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Impact of Special Phosphorus Removal Procedures in the Upper Pelican River Watershed, 1978-79

INTERIM REPORT II

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INTRODUCTION

The wastewater treatment areas (Figure 1) and the upper Pelican River watershed (Figure 2) have been described in previous reports and, except for the above figures to locate sampling sites, no study area description is given here. Analytical data incorporated in this report cover the period June 1, 1978 - May 31, 1979; ground water elevations were measured from November, 1978, through May, 1979. Sampling sites and parameters considered were those given in the introduction to the 1977-78 interim report.

GROUNDWATER

Elevation

Height of water table at each of the five sampling wells, November, 1978 - May, 1979, indicates that groundwater movement was toward the spray irrigation and infiltration basin areas from the upper airport region (Figure 3). The general groundwater decline beginning in early winter was rather abruptly reversed in most areas by snow melt in April, but relative elevations exhibited earlier were maintained.

Dilution and Replacement by Wastewater Effluent

On the basis of chloride increase (see tracer discussion in Interim Report I), wastewater evidently replaced native groundwater in infiltration and spray irrigation areas shortly after land application began in 1978 (Figure 4). Replacement was earlier in the infiltration basin area (PC 3) which went into operation a month before spray irrigation plots (PC 10 and PC 11). PC 11 again showed the effects of greater native groundwater inflow, seldom achieving chloride levels comparable to those at PC 10. PC 19 which appeared from chloride data to receive water from Irrigation Area 1 that remained from November, 1977, through January, 1978, was less affected in 1978-79, although a slight chloride elevation occurred there in December, 1978. Elevation at PC 20 in Area 1 has exceeded that at PC 19 several times during summer of 1979. PC 13 was unaffected by wastewater chloride in 1978-79.

Temperature

Land application of the waste effluent elevated groundwater temperature, which remained above ambient in those areas until December, 1978 (Figure 5). Groundwater in areas unaffected by the waste effluent (PC 13 and PC 19) exhibited rather uniform temperatures the year round.

pH

Groundwater pH was elevated by infiltrating effluent during seasons of application, but fell to near the ambient range after application ceased (Figure 6). Increase of pH was directly caused by effluent which exhibited high values several times during the growing season referable to plant activity in the stabilization pond (Table 1).

Mineral Content

Groundwater was more mineralized under areas receiving wastewater effluent than at higher elevations. This phenomenon was demonstrated by alkalinity (Figure 7), calcium (Figure 8), magnesium (Figure 9), and especially by conductivity (Figure 10), which is influenced by a larger number of mineral compounds, e.g., sodium chloride. The wastewater effluent had greater concentrations of alkalinity, chloride, and sulfate than native groundwater, but this was not true for calcium and magnesium, and increases in these two elements are assumed due to additional leaching from soils.

Oxygen

Passage through the pumping system apparently had a reducing action on oxygen concentration of the stabilization pond effluent that was not accompanied by a concurrent lowering of pH (Table 1). Mechanical depletion of oxygen, which would not affect pH, would bring levels down only to the saturation point or slightly less, and reduction to below this point without pH response is puzzling and merits furhter investigation. Oxygen content of groundwater under unaffected areas was higher than that under effluent applied areas during the operational period, as would be expected (Figure 11).

Phosphorus

Phosphorus variation at the five groundwater sites (Figure 12) appeared affected by wastewater effluent and other sources. Peaks occurred concurrently at PC 19 and PC 11 on June 30; at PC 3 and PC 10, September 8; and at PC 10, 11, 13, and 19 on December 2, 1978. The last named apparently did not originate in wastewater, since application to those areas ceased October 9, 1978, and no peak was noticeable at PC 3 where application stopped December 1. The June 30 peak at PC 19, although coinciding with one at PC 11, is not now believed referable to wastewater as chloride increase did not occur there until winter in 1977.

Mean phosphorus concentration over the period June - December, 1978, was greater than that over July - December, 1977, in the wastewater effluent and in the upper water table at PC 3, 10, 11 and 19. Concentrations in groundwater were greater in 1978 than during any previous record period except at PC 19 and it seems justified to assume that a more concentrated effluent produced them at PC 3, 10 and 11. At PC 19 1978 mean P concentration was 0.04 mg/1 greater than that of 1977, but only 53% of the 1973-74 mean.

Nitrogen

Total nitrogen was considerably less concentrated in the wastewater effluent during the growing season (May - November) than from December - April (Table 1). Growth and proliferation of plants in the stabilization pond are assumed mainly responsible for the lower values. In groundwaters (Figure 13) nitrogen was more concentrated at PC 13 and 19 than under irrigated areas and infiltration basins. Nitrogen was largely in the nitrate form.

SURFACE WATERS

Discharge

The greatest water flow of 1978-79 was in spring of the latter year (Figure 14). It was initiated by snow melt and augmented and sustained by later precipitation. Backflow or minus discharge endured at Station N from early September until mid-December, 1978. All stop logs were in place in the control structures at Station 1 and some channel obstruction by dead and dying vegetation affected the river just below the mouth of the ditch near Station N. Downstream discharge was renewed with removal of the top spillway log at Station 1 on December 18. Zero discharges occurred as follows: Station 1 spillway, July 30 - August 23 and November 3 - 5; Station 1 lock, August 13 - 23 and September 7 - December 17; Station F, December 5 - 11 and January 6 - 29; Station 8, October 6 - January 6. Eighteen days were required for renewal of discharge at Station 8 following removal of the top spillway log at Station 1.

Temperature

Temperature at all surface water sites peaked in early July, 1978, and, with the exception of a brief leveling or slight increase near mid-August, declined progressively to seasonal lows reached in early December (Figure 15). A noticeable warming was evident at all sites by May 25, 1979. Station 8 preceded all others in this trend, and had an increase that built up to 5°C on January 12, 1979. The only other area in Lake Sallie with a comparable temperature at the time was water below six meters (20 ft.) at Station 4. The common pattern of temperature variation at different depths near the center of Lake Sallie (Figure 16) indicates no thermal stratification in summer of 1978.

pH

Maximum pH values occurred in water discharged from St. Clair Lake followed by that from Lake Sallie, Muskrat and Detroit Lakes in that order (Figure 17).

The river site M had a pH in excess of 8.0 only on September 15, 1978. Height of pH above 8.0 has appeared to be a more reliable measure of photosynthetic effects than oxygen concentration in these waters, since the latter has been depressed by photosynthesizing nitrogen fixing blue-green algae. Maximum intensity during the growing season was in St. Clair discharge, but Lake Sallie showed more uniformity and longer persistence of photosynthetic influence. St. Clair discharge preceded other sites in renewal of photosynthesis in May, 1979, but it was generally in full swing except at M on May 25 (Figure 17). Longer persistence of high values in Lake Sallie, especially under ice, is believed aided by isolation of surface water from areas of most active organic decomposition, but photosynthetic elevations have been noted under ice and snow. Upper waters had a generally higher pH level than those near the bottom in the deepest region of Lake Sallie (Figure 18).

Alkalinity

Variation in total alkalinity (Figure 19) resembled that of calcium (Figure 21) in being higher at M and F and generally lower during photosynthetic periods. However, it had a more definite winter increase at all sites that began later at M and F than that of calcium. This increase occurred at all sites on February 9, 1979, was not accompanied by any growth in calcium, and by one in magnesium only at Station N. In the winter of 1977-78 alkalinity increase was concurrent with one in calcium, which is the expected relationship since both respond similarly to photosynthetic variation. The simultaneous February, 1979, increase in alkalinity at all stations suggests a reagent change unreported or unnoticed by the analyst. Alkalinity was greater in deeper water than nearer the surface at Station 4 (Figure 20).

Calcium

Calcium variation among sampling sites and over the seasons (Figure 21) indicates the spread of photosynthetic influences over the studied part of the upper watershed. Actively photosynthesizing plants soon exhaust free carbon dioxide and resort to calcium bicarbonate, $Ca(HCO_3)_2$, for a continuing supply, producing weakly soluble calcium carbonate, $CaCO_3$, much of which precipitates. Stations M and F, nearer groundwater and wastewater sources of flow, exhibited higher calcium concentrations than the outlets of Detroit and Muskrat Lakes and Lake Sallie. During the growing season calcium was noticeably reduced in St. Clair Lake (Station F) but was built up again as this water was replaced in fall and winter. Demineralization by the chemical precipitation plant had no discernible effects on winter calcium concentration at Station F, which remained near that at Station M; however, F preceded M in calcium decline by about four weeks in late winter. Lower calcium levels were initiated by inflow of snowmelt and maintained for some time by high discharges alone. Calcium carbonate, indicating the presence of active photosynthesis, was first noted at F on May 11, 1979, but did not occur at M during the 1979 spring period covered in this report. In 1978 $CaCO_3$ was found at M only on September 15, when there was a decided drop in calcium (Figure 19). At F $CaCO_3$ was present without interruption from June 8 - September 1, from September 29 - October 13, and from November 10 - 24. A calcium increase over the period October 27 - November 10 was noticeably reduced by November 24.

Maintenance of low calcium concentrations over winter in the three lower lakes (Detroit, Muskrat, and Sallie) was referable to larger volumes which diluted inflows (Muskrat Lake was diluted by Detroit Lake outflow), some photosynthesis under ice cover, and isolation of surface waters from regions with most active carbon dioxide production (aerobic decomposition). There was a gradual calcium build-up from early December to late March in Muskrat Lake, despite detectable photosynthetic activity on January 25 and February 9. In surface waters of Lake Sallie (two exceptions at Station 8) $CaCO_3$ was present from June 1, 1978 - April 20, 1979, and after May 17, 1979. It was missing at nine meters depth (30 feet) from early February until May 17, 1979. Some photosynthesis occurred under ice cover in Sallie and calcium decline in April resulted from dilution by melting snow. Vertical variation in Sallie (Figure 22) indicates a greater winter increase with depth, peaking at the lowest level, and generally higher concentration with depth at all seasons. Surface waters were more affected by photosynthesis and were the only level appreciably influenced by melt of snow cover (Figure 22, April 20, 1979).

Magnesium

Since magnesium bicarbonate ($Mg(HCO_3)_2$, appears less liable to photosynthetic breakdown than $Ca(HCO_3)_2$, and since magnesium carbonate ($MgCO_3$) is more soluble than $CaCO_3$, magnesium usually exhibits much less change than calcium in passage through a lake-river system. Variations that do occur are more apt to indicate a different basic water quality rather than conditions imposed by biological activities. Profiles for individual sites (Figure 23) show greater uniformity than calcium (Figure 21) over the sampled area, and profiles for various depths in Lake Sallie (Figure 24) show less winter build-up in deeper waters. Magnesium was subject, as was calcium, to great dilution by snow melt at the surface of Lake Sallie and in the Pelican River above Detroit Lake (Station M). Extremes at M and F were ironed out to some extent in the larger lakes, but to a lesser degree than calcium, since magnesium suffered little if any biotic reduction. An illustration of the differing fates of calcium and magnesium is offered by mean values of each (1978-79) in Lake Sallie influent and effluent: magnesium was 142 mgl in the former and 143 in the latter, whereas corresponding values for calcium were 96 and 76 mgl.

Conductivity

Conductivity of surface water feed into this studied area, as exemplified by the Pelican River just above Detroit Lake (Station M) was rather uniform (near 600 µmhos/cm) when not diluted by surface runoff, concentrated by evaporation, or reduced by photosynthesis of aquatic plants (Figure 25). Dilution was largely restricted to spring 1979, concentration to late summer 1978, and photosynthetic reduction was noted on September 15, 1978, when calcium also declined. In St. Clair Lake conductivity reached considerably higher levels in winter, was decreased by spring runoff, and reduced by green plant life over much of the 1978 growing season. Winter conductivity levels have increased progressively in this lake since special phosphorus removal procedures went into effect; mean December - March values were: 1975-76, 709; 1977-78, 740; and 1978-79, 880 µmhos/cm. Causes of this increase are obscure at present and the role of the precipitation plant effluent somewhat contradictory. During the 1975-76 winter, wastewater effluent went directly from the stabilization pond toward St. Clair Lake and in 1978-79 passed through the chemical precipitation plant, which effected a 10% conductivity reduction, enroute to St. Clair. Groundwater conductivity at PC 3 and PC 10 averaged 115 µmhos/cm greater than that of the precipitation plant effluent, and its movement may have possibly carried it into St. Clair Lake. It averaged 11 µmhos/cm greater than the stabilization pond in 1978-79, but this amount of gain is insufficient to account for the 1975 - 1979 increase in St. Clair.

Discharges from the other three lakes (Detroit, Station N; Muskrat, Station 1; and Sallie, Station 8) had noticeably lower conductivity than St. Clair Lake or Station M, and Detroit and Sallie showed less variation than Muskrat over the 1978-79 study period (Figure 25). Allowing for demineralizing effects of photosynthesis in each water body, the greater unformity of the two larger lakes reflects the higher resistance their greater volumes afford against change by influent waters of differing quality and varying photosynthetic rate. This resistance is augmented by larger quantities of direct precipitation that their greater areas provide. In Muskrat conductivity was held to a lower level in winter than in St. Clair by dilution of St. Clair discharge with that from Detroit Lake. Very slight conductivity changes at Station M from late September until early April (Figure 25) indicate a consistent quality of water passing that point which, although diluted, made some contribution toward uniformity in Detroit Lake. Vertical measurements in Lake Sallie (Figure 26) showed a higher range near the bottom (Station 4-4).

Oxygen

Greatest oxygen concentrations occurred during periods of high photosynthetic intensity, but blue-green algae had depressing effects, giving lows that were unaccompanied by pH change on several dates (Figures 17 and 27). Oxygen was not reduced as much under ice in Detroit and Sallie as in St. Clair and Muskrat Lakes. Increases in spring, 1979, were initiated by snow melt and entrance of new water and then augmented by photosynthesis. These events were most striking in St. Clair Lake, where oxygen level increased from 0 to 20+ mgl. Oxygen showed its usual decline with depth in Lake Sallie (Figure 28), particularly in early spring, but very high values occurred at all depths coincident with temperature decline in fall of 1978.

Phosphorus

With the exceptions of St. Clair and Muskrat Lakes (Stations F and 1), total phosphorus reached greater concentrations during the 1978 growing season than in that of 1977, and 1977-78 levels were generally higher than those of 1975-76 (Figures 29, 30, and 31). This may represent a general watershed trend since inflow and outflow of both Detroit Lake and Lake Sallie were involved. Phosphorus loads contributed from the east side of the upper watershed (Station N) exceeded those from the wastewater recipient west side (Station F) in 1978-79 despite the long period of minus flows at N (Figure 32). A similar relationship characterized the first six months of 1975 when 13,139 pounds of P from F joined 22,002 pounds from N. In 1973 and '74 quantities from F markedly exceeded those from N (23,060 to 14,109 pounds in 1973; 12,963 to 7,760 pounds in 1974). Lower contributions from F in 1978-79 accompanied higher concentrations in Lake Sallie and its discharge. Heavier phosphorus loads occurred in summer of 1978 as discharge was declining, and in late winter and spring as discharge increased. The heaviest loads were in April, whereas discharge peaked in May.

Nitrogen

St. Clair Lake has been the major contributor of nitrogen to Lake Sallie. Over the past five years N concentration there has greatly exceeded that at more downstream locations (Stations 1 and 8) and on the east side of the upper watershed (Stations M and N), as shown in Figures 33, 34, and 35. St. Clair Lake supplied the major portion of nitrogen poundage going to Lake Sallie (Figure 36). From January - May, 1979, it supplied 18,279 of the 30,882 pounds entering Lake Sallie at Station 1. Detroit Lake contributed 8,137 pounds, and the remaining 4,466 pounds originated in Muskrat Lake, in the river below Station N, and in the ditch from St. Clair Lake. Greatest loads and concentrations occurred from mid-winter to early spring. Load was related to discharge, but not entirely, as the latter peaked after the maximum loads had passed (Figure 14). Unlike phosphorus (Figure 32), nitrogen had low or near annual low loads in early summer.

plankton

Phytoplankton densities of 1977-78 were compared with those of previous in the 1977-78 interim report; 1978-79 densities of Stations 1, 4-1, and 8 ontrasted with those at the same sites in 1977-78 in Figures 37, 38, and 39.

In Muskrat Lake (Station 1) heterocystous blue-green algae attained er numbers in 1978-79 (Figure 37) whereas at Stations 4-1 and 8 (Lake e) all figured groups reached higher peaks in 1977-78 (Figures 38 and 39), d non-heterocystous blue-greens at Station 1. Since the heterocystous green algae are usually involved in development of conditions offensive to people, Muskrat Lake may have suffered some regression, but a trend toward density of this and other phytoplankton groups continued in Lake Sallie.

Phytoplankton densities are broken down into major groups in Figures 40, d 42. Diatoms and blue-green algae formed the bulk of the population at ıree sites.

TREATMENT EFFICIENCY

Phosphorus Reduction

Amount of phosphorus removed from the wastewater effluent by the chemical precipitation plant and the two types of ground application is detailed in Table 2. Mean reduction of P by infiltration basins was about 5% below that achieved in 1977-78 and that removed by spray irrigation about 4% less than its 1977-78 record. Chemical precipitation took out an average of 75%, whereas its 1977-78 mean reduction was 81%. Monthly performance figures for each month and groundwater site indicate considerable chronological and spatial variation.

Nitrogen Reduction

Performance of the precipitation plant in this respect was very low and that of ground application not particularly outstanding over an annual operating period (Table 3). Over some months decline of nitrogen in water under the infiltration basins and spray irrigation areas was quite marked (e.g., 98.66% at PC 11 and 97.74% at PC 3 in September, 1978). Increase under these areas during some months is assumed to represent quantities brought in by native groundwater, and nitrogen variation in this water could have had a role in producing low concentrations also. It appears that nitrogen changes produced in wastewater by flow over and through the ground will be difficult to assess. Areas little or unaffected by the wastewater effluent (PC 13 and PC 19) exhibited higher nitrogen concentrations than those infiltrated by this effluent (Figure 13).

DISCUSSION

Despite higher phosphorus concentrations and loads, 1978 Lake Sallie phytoplankton densities were lower than those of 1977. This relationship of lower phytoplankton to higher P concentration was also characteristic of 1977 when compared to previous years, and suggests that removal of wastewater elements other than phosphorus has been largely responsible for the progressive phytoplankton decline in Lake Sallie. The 1978-79 increase of heterocystous blue-green algae in Muskrat Lake seems of questionable significance in view of events in Lake Sallie.

None of the three treatment methods applied to the wastewater effluent removed as much phosphorus in 1978-79 as in 1977-78. Since lowered efficiency characterized chemical precipitation as well as ground application, it is difficult to ascribe reasons for it at this time.

Figure 1. Details of Treatment Area

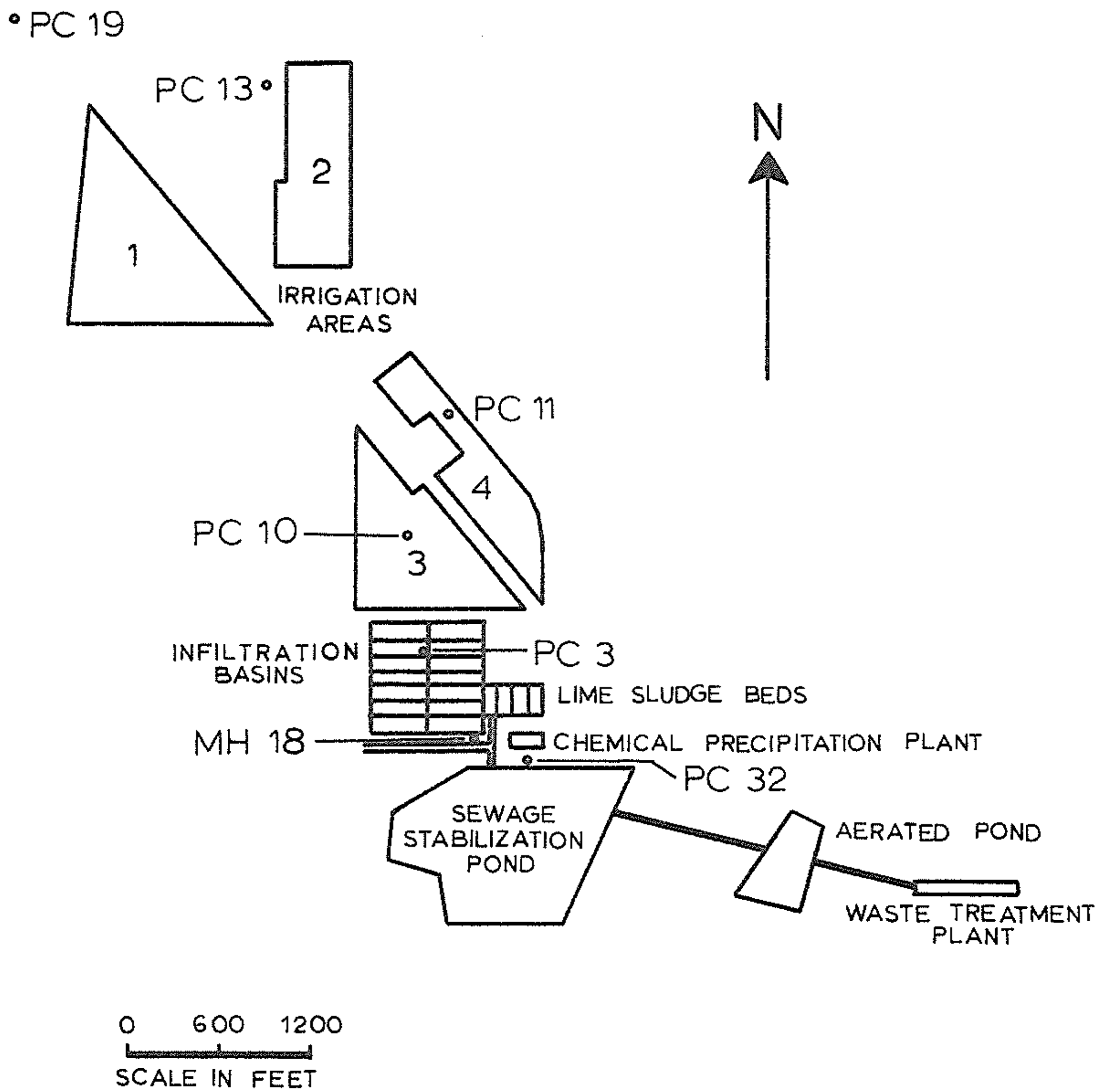
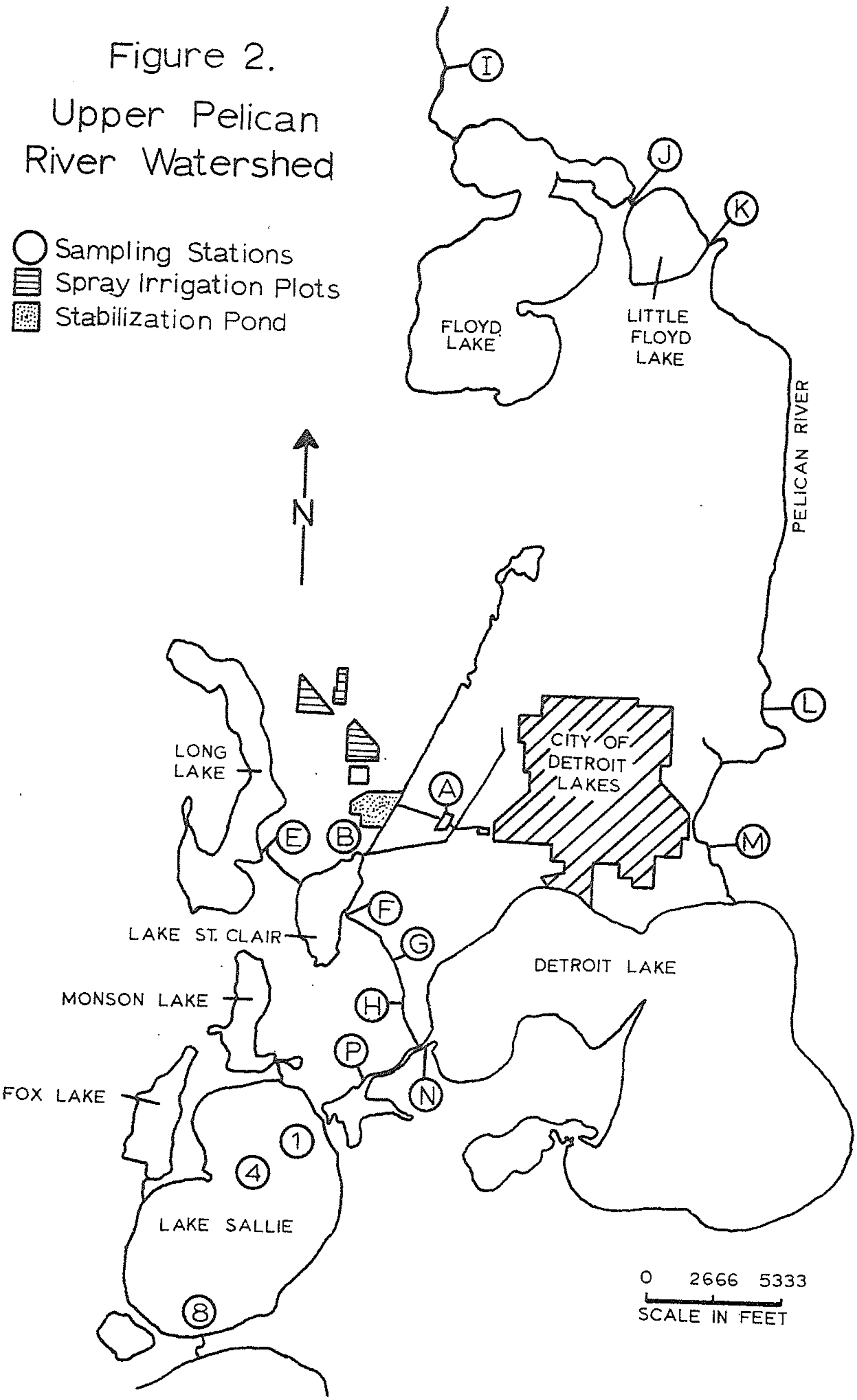


Figure 2.
Upper Pelican River Watershed



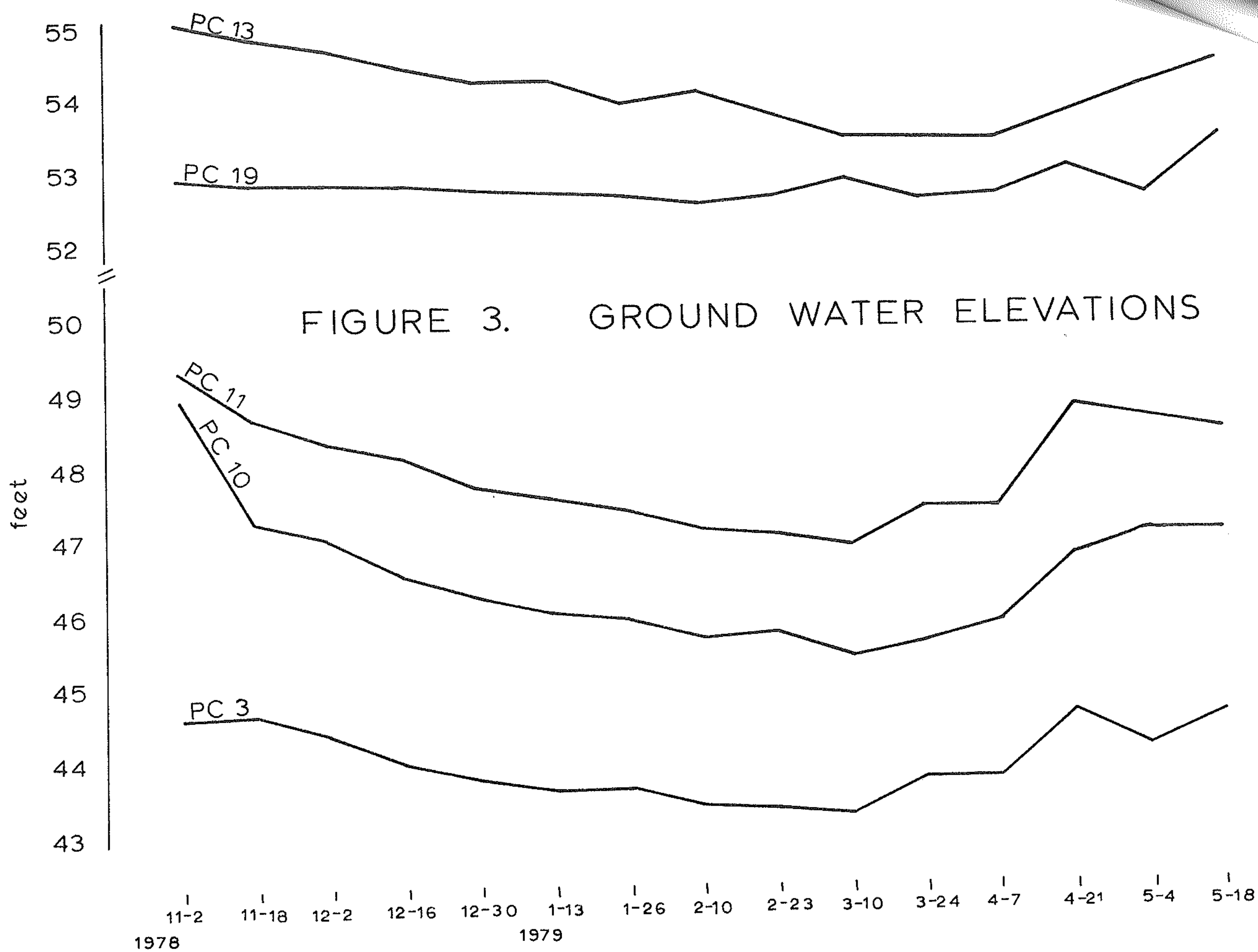


FIGURE 3. GROUND WATER ELEVATIONS
feet
55
54
53
52
50
49
48
47
46
45
44
43
PC 13
PC 19
PC 11
PC 10
PC 3
11-2
1978
11-18
12-2
12-16
12-30
1-13
1979
1-26
2-10
2-23
3-10
3-24
4-7
4-21
5-4
5-18

FIGURE 4.
CHLORIDE IN WASTEWATER
EFFLUENT AND
GROUND WATERS

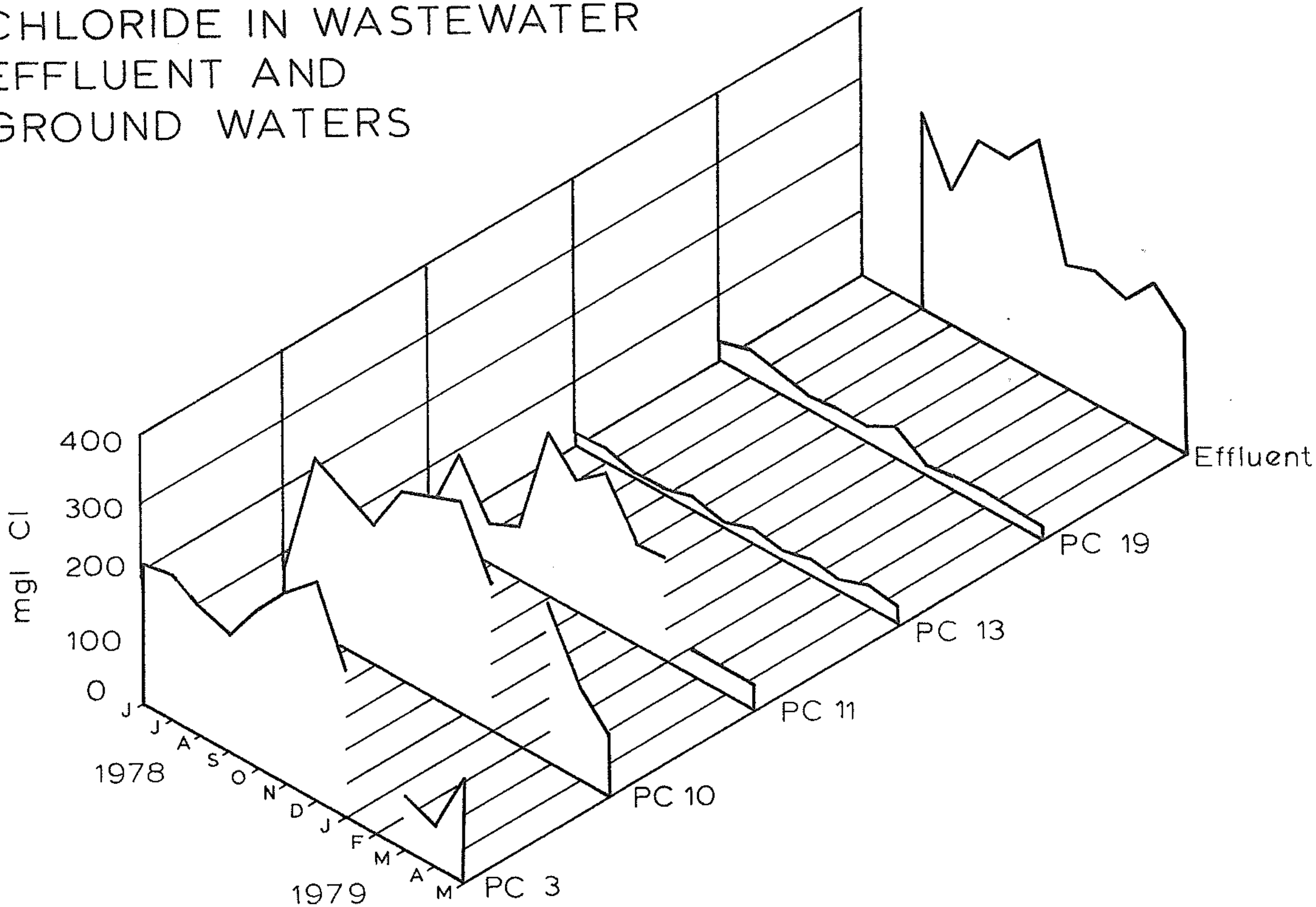


FIGURE 5.
TEMPERATURE OF
GROUND WATERS

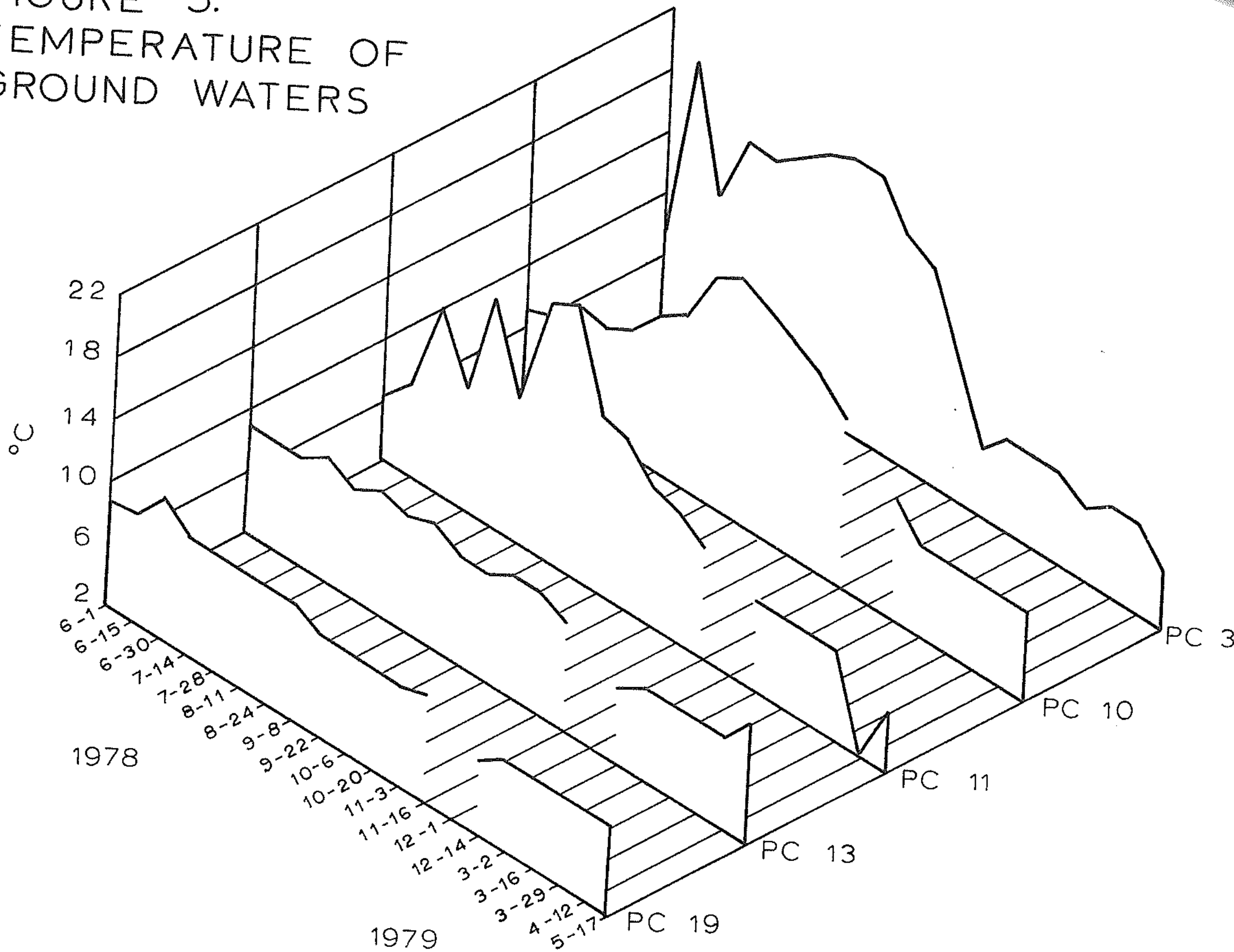


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FIGURE 6.
pH OF GROUND WATERS

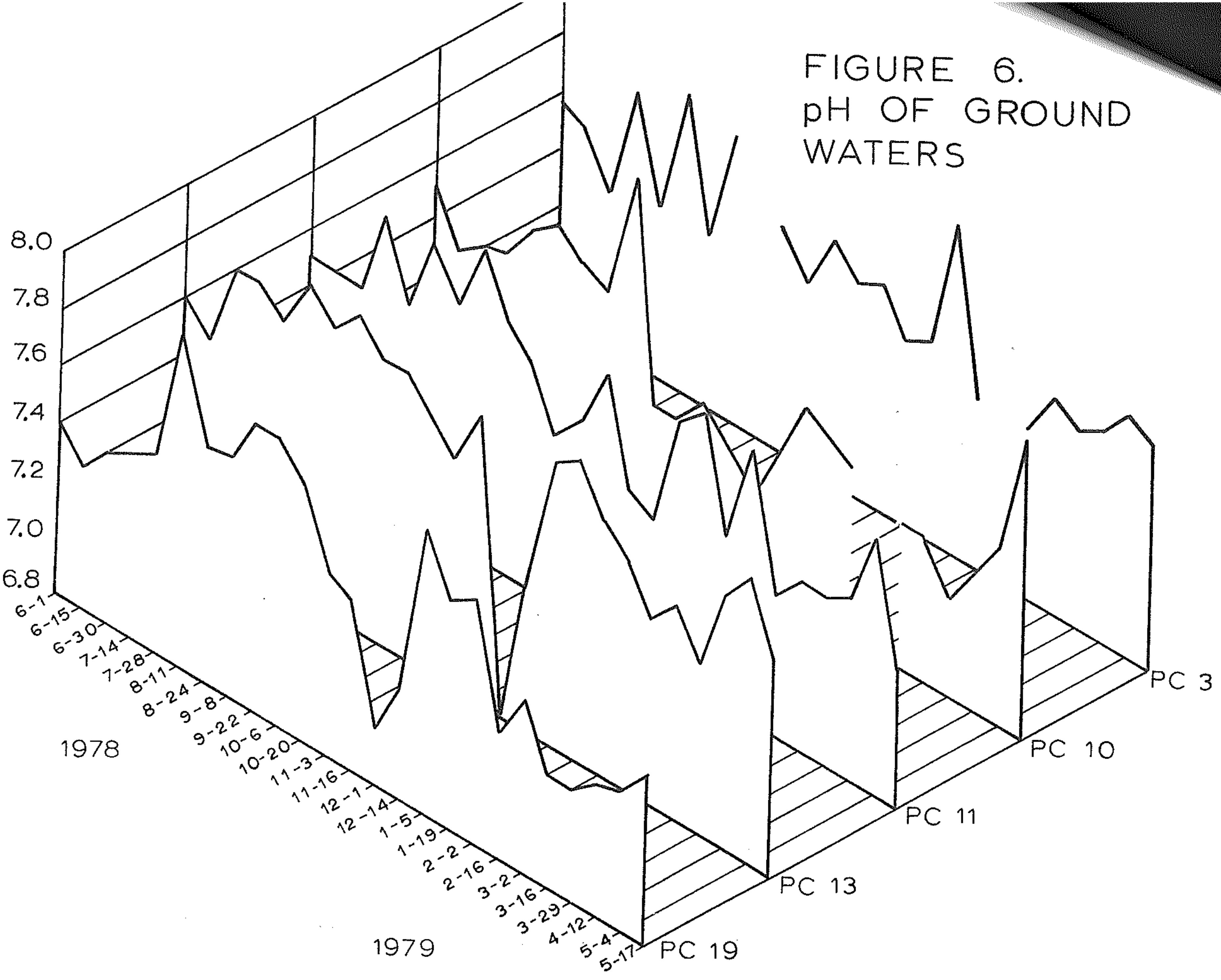


FIGURE 7.
TOTAL ALKALINITY
OF GROUND WATERS

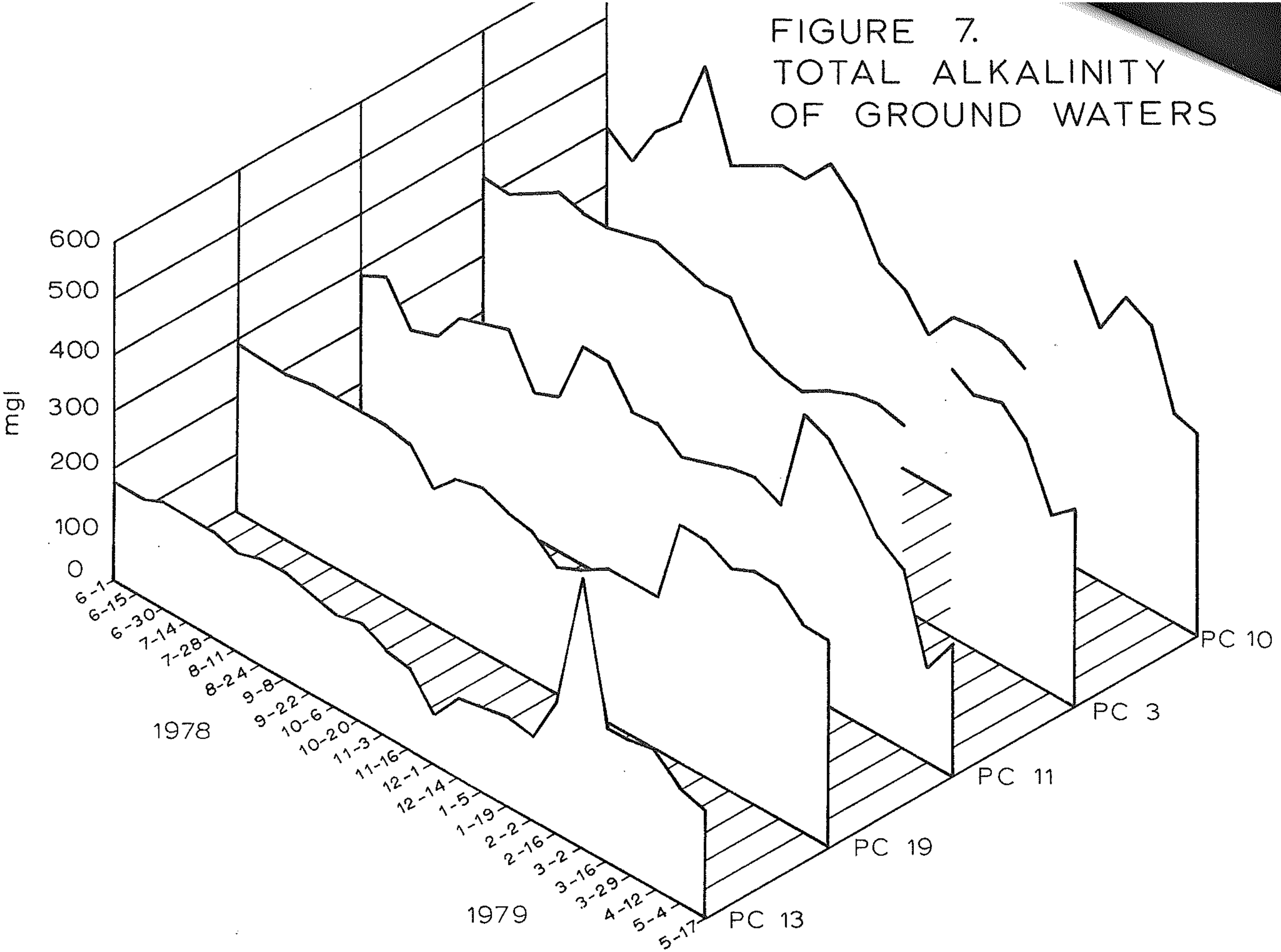
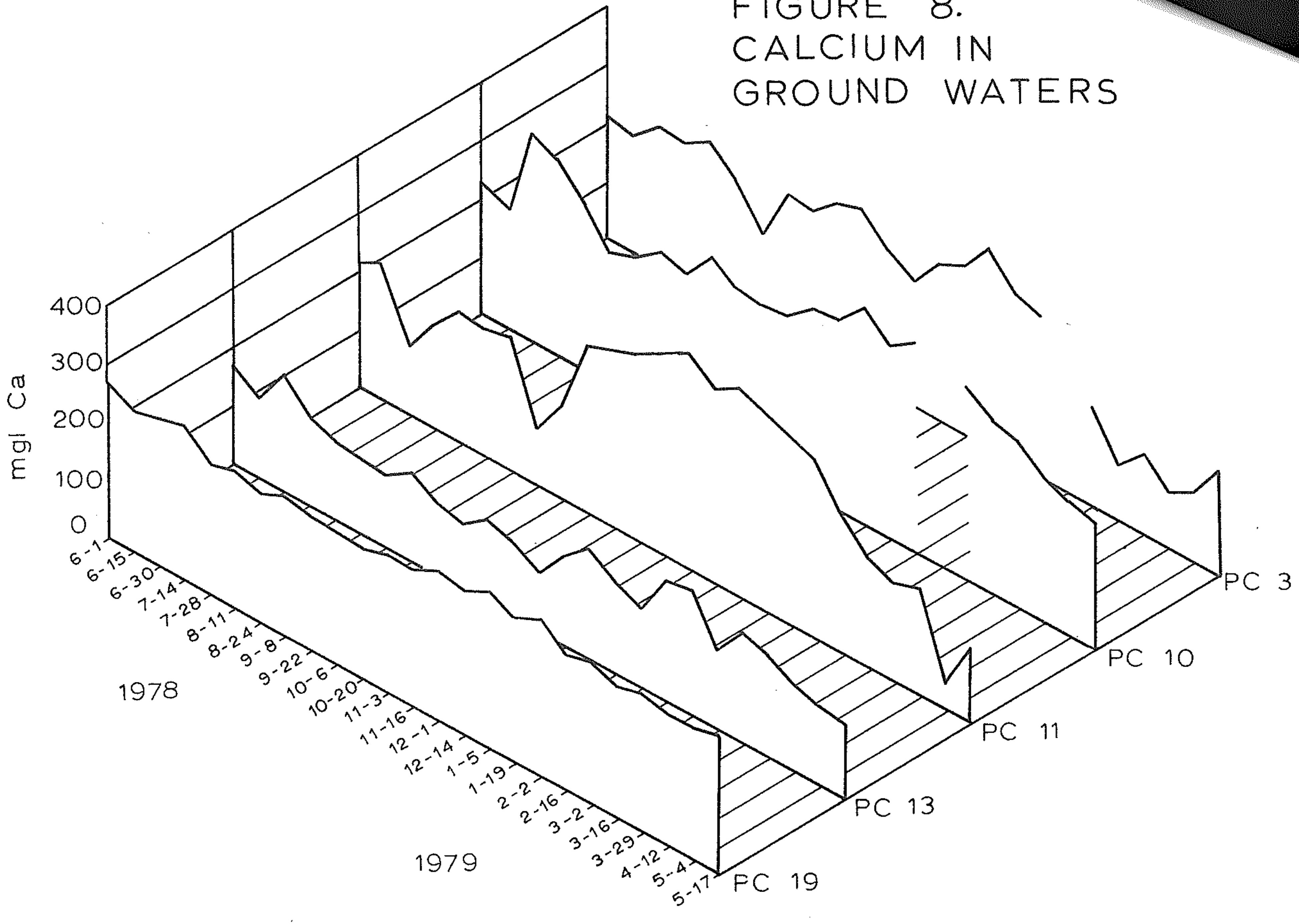


FIGURE 8.
CALCIUM IN
GROUND WATERS



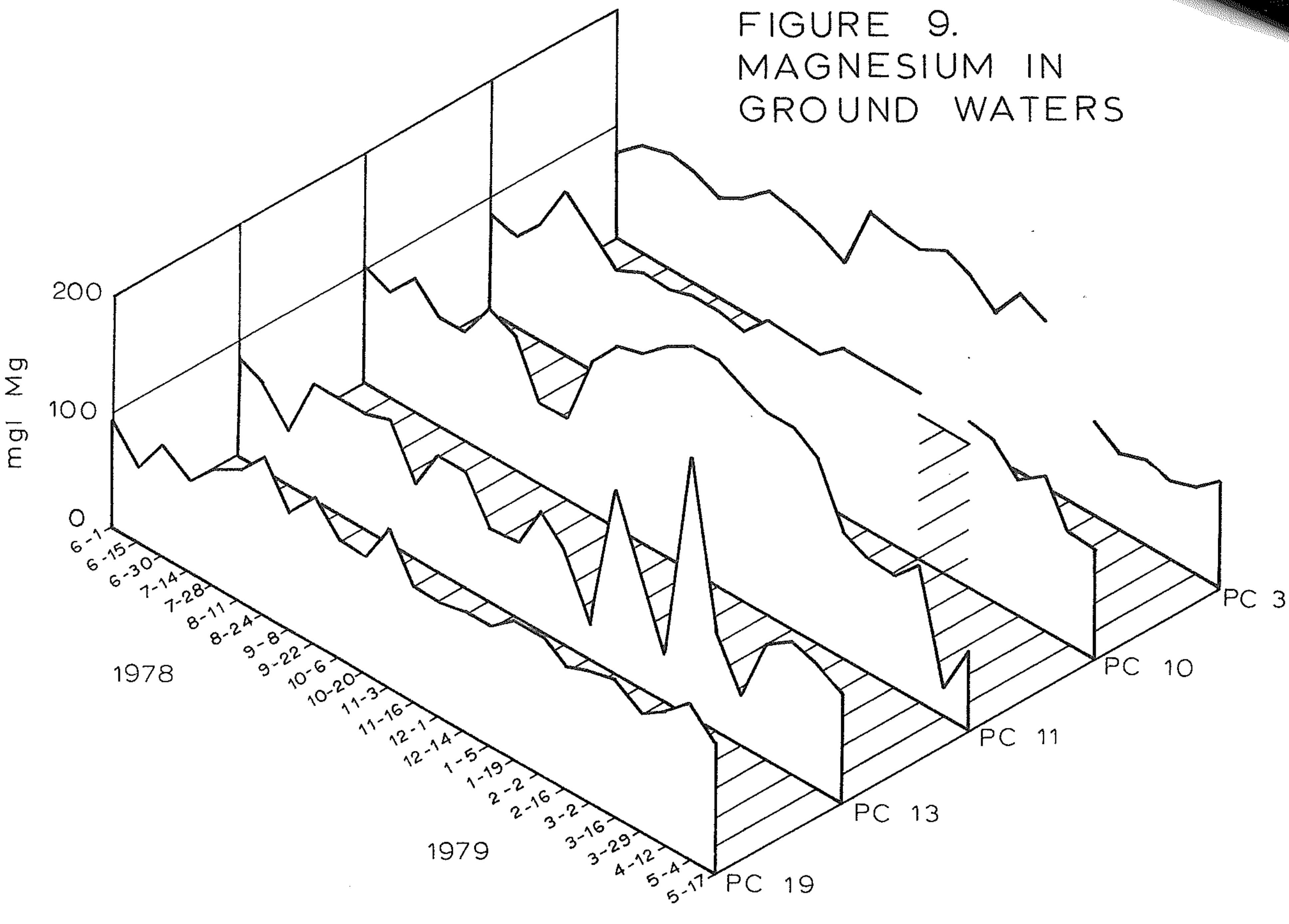


FIGURE 9.
MAGNESIUM IN
GROUND WATERS

FIGURE 10.
CONDUCTIVITY OF
GROUND WATERS

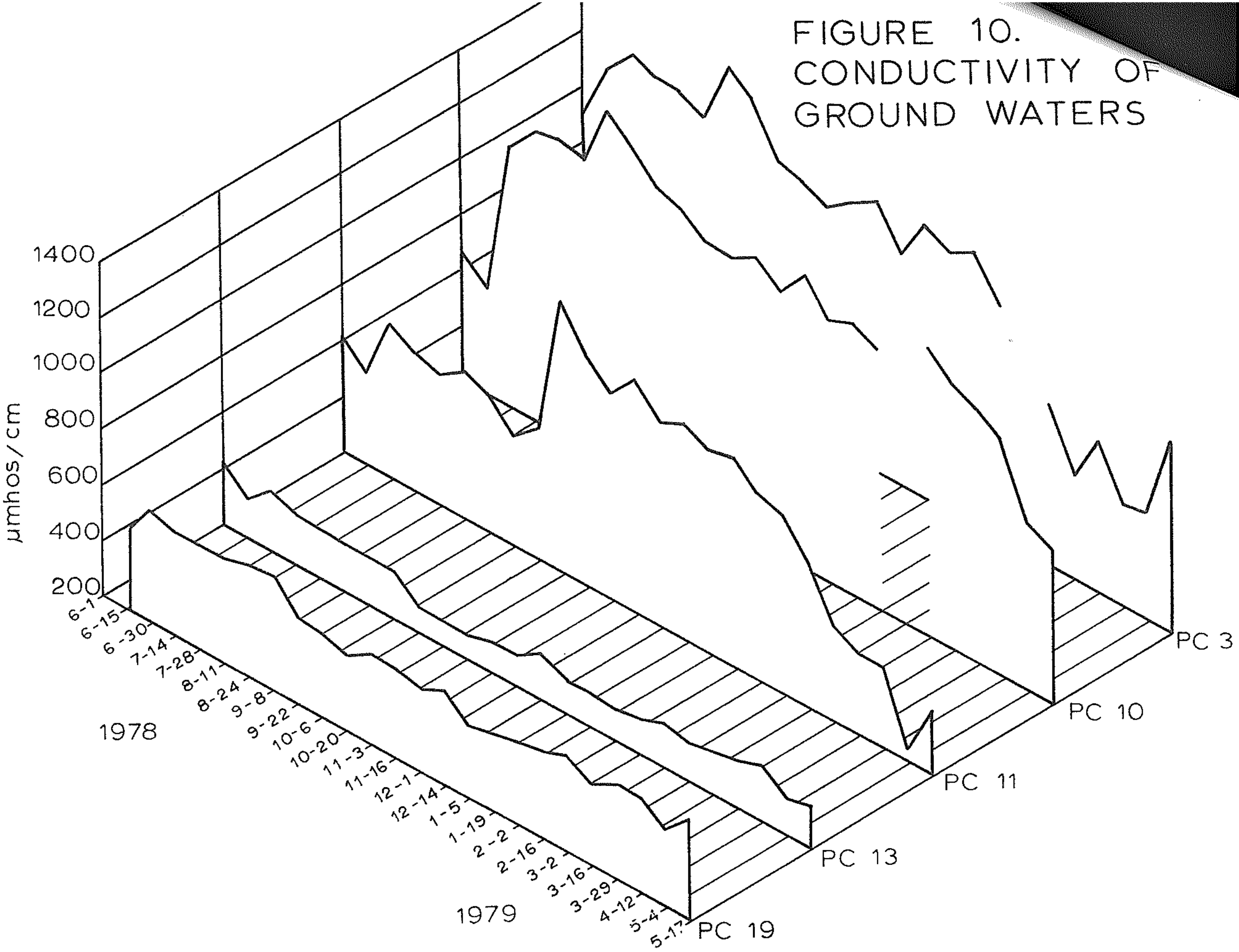


FIGURE 11.
OXYGEN IN
GROUND WATERS

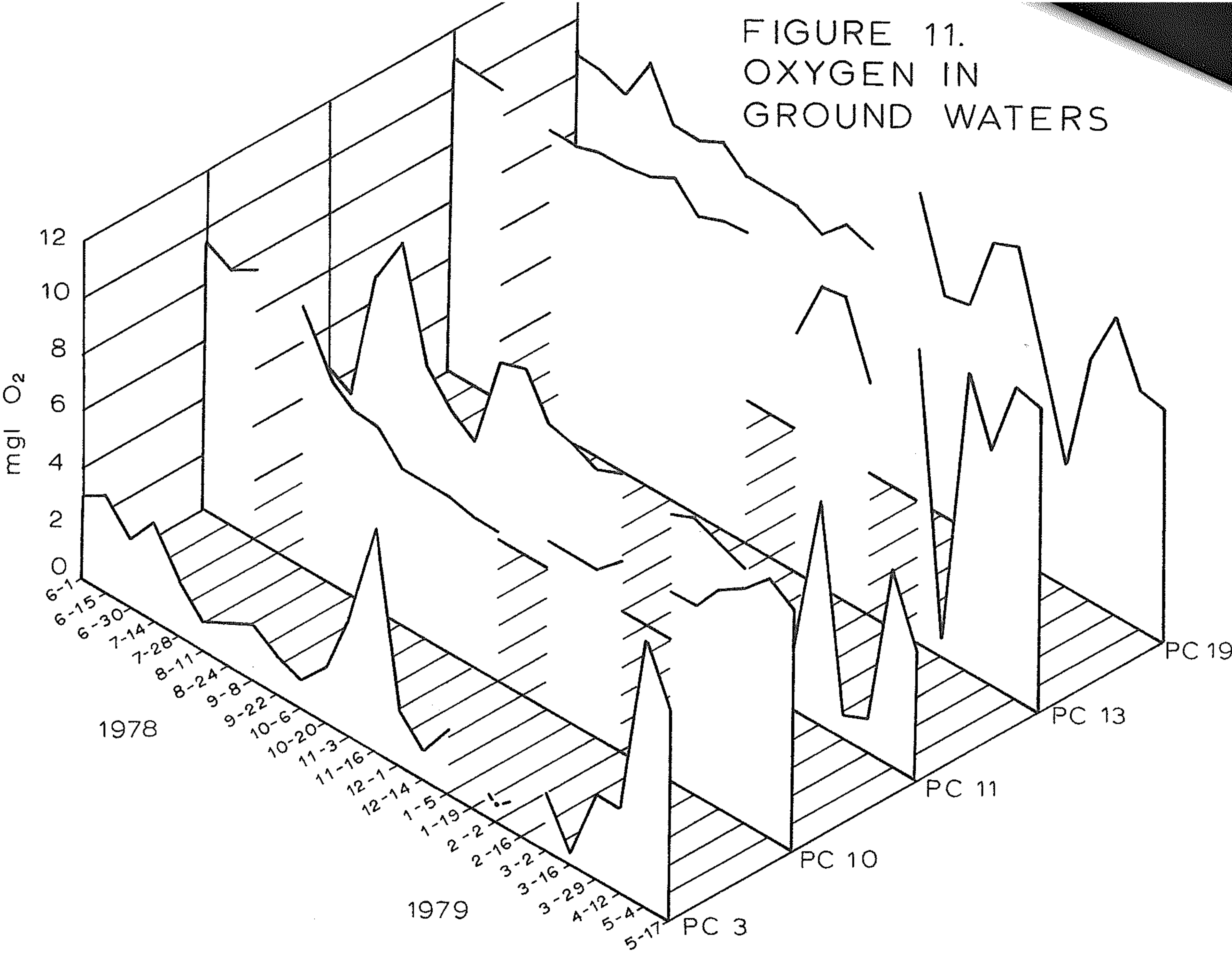


FIGURE 12.
TOTAL PHOSPHORUS
IN GROUND WATERS

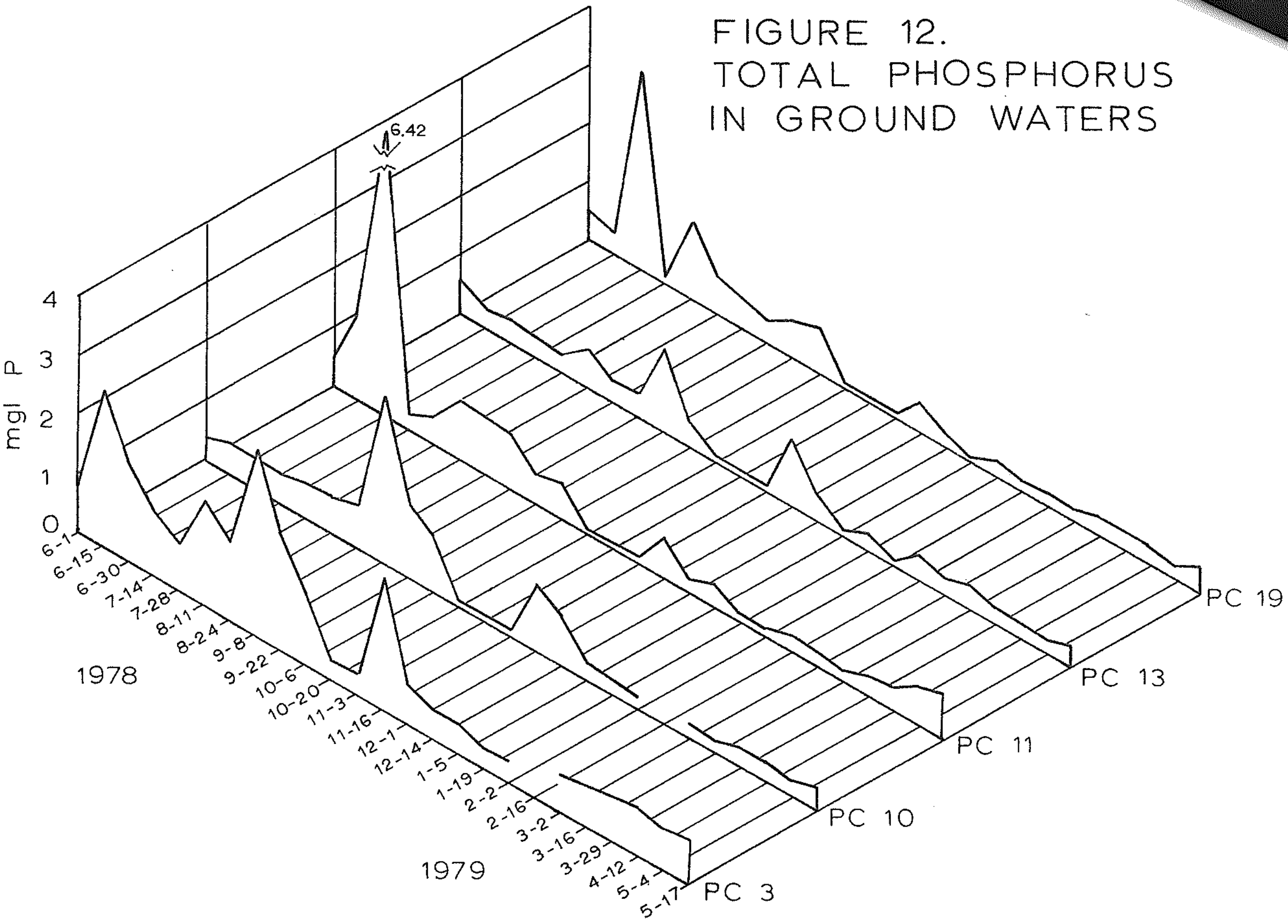


FIGURE 13. TOTAL NITROGEN IN GROUND WATERS

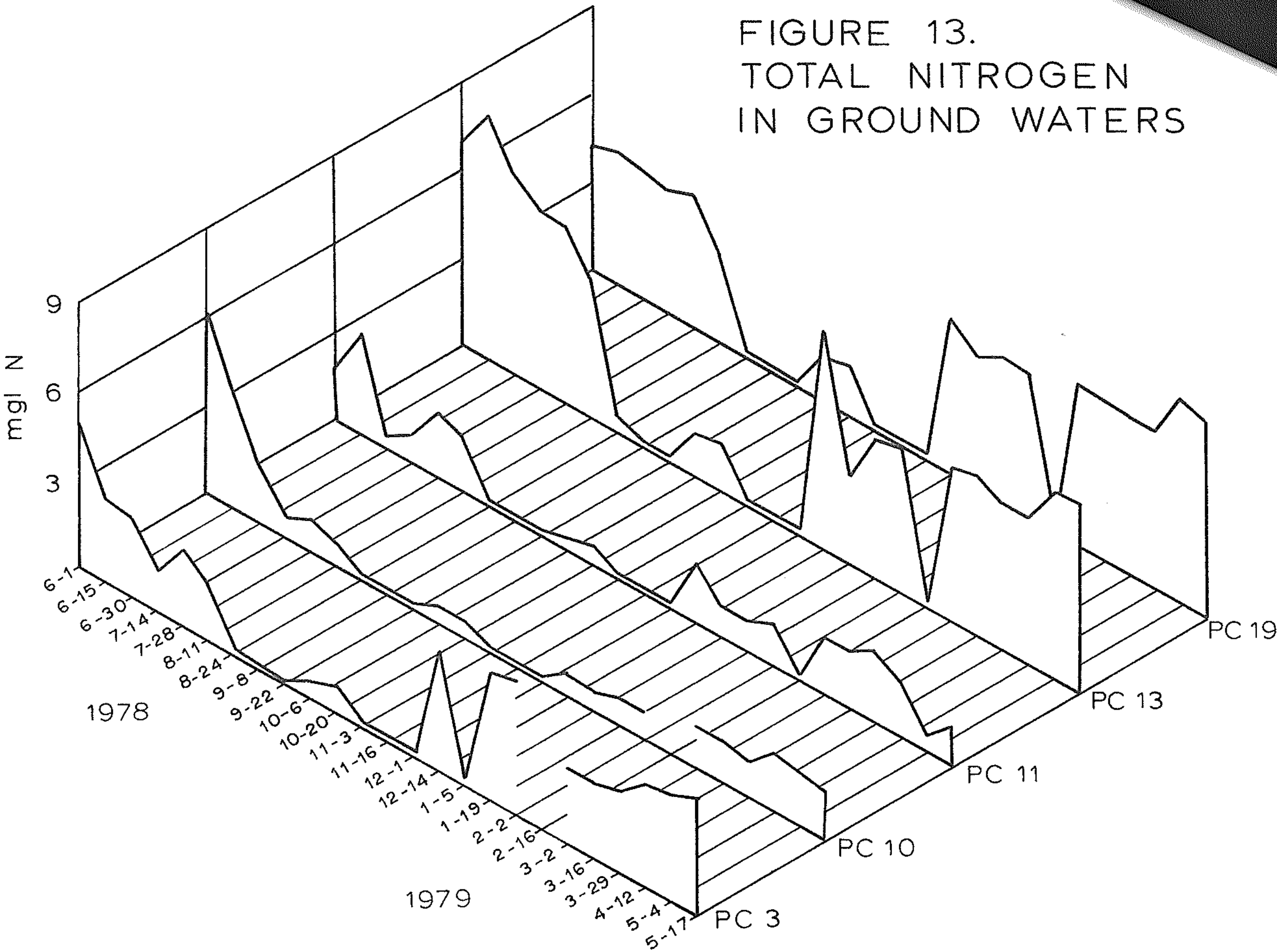


FIGURE 14.
TOTAL MONTHLY
DISCHARGE

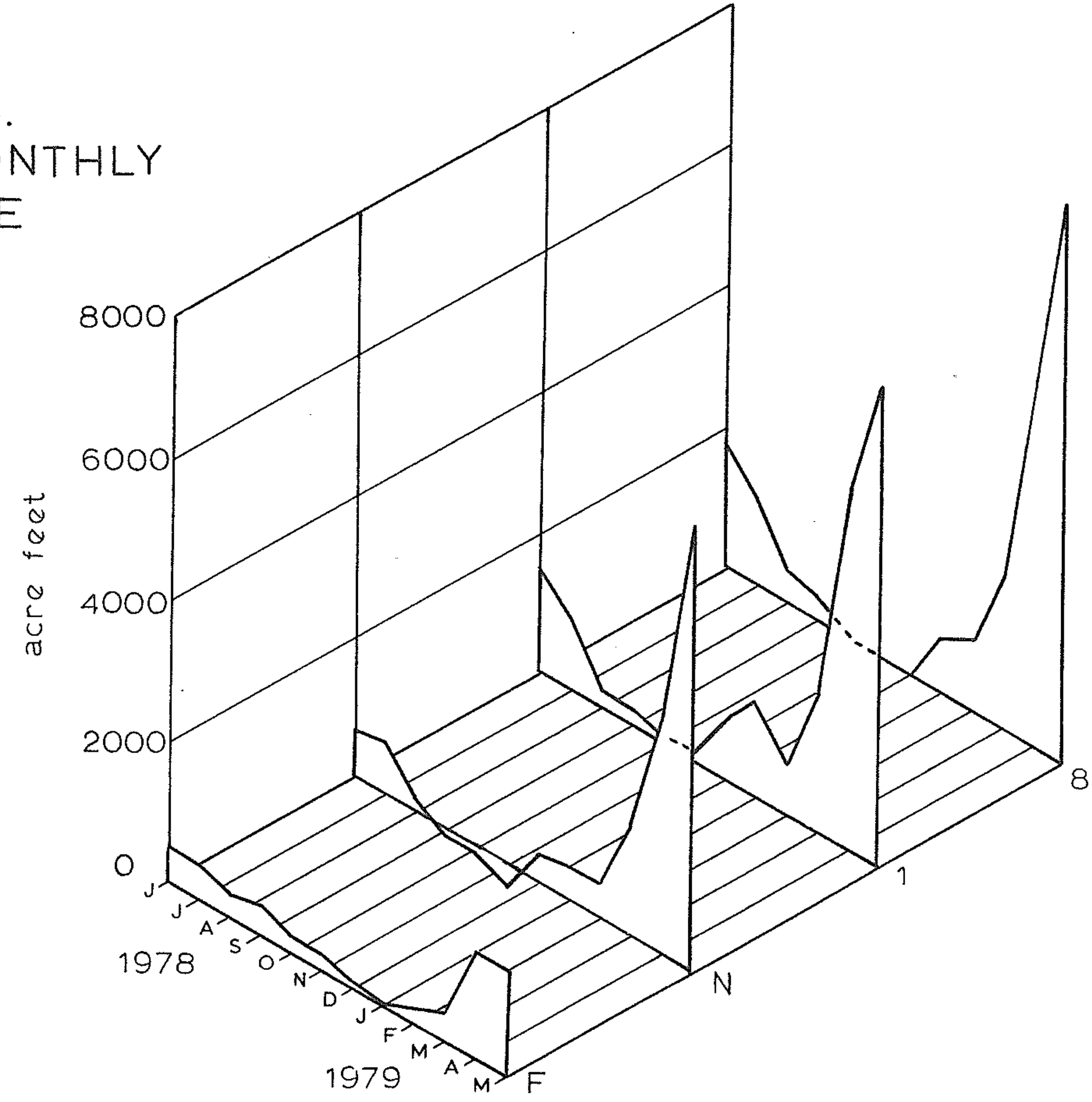


FIGURE 15.
TEMPERATURE OF
SURFACE WATERS

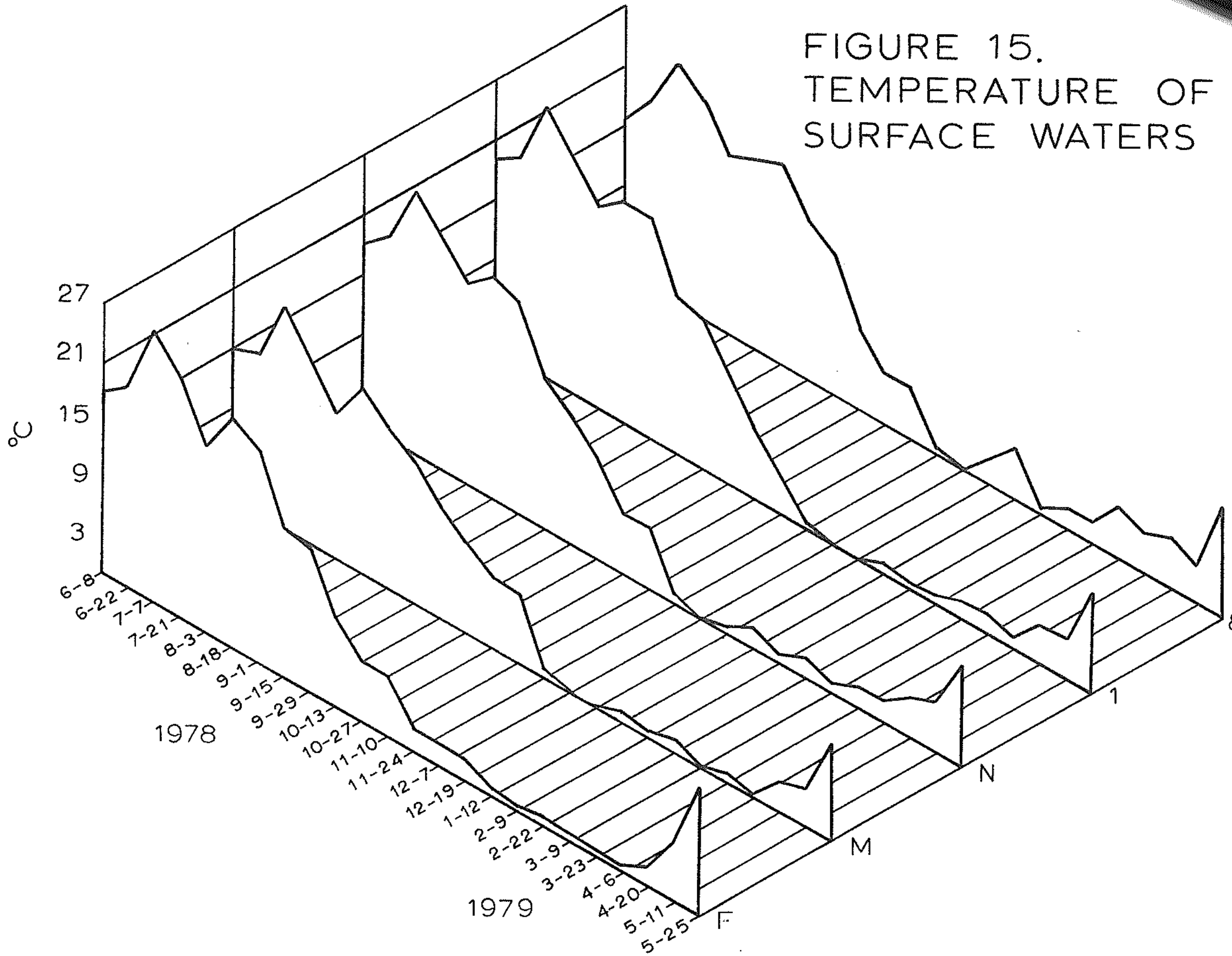
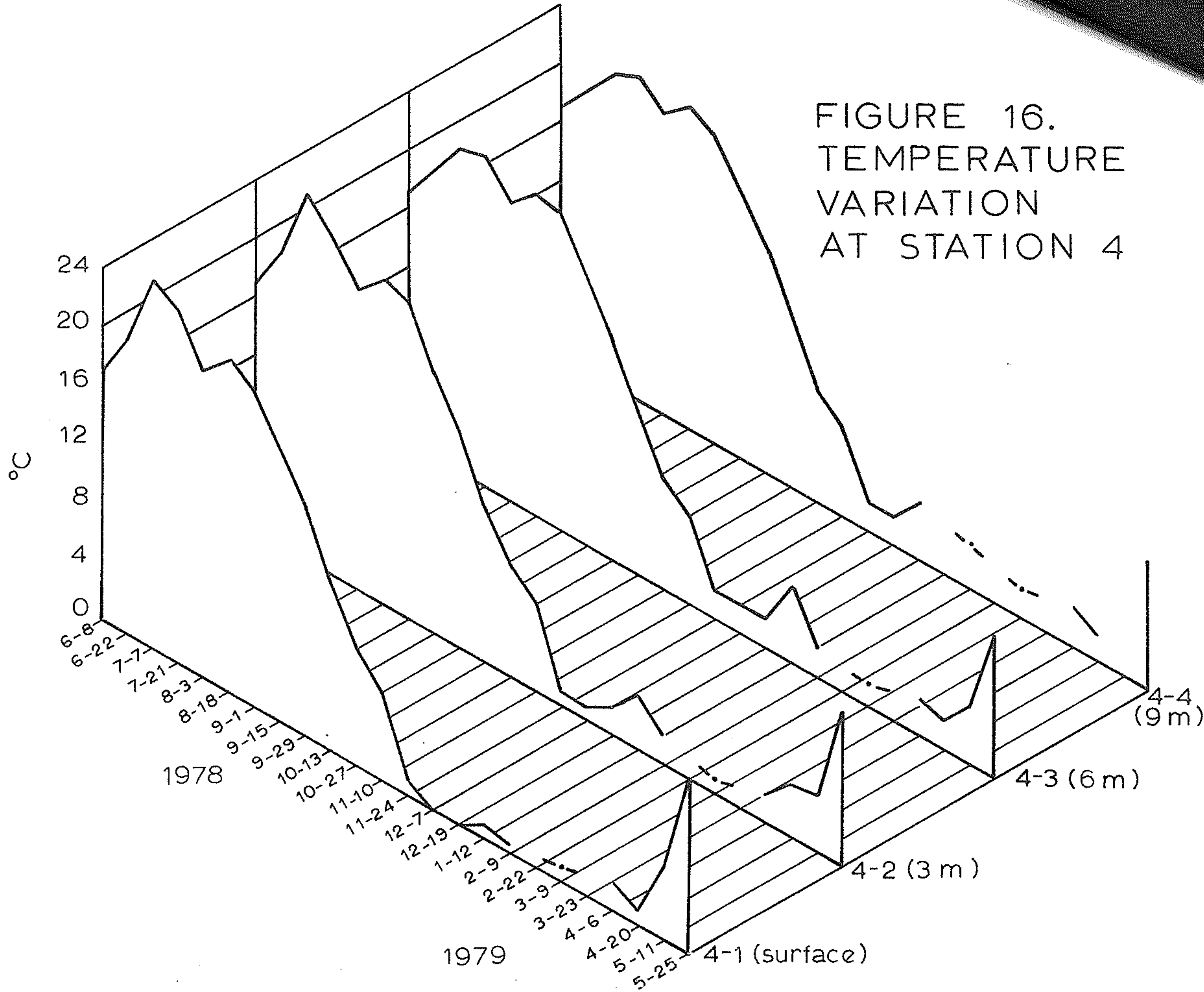


FIGURE 16.
TEMPERATURE
VARIATION
AT STATION 4



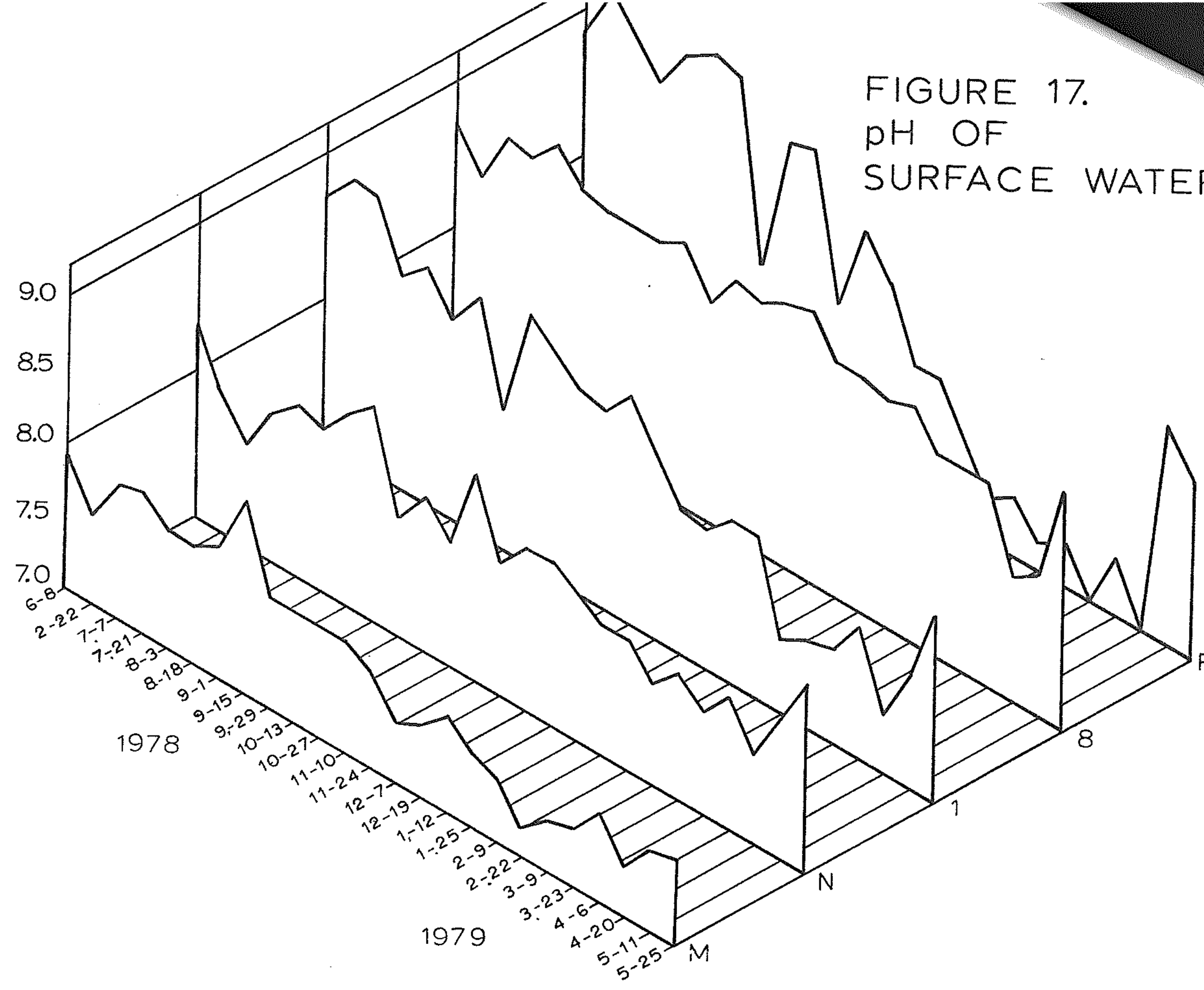


FIGURE 17.
pH OF
SURFACE WATERS

FIGURE 18.
pH VARIATION
AT STATION 4

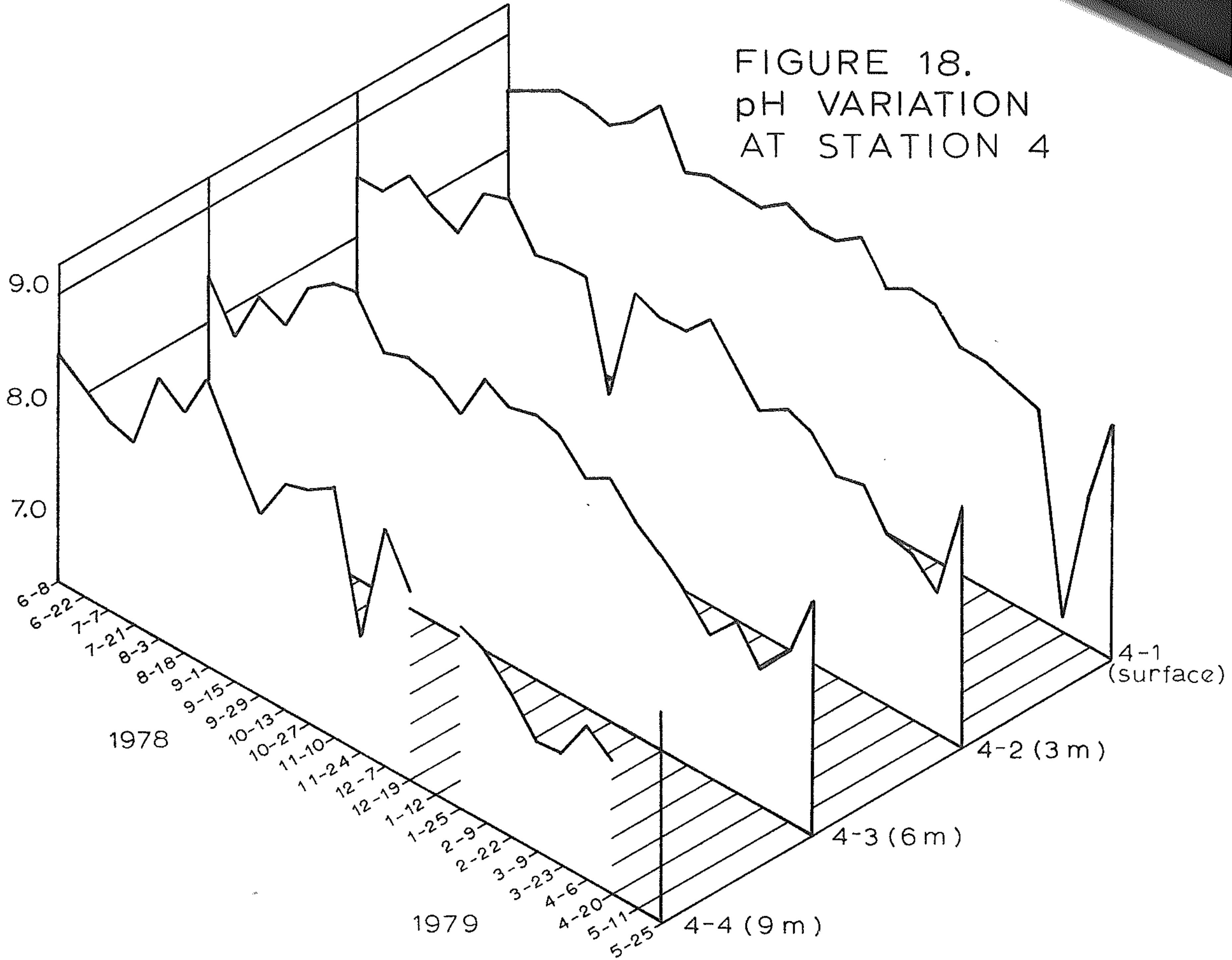


FIGURE 19.
TOTAL ALKALINITY
IN SURFACE WATERS

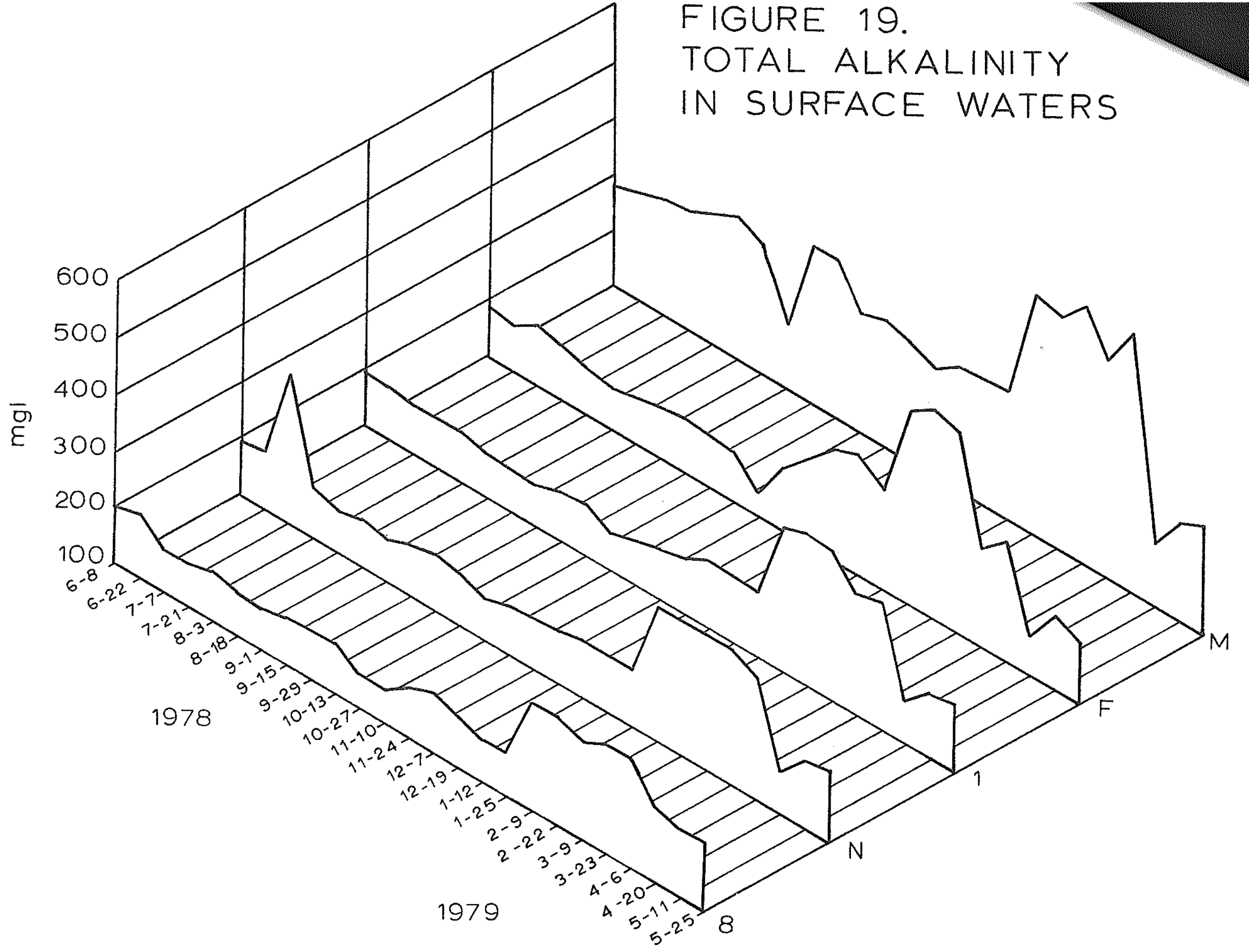


FIGURE 20.
VARIATION OF
TOTAL ALKALINITY
AT STATION 4

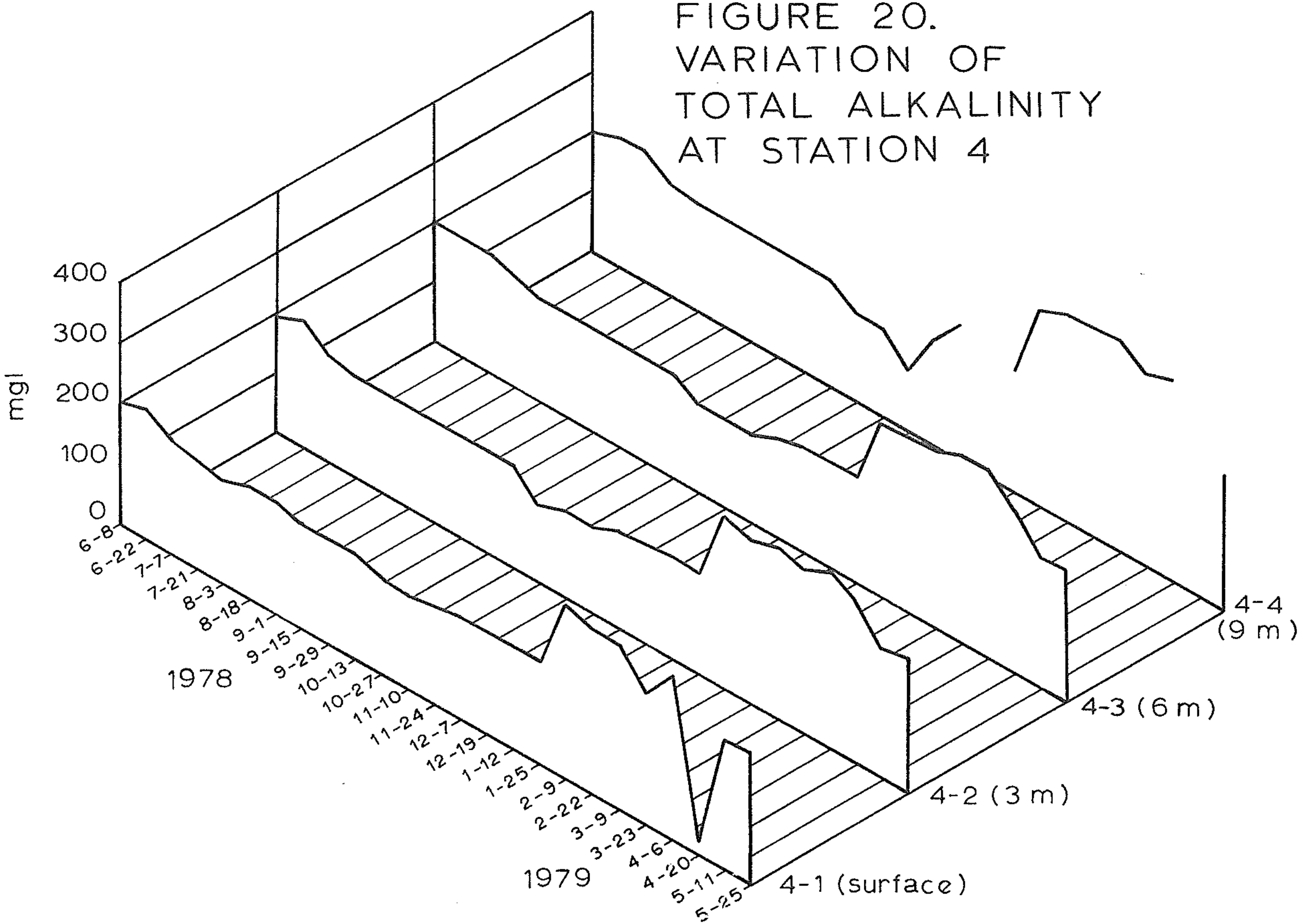


FIGURE 21.
CALCIUM IN
SURFACE WATERS

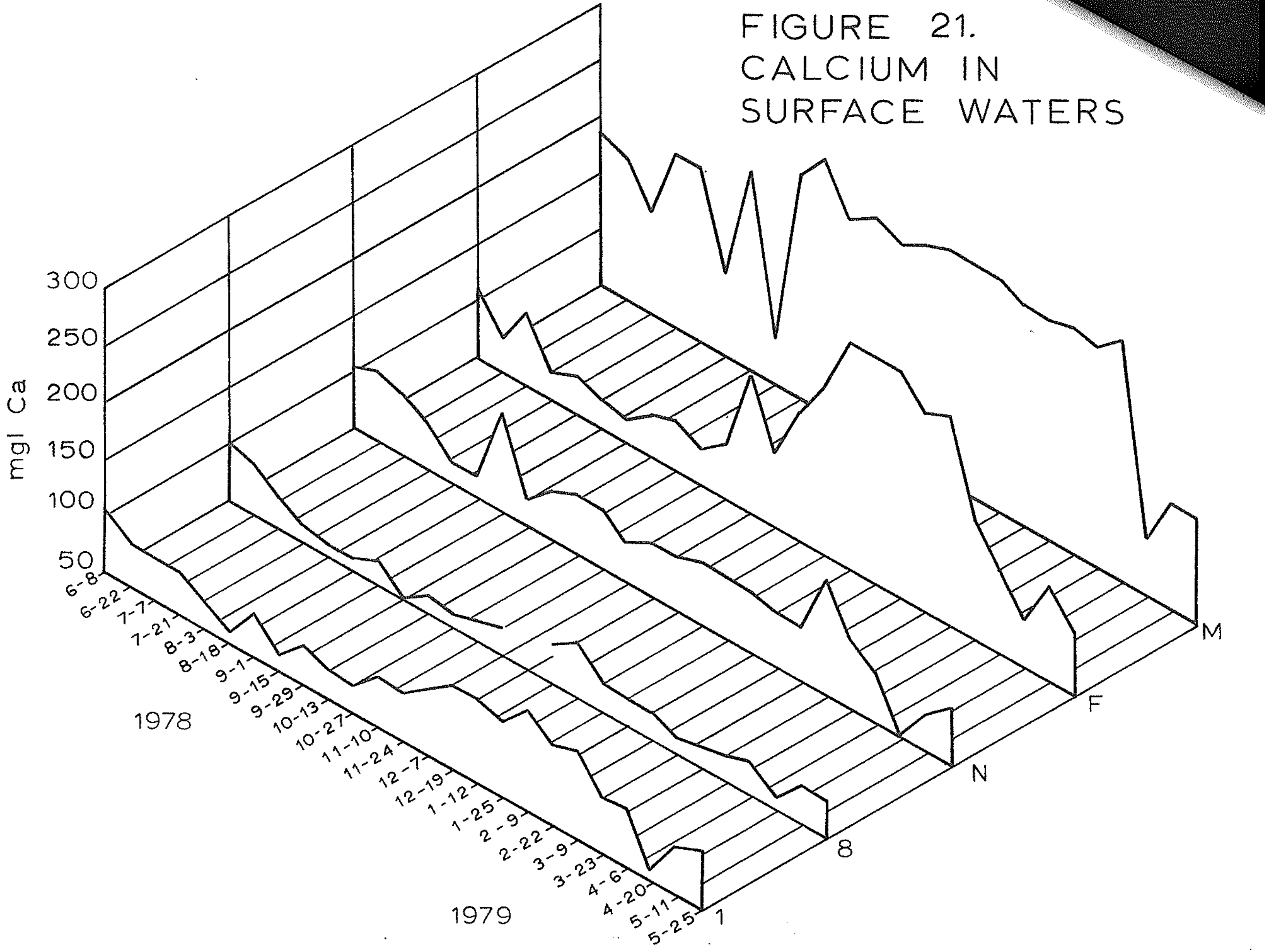


FIGURE 22.
CALCIUM VARIATION
AT STATION 4

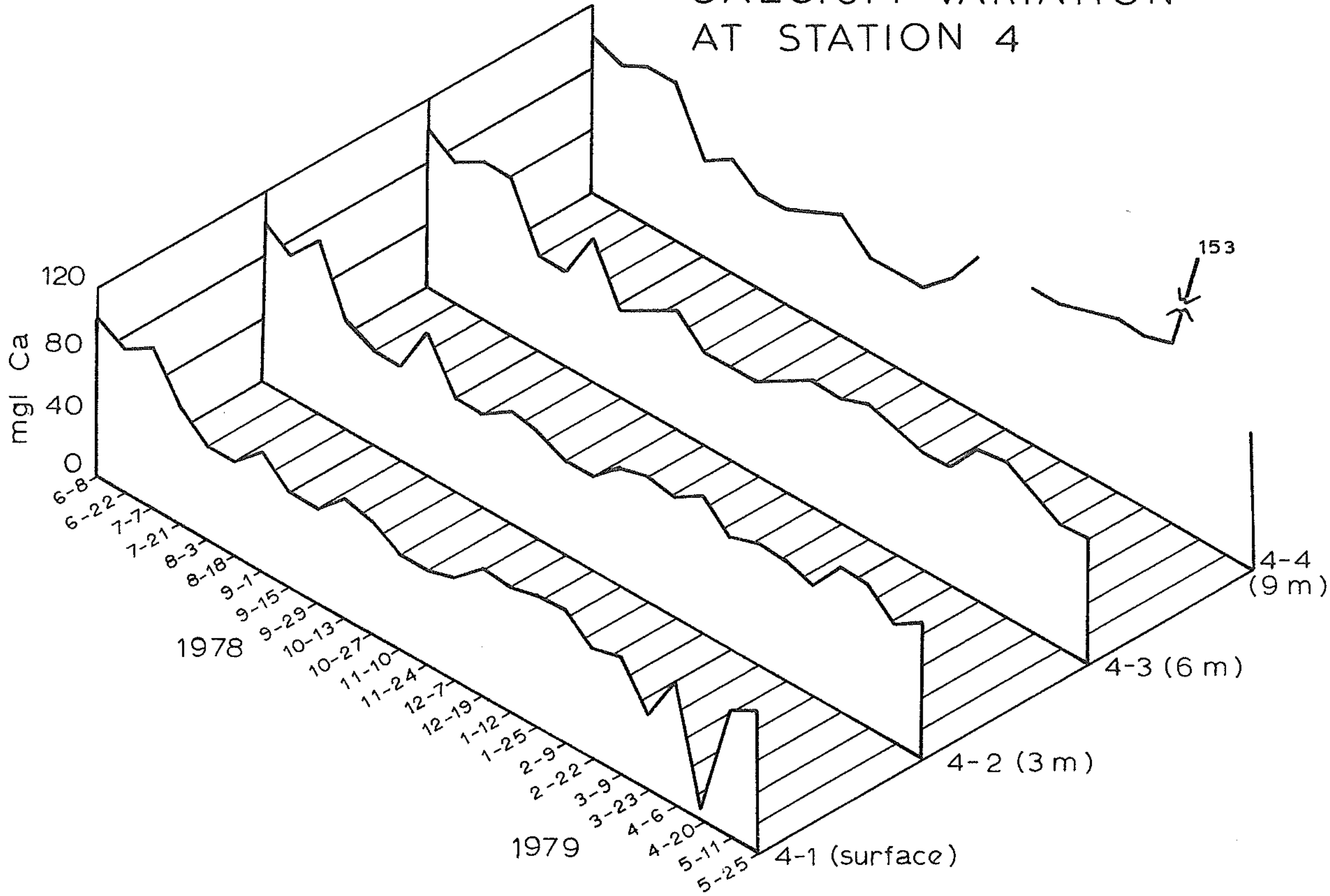


FIGURE 23. MAGNESIUM IN SURFACE WATERS

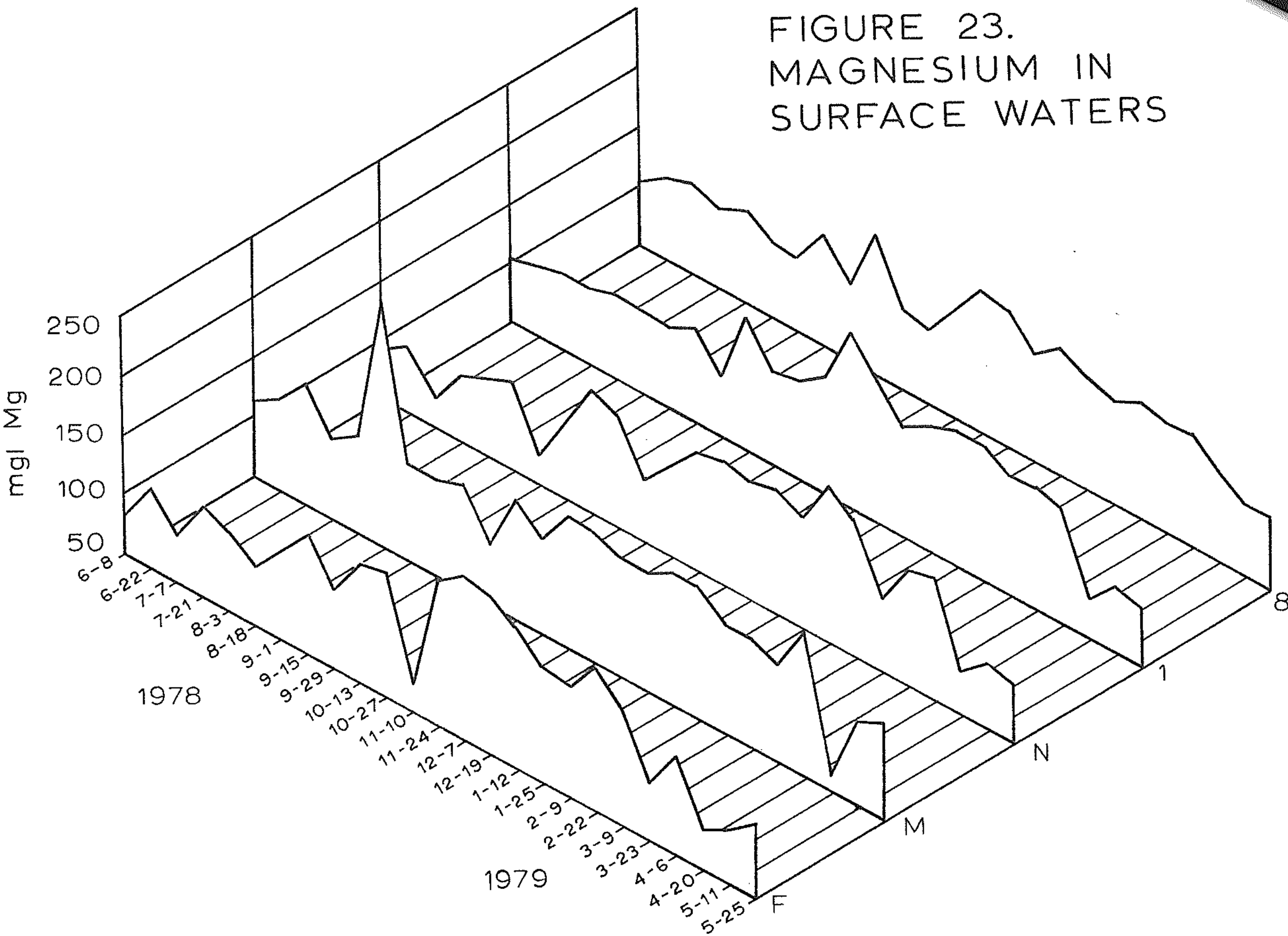
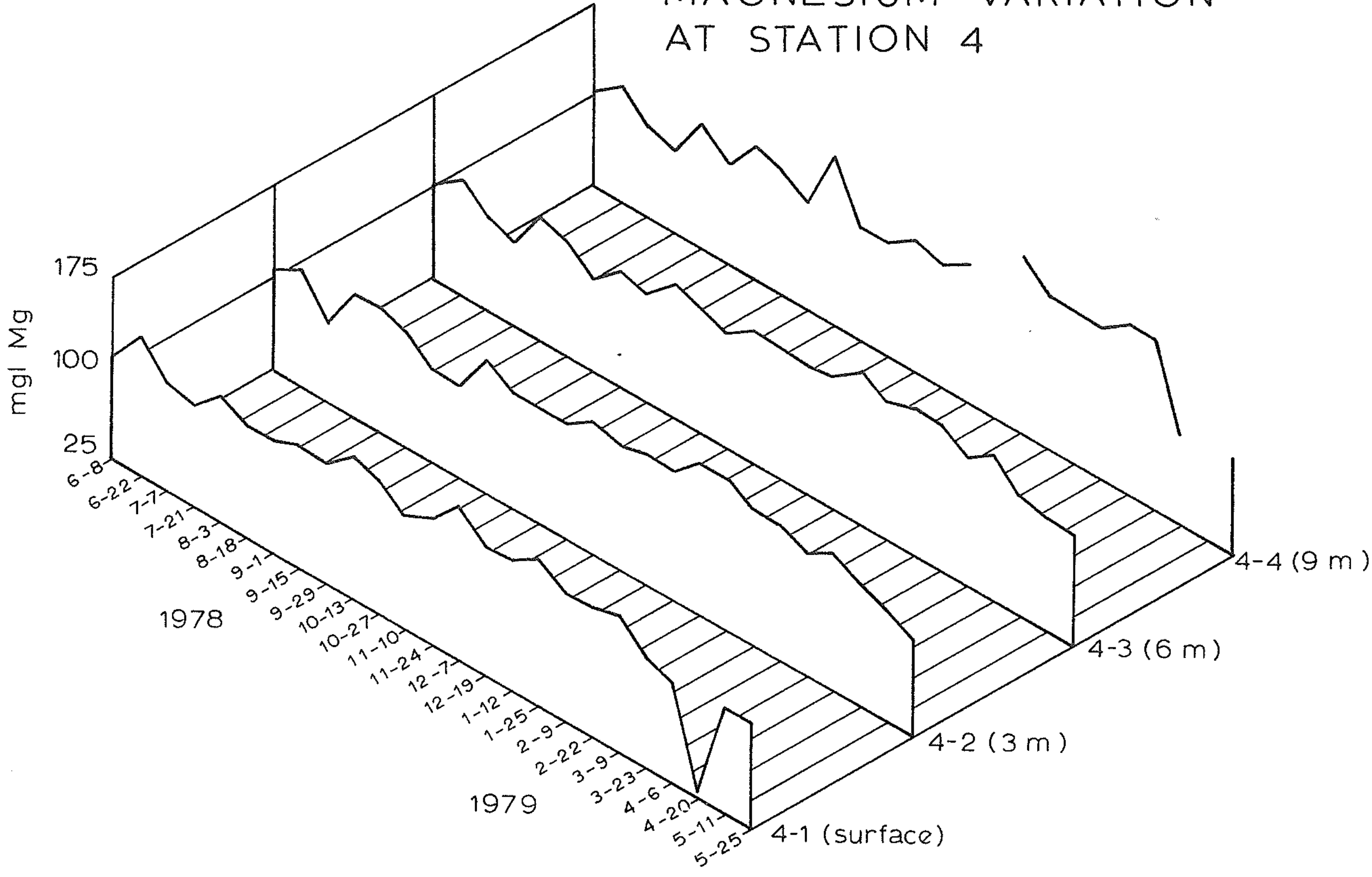


FIGURE 24.
MAGNESIUM VARIATION
AT STATION 4



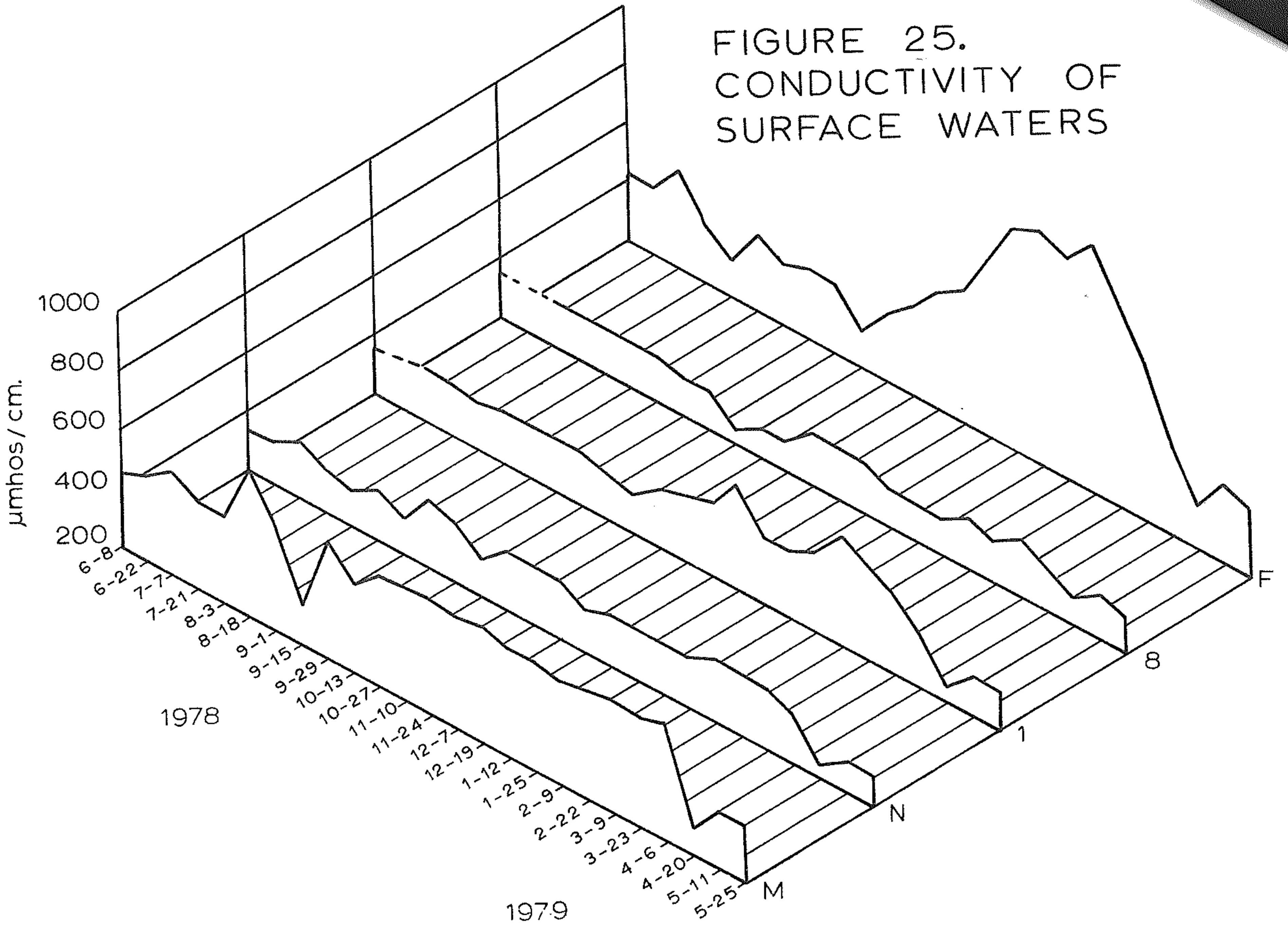


FIGURE 25.
CONDUCTIVITY OF
SURFACE WATERS

FIGURE 26.
VARIATION OF
CONDUCTIVITY
AT STATION 4

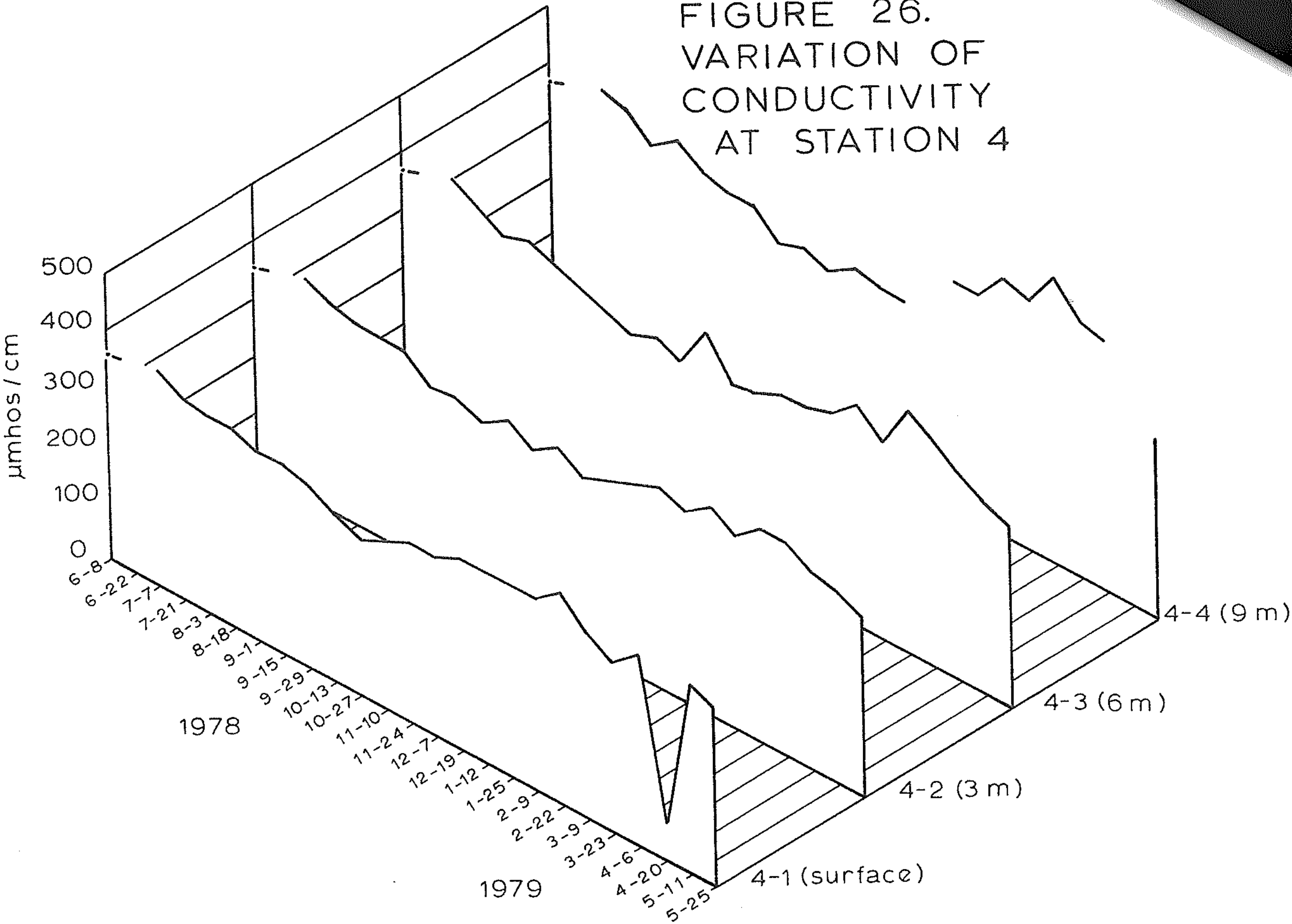


FIGURE 27.
OXYGEN IN
SURFACE WATERS

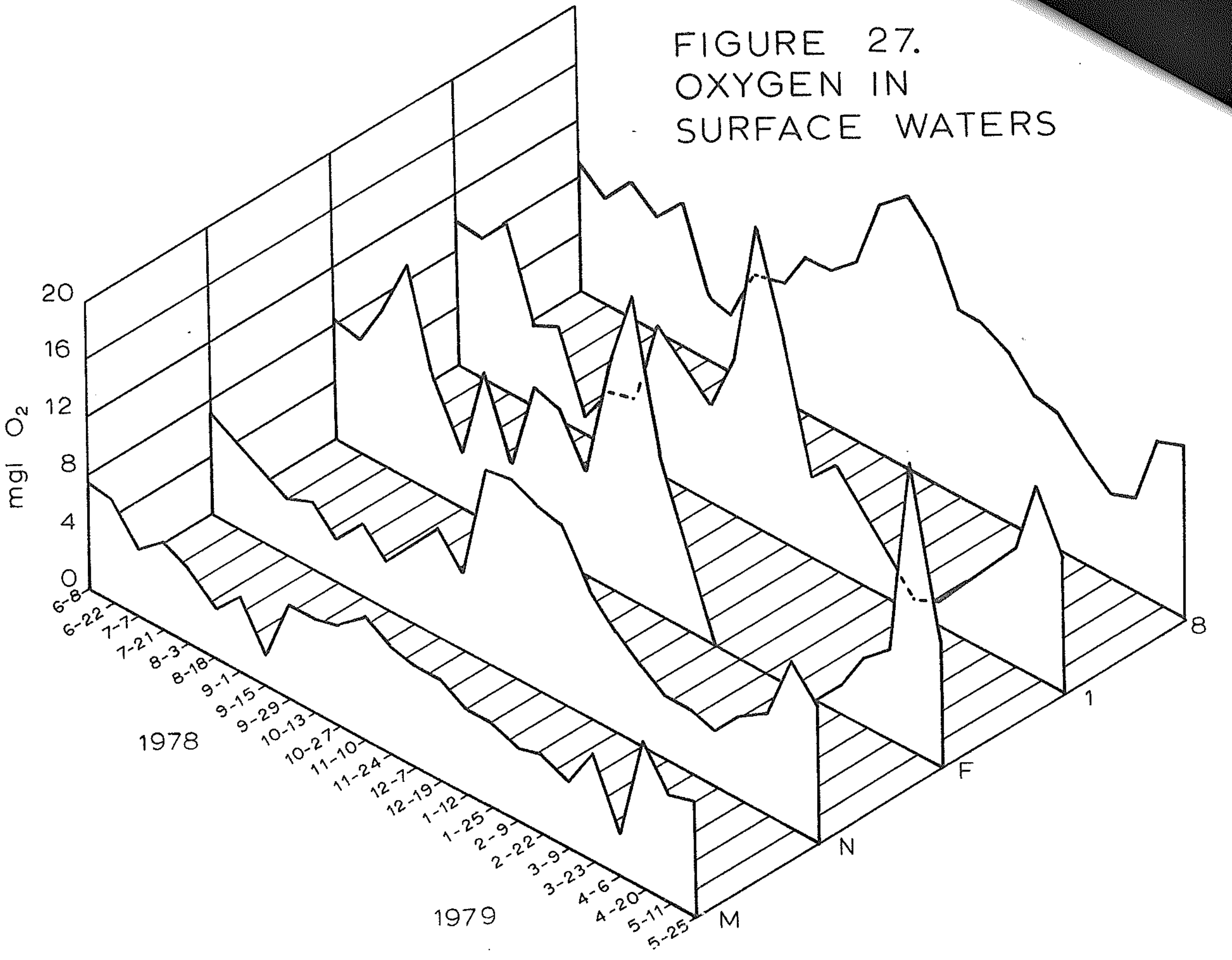


FIGURE 28. OXYGEN VARIATION AT STATION 4

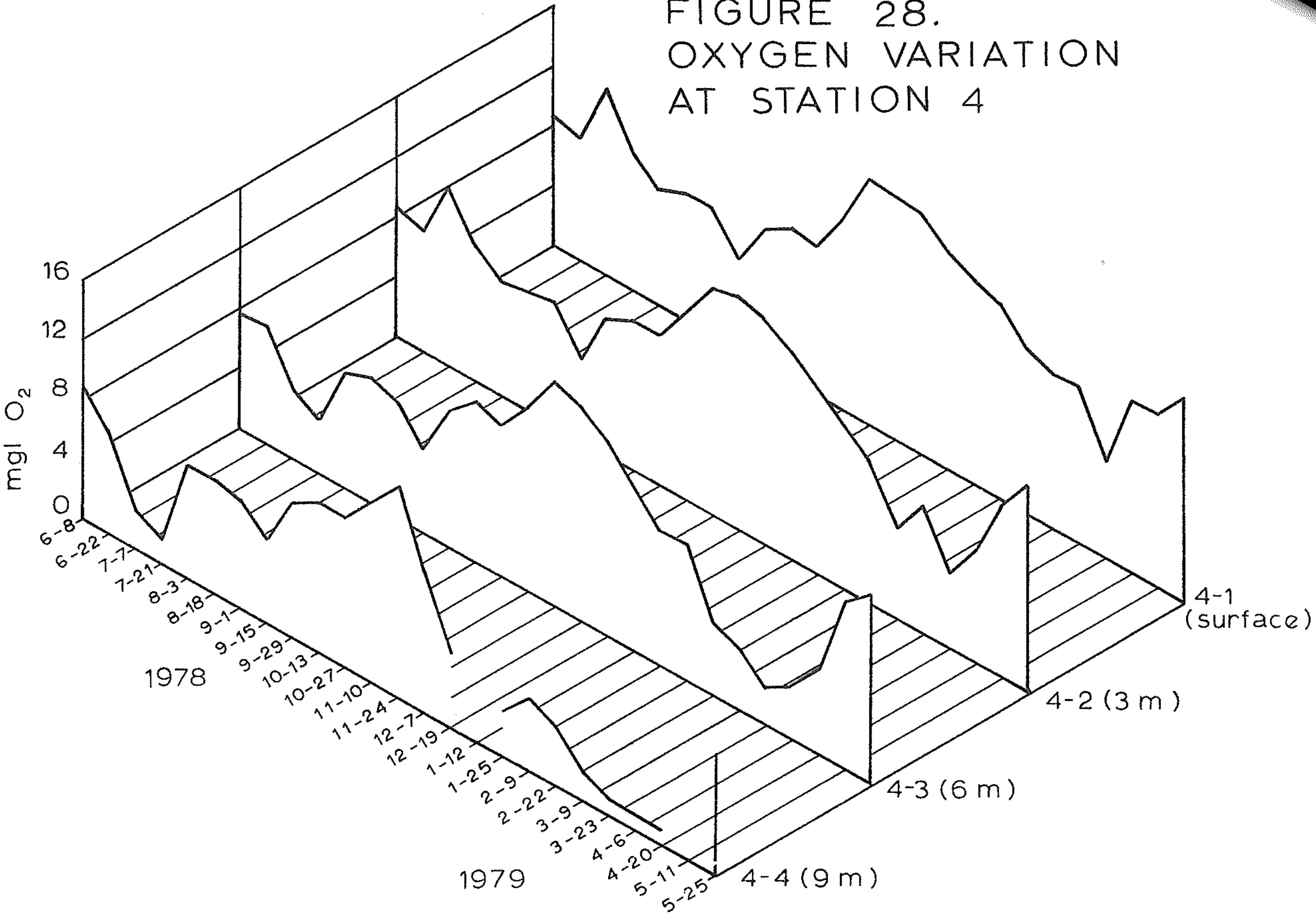
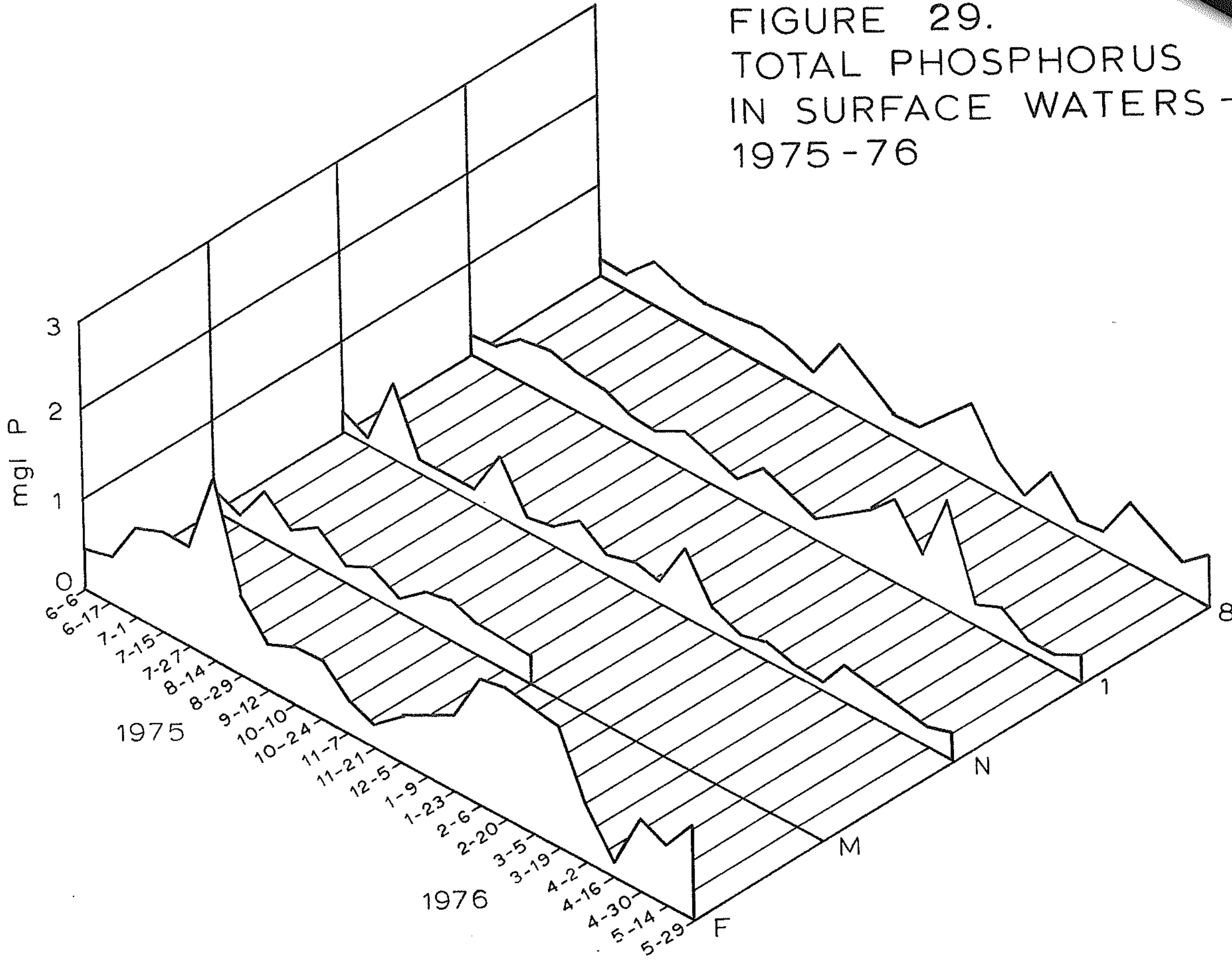


FIGURE 29.
TOTAL PHOSPHORUS
IN SURFACE WATERS -
1975-76



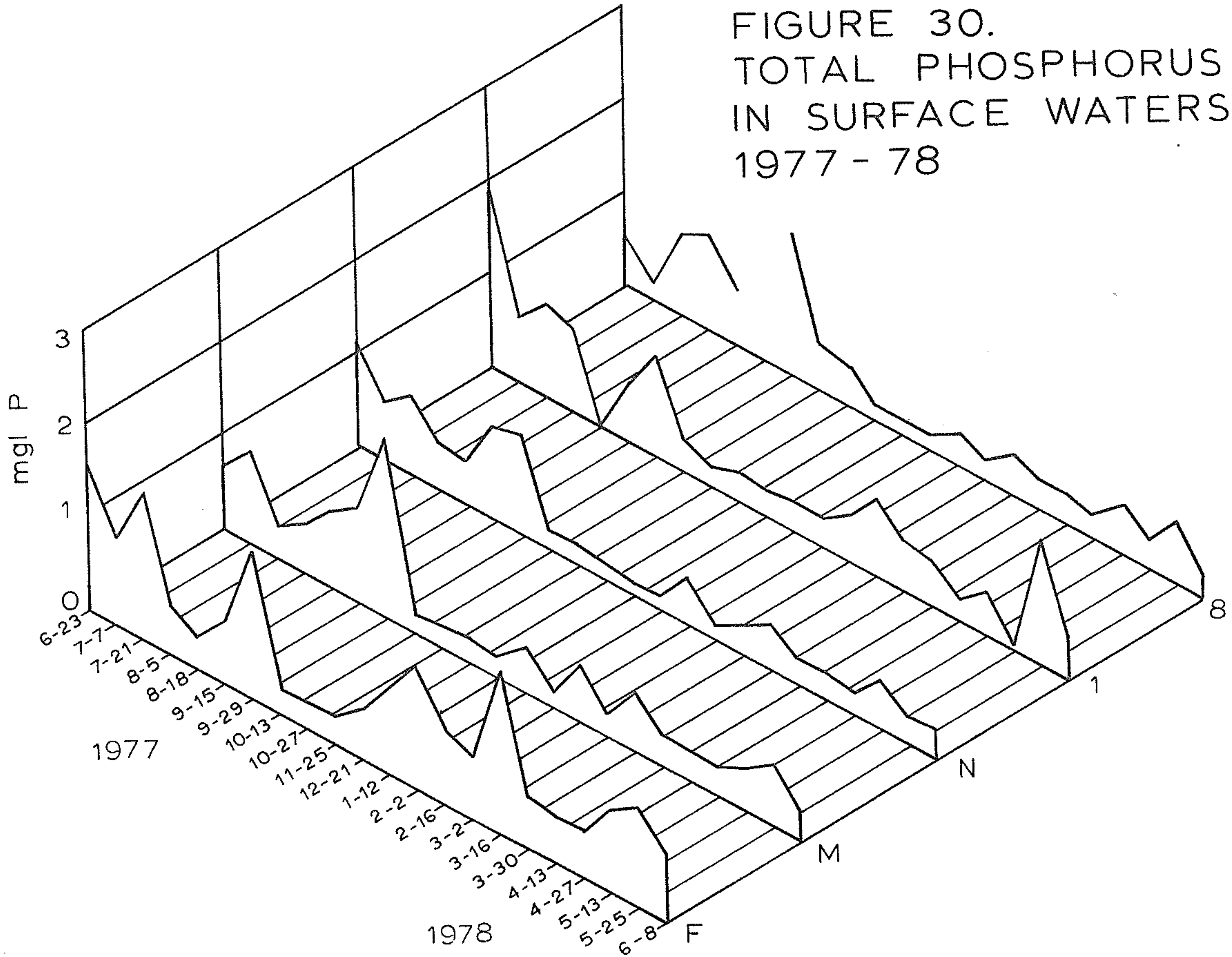
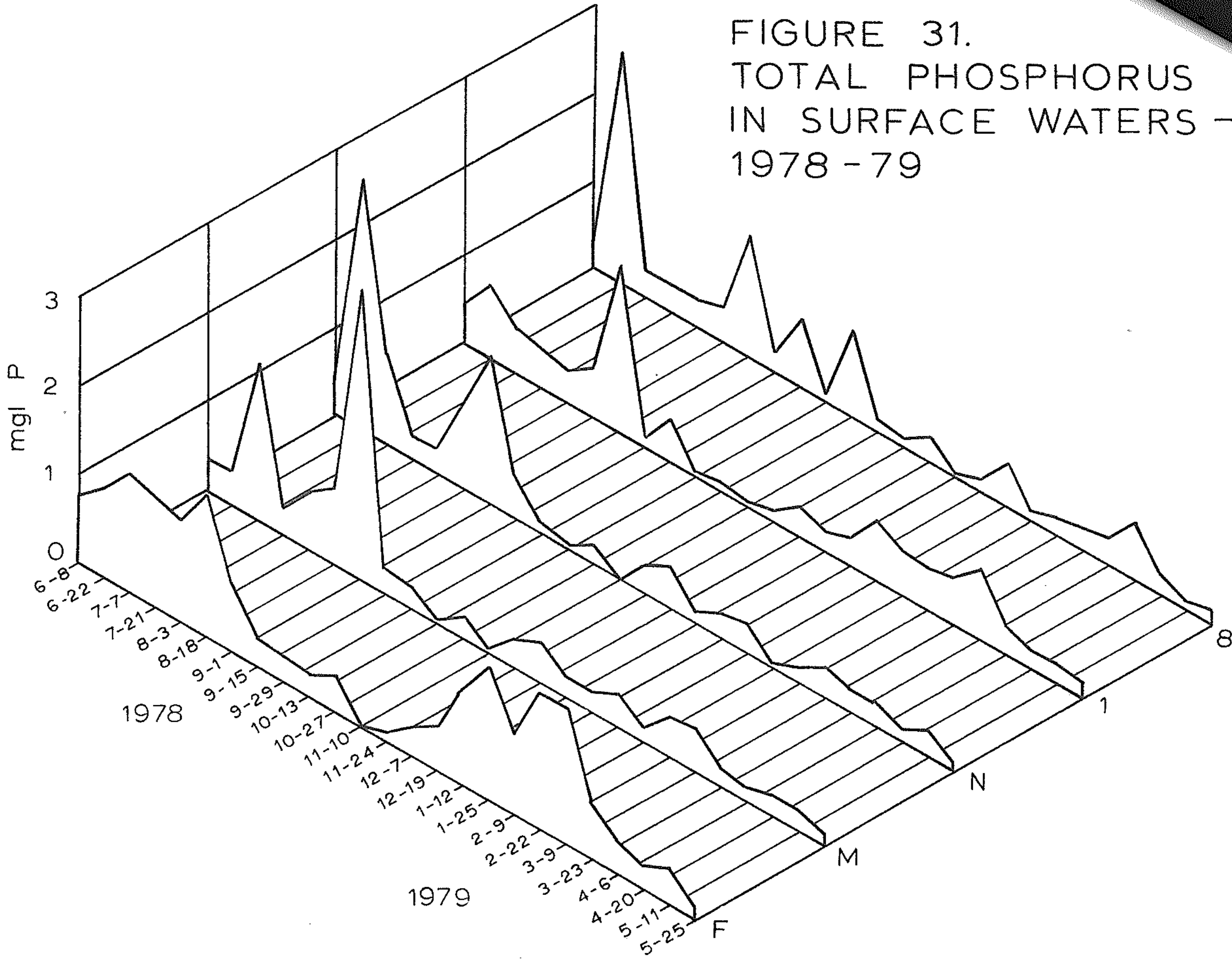


FIGURE 30.
TOTAL PHOSPHORUS
IN SURFACE WATERS –
1977 – 78

FIGURE 31. TOTAL PHOSPHORUS IN SURFACE WATERS - 1978-79



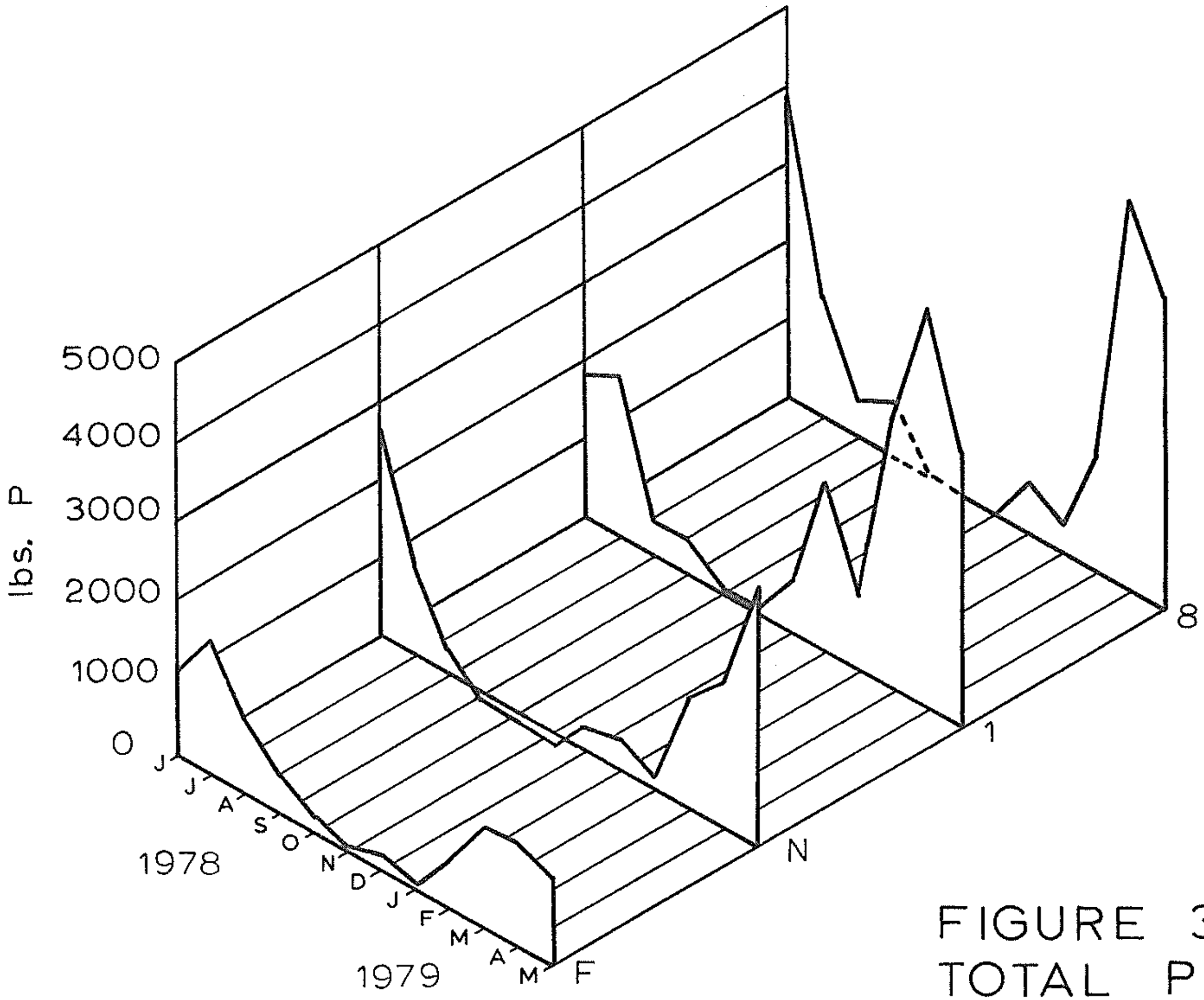


FIGURE 32.
TOTAL PHOSPHORUS
LOADS

FIGURE 33.
TOTAL NITROGEN IN
SURFACE WATERS -
1975-76

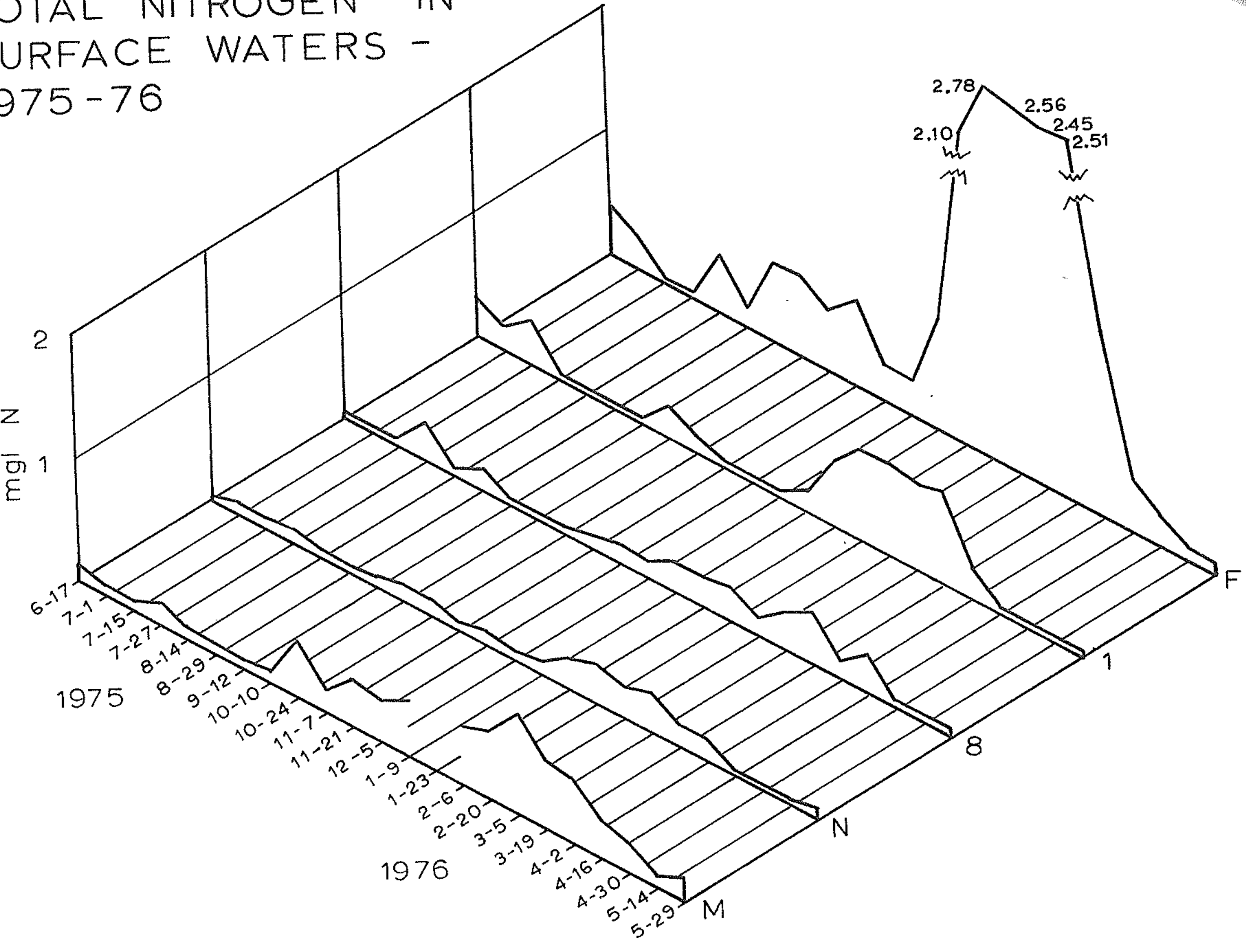


FIGURE 34.
TOTAL NITROGEN
IN SURFACE WATERS -
1977-78

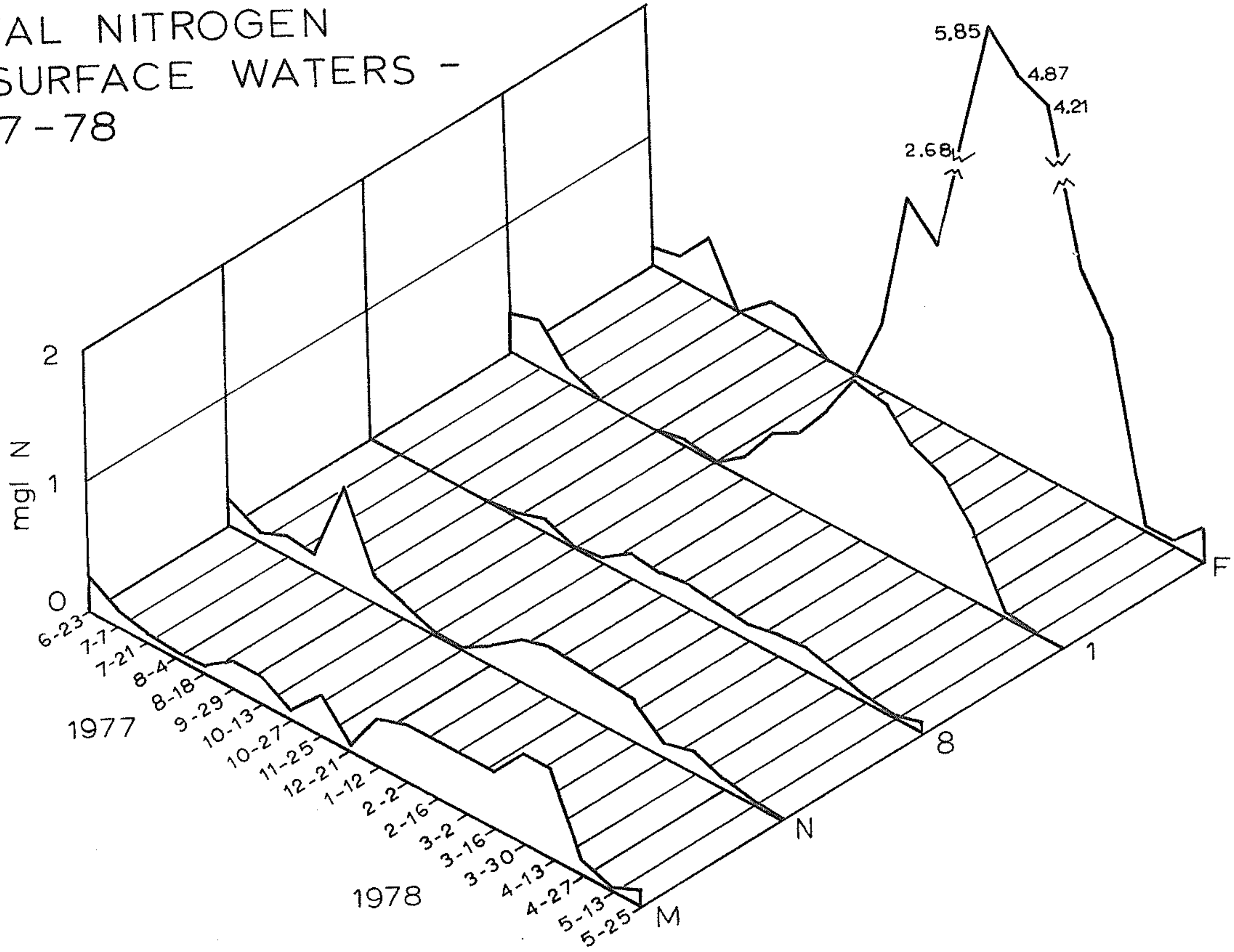
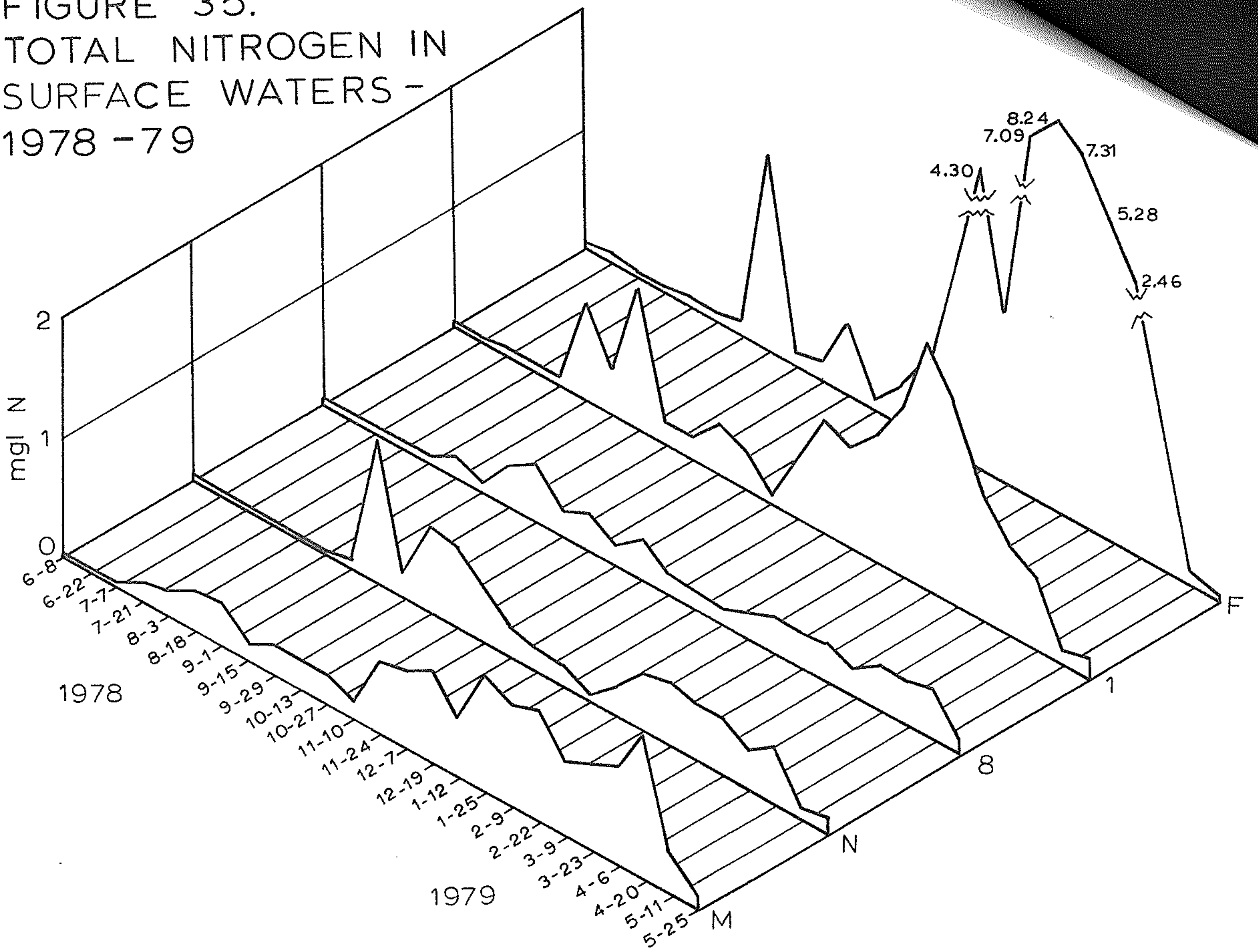


FIGURE 35.
TOTAL NITROGEN IN SURFACE WATERS - 1978 -79



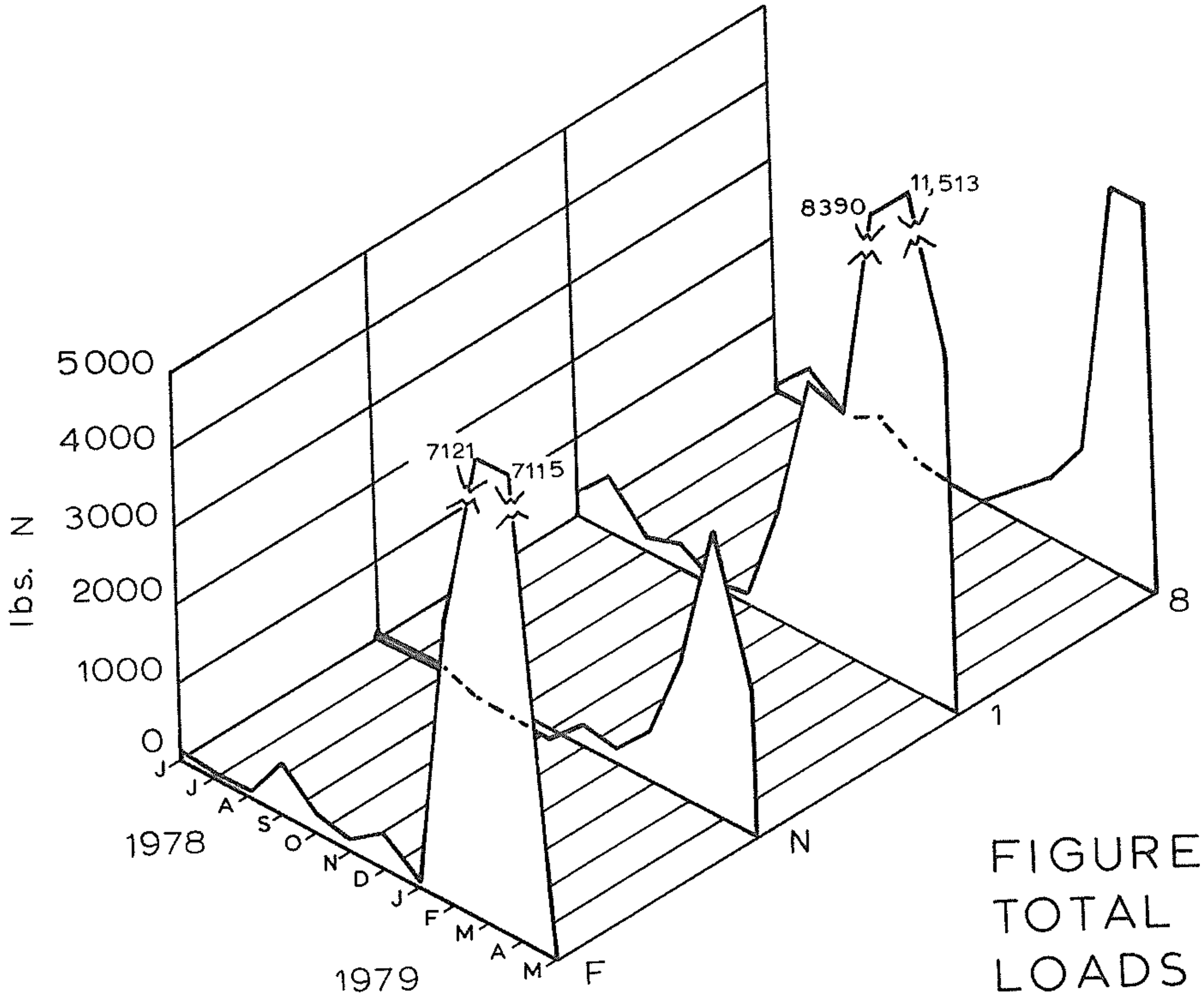


FIGURE 36.
TOTAL NITROGEN
LOADS

FIGURE 38.
NONHETEROCYSTOUS
BLUE - GREEN
ALGAE

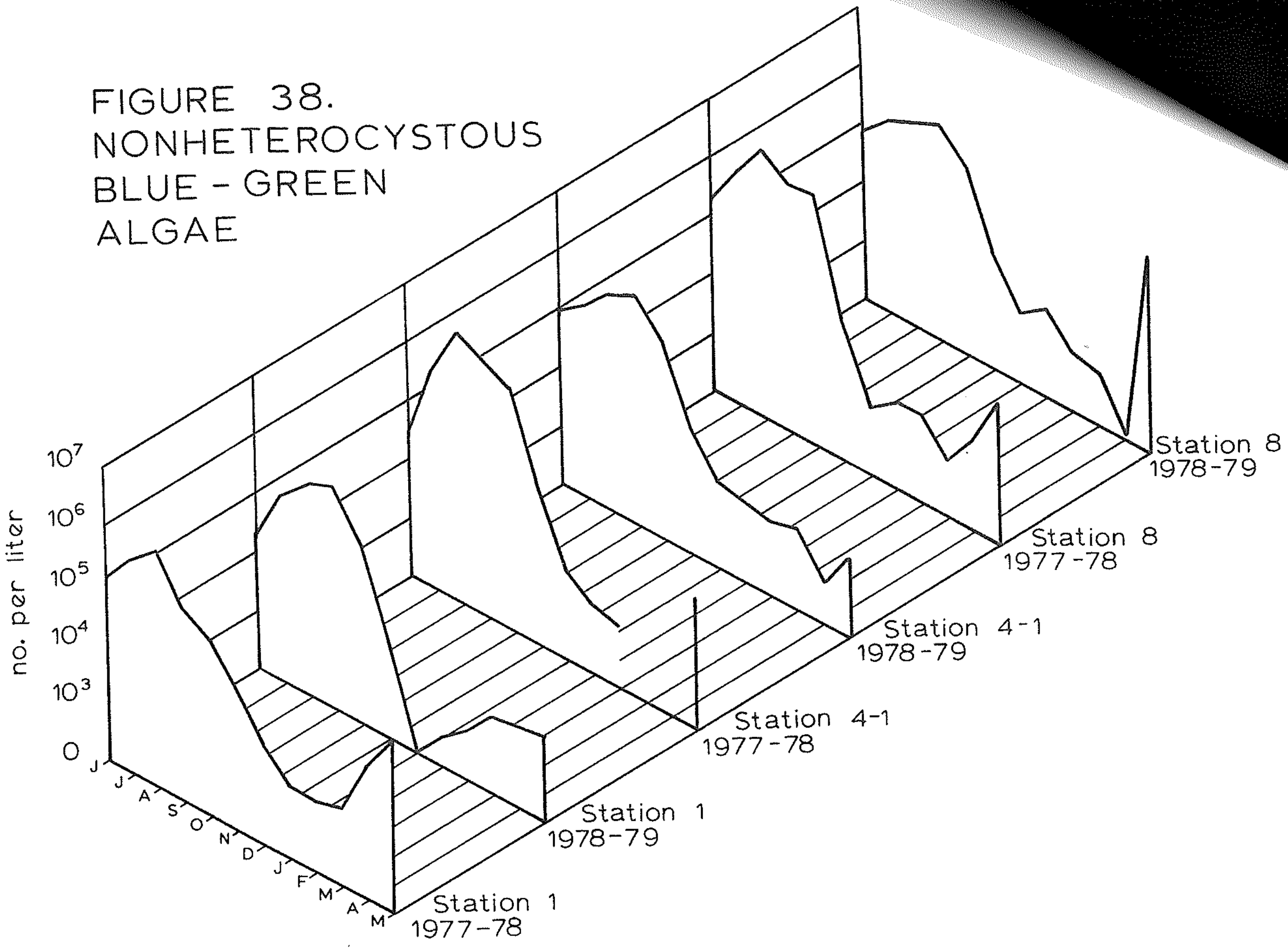


FIGURE 39.
DIATOMS

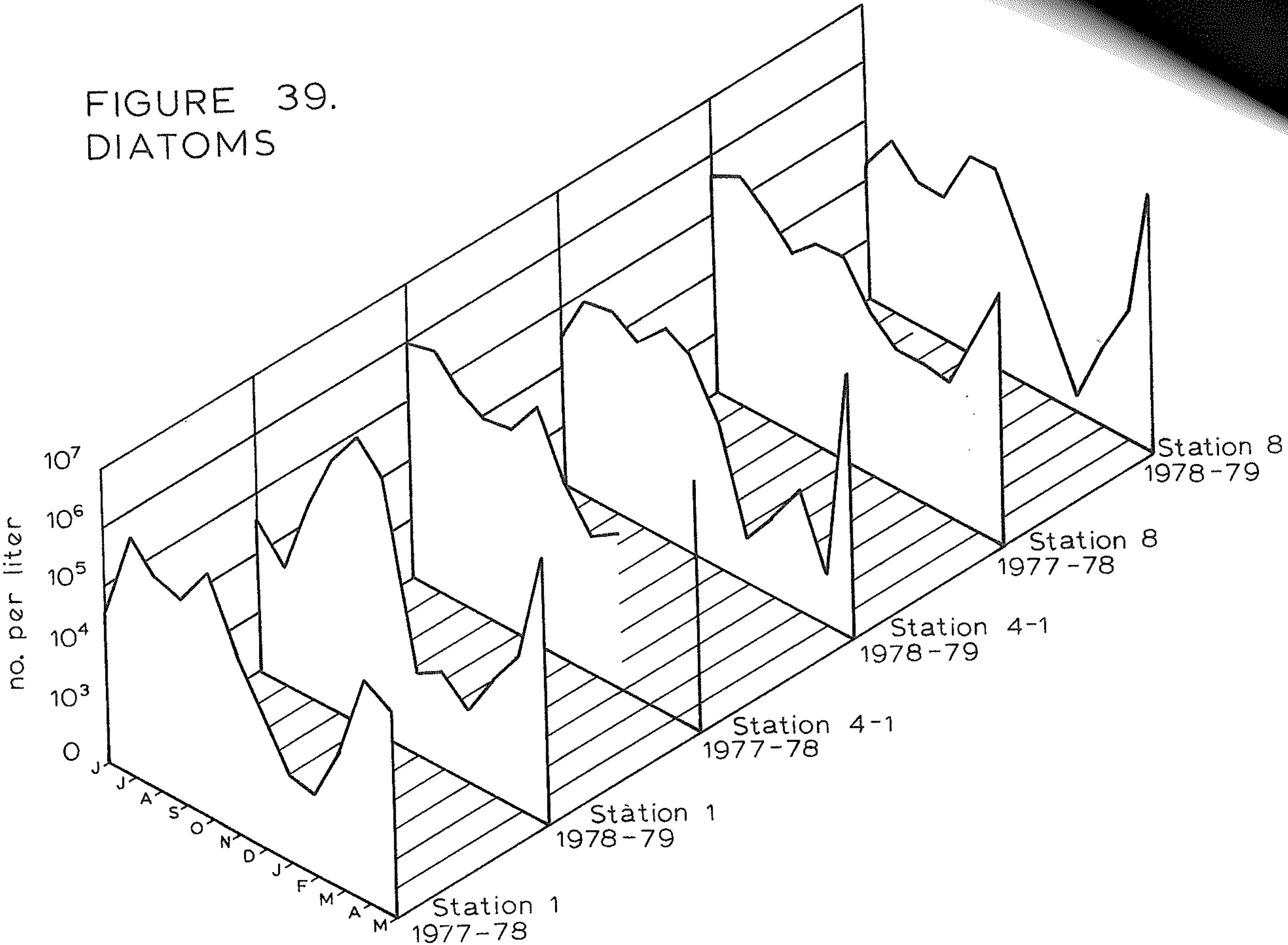


FIGURE 40.
PLANKTON DENSITY
AT STATION 1

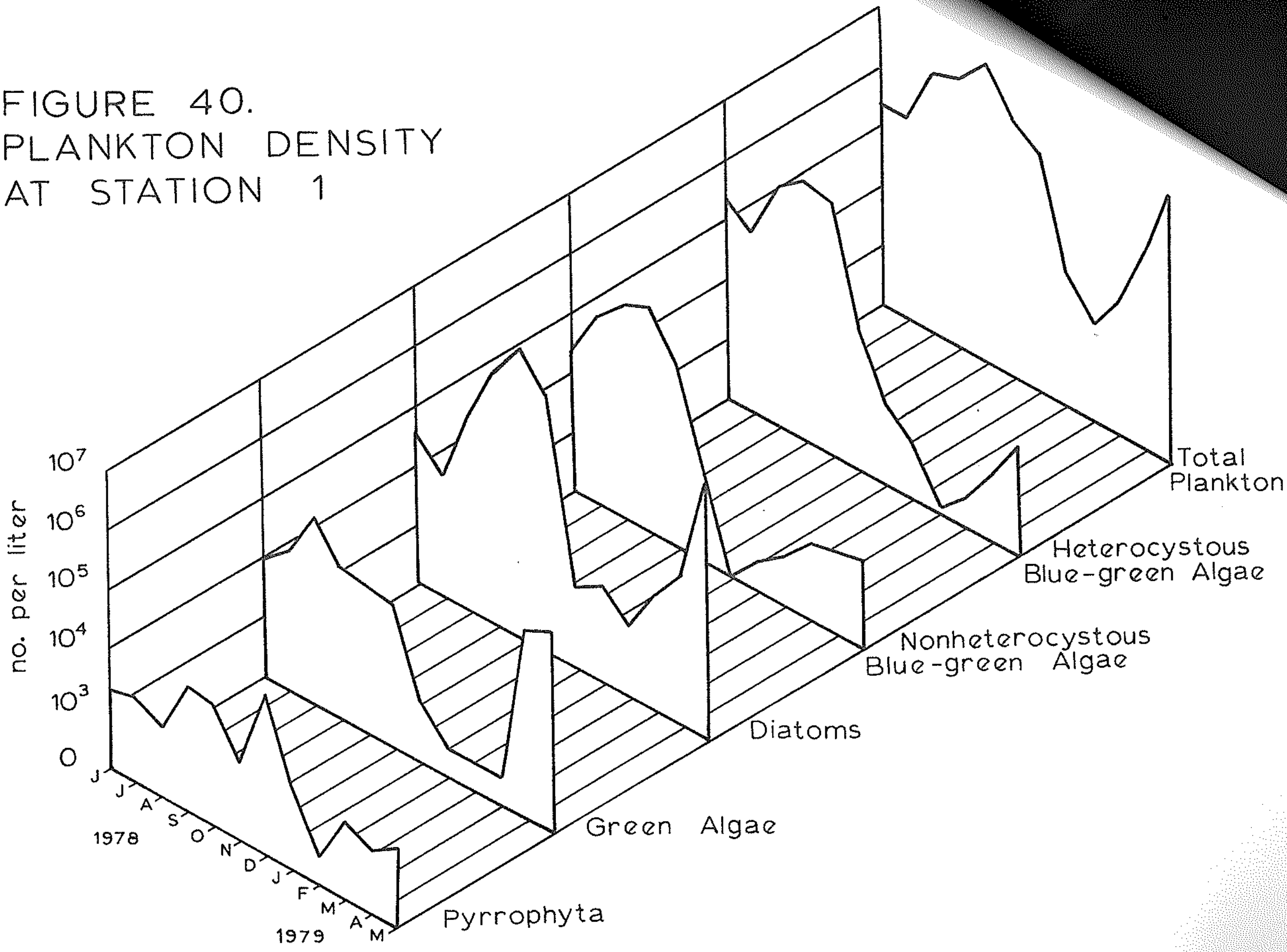


FIGURE 41.
PLANKTON DENSITY
AT STATION 4-1

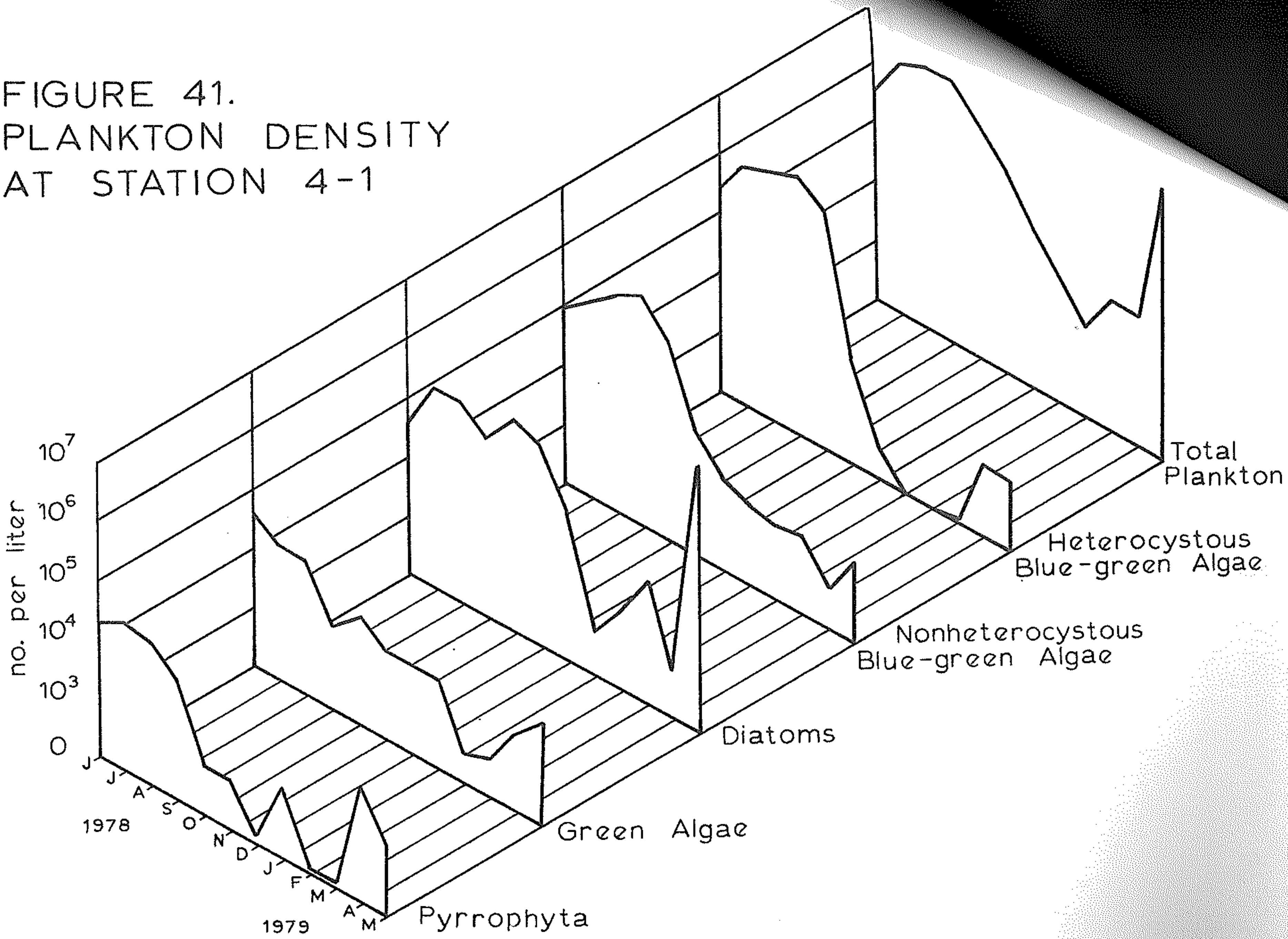
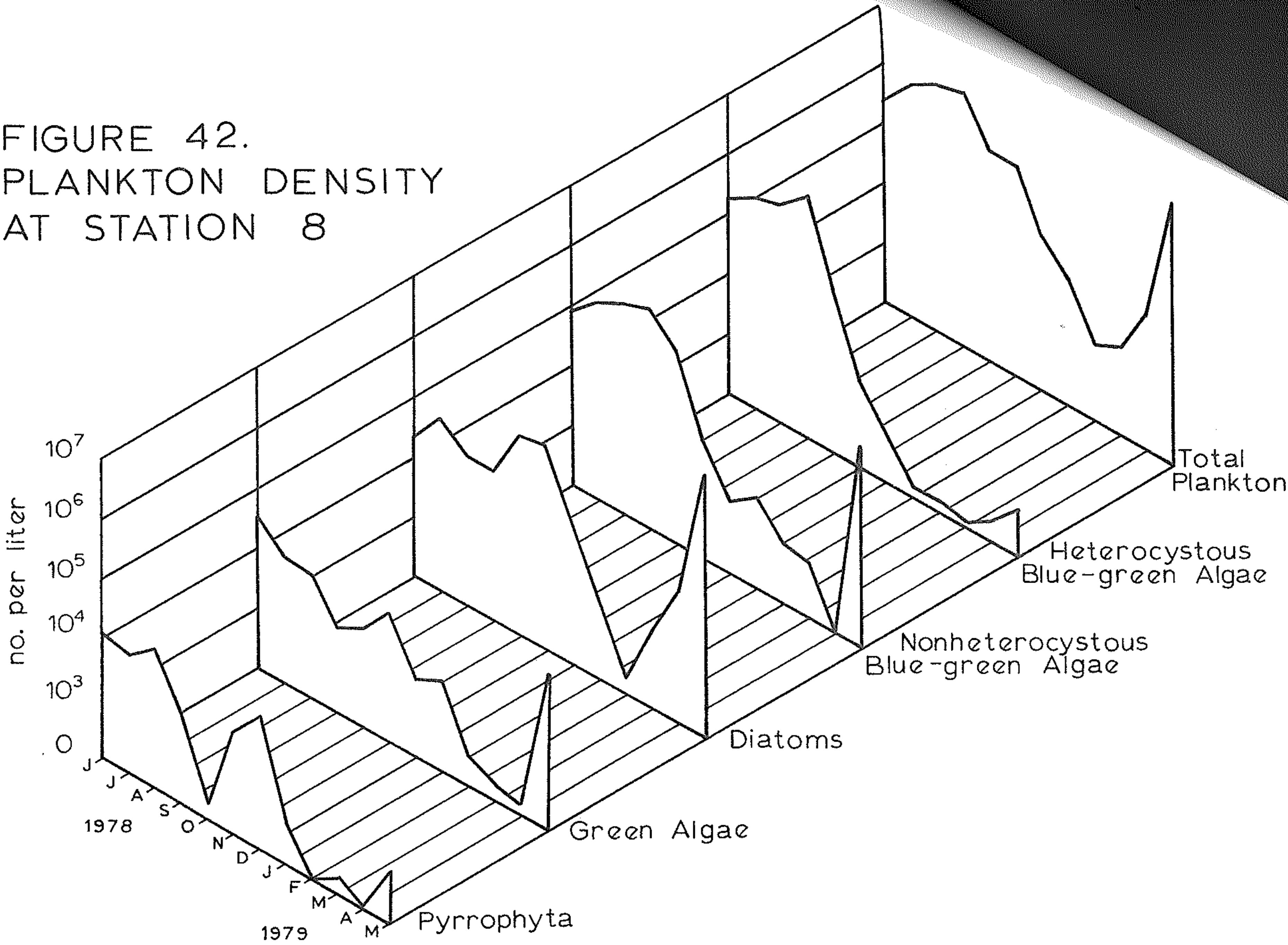


FIGURE 42.
PLANKTON DENSITY
AT STATION 8



1. Temperature and Chemical Measurements of Wastewater Effluent

	°C	pH	Total Alk.	Ca	Mg	µmhos	O_2	Total P	Total N
1978									
6/8	18.5	8.50	335	181	113	1080	5.4	3.42	3.409
6/22	-	7.70	358	286	36	1220	3.9	3.96	4.000
7/7	25.5	9.25	267	127	98	1165	4.1	3.00	0.393
7/21	21.0	8.50	326	153	128	1400	1.8	3.79	1.498
8/3	16.5	8.00	400	214	118	1240	0.7	5.56	12.300
8/18	20.5	8.50	347	153	133	1360	1.0	4.00	0.982
9/1	19.0	8.50	327	204	163	1160	2.1	3.30	1.960
9/15	15.0	7.81	388	296	41	1240	7.6	7.26	12.521
9/29	13.0	8.35	360	211	113	1160	3.0	3.21	1.870
10/13	18.0	7.80	352	268	93	1160	4.3	2.92	1.410
10/27	5.0	8.00	330	262	87	1130	6.5	6.02	2.540
11/10	6.5	8.00	330	205	149	1230	8.7	6.50	4.570
11/24	2.5	7.65	374	-	-	1400	6.9	5.81	2.490
12/7	2.0	8.05	376	286	133	1340	6.1	8.19	19.020
12/19	1.0	7.75	412	319	124	1440	3.9	8.37	15.420
1979									
1/12	1.0	7.65	350	330	31	1130	5.7	5.43	19.530
1/25	-	7.90	347	292	76	1100	9.1	6.13	15.539
2/9	1.2	7.90	560	204	122	975	3.6	6.10	15.804
2/22	1.6	7.65	575	245	92	1080	2.5	5.92	15.795
3/9	1.5	8.70	424	153	92	930	5.1	3.55	15.412
3/23	2.0	7.70	519	184	107	975	2.7	5.36	14.937
4/6	2.0	8.10	542	189	122	940	2.2	5.69	12.914
4/20	4.0	7.65	377	148	82	805	7.4	4.05	9.525
5/11	7.0	8.10	382	173	112	855	10.0	4.66	7.460
5/25	5.0	8.15	377	204	122	910	11.1	2.79	3.826

Table 2. Details of Phosphorus Removal

		Infiltration Basins					Spray Irrigation					Precipitation Plant	
	W.W. Eff.	PC3 mgl	PC3 % Reduc.	MH18 mgl	MH18 % Reduc.	Mean Reduc.	PC10 mgl	PC10 % Reduc.	PC11 mgl	PC11 % Reduc.	Mean Reduc.	Plant Eff.	% Reduc.
1978													
June	3.84	1.61	58.07	1.20	68.75	63.41	0.48	87.50	2.77	27.86	57.68	-	-
July	3.40	0.95	72.06	0.92	72.94	72.50	0.55	83.82	0.37	89.12	86.47	-	-
Aug.	4.78	1.54	67.78	0.72	84.94	76.36	0.64	86.61	0.99	79.29	82.95	-	-
Sept.	4.59	2.47	46.19	0.89	80.61	63.40	2.00	56.43	0.70	84.75	70.59	-	-
Oct.	4.47	0.77	82.77	0.46	89.71	86.24	-	-	-	-	-	-	-
Nov.	6.16	1.30	78.90	1.60	74.03	76.47	-	-	-	-	-	-	-
Dec.	8.28	-	-	-	-	-	-	-	-	-	-	1.60	80.68
1979													
Jan.	5.78	-	-	-	-	-	-	-	-	-	-	1.55	73.18
Feb.	6.01	-	-	-	-	-	-	-	-	-	-	1.03	82.86
Mar.	4.46	-	-	-	-	-	-	-	-	-	-	1.14	74.44
Apr.	4.87	-	-	-	-	-	-	-	-	-	-	1.74	64.27
May	3.72	0.73	80.38	0.62	83.33	81.86	0.45	87.90	0.73	80.38	84.14	-	-
Annual Mean			69.45		79.19	74.32		80.45		72.28	76.37		75.09

Table 3. Details of Nitrogen Reduction

		Infiltration Basins					Spray Irrigation					Precipitation Plant	
	W.W. Eff.	PC3 mgl	PC3 % Reduc.	MH18 mgl	MH18 % Reduc.	Mean Reduc.	PC10 mgl	PC10 % Reduc.	PC11 mgl	PC11 % Reduc.	Mean Reduc.	Plant Eff.	% Reduc.
1978													
June	3.705	3.477	6.15	3.890	4.99*	0.58	4.021	8.53*	1.861	49.77	20.62	–	–
July	0.946	1.902	101.06*	1.447	52.96*	77.01*	0.851	10.04	1.592	68.29*	29.13*	–	–
Aug.	6.641	1.025	84.57	2.282	65.64	75.11	0.367	94.47	0.903	86.40	90.44	–	–
Sept.	5.450	0.123	97.74	0.942	82.72	90.23	0.121	97.78	0.073	98.66	98.22	–	–
Oct.	1.975	0.672	65.97	0.752	61.92	63.95	–	–	–	–	–	–	–
Nov.	3.530	0.145	95.89	0.885	74.93	85.41	–	–	–	–	–	–	–
Dec.	17.220	–	–	–	–	–	–	–	–	–	–	15.860	7.90
1979													
Jan.	17.535	–	–	–	–	–	–	–	–	–	–	16.557	5.58
Feb.	15.800	–	–	–	–	–	–	–	–	–	–	16.911	7.03*
Mar.	15.175	–	–	–	–	–	–	–	–	–	–	15.081	0.62
Apr.	11.220	–	–	–	–	–	–	–	–	–	–	11.027	1.72
May	5.643	4.121	26.97	0.223	96.05	61.51	1.760	68.81	1.310	76.79	72.80	–	–
Annual Mean			39.46		46.19	42.83		52.51		48.67	50.59		1.76

*Increase