Digitizing and Processing Drum-Type (Analog) Data Charts: A Manual

by

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Preface

Recently developed electronic data-logging systems, which combine microchip storage capability with digital computers, are capable of directly recording data in digital form ready for numerical analysis. For large-scale applications the utilization of such an electronic data-logging system can be cost prohibitive. Mechanical drum-type data recorders have enjoyed and continue to enjoy popularity both in the field and in the laboratory. Graphic information must be manually translated into numbers to be amenable to numerical analysis. This interpretation procedure is often tedious and time-consuming. For scientific investigations involving continuous monitoring activities, such as the ongoing groundwater recharge assessment project of the Big Bend Groundwater Management District No. 5 (GMD5), manual interpretation of accumulated recording charts becomes a major undertaking. An automated chart interpretation process is undoubtedly in need.

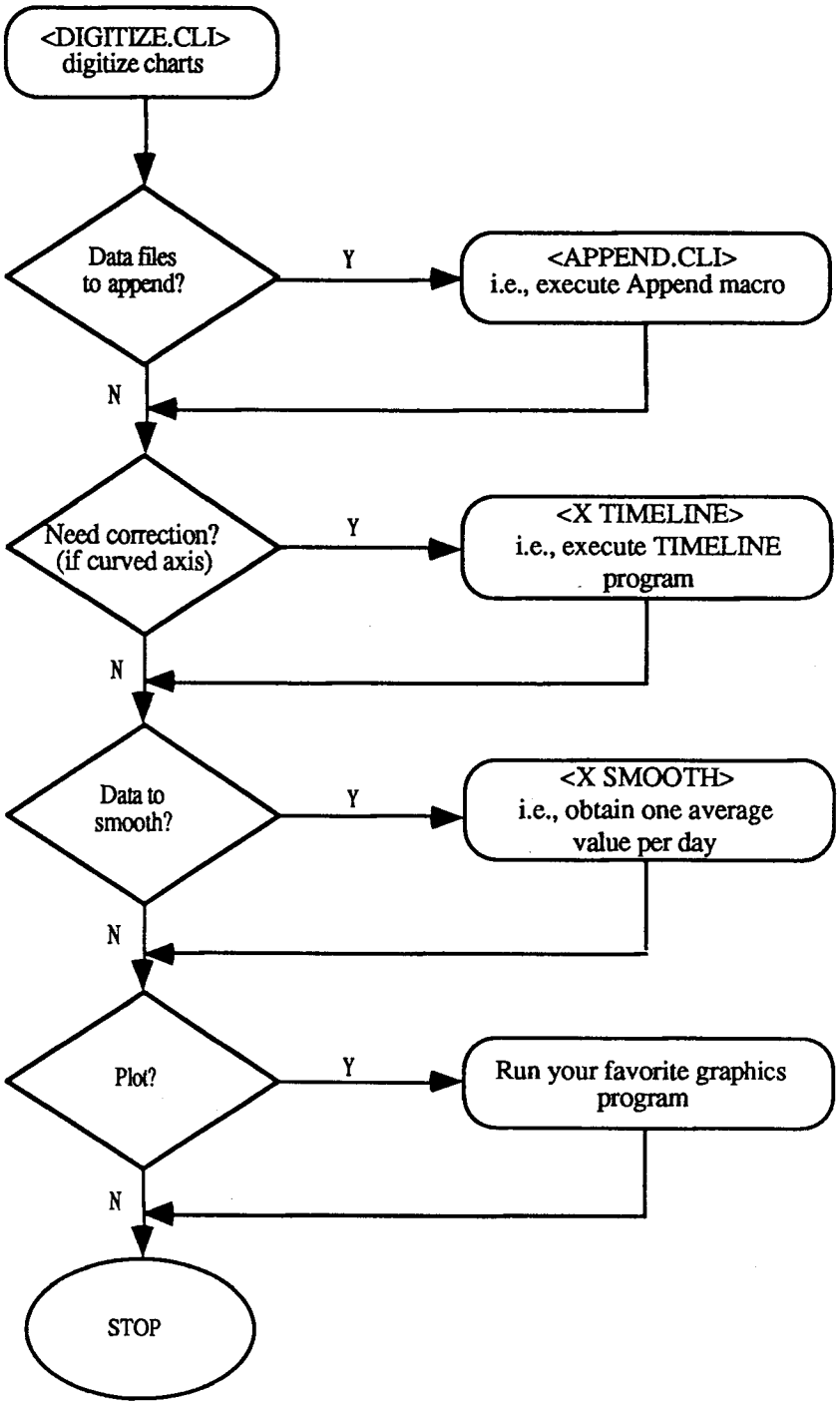
A rectilinear digitizer is designed to identify a data point on a Cartesian coordinate system. By placing the digitizer's cursor over a data point and pressing a button, the digitizer will capture the x and y coordinates and transmit them to a computer. Our experience indicates that using the digitizer for automatic interpretation of drum-type recording charts is fast and accurate.

This report is a manual for digitizing and manipulating field-recorded meteorologic and hydrologic data on analog charts. In fact, any rectilinear or curved chart (arc-shaped time-line event-recording chart) can be handled using the procedures of this manual. The programs employed are written in FORTRAN 77 for the Data General MV20000 super minicomputer (AOS/VS operating system). The digitizing system employed consists of a GTCO corporation-made DIGI-PAD (3648L) digitizing table, and a Raster Technologies graphics terminal (model ONE/10). The impetus for developing this analog chart digitizing and processing system was provided by the KGS–GMD5 cooperative project on field assessment of groundwater recharge in the GMD5 district.

Any suggestions for improving this manual and making it more user-friendly are welcome.

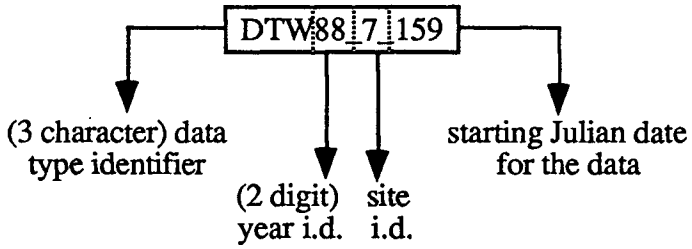
1. Chart Processing Flowchart

The following flowchart is intended to illustrate the general process followed to digitize and manipulate data from chart recorder instruments in the field.



2. Naming Data Files

Files are named in a certain sequence to indicate the type of data, period, and site number for the data. For example:



The site identifier may be alphanumeric. Some of the presently used data type identifiers are:

DTW	depth to water
BAR	barometric pressure (mbar)
HUM	humidity
TMP	temperature
PYR	pyranograph (radiation)
BRW	(weekly) barometric pressure (in. Hg.)
BRM	(monthly) barometric pressure (in. Hg.)

BAR, HUM, and TMP data are recorded simultaneously on the same chart.

3. Digitizing Field Charts

3.1 Getting Started

•Set control switch to DIGITIZER (instead of Dasher).
•Switch on the digitizer.
•Call operator (ext. 354) to disable console (currently terminal #93).
•Log on.

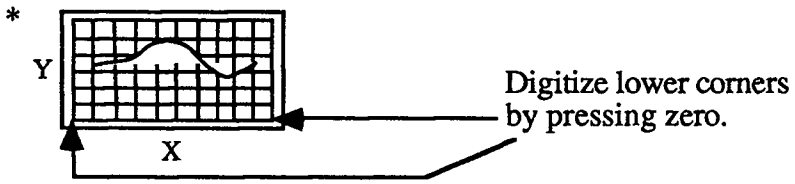
The modified program Prog_digitizer, accessed from the DIGITIZE.CLI macro, forms the interface between the user and the digitizer. A typical session is outlined in what follows.

3.2 A Typical Session

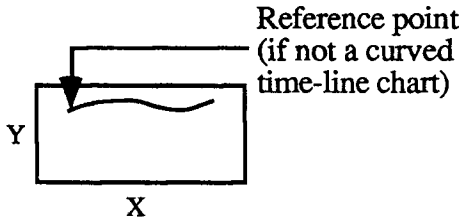
(Terminal Prompt)	Type
	<DIGITIZE>
Data types 1. Barometric pressure 2. Relative humidity 3. Air temperature 4. Mech. pyranograph 5. Microbarograph (monthly) 6. Microbarograph (weekly) 7. Depth to water 8. Other 9. To quit	
Data type = ?	<7> [or other type from list]
Starting date = ?	<1_31_89> [give starting date]
Site = ?	<4> [give site number]
Data file = ?	<Dtw89_4_31> [give file name]
Enter X-scale Enter Y-scale	[refer to following write-up for the data type selected]
Digitize two marker points on the *x* axis (for chart alignment)	[digitize lower corners of chart by pressing zero]*
Digitize reference point	[digitize the reference point for the chart by pressing zero]**
Enter X and Y values of reference point (X = Julian day, Y = *y* axis parameter value)	[refer to following digitizing specifications section for the data type selected. Also see examples of recorded charts on the pages following the specifications.]

Start digitizing	[digitize by pressing 2 on the hand control]***
STOP	[press 3 on the hand control when done with a chart. The program will prompt for new data type]

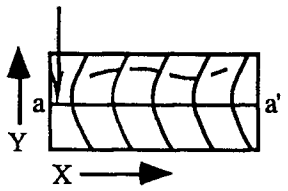
3.3 Notes



**If the data are on a curved (i.e., not rectilinear) chart, then to specify the reference point, refer to section on 5 for the data type selected; otherwise the reference point is the start of the data.



For curved time-line charts, the reference point needs to be somewhere on the radius of curvature *aa'*



For example, if the chart is for air temperature and begins at 12:00 on Jan. 4, then the reference point could be 4.5, 19.89 on the radius of curvature, where 4.5 is the Julian day, and 19.89 is the *y*-axis value of the radius of curvature (see section 5.4).

***Even if the reference point for the data and the starting point coincide, you need to press *2* at that point. That is, press *1* for the reference point and then 2 to start digitizing at that same point. Also, DO NOT HAVE A GAP OF MORE THAN ONE DAY BETWEEN TWO DIGITIZED POINTS. This is to ensure that the SMOOTH program, which along with smoothing also checks for missing days, functions properly.

4. (Hand-Control) Options on the Digitizer Cursor

The following are (hand-control) options on the digitizer. You need to press the appropriate number to perform the corresponding task.

0 Digitize marker points for the axes.

1 Digitize reference point for the graph.

2 Normal digitizing.

3 Quit digitizing a chart.

4 Digitize a new reference point.

5 Open a new output file.

6 Digitize a new reference point (by setting the last digitized value as the new reference value). This is used when the curve wraps around itself because the chart was not changed in the field on time. Refer to example of the barometric pressure chart. This option takes effect during execution of the TIMELINE program. Therefore use this option if digitized data are to be processed by the TIMELINE program (for rectilniear charts use option 4).

7 A handy marker—generally used with pyranograph data to mark the end of a day on the chart. This permits calculation of solar radiation from day to day (see "Pyranograph" in the next section).

8 Initialize or reintialize a constant value to be printed in the third column of the output file. This option is used only when you want each digitized data point to be referenced to some value. For example, a set of digitizied X, Y data corresponding to a certain hydraulic head may be distinguished from another set of X, Y data (corresponding to a different value of hydraulic head) by providing the hydraulic head for each set of data. The value of the hydraulic head provided by the user is then printed in the third column of the generated data file. A practical example of this case is when you want to digitize a number of water table contours and would like to produce a file with the X, Y values and the corresponding Z values (water table elevation, in this case). Prior to digitizing each contour, one would need to press 8 on the hand-control. This causes the digitizing program to prompt the user to provide a water-table elevation (Z) value for the contour. This value is then printed in the third column of the digitized output file. The X, Y values, which refer to the location (Cartesian coordinates) of the digitized point, are printed in the first and second columns.

5. Specifications (for Data Types)

Digitizing information for some of the commonly used field charts is given in what follows. Charts with arc-shaped time lines are called time-line charts in this manual. For such nonrectilinear charts the reference point for the data should always be a point on the radius of curvature and not a point at the start of the data or anywhere else because digitized data for time-line charts need to be corrected for the curved time axis, and therefore we need to know where each point lies with respect to the center of the curvature. The center of curvature is the line that does not need any correction, for it represents the true time on a rectilinear axis.

5.1 Depth to Water

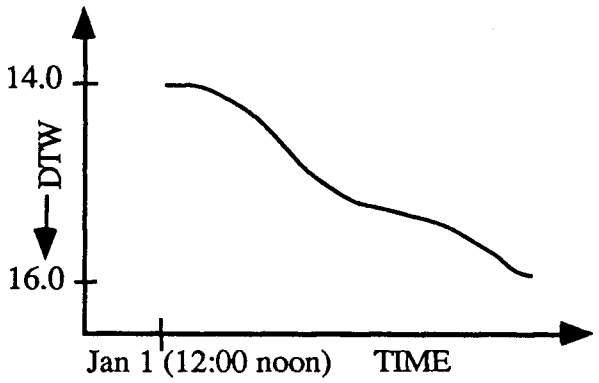
Recorder: Stevens type F.

X scale (for 32 day chart): 1 (inch) = 3.33333 (days).

Y scale: 1 (inch) = 0.08333 (ft).

Data type identifier: DTW.

X and Y values of reference point (for digitizing): Need the Julian day (*X*) and the depth to water below land surface (*Y*) values for the reference or starting point. Note that an increase in the water table is generally in the upward direction on the chart, and therefore a reference point may need to be given a negative value. For example, the reference value for the following figure is 1.5, –14.0



5.2 Barometric Pressure (mbar)
(Time-Line Chart)

Recorder: HI-Q Meteorograph Model 5011 (Qualimetrics, Inc. Catalog).
Chart number: 50112 (weekly).

X scale: 1 (inch) = 0.6336 (days).
Y scale: 1 (inch) = 33.334 (mbar).
Data type identifier: BAR.
Y value of reference point (at center of curvature): 992.0.

5.3 Relative Humidity
(Time-Line Chart)

Recorder: HI-Q Meteorograph Model 5011 (Qualimetrics, Inc. Catalog).
Chart number: 50112 (weekly).

X scale: 1 (inch) = 0.6336 (days).
Y scale: 1 (inch) = 31.68 (%).
Data type identifier: HUM.
Y value of reference point (at center of curvature): 50.5.

5.4 Air Temperature (°C)
(Time-Line Chart)

Recorder: HI-Q Meteorograph Model 5011 (Qualimetrics, Inc. catalog).
Chart number: 50112 (weekly).

X scale: 1 (inch) = 0.6336 (days)
Y scale: 1 (inch) = 18.39 (°C)
Data type identifier: TMP
Y value of reference point (at center of cuvature): 19.89

5.5 (Monthly) Microbarograph (in Hg)
(Curved Time-Line Chart)

Recorder: HI-Q Meteorograph Model 7012 (Qualimetrics, Inc. catalog).
Chart number: 70105.

X scale: 1 (inch) = 2.66 (days).
Y scale: 1 (inch) = .4896 (in Hg).
Data type identifier: BRM.
Y value of reference point (at center of curvature): 29.355.

5.6 (Weekly) Microbarograph (in Hg)
(Curved Time-Line Chart)

Recorder: HI-Q Meteorograph Model 7010 (Qualimetrics, Inc. catalog).
Chart number: 70102 (weekly).

X Scale: 1 (inch) = .6324 (days)
Y Scale: 1 (inch) = .4896 (in Hg)
Data type identifier: BRW
Y value of reference point (at center of curvature): 29.355

5.7 Mechanical Pyranograph (ly/min)
(Time-Line Chart)

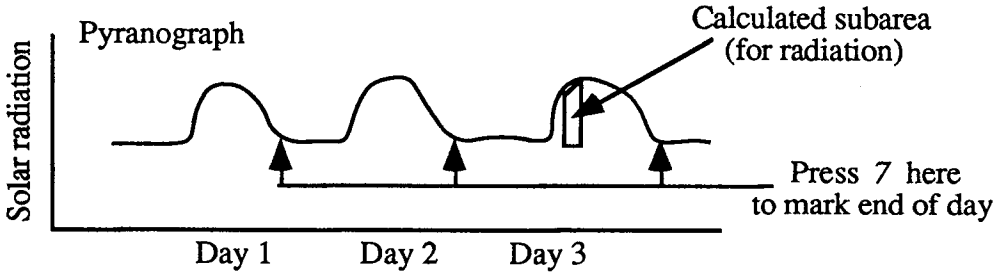
Recorder: HI-Q Meteorograph Model 5011 (Qualimetrics, Inc. catalog)
Chart No: 50112 (weekly)

X Scale: 1 (inch) = .6324 (days)
Y Scale: 1 (inch) = 2.509 (kcal/cm**2/min)
Data type identifier: PYR
Y value of reference point (at center of cuvature): 1.0

When running the time-line correction program (TIMELINE), the daily radiation is also calculated and stored in an output file that has the same name as the input file, but with an extension of RAD (for example, PYR88_5_129RAD).

While digitizing, curves should be followed closely because the radiation between two points is calculated by taking the trapezoidal area under two consecutive points.

At the end of the day (i.e., at dusk), press *7* on the hand-control. This is a marker for the end of the day. This is needed to calculate total radiation for a day.



5.8 Other Charts

This option is used if the chart to be digitized does not belong to any of the other seven data types. The *X* and *Y* axis scales need to be measured and input to the program (calculate the values of one-inch length on the *X* and *Y* axes).

6. Examples of Field Data Charts

In figs. 1–3 are some of the charts presently used in the field. A brief explanation is given for each chart regarding the reference point, etc.

DEPTH TO WATER (DTW) CHART

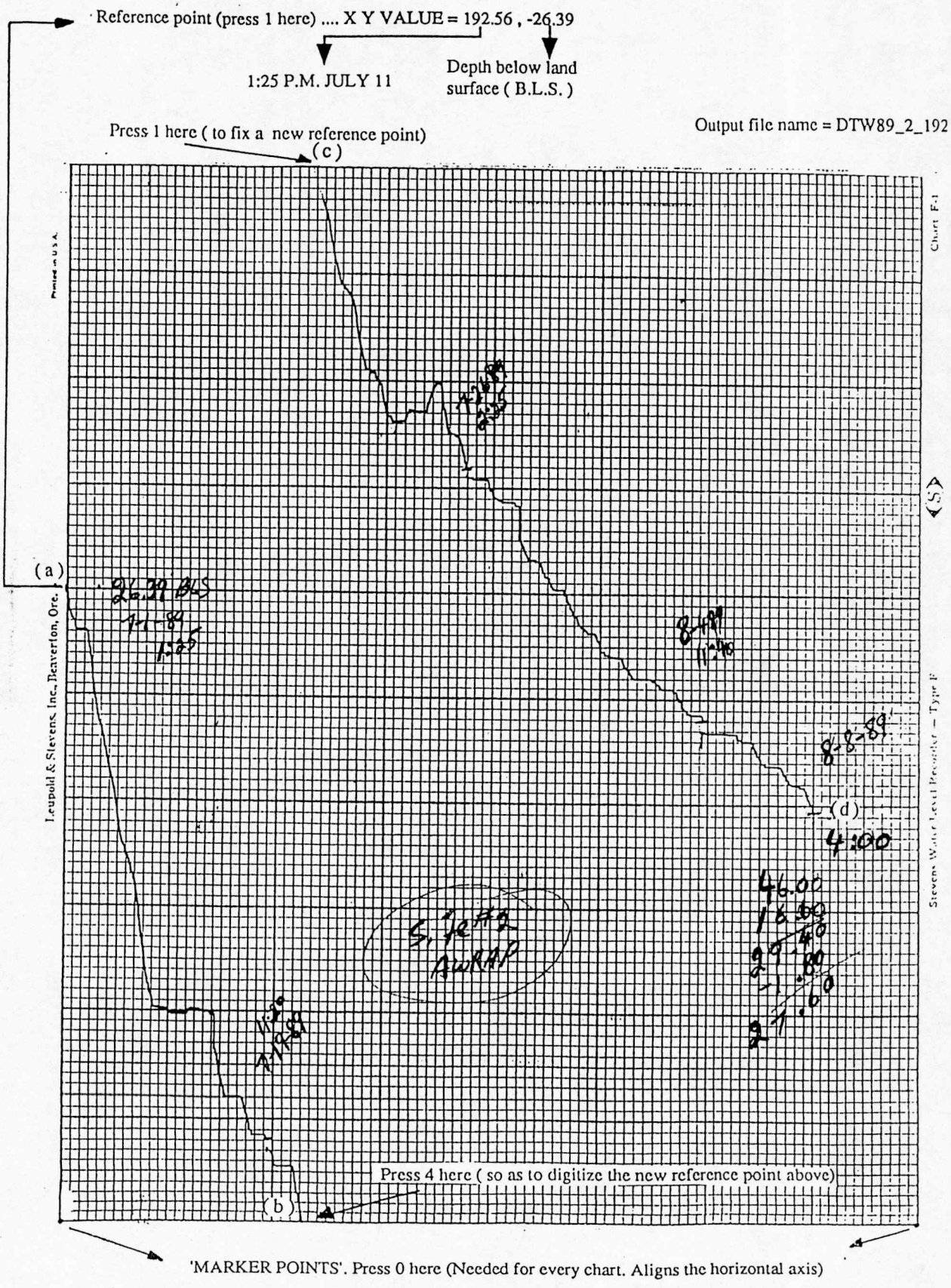
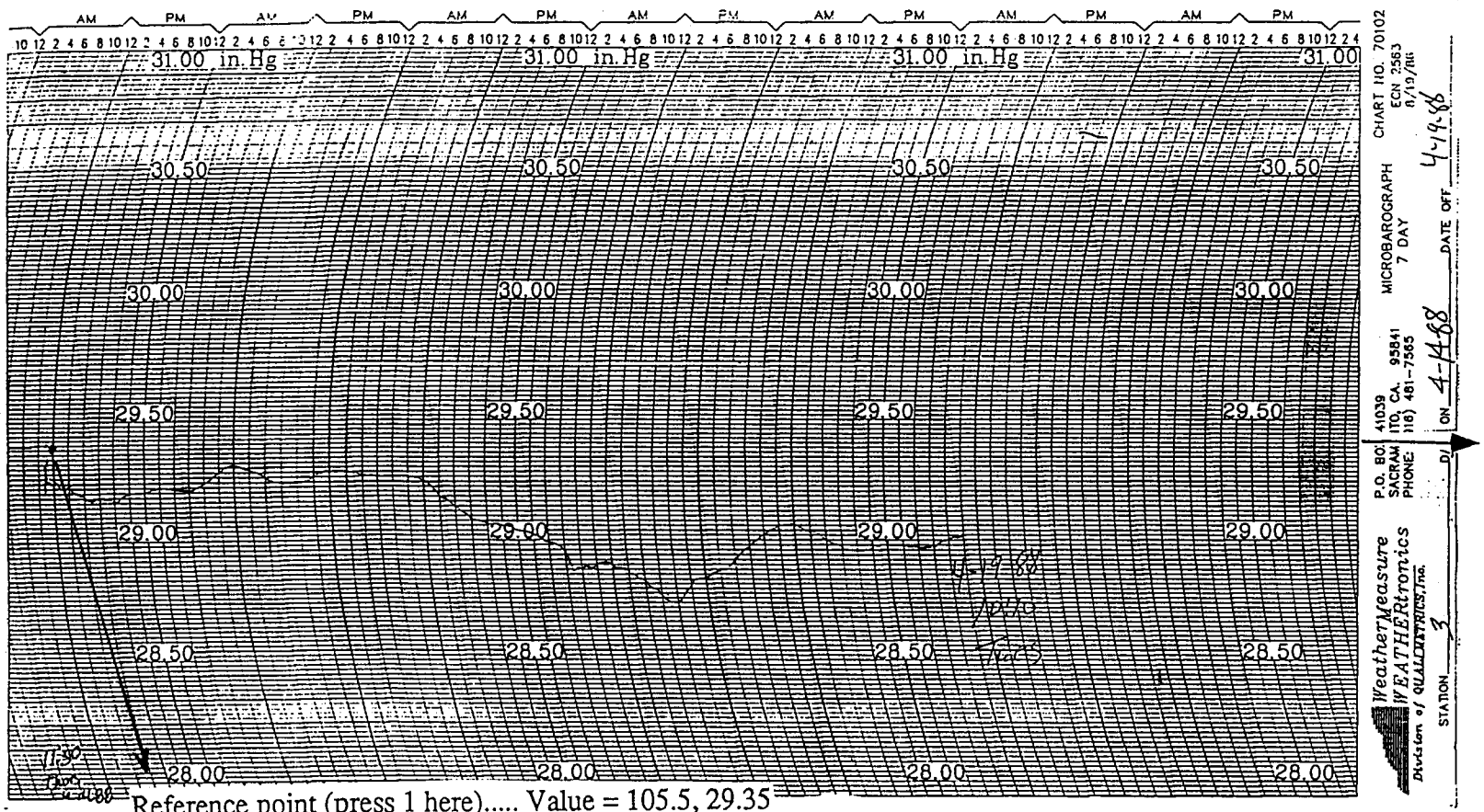


Fig. 1

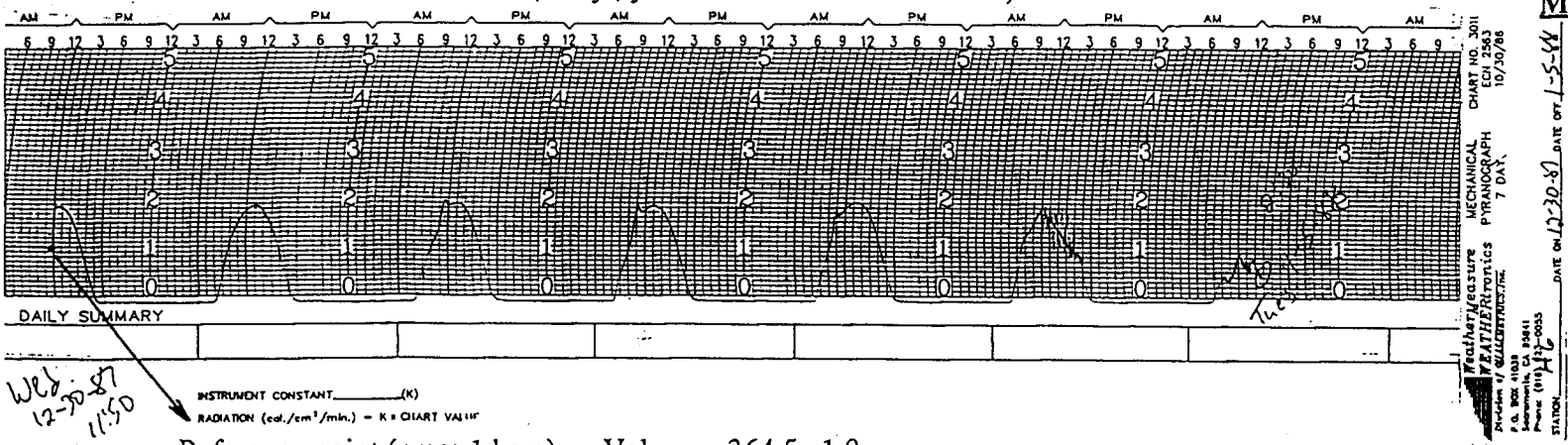


WEEKLY BAROGRAPH

Note: Reference point for all curved axis charts should be somewhere on the center of the curvature.

Reference point (press 1 here)..... Value = 105.5, 29.35

(Day , y value of center of curvature)



MECHANICAL PYRANOGRAPH

Reference point (press 1 here)..... Value = 364.5 , 1.0

Fig. 2

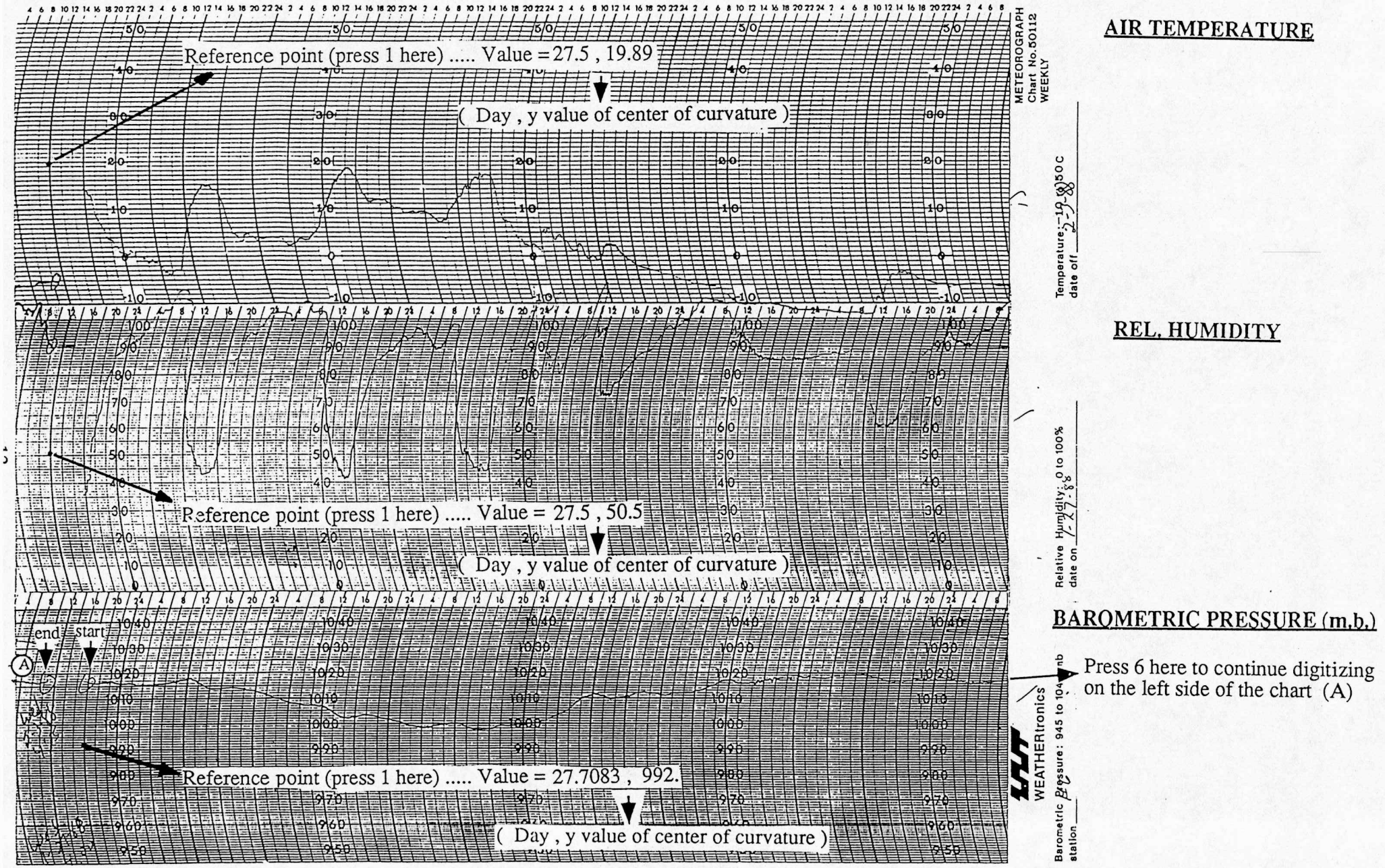

AIR TEMPERATURE
Reference point (press 1 here) ..... Value = 27.5 , 19.89
(Day , y value of center of curvature)
METEOROGRAPH
Chart No.50112
WEEKLY
Temperature: -10 - 50C
date off 2-3-88
REL. HUMIDITY
Reference point (press 1 here) ..... Value = 27.5 , 50.5
(Day , y value of center of curvature)
Relative Humidity: 0 to 100%
date on 27-2-88
BAROMETRIC PRESSURE (m.b.)
end
start
A
Press 6 here to continue digitizing on the left side of the chart (A)
Reference point (press 1 here) ..... Value = 27.7083 , 992.
(Day , y value of center of curvature)
WEATHERtronics
Barometric Pressure : 945 to 104 mb
station

Fig. 3

7. An Example of a Digitizing Session

We now give an example of a digitizing session for fig. 1, following the instructions to access the digitizing program.

) DIGITIZE

Terminal Prompt:	**Type**
Data Types:	
1. Barometric Pressure	
2. Relative Humidity	
3. Air Temperature	
4. Mech. Pyranograph	
5. Microbarograph (Monthly)	
6. Microbarograph (Weekly)	
7. Depth to Water	
8. Other	
9. Quit digitizing	
Give data type from above?	7
Starting Date?	7 11 89
Site Designation?	2

Digitize two points on the X-axis (for chart alignment).
(digitize the two lower corners of the printed chart by pressing *0* on the hand-control).

Enter X-scale (1 inch = ?)	[3.33333 by default] <CR>[1]
Enter Y-scale (1 inch = ?)	[8.33E-02 by default] <CR>
Output File Name?	[DTW88_2_192 by default] <CR>

Digitize the reference point[2]
Enter value of the reference point (X, Y).

X = Julian day; Y=Y-axis value	[see fig. 1] 192.56, –26.39

Go ahead, start digitizing

192.543	–26.390	2[3]
192.881	–26.435	2

[1]CR = Carriage Return. If default values are acceptable, simply press the (carriage) return key.
[2]Digitize the starting location marked *a* (in fig. 1) by pressing *1* on the hand-control.
[3]If a referenced point is to be stored as a data value in addition to serving as a reference point, it needs to be digitized by pressing *2* after pressing *1* for the reference point. Also note that all digitized data are automatically echoed on the terminal. The third column of data indicates the option used on the hand-control.

193.313 –26.439 2
- - -
- - -
- - -
201.638 –26.988 2[4]

Digitize the Reference Point[5]

Reference point (X,Y) = ? [201.638, –26.988 by default][6] <CR>

201.638 –26.988 2
- - -
- - -
- - -
220.56 –27.593 -3[7]

Data Types
---

1. Barometric Pressure
   -
   -
   -

---

[4]This point corresponds to location *b* on the chart (fig. 1). Press *4* here (in addition to pressing *2*) to indicate to the digitizing program that a new reference point is desired. The new reference point will be at location *c*, where the chart wraps around (fig. 1).

[5]Press *1* at location *c* to fix a new reference point, and then, after providing the reference point values, continue with normal digitizing by pressing *2*.

[6]Because point *c* is a continuation of point *b* on the chart (fig. 1), use the default reference point values (i.e., hit carriage return).

[7]This point corresponds to the end of the chart marked *d*. Press *3* here to quit digitizing the chart. Note that the third column, which indicates the option used on the hand-control, shows –3 and not 3. This is merely for programming convenience.

8. Correction for (Time-Line) Curved Charts

Several meteorographs have curved lines that must be corrected before plotting because the digitizer digitizes data on a rectilinear scale and the data is recorded on a curvilinear scale. The program TIMELINE performs this task of correcting. It also calculates the daily radiation (for pyranograph charts). In case the chart is not properly mounted on the meter (in the field), the data on the chart may be off-center. To correct this possible discrepancy, the TIMELINE program shifts the digitized data automatically in such cases.

Figure 4 illustrates the scale correction performed by TIMELINE. All points on the arc *ABC* represent the values of the variable of interest (e.g., barometric pressure) at a single specific time. *AC* represents the width of the chart, and *R* represents the radius of the arc that is instrument dependent. The vertical or *Y* coordinate represents the barometric pressure and is on a linear scale and hence needs no correction. From the geometry of the recording chart shown in fig. 4, it is easy to see that for any point D on the timeline curve, the time or *X*-value correction needed to obtain an equivalent Cartesian point E is *DE*, the magnitude of which is

$$\overline{DE} = R - \sqrt{R^2 - y^2}$$

The TIMELINE program was developed to perform the needed transformation and also corrections resulting from misalignment of the chart caused by slippage or improper chart loading.

All digitized files containing data recorded on charts having a curved time axis should be processed by the TIMELINE program for the corrections noted A typical session is outlined in what follows.

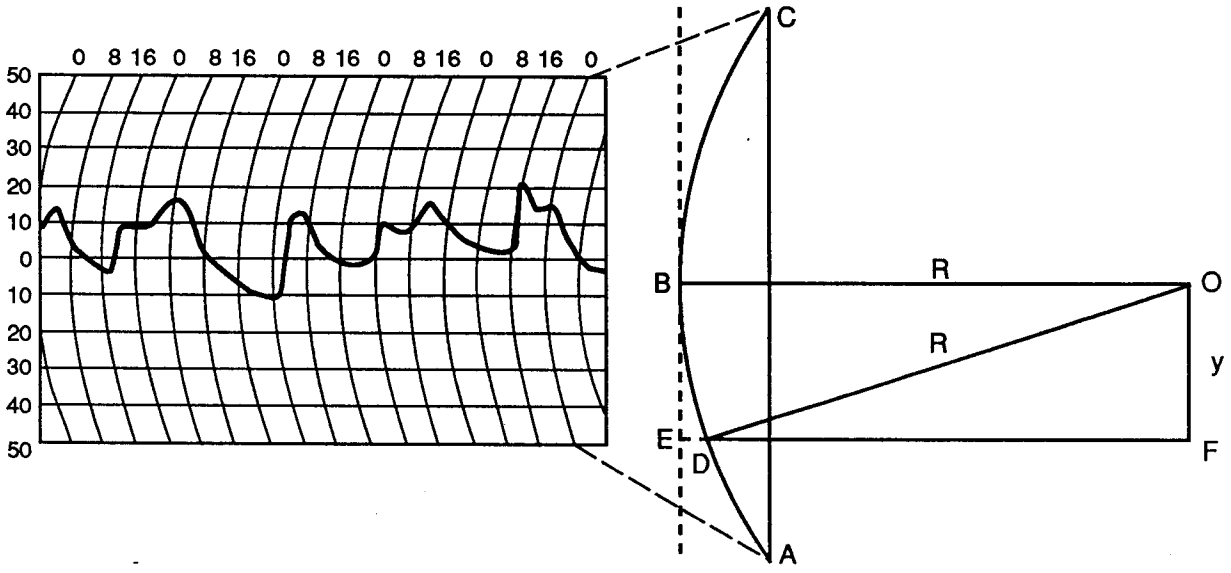

0 8 16 0 8 16 0 8 16 0 8 16 0 8 16 0
50
40
30
20
10
0
10
20
30
40
50
C
B
R
O
R
y
E
D
F
A

Figure 4

Prompt	Type
	<X TIMELINE>
Name of input file to mend?	<PYR88_9_123> [Give name of file.]
Output in file with same filename as input file but with the suffix CORR.	[Use same file name as in previous step.]
Daily radiation in file with same filename as radiation input file but with the suffix RAD, used for pyranograph data only (for example, PYR88_9_123RAD).	

9. Appending Data Files

Each digitized chart may contain weekly or monthly data that need to be combined to obtain a yearly data file. Any number of data files (with a common name segment) can be linked or connected into a single file using the APPEND.CLI program.

Prompt	Type
	<APPEND>
Give data designation	<DTW88_A_+> [Will append all 1988 DTW files for site A]

Output in file APPENDAT4
(This file may be renamed, if desired).

APPEND.CLI performs the following tasks:

1. Asks for data designation, e.g., DTW88_A_+. This extracts all 1988 DTW files for site A and stores them in file APPENDDAT1
2. Executes program APPEND1: Extracts the Julian Day value for each appended file.
3. Sorts the appended file in chronologic order using program APPEND3 as a command file for sorting.
4. Executes program APPEND4 which performs the following:
   a. Creates a file (APPENDDAT5) that lists all appended files.
   b. Creates a backup of each original file that has been appended.
   c. If the appended file is to be used as input to the TIMELINE program, then a marker (0,0,0) is inserted at the end of each appended file to identify the beginning and end of each data file appended. The program will prompt you for that. This is needed because the TIMELINE program, in addition to other tasks, also corrects for any misalignment of the digitized chart, and because each file appended represents information obtained from a single chart, the individual files need to be isolated for any possible correction.
   d. The appended data files are stored in file APPENDDAT4.

10. Smoothing Data

Raw data is generally unsuitable for plotting purposes because a large number of the data points need to be plotted, and more important, because the plots are too jagged if not averaged for the day. The raw digitized data needs to be "smoothed" or averaged to obtain an average daily value. The following outlines a typical session.

Prompt	Type
	<X SMOOTH>
Enter input file to smooth	<DTW88_4> [Give file name.]
Output in file with same filename as input file but with the prefix S (for smoothed input file name).	

Smoothed files containing annual data should have the same name convention as the digitized file except the Julian day suffixes are absent. For example, all 1988 smoothed depth-to-water data for site 2 should finally reside in DTW88_2. The unsmooothed DTW88_2 file is obtained by appending all the different individual digitized depth-to-water files (such as DTW88_2_106) for the year for site 2, using the APPEND.CLI program.

Acknowledgements

Nadeem Shaukat kindly provided a digitizing program employed in a modified form in the DIGITIZE.CLI macro (see section 1), and assisted us in straightening out some of our problems. Geoff Coble also assisted us during the early stages of development of this system.