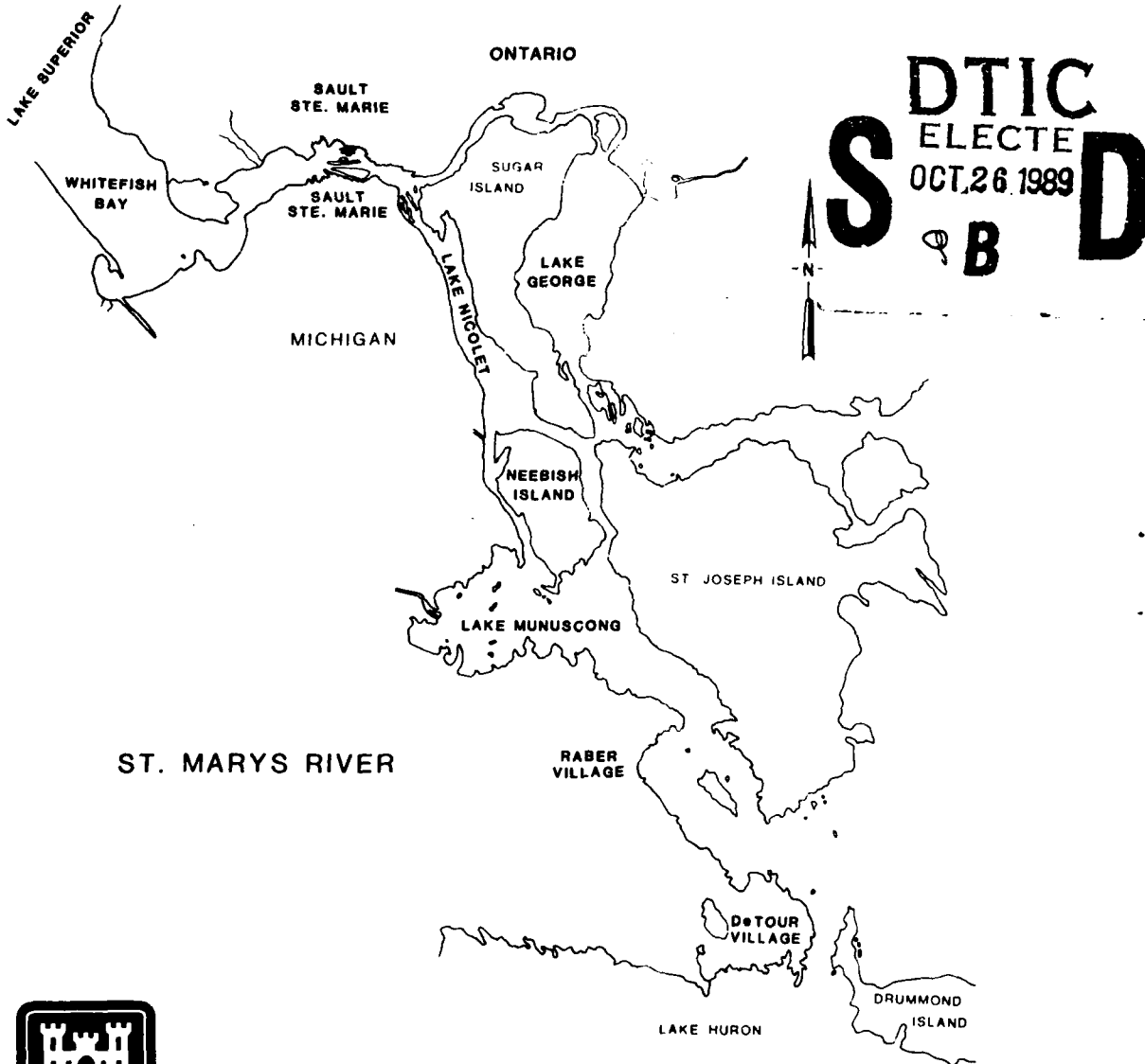


# ST. MARYS RIVER Oil/Toxic Substance Spill Study Current Velocities and Directions 1980-1983

AD-A213 748



**US Army Corps  
of Engineers**  
Detroit District

DECEMBER 1984

**Great Lakes Hydraulics and Hydrology Branch**

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		7a. NAME OF MONITORING ORGANIZATION	
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Corps of Engineers	6b. OFFICE SYMBOL (If applicable)	7b. ADDRESS (City, State, and ZIP Code)	
6c. ADDRESS (City, State, and ZIP Code) Great Lakes Hydraulic and Hydrology Branch Detroit District, P.O. Box 1027 Detroit MI 48231		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	10. SOURCE OF FUNDING NUMBERS	
8c. ADDRESS (City, State, and ZIP Code)		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) St. Marys River - Oil/Toxic Substance Spill Study Current Velocities and Directions 1980 - 1983			
12. PERSONAL AUTHOR(S) Personnel U.S. Army Engineer District, Detroit			
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) December 1984	15. PAGE COUNT 132
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	Flow Conditions; Wind Effects, Data Reduction; Program Results, Flow Discharges During Periods of Measure	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
<p>The purpose of this report was to present the data collected over a four year period, from 1980 through 1983, specifically for the calibration of an Oil/Toxic Substance Spill mathematical model. The work involved the collection of flow velocities and directions for the St. Marys River for both open water and during periods of ice cover; and included an ice/riverbed contact footing feasibility study for Lake Nicolet.</p>			
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Jimmie L. Glover		22b. TELEPHONE (Include Area Code) (313) 226-7590	22c. OFFICE SYMBOL CENCE-PD-EA

ST. MARYS RIVER

OIL/TOXIC SUBSTANCE SPILL STUDY

CURRENT VELOCITIES AND DIRECTIONS

1980-1983

BY

U.S. ARMY CORPS OF ENGINEERS

DETROIT DISTRICT

GREAT LAKES HYDRAULICS & HYDROLOGY BRANCH

DECEMBER 1984

ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
1980-1983

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APPENDIX A

This appendix presents current velocities and directions for St. Marys River, Reach 1, which commences at Point Iroquois, Michigan, in Lake Superior and concludes at the Soo Locks at Sault Ste. Marie, Ontario, and Michigan.

APPENDIX B

This appendix presents current velocities and directions for St. Marys River, Reach 2, which commences just above the Soo Locks on the upper river, encompasses Soo Harbor, the North Channel to Cass Point and Little Rapids Cut to Frechette Point.

APPENDIX C

This appendix presents current velocities and directions for St. Marys River, Reach 3, Lake Nicolet, which commences at the lower end of Little Rapids Cut and concludes at Neebish Island, where the St. Marys River branches out into Middle Neebish and West Neebish Channels.

APPENDIX D

This appendix presents current velocities and directions for St. Marys River, Reach 4, which commences at the mouth of Lake Nicolet and concludes at Kemps Point on West Neebish Channel and Johnsons Point on Munuscong Channel.

APPENDIX E

This appendix presents current velocities and directions for St. Marys River, Reach 5, Lake Munuscong, which commences at the mouths of the West Neebish and Munuscong Channels. The reach concludes at Point aux Frenes.

APPENDIX F

This appendix presents current velocities and directions for St. Marys River, Reach 6, which commences at the extreme lower end of Lake Munuscong near Point aux Frenes and concludes at the south end of Detour Passage at Lake Huron.

APPENDIX G

(bound separately)

Ice/Riverbed Contact Footing Survey, Lake Nicolet; a documentation of the data collected during the winter of 1980 for this study. It describes the methods and techniques employed in obtaining the data. It also contains pictorial representations of these data.

ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
1980-1983

INTRODUCTION

The St. Marys River is an integral part of the Great Lakes-St. Lawrence River navigation system. The mission of the Great Lakes Hydraulics and Hydrology Branch, Detroit District, Corps of Engineers includes the collection of data on this system. In 1975 for the first time in history, the Great Lakes navigation season was extended to a full twelve months on the upper four Great Lakes. This extension intensified concerns regarding the possibility of an oil/toxic substance spill. The Great Lakes Hydraulics and Hydrology Branch was requested to develop a program and to collect data related to velocities and flow directionals for the St. Marys River. These data provide information that could be employed to define the probable areas that might be impacted by an oil/toxic spill.

PURPOSE

The purpose of this report is to present the data collected over a four year period, from 1980 through 1983, specifically for the calibration of an Oil/Toxic Substance Spill mathematical model.

SCOPE OF WORK

The scope of work involved the collection of flow velocities and directions for the St. Marys River system for both open water and during periods of ice cover. The work also included an ice/riverbed contact footing feasibility study for Lake Nicolet (Appendix G).

GENERAL STUDY AREA DESCRIPTION

The study area of the St. Marys River (Figure 1) has a length of approximately 67 miles from its beginning in Lake Superior to its end at Lake Huron with a vertical fall of approximately 22 feet (Figure 2). In general, the St. Marys River may be subdivided into three distinct areas; the upper river, the St. Marys Falls, and the lower river. The upper river has a length of approximately 14 miles, from Point Iroquois, Michigan, on Lake Superior to the St. Marys Falls located at Sault Ste. Marie, Michigan and Ontario. The fall on the upper river is about two tenths of a foot. The St. Marys Falls area covers a distance of approximately two miles. Within this two mile area are; five navigational locks, three power canals, two bridges, the Compensating Works and the Falls. The fall in this area is approximately 20 feet. The lower St. Marys River has an approximate length of 51 miles from just below the St. Marys Falls, through several channels and lakes to Detour Passage, where the river flows into Lake Huron. The fall on the lower river is approximately one and a half feet.

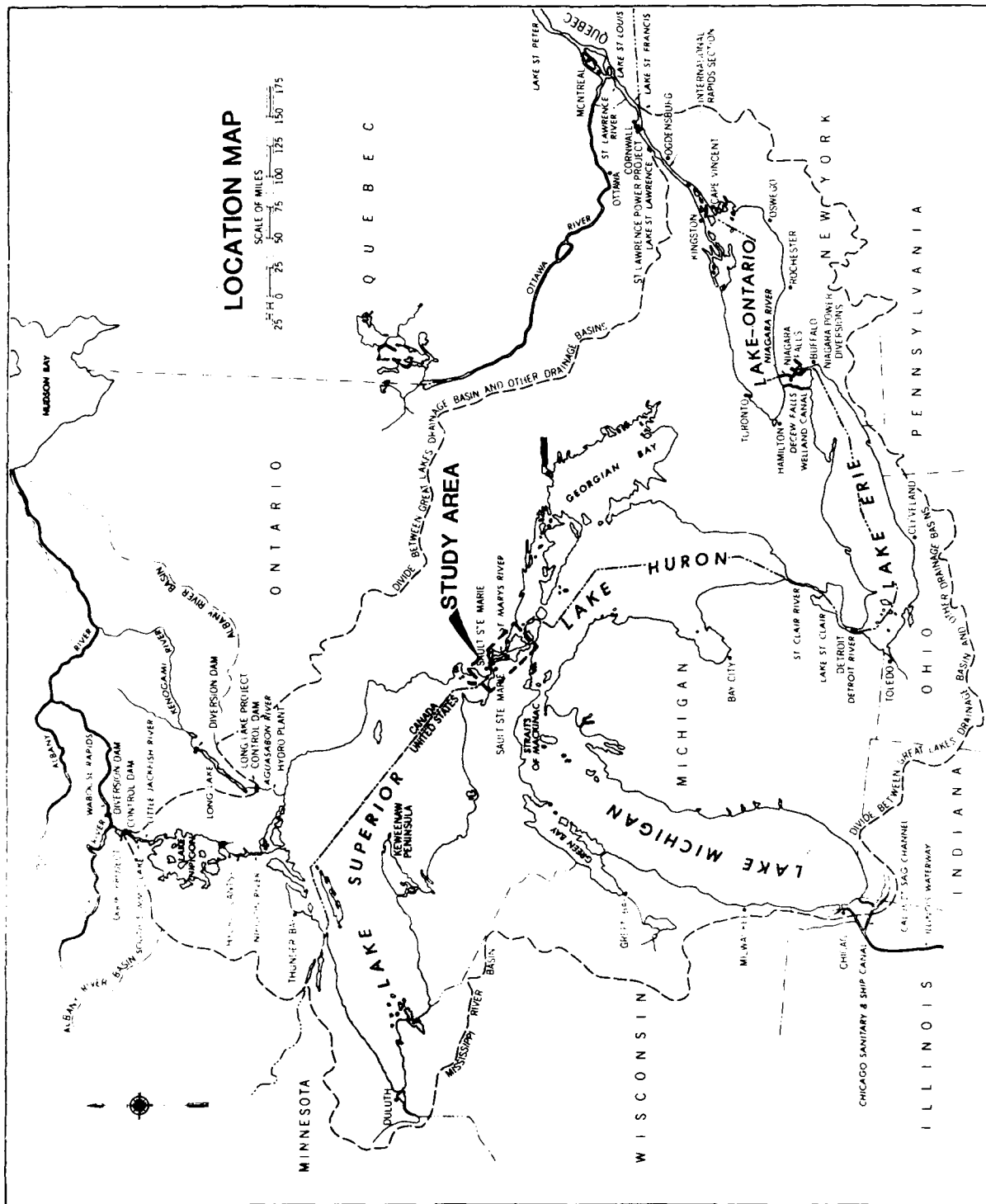
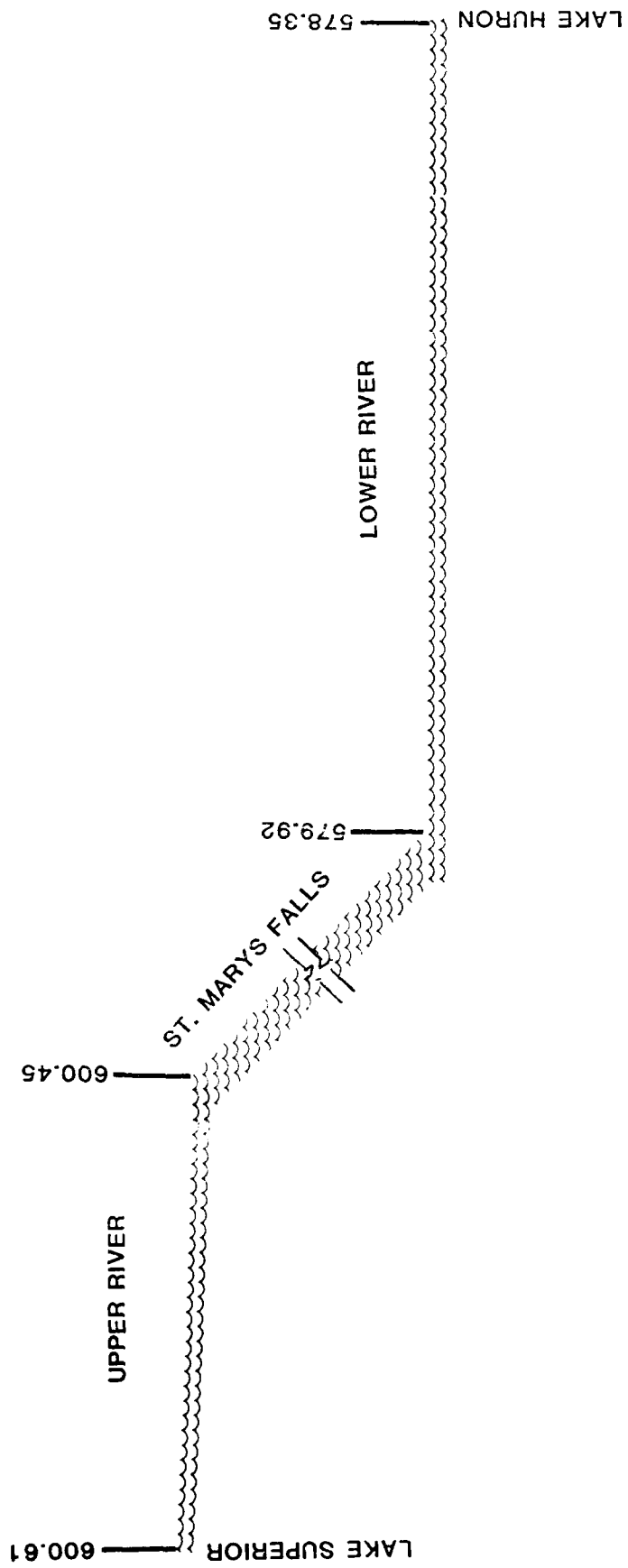


FIGURE 1

# ST. MARYS RIVER PROFILE



LONG TERM AVERAGE ELEVATIONS

FIGURE 2

## HISTORICAL DATA

River flow and water level data on the St. Marys River have been collected by the Corps of Engineers since 1895. Ice thicknesses and ice volumes have been collected since 1969 and 1978, respectively. These data are on file in the office of the Detroit District's Great Lakes Hydraulics and Hydrology Branch. To supplement this report, related publications and reports have been included in the bibliography (pages 11-13).

## DATA ACQUISITION

Since February of 1980, the Great Lakes Hydraulics and Hydrology Branch has been collecting data for the Oil/Toxic Substance Spill Study. Data were acquired by the following five measurement techniques:

Open water current measurements: Subsurface measurements consisting of velocities and directions taken at 2, 4 and 8 tenths of the total river depth, at given locations. These data will provide input to a future mathematical model for predicting the subsurface path of a possible spill.

Drogue Surveys: The following two methods were used to collect surface current data.

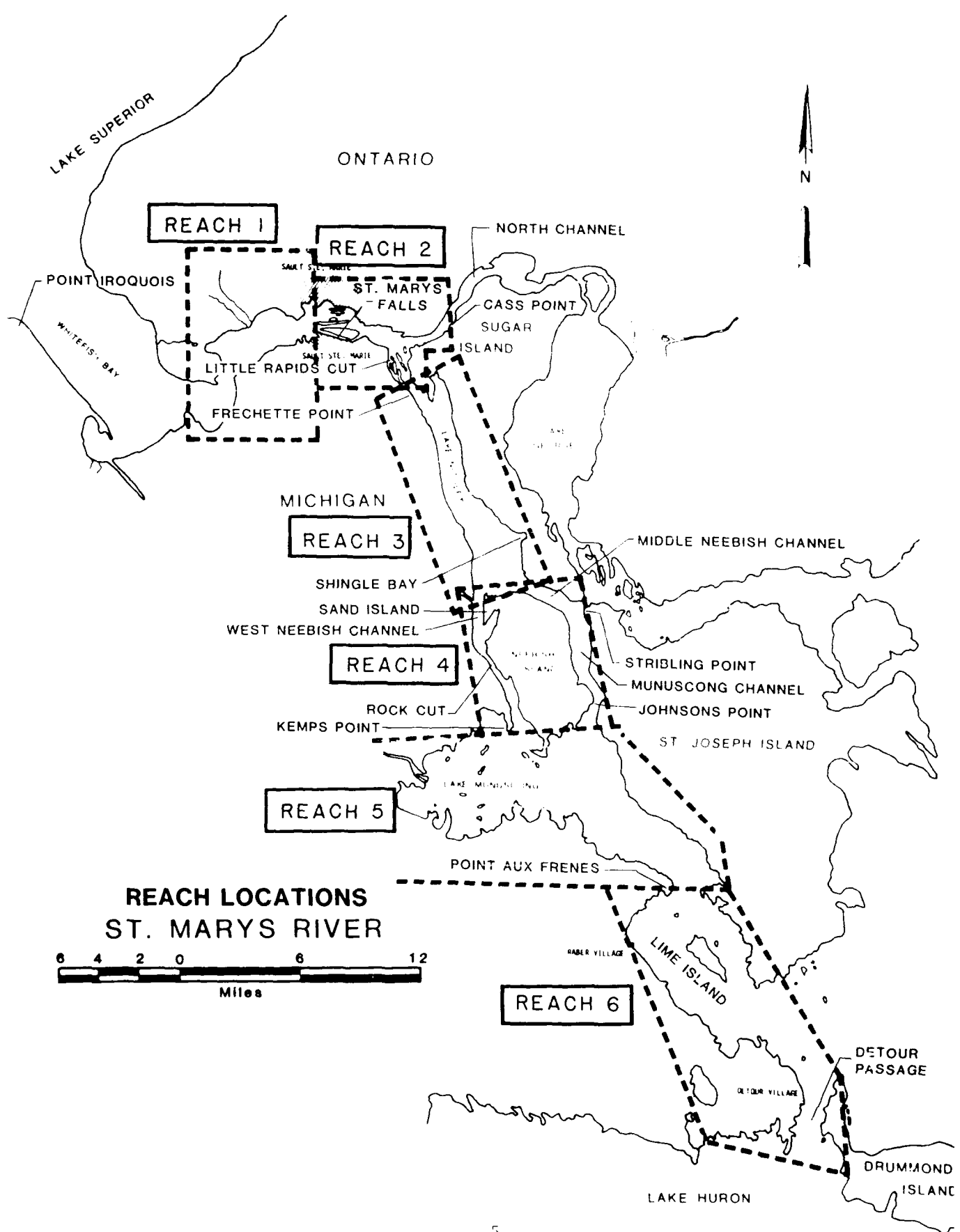
Method 1: An airplane was used to take aerial time-lapse photographs of drogues floating downstream. The drogues for this survey were 4' x 4' pieces of plywood, which have a line down to a weighted vane. These drogues, which float on the water surface, are painted white for visibility and are individually numbered for identification. This method is also referred to as an aerial drogue survey.

Method 2: Two survey stations are set up to track drogues floating downstream at specified time intervals. The drogues for this survey were long cylindrical devices, which have a line down to a weighted vane. These drogues, which float vertically in the water, are made of aluminum tubing filled with styrofoam. Each drogue is identified by bright red flagging. This method is also referred to as a transit cut-off drogue survey.

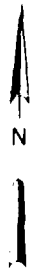
Under ice current measurements: Subsurface measurements of current velocities and directions at 2 and/or 4 tenths of the total river depth at given locations. These data will allow for a comparison with velocities and directions of open water current measurements.

Ice/riverbed contact footing survey: Survey to establish the furthest lakeward point the ice contacts the riverbed. This point is referred to as the location of the ice footing. By determining the extent of the ice footing, the scientist may use this information to determine if the ice footing would impact on shoreline spawning and wetland areas in the event of a winter spill.

For the purpose of describing the study's areas of data acquisition, the St. Marys River was divided into six reaches, (see Figure 3). For each reach one or more of the above measurement techniques were used (see Table on page 7).



**REACH LOCATIONS  
ST. MARYS RIVER**



### EQUIPMENT USED FOR COLLECTING CURRENT DATA

During the open water surveys, the 35-foot survey launch the "Korkigian," or the 21 foot "Mon Ark" trihull was used as the data collection platform. A 16-foot skiff was used to set-up the electronic positioning survey system. Two Marsh McBirney, Model #527, electromagnetic current meters were used for the collection of data. This meter provides a direct readout of magnitude and direction of water velocity.

During under ice surveys, two snowmobiles with sleds were used as data collection vehicles. They were used to set up the electronic positioning survey system. The sleds were further used to transport an electromagnetic current meter and an ice-auger. A Marsh McBirney, Model #511 electromagnetic current meter, was used for the collection of data. This model, more appropriate for winter use due to its small size and ability to function at low temperatures also provides a direct readout of magnitude and direction of water velocity.

### FLOW CONDITIONS

The St. Marys River's flow is monitored and regulated by the International Lake Superior Board of Control. The average monthly flow during periods of measurement are shown in the Table, Lake Superior Outflows During Measurement Periods (page 7).

### WIND EFFECTS

Wind patterns have an effect on the surface and subsurface flow patterns of lakes and rivers which have a substantial amount of water surface area. Winds in the same direction as the flow tend to increase velocities and winds in the opposite direction tend to decrease velocities, with varying results with winds in between. For example, in low flow areas, such as Lake Nicolet's shallows, strong southerly winds will retard the flow and/or alter its direction. The exact amount of the winds impact on the St. Marys River's velocity and direction depends on water depth, the length and width of the water body over which the wind travels and normal velocity and direction.

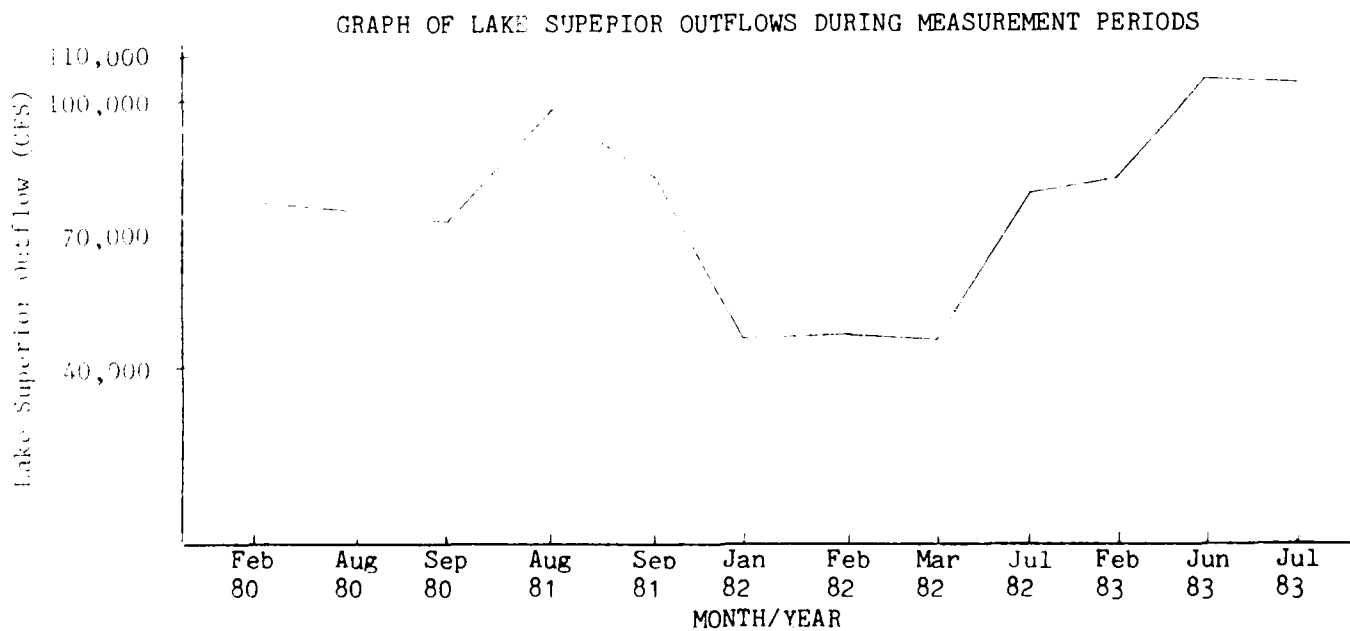
During some of the measurement periods, winds had a noticeable effect on the direction and magnitude of surface flow. To document the winds that occurred during the measurement periods the daily wind speed and direction have been shown on each of the data figures in the appendices. The wind speed and directional data were recorded at the Sault Ste. Marie, Michigan, National Weather Service station.

During periods of total ice cover, direct wind effect on flow is negligible. However, winds can cause the rafting of ice, ice buildups and possibly ice jams along the river.

TABLE  
 Oil/Toxic Substance Spill Study  
 Lake Superior Outflows During Measurement Periods

MONTH - YEAR	REACH	MEASUREMENT	FLOW* CUBIC FEET/SECOND (CFS)
Feb 80	2	Ice/riverbed Contact Footing	75,450
Aug 80	6	Open Water	74,500
Sep 80	6	Open Water	71,980
Aug 81	1	Open Water	97,230
Sep 81	1	Open Water	81,100
Jan 82	6	Under Ice	45,380
Feb 82	6	Under Ice	45,450
Mar 82	6	Under Ice	45,390
Jul 82	2,4	Method 1, Drogue Survey	78,450
Feb 83	4	Under Ice	81,740
Jun 83	2,3,4,5	Open Water, Method 2, Drogue Survey	104,000
Jul 83	5	Open Water	102,890

\*Noble and Woodards Report on Lake Superior Regulation



To further document the long term wind patterns in the study area, a wind graph was prepared (Figure 4), using the 16 principal points of the compass and showing the relative frequency and strength of winds from these directions. The wind speed and direction observations used for this graph were recorded at the Sault Ste. Marie, Michigan, National Weather Service station.

#### DATA REDUCTION

As stated earlier, open water and under ice measurements were made with Marsh McBirney electromagnetic meters. The meters provided a direct readout of the horizontal angle of flow (with respect to magnetic north) and the magnitude (velocity in feet per second) of flow. Drogue survey data were reviewed as follows. Method 1 data consisted of aerial time-lapse photographs of drogues floating downstream. Drogue positions were scaled from the individual photos and were plotted on drogue charts. The positions deduced from each exposure, combined with the recorded time to the nearest second gave the path and velocity of each target as it floated downstream. Method 2 utilized transit cut-off data. The drogue paths were plotted at the intersection of the two angles for each specified time interval. Drogue velocities were determined by computer using the drogues sequential positions and their associated time intervals.

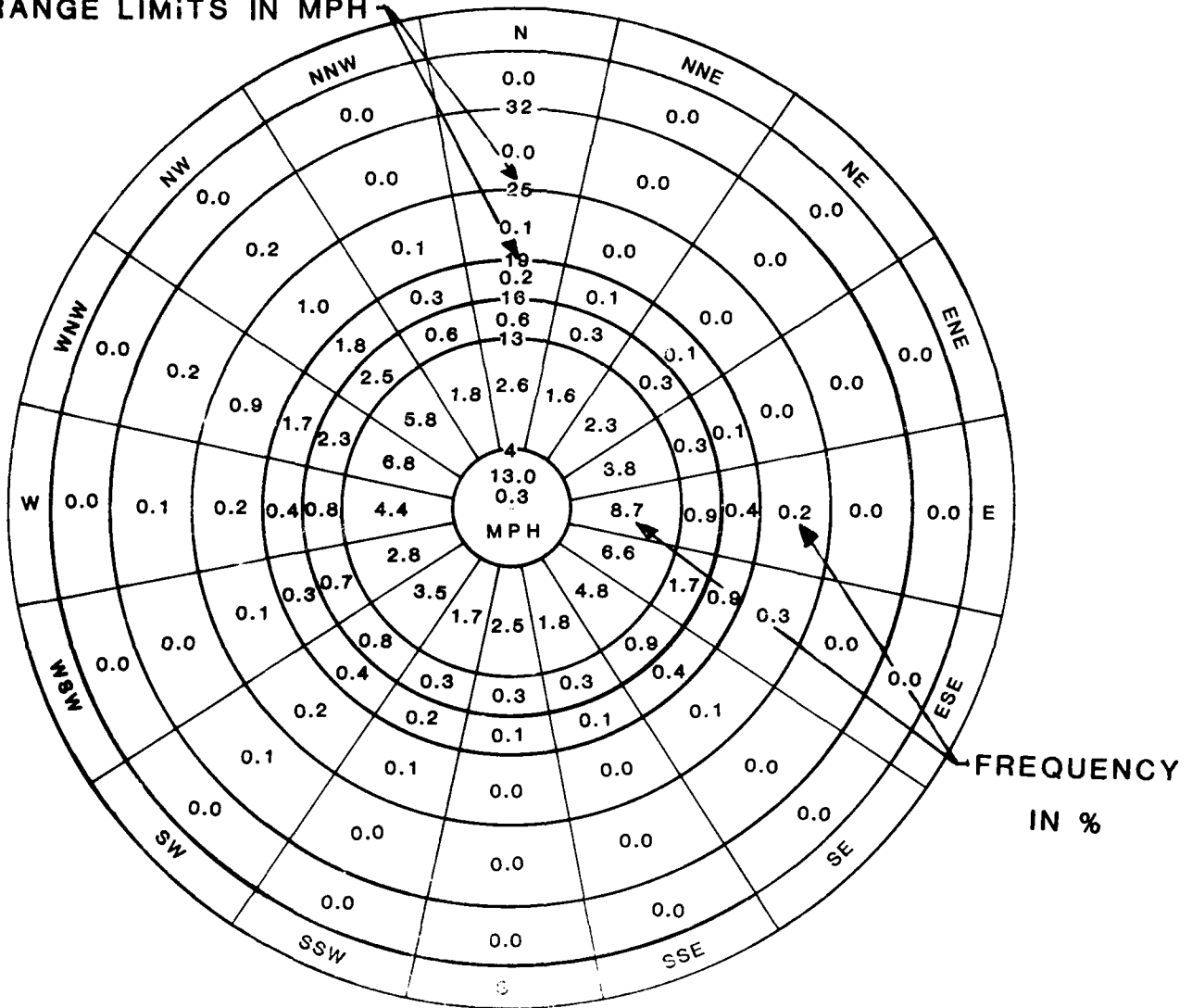
To adequately display the data on the figures in this report the configuration of the St. Marys River required divisions and subdivisions of the reaches. For this reason, each figure has its own scale. Scales of adjacent figures should be noted when making area comparisons. Each figure is identified by reach, shows current and wind data, has a scale and displays a north arrow. To develop these figures the open water, under ice and drogue data in each reach were plotted onto mylar sheets used as overlays. The mylar overlays provided a means of keying in data to the base maps. The base maps were compiled from National Oceanic and Atmospheric Administration (NOAA), National Ocean Survey (NOS), Navigational Charts of the St. Marys River. By using NOAA, NOS charts as base maps, depths, contours, channels, shoreline and landmarks can be identified. The results for each reach are described and shown in Appendices A-F. The designation of the types of data on each figure is noted in the List of Figures of each appendix.

#### PROGRAM RESULTS

The Great Lakes Hydraulics and Hydrology Branch developed a program directed toward collection of data related to velocity and flow direction during open water and under ice conditions on the St. Marys River. The program implemented open water and under ice current measurements, and drogue surveys. Subsurface velocity and direction (open water and under ice) measurement techniques were developed which required less manpower in the field than previous Corps methods and reduced data processing times. Surface velocities (drogue surveys) were best accomplished by using Method 1, type of survey. This type of survey required less manpower than Method 2 and was able to cover great expanses of the river.

# WIND GRAPH ( SAULT STE. MARIE, MICHIGAN )

WIND SPEED  
RANGE LIMITS IN MPH



ALL CEILING AND VISIBILITY CONDITIONS

FIGURE 4

During development of the program it was noted that there were two conditions, flow and wind, that required special consideration.

Flow on the St. Marys River fluctuates with seasonal changes and regulation. Reaches 4 and 6, had winter and summer data at the same locations. The reason for measuring at the same locations was to determine if a relationship existed between currents under an ice cover and those for open water. Data collected thus far does not indicate that such a definable relationship exists. This could be the result of the large flow differences that occurred. Reach 4 had summer flows of 78,450 cubic feet per second (cfs) and 104,000 cfs and a winter flow of 81,740 cfs. Reach 6 had a summer flow of 73,240 cfs and a winter flow of 45,410 cfs.

Wind speed and direction had some impact in the flow patterns shown in this study. Open water patterns are impacted mainly on the surface, but some subsurface impacts are probable. The exact magnitude of the wind related impacts is difficult to determine without an indepth analysis, which is not under the scope of this study. Wind related impacts on velocities during an ice cover, since indirect, are much more difficult to determine and again are out of the scope of this study.

#### RECOMMENDATIONS

The data presented herein provide hydraulic information for preparation of an oil spill mathematical model of the St. Marys River. However, since the data collected were not adequate to determine if a relationship between summer and winter exists, it is recommended that additional under ice current measurement data be collected. This type of measurement will provide additional data for analyzing the summer/winter relationship and would enhance the calibration and verification of the oil spill model.

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APPENDIX A  
ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 1

This appendix presents current velocities and directions for Reach 1 of the St. Marys River, Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into three figures as shown in the Index Figure (page A-1).

Open water current measurements were conducted between 10 and 24 September 1981 (Flow (SEP) = 81,000 cubic feet per second). Figures A-C display current data collected for each of the 2, 4 and 8 tenths depth, of the total river depth at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second. In addition, each figure has a composite drawing developed from the data documented for that figure.

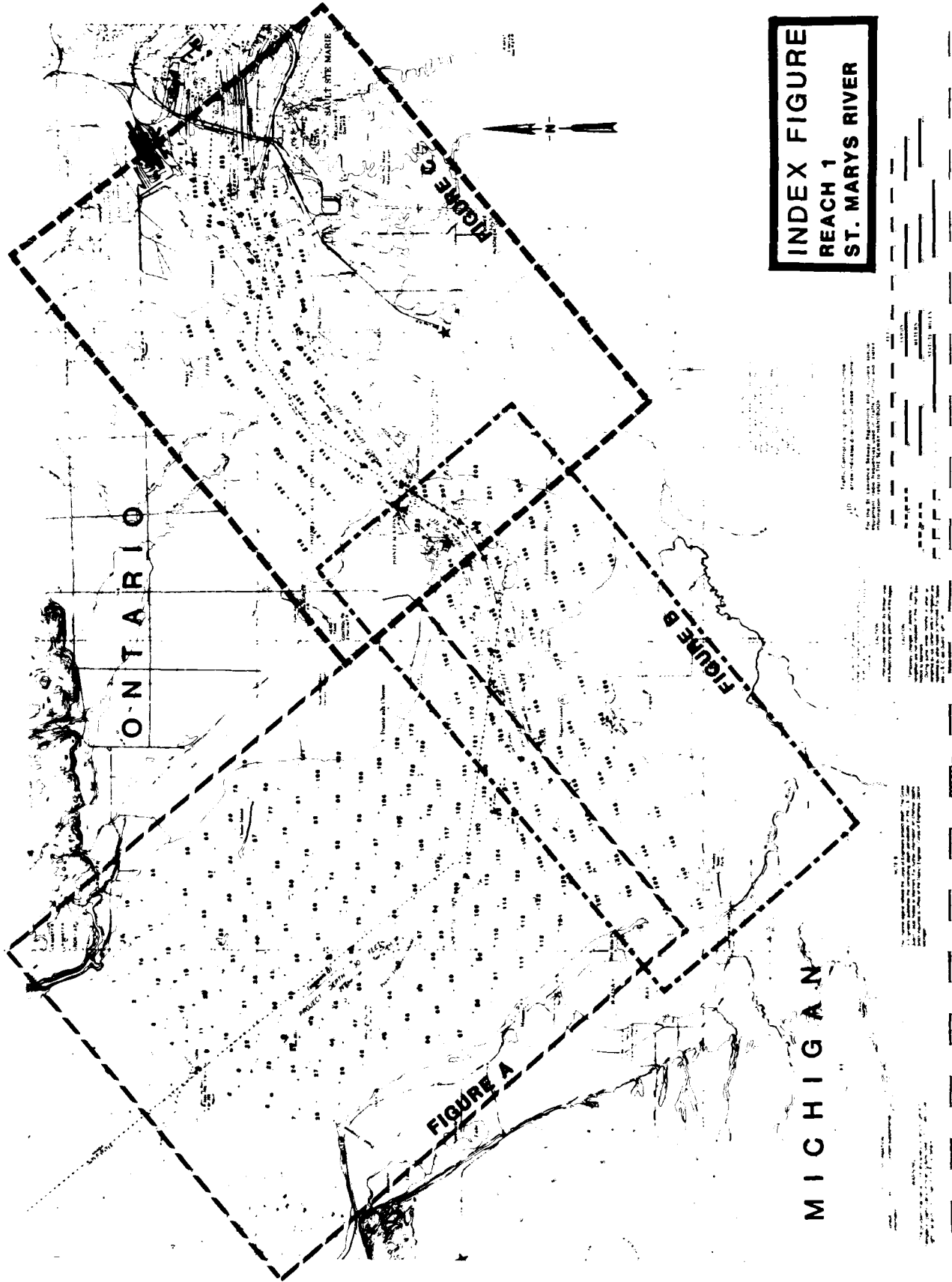
A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX A  
REACH 1

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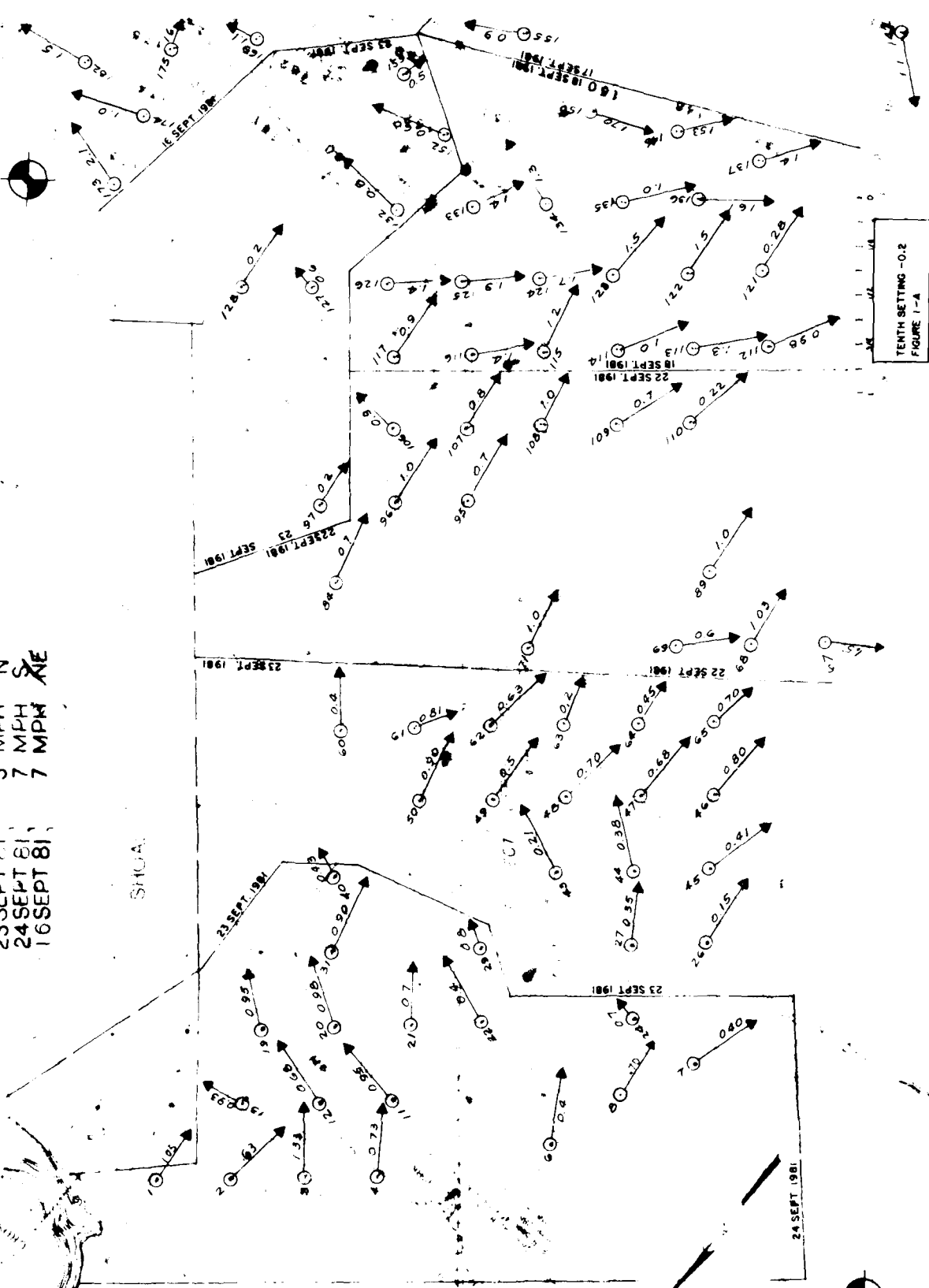
**INDEX FIGURE  
REACH 1  
ST. MARYS RIVER**



WIND DATA

17 SEPT 81	9 MPH	N
18 SEPT 81	15 MPH	WSW
22 SEPT 81	11 MPH	NW
23 SEPT 81	3 MPH	N
24 SEPT 81	7 MPH	S
16 SEPT 81	7 MPH	NNE

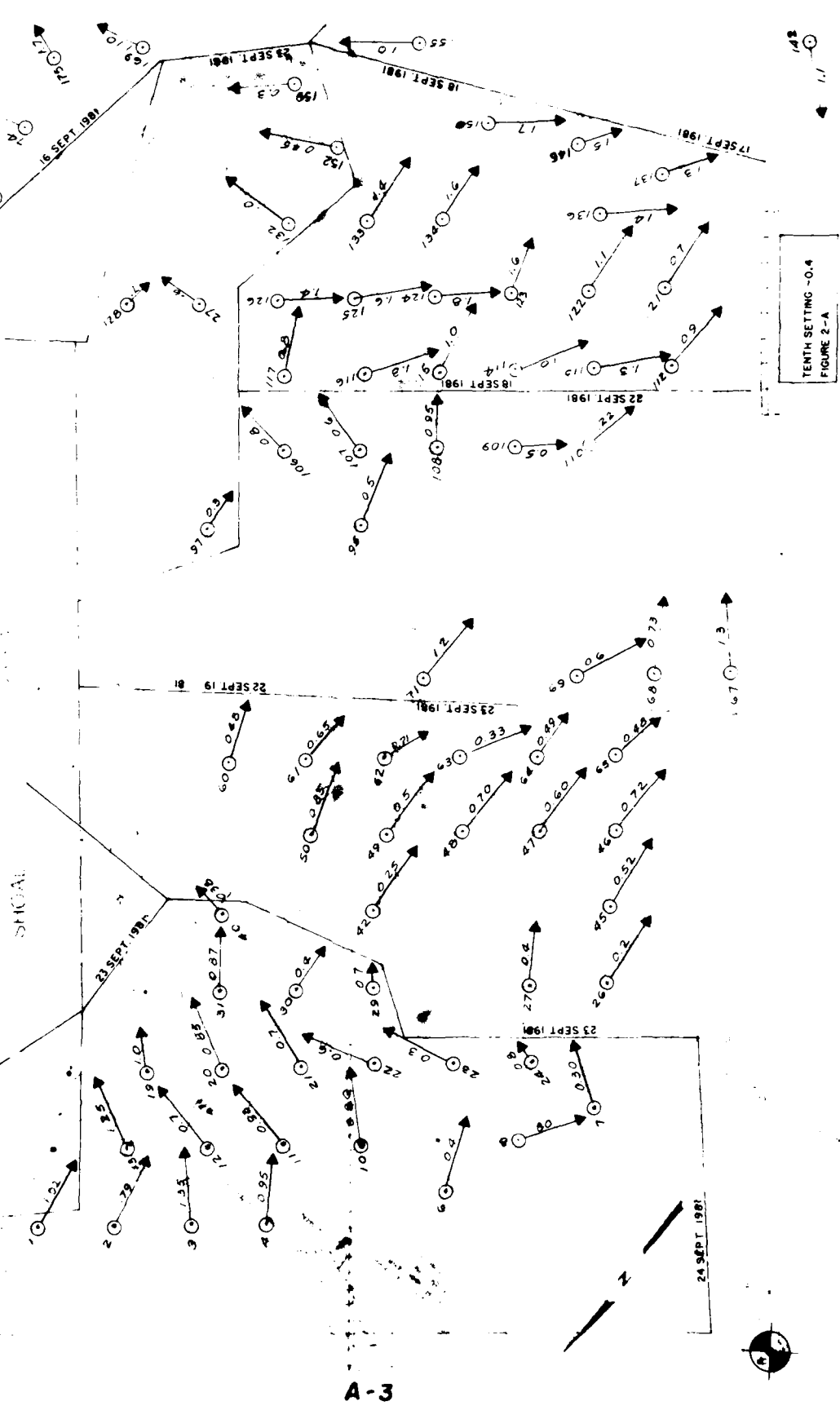
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TENTH SETTING -0.2  
FIGURE 1-4

WIND DATA

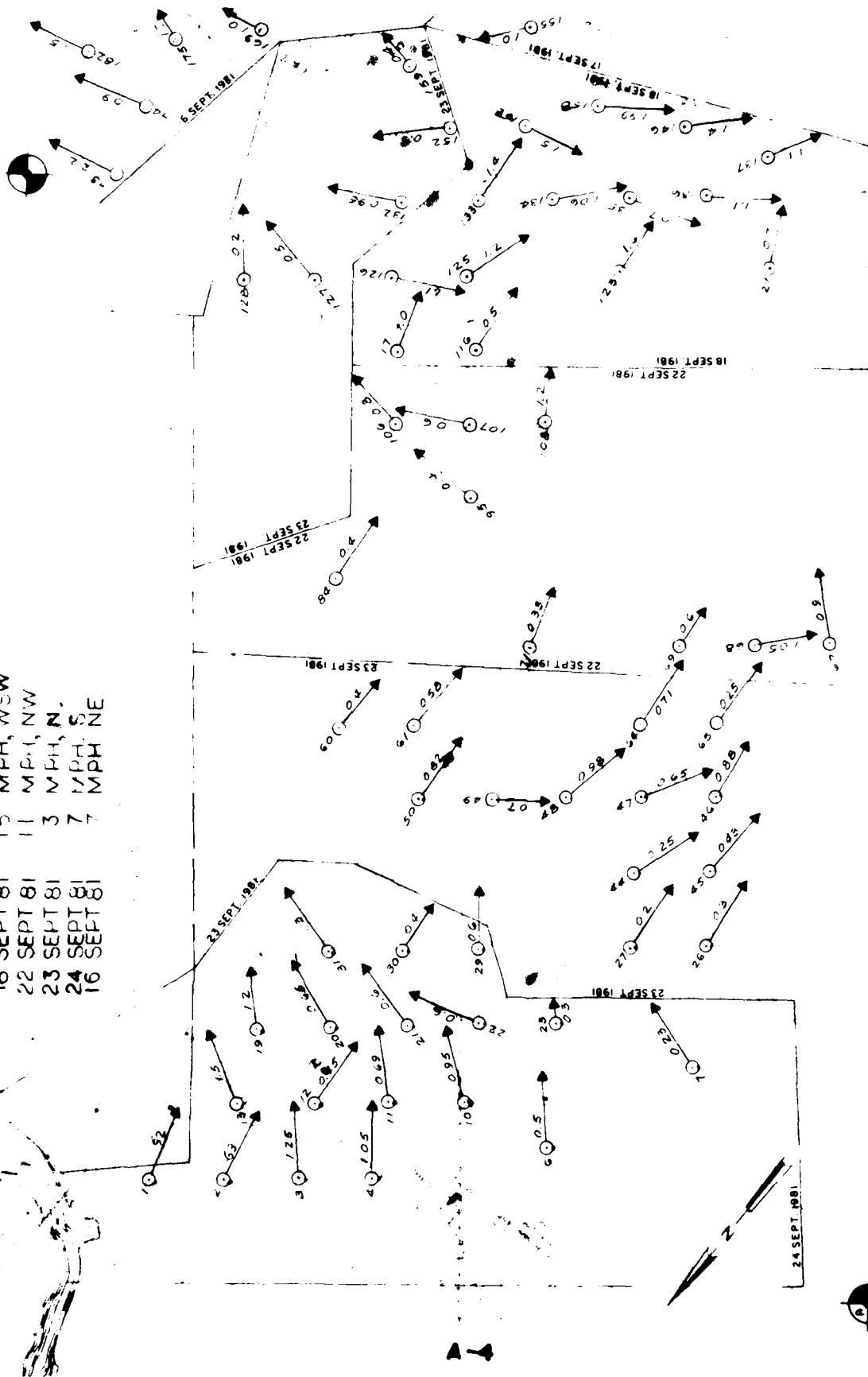
Date	Direction	Speed (MPH)
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16 SEPT 81	WSW	15
22 SEPT 81	NW	11
23 SEPT 81	N	3
24 SEPT 81	S	7
16 SEPT 81	NE	7



TENTH SETTING - 0.4  
FIGURE 2-A

WIND DATA

17 SEPT 81 9 MPH, N  
 18 SEPT 81 15 MPH, WSW  
 22 SEPT 81 11 MPH, NW  
 23 SEPT 81 3 MPH, N.  
 24 SEPT 81 7 MPH, S.  
 16 SEPT 81 7 MPH, NE

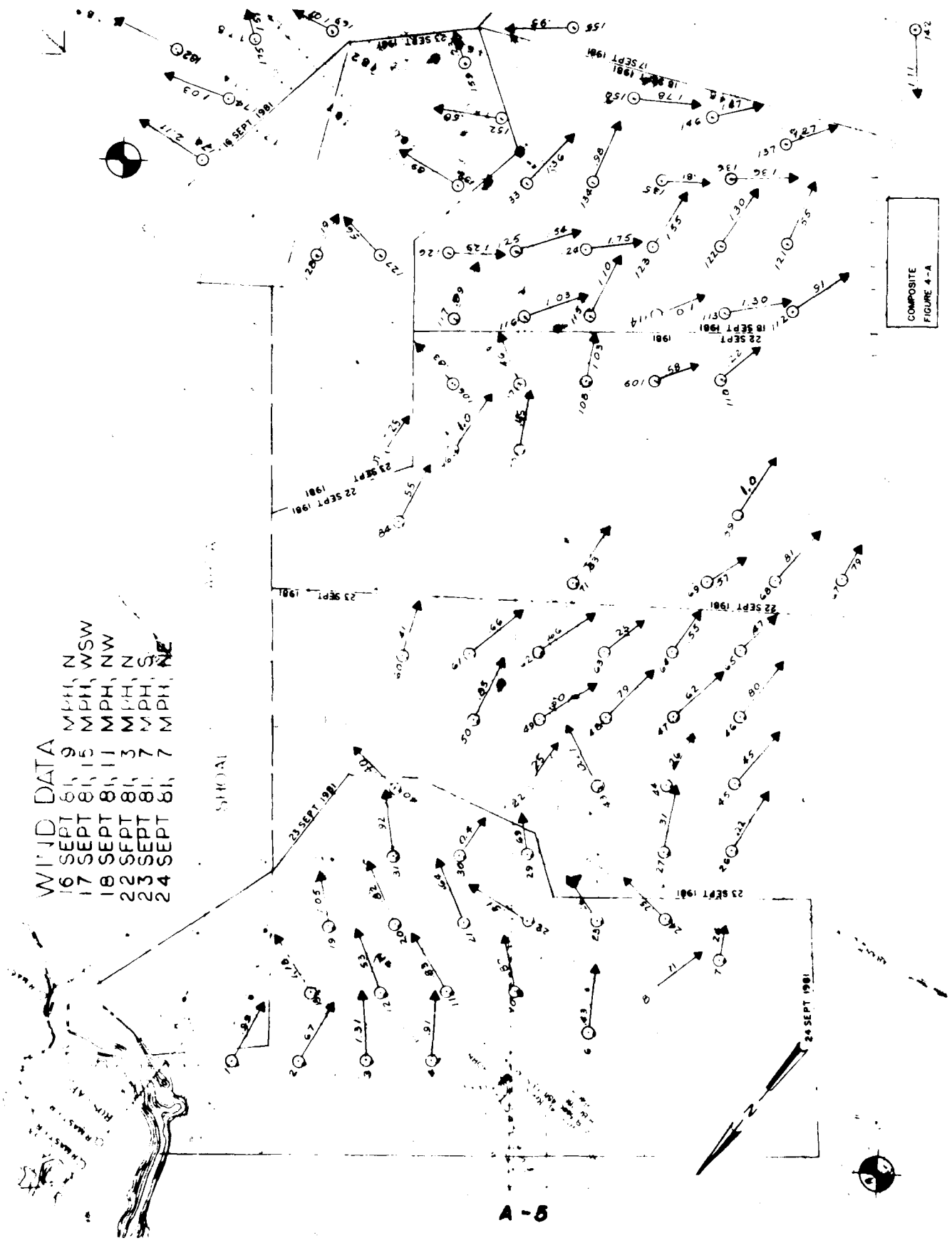


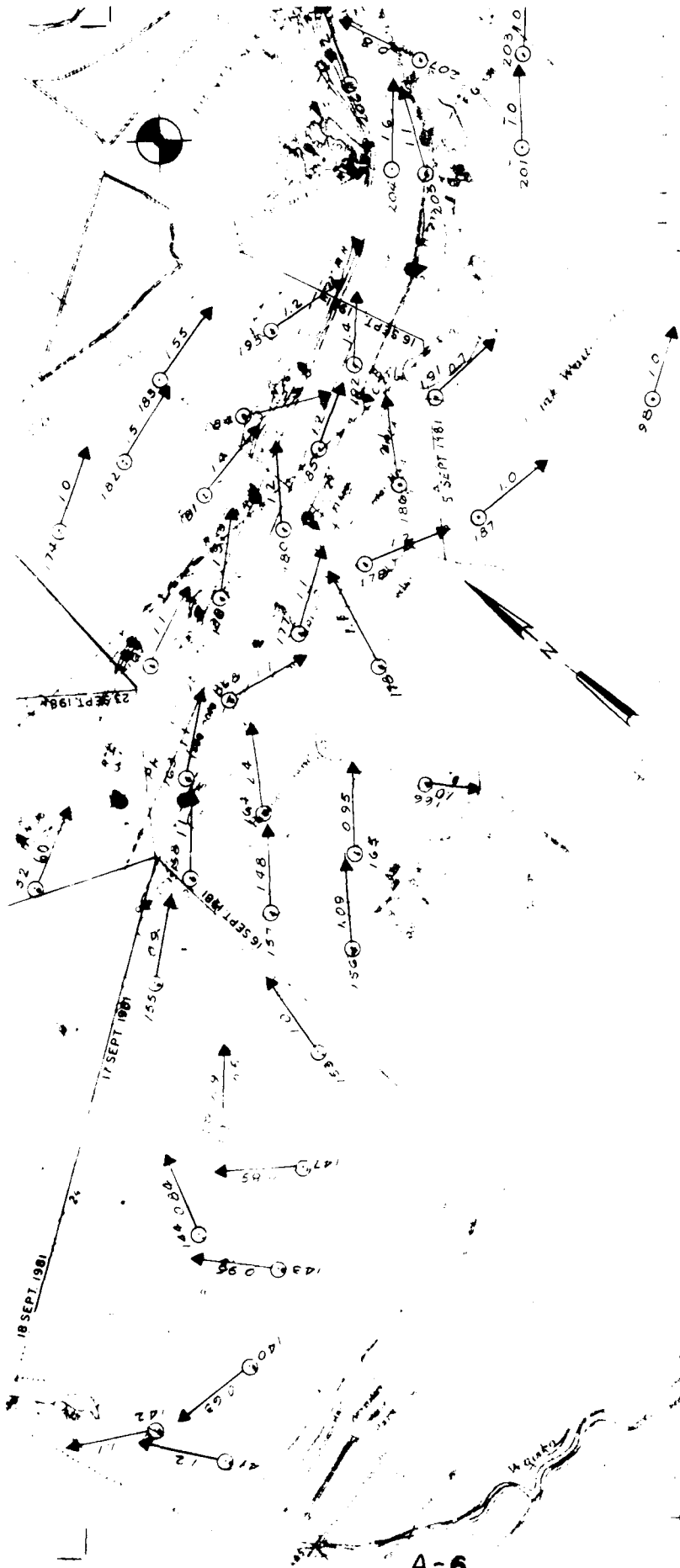
TENTH SETTING - 0.8  
 FIGURE 3-A

**WIND DATA**  
 16 SEPT 81, 9 MPH, N  
 17 SEPT 81, 15 MPH, WSW  
 18 SEPT 81, 11 MPH, NW  
 23 SEPT 81, 3 MPH, S  
 24 SEPT 81, 7 MPH, NE

SPECIAL

COMPOSITE  
FIGURE 4-A





TENTH SETTING - 0.2  
FIGURE 1-8

18 SEPT 1981  
17 SEPT 1981  
16 SEPT 1981  
15 SEPT 1981  
5 SEPT 1981  
23 SEPT 1981



TENTH SETTING -0.4  
FIGURE 2-B

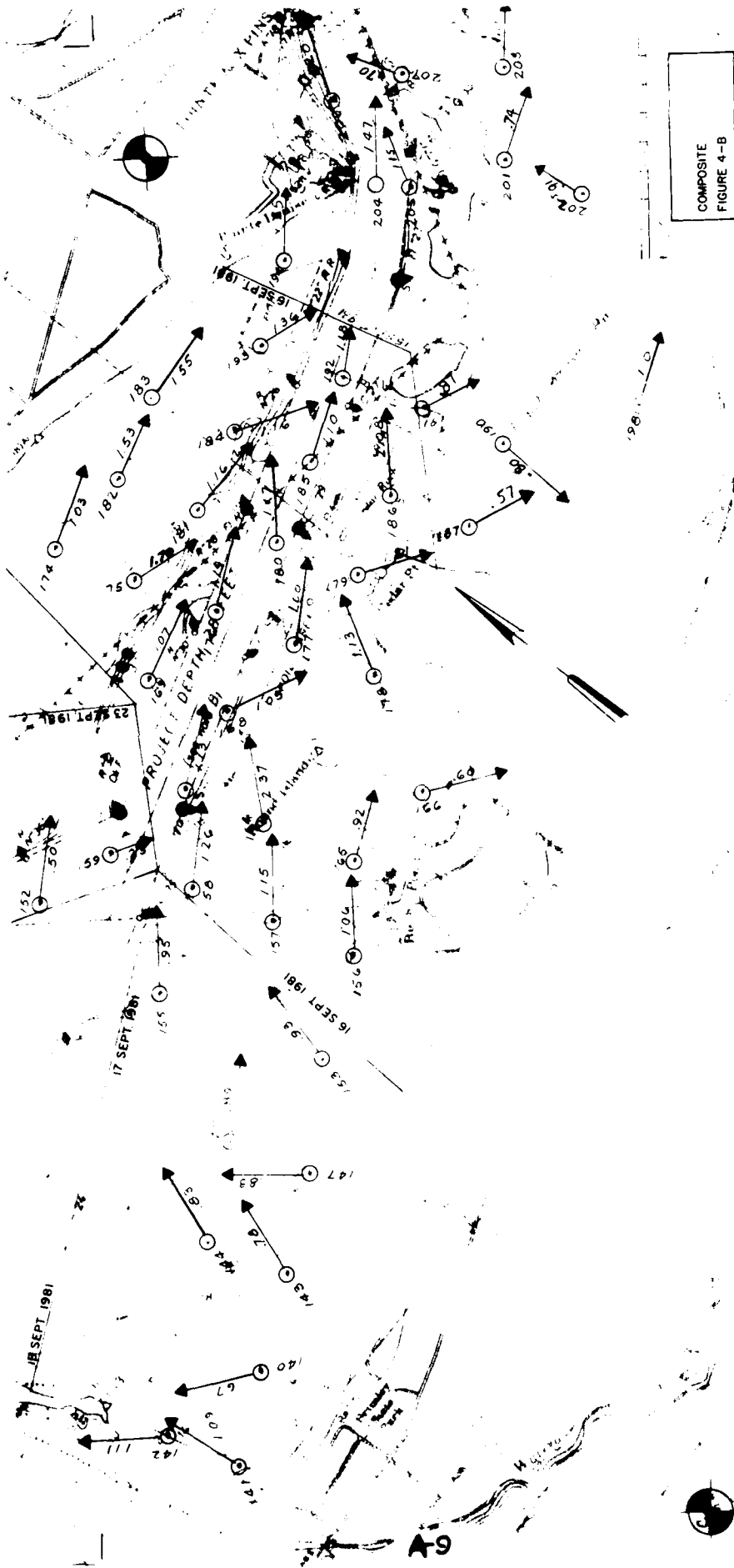
WIND DATA  
 15 SEPT 81 1 MPH S.W  
 16 SEPT 81 7 MPH E  
 17 SEPT 81 2 MPH  
 23 SEPT 81 3 MPH



TENTH SETTING - 0.8  
FIGURE 3-B

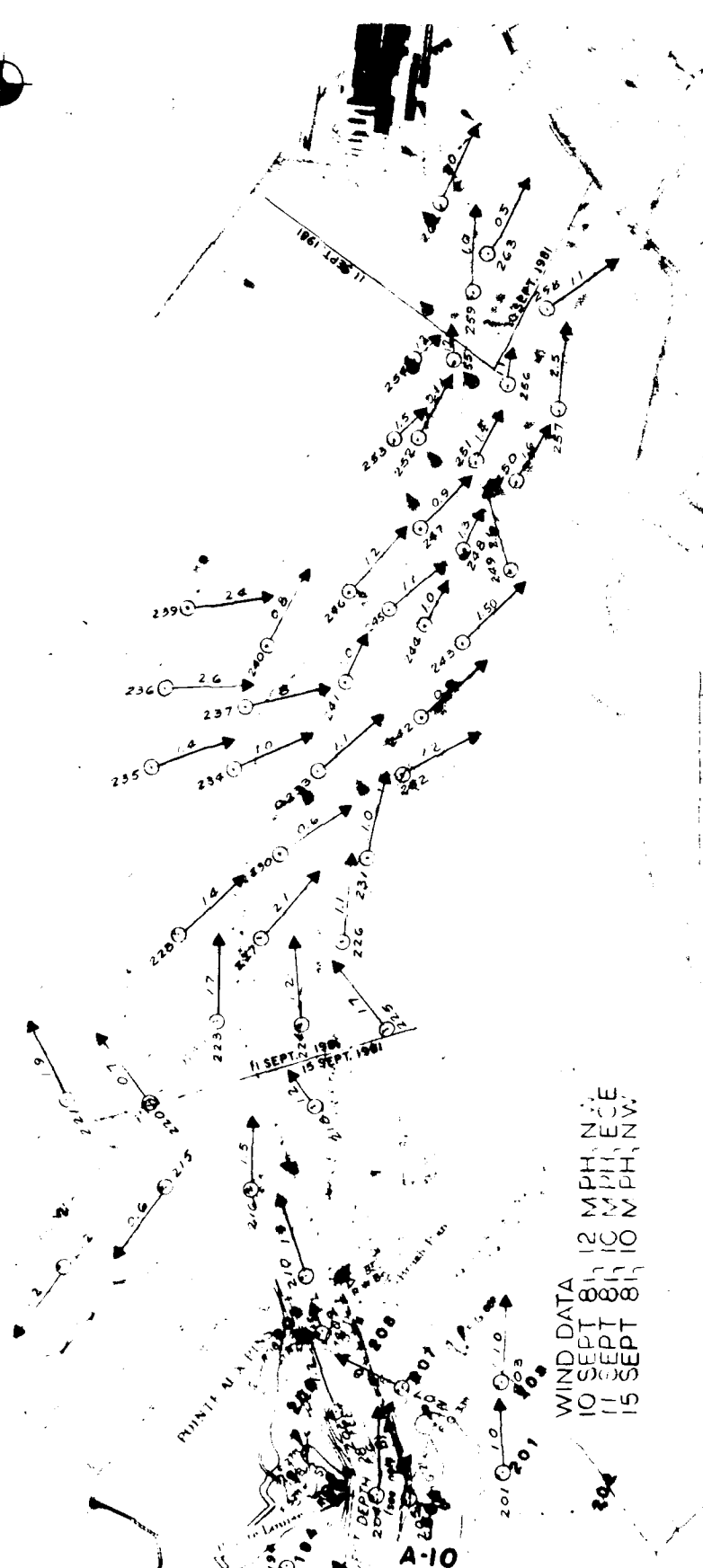
MINL DAT  
5 SEPT 81 7 MPH, IV7  
16 SEPT 81 7 MPH, IV7  
17 SEPT 81 3 MPH, IV7  
23 SEPT 81 3 MPH, IV7

A-8



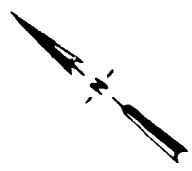
COMPOSITE  
FIGURE 4-B

1 SEPT 1981  
 2 SEPT 1981  
 3 SEPT 1981  
 4 SEPT 1981  
 5 SEPT 1981  
 6 SEPT 1981  
 7 SEPT 1981  
 8 SEPT 1981  
 9 SEPT 1981  
 10 SEPT 1981  
 11 SEPT 1981  
 12 SEPT 1981  
 13 SEPT 1981  
 14 SEPT 1981  
 15 SEPT 1981  
 16 SEPT 1981  
 17 SEPT 1981

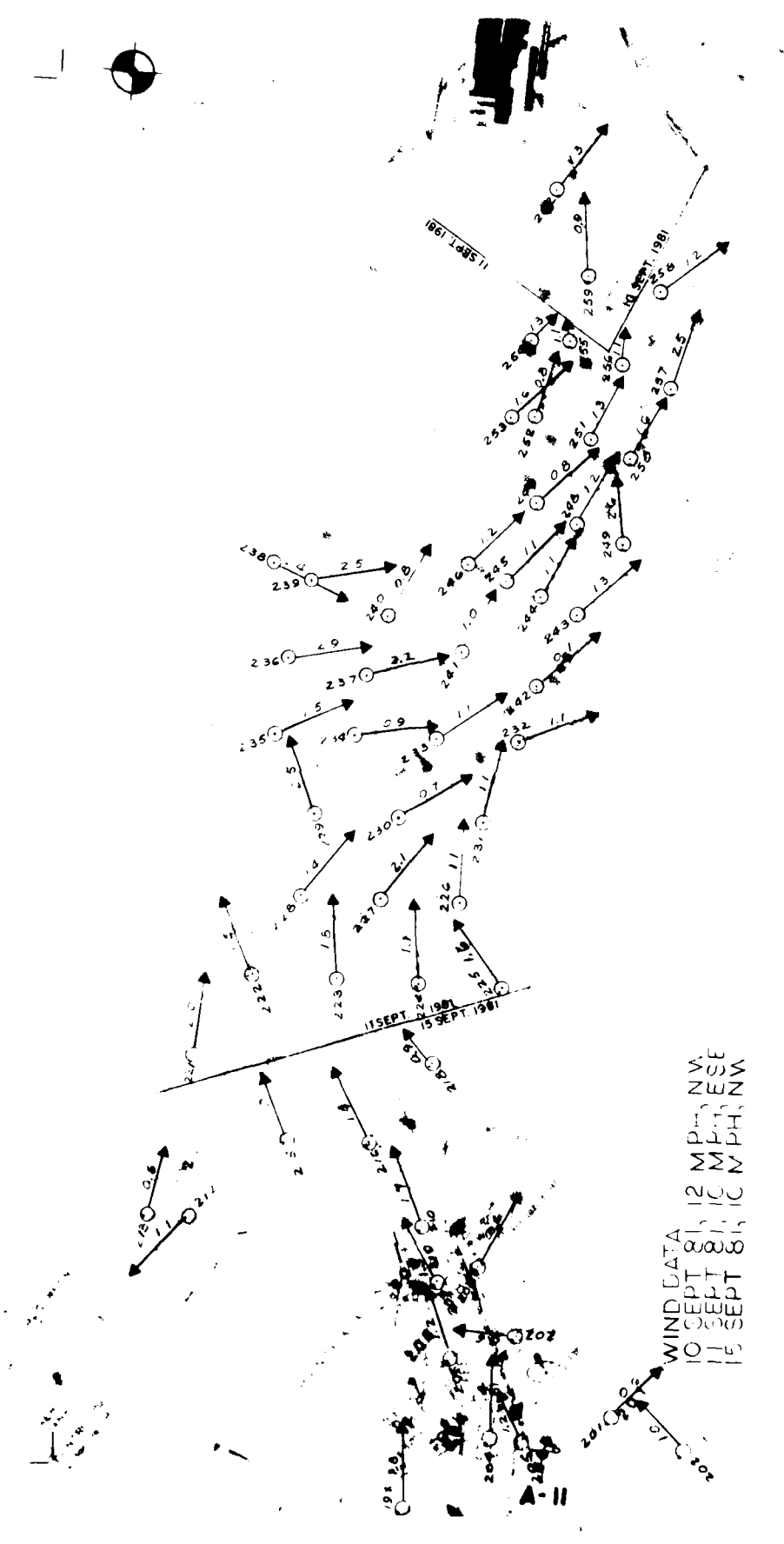


TENTH SETTING - 0.2  
FIGURE 1-C

WIND DATA  
 10 SEPT 81 12 MPH, NCE  
 11 SEPT 81 10 MPH, ECE  
 15 SEPT 81 10 MPH, NW

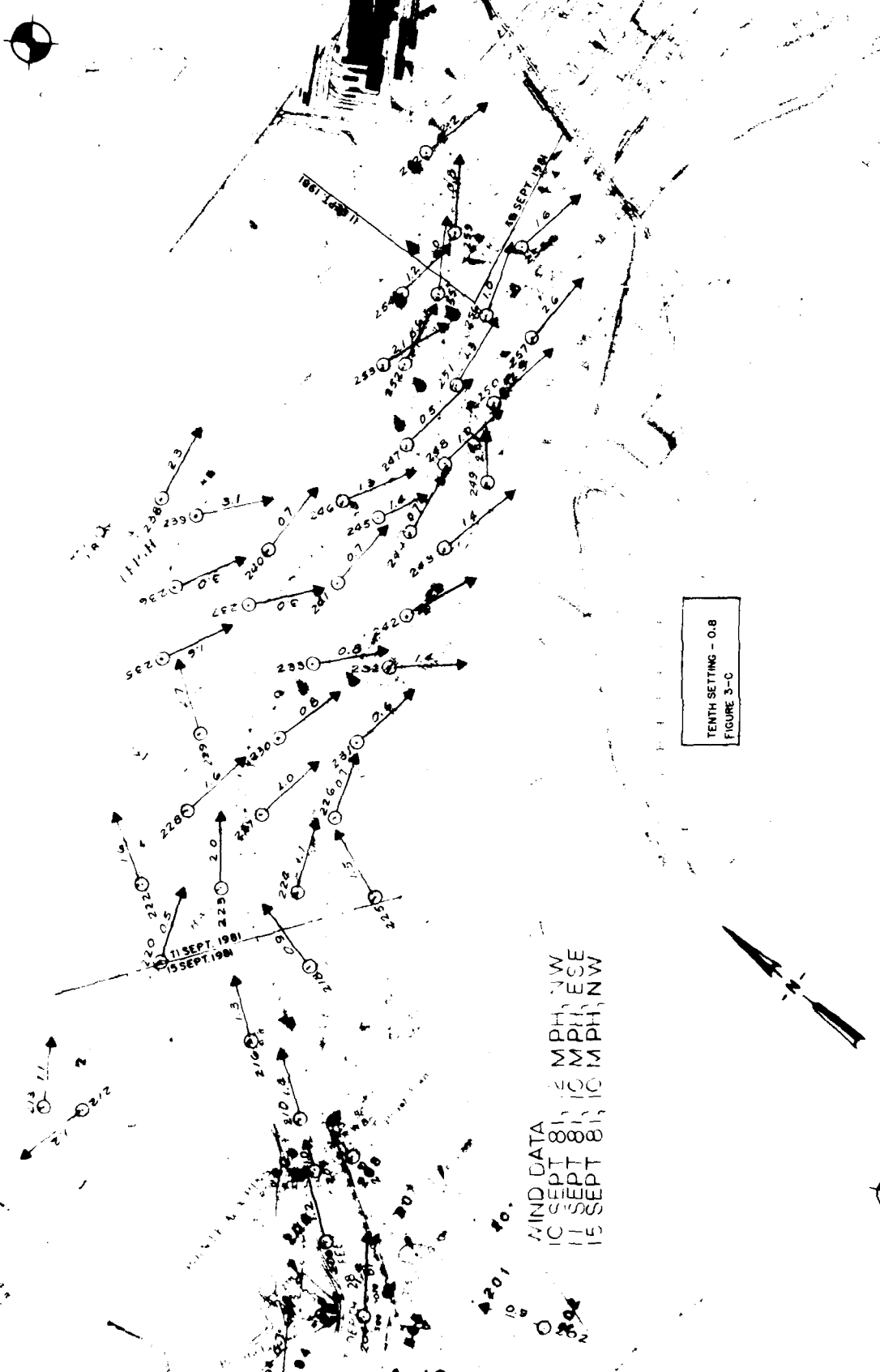


A-10



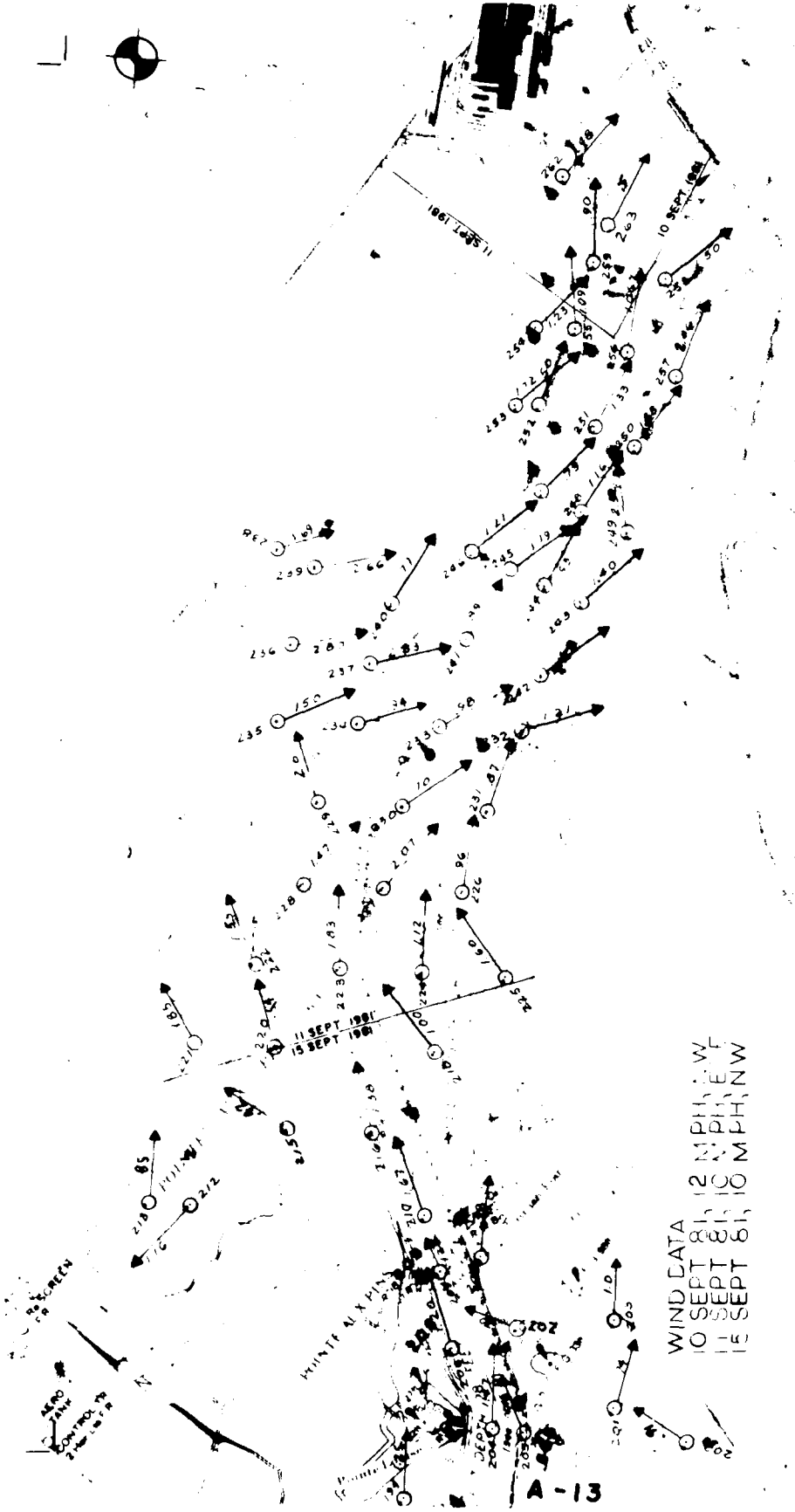
TENTH SETTING - 0.4  
FIGURE 2-C

WIND DATA  
 10 SEPT 81, 12 M.P.H., NW;  
 11 SEPT 81, 10 M.P.H., ESE;  
 15 SEPT 81, 10 M.P.H., NW



TENTH SETTING - 0.8  
FIGURE 3-C

WIND DATA  
 11 SEPT 81, 2 MPH, V, W  
 12 SEPT 81, 10 MPH, ESE  
 13 SEPT 81, 10 MPH, NW



WIND DATA  
 10 SEPT 81, 12 N PH, W  
 11 SEPT 81, 10 N PH, E, F  
 12 SEPT 81, 10 N PH, E, W  
 15 SEPT 81, 10 N PH, NW

COMPOSITE  
 FIGURE 4-C

APPENDIX B  
ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 2

This appendix presents current velocities and directions for Reach 2 of the St. Marys River, Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into six figures as shown in the Index Figure (page B-1).

Open water current measurements were conducted between 6 and 10 June 1983 (Flow (JUN) = 104,000 cubic feet per second (cfs)). Figures A and B display current data collected for each of the 2, 4 and 8 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second (fps). In addition, Figures A and B have a composite drawing developed from the data documented for that figure.

Drogue surveys were conducted on 2 and 3 June 1983 (Flow (JUN) = 104,000 cfs). Data collected are shown in Figure C as point of transit intersection (dot), drogue path (line connecting two consecutive dots) and computed velocity in fps (number).

Aerial drogue surveys were conducted on 13 and 20 July 1982 (Flow (JUL) = 78,450 cfs). Data collected are shown in Figures D-F as velocity in fps (number) and direction (arrow).

A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX B  
REACH 2

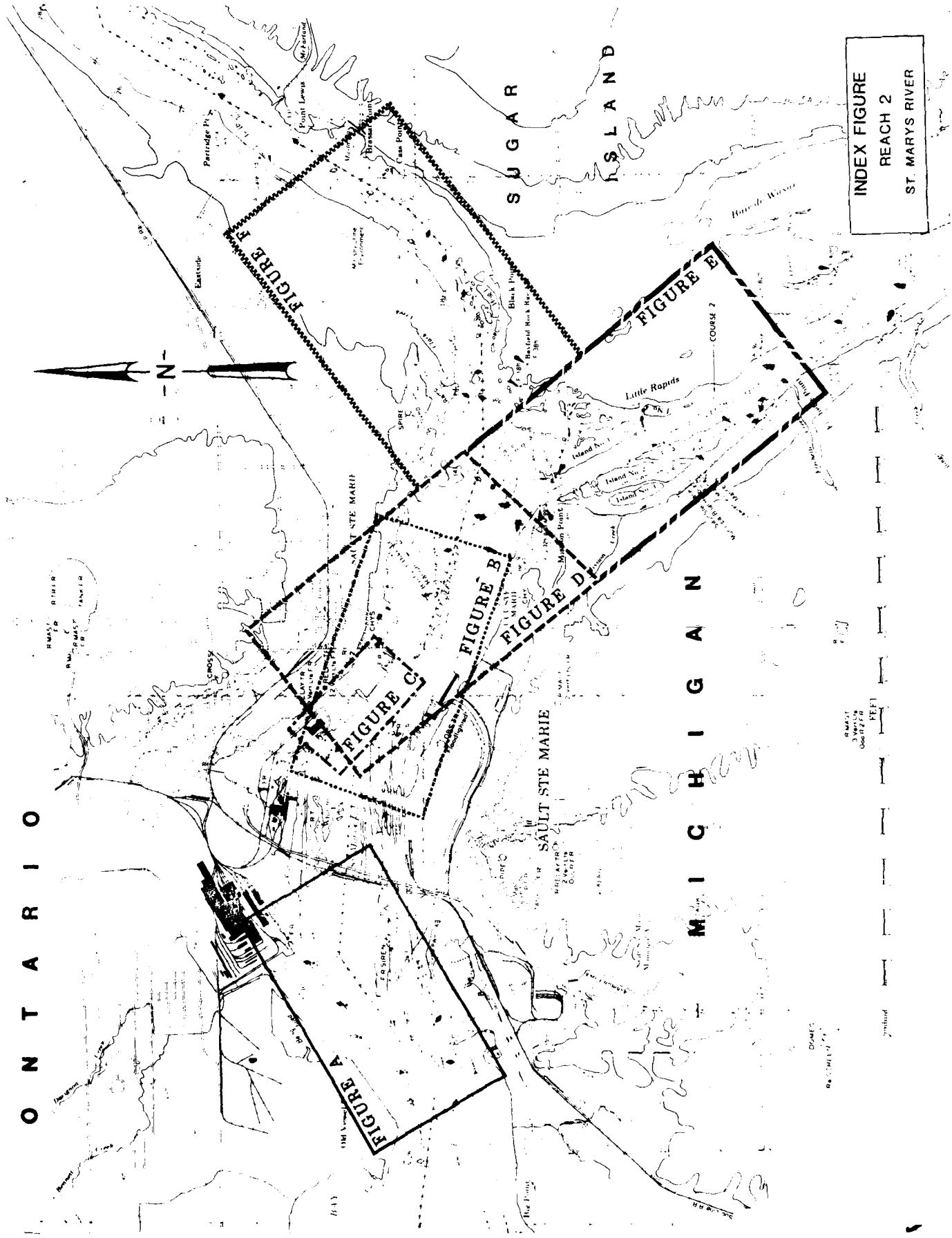
LIST OF FIGURES

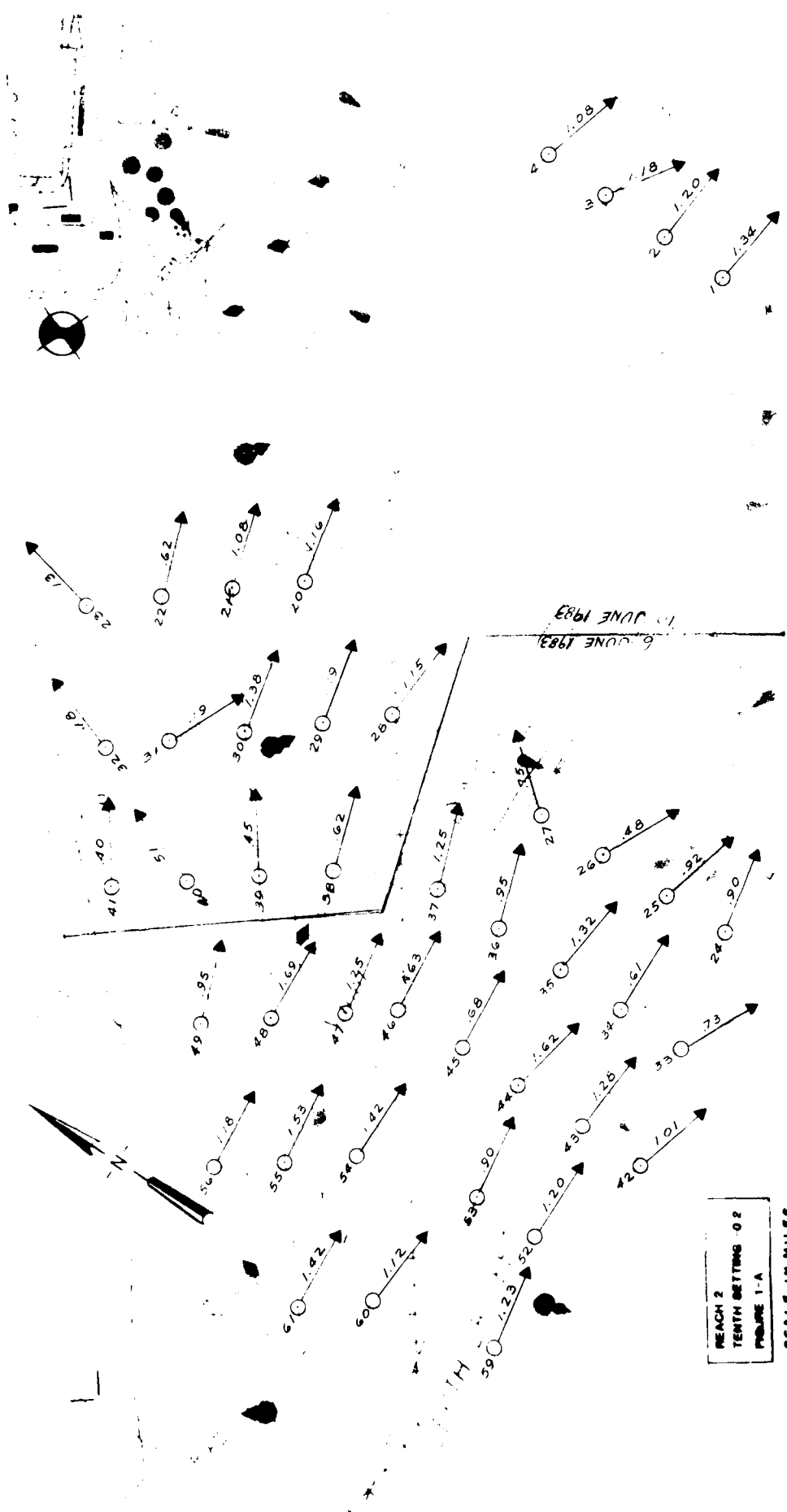
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Figure 3-A	Eight Tenths Setting	B-4
Figure 4-A	Composite	B-5
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Figure C	Drogue Study	B-9
Figure D	Aerial Drogue Study	B-10
Figure E	Aerial Drogue Study	B-11
Figure F	Aerial Drogue Study	B-12

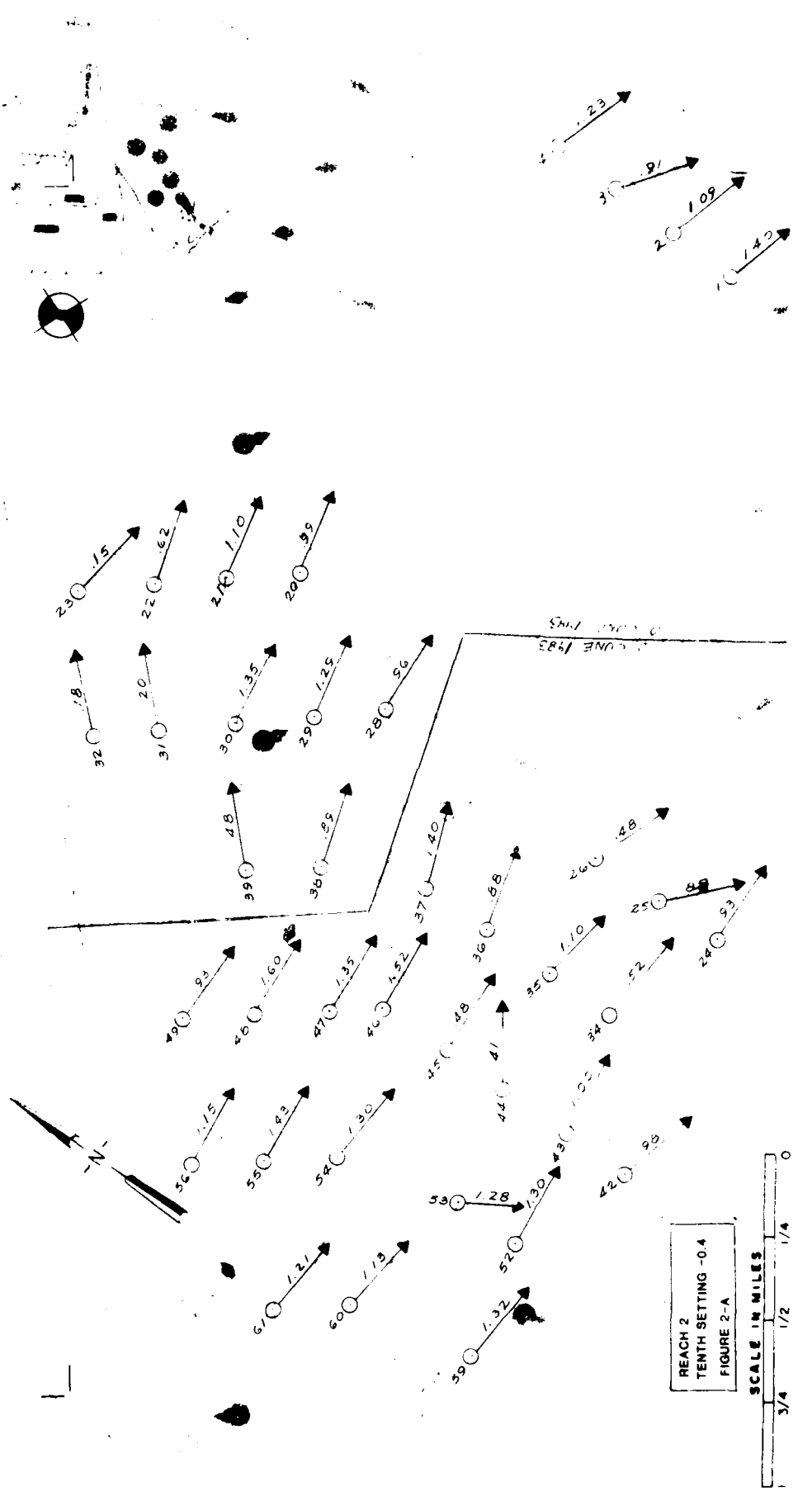
O N T A R I O

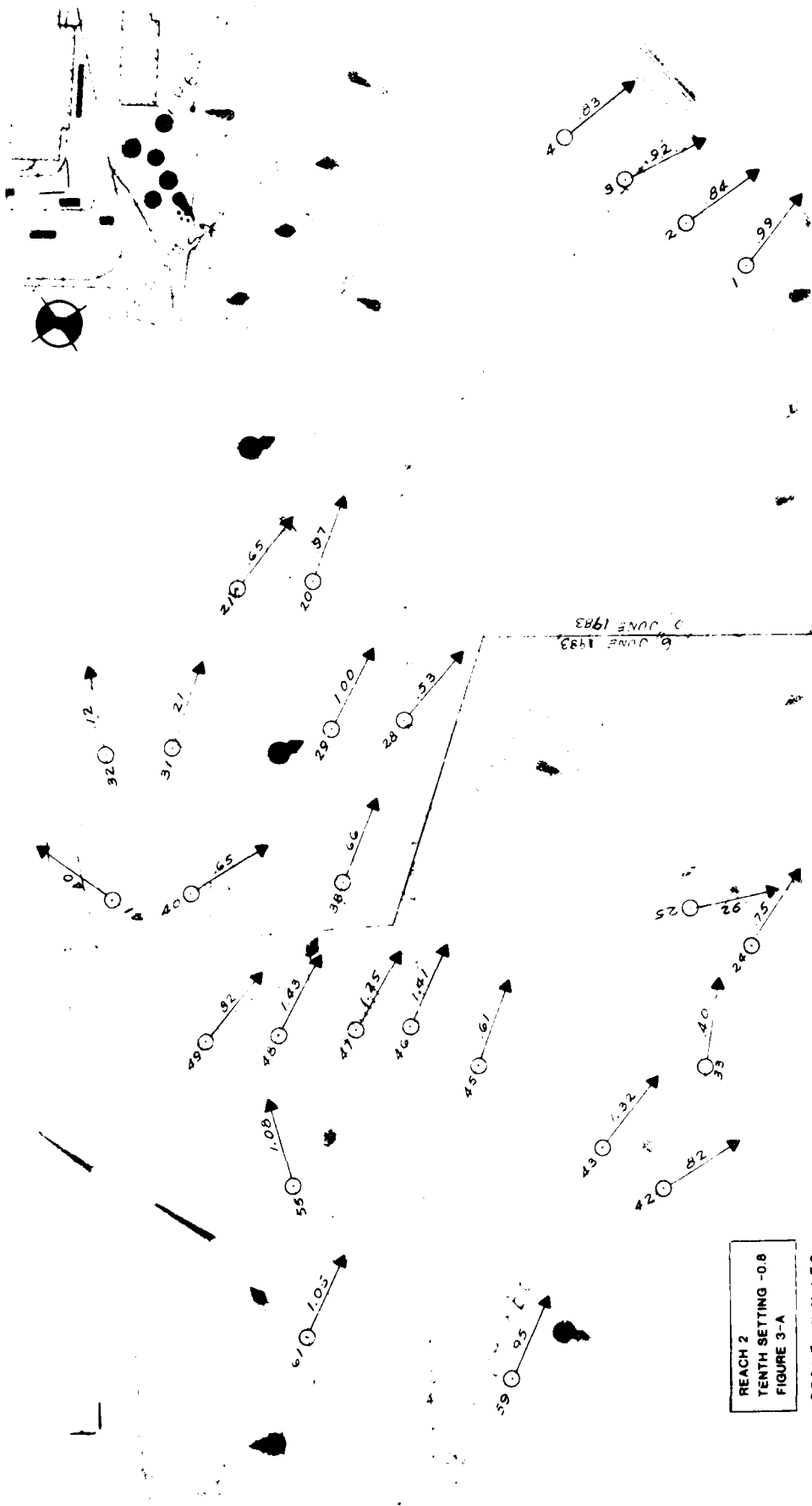
M I C H I G A N

INDEX FIGURE  
REACH 2  
ST. MARYS RIVER

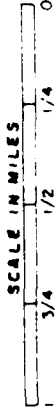




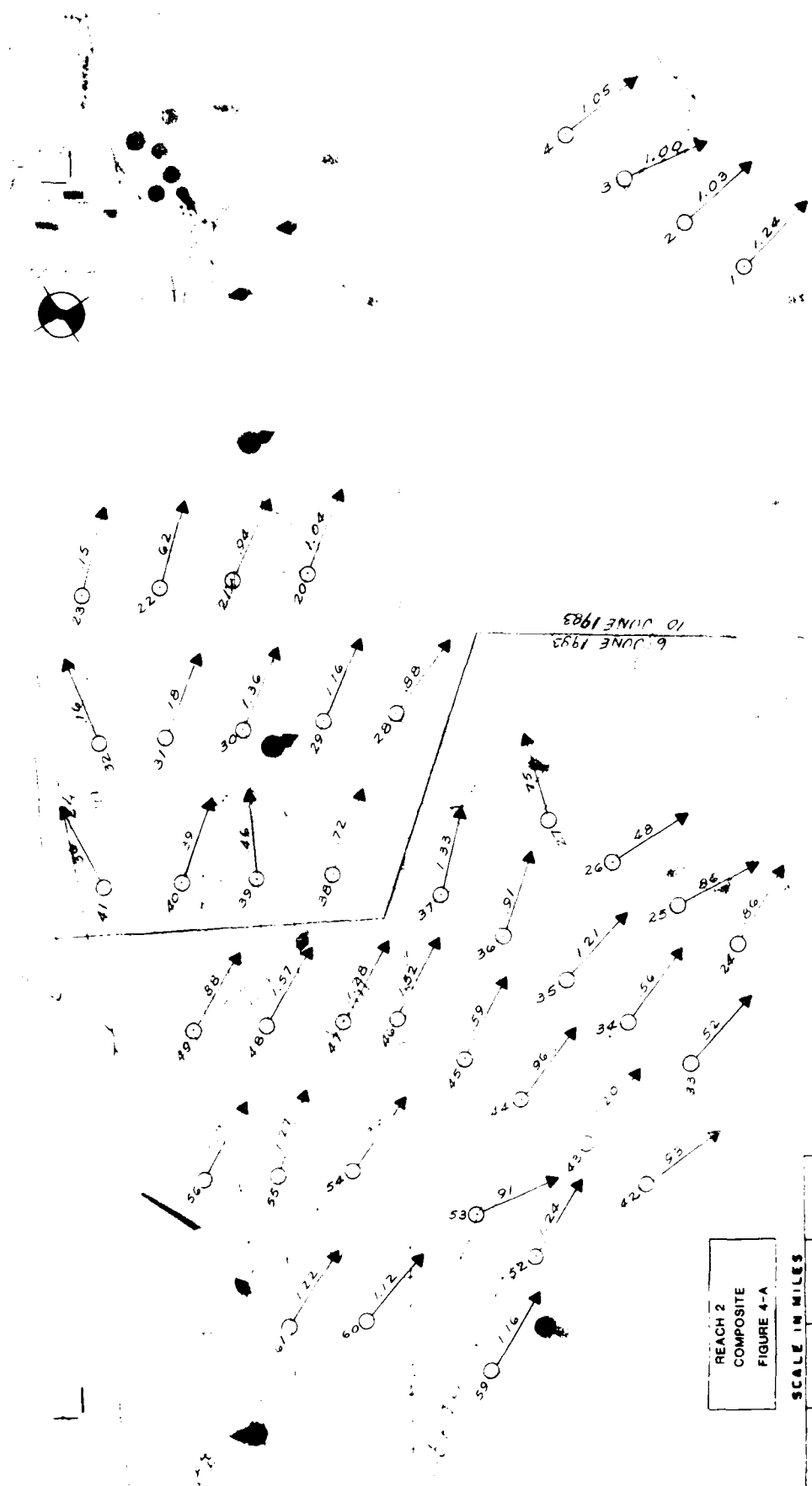




REACH 2  
TENTH SETTING -0.8  
FIGURE 3-A



WIND DATA  
6 JUNE 83 10 MPH IN W  
6 JUNE 83 10 MPH IN W

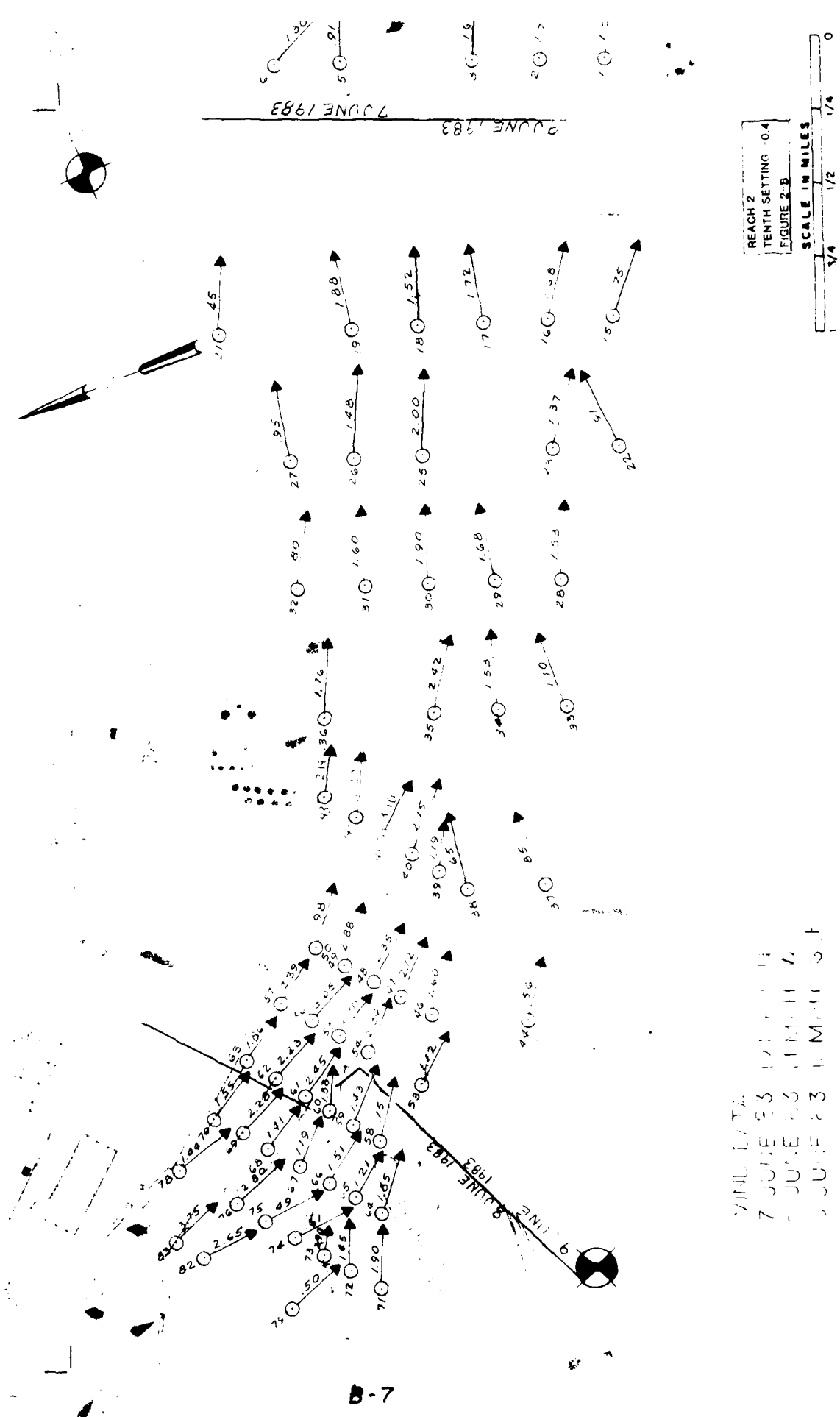




REACH 2  
TENTH SETTING -0.2  
FIGURE 1-B

B-6

7 June 1983  
8 June 1983  
NW  
W  
SE

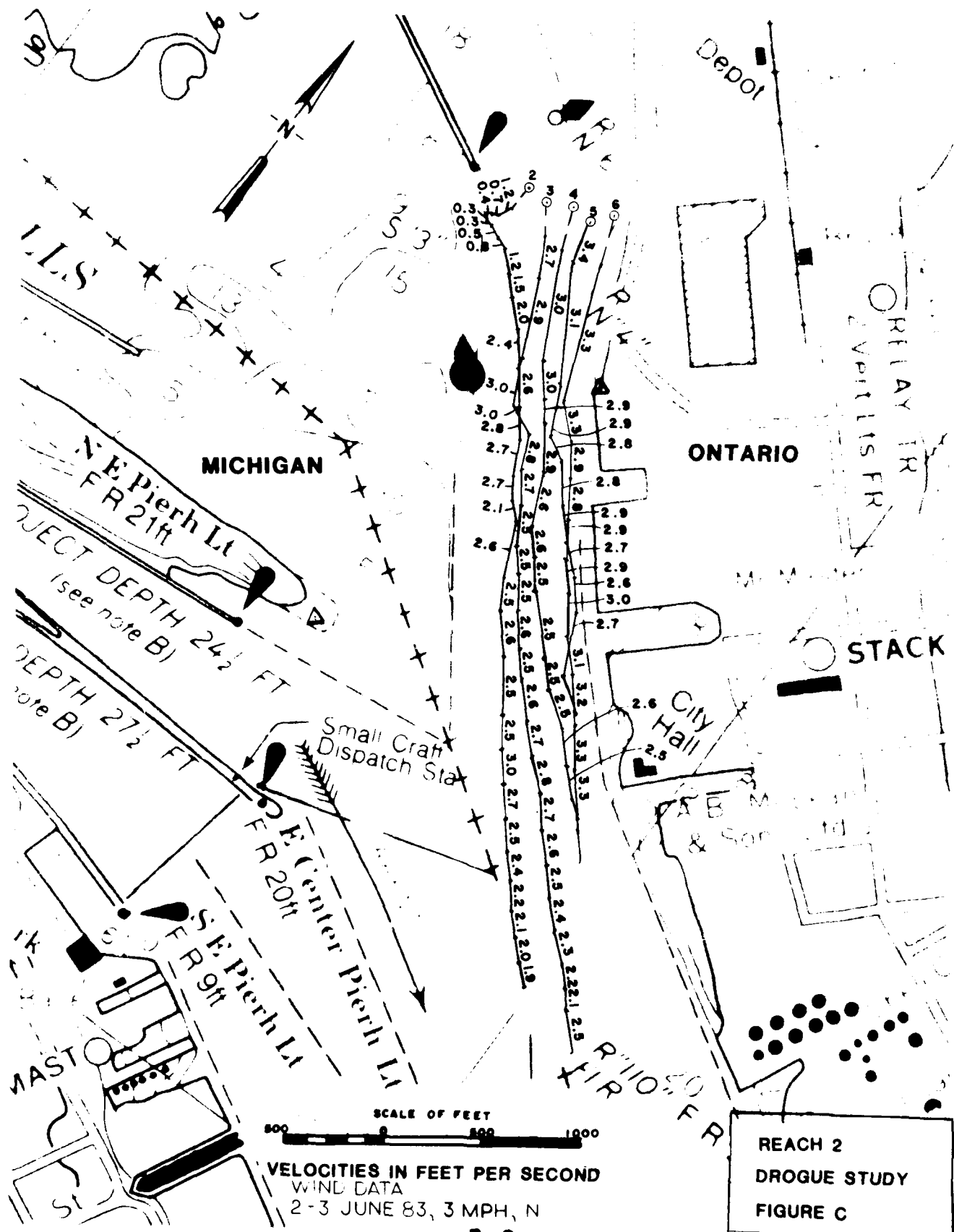


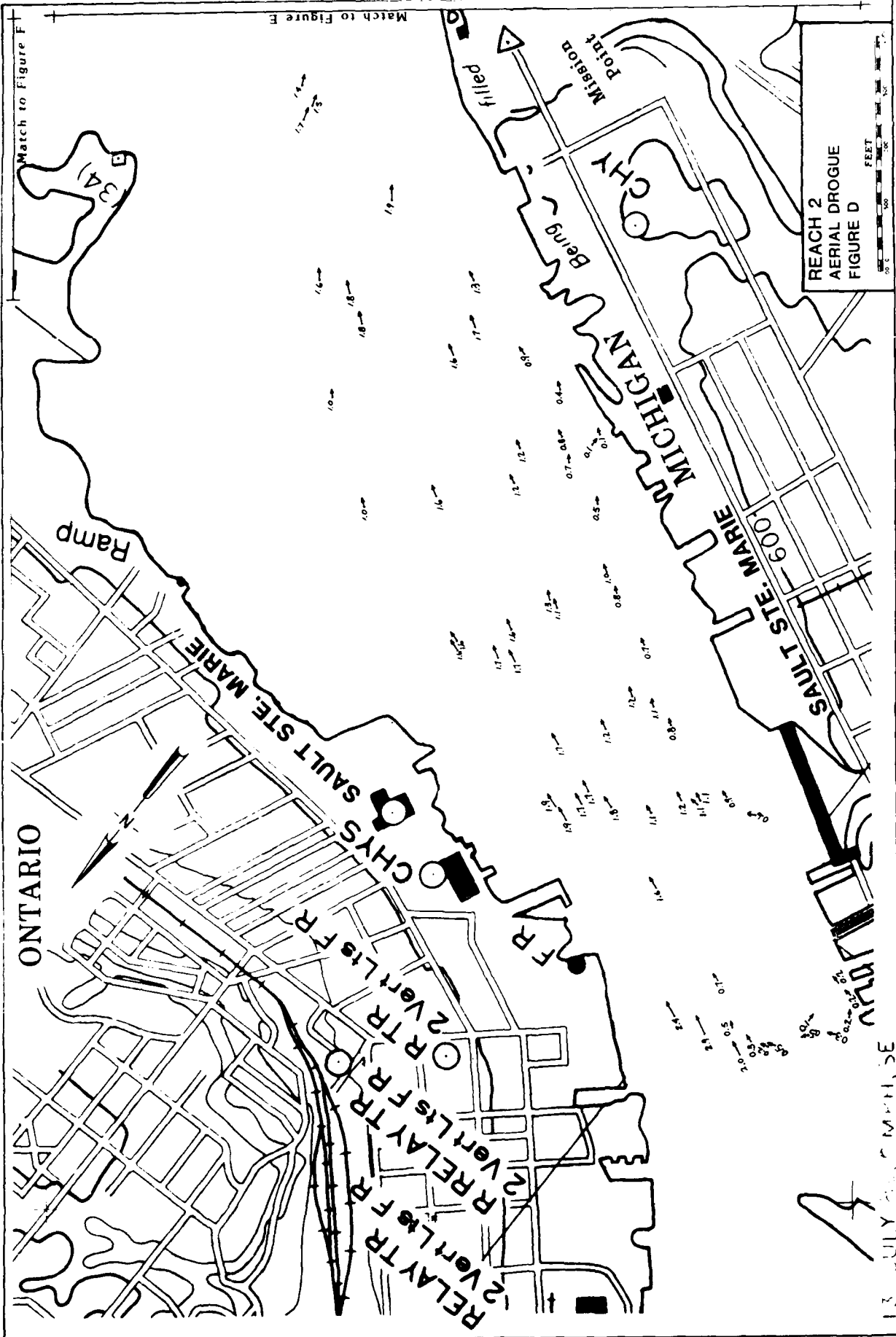


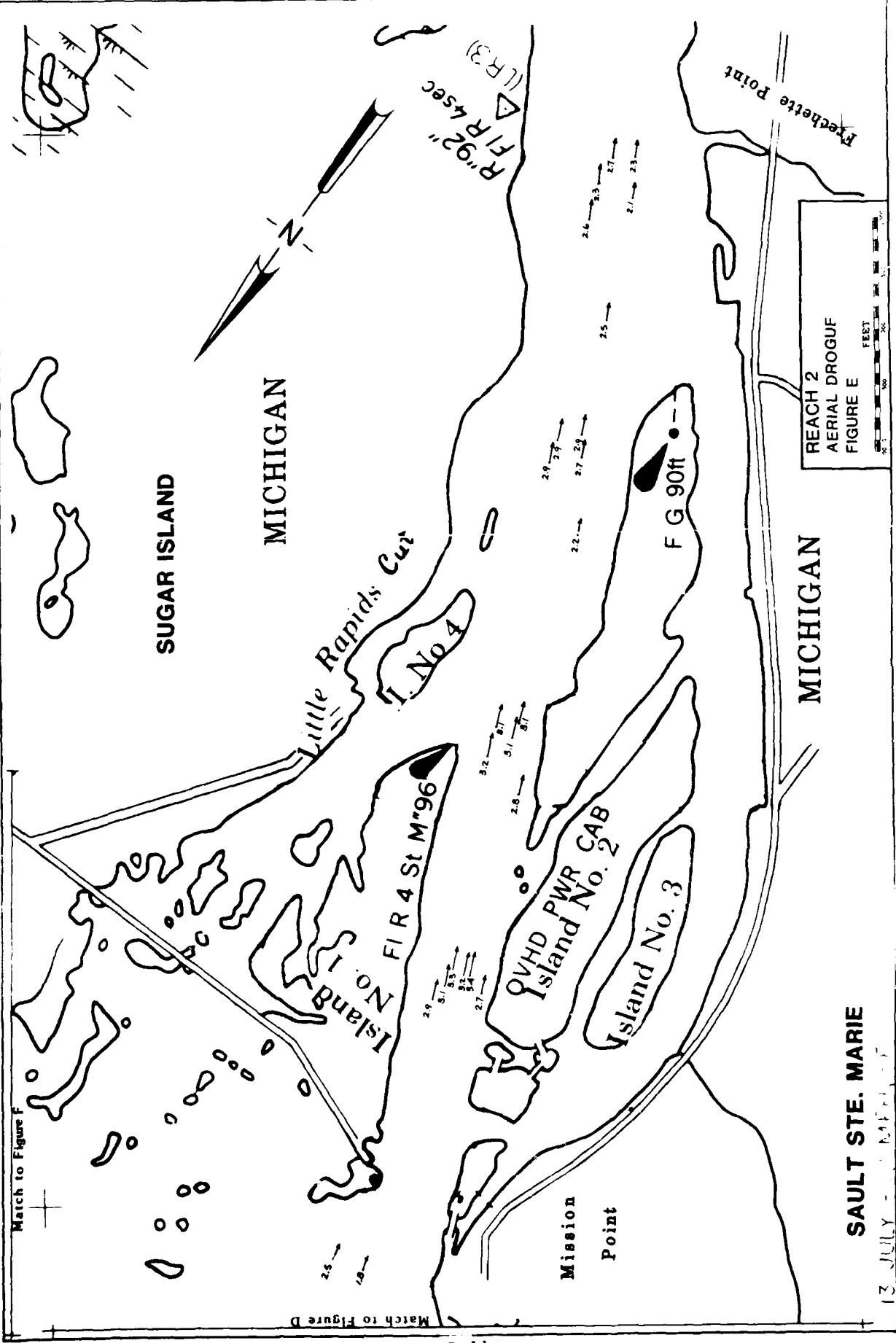
WIND DATA  
 7 JUNE 83, 11M11, NV  
 8 JUNE 83, 11M11, V  
 9 JUNE 83, 10M11, VCE

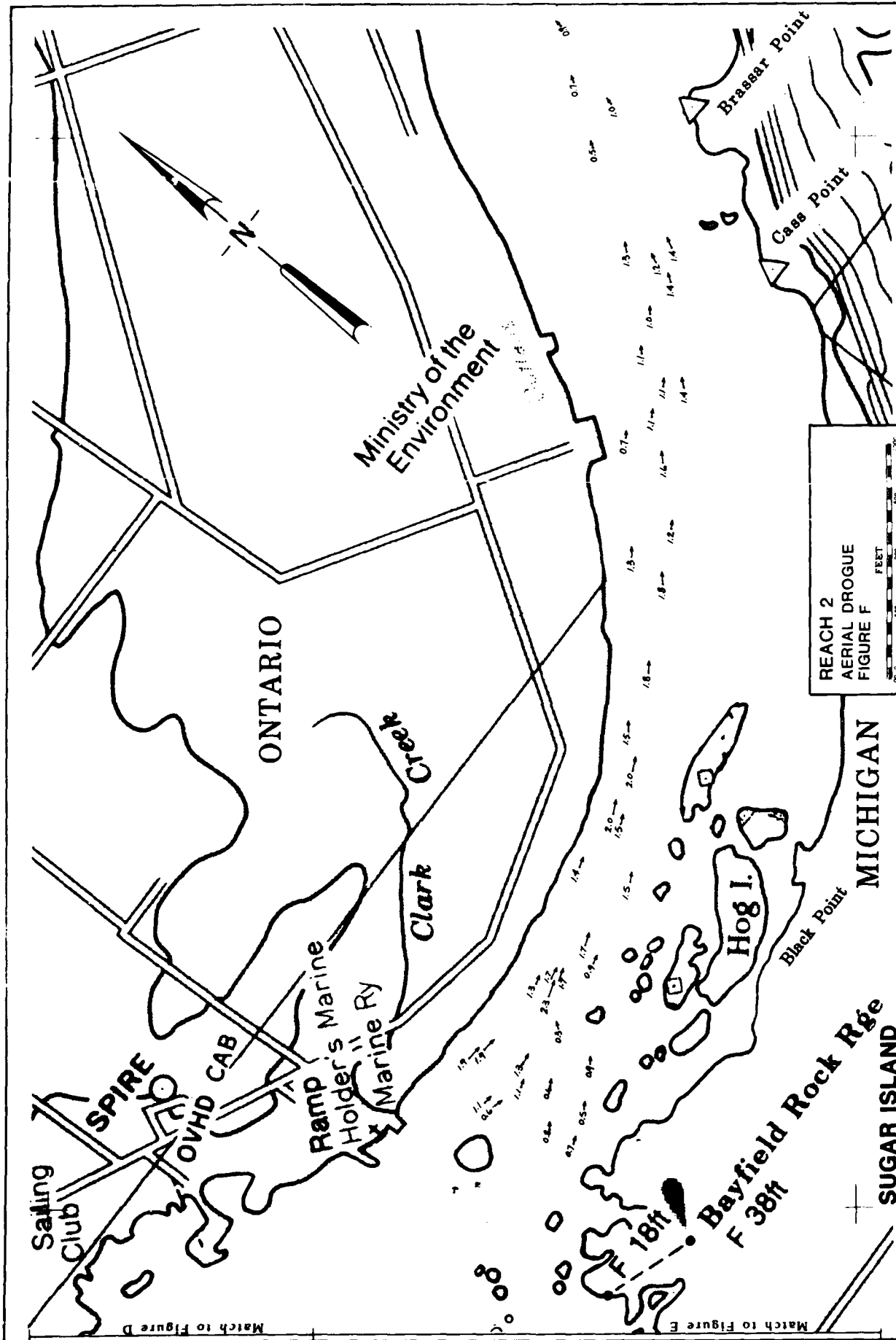
REACH 2  
 COMPOSITE  
 FIGURE 3-B  
 SCALE IN MILES  
 1/4 1/2 3/4 0

9 JUNE 1983  
 7 JUNE 1983









B-12

20 JULY 22 14 MET

APPENDIX C  
ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 3

This appendix presents current velocities and directions for Reach 3 of the St. Marys River, Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into three figures as shown in the Index Figure (page C-1).

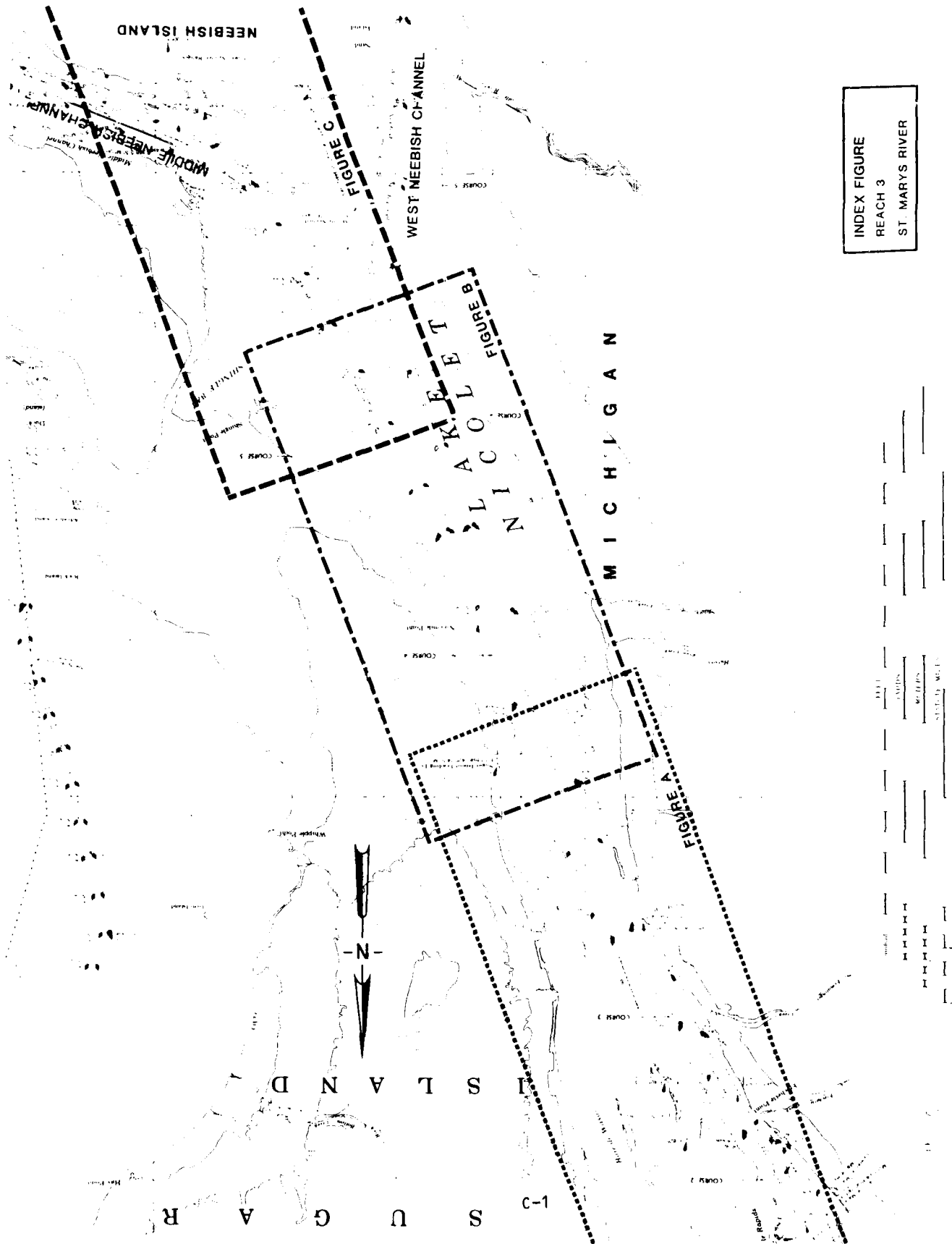
Open water current measurements were conducted on 13 and 14 July 1983 (Flow (JUL) = 102,890 cubic feet per second). Figures A-C display current data for each of the 2, 4 and 8 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second. In addition, each figure has a composite drawing developed from the data documented for that figure.

A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX C  
REACH 3

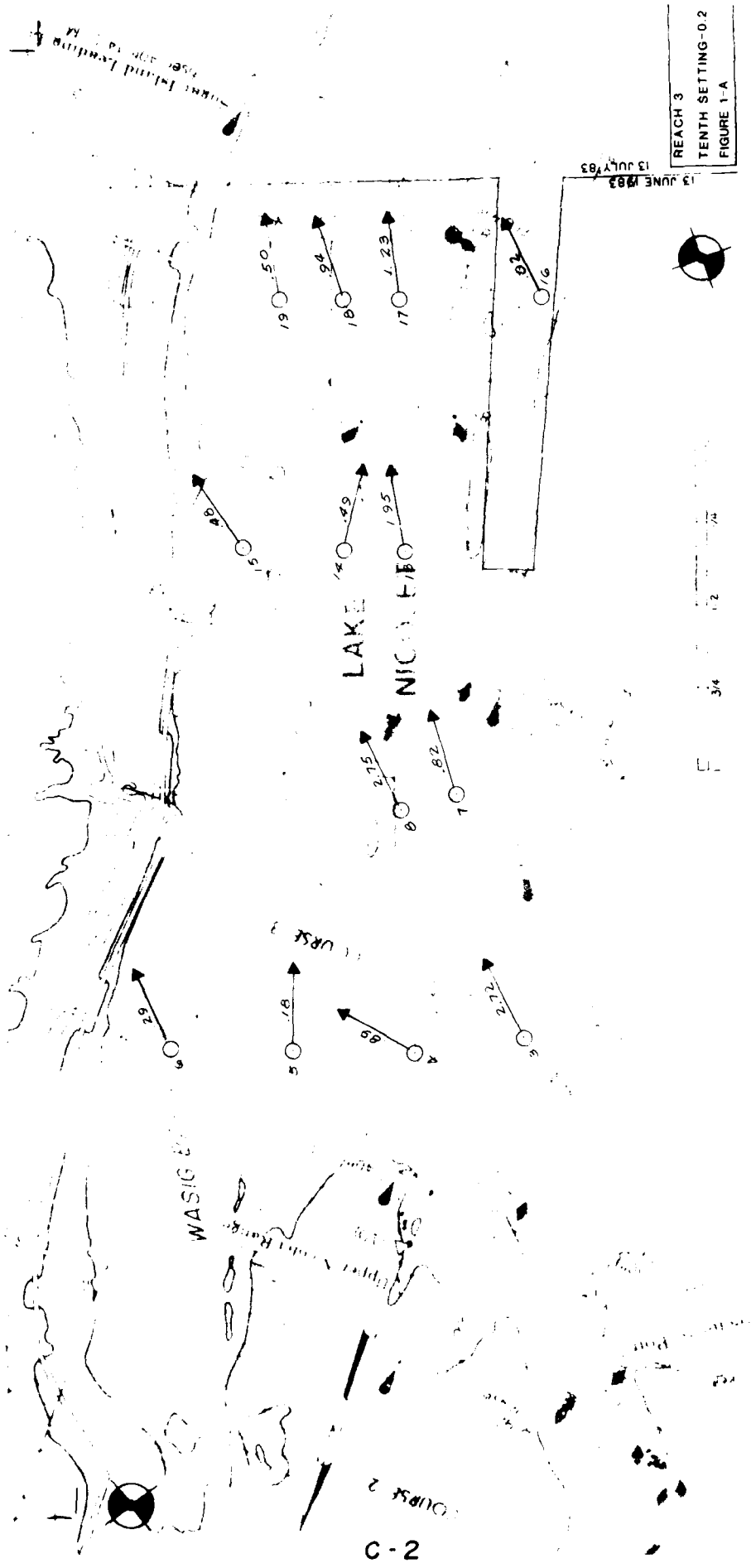
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Figure 2-B	Four Tenths Setting	C-7
Figure 3-B	Eight Tenths Setting	C-8
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Figure 1-C	Two Tenths Setting	C-10
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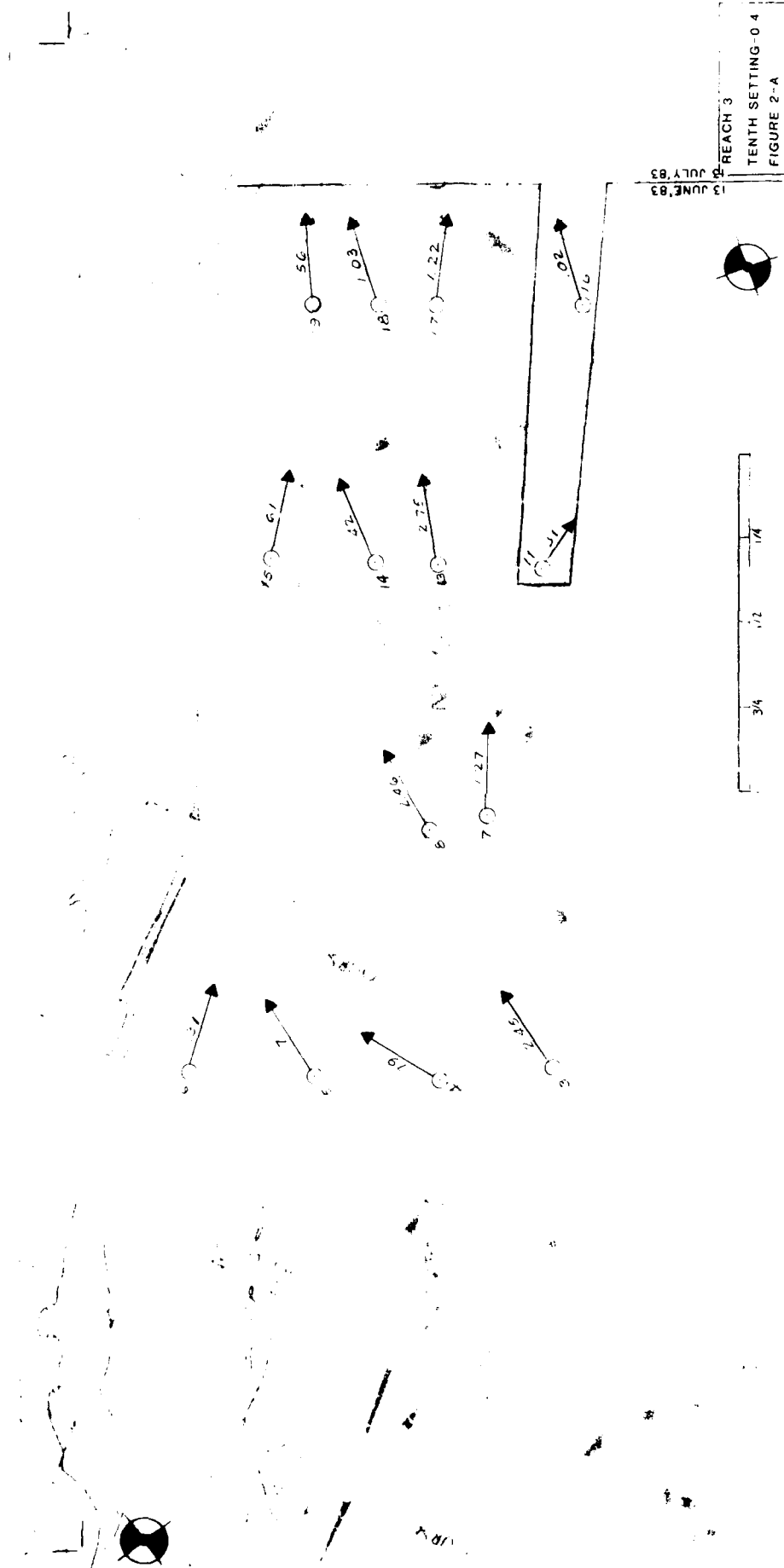


INDEX FIGURE  
 REACH 3  
 ST. MARYS RIVER

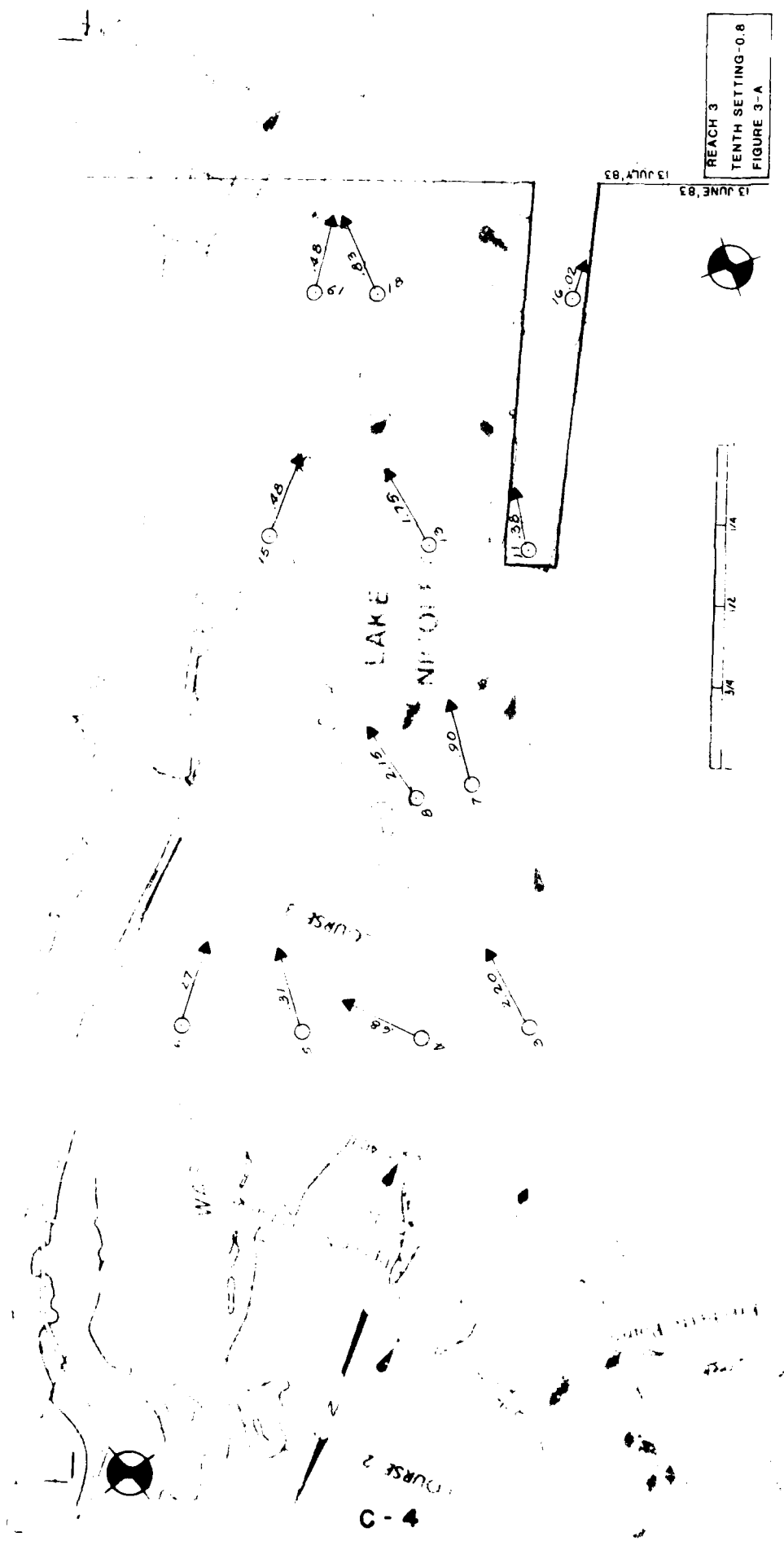
- DUNE
- LADDER
- WELLS
- STUDY WELLS



WIND DATA:  
13 JUNE 83, 2 MPH, S  
13 JULY 83, CALM



WIND DATA  
13 JUNE 83 2140L  
13 JULY 83 0417

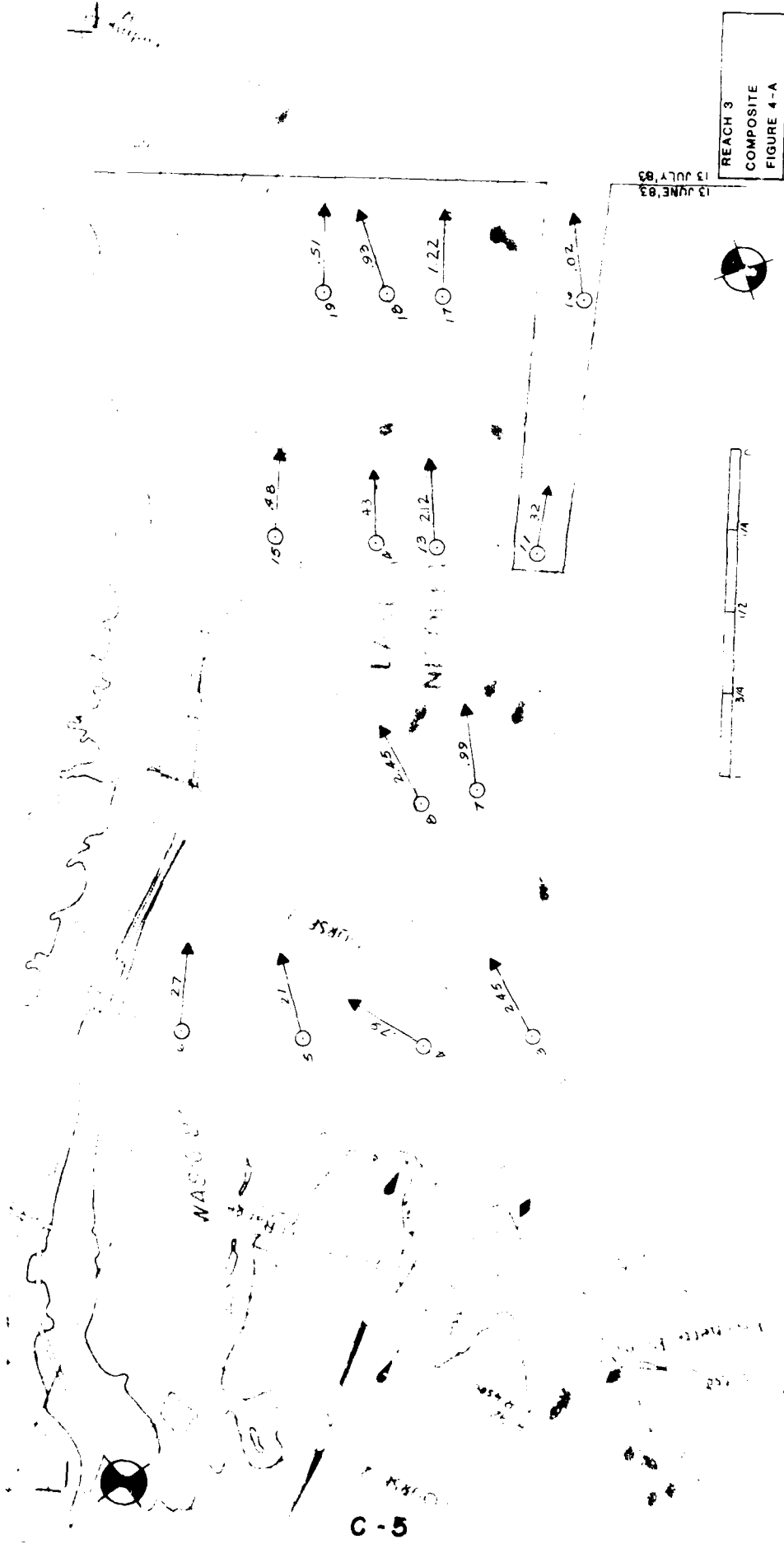


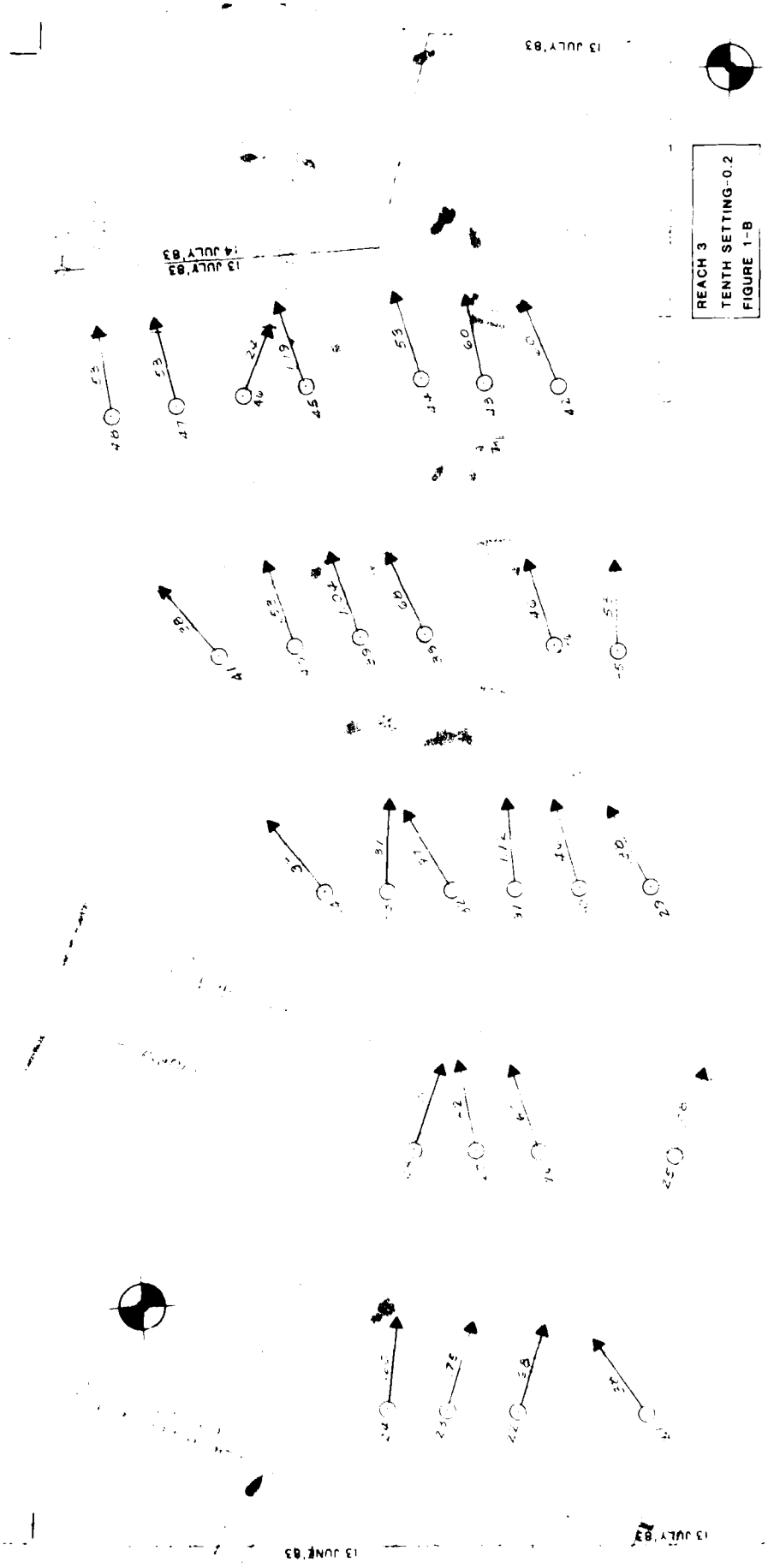
REACH 3  
TENTH SETTING - 0.8  
FIGURE 3-A

13 JUNE '83  
13 JULY '83

WIND DATA  
7 JUNE 83 2100H  
13 JULY 83 0400H

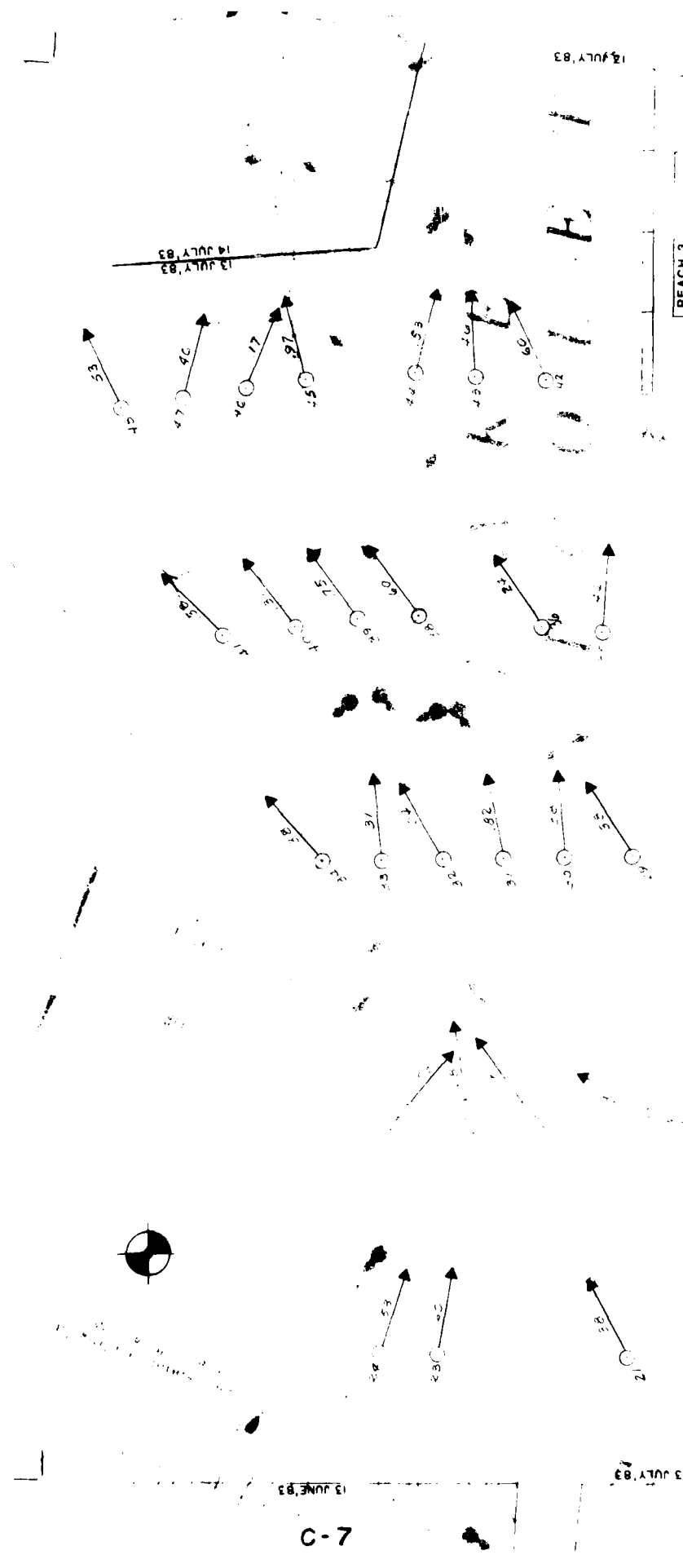
C-4  
COURSE 2





REACH 3  
TENTH SETTING-0.2  
FIGURE 1-B

13 JULY 83  
13 JUNE 83



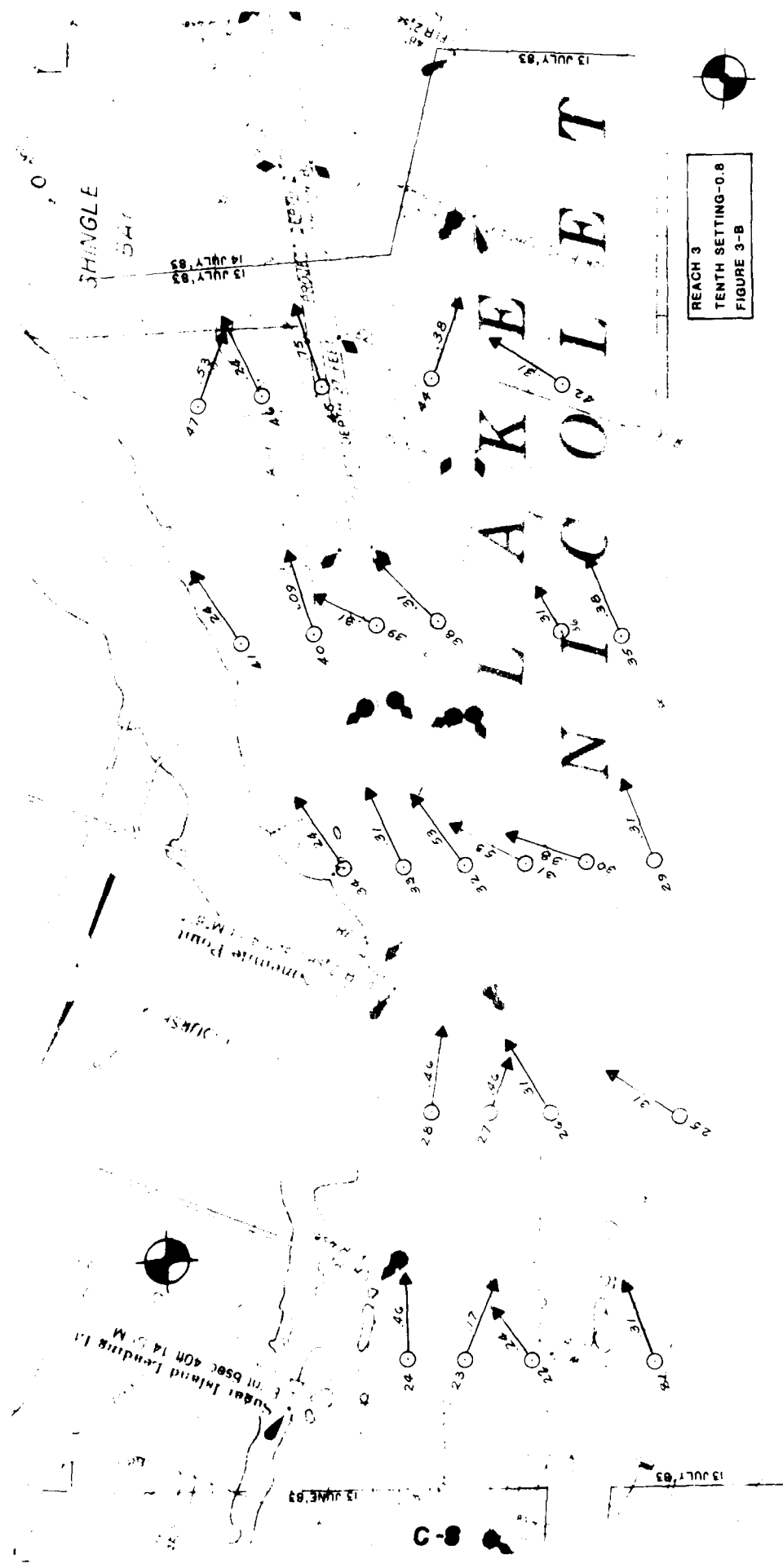
REACH 3  
TENTH SETTING-0.4  
FIGURE 2-B

WIND DATA  
13 JULY 1983

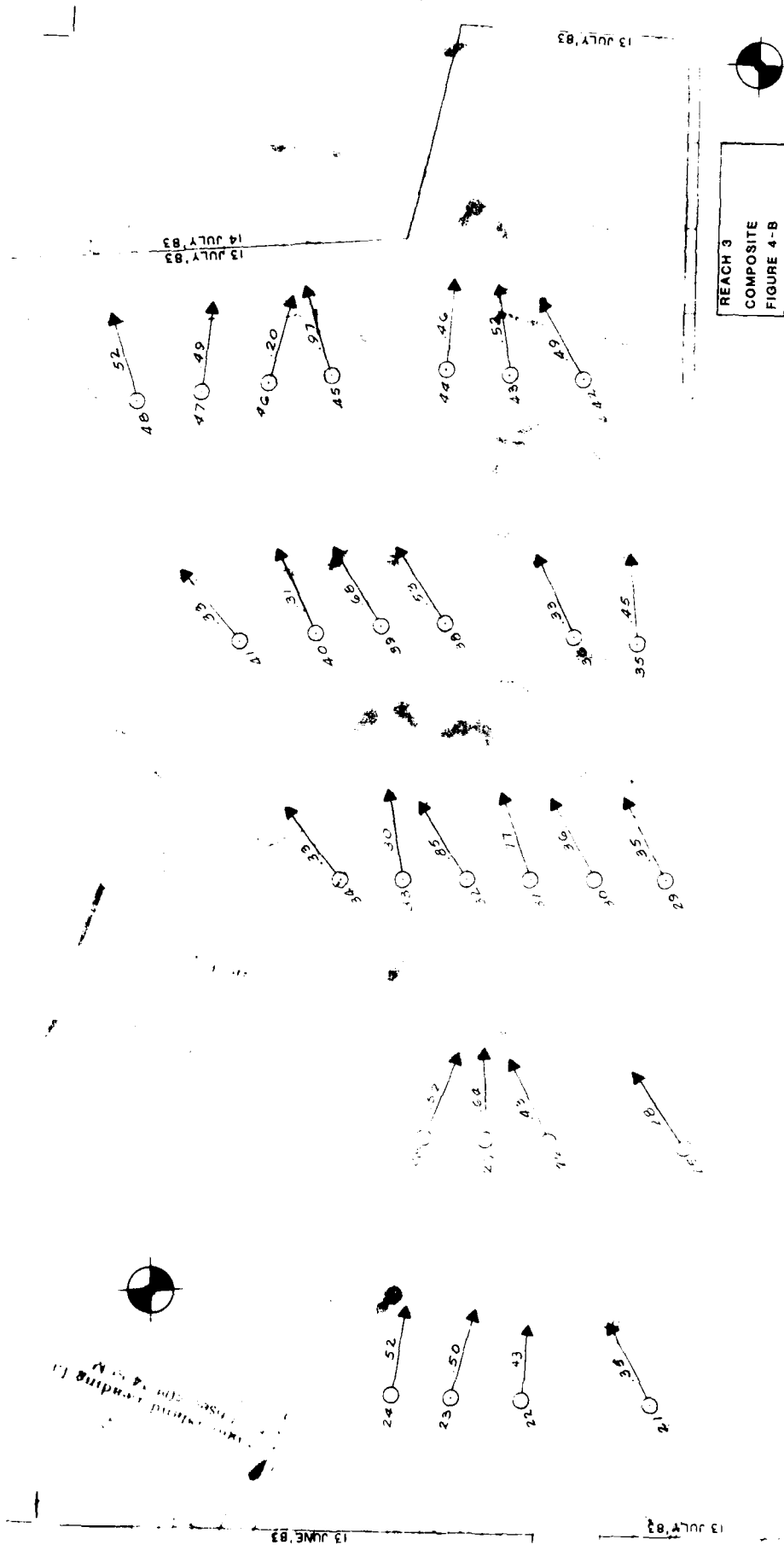
13 JUNE 83

13 JULY 83

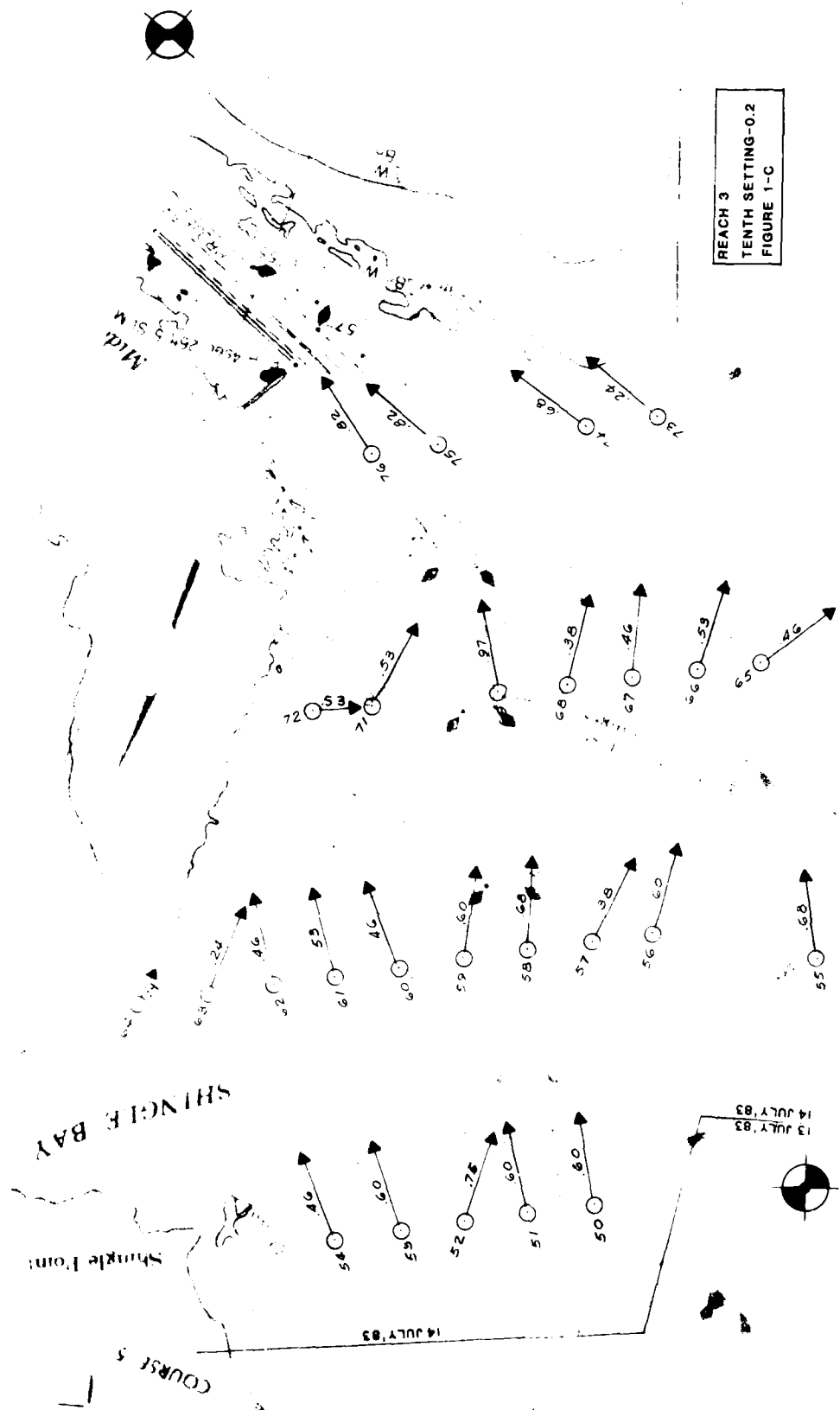
C-7



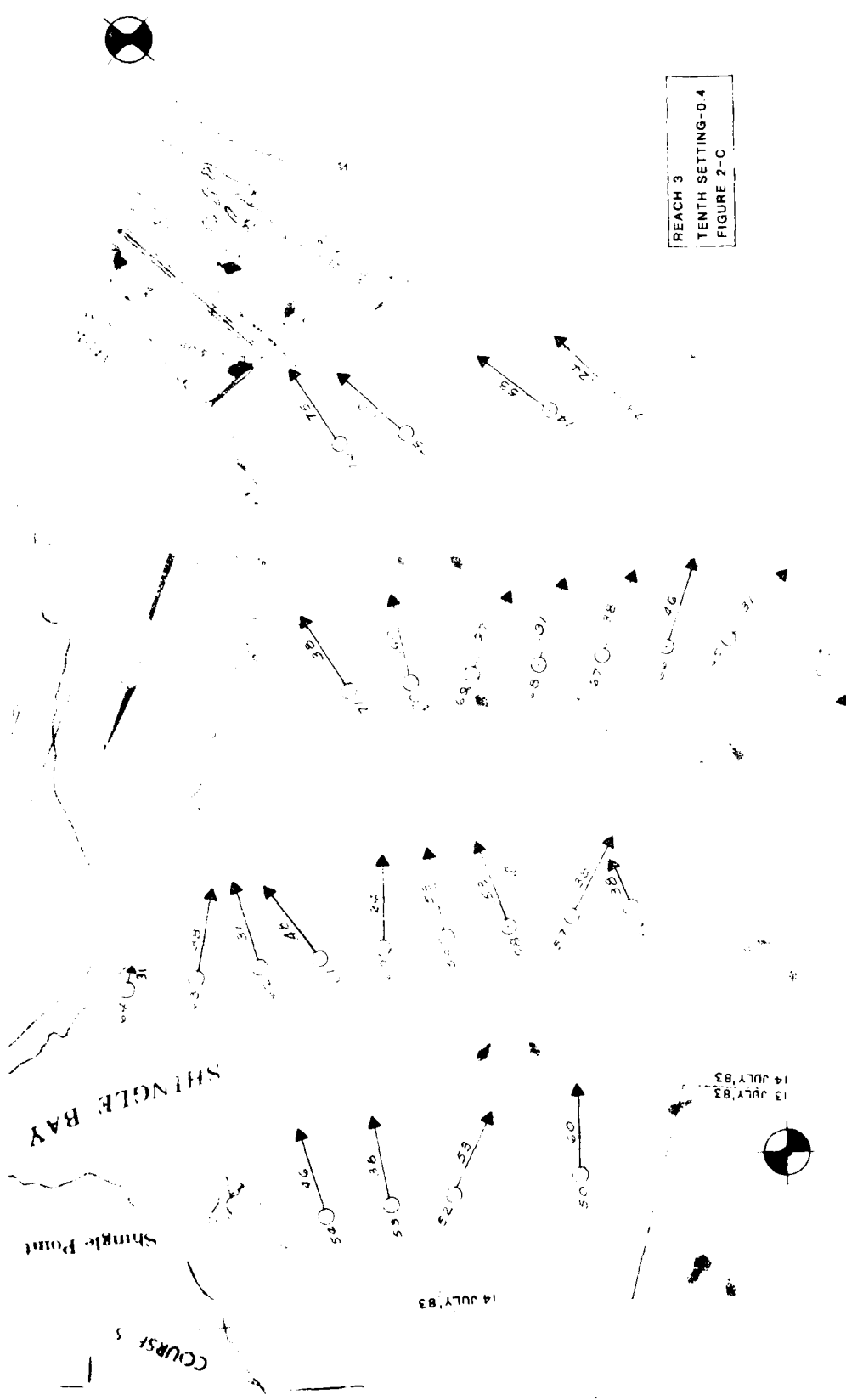
WIND DATA  
13 JULY '83, 0600 LT



WIND DATA  
13 JULY 83, C. L.



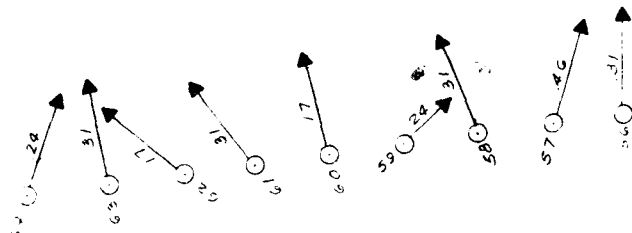
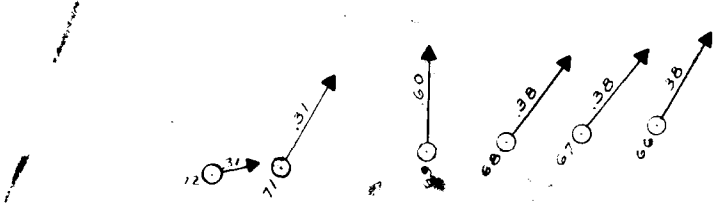
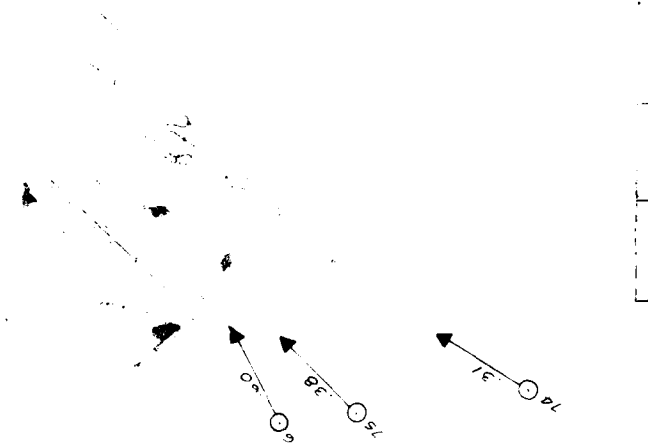
WIND DATA  
14 JULY - 3, ALTA



WIND DATA  
13 JULY 83 CALIA



REACH 3  
TENTH SETTING-0.8  
FIGURE 3-C



SHINGO BAY

Shingo Bay

COURSE

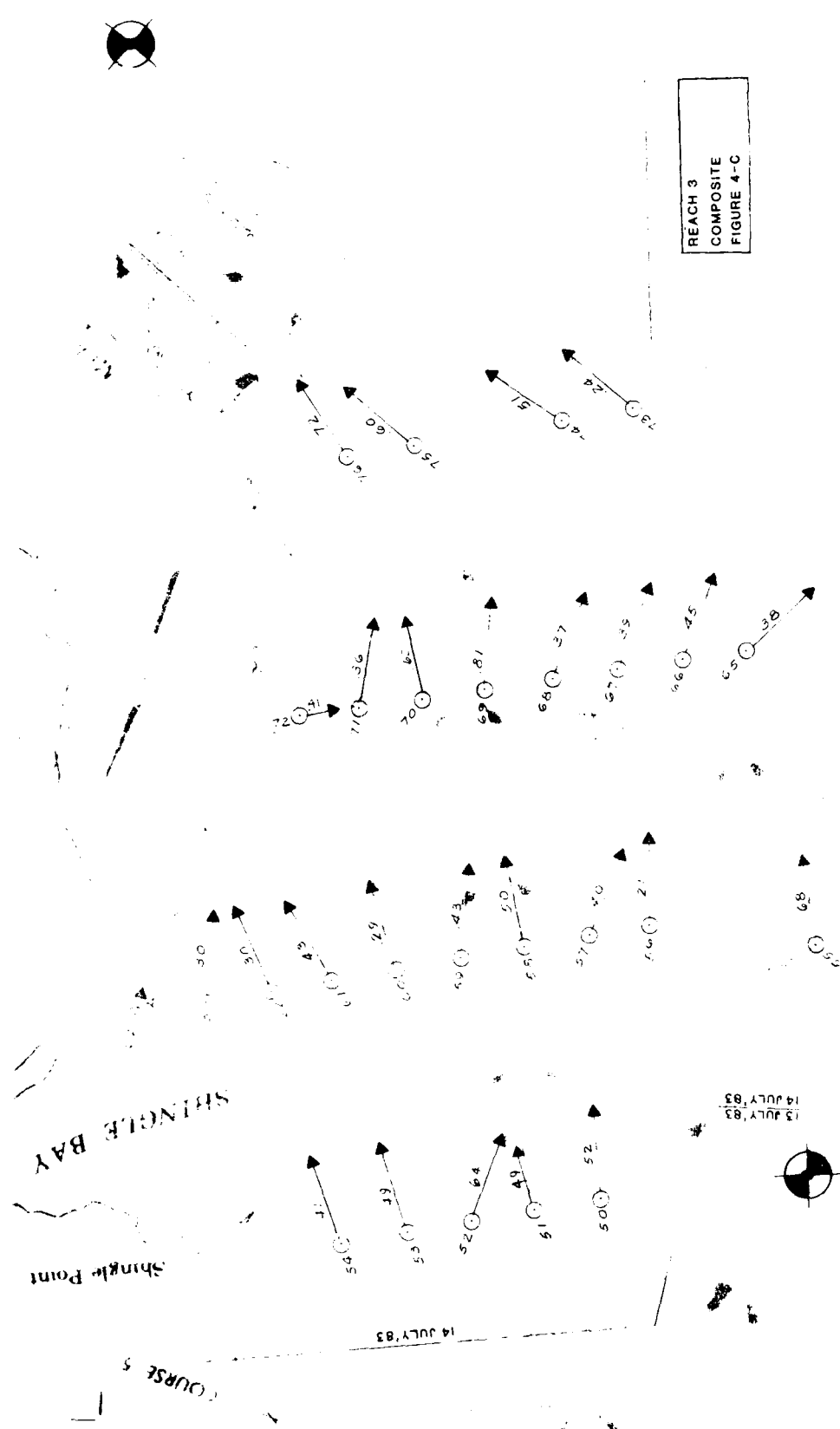
14 JULY '83

13 JULY '83

14 JULY '83



III- DELTA  
1 JULY 83 CALM



REACH 3  
COMPOSITE  
FIGURE 4-C

SHINGLE BAY

Shingle Point

COURSE 5

14 JULY 83

C - 13

13 JULY 83

WIND DATA  
14 JULY 83 0-1M

APPENDIX D  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 4

This appendix presents current velocities and directions for Reach 4 of the St. Marys River, Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into five figures as shown in the Index Figure (page D-1).

Under ice current measurements were conducted between 10 and 18 February 1983 (Flow (FEB) = 81,740 cubic feet per second (cfs)). Figures A, B and D, display under ice current data collected for the 2 and/or 4 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second (fps).

Open water current measurements were conducted between 15 and 17 June 1983 (Flow (JUN) = 104,000 cfs). Figures A, C and D display current data collected for each of the 2, 4 and 8 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle) direction of flow (arrow) and velocity in fps. In addition, each figure has a composite drawing developed from the data documented for that figure.

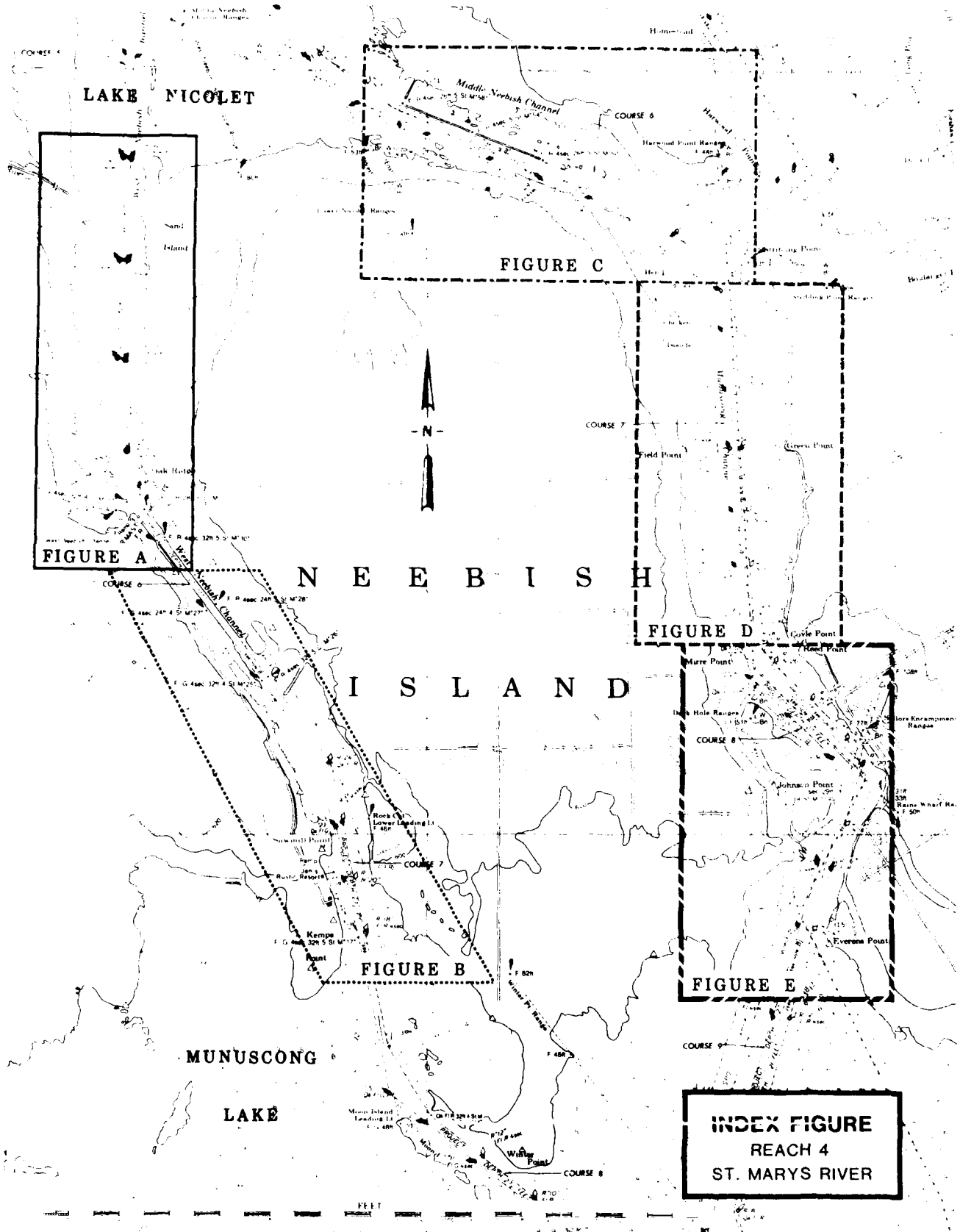
Aerial drogue surveys were conducted on 21 July 1982 (Flow (JUL) = 78,400 cfs). Data collected are shown in Figures B, D and E as velocity in fps (number) and direction (arrow).

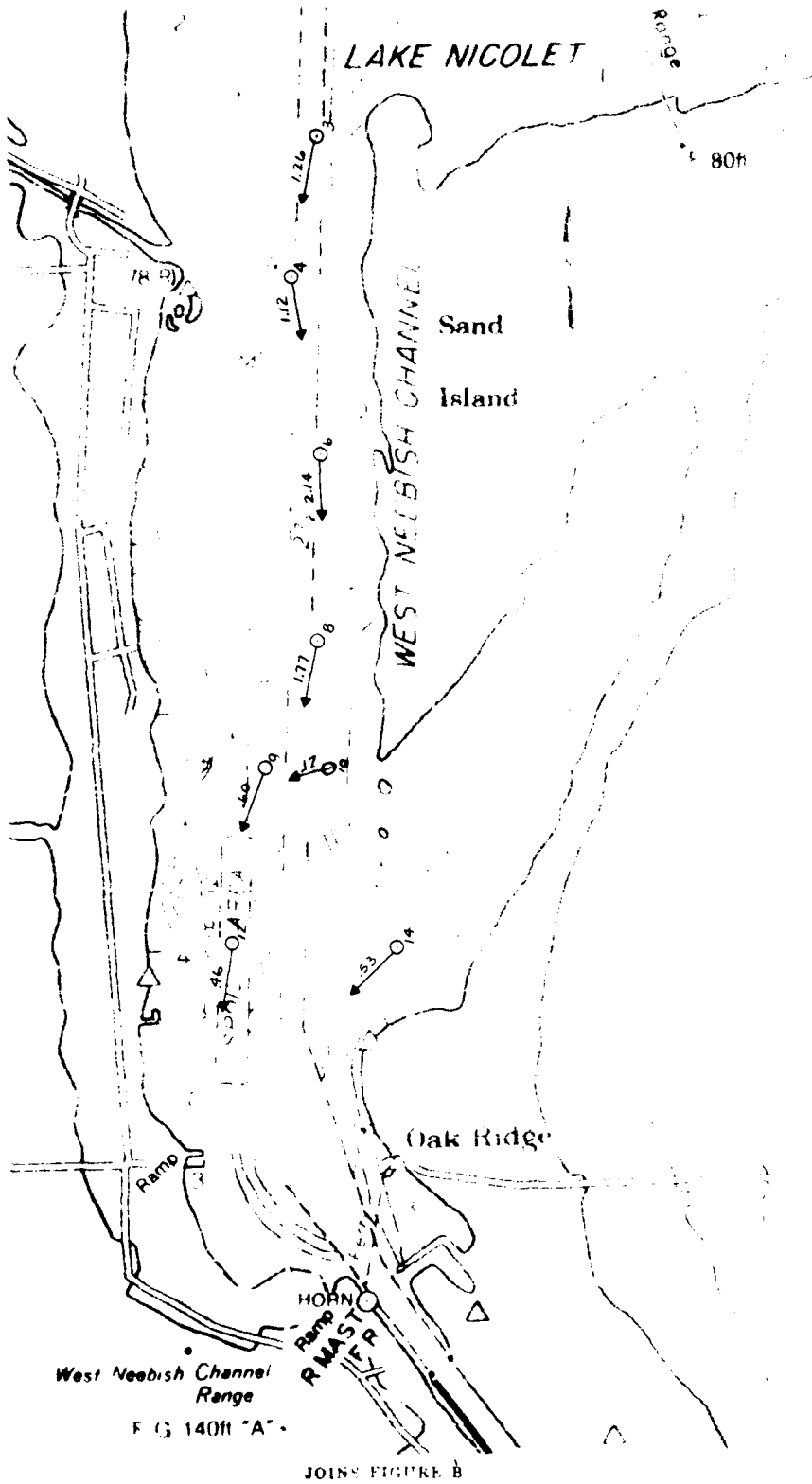
A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX D  
REACH 4

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Figure 2-C	Four Tenths Setting	D-11
Figure 3-C	Eight Tenths Setting	D-12
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Figure 3-D	Eight Tenths Setting	D-16
Figure 4-D	Composite	D-17
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Figure 6-D	Four Tenths Setting (Winter)	D-19
Figure E	Aerial Drogue	D-20





REACH 4  
TENTH SETTING -0.2  
FIGURE 1-A

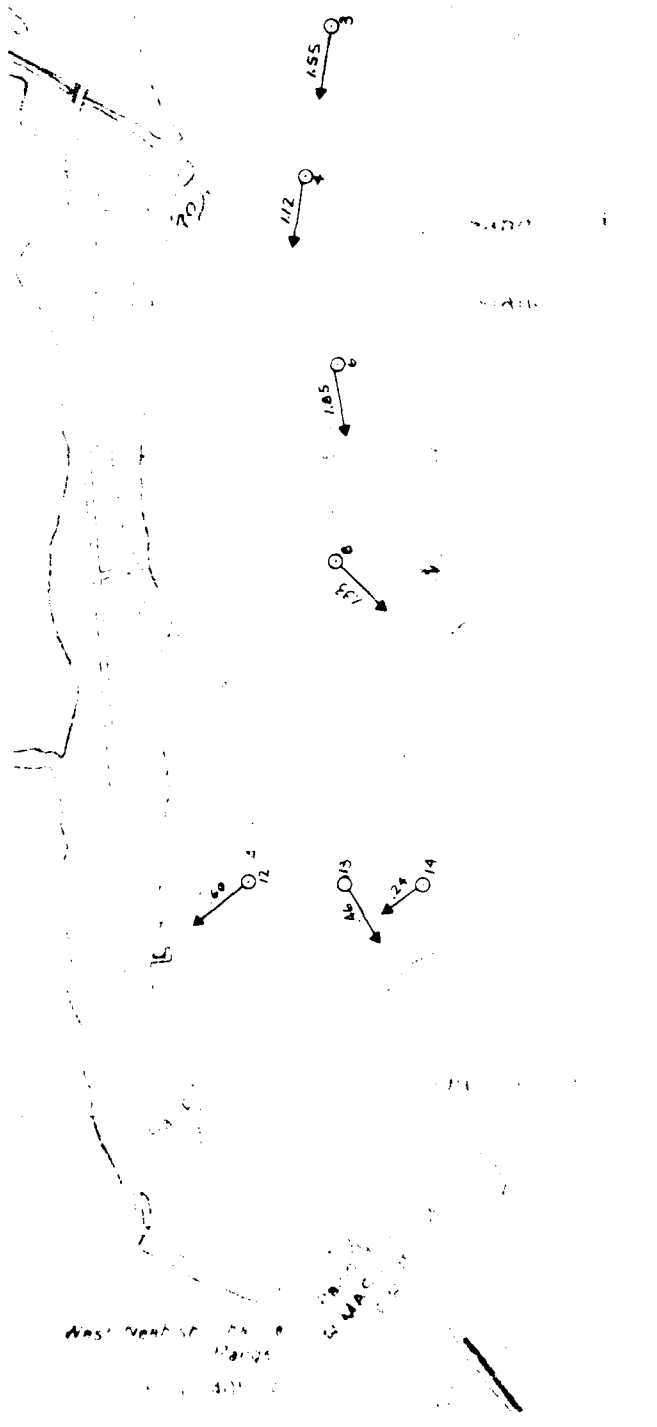
WIND DATA  
15 JULY 63, 13 METER



REACH 4  
 TENTH SETTING -0.4  
 FIGURE 2-A

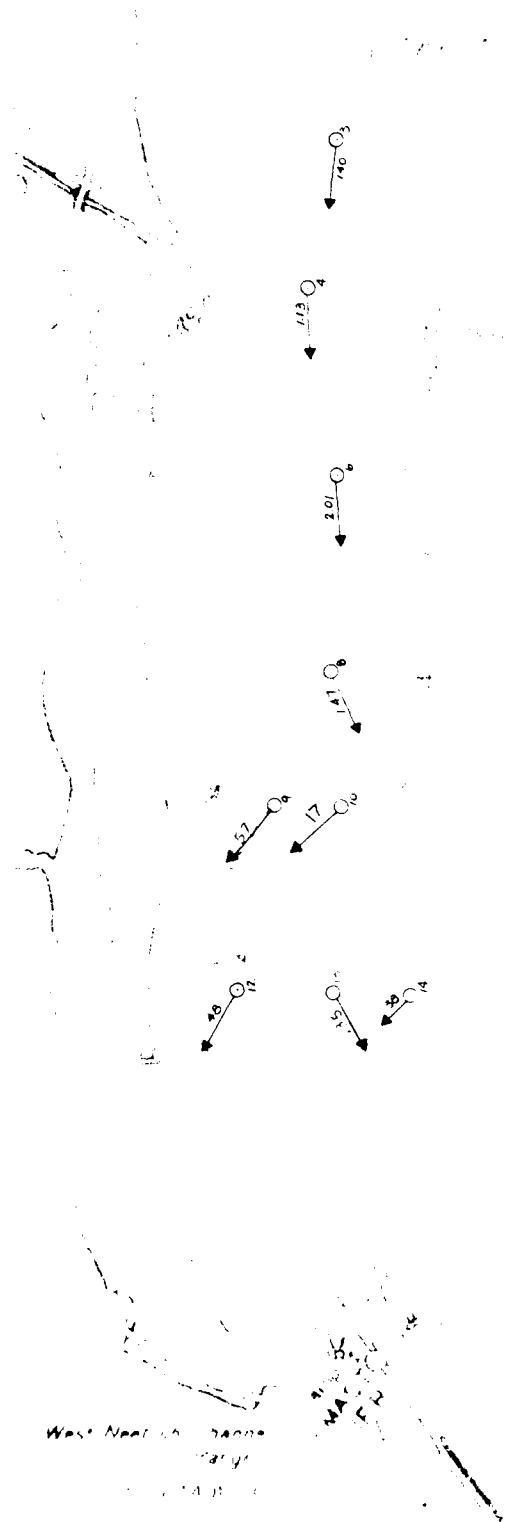
WIND DATA  
 15 JULY 83 13:21 H. 18

DAYVILLE



REACH 4  
 TENTH SETTING -0.8  
 FIGURE 3-A

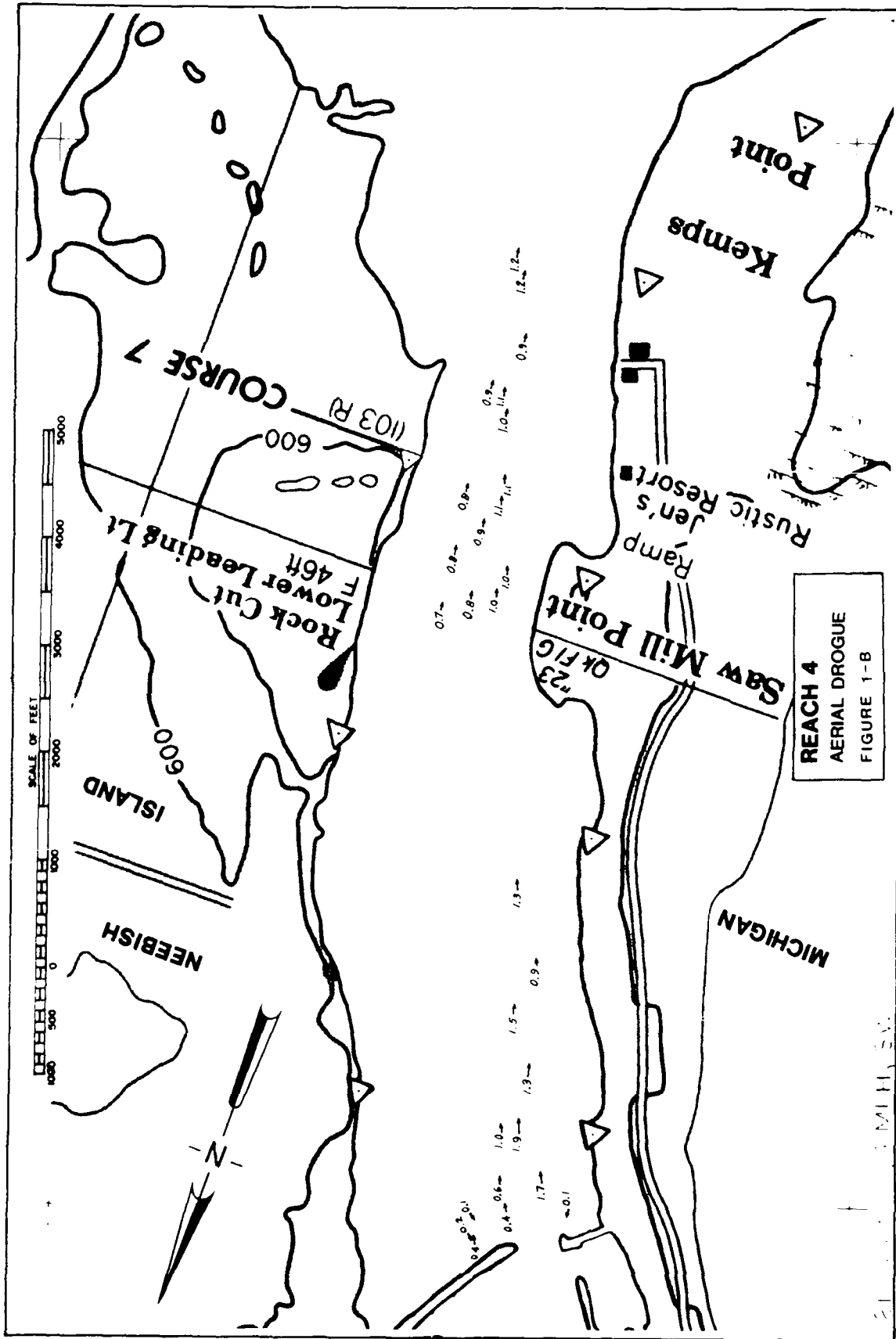
WIND DATA  
 15 JULY 83, 13 MPH, NY



REACH 4  
COMPOSITE  
FIGURE 4-A

WIND DATA  
15 JULY 1971 13:00 - 14:00



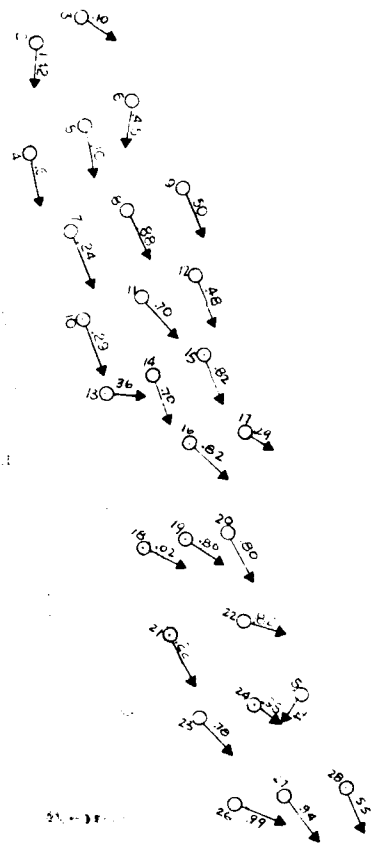




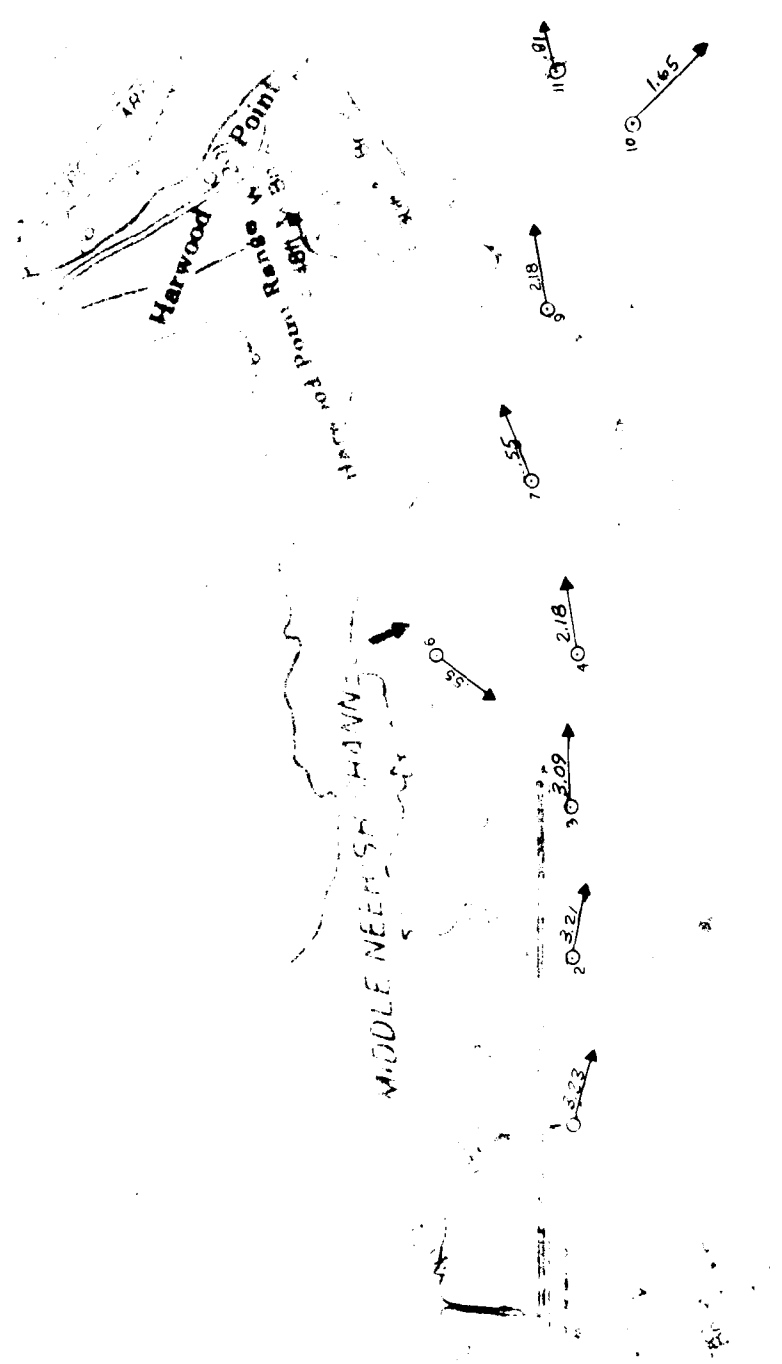
REACH 4 (WINTER)  
TENTH SETTING -0.2  
FIGURE 28-B

FEB 83

REACH 4 (WINTER)  
TENTH SETTING -0.4  
FIGURE 2b-B  
FEB 83

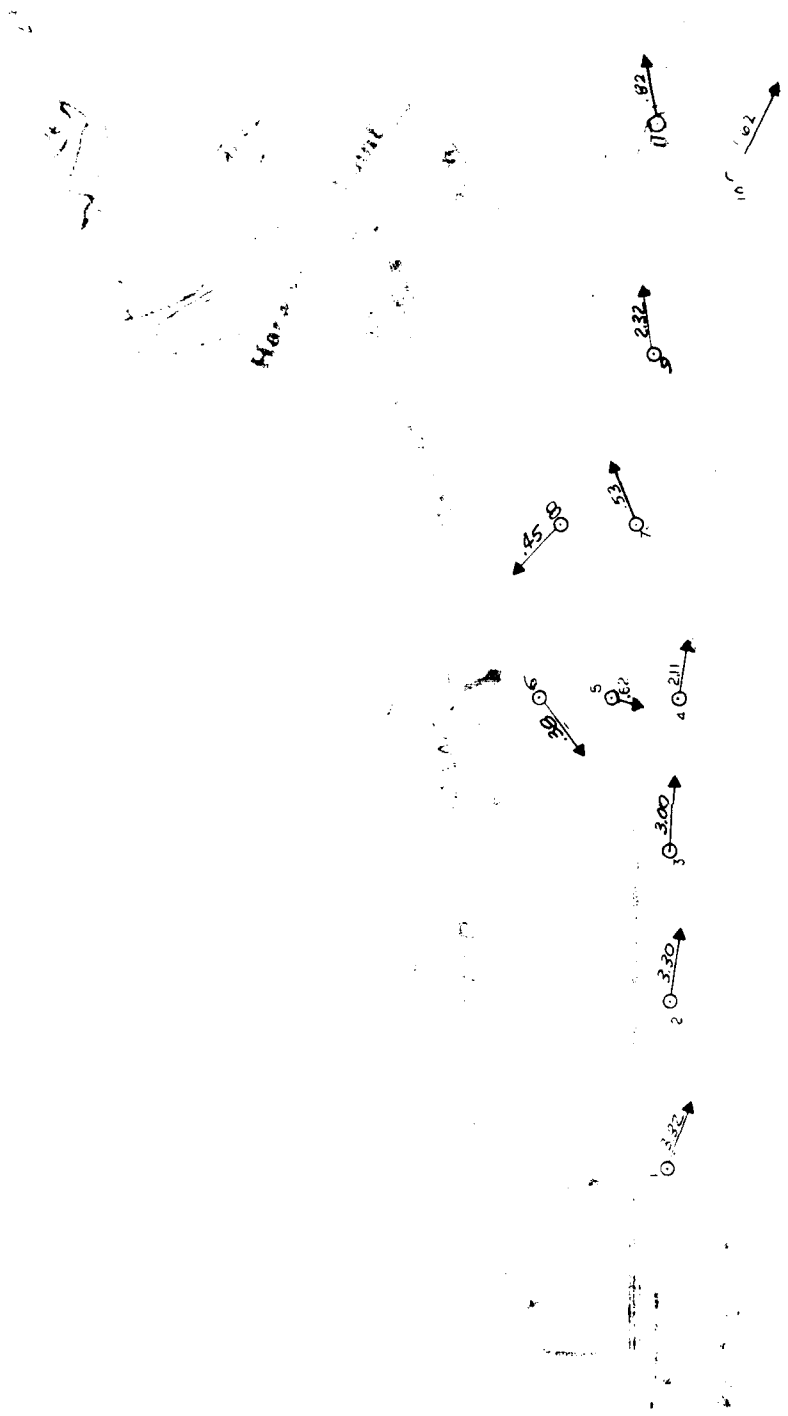


MUNICIPALITY  
OF



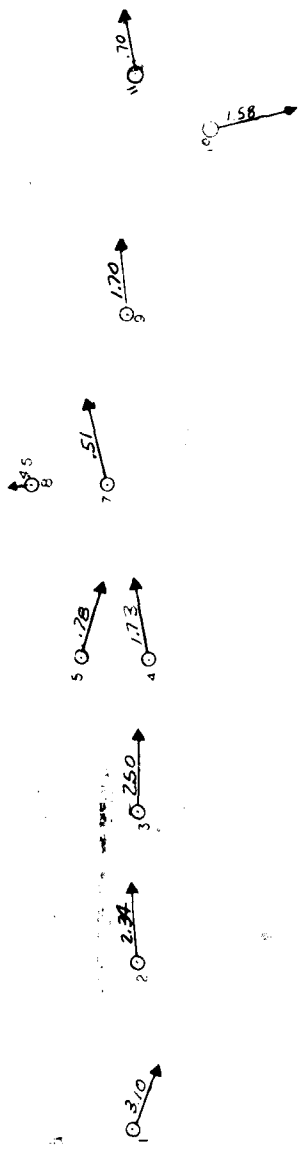
REACH 4  
TENTH SETTING -0.2  
FIGURE 1-C

ATLANTA  
17 JULY 83, 3 MPH, 1W



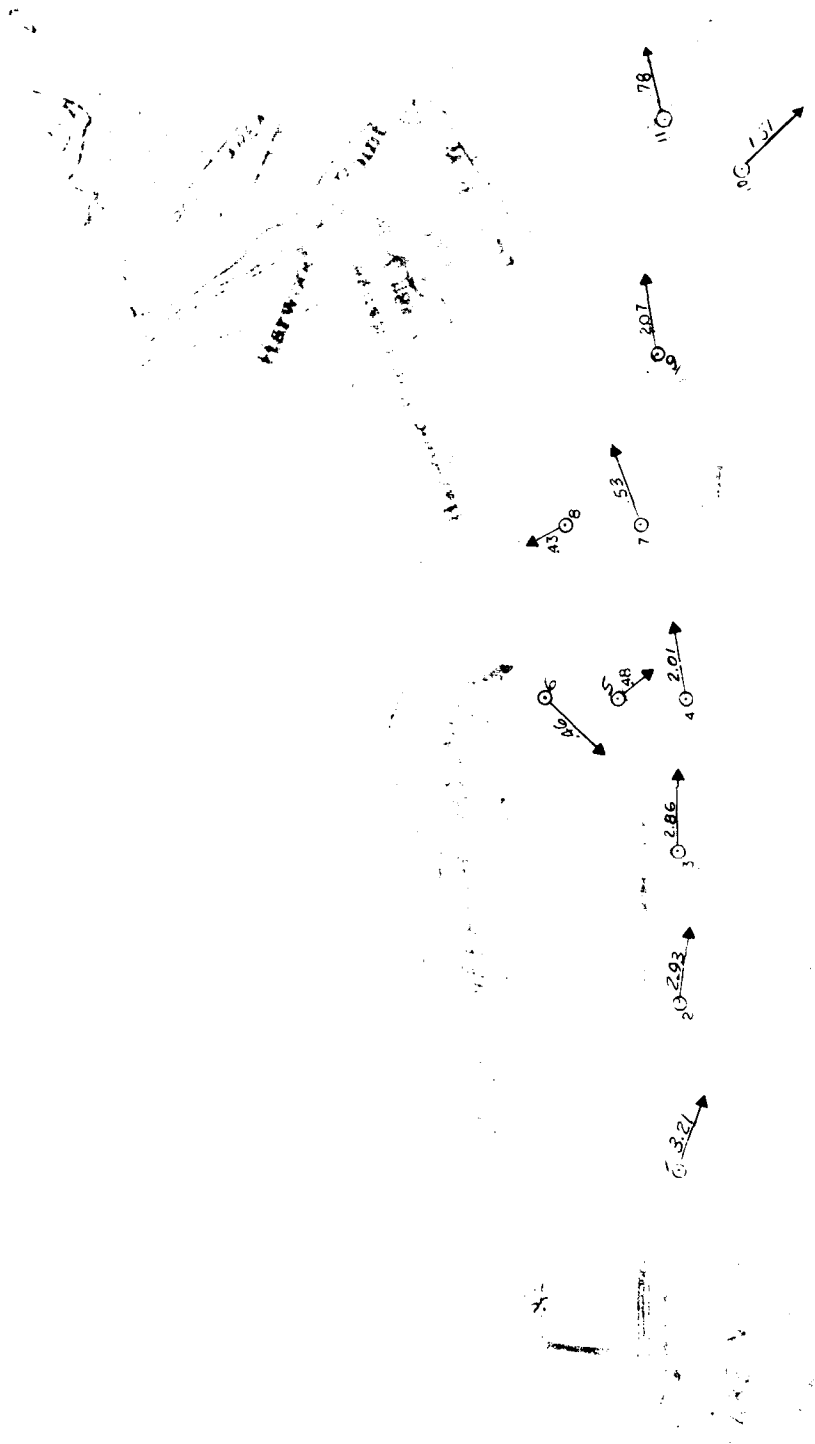
REACH 4  
TENTH SETTING -0.4  
FIGURE 2-C

WINE D/T/A  
17 JUL 63, 3M-... NV

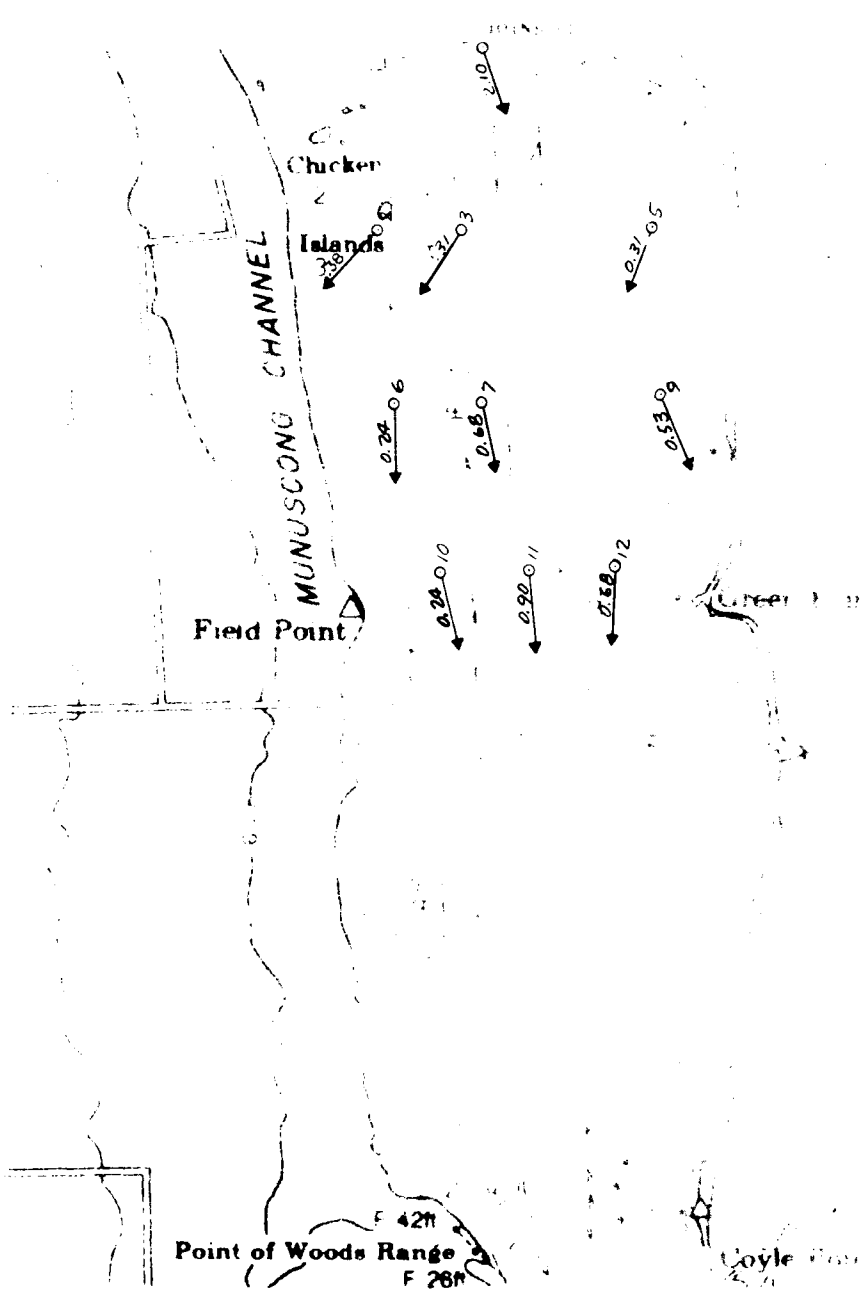


REACH 4  
TENTH SETTING -0.8  
FIGURE 3-C

17 JUN 1957 3 21 1 1.77

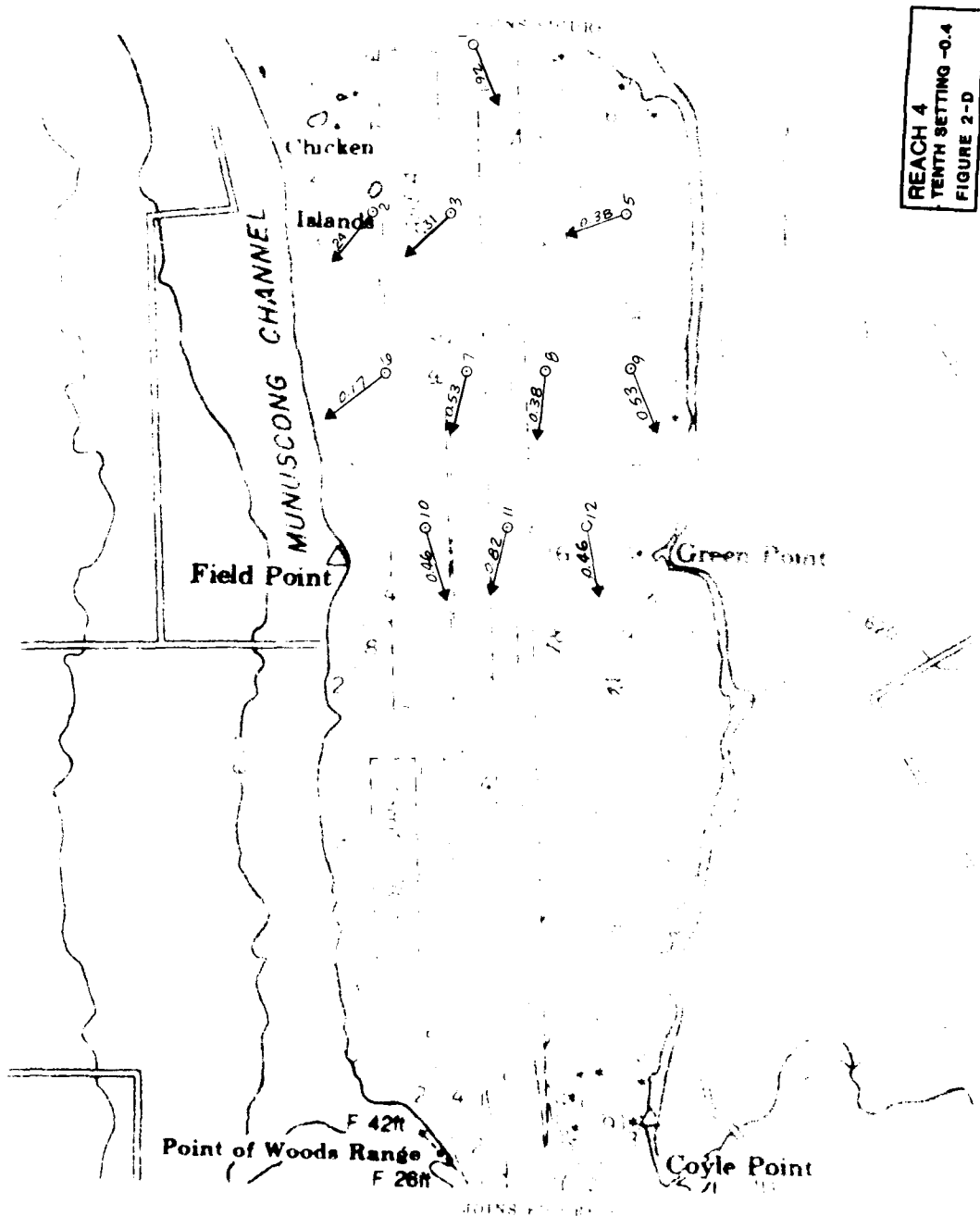


REACH 4  
COMPOSITE  
FIGURE 4-C



REACH 4  
TENTH SETTING -0.2  
FIGURE 1-D

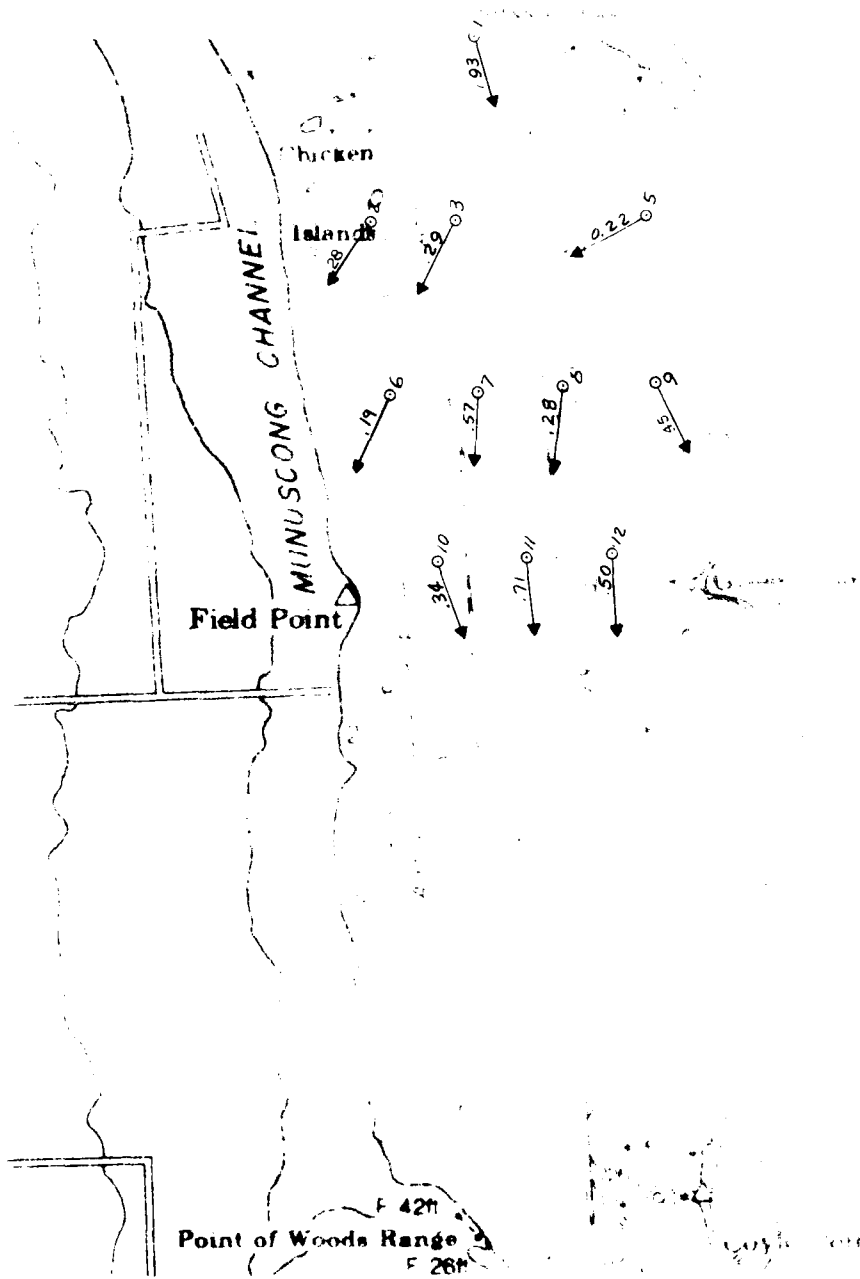
MINE DATA  
5 JULY 53, 3 11 PM '53



REACH 4  
TENTH SETTING -0.4  
FIGURE 2-D

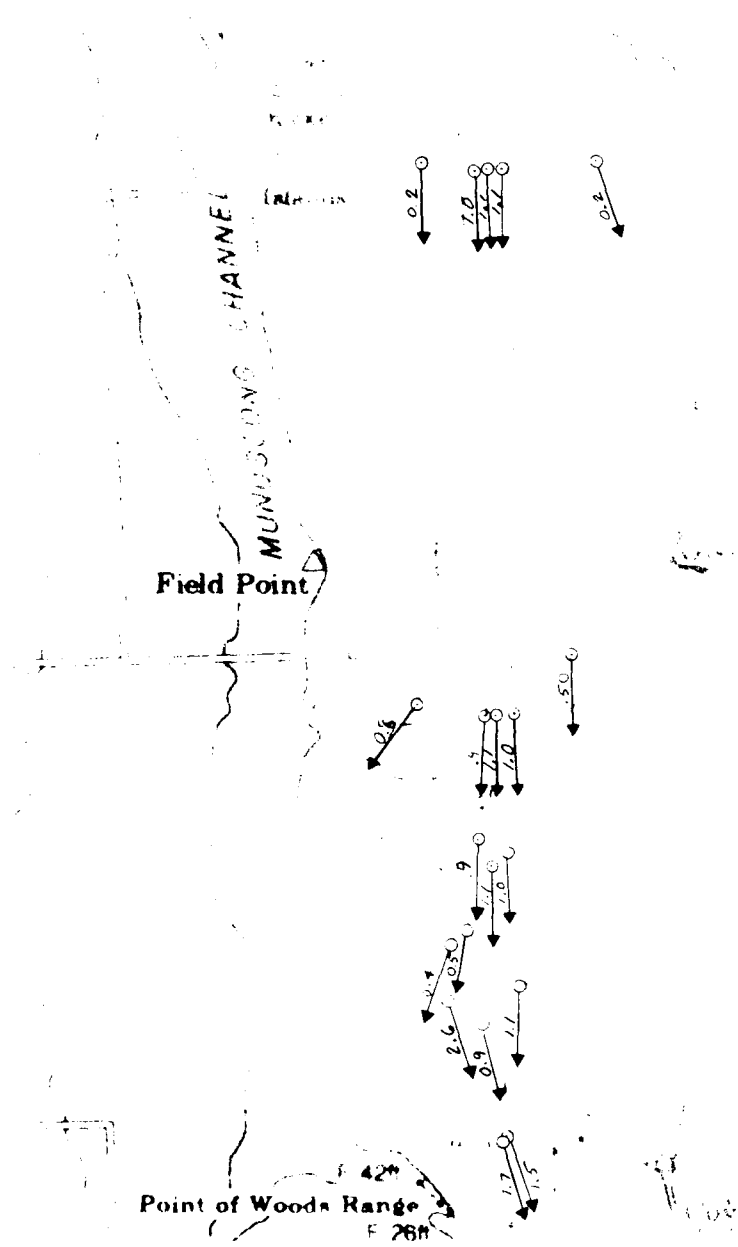
WIND DATA  
DATE: JULY 1971  
TIME: 11:17





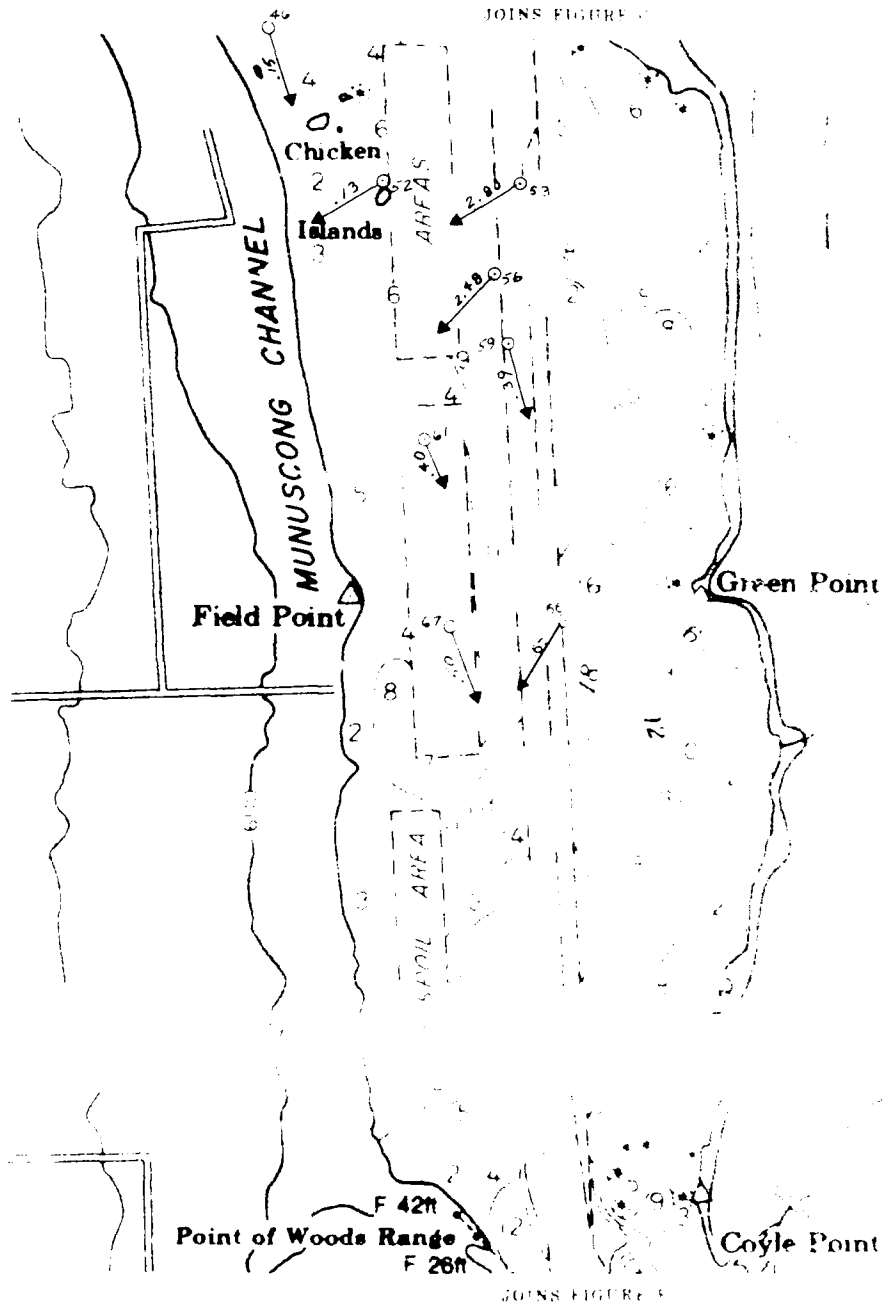
REACH 4  
COMPOSITE  
FIGURE 4-D

DATE: JULY 13 1964



WIND DATA  
21 JULY 62, 4 MPH, SW

REACH 4  
AERIAL DROGUE  
FIGURE 5-D



REACH 4  
TENTH-0.4 (WINTER)  
FIGURE 6-D  
FEB 83



APPENDIX E  
ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 5

This appendix presents current velocities and directions for Reach 5 of the St. Marys River, Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into two figures as shown in the Index Figure (page E-1).

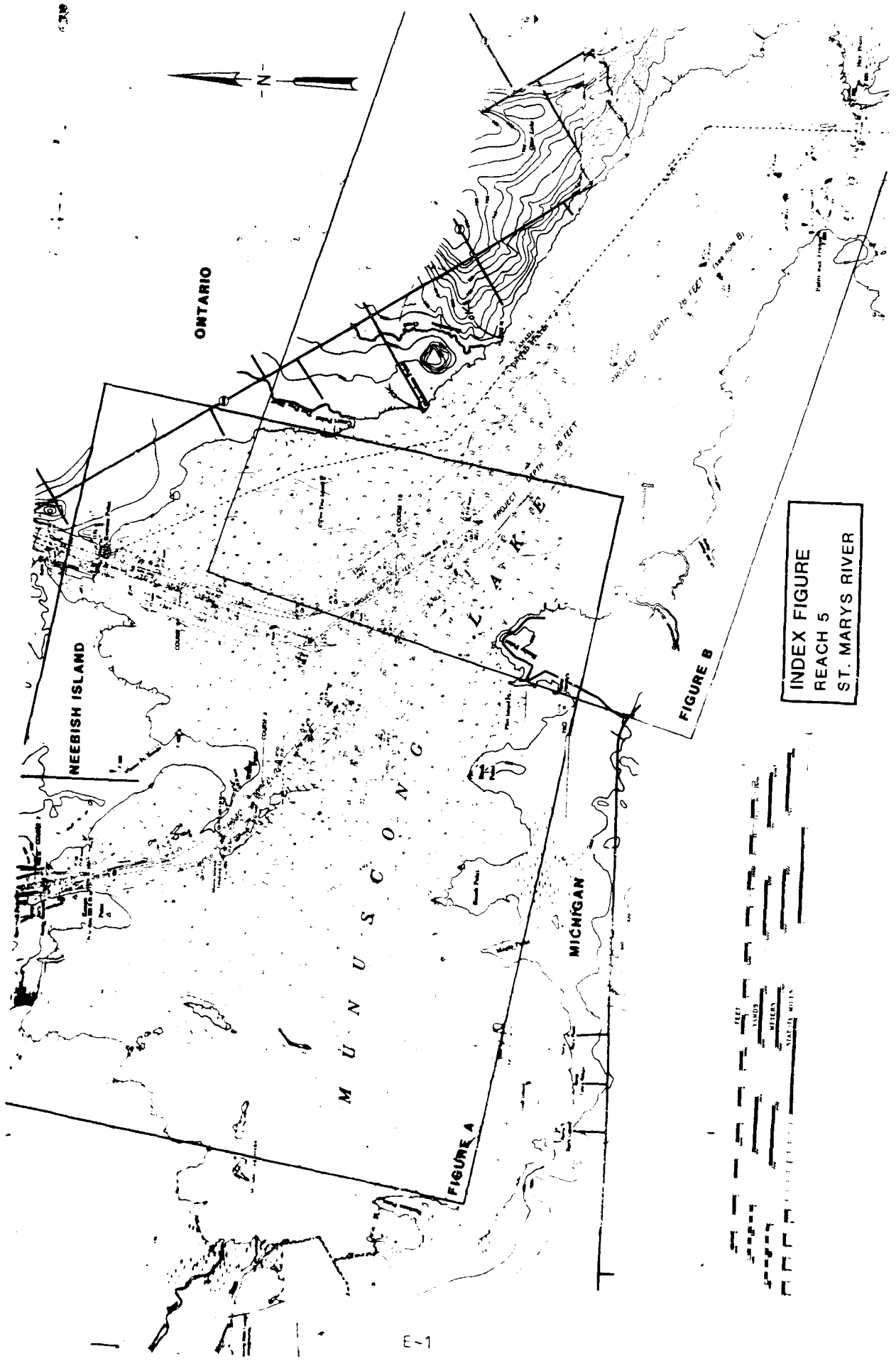
Open water current measurements were conducted between 18 and 20 July 1983 (Flow (JUL) = 102,890 cubic feet per second). Figures A and B are the current data collected for each of the 2, 4 and 8 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second. In addition, each figure has a composite drawing developed from the data documented for that figure.

A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX E  
REACH 5

LIST OF FIGURES

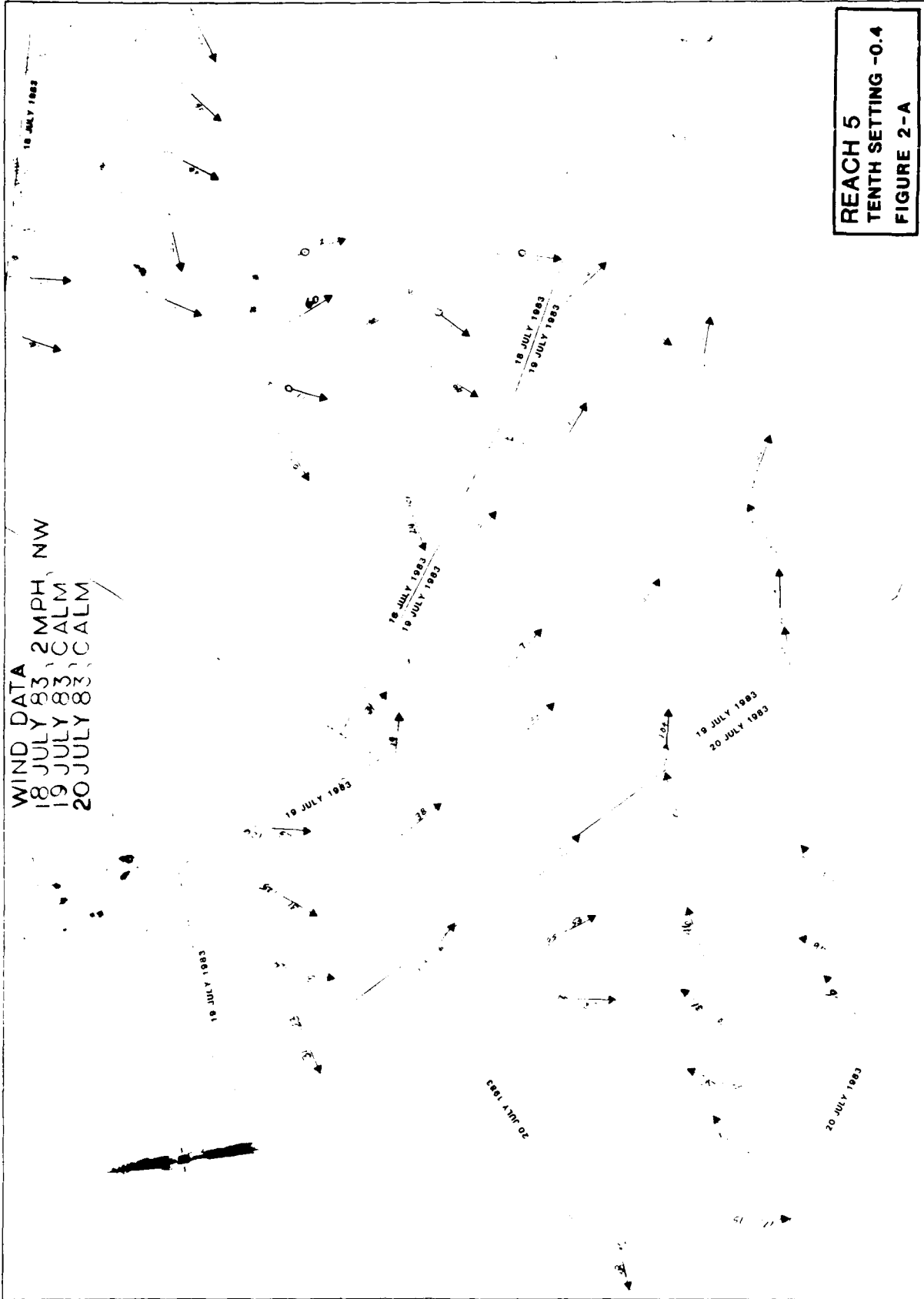
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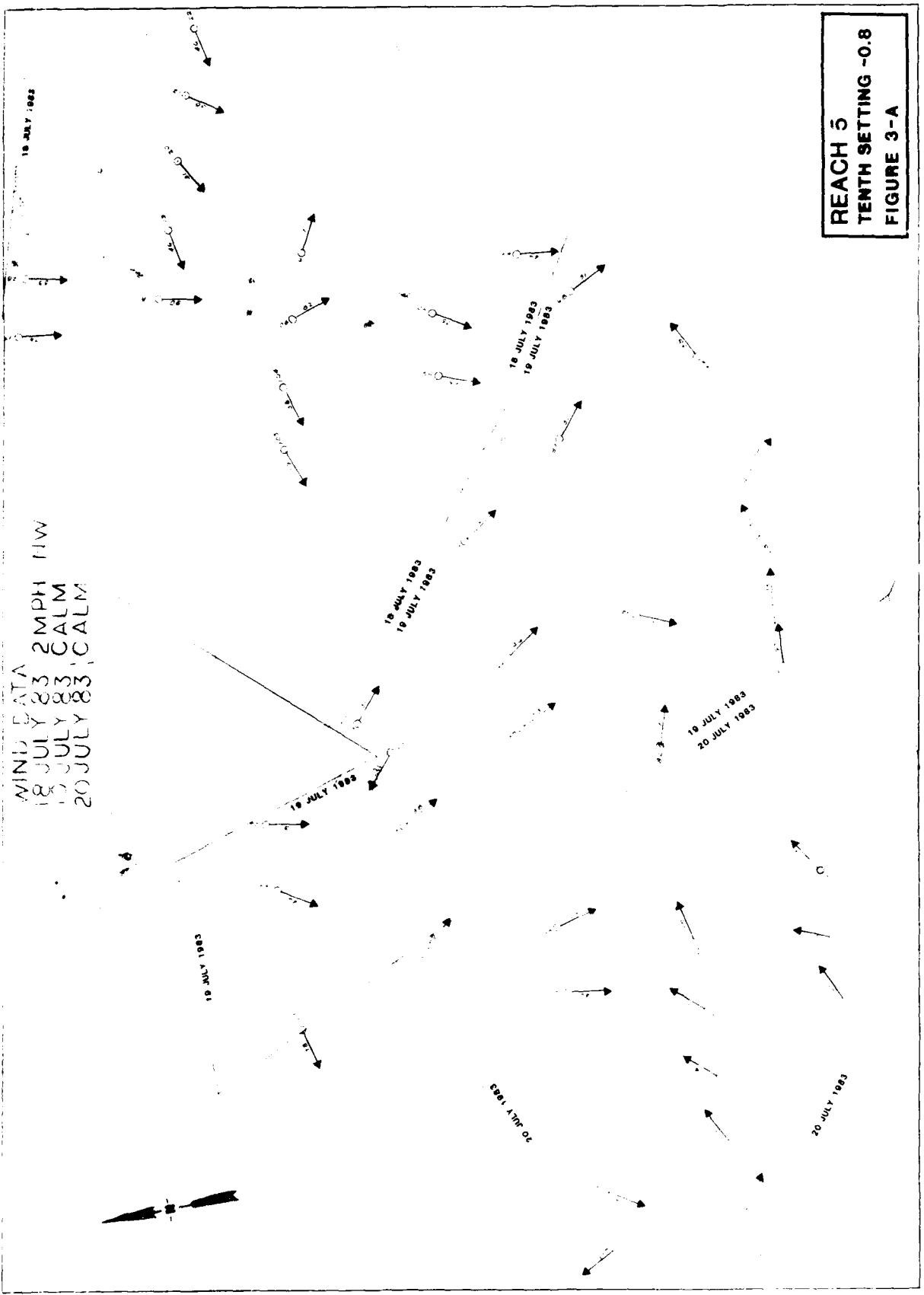


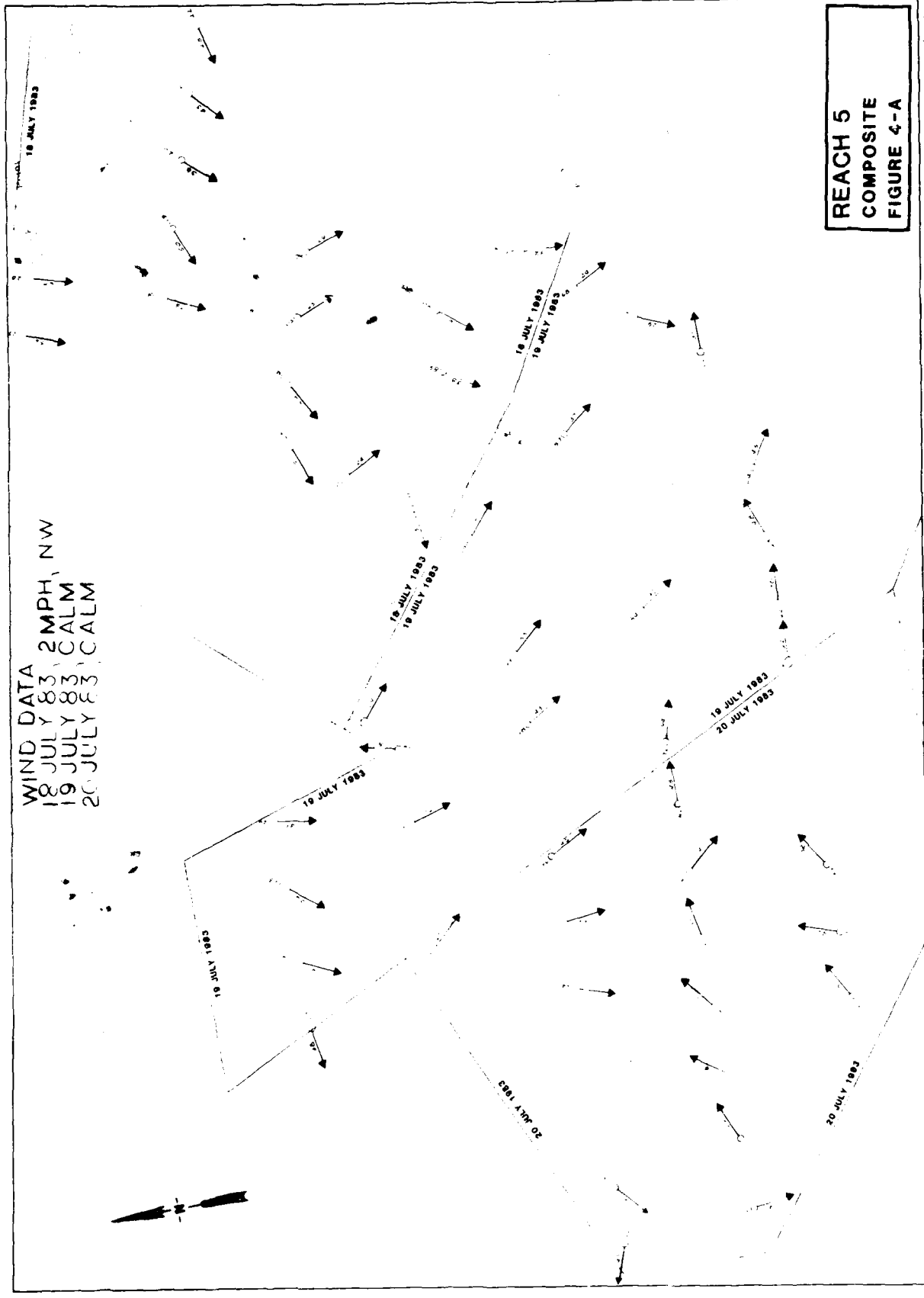
INDEX FIGURE  
 REACH 5  
 ST. MARYS RIVER





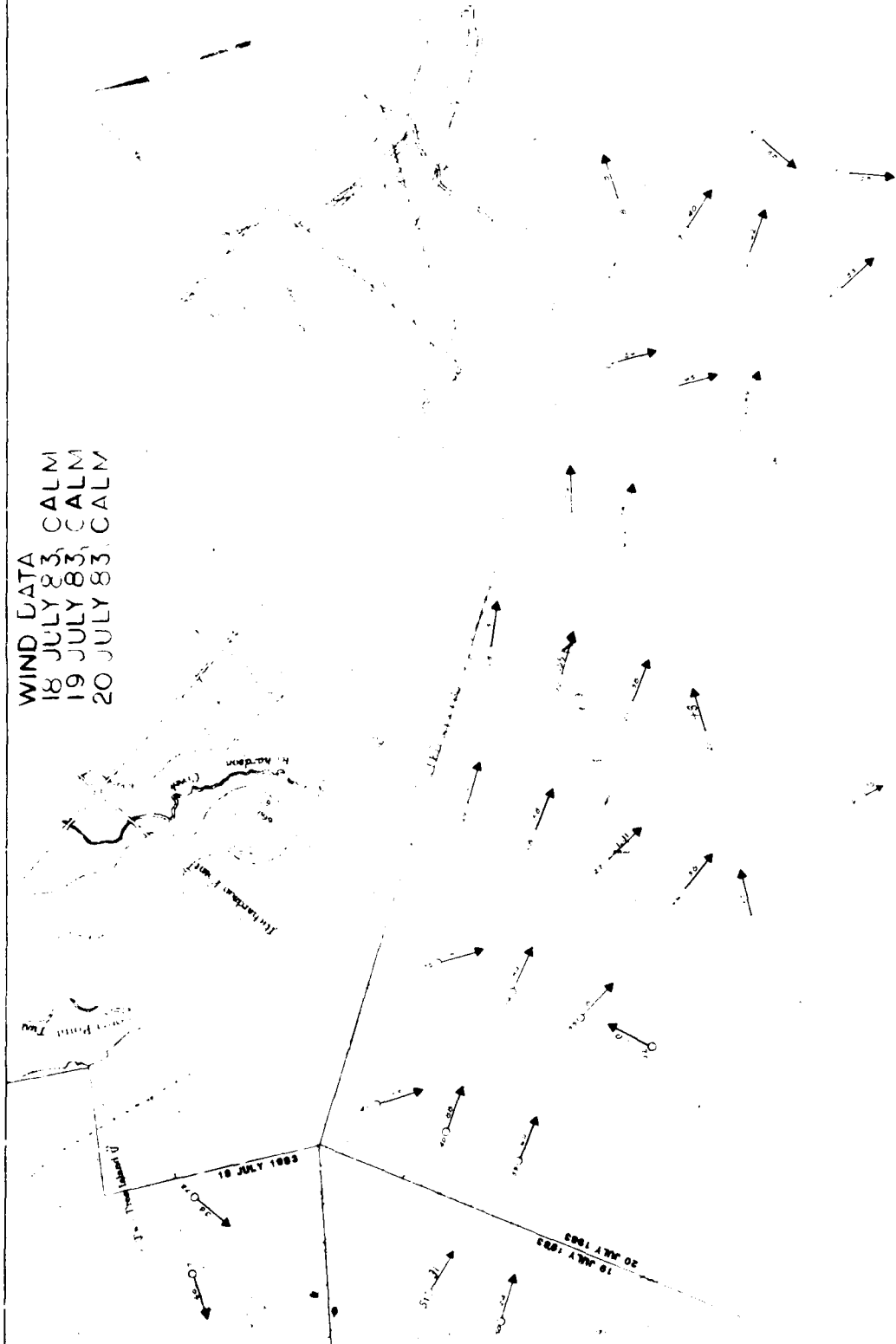








WIND DATA  
18 JULY 83, CALM  
19 JULY 83, CALM  
20 JULY 83, CALM



REACH 5  
TENTH SETTING -0.4  
FIGURE 2-B

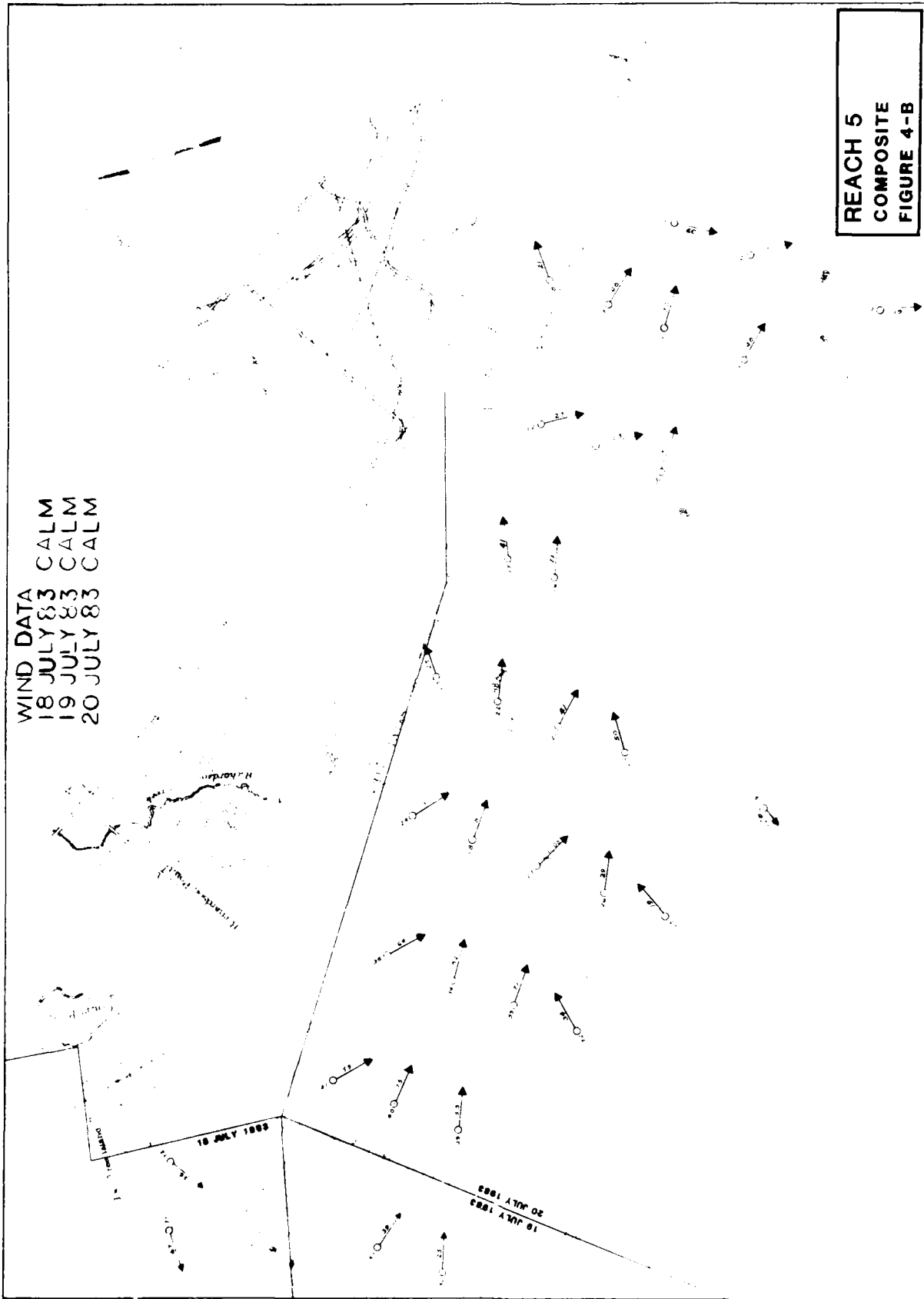
WIND DATA CAL  
18 JULY 83, CAL  
19 JULY 83, CAL  
20 JULY 83, CAL



REACH 5  
TENTH SETTING -0.8  
FIGURE 3-B

WIND DATA  
18 JULY 83 CALM  
19 JULY 83 CALM  
20 JULY 83 CALM

REACH 5  
COMPOSITE  
FIGURE 4-B



APPENDIX F  
ST. MARYS RIVER  
OIL/TOXIC SUBSTANCE SPILL STUDY  
CURRENT VELOCITIES AND DIRECTIONS  
REACH 6

This appendix presents current velocities and directions for Reach 6 of the St. Marys River Oil/Toxic Substance Spill Study (see Figure 3 of the main report). This reach has been divided into six figures as shown in the Index Figure (page F-1).

Open water current measurements were conducted between 19 August and 24 September 1980 (Flow (AUG) = 74,500 cubic feet per second (cfs) and Flow (SEP) = 71,980 cfs). Figures A-F display current data collected for each of the 2, 4 and 8 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in feet per second (fps). In addition, each figure has a composite drawing developed from the open water data documented for that figure.

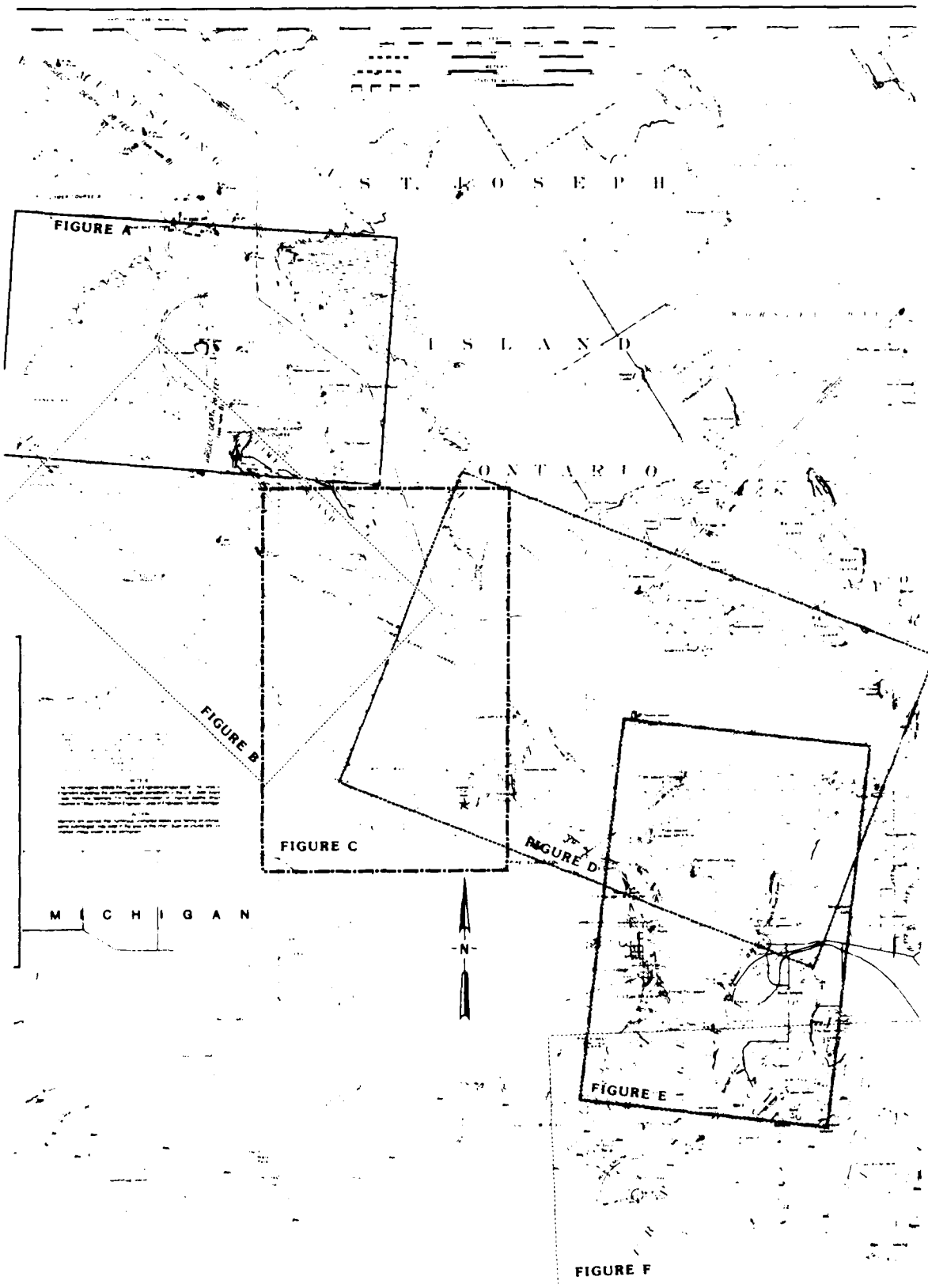
Under ice current measurements were conducted between 12 January and 12 March 1982 (Flow (JAN) = 45,380 cfs, Flow (FEB) = 45,450 cfs and Flow (MAR) = 45,390 cfs). Figures A-F display under ice current data collected for the 2 and/or 4 tenths depth of the total river depth, at selected locations. Data are shown as location point (number and circle), direction of flow (arrow) and velocity in fps.

A discussion of measurement and data reduction techniques can be found in the main report.

APPENDIX F  
REACH 6

LIST OF FIGURES

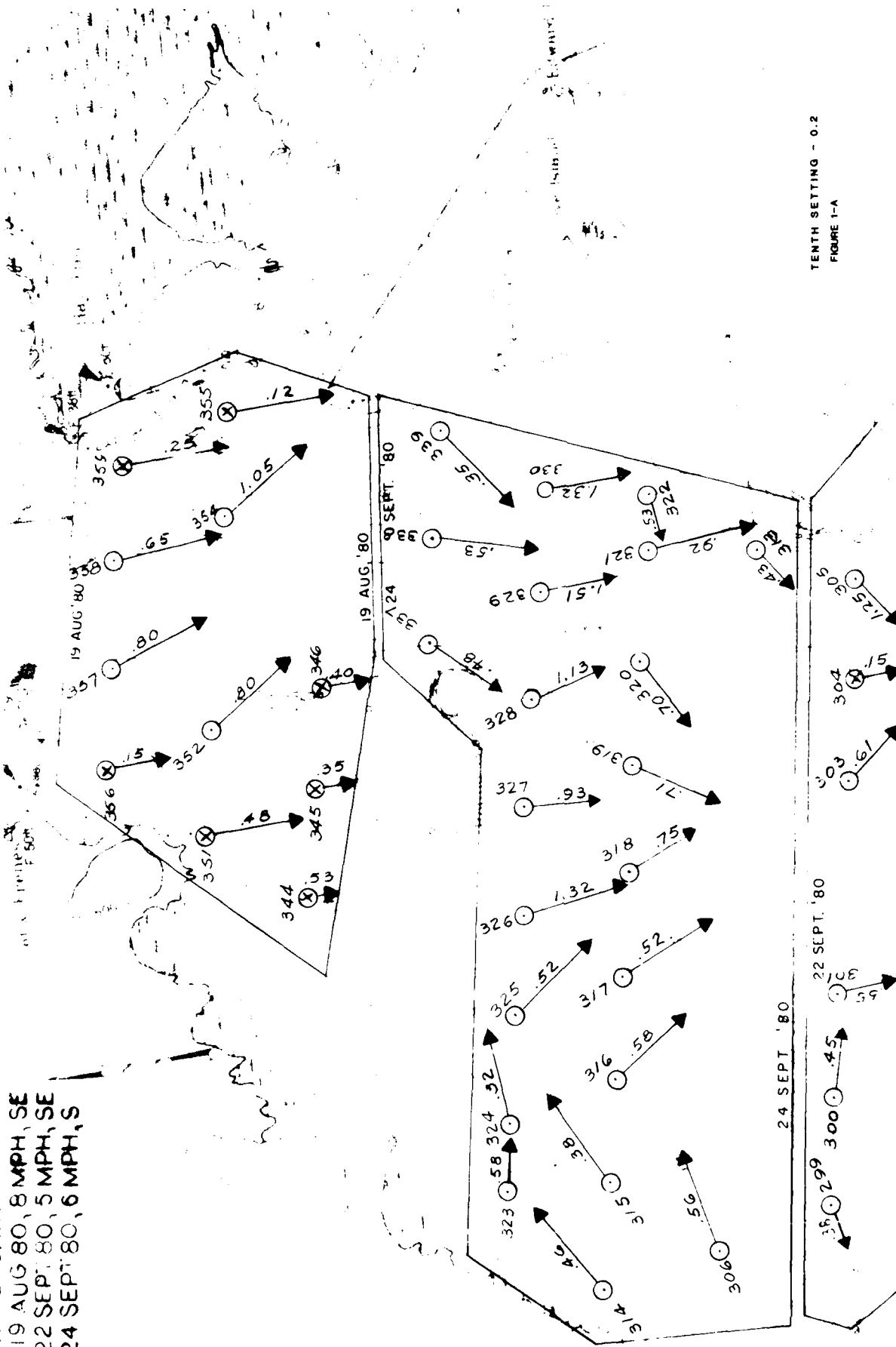
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INDEX FIGURE  
 REACH 6  
 ST. MARYS RIVER

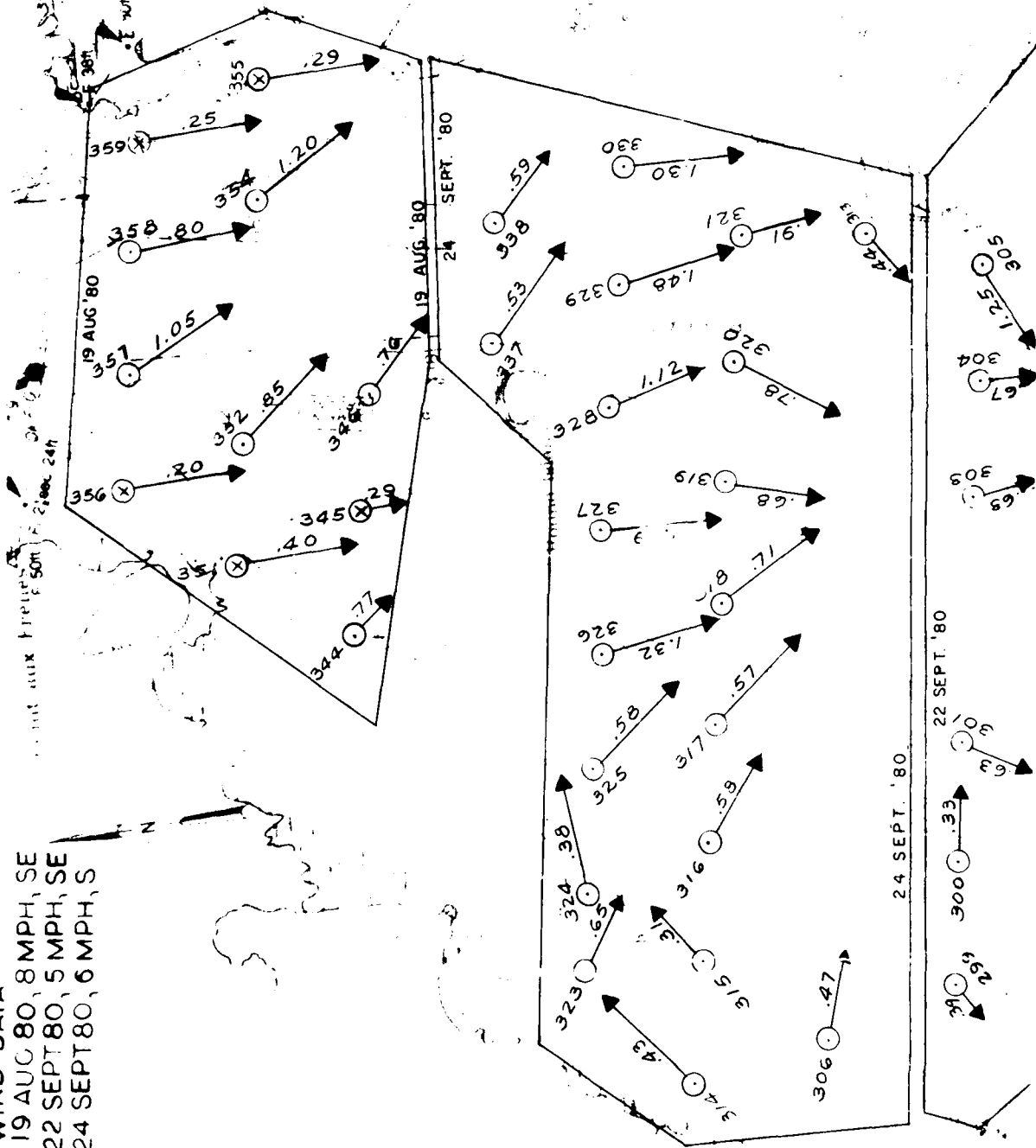
WIND DATA

19 AUG 80, 8 MPH, SE  
22 SEPT 80, 5 MPH, SE  
24 SEPT 80, 6 MPH, S



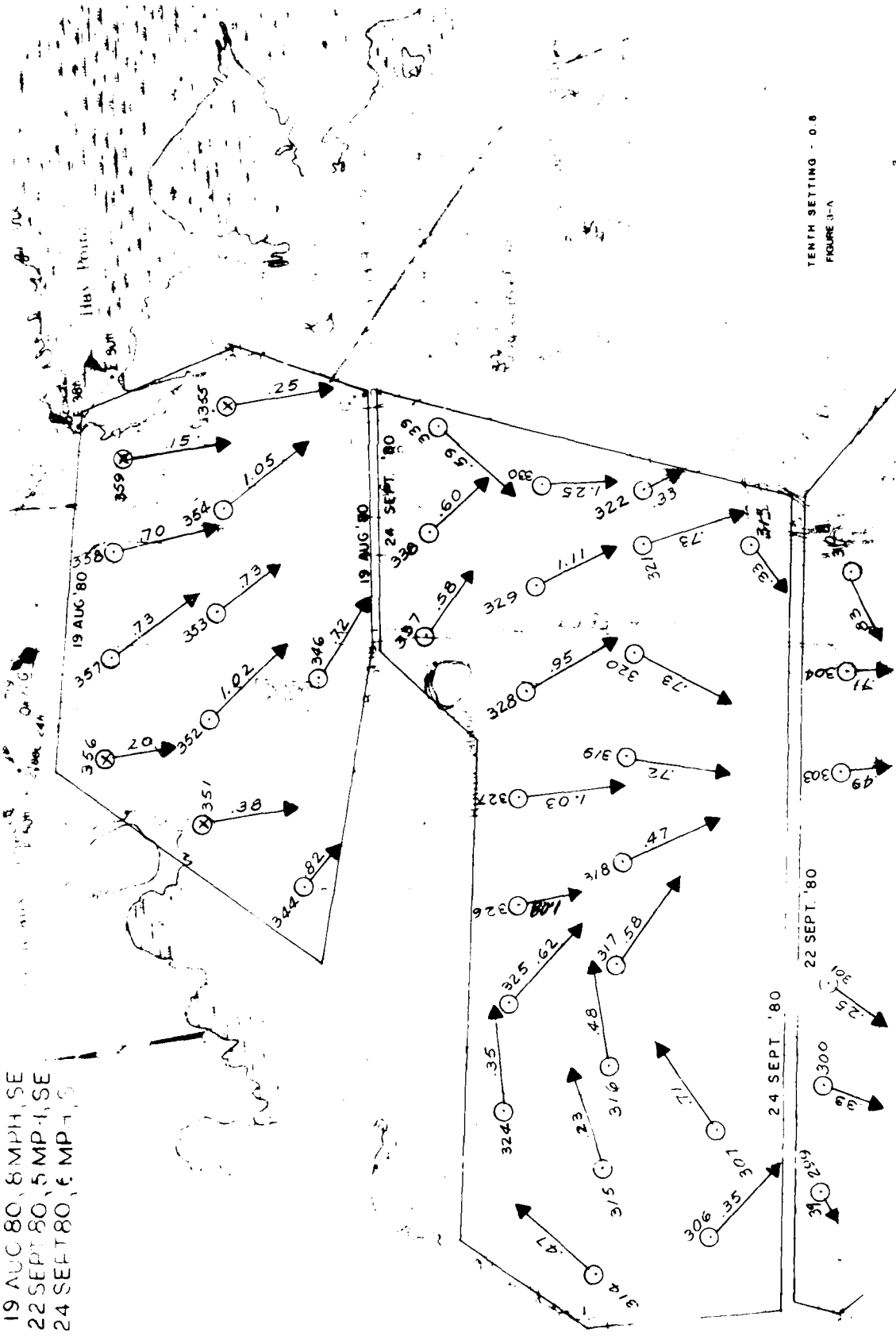
TENTH SETTING - 0.2  
FIGURE 1-A

WIND DATA  
 19 AUG 80, 8 MPH, SE  
 22 SEPT 80, 5 MPH, SE  
 24 SEPT 80, 6 MPH, S



TENTH SETTING - 0.4  
 FIGURE 2-A

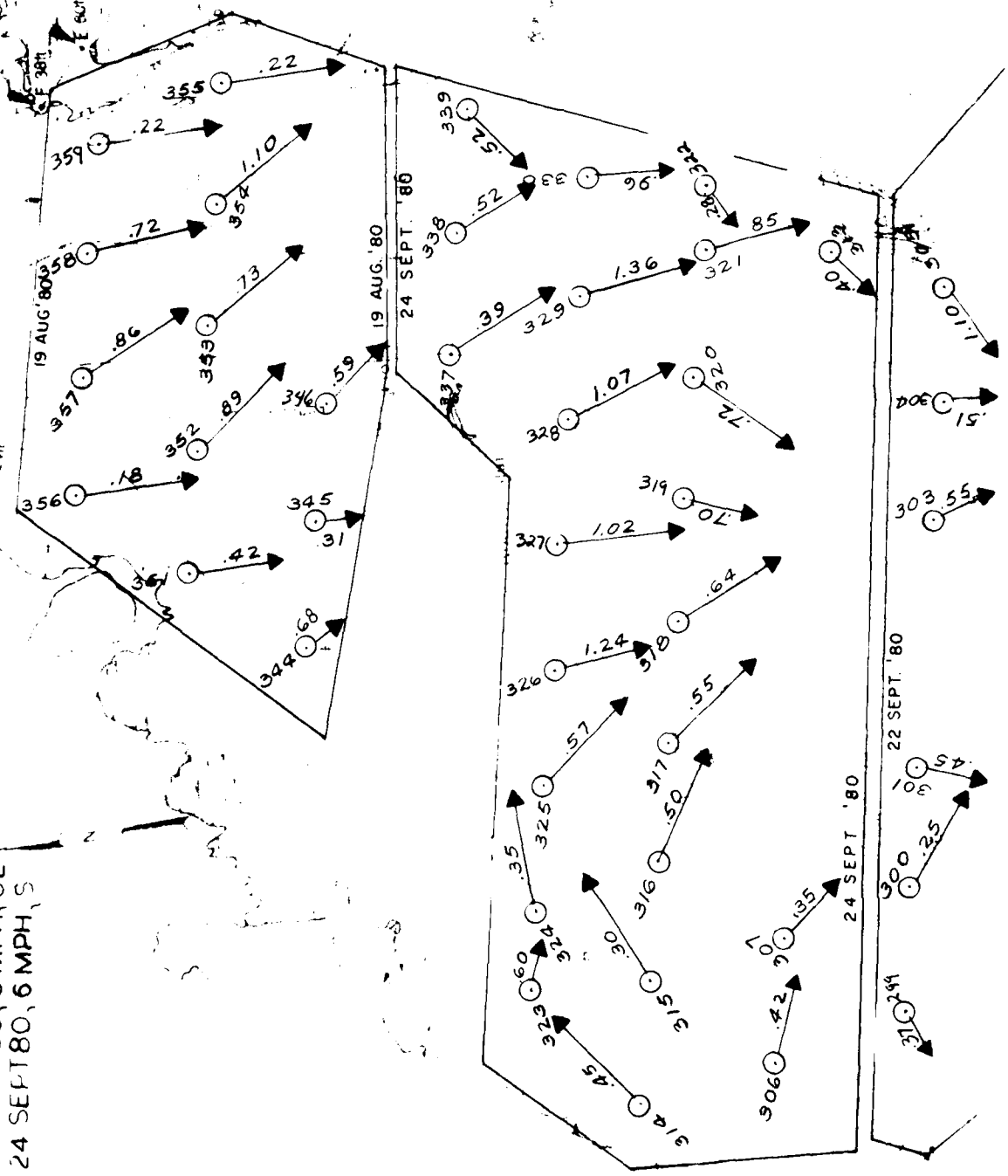
WIND DATA  
 19 AUG 80, 8 MPH, SE  
 22 SEPT 80, 5 MPH, SE  
 24 SEPT 80, 6 MPH, E

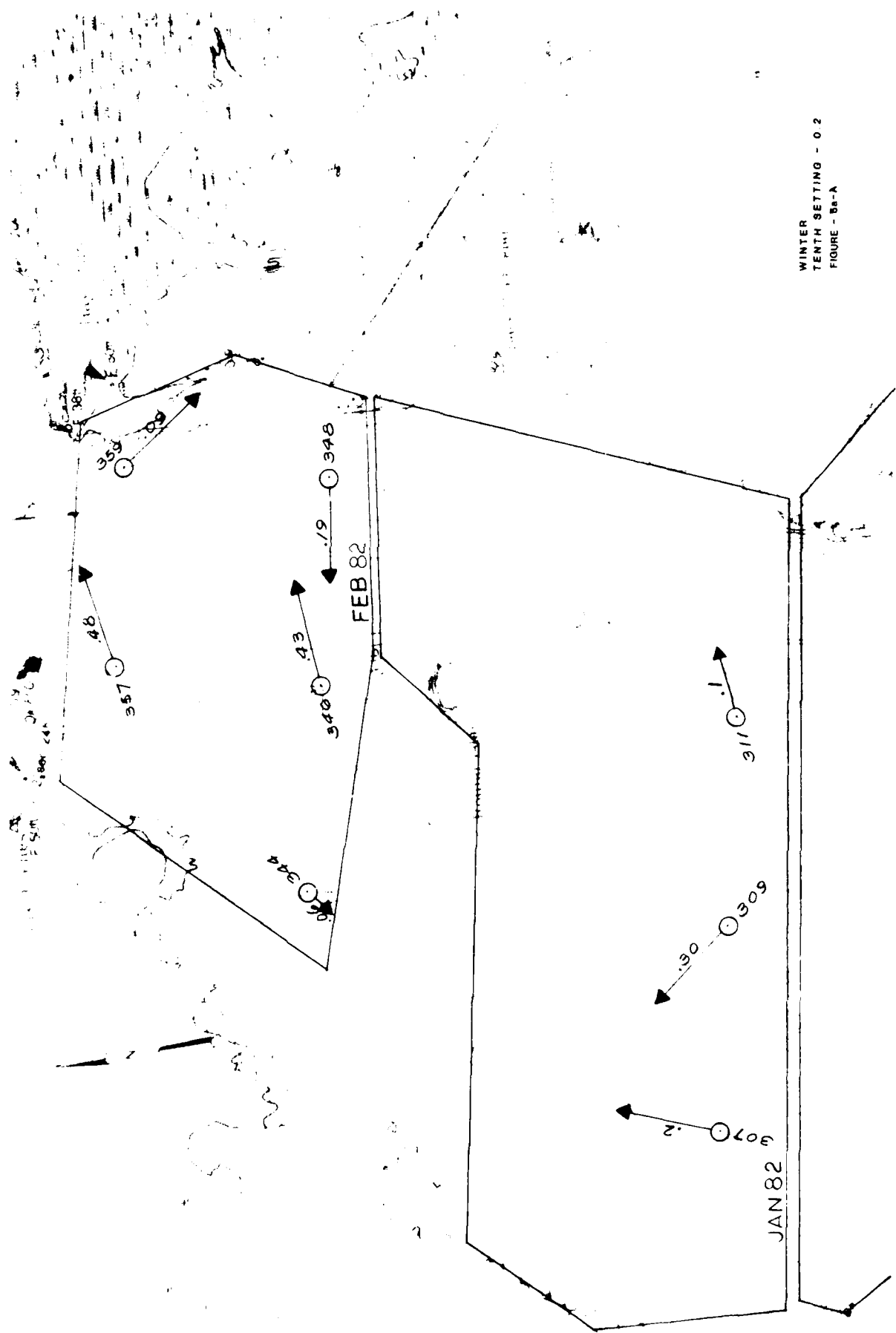


TENTH SETTING - 0.8  
 FIGURE 3-A

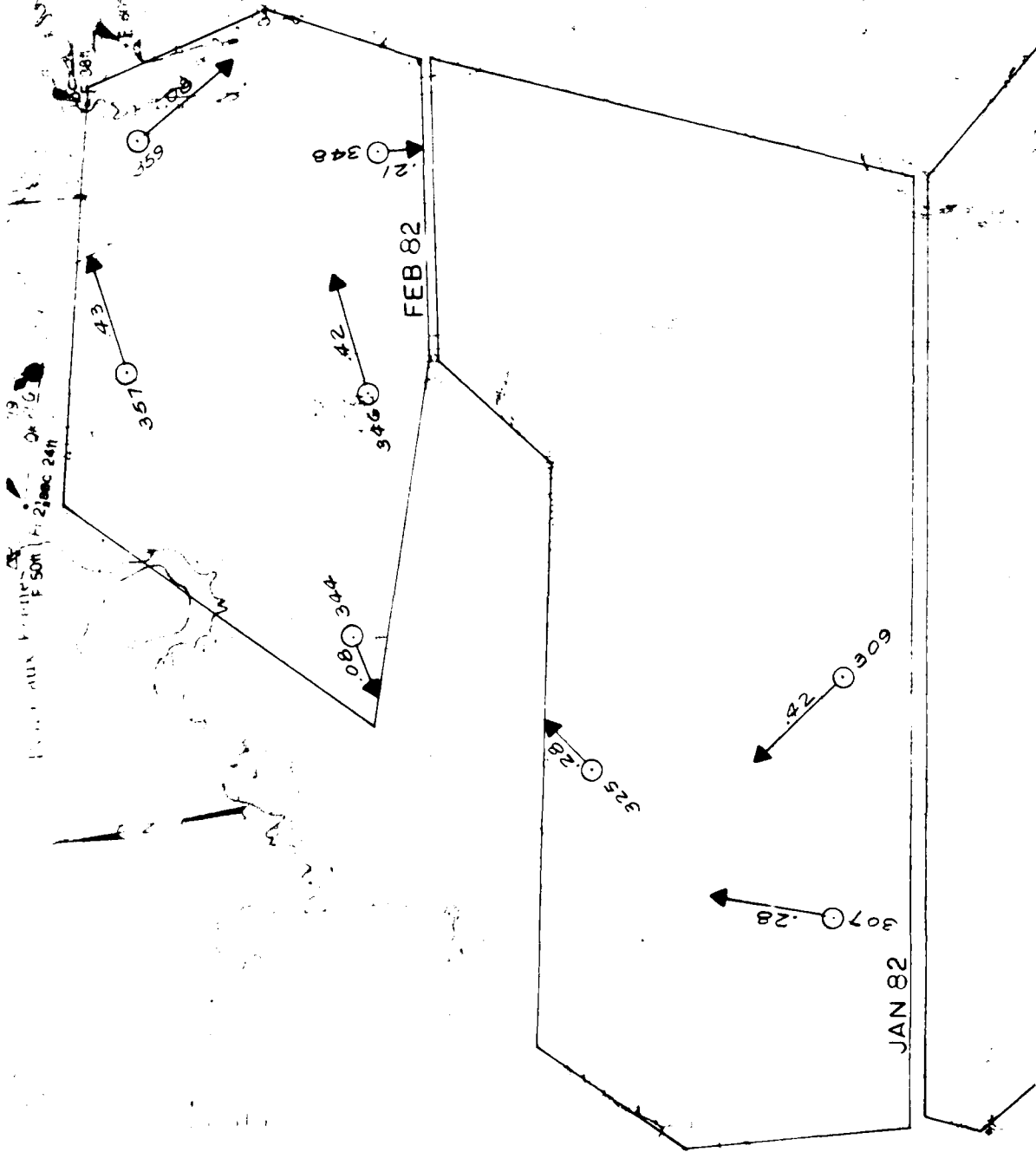
WIND DATA  
 19 AUG 80, 8 MPH, SE  
 22 SEPT 80, 5 MPH, SE  
 24 SEPT 80, 6 MPH, S

COMPOSITE  
 FIGURE 4-A

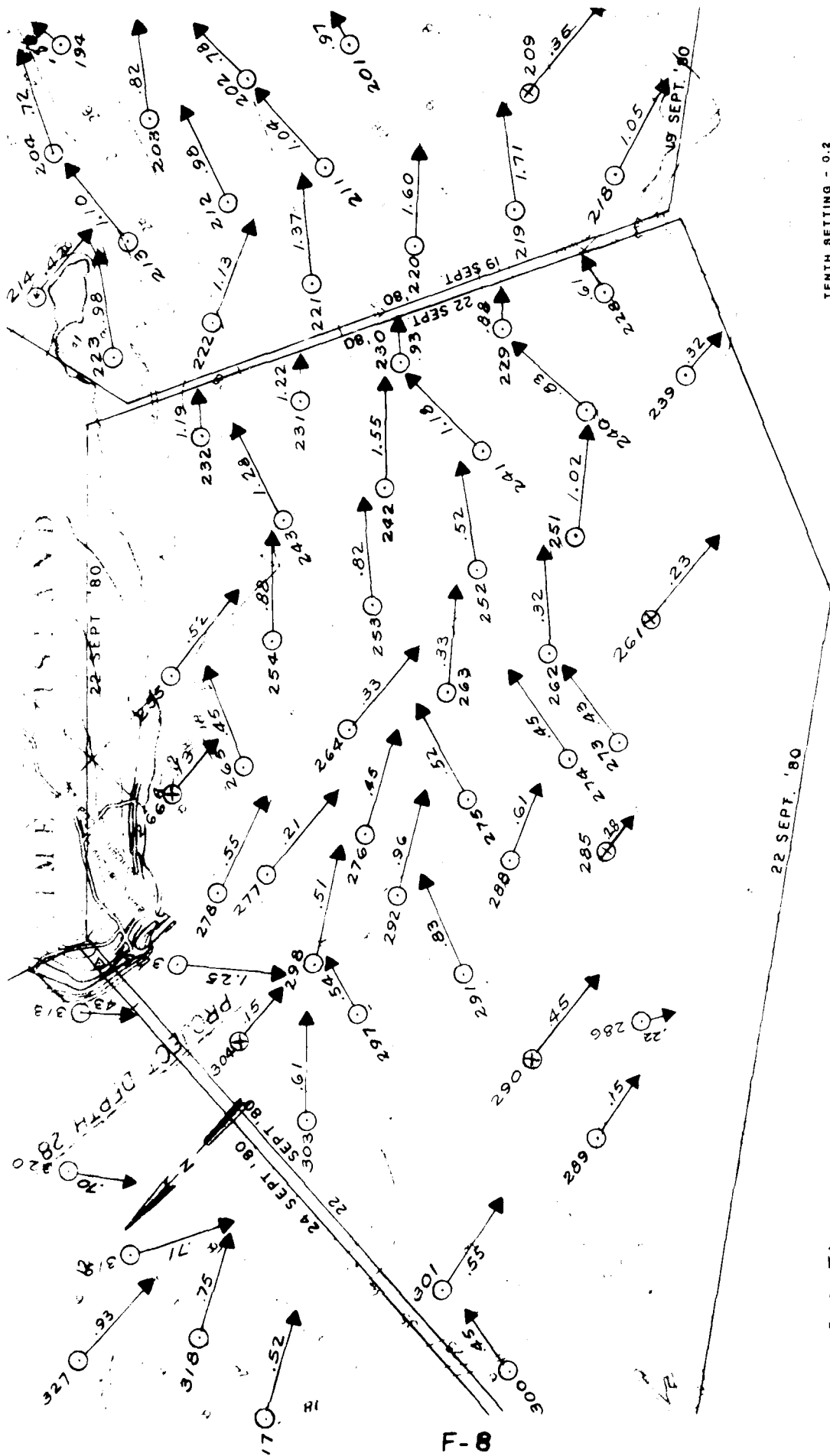




WINTER  
TENTH SETTING - 0.2  
FIGURE - 5a-A



WINTER  
 TENTH SETTING - 0.4  
 FIGURE - 58-A

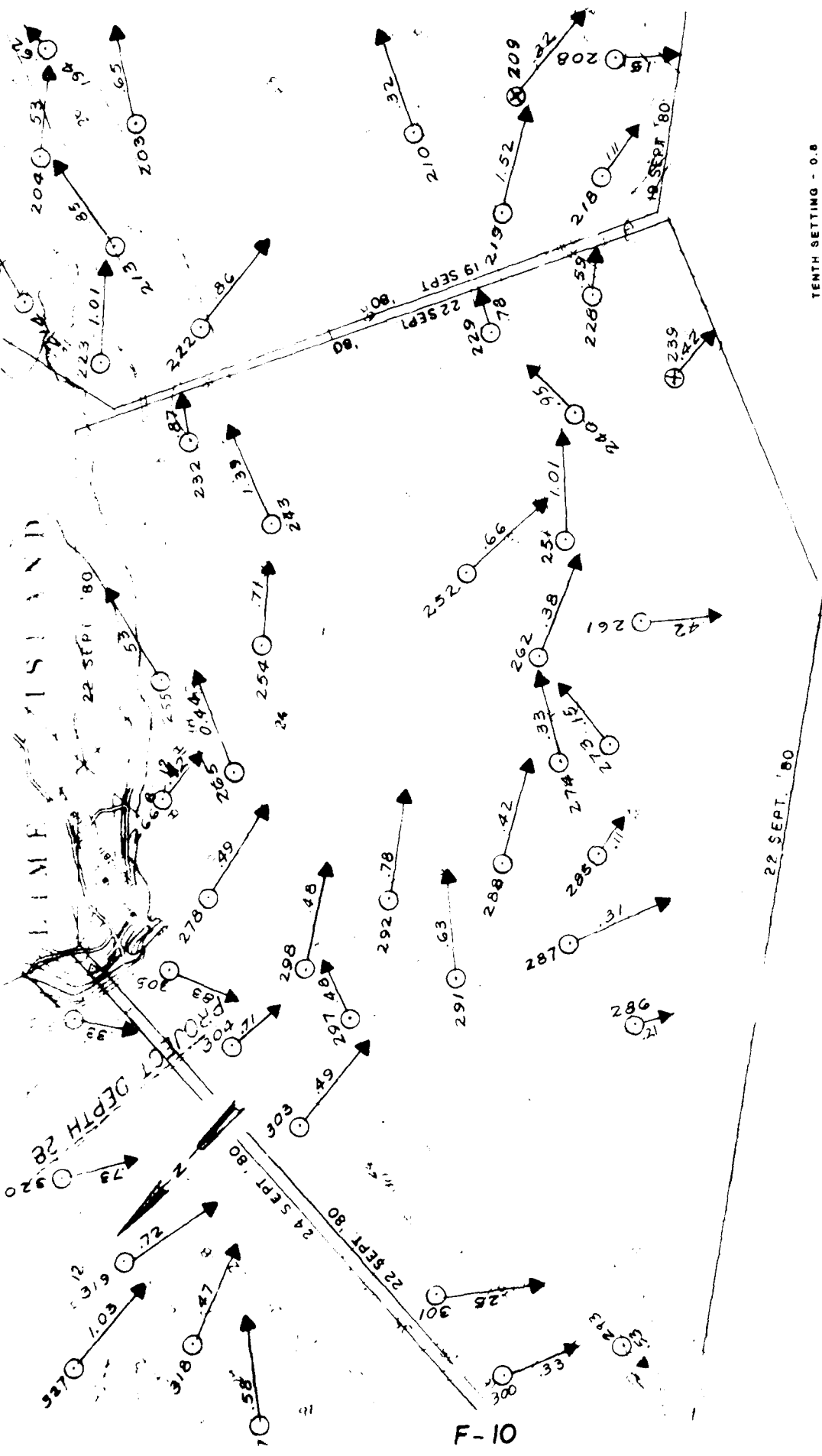


TENTH SETTING - 0.2  
FIGURE 1-B

WIND DATA  
19 AUG 80, 8 MPH, SE  
22 SEPT 80, 5 MPH, SE  
24 SEPT 80, 6 MPH, S

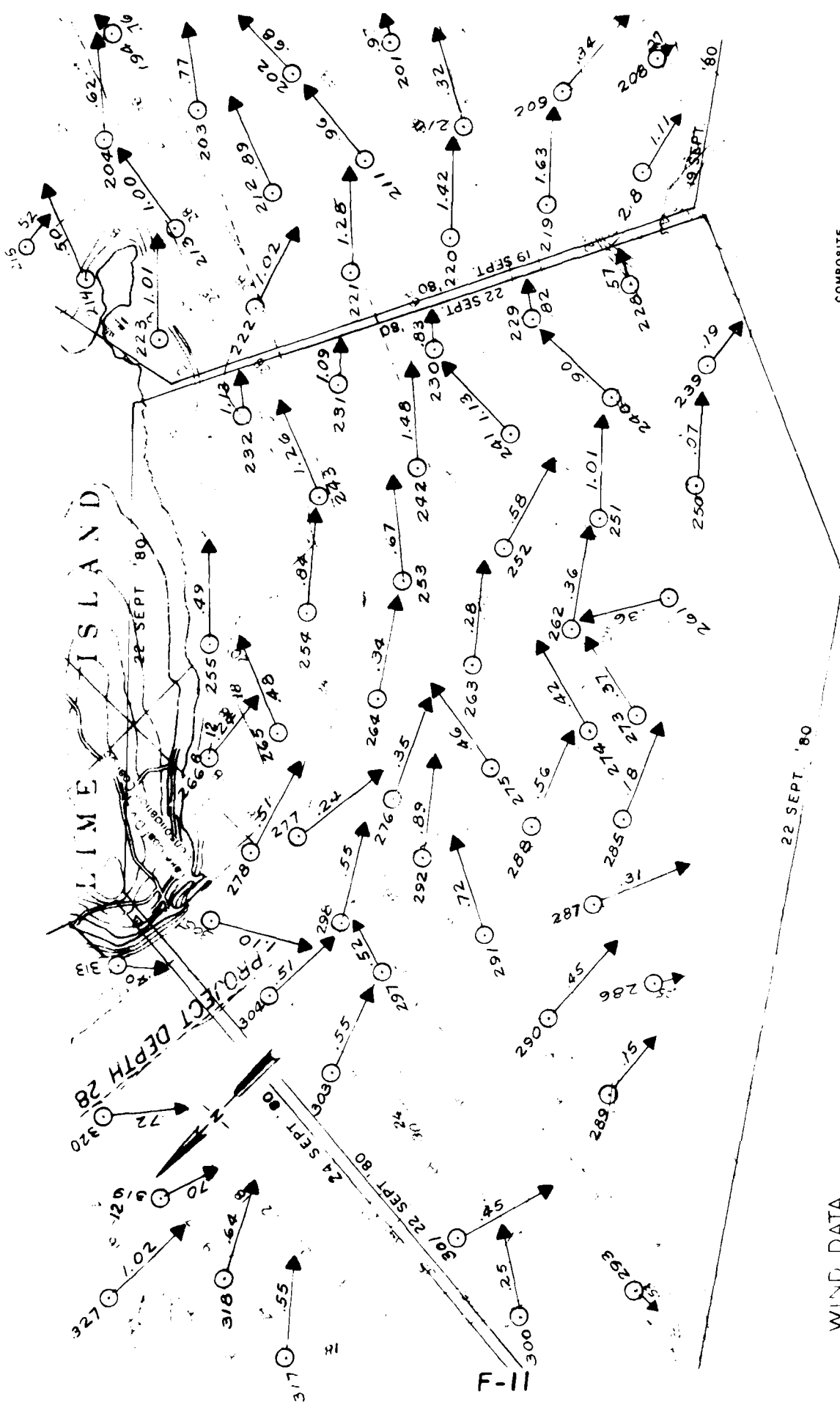
F-8





TENTH SETTING - 0.8  
FIGURE 3-B

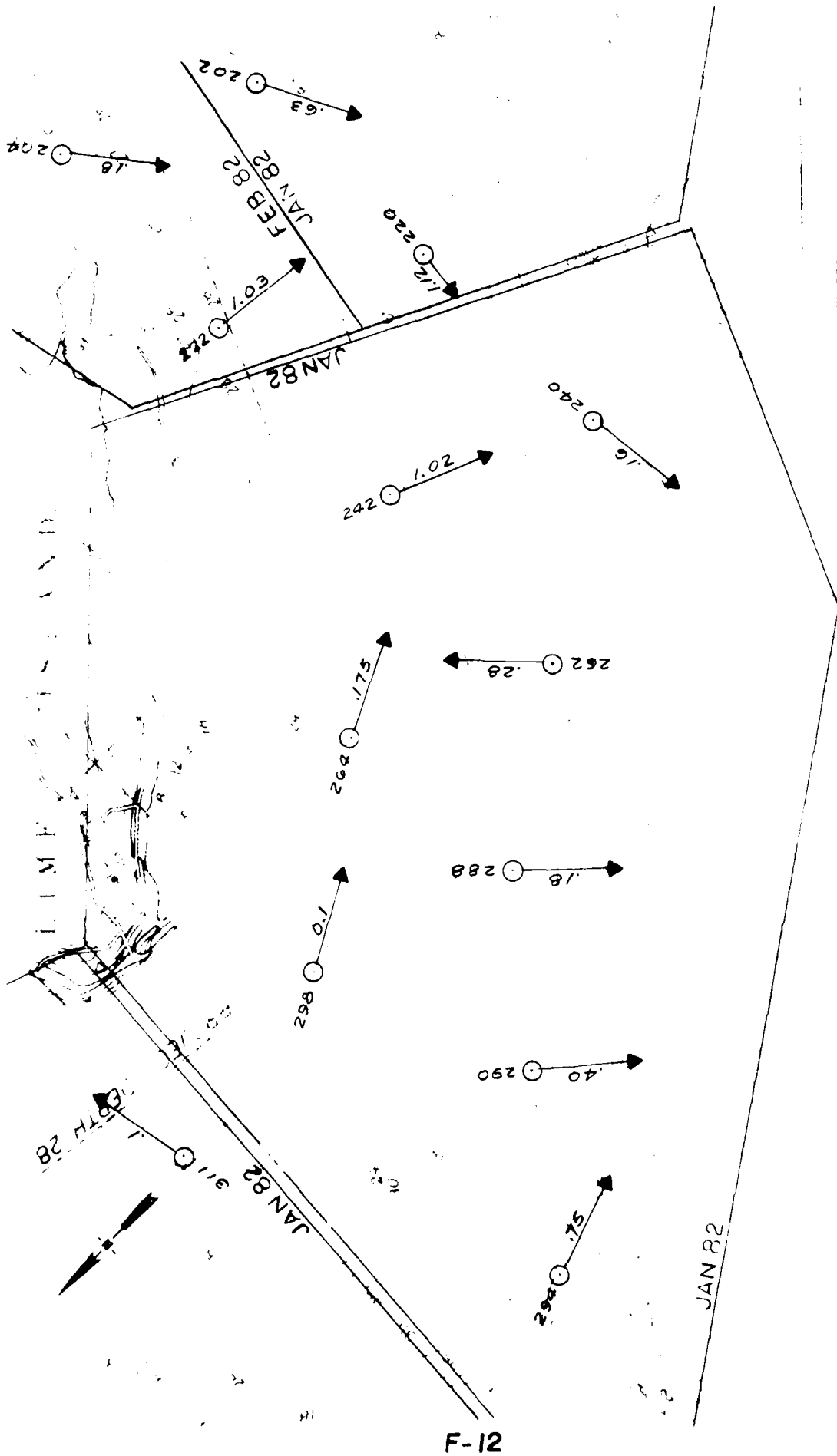
WIND DATA  
19 AUG 80, 8 MPH, SE  
22 SEPT 80, 5 MPH, NE  
24 SEPT 80, 6 MPH, S



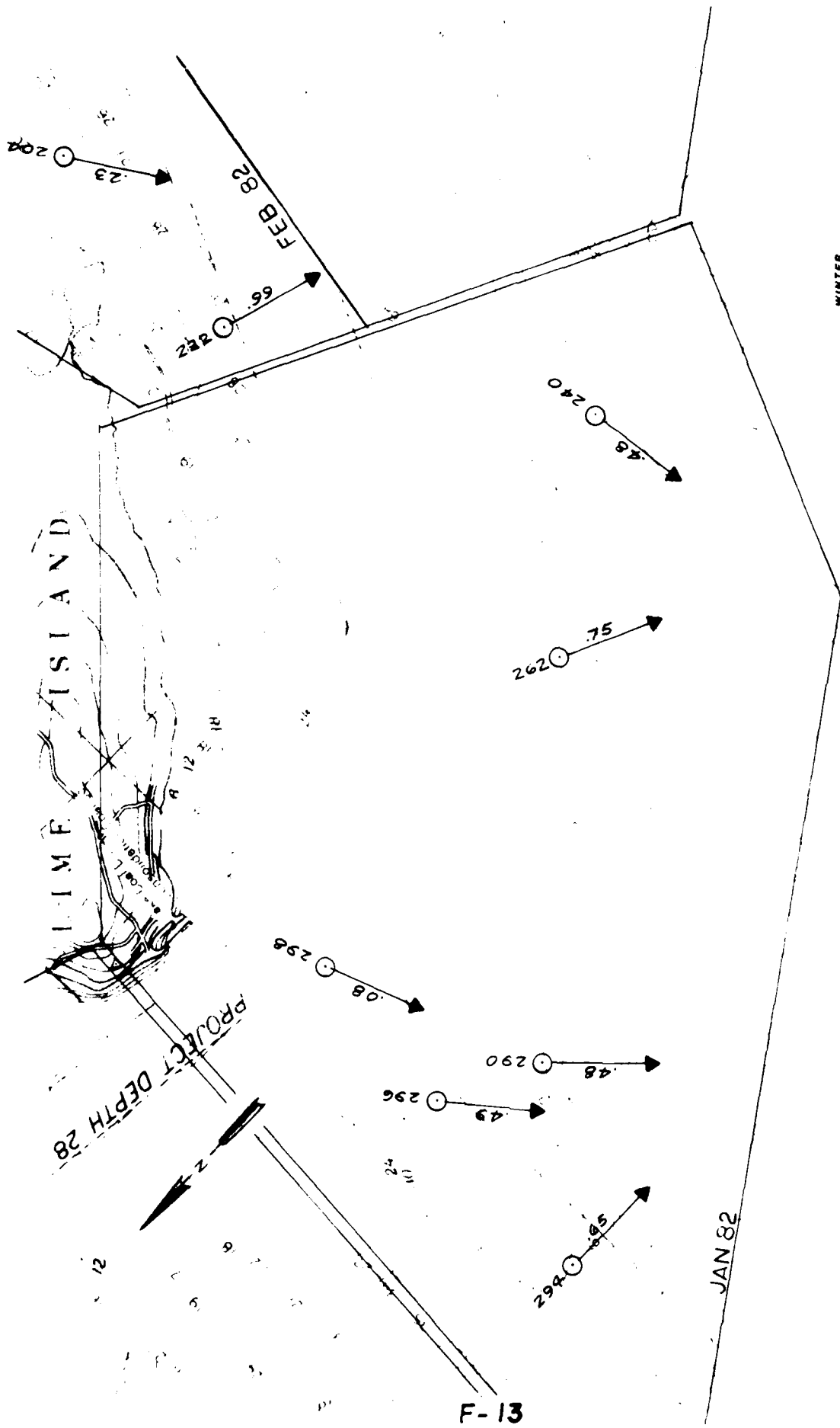
COMPOSITE  
FIGURE 4-B

WIND DATA  
10 AUG 80, 2 MPH, SE  
22 SEPT 80, 5 MPH, SE  
24 SEPT 80, 6 MPH, SE

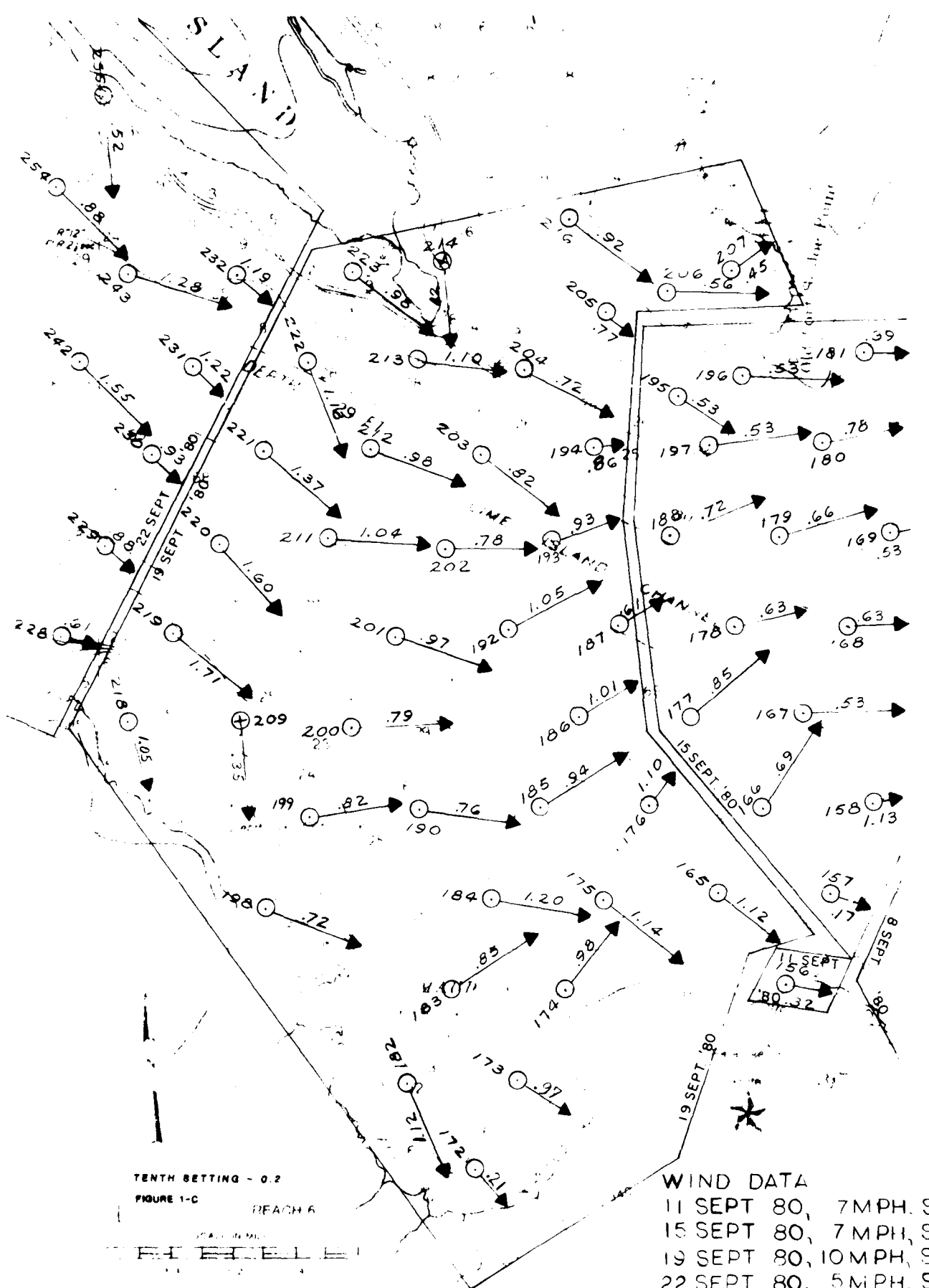
F-11



WINTER  
TENT SETTING - 0.2  
FIGURE - 08-B



WINTER TENTH SETTING - 0.4  
 FIGURE - 6B-B



TENT BETTING - 0.2

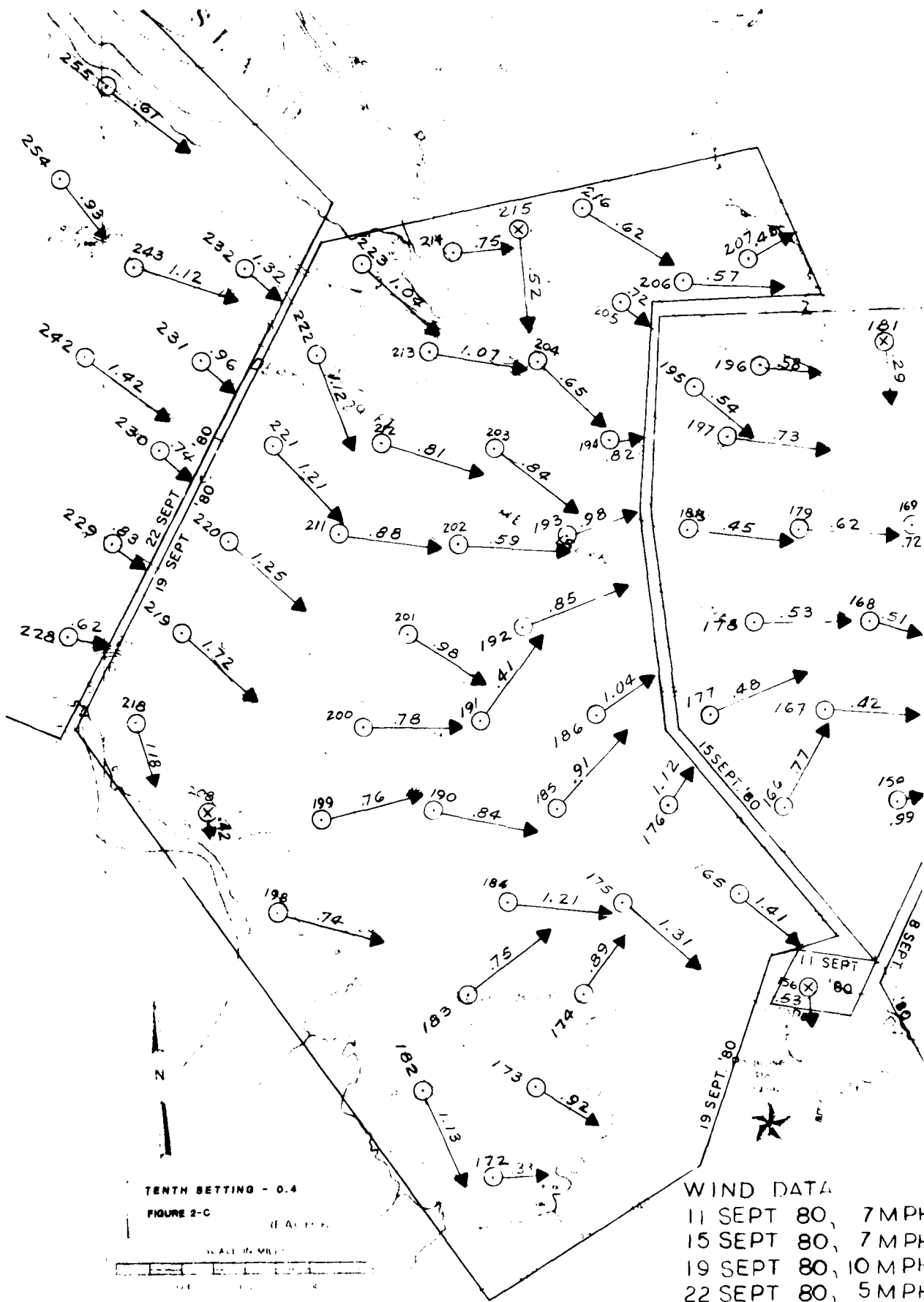
FIGURE 1-C

BEACH 6

100 FEET

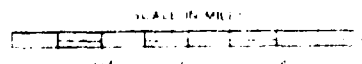
WIND DATA

- 11 SEPT 80, 7MPH, S
- 15 SEPT 80, 7MPH, SE
- 19 SEPT 80, 10MPH, SE
- 22 SEPT 80, 5MPH, SE

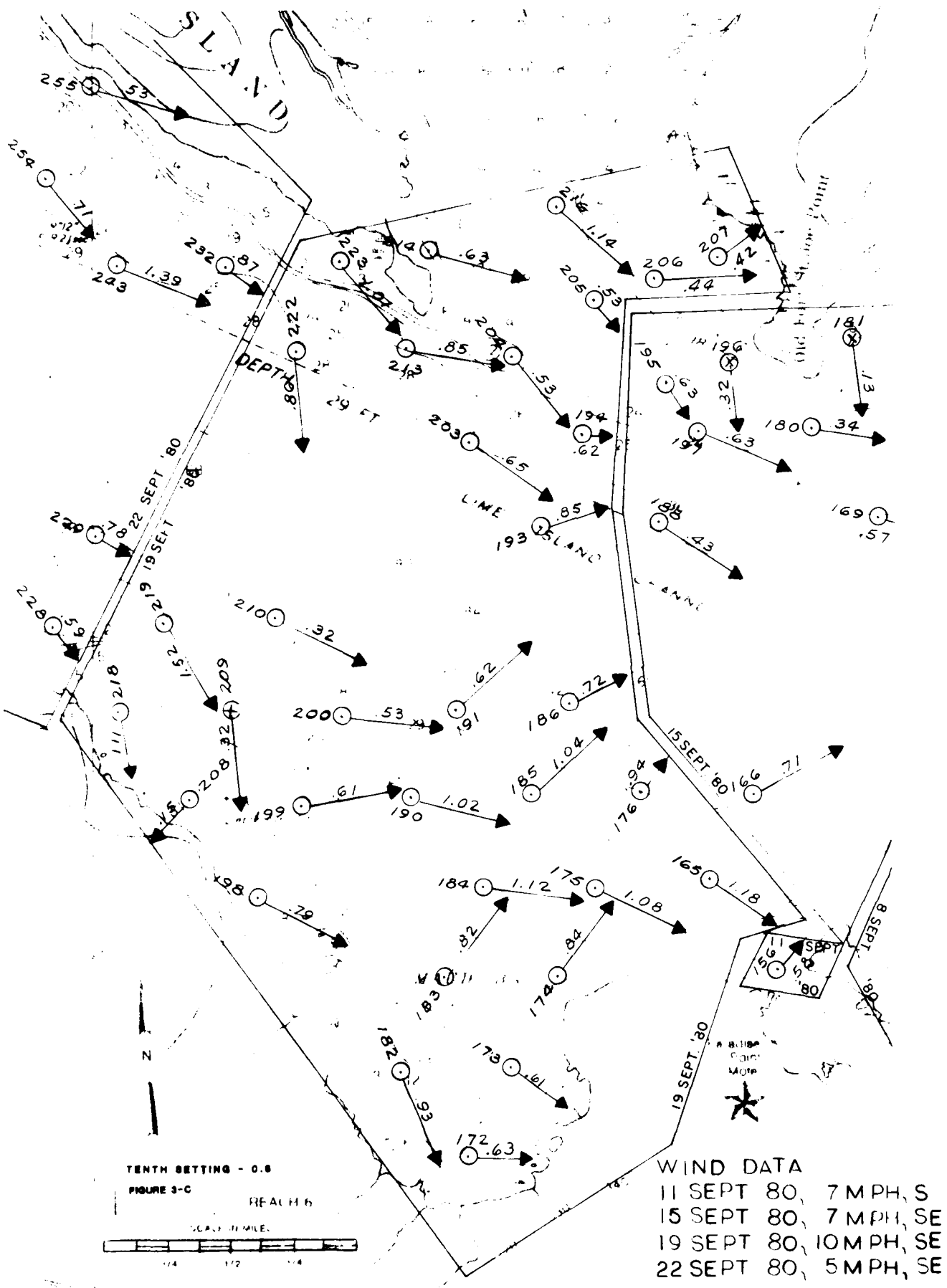


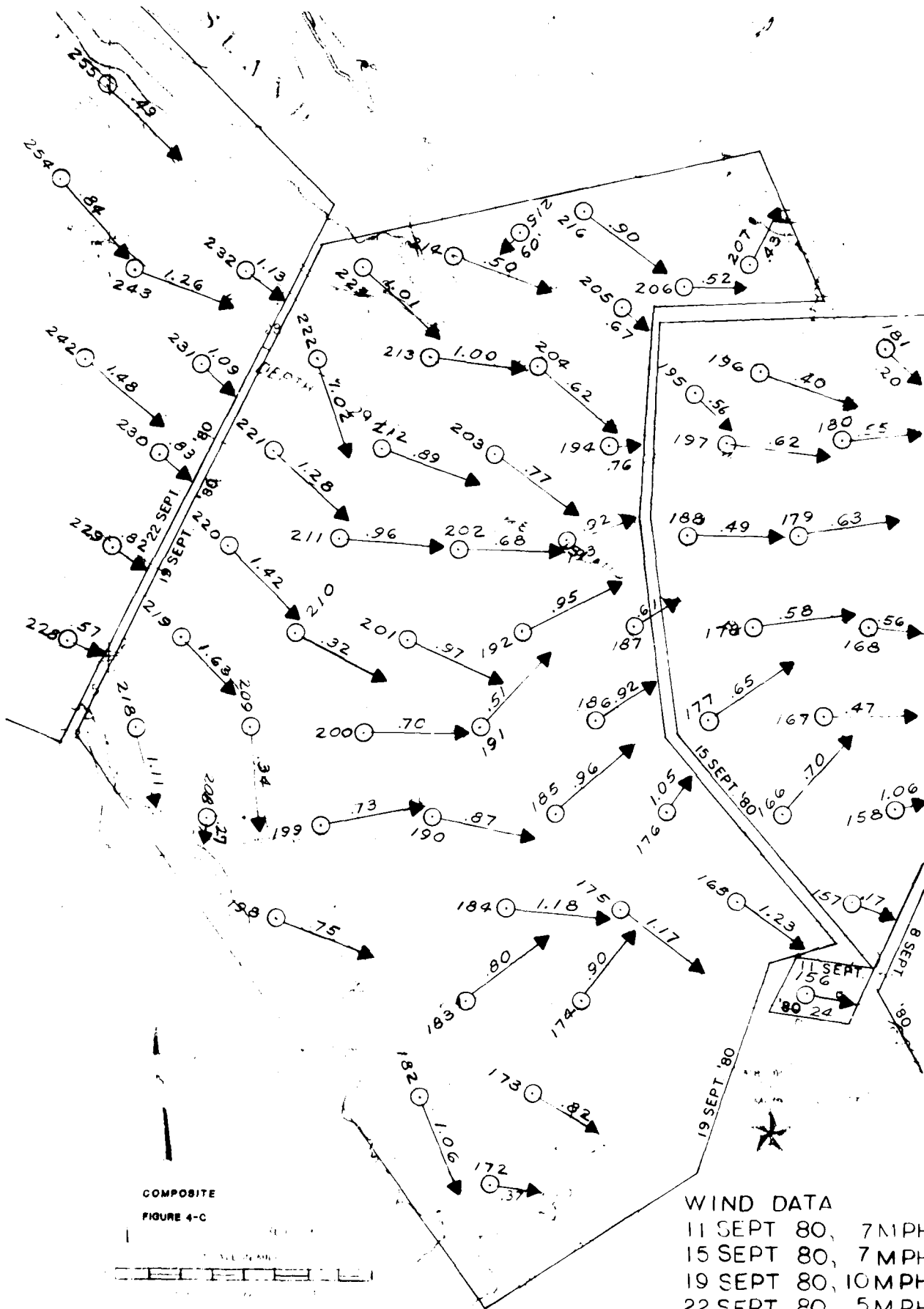
TENTH SETTING - 0.4

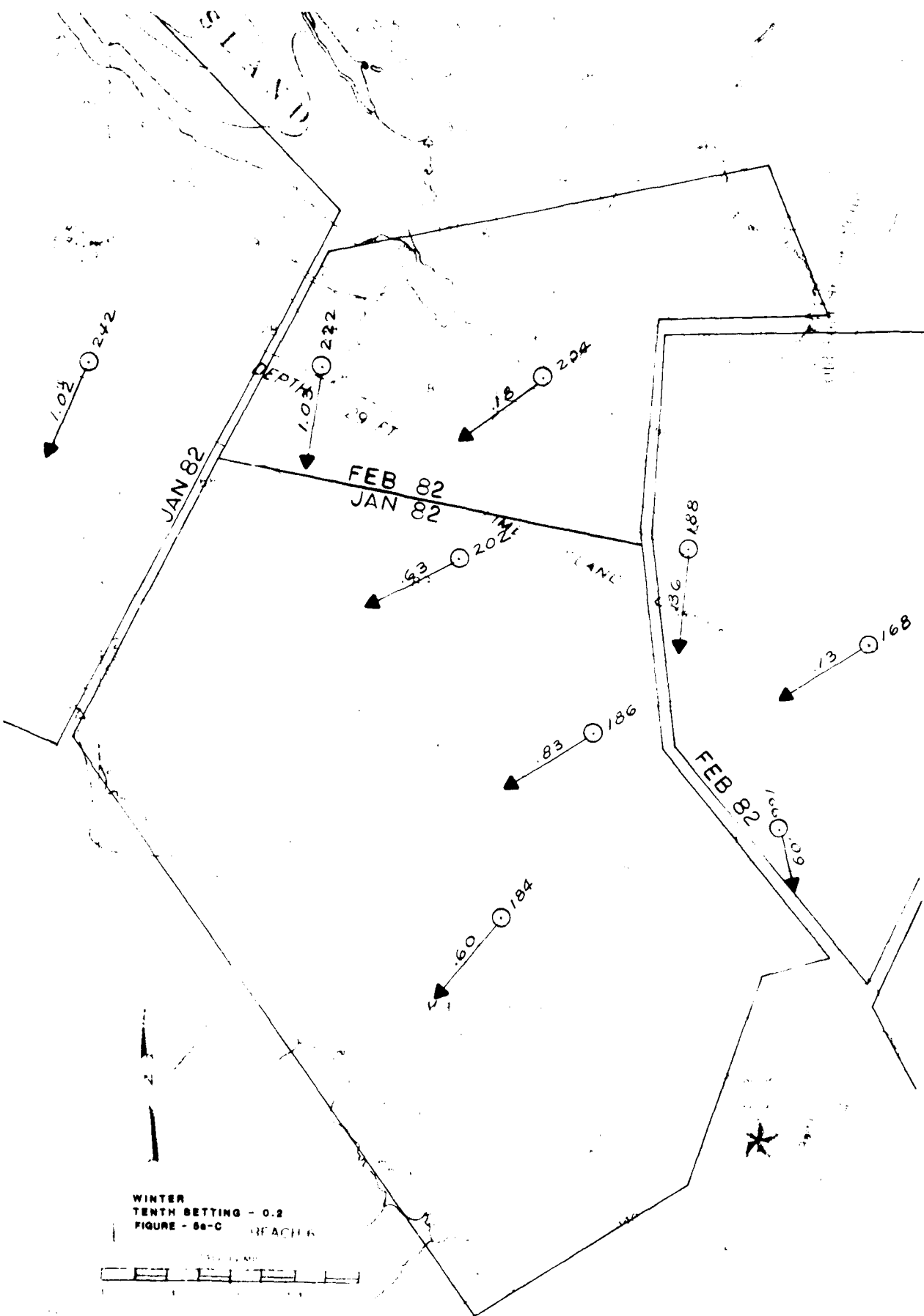
FIGURE 2-C



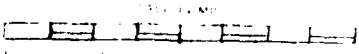
WIND DATA  
 11 SEPT 80, 7 MPH, S  
 15 SEPT 80, 7 MPH, SE  
 19 SEPT 80, 10 MPH, SE  
 22 SEPT 80, 5 MPH, SE

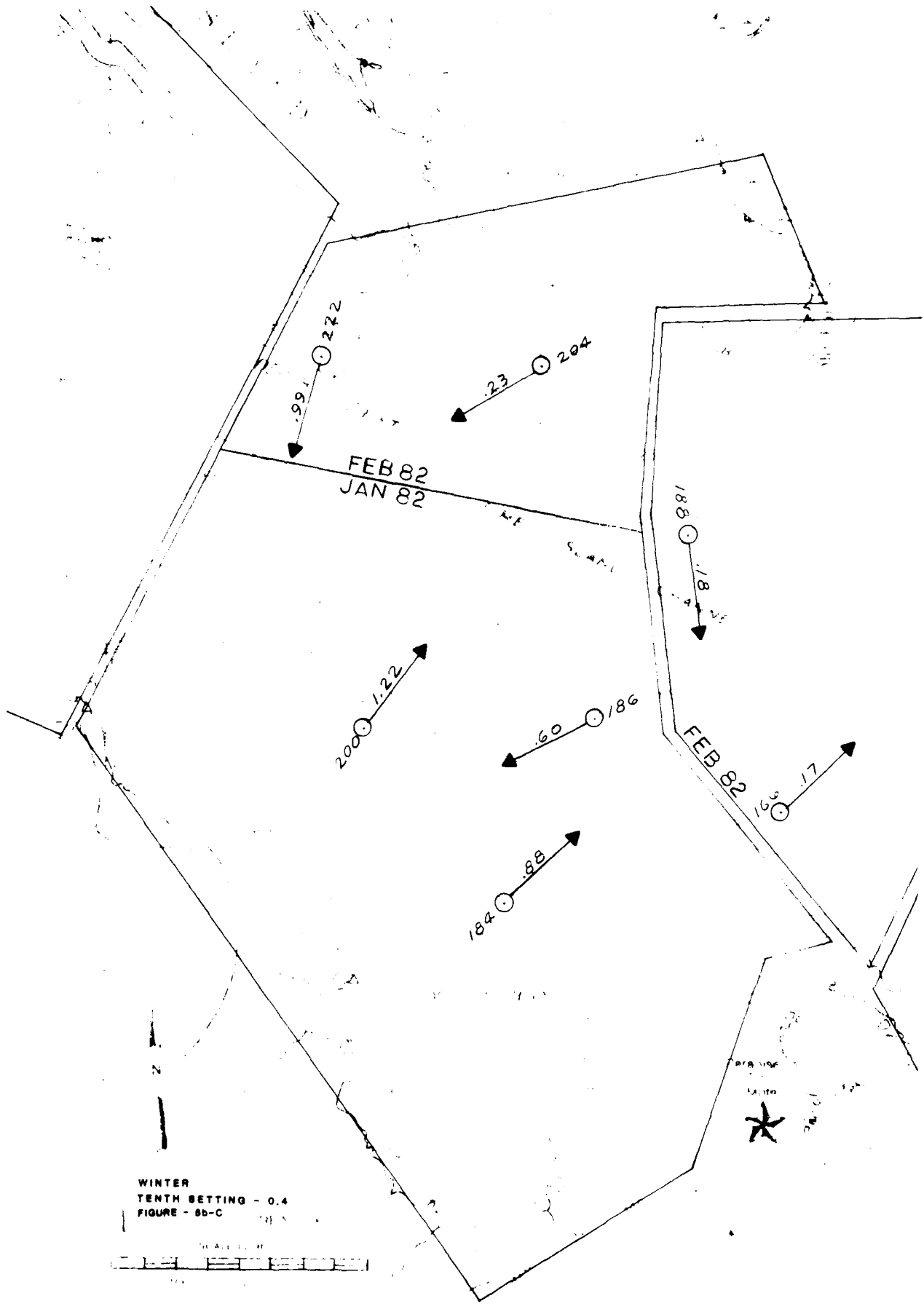




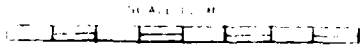


WINTER  
TENTH BETTING - 0.2  
FIGURE - 86-C BEACH K



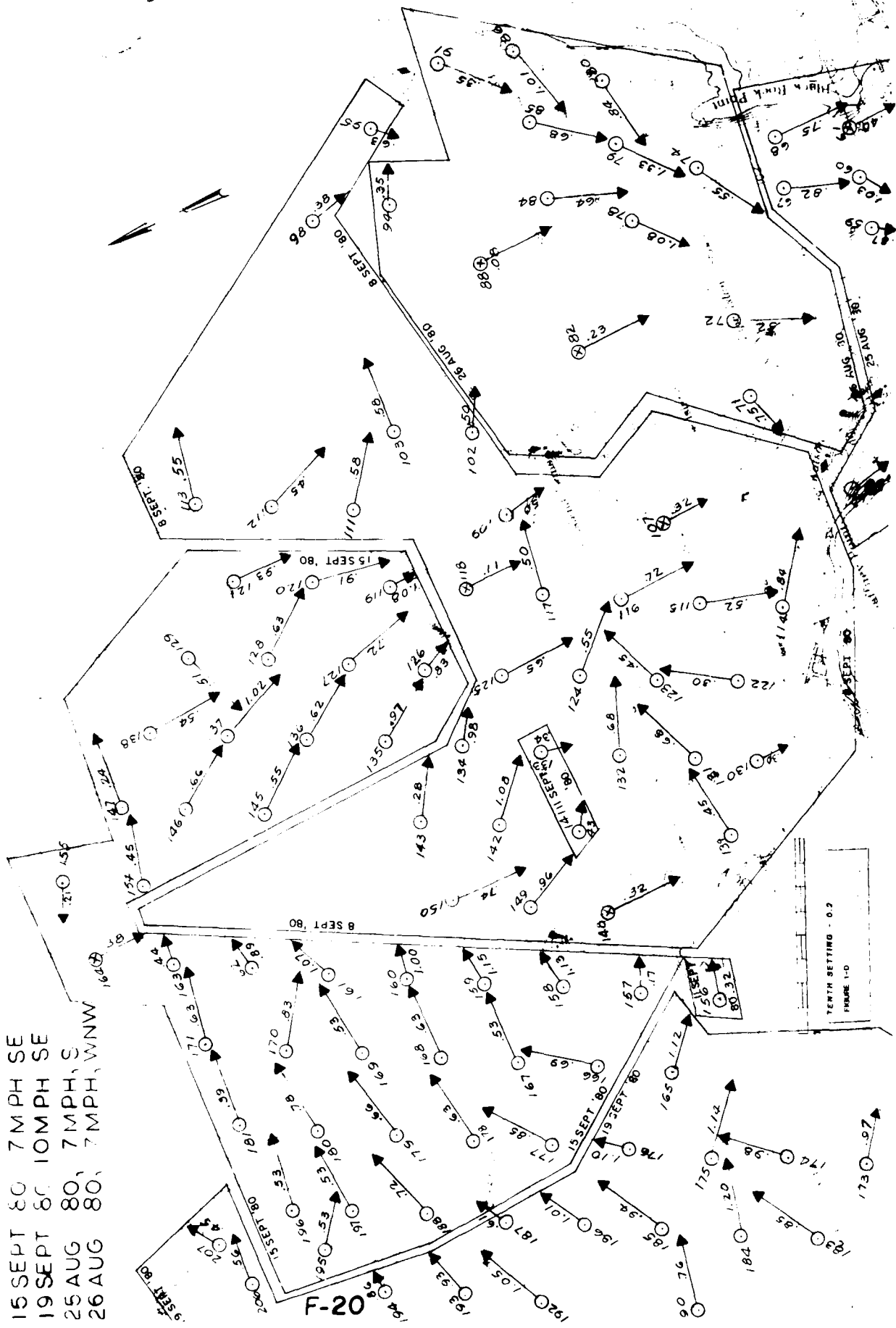


WINTER  
TENTH SETTING - 0.4  
FIGURE - 8b-C

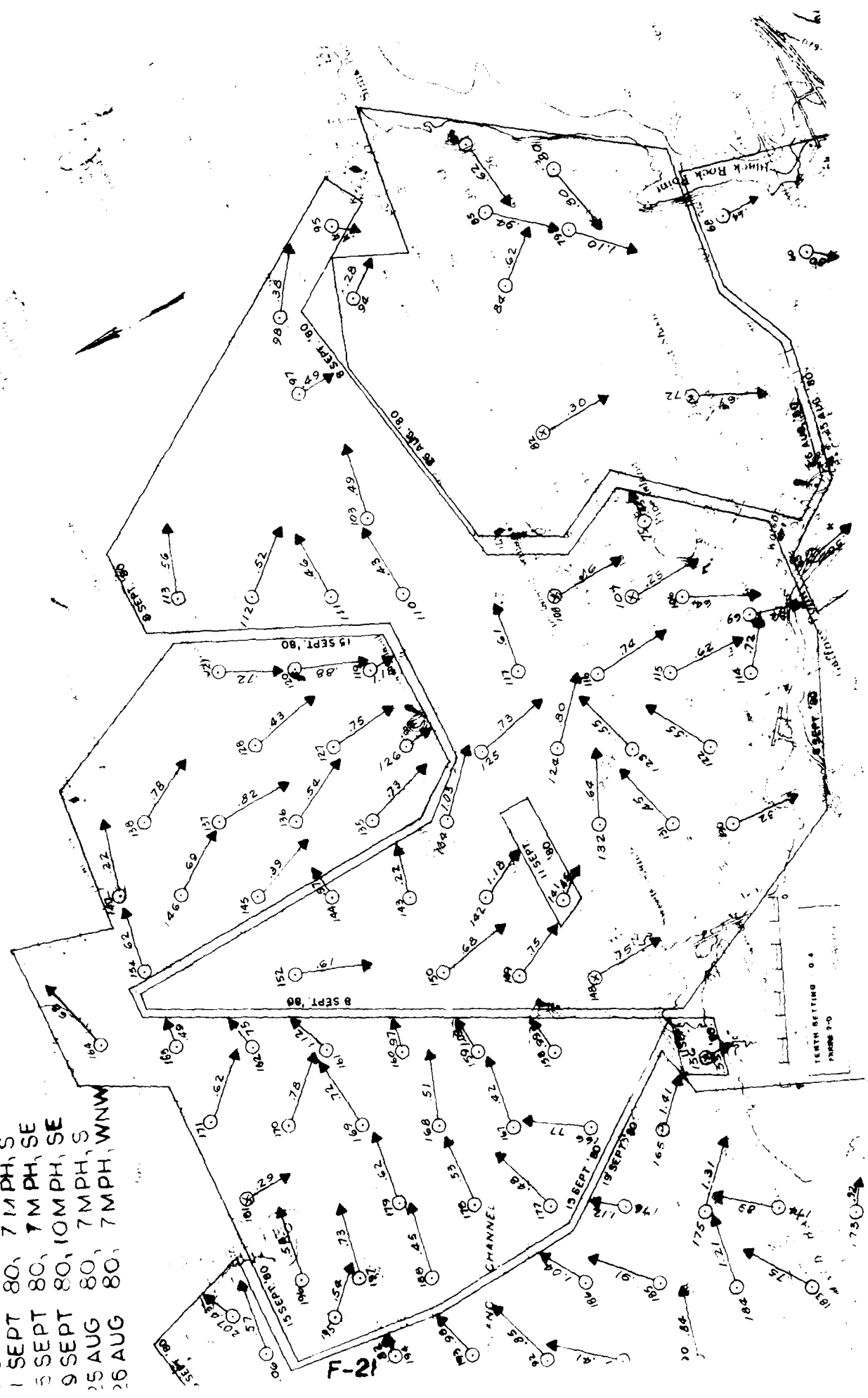


WIND DATA

- 8 SEPT 80 7 MPH SE
- 11 SEPT 80 7 MPH S
- 15 SEPT 80 7 MPH SE
- 19 SEPT 80 10 MPH SE
- 25 AUG 80, 7 MPH, S
- 26 AUG 80, 7 MPH, WNW

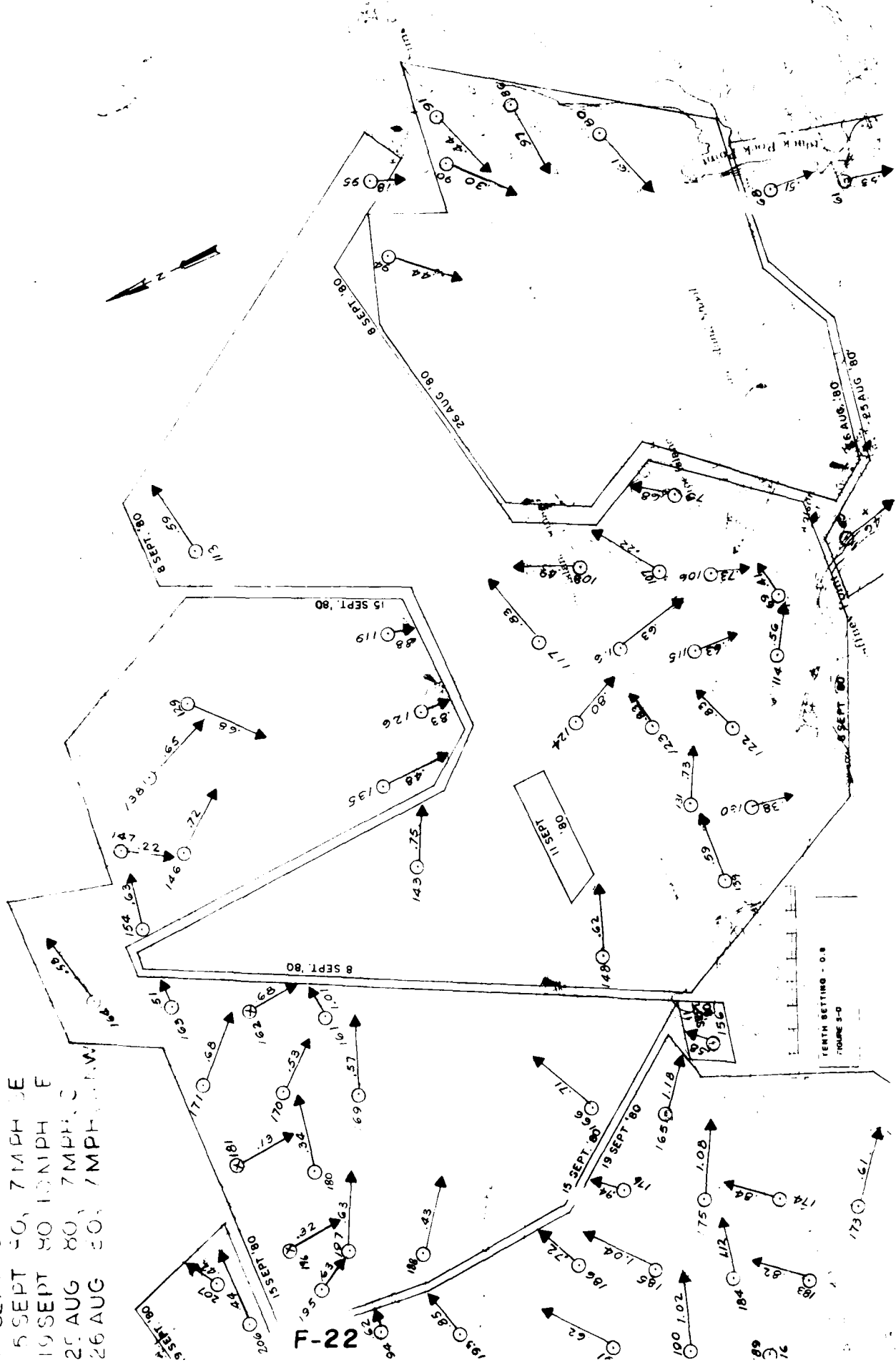


WIND DATA  
 8 SEPT 80, 7 MPH, SE  
 1 SEPT 80, 7 MPH, S  
 3 SEPT 80, 7 MPH, SE  
 9 SEPT 80, 10 MPH, SE  
 25 AUG 80, 7 MPH, S  
 26 AUG 80, 7 MPH, WNW

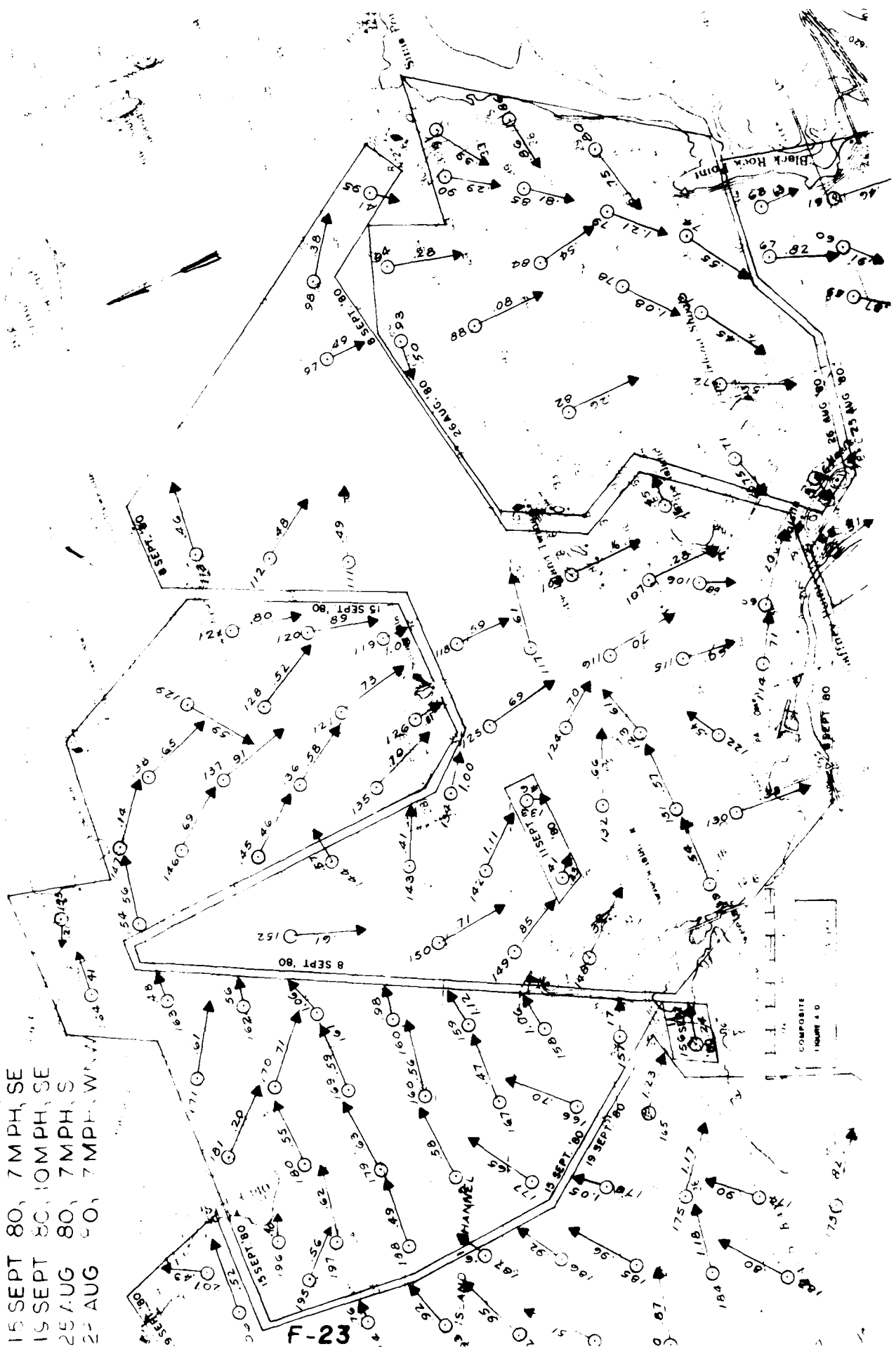


TERTIARY SETTING 0 4  
 FORM 2-0

WIND DATA  
 8 SEPT 80 7 MPH CE  
 11 SEPT 80 7 MPH CE  
 15 SEPT 80 7 MPH CE  
 19 SEPT 80 10 MPH CE  
 25 AUG 80 7 MPH CE  
 26 AUG 80 7 MPH CE



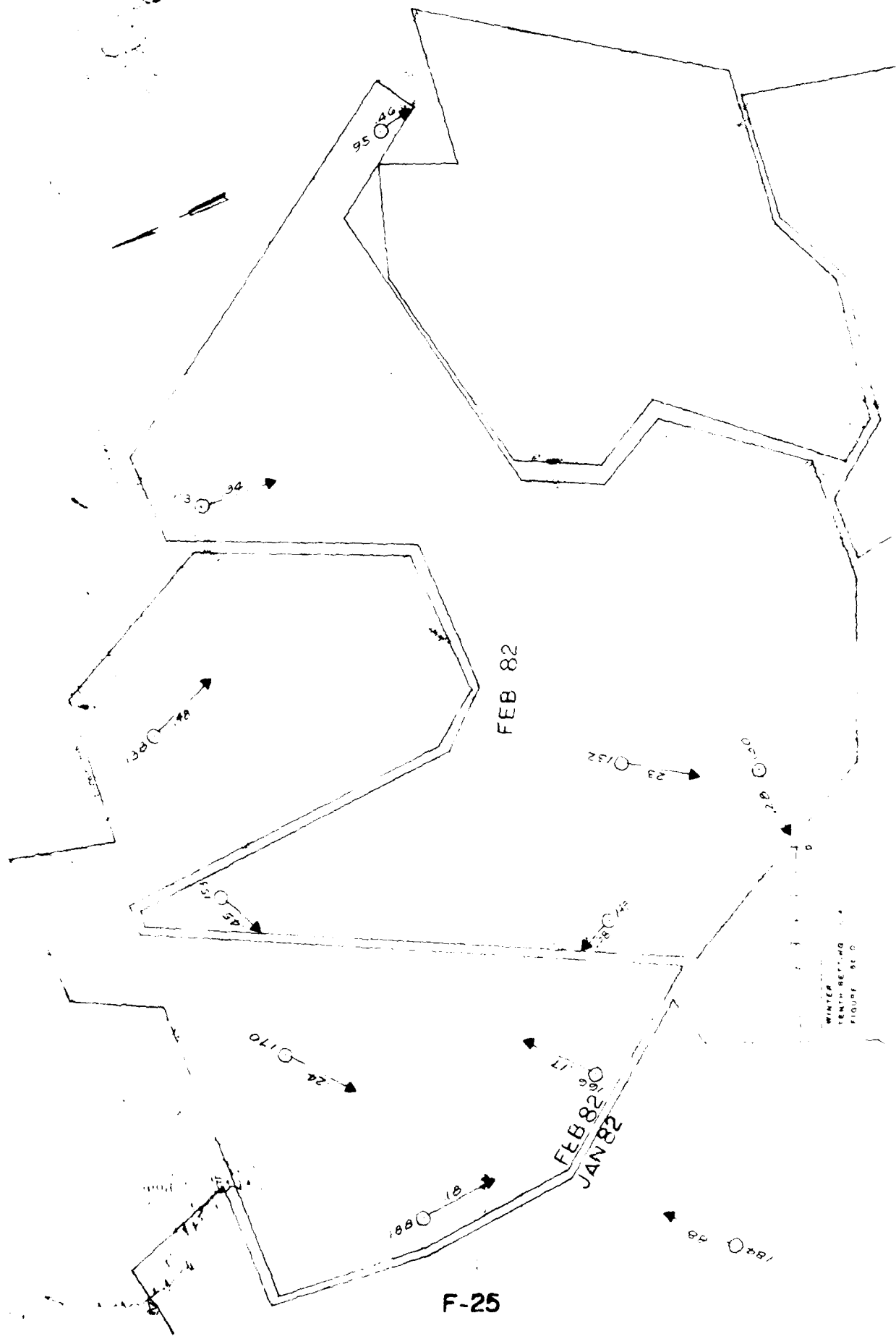
WIND DATA  
 8 SEPT 80, 7 MPH SE  
 11 SEPT 80, 7 MPH S  
 15 SEPT 80, 7 MPH SE  
 19 SEPT 80, 10 MPH SE  
 25 AUG 80, 7 MPH S  
 27 AUG 80, 7 MPH W



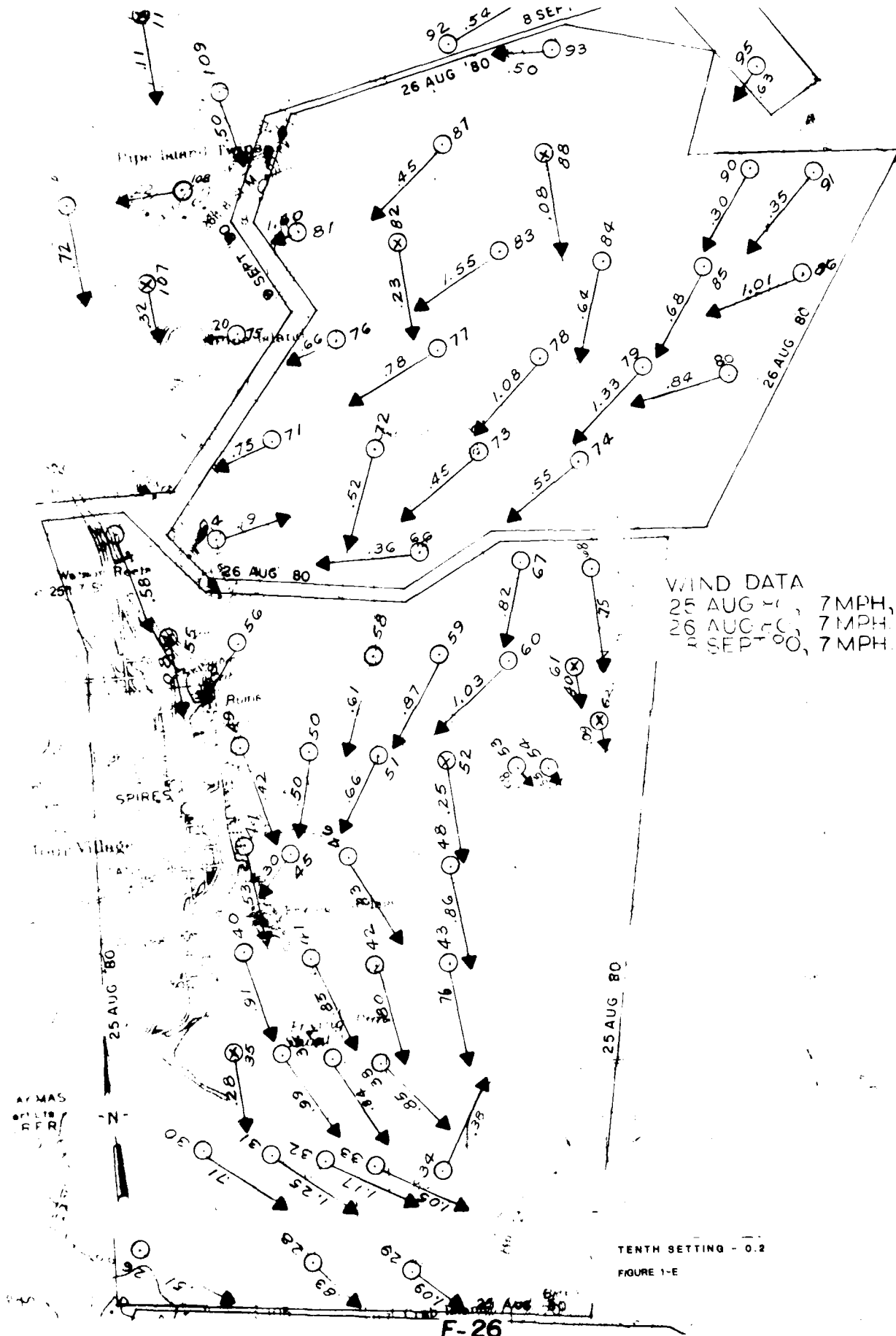
F-23

COMPOSITE  
FIGURE 4-D



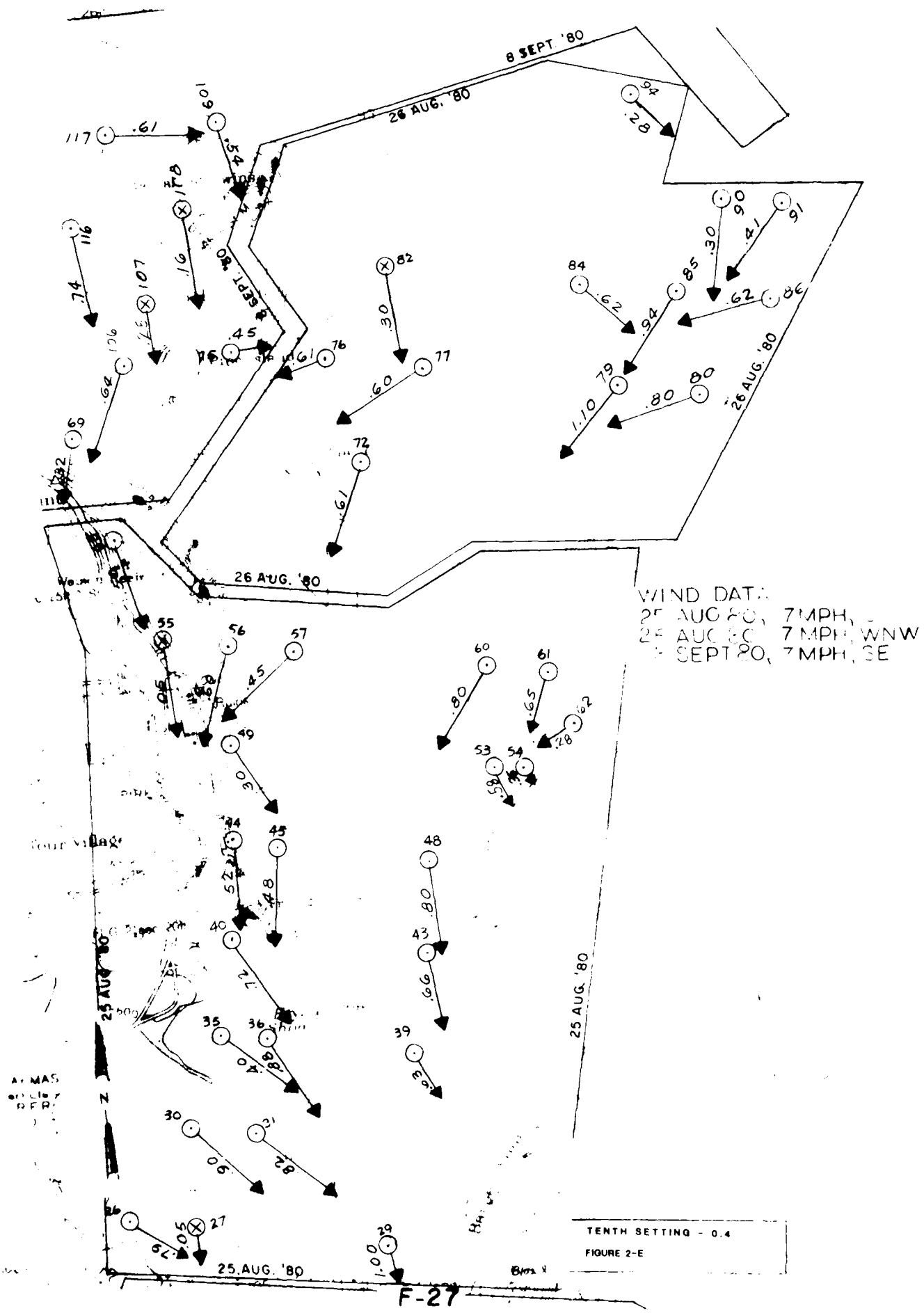


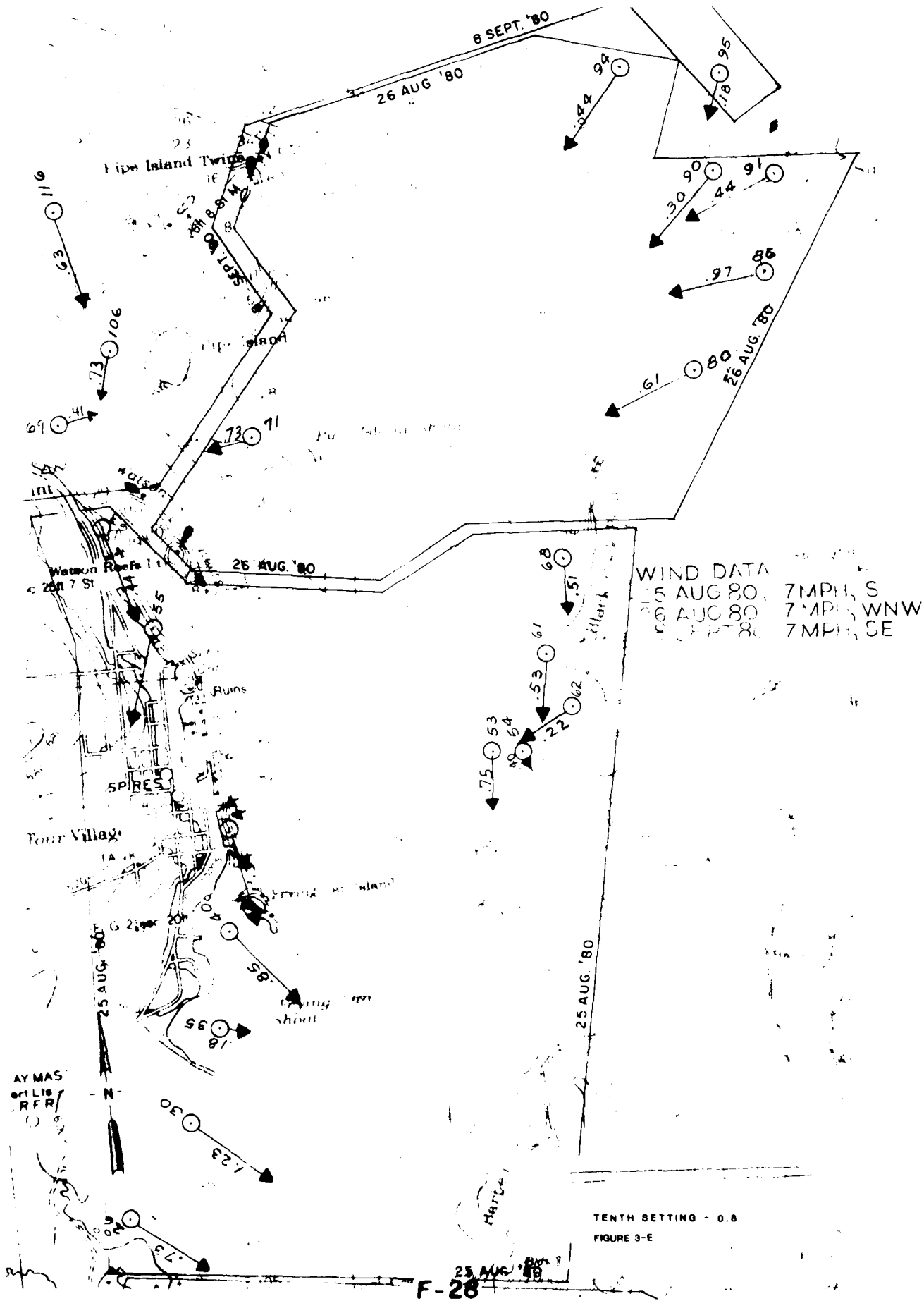
F-25



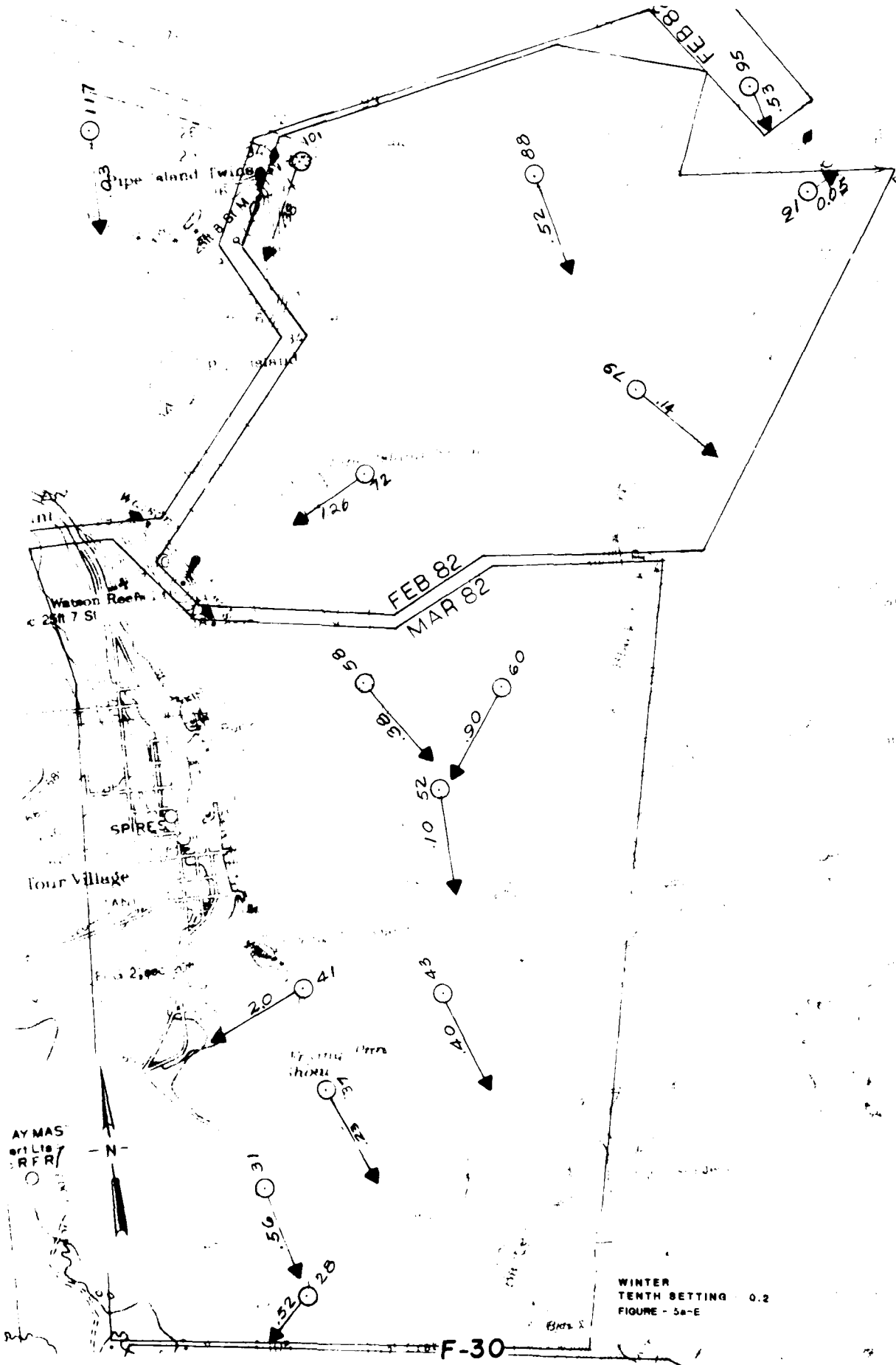
WIND DATA  
 25 AUG '80, 7 MPH, E  
 26 AUG '80, 7 MPH, WNW  
 8 SEPT '80, 7 MPH, SE

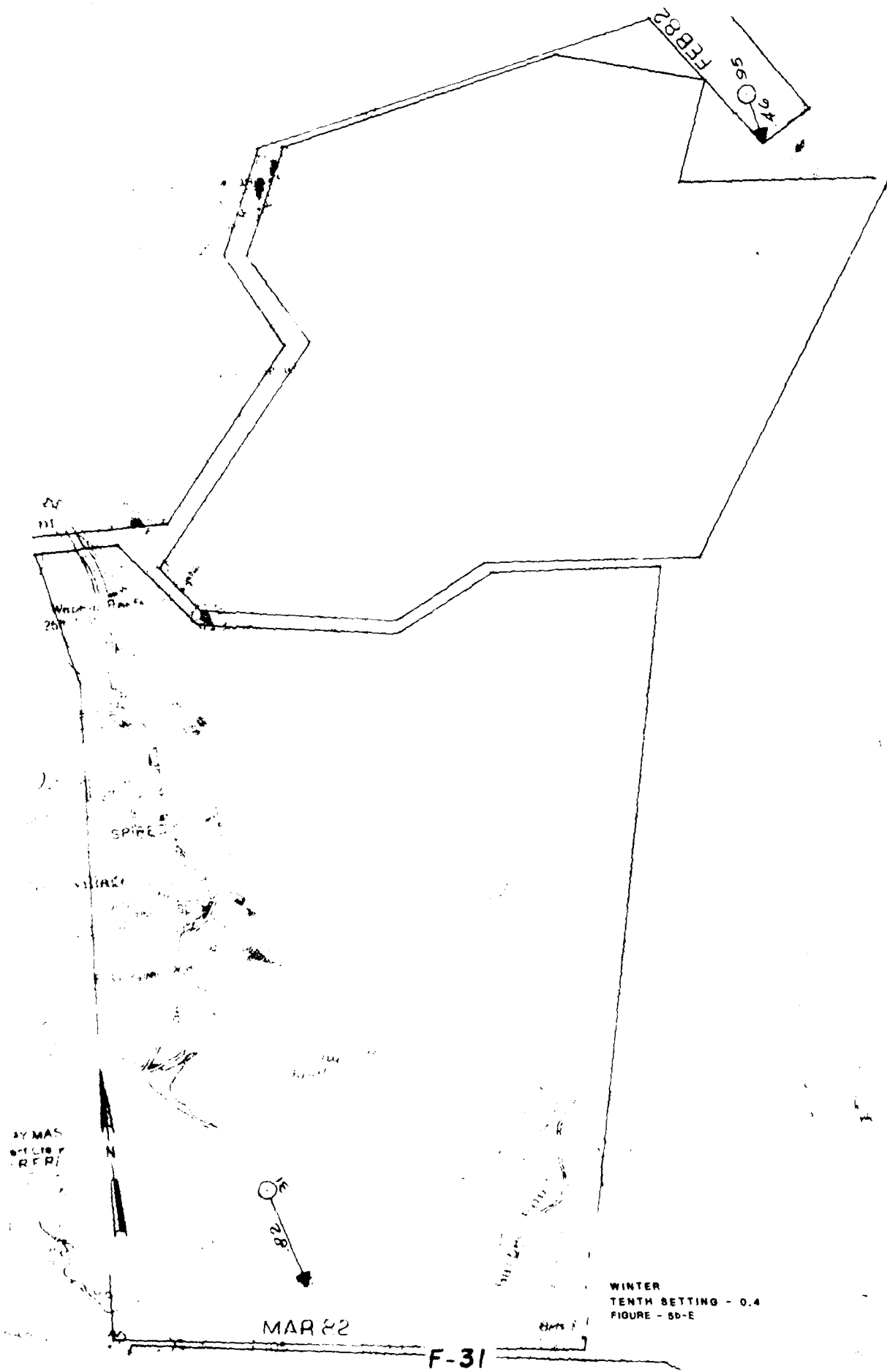
TENTH SETTING - 0.2  
 FIGURE 1-E











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REF

N

0.2

MAR 82

WINTER  
TENTH SETTING - 0.4  
FIGURE - 5D-E

F-31



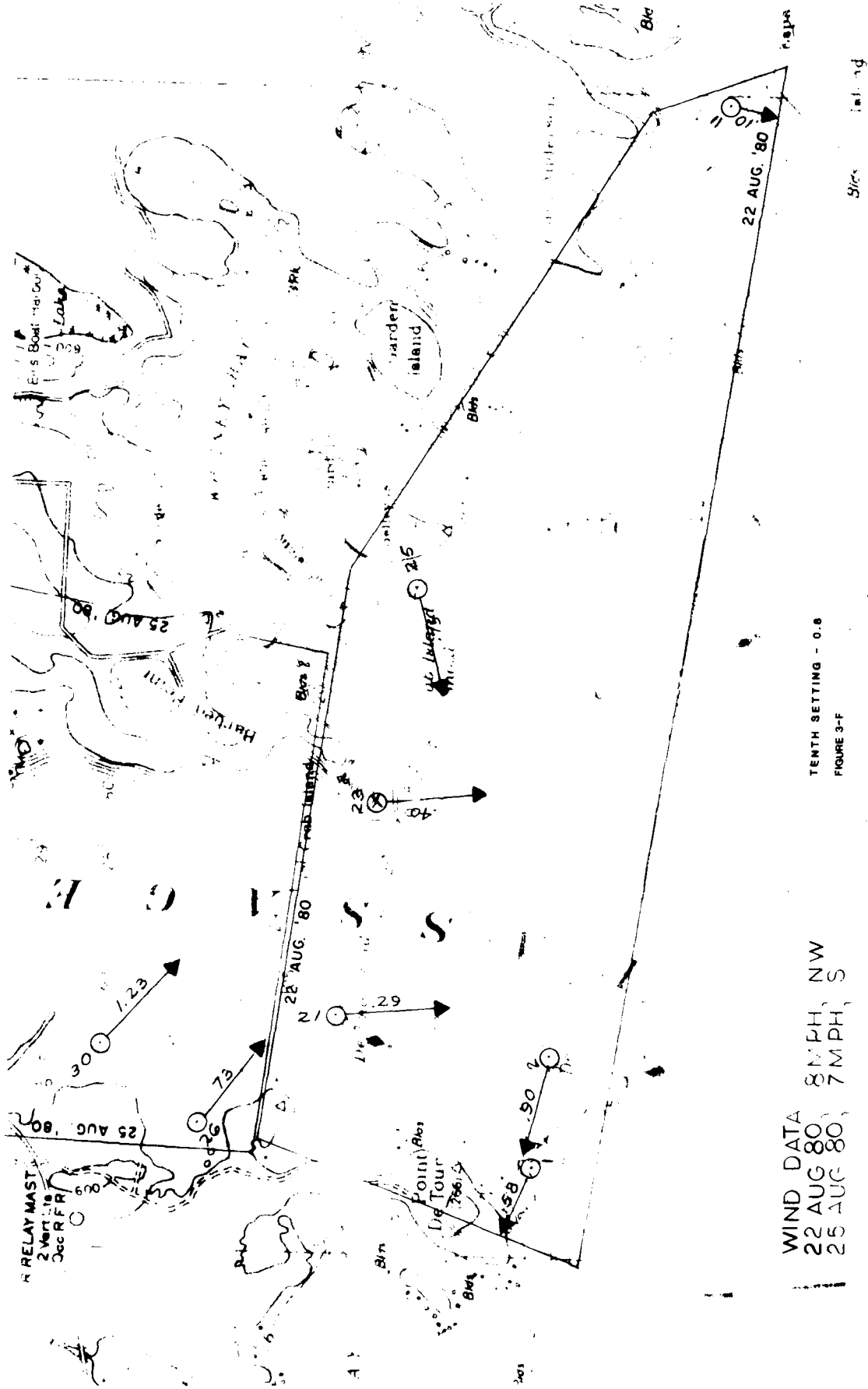
WIND DATA  
 22 AUG 80, 8 MPH, NW  
 25 AUG 80, 7 MPH, S

TENT SETTING - 0.2  
 FIGURE 1-F



WIND DATA  
 22 AUG 80, 8 MPH, NW  
 25 AUG 80, 7 MPH, E

TENTH SETTING - 0.4  
 FIGURE 2-F



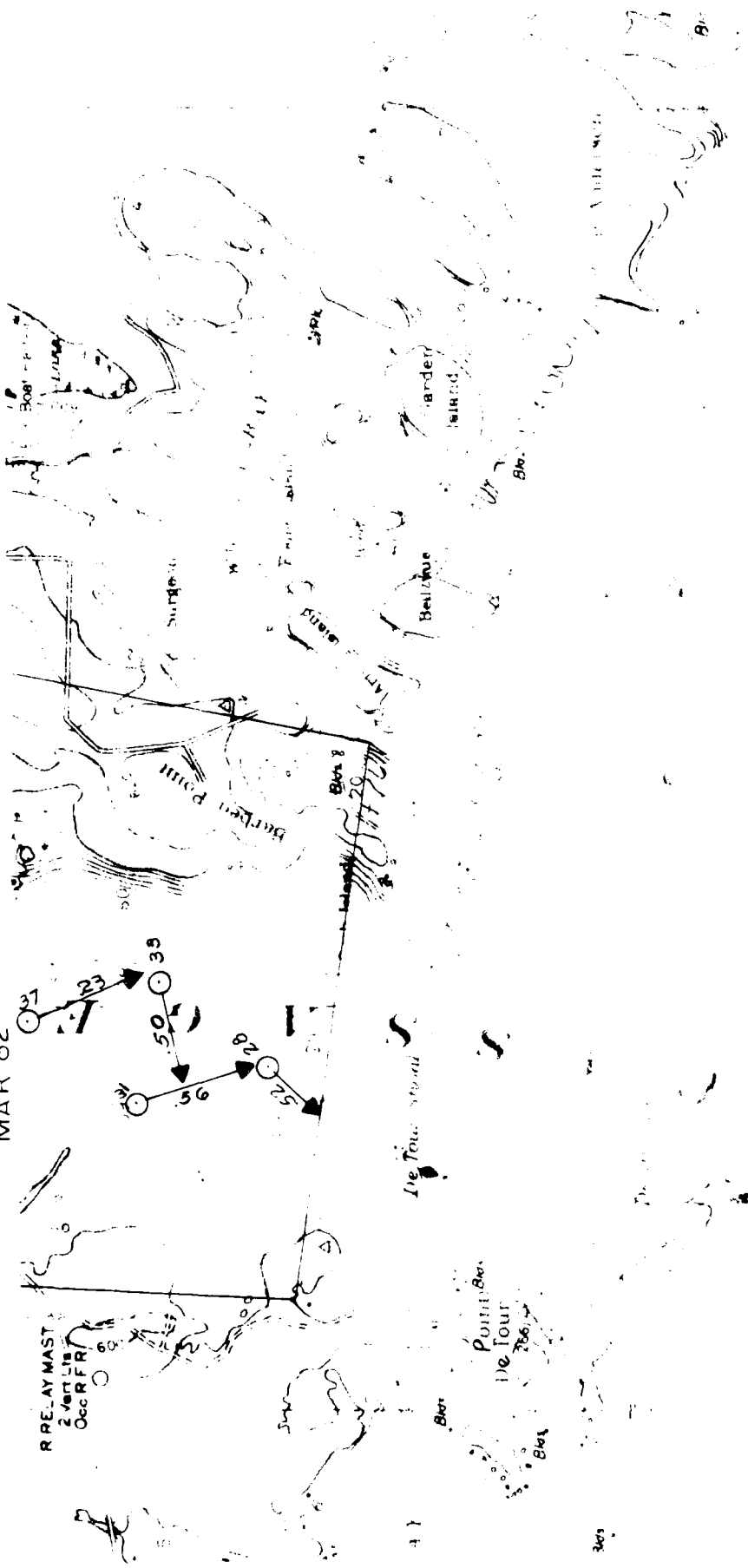
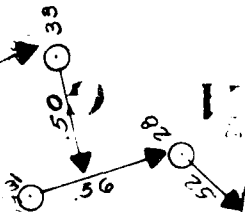


WIND DATA  
 22 AUG 80, 8 MPH, NW  
 25 AUG 80, 7 MPH, S

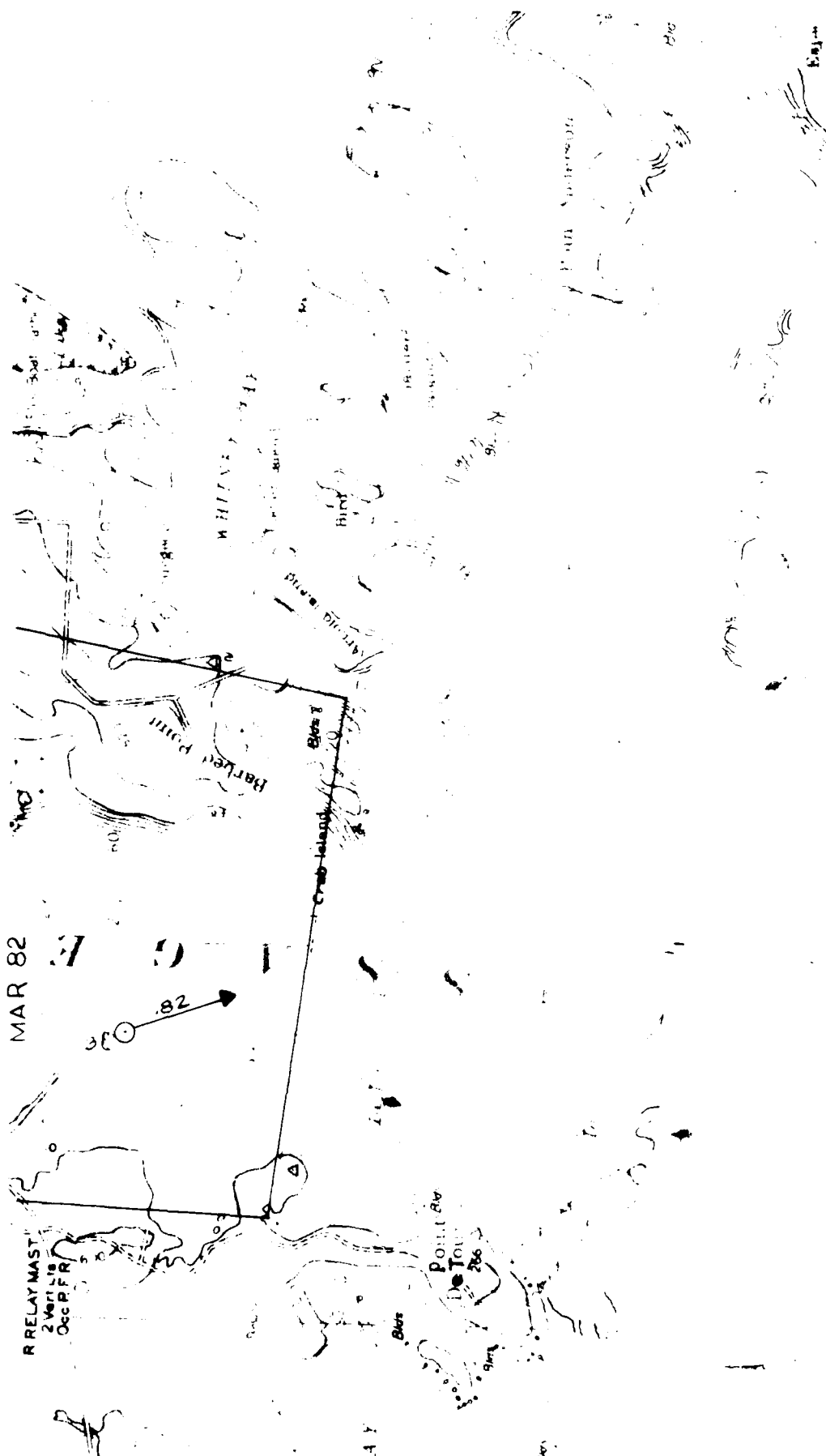
COMPOSITE  
 FIGURE 4-F

MAR 82

R RELAY MAST  
2 Vert Lis  
Occ RFR



WINTER  
TENTH SETTING - 0.2  
FIGURE - 58-F



WINTER TENT SETTING - 0.4  
FIGURE - 80-F