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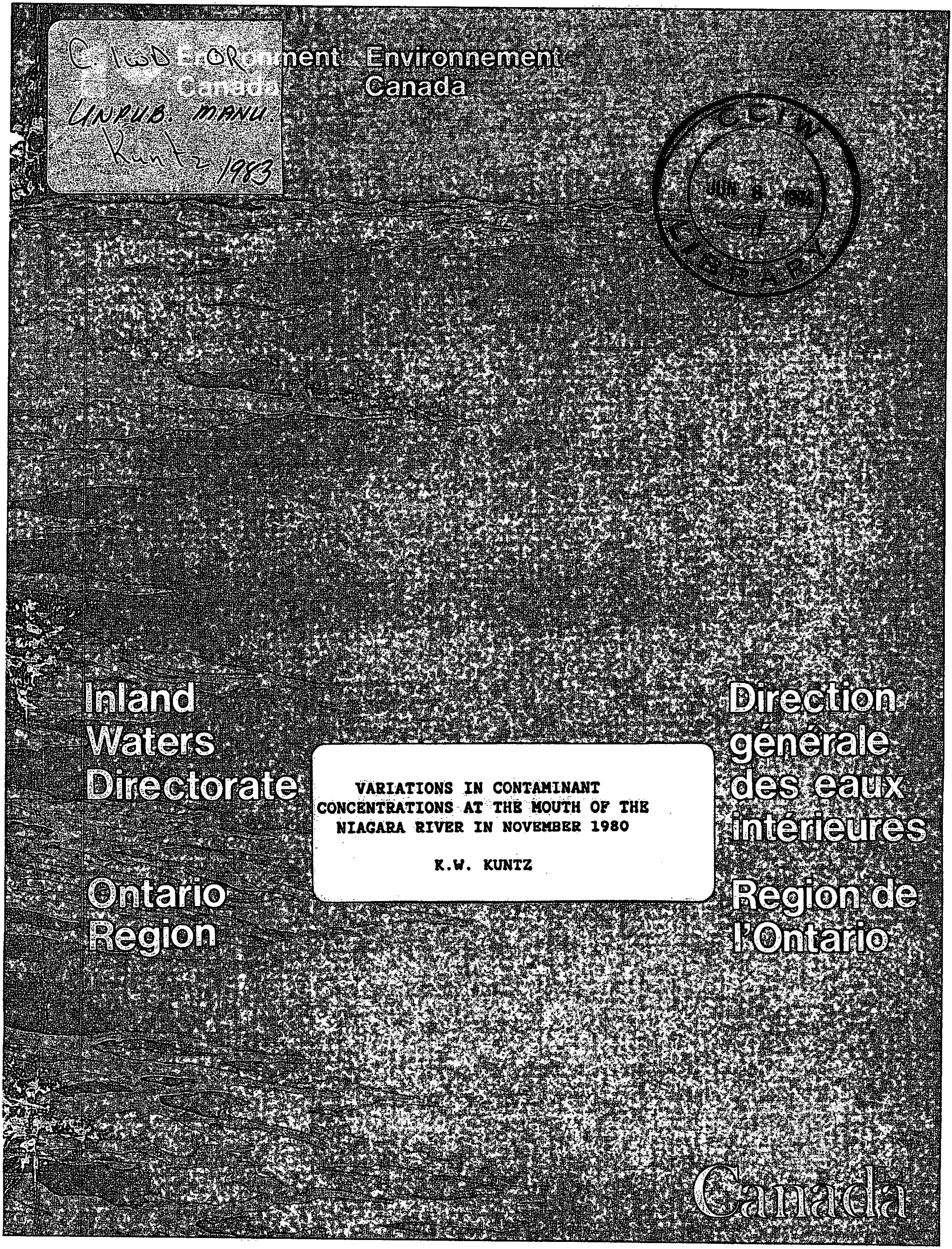

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K.W. KUNTZ

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ABSTRACT:

In 1975 the Water Quality Branch, Ontario Region initiated a daily water quality sampling program at a single station in the Niagara River at Niagara-on-the-Lake. By 1978, increasing public concern had developed over the recurring detection of persistent toxic contaminants in the Lake Ontario ecosystem and their probable source, the Niagara River. Therefore, a weekly sampling program for toxic contaminants was started in 1978. After collecting this data for about two years, it became apparent that considerable quantities of toxic contaminants were being loaded to Lake Ontario by the Niagara River. It also became apparent that significant short term variations occurred in these contaminants. As a result, this ten day survey was undertaken in November 1980 to further define these shore term variations and also the short term frequency of non-compliance with 1978 G.L.W.Q.A. objectives.

Data for both metals and toxic organics is reported for both suspended sediments and unfiltered water samples, and is compared with previous data collected at the same location from 1978 to 1981.

INTRODUCTION

In 1975, the Water Quality Branch - Ontario Region (WQB-OR) ,initiated a daily sampling program at a single station in the Niagara River at Niagara-on-the-Lake (Figure 1).The main purpose was to measure nutrient loading by the Niagara River to Lake Ontario. By 1978,public concern had developed over the recurring detection of persistent toxic substances especially PCB's and mirex in the Niagara River and Lake Ontario ecosystems. Mirex was first discovered in Lake Ontario by Kaiser (1974) in Lake Ontario fishes. Other studies by Frank et al (1979), Holdrinet et al (1978) and Hallett et al (1977), have indicated the large extent of the toxics problem in Lake Ontario and their probable source, the Niagara River. Since, levels of these toxic contaminants in ambient water were usually near or below the detection limits of the analytical methods, WQB-OR decided to measure the levels of organic contaminants in the suspended sediments of the Niagara River as a possible source of toxic organics to Lake Ontario. This sampling program was initiated in 1978 on a weekly or bi-weekly basis.

After collecting this type of data for about two years, it became apparent that considerable quantities of toxic organic contaminants were being loaded to Lake Ontario by the Niagara River each year. A report by Warry and Chan (1981) indicated that the suspended sediments of the Niagara River carried considerable quantities of PCB's, mirex, DDT and other contaminants to Lake Ontario. It also indicated that large temporal variations, up to a factor of three times, were quite common within a month.

Therefore, WQB-OR decided to collect suspended sediments from the Niagara-on-the-Lake station during a continuous ten day period from November 18-28, 1980 to further define these short term variations and also the short term frequency of non-compliance with the 1978 Agreement objectives for water quality. Sampling methodology employed at Niagara-on-the-Lake has been described by Kuntz et al (1982) and all analytical methods employed are described in the Water Quality Branch Analytical Methods Manual (1979).

This report will present the data collected during this ten day period and compare it with other data collected at this location during the period from 1978 to 1981.

DATA COLLECTION

Since a daily sampling station was already being operated at Niagara-on-the-Lake by WQB-OR, it was comparatively easy to increase the sampling frequency to include daily trace metals and organics samples on ambient water as well as continuously collecting suspended sediments using a Westfalia separator for organics and trace metals analysis during this period.

DISCUSSION

A. Trace Metals

A. Turbidity and Suspended Sediment Concentrations

Turbidity measurements obtained from the Buffalo Water Authority from their intake in the Emerald Channel at the headwaters of the Niagra River are compared with similar measurements obtained from the Regional Municipality of Niagara from their water intake at Niagara-On-the-Lake in Figure 2. Also shown in this figure are suspended sediment concentration data from this survey. These data were obtained by weighing the suspended sediments collected by the Westfalia separator and measuring the volume of water centrifuged using a calibrated flowmeter. As shown in Figure 2, these data show a good correlation Turbidity measurements at each end of the river seem to fluctuate together. The Niagara-on-the-Lake turbidity is always higher than at Buffalo. This increase in turbidity within the Niagara River is probably due to both inputs and erosion within the river system. As expected, the suspended sediment concentrations, as measured at Niagara-on-the-Lake by the Westfalia clarifier, show a pattern similar to that of turbidity. Average daily and fastest daily windspeeds shown in Figure 2 also show a good relationship with turbidity and sediment concentrations. Windspeeds appear to preface the increases in turbidity and sediment concentrations by about a one day period. It appears that the wind induced turbidity and suspended sediment concentration increases show up at Niagara-on-the-Lake about a day after the increases in wind velocity.

B. Organic Carbon and Nitrogen in Suspended Sediments

Both organic carbon and nitrogen (shown in Figure 3) measured on suspended sediments collected at Niagara-on-the-Lake, show similar patterns. Both carbon and nitrogen concentrations decrease in the suspended sediments as the concentration of sediments increases. This is believed to be related to the increased erosion of bottom sediments from Lake Erie and in the Niagara River during periods of higher winds. During low wind periods, the source of the suspended sediments at Niagara-on-the-Lake is Lake Erie surface waters. These suspended sediments are therefore high in organic carbon and nitrogen. As the wind velocity increases, more erosion and resuspension of bottom sediments occurs. These bottom sediments are lower in organic carbon and nitrogen. They are flushed down the Niagara River to Niagara-on-the-Lake and hence dilute the higher carbon and nitrogen containing suspended sediments from Lake Erie surface waters.

C. Trace Metals

(i) In Water

Once daily, water samples were collected for trace metals from the intake line at Niagara-on-the-Lake by WQB-OR personnel. Samples were preserved upon return to the Burlington lab. Eleven metals including, aluminum, chromium, manganese, iron, nickel, copper, zinc, arsenic, cadmium, mercury and lead were analysed. Of these metals, all were analysed for total metals except mercury and aluminum, which were extractable, and arsenic, which was filtered. These data are summarized in Table 1 for the ten day period, November 18-28, 1980.

Concentrations of all parameters except cadmium and mercury which were never detected, were above detection limits more than 90% of the time during the ten day period. No violations to the 1978 Agreement were observed except for total iron, which was above the .300 mg L^{-1} objective 75% of the time during the ten days. Concentrations of all parameters during the ten day sampling period were about the same as during the 1978-81 period, except total iron and manganese and extractable aluminum, which were more than twice the long term mean concentrations for the 1978-81 period at Niagara-on-the-Lake (given in Table 2). These three parameters were greater than the long term mean because of their association with particulate matter, which is eroded from shorelines and bottom sediments at this time of year by more intense storms in the Eastern Basin of Lake Erie (Kuntz and Chan, 1982). Violations to the 1978 Agreement for total iron were also more numerous on a percentage basis during this ten day period because this increase of particulate matter and its resultant increase in total iron appears to be mainly a seasonal occurrence in the November - March period (Environmental Baseline Report, 1981).

Daily variations in trace metal concentrations are shown for iron, aluminum, manganese, zinc, chromium, lead, nickel and copper in Figures 4-7 respectively. These metals showed peak concentrations on November 21 and November 26, about the same time as the windspeed, turbidity and suspended sediment measurements reached their peaks.Total iron and extractable aluminum showed particularly large increases as the suspended sediments increased in concentration. This is not surprising since clay minerals are known to contain large proportions of iron and aluminum.

ii) In Suspended Sediments

Concentrations of trace metals measured using a 0.5 N HCL extraction of suspended sediments collected by a Westfalia separator at Niagara-on-the-Lake during this ten day period are given in Table 3. Data for zinc, cadmium, copper, lead, chromium, cobalt and nickel were considerably lower during this ten-day survey than data shown in Table 4 for the 1978-80 period at the same location. At this time, there is no known reason for this decrease. However, one possible reason could be a dilution effect from bottom sediments which could have been eroded from the eastern basin of Lake Erie during this time of year. Violations to MOE dredge spoil criteria occurred 100% of the time for zinc and cadmium, 56% of the time for copper and 11% of the time for lead and chromium. It should be noted that these objectives are for dredged spoils from bottom sediment locations and are, therefore, not necessarily applicable to suspended sediments. However, no other standards exist for suspended sediments. It is not known what percentage of the suspended sediments are deposited on the lake bottom and to what degree the suspended sediments are diluted by other larger coarser particles such as sand, which have less affinity for metals uptake during their transport. Mercury, arsenic and selenium concentrations during the ten day survey were similar to the longer term 1978-80 data collected.

Variations in metal concentrations in suspended sediments are shown in Figures 8-12 for zinc, cadmium, chromium, copper, lead, arsenic, selenium, mercury, nickel and cobalt. Largest variations occurred for zinc, cadmium, chromium, copper, lead, arsenic and selenium. Smaller variations occurred in mercury, cobalt and nickel concentrations. Highest concentrations for every metal except arsenic and selenium occurred on November 26. This peak corresponds with the small second peak in turbidity and suspended sediments concentration. However, the metals concentrations in suspended sediments do not seem to fit well with the increase in suspended sediments in the Niagara River on November 20,21 and 22. In fact, most of the metals concentrations on suspended sediments except arsenic decreased during this period. Perhaps, this is a dilution factor by Lake Erie sediments similar to that observed for carbon and nitrogen. Arsenic concentrations appeared to increase during the November 20-23 period when the suspended sediment concentrations were increasing. No reason is known for this increase. The large increase in metals concentrations on suspended sediments on November 26 remains unexplained. It could have been caused by inputs within the river system.

B. Chlorinated Organic Contaminants

(i) In Water

Daily samples for the nineteen organochlorine compounds measured including PCB's were collected at the Niagara-on-the-Lake station during the ten day period from November 18-28, 1980.

Mean ambient water concentrations observed during this ten day period are given in Table 5. These data indicated that of the nineteen organochlorine compounds monitored during the ten day period, nine were observed in more than 80% of the samples collected. These compounds are PCB's, α and γ -BHC, α and γ -chlordane, HCB, dieldrin, heptachlor epoxide and p,p-DDE. In addition, p,p-DDT, B-endosulfan, and endrin were detected 45, 36 and 18% of the time respectively. Seven other compounds including o,p-DDT, p,p-TDE, methoxychlor, heptachlor, α -endosulfan, mirex and aldrin were not detected during this ten day survey. Of the twelve compounds detected, only three ie. total PCB's and α and γ -BHC occurred at median values above 1 ppt. Similar data collected at Niagara-on-the-Lake during the 1978-82 period for long term trend evaluation is given in Table 6. These data indicated that means and medians were similar. The same three compounds were detected at values above 1 ppt. Only α and γ -BHC, total PCB's, dieldrin and HCB were detected in more than 80% of the samples collected. Other parameters varied from 61% detections for p,p-DDE to 1% detections for mirex and o,p-DDT and only heptachlor was never detected in this accumulation of about 100 samples. Violations to the 1978 Agreement objective of 0.001 ug L^{-1} for heptachlor epoxide occurred 45% of the time during the ten day survey in November 1980 but only 15% of the time during the 1980-81 period for which data is presented in Table 8. Only one violation to this Agreement for total DDT residues occurred during the 1980-81 interval.

Daily variations in organic contaminants in water are shown in Figures 13-18. Generally, these data appeared to be unrelated to the increase in suspended sediments and turbidity on November 21-23 and November 26-27. Only a few parameters such as HCB, possibly DDT, and PCB showed any resemblence to the turbidity curves. This indicates that probable sources of most of these organic contaminants exist within the river and Lake Erie sediments are unimportant as sources of these compounds.

ii) In Suspended Sediments

Suspended sediment data collected during the ten day period in November 1980 are given in Table 7. Of the nineteen organochlorine compounds measured, eight occurred more than eighty percent of the time. These compounds are total PCB's, HCB, p,p-DDE, p,p-TDE, α -endosulfan, dieldrin and α and γ -chlordane. Endrin and γ-BHC were detected 20% of the time or less in this survey. Aldrin, o,p-DDT, heptachlor, and B-endosulfan were not detected during this survey.

Each of the chlorobenzene groups ie. di, tri, tetra, penta and hexachlorobenzenes were detected in 100% of the samples collected during this ten day period. Mean concentrations of dichlorobenzenes were highest, followed by tetrachlorobenzenes, hexachlorobenzenes, pentachlorobenzenes and trichlorobenzenes.

Similar data for organochlorine contaminants in suspended sediments collected from the Niagara River at Niagara-on-the-Lake during the 1979-81 period, for long term trend evaluation, is given in Table 8. From this table , it is clear that total PCB, HCB, DDE, p,p-DDT and mirex have substantially higher long term means than those observed during the ten day survey in November 1980. Also, all of the chlorobenzenes appear to have substantially larger mean values over the long term than those observed during the ten day survey in November 1980. Except for p,p-TDE, which seems to be slightly lower over the long term than observed during the ten day survey, the remaining parameters appear to be about the same.

Variations of chlorinated organic contaminants concentrations on suspended sediments during this ten day period (shown in Figures 19-27) do not appear to be related to either suspended sediment concentrations, turbidity or average daily windspeed. Variations were generally small during this period and did not show fluctuations as large as shown by Warry and Chan (1981) over the longer term. Generally, most of the concentrations measured were below 10 ug Kg^{-1} except for total PCB's, total DDT and several of the chlorobenzene isomers.

SUMMARY

1. Turbidity, suspended sediment concentrations and wind velocity parameters appear to be correlated in the Niagara River system.

2. Organic carbon and nitrogen in suspended sediments are correlated with one another. However, concentrations of carbon and nitrogen decrease in suspended sediments as the concentration of sediments increases. This is believed to be caused by a dilution effect as low carbon and nitrogen sediments are eroded from the shorelines and bottom of Lake Erie as wind velocity increases. These sediments are then flushed down the Niagara River and dilute the high carbon and nitrogen suspended sediments from Lake Erie surface waters.

3. Concentrations of most metals measured in ambient water samples at Niagara-on-the-Lake except cadmium and mercury were above the detection limits of the analytical methods more than 90% of the time, but below the 1978 Agreement objectives except for total iron which was above the .300 mg L^{-1} objective 75% of the time during the ten day survey.

4. Total iron and manganese and extractable aluminum concentrations in water during this ten day survey were more than double the long term mean concentrations observed at Niagara-on-the-Lake during the 1978-81 period. These increases were most likely the result of wind induced erosion in the eastern basin of Lake Erie.

5. Daily variations for most metals in water showed peak concentrations on November 21 and 26, about the same time as suspended sediments, windspeed and turbidity reached their peaks. Total iron and extractable

alumiunum showed particularly large increases as the suspended sediments increased in concentrations, probably due to their suspected large clay mineral fraction.

6. Suspended sediment concentrations violated the MOE dredge spoil criteria 100% of the time for zinc and cadmium, 56% for copper and 11% for lead and chromium.

7. Metals concentrations in suspended sediments for every metal measured except arsenic and selenium peaked on November 26, corresponding to the small second peak in turbidity and suspended sediments concentrations. However, metals concentrations were generally decreasing during the period from November 20-22 when turbidity and suspended sediments were rapidly increasing. Perhaps this is once again the dilution factor similar to that observed for carbon and nitrogen.

8. Nine of the organochlorine compounds measured in ambient waters during this ten day survey were observed in more than 80% of the samples collected. These compounds are PCB's, α and γ – BHC, α and γ -chlordane, HCB, dieldrin, heptachlor epoxide and p,p-DDE. Seven other compounds, including o,p-DDT, p,p-TDE, methocychlor, heptachlor, -endosulfan, mirex and aldrin were not detected during this ten day survey.

9. Violations of the 1978 Agreement objectives occurred 45% of the time for heptachlor epoxide in water during this ten day survey.

10. Eight of the organochlorine compounds measured in suspended sediments during this ten day survey occurred more than eighty percent of the time. These compounds are total PCB's, HCB, p,p-DDE, p,p-TDE, α -endosulfan, dieldrin and α and γ -chlordane. Aldrin, o,p-DDT, heptachlor and B-endosulfan was never detected. Each of the chlorobenzene groups measured eg., di, tri, etc., were detected in 100% of the samples collected with dichlorobenzenes followed by tetrachlorobenzenes found at highest concentrations.

11. Long term means (1978-81) for total PCB, HCB, DDE, p,p-DDT, mirex and all of the chlorobenzenes in suspended sediments are substantially larger than those observed during this ten day survey in November 1980.

12. Variations in chlorinated organic contaminants in both ambient waters and suspended sediments, did not appear to be related to turbidity, wind velocity, suspended sediment concentration or organic carbon content of the sediments. This indicates that Lake Erie sediments appear to have little to contribute in terms of contaminant loading to the Niagara River.

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TABLE 1

TRACE METAL CONCENTRATIONS (mg L^{-1}) IN AMBIENT WATER OF THE NIAGARA RIVER
AT NIAGARA-ON-THE-LAKE - NOVEMBER 18 - 28, 1980

PARAMETER	1978 AGREEMENT OBJECTIVE	% VIOLATIONS	% DETECTIONS	MEAN	MEDIAN	RANGE	ST.DEV.
IRON	.300	75	100	1.000	.630	.180 - 2.40	.730
ALUMINUM			100	.318	.210	.061 - .750	.244
MANGANESE			100	.037	.028	.020 - .063	.018
ZINC	.030	0	91	.006	.004	<.001 - .014	.004
CHROMIUM	.100	0	100	.003	.002	.002 - .007	.002
NICKEL	.025	0	100	.003	.003	.001 - .004	.001
LEAD	.025	0	91	.002	.001	<.001 - .004	.001
COPPER	.005	0	100	.002	.002	.001 - .003	.001
CADMIUM	.0002	0	0	<.001	<.001		
ARSENIC			100	.0005	.0005		
MERCURY	.0002	0	0	<.00005	<.00005		

TABLE 2

TRACE METAL CONCENTRATIONS (mg L^{-1}) IN AMBIENT WATER OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - 1978 to 1981

PARAMETER	% VIOLATIONS	N. OBS.	MEAN	MEDIAN	RANGE	ST. DEV.
IRON	36	219	.444	.210	.010 - 7.20	.660
ALUMINUM		216	.131	.070	.001 - 0.95	.160
MANGANESE		207	.018	.014	$<$.001 - 0.070	.018
ZINC		219	.004	.003	$<$.001 - 0.020	.003
CHROMIUM		216	.002	.001	$<$.001 - 0.010	.002
NICKEL		218	.002	.002	$<$.001 - 0.013	.002
LEAD		219	.001	.001	$<$.001 - 0.008	.001
COPPER	22	219	.004	.003	$<$.001 - 0.023	.004
CADMIUM		219	$<$.001	$<$.001	$<$.001 - 0.010	$<$.001
ARESENIC		86	.0005	.0005	0.0004 - 0.0009	.0002
MERCURY		145	$<$.00005	$<$.00005	$<$.00005 - 0.00036	

TABLE 3

TRACE METAL CONCENTRATIONS* (mg kg^{-1}) IN SUSPENDED SEDIMENTS OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - NOVEMBER 10 - 28, 1980

PARAMETER	MOE DREDGE DISPOSAL CRITERION	% VIOLATIONS	MEAN	MEDIAN	RANGE	ST. DEV.
ZINC	30	100	117.1	97.0	79.0-254.0	53.8
CADMIUM	1	100	1.8	1.3	1.0-5.8	1.5
COPPER	25	56	27.3	22.0	17.0-63.0	13.9
LEAD	50	11	45.6	41.0	38.0-70.0	9.6
CHROMIUM	25	11	25.6	19.0	15.0-82.0	21.3
COBALT	50	0	3.9	3.6	3.2-4.7	0.5
NICKEL	25	0	16.0	16.0	14.0-19.0	1.4
MERCURY			0.29	0.22	0.20-0.47	0.10
ARSENIC			12.1	11.7	10.5-14.2	1.1
SELENIUM			0.74	0.65	0.57-1.30	0.22

* 0.5N HCI EXTRACTION

TABLE 4

TRACE METAL CONCENTRATIONS* (mg kg^{-1}) IN SUSPENDED SEDIMENTS OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - 1978-80

PARAMETER	N. OBS	MEAN	MEDIAN	RANGE	ST. DEV
ZINC	57	159.1	152.0	67.0 - 262.0	52.3
CADMIUM	56	2.3	2.1	0.7 - 7.2	1.2
COPPER	57	38.7	36.0	4.1 - 76.0	15.8
LEAD	57	61.5	56.0	29.0 - 145.0	22.5
CHROMIUM	57	31.4	26.0	11.0 - 134.0	19.4
COBALT	57	6.1	5.5	1.6 - 16.0	2.8
NICKEL	57	24.0	22.0	9.0 - 76.0	12.5
MERCURY	20	0.23	0.20	0.12 - 0.47	0.10
ARSENIC	17	11.1	11.6	6.9 - 15.0	2.7
SELENIUM	17	0.61	0.57	0.26 - 1.30	0.22

* 0.5N HCI EXTRACTION

TABLE 5

ORGANOCHLORINE CONCENTRATIONS (ug L^{-1}) IN AMBIENT WATER OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - NOVEMBER 18-28, 1980

PARAMETER	% DETECTED	MEAN	MEDIAN	RANGE	ST. DEV.
TOTAL PCB	100	.0303	.0240	.0070 - .076	.0230
α - BHC	100	.0132	.0128	.0100 - .0164	.0021
γ - BHC	100	.0017	.0018	.0005 -.0025	.0007
γ - CHLORDANE	100	.0015	.0007	.0003 - .0040	.0013
HCB	100	.0010	.0004	.0002 - .0040	.0011
DIELDRIN	91	.0006	.0006	< .0001 - .0009	.0003
α - CHLORDANE	91	.0005	.0003	< .0001 - .0015	.0004
HEPT. EPOXIDE	82	.0017	.0003	< .0001 - .0047	.0017
p,p-DDE	82	.0004	.0001	< .0001 -.0015	.0004
p,p-DDT	45	.0003	.0001	< .0001 - .0008	.0003
B-ENDOSULFAN	36	.0002	.0001	< .0001 - .0008	.0002
ENDRIN	18	< .0001	< .0001	< .0001 - .0003	.0001
o,p-DDT	0	< .0001	< .0001		
p,p-TDE	0	< .0001	< .0001		
METHOXYCHLOR	0	< .0001	< .0001		
HEPTACHLOR	0	< .0001	< .0001		
α -ENDOSULFAN	0	< .0001	< .0001		
MIREX	0	< .0001	< .0001		
ALDRIN	0	< .0001	< .0001		

TABLE 6

ORGANOCHLORINE CONCENTRATIONS (ug L^{-1}) IN AMBIENT WATER OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - 1980-81

PARAMETER	% DETECTED	MEAN	MEDIAN	RANGE	ST. DEV.
α - BHC	100	.0093	.0088	.0012 - .0261	.0051
γ - BHC	92	.0018	.0016	< .0001 - .0080	.0014
TOTAL PCB	90	.0147	.0110	< .0001 -.0760	.0144
DIELDRIN	86	.0005	.0005	< .0001 - .0017	.0003
HCB	81	.0007	.0005	< .0001 - .0049	.0008
p,p-DDE	61	.0003	.0001	< .0001 - .0027	.0005
γ -CHLORDANE	54	.0005	.0002	< .0001 - .0040	.0007
α -CHLORDANE	50	.0003	< .0001	< .0001 - .0018	.0003
HEPT. EPOXIDE	44	.0006	< .0001	< .0001 - .0047	.0009
p,p-DDT	44	.0003	< .0001	< .0001 - .0037	.0005
α -ENDOSULFAN	11	.0002	< .0001	< .0001 - .0027	.0004
B-ENDOSULFAN	11	.0002	< .0001	< .0001 - .0036	.0004
p,p-TDE	8	.0002	< .0001	< .0001 - .0014	.0002
ENDRIN	8	< .0001	< .0001	< .0001 - .0008	.0001
METHOXYCHLOR	4	< .0001	< .0001	< .0001 - .0016	.0002
ALDRIN	2	< .0001	< .0001	< .0001 - .0016	.0002
MIREX	1	< .0001	< .0001	< .0001 - .0001	
o,p-DDT	1	< .0001	< .0001	< .0001 - .0004	
HEPTACHLOR	0	< .0001	< .0001		

(102 SAMPLES)

TABLE 7

ORGANOCHLORINE CONCENTRATIONS (mg kg^{-1}) IN SUSPENDED SEDIMENTS OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - NOVEMBER 18-28, 1980

PARAMETER	% DETECTED	MEAN	MEDIAN	RANGE	ST. DEV
TOTAL PCB	100	.204	.160	.130 - .400	.093
HCB	100	.014	.013	.007 - .022	.004
p,p-DDE	100	.005	.004	.003 - .007	.001
p,p-TDE	100	.008	.008	.003 - .011	.002
α-ENDOSULFAN	90	.004	.003	<.001 - .009	.003
DIELDRIN	90	.004	.004	<.001 - .007	.002
α-CHLORDANE	90	.002	.001	<.001 - .003	.001
γ-CHLORDANE	80	.002	.002	<.001 - .004	.001
METHOXYCHLOR	70	.003	.002	<.001 - .013	.004
HEPT EPOXIDE	60	.001	.001	<.001 - .001	
α-BHC	50	.001	.001	<.001 - .003	.001
p,p-DDT	44	.002	.001	<.001 -.005	.001
MIREX	33	.002	.001	<.001 - .009	.003
ENDRIN	20	<.001	<.001	<.001 - .002	
γ-BHC	10	<.001	<.001	<.001 - .002	
ALDRIN	0	<.001	<.00		
o,p-DDT	0	<.001	<.001		
HEPTACHLOR	0	<.001	<.001		
B-ENDOSULFAN	0	<.001	<.001		
DICHLOROBENZENES	100	.028	.029	.004 - .040	.013
TRICHLOROBENZENES	100	.007	.007	.002 - .009	.002
TETRACHLOROENZENES	100	.019	.019	.007 - .038	.010
PENTACHLOROBENZENE	100	.010	.012	.003 - .019	.006
HEXACHLOROBENZENE	100	.013	.012	.007 - .024	.005
TOTAL - CHLOROBENZENES	100	.077	.089	.043 - .108	.023

TABLE 8

ORGANOCHLORINE CONCENTRATIONS (mg kg^{-1}) IN SUSPENDED SEDIMENTS OF THE NIAGARA RIVER AT NIAGARA-ON-THE-LAKE - 1979-81

PARAMETER	% DETECTED	MEAN	MEDIAN	RANGE	ST. DEV.
TOTAL PCB	100	.590	.400	.030 - 2.700	.566
HCB	99	.074	.040	<.001 - .577	.100
p,p-DDE	87	.019	.013	<.001 - .129	.020
DIELDRIN	76	.004	.004	<.001 - .015	.003
p,p-DDT	75	.009	.005	<.001 - .045	.011
γ-CHLORDANE	74	.006	.002	<.001 - .058	.008
α-BHC	73	.010	.003	<.001 - .130	.020
MIREX	68	.010	.004	<.001 - .258	.028
p,p-TDE	67	.005	.003	<.001 - .031	.007
α-CHLORDANE	65	.003	<.001	<.001 - .016	.003
METHOXYCHLOR	43	.006	<.001	<.001 - .091	.012
α-ENDOSULFAN	43	.004	<.001	<.001 - .018	.004
HEPT. EPOXIDE	38	<.001	<.001	<.001 - .012	.001
γ-BHC	31	.002	<.001	<.001 - .027	.003
o,p-DDT	23	.004	<.001	<.001 - .056	.011
ENDRIN	10	<.001	<.001	<.001 - .007	.001
ALDRIN	7	.002	<.001	<.001 - .046	.006
HEPTACHLOR	7	.002	<.001	<.001 - .019	.003
B-ENDOSULFAN	6	<.001	<.001	<.001 - .003	
*DICHLOROBENZENES	77	.228		<.001 - 1.286	.314
*TRICHLOROBENZENES	97	.068		<.001 - 0.275	.066
*TETRACHLOROBENZENES	98	.072		<.001 - 0.248	.073
*PENTACHLOROBENZENE	98	.042		<.001 - 0.242	.048
*HEXACHLOROBENZENE	100	.072		<.003 - 0.442	.087
*TOTAL CHLOROBENZENES	100	.475		<.022 - 2.236	.467

*ONLY DATA FROM 1980 AND 1981 INCLUDED

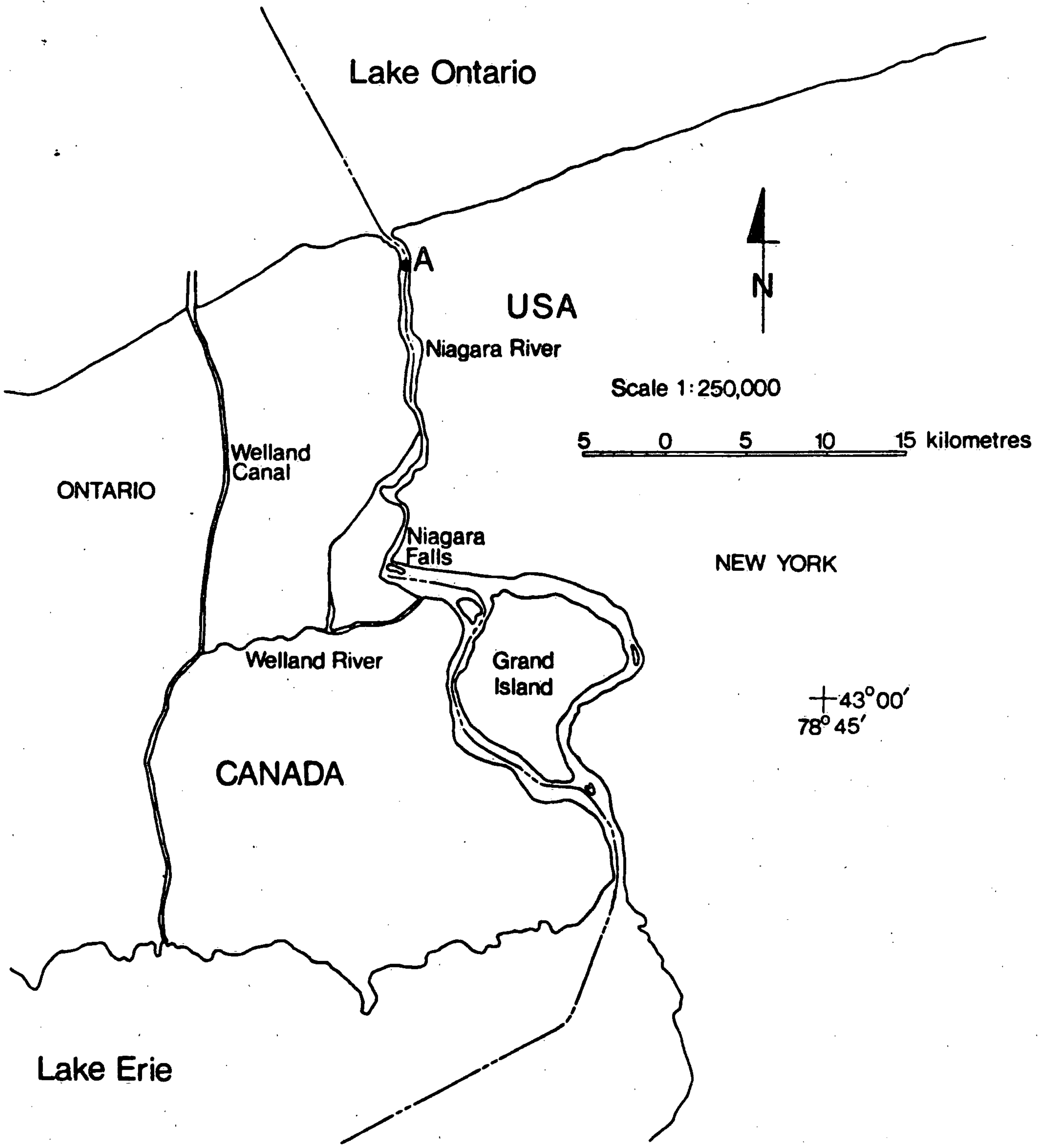


Figure 1 Sampling location on the Niagara river.

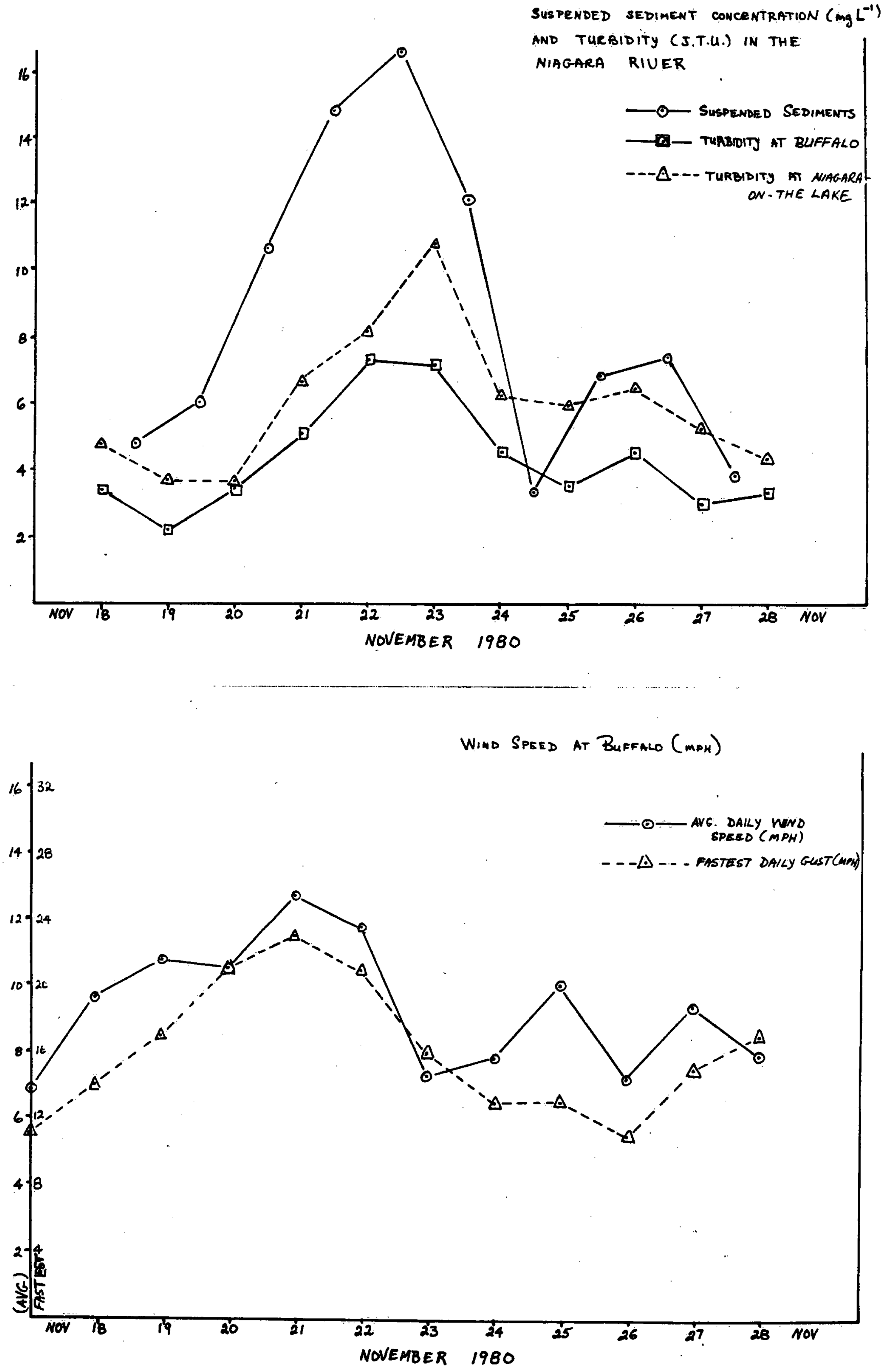
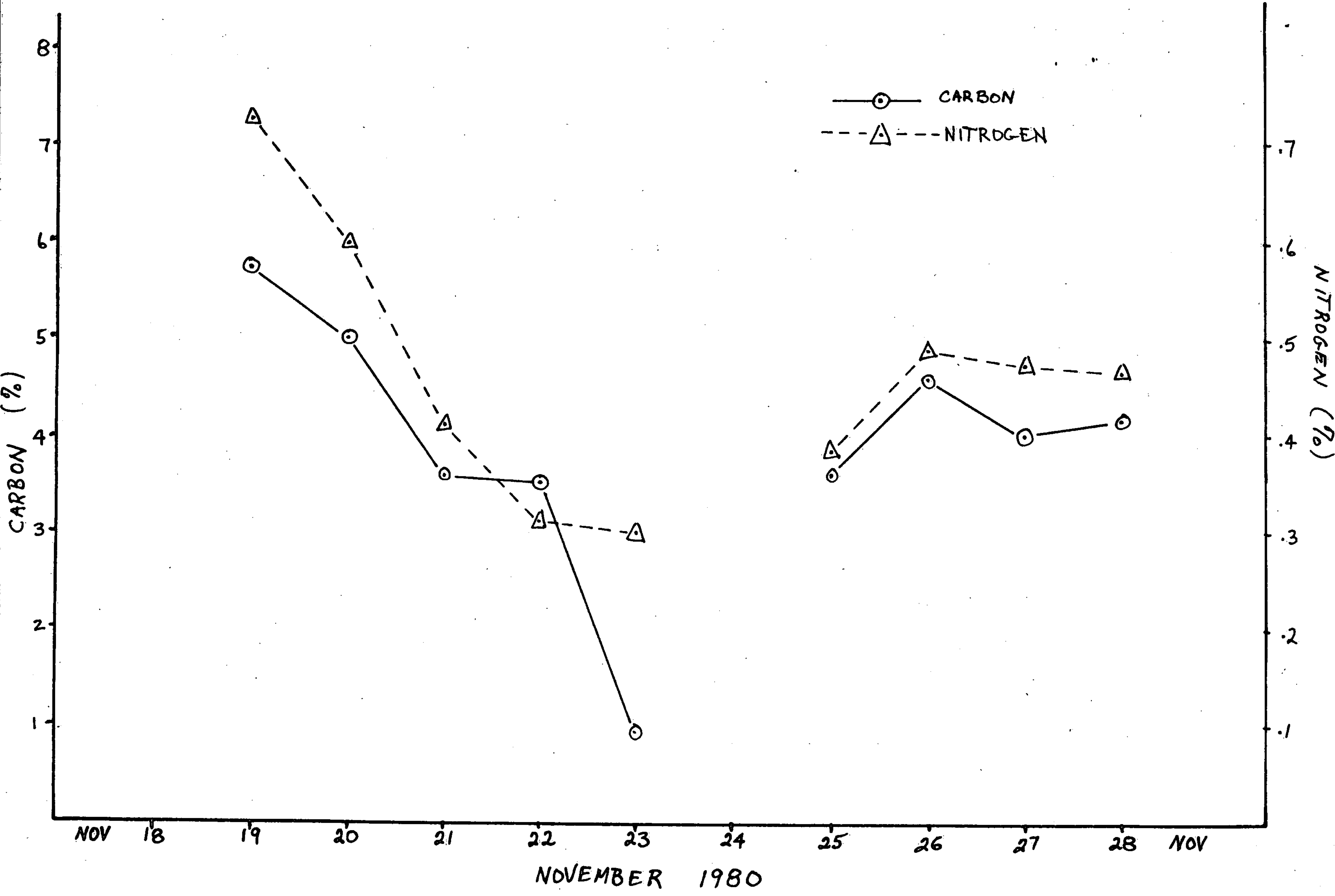
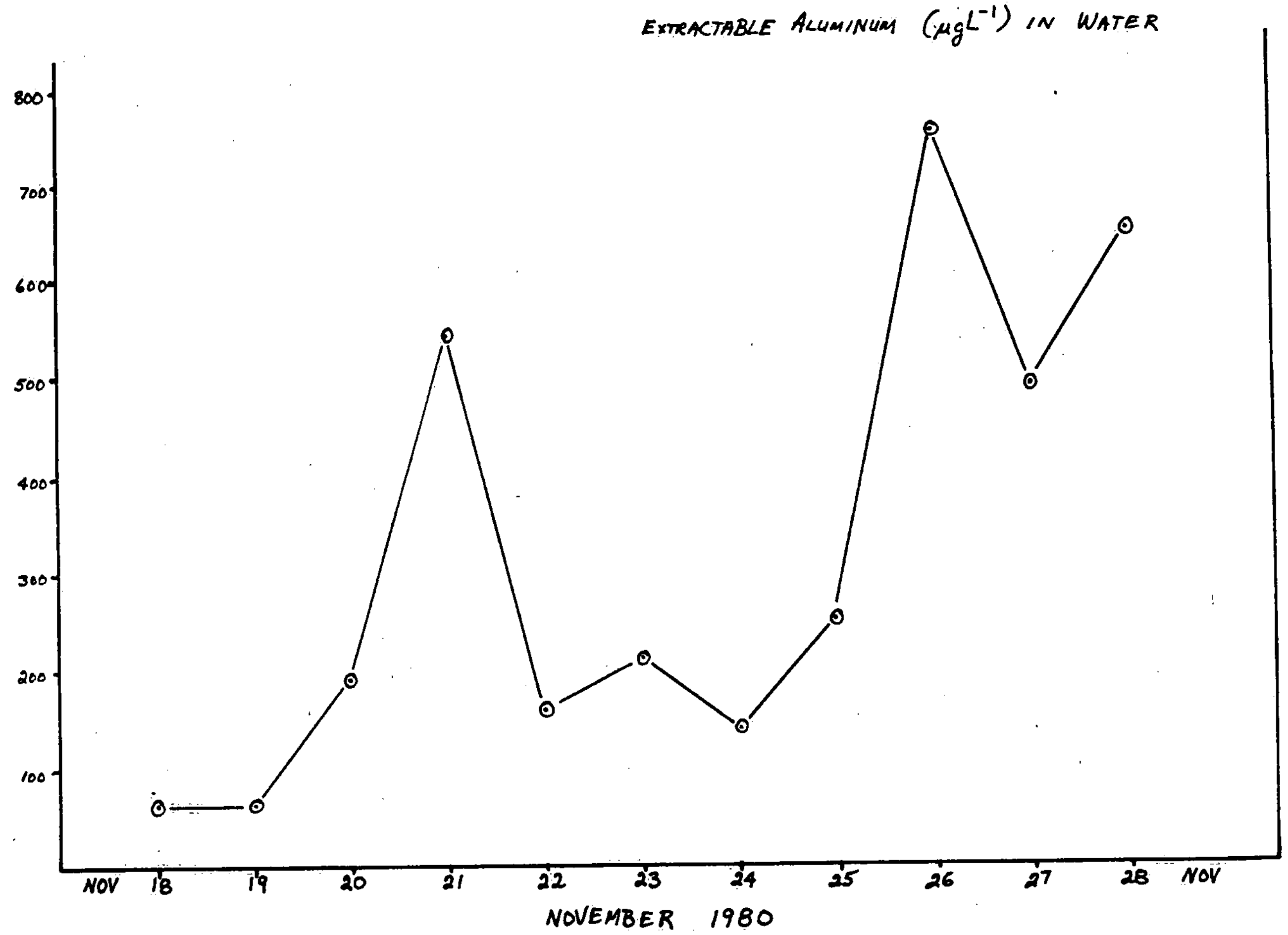

SUSPENDED SEDIMENT CONCENTRATION (mg L⁻¹) AND TURBIDITY (J.T.U.) IN THE NIAGARA RIVER
SUSPENDED SEDIMENTS
TURBIDITY AT BUFFALO
TURBIDITY AT NIAGARA-ON-THE LAKE
16
14
12
10
8
6
4
2
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
WIND SPEED AT BUFFALO (MPH)
AVG. DAILY WIND SPEED (MPH)
FASTEST DAILY GUST (MPH)
16 32
14 28
12 24
10 20
8 16
6 12
4 8
2 4
(AVG.)
FASTEST
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 2

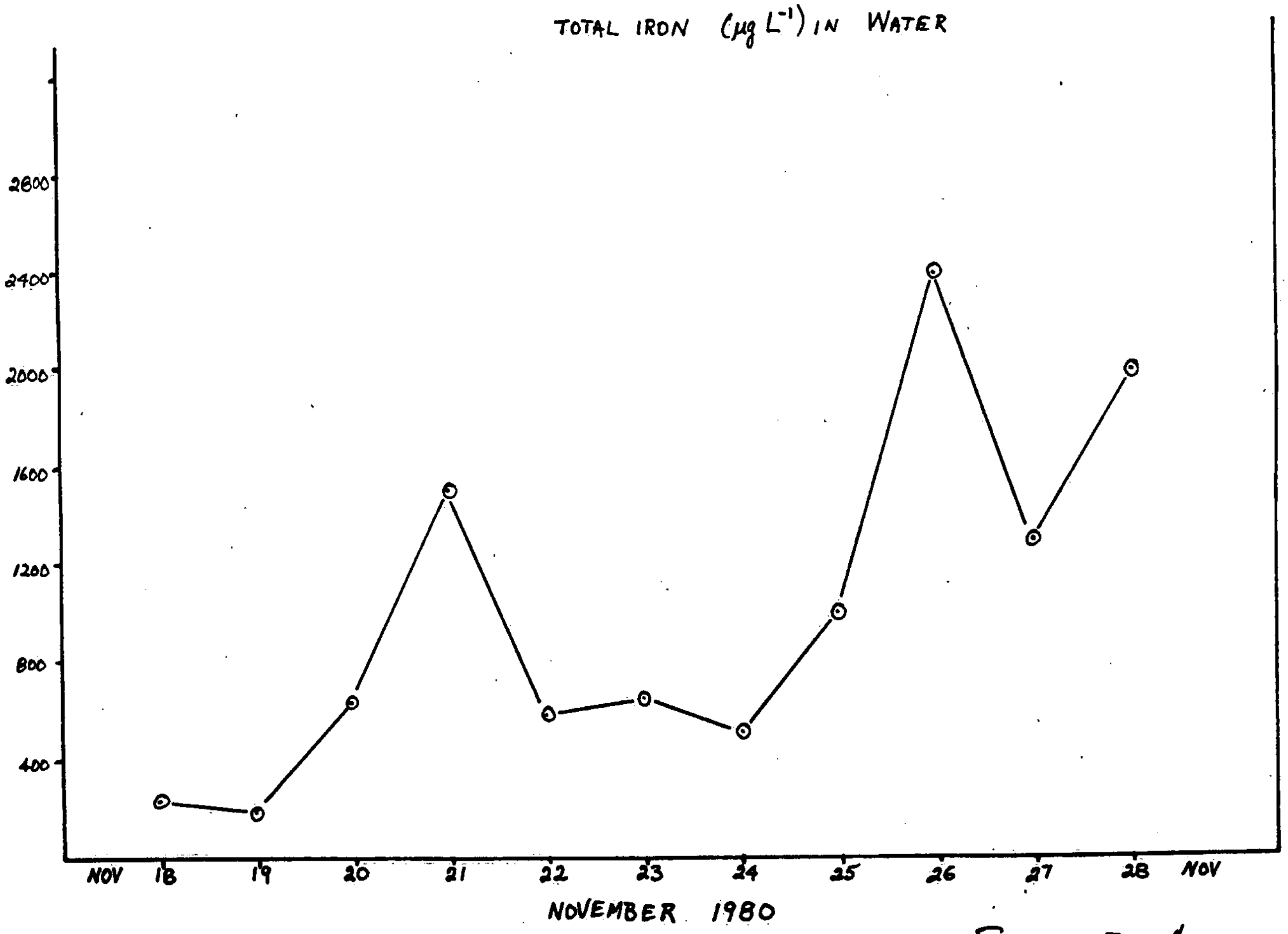


CARBON AND NITROGEN (%) IN SUSPENDED SEDIMENTS

FIGURE 3

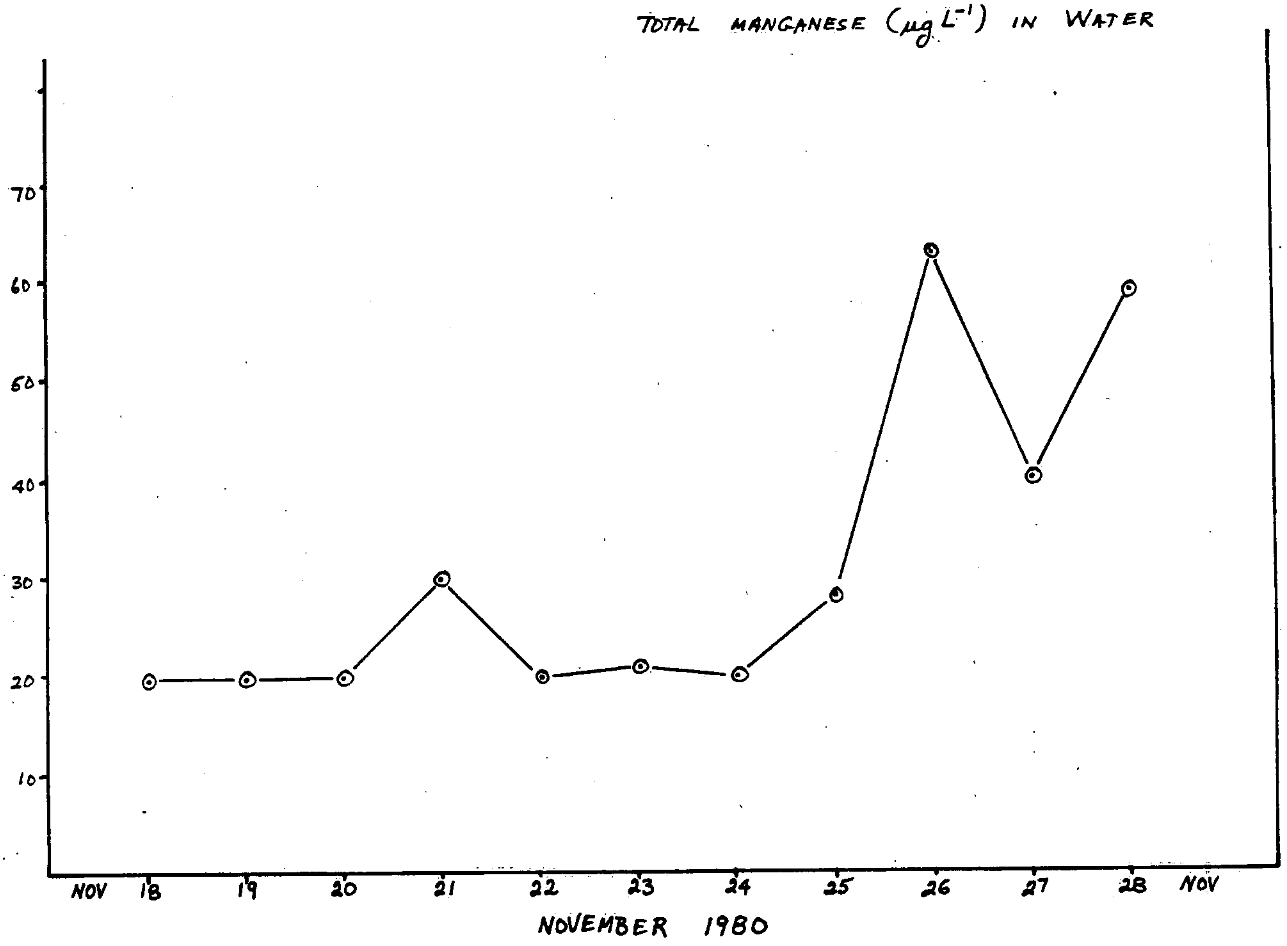


EXTRACTABLE ALUMINUM ($\mu g L^{-1}$) IN WATER



TOTAL IRON ($\mu g L^{-1}$) IN WATER

FIGURE 4


TOTAL MANGANESE (µg L⁻¹) IN WATER
70
60
50
40
30
20
10
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

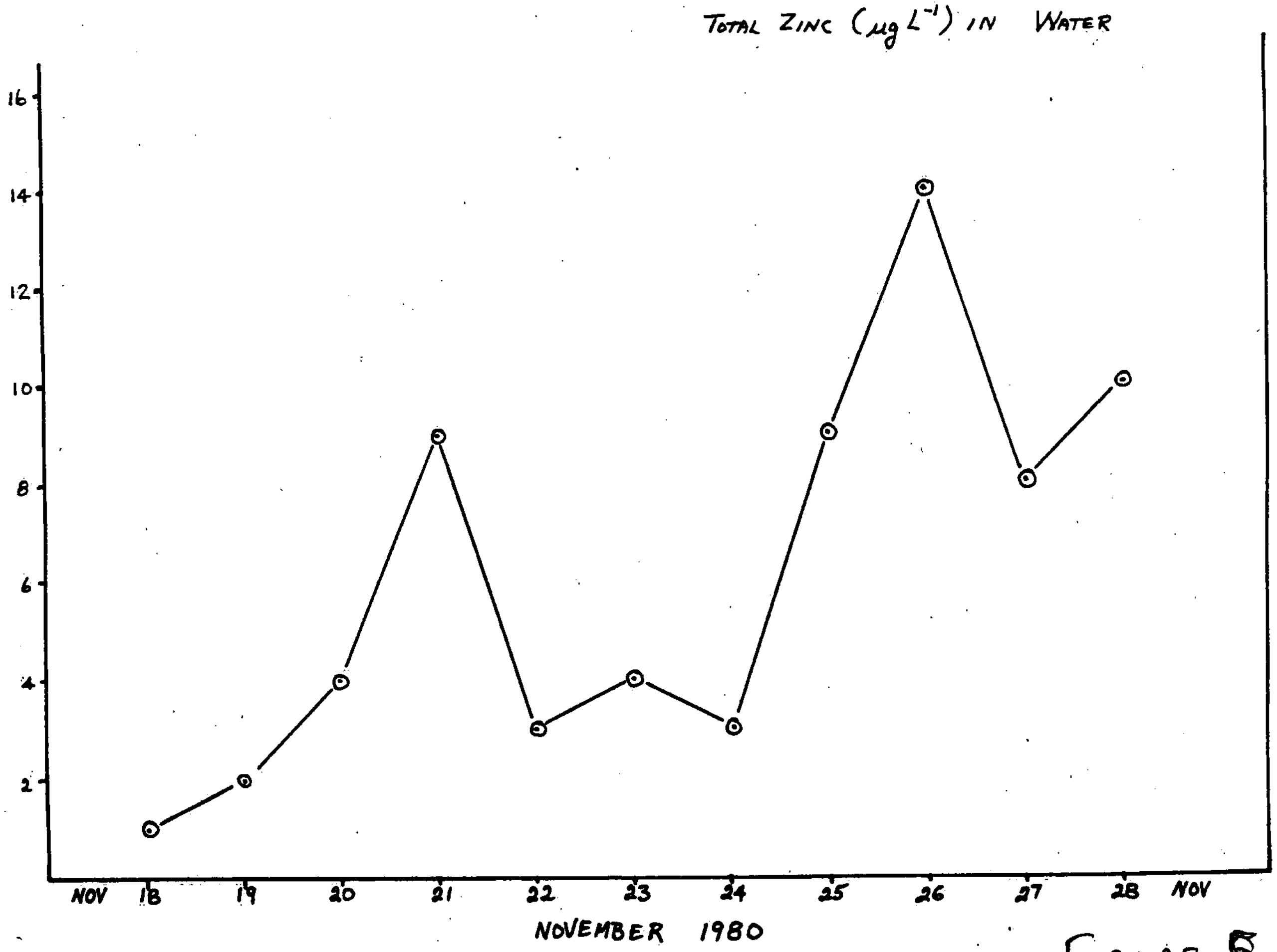
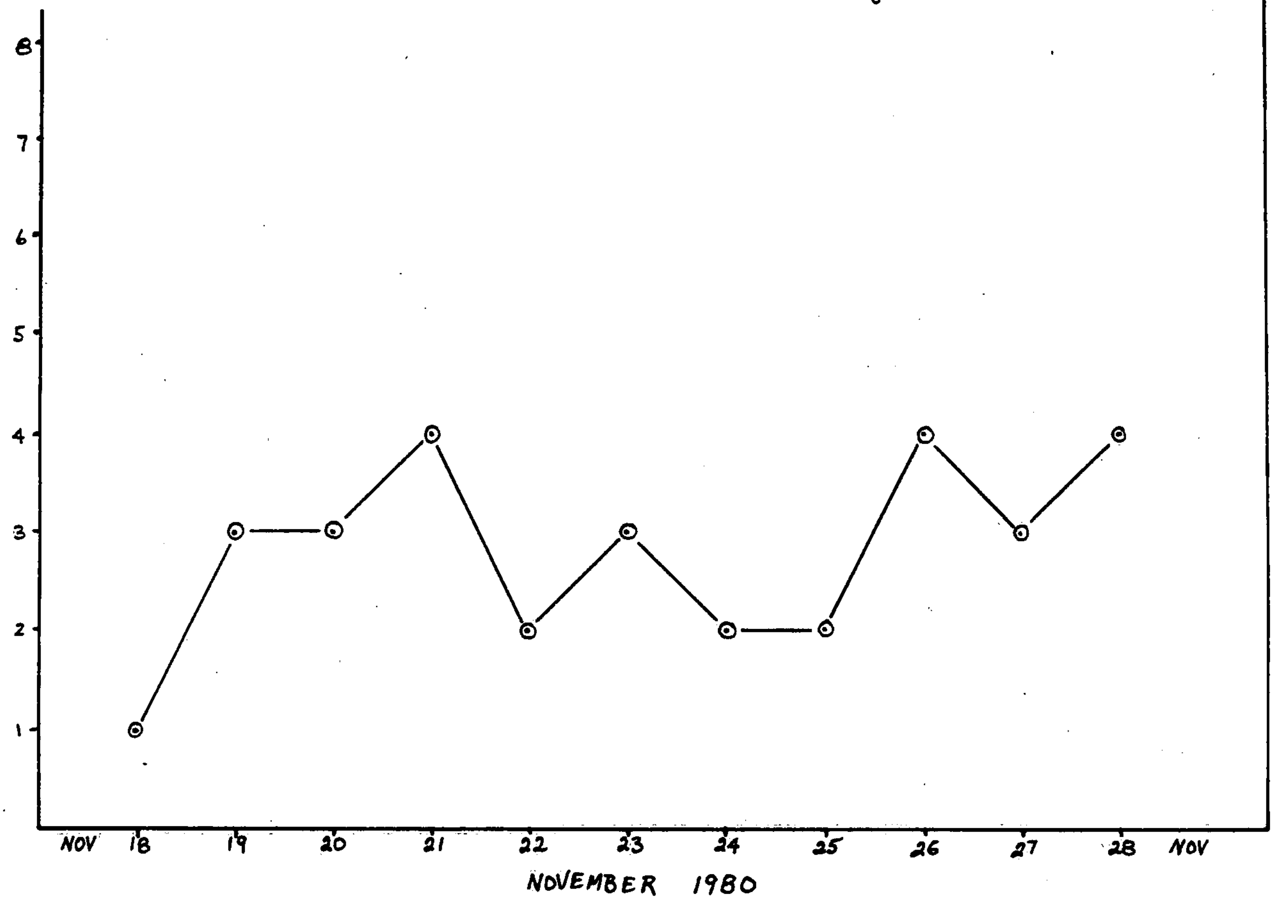
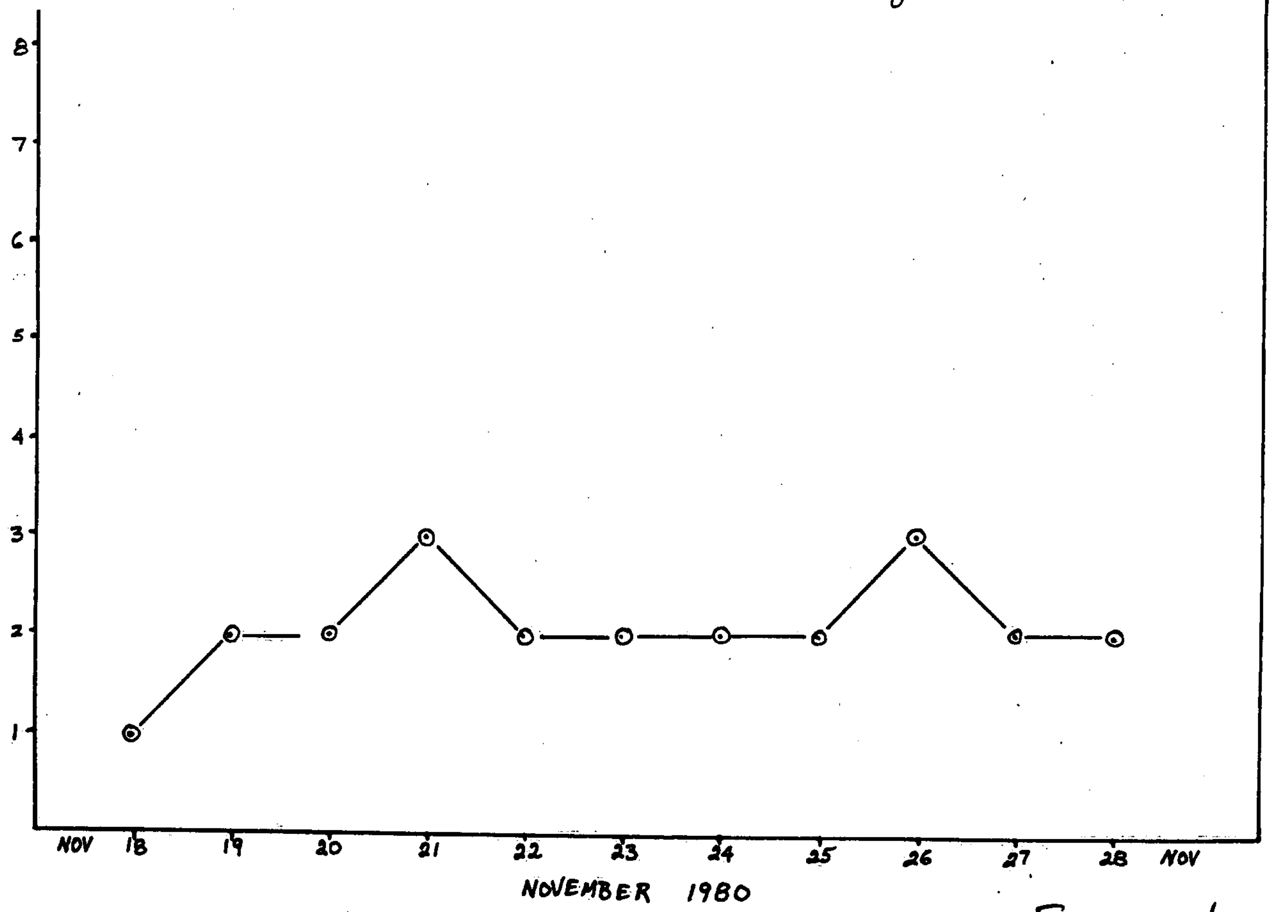

TOTAL ZINC (µg L⁻¹) IN WATER
16
14
12
10
8
6
4
2
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 5



Total Nickel ($\mu g\,L^{-1}$) in Water



Total Copper ($\mu g\,L^{-1}$) in Water

Figure 6

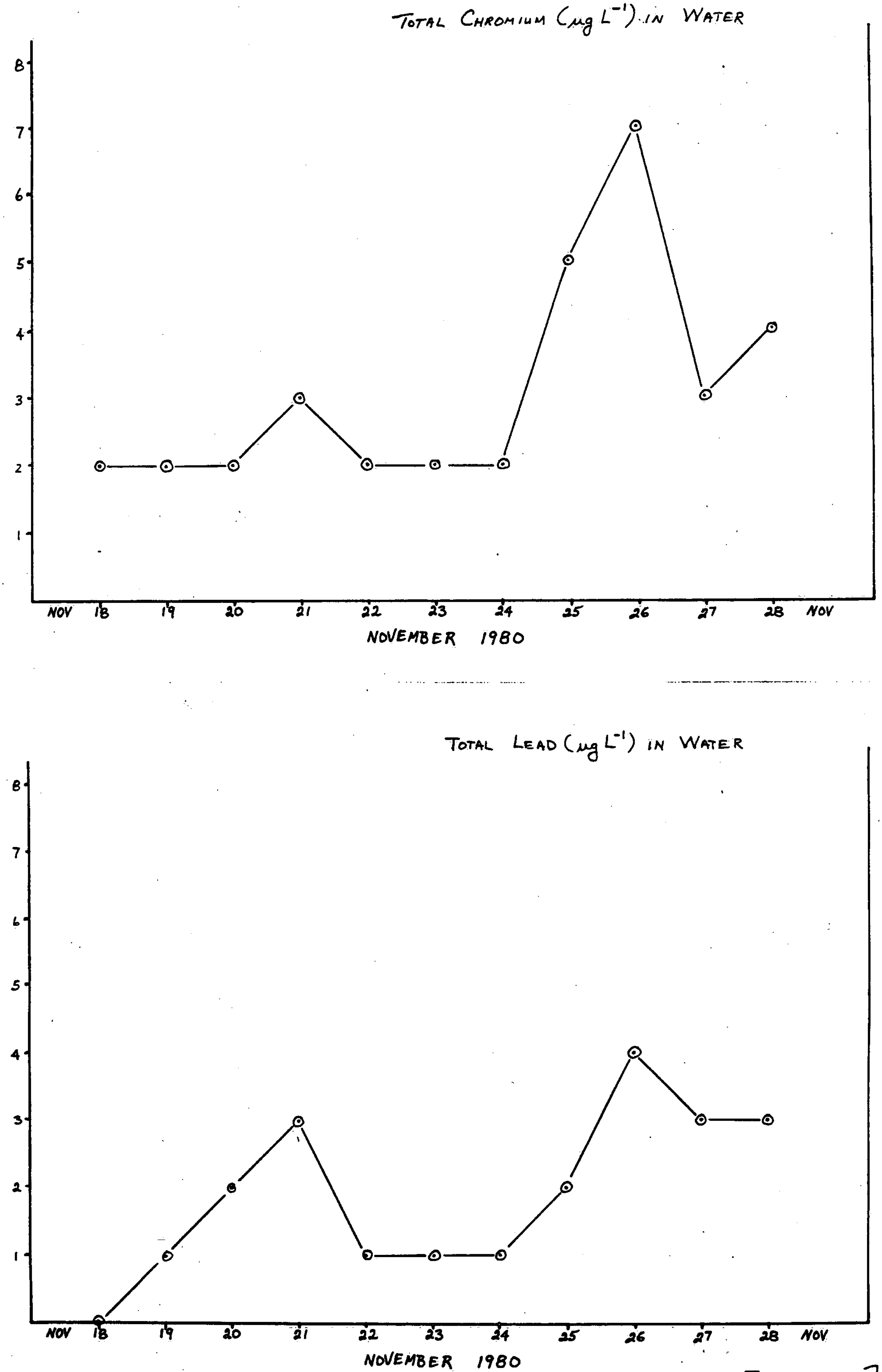
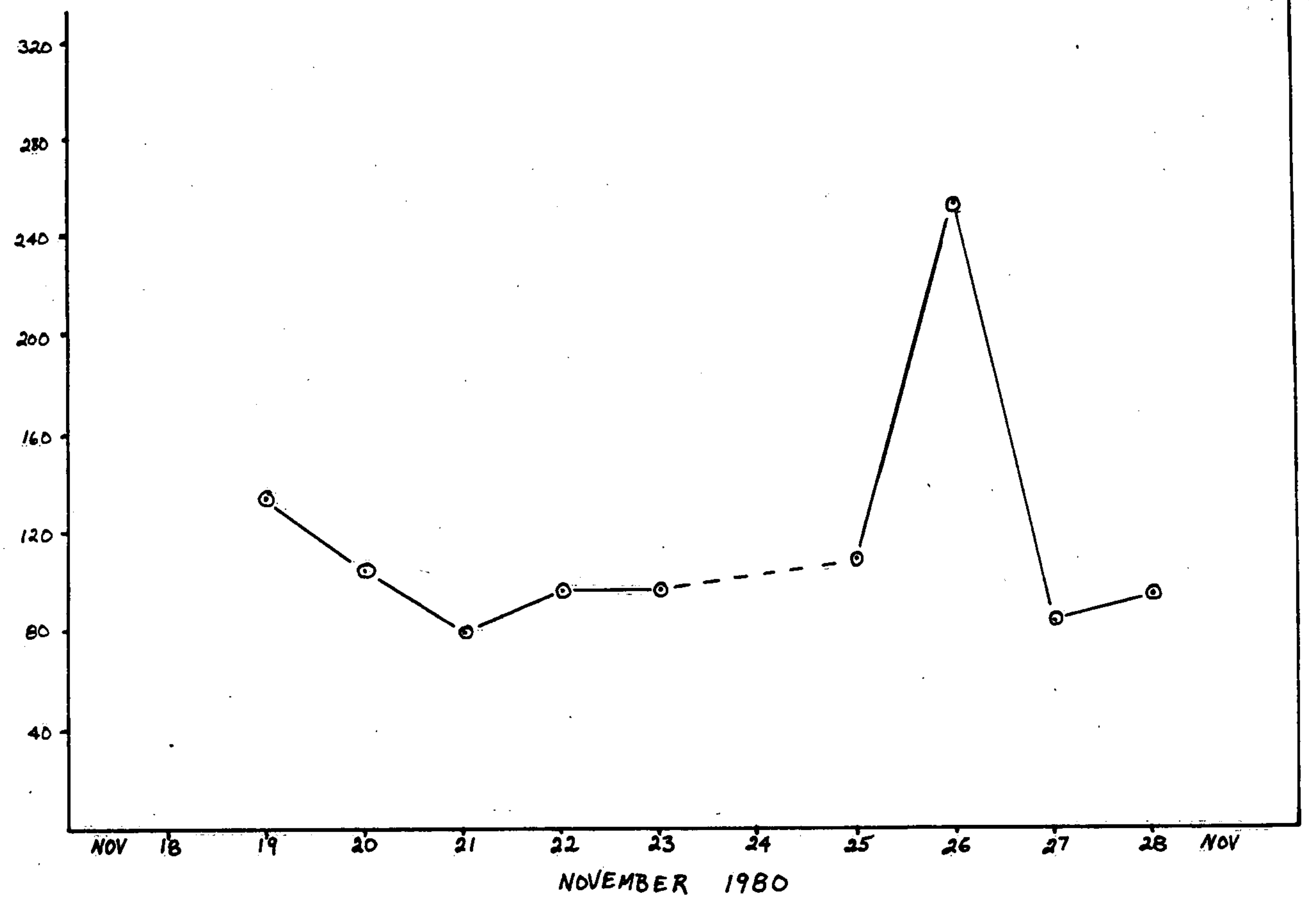

TOTAL CHROMIUM ($\mu g\ L^{-1}$) IN WATER
8
7
6
5
4
3
2
1
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
TOTAL LEAD ($\mu g\ L^{-1}$) IN WATER
8
7
6
5
4
3
2
1
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 7

EXTRACTABLE ZINC (0.5N HCl) IN SUSPENDED SEDIMENTS (mg kg^{-1})



EXTRACTABLE MERCURY (mg kg^{-1}) IN SUSPENDED SEDIMENTS

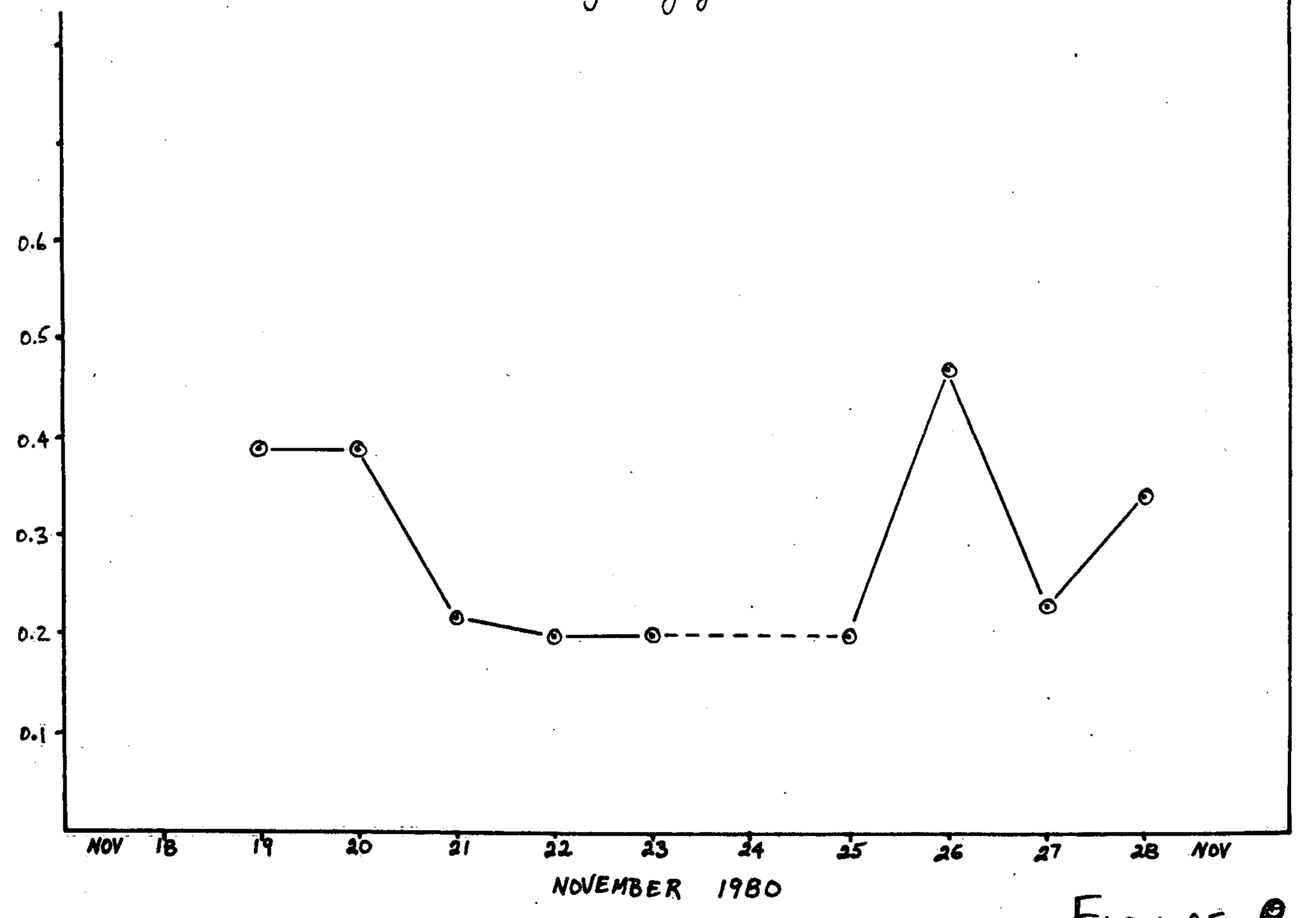
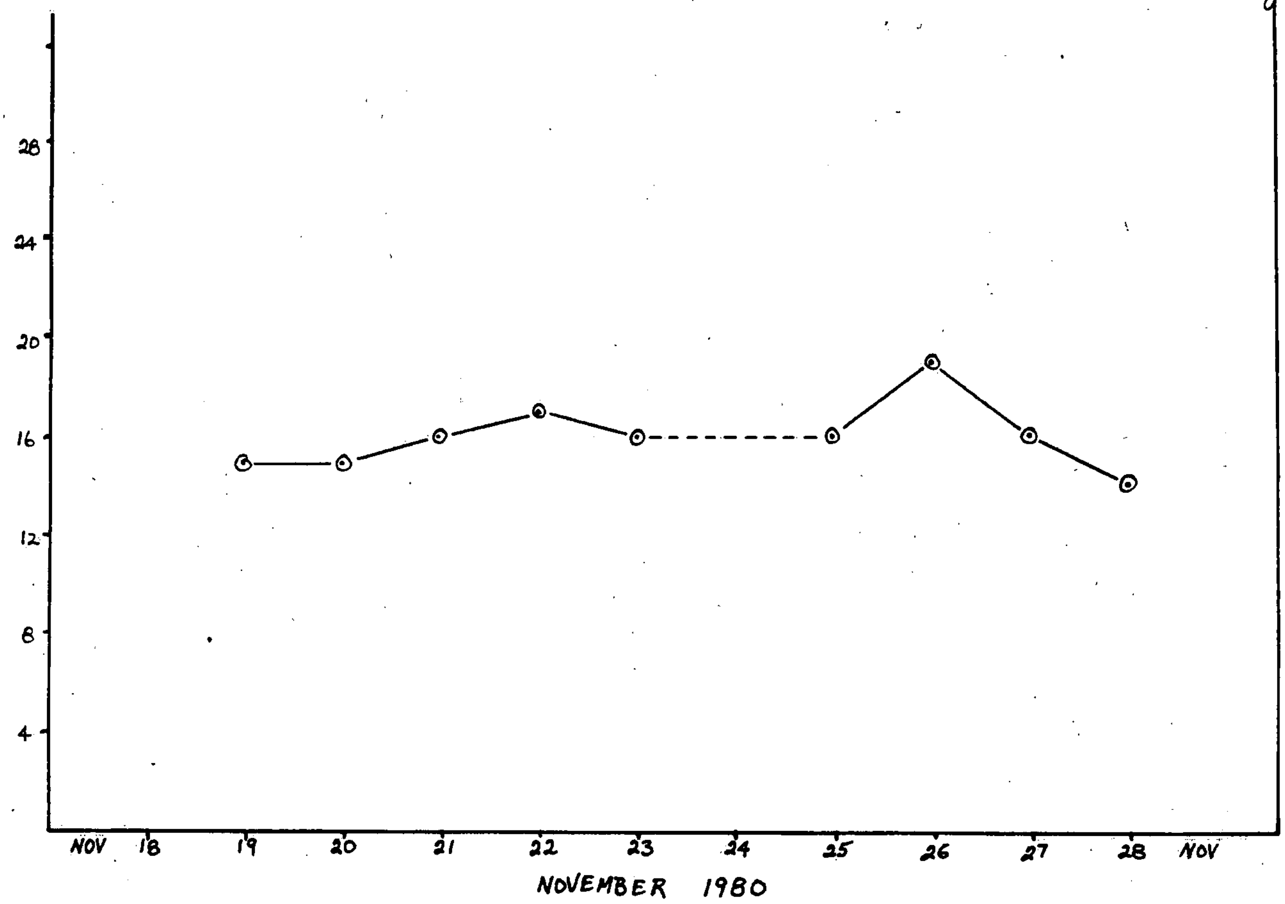


FIGURE 8


EXTRACTABLE NICKEL (0.5N HCl) IN SUSPENDED SEDIMENTS (mg kg⁻¹)

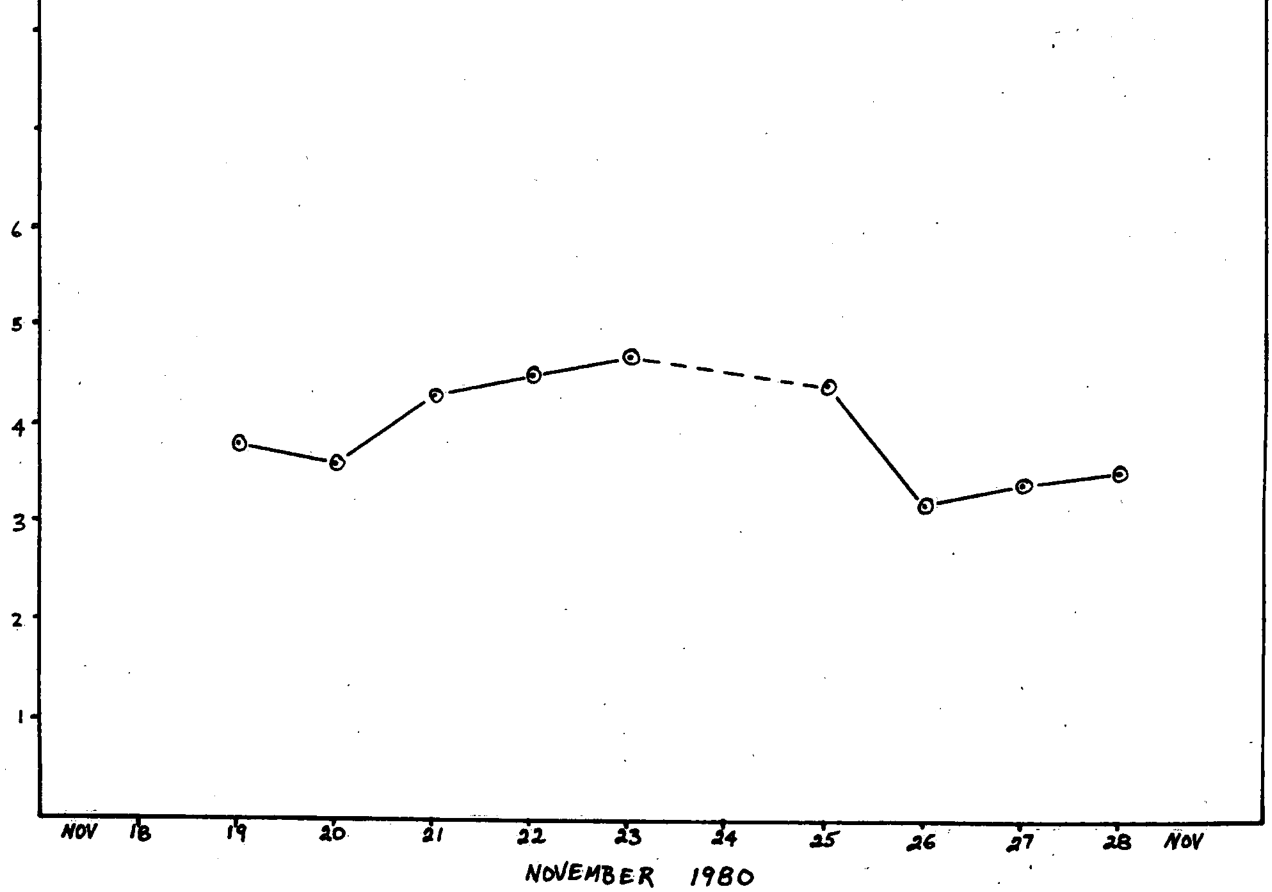

EXTRACTABLE COBALT (0.5N HCl) IN SUSPENDED SEDIMENTS (mg kg⁻¹)

FIGURE 9

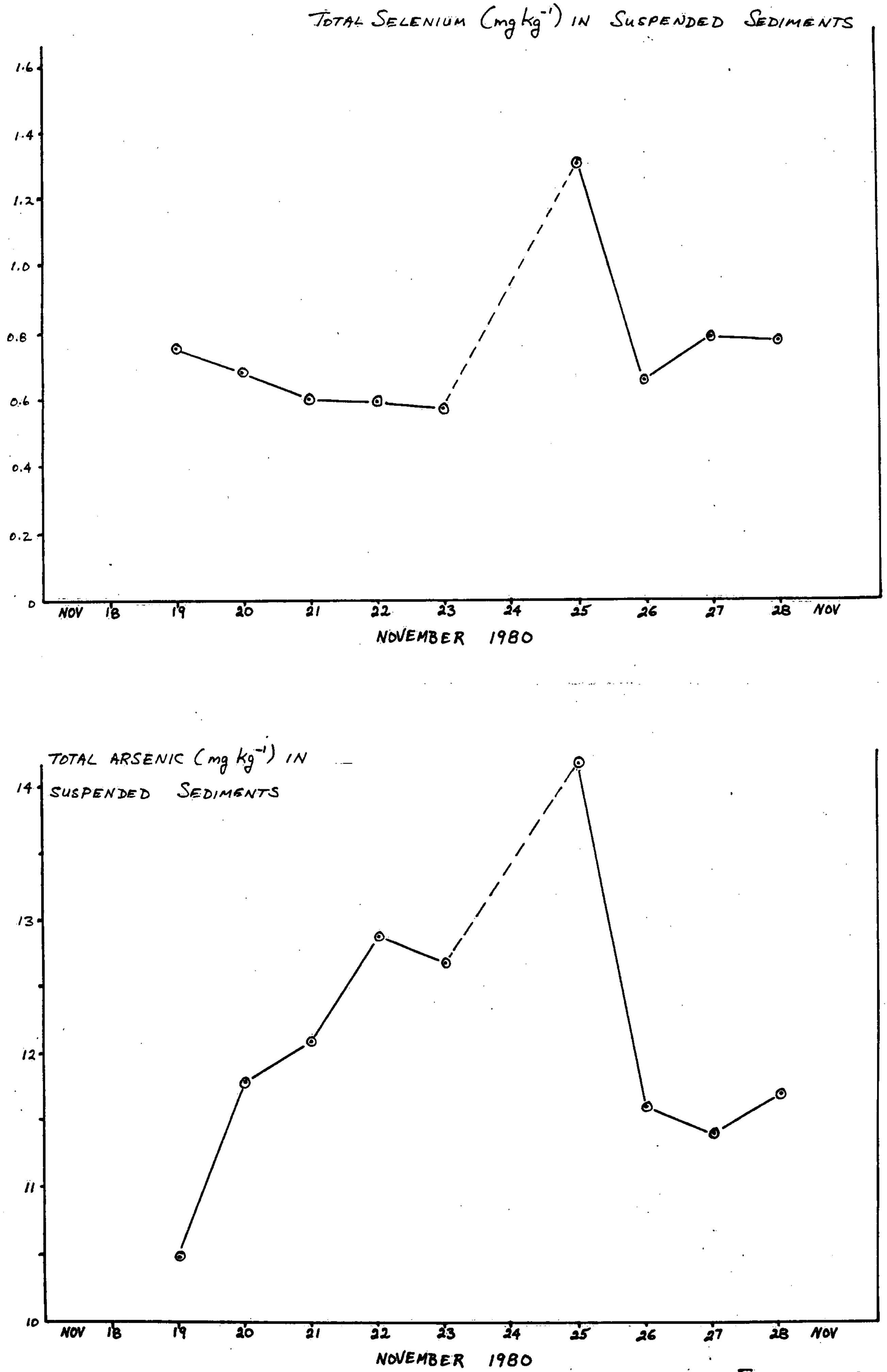
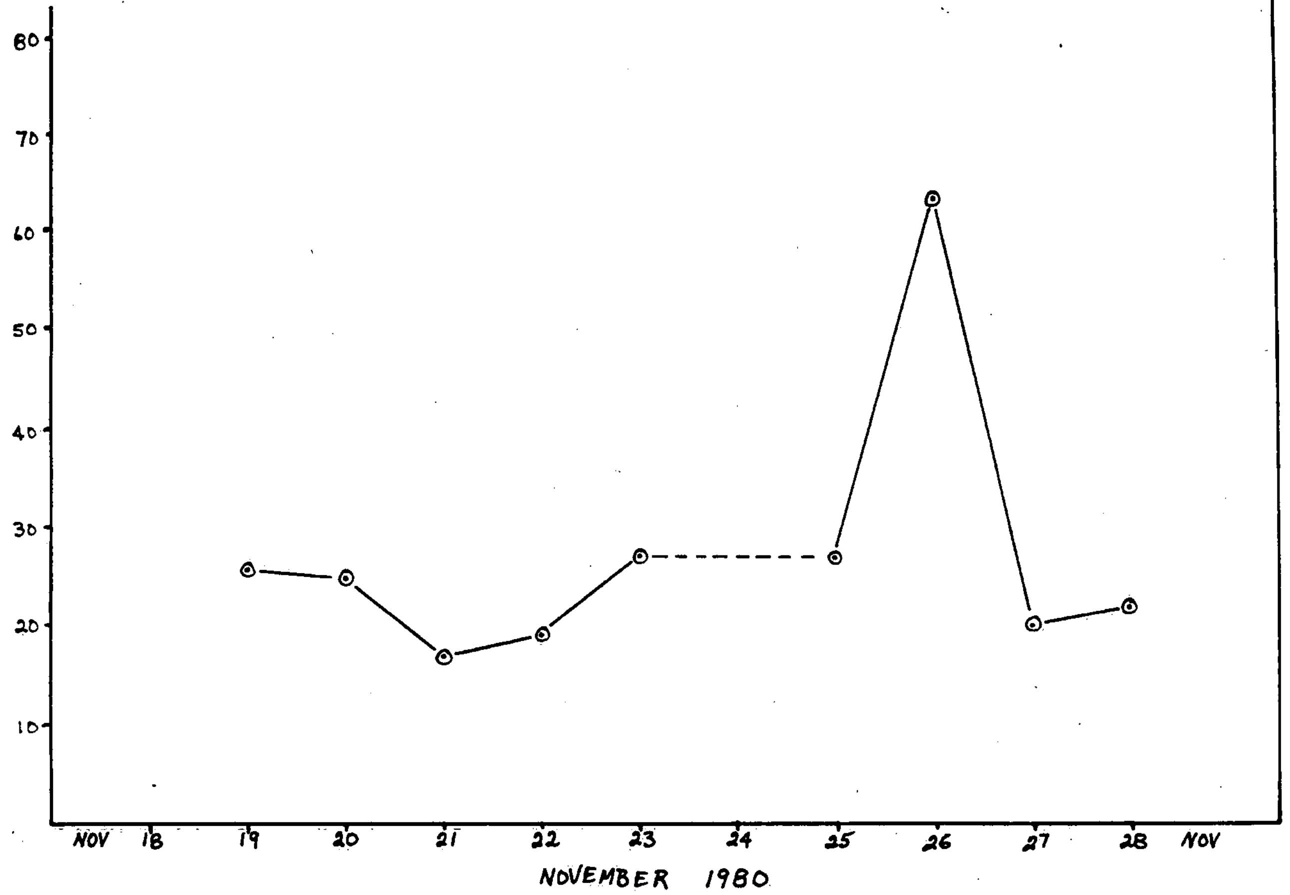
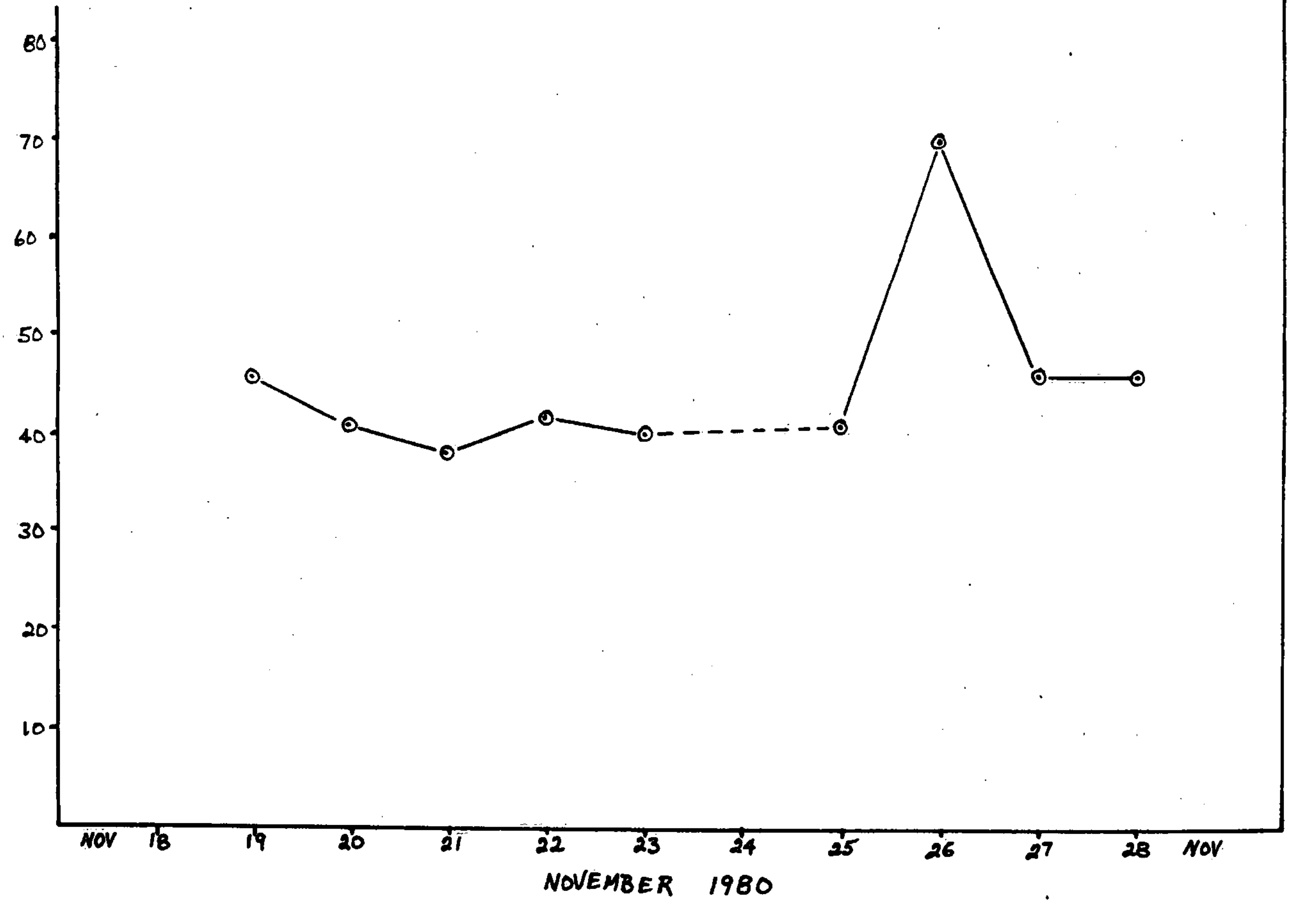

TOTAL SELENIUM (mg kg⁻¹) IN SUSPENDED SEDIMENTS
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
TOTAL ARSENIC (mg kg⁻¹) IN SUSPENDED SEDIMENTS
14
13
12
11
10
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 10



EXTRACTABLE COPPER (0.5 N HCl) IN SUSPENDED SEDIMENTS (mg kg^{-1})



EXTRACTABLE LEAD (0.5 N HCl) IN SUSPENDED SEDIMENTS (mg kg^{-1})

FIGURE 11

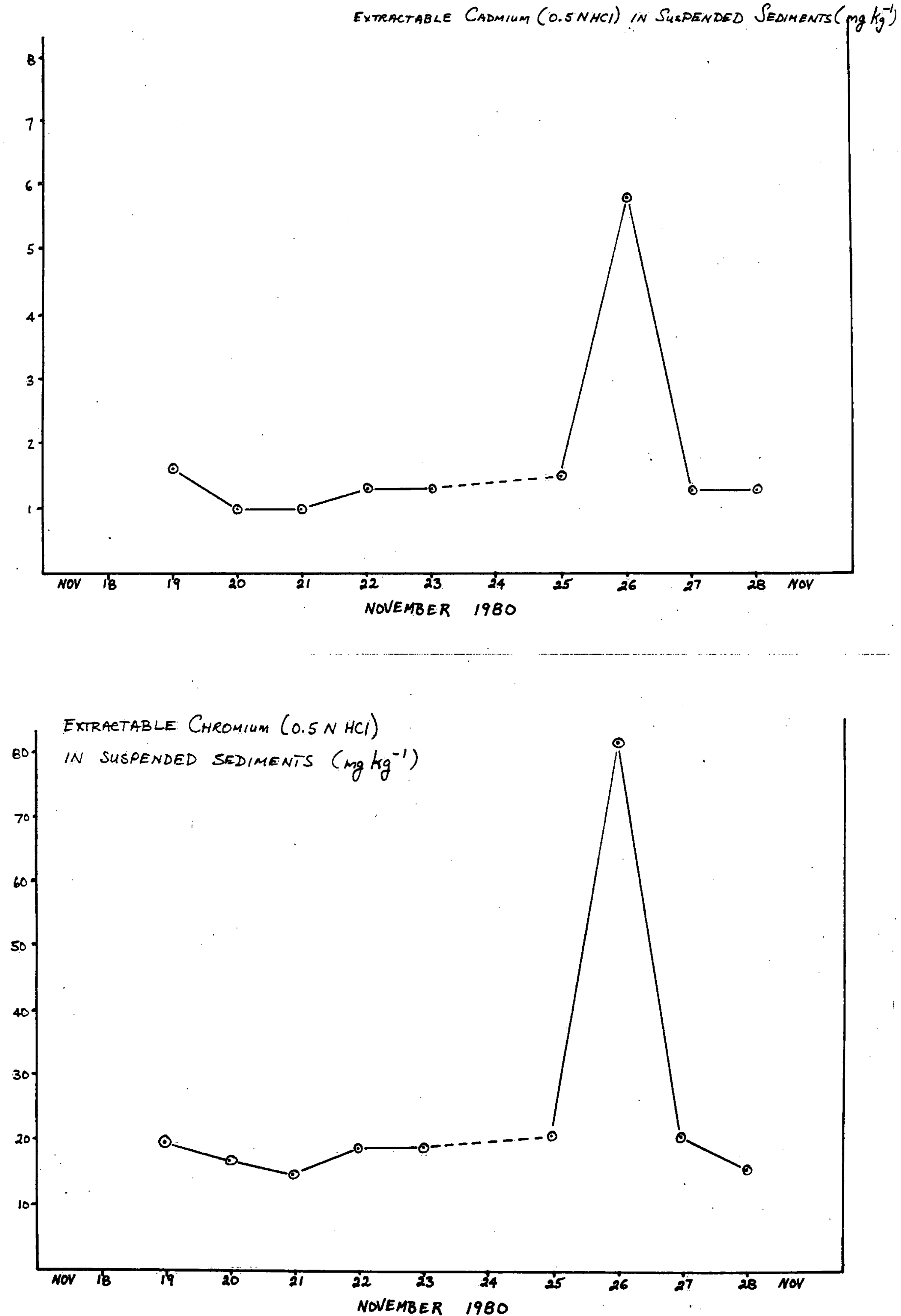

EXTRACTABLE CADMIUM (0.5 N HCl) IN SUSPENDED SEDIMENTS (mg kg⁻¹)
8
7
6
5
4
3
2
1
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
EXTRACTABLE CHROMIUM (0.5 N HCl)
IN SUSPENDED SEDIMENTS (mg kg⁻¹)
80
70
60
50
40
30
20
10
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 12

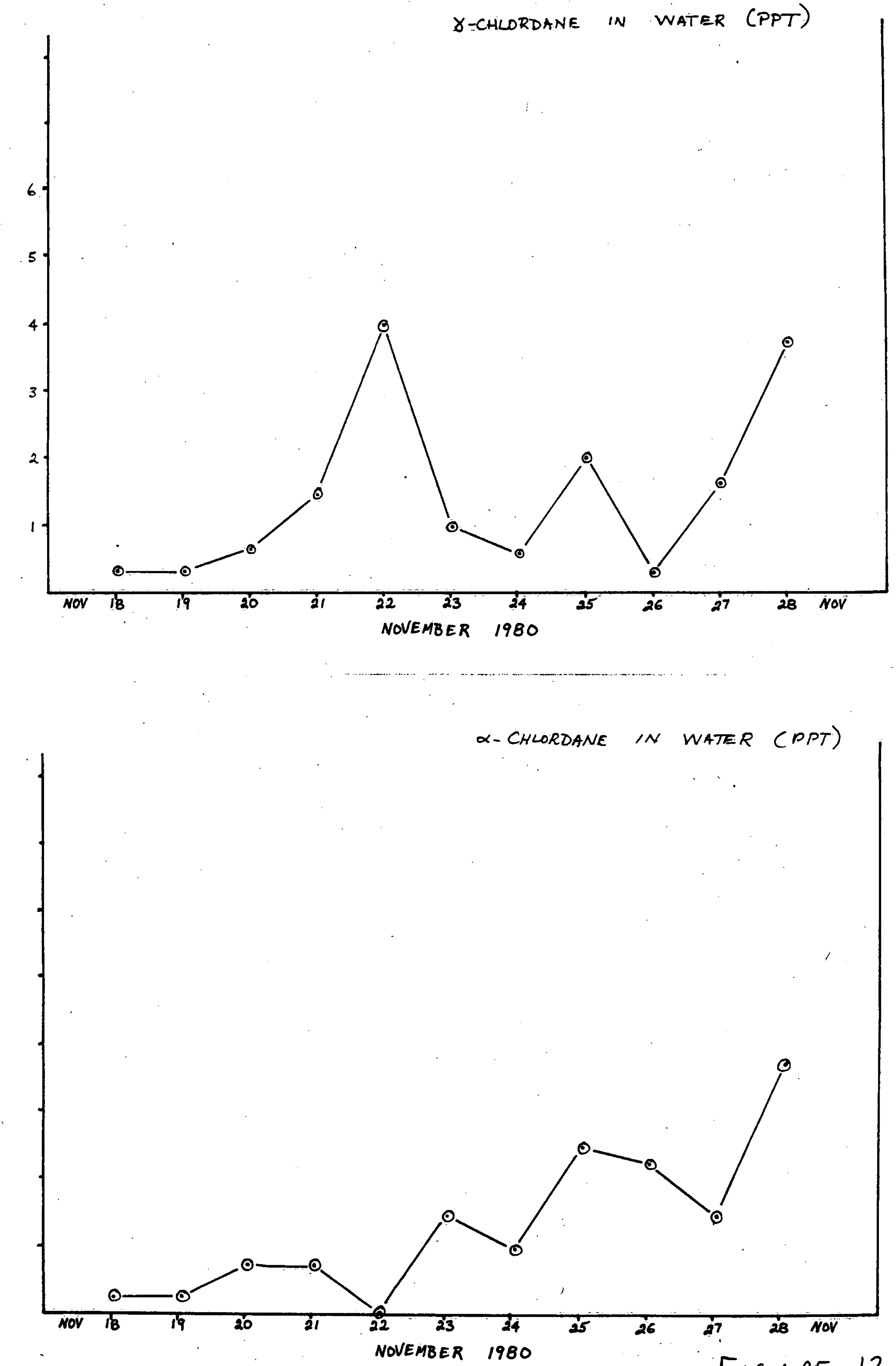
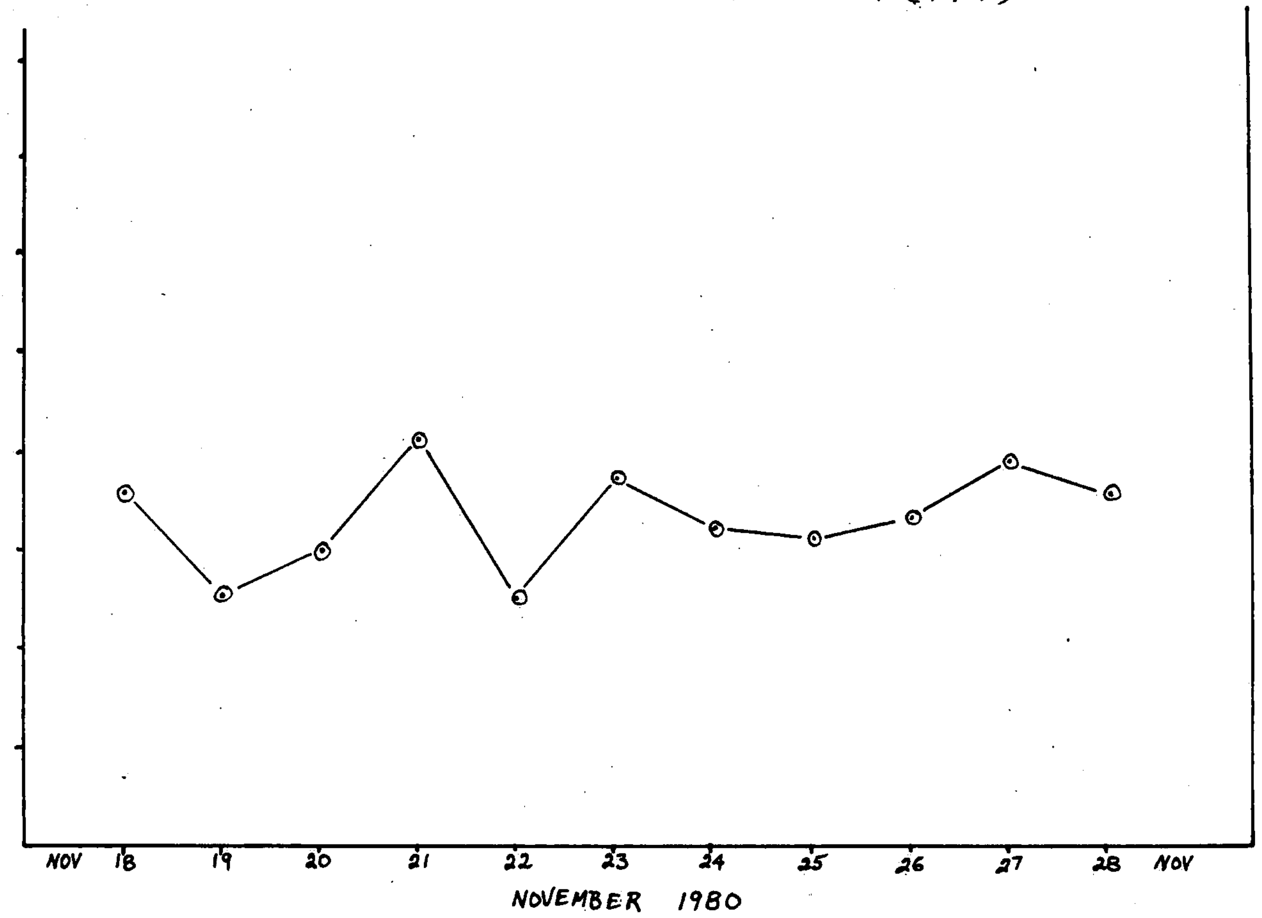

γ-CHLORDANE IN WATER (PPT)
6
5
4
3
2
1
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
α-CHLORDANE IN WATER (PPT)
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 13

α-BHC IN WATER (PPT)



γ-BHC IN WATER (PPT)

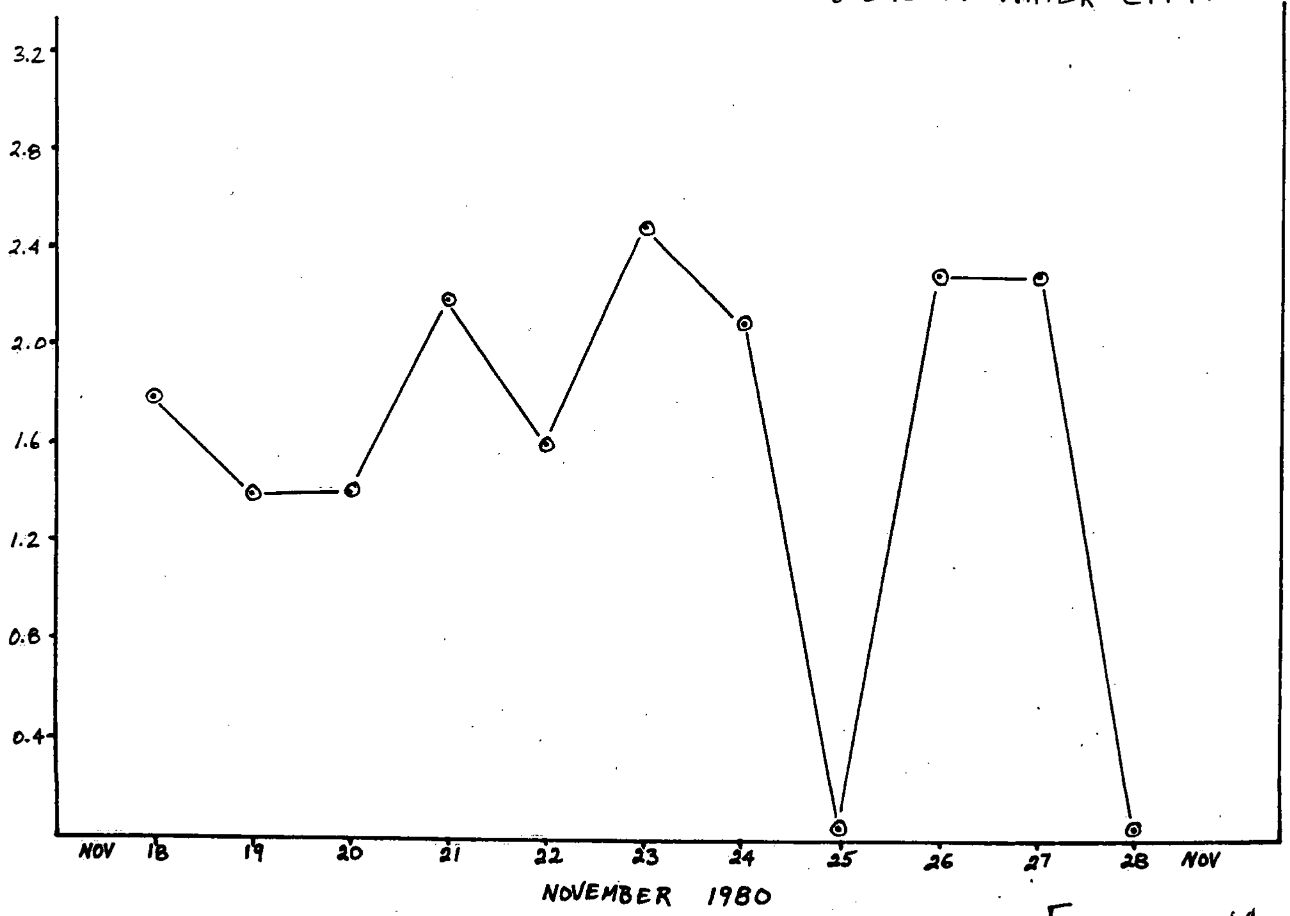
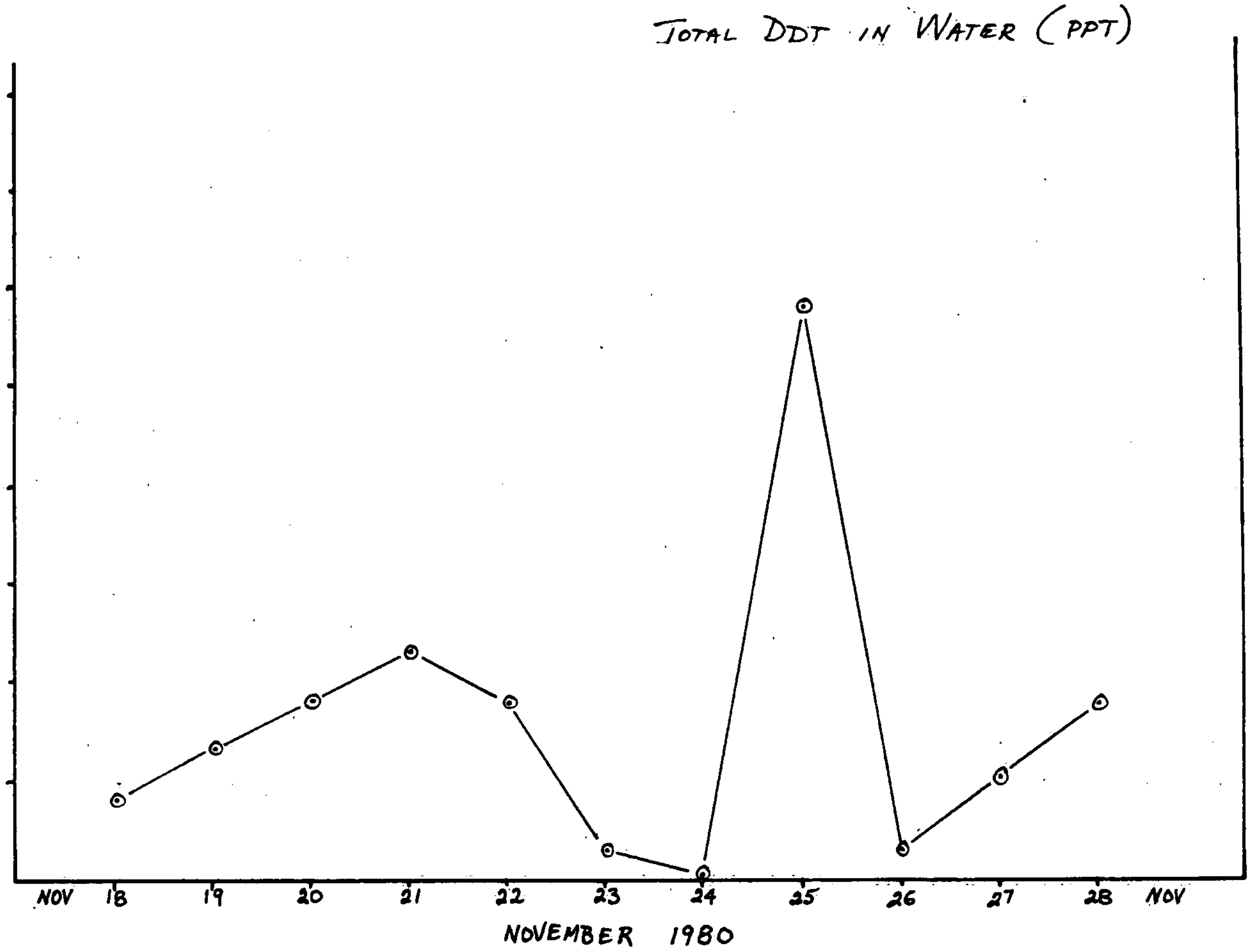
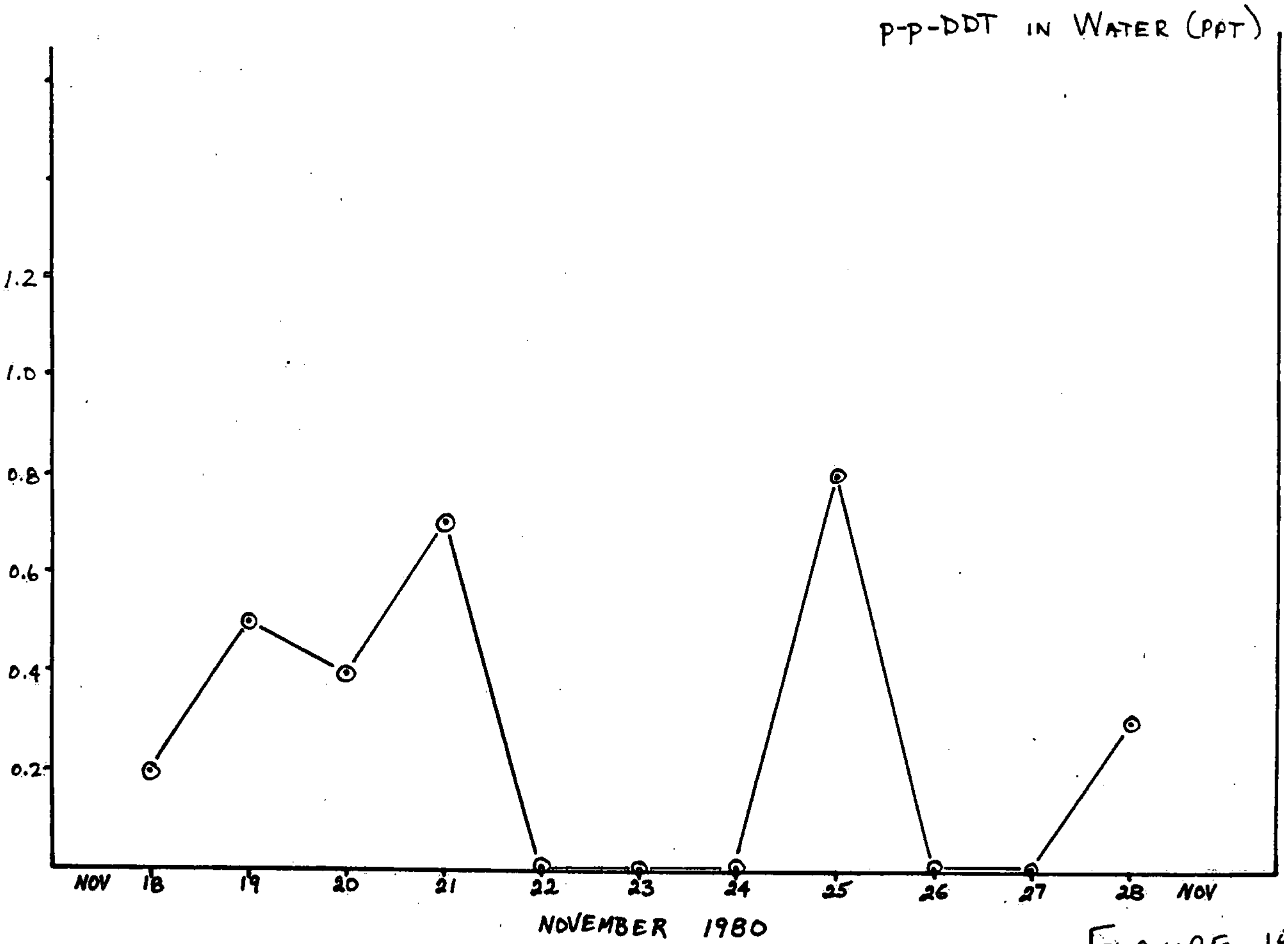


FIGURE 14



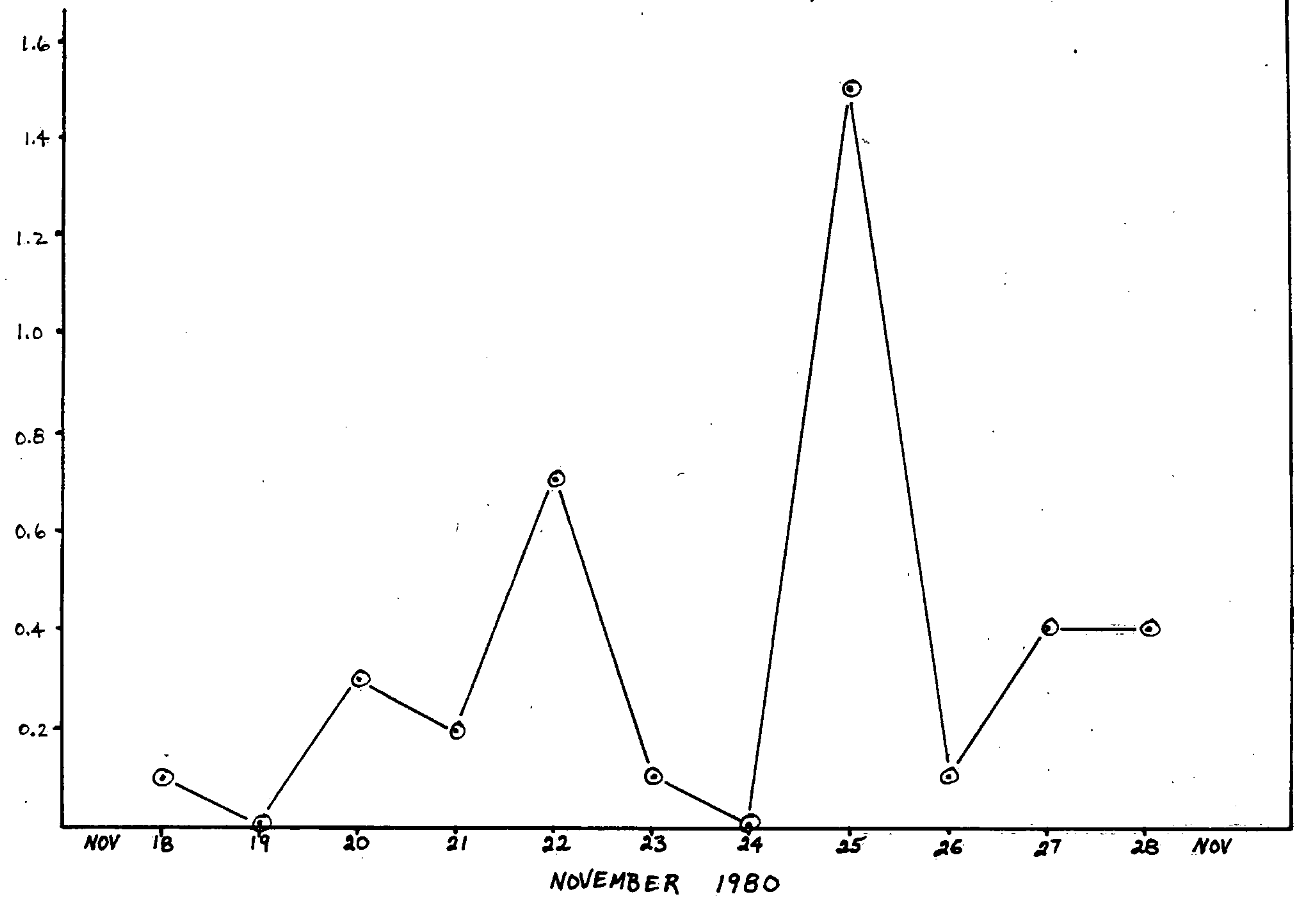
TOTAL DDT IN WATER (PPT)
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980



p-p-DDT IN WATER (PPT)
1.2
1.0
0.8
0.6
0.4
0.2
NOV
18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 15

P-P-DDE IN WATER (PPT)



DIELDRIN IN WATER (PPT)

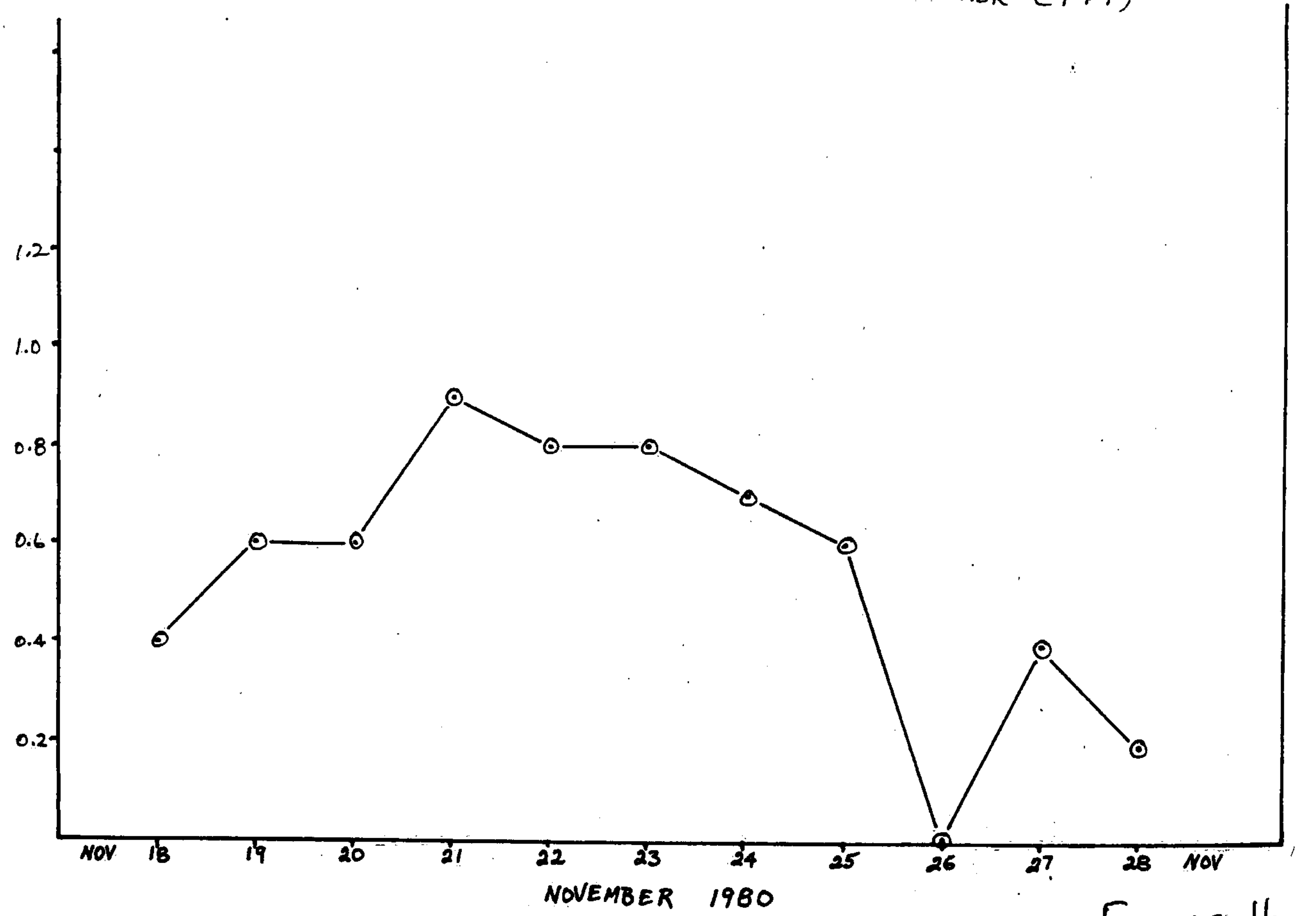
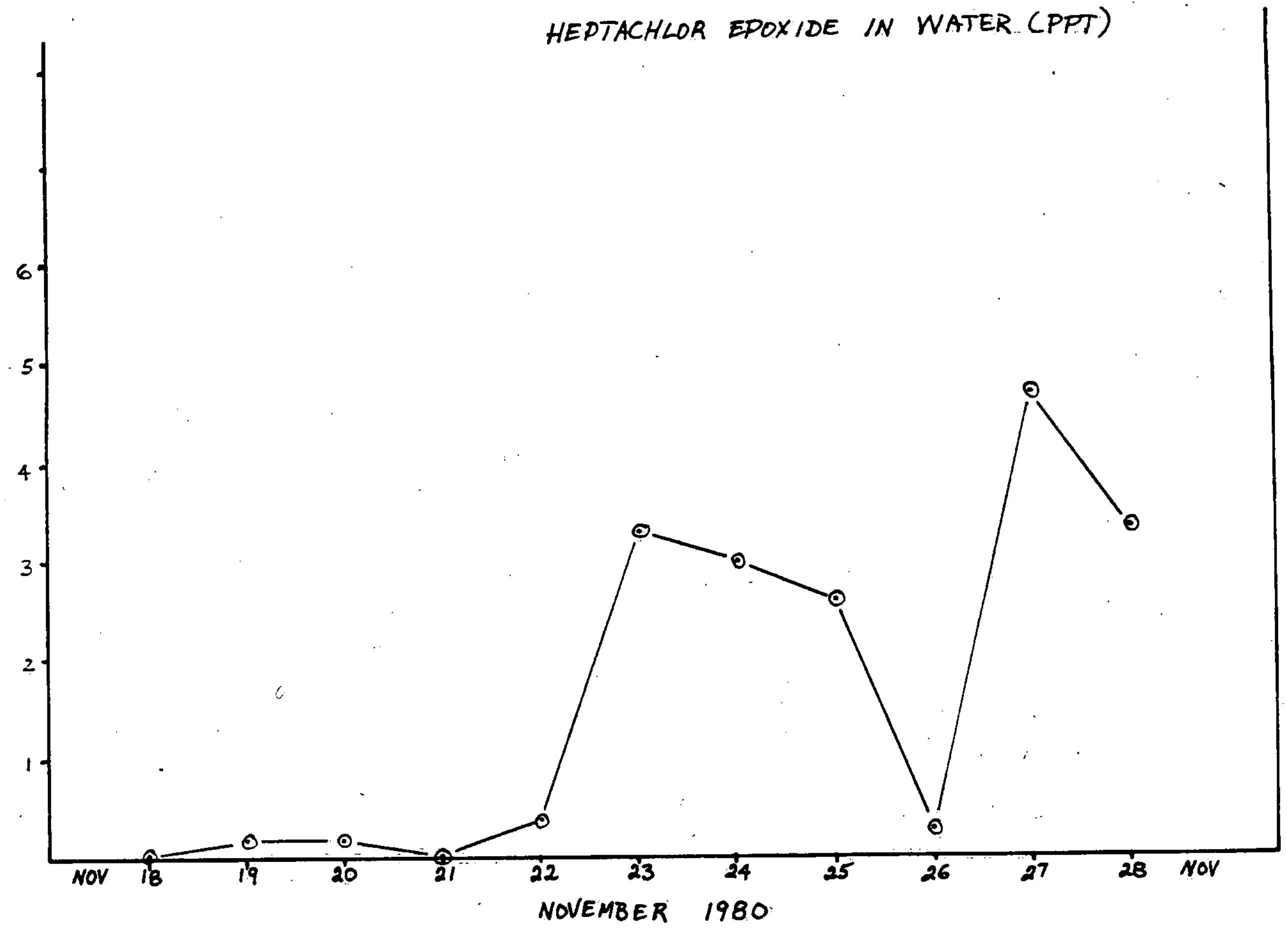


FIGURE 16


HEPTACHLOR EPOXIDE IN WATER (PPT)

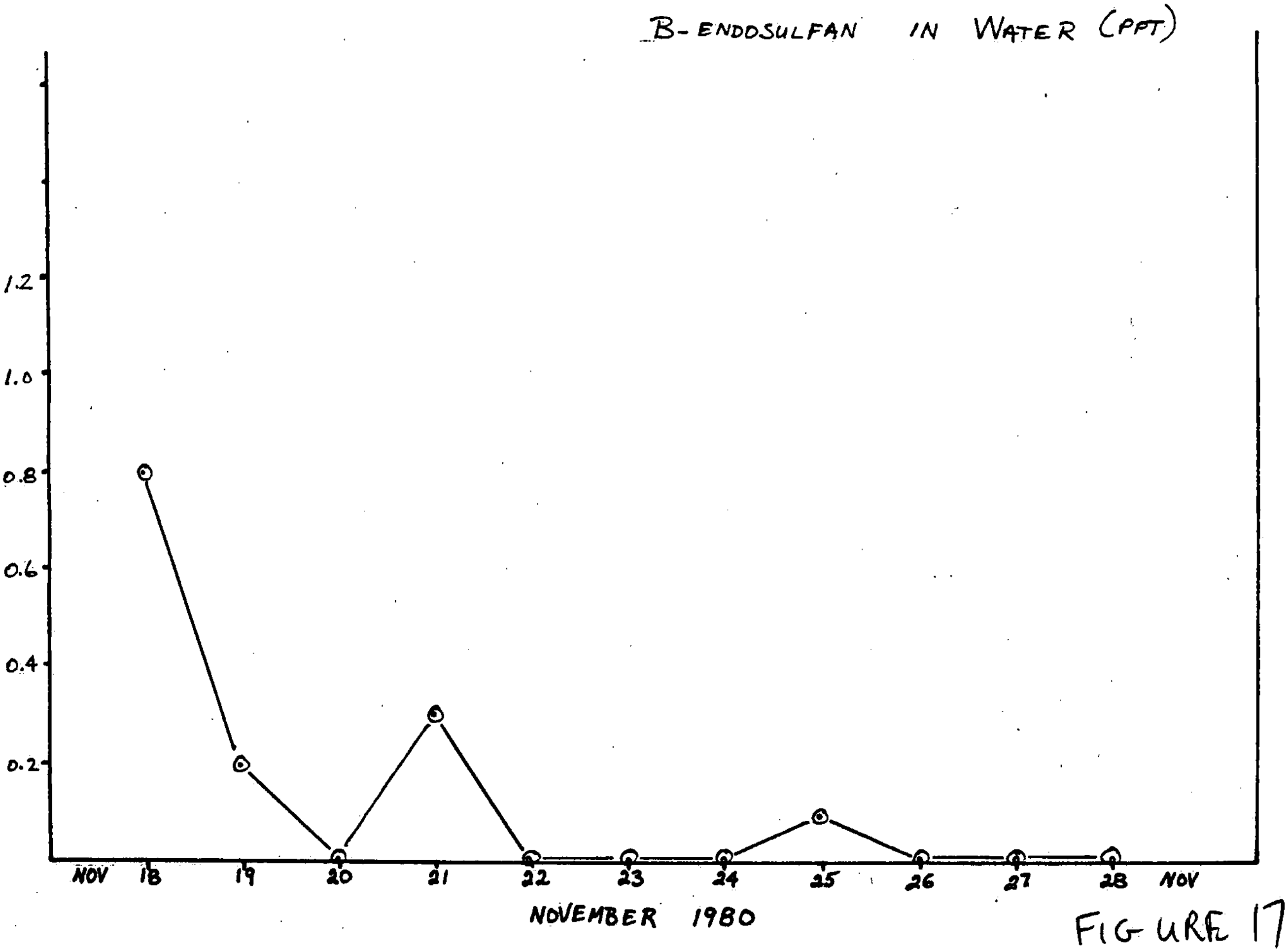
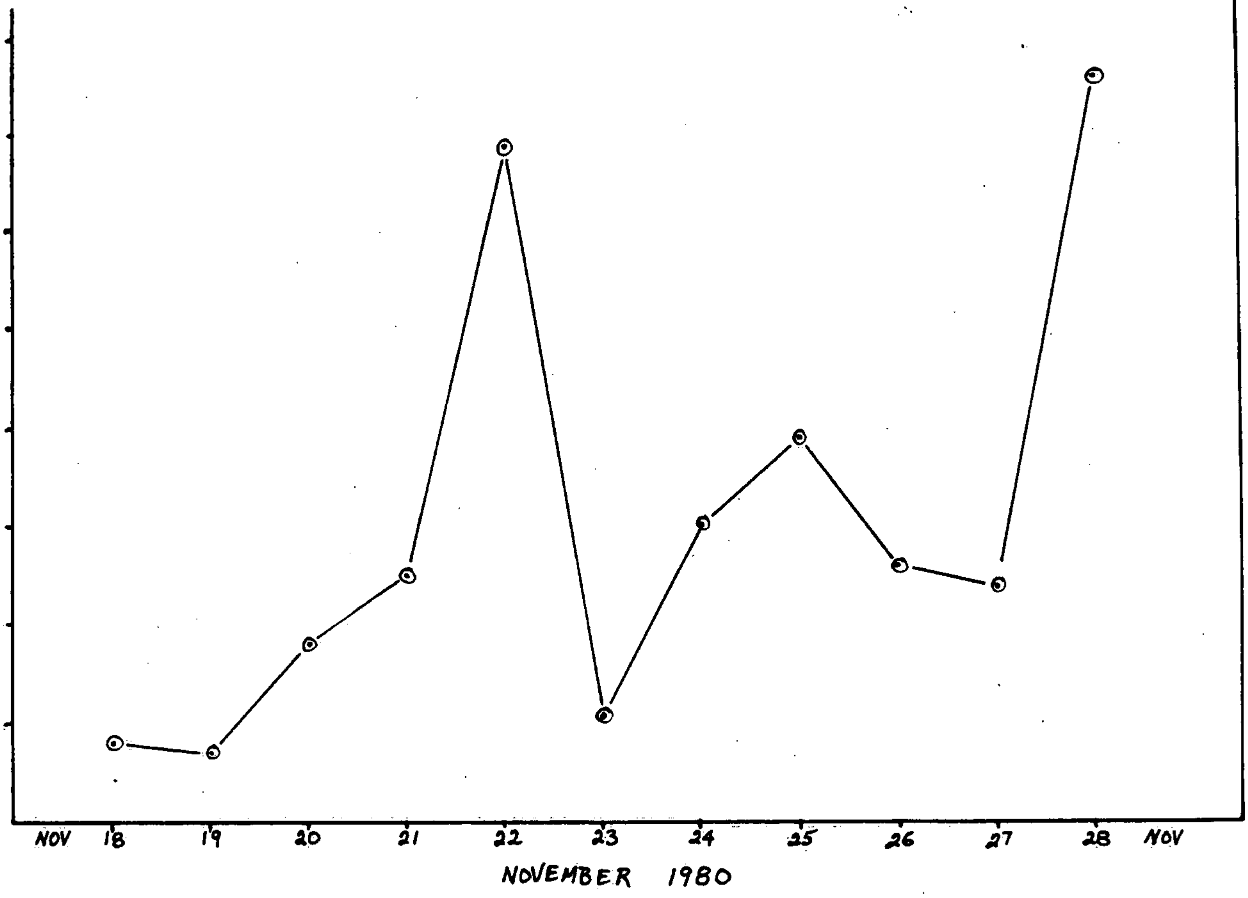

B-ENDOSULFAN IN WATER (PPT)

FIGURE 17

TOTAL PCB IN WATER (PPT)



HEXACHLOROBENZENE IN WATER (PPT)

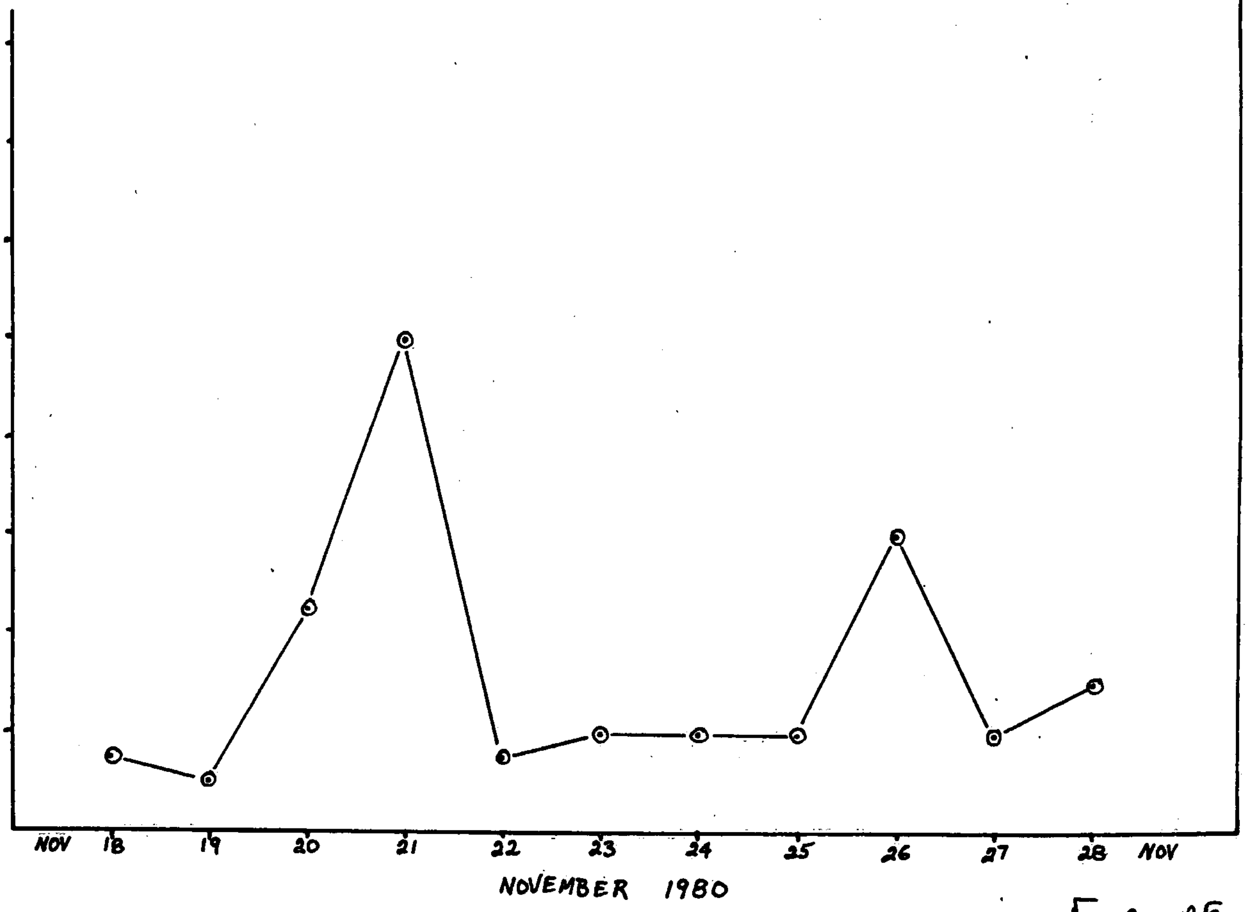
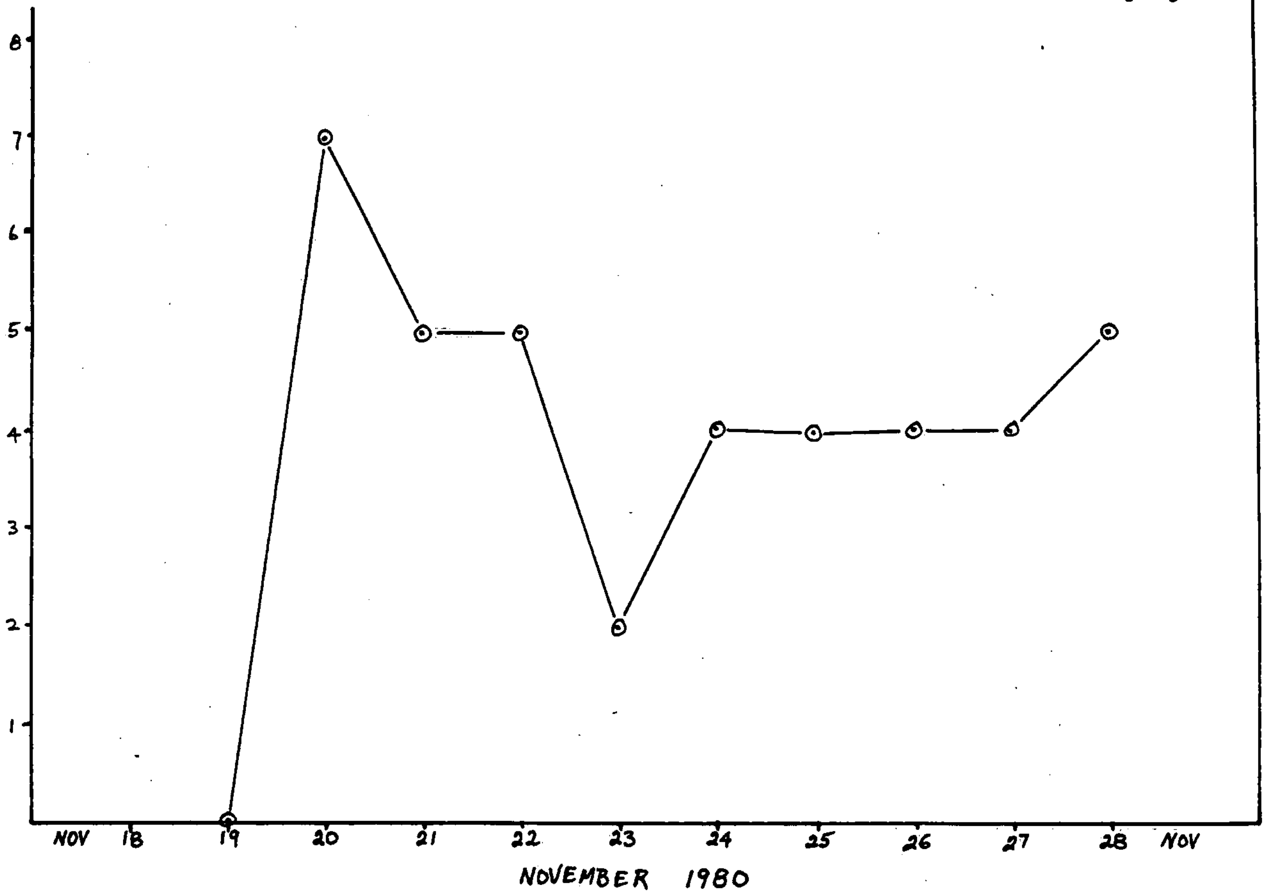


FIGURE 18

DIELDRIN IN SUSPENDED SEDIMENTS ($\mu g\ kg^{-1}$)



METHOXYCHLOR IN SUSPENDED SEDIMENTS ($\mu g\ kg^{-1}$)

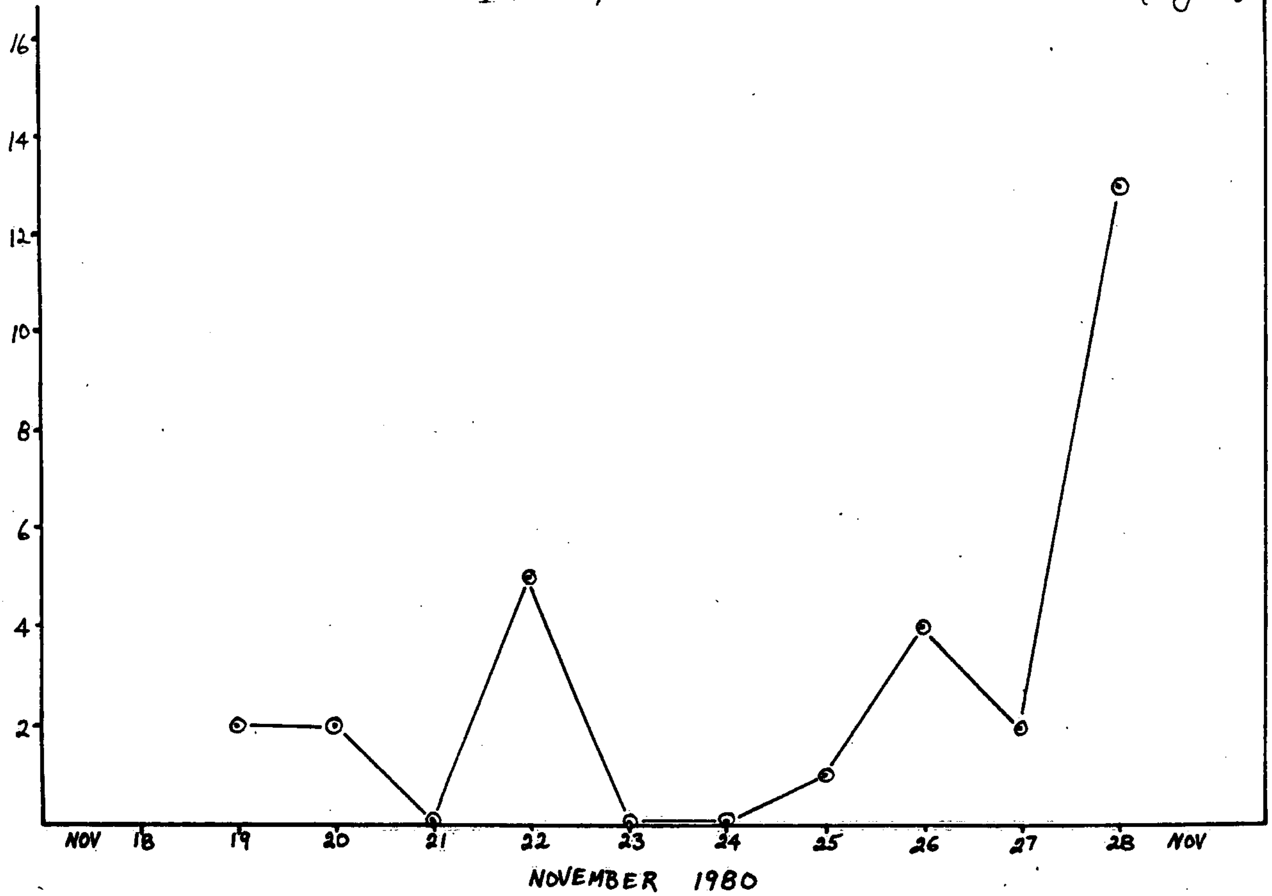


FIGURE 19

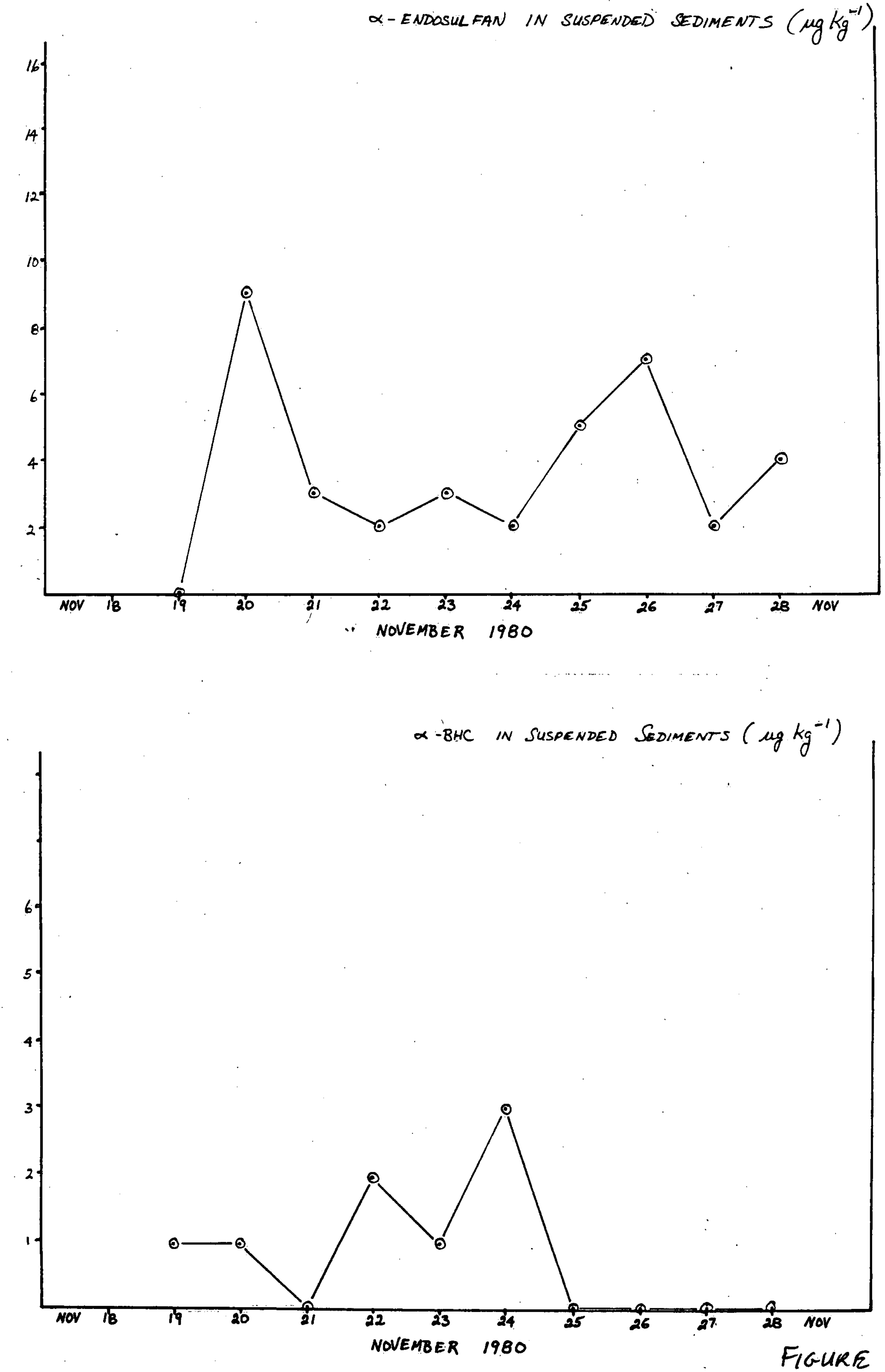
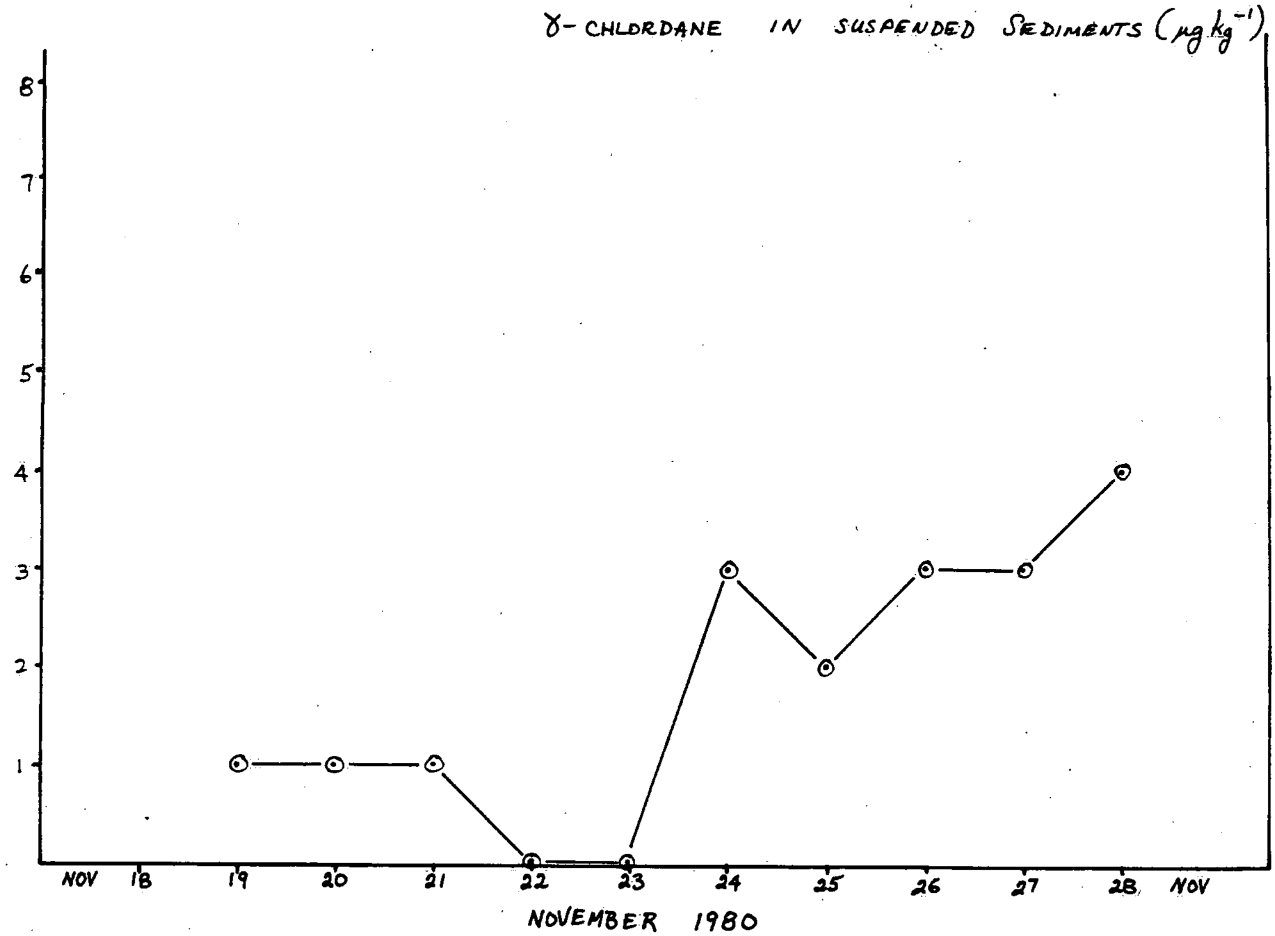

α - ENDOSULFAN IN SUSPENDED SEDIMENTS ($\mu g\ kg^{-1}$)
16
14
12
10
8
6
4
2
NOV 18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980
α -BHC IN SUSPENDED SEDIMENTS ($\mu g\ kg^{-1}$)
6
5
4
3
2
1
NOV 18
19
20
21
22
23
24
25
26
27
28
NOV
NOVEMBER 1980

FIGURE 20


γ-CHLORDANE IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)

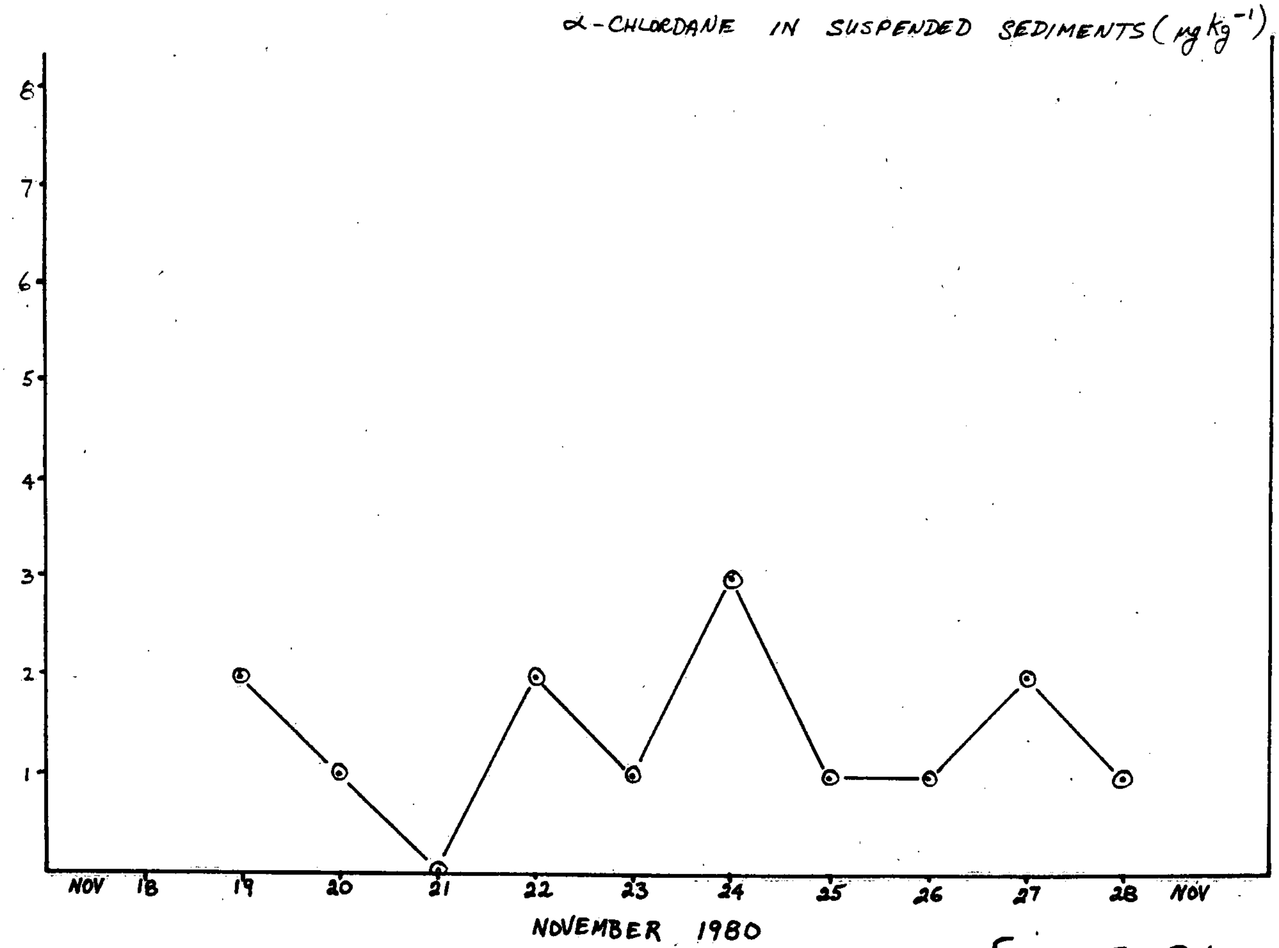
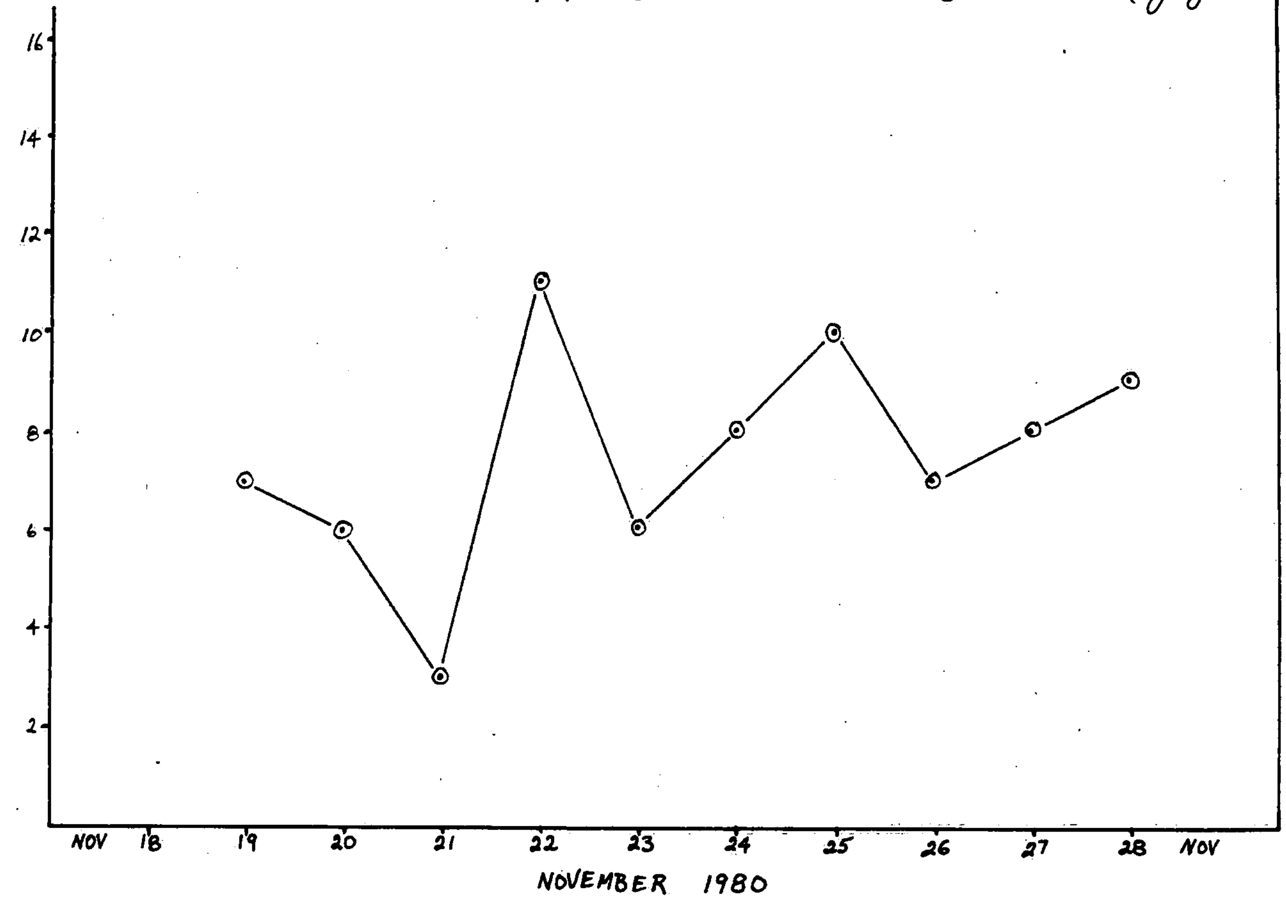

α-CHLORDANE IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)

FIGURE 21

P-P-TDE in Suspended Sediments ($\mu g\ kg^{-1}$)



P-P-DDE in Suspended Sediments ($\mu g\ kg^{-1}$)

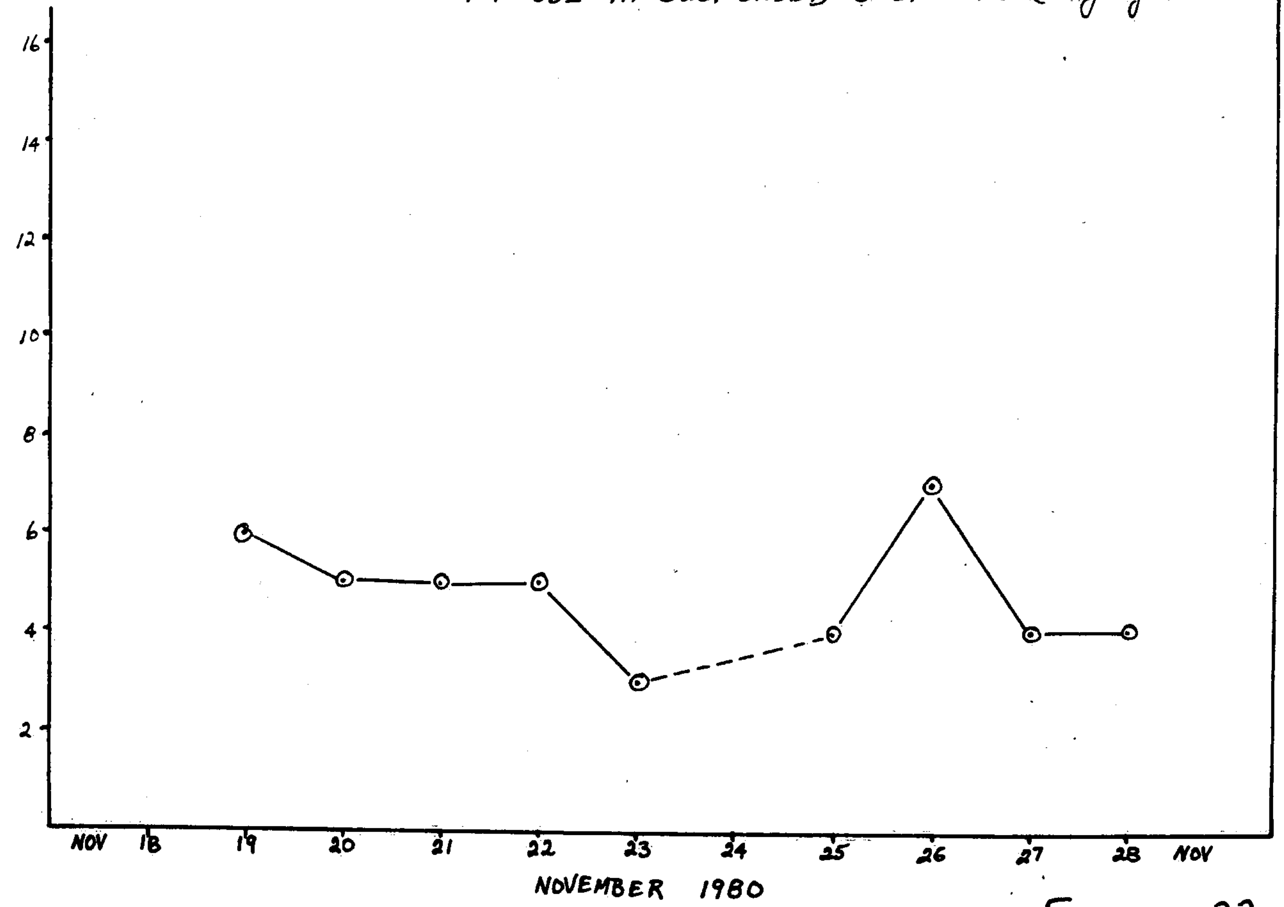
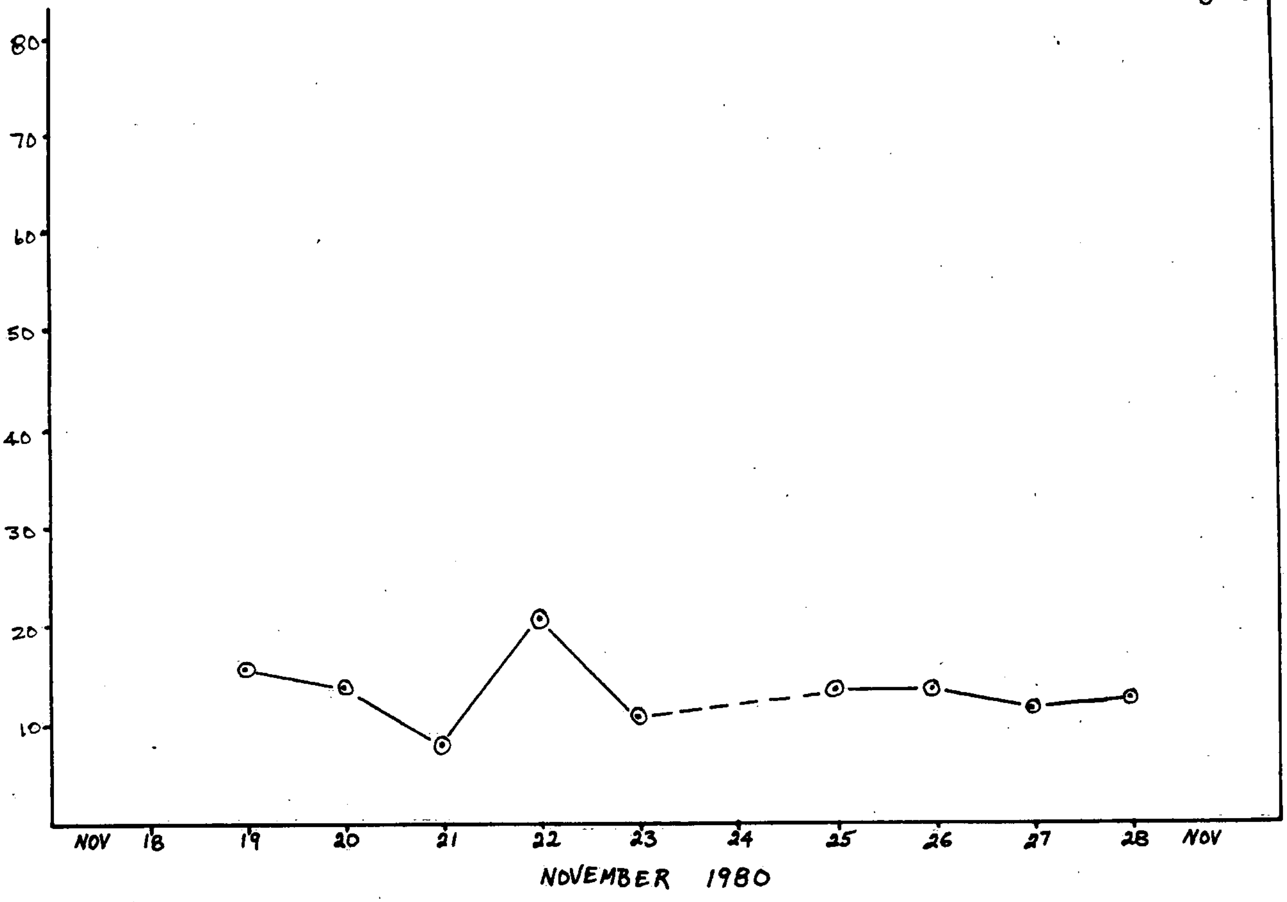


FIGURE 22

TOTAL DDT IN SUSPENDED SEDIMENTS ($\mu g\, kg^{-1}$)



P-P-DDT IN SUSPENDED SEDIMENTS ($\mu g\, kg^{-1}$)

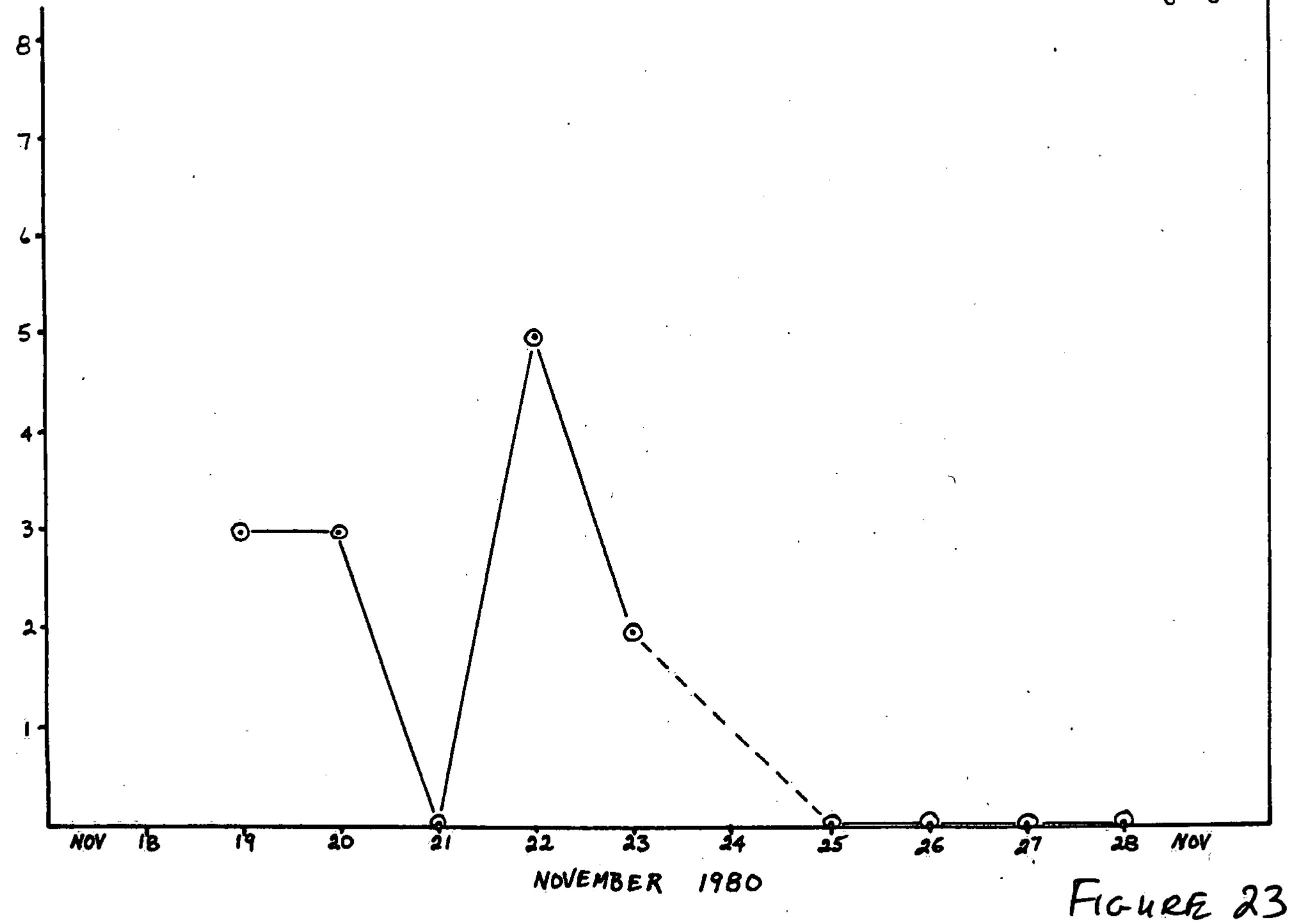
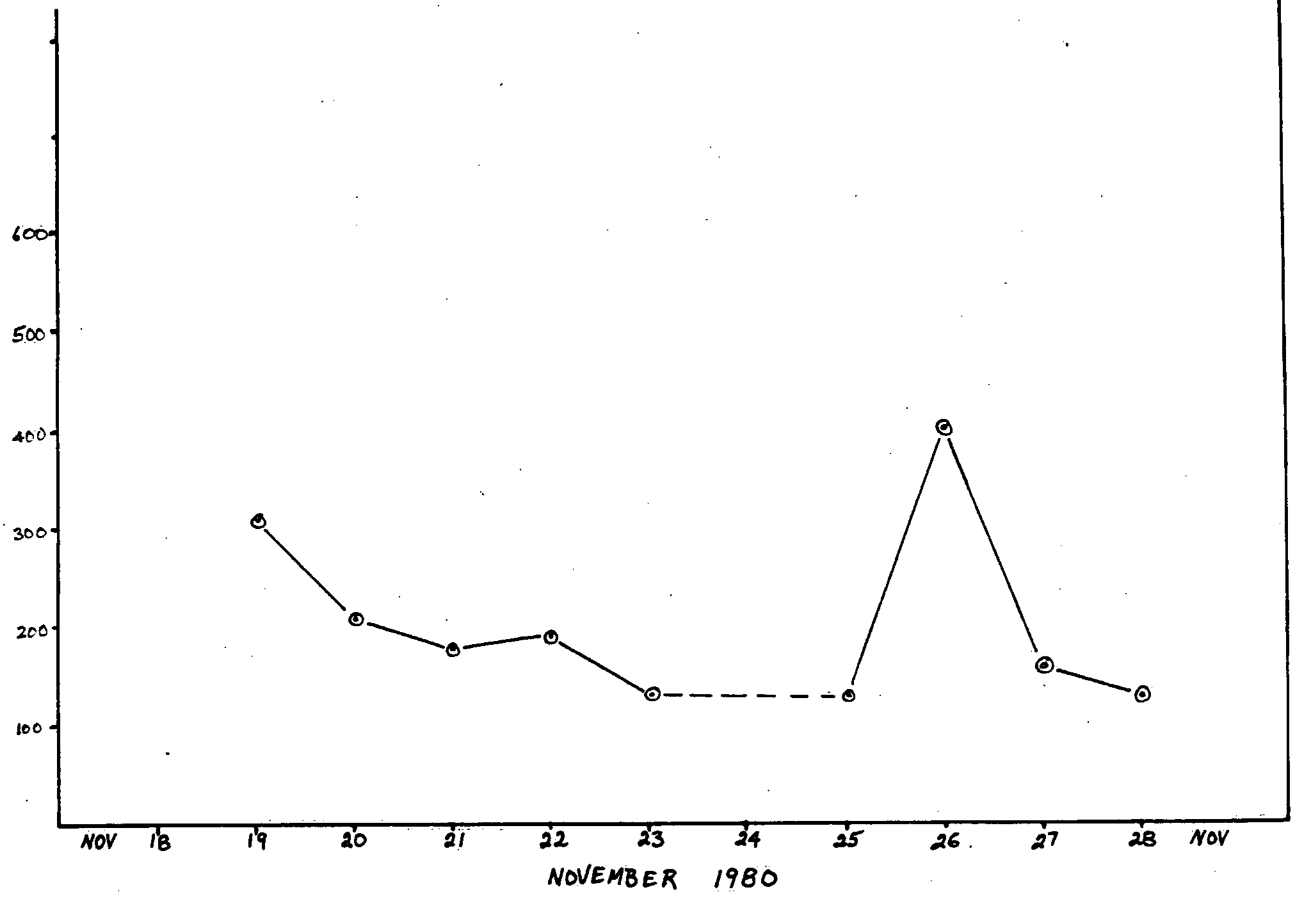


FIGURE 23

TOTAL PCB IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)



MIREX IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)

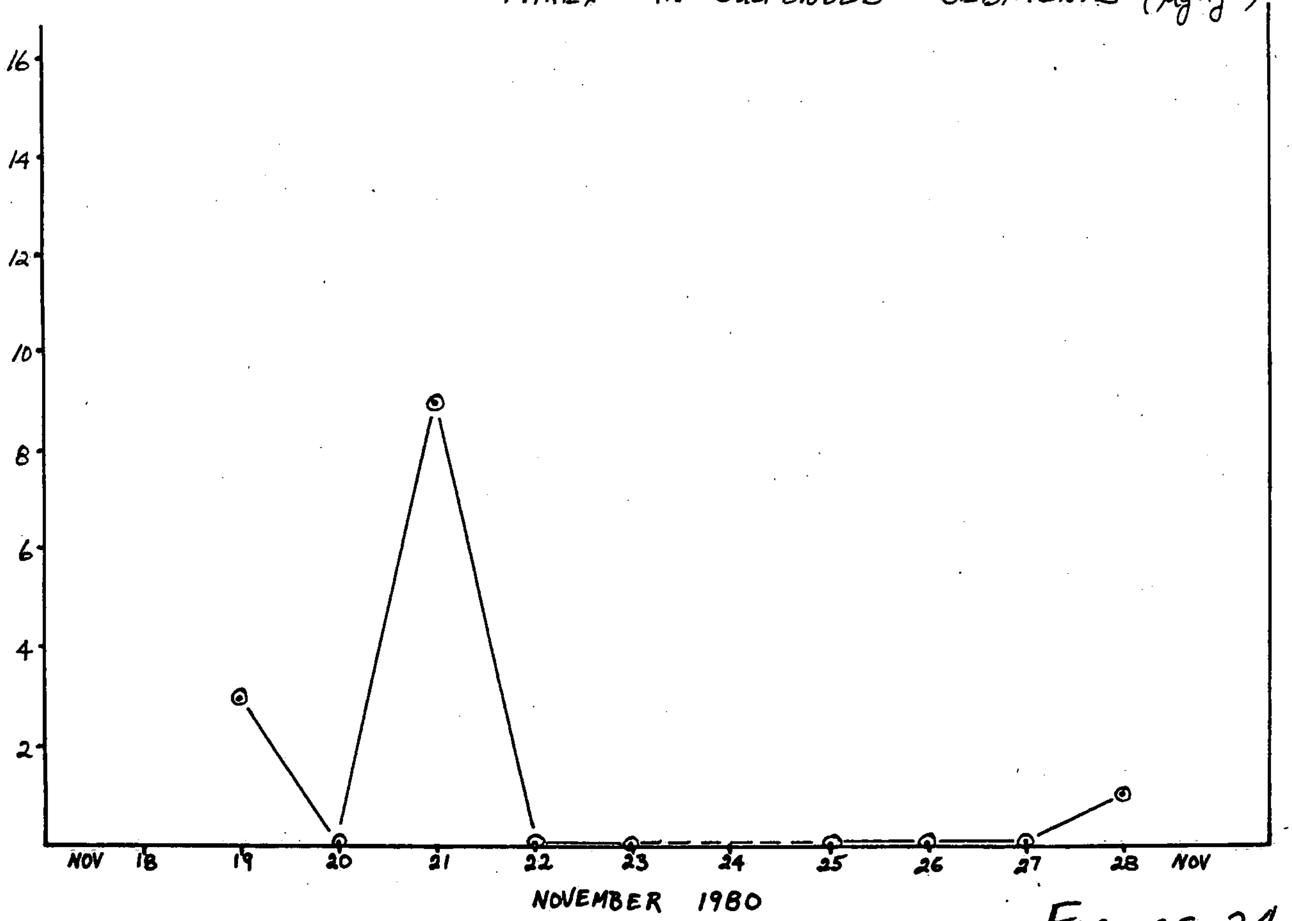
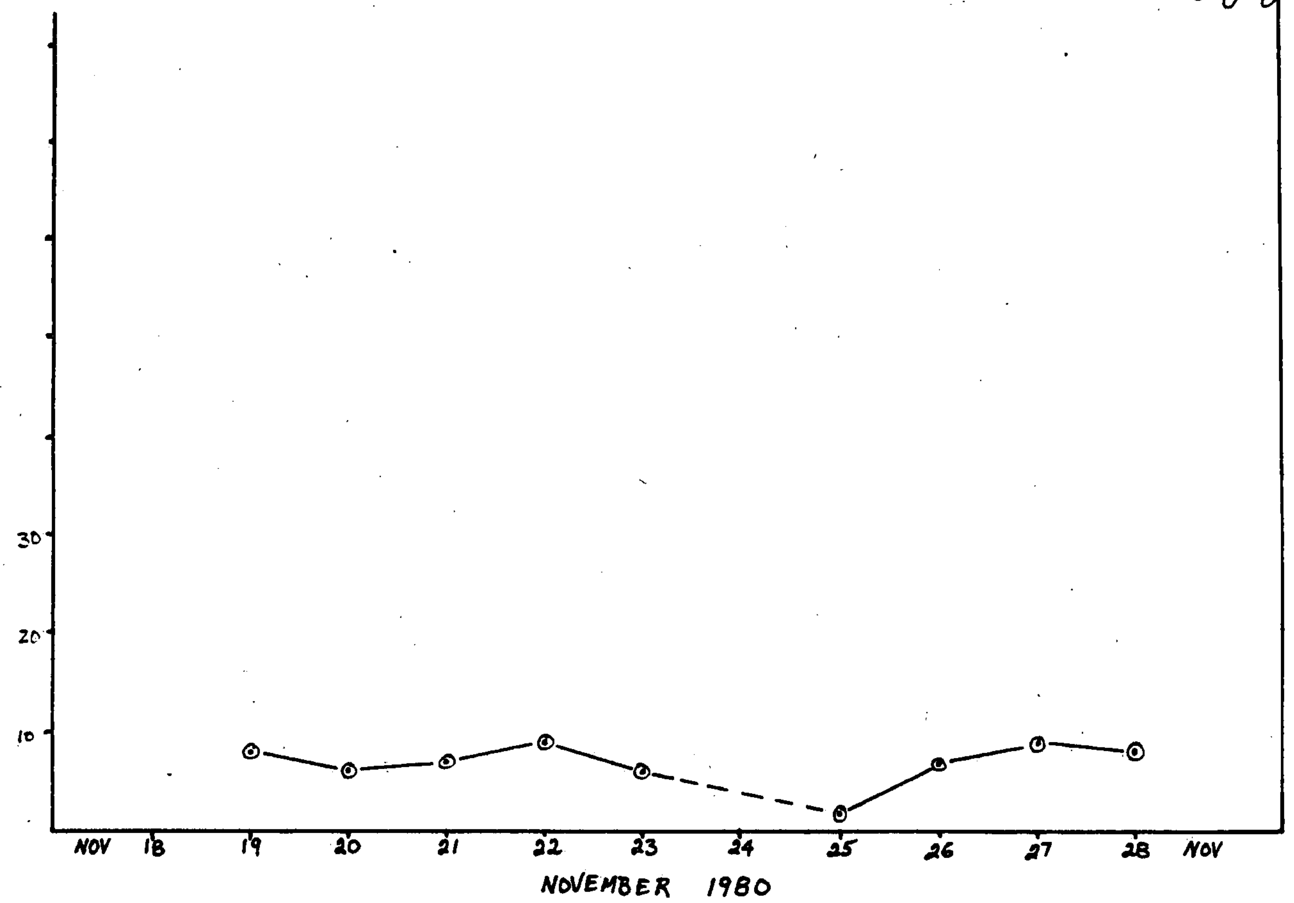


FIGURE 24


TRICHLOROBENZENES IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)

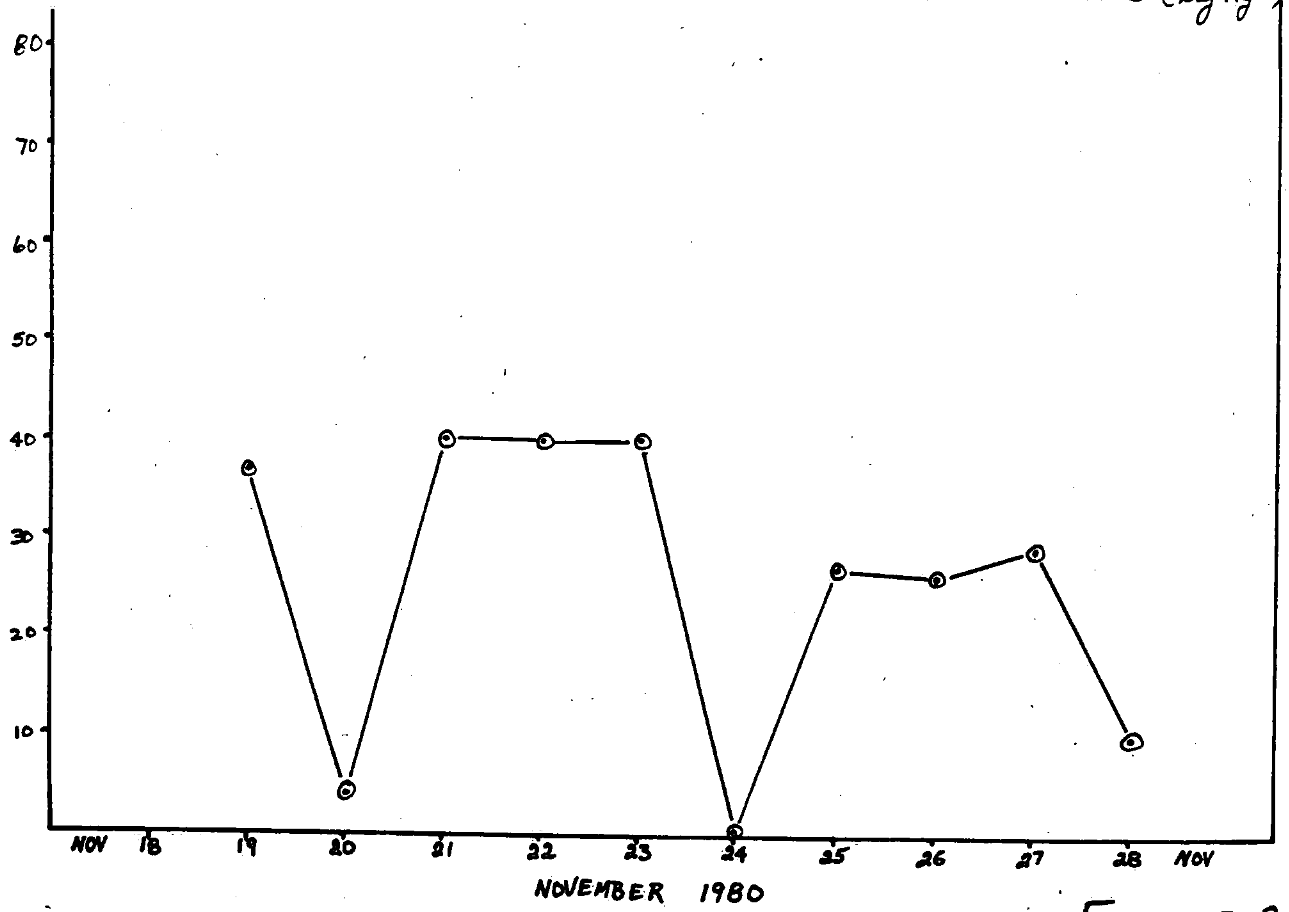
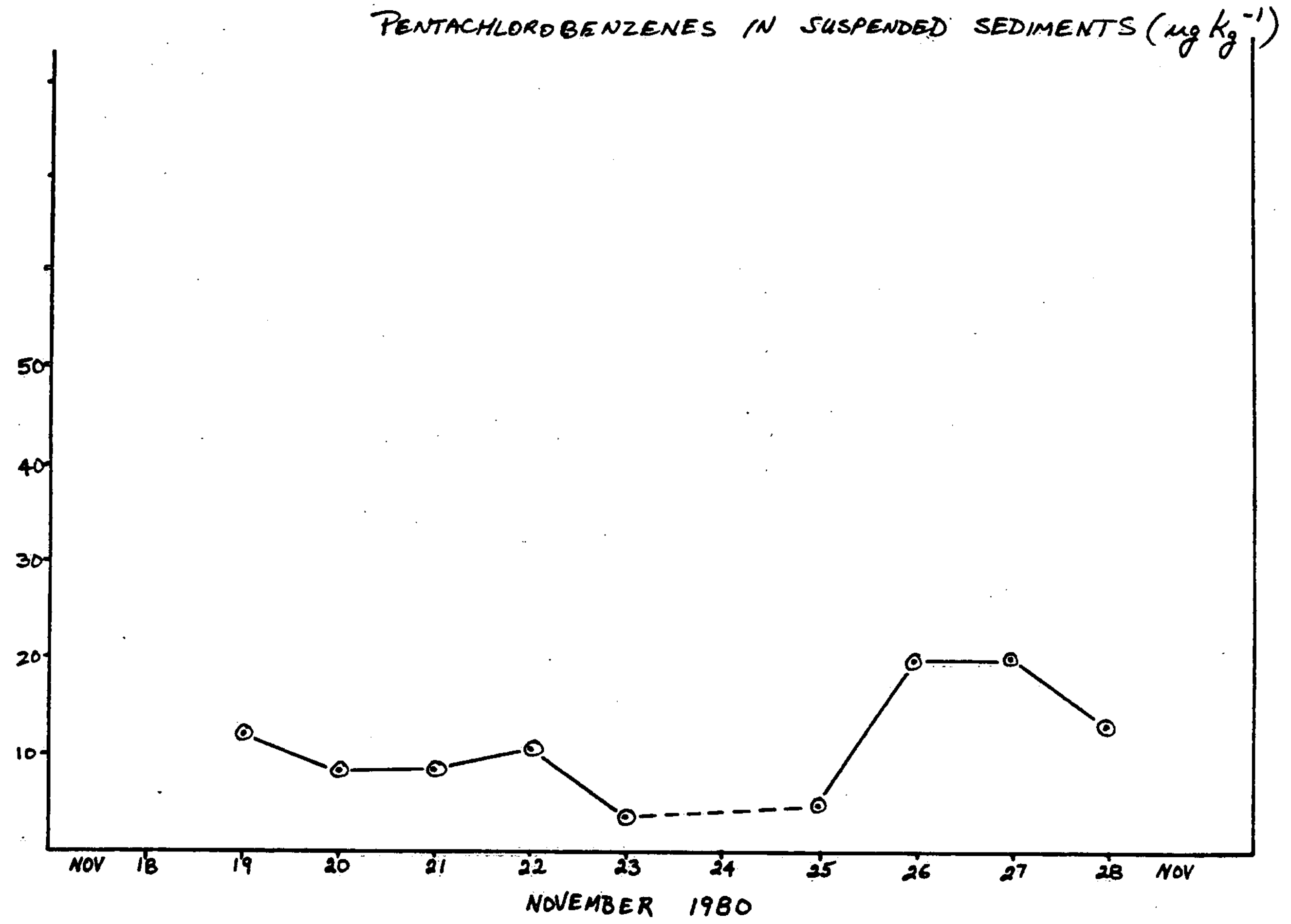
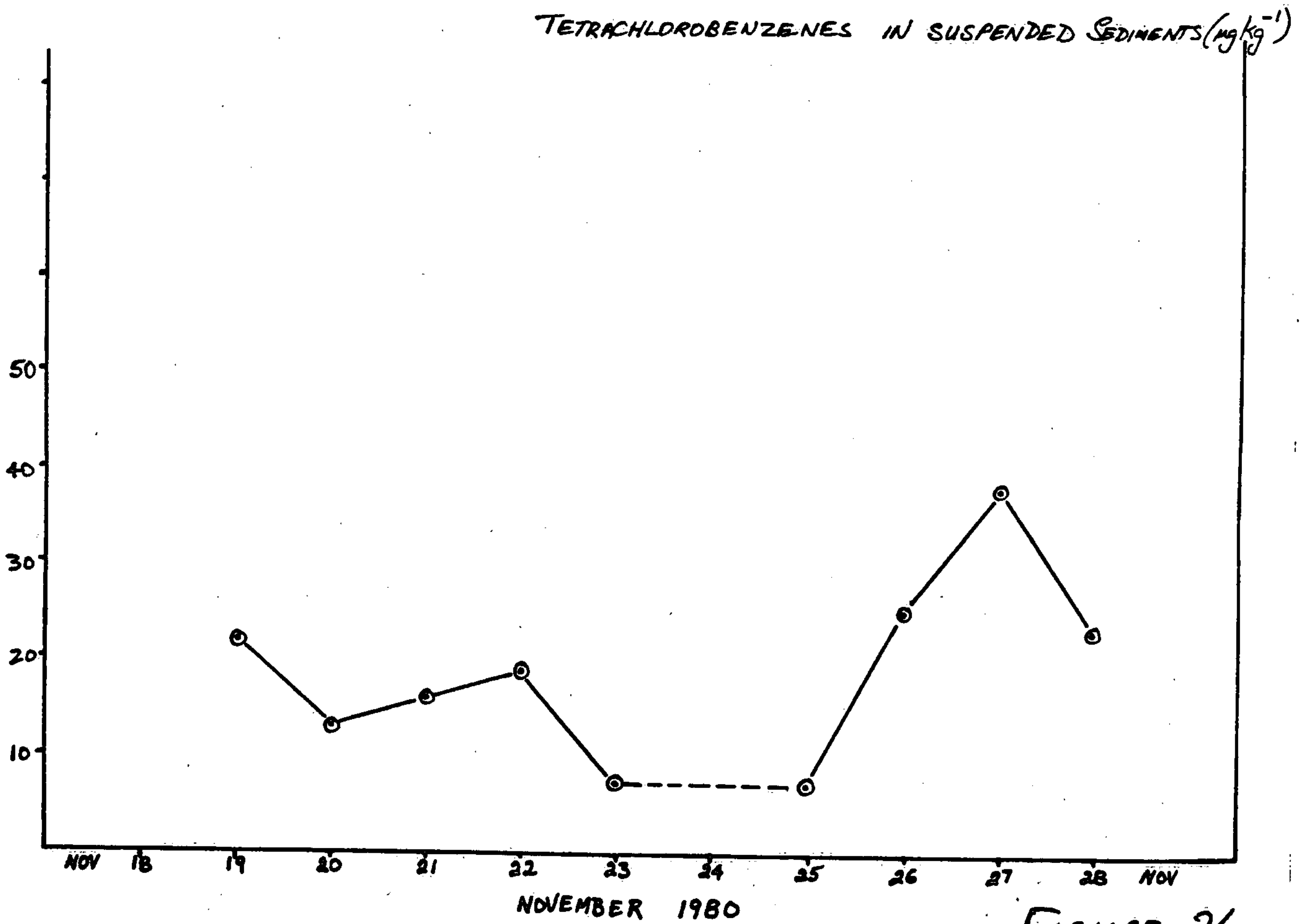

DICHLOROBENZENES IN SUSPENDED SEDIMENTS ($\mu g\,kg^{-1}$)

FIGURE 25

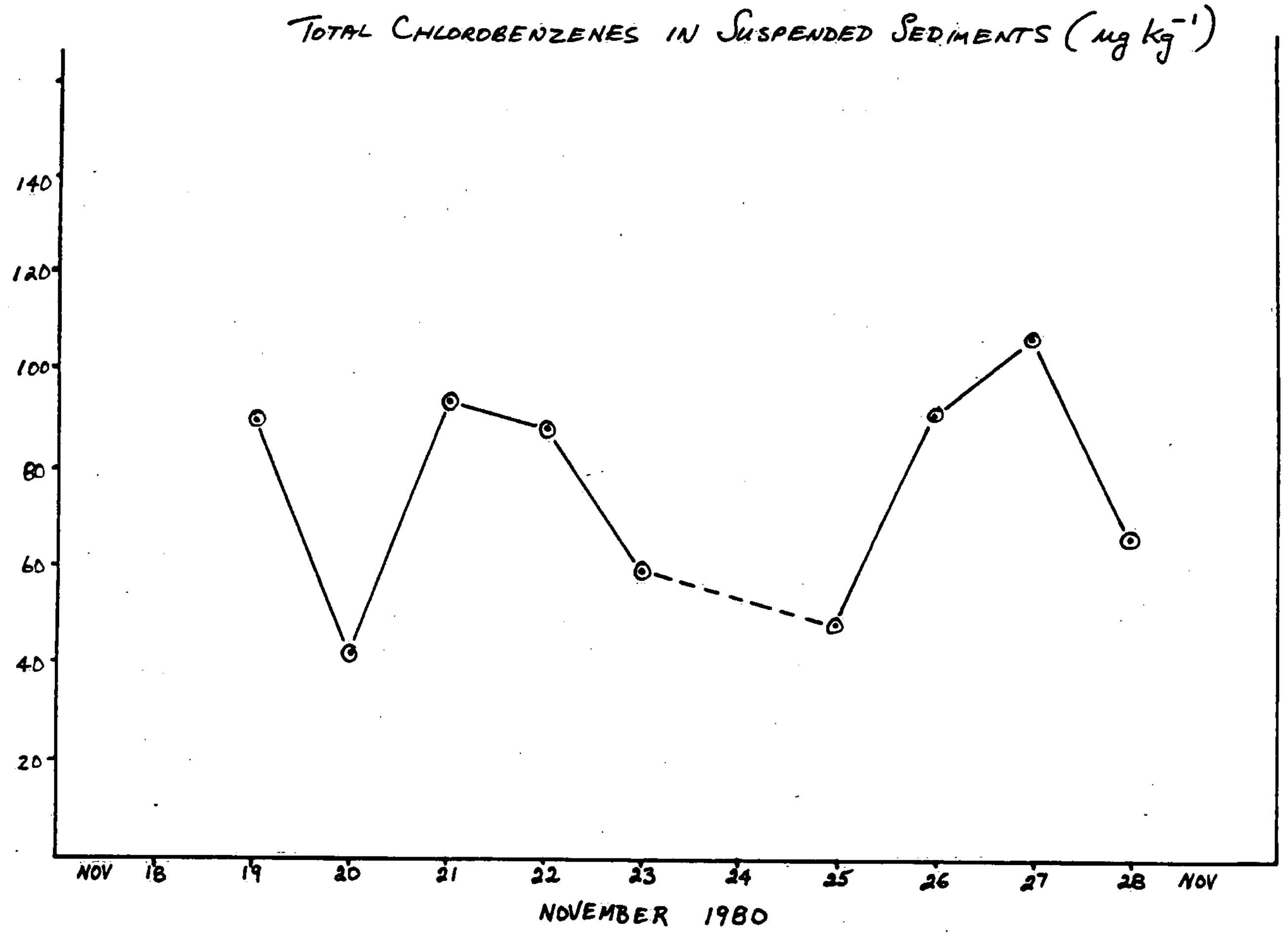


PENTACHLOROBENZENES IN SUSPENDED SEDIMENTS (μg kg^{-1})



TETRACHLOROBENZENES IN SUSPENDED SEDIMENTS (μg kg^{-1})

FIGURE 26


Total Chlorobenzenes in Suspended Sediments ($\mu g\, kg^{-1}$)

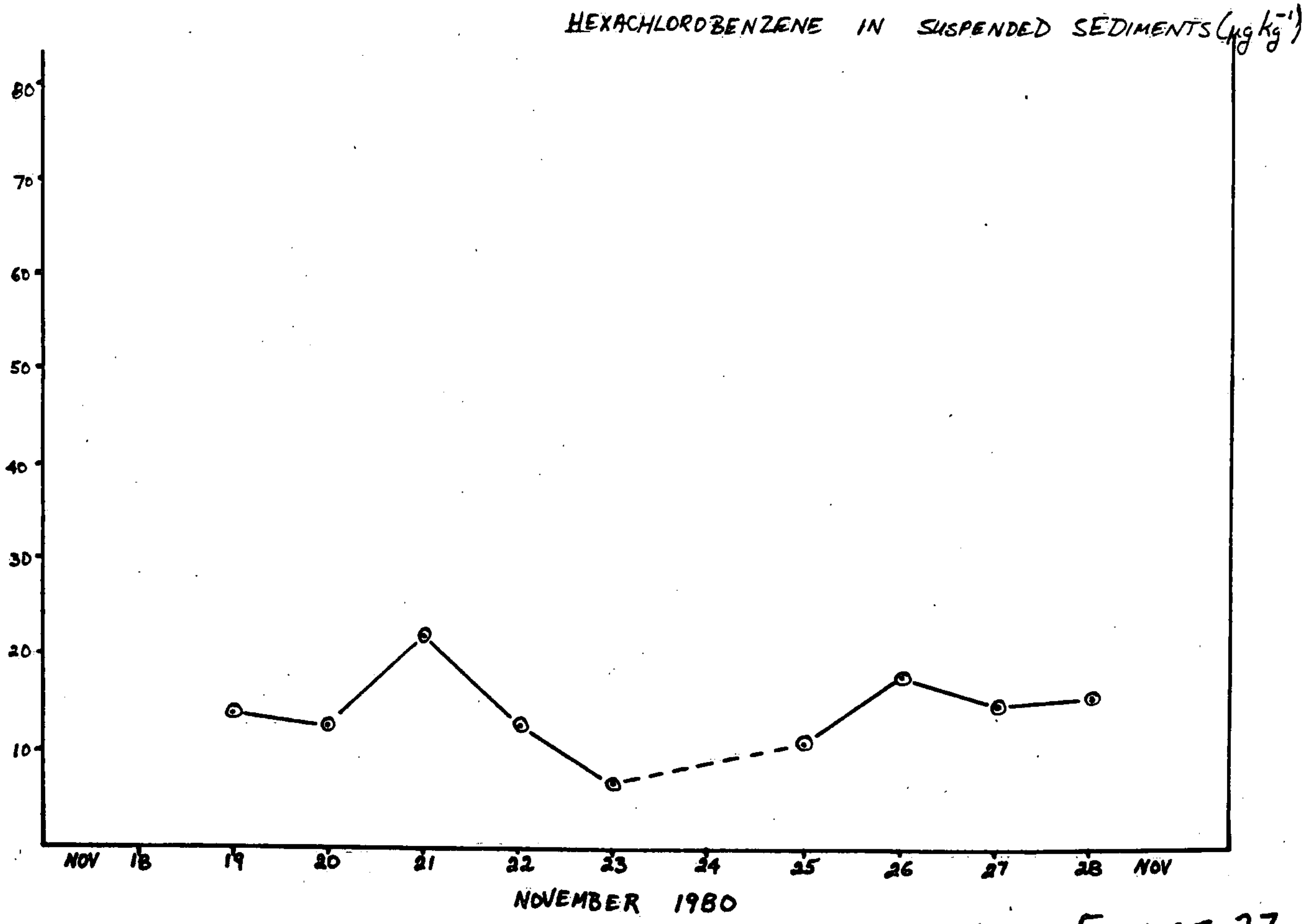

HEXACHLOROBENZENE IN SUSPENDED SEDIMENTS ($\mu g\, kg^{-1}$)

FIGURE 27

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