NATIONAL WATER RESEARCH INSTITUTE

INSTITUT NATIONAL de RECHERCHE sur les EAUX

WATER LEVEL AND CONDUCTIVITY OBSERVATIONS IN THE BURLINGTON SHIP CANAL: WINTER 1988-1989

P.F. Hamblin

NWRI Contribution No. 92-58

WATER LEVEL AND CONDUCTIVITY OBSERVATIONS IN THE BURLINGTON SHIP CANAL: WINTER 1988-1989

P.F. Hamblin

Lakes Research Branch
National Water Research Institute
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario L7R 4A6

NWRI Contribution No. 92-58

MANAGEMENT PERSPECTIVE

The winter exchange behaviour between Lake Ontario and Hamilton Harbour is responsible, in part, for reducing the toxic ammonia buildup at the end of winter in Hamilton Harbour. In 1989, data were collected in conjunction with the evaluation of the AFFRA flow meter in Burlington Ship Canal. The report displays the final edited data collected in support of the AFFRA study.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Le comportement d'échange, en hiver, entre le lac Ontario et le port de Hamilton, est responsable en partie de l'accumulation réduite d'ammoniac toxique à la fin de l'hiver dans le port de Hamilton. En 1989, des données ont été recueillies de concert avec l'évaluation du débitmètre AFFRA dans le canal de navigation de Burlington. Le rapport présente les données finales recueillies à l'appui de l'étude AFFRA.

1. INTRODUCTION

In the review of earlier studies of the winter exchange in the Burlington Ship Canal, Hamblin (1989) pointed out the need for more reliable observations of flow, meteorological forcing and water levels than were currently available. These data are required for the purposes of validation of a numerical model of the winter exchange between Hamilton Harbour and Lake Ontario. To this end, a flow meter, AFFRA, was established in the Burlington Ship Canal during the earlier portion of 1989. The results of this study have been reported by Hamblin et al. (1989). As well as flow measurements, meteorolgical data and water levels were collected simultaneously in order to drive the numerical model of the exchange flow of Hamblin (1989). In addition, conductivities at two locations were observed in order to provide an independent test of the exchange flow based on the mass balance of dissolved solids.

The following reports on this ancillary data set by displaying the data and provides archival information on the data storage.

2. STUDY LOCATION, DATA REDUCTION AND DISPLAY

The locations of the measurement stations are given in Figure 1 in plan view and as a cross-section along the ship canal in Figure 2. The levels of the instruments were surveyed from a bench mark on the left bridge to an accuracy of 0.2 cm (H. Don, personal communication). All the data sets to be described below were first plotted and obviously erroneous

points were deleted and replaced by an error flag (see Appendix).

2.1 Water Level

Water levels were measured by a Sea-Data wave-and-tide pressure recorder and by two Applied Microsystems tide gauges. Each of these gauges also measured water temperature which was used to internally correct the readings for thermal effects. Standard calibration formulae obtained by the National Water Research Institute's calibration laboratory were applied to the raw data to convert them to a pressure in mb. In the case of the wave-and-tide recorder, a standard atmospheric pressure of 1013 mb was subtracted from the total reading. Next, the readings were converted to water depth in metres by dividing by 100 and adding the result to the elevation of the tide guage with respect to the International Great Lakes Datum (IGLD) (1955) (see Figure 2).

Additional water level data at the permanent water level gauge on the lake end of the pier were obtained from the Water Survey of Canada. After converting these data to GMT, the water level was obtained by adding the local gauge elevation of 74.005 m to the readings. In all plots, the monthly means have been subtracted (see Table 1).

Figure 3 shows the two tide gauges at opposite ends of the ship canal. Similarly, the tide-and-water level and the Water Survey of Canada guages are presented in Figure 4.

Due to the failure of the wave-and-tide recorder after two weeks operation, no attempt was made to process and display wave amplitudes and periods.

2.2 Meteorological Data

The wind speeds and directions were averaged with a uniform average of 15-minute readings over a 2.25-hour period. The 15-minute readings were obtained by interpolation (in some cases) from the standard 10-minute sample of the Campbell Scientific meteorological system. The averaged winds were plotted in stick vector format in Figure 5.

Relative humidities and air temperatures are plotted at 15-minute intervals in Figure 6 and Figure 7, respectively.

2.3 Water Temperature

Measured water temperatures are displayed at four locations in Figures 8 to 11.

2.4 Conductivities

At each instrument, laboratory calibrations were applied to the conductivity readings and temperature sensors and the data were corrected at 25°C using a relationship for Lake Ontario (G.K. Rodgers, personal communication). These data

series are plotted in Figures 12 and 13. The formula used for this conversion is:

$$\text{Cond corrected} = \text{Cond} \times (1.8375 - 0.0456 \times \text{Temp} + 0.000484 \times \text{Temp}^2)$$

where Cond is the Conductivity (µs)
and Temp is the Temperature (°C)

2.5 Merged Data File

The data reported in this study were merged with the AFFRA file (Hamblin *et al*. 1989). The reader is referred to the Appendix for details on the merged data file and for archival information on the data. In addition, the combined file was transferred to 3.5-inch personal computer diskettes. The computer programs used to process and display the data are briefly listed in the Appendix. All the calculations were performed using the Natonal Water Research Institute's Control Data 830 computer. Graphs were produced using a Calcomp plotter. Please note that the speed correction to the AFFRA data indicated by Hamblin *et al*. (1989) has not been applied to the AFFRA data.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of M. Fellowes who prepared the preliminary data plots, edited the erroneous data, and produced new plots and established the merged data file under Contract No. KW4059-3740. M. Kerman, J. Bull, F. Chiocchio, R. Sandilands, C. Pulley, all of the Canada Centre for Inland Waters, and R. Taylor of the Marine Environmental Data Centre are thanked for their assistance.

REFERENCES

Hamblin, P.F. 1989. Notes on the hydraulics of Hamilton Harbour. National Water Research Institute Contribution No. 89-36.

Hamblin, P.F., Robertson, D.S. and Roy, F.E. 1989. A preliminary evaluation of an acoustic flow meter in a ship canal including data summary. National Water Research Institute Contribution No. 89-46.

IGLD, 1955. International Great Lakes Data.

FIGURE CAPTIONS

Figure 1: Location of instruments by the Burlington Ship Canal.

Figure 2: Cross-section along the ship canal of instrument locations and elevations (IGLD, 1955).

Figure 3: Time history of water levels in Burlington Ship Canal (m) with respect to monthly mean water level. Solid line, Lake Ontario, dashed line, Hamilton Harbour. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) end April 1989.

Figure 4: Time history of Water Survey of Canada guage (solid line) and wave and tide guage levels in Burlington Ship Canal (dashed line) with respect to monthly mean water level. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April and May 1989, (f) May 1989.

Figure 5: Stick vector plots of winds on Burlington Pier (m/s). Winds are in direction towards east (parallel) to time axis. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April and May 1989, (f) May 1989.

Figure 6: Burlington Pier, relative humidity (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April and May 1989, (f) May 1989.

Figure 7: Burlington Pier, relative air temperature (°C). (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April and May 1989, (f) May 1989.

Figure 8: Water temperature at harbour end of the Burlington Ship Canal from the upper conductivity guage (°C). (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April end 1989.

Figure 9: Water temperature at harbour end of the Burlington Ship Canal from the lower conductivity guage (°C). (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) April end 1989.

Figure 10: Water temperature (°C) at the Lake Ontario tide guage. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989.

Figure 11: Water temperature (°C) at the Hamilton Harbour tide guage. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989.

Figure 12: Conductivity corrected to 25°C in μs/cm at the upper level. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) end of April 1989.

Figure 13: Conductivity corrected to 25°C in μs/cm at the lower conductivity gauge. (a) January 1989, (b) February 1989, (c) March 1989, (d) April 1989, (e) end of April 1989.

TABLE 1: MONTHLY MEANS OF FOUR WATER LEVEL GUAGES (m)

Month	Lake Pressure		Harbour Pressure		WSC Level		Wave and Tide Recorder	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
December	73.990	0.098	73.568	0.100	-	-	74.527	0.099
January	74.005	0.099	73.578	0.103	74.321	0.051	74.518	0.121
February	74.044	0.115	73.628	0.117	74.337	0.043	-	
March	74.029	0.107	73.614	0.108	74.334	0.057	-	
April	74.071	0.059	73.819	0.120	74.625	0.096	-	
May	-		-		74.916	0.105	-	

WSC stands for Water Survey of Canada
Monthly means of data were calculated using the SPSSX statistics package

TABLE 2: FORMAT OF MERGED DATA FILE MARCH 1990

Sequence #	Variable Name	Format	Columns	Missing value	Units	Comment
1	Decimal Date	F8.2	1-8	None	days	1
2	Year	I2	11-12	None		
3	Month	I2	14-15	None		
5	Hour	I2	20-21	None		
5	Hour	I2	20-21	None		
6	Minute	I2	23-24	None		
7	Week	I2	26-27	-9		2
8	Wind Speed	F9.4	28-36	-99.9	(dm/s)	3
9	Wind Direction	F8.4	39-46	-99.9		
10	Air Temperature	F10.4	47-56	-99.9	Degrees C	
11	Humidity	F9.4	57-65	-99.9	%	
12	Water Temperature	F8.4	66-73	-99.9	Degrees C	
13	Flow	F6.3	74-79	9.999	(m/s)	9
14	Sound	F10.3	81-90	9999.999	(m/s)	10
15	Temperature (cond upper)	F8.2	92-99	-999.	Degrees C	4
16	Conductivity (upper)	F5.0	100-104	-999.	micros/cm	4
17	Temperature (cond lower)	F8.2	105-112	-999.	Degrees C	5
18	Conductivity (lower)	F5.0	113-117	-999.	micros/cm	5
19	Tide Pressure (lake)	F9.3	118-126	-999.	meters	7
20	Tide Temperature (lake)	F8.2	127-134	-999.	Degrees C	7
21	Tide Pressure (harbour)	F9.3	135-143	-999.	meters	8
22	Tide Temperature (harbour)	F8.2	144-151	-999.	Degrees C	8
23	Water Level	F5.2	153-157	-9.99	meters	6
24	Pressure (wave & tide)	F8.2	159-166	-999.	meters	11
25	Temperature (wave & tide)	F6.2	167-172	-9.00	Degrees C	11

1. Date starts at zero and is rounded to 2 decimal places
2. Week # from beginning of the year. For example Jan. 1 - Jan. 7 = 1
3. Wind speed needs to be divided by 100 to make it metres/sec
4. File BURL2146 Upper Conductivity Calibrated
5. File BURL2147 Lower Conductivity Calibrated
6. Water Level times adjusted to GMT. Obtained from the Water Survey of Canada
7. File TIDE225 Lakeside
8. File TIDE 787 Harbour Sise
9. Positive flow to lake in meters per second: taken from AFFRA file (not corrected for calibration)10. Velocity of sound: taken from the AFFRA file
11. Information for part of December 1988 and January 1989. Questionable.

TABLE 3: DESCRIPTION OF COMPUTER PROGRAMS

Name	Description
ADDWT	add wave and tide recorder data to unified file
COMBIN4	merge conductivity and AFFRA files (NOS/VE) version
COMDATES	merge decimal dates with data file
COMTID15	merge and interpolate tide data to the large file
MAKELEVEL	perform transformations on the water level data for datum
MAKES	creates a binary subfile of plotting parameters
PLOT2	test of the format of the plotting subroutines
PLOT3	batch version of program PLOT2
PLOT4	four panel plot of data set
PLOT5	batch version of program PLOT4 with special symbols
TESTX	plotting subroutines with months in upper & lower case
STICK	wind vector plotting program
WINDM	moving average of wind speed and direction
TESTC	fancy letter subroutine to replace for NOS/VE
ADDLEV	merger WSC water level with the conductivity file
BIGSMAL	reformat WSC data from large to small blocks
CHTIME	change WSC data to GMT
COMAFRA	merge conductivity, AFFRA and interpolated meteorological files
COMTIDE	merge the two tide files TIDE225 and TIDE787
GETTIDE	extract tide data from the wave and tide recorder raw data file
JOINS	join two conductivity files and apply the transformation
MET15	intepolates meteorological data from 10 to 15 minute intervals
TIDE	changes sea data words into time and tide (source J. Bull)
TIDEC	convert wave and tide recoder units to datum units
WATLEV	reformat WSC records

APPENDIX

Reclaim TAPE DIRECTORY

All Files are backed up on reclaim

TAPE NO WA67

FILE NAME	CONTENTS
BSCDEC8	Merged Data Dec 1988
BSCJAN9	Merged Data Jan 1989
BSCFEB9	Merged Data Feb 1989
BSCMAR9	Merged Data Mar 1989
BSCAPR9	Merged Data Apr 1989
BSCMAY9	Merged Data May 1989
RAWBSC	Raw Tide and Conductivity Data
RAWBSC2	WSC and Meteorological Data
PROGBSC	All Fortran source code

These files may be recalled by the reclaim command,

LOAD, TN=WA67, D=GE, FN=File name

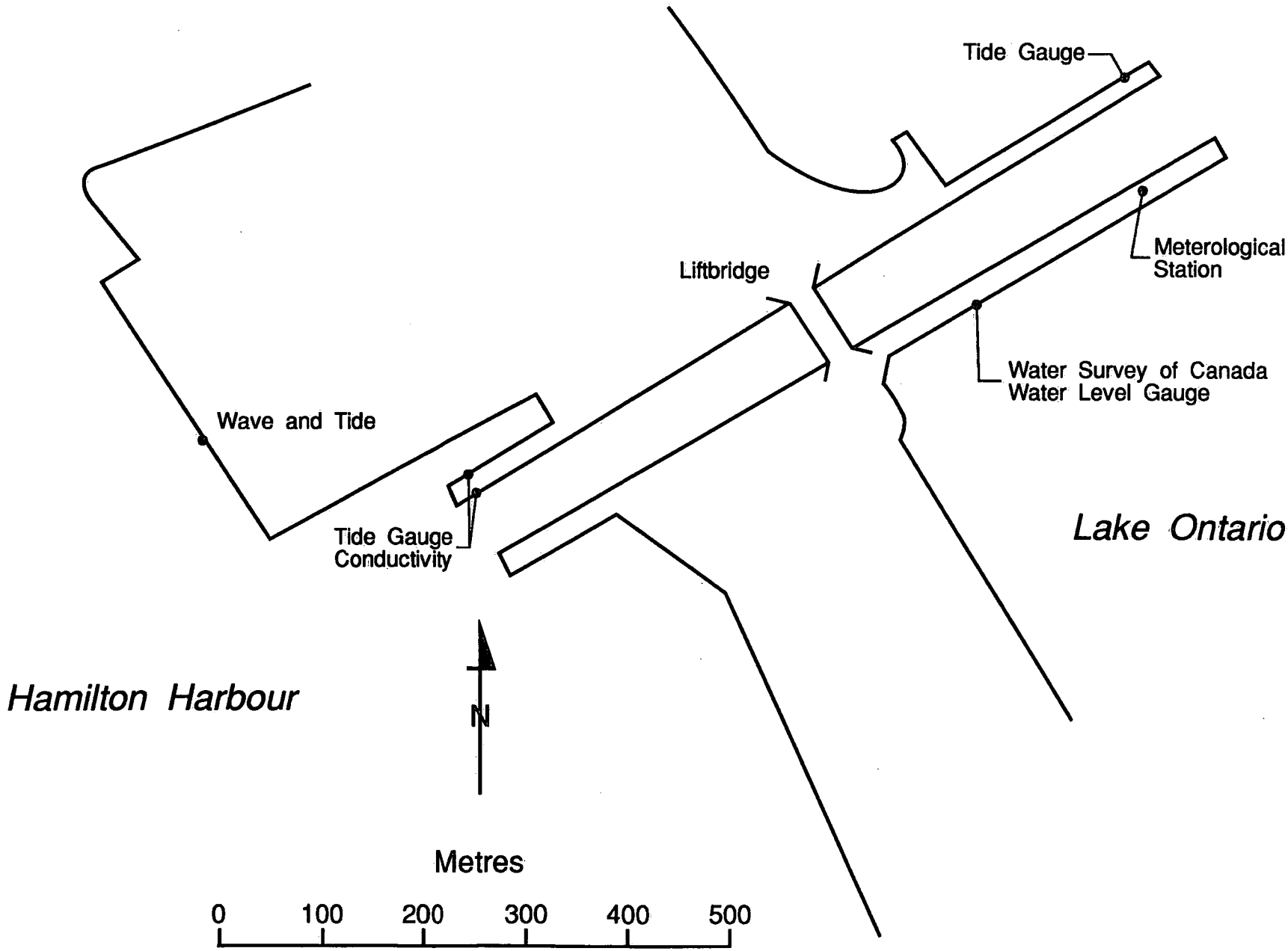
Tide Gauge
Meterological Station
Liftbridge
Water Survey of Canada Water Level Gauge
Wave and Tide
Tide Gauge Conductivity
Lake Ontario
Hamilton Harbour
N
Metres
0
100
200
300
400
500

FIGURE 1

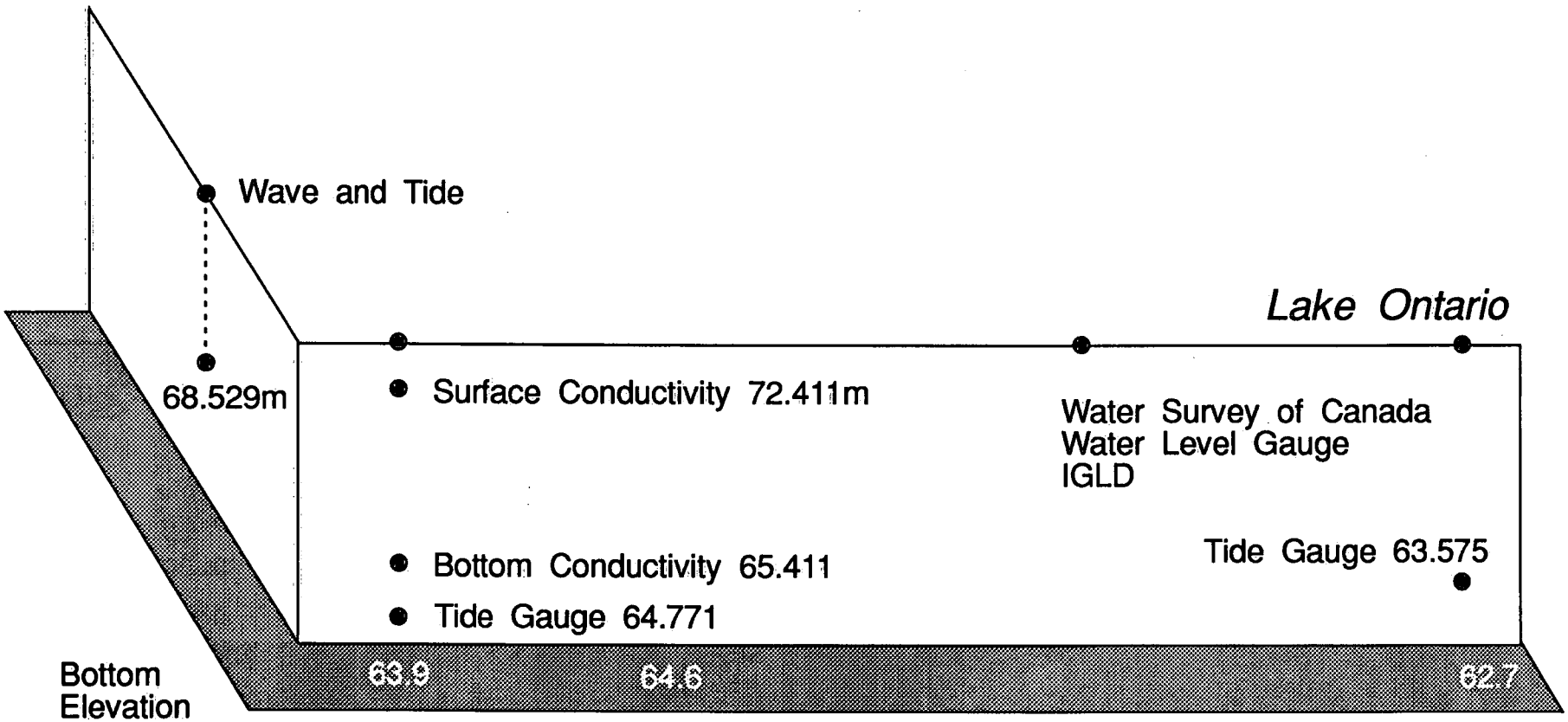
Wave and Tide
68.529m
Lake Ontario
Surface Conductivity 72.411m
Water Survey of Canada
Water Level Gauge
IGLD
Tide Gauge 63.575
Bottom Conductivity 65.411
Tide Gauge 64.771
Bottom
Elevation
63.9
64.6
62.7

FIGURE 2

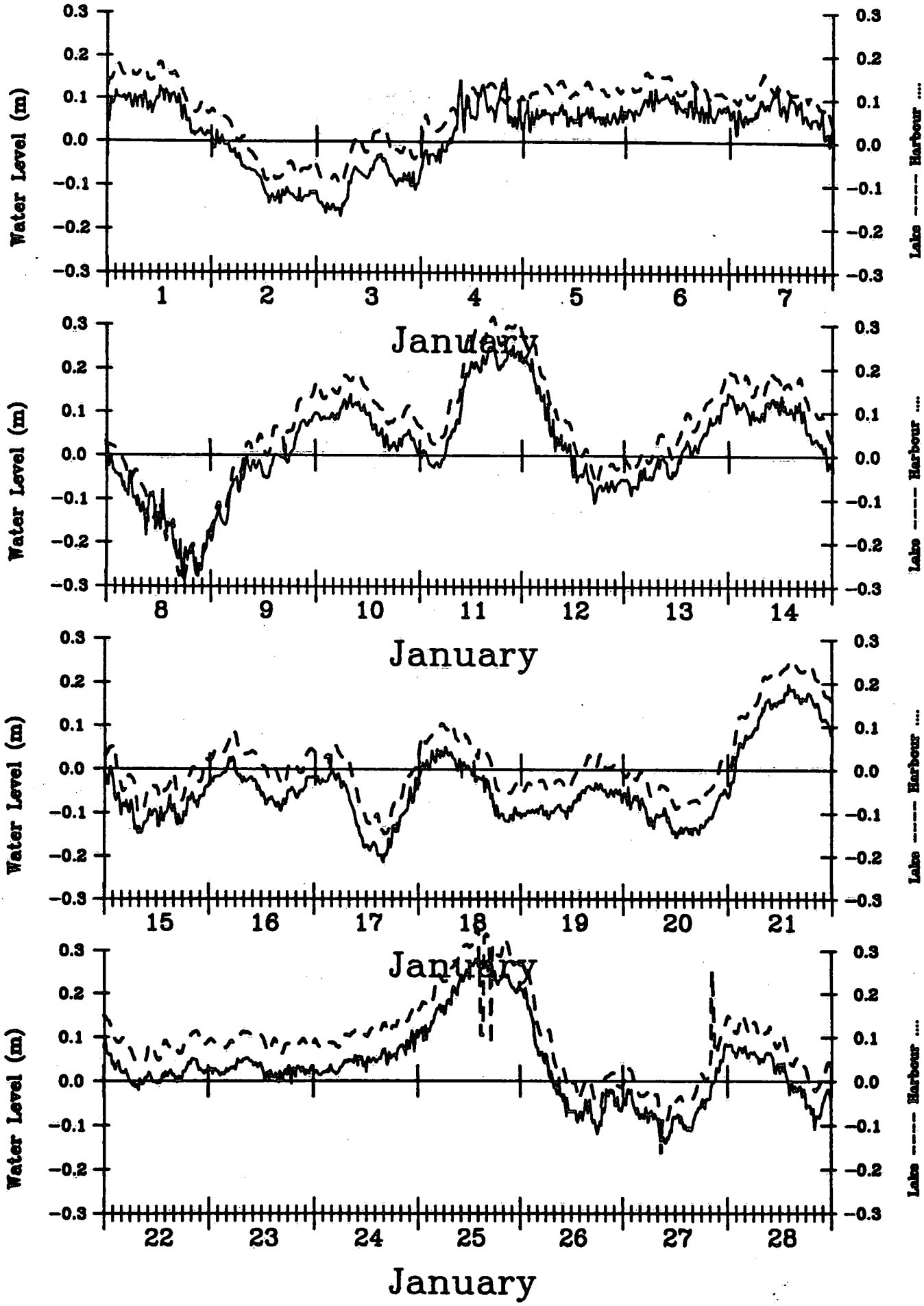
Water Level (m)
Lake ----- Harbour ....
January
January
January
January

FIGURE 3a.

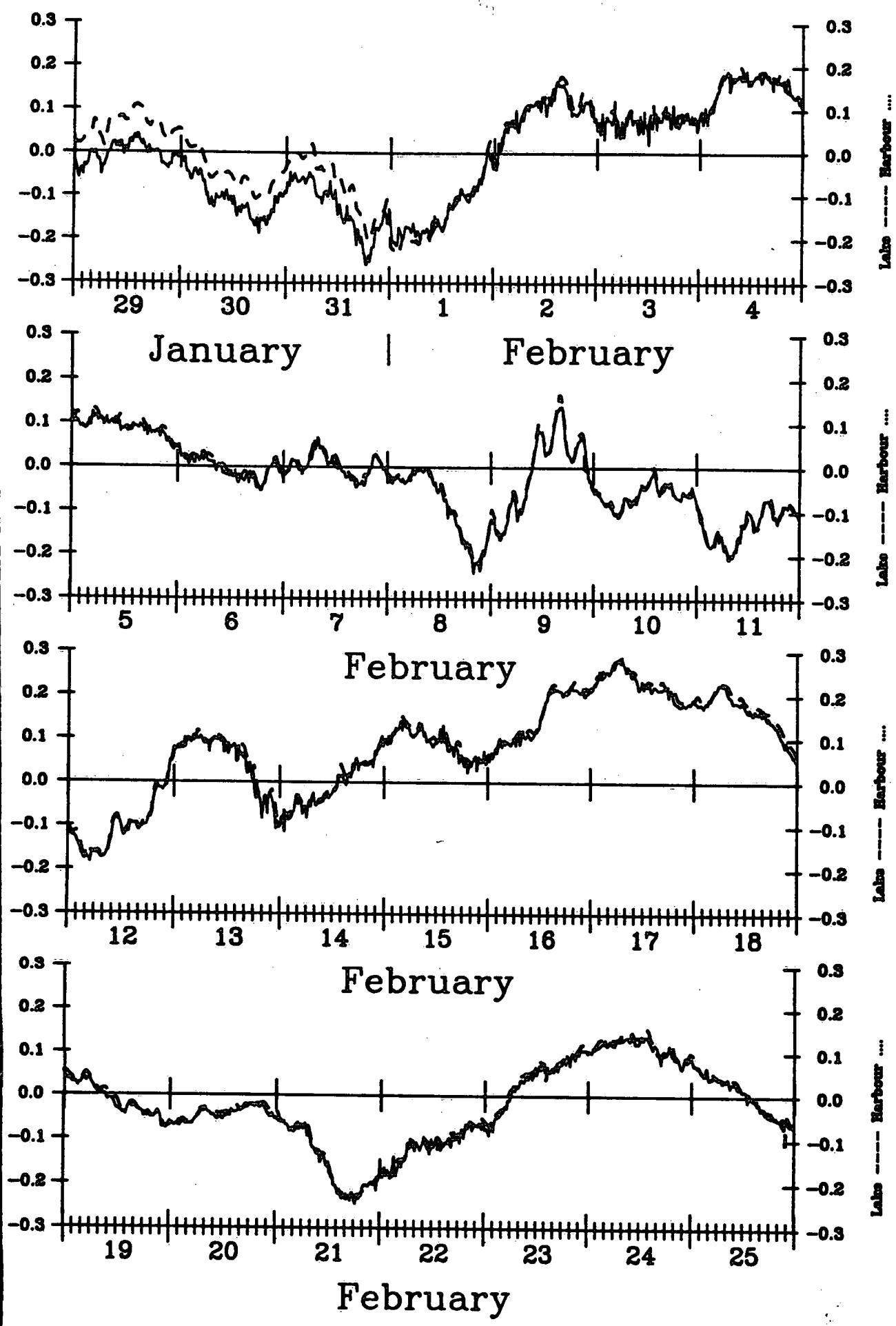
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February
Lake ---- Harbour ...

FIGURE 3b.

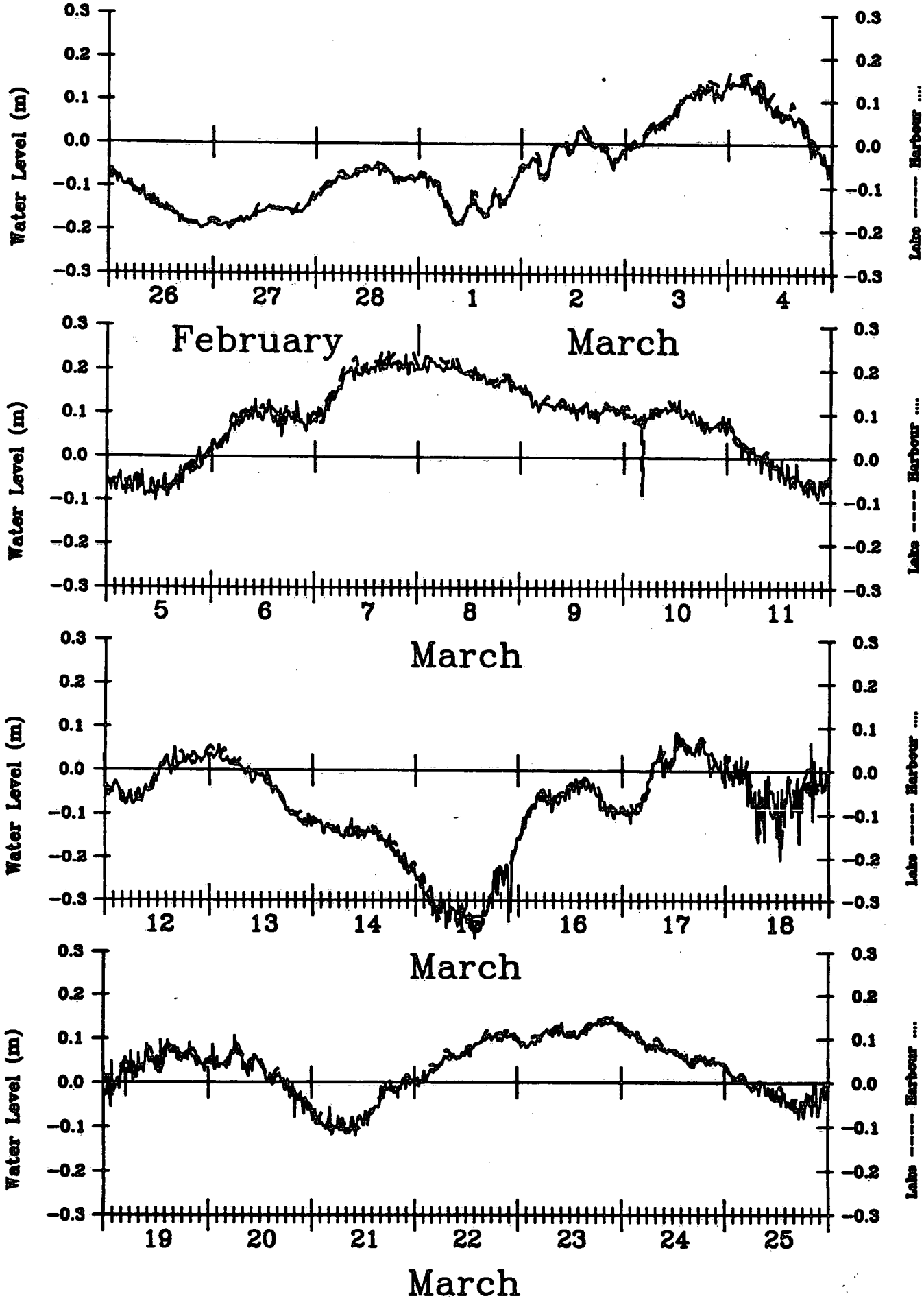
Water Level (m)
Lake ---- Harbour ...
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 3c.

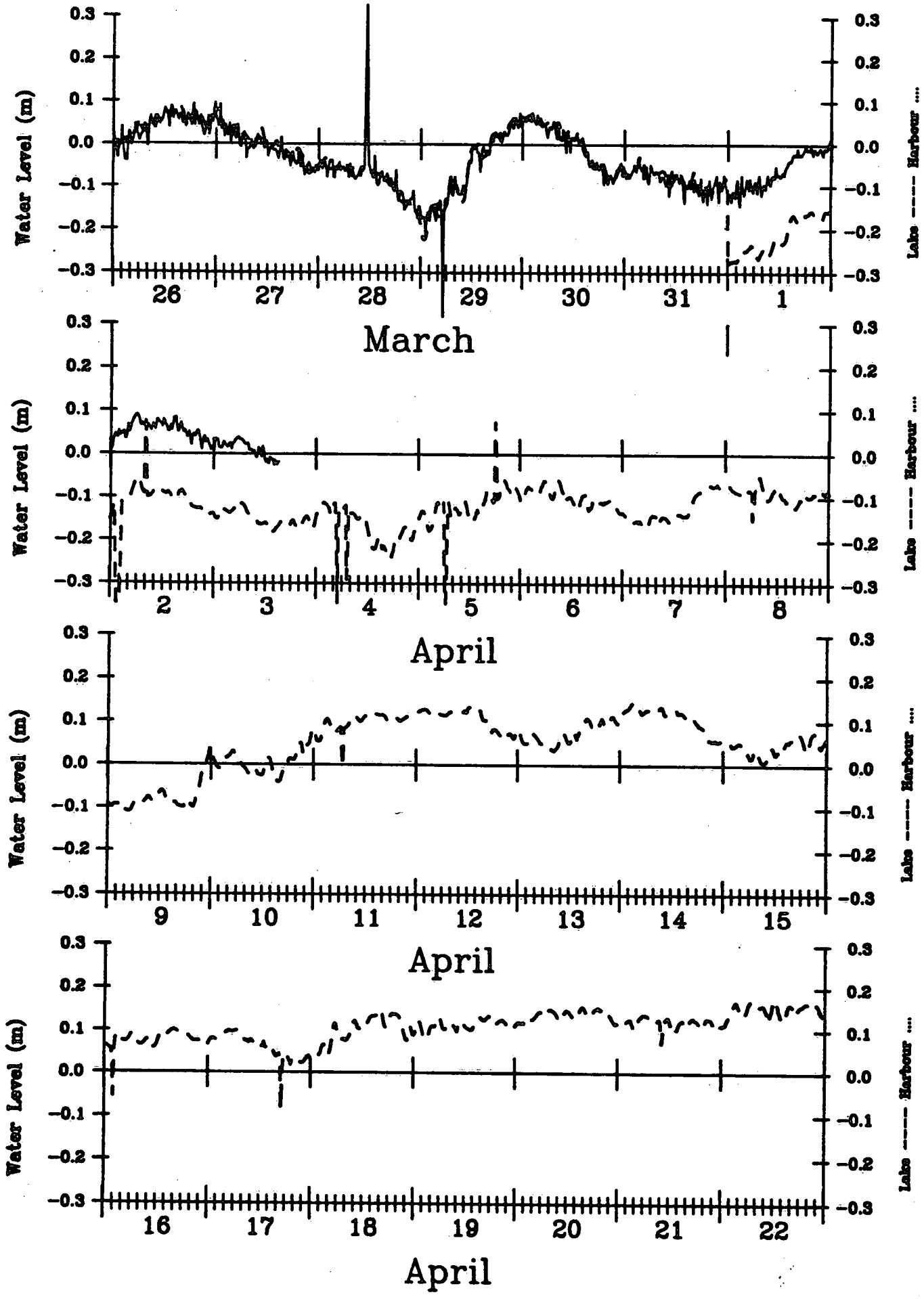
Water Level (m)
Lake ---- Harbour ...
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 3d.

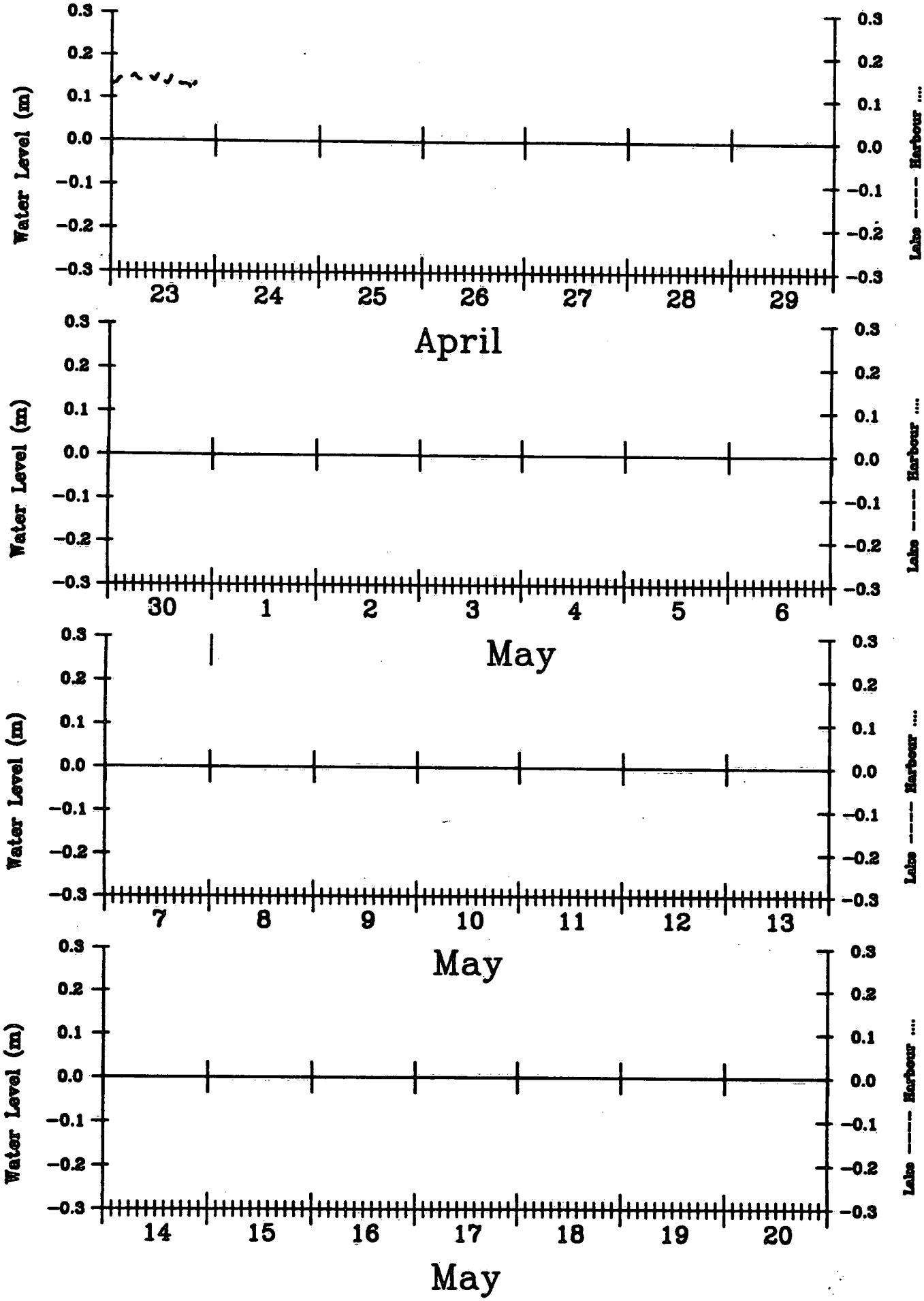
Water Level (m)
Lake ---- Harbour ...
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 3e.

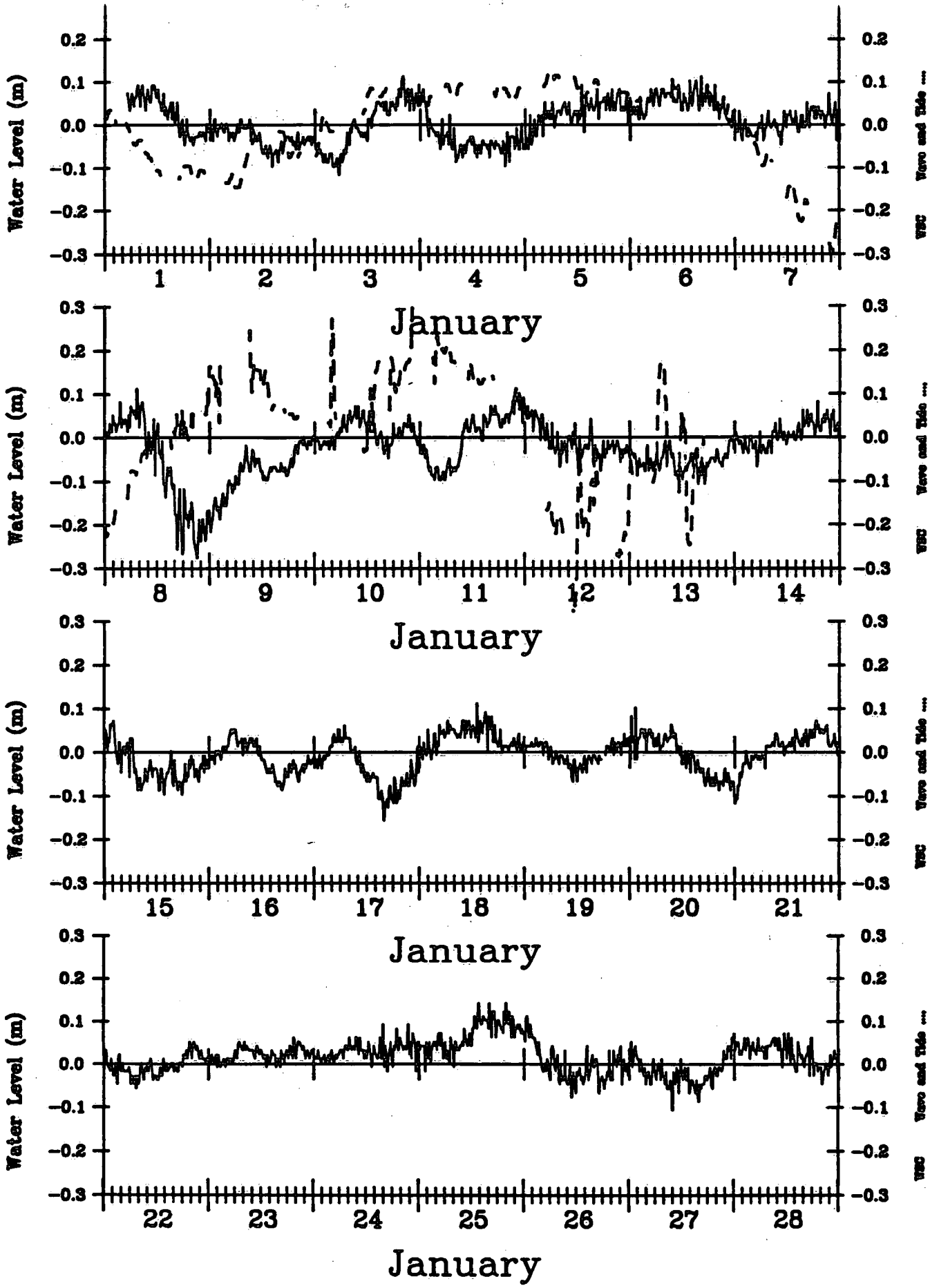
Water Level (m)
Wave and Tide ...
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 4a.

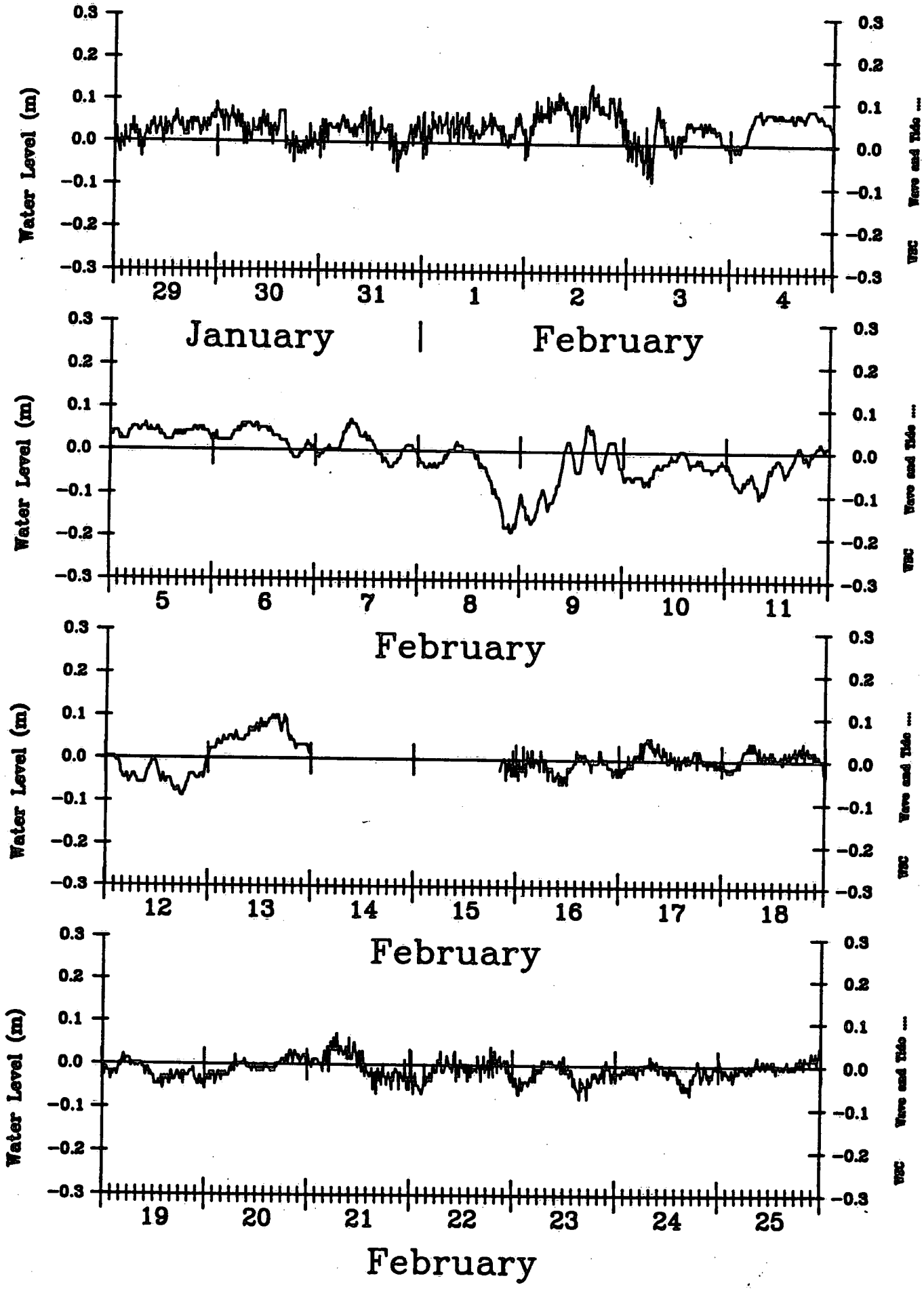
Water Level (m)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 4b.

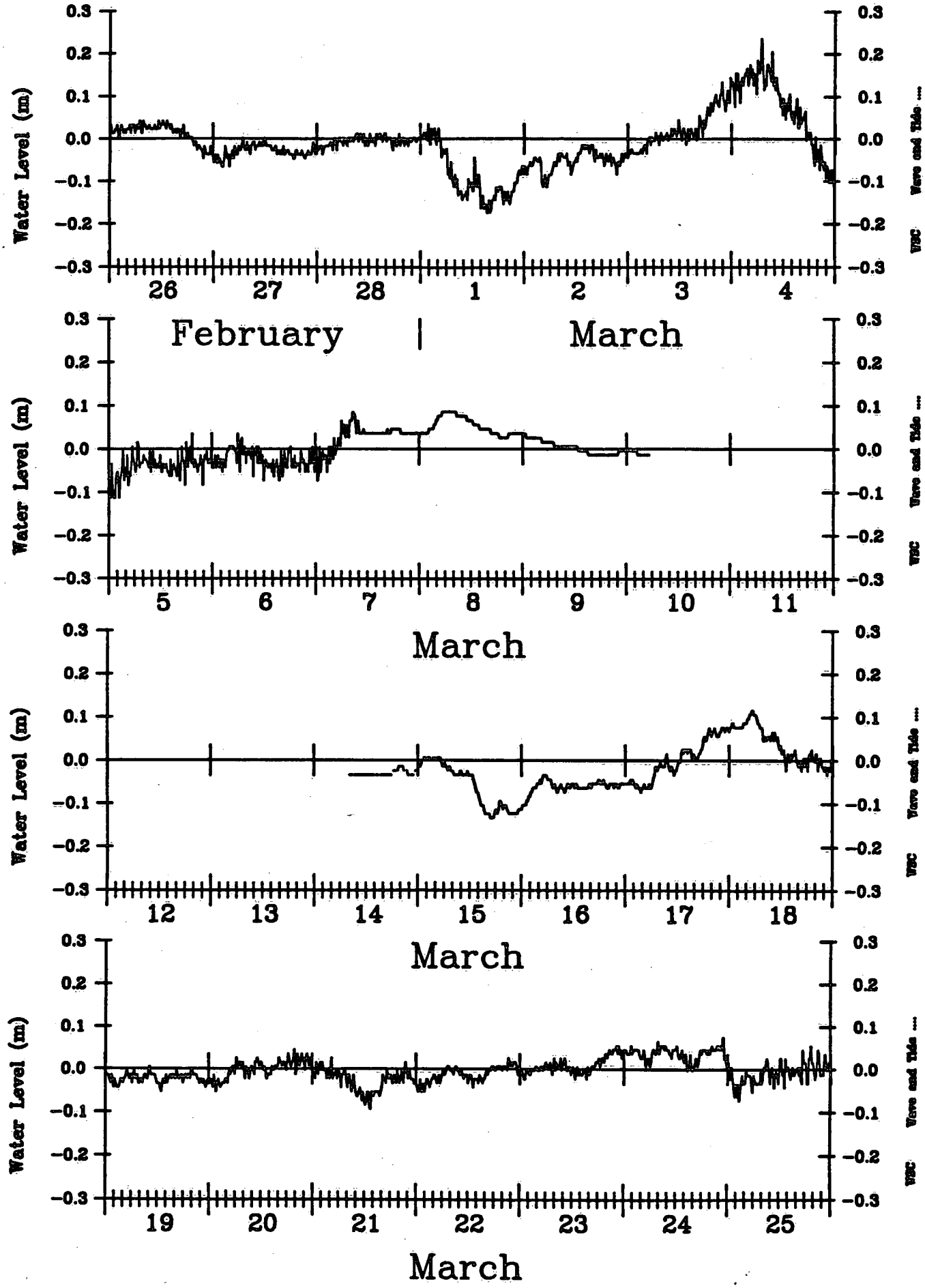
Water Level (m)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 4c.

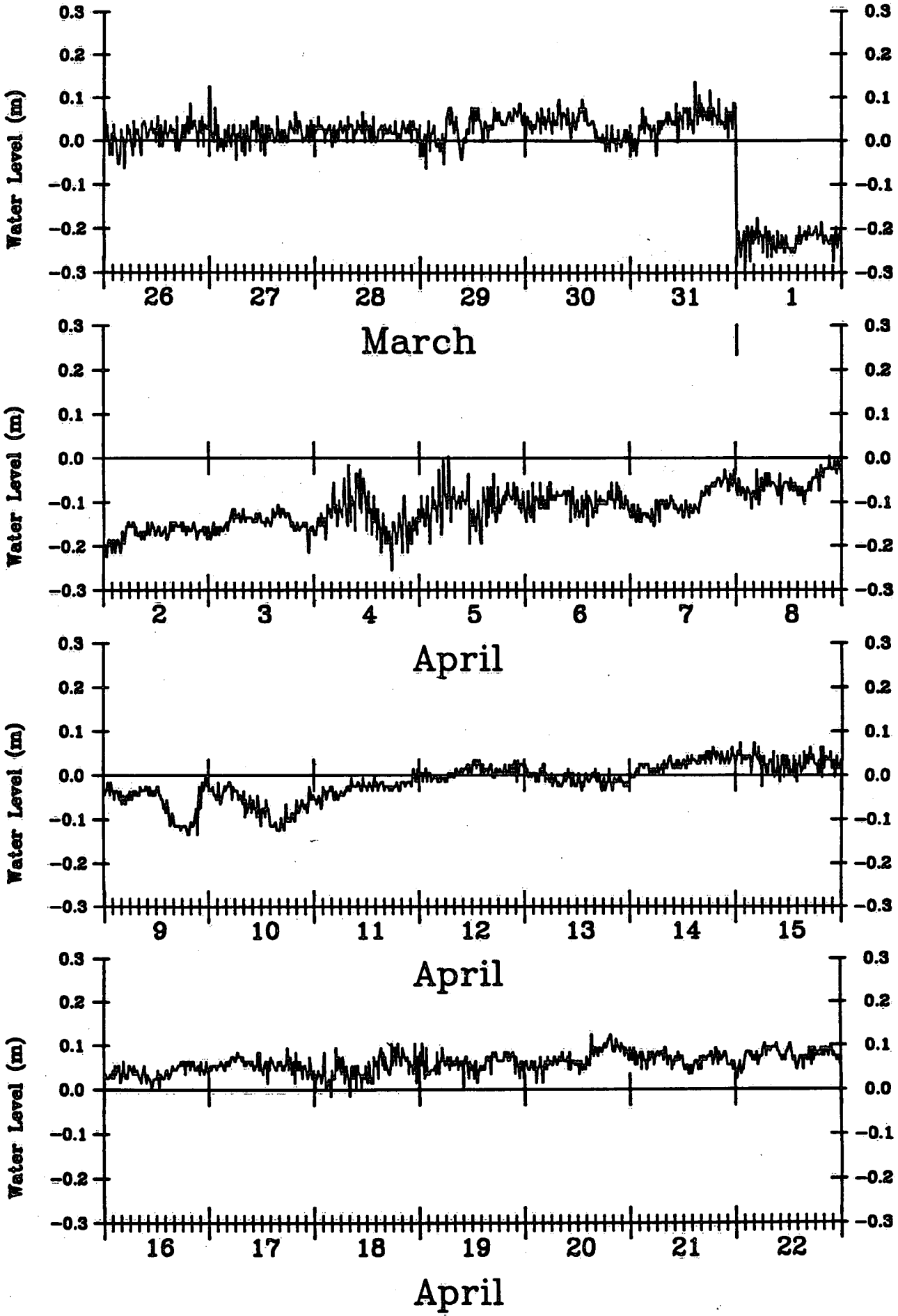
Water Level (m)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 4d.

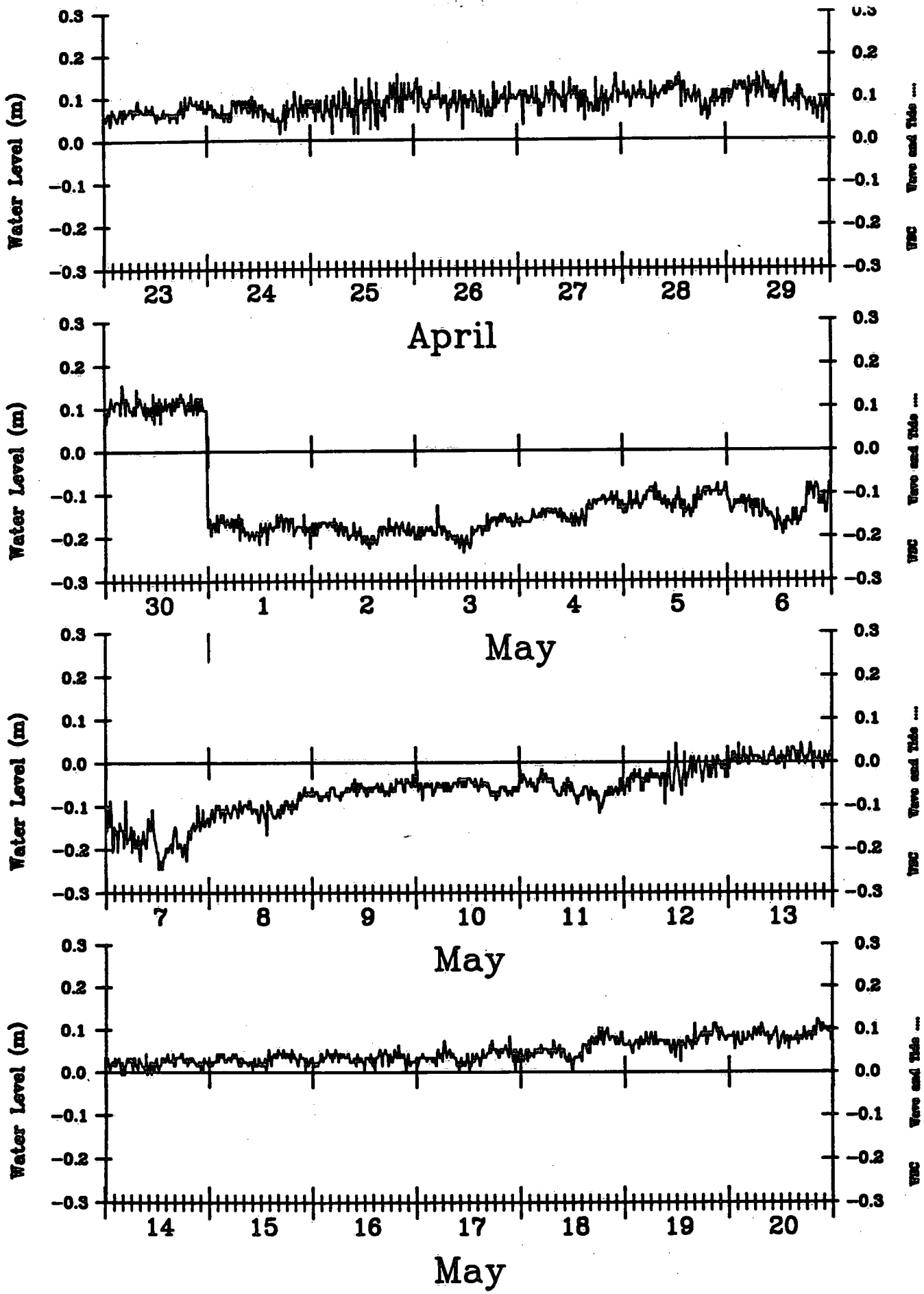
Water Level (m)
Wave and Tide ...
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 4e.

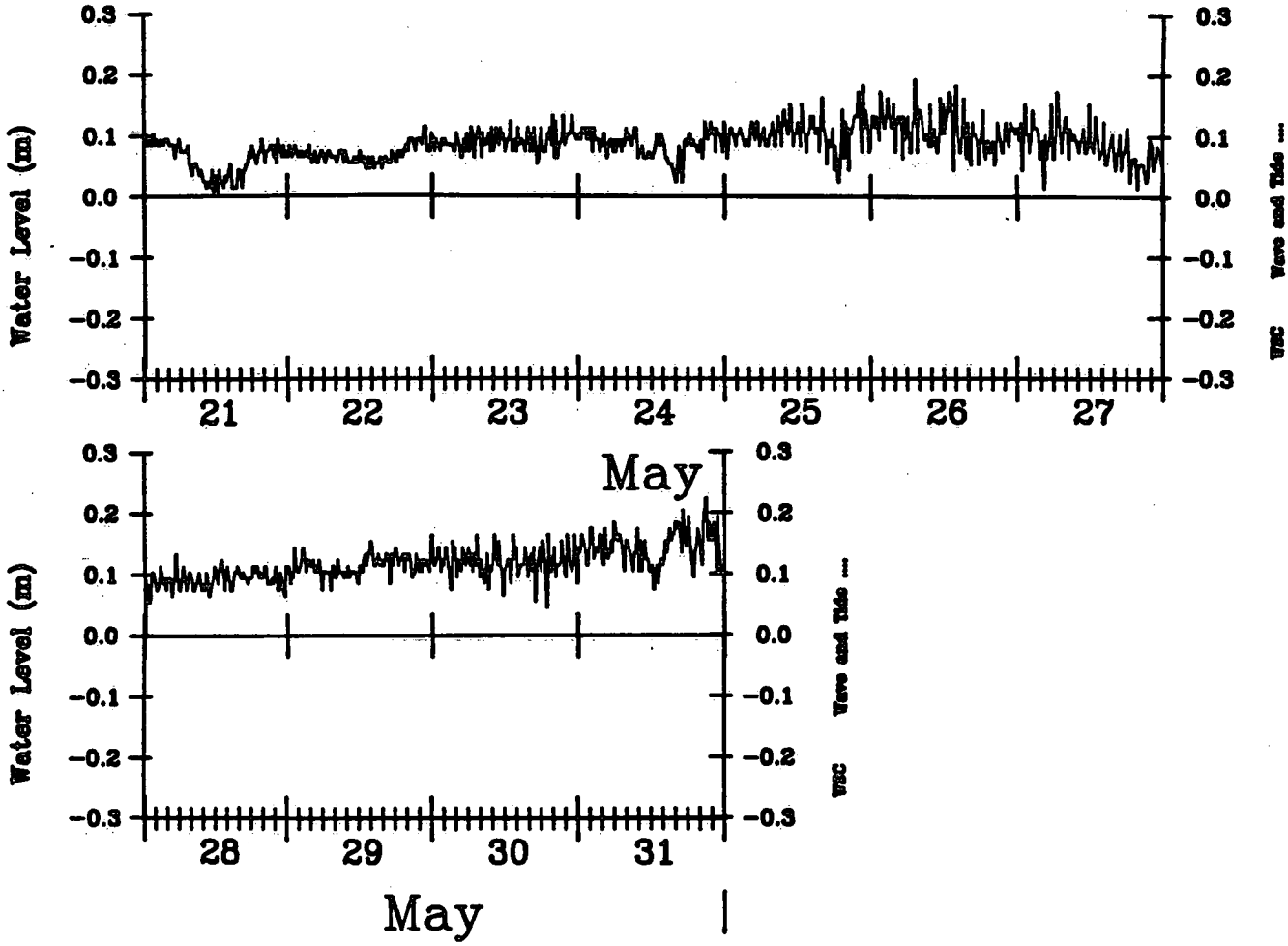
Water Level (m)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
21
22
23
24
25
26
27
May
28
29
30
31
May

FIGURE 4f.

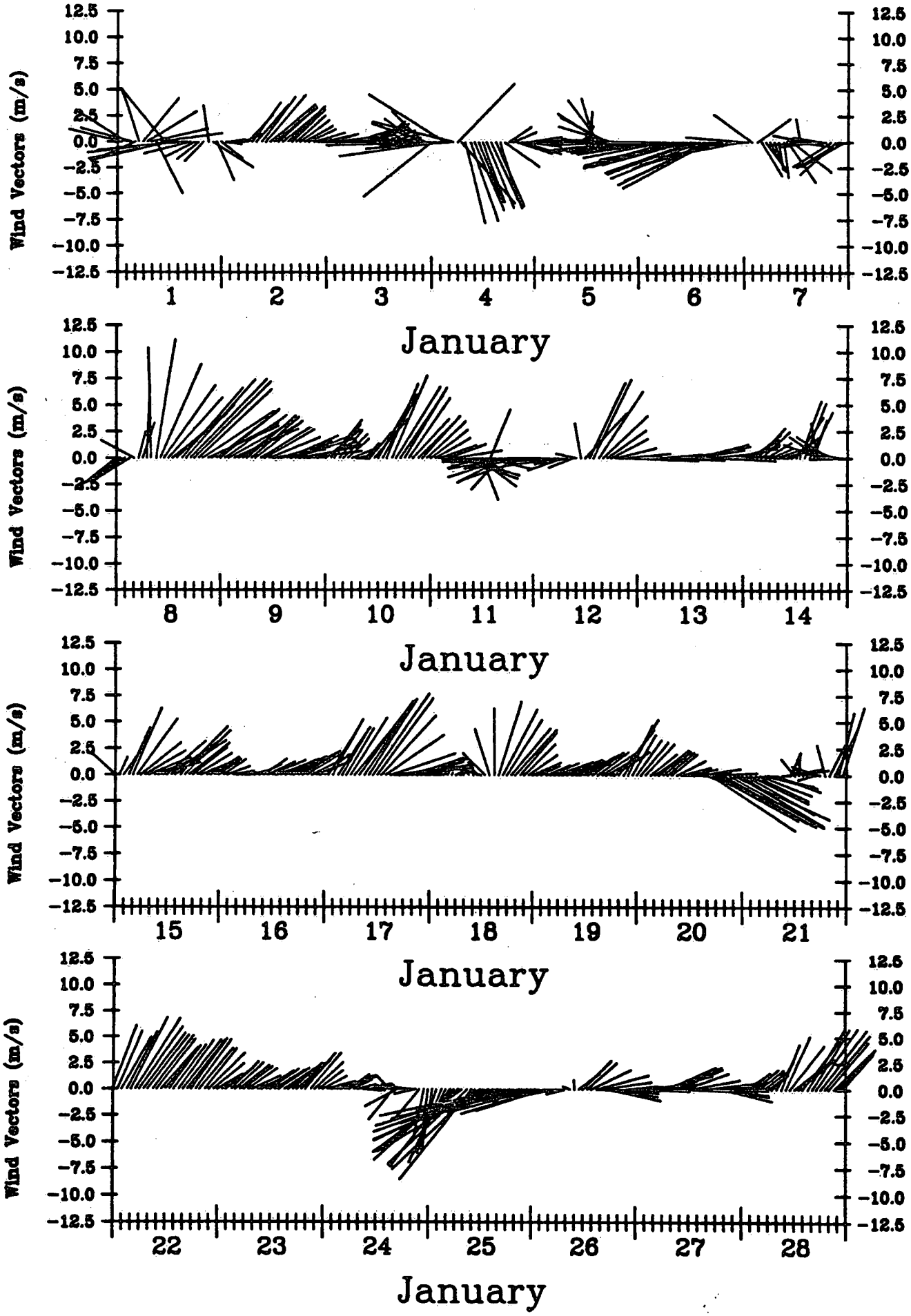
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
1 2 3 4 5 6 7
January
8 9 10 11 12 13 14
January
15 16 17 18 19 20 21
January
22 23 24 25 26 27 28
January

FIGURE 5a.

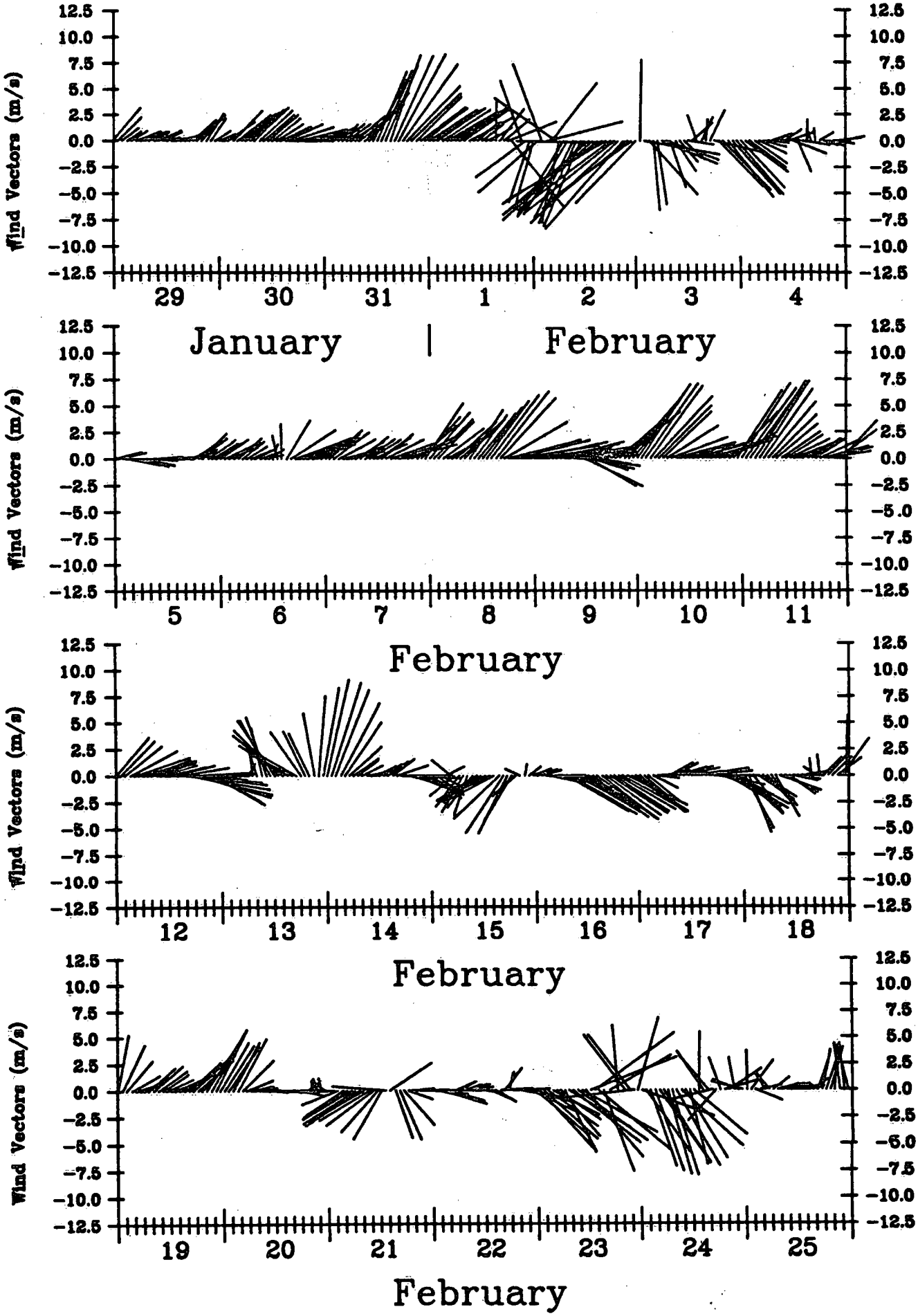
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 5b.

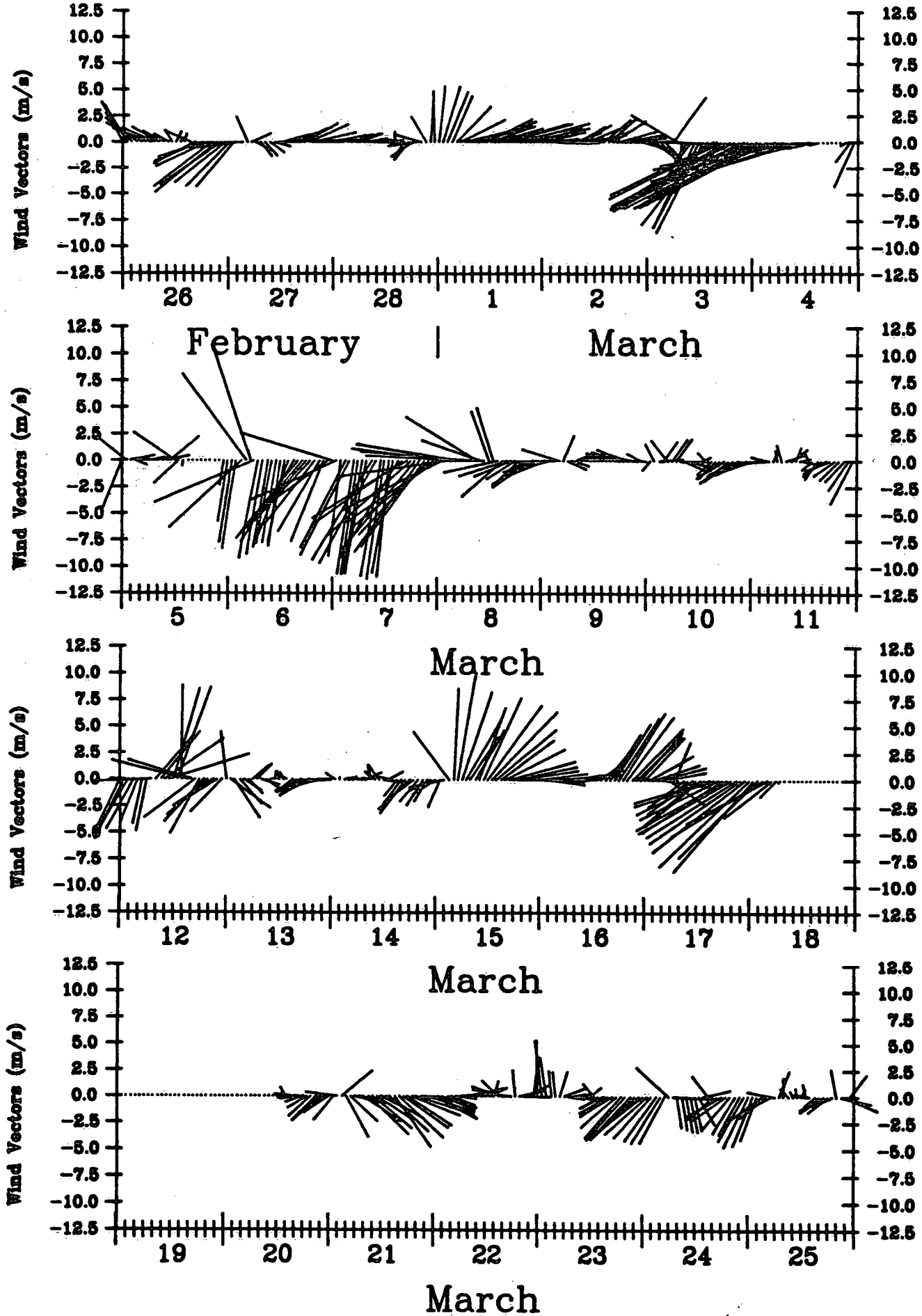
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 5c.

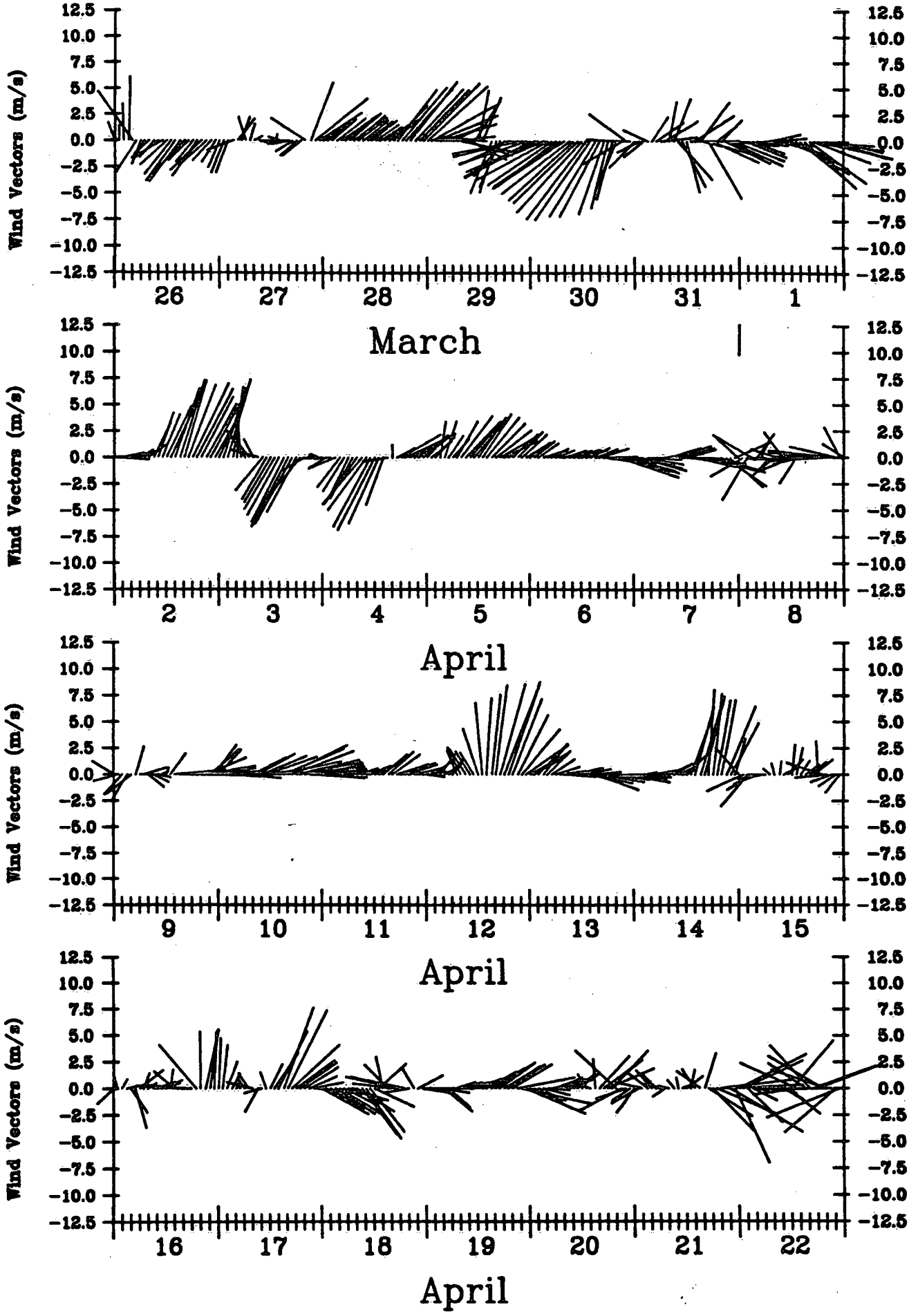
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 5d.

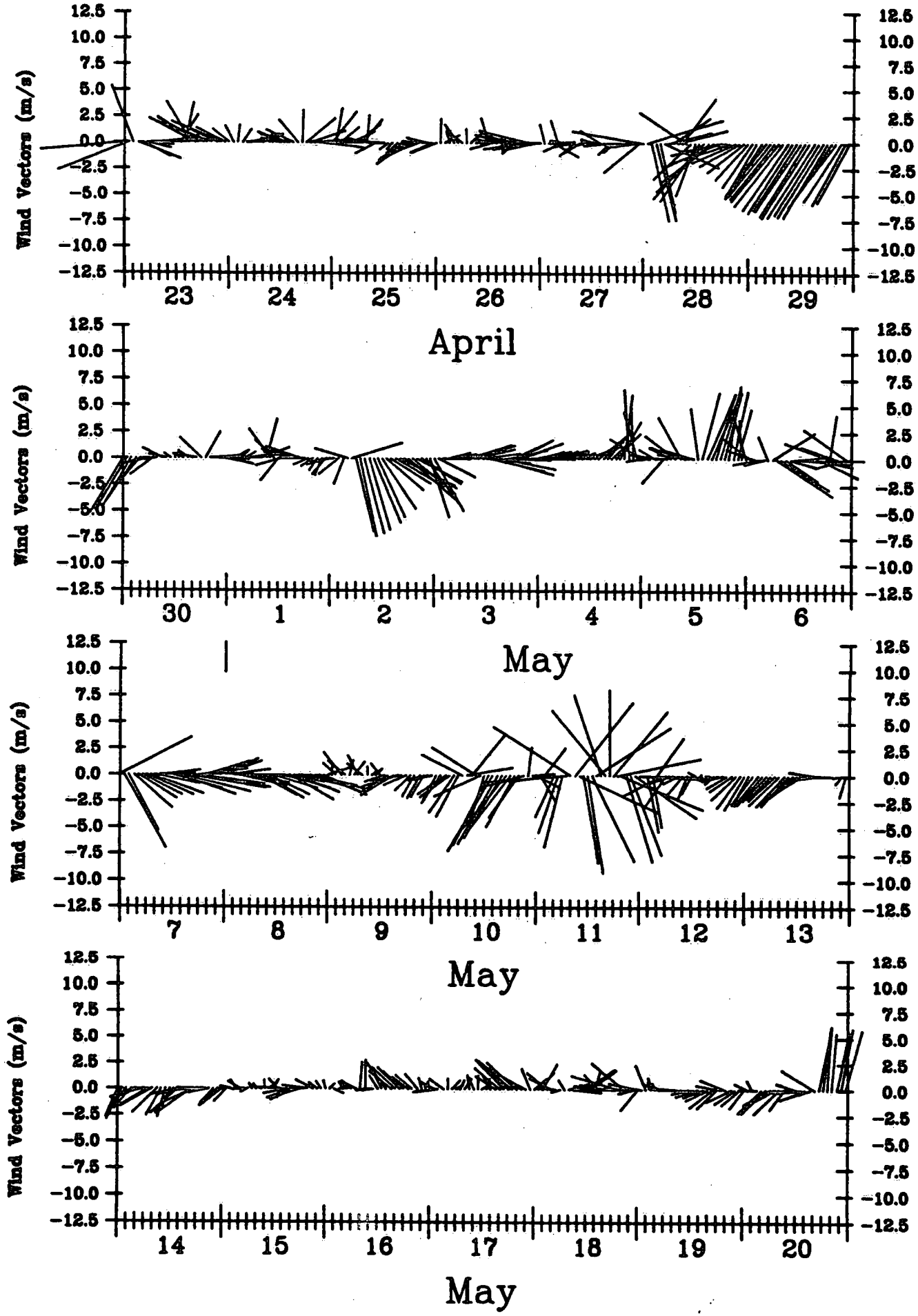
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 5e.

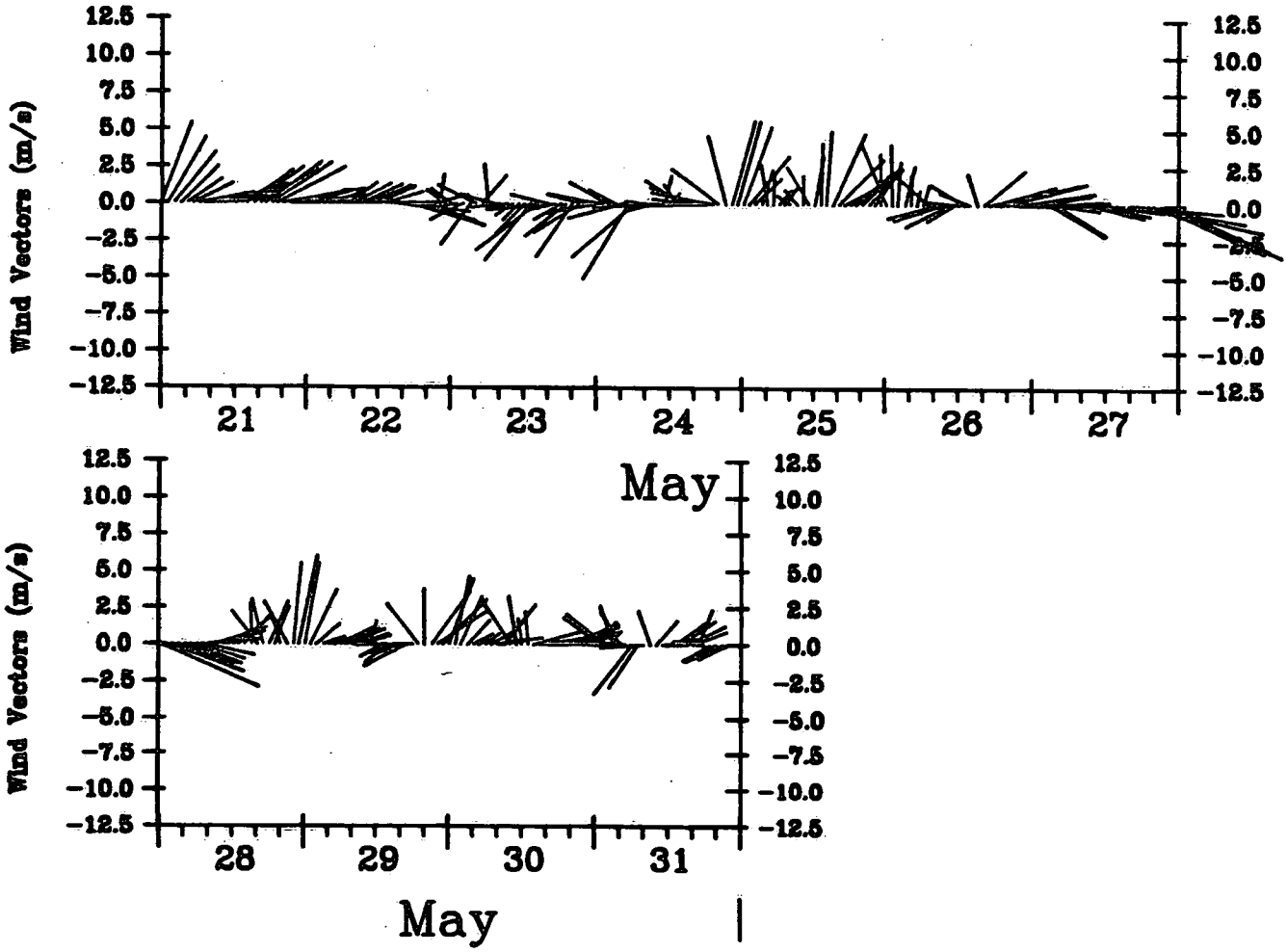
Wind Vectors (m/s)
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
21
22
23
24
25
26
27
May
28
29
30
31
May

FIGURE 5f.

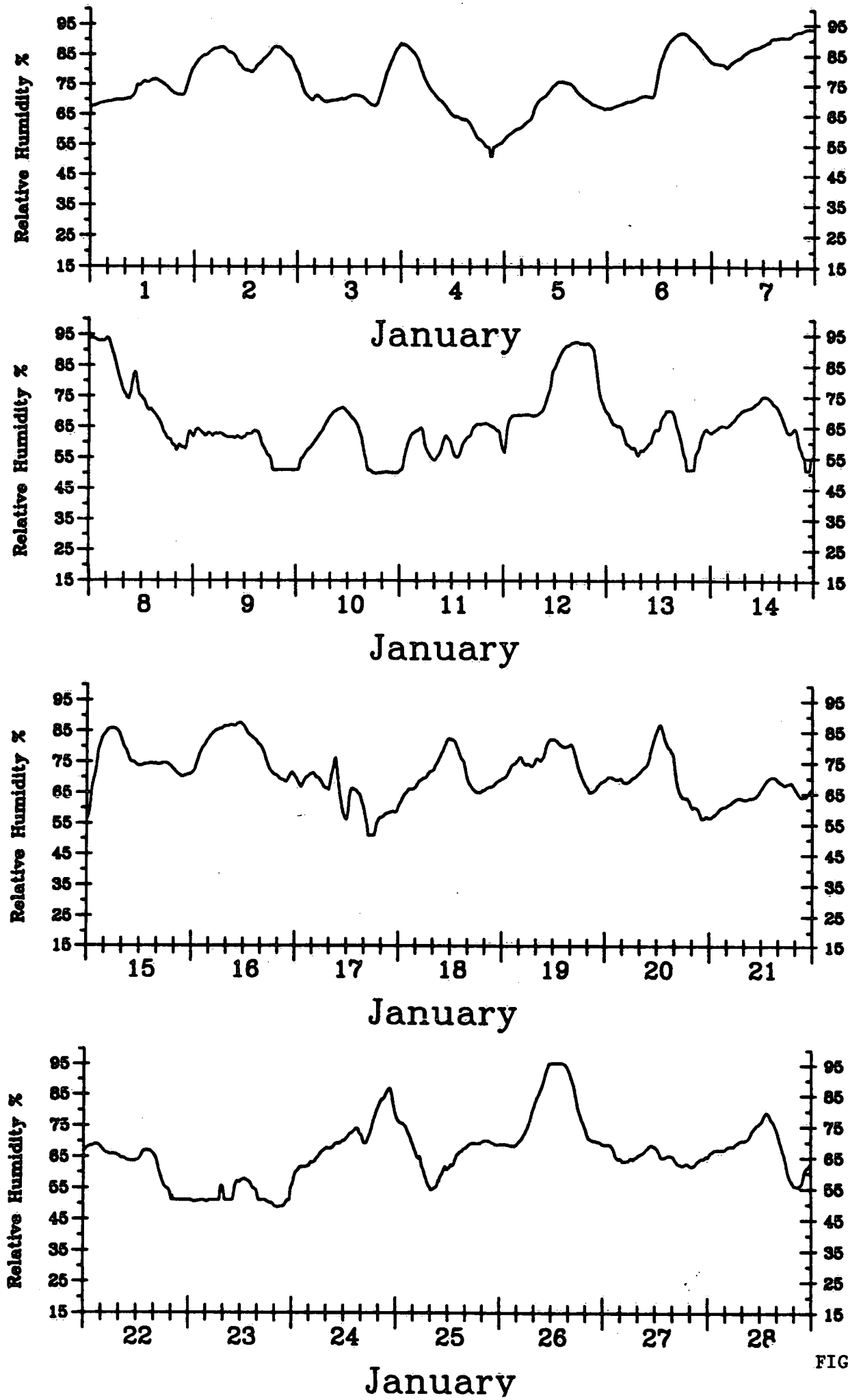
Relative Humidity %
95
85
75
65
55
45
35
25
15
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 6a.

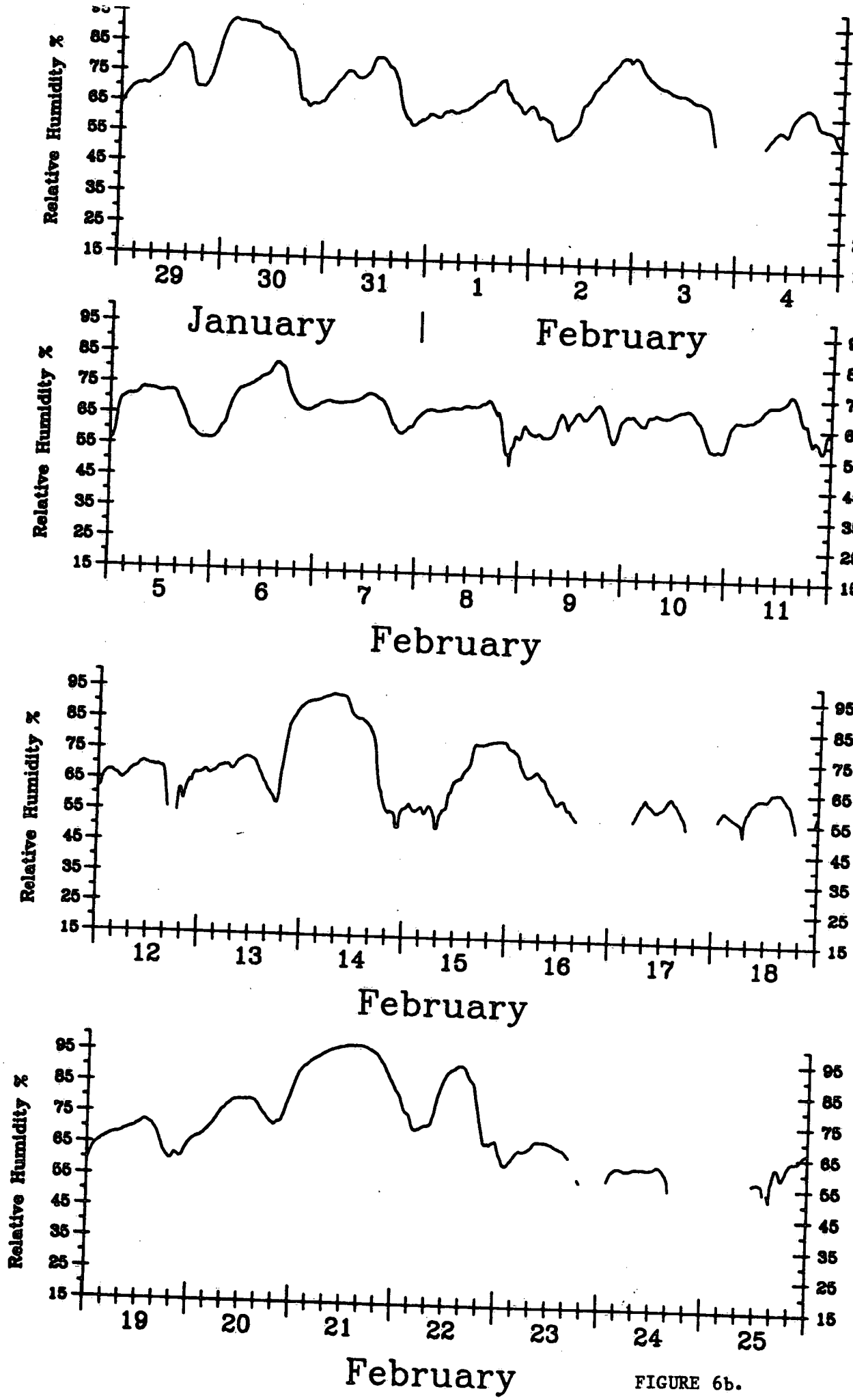
Relative Humidity %
85
75
65
55
45
35
25
15
29
30
31
1
2
3
4
January
February
95
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 6b.

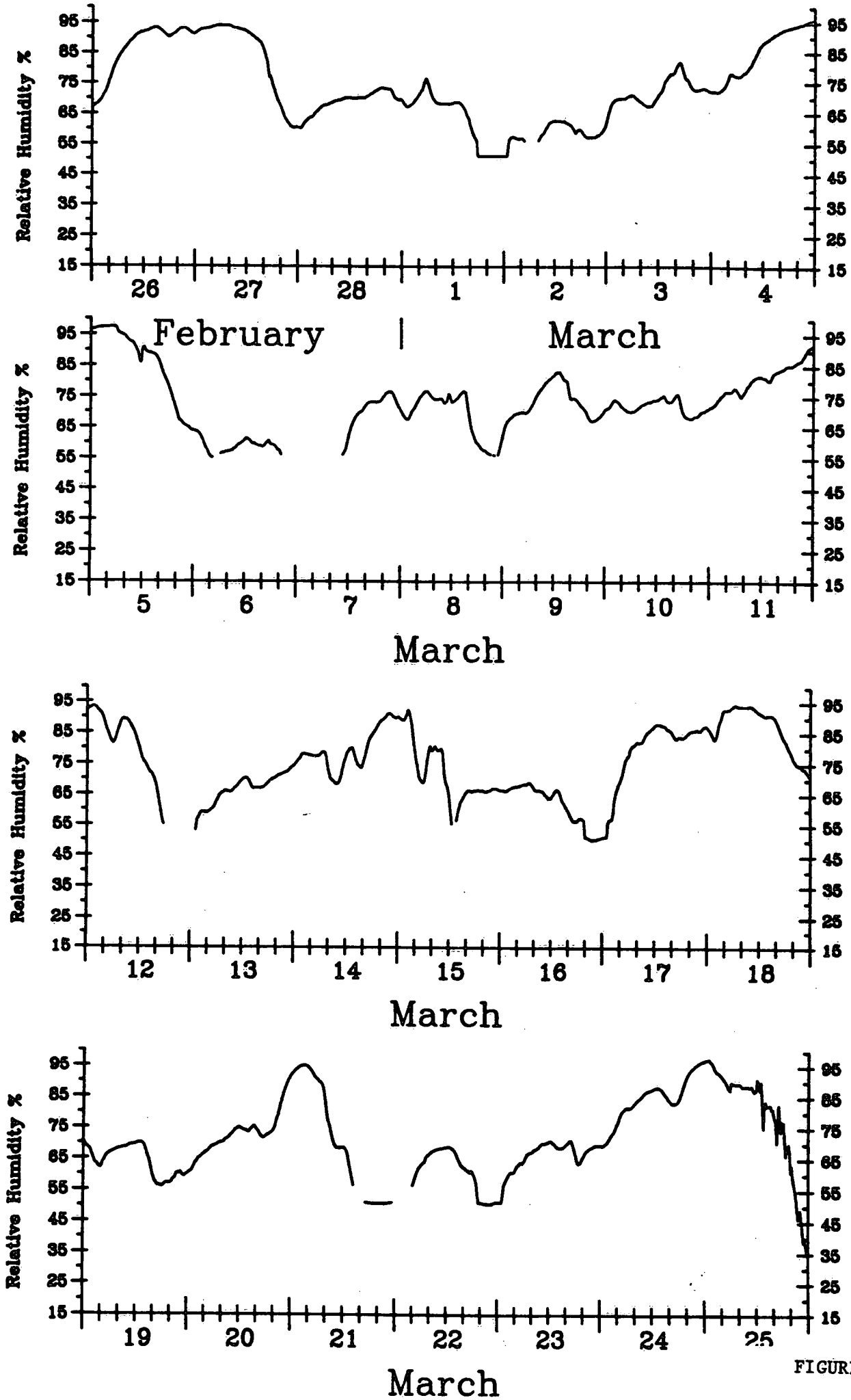
Relative Humidity %
95
85
75
65
55
45
35
25
15
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 6c.

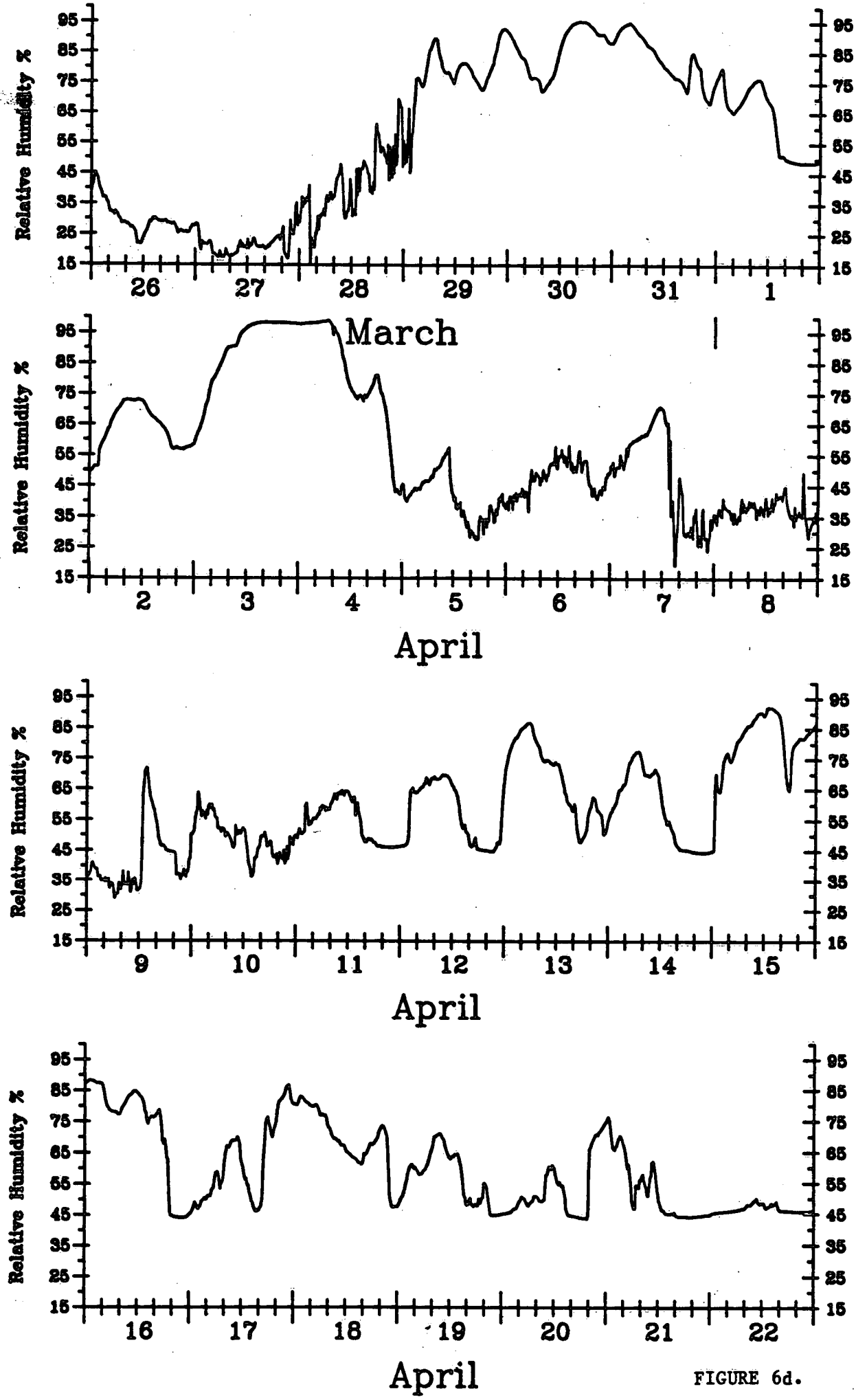
Relative Humidity %
95
85
75
65
55
45
35
25
15
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 6d.

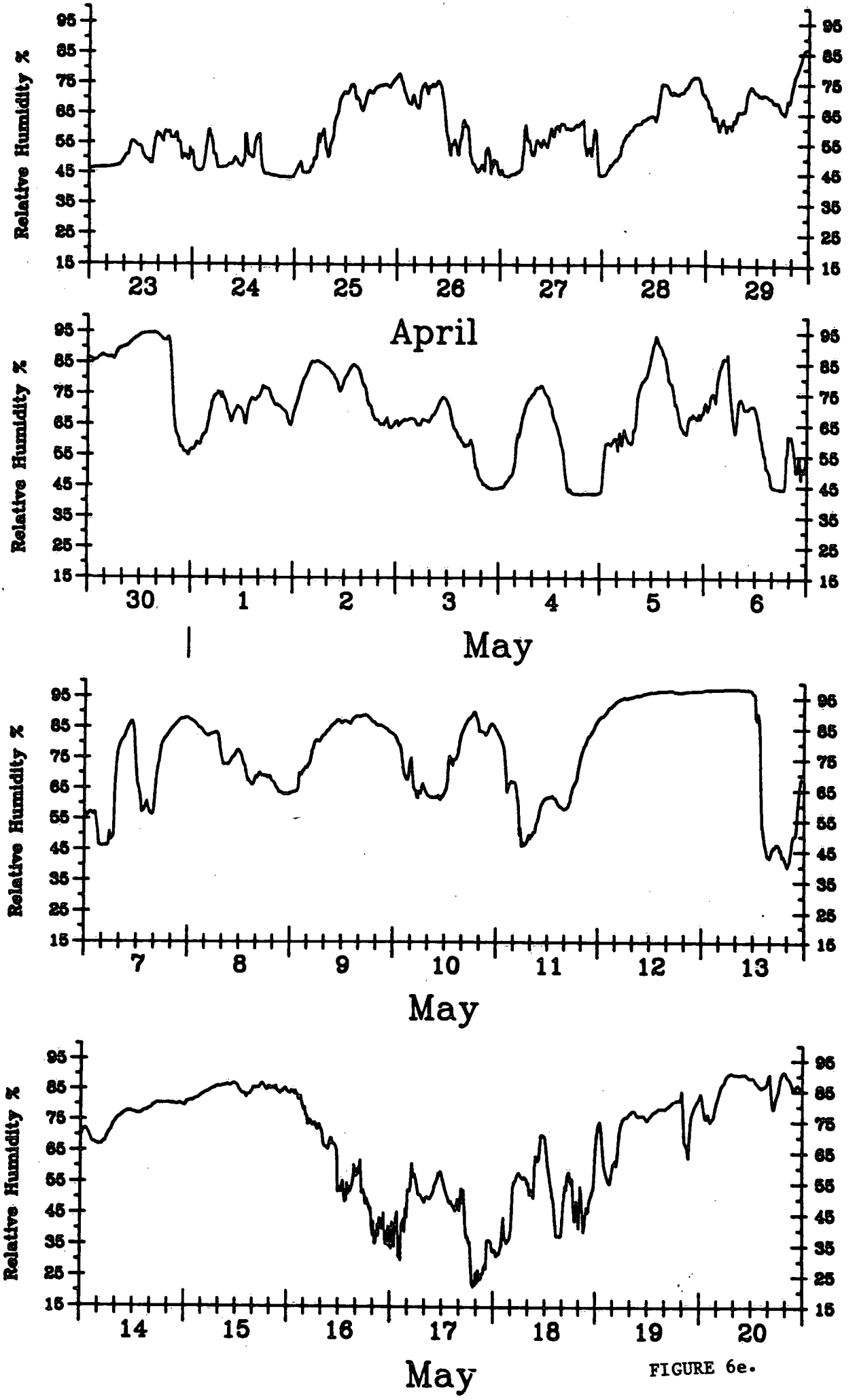
Relative Humidity %
95
85
75
65
55
45
35
25
15
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 6e.

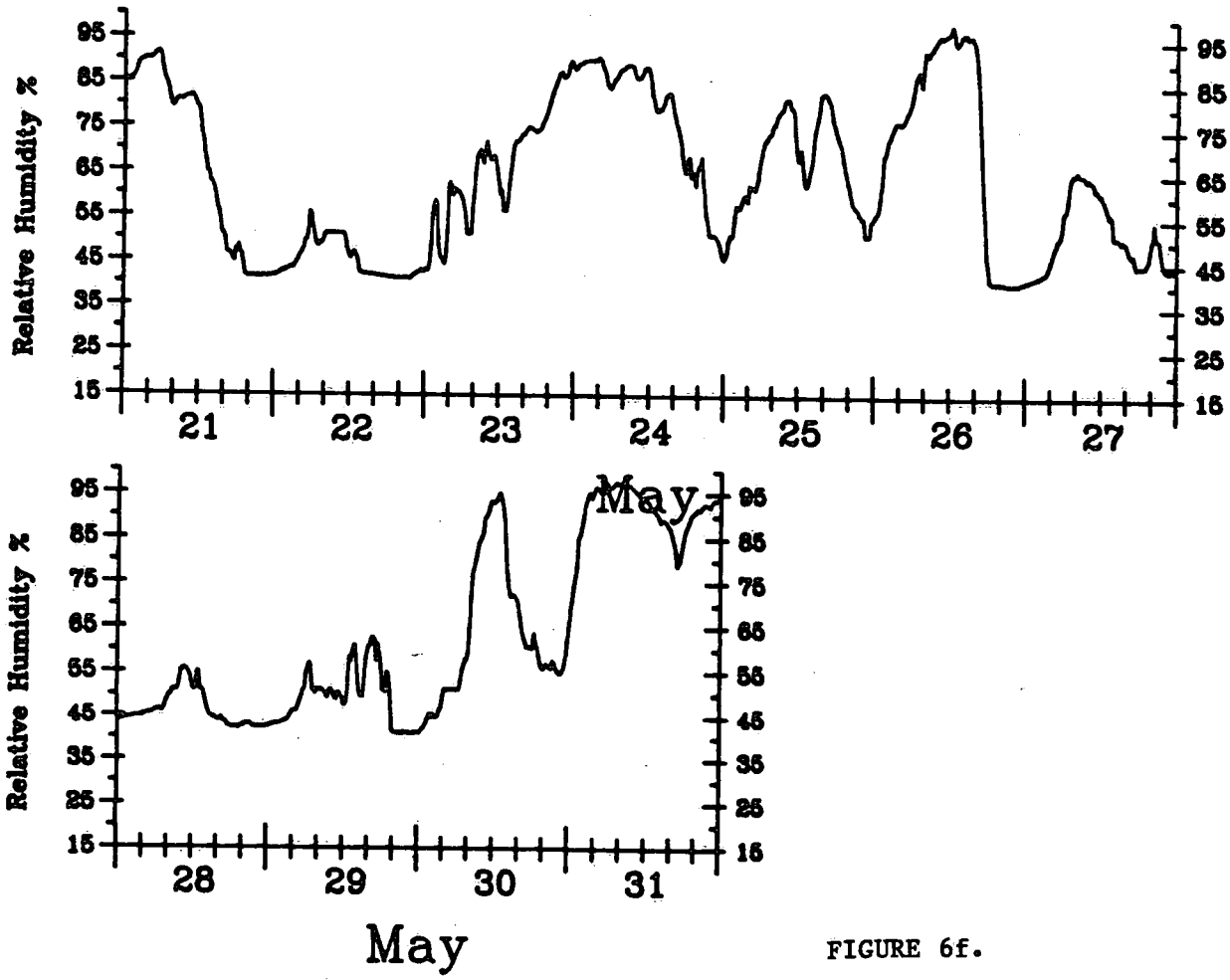
Relative Humidity %
95
85
75
65
55
45
35
25
15
21
22
23
24
25
26
27
May
28
29
30
31
May

FIGURE 6f.

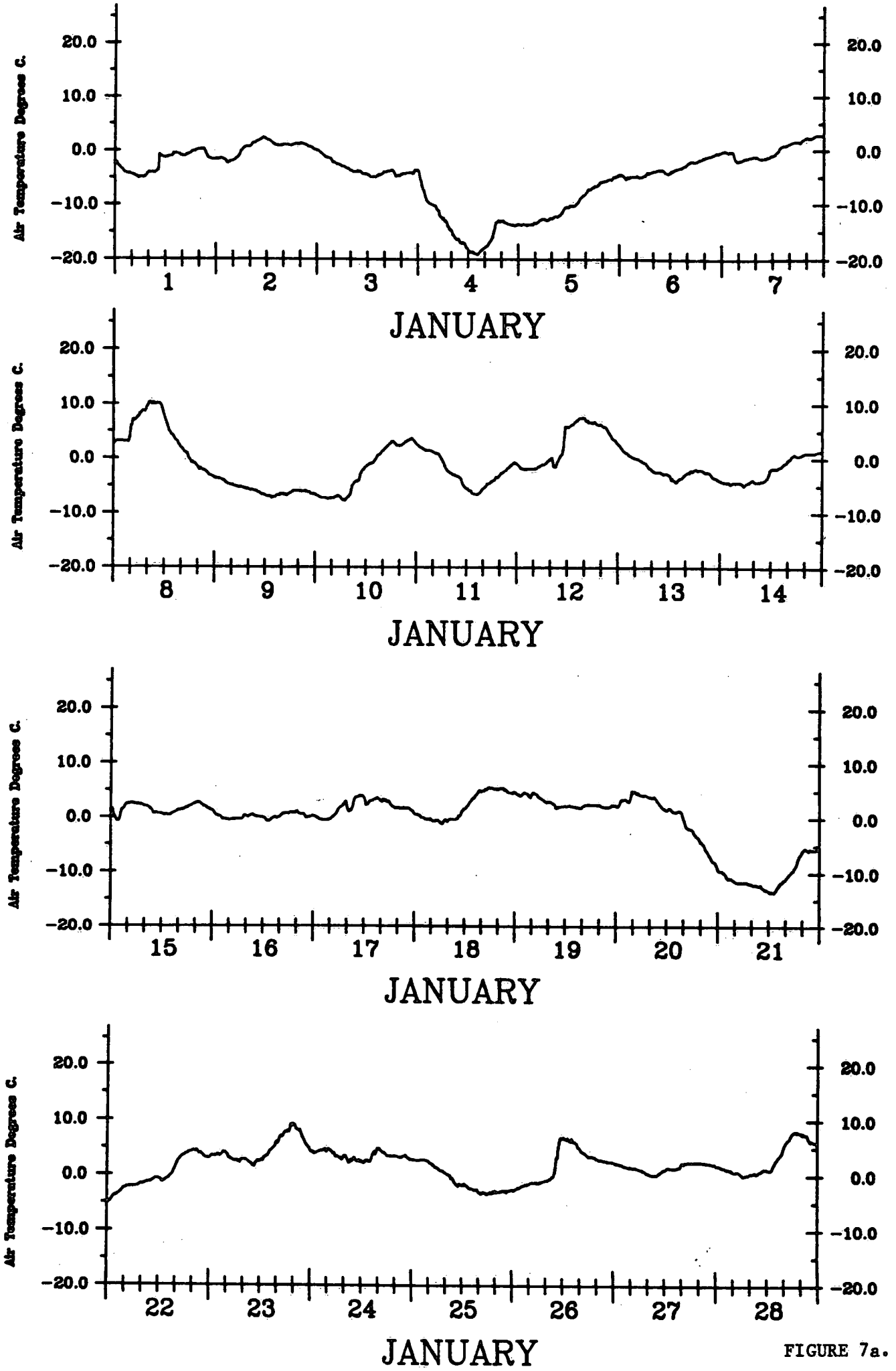
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
1
2
3
4
5
6
7
JANUARY
8
9
10
11
12
13
14
JANUARY
15
16
17
18
19
20
21
JANUARY
22
23
24
25
26
27
28
JANUARY

FIGURE 7a.

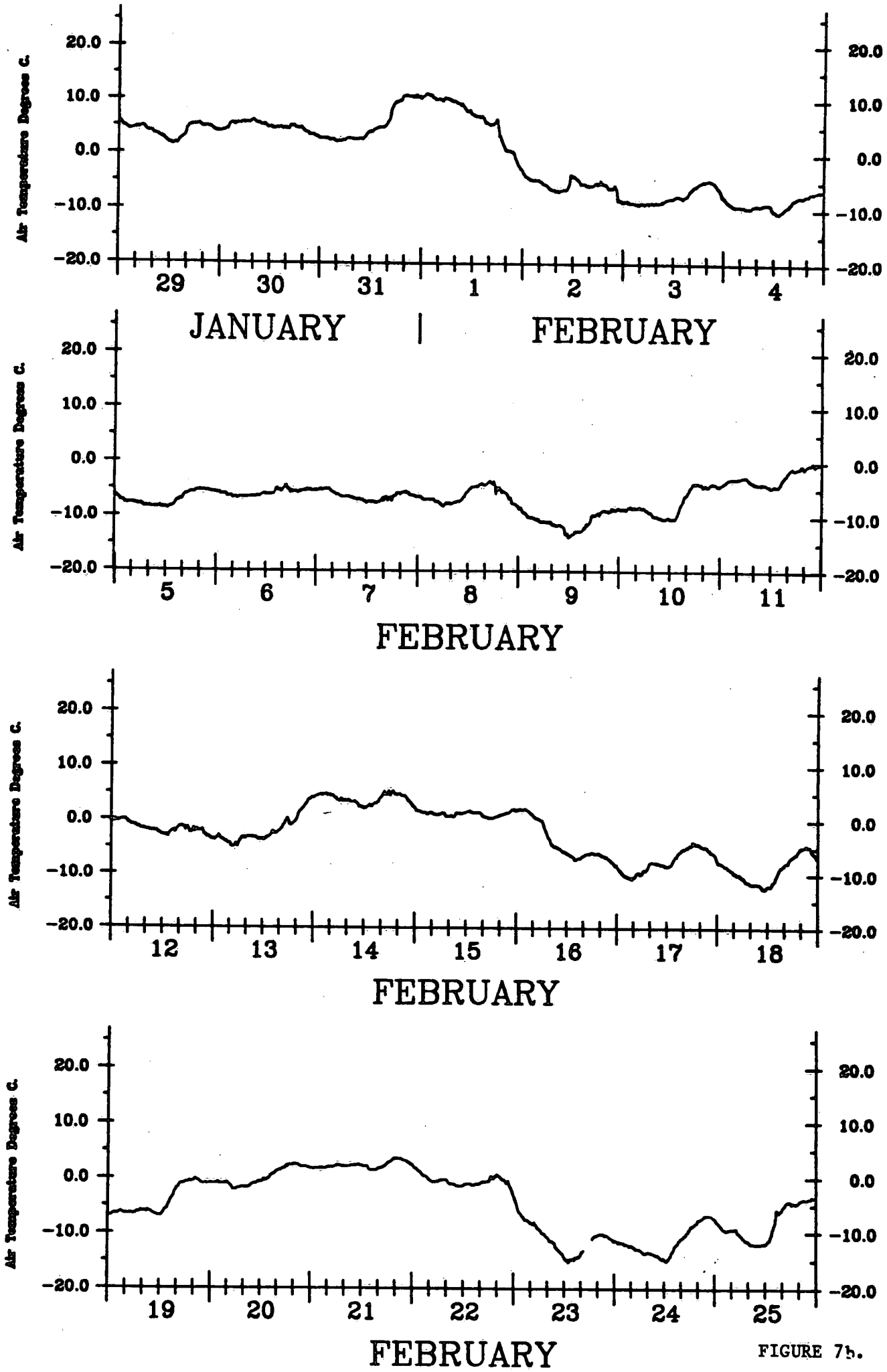
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
29
30
31
1
2
3
4
JANUARY
FEBRUARY
5
6
7
8
9
10
11
FEBRUARY
12
13
14
15
16
17
18
FEBRUARY
19
20
21
22
23
24
25
FEBRUARY

FIGURE 7b.

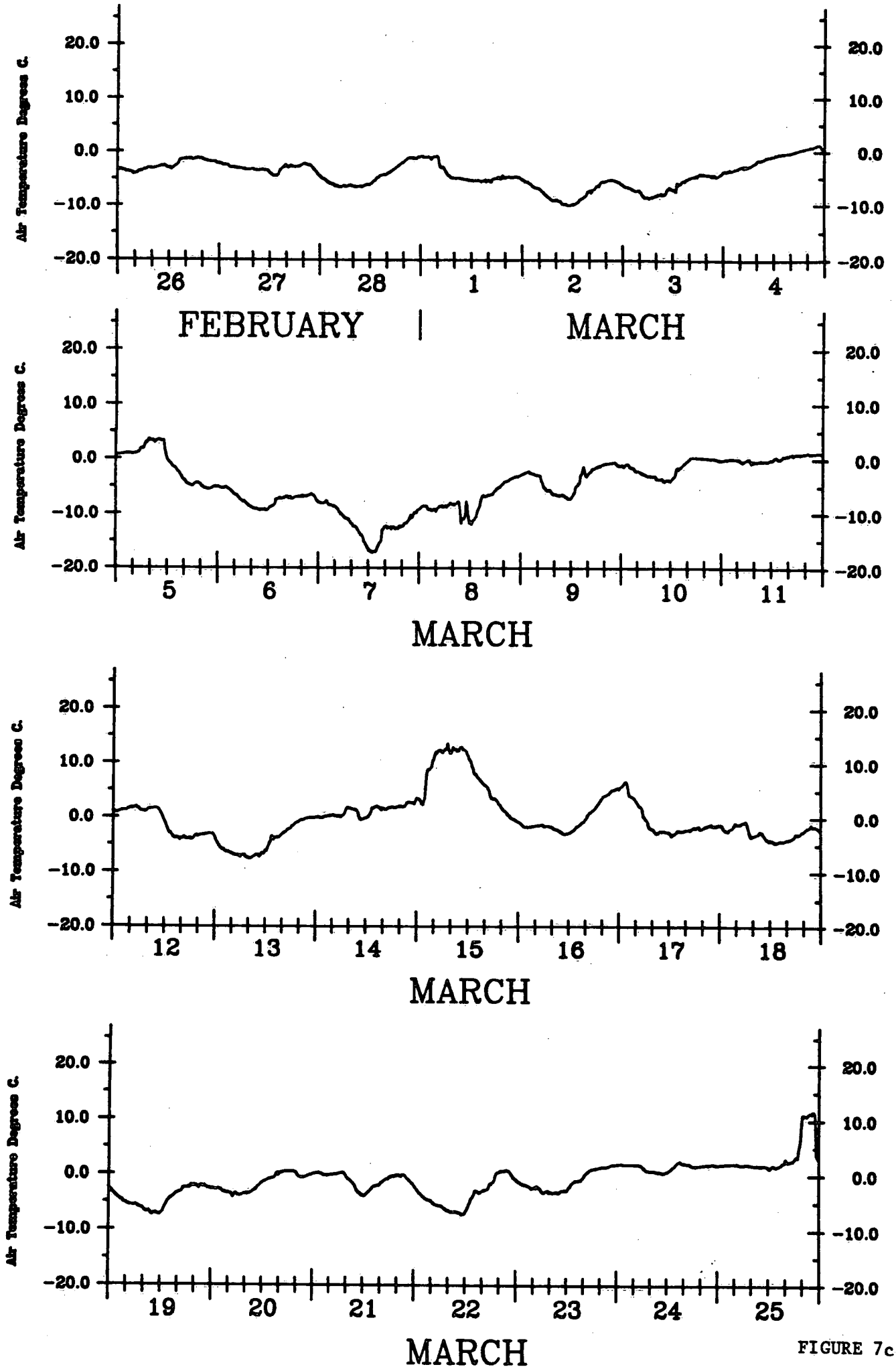
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
26
27
28
1
2
3
4
FEBRUARY
MARCH
5
6
7
8
9
10
11
MARCH
12
13
14
15
16
17
18
MARCH
19
20
21
22
23
24
25
MARCH

FIGURE 7c.

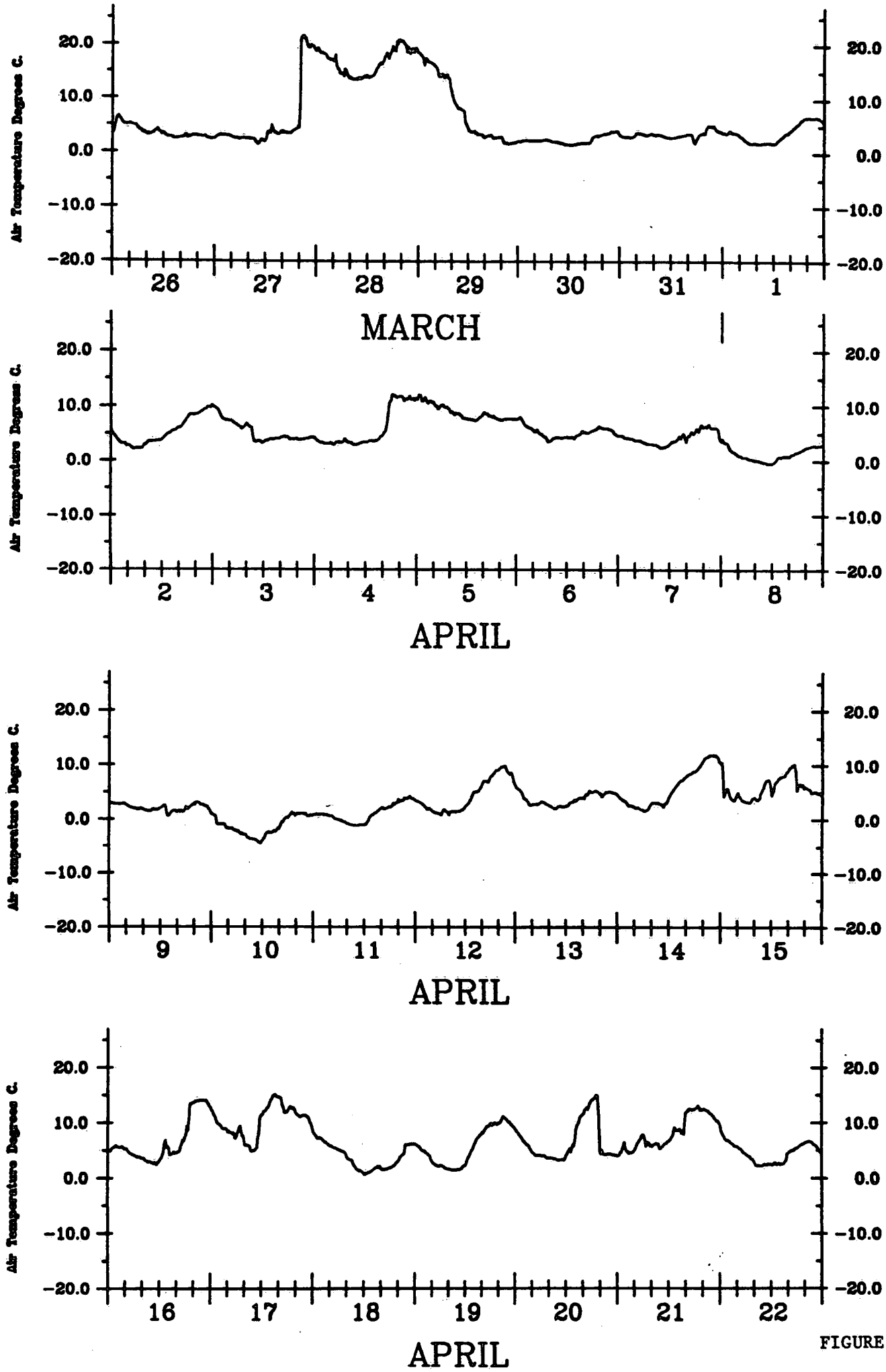
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
26
27
28
29
30
31
1
MARCH
2
3
4
5
6
7
8
APRIL
9
10
11
12
13
14
15
APRIL
16
17
18
19
20
21
22
APRIL

FIGURE 7d.

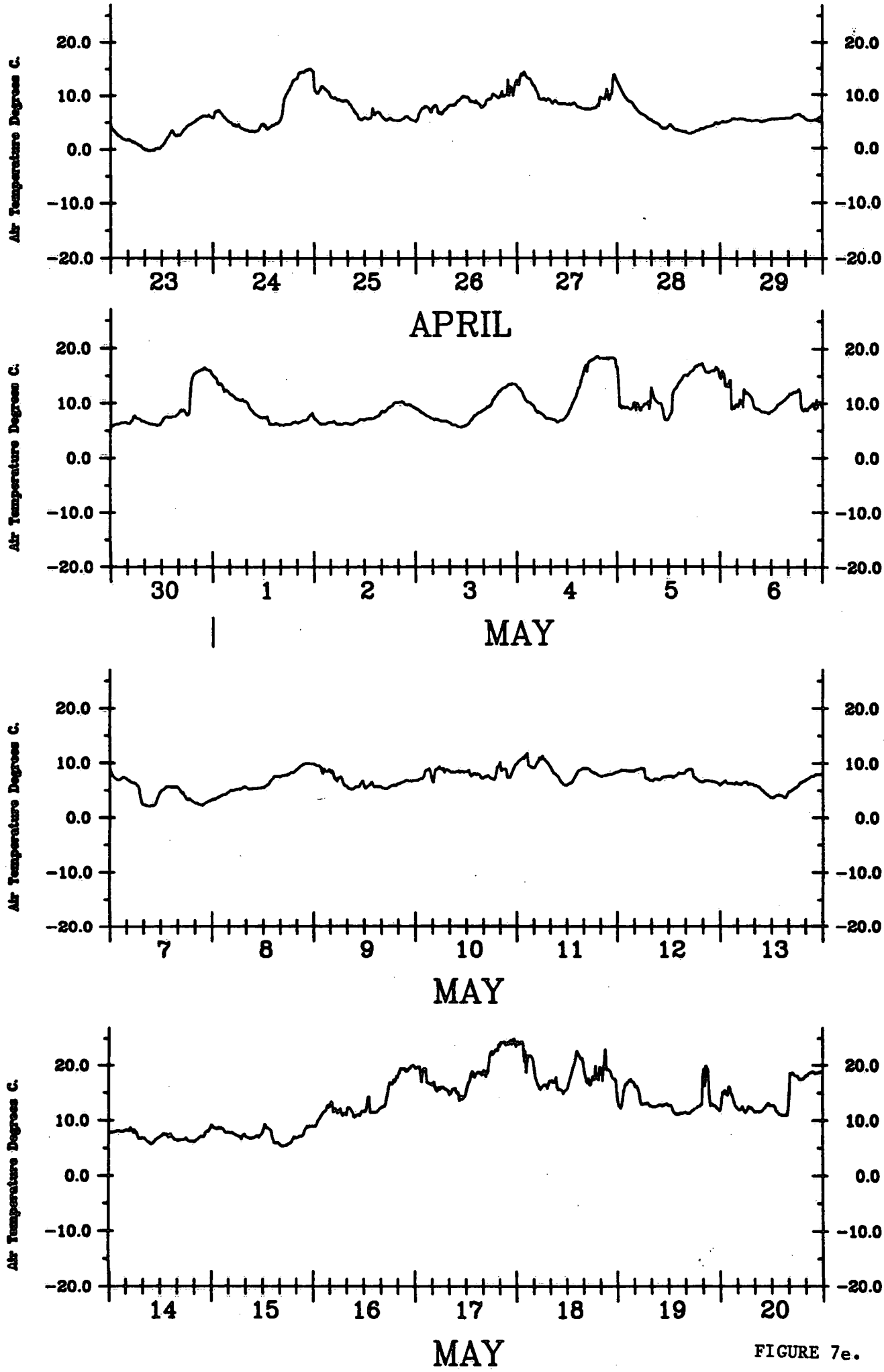
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
23
24
25
26
27
28
29
APRIL
30
1
2
3
4
5
6
MAY
7
8
9
10
11
12
13
MAY
14
15
16
17
18
19
20
MAY

FIGURE 7e.

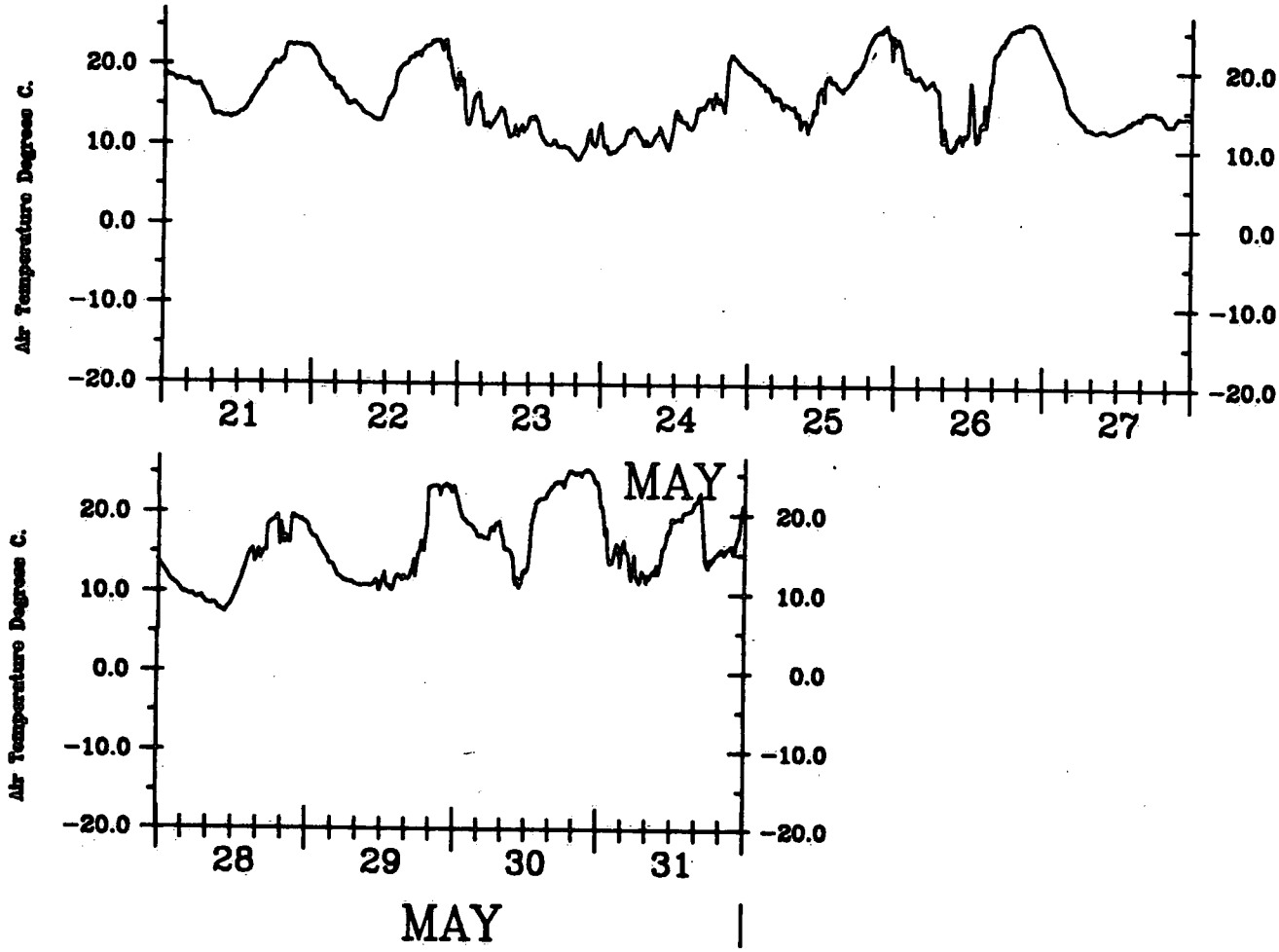
Air Temperature Degrees C.
20.0
10.0
0.0
-10.0
-20.0
21
22
23
24
25
26
27
MAY
28
29
30
31
MAY

FIGURE 7f

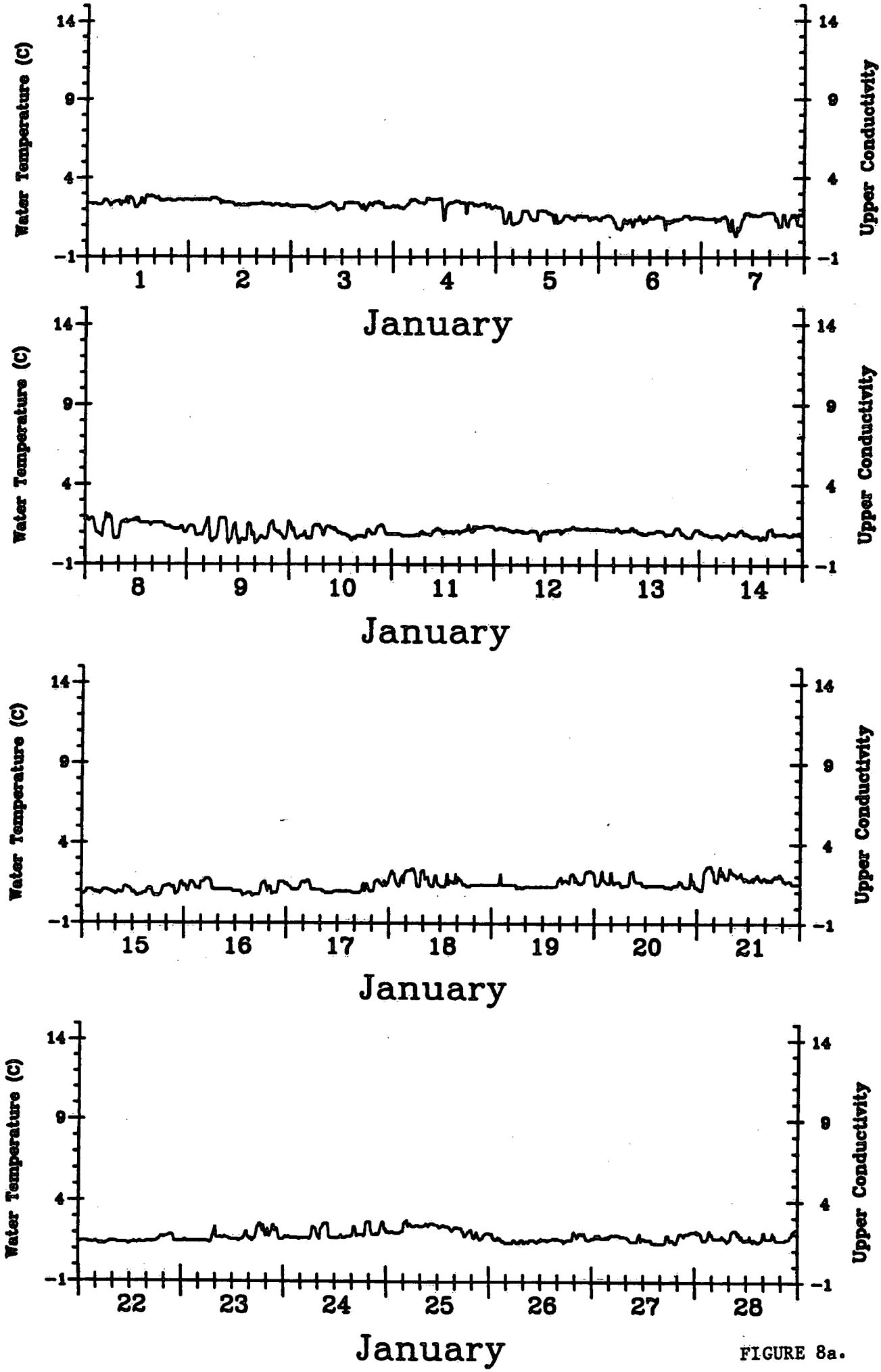
Water Temperature (C)
Upper Conductivity
14
9
4
-1
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 8a.

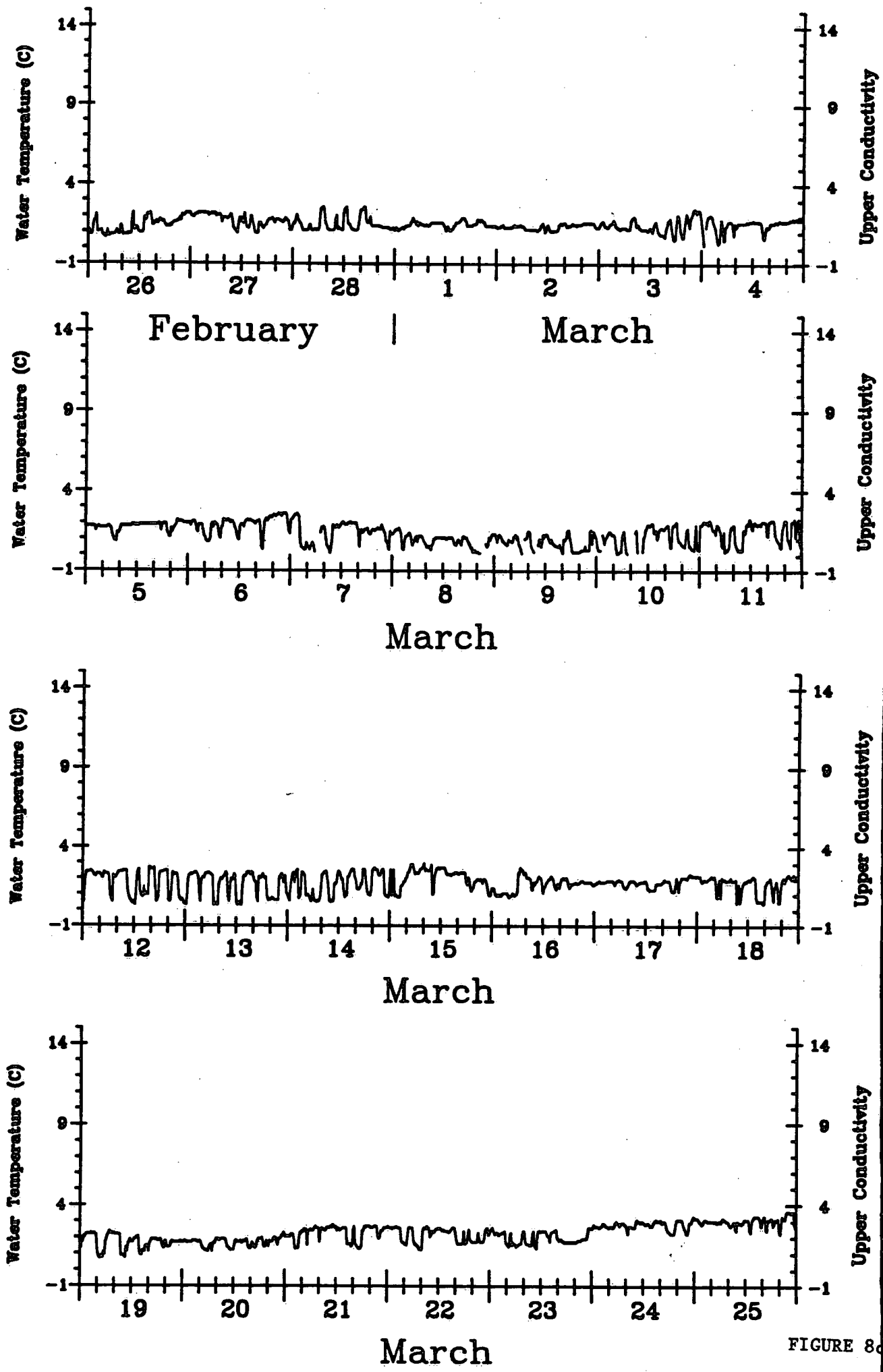
Water Temperature (C)
Upper Conductivity
14
9
4
-1
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 8c

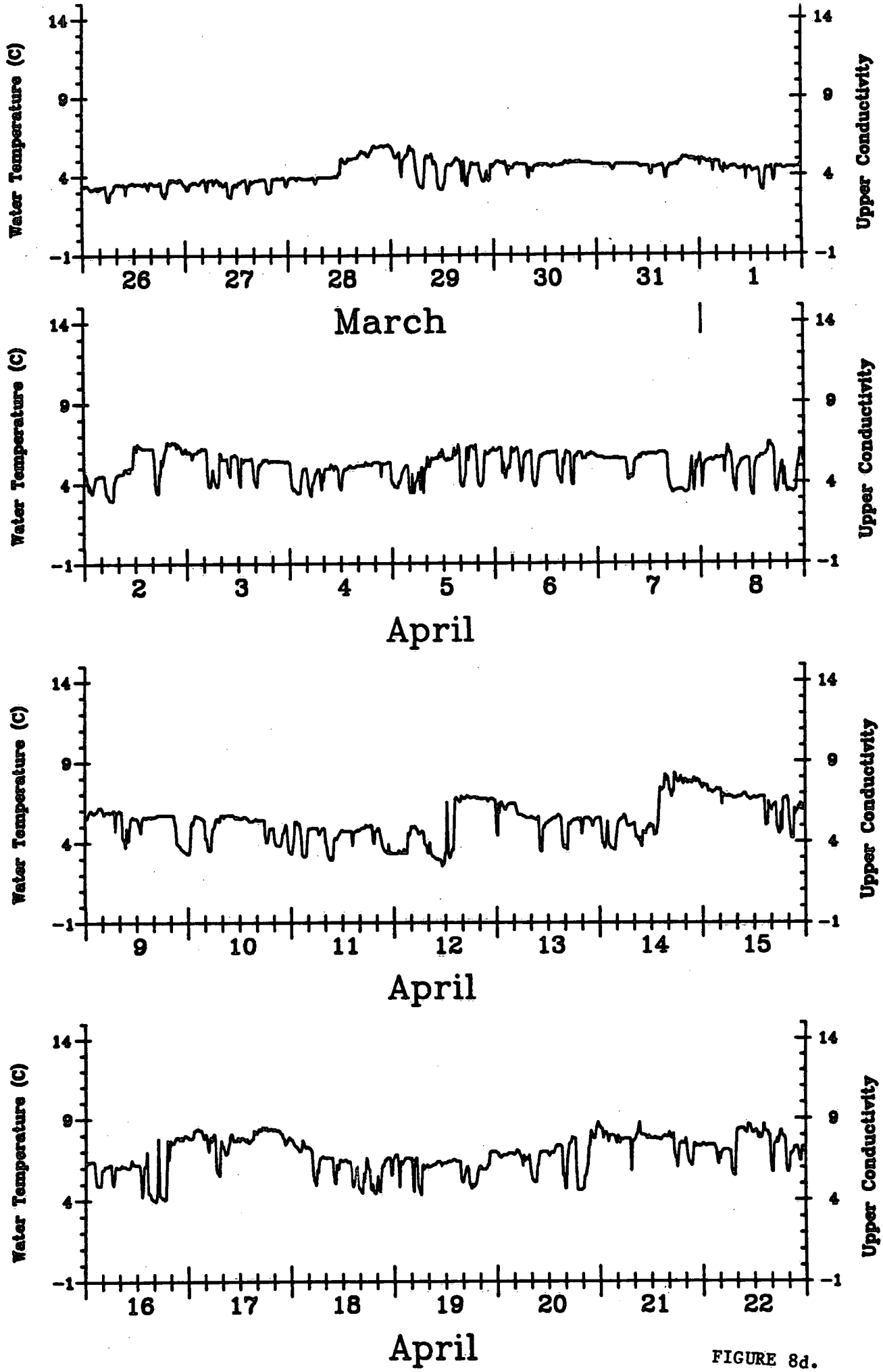
Water Temperature (C)
Upper Conductivity
14
9
4
-1
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 8d.

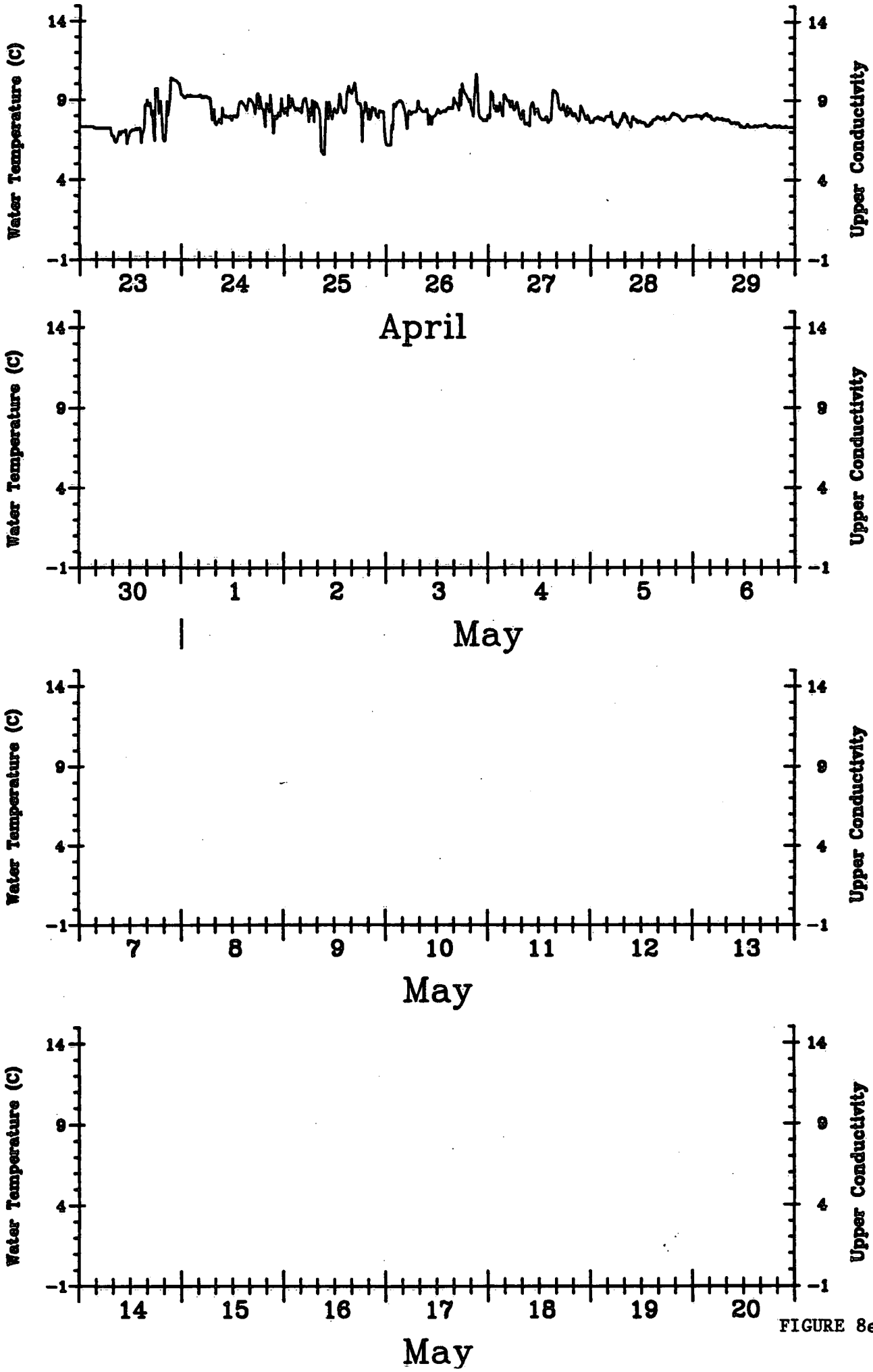
Water Temperature (C)
Upper Conductivity
14
9
4
-1
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 8e

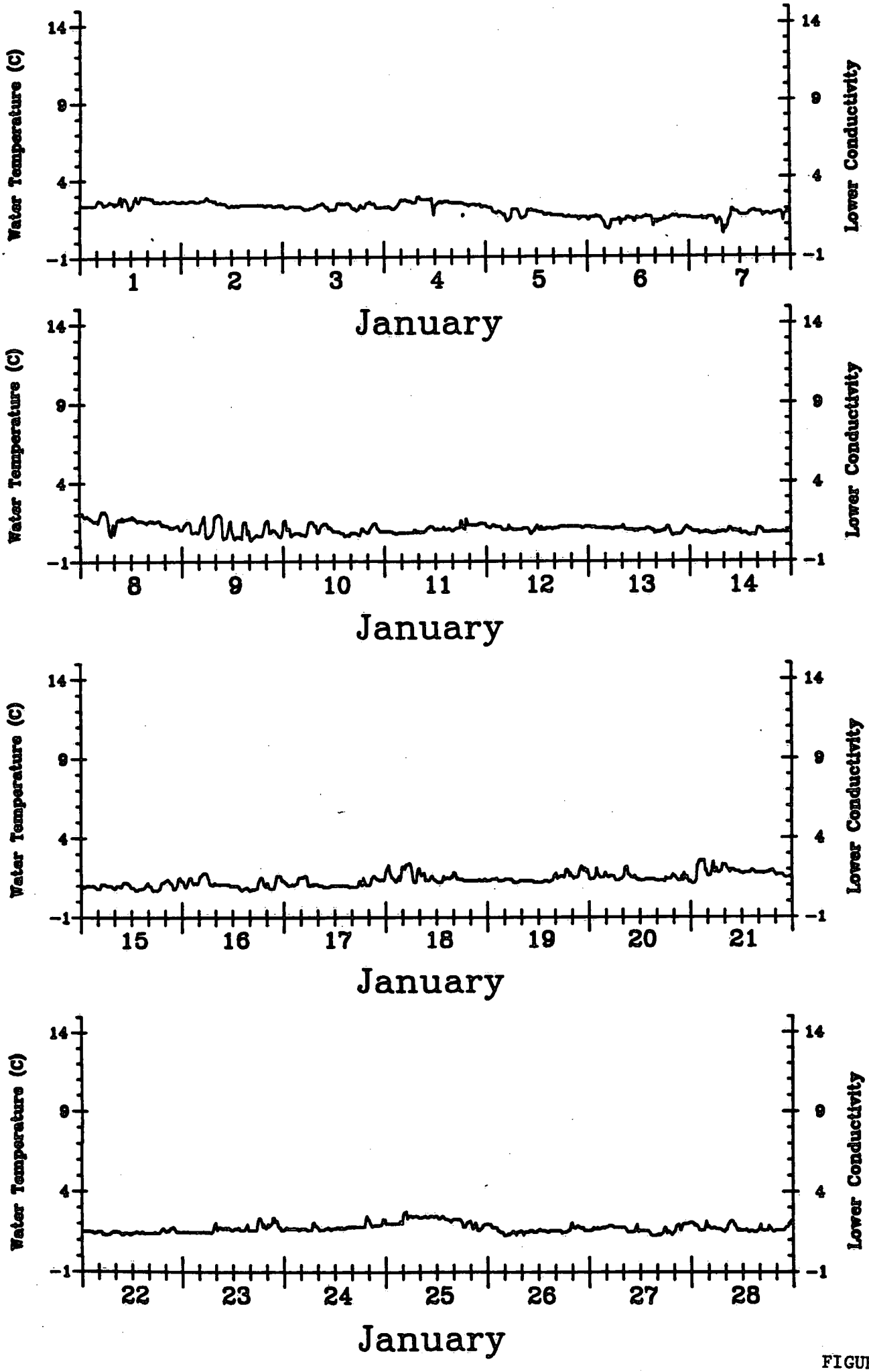
Water Temperature (C)
Lower Conductivity
14
9
4
-1
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 9a.

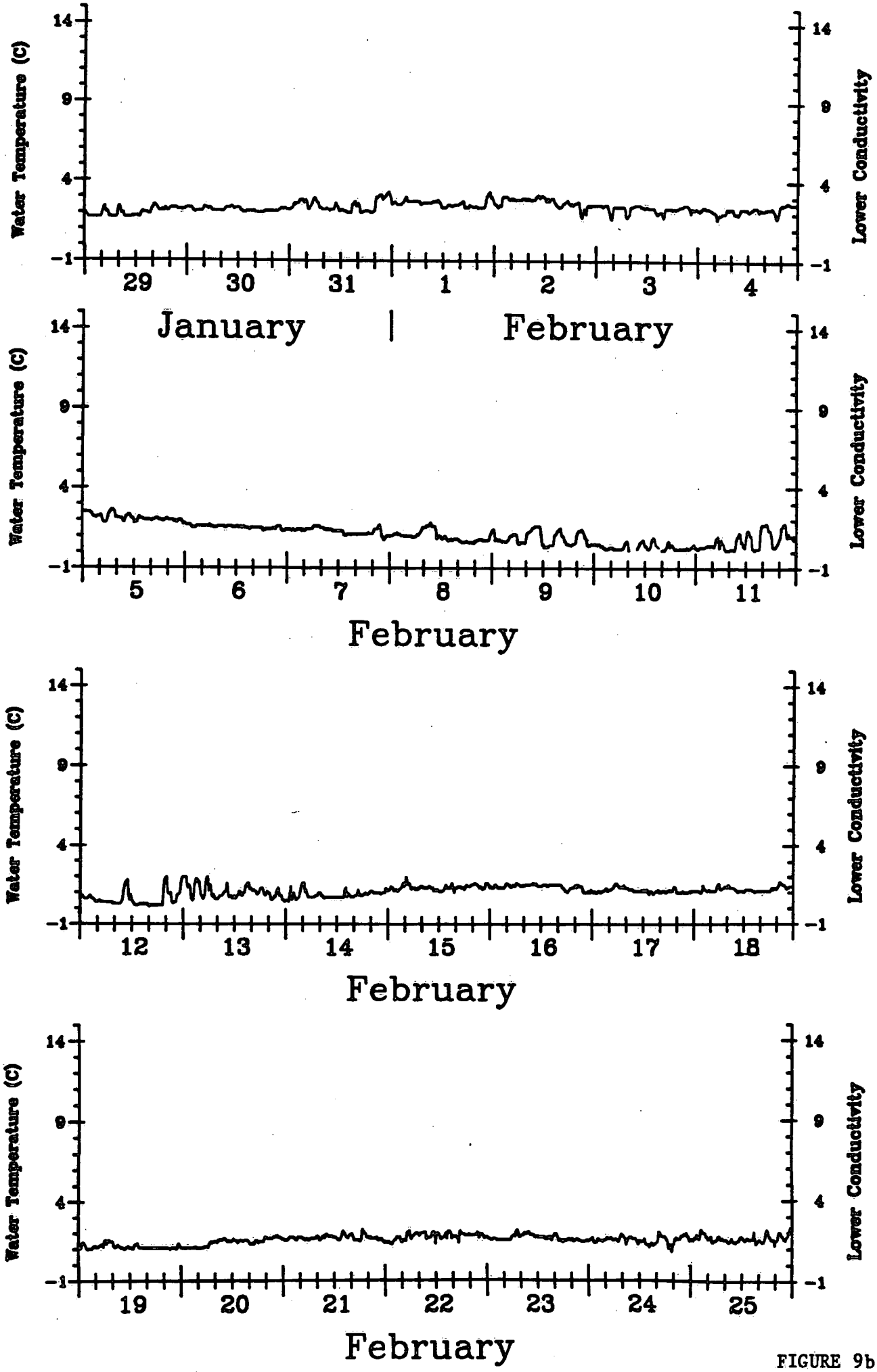
Water Temperature (C)
Lower Conductivity
14
9
4
-1
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 9b.

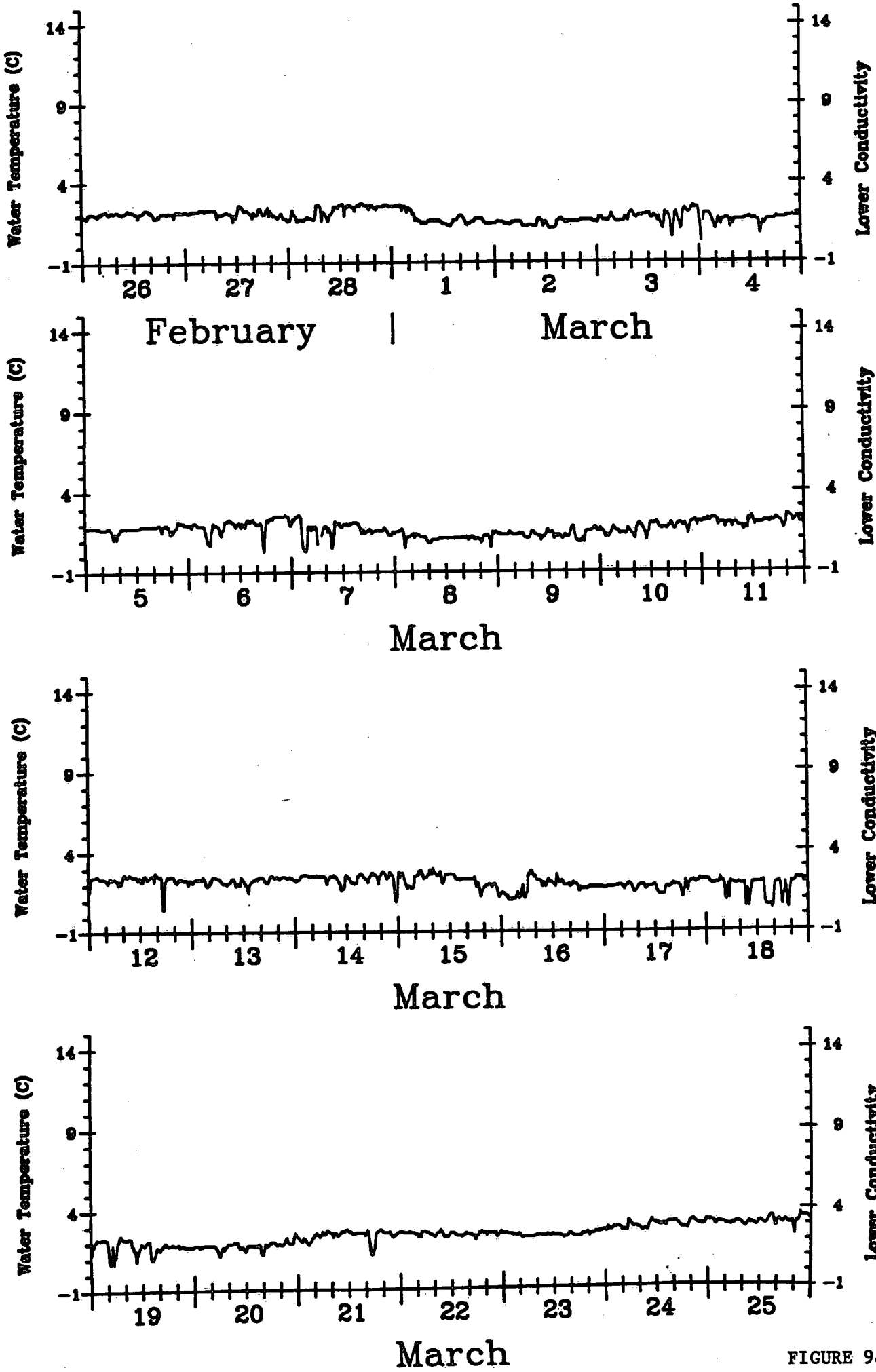
Water Temperature (C)
Lower Conductivity
14
9
4
-1
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 9c.

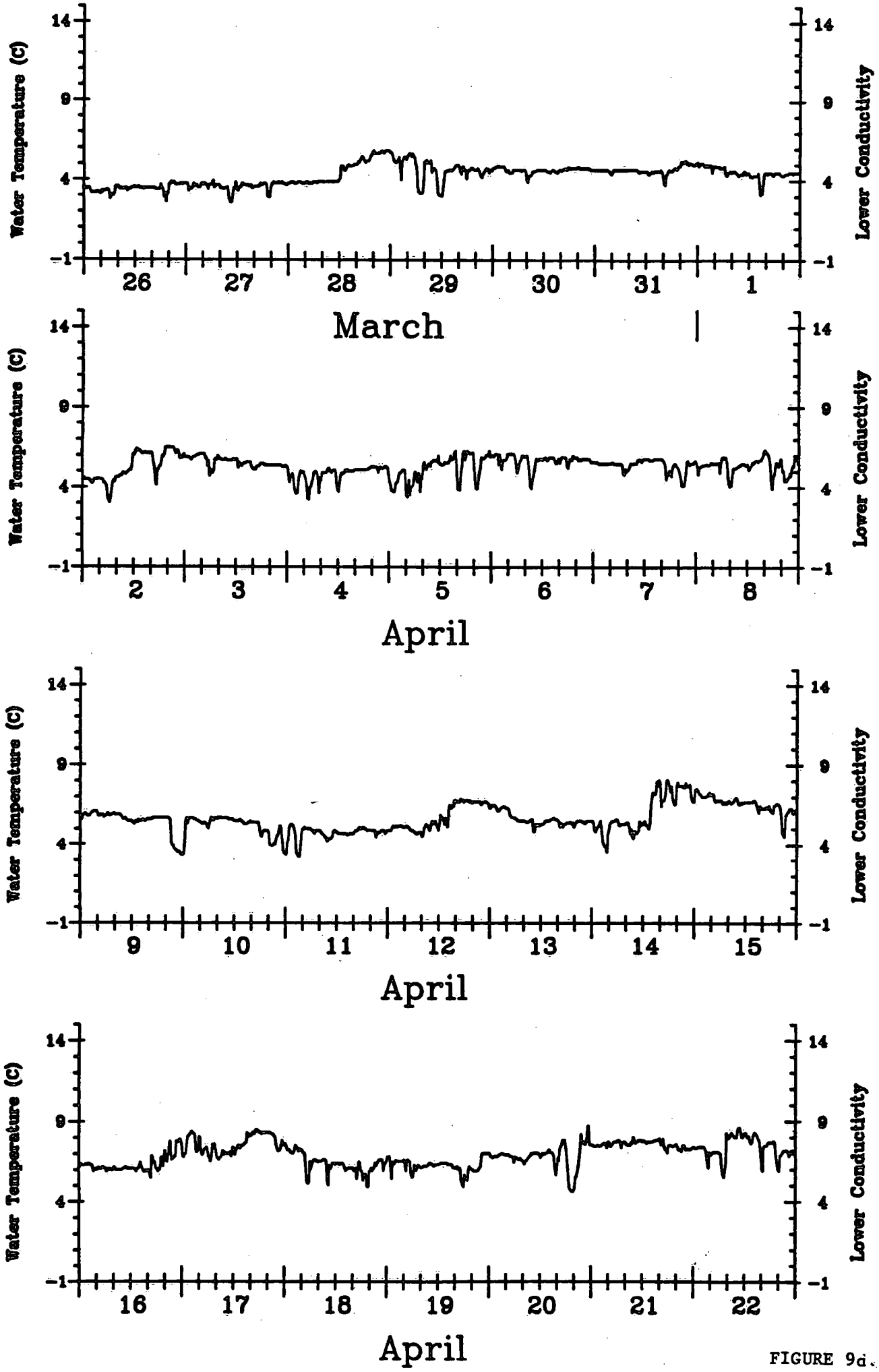
Water Temperature (C)
Lower Conductivity
14
9
4
-1
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 9d.

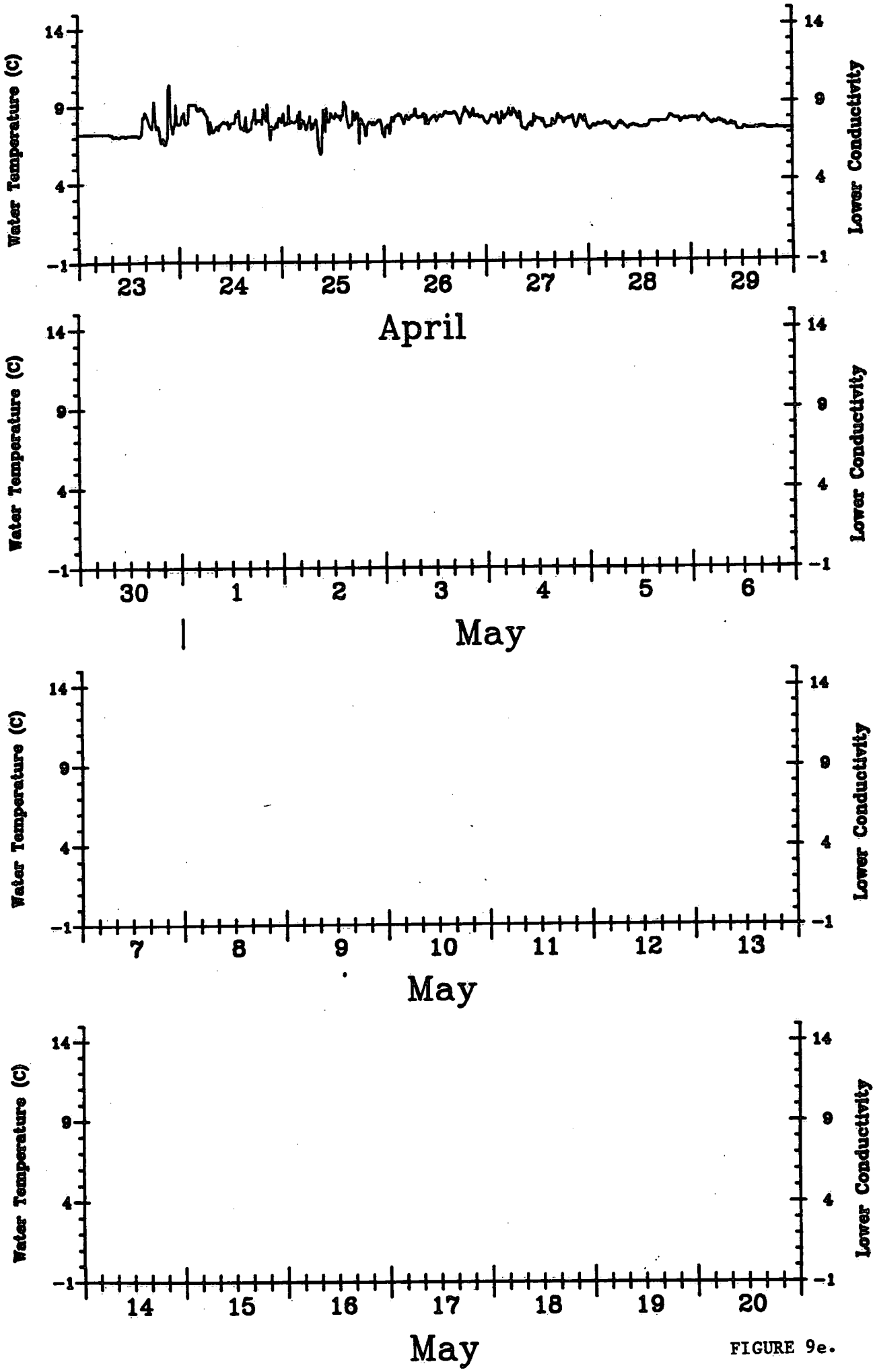
Water Temperature (C)
Lower Conductivity
14
9
4
-1
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 9e.

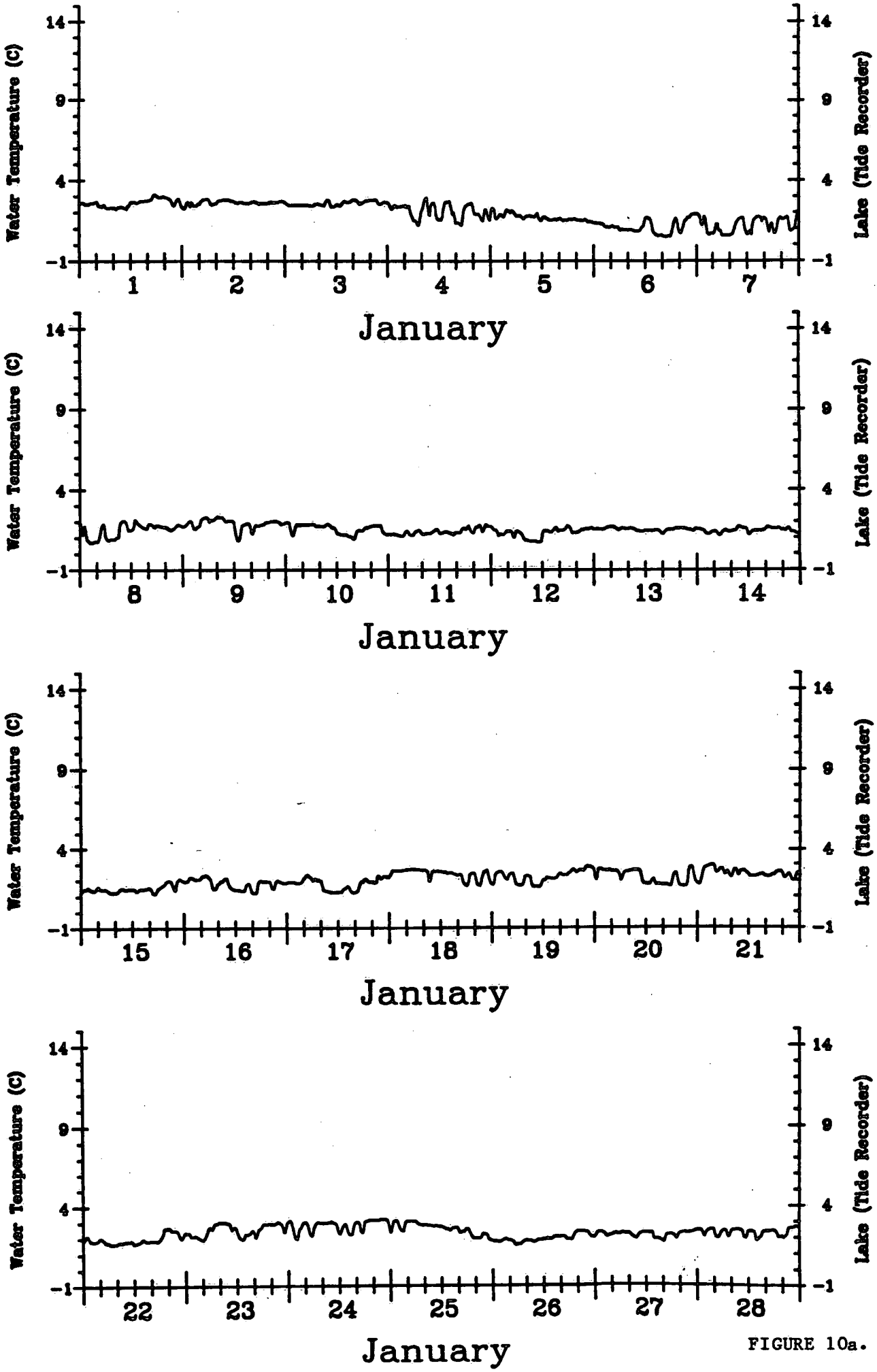
Water Temperature (C)
Lake (Tide Recorder)
14
9
4
-1
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 10a.

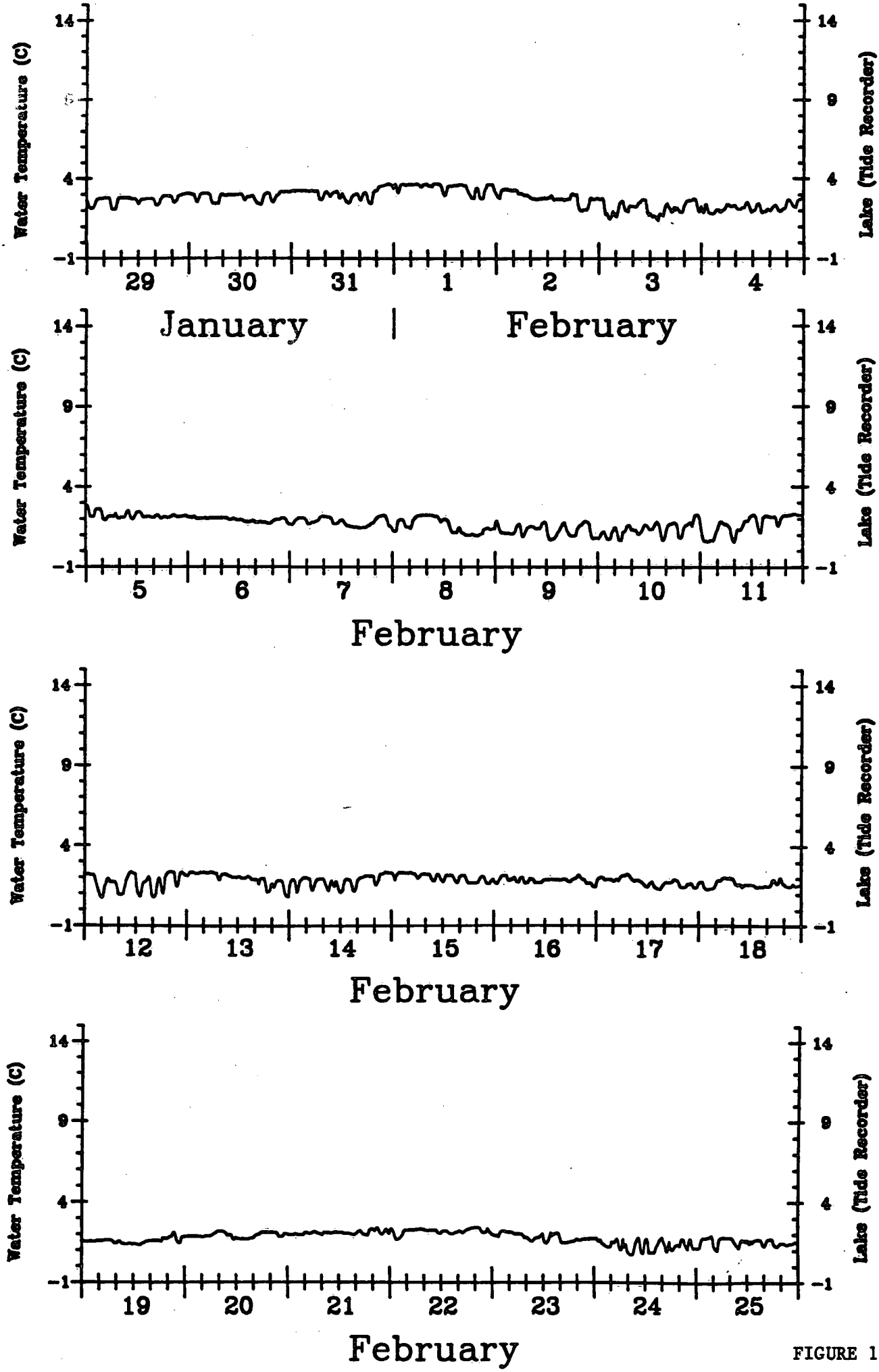
Water Temperature (C)
Lake (Tide Recorder)
14
9
4
-1
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 10b.

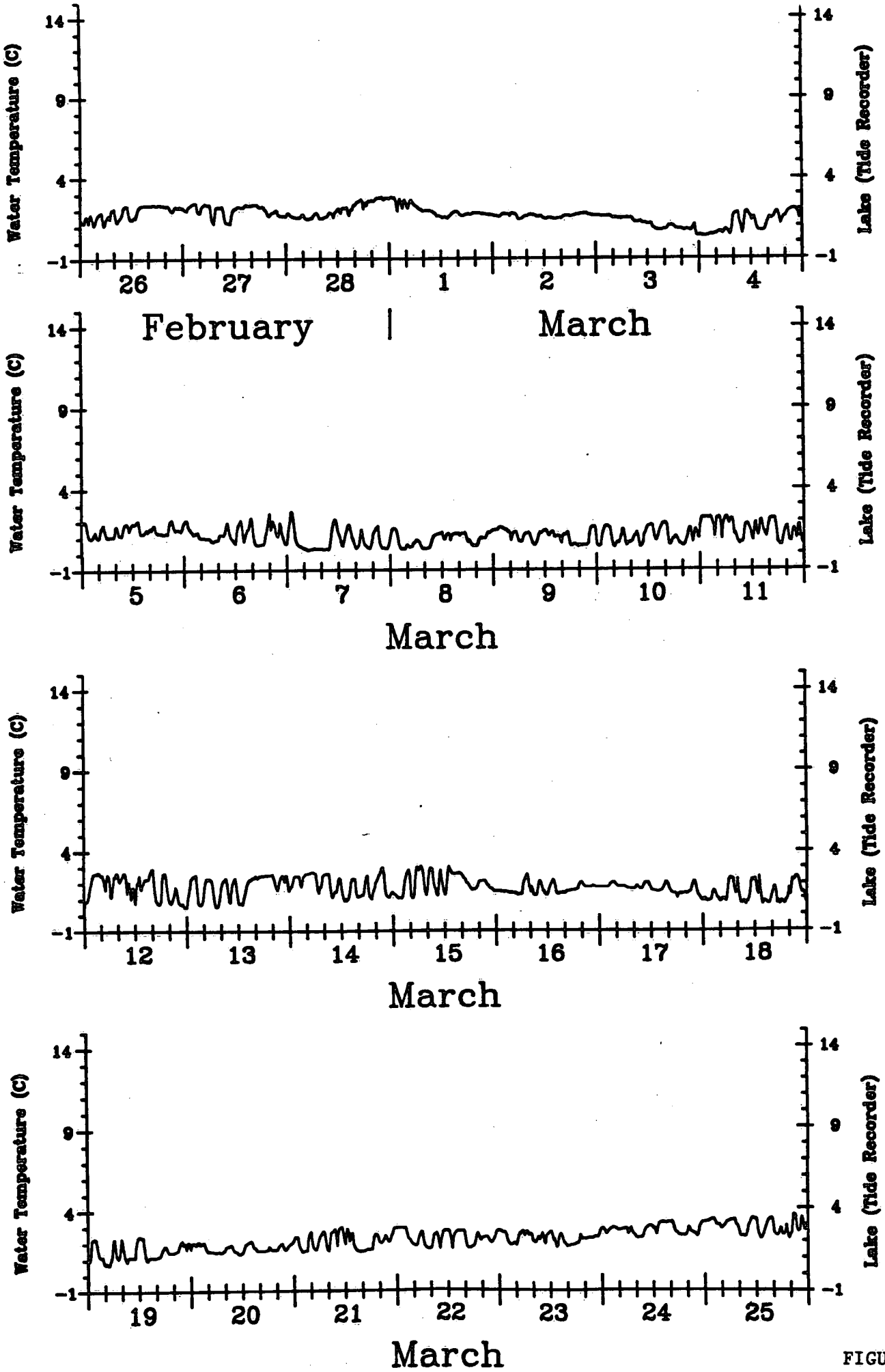
Water Temperature (C)
Lake (Tide Recorder)
14
9
4
-1
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 10c.

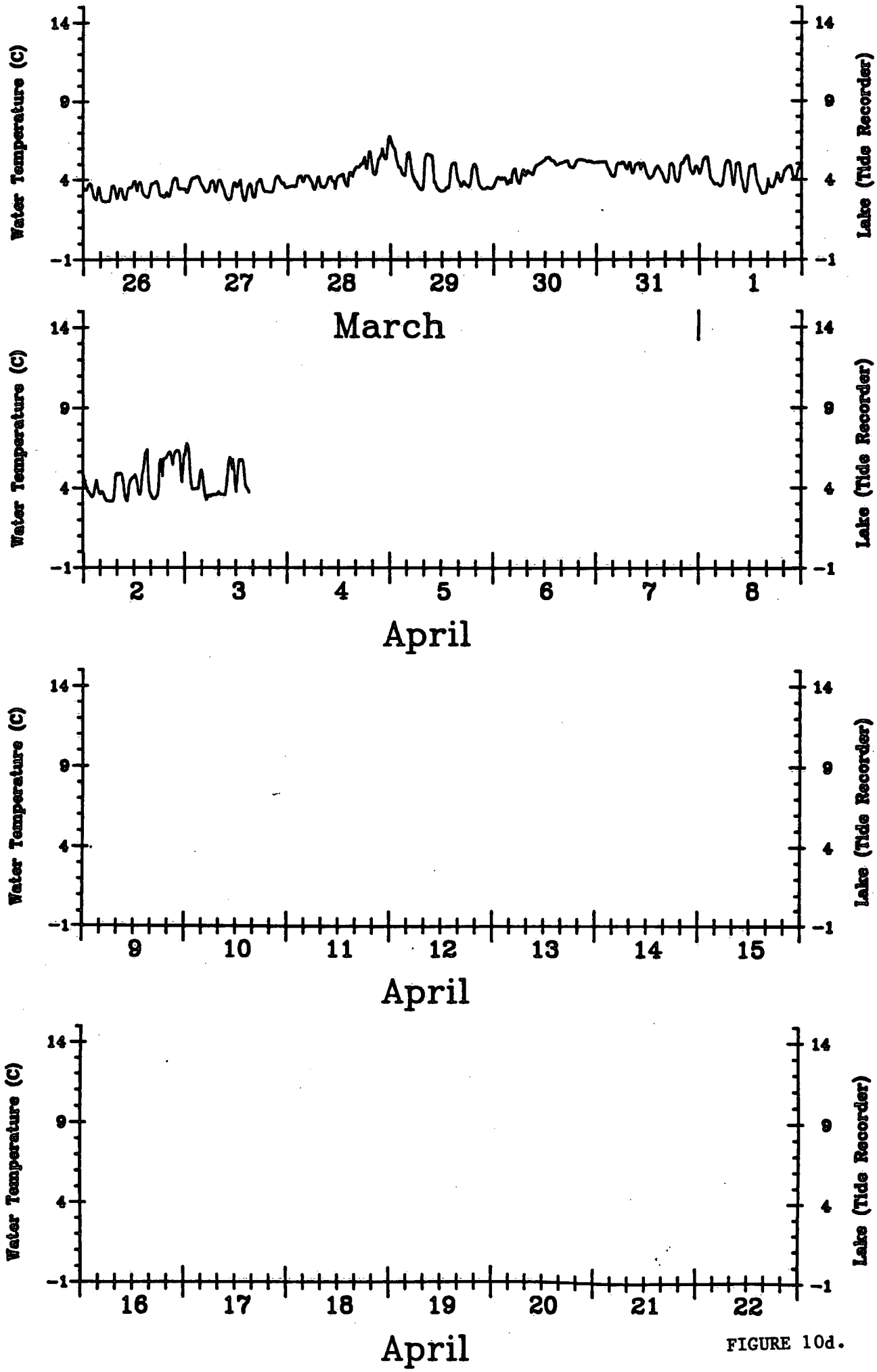
Water Temperature (C)
Lake (Tide Recorder)
14
9
4
-1
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 10d.

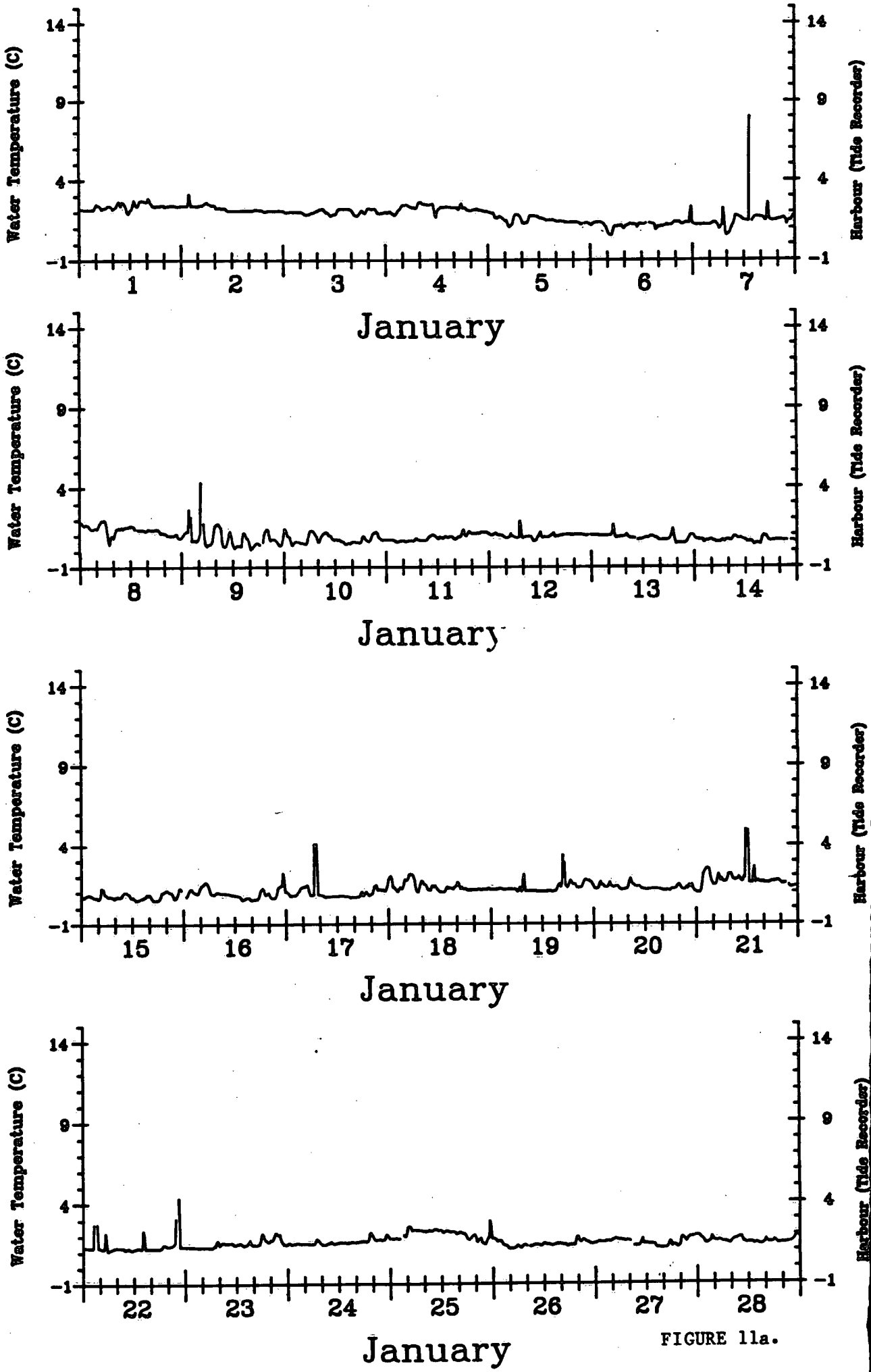
Water Temperature (C)
Harbour (Tide Recorder)
14
9
4
-1
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
January
15
16
17
18
19
20
21
January
22
23
24
25
26
27
28
January

FIGURE 11a.

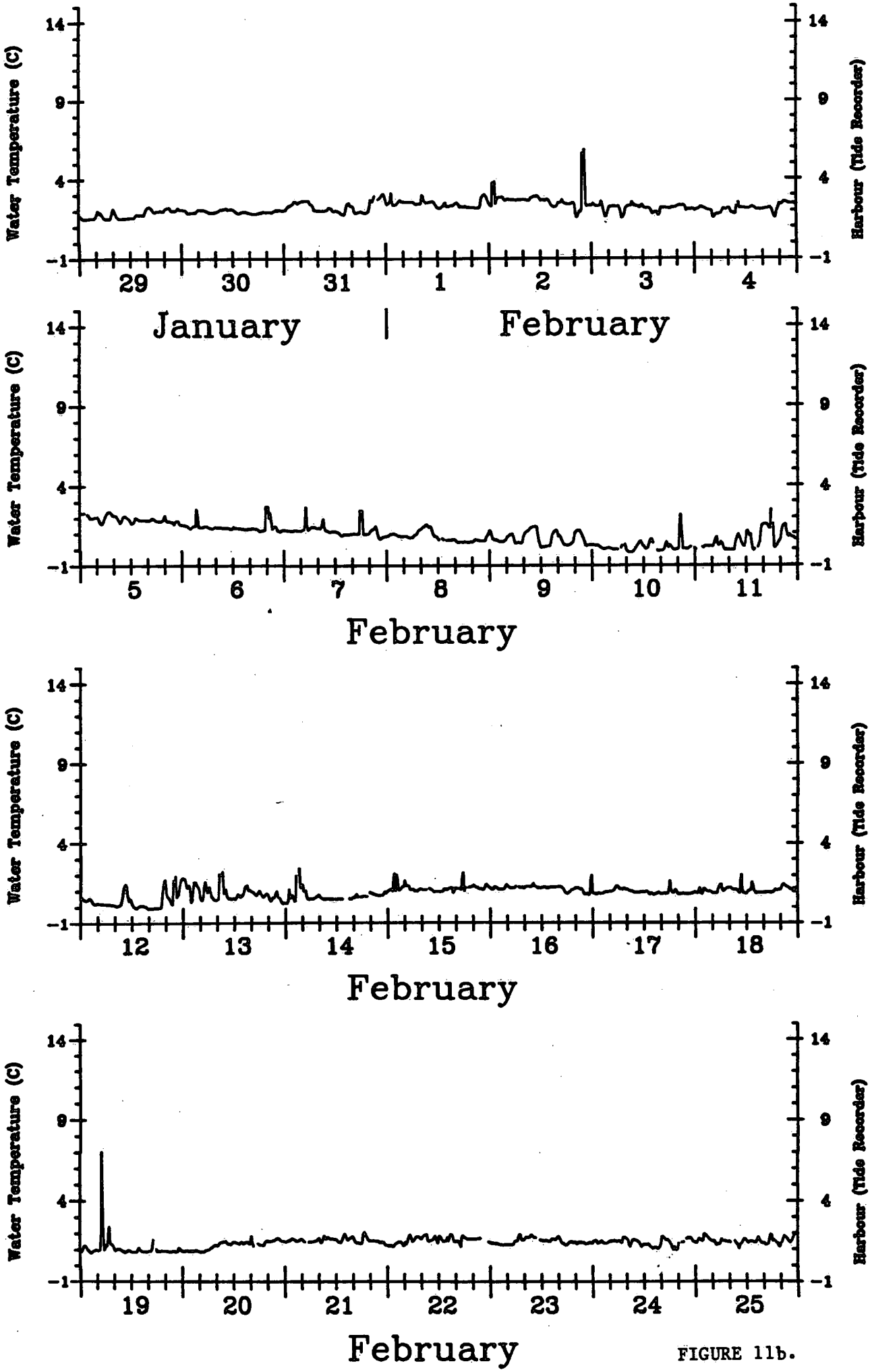
Water Temperature (C)
Harbour (Tide Recorder)
14
9
4
-1
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 11b.

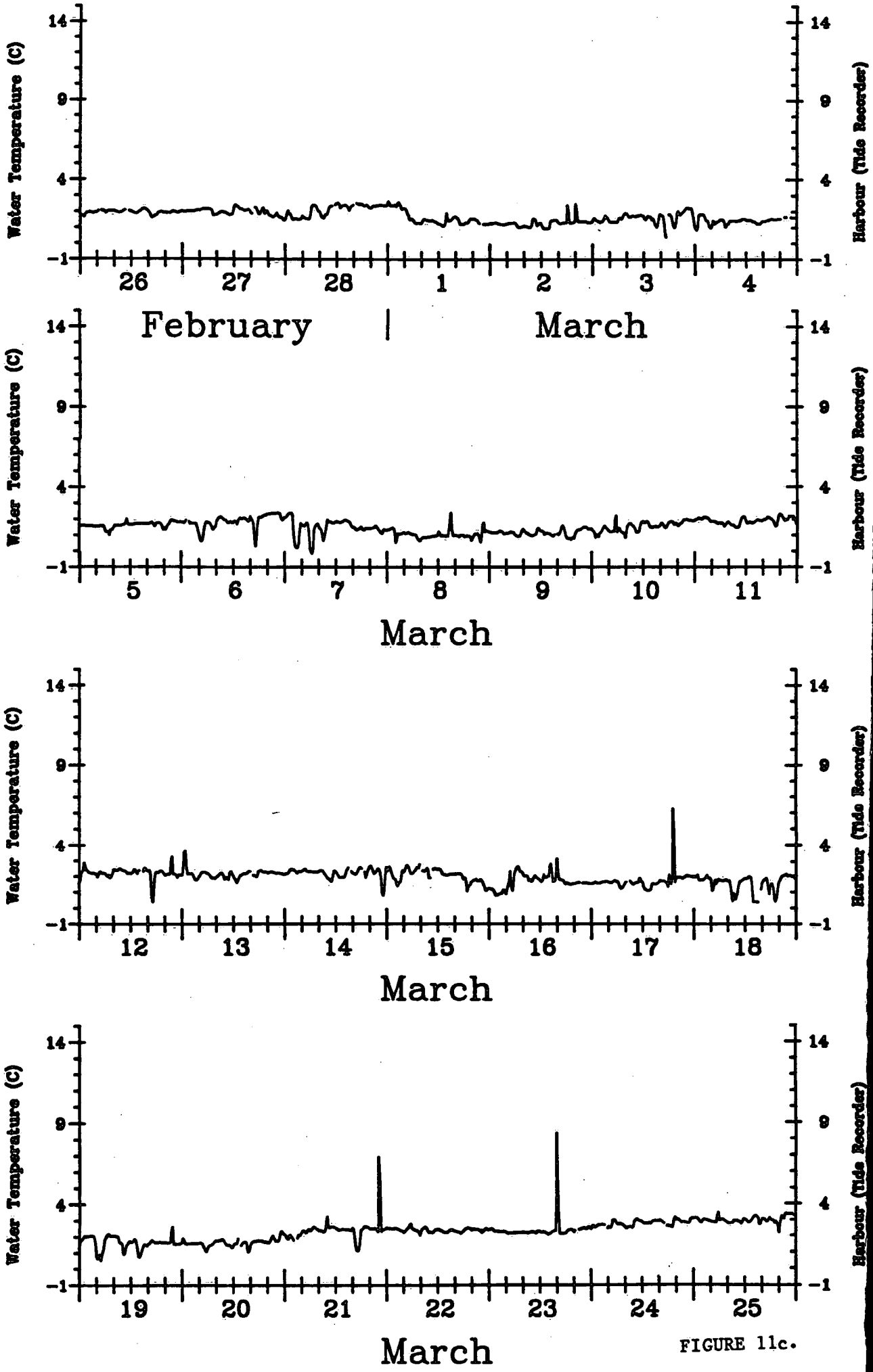
Water Temperature (C)
Harbour (Tide Recorder)
14
9
4
-1
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 11c.

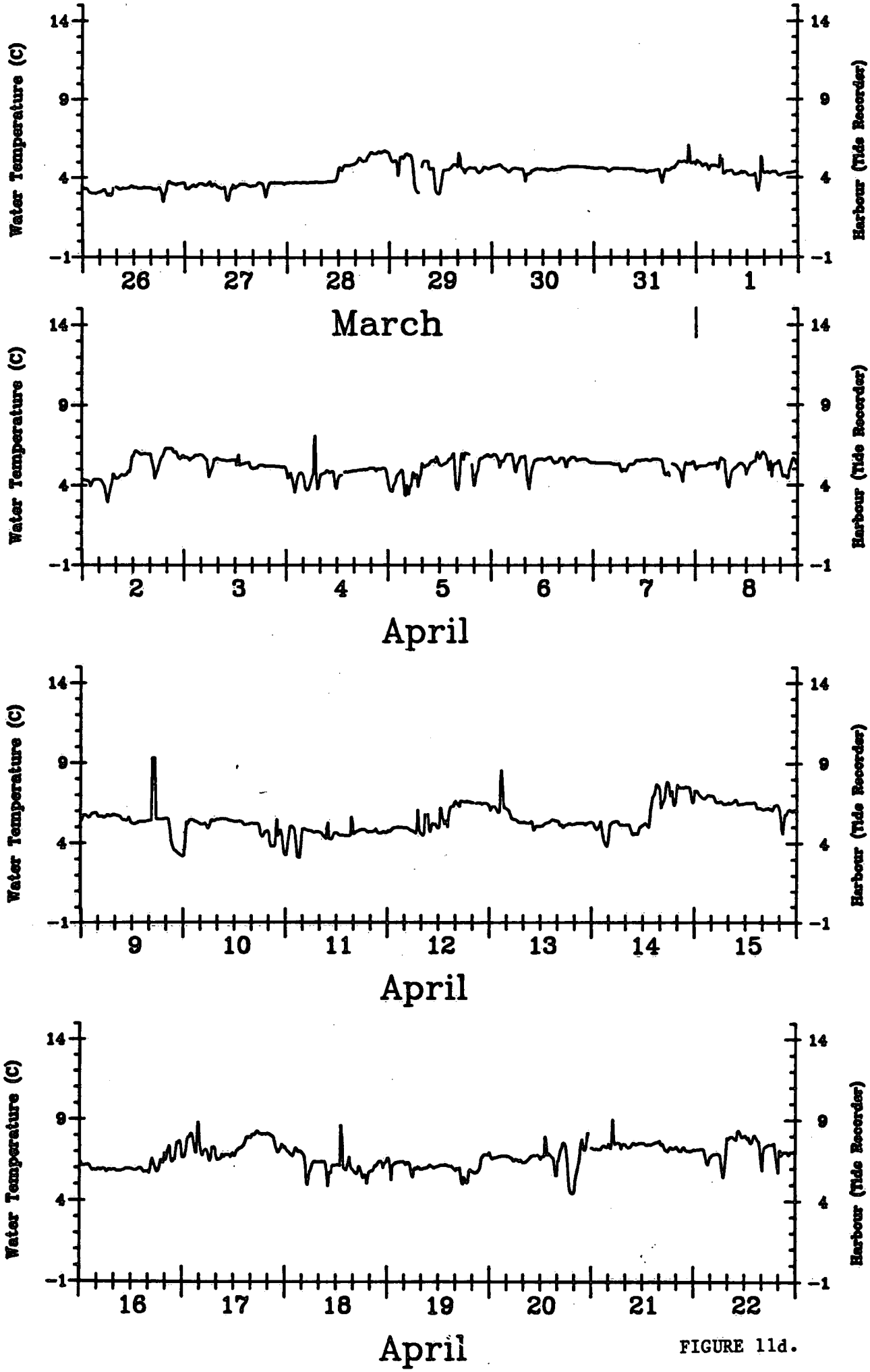
Water Temperature (C)
Harbour (Tide Recorder)
14
9
4
-1
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 11d.

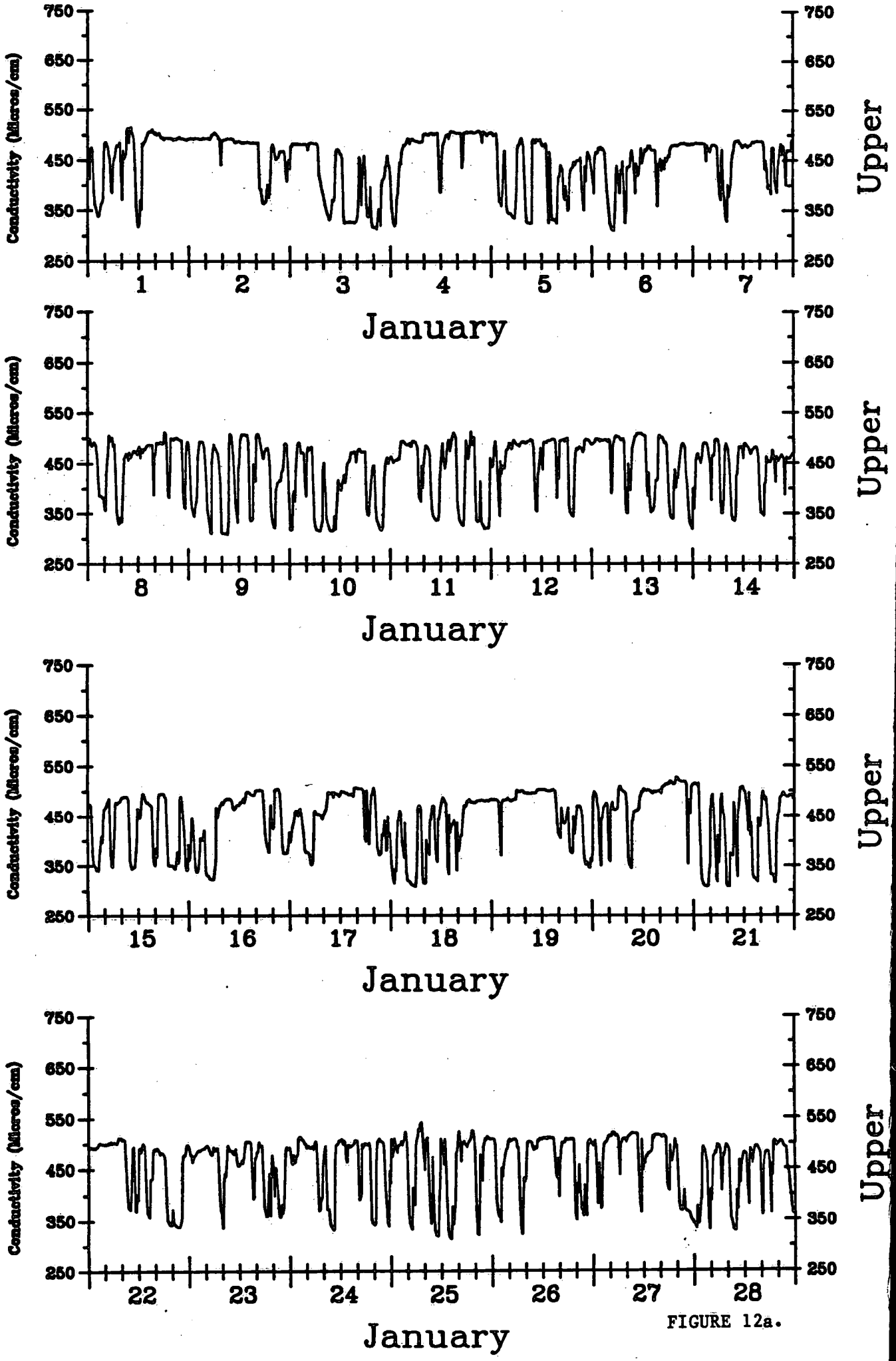
Conductivity (Micros/cm)
750
650
550
450
350
250
1
2
3
4
5
6
7
January
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
Upper

FIGURE 12a.

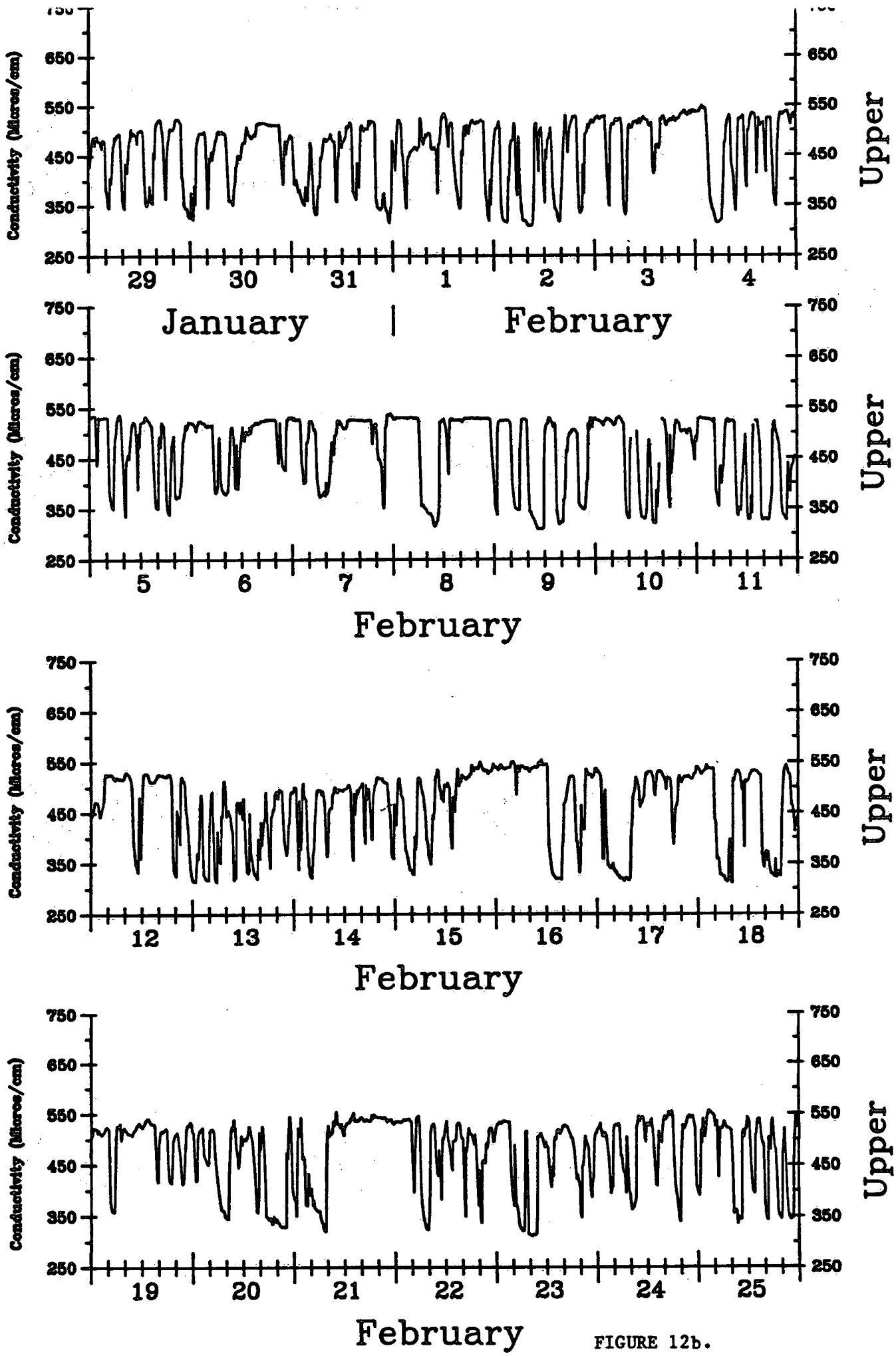
Conductivity (Micros/cm)
750
650
550
450
350
250
Upper
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 12b.

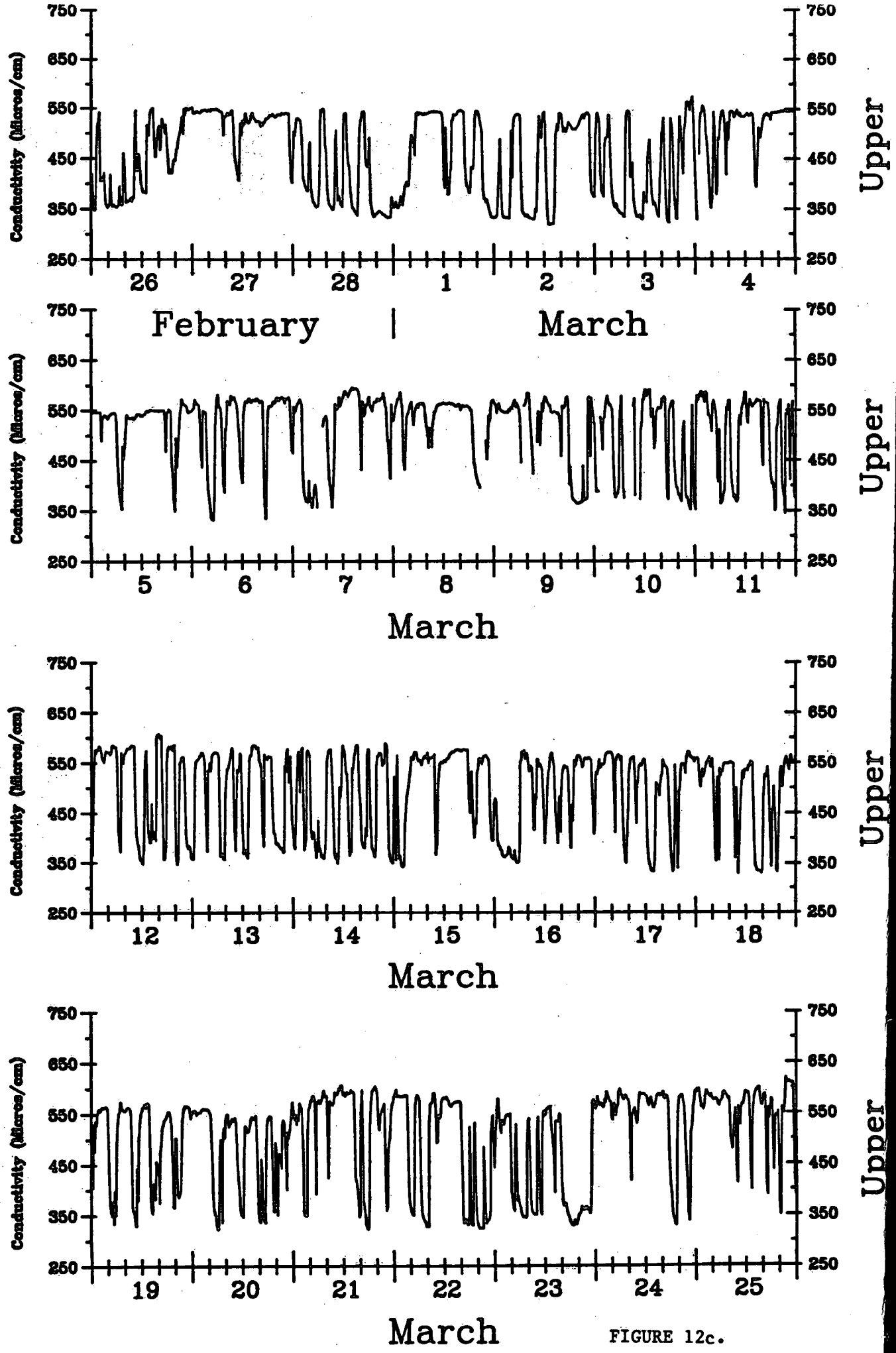
Conductivity (Micros/cm)
750
650
550
450
350
250
Upper
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 12c.

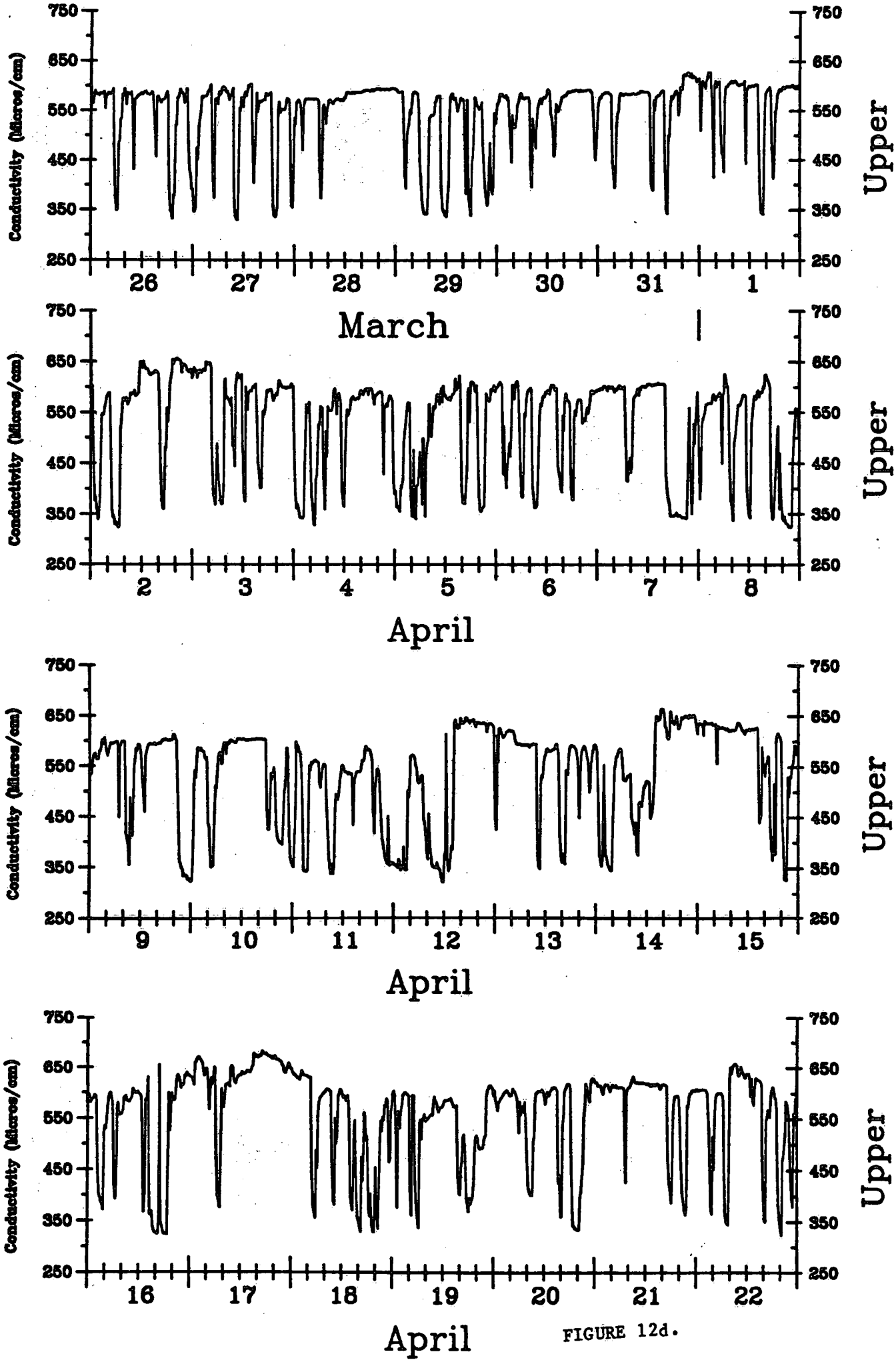
Conductivity (Micros/cm)
750
650
550
450
350
250
Upper
26
27
28
29
30
31
1
March
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
April
16
17
18
19
20
21
22
April

FIGURE 12d.

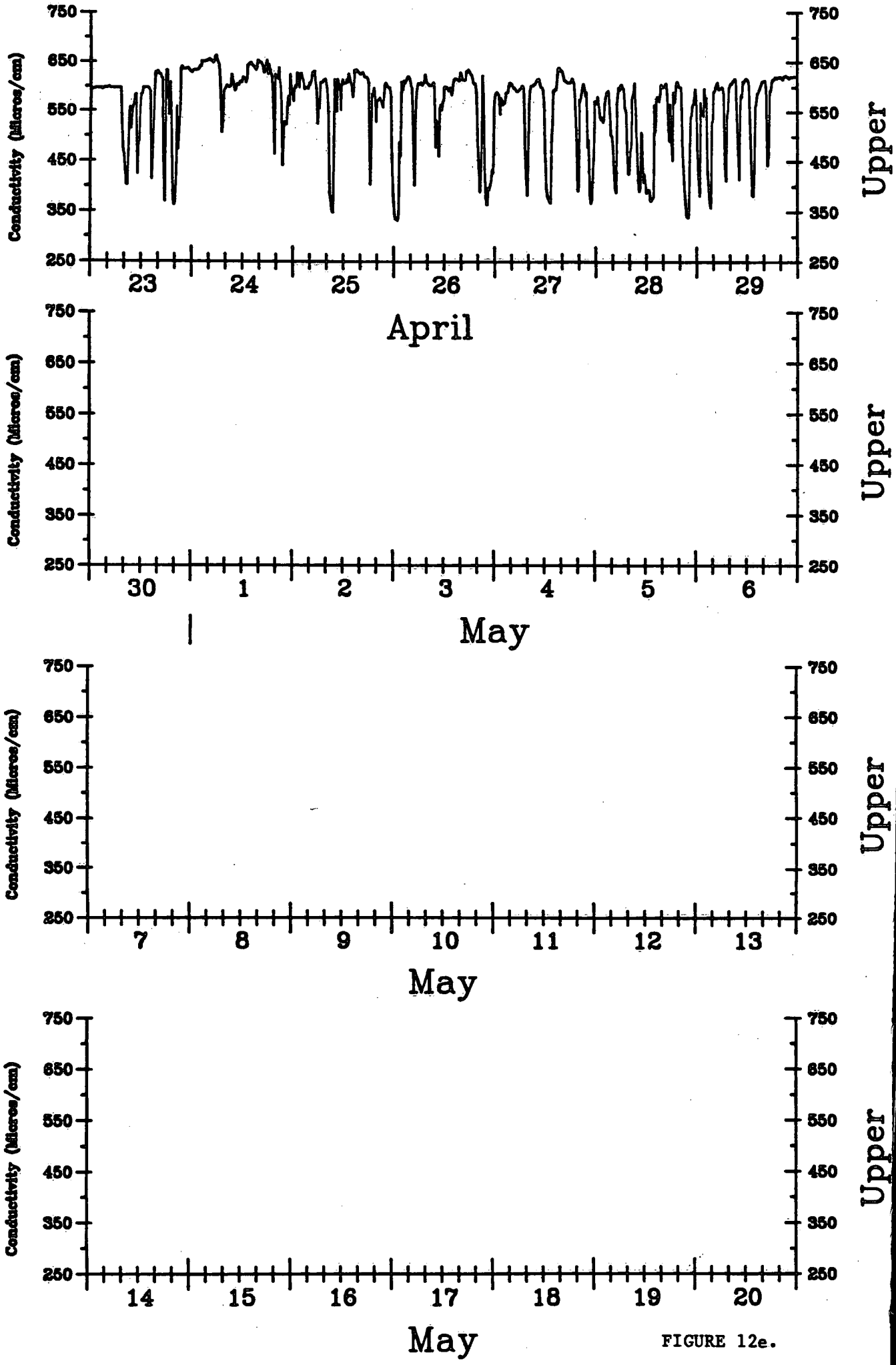
Conductivity (Microns/cm)
750
650
550
450
350
250
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May
Upper
Upper
Upper
Upper

FIGURE 12e.

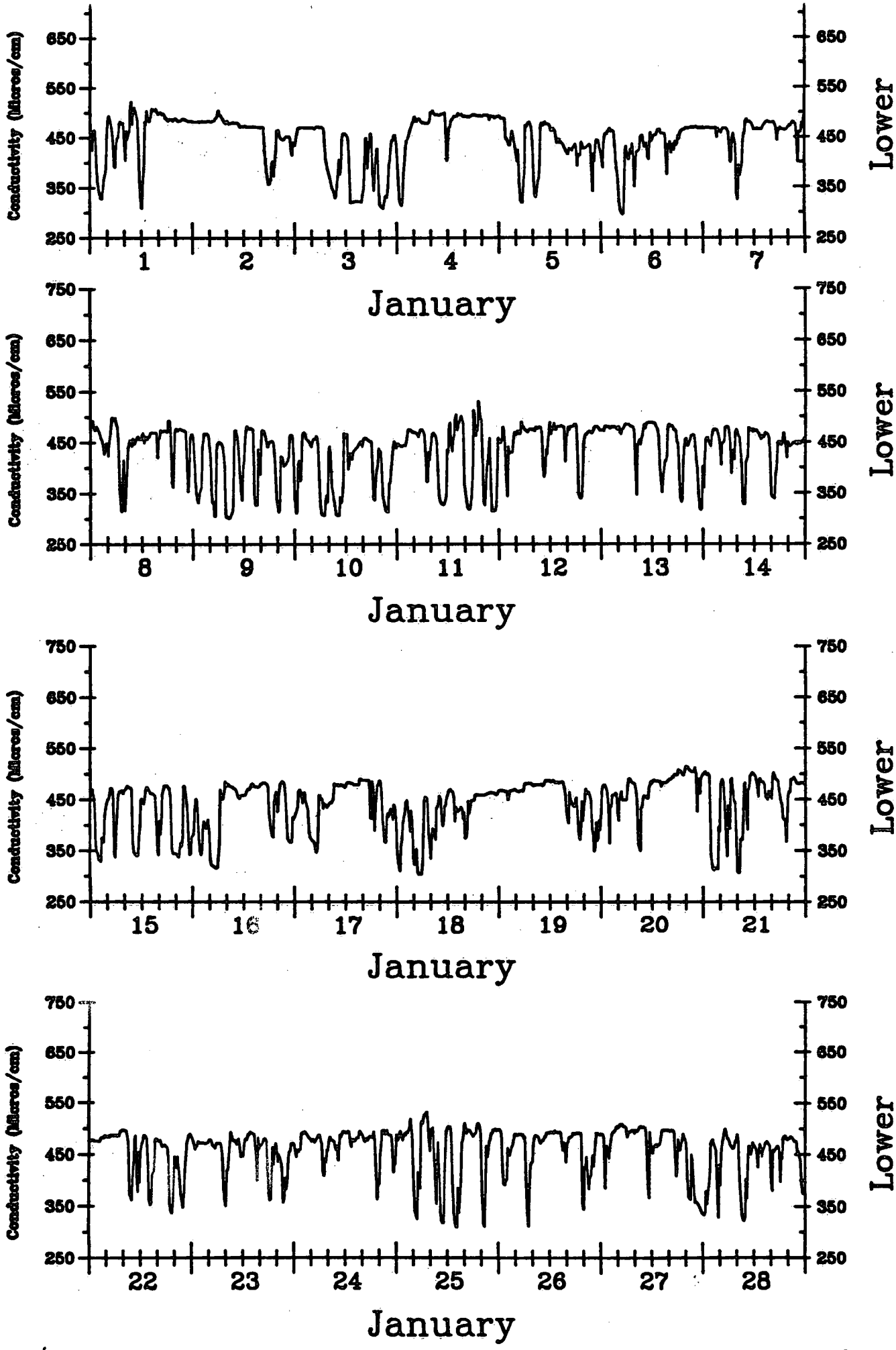
Conductivity (Micros/cm)
650
550
450
350
250
750
Lower
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
January

FIGURE 13a.

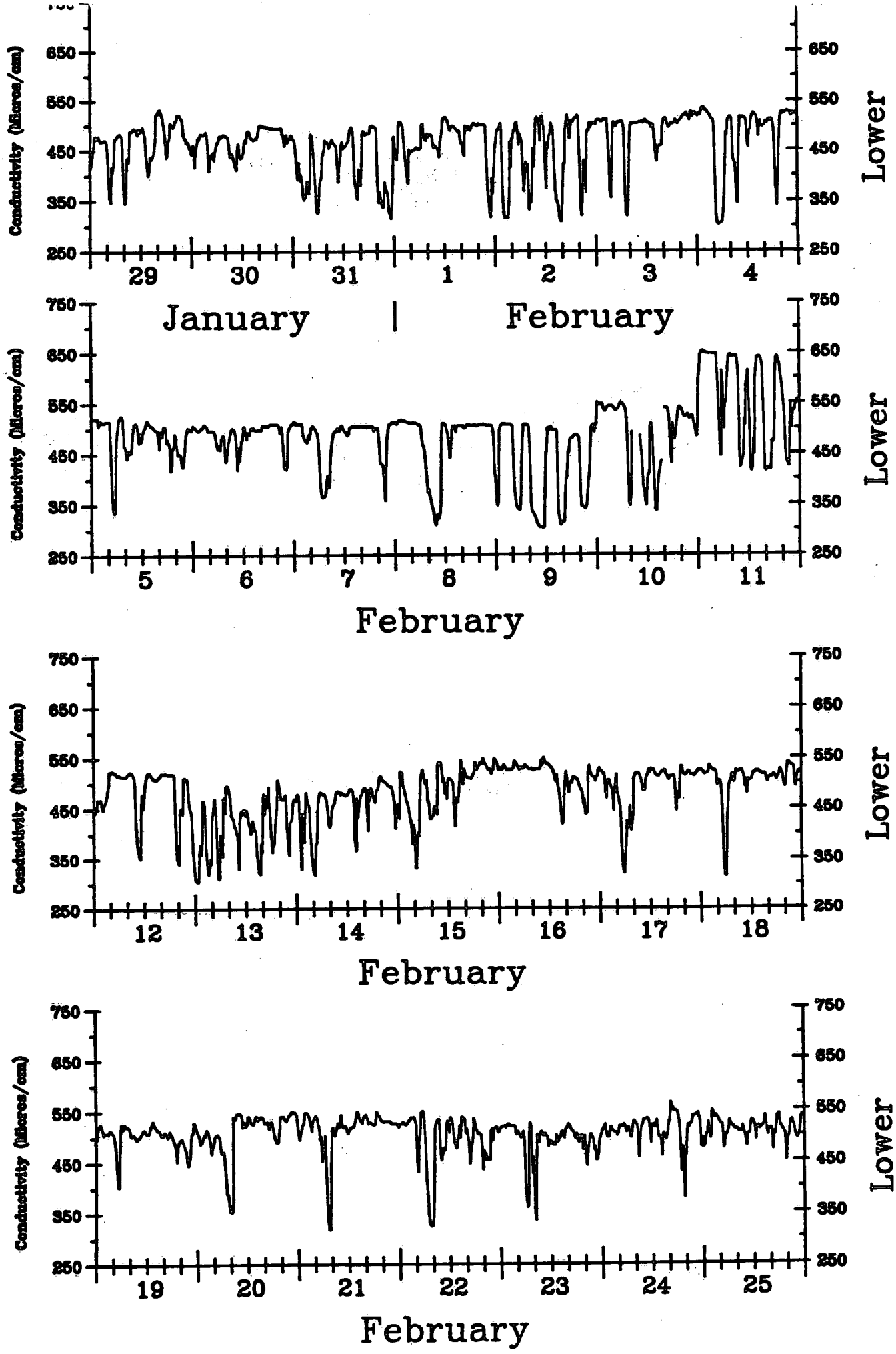
Conductivity (Microns/cm)
750
650
550
450
350
250
Lower
29
30
31
1
2
3
4
January
February
5
6
7
8
9
10
11
February
12
13
14
15
16
17
18
February
19
20
21
22
23
24
25
February

FIGURE 13b.

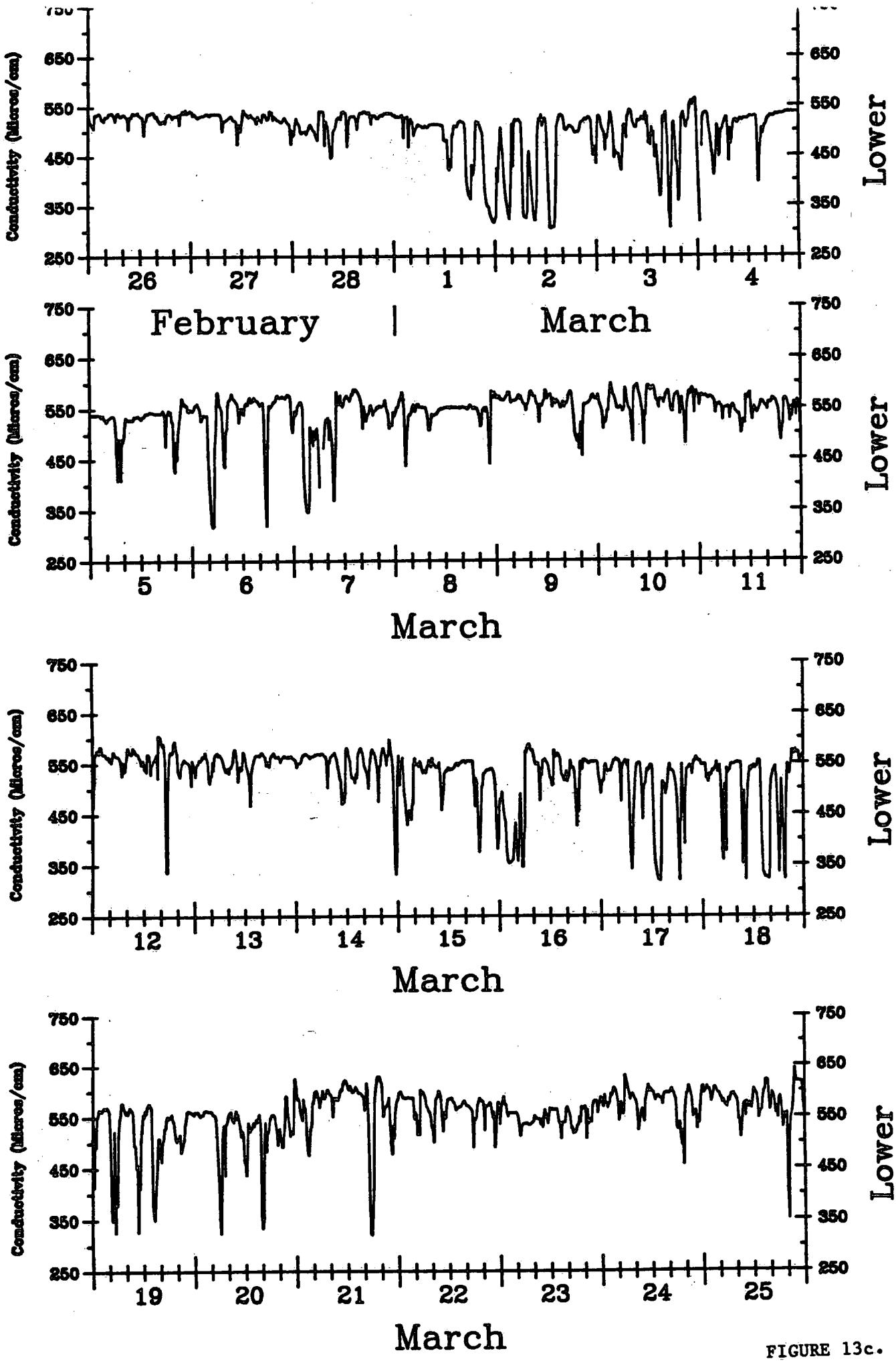
Conductivity (Micros/cm)
750
650
550
450
350
250
Lower
26
27
28
1
2
3
4
February
March
5
6
7
8
9
10
11
March
12
13
14
15
16
17
18
March
19
20
21
22
23
24
25
March

FIGURE 13c.

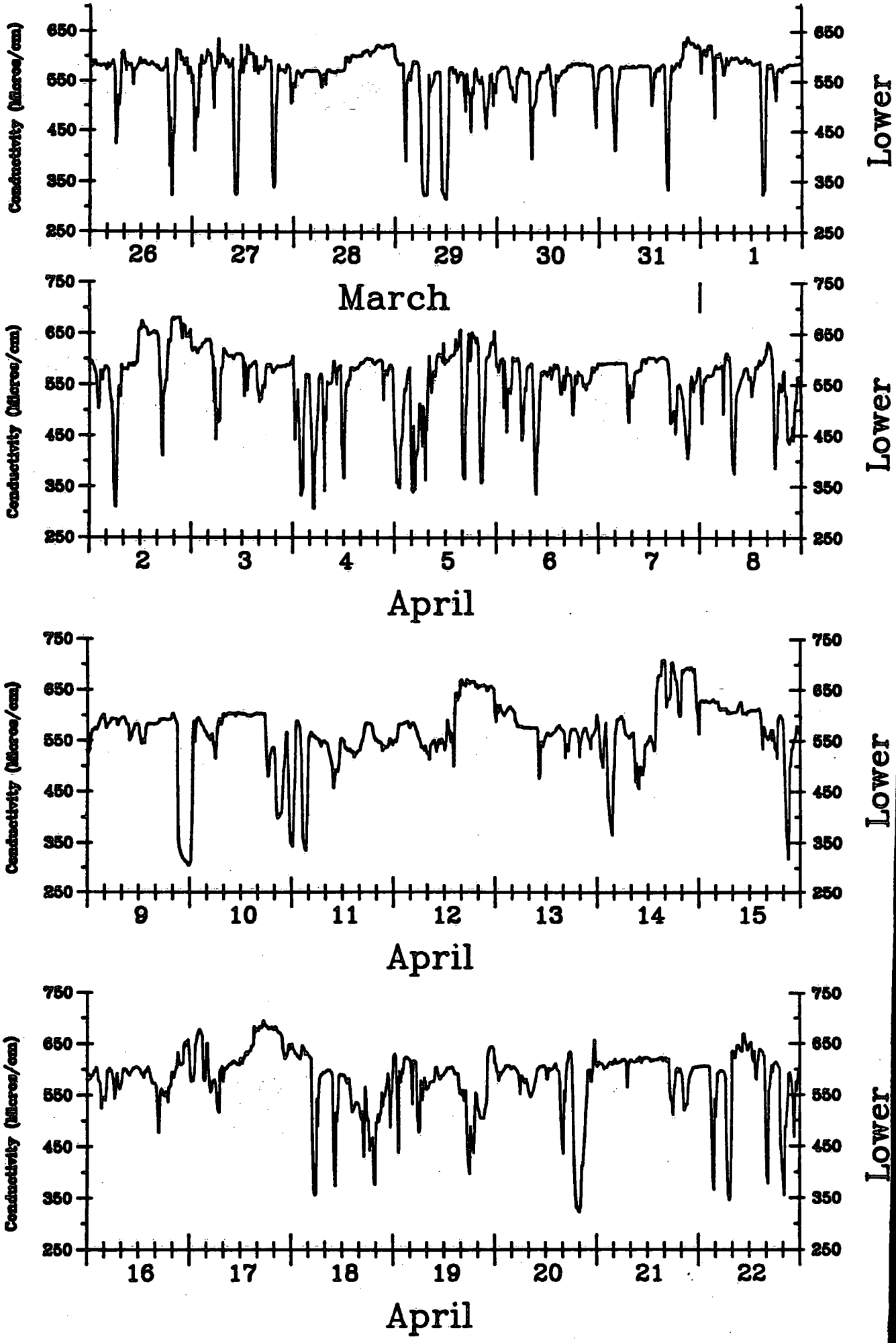
Conductivity (Micros/cm)
650
550
450
350
250
26
27
28
29
30
31
1
March
750
2
3
4
5
6
7
8
April
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Lower

FIGURE 13d.

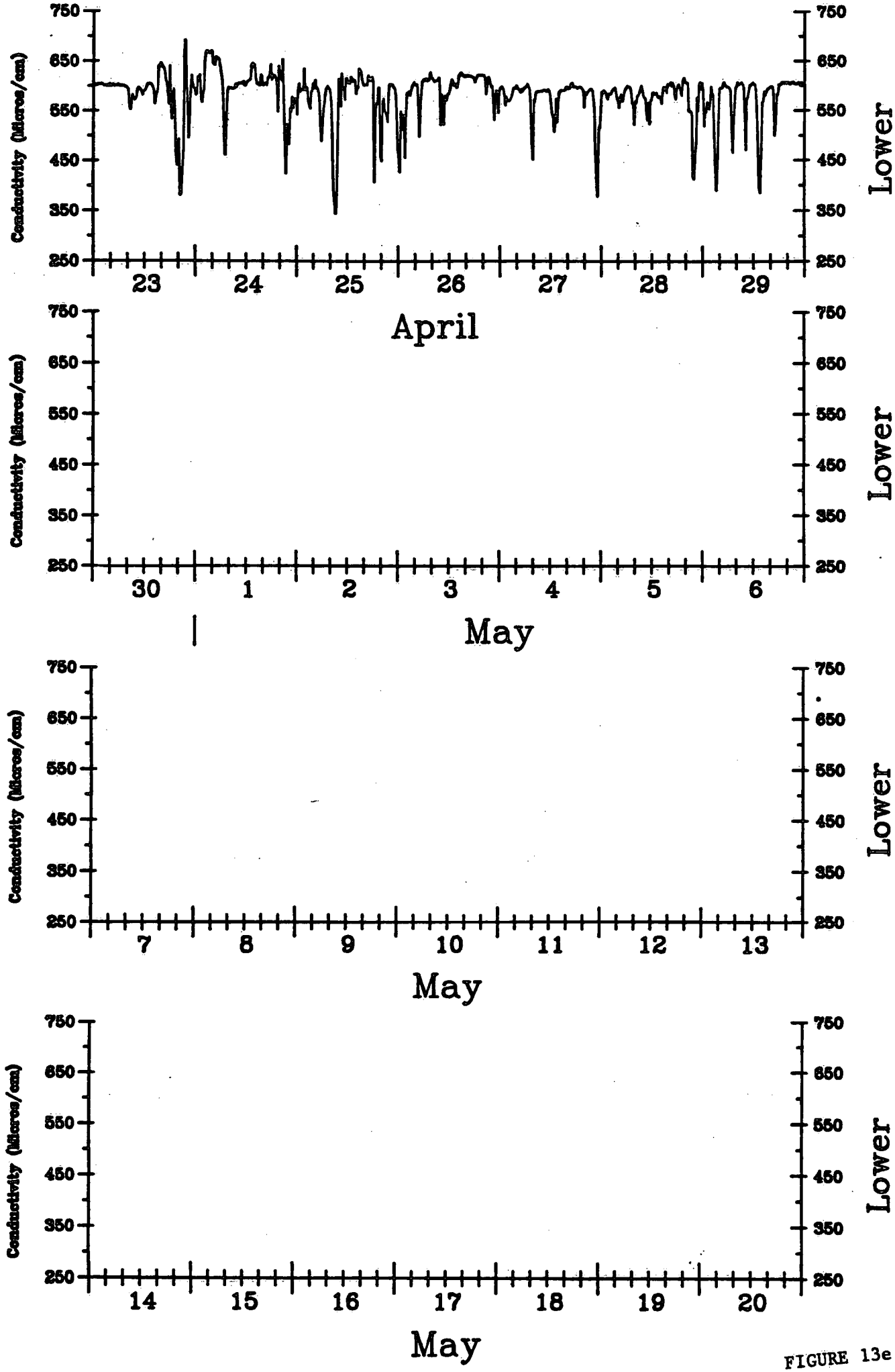
Conductivity (Micros/cm)
750
650
550
450
350
250
Lower
23
24
25
26
27
28
29
April
30
1
2
3
4
5
6
May
7
8
9
10
11
12
13
May
14
15
16
17
18
19
20
May

FIGURE 13e.

NATIONAL WATER RESEARCH INSTITUTE
P.O. BOX 5050, BURLINGTON, ONTARIO L7R 4A6

Environment Canada Environnement Canada

Canada

INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX
C.P. 5050, BURLINGTON (ONTARIO) L7R 4A6