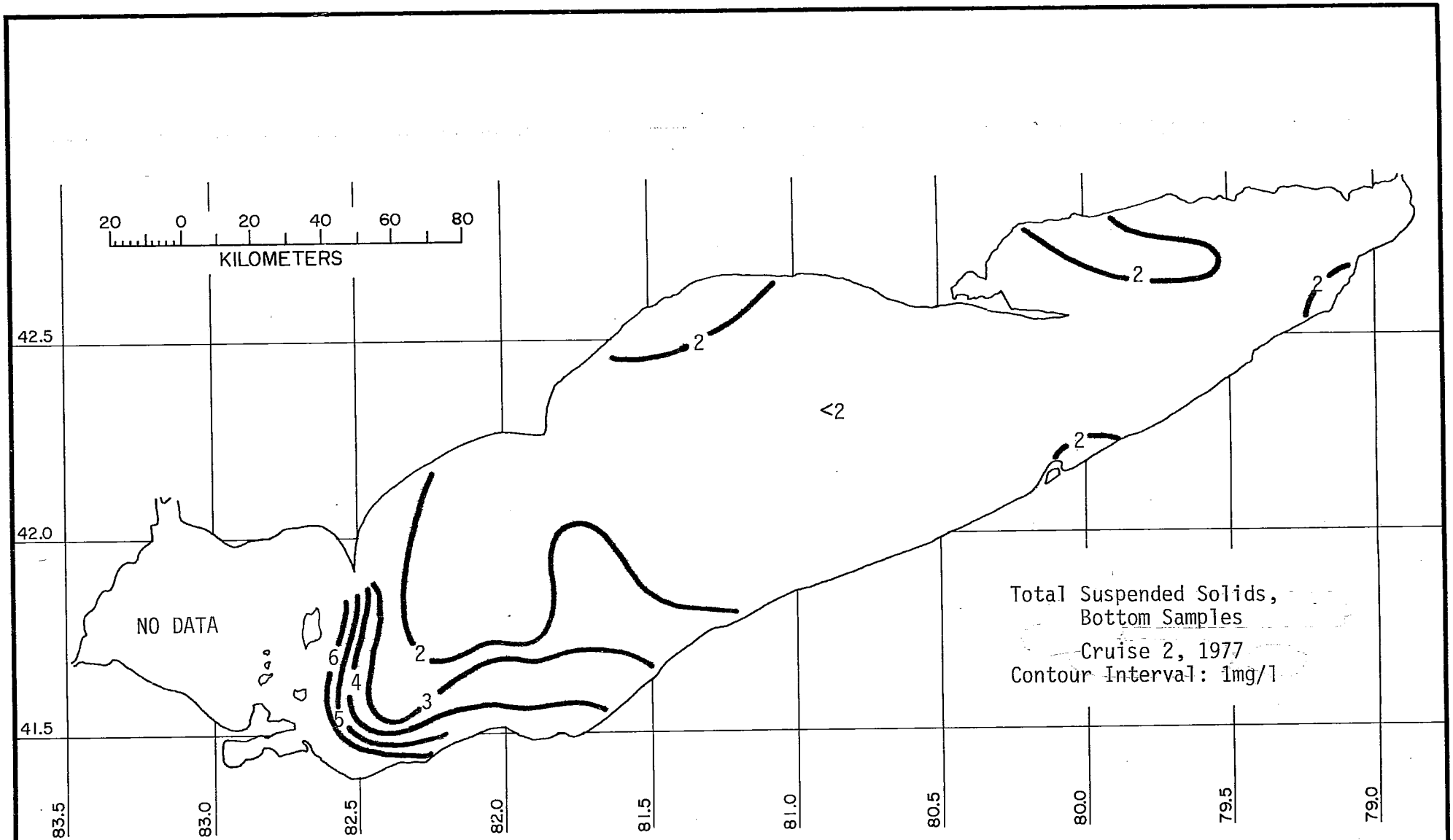


FIGURE 17. Bottom Suspended Solids (mg/l) for Cruise No. 2 (April 28 - May 8, 1977).

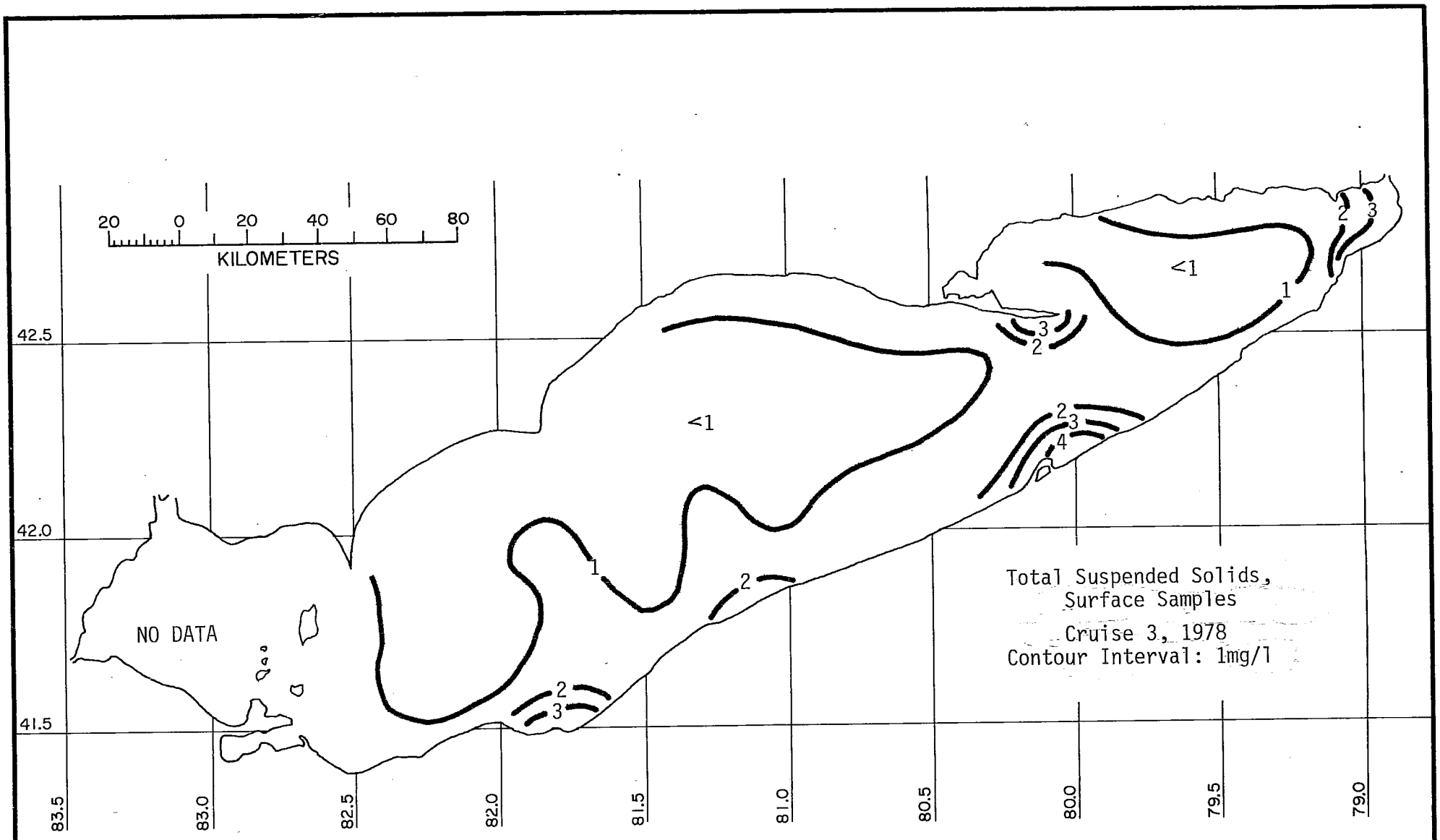


FIGURE 18. Surface Suspended Solids (mg/l) for Cruise No. 3 (June 20 - 30, 1977).

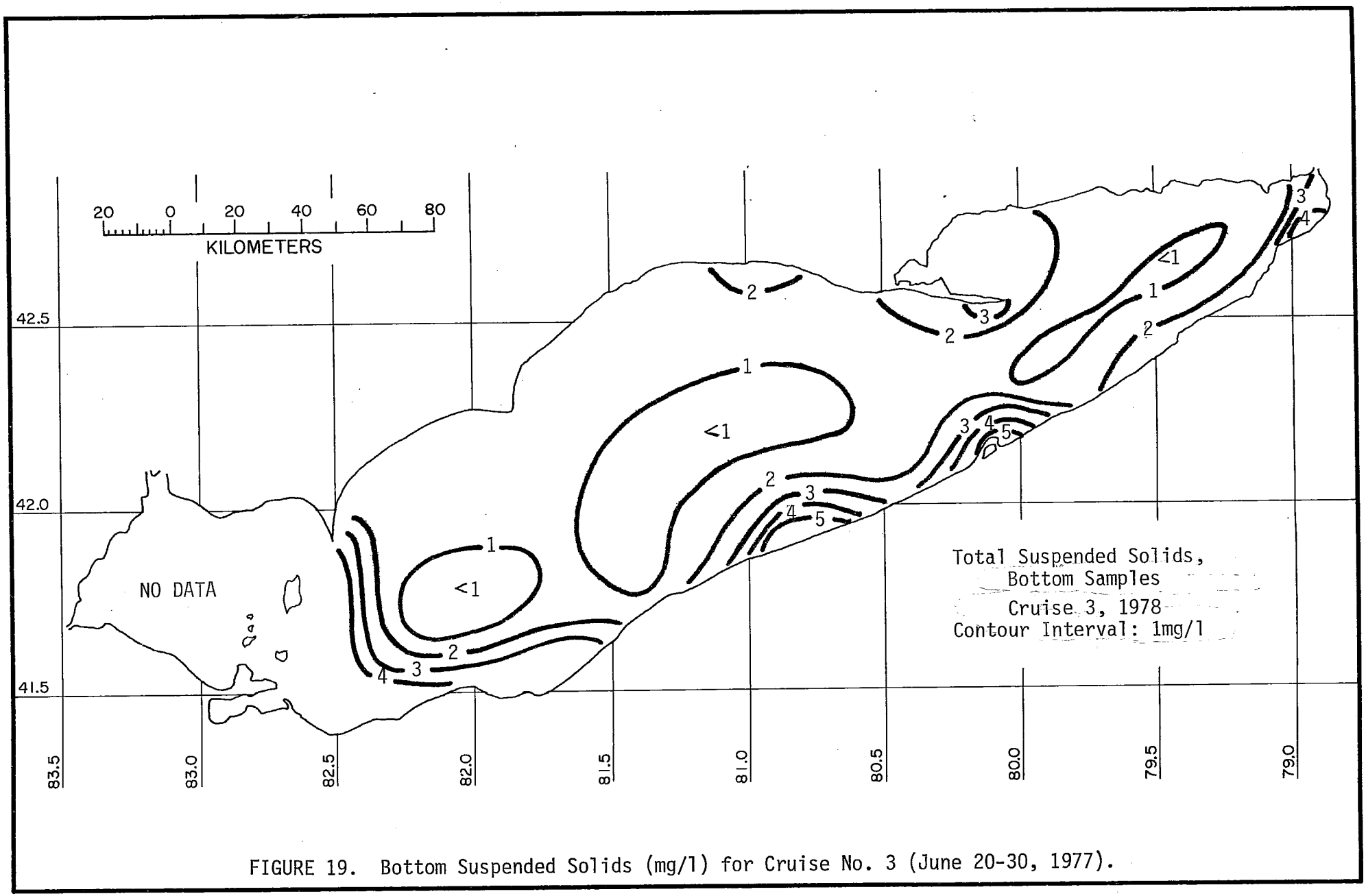


FIGURE 19. Bottom Suspended Solids (mg/l) for Cruise No. 3 (June 20-30, 1977).

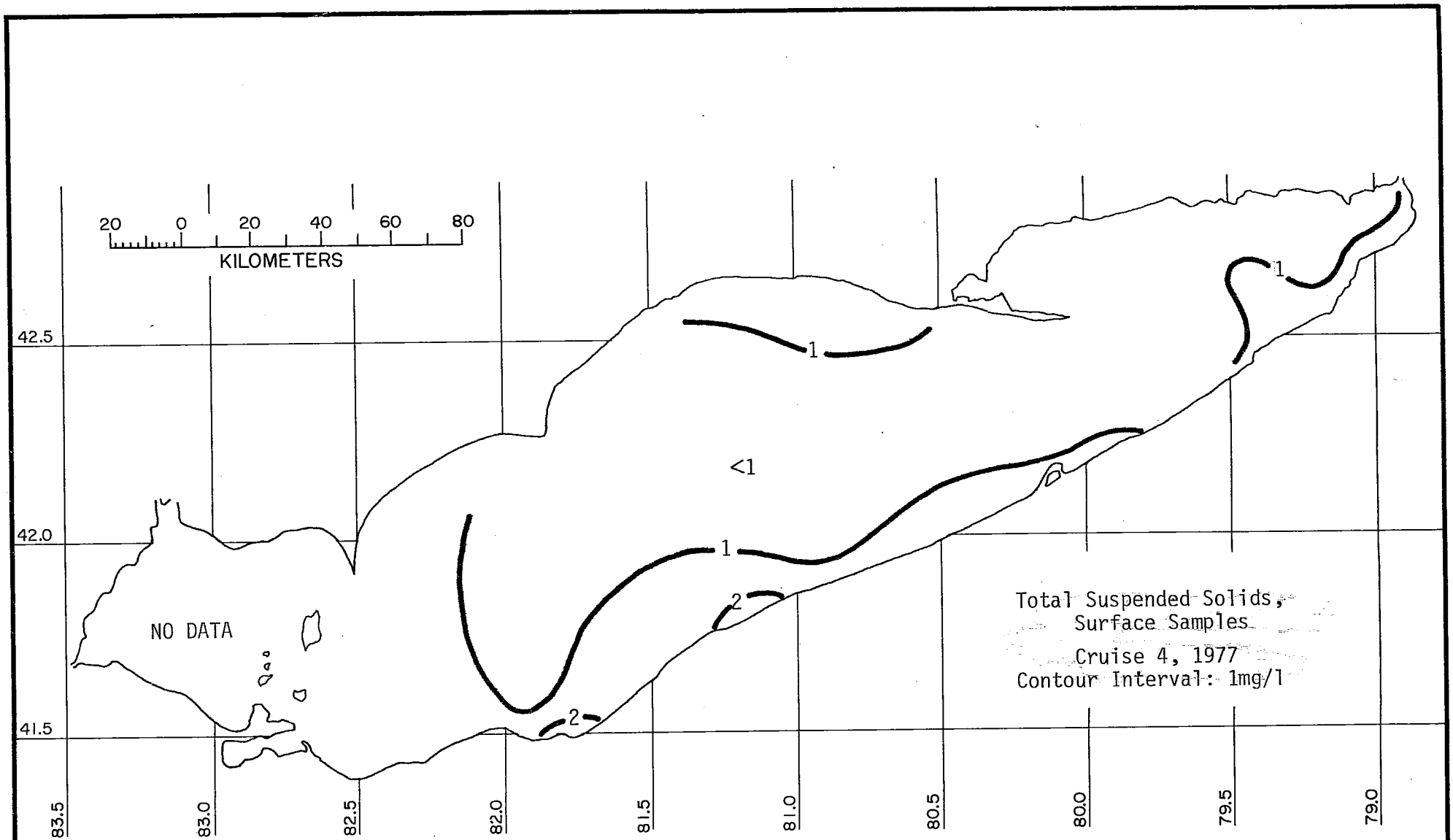


FIGURE 20. Surface Suspended Solids (mg/l) for Cruise No. 4 (July 12-31, 1977).

FIGURE 21. Surface Suspended Solids (mg/l) for Cruise No. 5 (August 11-21, 1977).

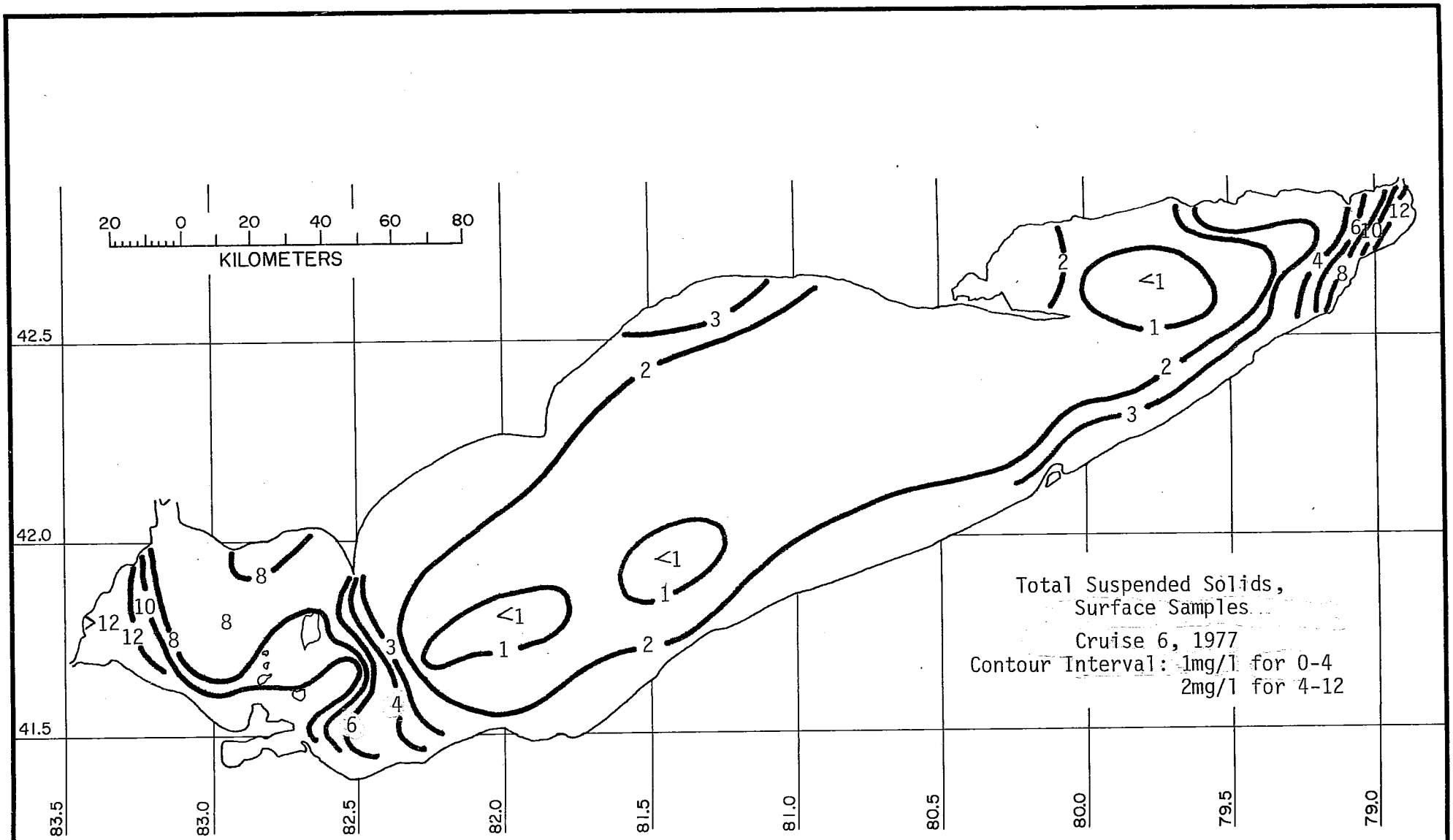


FIGURE 22. Surface Suspended Solids (mg/l) for Cruise No. 6 (September 10 - October 9, 1977).

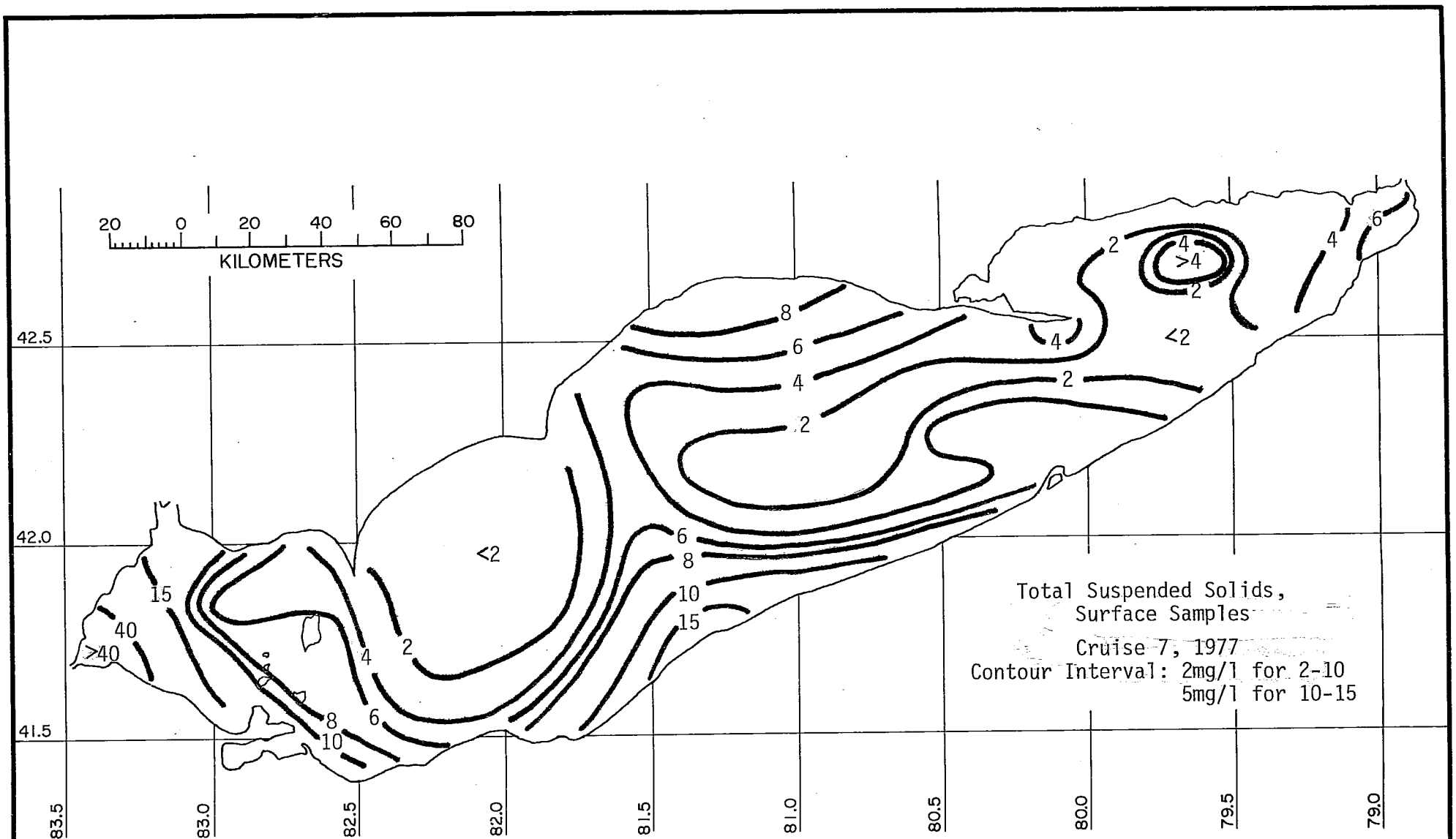


FIGURE 23. Surface Suspended Solids (mg/l) for Cruise No. 7 (November 7-20, 1977).

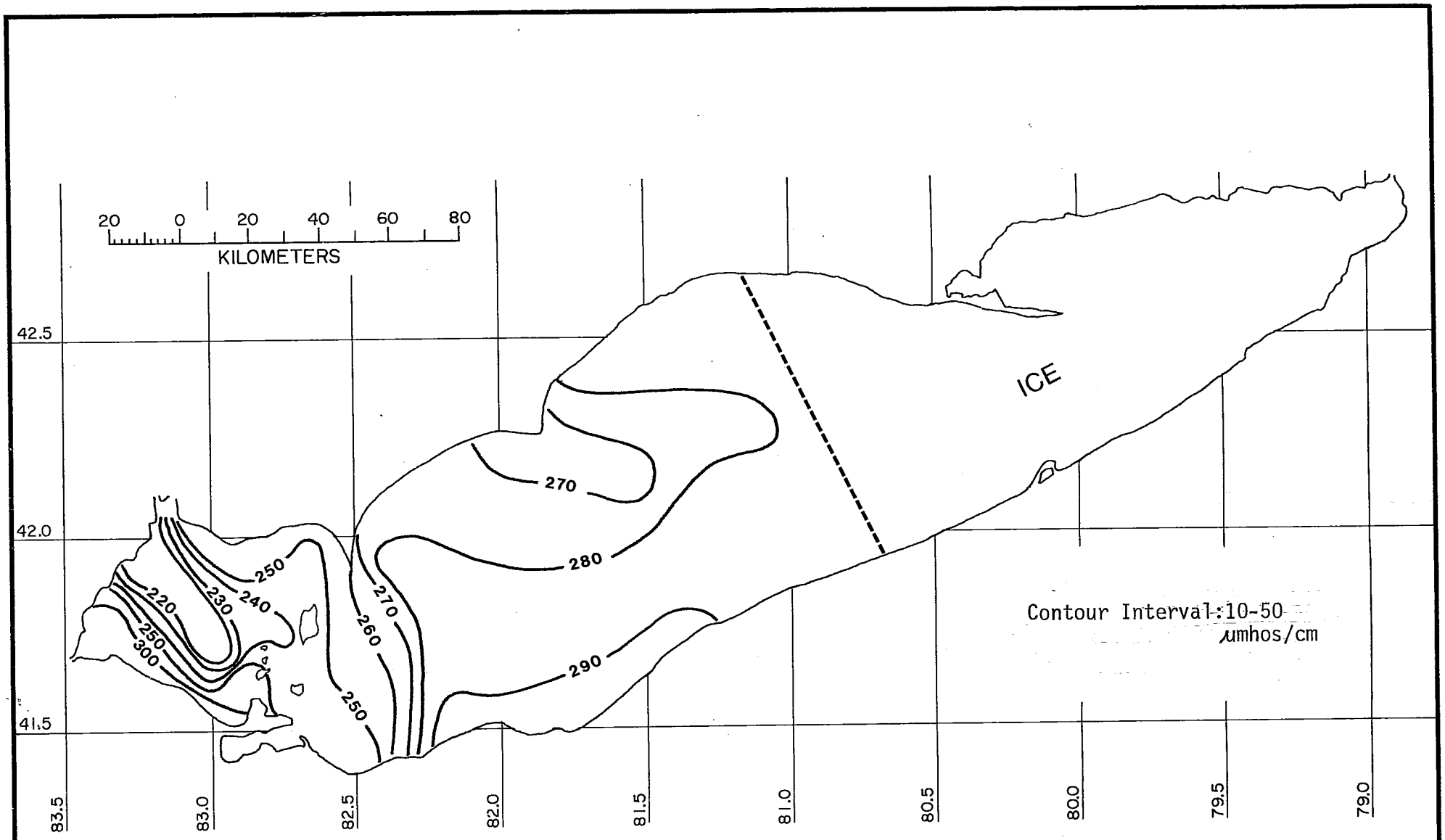


FIGURE 24. Surface Conductivity (μmhos/cm) for Cruise No. 1 (March 21 - April 3, 1977).

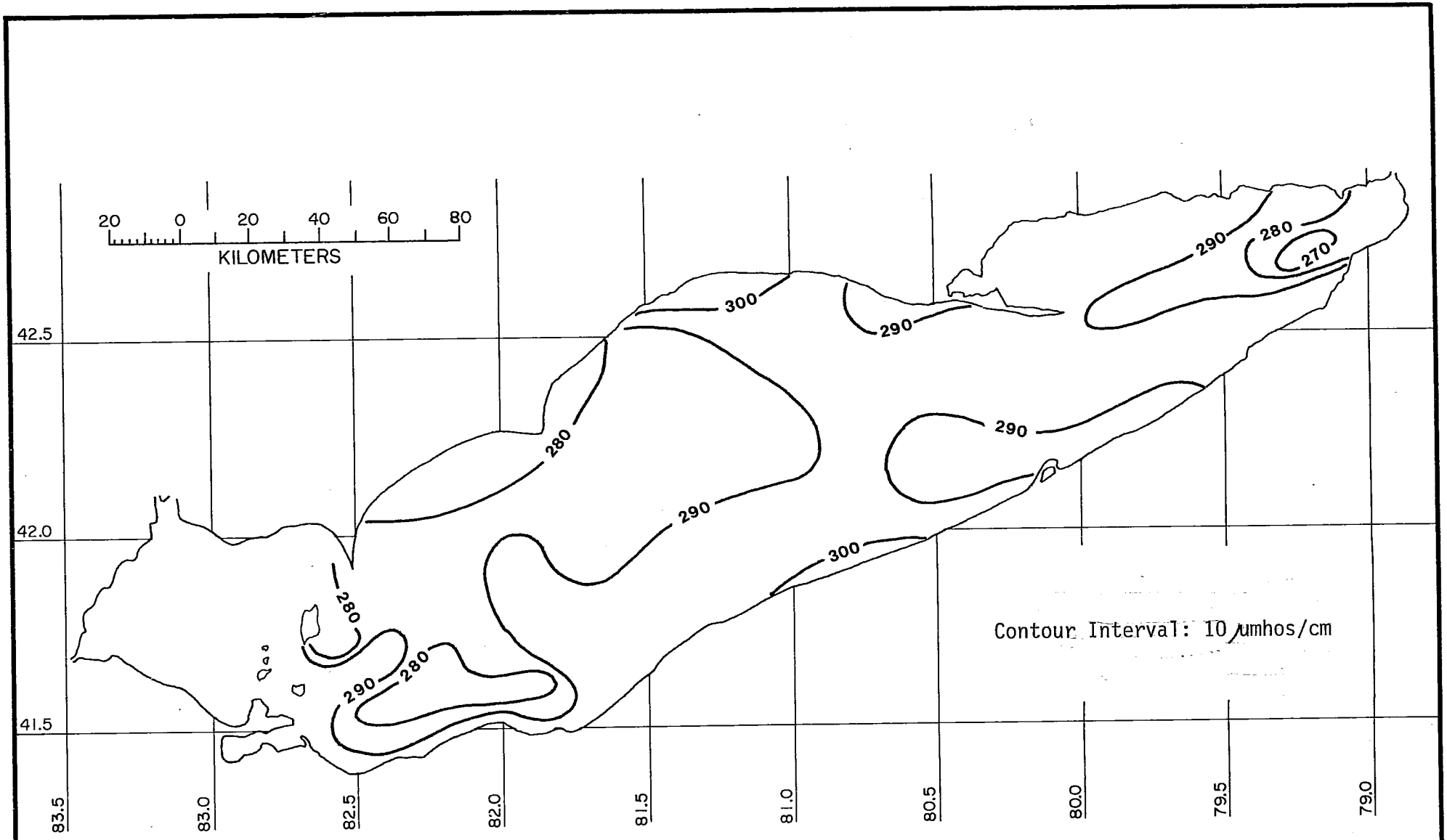


FIGURE 25. Surface Conductivity (μmhos/cm) for Cruise No. 2 (April 28 - May 8, 1977).

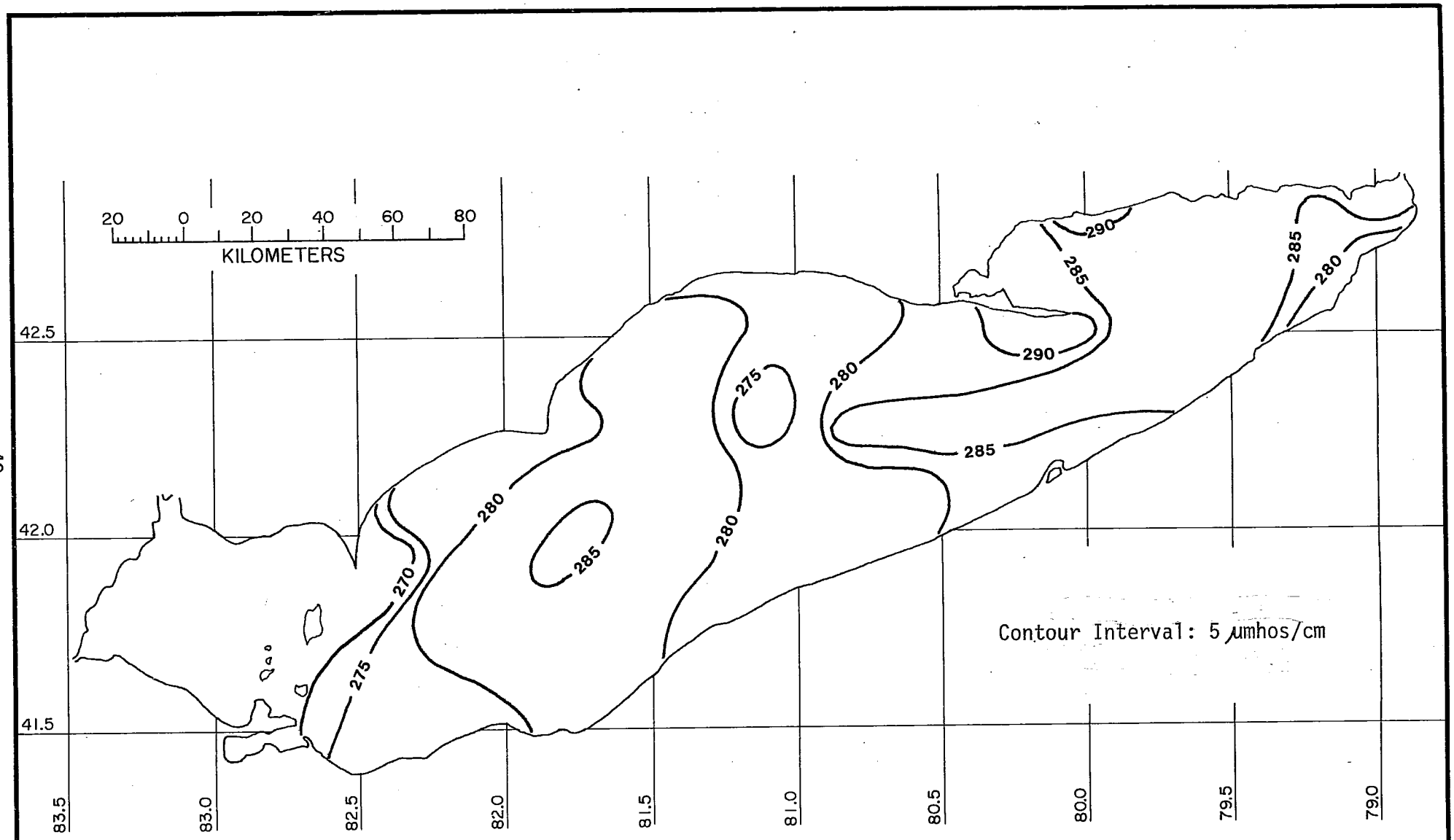


FIGURE 26. Surface Conductivity (μmhos/cm) for Cruise No. 3 (June 20-30, 1977).

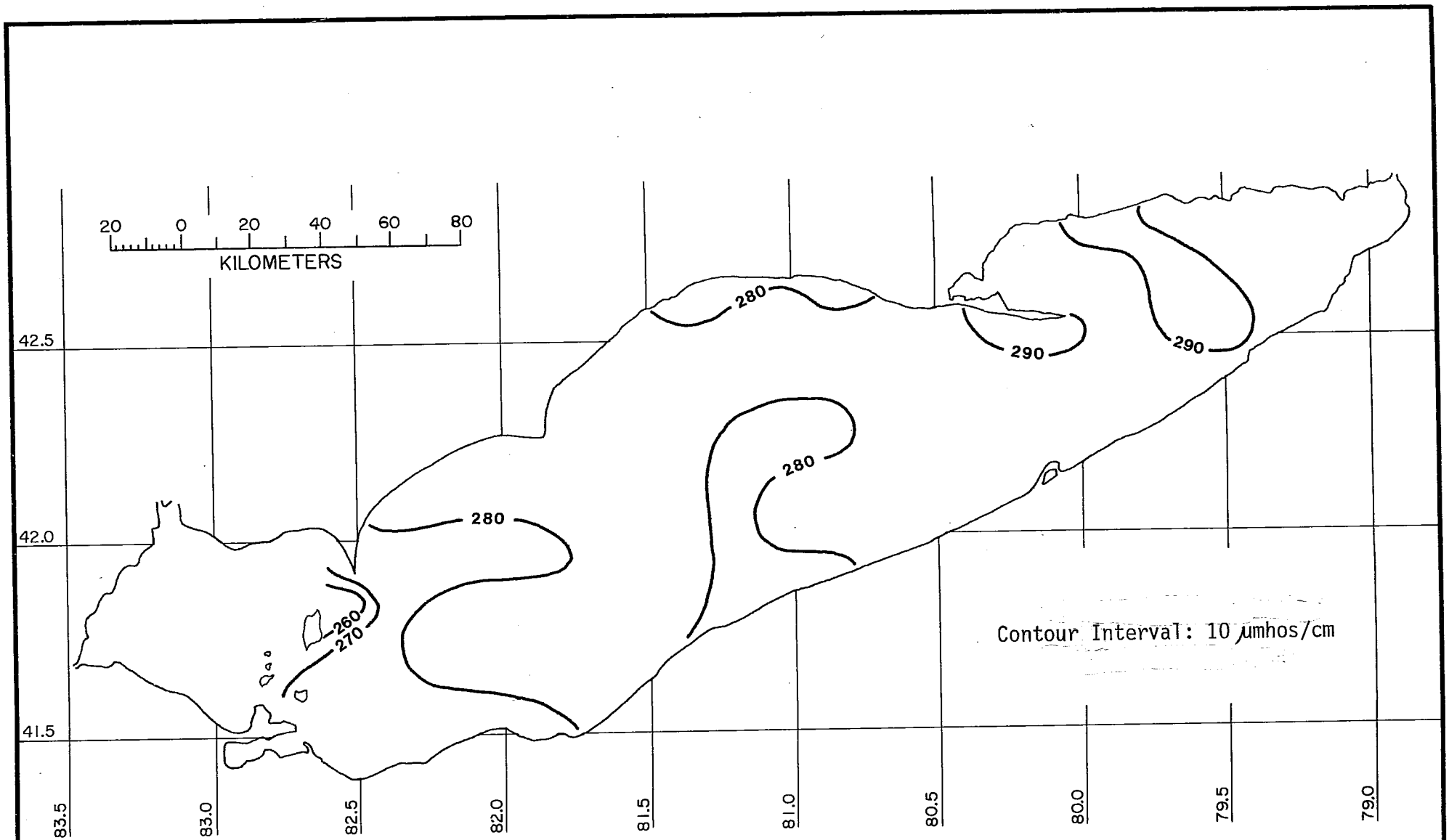


FIGURE 27. Mid-water Conductivity (μmhos/cm) for Cruise No. 3 (June 20-30, 1977).

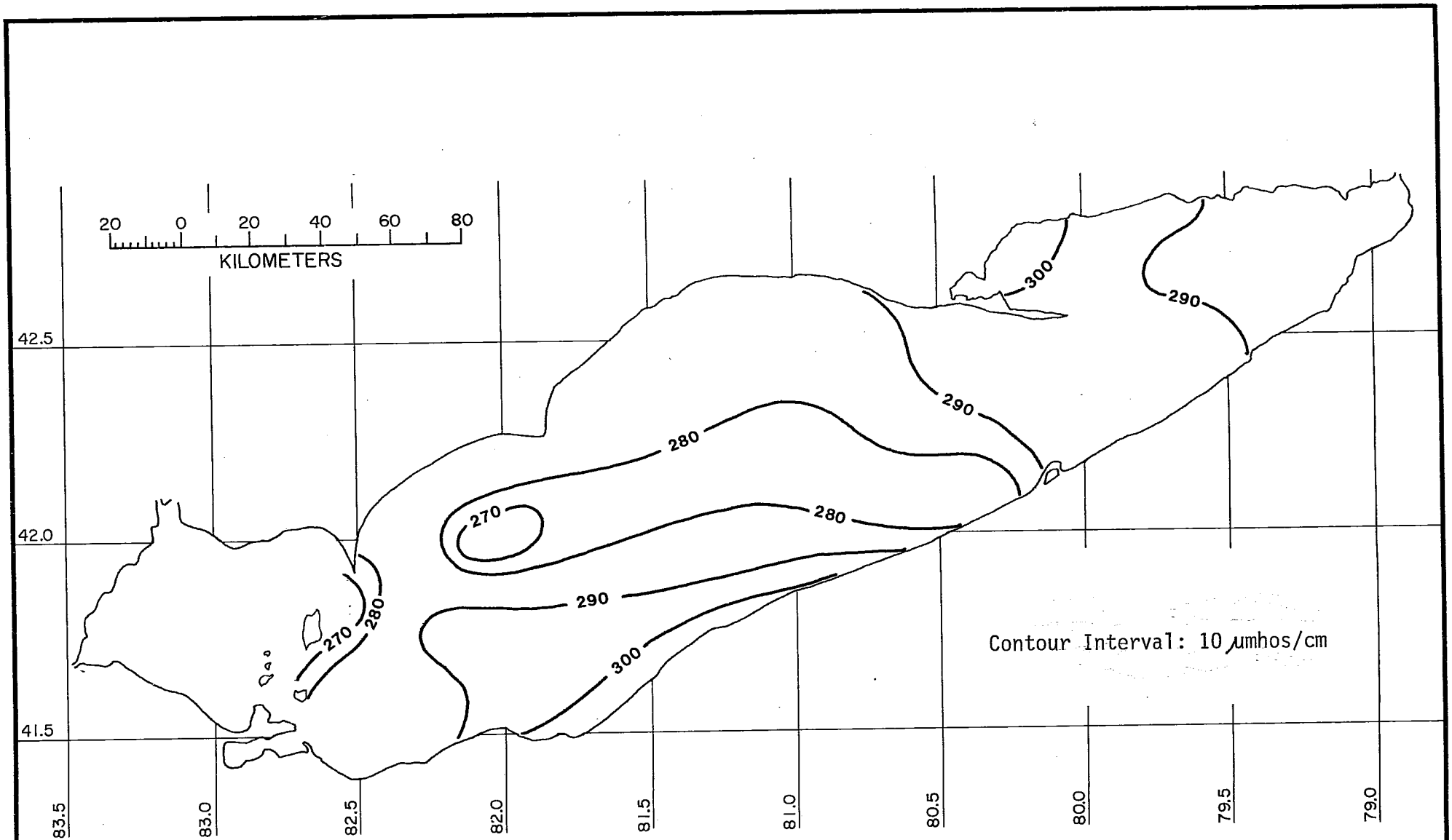


FIGURE 28. Bottom Conductivity (μmhos/cm) for Cruise No. 3 (June 20-30, 1977).

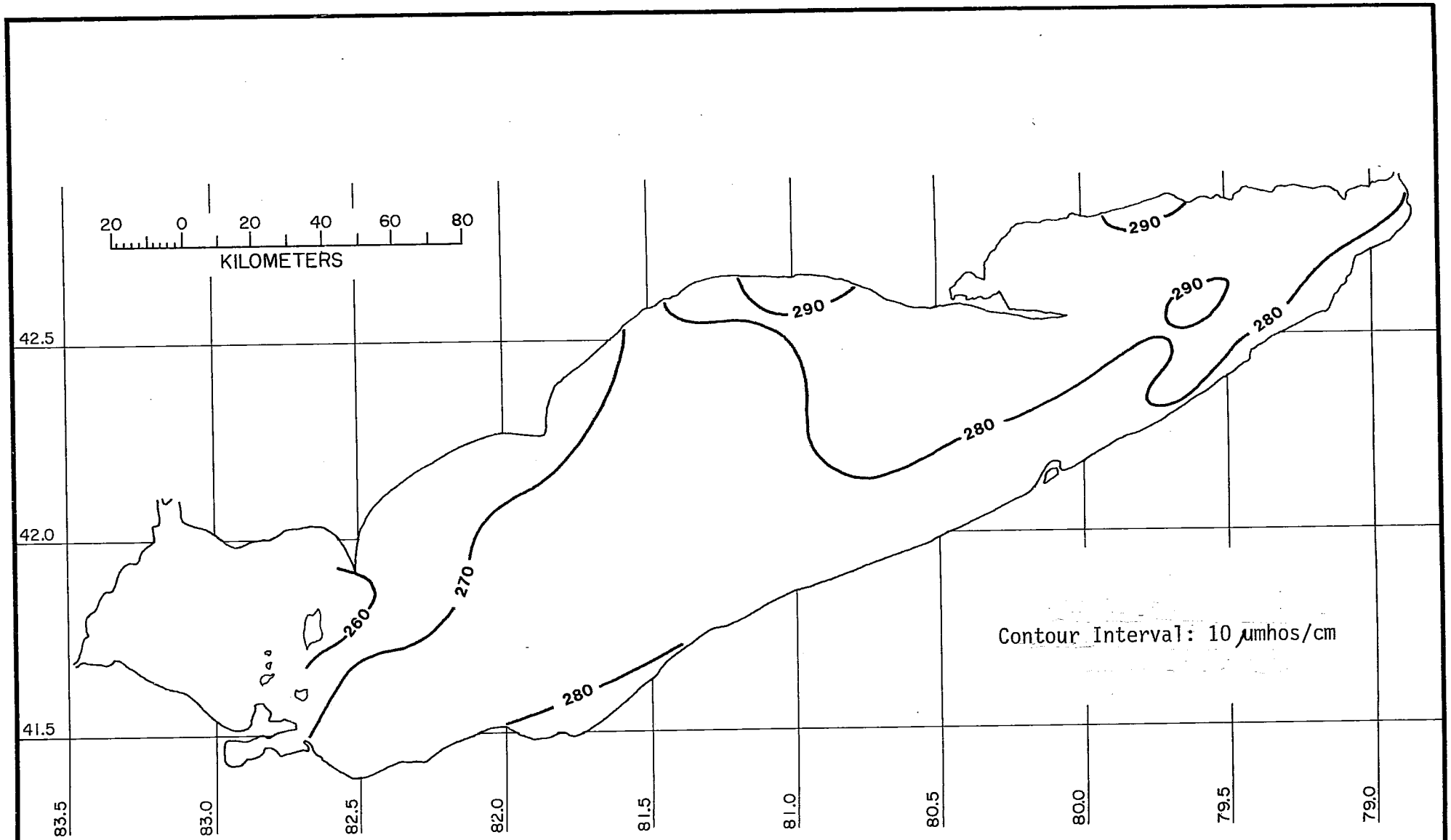


FIGURE 29. Surface Conductivity (μmhos/cm) for Cruise No. 4 (July 12-31, 1977).

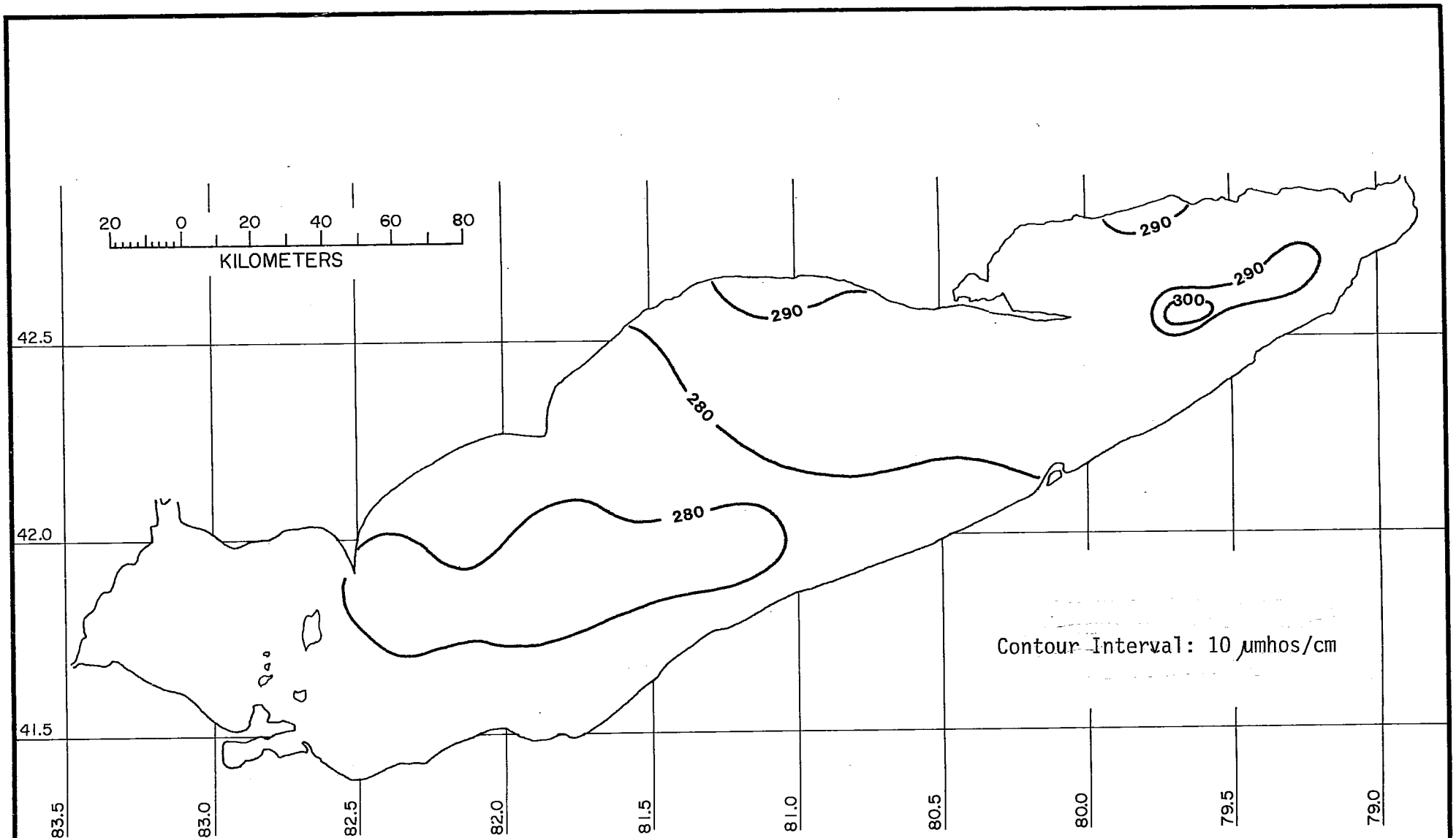


FIGURE 30. Mid-water Conductivity (μmhos/cm) for Cruise No. 4 (July 12-31, 1977).

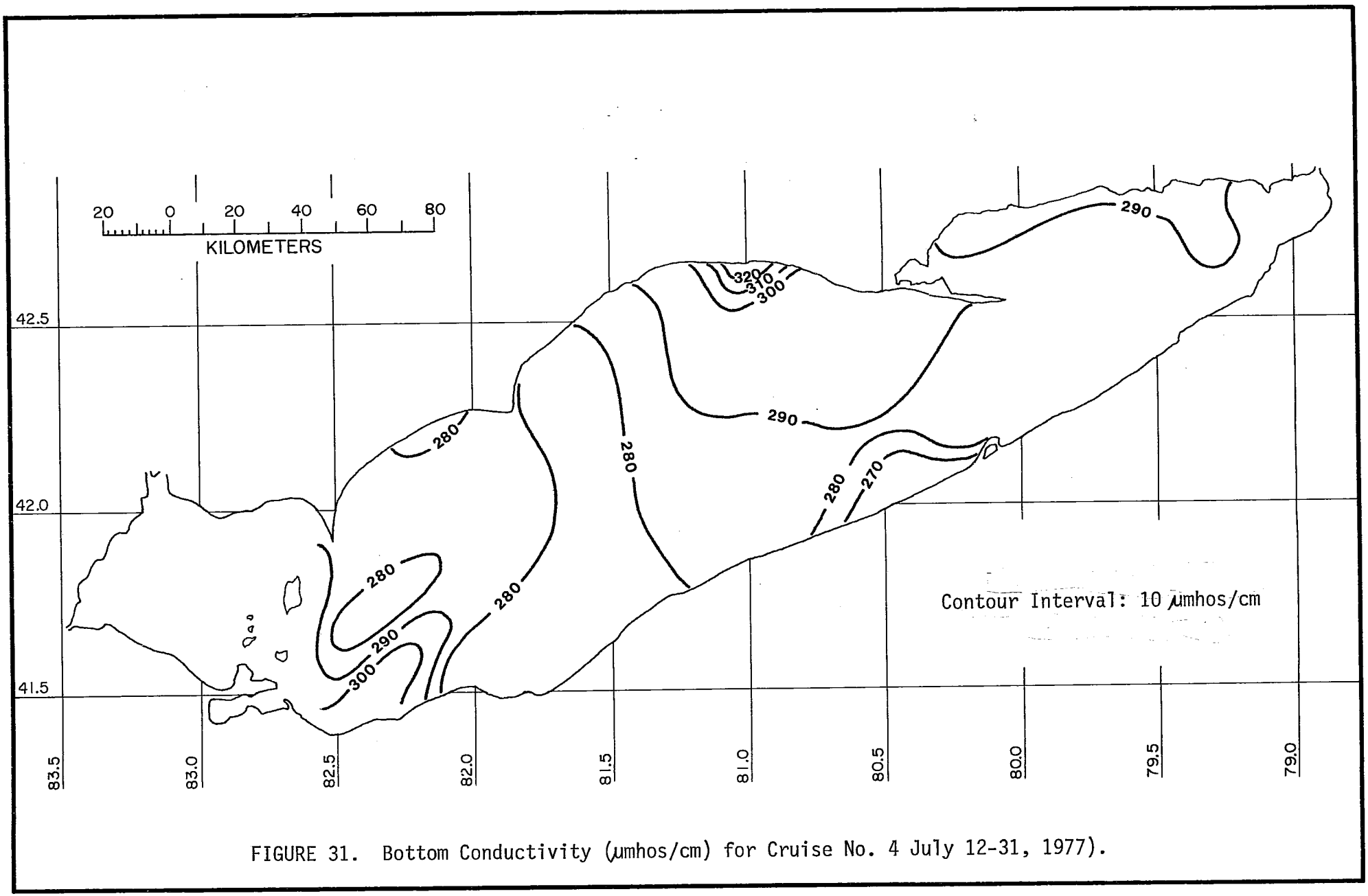


FIGURE 31. Bottom Conductivity (μmhos/cm) for Cruise No. 4 July 12-31, 1977).

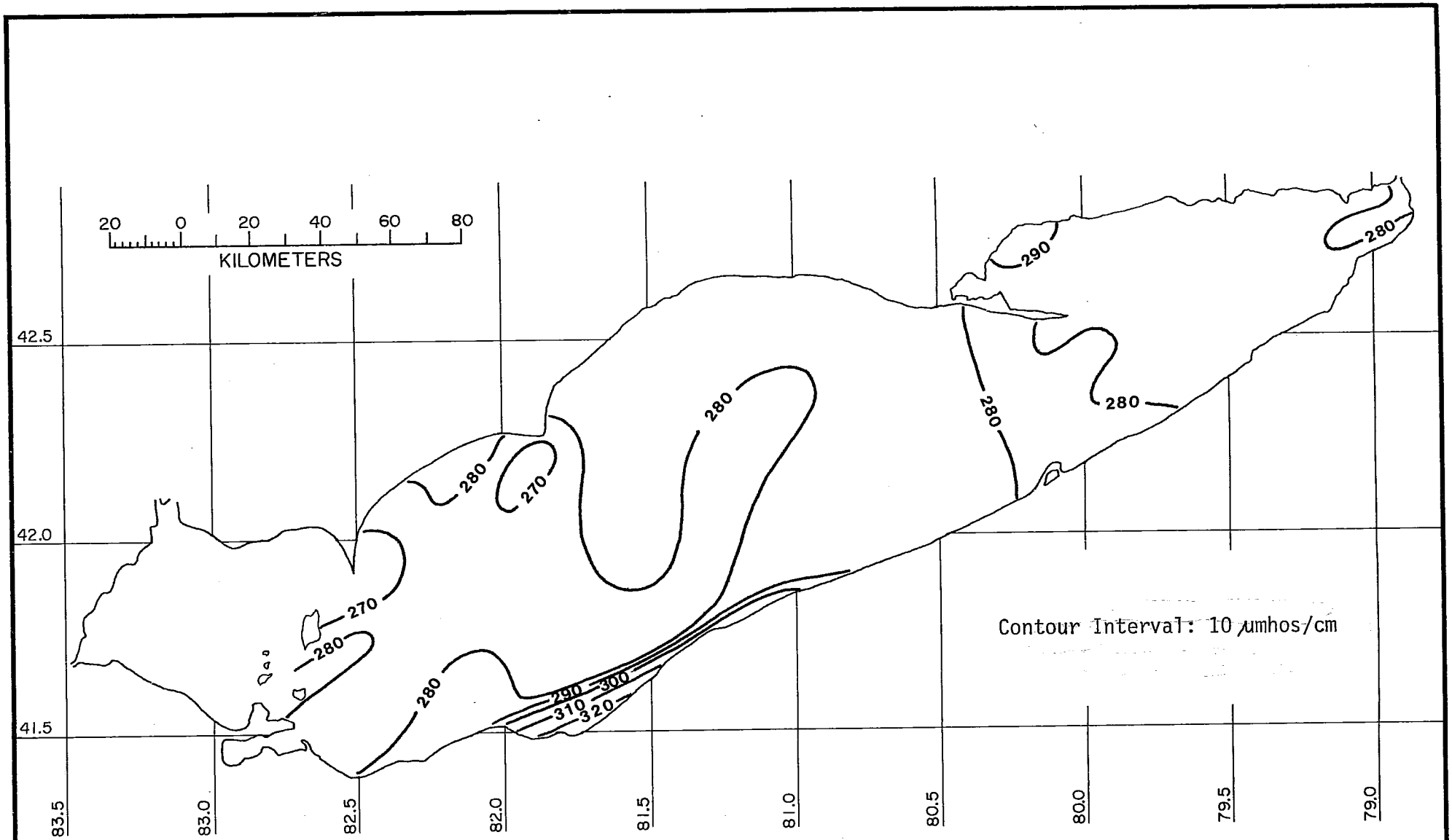


FIGURE 32. Surface Conductivity (μmhos/cm) for Cruise No. 5 (August 11-21, 1977).

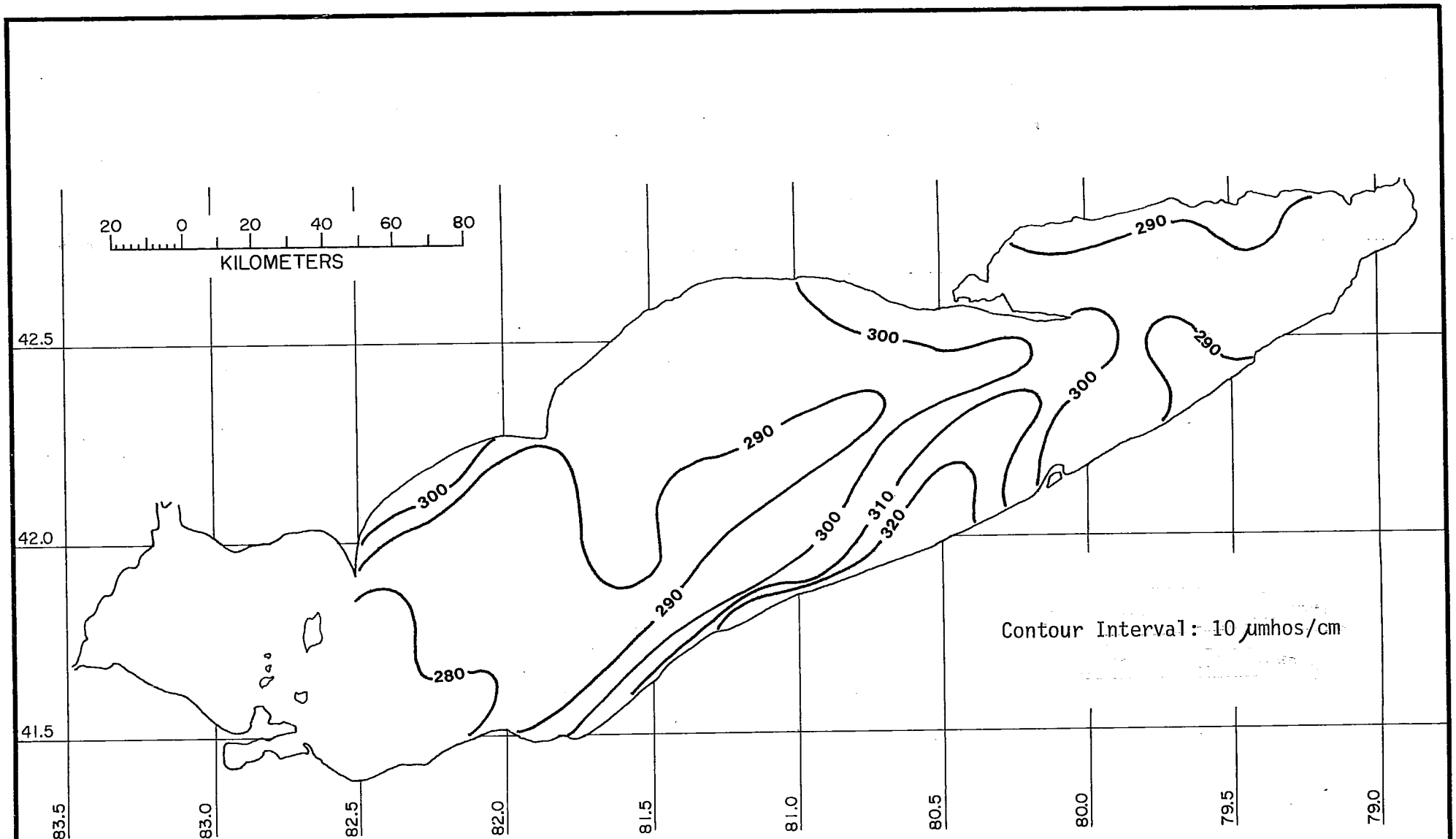


FIGURE 33. Mid-water Conductivity (μmhos/cm) for Cruise No. 5 (August 11-21, 1977).

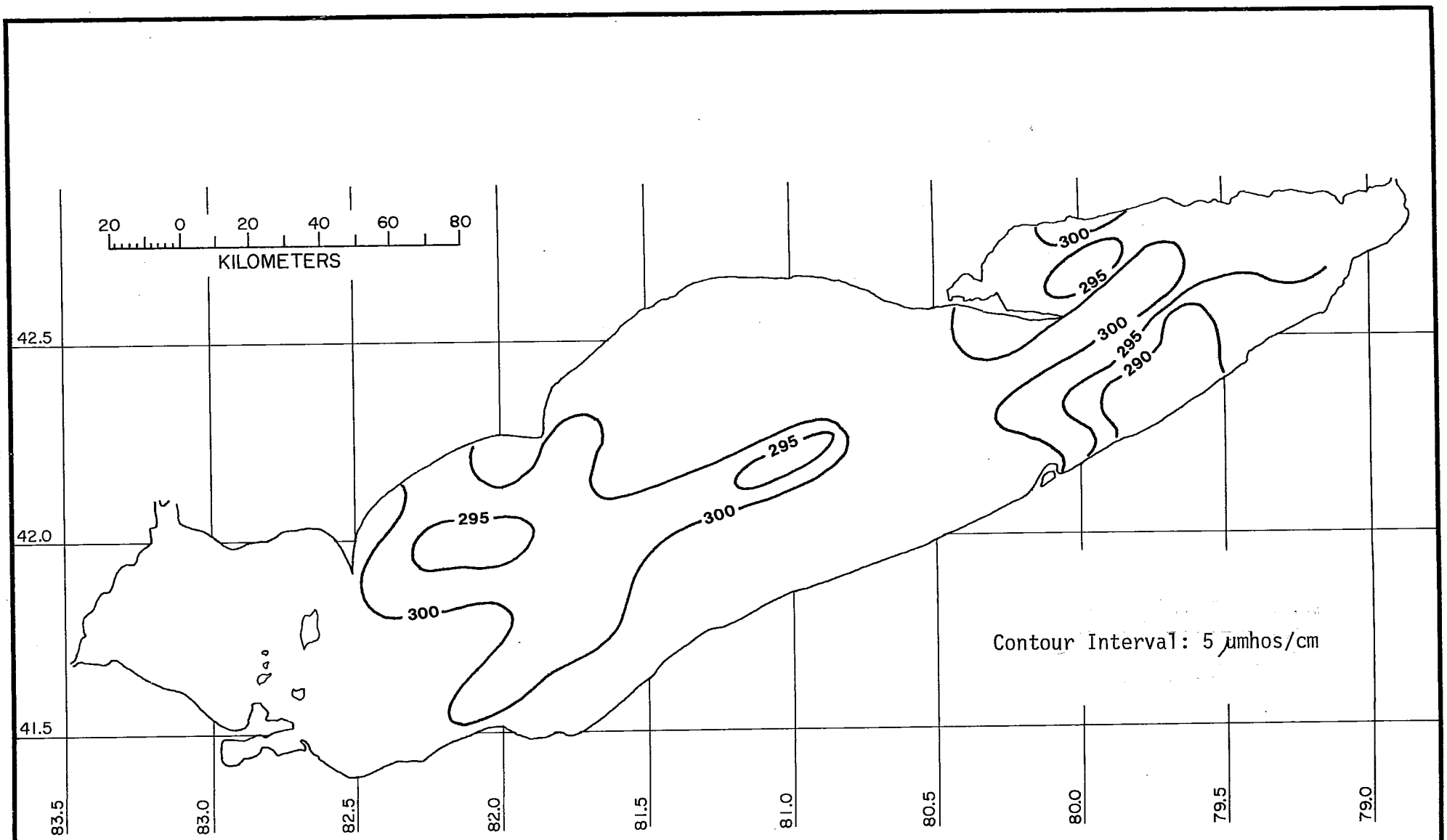


FIGURE 34. Bottom Conductivity (μmhos/cm) for Cruise No. 5 (August 11-21, 1977).

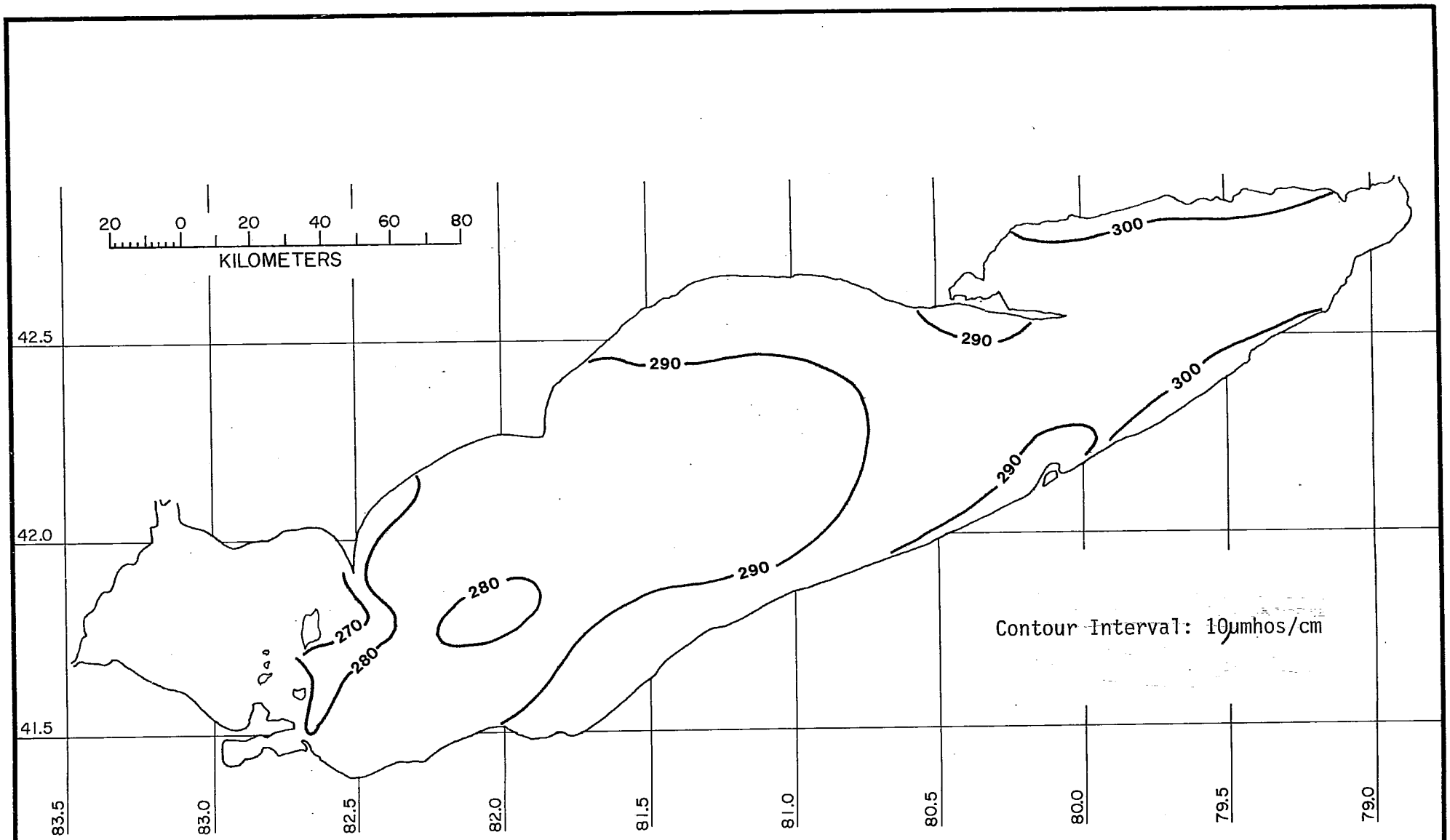


FIGURE 35. Surface Conductivity (μmhos/cm) for Cruise No. 6 (September 10 - October 9, 1977).

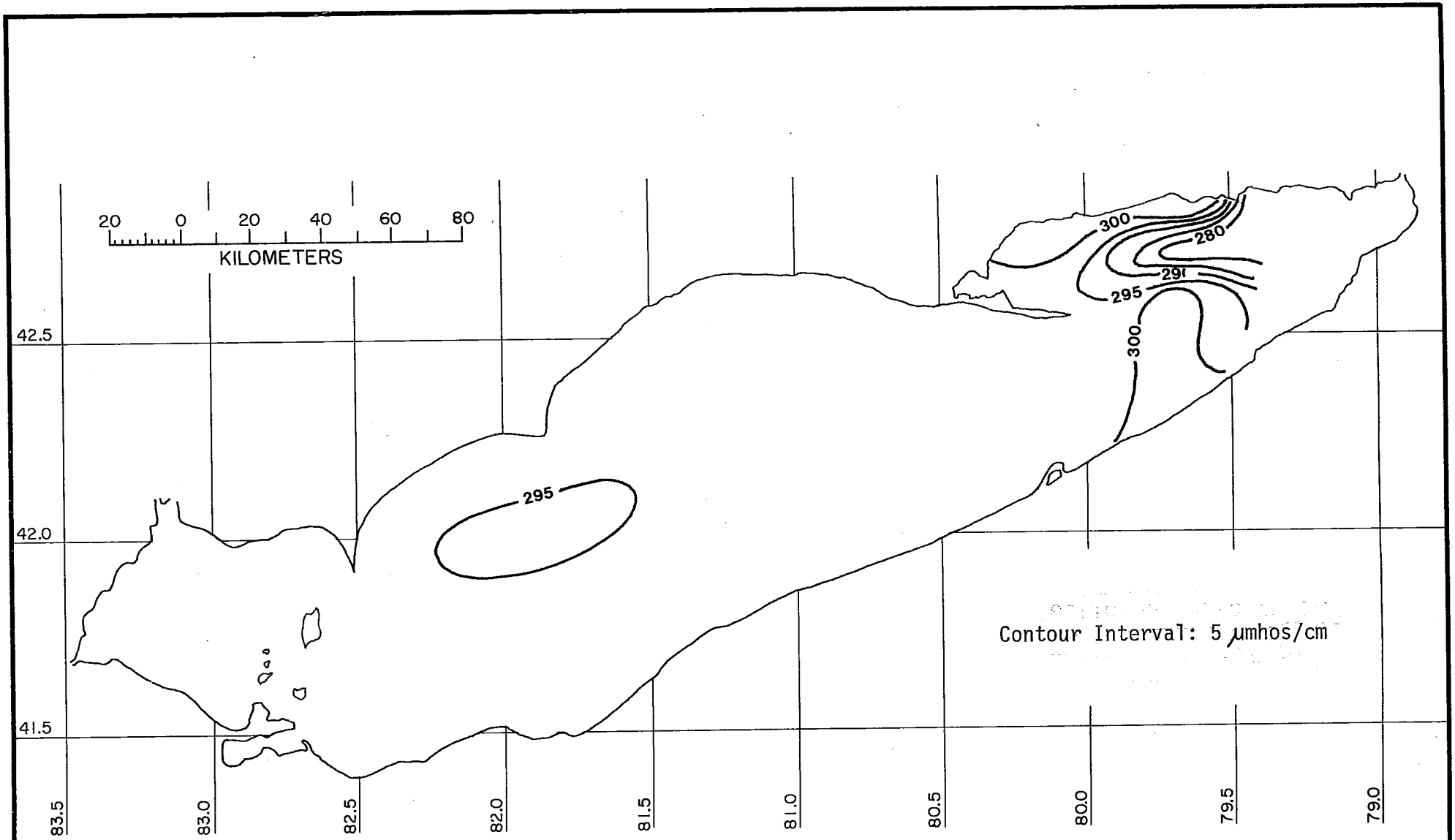


FIGURE 36. Mid-water Conductivity (μmhos/cm) for Cruise No. 6 (September 10 - October 9, 1977).

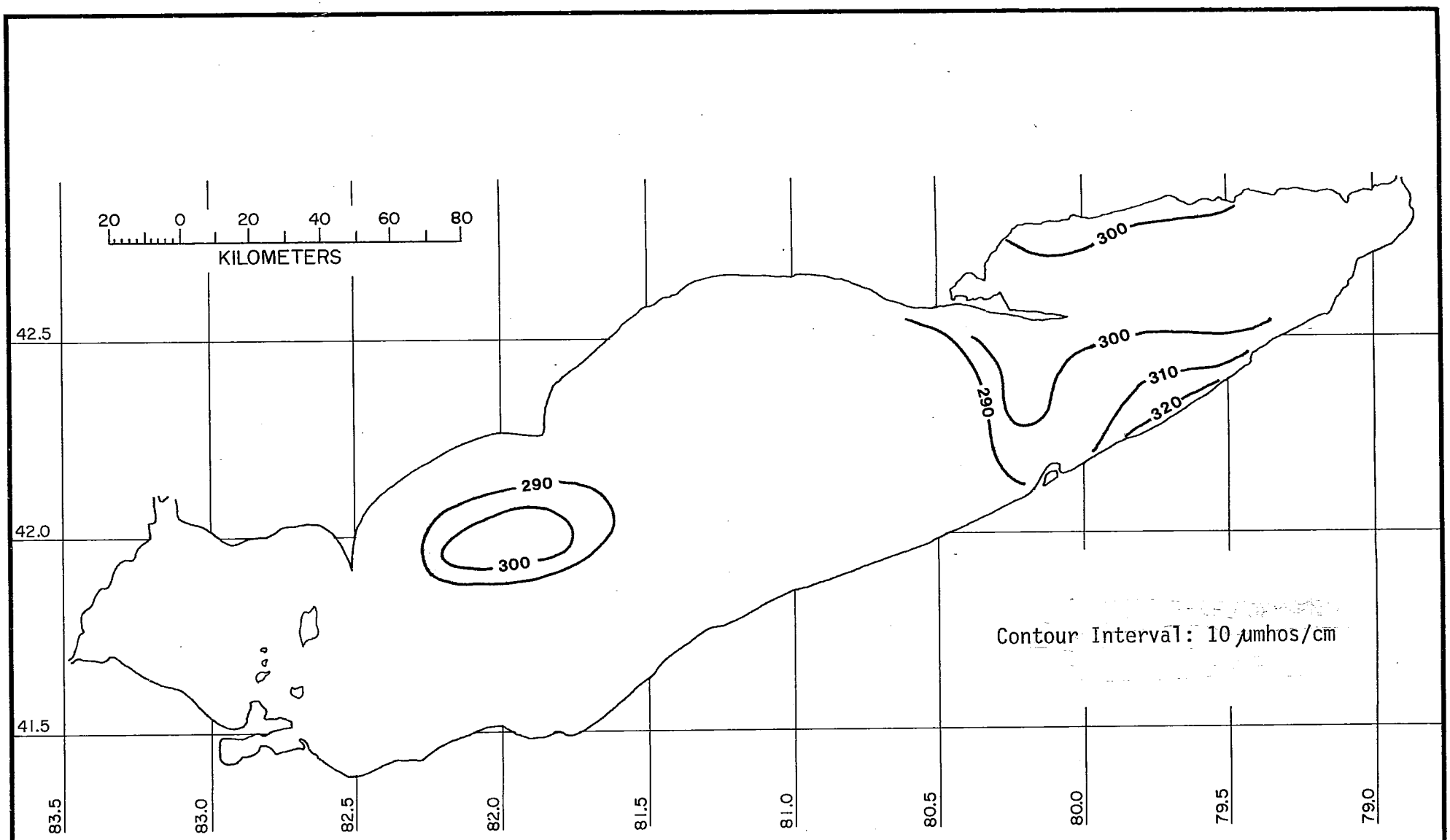


FIGURE 37. Bottom Conductivity (μmhos/cm) for Cruise No. 6 (September 10 - October 9, 1977).

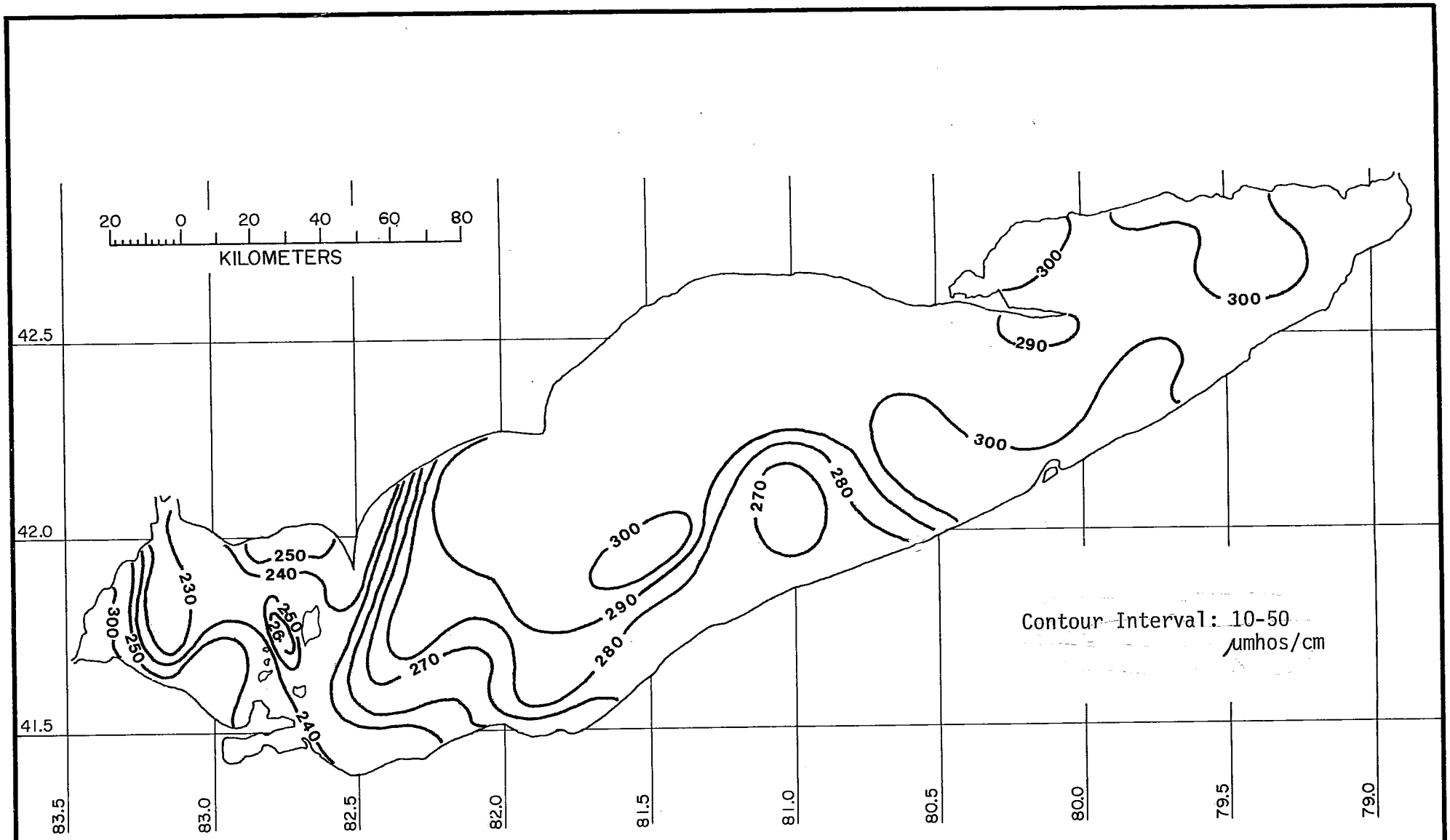


FIGURE 38. Surface Conductivity (μmhos/cm) for Cruise No. 7 (November 7-20, 1977).

SPECIFIC CONDUCTIVITY OF LAKE ERIE WATER DURING 1977 SURVEY SEASON
MARCH 21 - NOVEMBER 22 (VOLUME WEIGHTED)

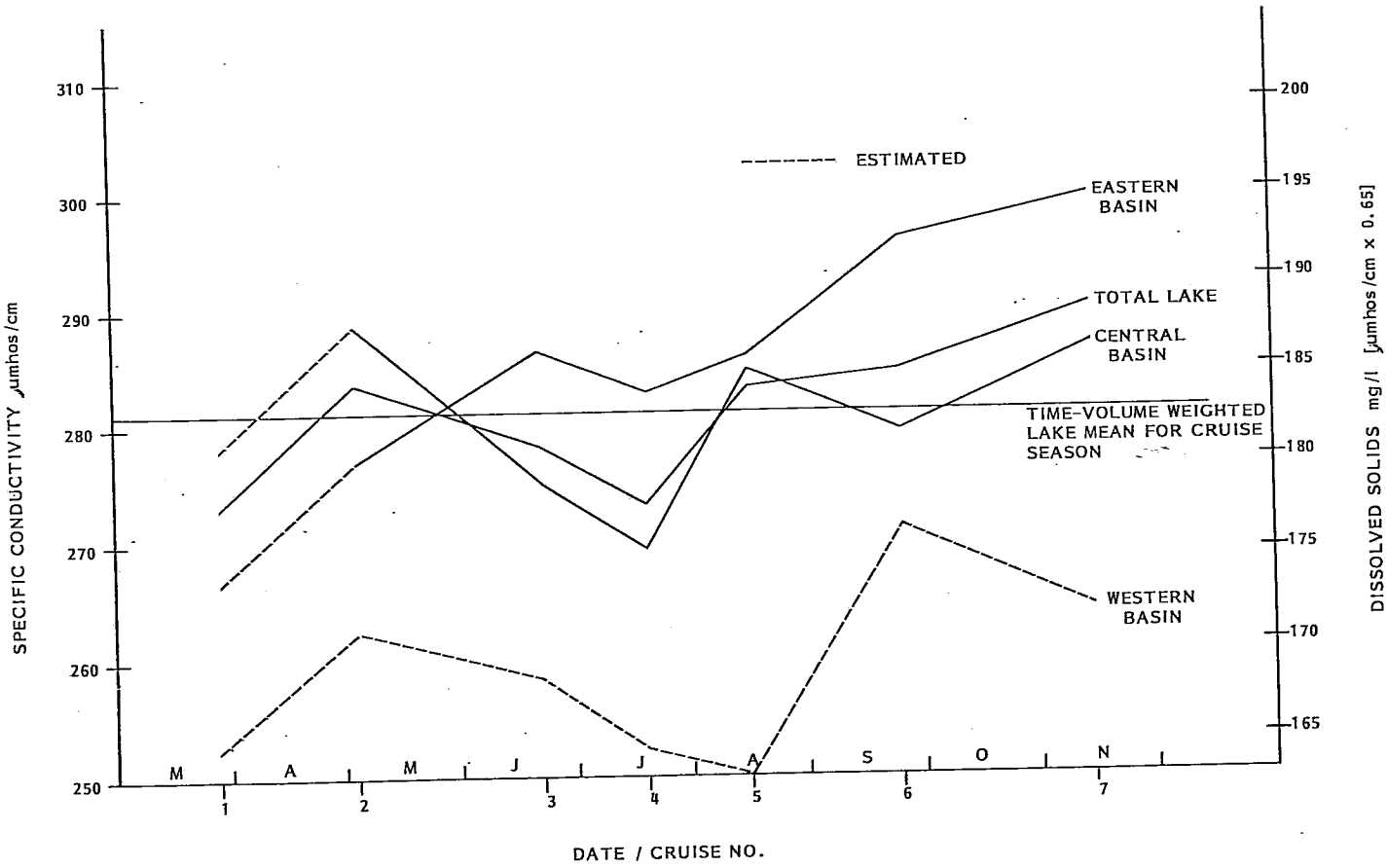


FIGURE 39. Conductivity of Lake Erie Basins in 1977.

SPECIFIC CONDUCTIVITY OF LAKE ERIE WATER (CENTRAL BASIN)
DURING 1977 SURVEY SEASON MARCH 21 - NOVEMBER 22
(VOLUME WEIGHTED)

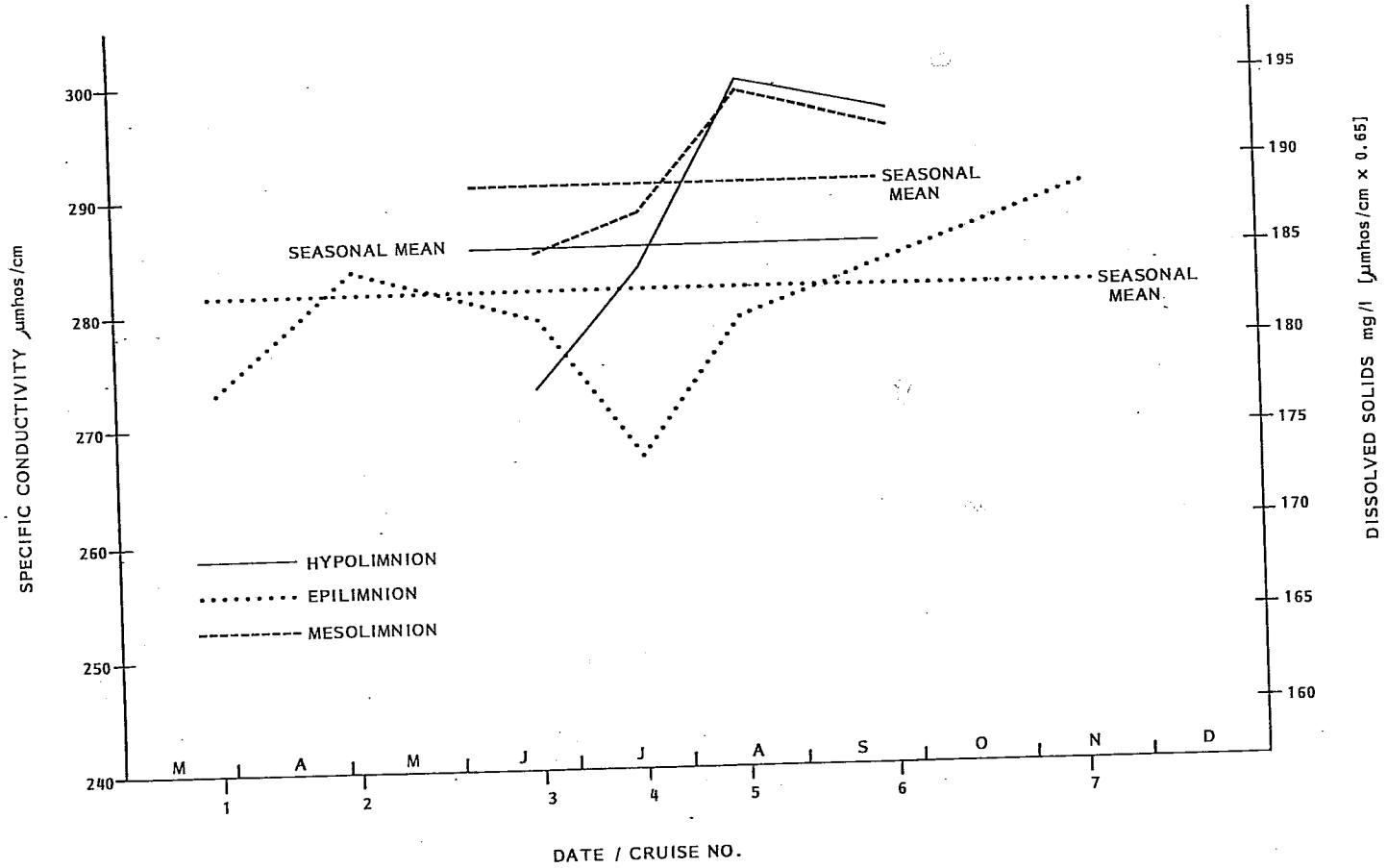


FIGURE 40. Conductivity of the Central Basin of Lake Erie in 1977.

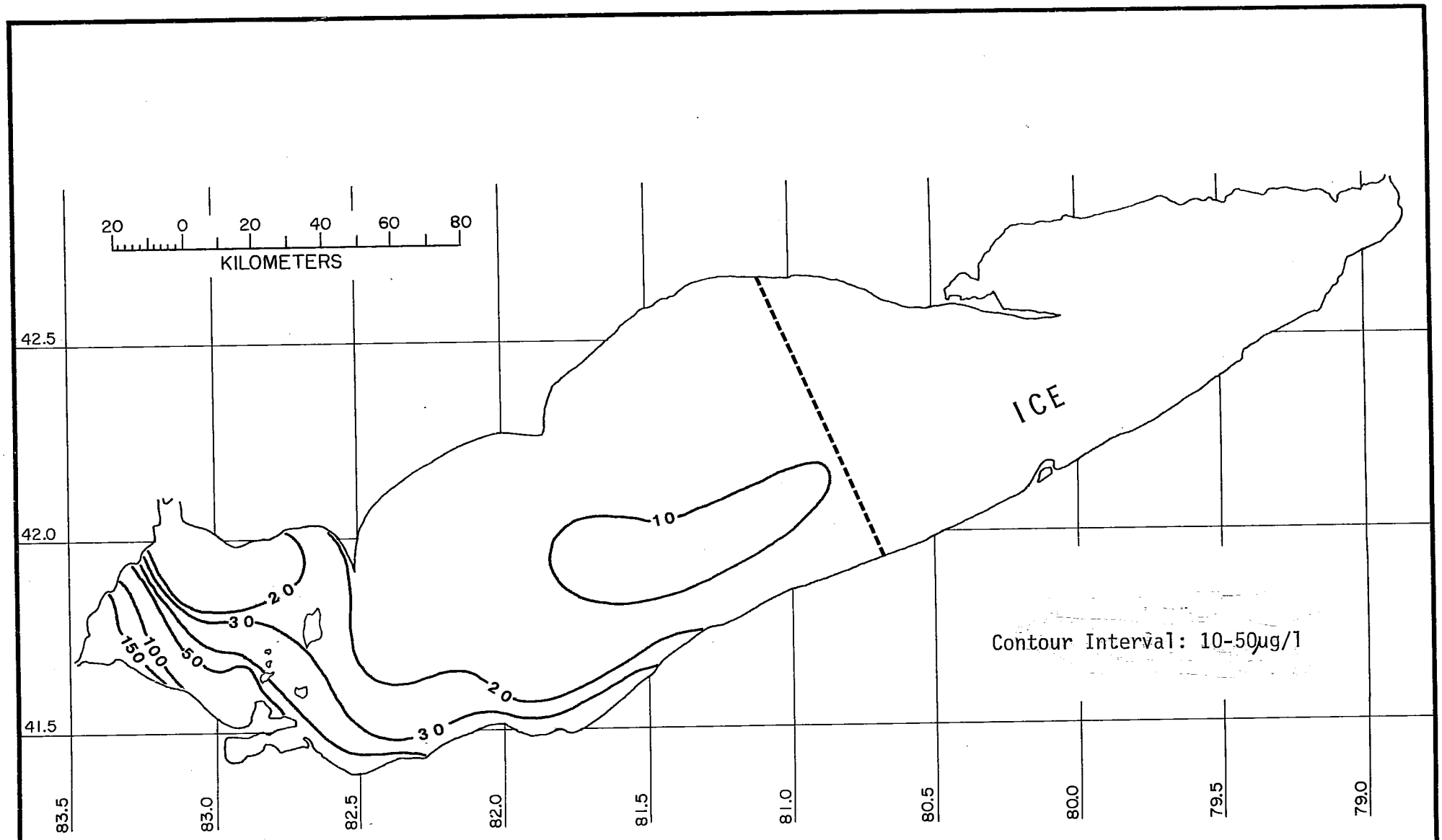


FIGURE 41. Surface Total Phosphorus (µg/l) for Cruise No. 1 (March 21 - April 3, 1977).

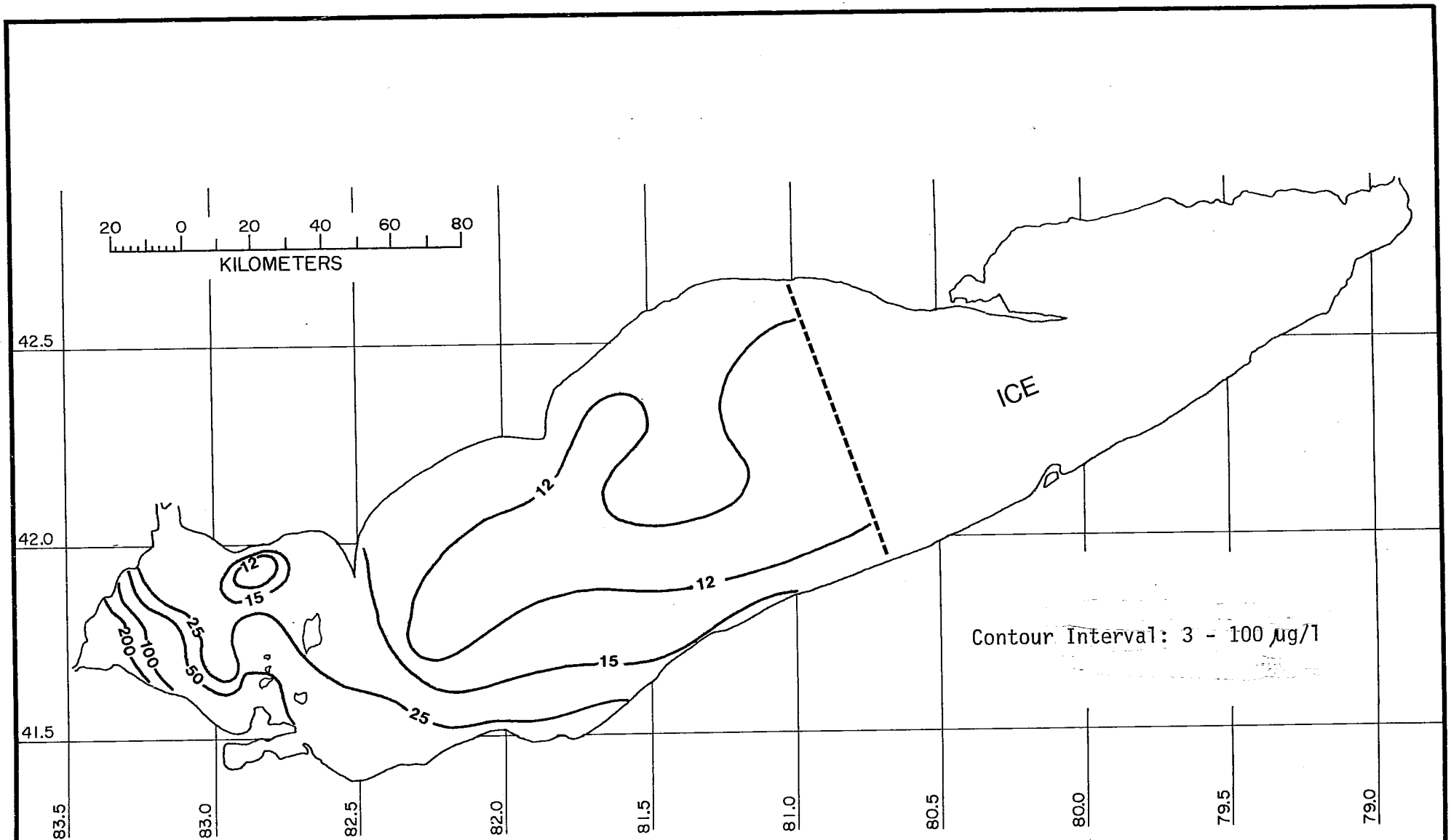


FIGURE 42. Bottom Total Phosphorus (µg/l) for Cruise No. 1 (March 21 - April 3, 1977).

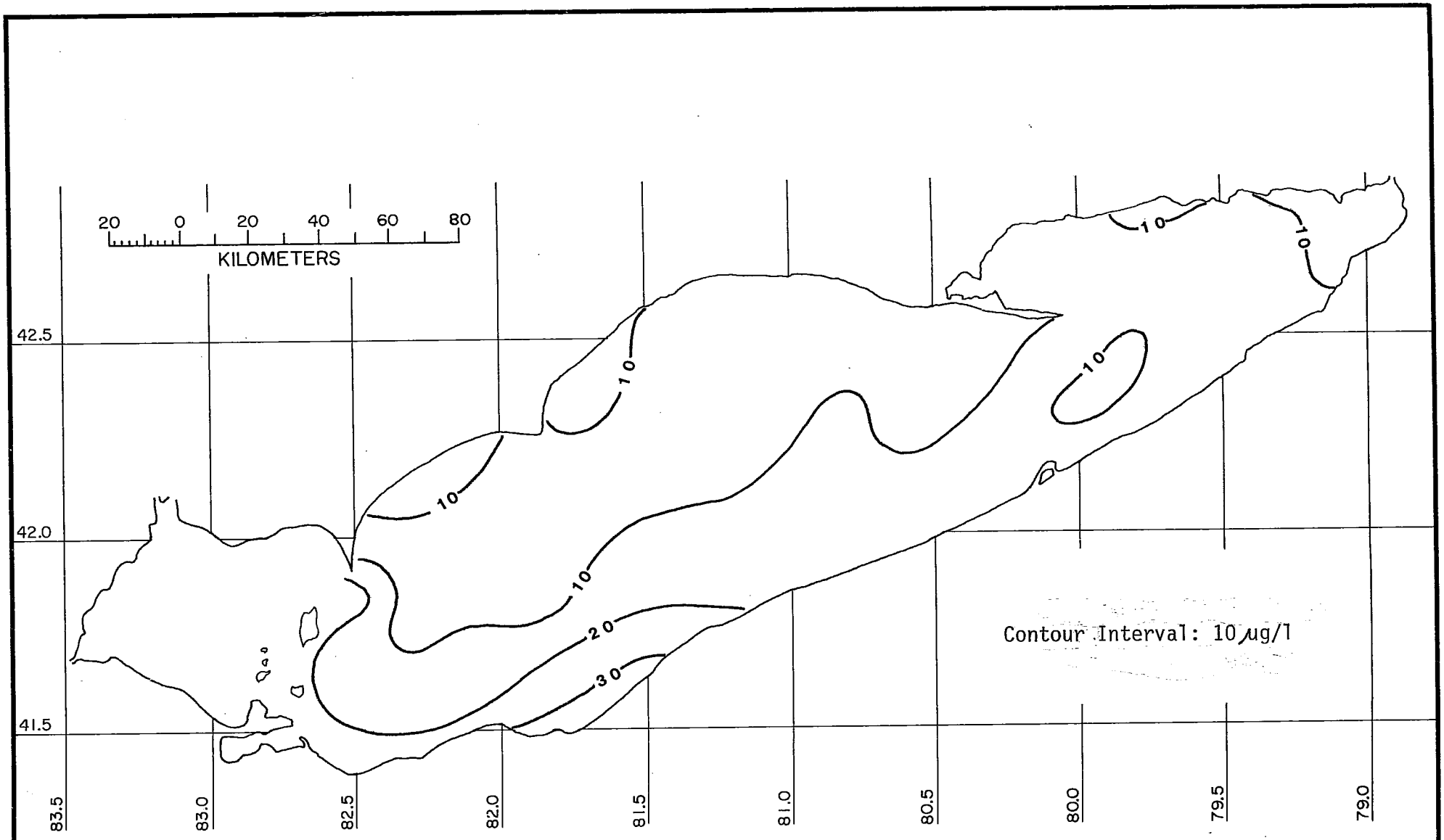


FIGURE 43. Surface Total Phosphorus (µg/l) for Cruise No. 2 (April 28 - May 8, 1977).

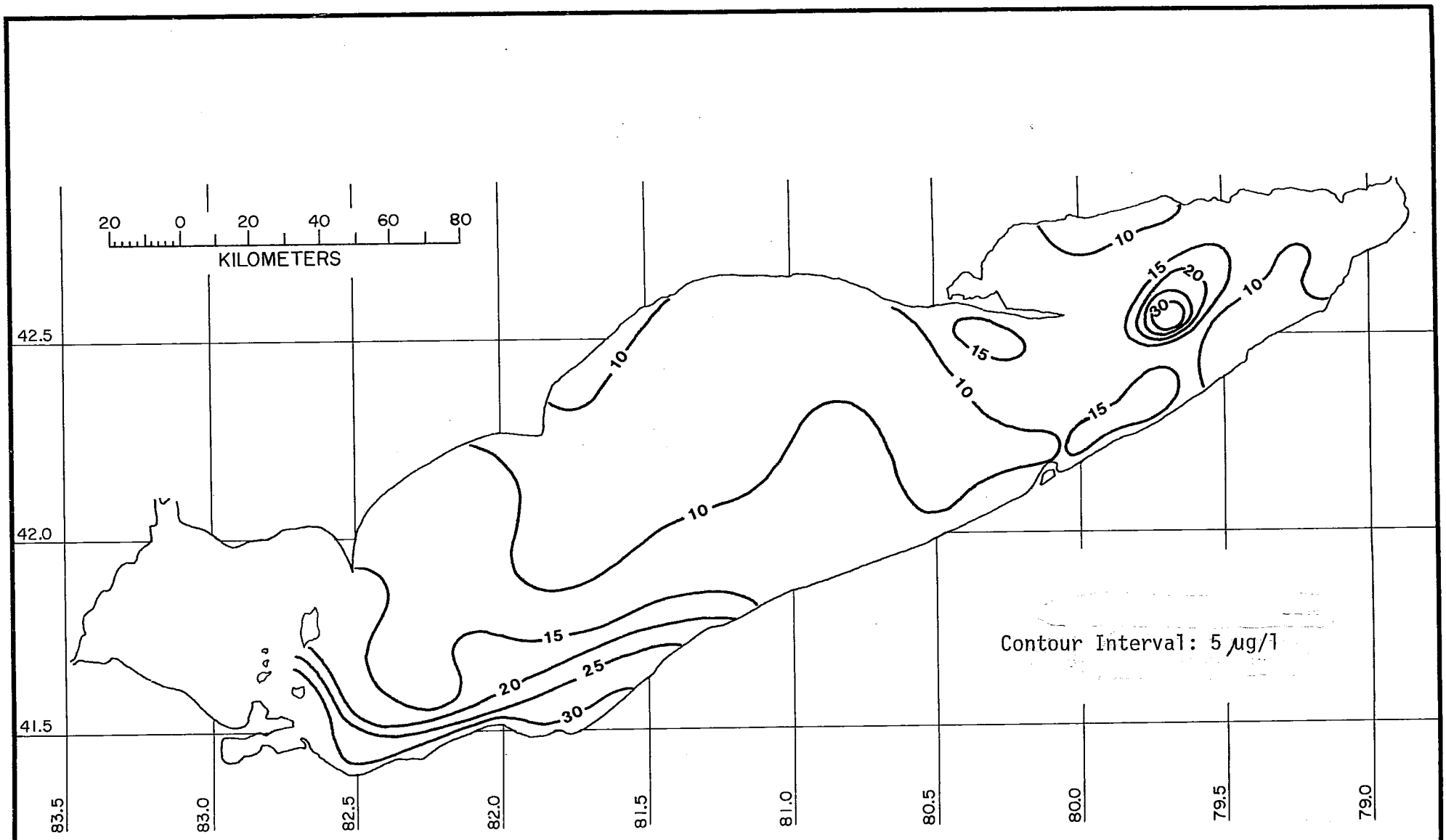


FIGURE 44. Bottom Total Phosphorus (µg/l) for Cruise No. 2 (April 28 - May 8, 1977).

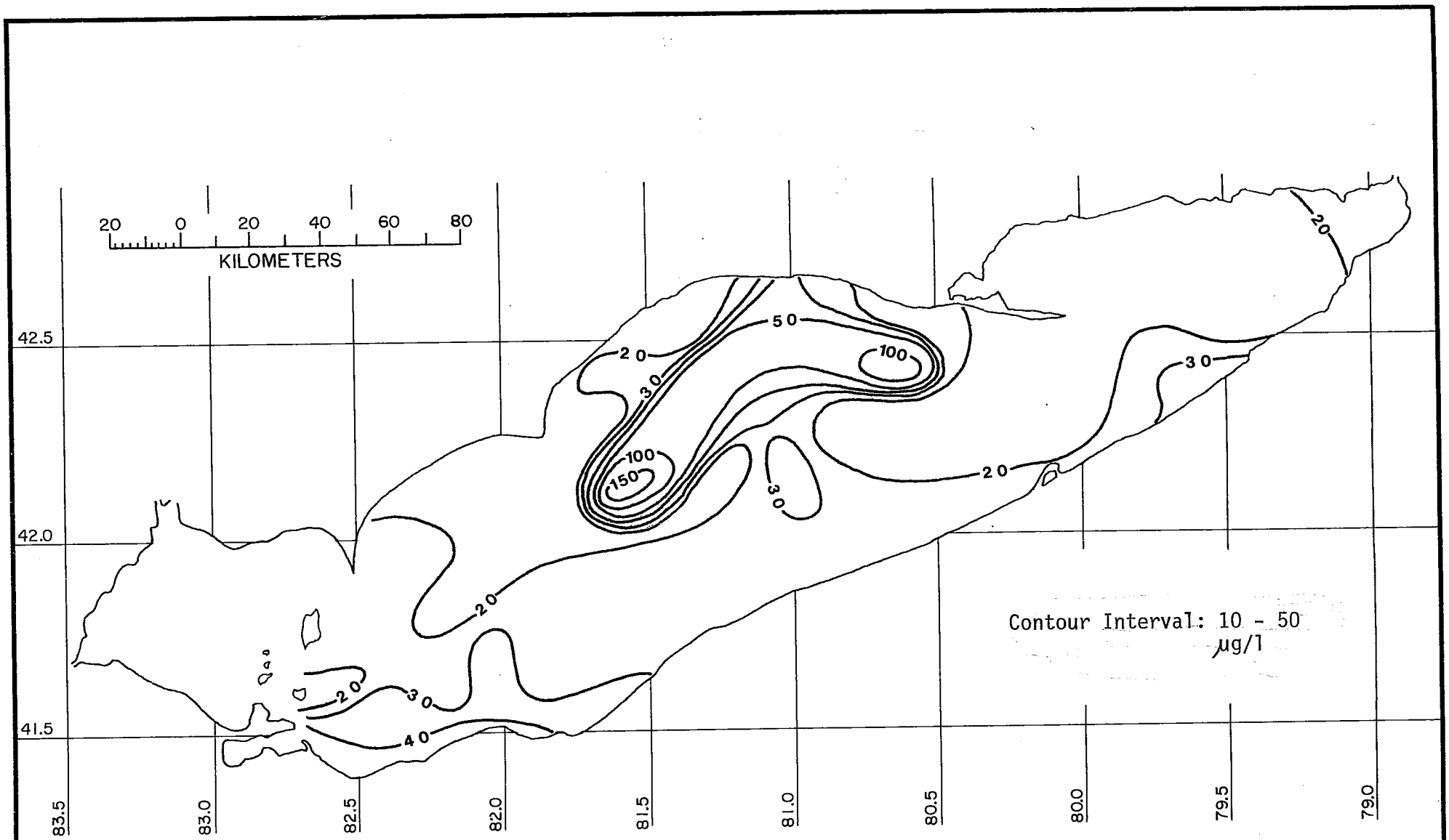


FIGURE 45. Surface Total Phosphorus (µg/l) for Cruise No. 3 (June 20-30, 1977).

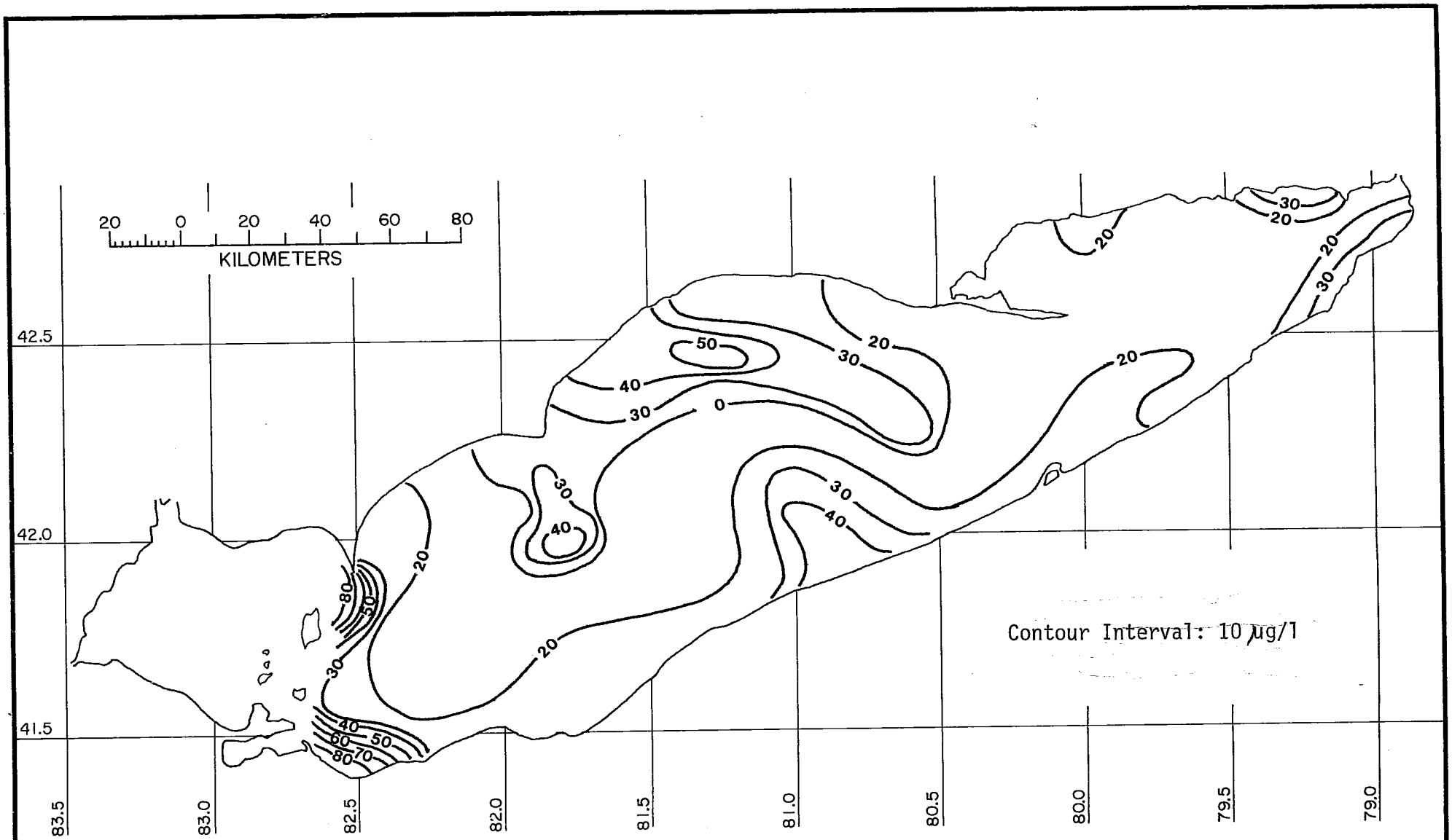


FIGURE 46. Bottom Total Phosphorus (µg/l) for Cruise No. 3 (June 20-30, 1977).

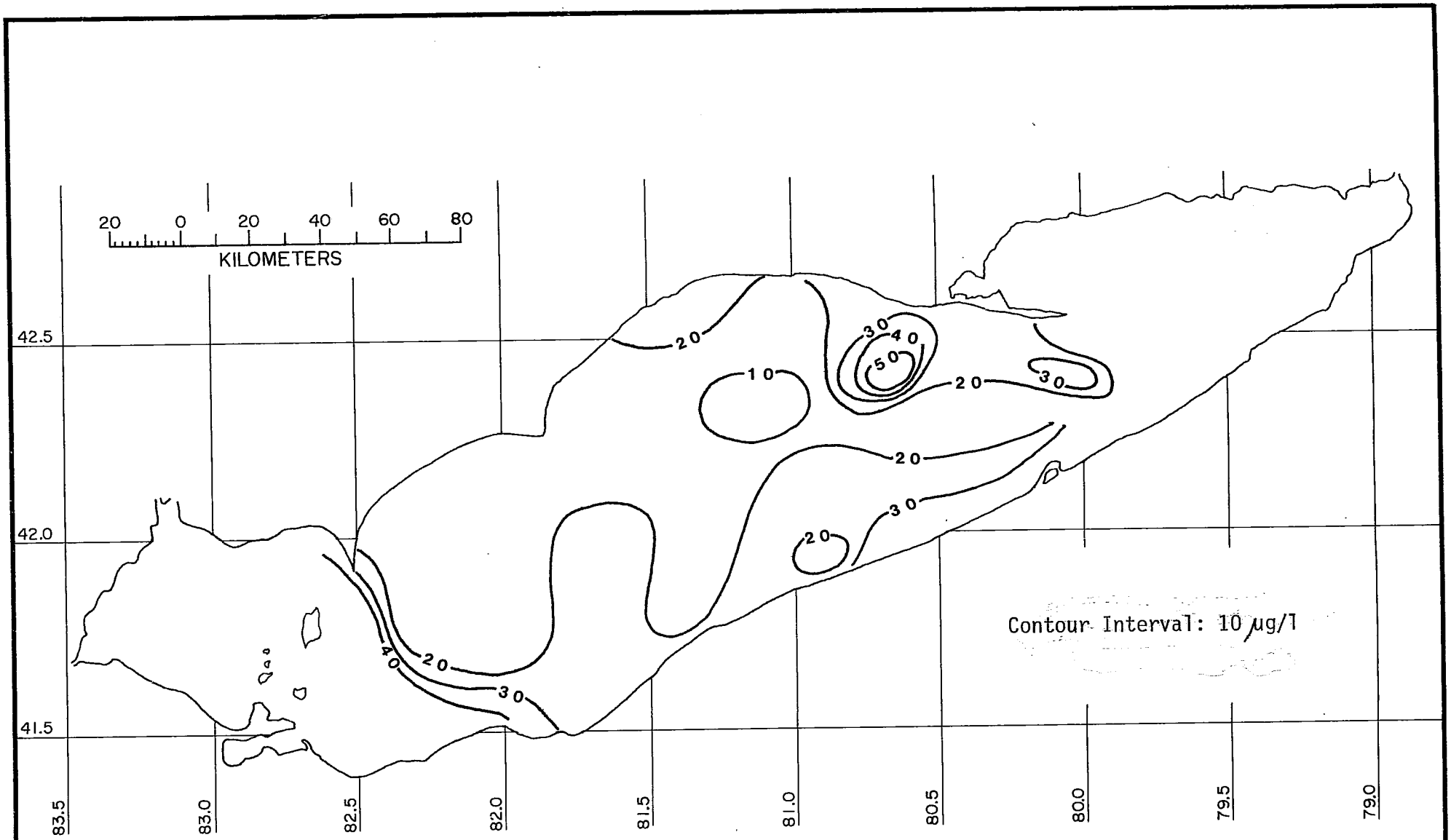


FIGURE 47. Surface Total Phosphorus (µg/l) for Cruise No. 4 (July 12-31, 1977).

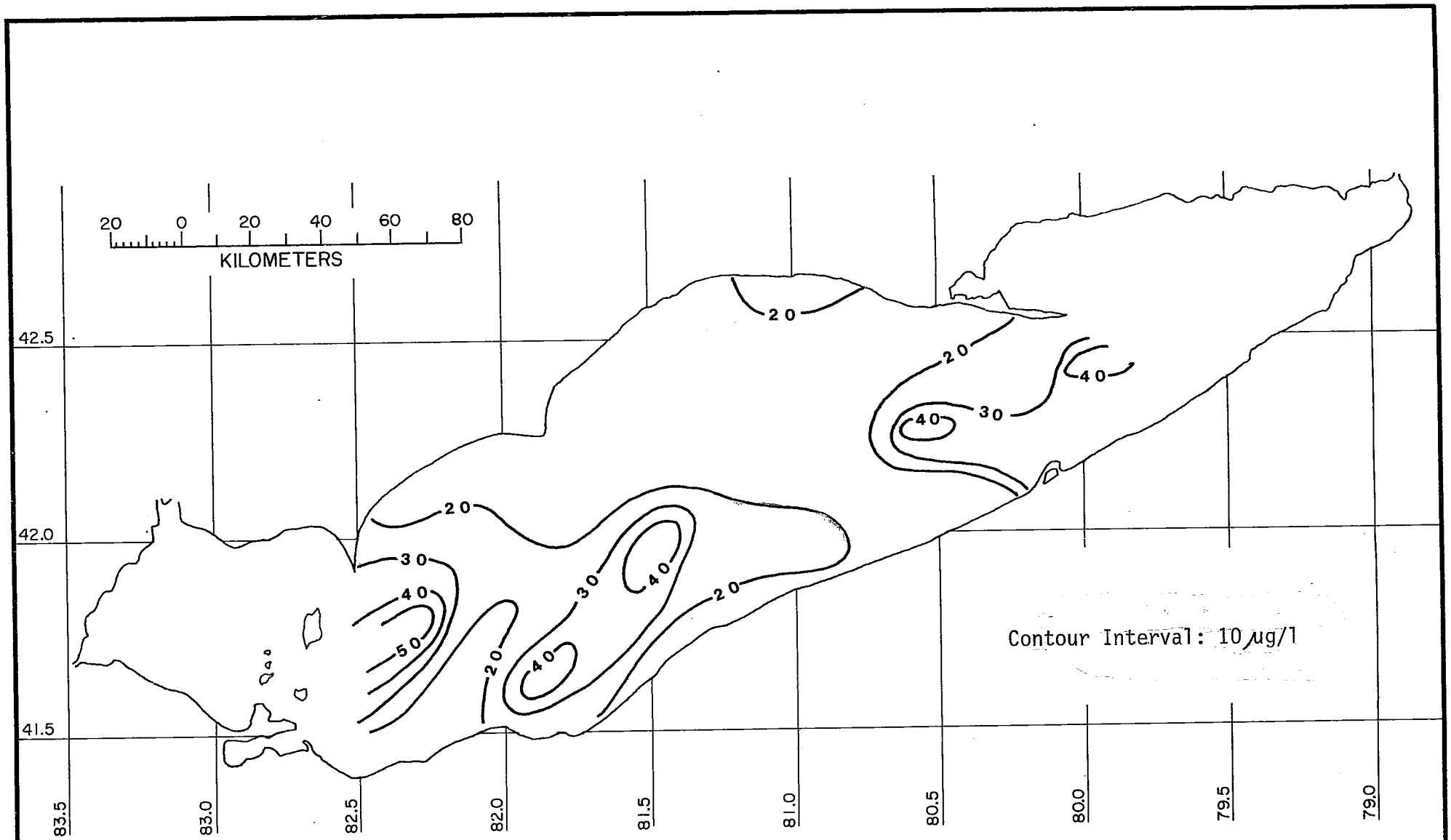


FIGURE 48. Bottom Total Phosphorus (µg/l) for Cruise No. 4 (July 12-31, 1977).

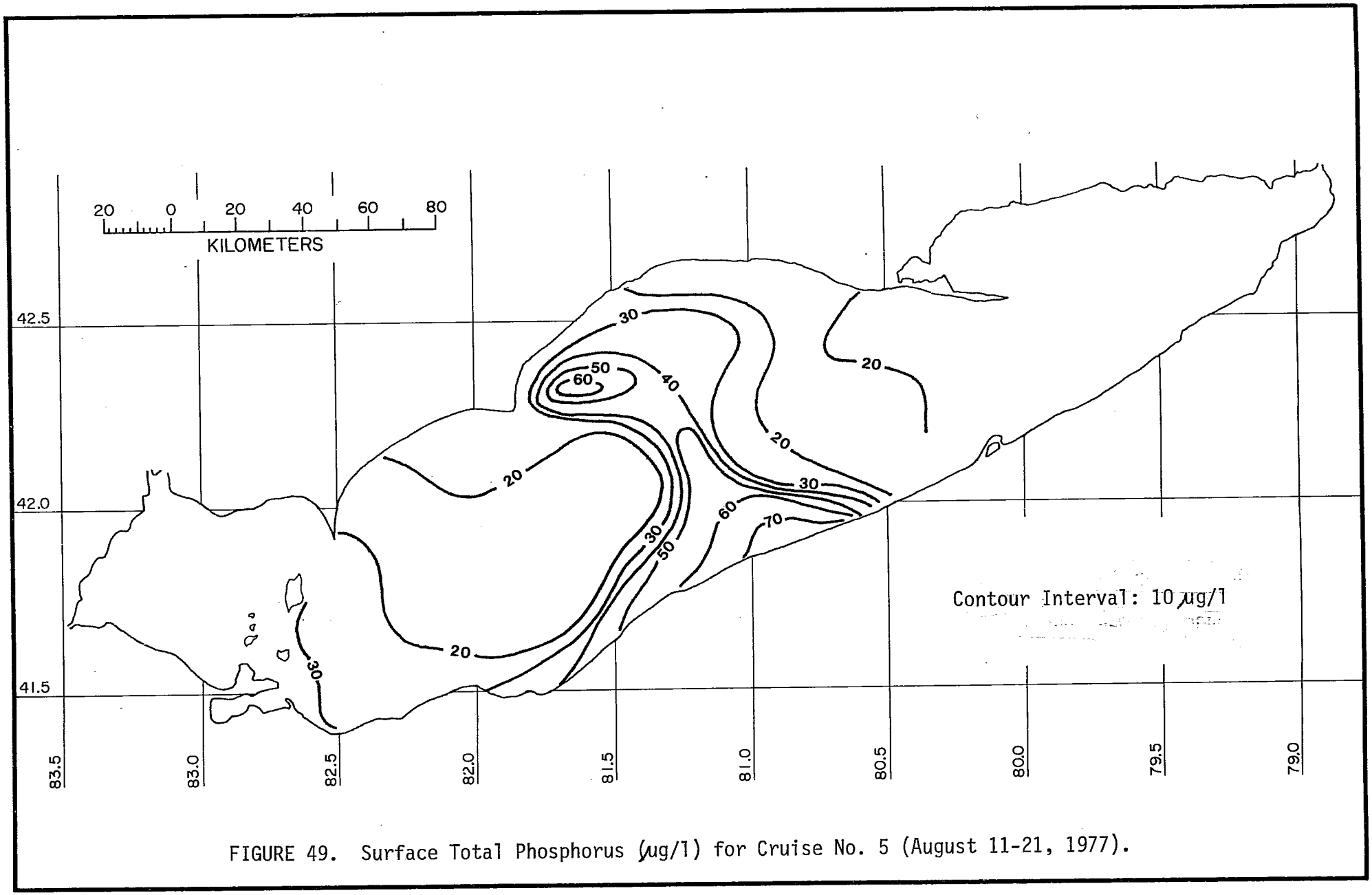


FIGURE 49. Surface Total Phosphorus (µg/l) for Cruise No. 5 (August 11-21, 1977).

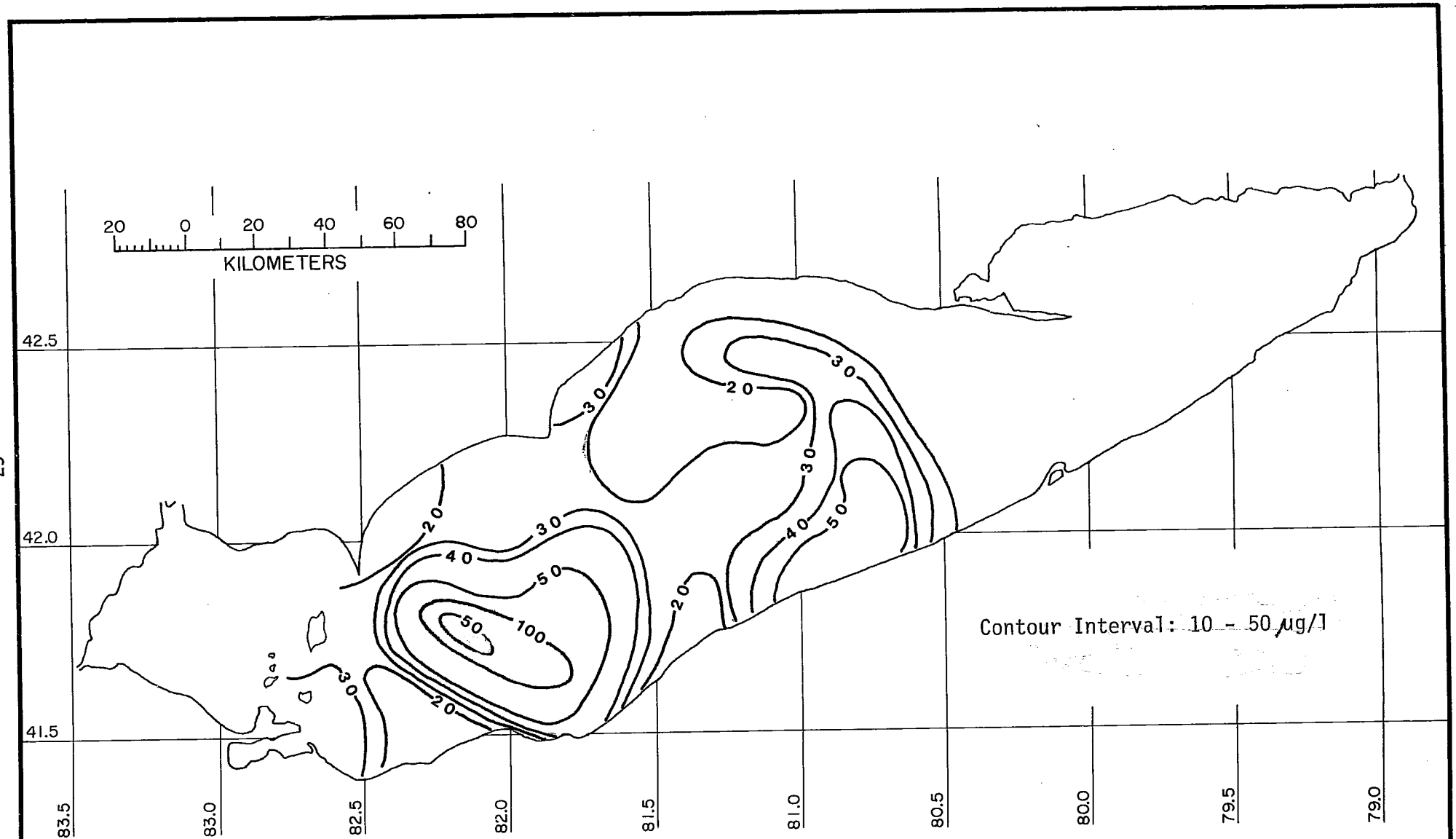


FIGURE 50. Bottom Total Phosphorus (µg/l) for Cruise No. 5. (July 11-21, 1977).

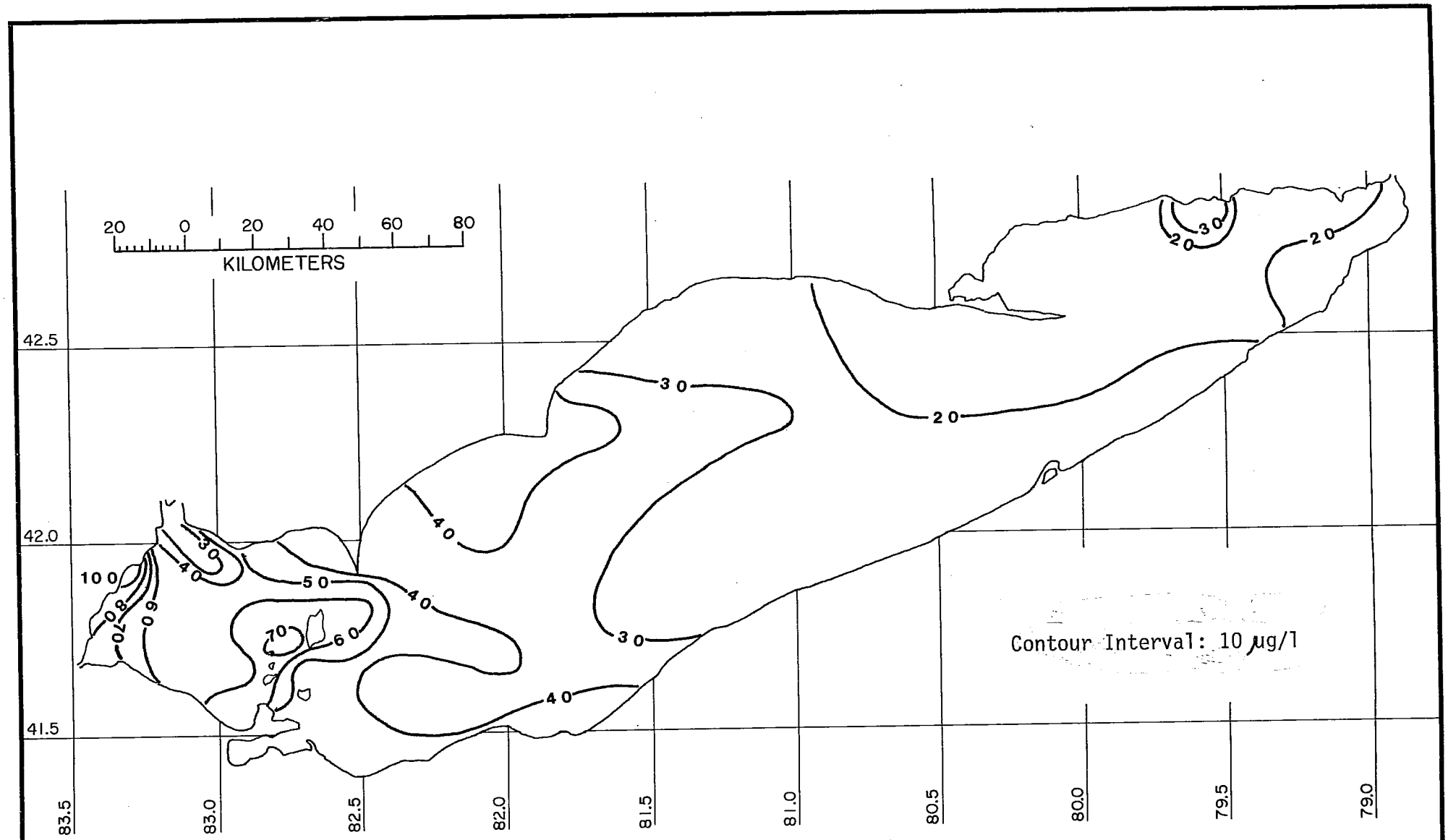


FIGURE 51. Surface Total Phosphorus (µg/l) for Cruise No. 6 (September 10 - October 9, 1977).

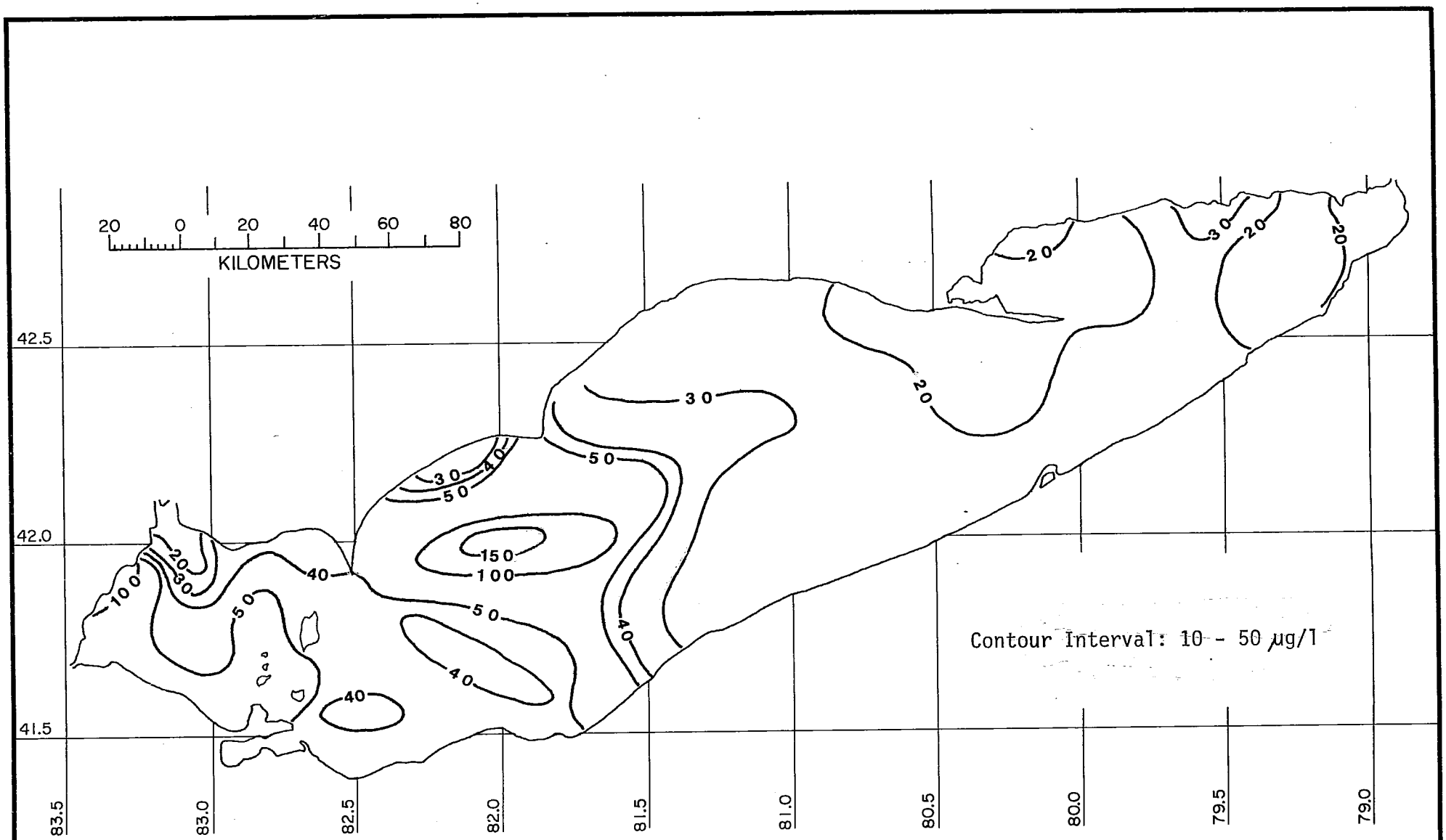


FIGURE 52. Bottom Total Phosphorus (µg/l) for Cruise No. 6 (September 10 - October 9, 1977).

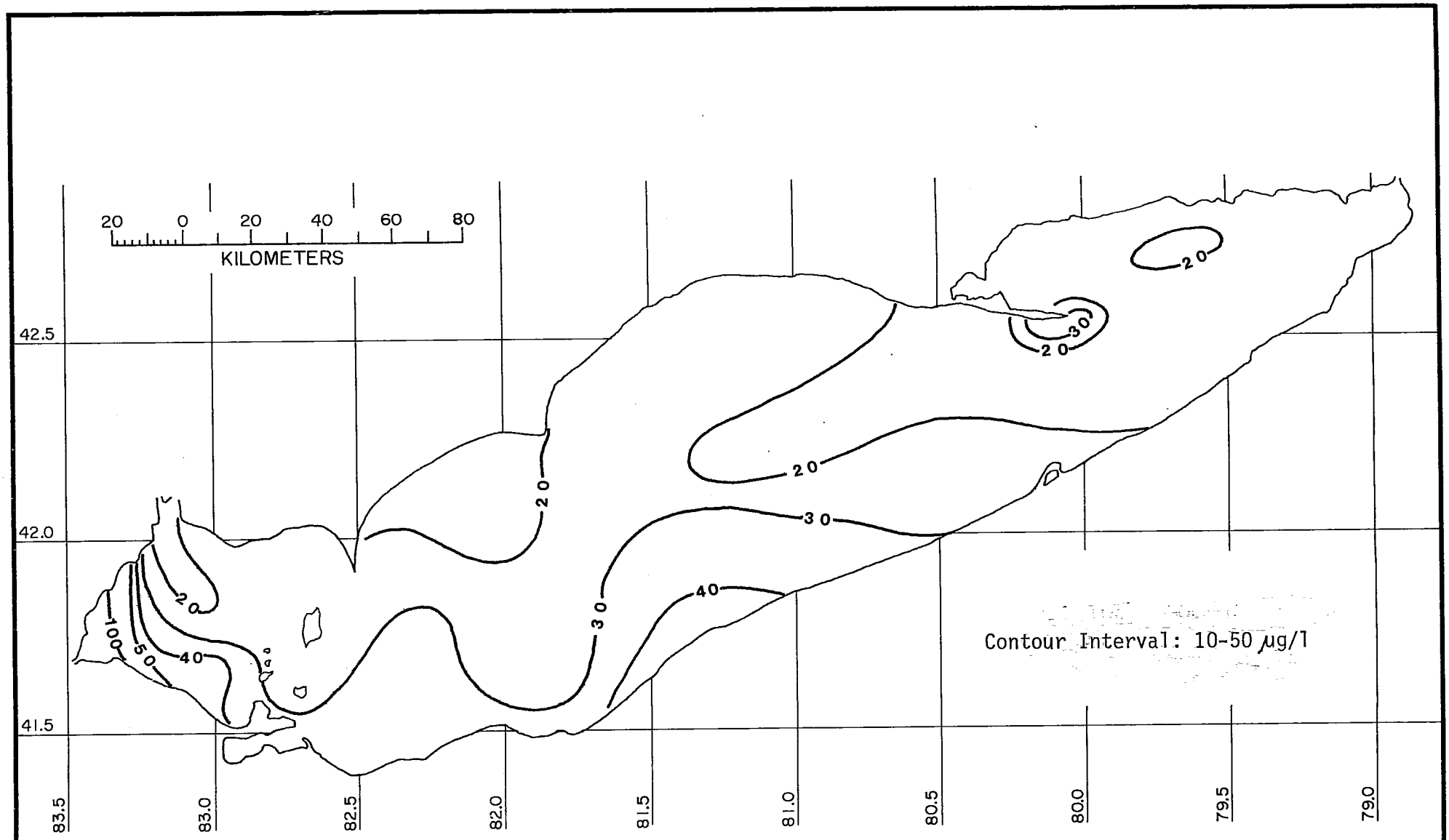


FIGURE 53. Surface Total Phosphorus (µg/l) for Cruise No. 7 (November 7-20, 1977).

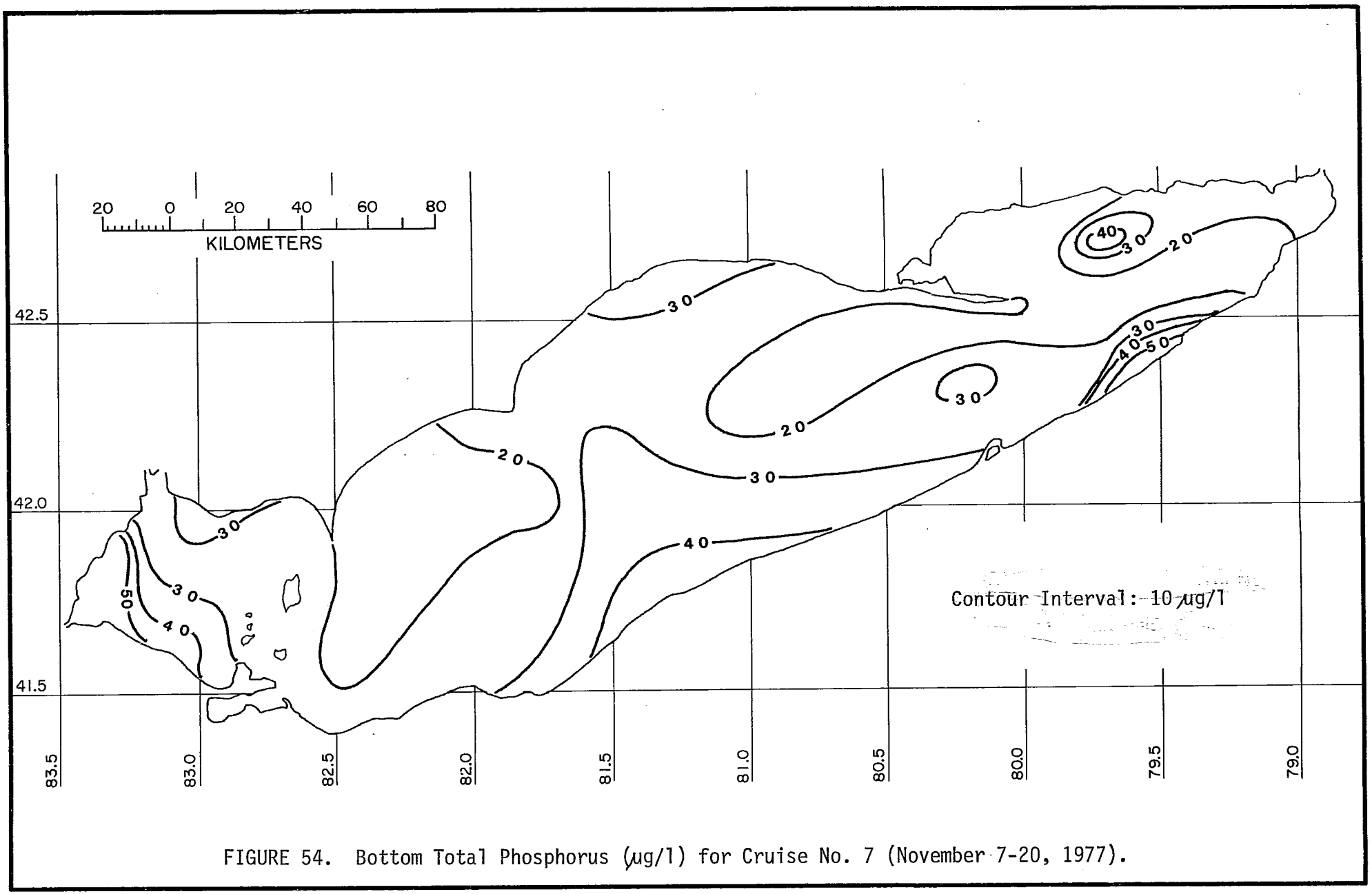


FIGURE 54. Bottom Total Phosphorus (µg/l) for Cruise No. 7 (November 7-20, 1977).

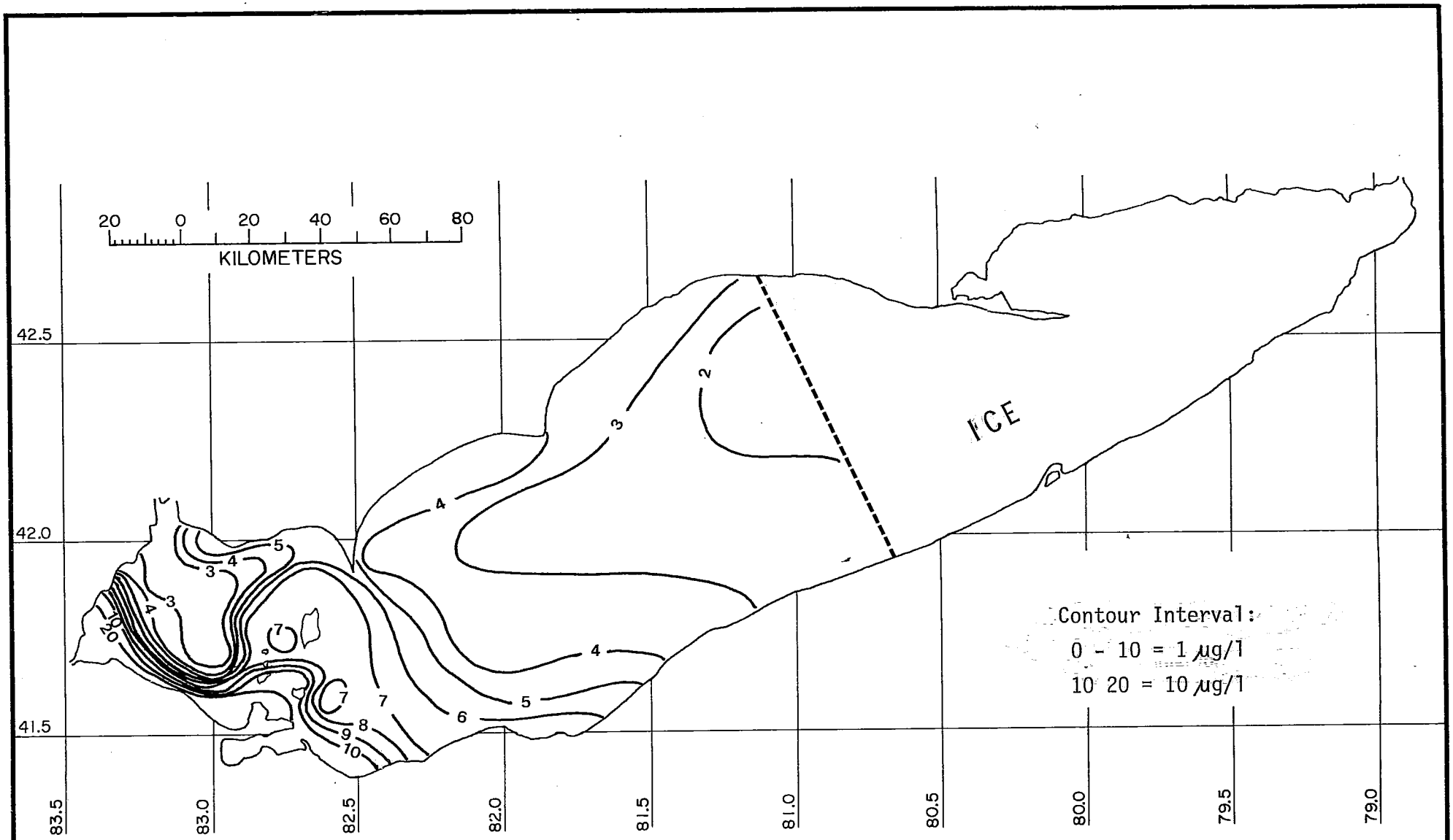


FIGURE 55. Surface Chlorophyll a (µg/l) for Cruise No. 1 (March 21 - April 3, 1977).

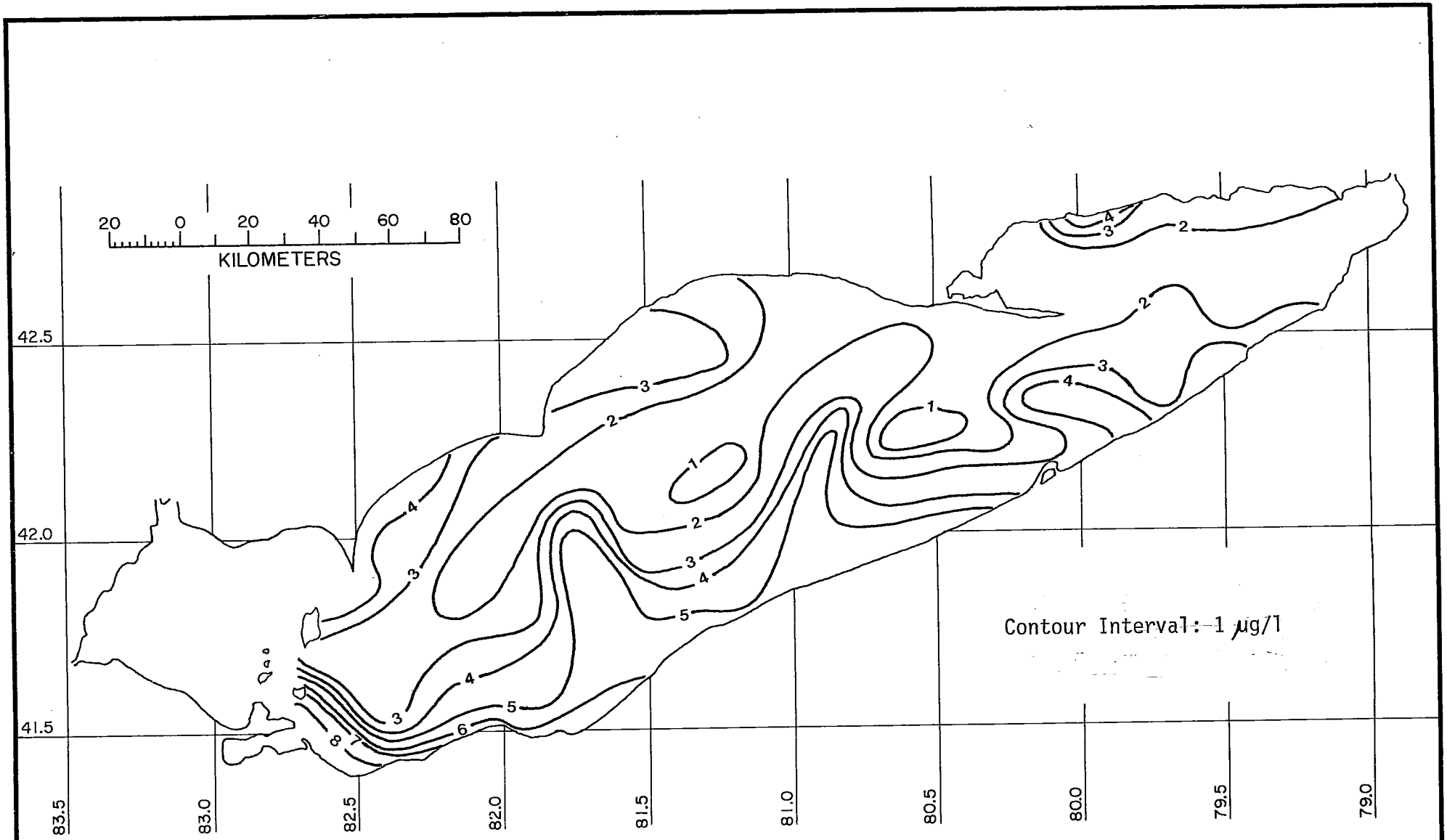


FIGURE 56. Surface Chlorophyll a (µg/l) for Cruise No. 2 (April 28 - May 8, 1977).

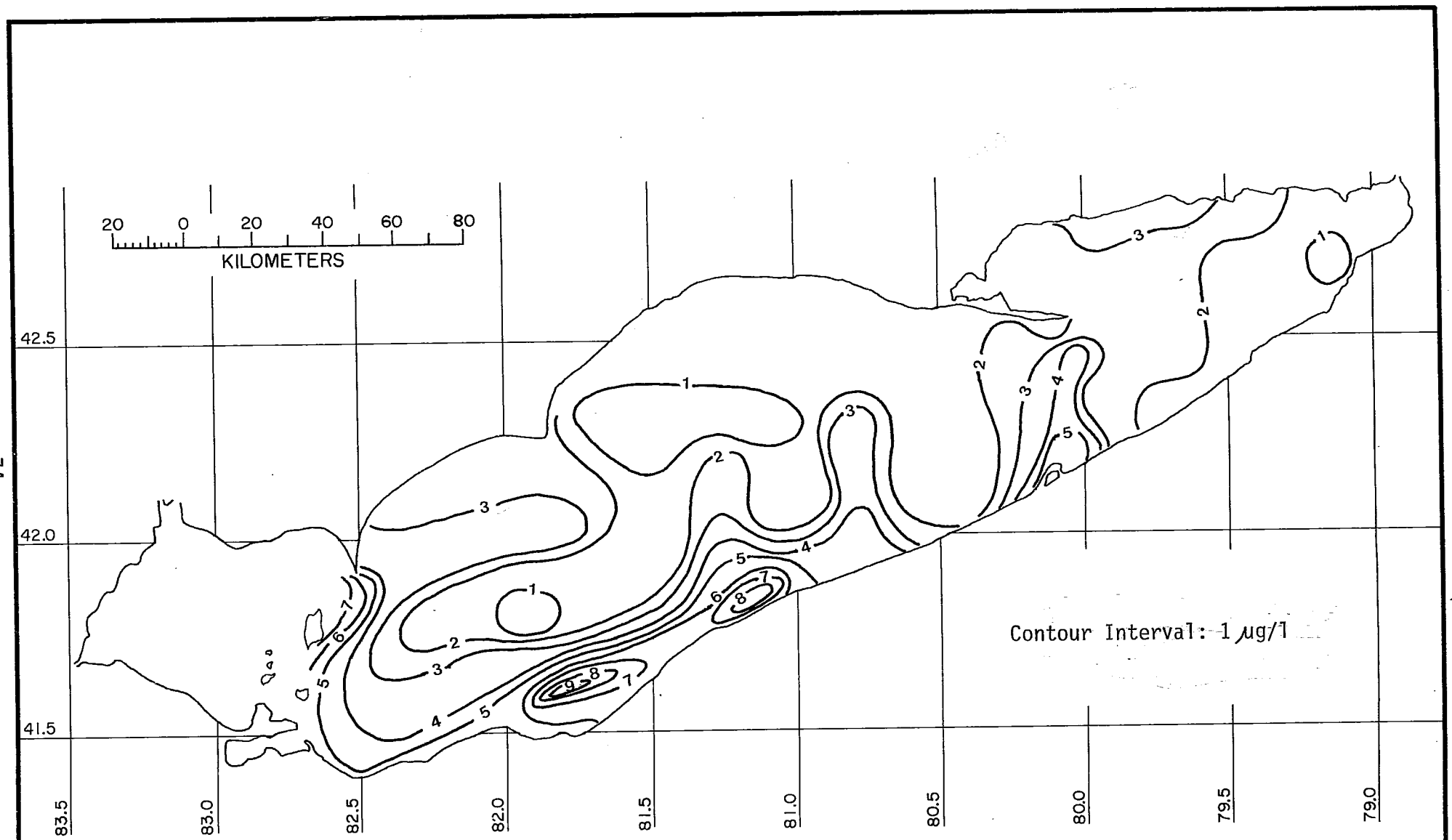


FIGURE 57. Surface Chlorophyll a (µg/l) for Cruise No. 3 (June 20 - 30, 1977).

FIGURE 58. Surface Chlorophyll a (µg/l) for Cruise No. 4 (July 12-31, 1977).

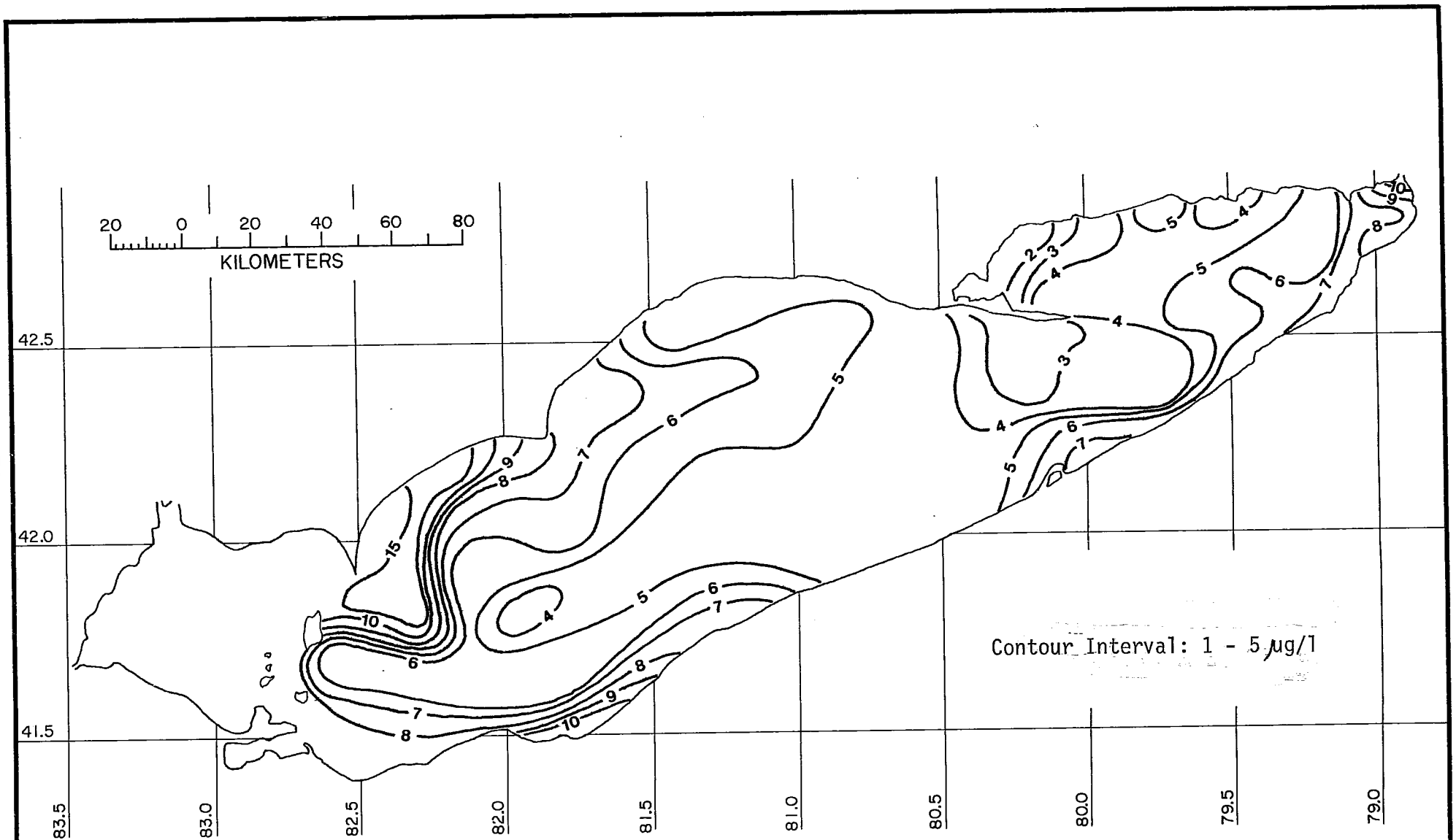


FIGURE 59. Surface Chlorophyll a (µg/l) for Cruise No. 5 (August 11 - 21, 1977).

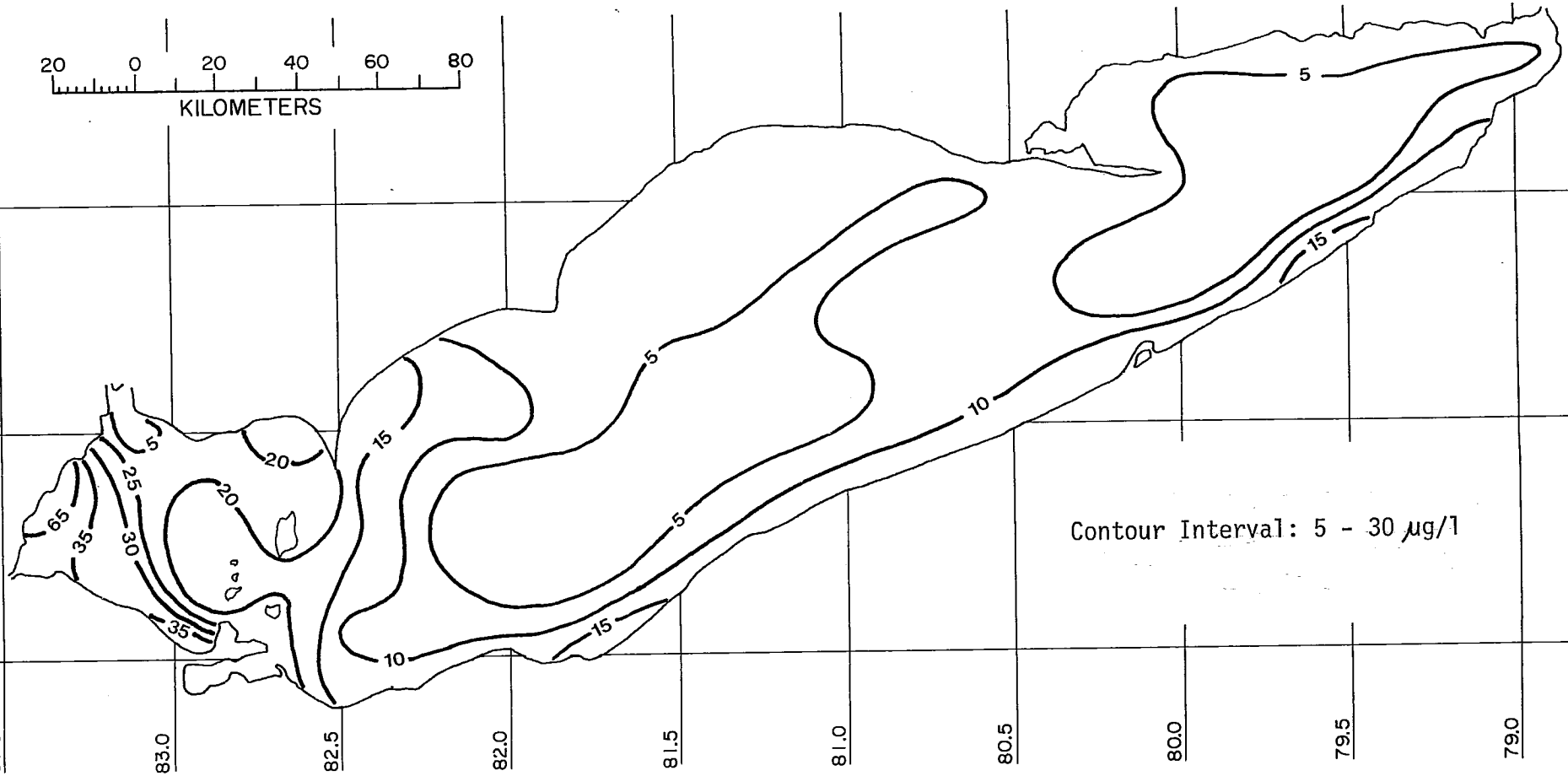


FIGURE 60. Surface Chlorophyll a (µg/l) for Cruise No. 6 (September 10 - October 9, 1977).

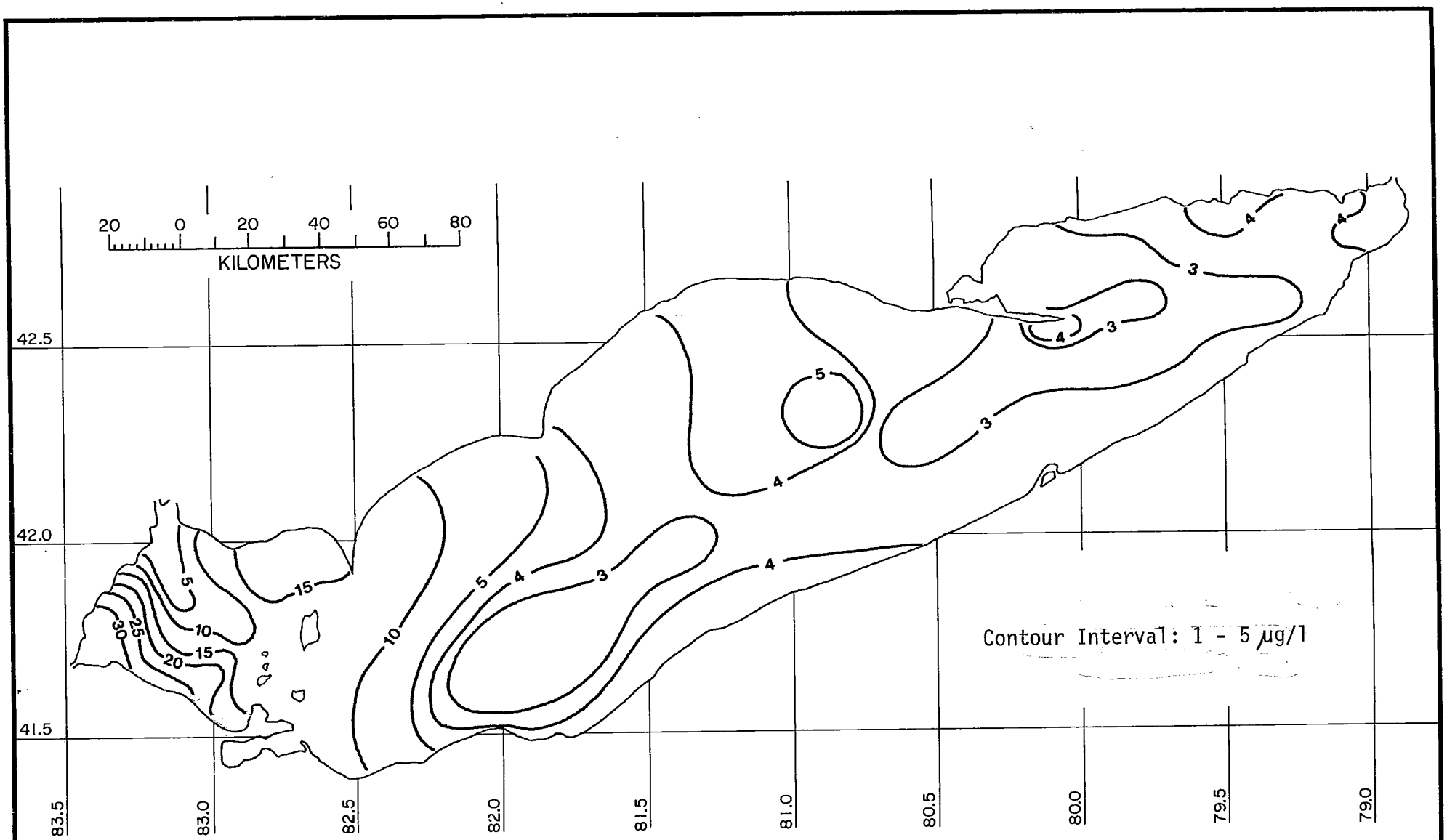


FIGURE 61. Surface Chlorophyll a (µg/l) for Cruise No. 7 (November 7-20, 1977).

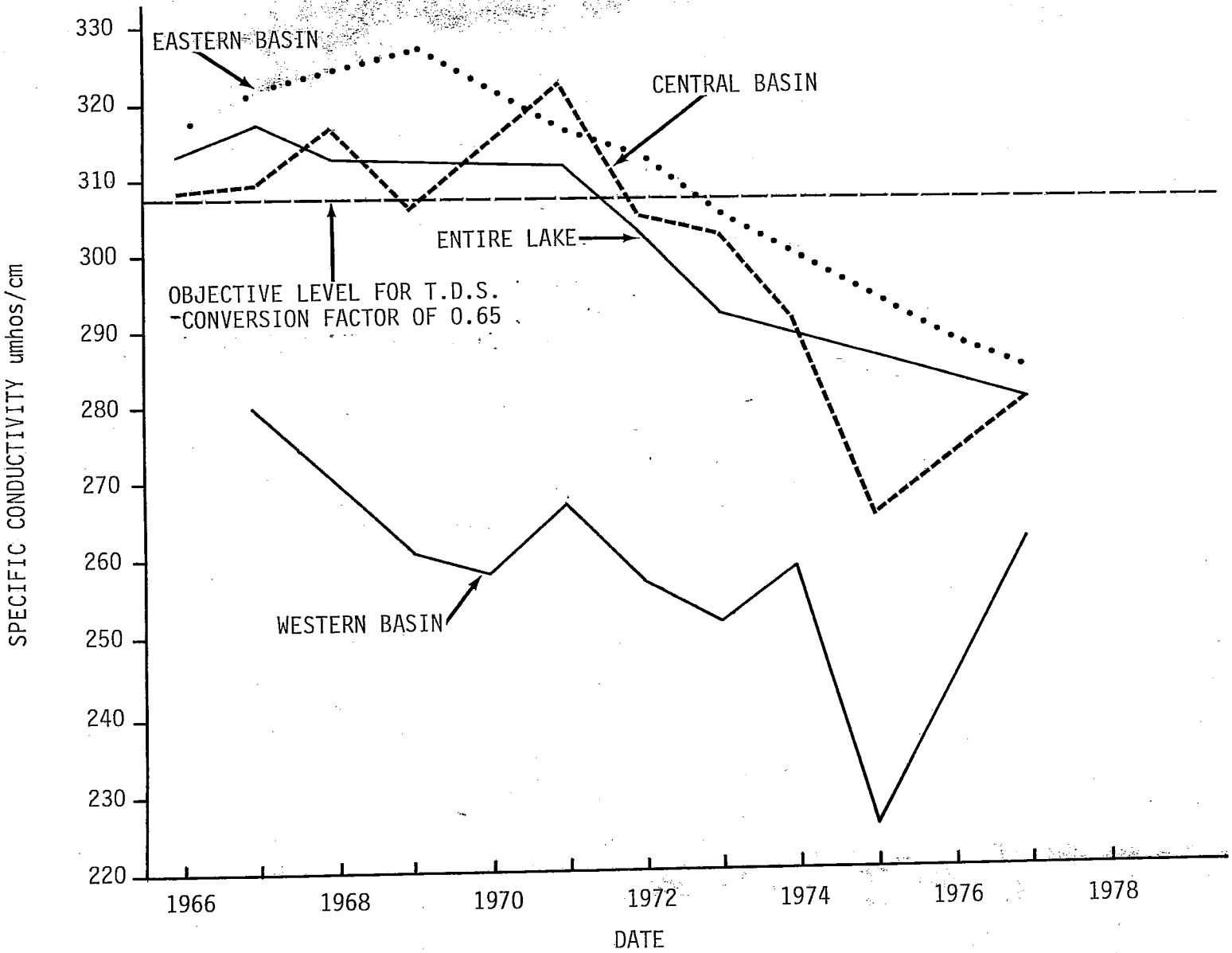
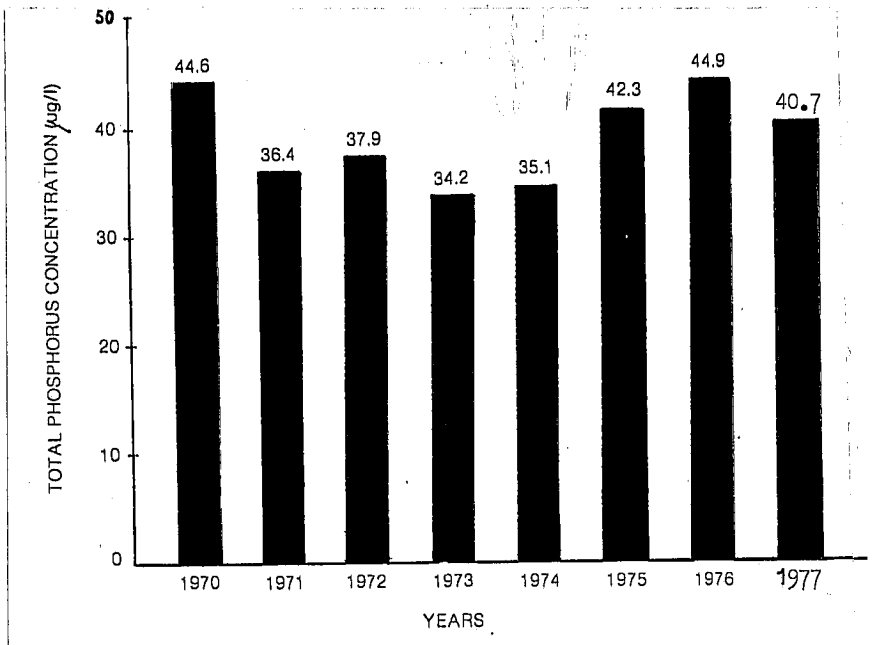
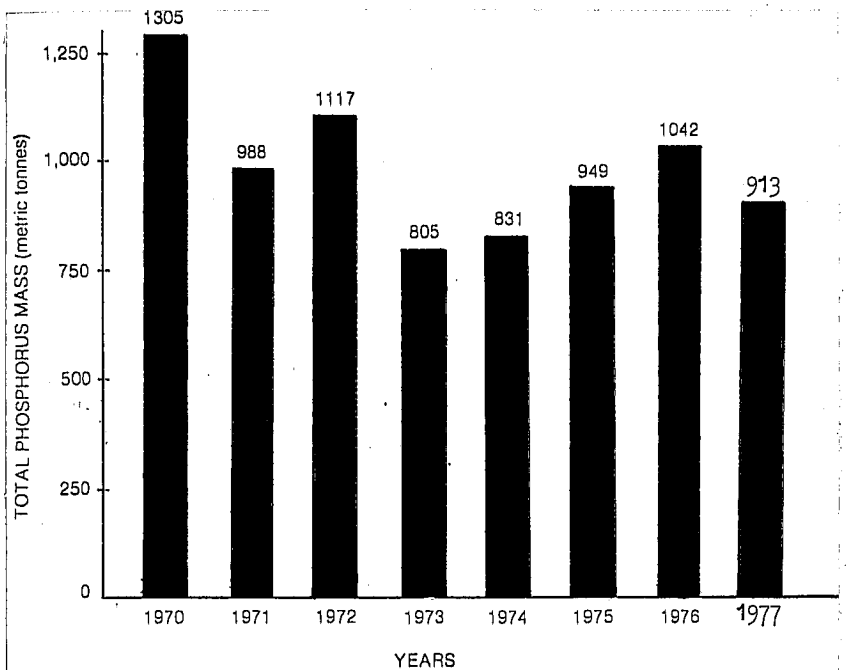


FIGURE 62. Trends in Lake Erie Conductivity 1966 - 1977.

FIGURE 63. Mean Annual Phosphorus Concentrations and Mass for the Western Basin of Lake Erie (1970 - 1977).

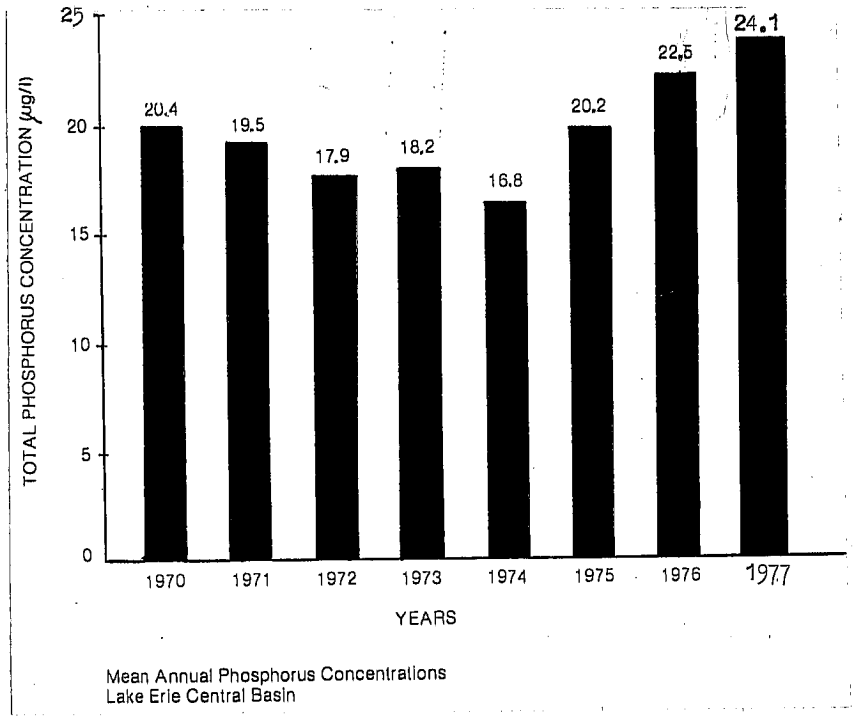


Mean Annual Phosphorus Concentrations
Lake Erie Western Basin

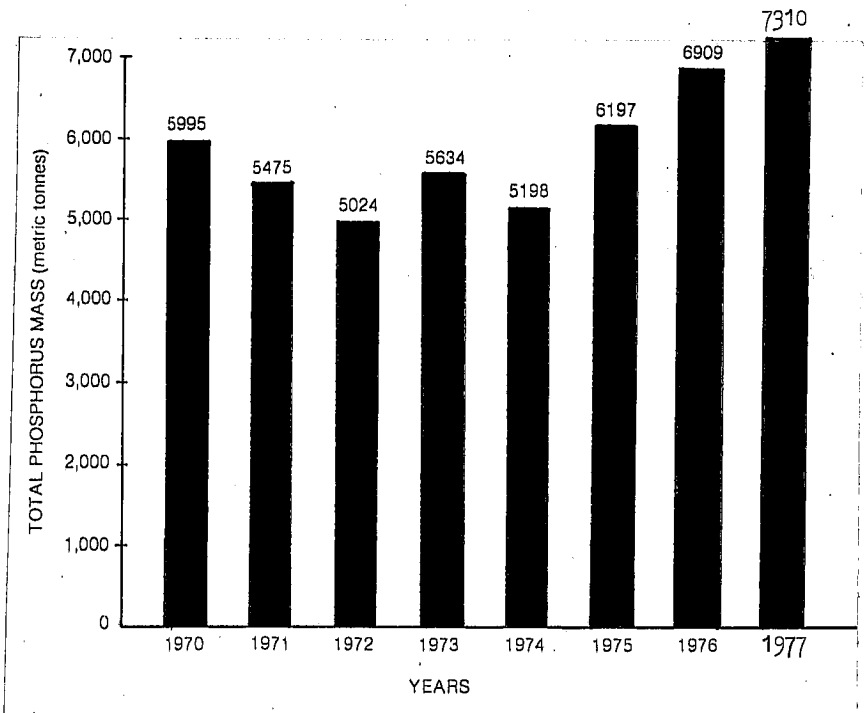


Mean Annual Phosphorus Mass
Lake Erie Western Basin

FIGURE 64. Mean Annual Phosphorus Concentrations and Mass for the Central Basin of Lake Erie (1970 - 1977).



Mean Annual Phosphorus Concentrations
Lake Erie Central Basin



Mean Annual Phosphorus Mass
Lake Erie Central Basin

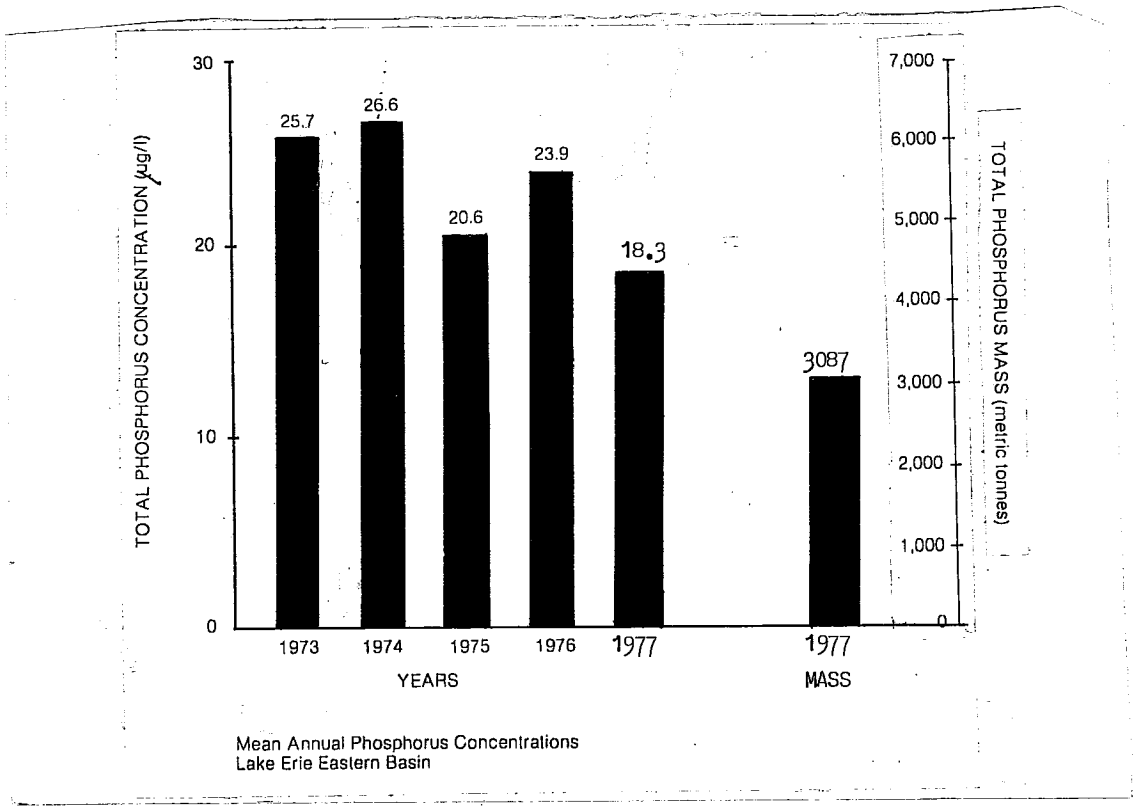


FIGURE 65. Mean Annual Concentrations and Mass for the Eastern Basin of Lake Erie (1973 - 1977).

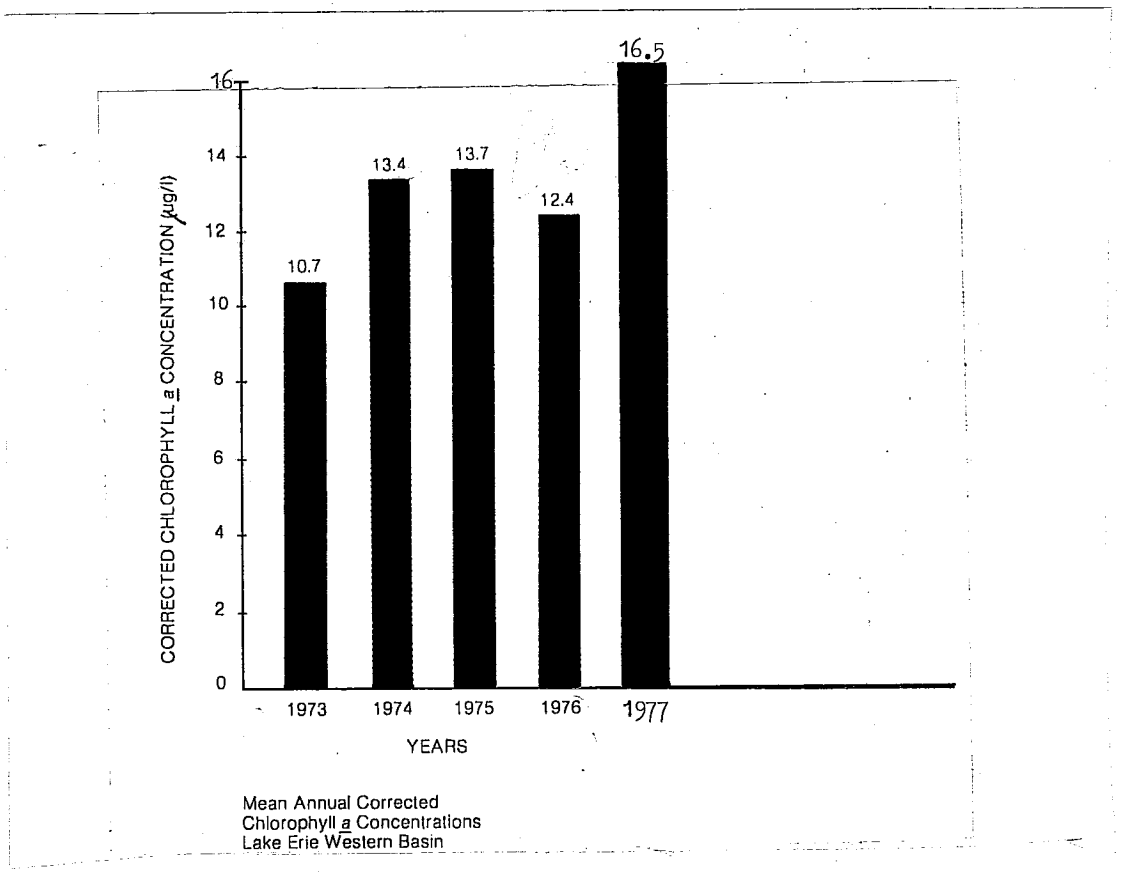


FIGURE 66. Mean Annual Chlorophyll a Concentrations for the Western Basin of Lake Erie (1973 - 1977).

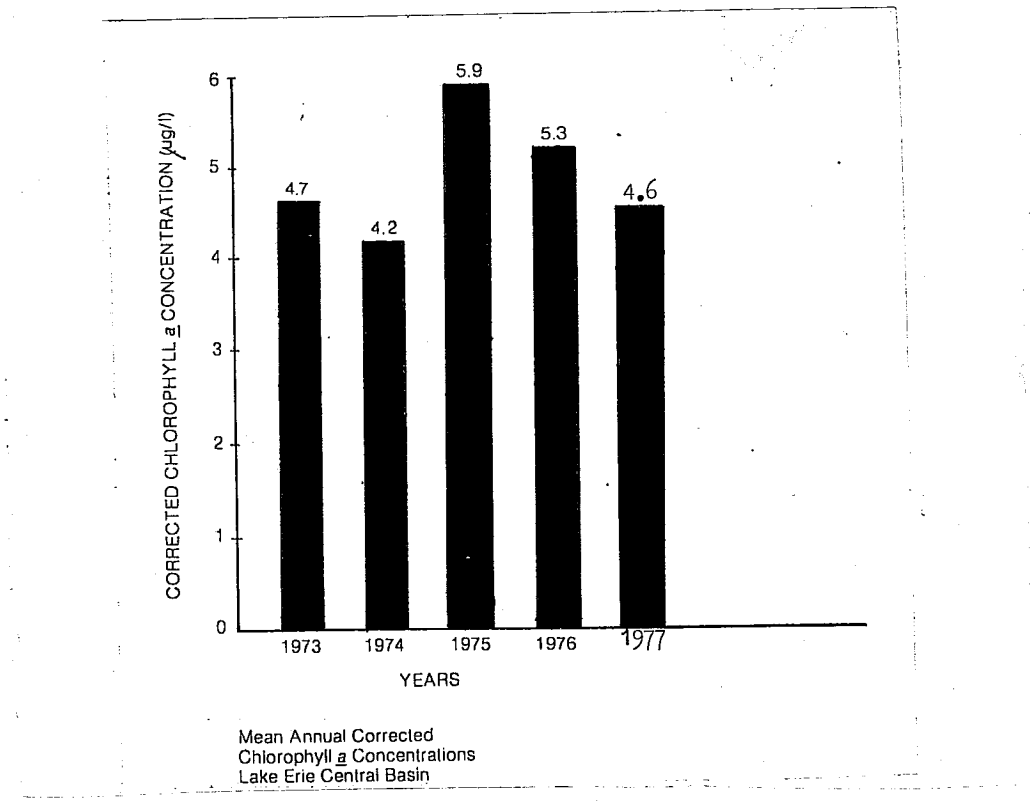


FIGURE 67. Mean Annual Chlorophyll a Concentrations for the Central Basin of Lake Erie (1973 - 1977).

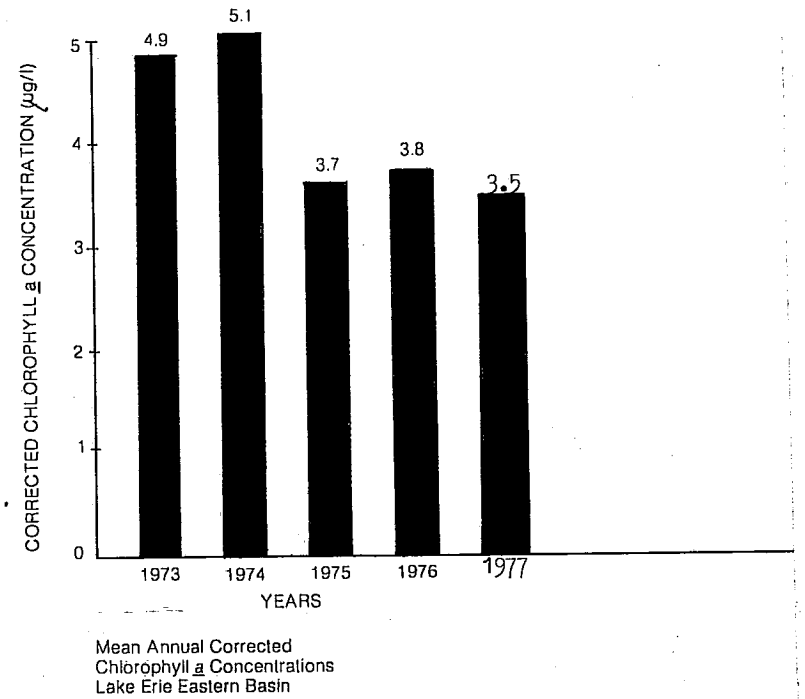


FIGURE 68. Mean Annual Chlorophyll a Concentrations for the Eastern Basin of Lake Erie (1973 - 1977).