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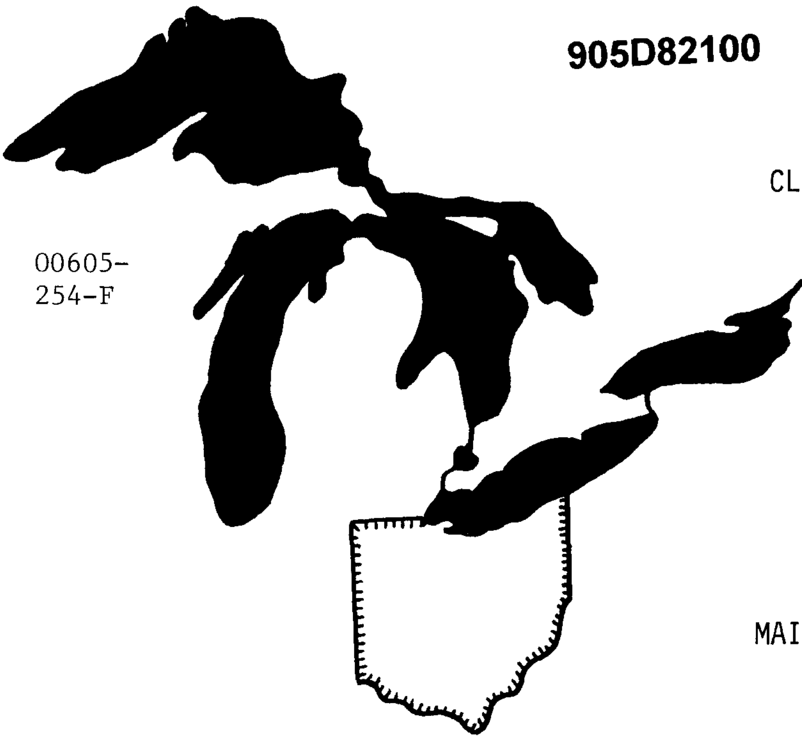

CLEAR TECHNICAL REPORT NO. 254-F

FINAL REPORT OF 1981 MAIN LAKE WATER QUALITY CONDITIONS FOR LAKE ERIE

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We wish to thank the USEPA Great Lakes National Program Office for the funds to complete the 1981 Lake Erie Field Season (Grant No. R 00 5556-02) and for their continued support which enables CLEAR to be an integral agency in obtaining data for the Lake Erie data base.

The editor and authors wish most to acknowledge Dr. Karlis Svanks, without whose help we wound never have been able to leave the dock.

EXECUTIVE SUMMARY

Summary 1981

Stratification existed in the central basin from early June to mid-September, an observed period of 109 days. The thermal structure was not as pronounced for the early June cruise as it was in 1980 but the other stratified cruises resembled a typical stratified year. The maximum anoxic area was recorded during cruise 5 (early September). The composite of the anoxic area is shown in Figure 7 and represents 29 percent of the total central basin surface area (4,280 km^2).

The nutrient distributions and concentrations were comparable to those found during other years with two exceptions. Increased western basin nutrient concentrations can be explained due to flooding in the Toledo Area on June 13th and 14th. NOAA (1981) reported 8.48 inches of rainfall over the 2-day period which resulted in increased concentrations of soluble reactive phosphorus, total phosphorus and soluble reactive silica. A slight increase in ammonia concentrations was observed (Figure 9). Another unusually heavy rain storm on September 3rd and 4th in the Toledo area resulted in 6.05 inches of rain. This storm was more widespread and extended to the Cleveland area dropping 6.8 inches of rain. Increases in nutrients were recorded for both the western basin and the central basin. Toledo reported a total annual rainfall of 38.4 inches which was 7 inches above the average annual Toledo rainfall of 31.5 and Cleveland reported 4 inches above its average annual rainfall of 35 inches. The increase in total annual rainfall for these two areas is not as significant as the magnitude of the rainfall received during discrete storms.

The heavy precipitation also increased the western basin concentrations of total solids, residual solids, and turbidity. The 1981 area weighted secchi data (Table 14, Figure 35) alluded to poorer water quality in the western basin when compared to the 1978-1980 data, possibly explained by the June and September storms.

The results of the 1981 apatite phosphorus study were compared to other Lake Erie investigators' available and non-available phosphorus results for tributaries (DePinto 1981; Logan 1979) and sediments (Williams 1976). The percentages of the apatite (nonavailable) phosphorus found in the western and central basins water column were intermediate between data reported for the tributaries and the sediments (Table 13). Data reported for the organic and NAIP types indicates fairly uniform percentages of availability of phosphorus (NAIP) for the western and central basins (22-27 percent) and a higher percentage of organic phosphorus in the central basin (63 percent) when compared to the western basin (45 percent). The availability of a portion of this organic fraction is variable.

Trends 1970-1981

Extensive analysis of Lake Erie trends have been reported by Fay and Herdendorf (1981) and by the Lake Erie Technical Assessment Team (Rathke 1982). It is not necessary to reiterate the conclusions of these reports, only to add the 1981 data to them. No trends are evident when utilizing the surface annual mean concentrations for corrected chlorophyll *a* for 1970 to 1981 (Figure 37 and 39). Data for total phosphorus annual mean concentrations also show no distinct pattern (Figures 41 and 42). The determination of trends is not a simple matter and cannot be determined by the simplistic calculation of mean annual concentrations. This technique reflects the variability enhanced by the changes in the number of stations, location of stations and the scheduling and number of cruises between the years. When proper filtering of the data is accomplished there appears to be a slight decrease in chlorophyll *a* lake concentrations since 1977 (Figures 38 and 40). The remaining mild fluctuations between years are explained by fluctuations in water level. Higher water level years had slightly lower levels of chlorophylls and lower water level years had higher chlorophyll concentrations (Fay and Herdendorf 1981).

The addition of station 202 located at the mouth of the Maumee River for field years 1980 and 1981 make the interpretation of long-term trends difficult because of the increased magnitude of the nutrient concentrations. Limnion means for the western basin have been recalculated (Table 15) excluding the two river mouth stations 202 (Maumee River) and 401 (Detroit River). There is a 25 percent reduction in the mean annual TP concentration with the elimination of these two stations from 41.80 ug/l to 32.16 ug/l. Before the long-term trends can be finalized, it will be necessary to repeat the western basin volume weighting procedure for both 1980 and 1981 to comply with the data available for 1973 to 1979.

Means Versus Medians

Statistical analysis of past years of Lake Erie data has demonstrated that the sample populations for total phosphorus and corrected chlorophyll *a* are not normally distributed about the sample mean. In other words, if all the data were plotted, one would not end up with the bell-shaped curve of a normal population. Statistical means and standard deviations are tools for the characterization of normal populations only. For other populations, non-parametric statistical tools (medians and quantiles) should be used. To examine the effect of using mean statistics on a non-Gaussian population we have presented means, standard deviations, and medians (the 50th percentile) by limnion, basin and cruise (Tables 8 and 9). The use of limnion mean concentrations may be justified for the central basin population due to the similarity in values of means and medians. When large differences did exist, it was rare and generally encountered for hypolimnion samples. However, the western basin repeatedly demonstrated means that were 100 percent greater than medians for total phosphorus, soluble reactive phosphorus, soluble reactive silica, nitrate plus nitrite, ammonia, turbidity, and solids. This is partially the result of the inclusion of station 202 at the mouth of the Maumee River which always has high concentrations biasing the western basin mean. Even with the elimination of station 202 data, the range of concentrations in the western basin is large. It appears that the median may provide the best characterization statistic for the lake (Table 15).

Future Sampling Design

To insure future reliability of the Lake Erie data base, scientific statistical analysis must be performed on the already existing data base to determine critical station locations, number of stations, times of sampling, and number of cruises. The fluctuations between years for the mean annual concentrations of TP and corrected chlorophyll *a* are supplied by the spring and fall data and, for some types of historical trends these data points are eliminated. The lake must be divided into homogeneous areas or zones using the clustering technique and the number of stations to be sampled within each zone should be calculated. The time and money expended to scientifically select numbers of stations and cruises will be returned in savings during cruise time and in data analysis. The technical ability to design a new lake program is available (El-Shaarawi 1982).

INTRODUCTION

Objectives of Sampling Plan

The 1981 sampling scheme was designed to obtain Lake Erie western and central basin data as an integral portion of the U.S. plan to study the lower lakes. The station pattern selected affords us the luxury of monitoring the extent of anoxia in the central basin, while obtaining data that can be utilized for trend analysis due to the continued sampling of these stations since 1973. The U.S. economic situation has presented a great impetus for the creation of the ultimate Lake Erie sampling design, one which would minimize use of our resources (time and money) and maximize our annual monitoring information on the lake. The resulting sampling program was an attempt at this design.

Description of Sampling Pattern

The 1981 station pattern (Figure 1) is a reduced version of the 1973 main lake plan with two exceptions. Stations have been added at the mouths of the Maumee (202) and Detroit (401) Rivers to define the loading sources and a twelve station transect from Locust Point, Ohio to Leamington, Ontario was added to characterize the mixing of the Detroit and Maumee River water masses. This transect was sampled monthly during March, April, May, November and December and on a bimonthly basis from June to October. The analysis of the western basin transect is not presented here, but the data corresponding to the 9 main lake cruises has been included in the western basin cruise means and contours (Table 1). A reduced station plan (n = 13) was followed for the central basin spring and fall cruises (1-3 and 7-9) while the full basin coverage plan (n = 31) was implemented during the stratified cruises. The original schedule required three cruises following the establishment of stratification and prior to turnover on a 3-4 week interval basis. However, due to boat mechanical failure no cruises could be made for the months of July and August. The geographic coordinates of all stations are presented in Table 3.

Parameter Selection

The rationale for measuring the selected parameters is based on the knowledge desired to answer standard limnological questions. Many of the parameters have been selected so that continuing records of data may be available for historical trend analyses. Anyone who has attempted historical data analysis knows of problems resulting from changing parameters or technology for valuable parameters. The value of the consistency of the following parameters to limnology and to historical data analysis is great; temperature, dissolved oxygen, pH, conductivity, secchi depth, turbidity and suspended solids. Other parameters are more valuable in determining the degree of the eutrophication and for estimating the benefit of many of the improvements made to sewage treatment plants, industrial effluents and agricultural runoff around the Lake Erie basin (total phosphorus, soluble reactive phosphorus, total filtered phosphorus, nitrate plus nitrite, ammonia and soluble reactive silica). Chlorophyll analysis has been carried out continually since 1970 and provides historical data for trophic status analysis and for estimation of the phytoplankton production. Other biological parameters (particulate organic carbon, particulate organic nitrogen, phytoplankton and zooplankton) are useful, but expensive and very time-consuming. Select stations and cruises were chosen for analysis of biological parameters to maximize knowledge gained. An explanation of the parameter monitoring program is presented in Table 4.

Methods

A summary of the methods employed for the 1981 season is presented in Table 5. A detailed description of the methods is presented in Letterhos (1982).

Report Objectives

The main objective of this technical report is to update the Lake Erie data base for total phosphorus, corrected chlorophyll *a* and dissolved oxygen for lake managers. The second thrust of this report is to pass on new information regarding Lake Erie, i.e., seasonality of nutrients other than total phosphorus, and the availability of phosphorus forms.

The volume weighted data presented in this report was produced by the Survey 8 program (Hanson et al. 1978). Tonnage and volume-weighted limnion mean concentrations were produced for total phosphorus, soluble reactive phosphorus, corrected chlorophyll *a*, nitrate plus nitrite, ammonia, and soluble reactive silica (Tables 6 and 7). Arithmetic limnion means were calculated for all parameters by basin (Tables 8 and 9) and for those persons wishing volume weights of other paramters, reasonable estimates may be obtained by multiplying the limnion concentrations (Tables 8 and 9) by the limnion volumes presented in Tables 6 and 7.

PHYSICAL DATA

Thermal Distributions

The main lake horizontal distribution of temperatures follows the pattern described by Zapotosky (1980); essentially, the lake warms in the spring and cools in the fall in a west-to-east gradient. Vertical temperature profiles during non-stratified periods in 1981 indicate differences from surface to bottom never exceeding 2.4^{o}C in either basin (Figure 2).

In 1981, thermal stratification was first observed during cruise 3 (June 3) remaining, although only at select stations, during cruise 6 (September 20), covering a span of at least 109 days. The thickest hypolimnion was found in the mid portion of the central basin, between Cleveland and Eireau (Figure 3). The thickest hypolimnion encountered was 9.7 m during cruise 3 (early June), decreasing steadily throughout the season. Initial hypolimnion temperatures were about 9°C. The minimum bottom temperature, 7.3°C, was found in the eastern portion of the central basin at (station 26) during cruise 4 (late June), which may be the result of intrusion of eastern basin mesolimnion water.

Temperature profiles for station 037 (Figure 4) located in the middle portion of the central basin, are presented for cruises 2-7 (May through October). Stratification began in early June; however, the thermocline at this time was not as pronounced as it was in June of 1980. The development of the limnions progressed according to the classic description (Hutchinson 1957). The location of the mesolimnion fluctuated between 14-16 meters throughout the stratified season while the slope of the rate of change of temperature per meter increased from 2°C/m in early June to 4.8°C/m in early September.

Due to the prevailing south-west winds and the Coriolis effect, downwelling occurs along the south shore and upwelling on the north shore of the central basin, giving a predominant tilt to the thermocline. However, during our sampling cruises of 1981, this condition was not as noticeable as during other years (Zapotosky and Herdendorf 1980). This may be a result of different wind and hydrodynamic forces encountered during 1981, but it more likely reflects conditions only during sampling cruises (Figure 5).

Although stable thermal stratification does not occur in the western basin, occasionally conditions are favorable for a temporary, ephemeral thermocline to develop. These conditions were encountered during only one cruise in 1981 (cruise 3). As is generally the case, the thermocline was within 1 m of the bottom, and the temperature difference above and below the thermocline was slight, usually only 2-4C. This stratification has been regarded as having little importance; however, due to the high oxygen demand of western basin sediments, the high temperatures to which the sediments are subjected, and the small volume of the hypolimnion, severe oxygen depletion leading to anoxia will probably accompany each occurence of thermal stratification in the western basin (Bartish 1983).

Although it is possible that western basin stratification may be an extension of the central basin meso- or hypolimnion, this condition is assumed not to exist for the purposes of this report, and western basin mesolimnion and hypolimnion data are not reported.

Dissolved Oxygen

The seasonality of dissolved oxygen concentrations in the central basin has been studied intensely since 1970. The decrease in oxygen concentrations throughout the summer is anticipated as a result of the climatic warming of the water, which causes decreased solubility. In spite of this, the DO saturation of the water column should remain near 100 percent. The central basin epilimnion waters remained above the 90 percent saturation level throughout the summer months and reached a minima of 89 percent during late October. The hypolimnion portion of the central basin has a continuously decreasing saturation during the stratified period (Figure 6) reaching a minimum of 14.5 percent during early September (cruise 5). A slight increase in hypolimnion percent saturation is seen between the early and mid-September cruises (Numbers 5 and 6) due to destratification of the shore stations and to reaeration of the hypolimnion due to mixing. Contours of dissolved oxygen hypolimnion concentrations (Figure 7) verify that the mid-September cruise (5) exhibited the largest area of anoxia (less than 0.5 mg/l). The composite area of anoxia found during the entire 1981 field season was 4,280 km^2 or 29 percent of the entire central basin area (Table 10). The summary of the central basin hypolimnetic cruises is provided in Table 11. Similar summaries have been provided in CLEAR Technical Reports for 1973 through 1980.

The central basin hypolimnion DO concentration dropped from 9.42 mg/l in early June to 1.54 mg/l in early September, a total of 7.88 mg/l in three months time. The oxygen depletion rate calculated from these data is 0.47 g O_2 m^{-2} day^{-1}. Oxygen demand rates from 1930 to 1981 are also presented on an areal and volumetric basis (Table 12).

% area went anoxic in Aug. these numbers are suspect

The net effect of the oxygen depletion in the central basin depends on the rate of depletion, the duration of anoxia and the areal extent of anoxia. The duration of anoxia is variable due to meteorological conditions making predictions difficult. The Sandusky sub-basin stations are the first to become anoxic as a result of the shallow depth and the high oxygen demand rate due to the heavy sedimentation that occurs here. As the western basin water passes over the Sandusky ridge, it slows down due to the increased depth. This area is reported to have the highest sedimentation rate in the central basin. The Sandusky sub-basin is also the first area to destratify. It would be impossible to determine with any certainty the maximum area of anoxia. The data in Table 12 represents estimates of the composite anoxic areas on the stratified cruises by year back to 1930 (Taken from Herdendorf 1980) when data was available.

NUTRIENTS

Nutrients monitored in 1981 included soluble reactive phosphorus (SRP), total phosphorus (TP), total filtered phosphorus (TFP), ammonia (NH_3), nitrate plus nitrite ($NO_3 + NO_2$) and soluble reactive silica (SRS). Water samples for SRP, NH_3, $NO_3 + NO_2$ and SRS were run on board the <u>R/V Hydra</u> while TP and TFP were sent to Columbus for analysis after each cruise.

Since the central basin was not sampled in July and August, data in Figures 8 to 12 show the change in nutrient concentrations from the beginning of July to the beginning of September rather than actual nutrient levels during this time period. In reality, soluble nutrient concentrations would probably have been at a minimum during the summer months due to reduced loading, little agitation by winds and waves, and high algal demand (Burns 1976; Rathke 1979; Herdendorf et al. 1980; Fay and Herdendorf 1981). It was possible to sample the western basin transect during the ship's down time (July and August) using a small boat so the graphs for the western basin represent the transect data only.

Vertical seasonal distribution patterns are presented in Figures 8 to 12 for both epilimnion and hypolimnion of the four central basin stratified cruises. Since stratification did not exist in the western basin means of surface and bottom concentrations are plotted to obtain basin seasonal distribution patterns.

Western basin concentrations exceeded those of the central basin epilimnion at all times. During periods of summer stratification and anoxia, central basin hypolimnion values surpassed the average western basin concentrations for SRP, NH_3 and SRS suggesting an appreciable amount of regeneration.

Nitrate plus nitrite concentrations in the western basin were highest in June, averaging 1168 ug/l, decreasing rapidly to 430 ug/l by early July. Values remained fairly constant through September and then rose to a peak of 630 ug/l in November. Central basin concentrations show a different and less dramatic seasonal distribution as seen in Figure 8. Highest values were measured in late March (369 ug/l) and steadily declined through September (143 ug/l) with slight pulses in early July, late October and early December. Central basin hypolimnion values showed a decrease throughout the period of stratification with concentrations becoming lower as the length of anoxic period increased.

Ammonia in the western basin was high in the spring (80.4 ug/l), falling to 22.2 ug/l by May. Following a slight rise in late June, levels fell to a low of 10.5 ug/l in mid-August and then rose steadily throughout autumn (48.2 ug/l). Concentrations increased rapidly in November (160.4 ug/l) and then returned to early fall levels by the beginning of December. Concentrations in the central basin epilimnion were much less variable than the western basin, ranging from 5.0 to 39.1 ug/l. Pulses occurred in early June and September. Hypolimnion ammonia values were higher than epilimnion values ranging from 26.1 to 58.5 ug/l (Figure 9).

Soluble reactive phosphorus and total phosphorus showed the same distribution pattern throughout the year for both the western and central basins (Figures 10 and 11). Western basin phosphorus levels were highest in late June and early September with values of approximately 10 ug/l for SRP and 56 ug/l for TP. Phosphorus concentrations in the central basin showed little variation throughout the year with SRP ranging from 1.3 to 5.7 ug/l and TP from 9.9 to 22.3 ug/l. Hypolimnion values in both cases were higher than epilimnion values, but still fell within the same ranges.

Soluble reactive silica was the most variable of all the nutrients measured. Western basin concentrations ranged from a low of 372 ug/l in early June to a high of 1521 ug/l in late September. Changes during cruise intervals were always abrupt as seen in Figure 12. Central basin distribution showed highest concentrations present from April to May, then steadily increased through September, at which time values began a gradual decline. Silica in the hypolimnion exhibited the widest range, beginning with 279 ug/l in early June, 488 ug/l by the first part of July, rising to 1730 ug/l by the beginning of September and then declining throughout the rest of the stratified period (mid-September).

Horizontal distribution patterns of all the above nutrients (Figures 13 to 17) tended to decrease from west to east and south to north. Highest concentrations appeared at the mouth of the Maumee River, being rapidly diminshed as river water mixed with higher quality lake water and Detroit River water. Concentrations continued to decrease with the increasing water volume moving east. Occasional high points were noted along the southern shore at the inflow of the Cuyahoga and Grand Rivers. Epilimnion and hypolimnion isopleths are presented for all stratified cruises and wherever any significant differences occurred between surface and bottom. Cruise 1 was not contoured for lack of sufficient data, and the same applies to ammonia for cruise 3.

The horizontal distribution of nutrients is controlled by a variety of factors: currents, extent of loading and location of point sources, wind direction, depth, and thermal structure. The Detroit River has the greatest influence on western basin concentrations due to the large volume of water being discharged. Highest nutrient levels are found along the southwest shore from the River Raisin to the eastern end of Maumee Bay. Anoxia in the central basin accounts for areas of high concentrations in the hypolimnion during stratified cruises.

Nutrients were volume-weighted utilizing the Survey 8 program (Hanson et al. 1978) to obtain estimates of the quantities (metric tons) of nutrients present in each basin. This data appears in Tables 6 and 7. Although concentrations in the western basin consistently surpass those in the central basin, the actual quantities available in the central basin exceed those in the western basin due to the greater volume of water in the basin.

For the most part, all nutrients followed the seasonal pattern shown to be characteristic of Lake Erie in previous studies, that is, higher concentrations in spring and fall and lower concentrations in the summer. High nutrient values are measured in the spring due mostly to increased loading from runoff of melting snow and ice, and rainfall. In addition, nutrient levels increase as a result of resuspension of sediments due to high wind velocities. In late spring and early summer, when the winds subside, sediment particles resettle, removing much of the available nutrients to the bottom. As loading diminishes, algal demand consumes a large percentage of the dissolved nutrients, further reducing concentrations. Once stratification is established, a thermal barrier inhibits mixing of epilimnion and hypolimnion waters, resulting in a decrease in epilimnion values while hypolimnion values increase. In the fall, when surface temperatures are low enough to cause turnover, nutrient-rich bottom waters are mixed throughout the water column and surface concentrations again rise.

If anoxia has been particularly extensive, nutrient levels could rise even higher than spring runoff values.

The western basin showed a different nutrient distribution than normal in 1981. Due to the shallowness of the basin, it is especially susceptible to even slight increases in loading and changes in the weather. In June of 1981, the Maumee River drainage basin, which has a major influence on western basin water quality, experienced a record rainfall of more than eight inches (NOAA 1981). Nitrate plus nitrite and silica concentrations were most notably affected by the increased runoff caused by the extensive flooding. Phosphorus concentrations also rose. Nutrient concentrations rapidly returned to "normal" levels, except for silica. Since diatoms, which are the major consumers of silica, are not dominant in the summer, the extreme amount of silica deposited by the June flood had no major sink and remained abnormally high through the rest of the year. Ammonia values in November (cruise 8), as seen in Figure 9), indicated a large increase, however, this reflects concentrations of over 1000 ug/l measured at the mouth of the Maumee River averaged with the western basin stations which averaged only about 25 ug/l. The difference in cruise 8 means with (160.4 ug/l) and without (25.9 ug/l) station 202 at the mouth of the Maumee River is 84 percent. The apparent increase in ammonia for the entire basin seen in Figure 9 is not valid.

PARTICULATES

Chlorophyll, Solids, Particulate Organic Carbon and Turbidity

Corrected chlorophyll a concentrations during the 1981 field season decreased from a spring pulse, reaching a minimum in early June, and then increased to a maximum in the late summer or early fall (Figures 18 and 19), which is about the time of turnover. These general trends occurred in each basin of the lake, although the central basin concentrations were lower than the western basin. Surface values generally showed greater fluctuation than the bottom values but the seasonal patterns were similar.

Total suspended solids (TSS), residual suspended solids (RSS), and volatile suspended solids (VSS) concentrations in the western basin were much higher than those in the central basin. The shallowness of the western basin explains for the most part the higher concentration of solids. The graphs of the western basin seasonal concentrations for TSS and RSS are mirror images (Figure 20 and 21) with a slight difference in concentration. The same holds true for the relationship in the central basin (Figures 22 and 23). Residual solids were about 75 to 85 percent of the total suspended solids (TSS) in the western basin and represented 45 to 55 percent of the TSS in the central basin. Although the western basin VSS concentrations were double those of the central basin (Figures 24 and 25), the percentage of VSS in the western basin ranged from 15 to 25 percent while the central basin was nearly triple that (45-55 percent) (Figures 26 and 27). The bottom values were slightly higher than the surface values for all three forms of solids, but followed the same pattern as the surface values.

Turbidity cruise means in Lake Erie were highly correlated with total suspended solids cruise means for the 1981 field season in both the western and central basins (Figures 28 and 29) (r = .95 western basin, r = .98 central basin). The western basin concentrations are approximately eight times higher than the central basin. As with solids, the turbidity surface values were usually slightly lower than bottom waters for both basins.

Particulate Organic Carbon (POC) is another parameter that has similar characteristics to TSS, RSS, VSS, turbidity and corrected chlorophyll a. POC concentrations were higher in the western basin than in the central basin (Figures 30 and 31), and correlated well with corrected chlorophyll a (r = .95 western basin, r = .76 central basin) and VSS (r = .83 western basin, r = .86 central basin). Corrected chlorophyll a and VSS also correlated well in the central basin surface waters (r = .91), showing a three-way relationship between corrected chlorophyll a, VSS and POC.

To demonstrate the relationship between the particulate parameters, surface data has been graphed seasonally for a station from the mid-lake portion of the central basin (no. 37). TSS, turbidity and the reciprocal of the secchi depth showed exceptional similarity in behavior (Figure 32).

The relationship between POC and VSS (Figure 33) is also similar throughout the season. Uncorrected chlorophyll a data which was thought to be more closely correlated with the organic parameters of VSS and POC did not display the same behavior. Corrected chlorophyll a, which represents only the actively photosynthesizing algae was much more in harmony with the fluctuations in concentrations of POC and VSS. The one anamoly in the similar behavior of these three parameters occurred during the December cruise when both chlorophyll a corrected and uncorrected, were observed to increase compared to the prior cruise while POC and VSS decreased. During all the other cruises, there was a positive correlation between the three parameters.

The isopleths for corrected chlorophyll a (Figure 34) show the highest concentrations in the southwestern end of the western basin and the lowest concentrations in the northeastern portion of the central basin. The distributional patterns for chlorophyll a for the spring and summer months were very similar to those of total phosphorus with the maximum concentrations along the Michigan and Ohio shores of the western basin and the United States shore of the central basin.

Future measurement of these "particulate" parameters (corrected chlorophyll a, VSS, turbidity and POC) may lead to formulation for prediction of concentrations of all these parameters by using only one measurement.

Secchi

Since the invention of the Secchi disk in 1865, it has been used as an oceanographic and limnological tool to estimate water clarity. Although the determination of secchi depth is a simple measurement, there are many sources of variability, for example, the patchiness of particulates and plankton in the water, the whiteness of the disc, the altitude of the sun, the reflection from the water surface, the height of the waves and the height of the observer above the water. However, compared to other parameters, secchi probably provides the longest continuously recorded data base with the fewest methodology changes and problems. For this reason, and for its usefulness in determining water clarity/quality, secchi depth data has been selected as a trophic status indicator (Gregor and Rast 1979; Dobson 1976).

As in past studies, individual station secchi values were area-weighted utilizing the grid pattern established for the 1973-1975 Lake Erie study (Zapotosky 1980). Theoretically, each of the 50 grids represents a homogeneous water quality area. The basin area weighted cruise mean has been calculated for only the three intensive stratified cruises because these were the only times when every grid was sampled. For a listing of the stations and their respective grid numbers, see Table 3. Data for area weighted secchi depth are presented for 1973-1981 (Table 14). As expected, the water clarity in the western basin is less than that for the central basin, with the yearly mean secchi depth only 20 percent of that for the central basin.

It is not possible to discuss the seasonality of secchi depth data based on only three data points for 1981. Graphs of area weighted cruise means from 1978 to 1981 have been plotted to verify the seasonal cycle (Figures 35 and 36). The western basin data is much more variable within one month over the four years than is the central basin data. The range of western basin values throughout the year (0.6-3.0 m) is lower than for the central basin (1.25-7.02 m). The data for 1981 appears to indicate lower water quality in general throughout the summer period when compared to 1978-1980. This may be the result of the Maumee River flooding that was discussed in the nutrient section. The central basin cycle is more easily discerned, the lowest secchi depths are found in the spring; the highest secchi depths occur in July and early August (6-7 m) which then decrease until after turnover. Secchi depths increased again after turnover in October and November to the level of those found in May and June.

Using the simplistic trophic classification system established by Dobson et al., 1974 for yearly mean secchi data, the western basin would be classified as eutrophic (0-3 m) and the central basin as mesotrophic (3-6 m).

Available and Nonavailable Particulate Phosphorus

The availability of phosphorus has been a widely researched and debated topic for some time. Since the Water Quality Agreement between Canada and the United States, along with their efforts to limit wastewater effluents of phosphorus to 1 mg/l along with the inception of phosphrus detergent bans in the early 1970's, the focus of Great Lakes researchers has switched from the total quantity of phosphorus entering the Great Lakes to the quality (or availability) of phosphorus entering the Great Lakes. Historically, phosphorus loading to Lake Erie has been based on total phosphorus input, but not all of this phosphorus is available for biological growth. There exists a need to better quantify the biological availability of total phosphorus within the lake itself for more accurate phosphorus loading values.

The objective of the study undertaken in 1981 was to determine the availability of particulate phosphorus within the water column of Lake Erie by a chemical fractionation procedure. This procedure has been used by other investigators to determine the biological availability of particulate phosphorus in tributaries around the Lake Erie drainage basin and in lake bottom sediments.

Once a particulate sample has been collected the phosphorus is separated into five basic fractions:

Non-apatite inorganic

1. Reactive Sodium Hydroxide Extractable Phosphorus.
   This phosphorus is mostly absorbed on inorganic material and is considered available for biological growth.

2. Citrate-Dithionite-Bicarbonate (CDB) Extractable Phosphorus.
   This phosphorus is chemically bound or sorbed on inorganic material and becomes available only under reducing conditions.

Organic

3. Nonreactive Sodium Hydroxide Extractable Phosphorus.
   Ths fraction is mostly organically bound phosphorus and its availability is variable.

4. Residual Phosphorus.
   This fraction comprises any phosphorus that is highly refractory organic or strongly bound with inorganic material and is not available for biological growth.

Apatite

5. Acid Extractable Phosphorus.
   This fraction is more commonly called apatite and is not available for biological growth. This phosphorus is basically in the form of complexes with calcium.

In summary, there are three types of particulate phosphorus: non-apatite inorganic, organic, and apatite phosphorus. Non-apatite inorganic phosphorus (NAIP) is considered to be an addition of Reactive Sodium Hydroxide Extractable Phosphorus and the CDB Extractable Phosphorus. Organic phosphorus is considered to be the sum of Nonreactive Extractable Phosphorus and the Residual Phosphorus fraction.

Table 13 shows the comparison of percentages of the three phosphorus types from 1981 data to that of area tributaries (DePinto 1981 and Logan 1979) and lake sediments (Williams 1976). NAIP is a high percentage of the total particulate phosphorus in the tributaries and bottom sediments studies (approx. 45%). This can be explained by the greater amount of clays and silts (inorganic material) in these areas. Only 22 percent and 27 percent NAIP was found in the water columns samples of the central and western basins respectively. The settling of sediments out of the water column can explain this lower percentage.

The apatite fraction of the lake bottom sediments contributed over 30 percent to the particulate phosphorus content (Williams 1976). This is attributed to the high inorganic content of insoluble material on the bottom. The percent of apatite P in tributaries samples is relatively low (7-10%). A majority of the particulate phosphorus in these tributaries is from agricultural runoff and point source input which is usually not in the apatite form. The open lake shows an intermediate percentage (17%) between the tributaries and bottom sediments. A combination of low apatite percentages coming into the lake from tributaries (7-10%) and resuspension of high apatite sediments (35-38) from the lake bottom can explain these percentages. Note the nearly double percentage of apatite phosphorus in the western basin (23%) to that of the central basin (11%). With the western basin being generally less than one-half as deep as the central basin, significantly more resuspension will occur, thus giving a higher percentage of apatite phosphorus.

The organic phosphorus fraction of the tributaries and bottom sediments show basically the same percentages (approximately 25%). This is low in comparison to the 45 percent and 63 percent of the water columns of the western and central basins respectively. The open lake (water column) portion is considerably higher in plankton concentrations compared to the tributaries due to slower flows, and lower turbidities and thus result in a much higher percentage of organic particulate phosphorus. Note the higher organic percentage in the central basin. There will be less resuspension of inorganic material in the central basin and this gives the increase in organic particulate phosphorus, percentage-wise.

Since this is the first year that available particulate phosphorus data on the open lake has been collected, no trends or direct comparisons can be made, but with continuous yearly research, total phosphorus loading values can be corrected by knowing the amount of nonavailable phosphorus within the water column.

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TABLE 1

DATES FOR 1981 WESTERN BASIN TRANSECTS

Cruise No.	Calendar Date	Julian Date
1	March 26	085
2	May 5	125
3	May 15	135
4	June 3	154
5	June 12	163
6	June 24	175
7	July 12	193
8*	July 21	202
9	August 12	224
10	September 11	254
11	September 23	266
12	September 29	272
13	October 23	296
14	October 31	304
15	November 14	318
16	December 5	340

*partial

TABLE 2

DATES FOR 1981 LAKE ERIE MAIN LAKE WATER QUALITY CRUISE

Cruise No.	Calendar Date	Julian Date	Julian Mid Point
1	March 24 - March 29	083-087	085
2	May 2 - May 6	122-126	124
3	June 2 - June 7	153-158	155
4	June 24 - July 3	175-184	179
5	September 1 - September 11	244-254	249
6	September 12 - September 24	255-267	261
7	October 23 - October 30	296-303	299
8	November 12 - November 19	316-323	319
9*	December 3 - December 6	337-340	338

*Only western basin and Sandusky sub basin

TABLE 3 GEOGRAPHIC COORDINATES OF 1981 LAKE ERIE WATER QUALITY MONITORING STATIONS

Station Number	Latitude (N)	Longitude (W)	Water Depth (m)	Basin	Water Quality Grid No.
024	42°05'54"	80°29'00"	19.5	C	19
025	42°14'54"	80°33'36"	21.5	C	20
026	42°24'00"	80°38'12"	19.8	C	20
027	42°32'54"	80°45'30"	16.0	C	21
028	42°35'30"	81°01'00"	16.5	C	22
029	42°36'18"	80°17'54"	12.3	C	22
030	42°25'48"	80°12'18"	20.5	C	23
031	42°15'12"	81°06'24"	21.3	C	24
032	42°04'54"	81°00'42"	21.5	C	25
033	41°55'54"	80°55'00"	17.7	C	26
035	41°45'48"	81°23'00"	12.6	C	27
036	41°56'06"	81°28'42"	22.9	C	28
037	42°06'36"	81°34'30"	23.9	C	29
038	42°16'54"	81°40'18"	21.6	C	30
039	42°21'30"	81°42'24"	18.7	C	31
040	42°11'30"	81°55'18"	16.8	C	32
041	42°08'06"	82°08'24"	20.4	C	32
042	41°57'54"	80°02'30"	22.2	C	33
043	41°47'18"	81°56'42"	22.6	C	34
044	41°31'48"	81°42'30"	12.3	C	36
045	41°36'24"	81°53'48"	17.5	C	35
046	41°40'54"	82°05'12"	19.5	C	37
047	41°50'18"	82°12'48"	18.9	C	38
048	42°02'48"	82°21'54"	17.0	C	39
050	41°48'48"	82°30'06"	11.0	C	40
051	41°38'30"	82°24'12"	13.5	C	41
053	41°25'12"	82°30'12"	10.8	C	42

(continued)

TABLE 3 (continued)

Station Number	Latitude (N)	Longitude (W)	Water Depth (m)	Basin	Water Quality Grid No.
054	41°34'00"	82°38'06"	11.9	C	43
055	41°44'18"	82°44'18"	10.3	W	44
057	41°49'54"	83°01'06"	9.9	W	48
059	41°43'36"	83°09'00"	8.2	W	47
061	41°56'48"	83°02'42"	8.8	W	61
073	41°58'40"	81°45'25"	24.9	C	34
075	41°54'00"	83°18'00"	6.1	W	49
076 (321)	41°36'30"	83°04'00"	4.0	W	46
082	41°34'30"	82°10'00"	15.2	C	41
084	41°46'00"	83°20'00"	9.7	W	49
202	41°41'48"	83°28'00"	9.6	W	N
321	41°36'30"	83°04'00"	4.2	W	46
322	41°38'36"	83°01'30"	6.3	W	46
323	41°40'54"	82°59'00"	9.4	W	46
324	41°43'06"	82°56'30"	9.8	W	46
325	41°45'18"	82°54'00"	10.0	W	46
326	41°47'36"	82°51'30"	10.6	W	46
327	41°49'54"	82°49'06"	10.6	W	45
328	41°52'12"	82°46'36"	11.4	W	45
329	41°54'30"	82°44'12"	11.5	W	45
330	41°56'48"	82°41'42"	11.2	W	45
331	41°59'00"	82°39'12"	10.8	W	45
332	42°01'18"	82°36'48"	7.6	W	45
401	42°03'00"	83°08'30"	10.4	W	N

TABLE 4

WATER QUALITY PARAMETERS FOR MAIN

LAKE ERIE MONITORING PROGRAM 1981

PARAMETER	STORET CODE	CENTRAL BASIN (DO)	CENTRAL BASIN	WESTERN BASIN	WESTERN BASIN (TRANSECT)
1. Temperature	00010	X(P)	X(P)	X(P)	X(P)
2. Dissolved Oxygen	00300	X	X	X	X
3. pH	00400	X	X	X	X
4. Conductivity	00094	X	X	X	X
5. Transparency	00078	X	X	X	X
6. Alkalinity	00410	X			X*A
7. Total Phosphorus	00665	X	X	X	X
8. Sol. React. Phosphorus	00671	X	X	X	X
9. Total Filtered Phosphorus	00666	X	X	X	X
10. Particulate Phosphorus		037M-S+B	037M-S+B		323+328 M-S
11. Non-Apatite Phosphorus		037M-S+B	037M-S+B		323+328 M-S
12. Nitrate + Nitrite	00630	X	X	X	X
13. Ammonia	00610	X	X	X	X
14. Sol. React. Silica	00955	X	X	X	X
15. Suspended Solids	70318	X	X	X	X
16. Volatile Solids	70322	X	X	X	X
17. POC	80102	Sp_1 S+B	Sp_1 S+B	R S+B	X* A-S
18. PON		Sp_1 S+B	Sp_1 S+B		X* A-S
19. Chl. a - corrected	32211	X	X	X	X
20. Phytoplankton/Zooplankton		Sp_2 S+B	Sp_2 S+B		X* A-S
21. Turbidity	00076	X	X	X	X
22. Meteorology		X	X	X	X
23. Chloride					X

P - Profile measurements

M - Monthly

S - Surface

B - Bottom

* - 6 of 12 Stations

A - Alternate Cruises

R - River stations 202 + 401

X - all stations - all depths

Sp_1 - 051, 042, 037, 031, 026

Sp_2 - 044 + Sp_1

TABLE 5 ANALYTICAL METHODS SUMMARY FOR 1981 LAKE ERIE WATER QUALITY DETERMINATIONS

Parameter	Storet Number	Unit	Method or Procedure	Accuracy (±) or Detection Limit
Temperature	00010	°C	InterOcean *in situ* probe, profile	± 0.05
Dissolved Oxygen	00300	mg/l	Azide modified winkler	± 0.1
Phosphorus, Total	00665	ug/l	Technicon AAII stannous chloride	0.5
Total Filtered	00666	ug/l	Technicon AAII stannous chloride	0.5
Soluble Reactive	00671	ug/l	Technicon AAII stannous chloride	0.5
Particulate	N.A.	ug/l	Technicon AAII stannous chloride	0.5
Nitrate plus Nitrite	00630	ug/l	Technicon AAII cadmium reduction	5
Ammonia	00610	ug/l	Technicon AAII phenate method	1
Dissolved Reactive Silica	00955	ug/l	Technicon AAII molybdosilicate-ascorbic-oxalic acid	30
Chloride	00940	mg/l	Technicon AAII ferricyanide	0.2
Solids, Total Suspended (residue, filterable)	00530	mgl/	Glass filter pads, drying and ignition	0.2
Solids, Volatile (residue, filter, volatile)	00520	mgl/	Glass filter pads, drying and ignition	0.2

(continued)

TABLE 5 (continued)

Parameter	Storet Number	Unit	Method or Procedure	Accuracy (±) or Detection Limit
Turbidity	00076	NTU	Hach nephelometer	0.1
Transparency	00078	meters	Secchi disk	0.1
Chlorophyll _a_, Corrected	32211	ug/l	Spectrophotometric, acetone extraction	0.3
Particulate Organic Carbon	N.A.	ug/l	Glass Fiber filter pads, combusted by Perkin Elmer Elemental Analyzer	15.4
Conductance, Specific at 25°C	00095	umhos/cm	InterOcean _in situ_ probe	± 2
pH	00400	units	InterOcean _in situ_ probe	± 0.02
Alkalinity	00410	mg/l as $CaCO_3$	pH end point titration	0.5

TABLE 6

LAKE ERIE WESTERN BASIN WATER QUALITY SUMMARY - 1981

Date	Cruise No.	Stratification	Limnion	Volume km^3	Total Phosphorus		Soluble Reactive Phosphorus		Corrected Chlorophyll a	
					Metric Tons	Conc. µg/l	Metric Tons	Conc. µg/l	Metric Tons	Conc. µg/l
3/24-3/29	1	unstratified	total	24.2	679.3	28.07	ND	ND	258.2	10.67
5/2 -5/6	2	unstratified	total	24.8	848.5	34.20	171.1	6.90	204.4	8.24
6/2 -6/7	3	unstratified	total	25.1	605.5	24.1	76.1	3.03	162.7	6.48
6/24-7/3	4	unstratified	total	24.9	971.6	38.98	272.7	10.95	155.4	6.24
9/1 -9/11	5	unstratified	total	24.8	1371.4	55.28	224.2	9.04	323.4	13.04
9/12-9/24	6	unstratified	total	24.8	1050.5	42.34	244.0	9.84	200.6	8.09
10/24-10/31	7	unstratified	total	24.8	1021.5	41.18	159.7	6.44	198.9	8.02
11/12-11/19	8	unstratified	total	24.5	707.3	28.87	115.9	4.73	225.4	9.20
12/3 -12/6	9	unstratified	total	24.2	904.6	37.38	197.2	8.15	107.9	4.46

TABLE 6

LAKE ERIE WESTERN BASIN WATER QUALITY SUMMARY - 1981
(continued)

Date	Cruise No.	Stratification	Limnion	Volume km^3	Nitrate + Nitrite Metric Tons	Nitrate + Nitrite Conc. µg/l	Ammonia Metric Tons	Ammonia Conc. µg/l	Silica Metric Tons	Silica Conc. µg/l
3/24-3/29	1	unstratified	total	24.2	18,464.6	763	1945.7	80.4	26,087.6	1078
5/2 -5/6	2	unstratified	total	24.8	23,808.0	960	550.6	22.2	14,334.4	578
6/2 -6/7	3	unstratified	total	25.1	28,847.8	1149	638.6	25.4	9,141.2	364
6/24-7/3	4	unstratified	total	24.9	28,137.0	1130	699.7	28.1	32,469.6	1304
9/1 -9/11	5	unstratified	total	24.8	11,680.8	471	545.6	22.0	33,281.6	1342
9/12-9/24	6	unstratified	total	24.8	10,664.0	430	1195.4	48.2	37,720.8	1521
10/24-10/31	7	unstratified	total	24.8	11,904.0	480	1197.8	48.3	29,512.0	1190
11/12-11/19	8	unstratified	total	24.5	16,978.5	693	3929.8	160.4	32,340.0	1320
12/3 -12/6	9	unstratified	total	24.2	15,197.6	628	1280.2	52.9	36,396.8	1504

TABLE 7

LAKE ERIE CENTRAL BASIN WATER QUALITY SUMMARY - 1981

Date	Cruise No.	Stratification	Limnion	Volume km^3	Total Phosphorus Metric Tons	Total Phosphorus Conc. µg/l	Soluble Reactive Phosphorus Metric Tons	Soluble Reactive Phosphorus Conc. µg/l	Corrected Chlorophyll a Metric Tons	Corrected Chlorophyll a Conc. µg/l
3/24-3/29	1	unstratified	total	310.4	6062.1	19.53	658.1	2.12	1719.6	5.54
5/2 -5/6	2	unstratified	total	313.7	5663.6	18.05	514.5	1.64	1800.6	5.74
6/2 -6/7	3	stratified	epi	177.1	2169.6	12.25	518.9	2.93	308.2	1.74
			meso	27.1	422.8	15.63	69.9	2.58	64.0	2.36
			hypo	111.2	1884.7	16.95	349.2	3.14	300.2	2.70
			total	315.4	4477.1	14.19	938.0	2.97	672.4	2.13
6/24-7/3	4	stratified	epi	207.8	2421.2	11.65	307.5	1.48	544.4	2.62
			meso	36.0	542.0	15.07	66.2	1.84	129.6	3.60
			hypo	71.5	1261.6	17.63	146.6	2.05	318.2	4.45
			total	316.3	4224.8	13.40	520.3	1.65	992.2	3.15
9/1 -9/11	5	stratified	epi	243.7	3915.6	16.06	370.4	1.52	1162.5	4.77
			meso	21.5	3219.2	14.96	82.4	3.83	63.4	2.95
			hypo	48.4	1029.0	21.25	284.6	5.88	101.6	2.10
			total	313.6	8163.8	26.03	737.4	2.35	1327.5	4.23
9/12-9/24	6	stratified	epi	286.0	4906.7	17.16	363.2	1.27	1819.0	6.36
			meso	10.1	170.7	16.89	20.9	2.07	30.7	3.04
			hypo	17.6	306.8	17.46	49.1	2.79	43.1	2.45
			total	313.7	5384.2	17.16	433.2	1.38	1892.8	6.03
10/24-10/31	7	unstratified	total	313.7	7580.7	24.16	1794.4	5.72	1618.7	5.16
11/12-11/19	8	unstratified	total	312.1	6800.2	21.79	1108.0	3.55	1638.5	5.25
12/3 -12/6	9	unstratified	total	310.4	5245.8	16.90	537.0	1.73	2213.2	7.13

TABLE 7

LAKE ERIE CENTRAL BASIN WATER QUALITY SUMMARY - 1981
(continued)

Date	Cruise No.	Stratification	Limnion	Volume km^3	Nitrate + Nitrite Metric Tons	Nitrate + Nitrite Conc. mg/l	Ammonia Metric Tons	Ammonia Conc. mg/l	Silica Metric Tons	Silica Conc. mg/l
3/24- 3/29	1	unstratified	total	310.4	114,537.6	369	1831.4	5.9	64,252.8	207
5/2 - 5/6	2	unstratified	total	313.7	95,364.8	304	3388.0	10.8	12,861.7	41
6/2 - 6/7	3	stratified	epi	177.1	38,076.5	215	3028.4	17.1	18,064.2	102
			meso	27.1	4,769.6	176	485.1	17.9	4,986.4	184
			hypo	111.2	16,124.0	145	2902.3	26.1	31,024.8	279
			total	315.4	58,970.1	187	6415.8	20.3	54,075.4	171
6/24- 7/3	4	stratified	epi	207.8	49,872.0	240	1184.5	5.7	50,703.2	244
			meso	36.0	8,244.0	229	669.6	18.6	13,068.0	363
			hypo	71.5	14,514,5	203	2166.5	30.3	34,892.0	488
			total	315.3	72,630.5	230	4020.6	12.8	98,663.2	313
9/1 - 9/11	5	stratified	epi	243.7	37,042.4	152	4679.0	19.2	88,219.4	362
			meso	21.5	3,569.0	166	842.8	39.2	21,650.5	1007
			hypo	48.4	8,518.4	176	2845.9	58.8	83,732.0	1730
			total	313.6	49,129.8	157	8367.7	26.7	193,601.9	617
9/12- 9/24	6	stratified	epi	286.0	40,898.0	143	2087.8	7.3	138,996.0	486
			meso	10.1	1,353.4	134	259.6	25.7	9,837.4	974
			hypo	17.6	2,657.2	152	688.2	39.1	25,854.4	1469
			total	313.7	44,926.6	143	3035.6	9.7	174,687.8	557
10/24-10/31	7	unstratified	total	313.7	64,308.5	205	2258.6	7.2	109,481.3	349
11/12-11/19	8	unstratified	total	312.1	56,178.0	180	3495.5	11.2	54,929.6	176
12/3 -12/6	9	unstratified	total	310.4	62,700.8	202	1552.0	5.0	47,180.8	152

TABLE 8

LAKE ERIE WATER QUALITY MEASUREMENTS 1981
WESTERN BASIN CRUISE MEANS CONCENTRATIONS

Cruise No.	Date	Statistics	Temp. (^oC)	DO (mg/l)	DO (%)	Corrected Conduct. (umhos/cm)	pH
1 epi	3/24-3/29	mean	2.77	13.45	104.2	255	7.93
		st. err.	0.15	0.09	0.9	15	6.97
		median	2.50	13.30	102.9	236	7.86
		n	40	40	40	40	40
2 epi	5/2-5/6	mean	11.93	10.76	97.8	267	8.34
		st. err.	0.21	0.14	1.2	12	7.05
		median	11.6	10.9	98.3	241	8.34
		n	40	40	40	40	40
3 epi	6/2-6/7	mean	16.73	9.07	90.9	295	8.37
		st. err.	0.23	0.08	0.8	16	7.13
		median	16.70	9.20	91.4	264	8.34
		n	35	35	35	35	35
4 epi	6/24-7/3	mean	20.68	8.11	88.6	261	8.22
		st. err.	0.16	0.12	1.4	6	7.08
		median	20.6	8.1	87.9	249	8.14
		n	40	40	40	40	40
5 epi	9/1-9/11	mean	20.88	8.90	97.7	249	8.37
		st. err.	0.09	0.15	1.7	8	7.28
		median	21.00	8.75	95.1	229	8.29
		n	40	40	40	40	40
6 epi	9/12-9/24	mean	16.84	8.70	87.4	253	8.04
		st. err.	0.11	0.13	1.3	9	6.52
		median	17.2	8.8	89.0	236	8.04
		n	40	40	40	40	40
7 epi	10/24-10/31	mean	10.09	10.46	91.9	267	7.97
		st. err.	0.12	0.17	1.6	15	6.56
		median	10.45	10.3	90.2	239	7.94
		n	40	39	39	40	40
8 epi	11/12-11/19	mean	9.04	11.27	97.1	268	8.13
		st. err.	0.09	0.17	1.4	14	6.99
		median	9.1	11.3	97.0	237	8.11
		n	40	40	40	40	40
9 epi	12/3-12/6	mean	4.92	11.94	95.8	273	8.04
		st. err.	0.06	0.06	0.5	17	6.42
		median	4.90	12.00	96.3	245	8.03
		n	40	40	40	40	40

TABLE 8 (continued)

Cruise No.	Date	Statistics	Total Phos. (ug/l)	Soluble Reactive Phos. (ug/l)	Nitrate Nitrite (ug/l)	Ammonia (ug/l)	Dissolved Reactive Silica (ug/l)
1 epi	3/24-3/29	mean	28.1	ND	763	80.4	1078
		st. err.	4.4	ND	140	31.8	148
		median	19.7	ND	508	9.6	1065
		n	40	ND	40	40	40
2 epi	5/2-5/6	mean	37.6	6.9	960	22.2	578
		st. err.	8.4	3.3	240	7.8	222
		median	17.9	2.1	400	2.7	50
		n	40	40	40	40	40
3 epi	6/2-6/7	mean	29.0	3.0	1168	25.8	372
		st. err.	5.6	1.1	221	12.3	166
		median	18.0	1.7	531	6.7	125
		n	35	35	35	18	35
4 epi	6/24-7/3	mean	46.4	11.0	1130	28.1	1304
		st. err.	10.7	3.5	212	5.7	245
		median	22.7	2.7	433	21.1	775
		n	40	40	40	40	40
5 epi	9/1-9/11	mean	65.4	9.0	471	22.0	1342
		st. err.	12.8	3.3	103	13.7	294
		median	35.8	2.6	248	3.2	940
		n	40	40	40	34	40
6 epi	9/12-9/24	mean	48.4	9.8	430	48.2	1521
		st. err.	8.3	3.0	92	20.0	282
		median	23.8	5.3	580	18.0	1110
		n	40	40	40	40	40
7 epi	10/24-10/31	mean	46.2	6.4	480	48.3	1190
		st. err.	6.4	2.2	75	23.2	214
		median	34.1	3.4	379	10.3	915
		n	40	40	40	40	40
8 epi	11/12-11/19	mean	37.7	4.7	693	160.4	1320
		st. err.	9.9	2.3	164	94.4	302
		median	21.1	1.2	380	16.7	1065
		n	40	40	40	16	40
9 epi	12/3-12/6	mean	37.4	8.2	628	52.9	1504
		st. err.	6.5	3.7	102	21.0	189
		median	23.7	1.8	457	4.1	1250
		n	40	40	40	40	40

TABLE 8 (continued)

Cruise No.	Date	Statistics	Secchi (m)	Turbidity (ntu)	Susp. Solids (mg/l)	Corr. Chlor. (ug/l)	SCOR Chlor. (ug/l)
1 epi	3/24-3/29	mean	1.4	7.0	5.17	10.67	11.39
		st. err.	0.1	0.8	0.38	3.02	3.14
		median	1.5	5.5	4.59	6.47	7.06
		n	36	40	29	40	40
2 epi	5/2-5/6	mean	1.7	14.8	16.61	8.24	9.95
		st. err.	0.2	4.6	5.02	1.23	1.36
		median	1.7	3.8	5.20	5.65	8.07
		n	16	40	40	40	40
3 epi	6/2-6/7	mean	1.9	6.1	6.62	6.61	7.74
		st. err.	0.2	1.2	1.31	1.37	1.76
		median	1.7	3.6	3.48	3.08	3.23
		n	16	35	35	35	35
4 epi	6/24-7/3	mean	1.2	34.9	29.33	6.24	6.66
		st. err.	0.1	14.6	11.65	0.87	0.70
		median	1.2	6.5	7.46	4.11	4.88
		n	20	40	40	40	40
5 epi	9/1-9/11	mean	0.6	26.2	29.35	13.04	17.99
		st. err.	0.1	6.7	8.18	1.55	1.69
		median	0.8	10.4	12.17	12.39	15.55
		n	20	40	40	40	40
6 epi	9/12-9/24	mean	0.8	19.1	19.57	8.09	11.67
		st. err.	0.1	3.5	3.13	0.80	0.86
		median	0.9	10.3	11.87	7.43	10.5
		n	13	40	40	40	40
7 epi	10/24-10/31	mean	0.6	20.9	21.87	8.02	11.64
		st. err.	0.1	2.1	2.37	0.69	0.93
		median	0.6	16.5	16.76	7.71	9.92
		n	17	40	39	40	40
8 epi	11/12-11/19	mean	1.2	11.5	16.53	9.20	11.41
		st. err.	0.1	2.1	5.09	0.93	1.03
		median	1.1	7.9	8.11	8.61	10.57
		n	40	40	38	40	40
9 epi	12/3-12/6	mean	0.9	17.7	18.00	4.46	7.27
		st. err.	0.1	2.2	2.19	0.41	0.61
		median	0.9	11.4	11.85	4.23	6.43
		n	14	40	40	40	40

TABLE 9

LAKE ERIE WATER QUALITY MEASUREMENTS 1981
CENTRAL BASIN CRUISE MEAN CONCENTRATIONS

Cruise No.	Date	Statistics	Temp. (^oC)	DO (mg/l)	DO (%)	Corrected Conduct. (umhos/cm)	pH
1 epi	3/24-3/29	mean	2.54	13.24	102.1	260	7.91
		st. err.	0.17	0.06	0.3	3	6.27
		median	2.80	13.30	102.2	263	7.90
		n	15	15	15	15	15
2 epi	5/2-5/6	mean	8.85	11.63	99.9	272	8.07
		st. err.	0.42	0.11	0.6	3	6.79
		median	8.30	11.20	99.8	274	8.03
		n	33	33	33	33	33
3 epi	6/2-6/7	mean	15.59	9.93	97.1	270	8.33
		st. err.	0.37	0.13	1.1	1	6.80
		median	15.5	10.0	99.1	272	8.34
		n	28	28	28	28	28
hypo	6/2-6/7	mean	9.17	9.42	81.3	276	7.94
		st. err.	0.18	0.21	1.7	1	6.67
		median	9.00	9.60	82.8	277	7.94
		n	22	22	22	22	22
4 epi	6/24-7/3	mean	19.59	9.10	97.1	265	8.41
		st. err.	0.17	0.05	0.5	1	6.89
		median	19.70	9.20	97.8	265	8.40
		n	60	61	60	61	61
hypo	6/24-7/3	mean	10.46	7.59	67.1	275	7.74
		st. err.	0.37	0.24	2.1	2	6.61
		median	10.1	8.00	70.5	274	7.70
		n	41	41	41	41	41
5 epi	9/1-9/11	mean	22.14	8.29	93.7	264	8.31
		st. err.	0.04	0.07	0.8	2	6.83
		median	22.2	8.40	94.8	261	8.33
		n	74	74	74	71	71
hypo	9/1-9/11	mean	12.95	1.54	14.5	276	7.26
		st. err.	0.48	0.26	2.5	1	6.15
		median	11.70	1.00	9.2	276	7.22
		n	31	31	31	31	31
6 epi	9/12-9/24	mean	19.79	8.59	92.2	271	8.16
		st. err.	0.20	0.08	1.2	1	6.89
		median	20.4	8.50	92.4	272	8.14
		n	75	75	75	72	72

TABLE 9 CONT.

Cruise No.	Date	Statistics	Temp. (^{o}C)	DO (mg/l)	DO (%)	Corrected Conduct. (umhos/cm)	pH
hypo	9/12-9/24	mean	14.67	3.02	30.0	280	7.62
		st. err.	0.83	0.74	8.3	1	7.11
		median	13.4	1.7	12.4	281	7.21
		n	17	18	17	18	18
7 epi	10/24-10/31	mean	11.53	9.93	89.6	268	8.00
		st. err.	0.09	0.05	0.4	1	6.46
		median	11.55	9.9	88.8	272	7.99
		n	48	48	48	48	48
8 epi	11/12-11/19	mean	10.26	10.59	93.4	270	8.23
		st. err.	0.08	0.05	0.3	2	6.86
		median	10.50	10.50	92.3	273	8.21
		n	51	50	50	51	51
9 epi	12/3-12/6	mean	6.03	11.81	96.4	266	8.12
		st. err.	0.15	0.06	0.3	3	6.44
		median	5.75	11.90	96.6	263	8.14
		n	18	17	17	18	18

TABLE 9 CONT.

Cruise No.	Date	Statistics	Total Phos. (ug/l)	Soluble Reactive Phos. (ug/l)	Nitrate Nitrite (ug/l)	Ammonia (ug/l)	Dissolved Reactive Silica (ug/l)
1 epi	3/24-3/29	mean	19.5	2.1	369	5.9	207
		st. err.	2.8	0.2	81	1.0	74
		median	14.2	2.0	186	5.8	30
		n	15	15	15	15	15
2 epi	5/2-5/6	mean	17.7	1.6	304	10.8	41
		st. err.	1.6	0.1	36	3.9	3
		median	14.8	1.6	305	2.7	30
		n	33	33	33	32	33
3 epi	6/2-6/7	mean	11.3	2.9	215	17.1	102
		st. err.	1.0	0.6	32	6.1	15
		median	9.5	2.3	153	10.0	60
		n	28	22	28	9	28
hypo	6/2-6/7	mean	14.2	3.1	145	26.1	279
		st. err.	0.9	0.6	22	4.1	29
		median	12.9	3.0	115	23.3	263
		n	22	16	22	5	22
4 epi	6/24-7/3	mean	9.9	1.5	240	5.7	244
		st. err.	0.5	0.1	24	1.0	25
		median	8.9	1.4	150	4.0	150
		n	61	51	61	48	61
hypo	6/24-7/3	mean	16.0	2.1	203	30.3	488
		st. err.	0.7	0.2	15	5.8	52
		median	15.1	1.7	182	23.6	450
		n	41	33	41	32	41
5 epi	9/1-9/11	mean	15.5	1.5	152	19.2	362
		st. err.	1.3	0.2	9	5.3	34
		median	12.5	1.1	137	7.4	250
		n	74	74	74	74	74
hypo	9/1-9/11	mean	20.6	5.9	176	58.8	1730
		st. err.	3.5	1.8	12	10.5	124
		median	13.3	2.0	170	44.1	1720
		n	31	31	31	31	31
6 epi	9/12-9/24	mean	16.6	1.3	143	7.3	486
		st. err.	0.8	0.1	8	0.7	32
		median	15.1	1.2	119	5.4	440
		n	75	75	75	75	75

TABLE 9 CONT.

Cruise No.	Date	Statistics	Total Phos. (ug/l)	Soluble Reactive Phos. (ug/l)	Nitrate Nitrite (ug/l)	Ammonia (ug/l)	Dissolved Reactive Silica (ug/l)
hypo	9/12-9/24	mean	17.1	2.8	152	39.1	1469
		st. err.	3.0	0.8	15	13.4	179
		median	14.1	1.6	156	17.0	1750
		n	18	18	18	18	18
7 epi	10/24-10/31	mean	22.3	5.7	205	7.2	349
		st. err.	0.9	0.6	17	0.9	29
		median	21.5	3.9	153	5.5	400
		n	47	48	48	48	48
8 epi	11/12-11/19	mean	18.4	3.6	180	11.2	176
		st. err.	1.1	0.5	16	3.7	22
		median	15.8	1.7	135	4.4	120
		n	51	51	51	51	51
9 epi	12/3-12/6	mean	16.9	1.7	202	5.0	152
		st. err.	0.6	0.1	25	0.7	27
		median	16.5	1.55	188	4.5	115
		n	18	18	18	18	18

TABLE 9 CONT.

Cruise No.	Date	Statistics	Secchi (m)	Turbidity (ntu)	Susp. Solids (mg/l)	Corr. Chlor. (ug/l)	SCOR Chlor. (ug/l)
1 epi	3/24-3/29	mean	2.9	3.3	3.82	5.54	6.16
		st. err.	0.8	0.8	0.71	1.05	1.20
		median	3.3	1.6	2.29	2.72	2.89
		n	5	15	15	15	15
2 epi	5/2-5/6	mean	3.3	2.7	3.26	5.74	6.37
		st. err.	0.6	0.5	0.54	0.64	0.72
		median	3.1	1.5	1.92	4.74	5.60
		n	8	33	27	33	33
3 epi	6/2-6/7	mean	4.6	1.5	1.39	1.74	1.82
		st. err.	0.5	0.3	0.31	0.19	0.20
		median	4.5	0.9	0.82	1.47	1.60
		n	11	28	28	28	28
hypo	6/2-6/7	mean	ND	1.5	1.82	2.70	3.20
		st. err.	ND	0.3	0.24	0.37	0.23
		median	ND	1.1	1.60	3.10	3.35
		n	ND	22	21	22	22
4 epi	6/24-7/3	mean	5.8	1.1	1.22	2.62	2.50
		st. err.	0.3	0.2	0.23	0.49	0.32
		median	5.7	0.7	0.75	1.67	1.72
		n	28	61	61	61	61
hypo	6/24-7/3	mean	ND	3.2	3.42	4.45	4.71
		st. err.	ND	0.4	0.37	0.39	0.39
		median	ND	2.3	2.78	3.89	4.25
		n	ND	41	39	41	41
5 epi	9/1-9/11	mean	2.9	2.1	2.28	4.77	5.62
		st. err.	0.2	0.3	0.27	0.32	0.35
		median	2.8	1.1	1.21	4.04	4.79
		n	25	71	72	74	74
hypo	9/1-9/11	mean	ND	1.8	1.91	2.18	2.77
		st. err.	ND	0.1	0.17	0.22	0.24
		median	ND	1.7	1.54	2.01	2.51
		n	ND	31	31	31	31
6 epi	9/12-9/24	mean	2.6	2.5	3.24	6.36	8.13
		st. err.	0.2	0.2	0.29	0.50	0.57
		median	2.8	1.9	5.12	4.86	6.53
		n	28	72	75	75	75

TABLE 9 CONT.

Cruise No.	Date	Statistics	Secchi (m)	Turbidity (ntu)	Susp. Solids (mg/l)	Corr. Chlor. (ug/l)	SCOR Chlor. (ug/l)
hypo	9/12-9/24	mean	ND	1.8	1.95	2.45	3.58
		st. err.	ND	0.2	0.30	0.26	0.33
		median	ND	1.3	1.48	2.33	3.30
		n	ND	18	18	18	18
7 epi	10/24-10/31	mean	2.1	4.3	4.74	5.16	6.72
		st. err.	0.2	0.3	0.33	0.32	0.34
		median	2.2	3.7	4.02	5.35	6.80
		n	11	48	46	48	46
8 epi	11/12-11/19	mean	3.3	2.7	3.42	5.25	6.44
		st. err.	0.3	0.2	0.38	0.31	0.35
		median	3.8	2.0	2.66	4.65	5.85
		n	9	51	50	51	51
9 epi	12/3-12/6	mean	2.1	4.1	5.23	7.13	8.46
		st. err.	0.4	0.4	0.36	0.25	0.25
		median	2.1	4.0	5.16	7.25	8.43
		n	4	18	18	18	18

TABLE 10

SUMMARY OF 1981 CENTRAL BASIN HYPOLIMNETIC SURVEYS OF LAKE ERIE

Date	Cruise No.	Area km^2	Volume km^3	Average Thickness (m)	Total Heat (Kcal x 10^{12})	Average Temp. (C°)	Total O_2 (KgO_2 x 10^6)	Mean O_2 mg/l	Avg. T-Grad (°C m-1)	Avg. O_2 Grad (gO_2 m-1)
6/2 -6/7	3	15,027	111.2	7.4	1012.4	9.10	1049.0	9.43	3.37	0.39
6/24-7/3	4	13,750	71.5	5.2	708.4	9.90	552.9	7.73	3.94	0.58
9/1 -9/11	5	11,256	48.4	4.3	617.9	12.76	108.7	2.24	5.52	3.63
9/12-9/24	6	5,867	17.6	3.0	245.7	13.98	48.1	2.73	4.48	4.48

TABLE 11 ESTIMATED AREA OF THE ANOXIC HYPOLIMNION OF THE CENTRAL BASIN OF LAKE ERIE 1930-1981

YEAR	AREA	PERCENT OF CENTRAL BASIN	
	(km^2)	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
1978	3,980	71.7	24.6
1979	N.A.	N.A.	N.A.
1980	4,330	35.9	26.8
1981	4,820	37.4	29.0

Data Sources:
1930--Fish (1960)
1959-1961--Thomas (1963)
1964--FWPCA (1968)
1970--CCIW (Burns and Ross, 1972)
1972-1977, 1981, OSU/CLEAR
1978--ANL (Zapotosky and White, 1980)

TABLE 12 TRENDS IN NET OXYGEN DEMAND OF THE CENTRAL AND EASTERN BASIN HYPOLIMNIONS OF LAKE ERIE 1930-1981

DATA SOURCE*	YEAR	NET OXYGEN DEMAND			
		Rate Per Unit Area ($g\ O_2\ m^{-2}\ day^{-1}$)		Rate Per Unit Volume ($mg\ O_2\ l^{-1}\ day^{-1}$)	
		Central Basin	Eastern Basin	Central Basin	Eastern Basin
1	1930	0.08	-	0.054	-
1	1940	0.15	-	0.067	-
1	1950	0.25	-	0.070	-
1	1960	0.37	-	0.093	-
2	1970	0.38	0.70	0.110	0.055
3,4	1973	0.53	0.23	0.120	0.016
3,4	1974	0.60	0.57	0.130	0.026
3,4	1975	0.67	0.76	0.100	0.040
3,4	1976	0.75	-	0.130	0.032
3	1977	0.58	0.68	0.130	0.060
2	1977	0.48	0.51	0.120	0.065
5	1978	0.51	0.58	0.092	0.048
2	1978	0.54	0.61	0.111	0.047
5	1979	0.41	0.58	0.090	0.049
3	1980	0.63	-	0.109	-
3	1981	0.47	-	0.085	-

*Data sources: 1) Dobson and Gilbertson, 1971; 2) CCIW--Noel Burns, personal communication; 3) OSU/CLEAR--Central Basin, 1973-1977; Eastern Basin, 1977; 4) SUNY/GLL--Eastern Basin, 1973-1976; 5) USEPA/GLNPO--rate calculation OSU/CLEAR.

TABLE 13

COMPARISON OF 1981 AVAILABLE AND NON-AVAILABLE PHOSPHORUS FRACTIONS BY PERCENT TO HISTORIC DATA

	NAIP Reactive NaOH P + CDB P	APATITE Acid Extractable P	ORGANIC Nonreactive NaOH P + Residual P
Lake Erie water column			
Central Basin	22%	11%	63%
Western Basin	27%	23%	45%
Ohio Tributaries Sediments Maumee + Sandusky R. DePinto, 1981	43%	7%	21%
Tributaries Sediments Western Lake Erie (Logan 1979)	51%	10%	30%
Lake Erie Bottom Sed. (Williams 1976)			
Central Basin	49%	38%	18%
Western Basin	40%	35%	26%

TABLE 14. LAKE ERIE TRANSPARENCY MEASUREMENTS 1973-1981

			Area-Weighted Transparency, Secchi Disk (m)		
Date	Year	Cruise No.	Western	Central	Eastern
6/28- 7/12	1973	1	1.92	4.31	N.A.
7/17- 7/23		2	N.A.	6.72	N.A.
7/25- 8/2		3	1.78	5.86	N.A.
8/7 - 8/11		4	N.A.	5.85	N.A.
8/29- 9/4		5	2.12	4.53	N.A.
9/19- 9/29		6	1.14	3.77	N.A.
10/14-10/24		7	0.87	3.35	N.A.
11/7 -11/15		8	1.01	2.26	N.A.
12/4		9	1.30	1.75	N.A.
4/7 - 4/17	1974	1	0.56	1.62	N.A.
4/25- 5/4		2	0.60	3.03	N.A.
5/14- 5/24		3	1.05	3.34	N.A.
6/1 - 6/10		4	2.35	4.38	N.A.
6/28- 7/7		5	1.31	6.28	N.A.
7/26- 8/4		6	2.16	5.93	N.A.
8/12- 8/19		7	1.54	6.36	N.A.
8/26- 9/7		8	1.25	5.51	N.A.
9/24- 9/27		9	1.08	N.A.	N.A.
10/21-11/1		10	1.96	3.31	N.A.
12/11-12/14		12	0.56	0.76	N.A.
3/19- 3/31	1975	1A	0.64	0.90	N.A.
4/21- 4/25		1B	0.45	1.65	N.A.
6/9 - 6/19		2	1.28	4.92	N.A.
7/13- 7/21		3	1.56	7.99	N.A.
8/30- 9/7		4	0.79	3.63	N.A.
9/27-10/6		5	0.94	2.70	N.A.
12/2 -12/10		6	0.44	1.03	N.A.
3/22- 3/30	1976	1	0.81	2.27	N.A.
6/2 - 6/10		2	2.78	4.39	N.A.
8/21- 8/29		3	N.A.	4.42	N.A.
9/8 - 9/17		4	0.85	3.12	N.A.
10/18-10/30		5	1.01	2.08	N.A.
3/20- 3/31	1977	1	1.75	4.90	N.A.
4/29- 5/8		2	N.A.	4.56	4.98
6/20- 6/30		3	N.A.	5.41	3.69
7/12- 7/22		4	N.A.	6.55	7.21
8/11- 8/21		5	N.A.	4.69	5.91
9/11-10/8		6	1.09	4.01	4.50
11/7 -11/20		7	1.36	2.22	2.88

(continued)

TABLE 14 CONT.

Date	Year	Cruise No.	Area-Weighted Transparency, Secchi Disk (m) Western	Central	Eastern
	1978	1	N.A.	N.A.	N.A.
5/18- 5/27		2	2.50	3.87	3.96
6/5 - 6/15		3	2.02	4.31	4.22
6/23- 7/1		4	2.00	4.22	6.87
7/19- 7/29		5	2.06	6.93	5.95
8/8 - 8/16		6	2.68	6.60	7.03
8/29- 9/6		7	1.94	5.16	4.65
10/3 -10/12		8	1.58	4.31	3.20
10/24-11/1		9	2.08	2.93	3.63
11/10-11/19		10	0.65	3.42	3.16
	1979	1	N.A.	N.A.	N.A.
4/17- 4/20		2	0.67	1.28	N.A.
5/15- 5/26		3	1.81	2.82	3.16
6/12- 6/21		4	1.44	3.49	3.07
7/11- 7/19		5	3.03	5.80	6.91
7/31- 8/4		6	2.38	5.78	N.A.
8/23- 9/4		7	1.91	N.A.	N.A.
9/11- 9/21		8	1.29	3.92	5.82
10/2 -10/14		9	1.59	3.50	4.26
11/7 -11/16		10	0.96	5.03	3.67
6/29- 7/6	1980	4	1.51	7.02	N.A.
7/28- 8/8		5	1.73	5.95	N.A.
8/18- 8/23		6	1.50	4.66	N.A.
6/24- 7/3	1981	4	1.19	6.08	N.A.
9/1 - 9/11		5	0.59	3.22	N.A.
9/12- 9/24		6	0.83	2.77	N.A.

TABLE 15

LAKE ERIE WATER QUALITY MEASUREMENTS 1981
WESTERN BASIN CRUISE MEAN CONCENTRATIONS
STATIONS 202 AND 401 EXCLUDED

Cruise No.	Date	Statistics	Temp. (°C)	DO (mg/l)	DO (%)	Corrected Conduct. (umhos/cm)	pH
1 epi	3/24-3/29	mean	2.62	13.32	102.9	235	7.85
		st. err.	0.08	0.02	0.2	3	0.01
		median	2.5	13.3	102.8	236	7.86
		n	36	36	36	36	36
2 epi	5/2-5/6	mean	11.82	10.93	99.2	256	8.35
		st. err.	0.17	0.07	0.8	8	0.02
		median	11.6	10.9	98.5	241	8.36
		n	36	36	36	36	36
3 epi	6/2-6/7	mean	16.53	9.10	90.8	276	8.36
		st. err.	0.19	0.08	0.9	6	0.02
		median	16.7	9.20	91.3	264	8.34
		n	31	31	31	31	31
4 epi	6/24-7/3	mean	20.69	8.18	89.4	259	8.21
		st. err.	0.16	0.10	1.3	5	0.03
		median	20.6	8.1	87.9	249	8.14
		n	36	36	36	36	36
5 epi	9/1-9/11	mean	20.94	9.02	99.1	242	8.36
		st. err.	0.08	0.13	1.6	5	0.03
		median	21.0	8.75	95.2	229	8.32
		n	36	36	36	36	36
6 epi	9/12-9/24	mean	16.91	8.85	89.0	242	8.05
		st. err.	0.11	0.05	0.5	3	0.01
		median	17.20	8.8	89.0	236	8.06
		n	36	36	36	36	36
7 epi	10/24-10/31	mean	10.15	10.62	93.5	248	7.96
		st. err.	0.12	0.15	1.4	4	0.02
		median	10.45	10.3	90.5	239	7.94
		n	36	35	35	36	36
8 epi	11/12-11/19	mean	9.02	11.49	99.0	250	8.12
		st. err.	0.08	0.10	0.8	6	0.03
		median	9.10	11.1	97.6	237	8.11
		n	36	36	36	36	36
9 epi	12/3-12/6	mean	4.93	11.98	96.1	252	8.03
		st. err.	0.06	0.06	0.5	5	0.01
		median	4.95	12.0	96.4	245	8.03
		n	36	36	36	36	36

TABLE 15 CONT.

Cruise No.	Date	Statistics	Total Phos. (ug/l)	Soluble Reactive Phos. (ug/l)	Nitrate Nitrite (ug/l)	Ammonia (ug/l)	Dissolved Reactive Silica (ug/l)
1 epi	3/24-3/29	mean	22.6	ND	572	39.2	886
		st. err.	1.7		45	11.3	84
		median	19.7		480	9.6	1035
		n	36		36	36	36
2 epi	5/2-5/6	mean	28.5	2.3	726	14.9	252
		st. err.	5.2	0.1	178	5.9	80
		median	17.9	2.1	400	2.7	40
		n	36	36	36	36	36
3 epi	6/2-6/7	mean	21.6	1.9	914	9.4	125
		st. err.	2.2	0.2	116	3.2	13
		median	17.4	1.7	531	6.7	120
		n	31	31	31	14	31
4 epi	6/24-7/3	mean	33.8	6.7	962	24.3	1022
		st. err.	5.4	1.5	174	3.4	160
		median	22.7	2.7	433	21.1	765
		n	36	36	36	36	36
5 epi	9/1-9/11	mean	52.2	4.7	334	3.6	916
		st. err.	8	1.3	38	0.5	106
		median	35.8	2.6	221	2.9	735
		n	36	36	36	32	36
6 epi	9/12-9/24	mean	37.9	5.9	304	20.9	1111
		st. err.	2.4	0.5	24	2.8	46
		median	32.8	5.3	235	18.0	1105
		n	36	36	36	36	36
7 epi	10/24-10/31	mean	38.8	3.4	364	15.8	867
		st. err.	2.3	0.3	16	2.8	57
		median	34.1	3.4	360	10.3	880
		n	36	36	36	36	36
8 epi	11/12-11/19	mean	24.8	1.5	458	25.9	877
		st. err.	2.5	0.2	48	10.2	81
		median	21.1	1.2	358	16.7	990
		n	36	36	36	12	36
9 epi	12/3-12/6	mean	29.2	3.0	502	26.0	1249
		st. err.	3.2	0.6	36	7.4	69
		median	21.5	1.8	457	3.8	1245
		n	36	36	36	36	36

TABLE 15 CONT.

Cruise No.	Date	Statistics	Secchi (m)	Turbidity (ntu)	Susp. Solids (mg/l)	Corr. Chlor. (ug/l)	SCOR Chlor. (ug/l)
1 epi	3/24-3/29	mean	1.4	6.2	5.07	6.53	7.06
		st. err.	0.1	0.7	0.39	0.30	0.34
		median	1.6	5.1	4.49	6.47	7.06
		n	17	36	28	36	36
2 epi	5/2-5/6	mean	1.8	9.9	13.15	8.72	10.37
		st. err.	0.2	3.3	4.78	1.34	1.49
		median	1.8	3.4	4.11	6.00	8.07
		n	15	36	36	36	36
3 epi	6/2-6/7	mean	1.9	4.7	5.06	5.20	5.77
		st. err.	0.2	0.8	1.04	0.96	1.09
		median	1.7	3.1	2.93	2.81	3.11
		n	15	31	31	31	31
4 epi	6/24-7/3	mean	1.3	15.5	13.72	6.68	7.05
		st. err.	0.1	5.7	3.76	0.94	0.74
		median	1.4	6.0	6.84	4.90	5.44
		n	18	36	36	36	36
5 epi	9/1-9/11	mean	0.7	19.4	24.5	14.17	19.31
		st. err.	0.1	4.5	7.9	1.61	1.73
		median	0.8	10.4	12.2	12.84	16.89
		n	18	36	36	36	36
6 epi	9/12-9/24	mean	0.9	15.0	16.07	8.55	12.13
		st. err.	0.1	2.3	2.23	0.84	0.88
		median	0.9	10.0	17.07	7.78	10.51
		n	11	36	36	36	36
7 epi	10/24-10/31	mean	0.7	20.2	19.95	8.02	11.50
		st. err.	0.1	1.8	1.92	0.69	0.87
		median	0.7	16.9	16.76	7.12	9.92
		n	16	36	35	36	36
8 epi	11/12-11/19	mean	1.1	9.2	9.95	9.97	11.99
		st. err.	0.1	1.0	1.23	0.95	1.09
		median	1.1	7.6	7.85	8.76	11.67
		n	17	30	34	36	36
9 epi	12/3-12/6	mean	1.0	16.5	16.63	4.24	6.86
		st. err.	0.1	2.3	2.33	0.33	0.48
		median	1.0	10.4	10.67	4.23	6.44
		n	12	36	36	36	36

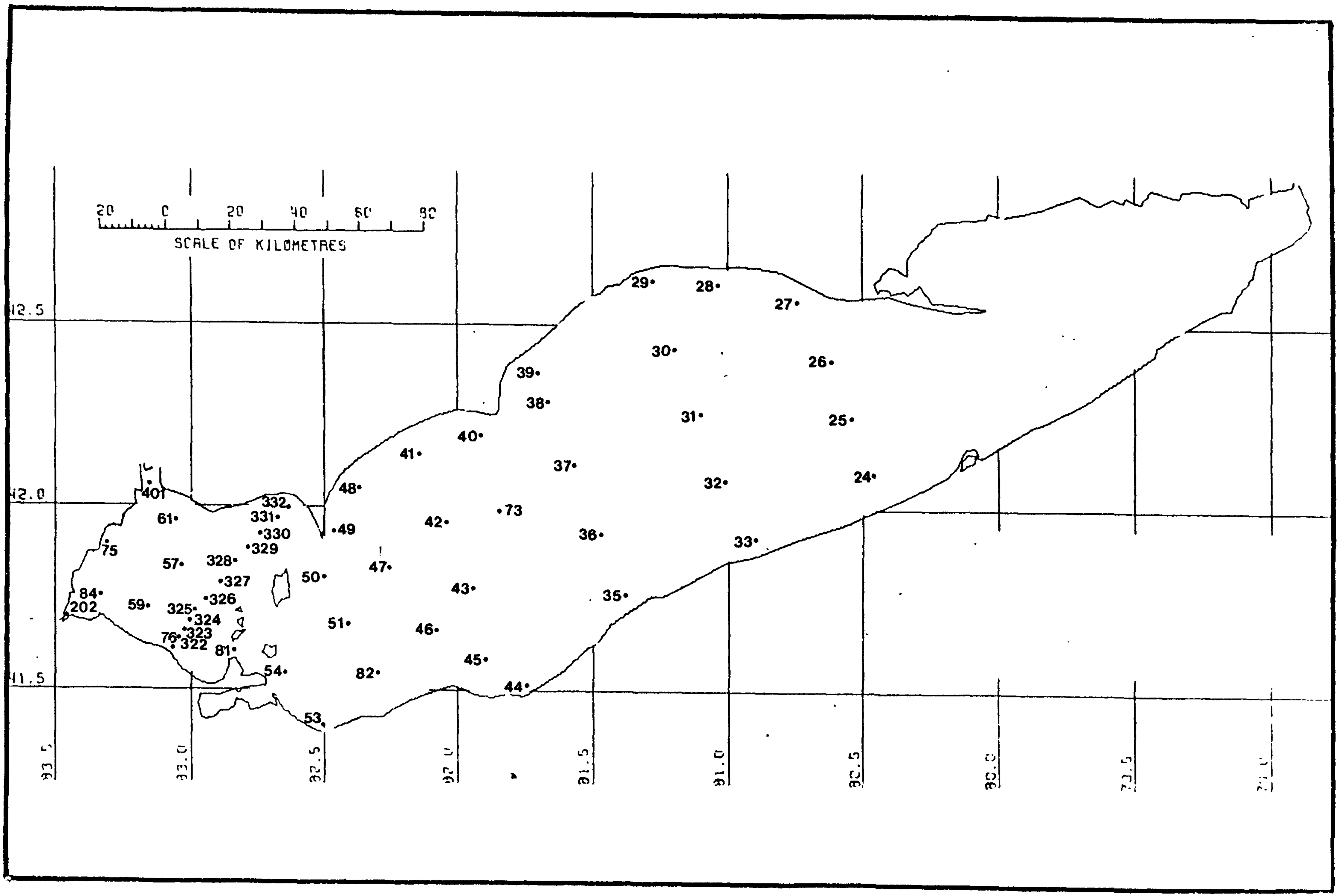


Figure 1. 1981 Station Pattern.

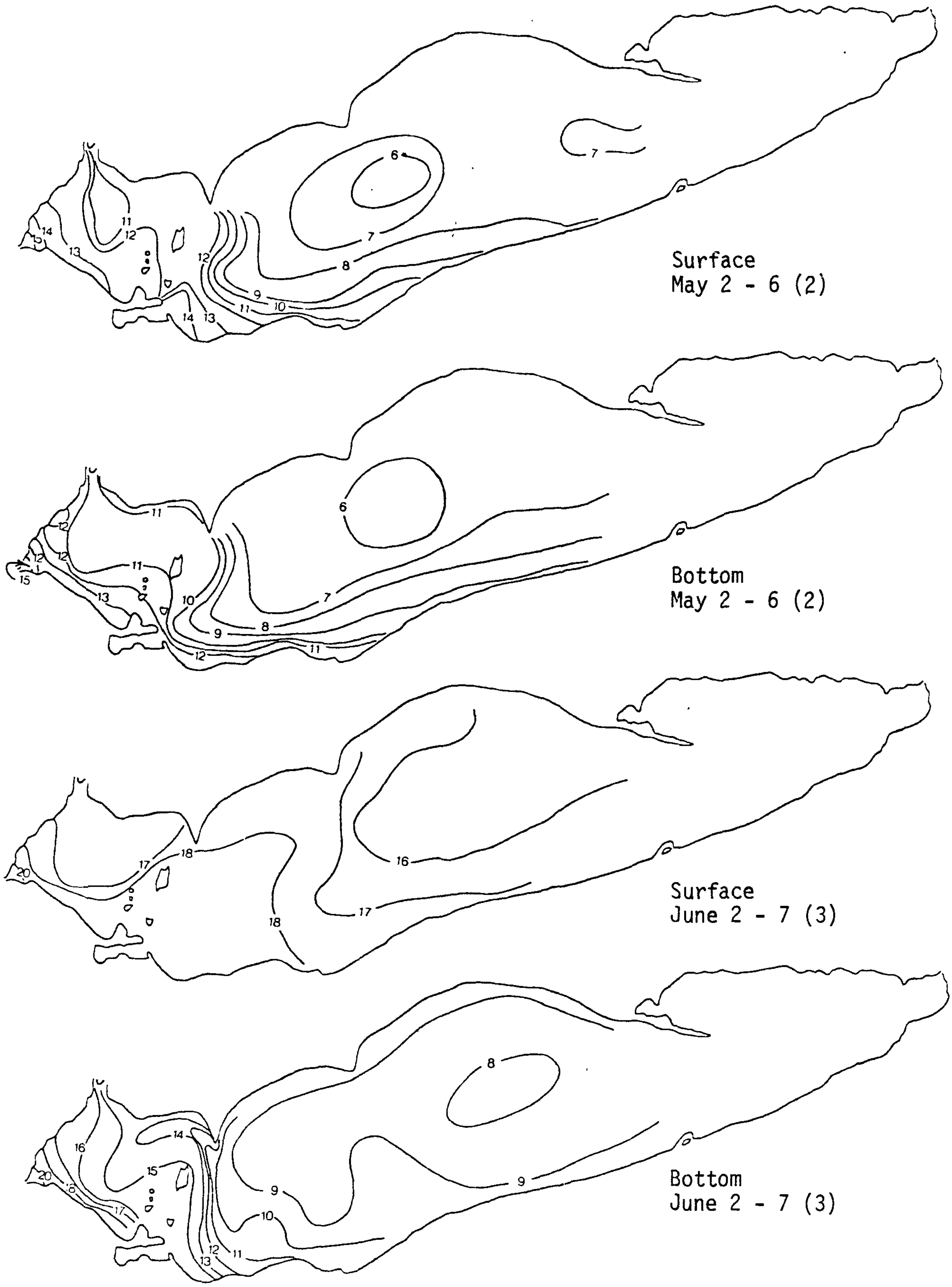


Figure 2. Limnion horizontal distribution maps, for temperature (°C), 1981

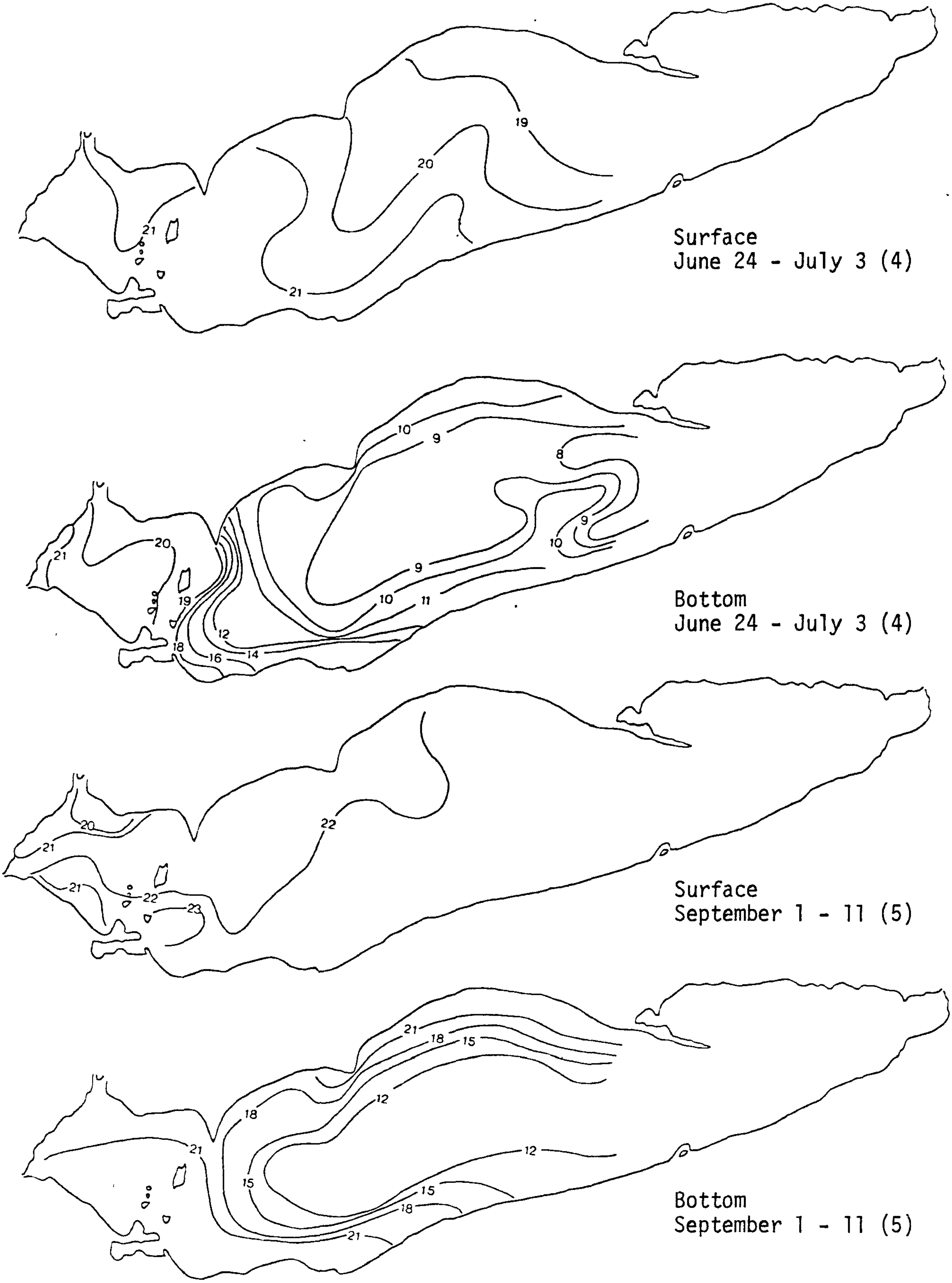
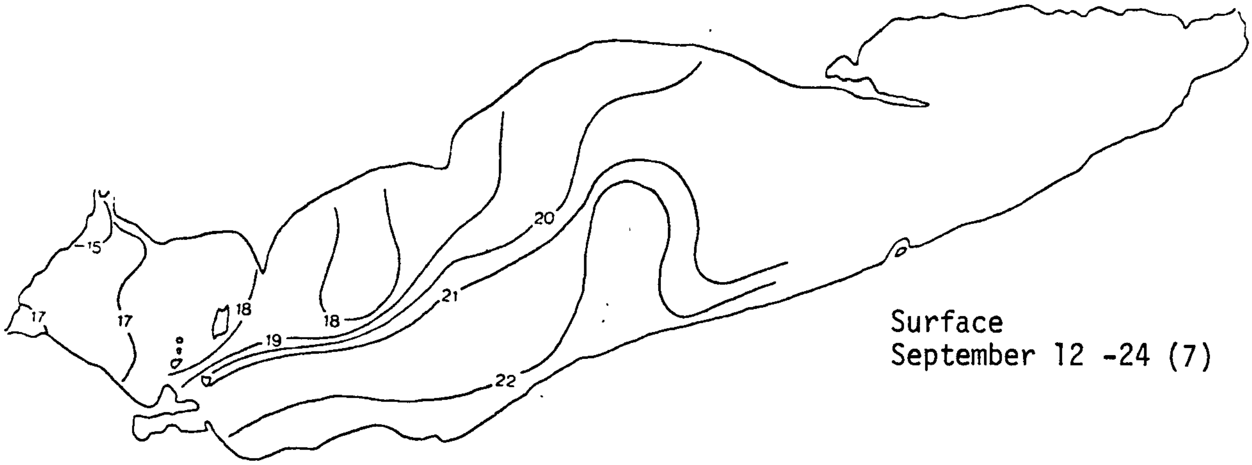
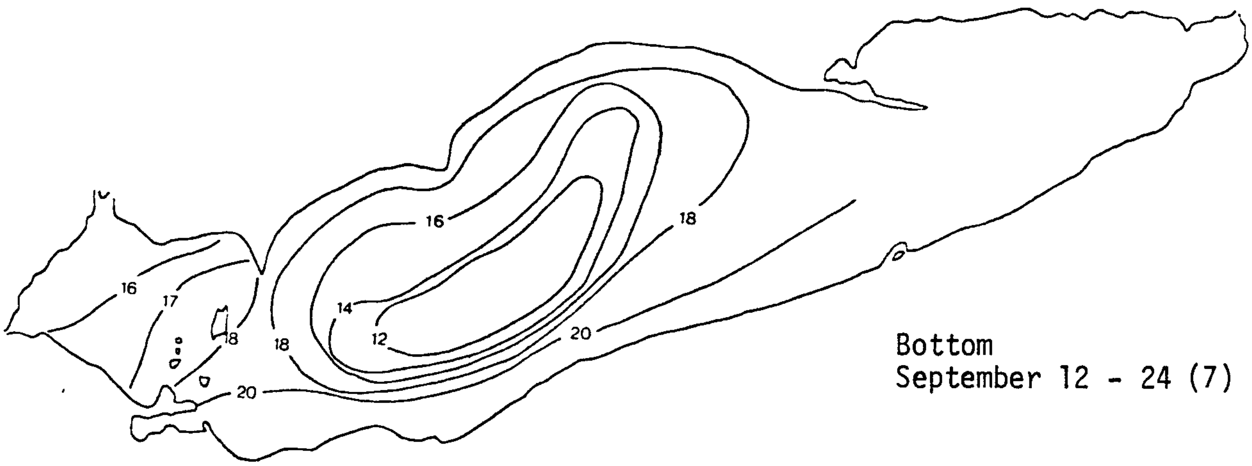


Figure 2 (continued). Limnion horizontal distribution maps, for temperature (°C), 1981



Surface
September 12 -24 (7)



Bottom
September 12 - 24 (7)

Figure 2 (continued). Limnion horizontal distribution maps, for temperature (°C), 1981

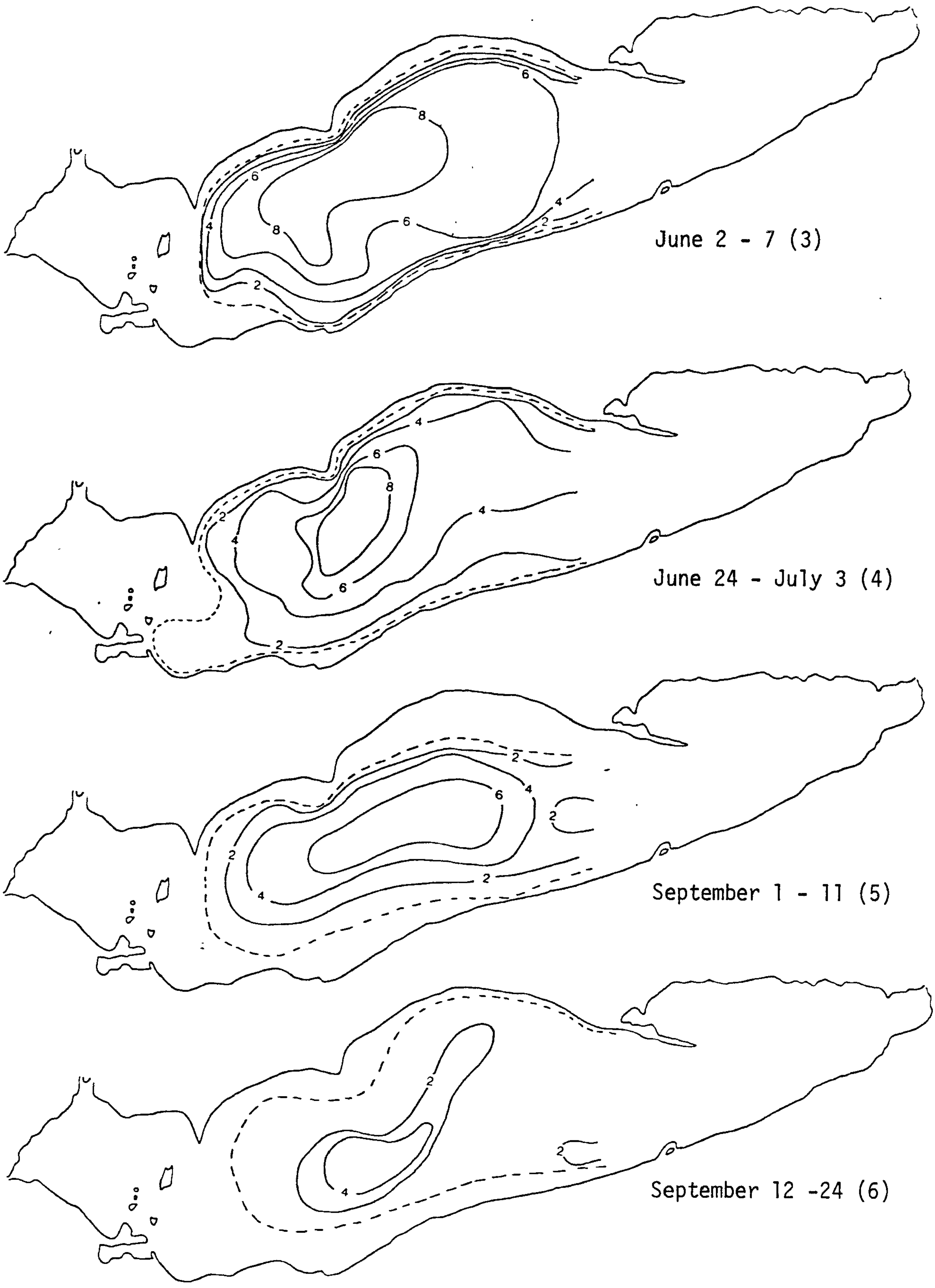


Figure 3. Distribution maps of Hypolimnion thickness (m), 1981.
The Dashed line shows the hypolimnion boundary.

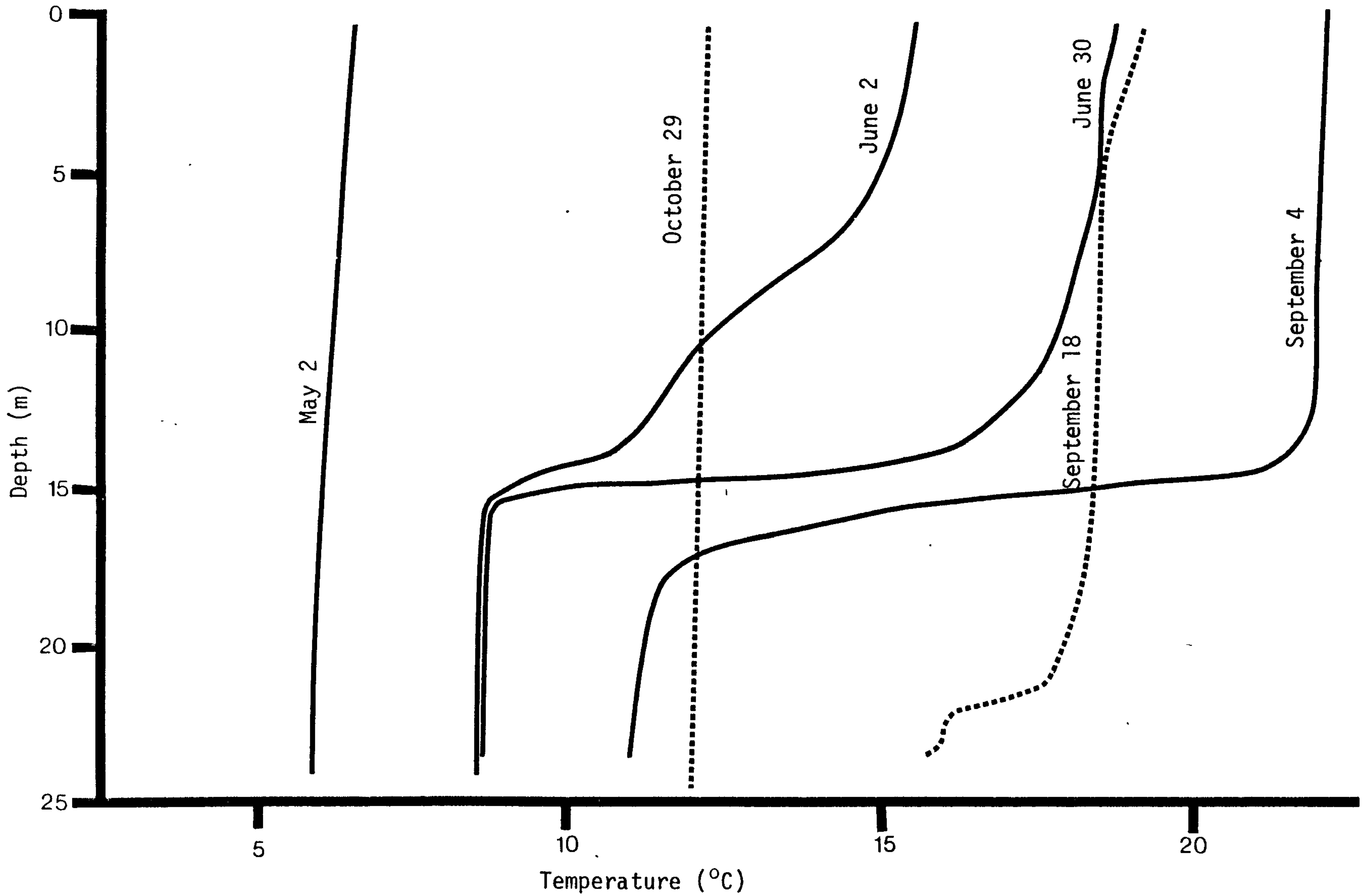


Figure 4. Thermal structure of central Lake Erie at Station 37, May to October, 1981.

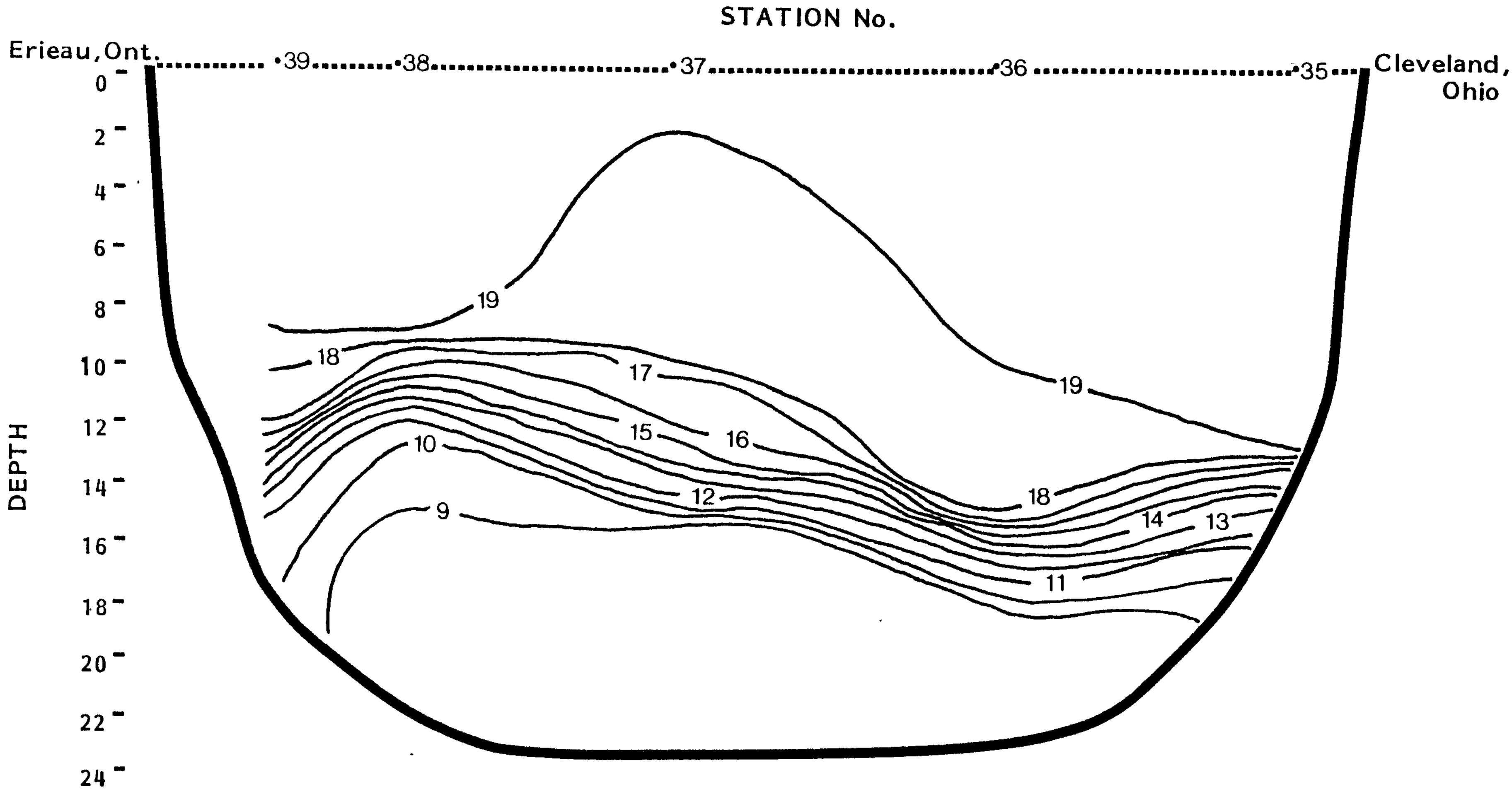


Figure 5. Thermal cross-section of central Lake Erie, Cruise 4 (June 24 - July 3) 1981.

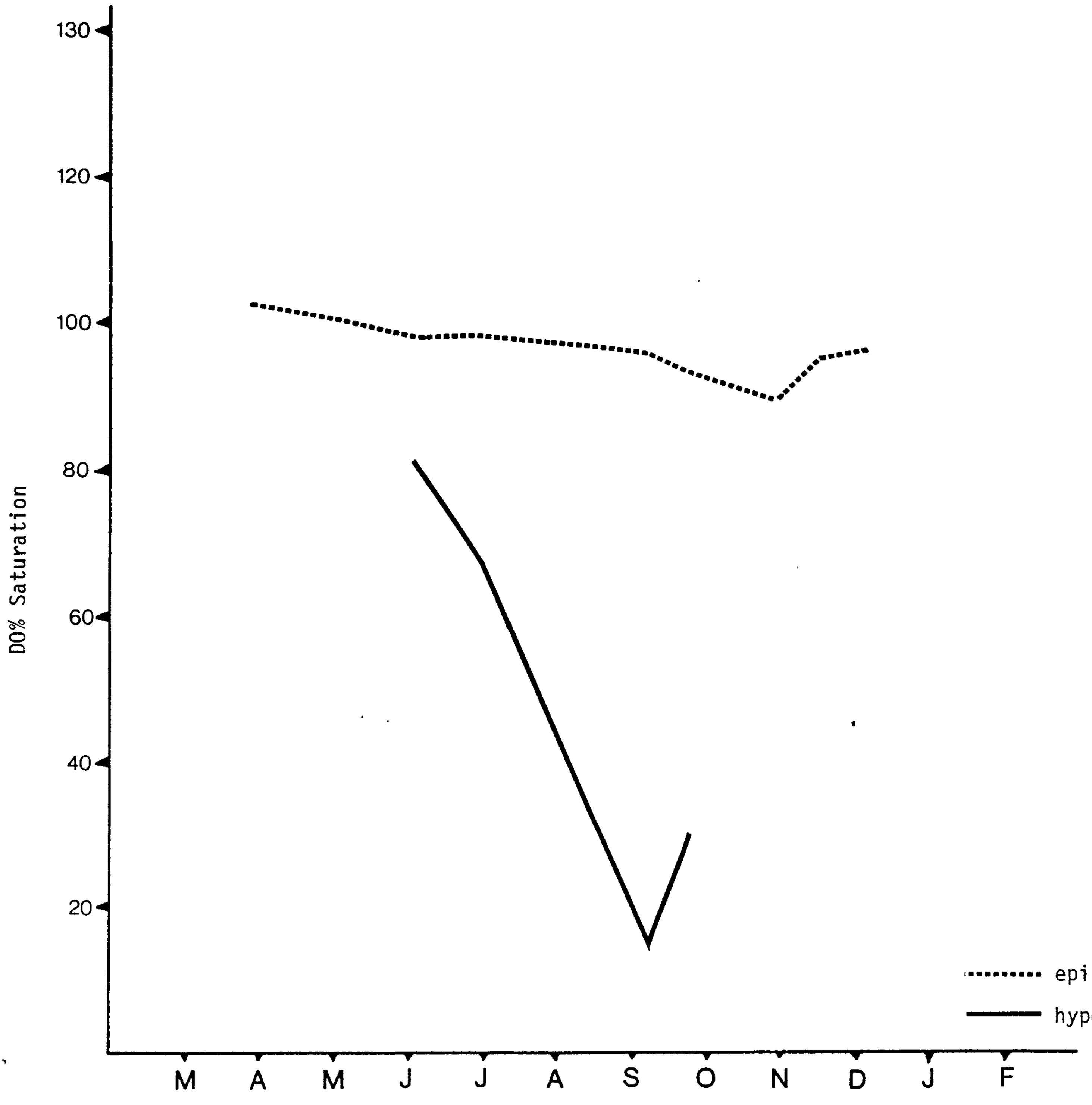


Figure 6. Central Basin 1981, Dissolved Oxygen Percent Saturation
Cruise means by limnion.

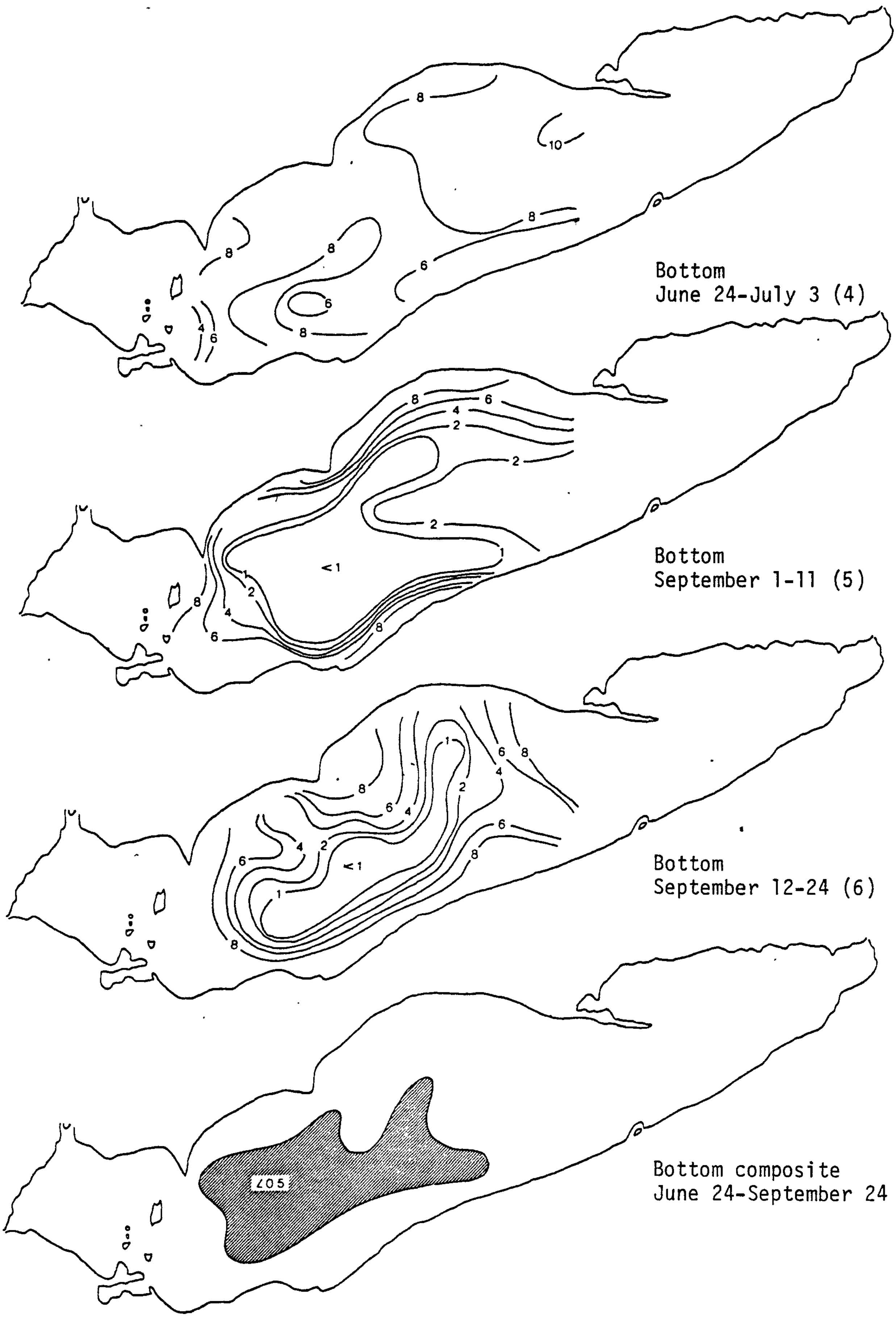


Figure 7. Limnion horizontal distribution maps for dissolved oxygen (mg/l) and for the composite anoxic area, 1981.

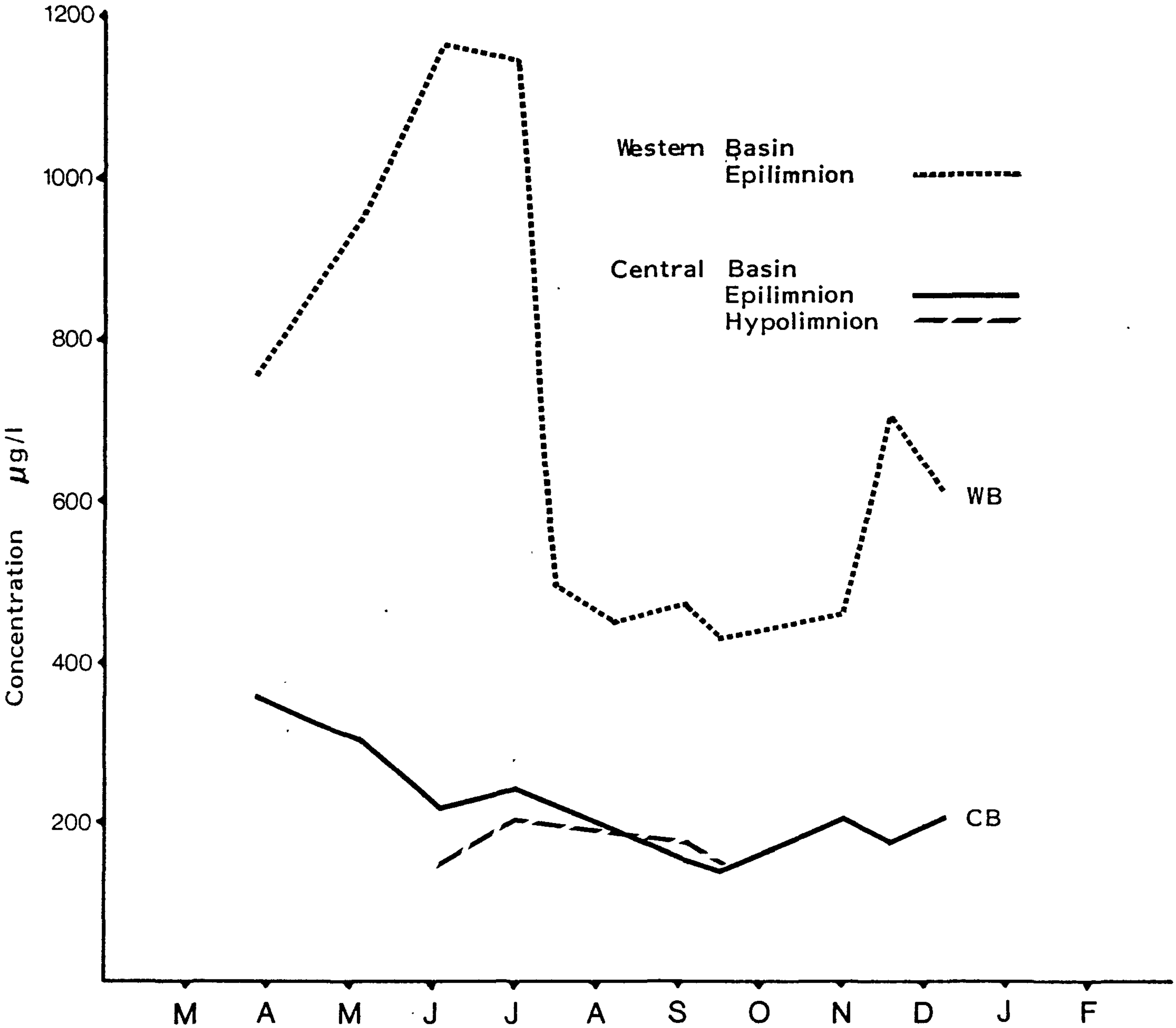


Figure 8. NO_3 + NO_2 Basin Comparison of Epi and Hypolimnion Concentrations.

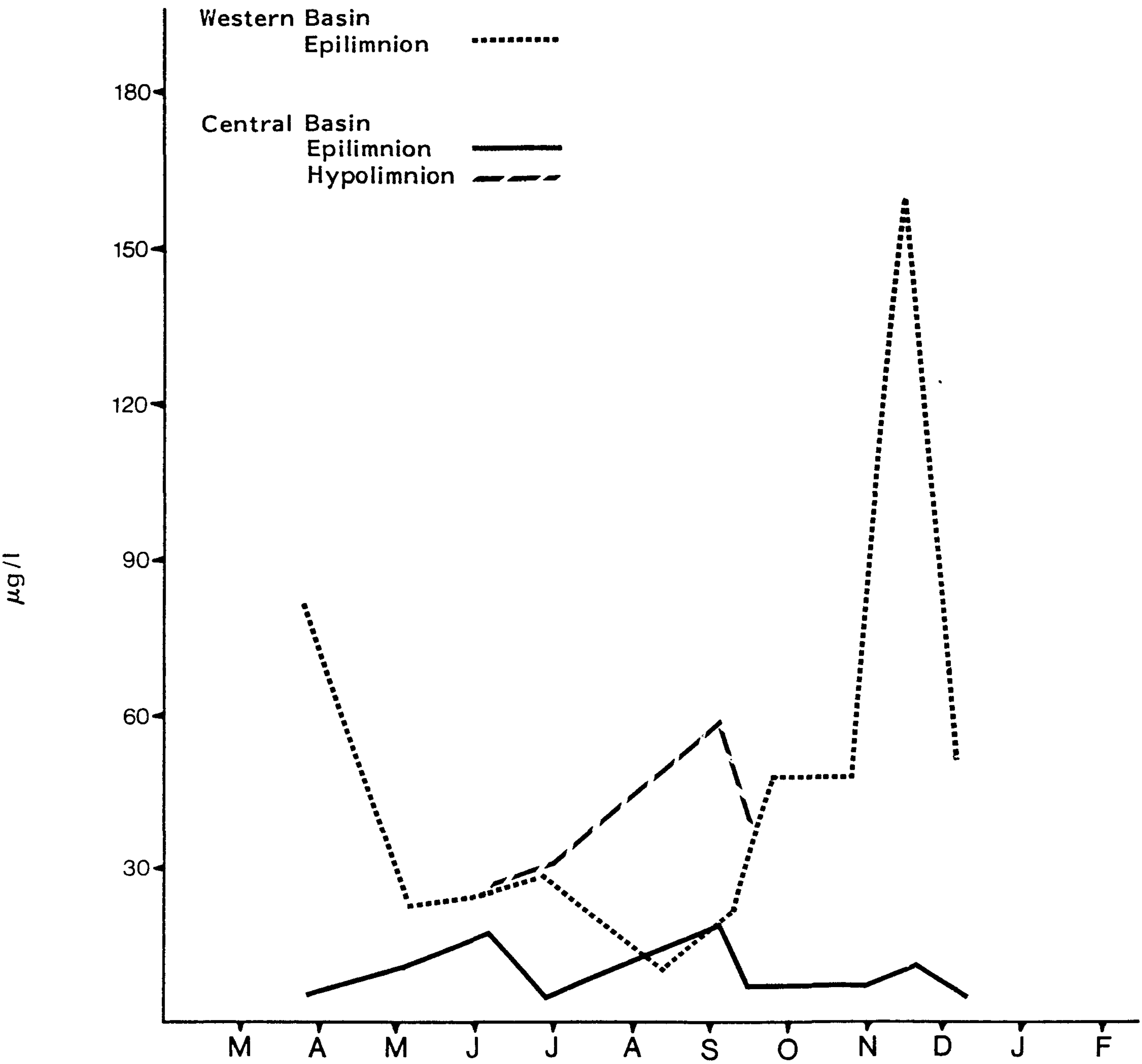


Figure 9. Ammonia Basin Comparison of Epi and Hypolimnion Concentrations.

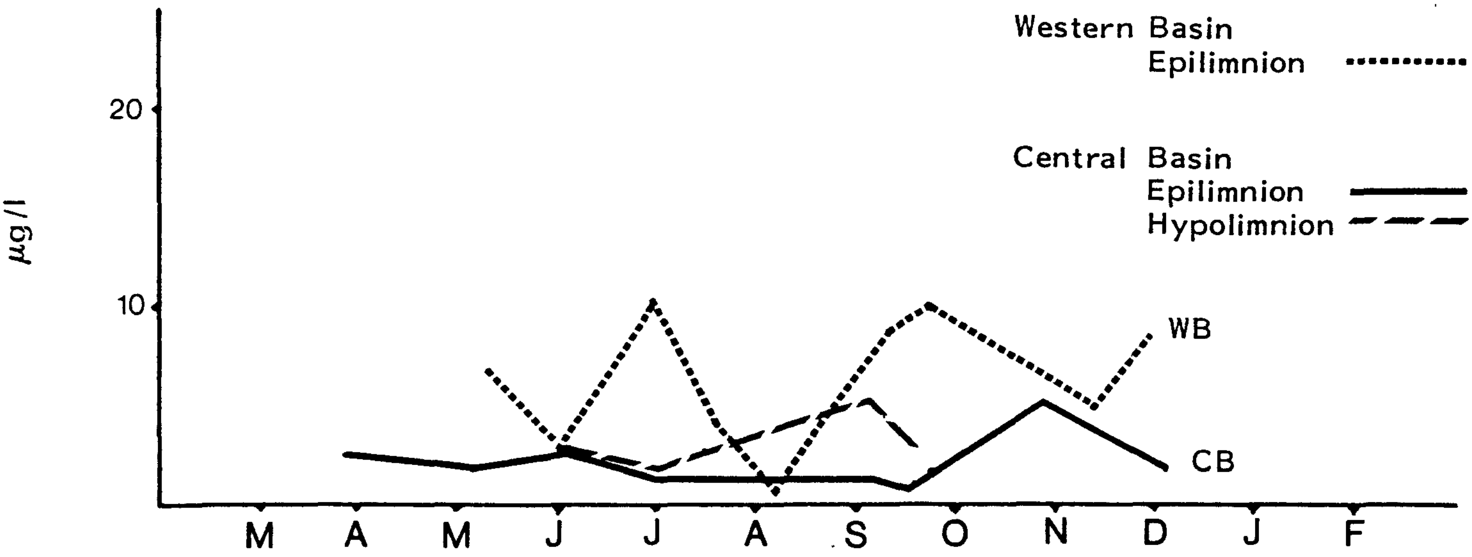


Figure 10. Soluble Reactive Phosphorus Basin Comparison of Epi and Hypolimnion Concentrations.

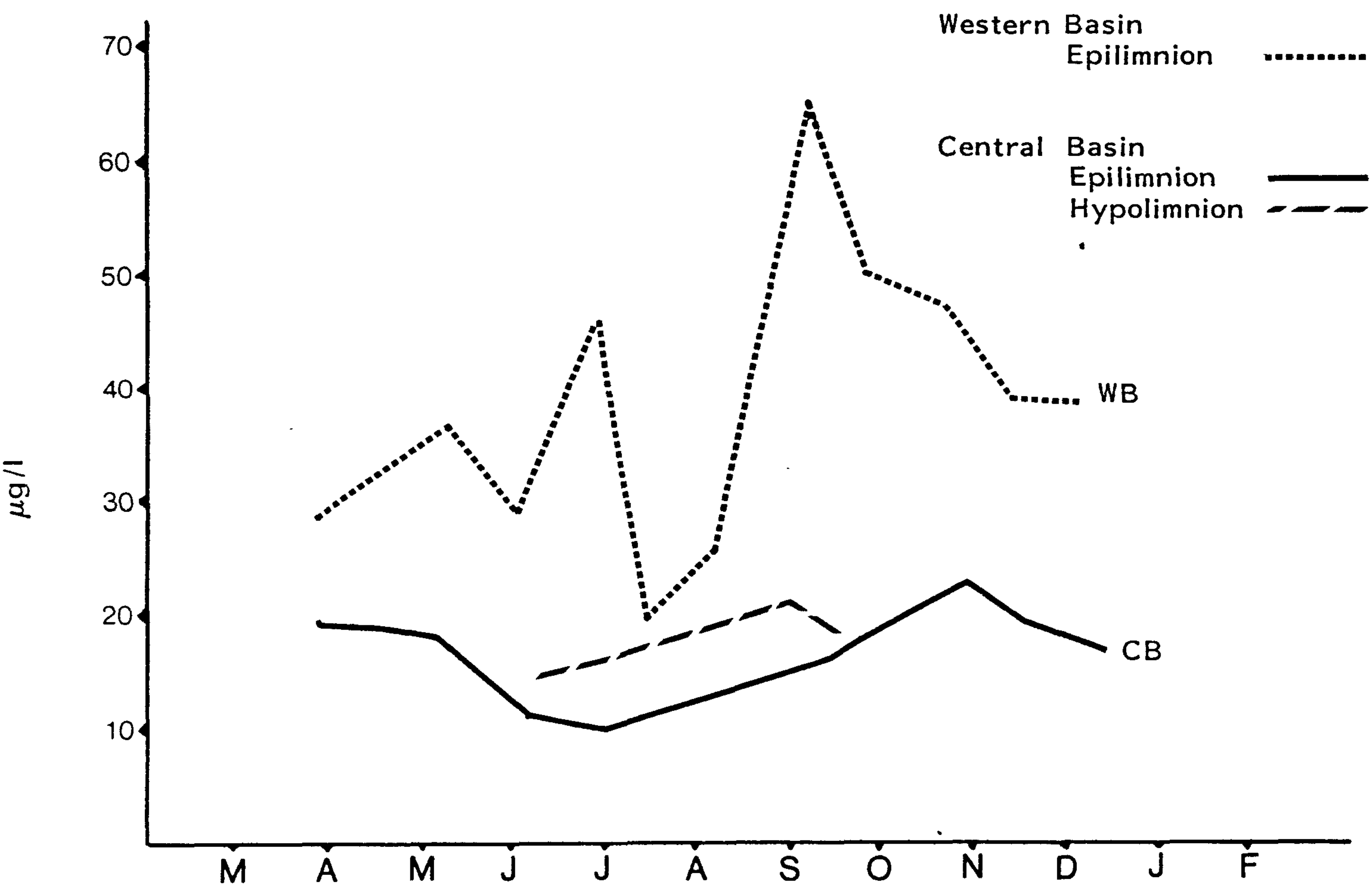


Figure 11. Total Phosphorus Basin Comparison of Epi and Hypolimnion Concentrations.

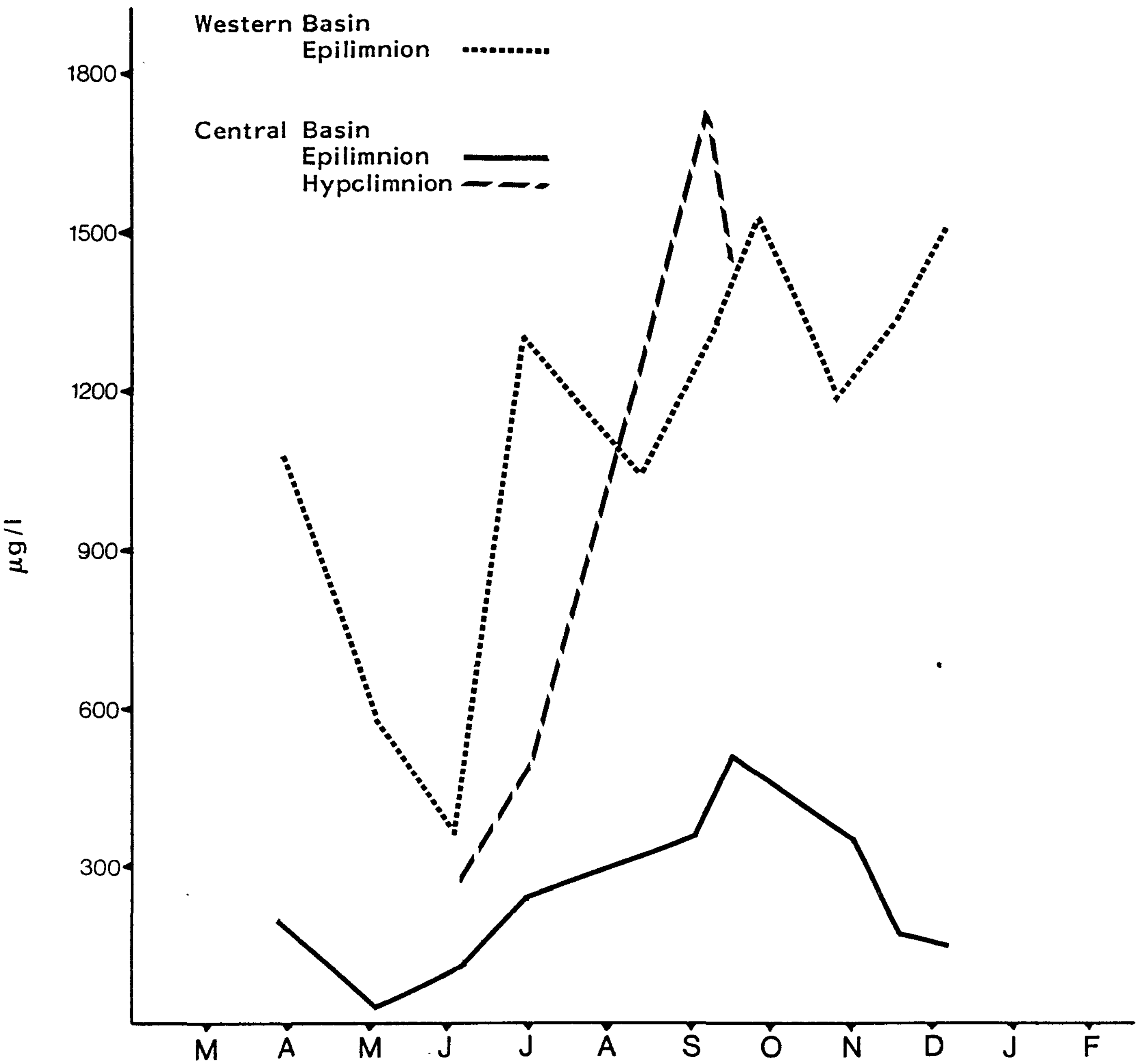


Figure 12. Soluble Reactive Silica Basin Comparison of Epi and Hypolimnion Concentrations.

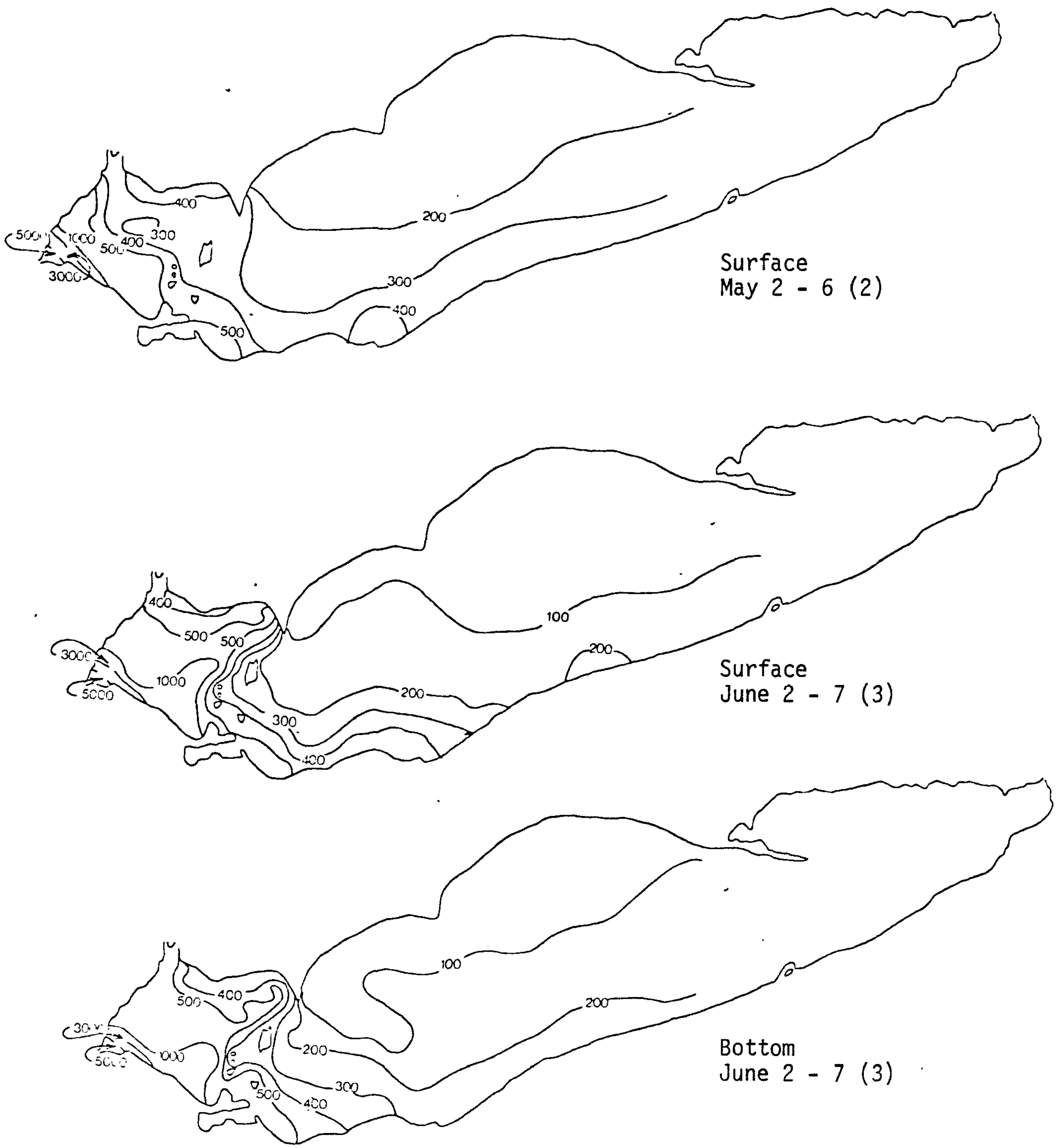


Figure 13. Limnion horizontal maps for nitrate plus nitrite (ug/l), 1981

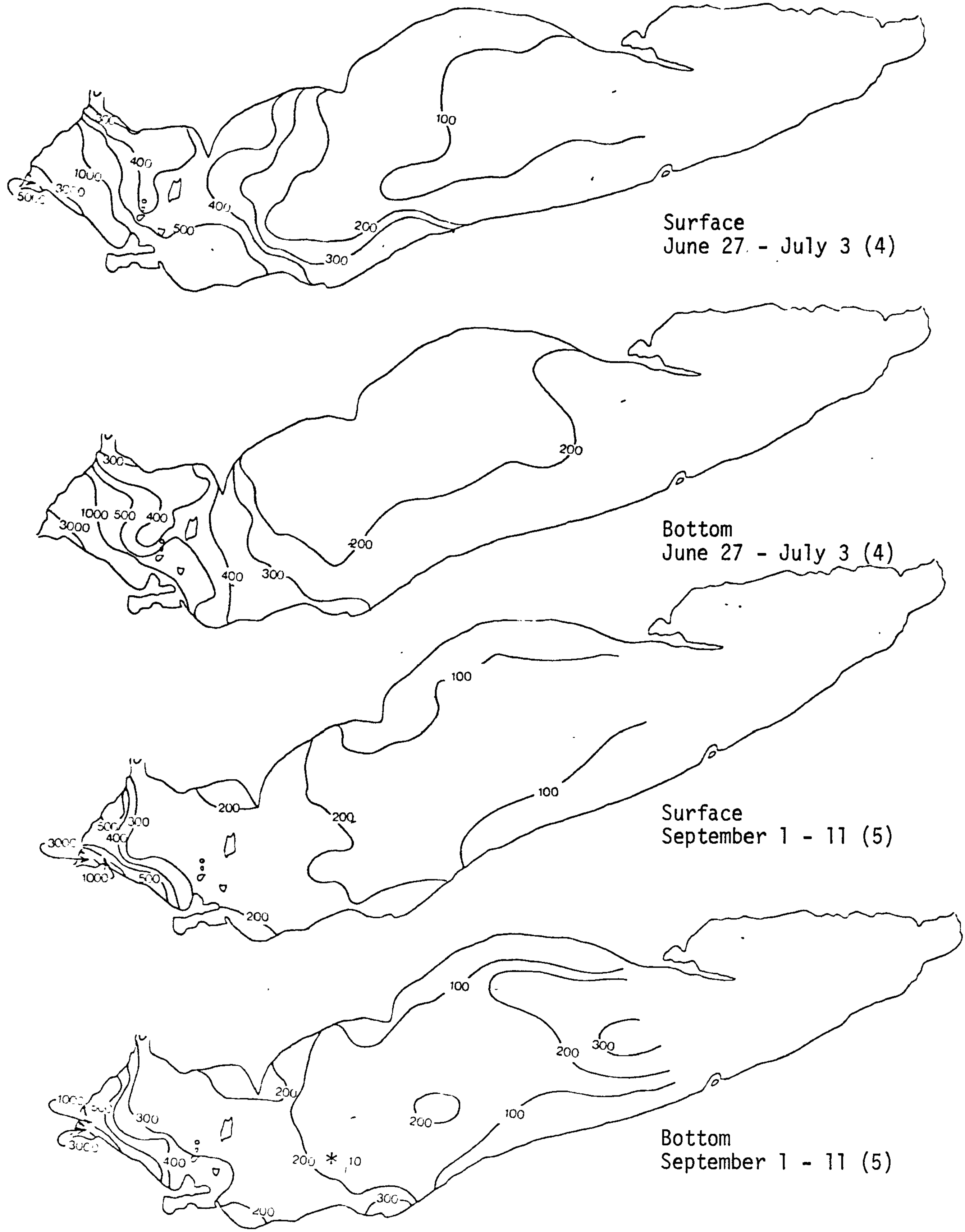


Figure 13 (continued). Limnion horizontal maps for nitrate plus nitrite (ug/l), 1981

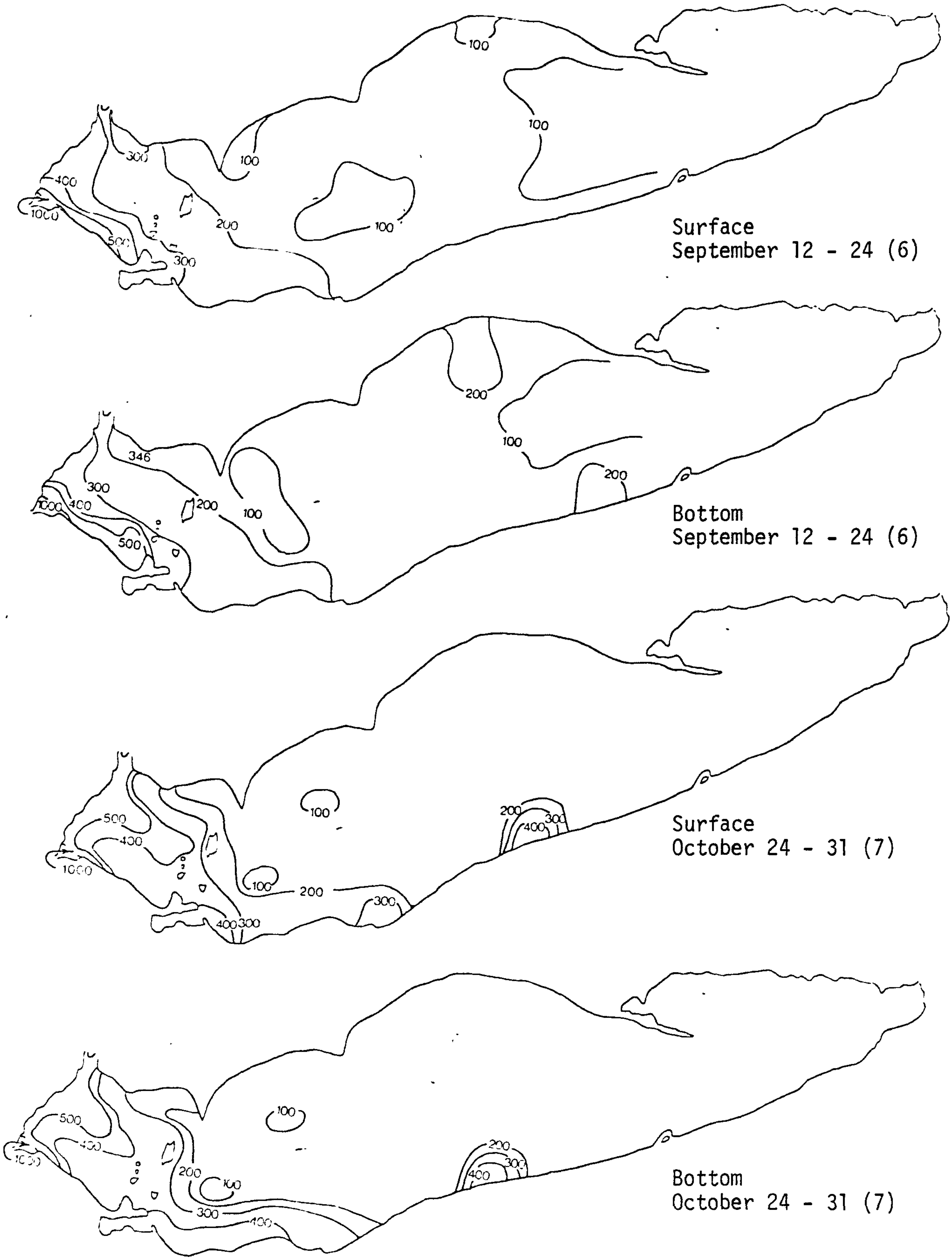
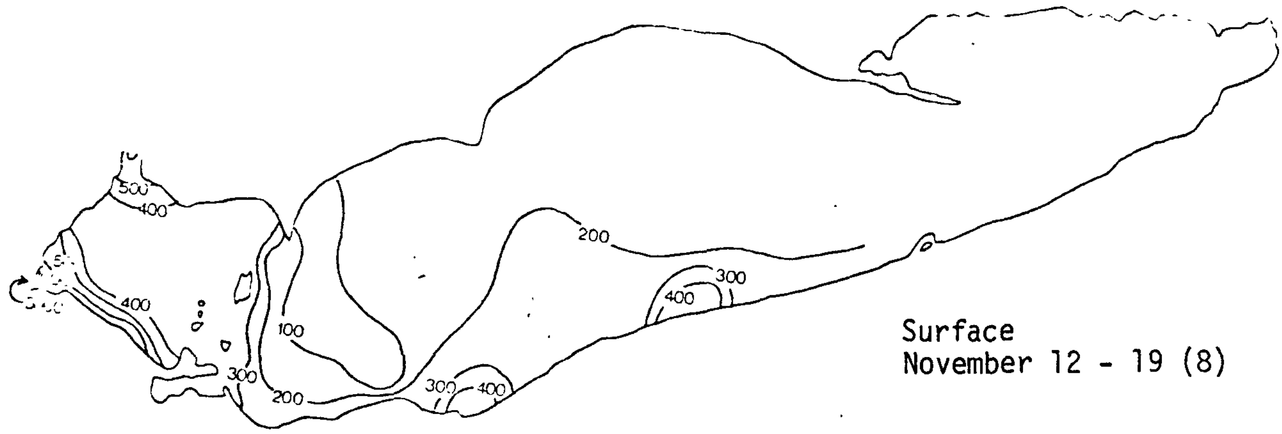


Figure 13 (continued). Limnion horizontal maps for nitrate plus nitrite (ug/l), 1981



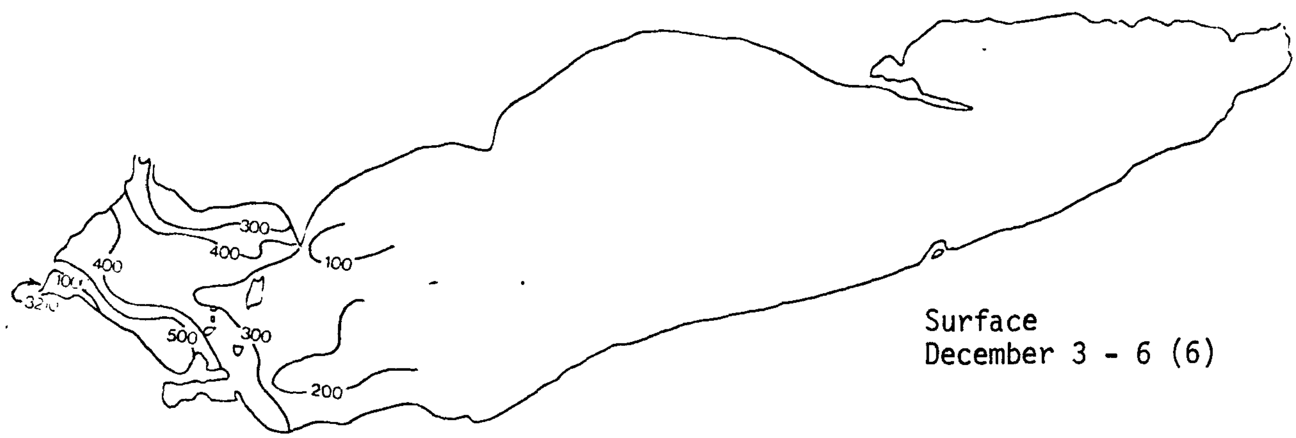


Figure 13 (continued). Limnion horizontal maps for nitrate plus nitrite (ug/l), 1981

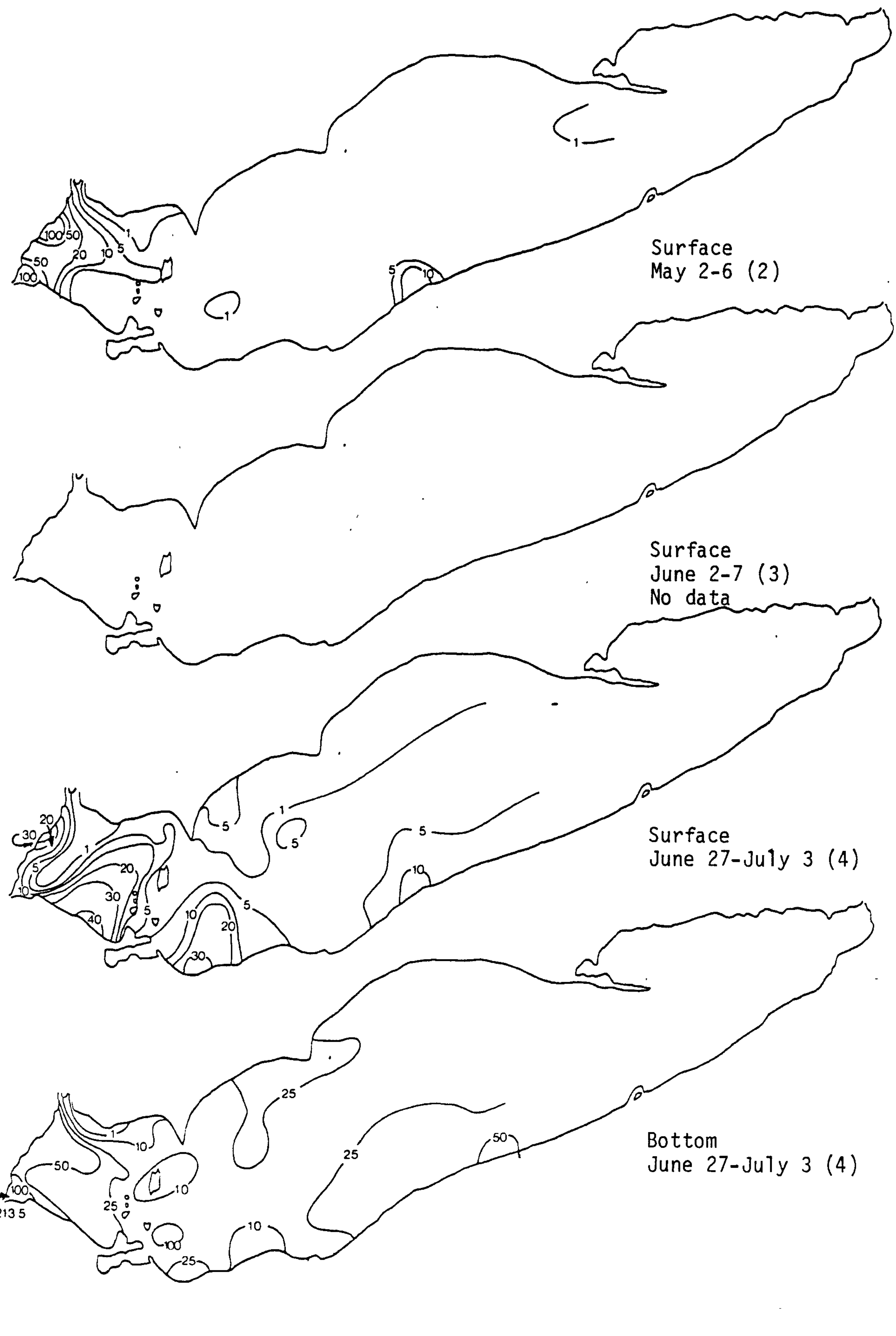


Figure 14. Limnion horizontal distribution maps for ammonia (ug/l), 1981.

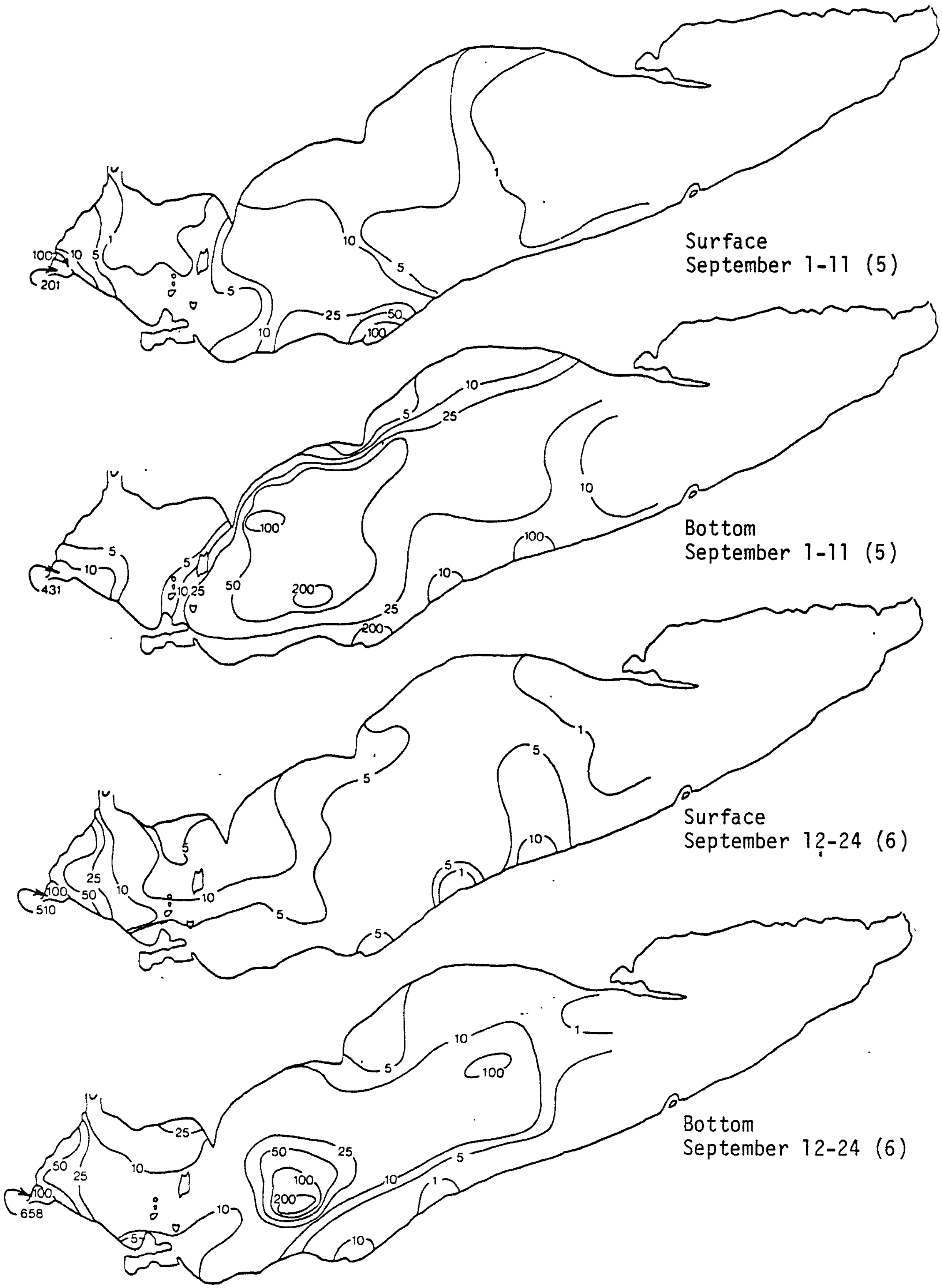


Figure 14. Limnion horizontal distribution maps for ammonia (ug/l), 1981.

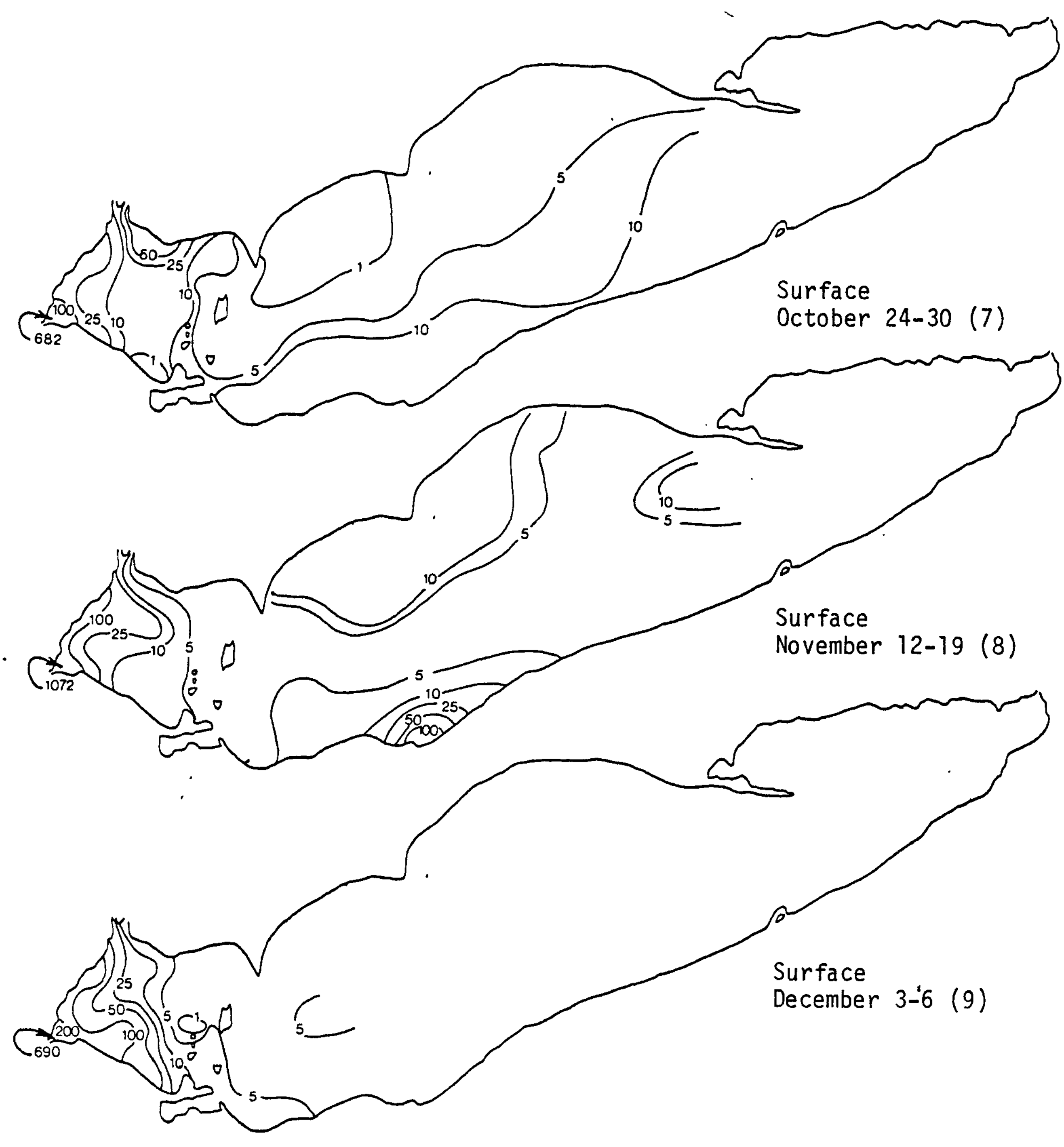


Figure 14 (continued). Limnion horizontal distribution maps for ammonia (ug/l), 1981.

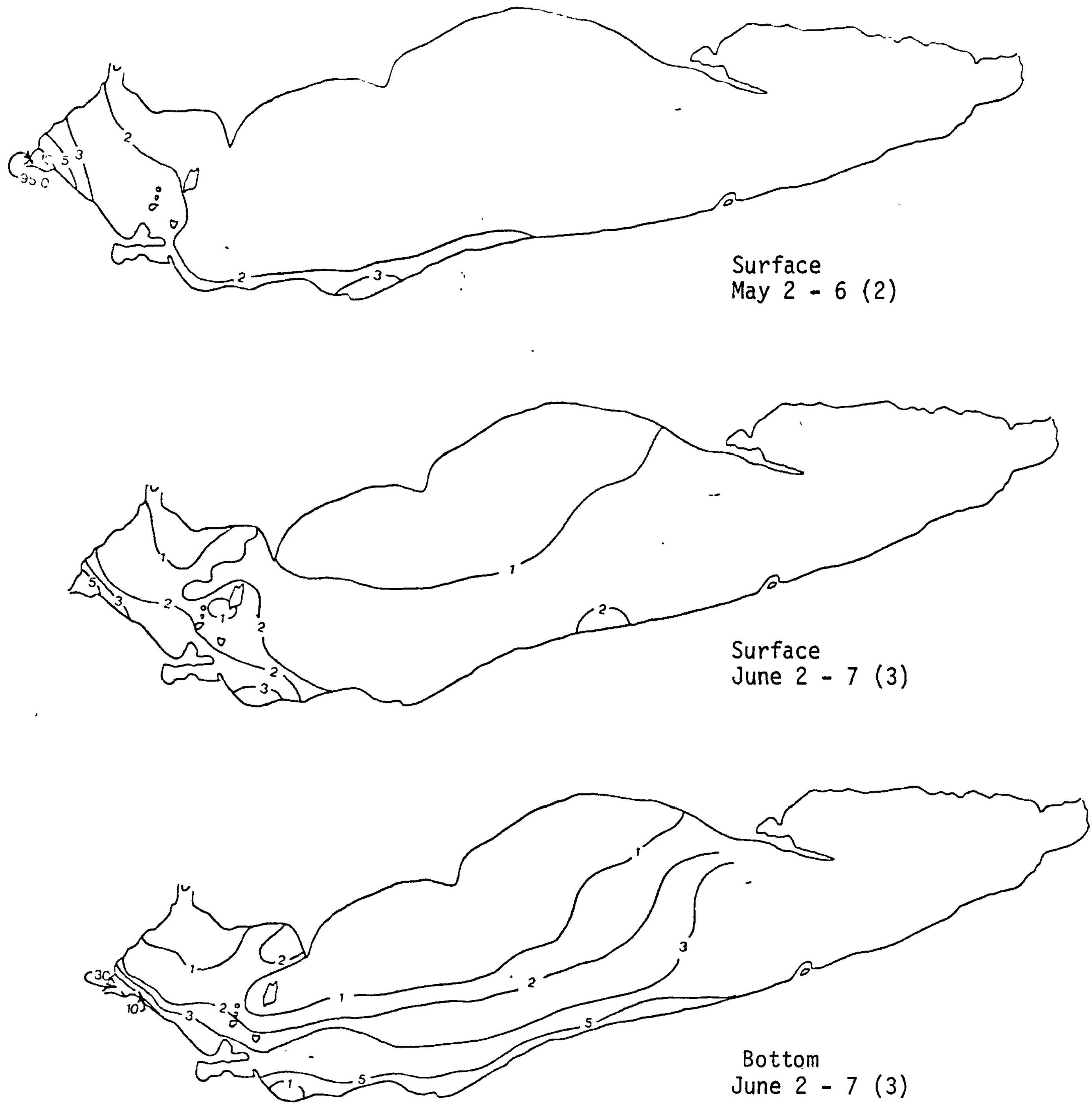


Figure 15. Limnion horizontal distribution maps for soluble reactive phosphorus (ug/l), 1981.

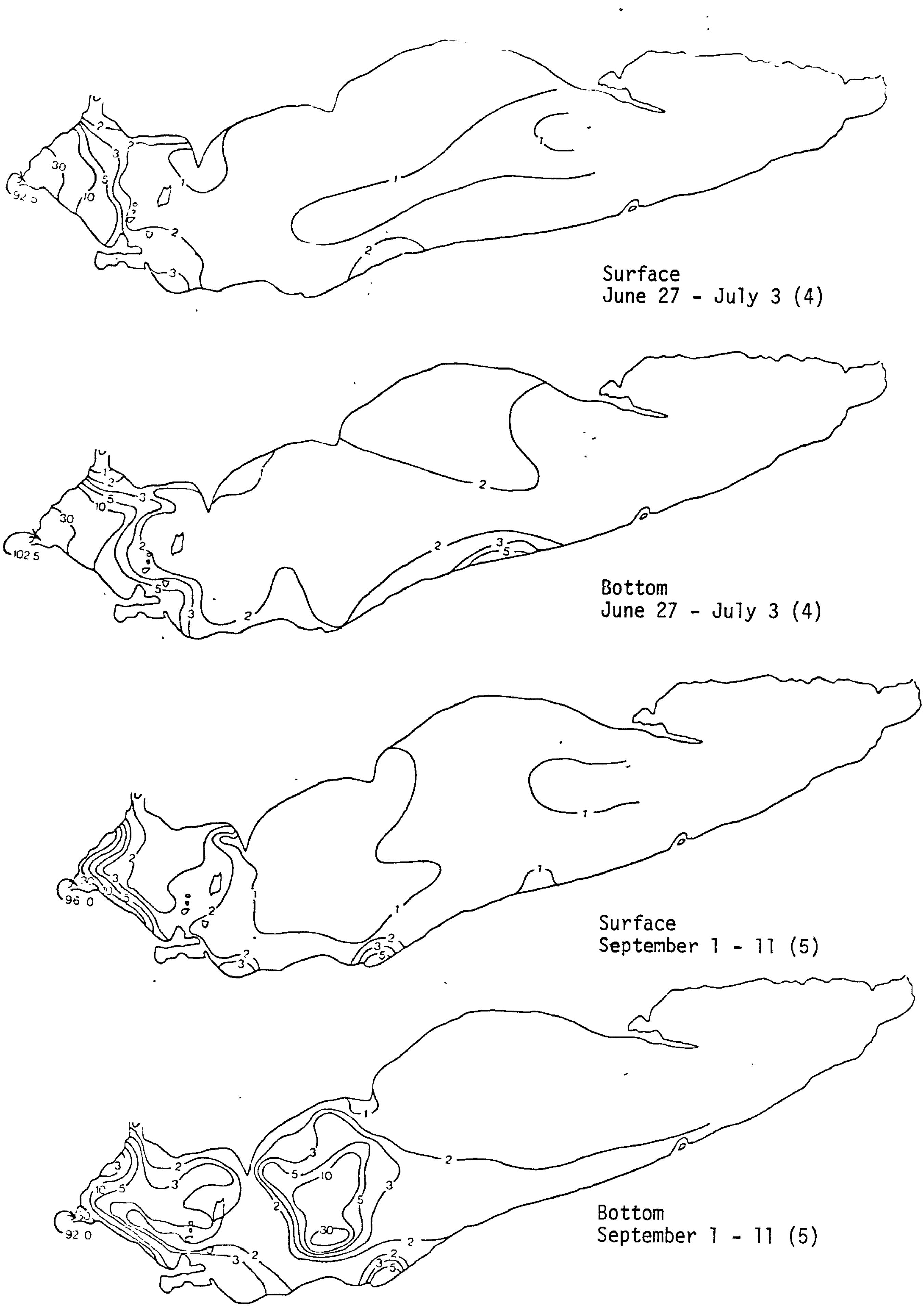


Figure 15 (continued). Limnion horizontal distribution maps for soluble reactive phosphorus (ug/l), 1981

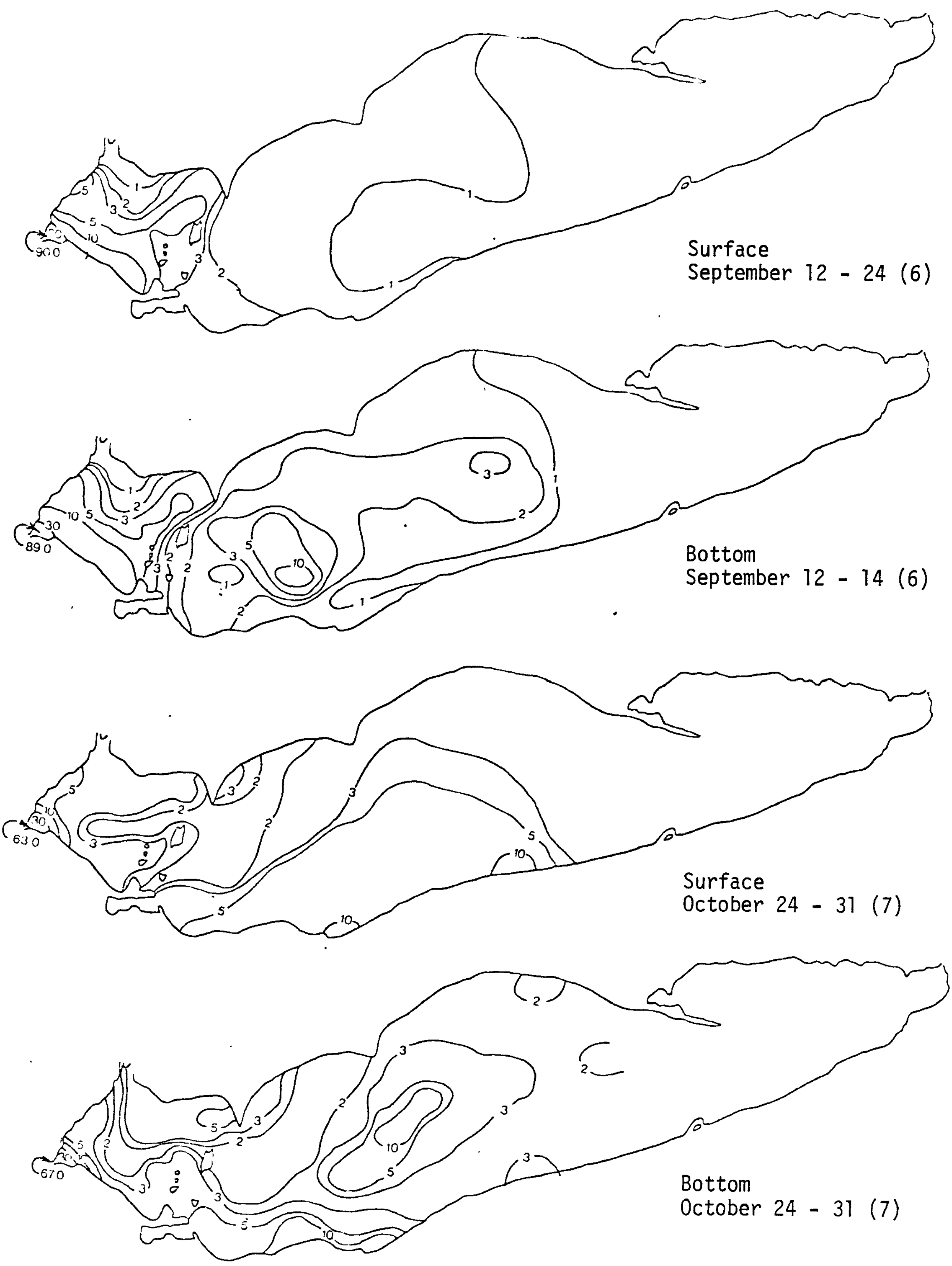
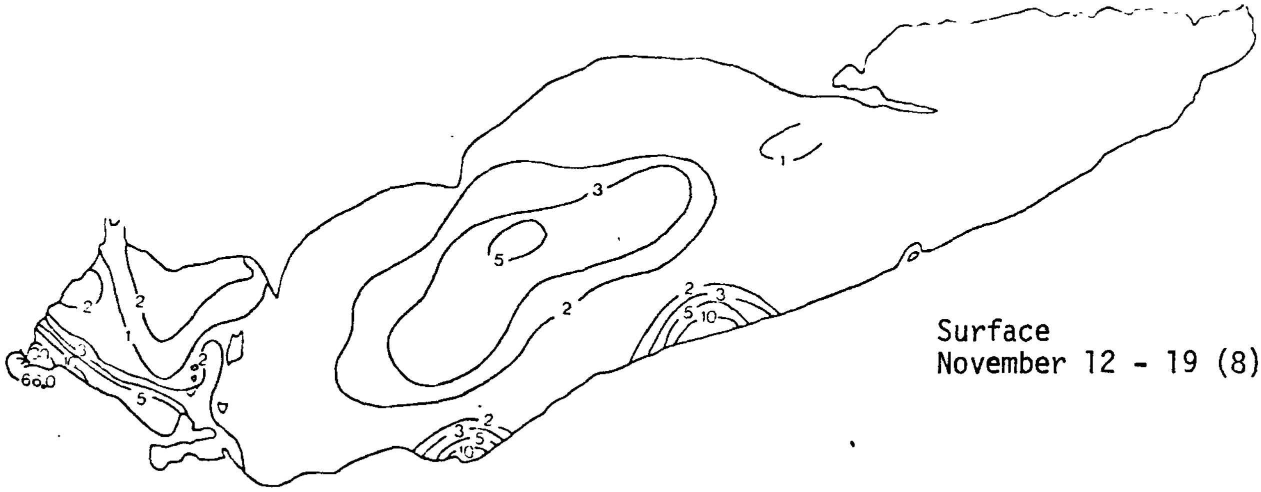
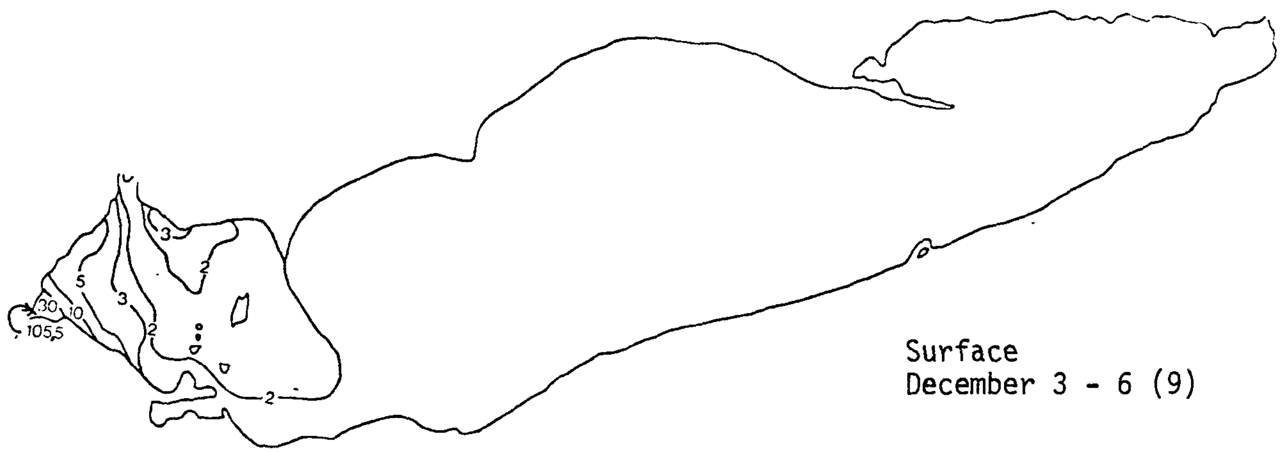


Figure 15 (continued). Limnion horizontal distribution maps for soluble reactive phosphorus (ug/l), 1981



Surface
November 12 - 19 (8)



Surface
December 3 - 6 (9)

Figure 15 (continued). Limnion horizontal distribution maps for soluble reactive phosphorus (ug/l), 1981.

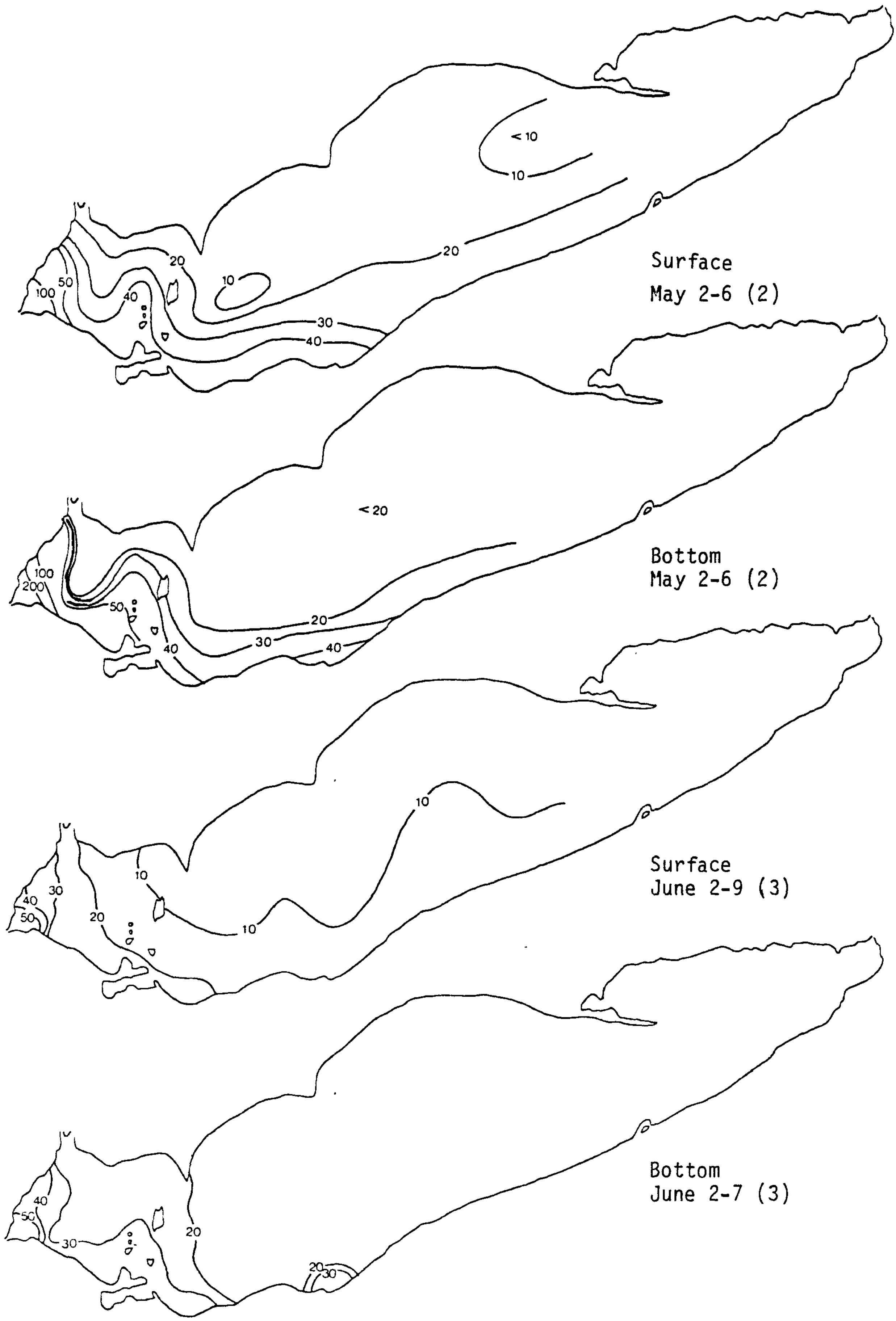


Figure 16. Limnion horizontal distribution maps for total phosphorus (ug/l), 1981.

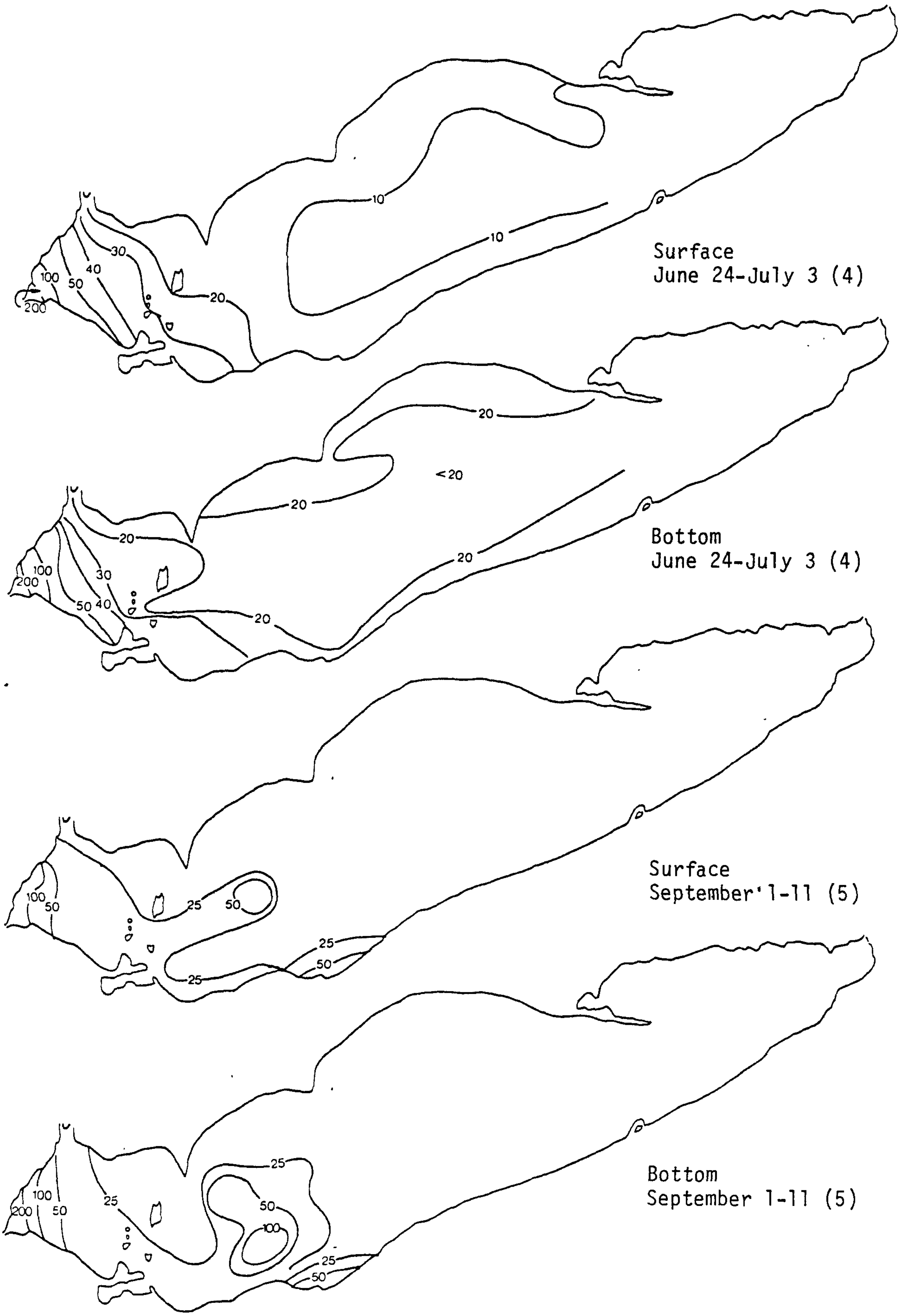


Figure 16 (continued). Limnion horizontal distribution maps for total phosphorus (ug/l), 1981.

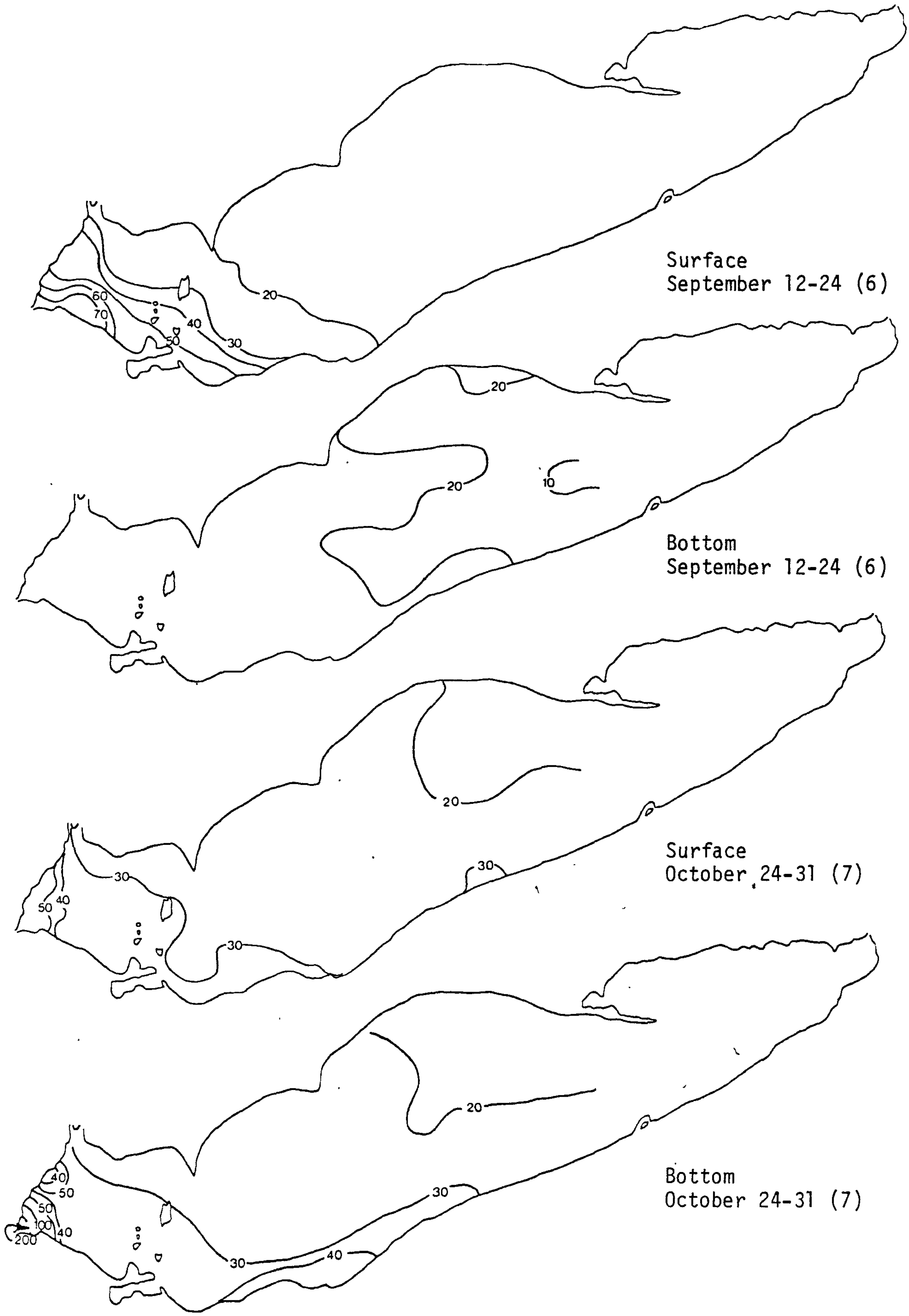


Figure 16 (continued). Limnion horizontal distribution maps for total phosphorus (ug/l), 1981.

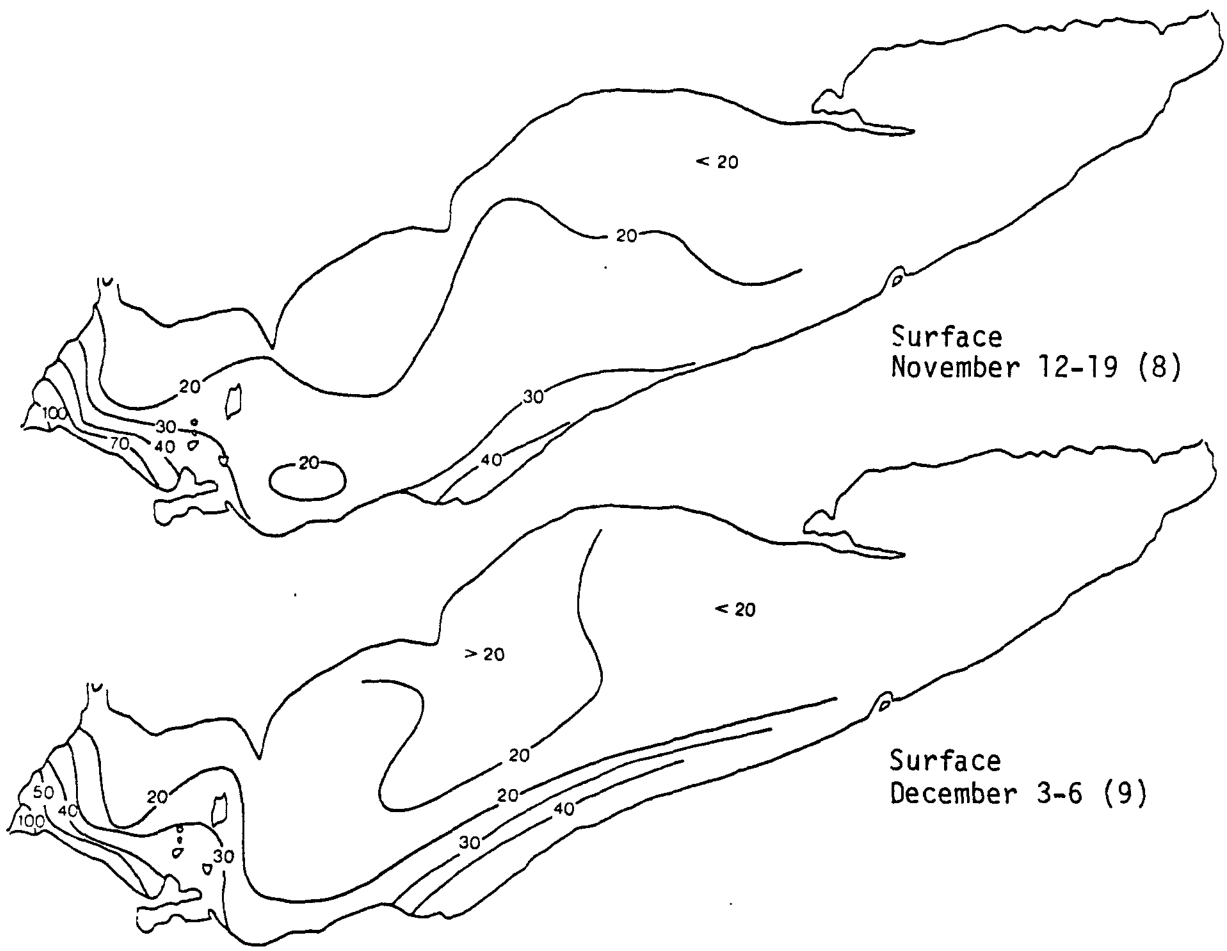


Figure 16 (continued). Limnion horizontal distribution maps for total phosphorus (ug/l), 1981.

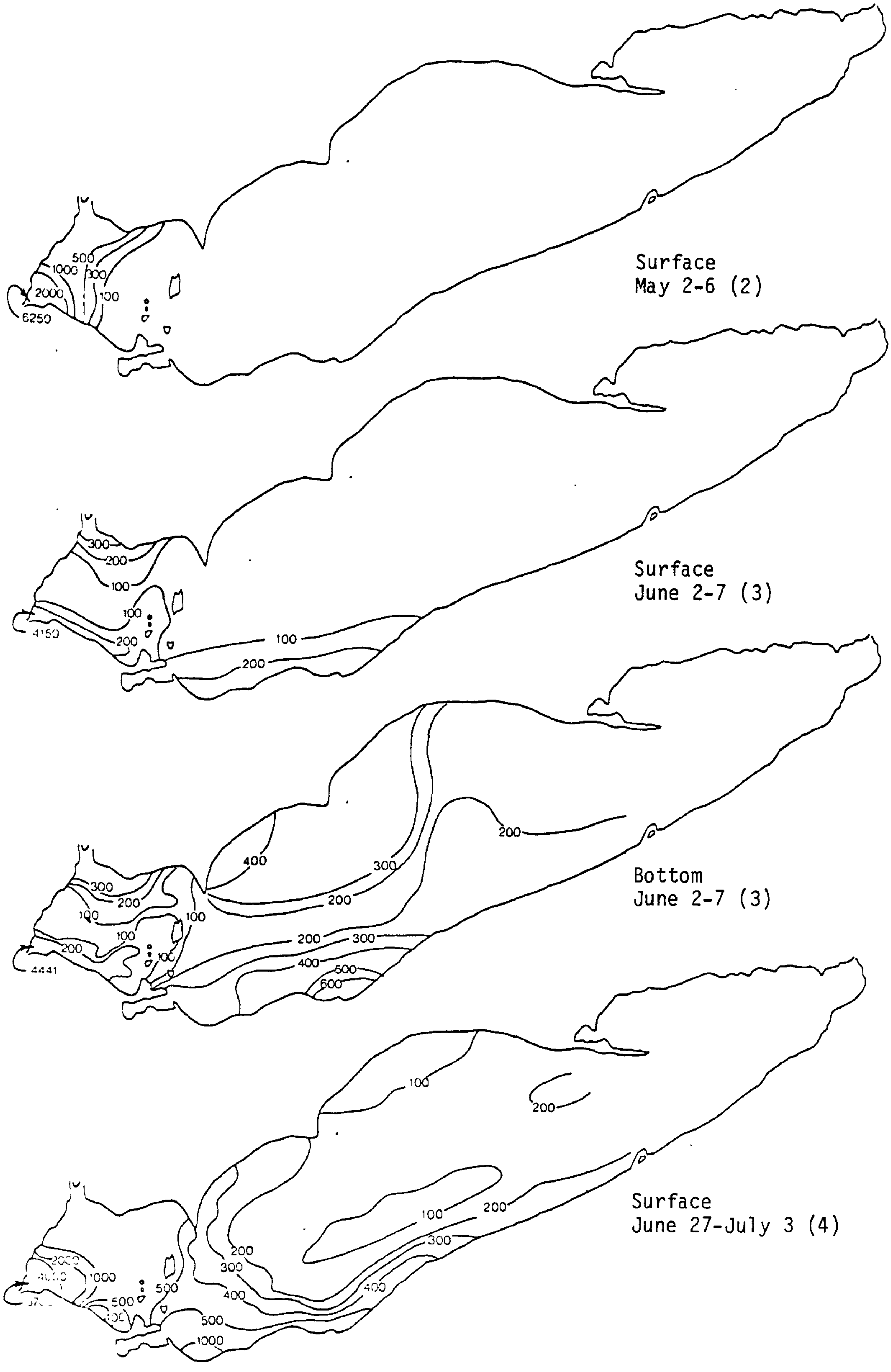


Figure 17. Limnion horizontal distribution maps for soluble reactive Silica (ug/l), 1981.

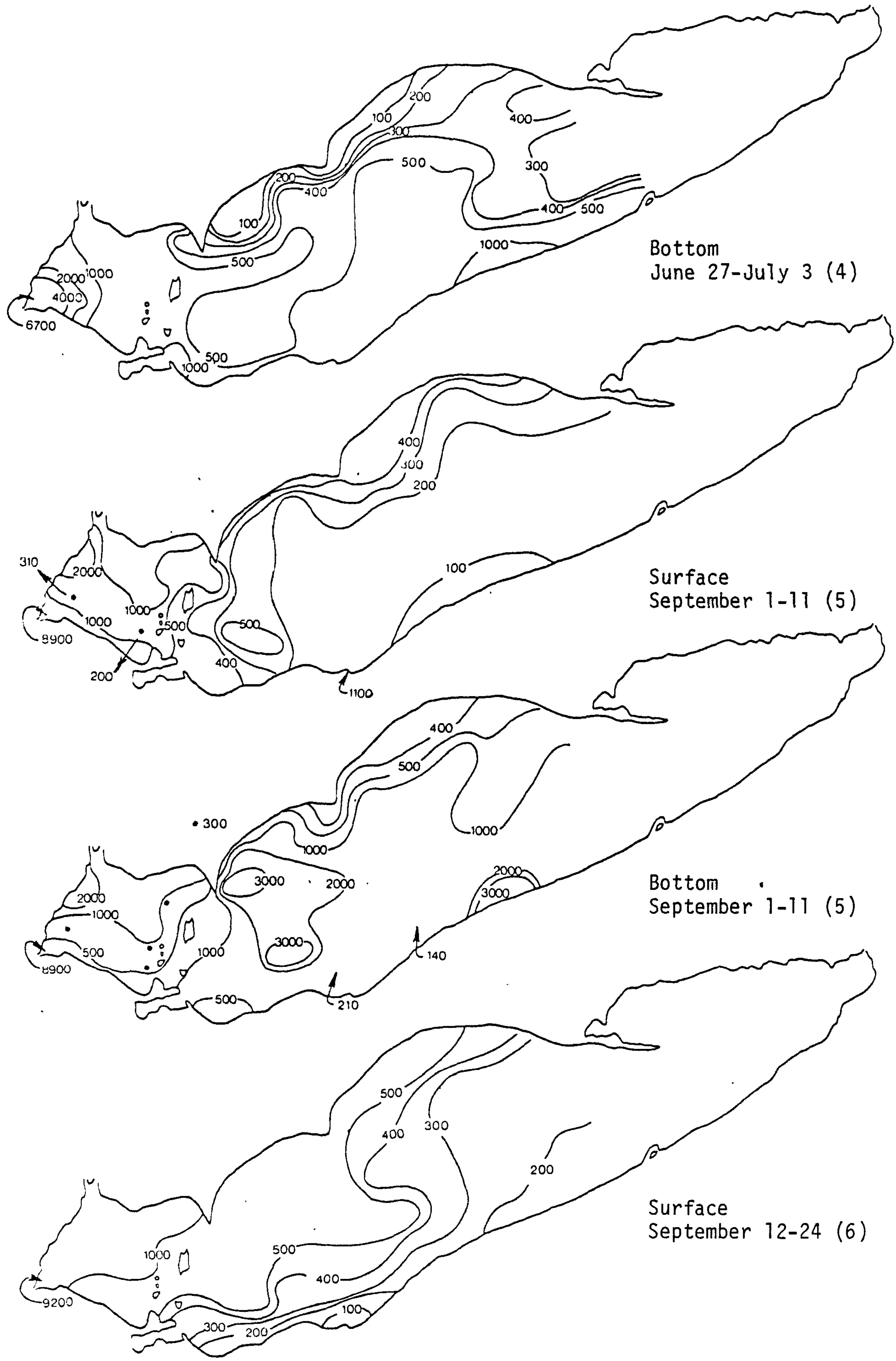


Figure 17 (continued). Limnion horizontal distribution maps for soluble reactive Silica (ug/l), 1981.

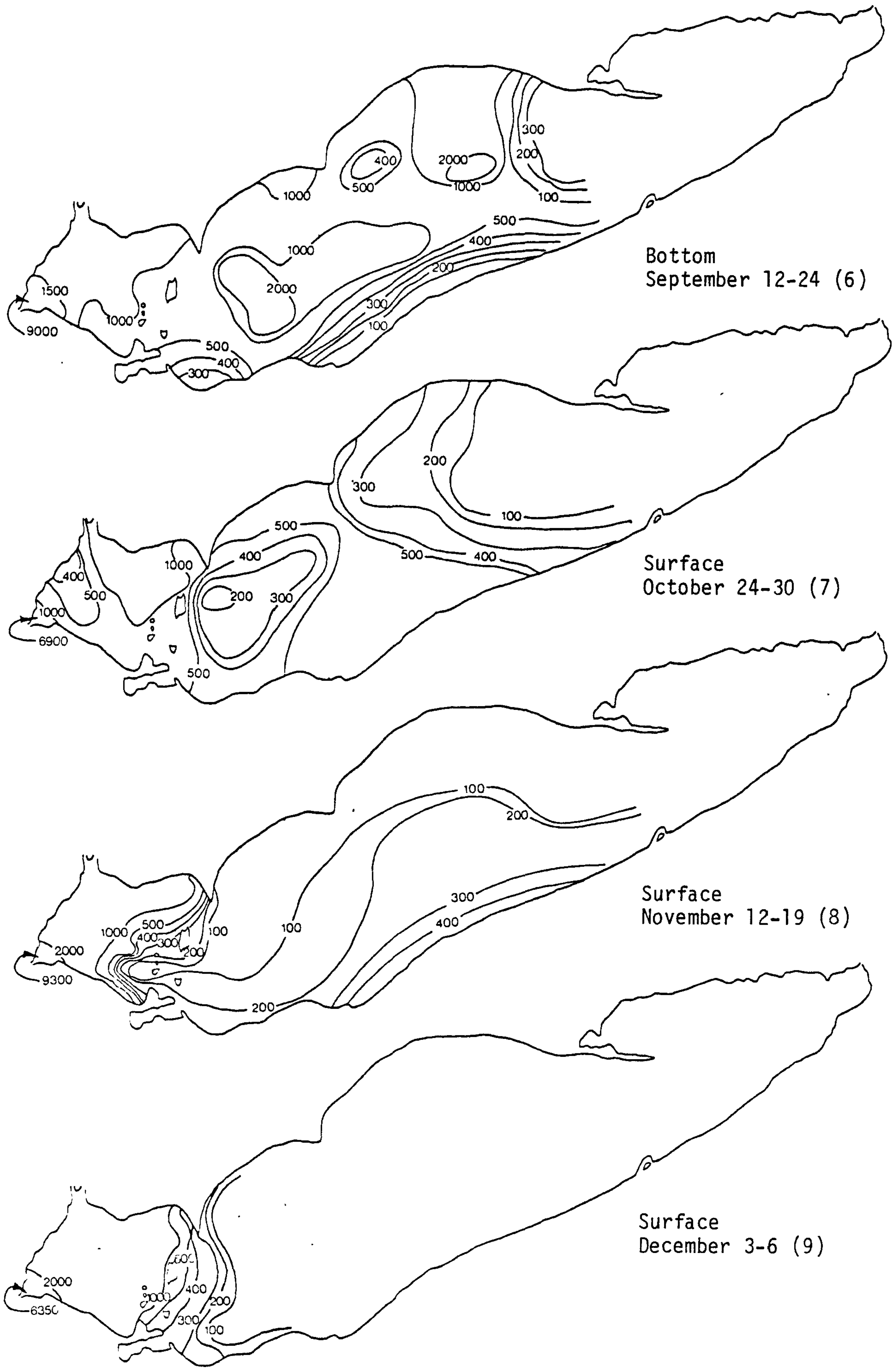
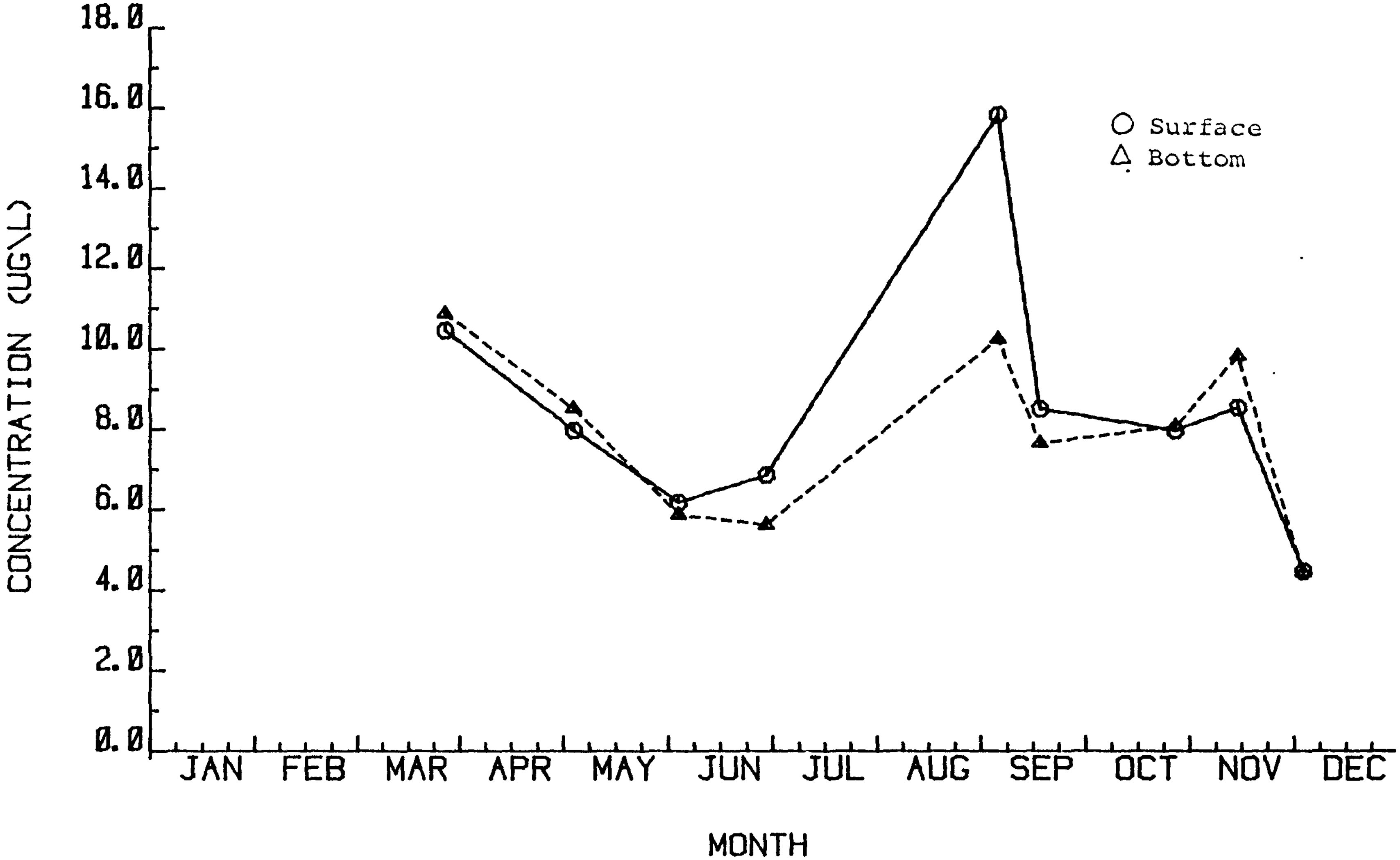


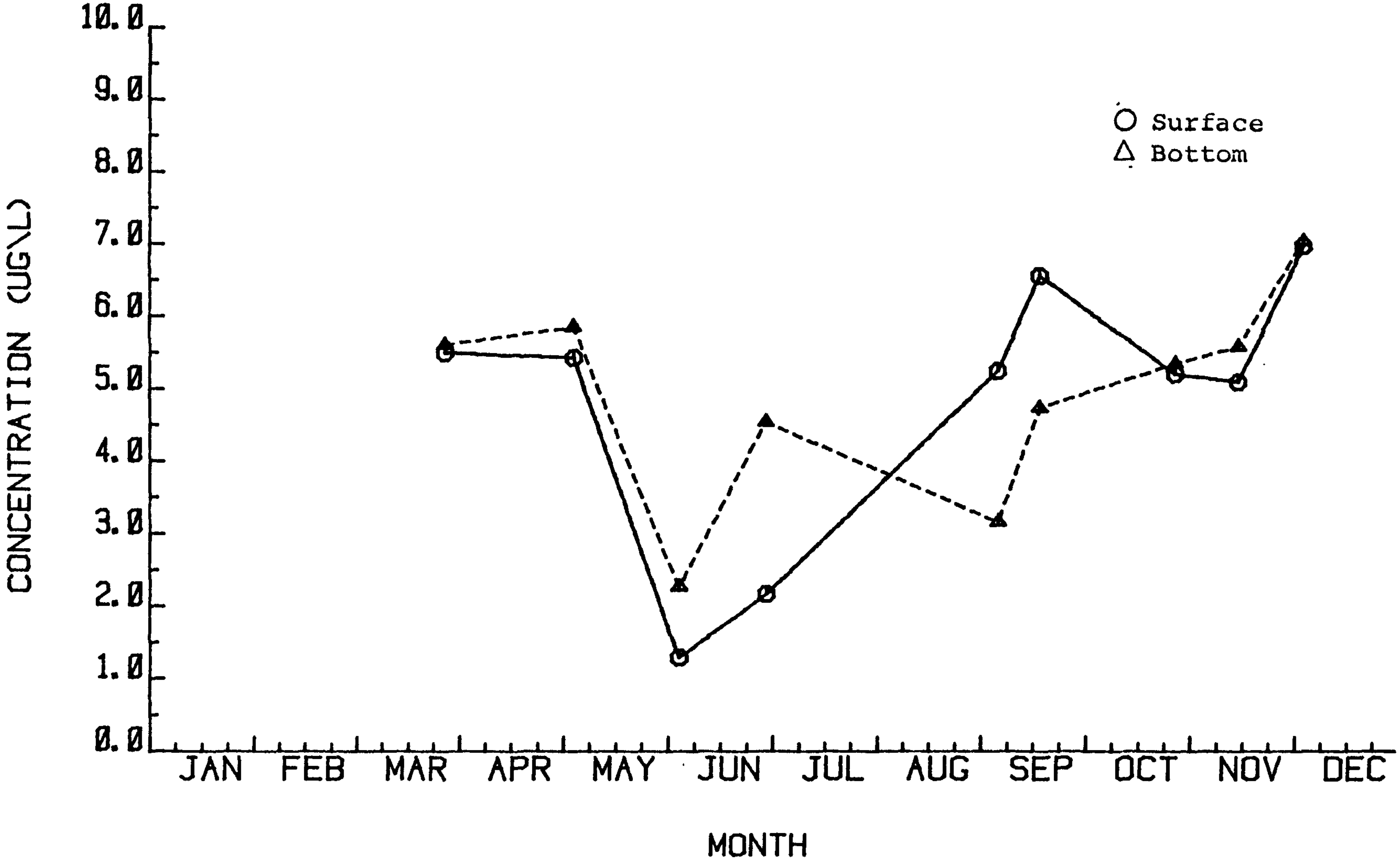
Figure 17 (continued). Limnion horizontal distribution maps for soluble reactive Silica (ug/l), 1981.



CORRECTED CHLOROPHYLL A

WESTERN BASIN 1981

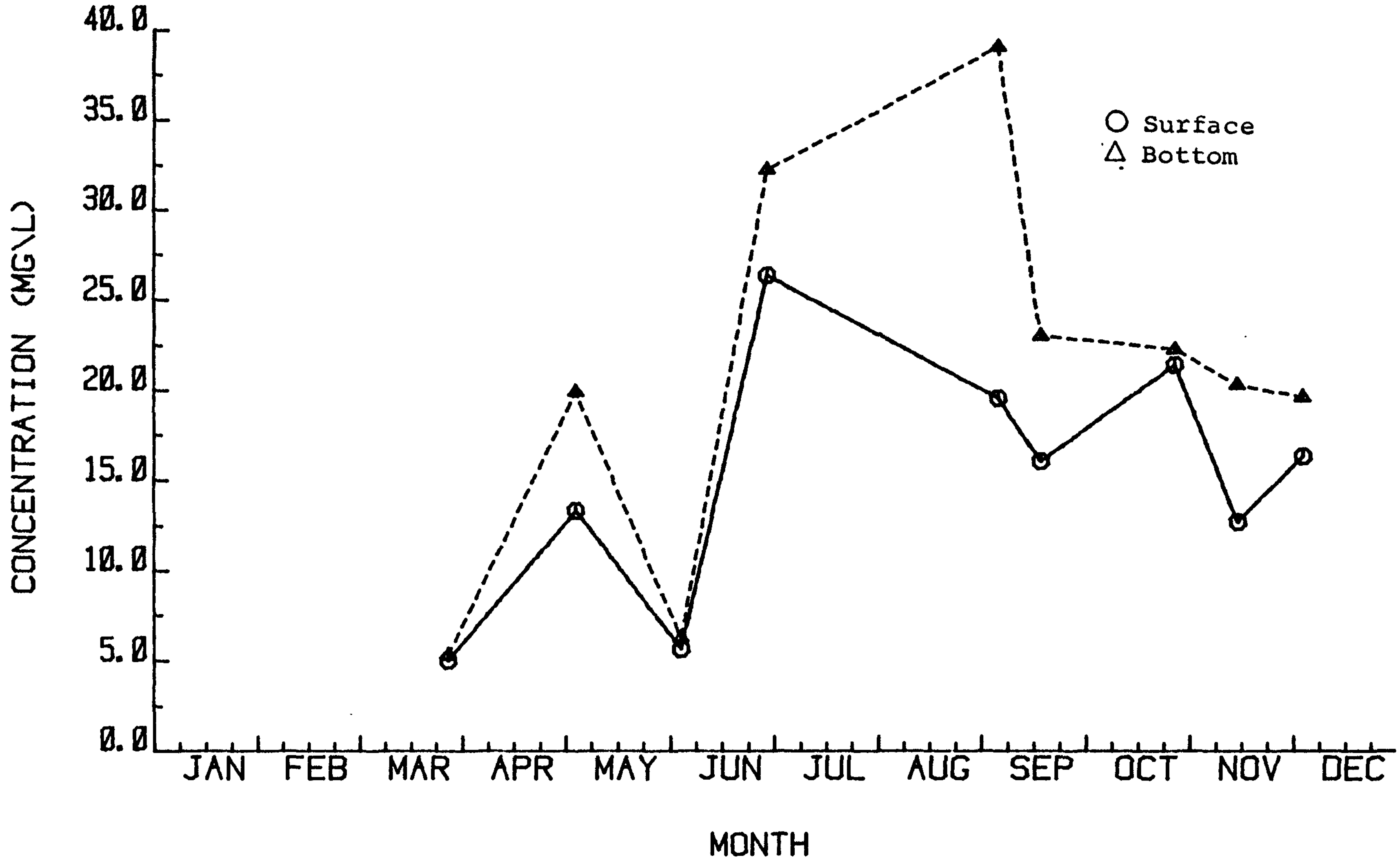
Figure 18



CORECTED CHLOROPHYLL A

CENTRAL BASIN 1981

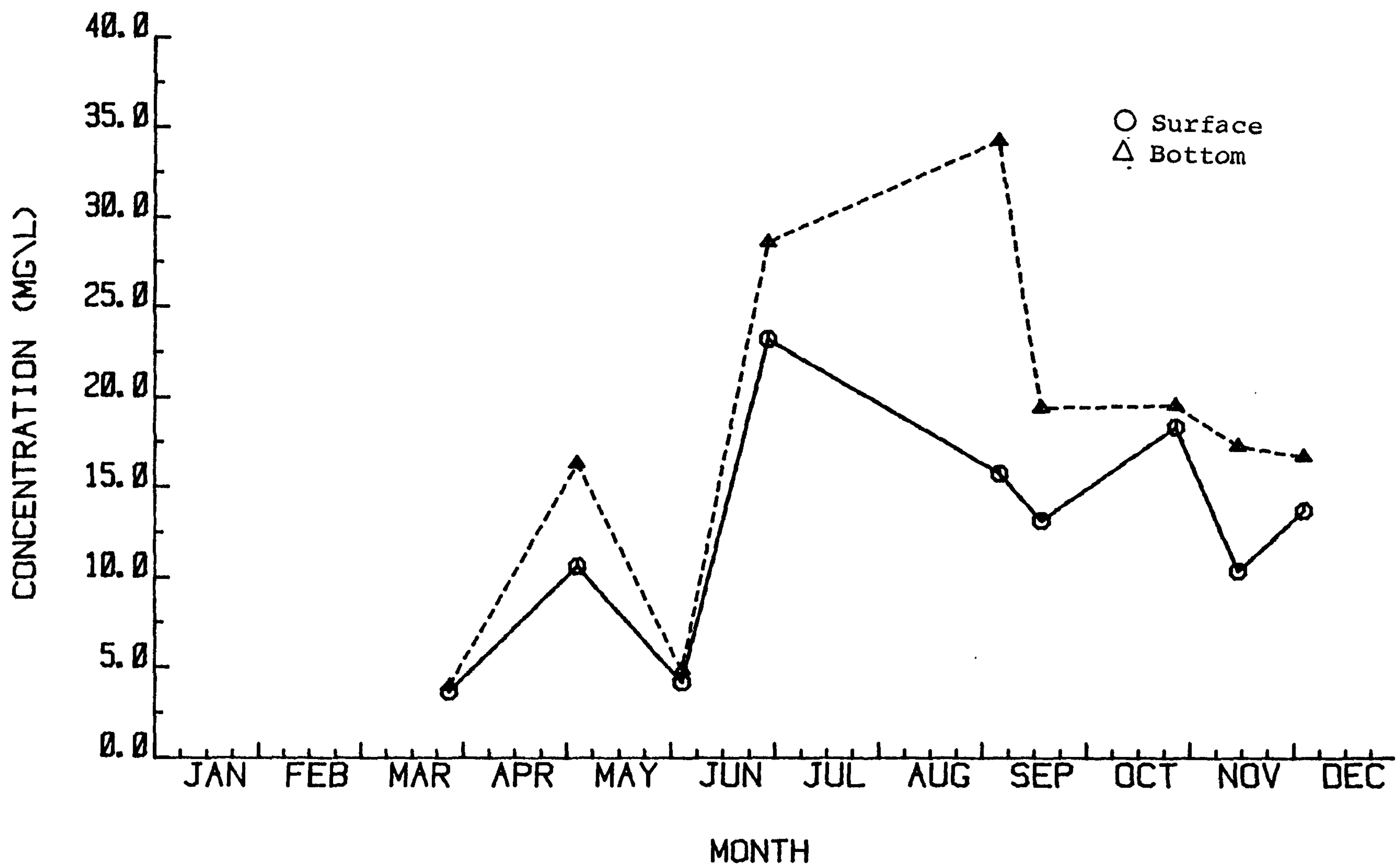
Figure 19



TOTAL SUSPENDED SOLIDS

WESTERN BASIN 1981

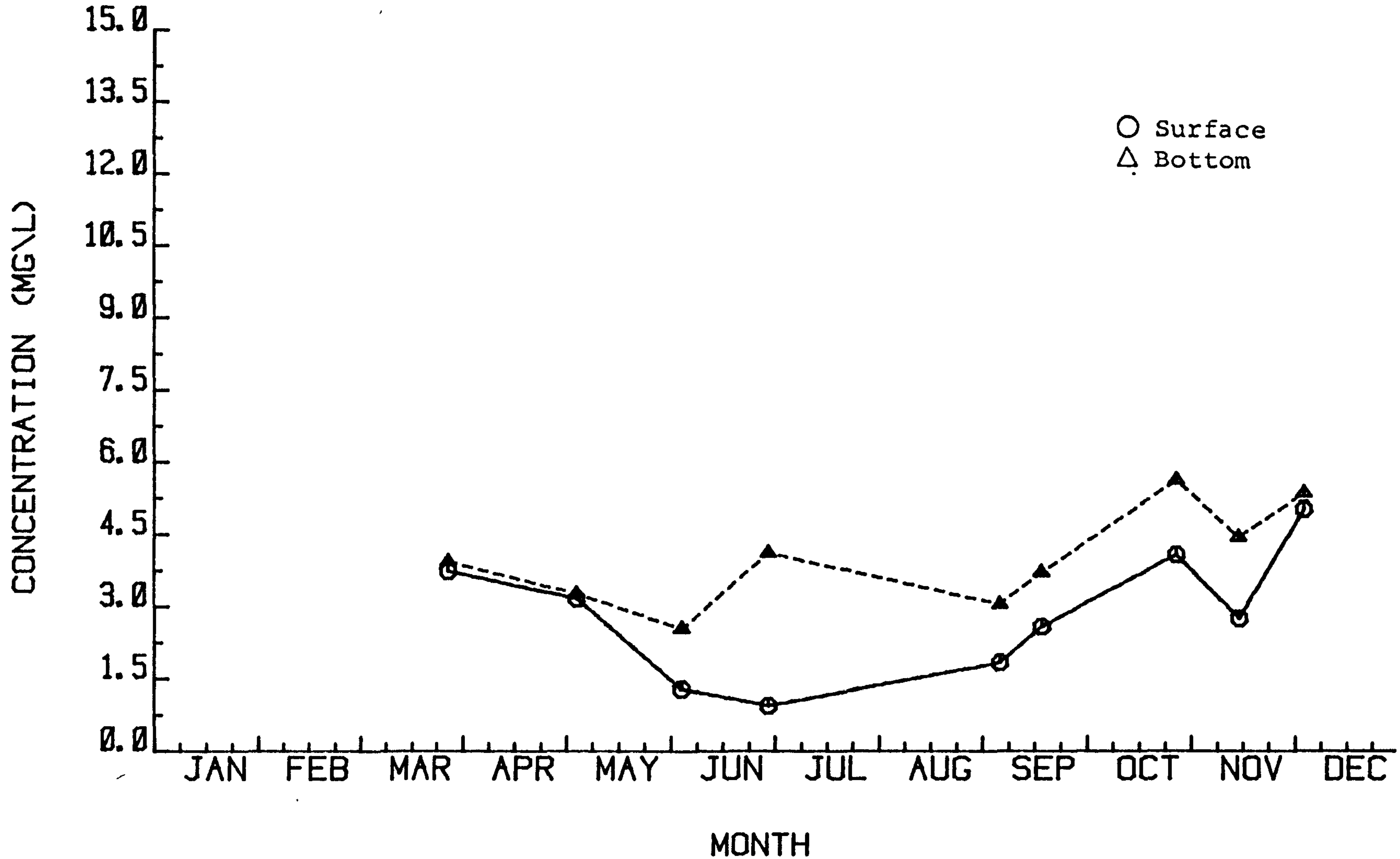
Figure 20



RESIDUAL SUSPENDED SOLIDS

WESTERN BASIN 1981

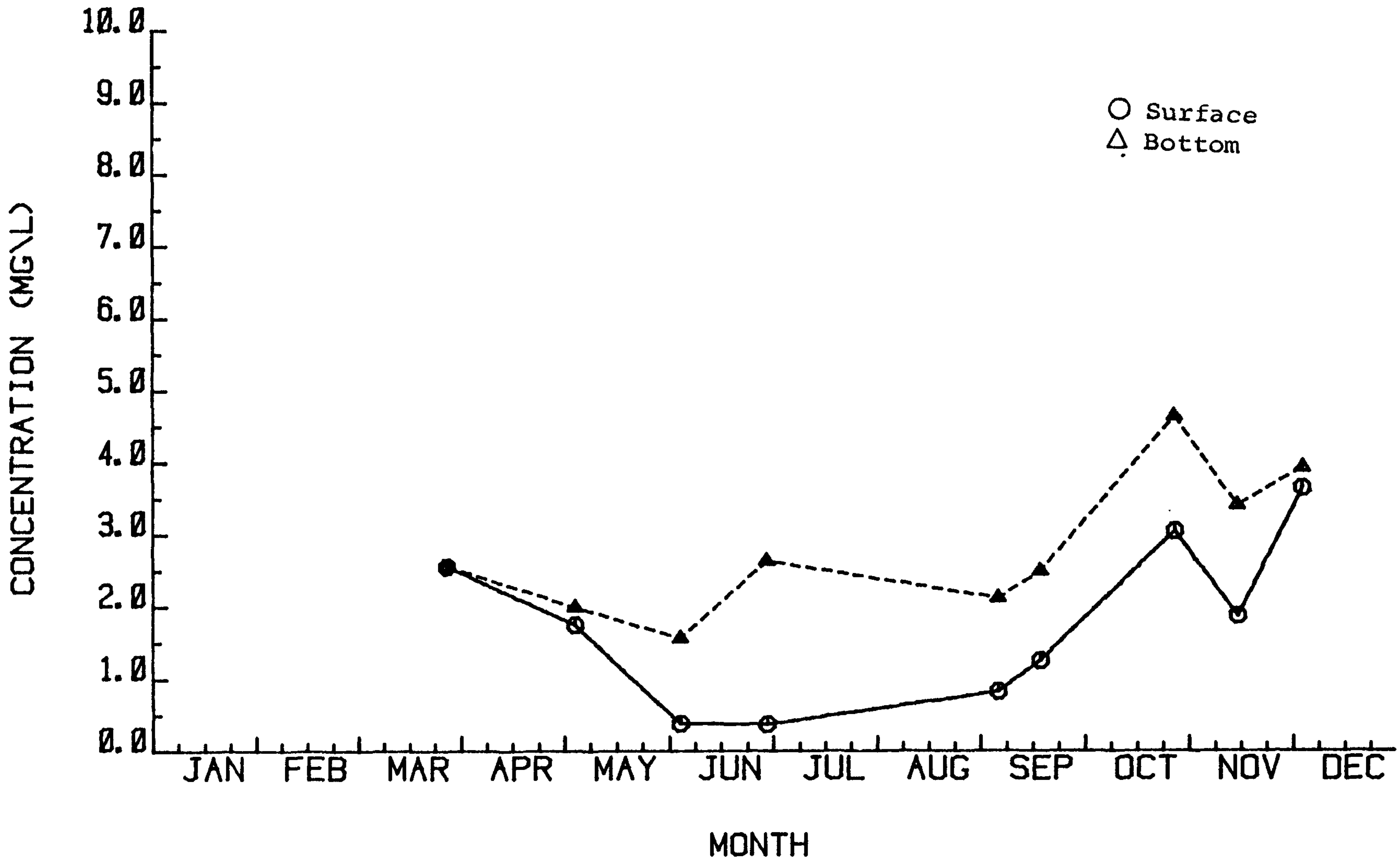
Figure 21



TOTAL SUSPENDED SOLIDS

CENTRAL BASIN 1981

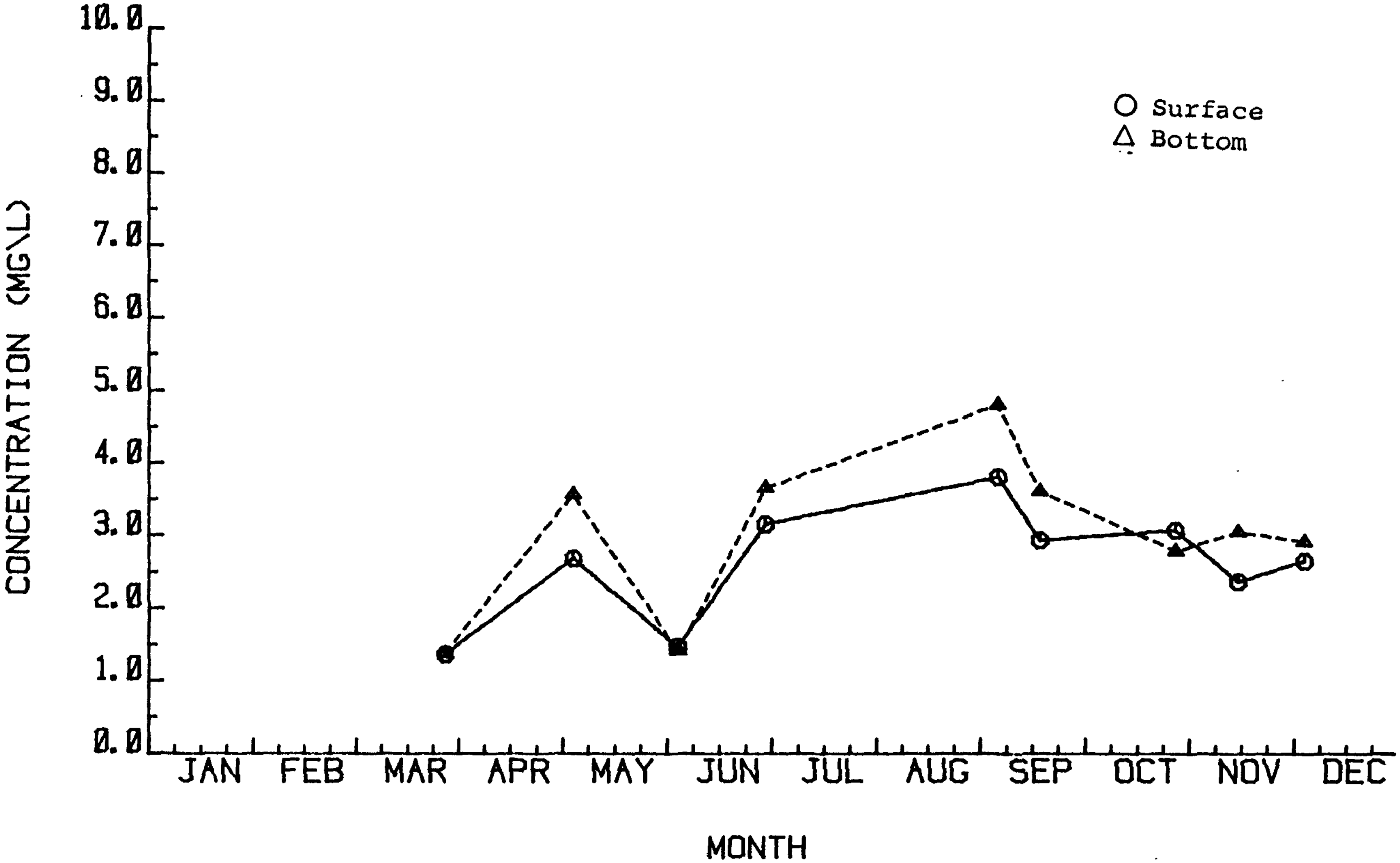
Figure 22



RESIDUAL SUSPENDED SOLIDS

CENTRAL BASIN 1981

Figure 23



VOLATILE SUSPENDED SOLIDS

WESTERN BASIN 1981

Figure 24

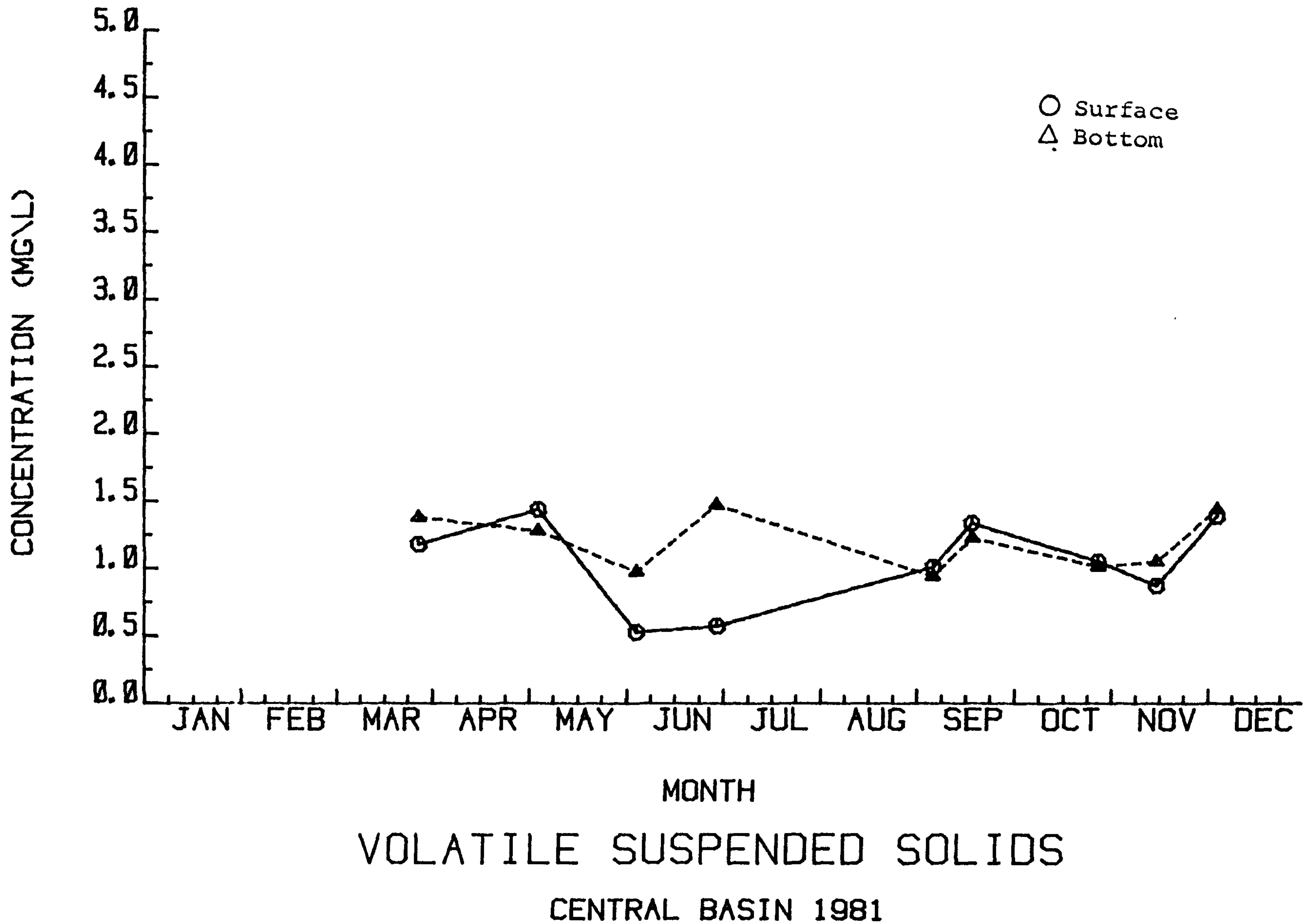
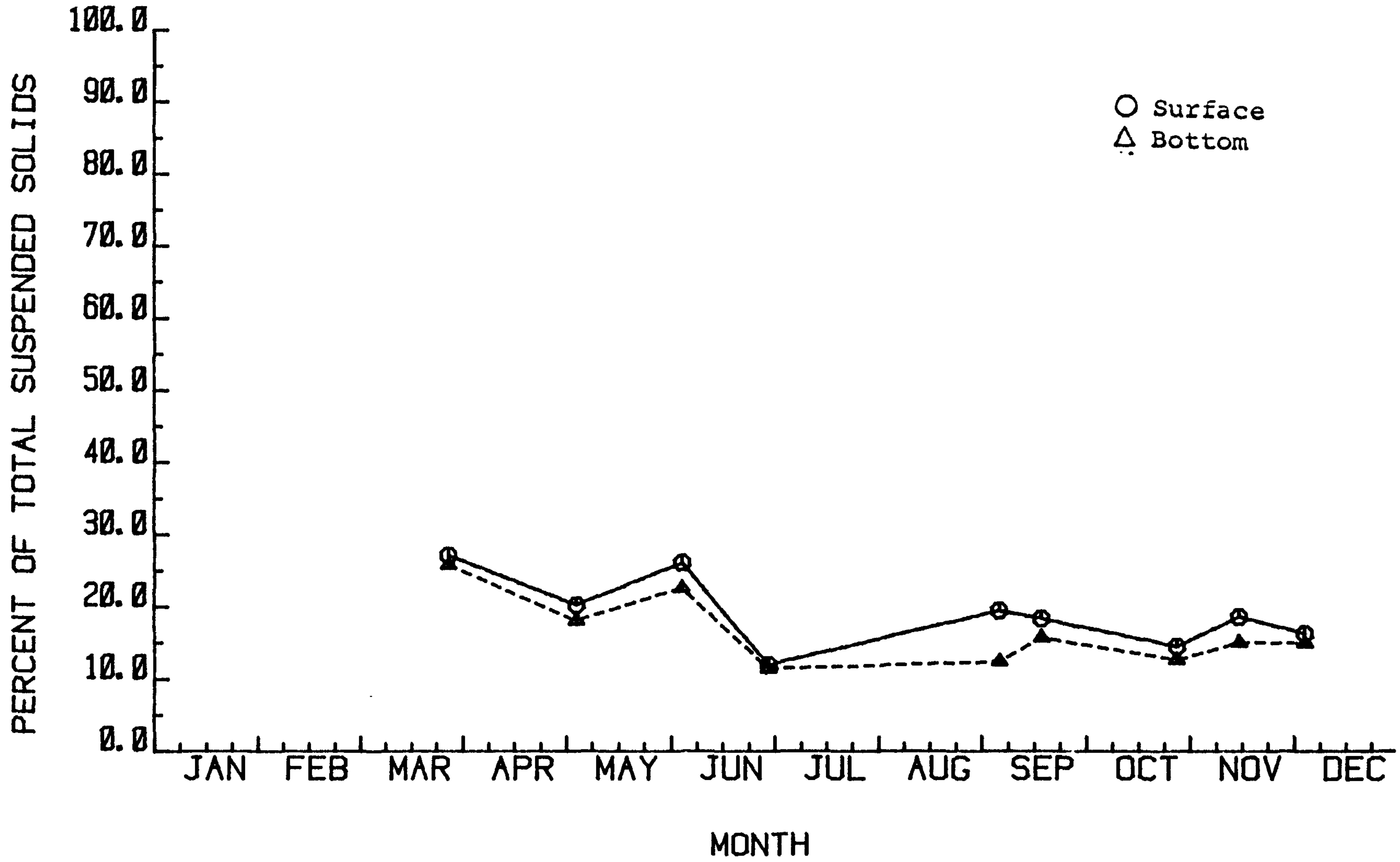

5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CONCENTRATION (MG\L)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH
VOLATILE SUSPENDED SOLIDS
CENTRAL BASIN 1981
Surface
Bottom

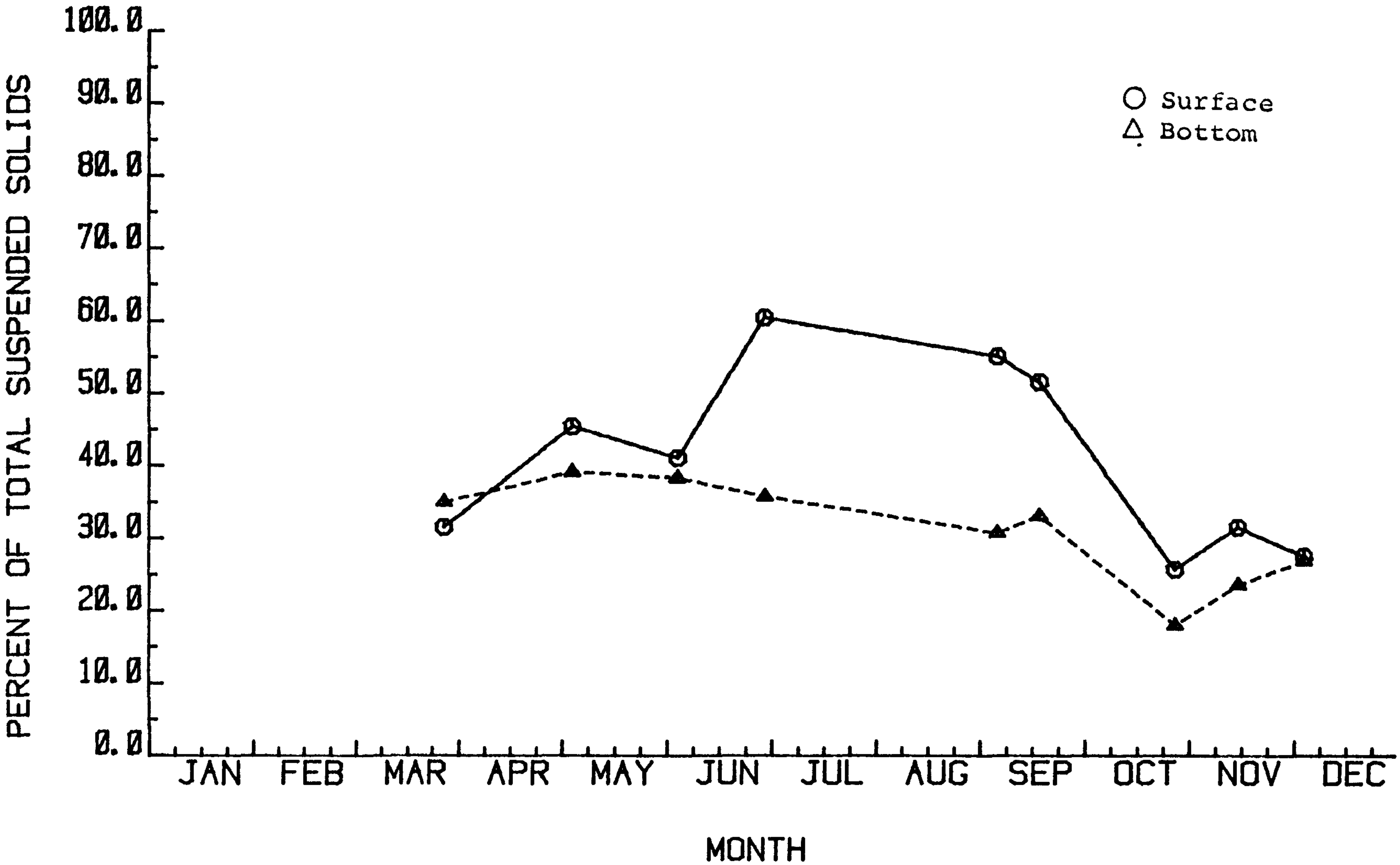
Figure 25



% VOLATILE SUSPENDED SOLIDS

WESTERN BASIN 1981

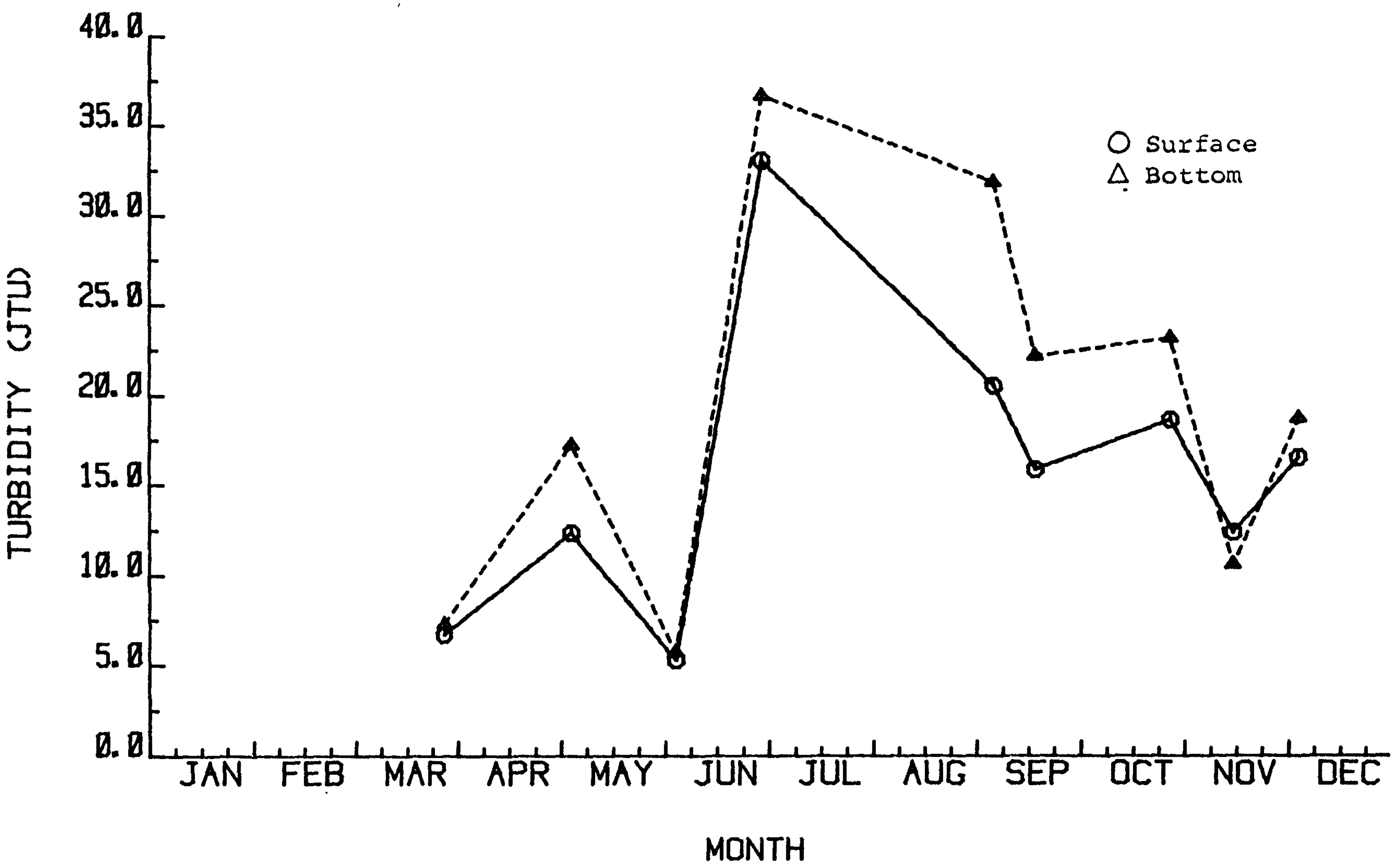
Figure 26



% VOLATILE SUSPENDED SOLIDS

CENTRAL BASIN 1981

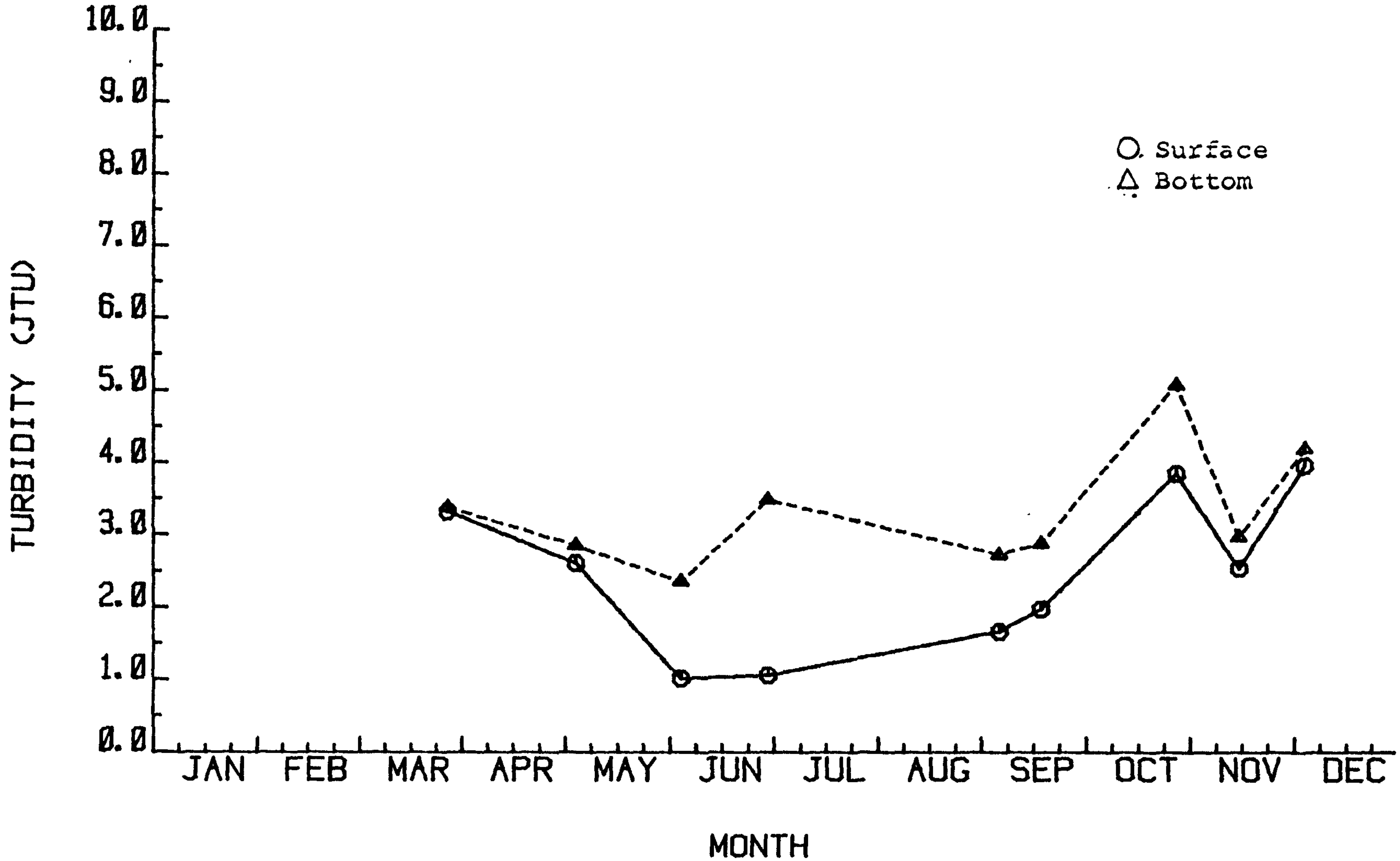
Figure 27



TURBIDITY

WESTERN BASIN 1981

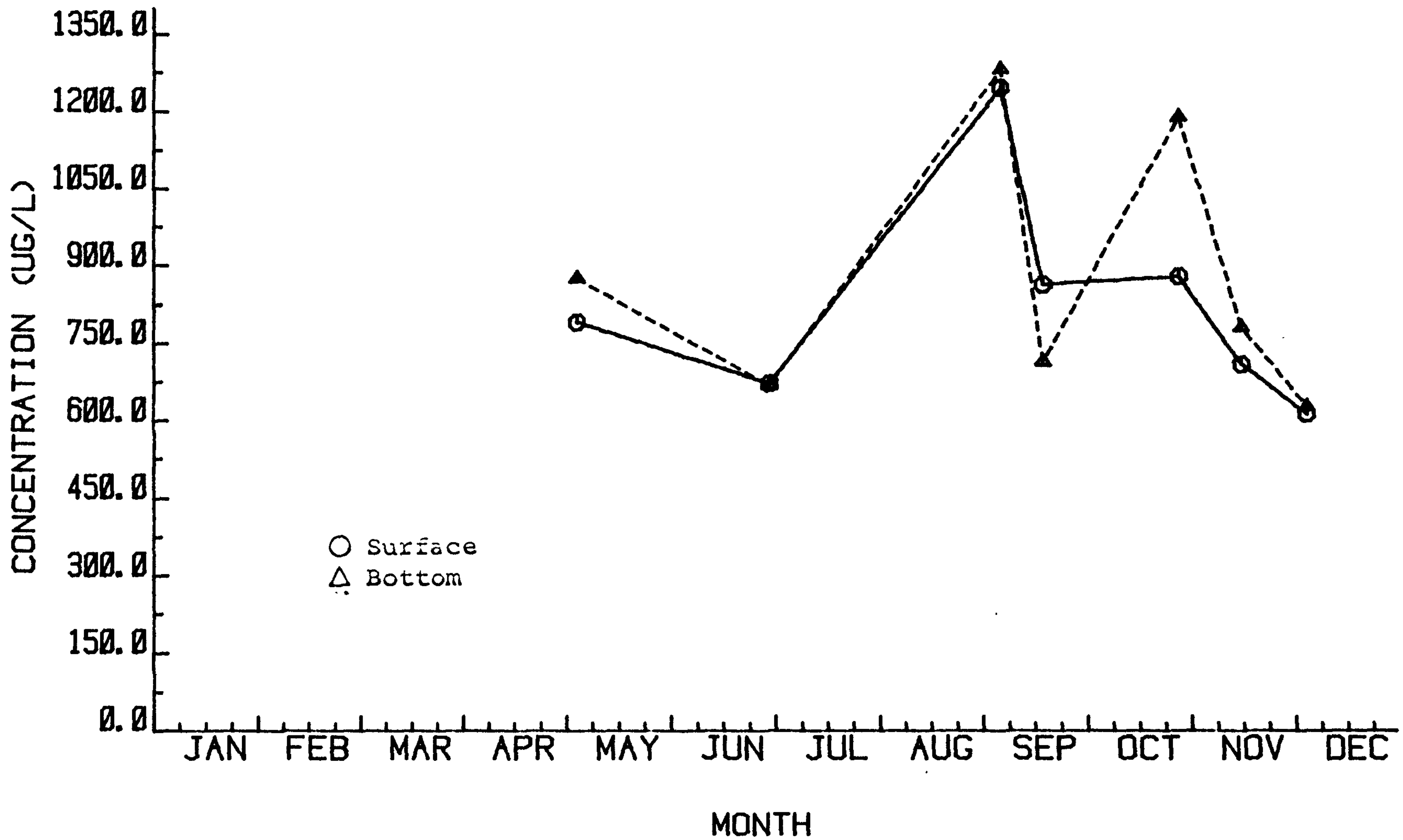
Figure 28



TURBIDITY

CENTRAL BASIN 1981

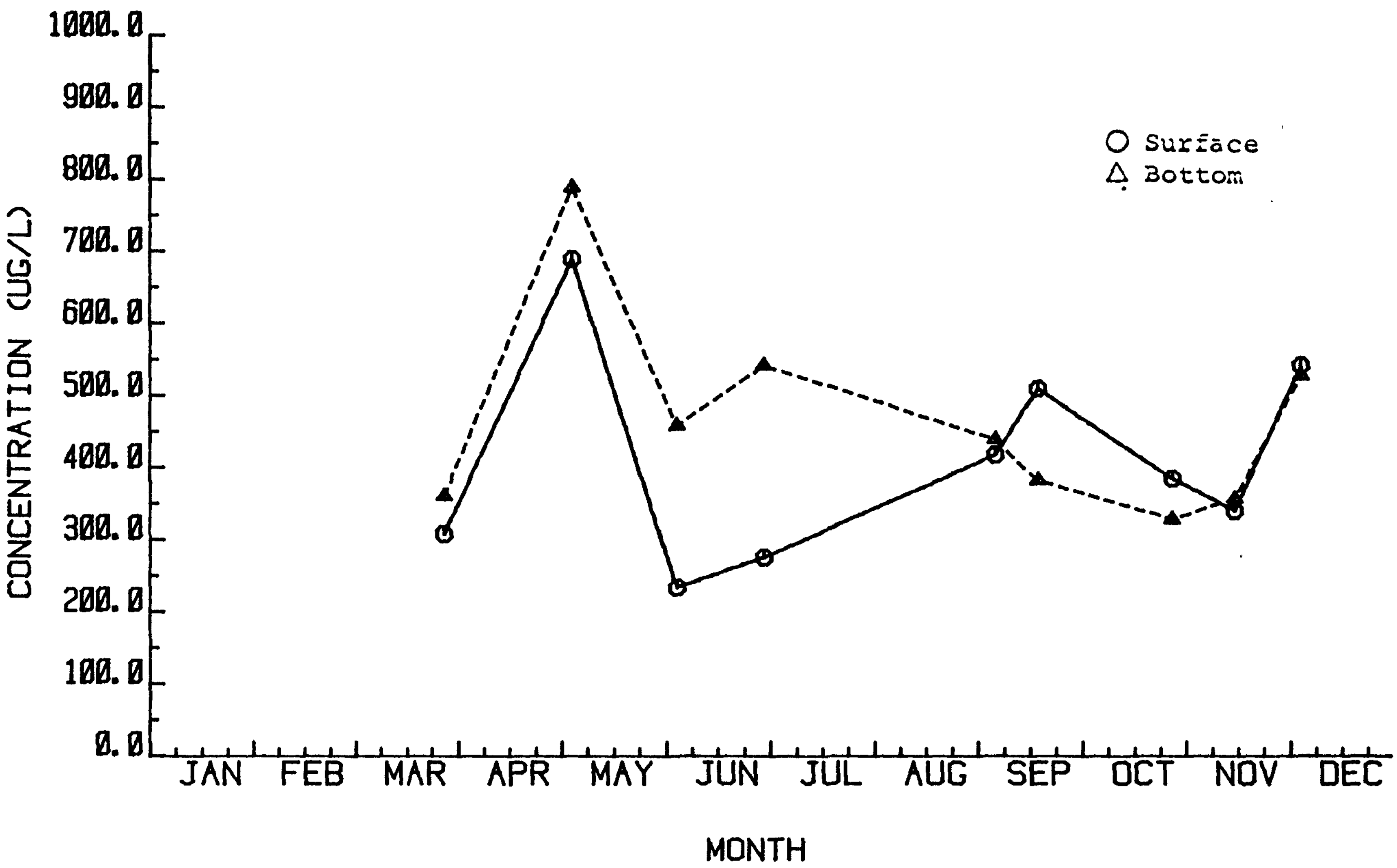
Figure 29



PARTICULATE ORGANIC CARBON

WESTERN BASIN 1981

Figure 30



PARTICULATE ORGANIC CARBON

CENTRAL BASIN 1981

Figure 31

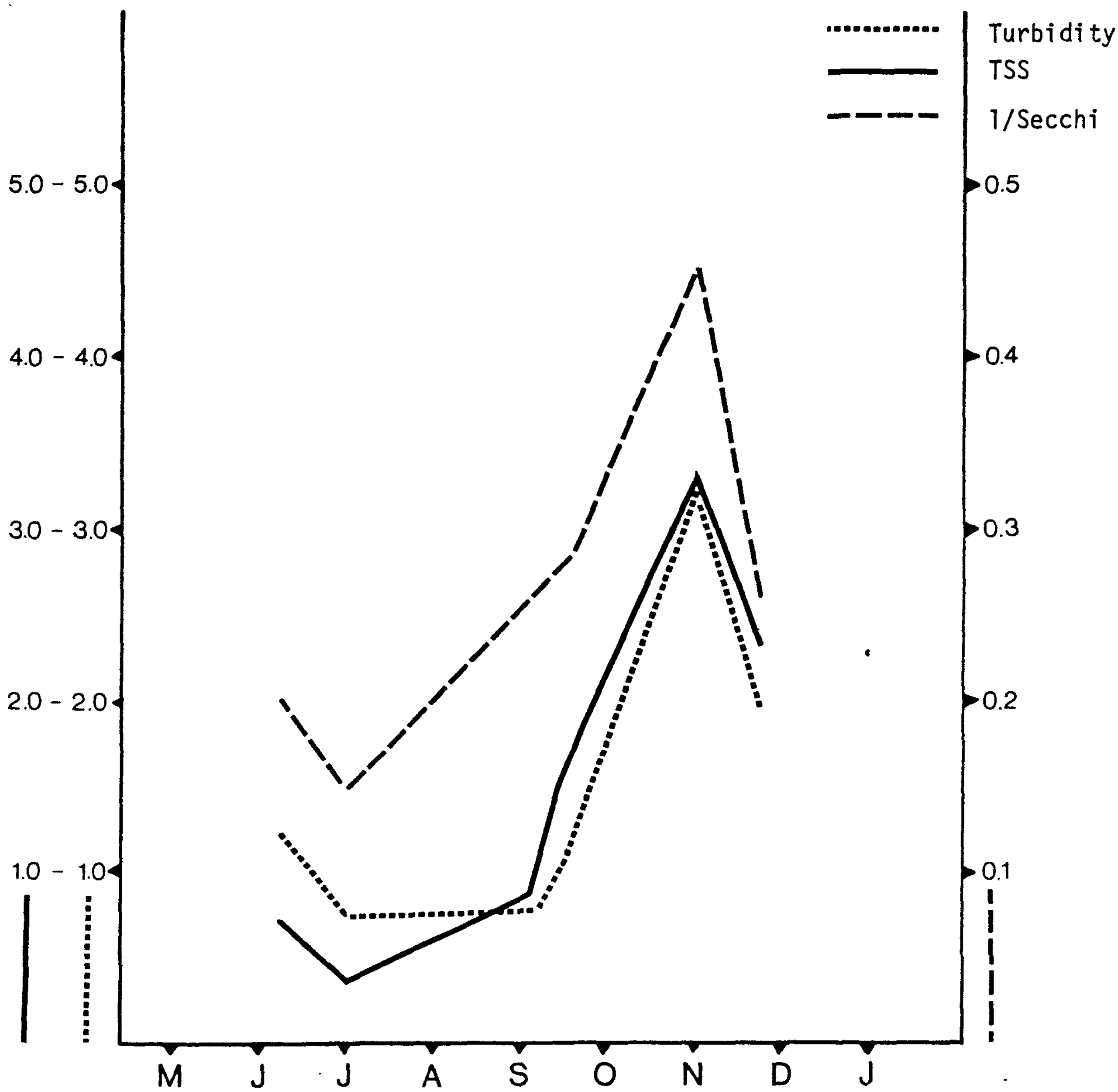


Figure 32. Station 037, 1981. Surface concentrations of Total Suspended Solids, Turbidity and reciprocal of Secchi.

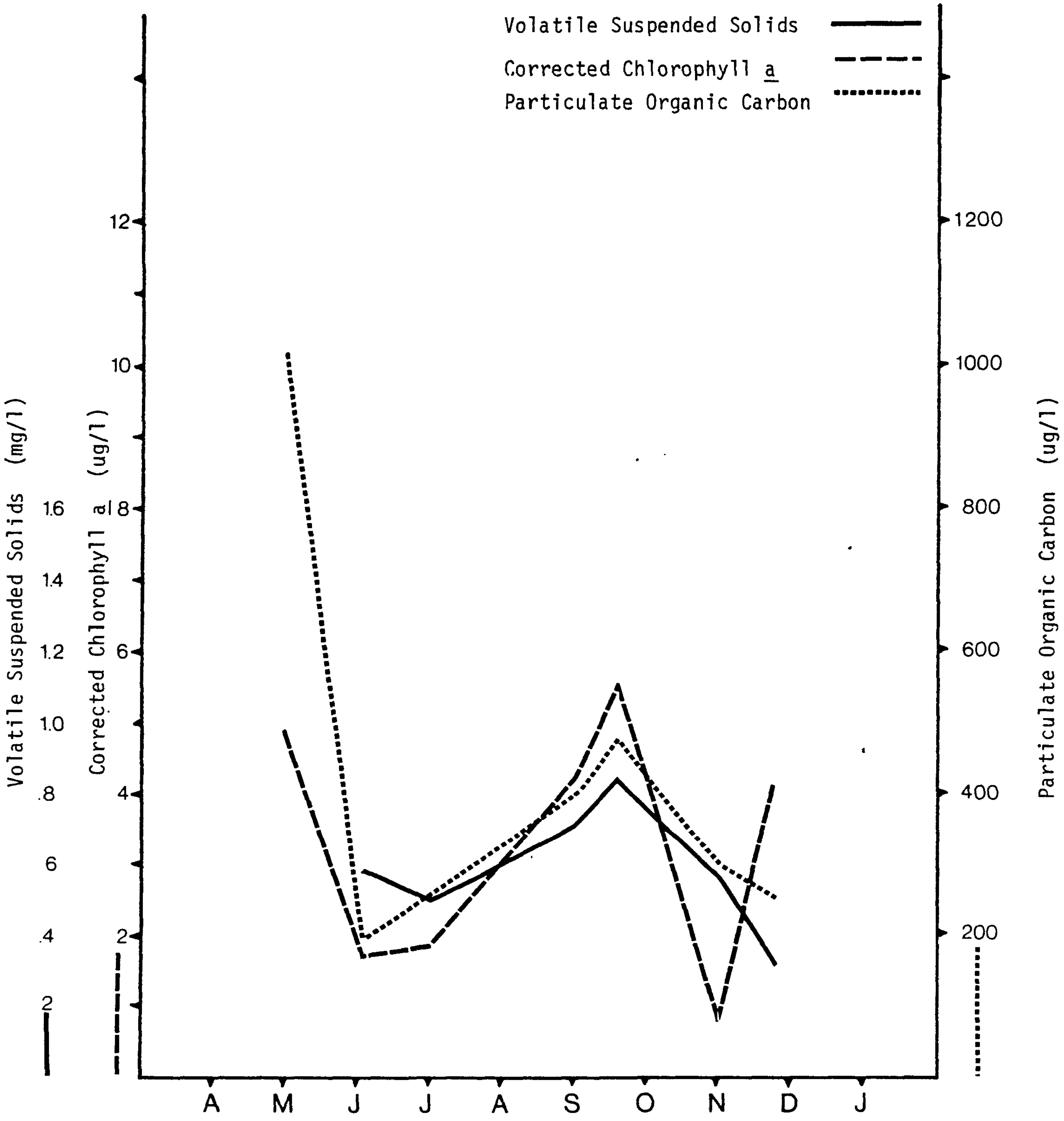


Figure 33. Station 037, 1981. Surface concentrations of Volatile Suspended Solids, Particulate Organic Carbon, and Corrected Chlorophyll a.

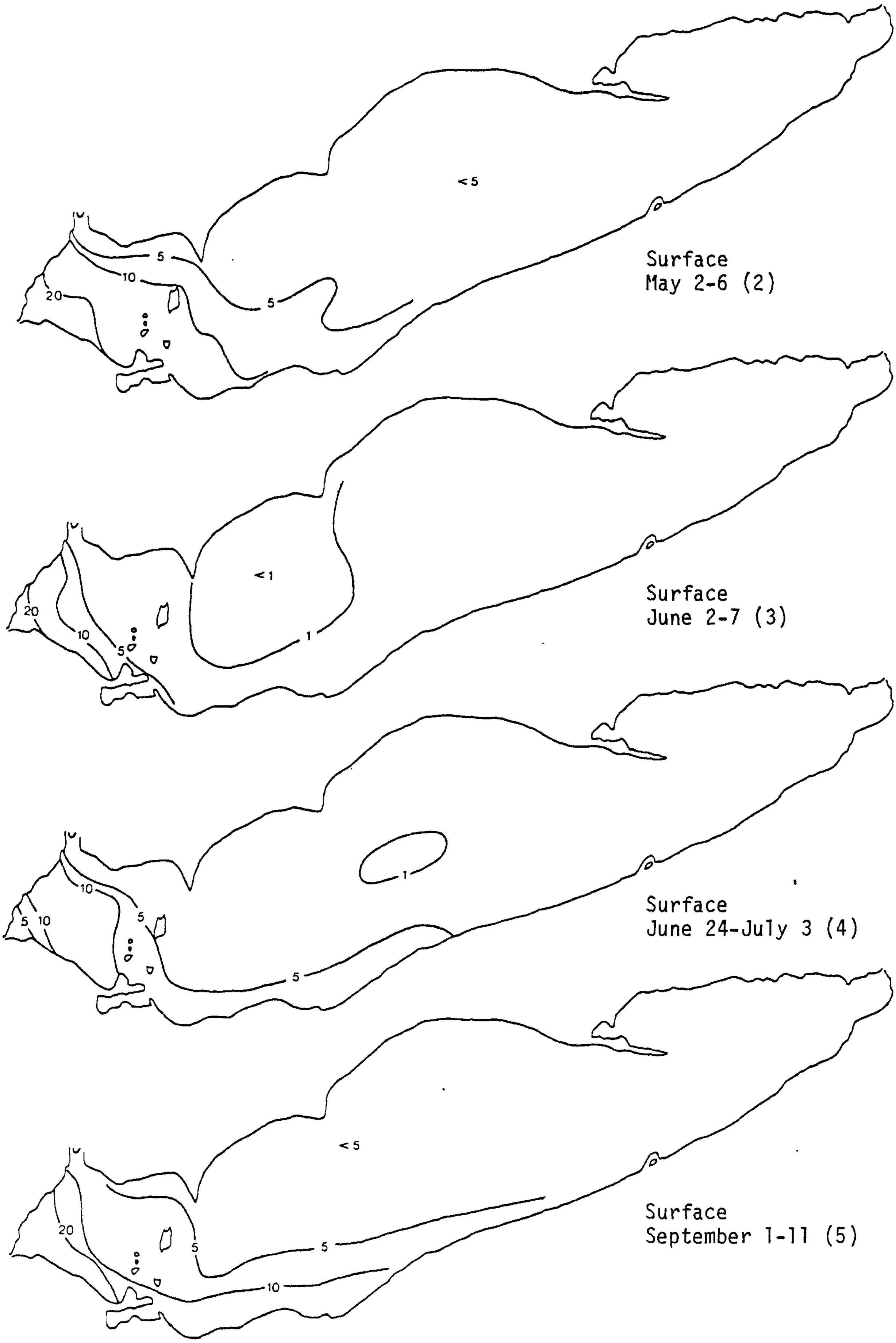


Figure 34. Limnion horizontal distribution maps for corrected chlorophyll a (ug/l), 1981.

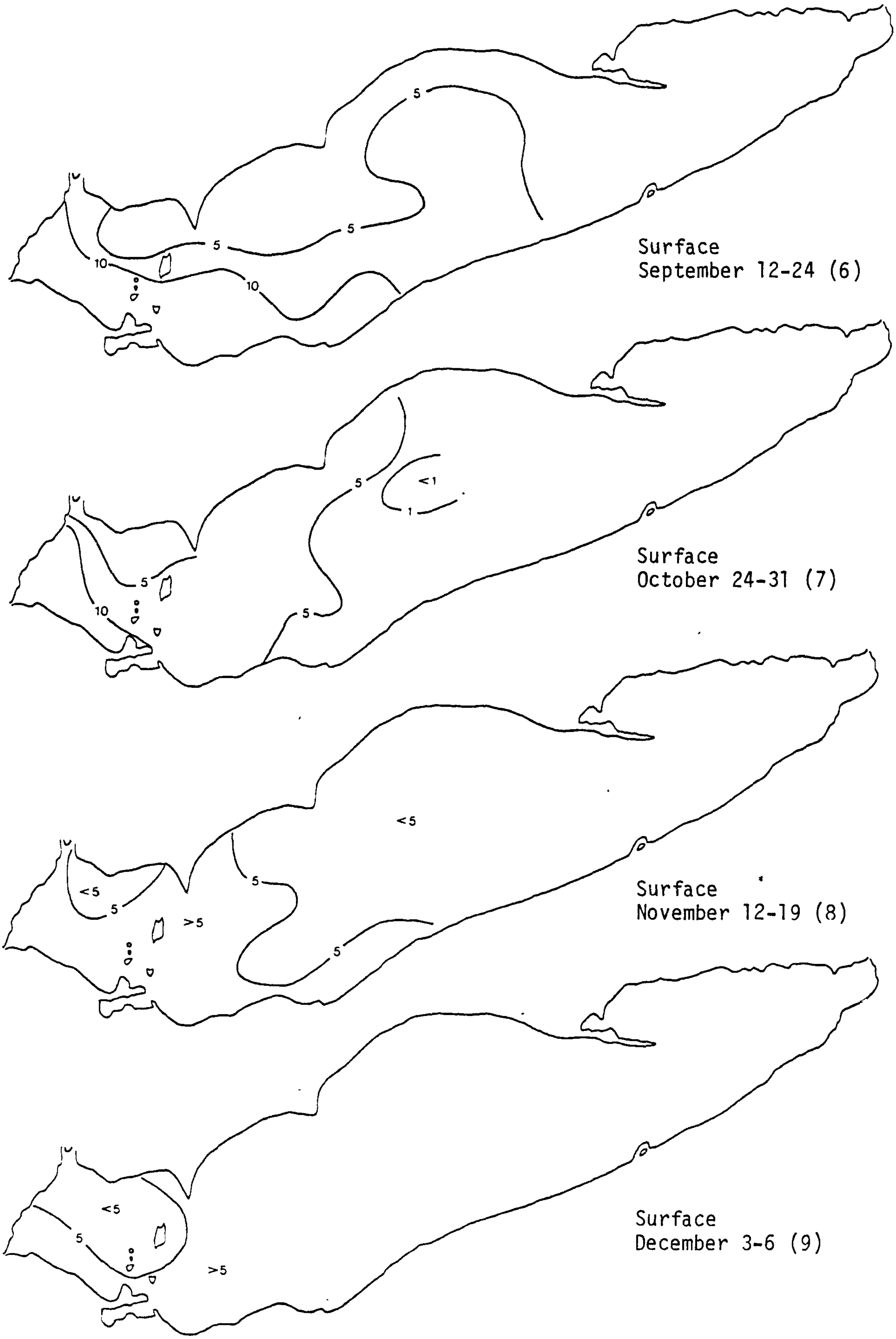


Figure 34 (continued). Limnion horizontal distribution maps for corrected chlorophyll a (ug/l), 1981.

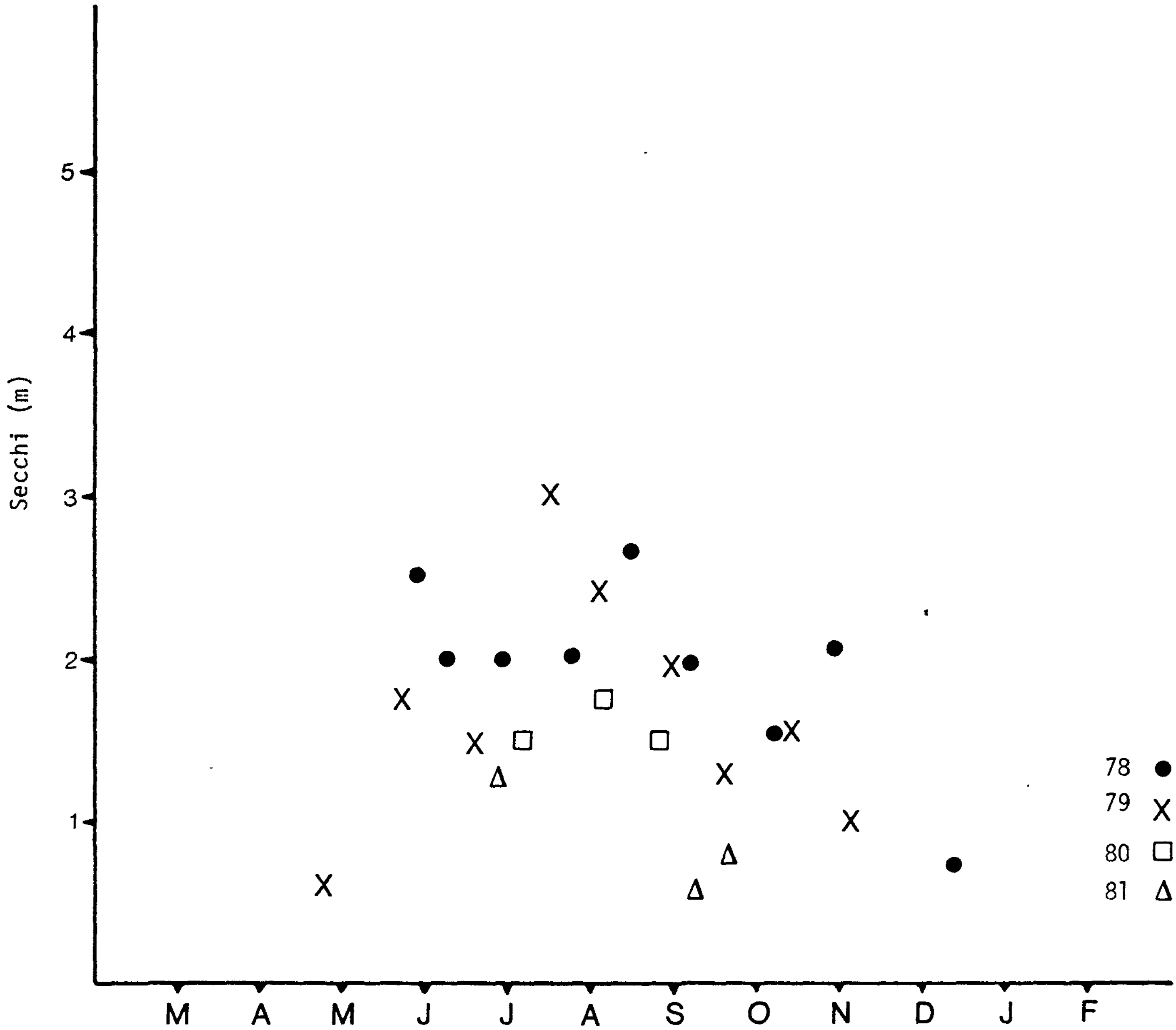


Figure 35. Western Basin Secchi Area weighted cruise values, 1978-1981.

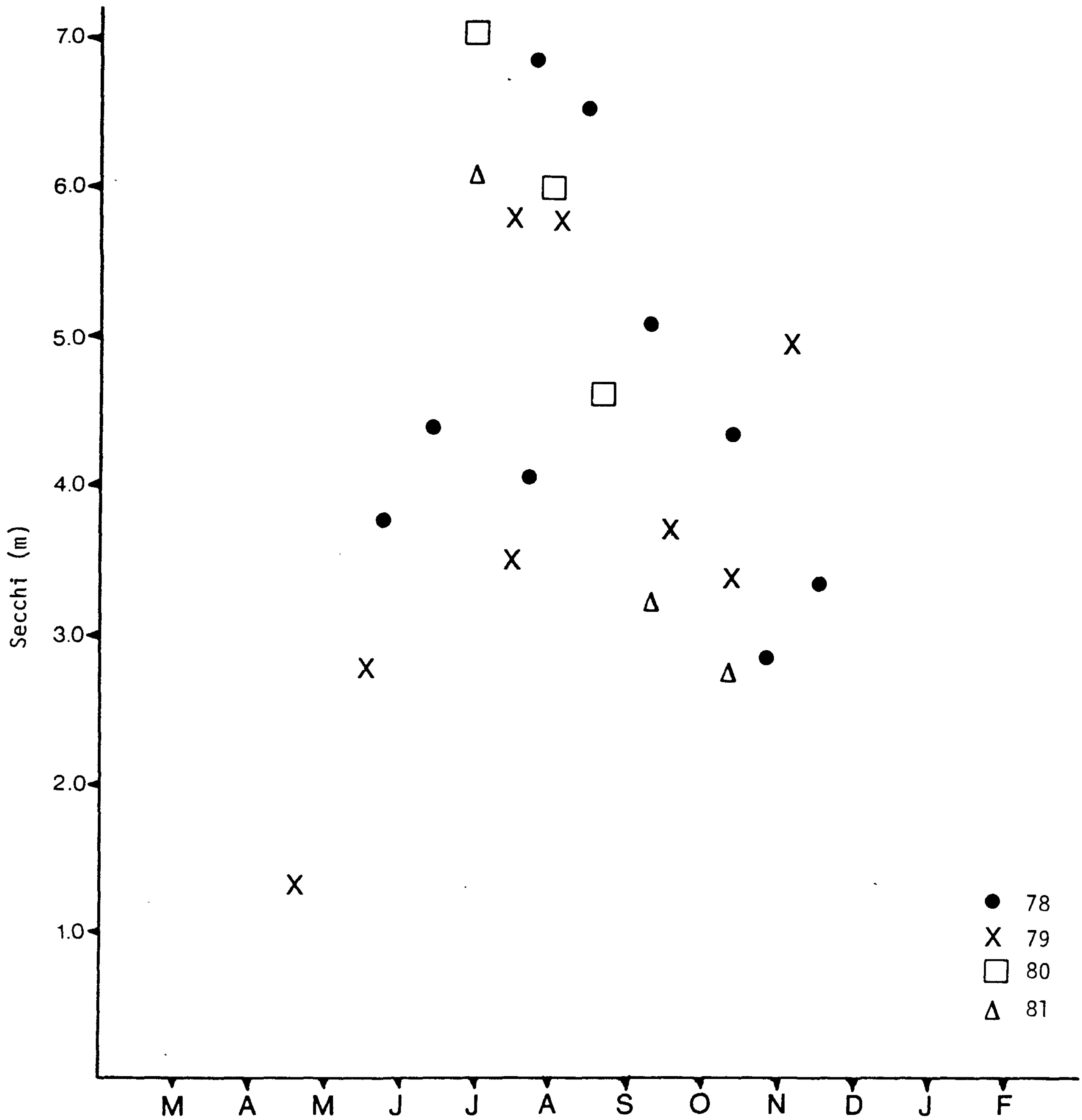
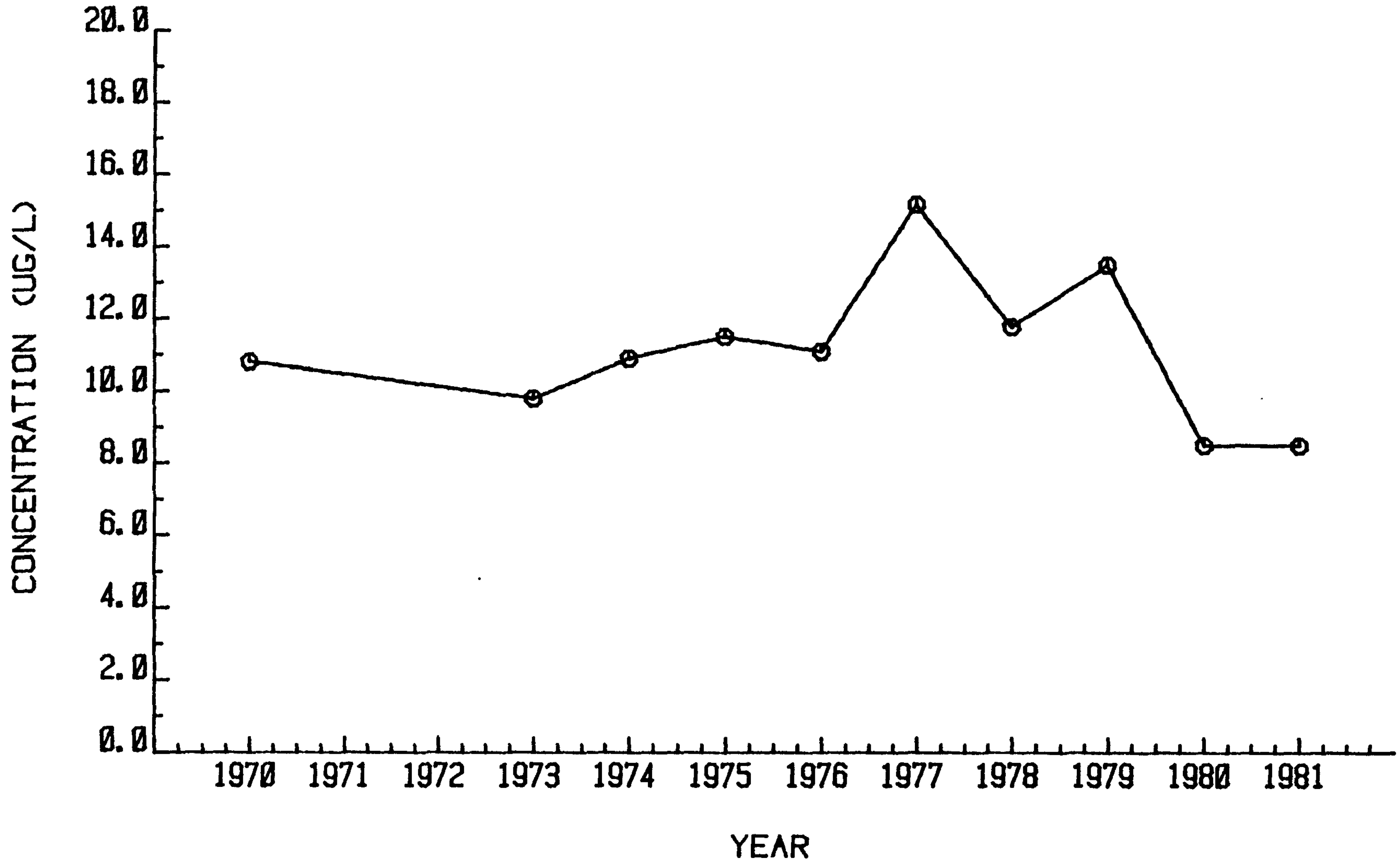


Figure 36. Central Basin secchi area weighted cruise values, 1978-1981.



CORRECTED CHLOROPHYLL A

YEARLY MEANS WESTERN BASIN SURFACE (1970-1981)

Figure 37

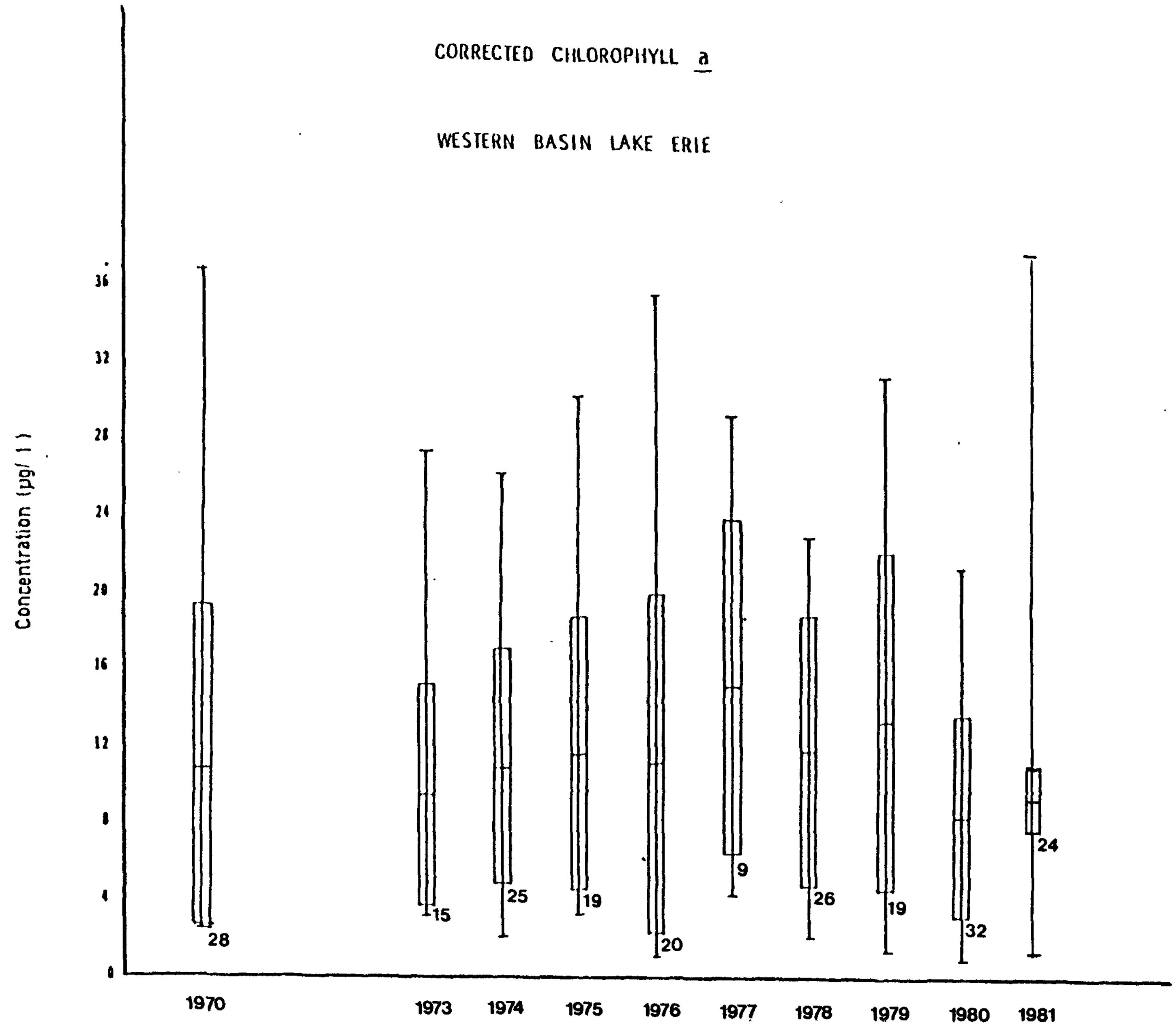
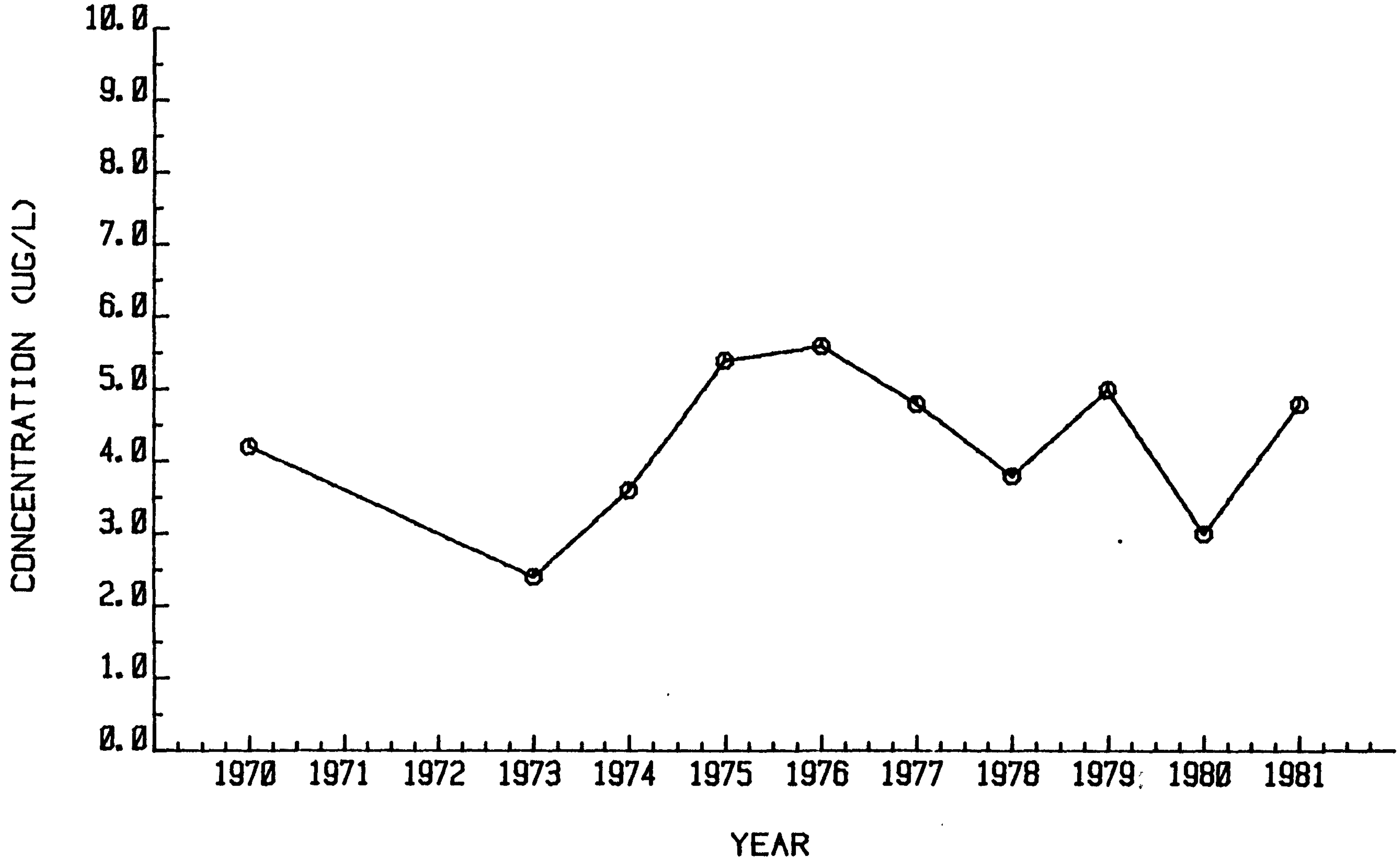


Figure 38. Corrected Chlorophyll a June to November mean concentrations (ug/l) in the surface waters of western Lake Erie, 1970-1981. The bracket represents standard error.



CORRECTED CHLOROPHYLL A

YEARLY MEANS CENTRAL BASIN SURFACE (1970-1981)

Figure 39

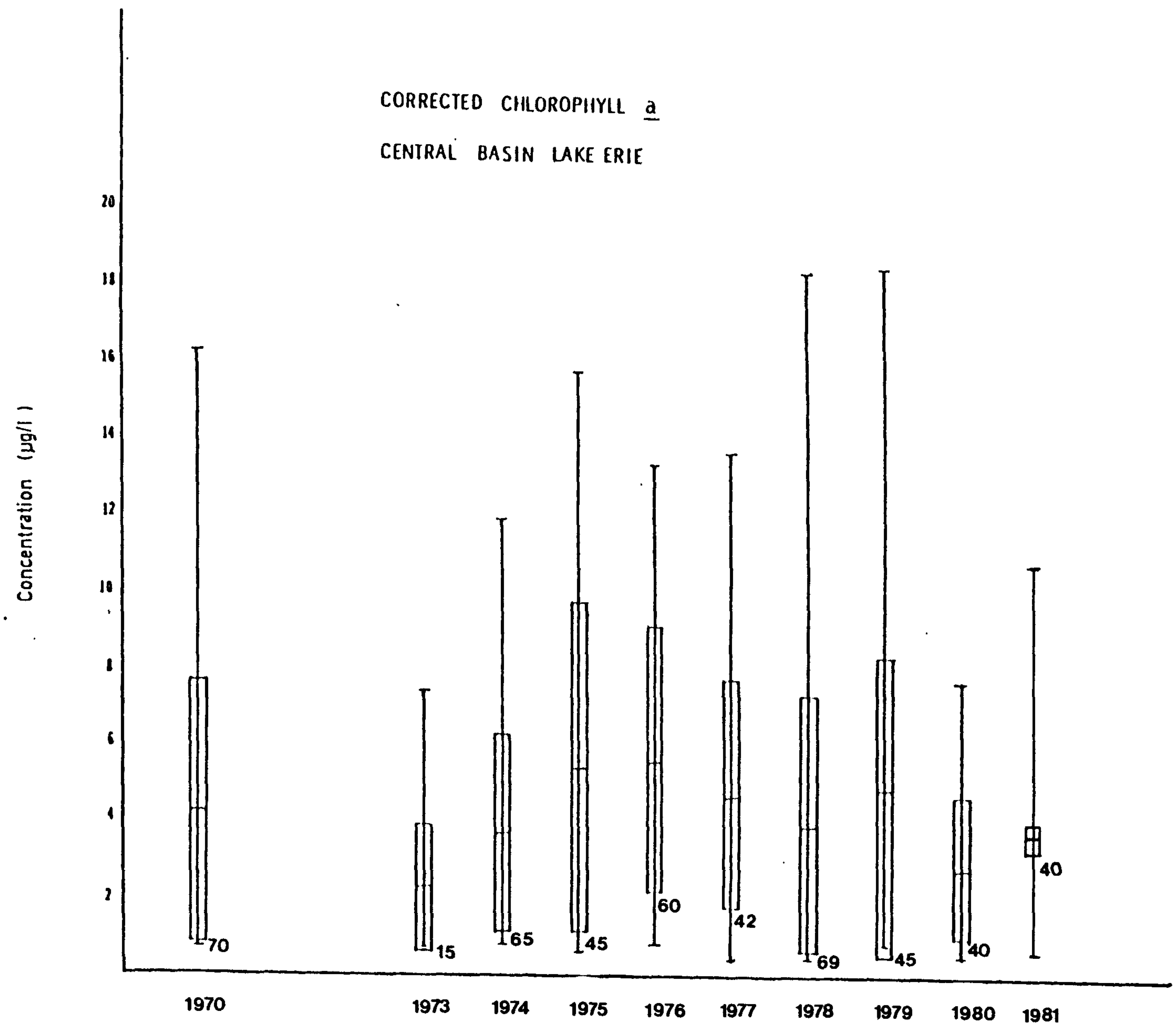
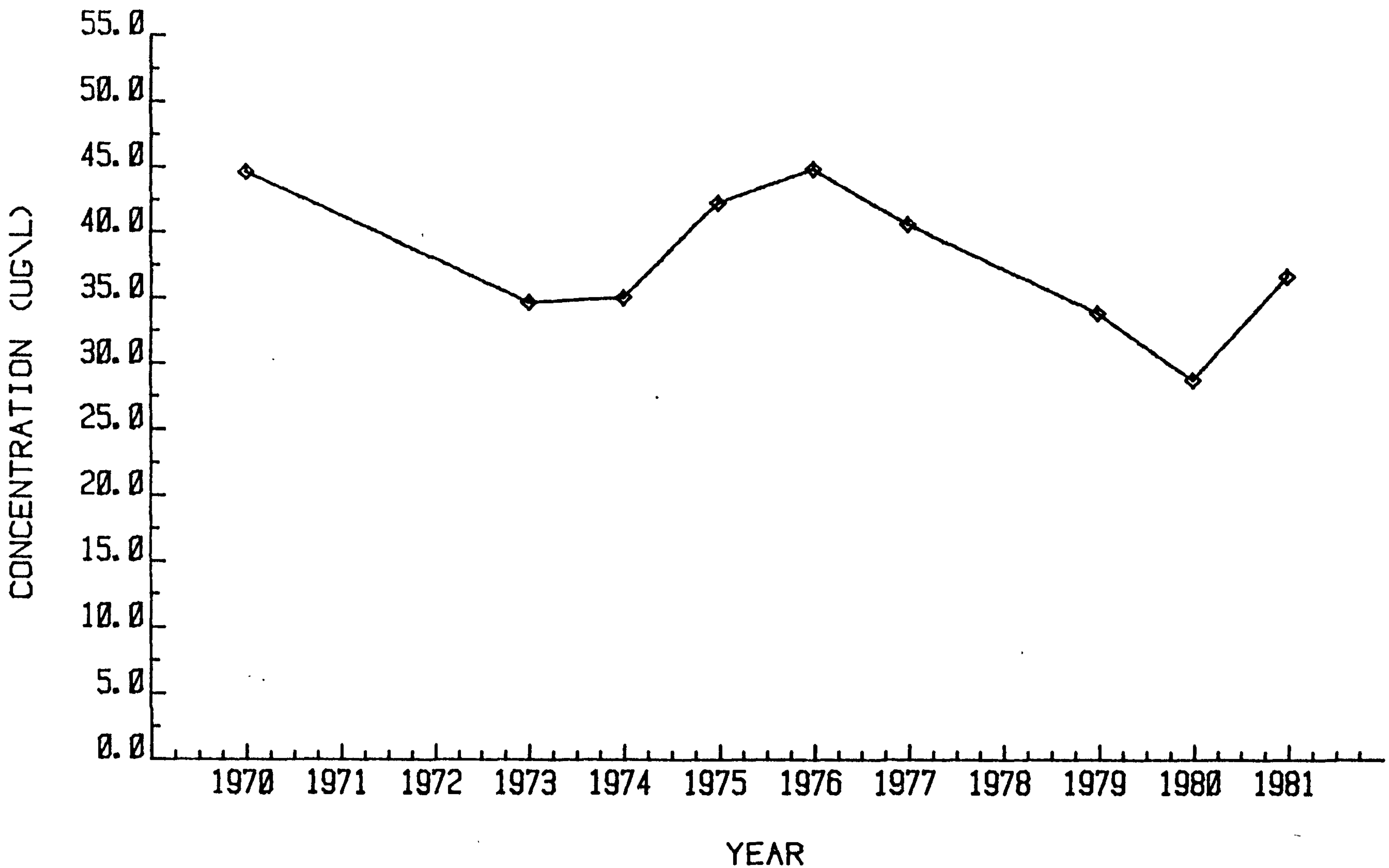


Figure 40. Corrected Chlorophyll a June to November mean concentrations (ug/l) in the surface waters of central Lake Erie, 1970-1981. The bracket represents standard error.



TOTAL PHOSPHORUS

YEARLY MEANS WESTERN BASIN (1970-1981)

Figure 41

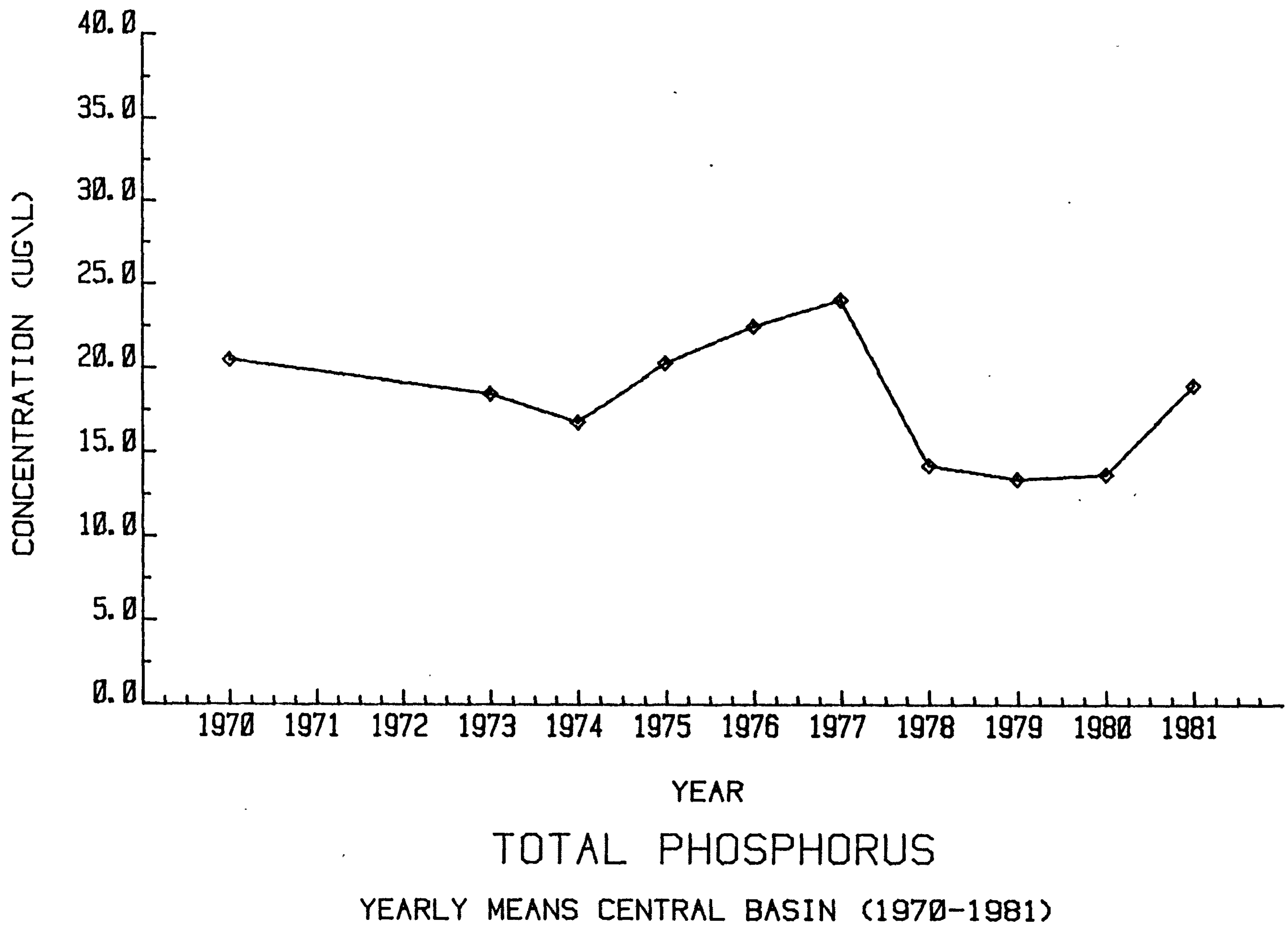

40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
CONCENTRATION (UG\L)
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981
YEAR
TOTAL PHOSPHORUS
YEARLY MEANS CENTRAL BASIN (1970-1981)

Figure 42