

AD-A134 563

NORFOLK HARBOR AND CHANNELS DEEPENING STUDY REPORT 1

1/4

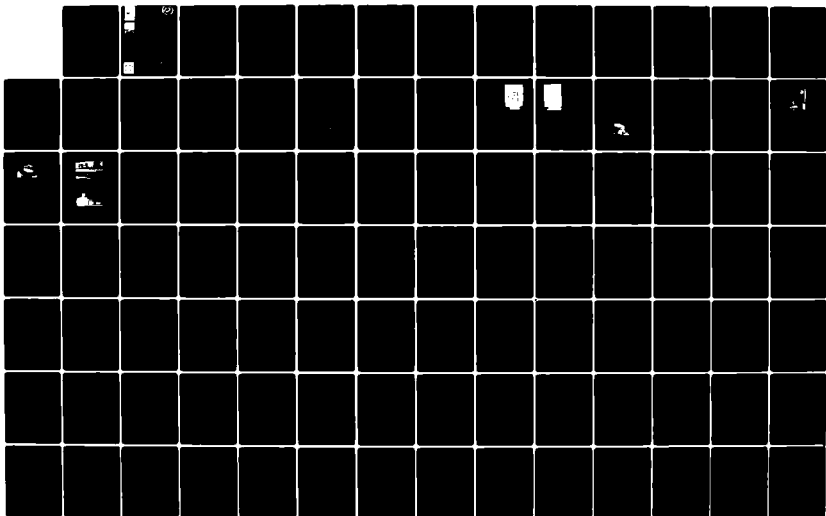
PHYSICAL MODEL RESULTS (U) ARMY ENGINEER WATERWAYS

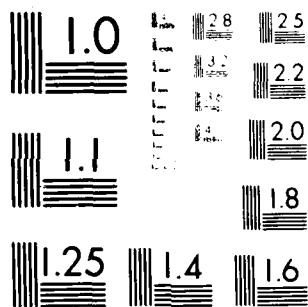
EXPERIMENT STATION VICKSBURG MS HYDRA.

UNCLASSIFIED

D R RICHARDS ET AL. JUN 83 WES/TR/HL-83-13 F/G 13/2

NL





MICROCOPY RESOLUTION TEST CHART
 NATIONAL BUREAU OF STANDARDS-1963-A

AD-A134 563

TECHNICAL REPORT HL-83-13



US Army Corps
of Engineers

NORFOLK HARBOR AND CHANNELS DEEPENING STUDY

Report 1

PHYSICAL MODEL RESULTS
Chesapeake Bay Hydraulic Model Investigation

by

David R. Richards, Michael R. Morton

Hydraulics Laboratory

U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180



June 1983

Final Report

Approved For Public Release; Distribution Unlimited

DTIC
ELECT
NOV 8 1983

DTIC FILE COPY

D

HYDRAULICS
LABORATORY

Prepared for U. S. Army Engineer District, Norfolk
Norfolk, Va. 23510

Destroy this report when no longer needed. Do not
return it to the originator.

The findings in this report are not to be construed as an
official Department of the Army position unless so
designated by other authorized documents.

The contents of this report are not to be used for
advertising, publication, or promotional purposes.
Citation of trade names does not constitute an
official endorsement or approval of the use of such
commercial products.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report HL-83-13	2. REPORT ACCESSION NO. AD-A134 503	3. REPORT CATALOG NUMBER
4. TITLE (and Subtitle) NORFOLK HARBOR AND CHANNELS DEEPENING STUDY; Report 1, PHYSICAL MODEL RESULTS; Chesapeake Bay Hydraulic Model Investigation	5. TYPE OF REPORT & PERIOD COVERED Report 1 of a series	
7. AUTHOR(s) David R. Richards Michael R. Morton	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory P. O. Box 631, Vicksburg, Miss. 39180	8. CONTRACT OR GRANT NUMBER(s)	
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Norfolk 803 Front Street Norfolk, Va. 23510	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12. REPORT DATE June 1983	
	13. NUMBER OF PAGES 371	
	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Channel deepening Salinity intrusion Current velocities Tides Hydraulic model Neap-spring salinity response		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the findings of physical model tests of deepening the approach channels to Norfolk and Newport News, Virginia. The tests in- cluded a steady-state portion for the determination of the tide and current velocity effects of channel deepening as well as a dynamic portion where vari- able tide and freshwater inputs were used to study salinity redistributions. (Continued)		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued).

The steady-state tests showed that tides would remain unaffected by channel deepening while the velocity studies indicated some subtle changes caused by the deepening. An overall decrease in velocity amplitude of 0.13 fps was noticed in the deepened condition. This decrease, however, was barely detectable by model instrumentation. Slight increases in flood predominance were noticed under average inflow conditions indicating that salinity intrusion may move upstream in the study area.

The dynamic tests served two purposes. First, they were intended to define the salinity patterns in detail throughout the lower Chesapeake Bay which had previously not been done, particularly with regard to the presence of the "neap-spring" salinity response to varying tide conditions. The study detected a strong neap-spring response in the study area and documented its magnitude at each of the stations in the lower Chesapeake Bay. Second and most important was predicting what changes to the existing salinity character of Chesapeake Bay would be brought on by the proposed channel deepening.

Salinity sampling stations were located at 193 positions throughout the Chesapeake Bay system with the vast majority being located near the project area in the lower bay and James River areas. A 2-1/2-year weekly stepped variable hydrograph taken from historical records and a 28-lunar-day, 56-cycle, 12-constituent variable tide were used as boundary conditions. Source salinity was maintained at a constant 32 ppt which is indicative of low flow conditions.

Results from 65 stations are given in the form of time-histories, plan-minus-base difference plots, depth-averaged and depth-averaged difference plots, isohaline and bottom difference maps. The graphics document the following observations:

- a. Neap-spring variations in salinity stratification are prevalent throughout the lower bay and project areas. Commonly, the variations are as great as 5 to 8 ppt at a given depth.
- b. Channel deepening caused an increase in salinity intrusion that was normally confined to the deepened channel areas. Adjacent shallow-water areas showed very little change in salinity. Areas outside the project area in the upper bay showed no changes that can be associated with channel deepening.
- c. Redistributions of salt within the cross section were noticed in channels with adjacent shallow-water areas. In some cases, the shallow waters freshened as the channels became saltier.
- d. Overall changes to the salinity structure could be characterized by a net increase in depth-averaged salt with an increase in stratification. Bottom variations in the neap-spring response were noticed in the form of damped salinity variations for equivalent tidal inputs.

Results of the tests indicate salinity changes to the estuary which can be attributed to channel deepening. On the average, the changes are small, normally less than 2 ppt, in an extremely dynamic portion of the estuary where natural salinity fluctuations due to variations in tides and freshwater input can cause weekly variations an order of magnitude greater.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

In October 1981, the U. S. Army Engineer Waterways Experiment Station (WES) was requested by the U. S. Army Engineer District, Norfolk, to perform a hydraulic model investigation of possible hydrodynamic changes to Chesapeake Bay as a result of the proposed deepening of the Norfolk approach channels.

The study was conducted by personnel of the Hydraulics Laboratory, WES, and its subcontractor Acres American, Inc., under the general direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory, R. A. Sager, Chief of the Estuaries Division, W. M. Dyok of Acres American, Inc., and Dr. R. B. Taylor of Tetra Tech, Inc. Testing was conducted under the supervision of Messrs. R. O. Bruno, Chief of the Chesapeake Bay Model Branch (WES), and S. R. Rives of Acres American, Inc. Data analysis and final report preparation were conducted under the supervision of Messrs. Bruno of WES and J. R. Pagenkopf of Tetra Tech, Inc. Project Engineers for the model study were Messrs. D. R. Richards for WES and M. R. Morton for Acres American/Tetra Tech. Additional key personnel for WES involved in the model study included Messrs. A. W. Crunk, M. A. Granat, and Ms. V. R. Pankow. Key personnel for Acres American and Tetra Tech included Messrs. D. G. Dionne, W. E. Hayes, P. S. Jayne, P. A. Waltz, and Ms. M. F. Capriotti. Special acknowledgment is made to Mr. Crunk for providing computer graphics assistance which was used extensively in this report. This report was prepared by Messrs. Richards and Morton.

Commander and Director of WES during the conduct of this study and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A11	



CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	5
Chesapeake Bay	5
Norfolk Harbor	6
Proposed Channel Improvements	6
Purpose	7
Scope of Testing	9
PART II: CHESAPEAKE BAY MODEL	10
Physical Model Description	10
Computer Facilities	12
Tide Generation and Measurement	13
Freshwater Inflow	13
Sewage Treatment Plants	17
Surry Nuclear Power Plant	18
Saltwater Supply System	20
Bubbler System	20
Current Meters	20
Vacuum Sampling System	23
Salinity Testing System	23
PART III: STEADY-STATE TIDE AND VELOCITY TESTS	26
Test Conditions	26
Tide Test Data and Results	27
Velocity Tests	32
Velocity Data Analysis	36
Velocity Test Results	38
Tide and Velocity Summary	46
PART IV: DYNAMIC SALINITY TESTING	48
Test Conditions	48
Salinity Data Analysis	56
Salinity Results	57
PART V: CONCLUSIONS	73
REFERENCES	75
TABLES 1-14	
PLATES 1-236	

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	0.4047	hectares
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres

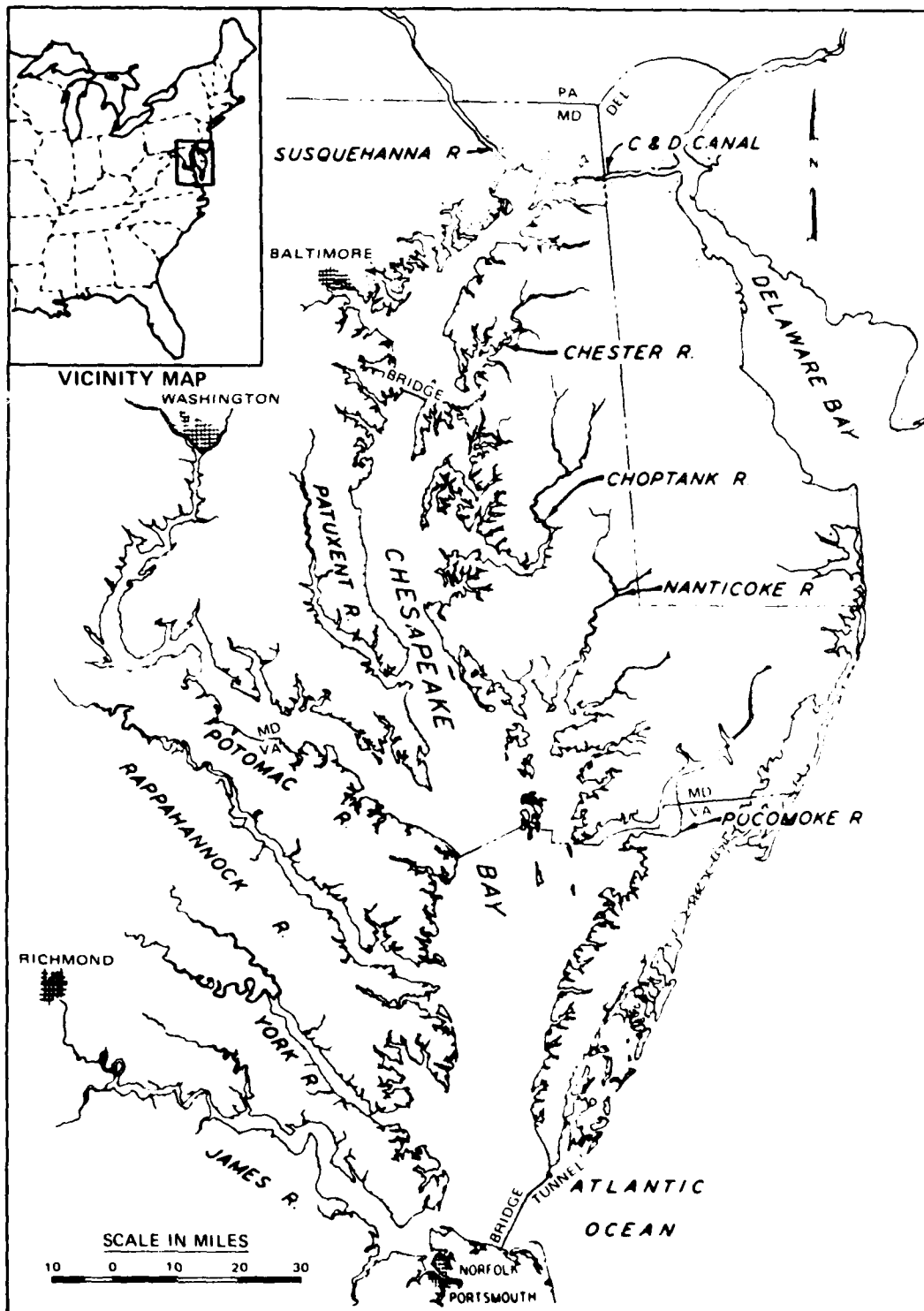


Figure 1. Location map

NORFOLK HARBOR AND CHANNELS DEEPENING STUDY

PHYSICAL MODEL RESULTS

Chesapeake Bay Hydraulic Model Investigation

PART I: INTRODUCTION

Chesapeake Bay

1. Chesapeake Bay with its tributary estuaries forms the largest estuarine system in North America. The 190-mile*-long estuary varies in width from 4 to 30 miles with an average depth of 28 ft (Figure 1). The mean annual discharge of its 126 freshwater tributaries is approximately 70,000 cfs, almost 90 percent of which is contributed by the Susquehanna, Potomac, Rappahannock, York, and James River basins. The Atlantic Ocean provides salt water to the bay, producing large salinity variations within its boundaries. The eastern shore is generally saltier than the western shore, attributed in part to the predominance of freshwater flow from the western shore tributaries and to the counterclockwise tendency of flow resulting from Coriolis force.

2. Chesapeake Bay is classified geologically as a drowned river valley estuary. The Holocene sea-level rise inundated the Susquehanna River Valley to form the bay. Sedimentation from the tributaries as well as erosion of the banks has contributed to maintaining the bay's broad, shallow character. The bay is classified as a partially mixed estuary, although various stages of freshwater discharge and tidal and wind mixing cause portions to alternate between well mixed and highly stratified. Tides are semidiurnal with mean ranges from 1 to 2 ft. The length of Chesapeake Bay is such that a complete tidal wave is contained within its limits at all times. Wind-generated waves are generally less than 3 ft in height, but larger waves can occur during high wind conditions. Average maximum velocities for tide and wind-driven currents range from 0.5 to 3 fps.

3. Chesapeake Bay contains a variety and abundance of wildlife that make it unique as a biological environment. Its estuarine waters are rich

* A table of factors for converting U. S. customary units of measurements to metric (SI) units is presented on page 3.

with nutrients and organic material that support some of the largest crops of oysters and clams in the world. The lower salinity portions of the estuary provide the spawning grounds for a variety of fishes including the striped bass, shad, and herring. Most of the organisms native to Chesapeake Bay are tolerant of natural fluctuations in the saltwater distribution, but sometimes permanent changes provide stresses that they cannot survive. The adverse effects of these sometimes man-induced changes are often realized through the depletion of existing spawning areas for fishes or by providing more conducive environments to the organisms' predators as is most noticeable in shellfish. Since man is capable of making permanent changes to the bay's salinity and hence its biota through his navigational improvement efforts, it is important to know the possible impacts on the environment prior to implementation of a project so that reasonable alternatives can be explored or trade-offs assessed in a responsible manner.

Norfolk Harbor

4. Navigational uses of Chesapeake Bay in the Norfolk area are of great importance to the Nation and the local communities. Due to its naturally protected harbors, the Norfolk area has historically been the home port of naval activities since colonial times. Commercially, Norfolk has played a major role in east coast bulk shipping for many years. Its closeness to the Appalachian coal fields and connecting rail lines has helped it become the largest coal exporting port in the United States. However, with the current trends toward deeper draft bulk cargo vessels and an ever-increasing demand for United States coal, Norfolk may lose some of this competitive advantage. There are currently several vessels calling on Norfolk that must carry partial loads to navigate through the existing channels. Since the majority of the cargo passing through Norfolk is high in volume and low in price, the efficient use of shipping is crucial to bring profits. Unless the harbor is deepened, future deep-draft vessels may be forced to use other ports.

Proposed Channel Improvements

5. The proposed improvements to channels and anchorages approaching

Norfolk Harbor are shown in Figure 2 and described as follows (USAED, Norfolk, 1980):

- a. Increasing the depth of Thimble Shoal Channel from 45 to 55 ft below mean low water over its existing 1,000-ft width.
- b. Increasing the depth of Norfolk Harbor Channel from 45 to 55 ft below mean low water over its existing 800- to 1,500-ft width to the coal terminal at Lamberts Point.
- c. Increasing the depth of the channel to Newport News from 45 to 55 ft below mean low water over its existing 800-ft width to the coal terminal at Newport News.
- d. Dredging a new channel, referred to as the Atlantic Ocean Channel, off Virginia Beach to a depth of 57 ft below mean low water and a width of 1,000 ft over a length of 10.5 miles.
- e. Constructing three fixed-mooring anchorage facilities, each capable of accommodating two large vessels simultaneously.
- f. Increasing the depth of the Elizabeth River and the Southern Branch of the Elizabeth River between Lambert Point (river mile 9) and the Norfolk and Western Railway bridge (river mile 15) from 40 to 45 ft below mean low water over its existing 375- to 750-ft width.
- g. Increasing the depth of the Southern Branch of the Elizabeth River between the Norfolk and Western Railway Bridge (river mile 15) and the U. S. Routes 460 and 13 highway crossing (river mile 17.5) from 35 to 40 ft below mean low water over its existing 250- to 500-ft width, and providing a new 800-ft turning basin at the terminus of the channel improvement.

6. The depths listed above are project depths and do not include allowable overdepth dredging. The actual depths for the proposed new channels with the required overdepth dredging should be 3 ft deeper. Previous deepening projects in the vicinity also had provisions for overdepth dredging. The model study of the proposed channel deepening used the existing channel depths as determined by the most recent surveys for the base condition with the plan condition using the project depths plus the 3-ft overdepth dredging.

Purpose

7. The purpose of this study was to investigate the impact of the proposed channel deepening on the hydrodynamic characteristics of Chesapeake Bay. The study was designed specifically to determine what changes in tidal elevations, current velocities, and salinities could be attributed to the proposed channel deepening.

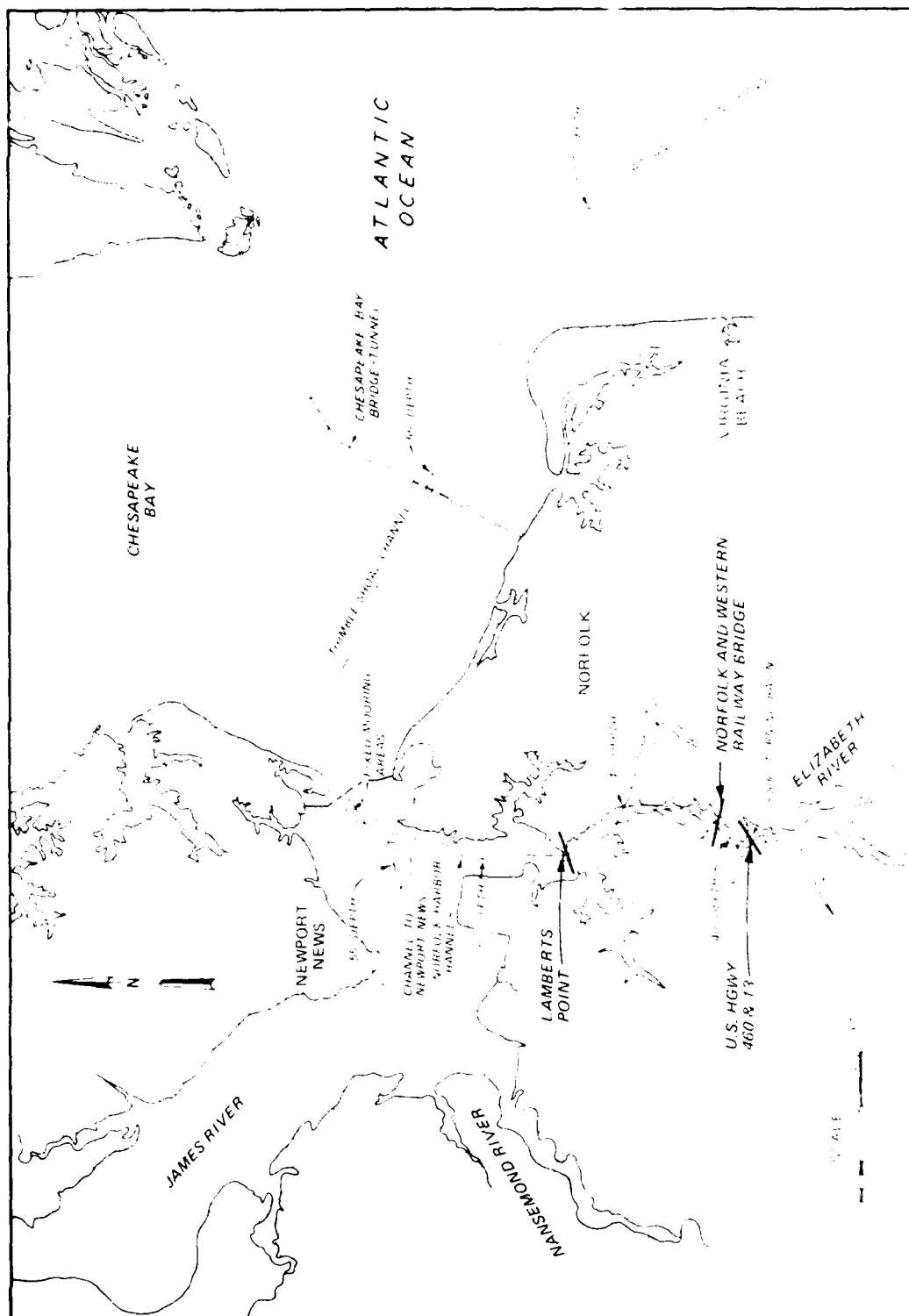


Figure 2 - Project map showing proposed Norfolk dredged channels.

Scope of Testing

8. The hydraulic model study consisted of two parts. The first was a series of four steady-state tests (constant discharge and cosine tides) designed to study base versus plan differences in tides and current velocities. Both base and plan geometries were tested under medium and high tide range and freshwater discharge conditions. The boundary conditions and sampling procedures for the steady-state tests were dictated by the needs of numerical models at the U. S. Army Engineer Waterways Experiment Station (WES) for subsequent studies of sediment transport and shoaling in the dredged channels and neighboring bottom areas.

9. The second part of the study was a dynamic test (variable discharge and variable tides) designed to predict base versus plan differences in salinity response. A 2-1/2-year variable hydrograph was used with a repetitive 28-lunar-day variable tide for both base and plan geometries. The ocean source salinity was the same for both steady-state and dynamic tests.

PART II: CHESAPEAKE BAY MODEL

Physical Model Description

10. The physical model of Chesapeake Bay is located on Kent Island in Matapeake, Maryland. The model is an 8.6-acre fixed-bed model molded in concrete to conform to the most recent National Ocean Survey charts. At the time of this study, all major ship channels had been molded with the proposed 50-ft channels leading into Baltimore and the existing channels elsewhere. Channels in the James and Elizabeth Rivers and Thimble Shoal area of the Lower Bay were molded to correspond to prototype information collected as late as 1981. The molded area of the model extends from approximately 30 miles offshore in the Atlantic Ocean to the heads of tide for all tributaries emptying into the Chesapeake. The entire length of the Chesapeake and Delaware (C&D) Canal and a portion of Delaware Bay are also molded. Overbank geometry is reproduced to the +20 ft contour. Model limits are shown in Figure 3.

11. The hydraulic model was designed based on the equality of Froude numbers, model to prototype, reflecting similitude of gravitational effects. Geometric scales of the model are 1:1,000 horizontally and 1:100 vertically, reflecting a distortion ratio of 10:1. These dimensions and Froudian model laws defined the following model-to-prototype ratios:

<u>Characteristic</u>	<u>Ratio</u>
Vertical length	1:100
Horizontal length	1:1,000
Slope	10:1
Time	1:100
Velocity	1:10
Volume	1:100,000,000
Discharge	1:1,000,000

The model-to-prototype ratio for salinity is 1:1. This is the general practice for distorted-scale models.

12. The model was designed and equipped so that selected prototype boundary conditions could be simulated and the model response to these conditions recorded. A discussion of appurtenances necessary to generate and record test boundary conditions follows.

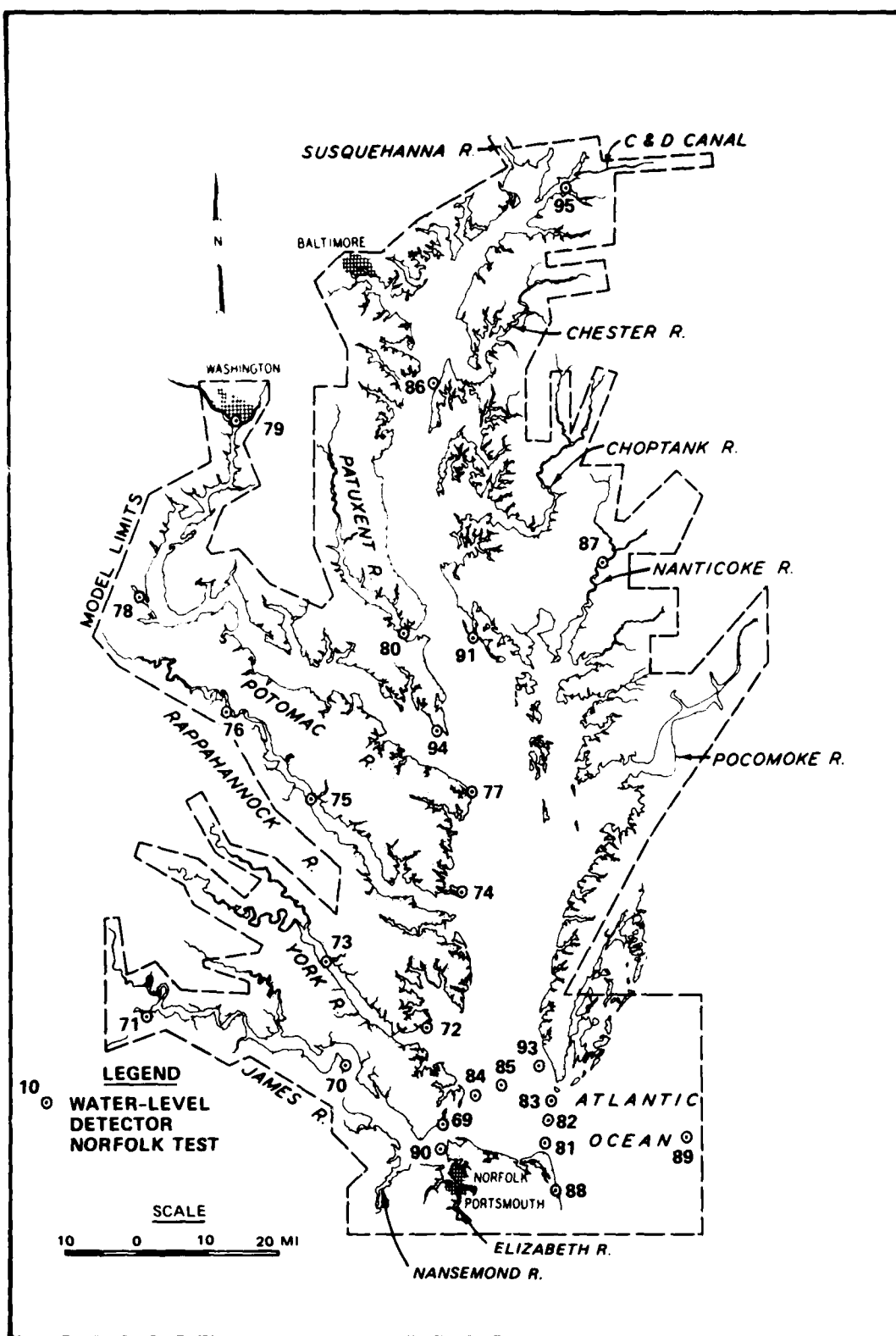


Figure 3. Model limits and automatic water-level detector locations with their computer number designations

Computer Facilities

13. The Chesapeake Bay model is equipped with five minicomputers that perform a variety of tasks ranging from model control and data logging to the analysis and graphical display of model test data. These include a Texas Instruments (TI) 960, a TI 980, an International Business Machines (IBM) 5110, a Digital Equipment Corporation (DEC) PDP 11/23, and a DEC PDP 11/44.

14. The TI 960 is a 64K minicomputer used solely for model control and data acquisition. It is equipped with a 2.5-megabyte magnetic disc that contains all necessary system software to compile and run the model control computer program. It also is equipped with two 250K flexible disc drives that are used to receive data from 75 different flowmeters and water-level detectors throughout the model. Output from these devices is displayed on a cathode-ray tube (CRT) or hardcopy terminal where it can be observed at the same time that it is recorded on flexible disc. Through the model control terminal, an operator can interactively observe model operations by displaying values from any combination of model control devices.

15. The TI 980 is a 56K minicomputer used primarily for data analysis. It has the same access to the magnetic disc and flexible discs as does the TI 960. In addition, it can interface with a 300 card-per-minute card reader, a 9-track, 800-bpi (bytes per inch) magnetic tape drive, and a Versatec electrostatic printer/plotter. Graphics for this report were partially supplied by the Versatec machine.

16. The IBM 5110 is a 64K minicomputer that has access to twin 250K flexible disc drives and Tektronix plotting peripherals. It uses an APL keyboard and is used in various data editing and analysis tasks.

17. Data logging at the model can be accomplished through the use of the PDP 11/23 minicomputer. The PDP 11/23 has 64K of main memory and can store 5.8 megabytes of data on a Winchester magnetic disc. Although it is being developed as a self-contained data logging system, it is also used for a variety of small data analysis tasks.

18. The largest of the model minicomputers is the PDP 11/44 which has a full megabyte of main memory and can service eight users simultaneously. Program and data storage in the system is supplied by twin 10.4 megabyte removable magnetic discs, a 1,600-bpi tape drive, twin 250K flexible disc drives, and a 600 card-per-minute card reader. The PDP 11/44 is connected to a

Tektronix graphics system that includes a 4112 video graphics screen, a 4662 flat bed plotter, and a 4612 hard copy unit. The graphics in this report were largely supplied by the PDP 11/44 and Tektronix system.

Tide Generation and Measurement

19. Source tides in the model can be generated by using the primary tide generator in the model ocean and by using the secondary tide generator in the Delaware Bay at the eastern end of the C&D Canal. Both tide generators can be operated to generate a repetitive tide, or by using the TI 960 model control computer a repetitive or variable tide can be generated.

20. The TI 960 computer controls the source tides by providing a continuously changing programmed voltage to the tide-generating mechanisms. These mechanisms consist of a feedback system that is entirely self-contained and is not dependent on computer feedback for adjustment. The system consists of a tide control amplifier that conditions the computer signal and a bubble tube positioner that senses the water-level position and positions the hydraulically controlled inlet and outlet gates via a hydraulic pilot amplifier. Figure 4 is a schematic of the tide-generating system. A more detailed description of the tide generators can be found in Scheffner et al. (1981).

21. Water-surface elevations throughout the model can be measured both manually by 75 distributed point gages, and automatically by 22 water-level detectors (WLD), which report their individual water levels to the computer where they are stored. Water-level elevations are monitored both manually at the ocean and automatically throughout the model during testing (Figure 3). Manual measurements at the ocean were used to check automatic devices.

Freshwater Inflow

22. The Chesapeake Bay model is capable of reproducing a variable hydrograph freshwater inflow through the use of positive feedback control of river discharges. Fresh water normally enters the model at 21 independent inflow points representing the major tributaries of the prototype. During the Norfolk test, however, an additional inflow was needed on the Elizabeth River to more accurately simulate the inflows in the lower James River watershed. Ordinarily, Elizabeth River flows enter the model through the inflow on the

OPERATION OF TIDE GENERATOR

THE WATER SURFACE OF THE MODEL (A) IS APPROXIMATELY 5 FT HIGHER THAN RETURN SUMP (B) AND 10 FT LOWER THAN SUPPLY SUMP (C) BECAUSE OF THESE DIFFERENCES IN WATER-SURFACE ELEVATIONS, THE FLOW OF WATER FROM THE MODEL INTO THE RETURN SUMP AND OUT OF THE SUPPLY SUMP INTO THE MODEL IS GRAVITY FLOW. THE TWO ROLLING GATES (D&E) OPERATE IN TANDEM SUCH THAT WHEN ONE GATE IS OPENING, THE OTHER GATE IS CLOSING. WHEN THE SUPPLY SUMP ROLLING GATE (D) IS OPENING AND THE RETURN SUMP ROLLING GATE (E) IS CLOSING, A NET POSITIVE FLOW RESULTS, AND THE MODEL FLOODS. WHEN THE SUPPLY SUMP ROLLING GATE IS CLOSING, AND THE RETURN SUMP ROLLING GATE IS OPENING, A NET NEGATIVE FLOW RESULTS AND THE MODEL EBBS. A PUMP (F) BETWEEN THE SUMPS MAINTAINS A CONSTANT AMOUNT OF WATER IN THE SUPPLY SUMP. SIGNALS FROM THE TIDE SENSOR (H) AND TIDE PROGRAMMER (I) OR COMPUTER (NOT SHOWN) ARE COMPARED BY THE TIDE CONTROL (G) WHICH THEN DETERMINES THE PROPER OPENING OF THE ROLLING GATES TO REPRODUCE THE DESIRED TIDE.

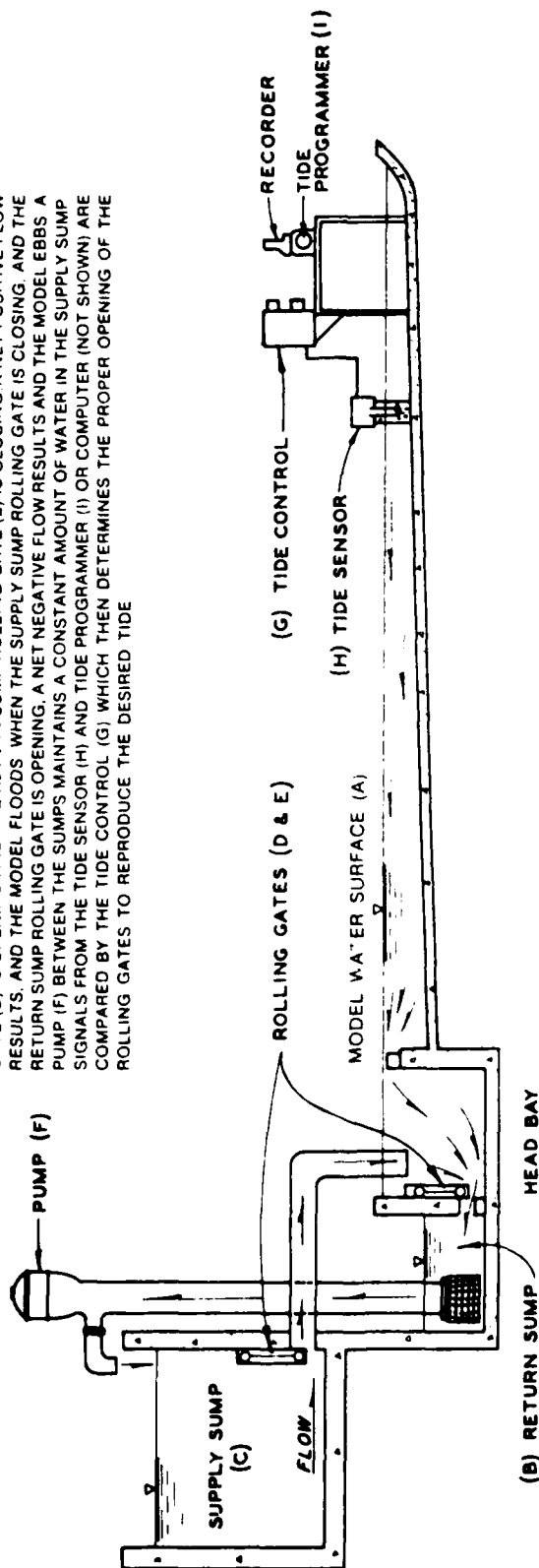


Figure 4. Tide-generating system

Nansemond River. Figure 5 is a map of the bay showing the positions of the discharge points. The Susquehanna River required two inflow systems (numbers 15 and 22) due to the range of freshwater inflow. As shown in Figure 5, both these systems lead to the same discharge point.

23. Although more than 100 separate tributaries empty into Chesapeake Bay, only 22 rivers were chosen to represent the total combined bay discharge. Providing a separate discharge point at each minor tributary is impractical. The sophisticated plumbing and equipment necessary for each inflow are expensive and require specialized maintenance. Many of the tributaries provide infinitesimal flows, immeasurable with the present system used. These flows are summed with the nominal discharge of the closest of the 22 chosen tributaries to provide a representative and well-balanced, as well as a cost-effective, inflow distribution.

24. Flow is controlled at the discharge points by an arrangement of solenoid-controlled discharge ports with graduated orifices. An electrical signal causes a solenoid to be activated, fully opening a discharge port. The configuration of the graduated orifices is such that 4,096 combinations of open and closed ports provide a range of flows which can be stepped from the smallest measurable flow to the individual tributary's maximum flow. These arrangements of ports are called digital valves.

25. Flow from the digital valves to the model is monitored continuously by bearingless flowmeters of varying ranges that can be used alone or in combinations to provide accurate flow readings covering the full range of a tributary's discharge. The flowmeters use fiber optics to count the revolutions of a water-driven rotor. Optical pulses are translated to electrical pulses that are summed on an arrangement of totalizers and latches on a counter card. This counter is strobed at predetermined intervals which causes the summed value of pulses to be transferred to a transmitter and the latches cleared for the next summation. During this study, inflows were strobed every 18 sec, or every half hour of prototype time; thus the values available for flow calculations are not instantaneous flows but are 18-sec averages.

26. Each flowmeter in use has its own transmitter where the binary totals from the counter are translated to ASCII code and transmitted to the TI 960 model control computer in serial form via a hard-wired, cascading, multiplexed 20-ma current loop communication system.

27. In the computer, the pulse totals are transformed to flows using a

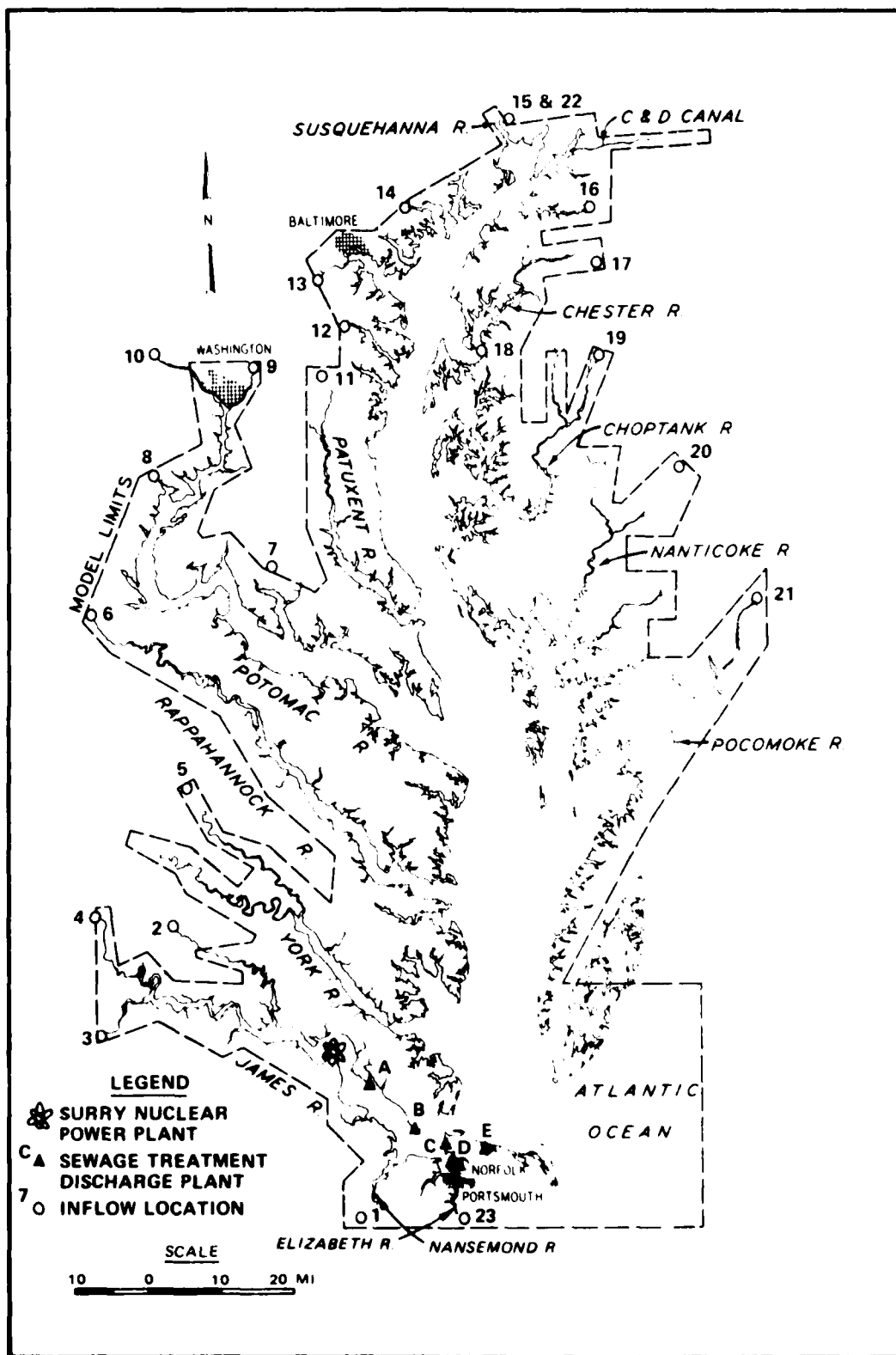


Figure 5. Freshwater inflow and sewage treatment plant locations

linear regression derived from pretest calibrations for each flowmeter/digital valve combination. The computer then compares these 18-sec averaged flows with the desired flows for each flowmeter and determines whether the digital valve setting should be adjusted at any of the inflows. The feedback system is activated when there is a discrepancy between the desired flow and the actual flow. Discharge ports are opened or closed to adjust the actual flow toward the desired flow. Time-averaged discharges controlled in this manner remain very close to the desired hydrograph step values. Some overshooting of flows may occur at the beginning of each hydrograph step as the computer adjusts, but flows are generally stable within just a few update cycles. This varies, of course, with the magnitude of the step change as well as with each individual flowmeter/digital valve combination. Figure 6 shows a typical inflow system used in this test.



Figure 6. Typical inflow system

Sewage Treatment Plants

28. During this study, changes in discharges of the rivers were supplemented by modeling major sewage treatment plants (STP's) in the Norfolk area. Figure 5 shows the locations of the five STP's modeled for the study. Table 1 is a list of the stations with their geographical locations. Discharges A and B are located on the James River, discharges C and D are located on the Elizabeth River, and discharge E is located near Little Creek in the Lower Chesapeake Bay. Engineering drawings of the STP's were consulted and the discharge points were located as near as possible to those in the prototype. Fresh water was used as the discharge medium in all modeled STP's. Since near-field flow patterns are not easily modeled in a distorted-scale

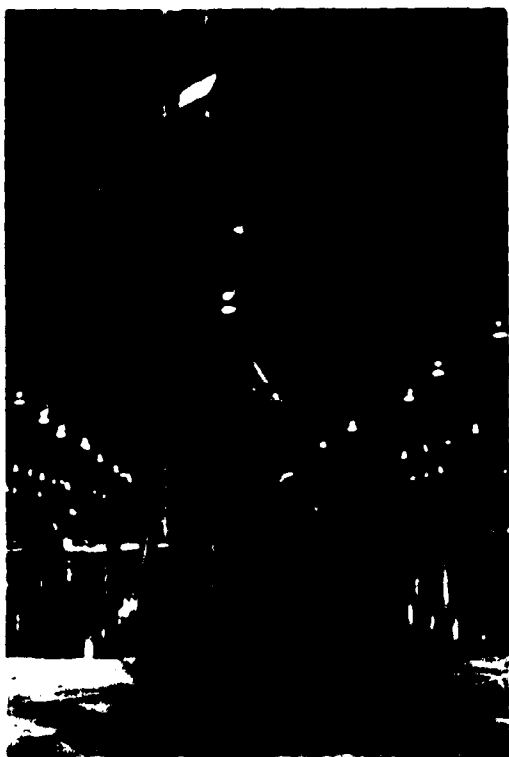


Figure 7. Typical SIP

model, and since a near-field flow/density structure was not an object of concern, no attempt was made to reproduce the injection methods of prototype. Brass diffusers were fitted to nylon tubing for outfalls. Figure 7 shows a typical portable inflow as used in the Norfolk Harbor study. A constant-head tank, approximately 10 ft above the model, feeds an array of adjustable rotameters which in turn feed the nylon discharge lines. Flow rates through the SIP's were adjusted manually, as required, throughout each hydrograph test.

Surry Nuclear Power Plant

29. The cooling water diversion from the Surry Nuclear Power Plant was simulated in model testing for the first time in the Norfolk Harbor study. The plant is located at Hog Island on the southern shore of the James River (Figures 5 and 8). Virginia Electric Power Company (VEPCO) officials have estimated the diversion at 3,740 cfs continuously even when the plant is not on line. A diversion of this magnitude is several times greater than the total James River inflow during drought conditions so its inclusion was deemed necessary for this study.

30. Engineering drawings and hydrographic surveys were consulted so that the intake and outfall geometries as well as their nearshore approach channels were modeled to closely approximate prototype conditions. Figure 8 shows the intake and outfall locations near Hog Island and the relative closeness to the nearest salinity sampling stations. During the model test, the 3,740-cfs (prototype) constant bypass was maintained by reading a discharge rotameter and adjusting a throttling valve which was attached to a constant rpm centrifugal pump (Figure 9). An identical calibrated backup pump was available in case the primary pump failed during testing. No significant differences in pump performance were noticed between the base and plan tests.

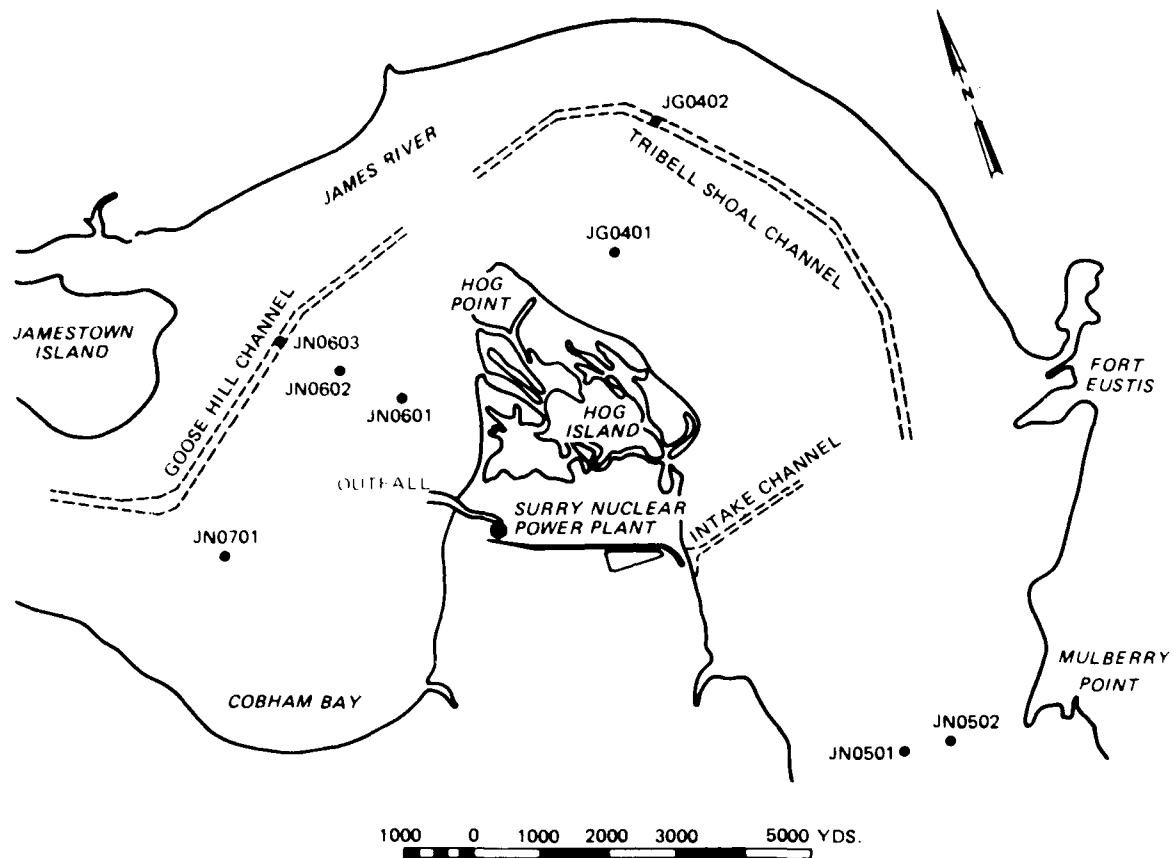


Figure 8. Surry Nuclear Power Plant intake and outfall locations

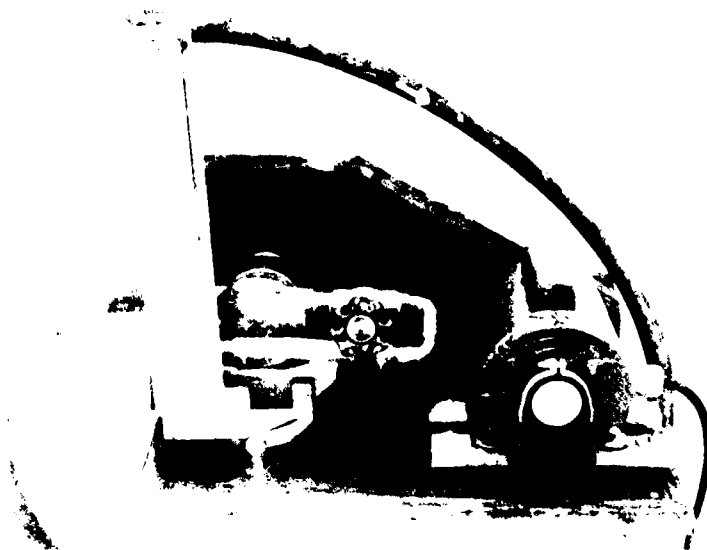


Figure 9. Surry bypass pump

Saltwater Supply System

31. A constant source salinity is provided to the model ocean by maintaining the supply sump (Figure 4) at the desired salinity. This is accomplished by adding sufficient quantities of saturated brine (approximately 280 ppt) to the return sump where it is mixed to the desired source salinity prior to being circulated to the supply sump and thence to the model ocean. The saturated brine solution is obtained by injecting fresh water into a bed of granular salt (NaCl) from which it is later released to the return sump in measured quantities. The saltwater supply system is capable of maintaining source salinity to within 0.2 ppt of that desired in steady-state conditions and to within 0.5 ppt of that desired during variable hydrographic conditions.

Bubbler System

32. The bubbler system in the model is designed to create a more realistic vertical salinity distribution. Since nonastronomical mixing energy (primarily wind) is not easily modeled by tides and supplemental roughness alone, it was necessary to add the bubbler system in order to maintain closer agreement with the vertical salinity distribution in the prototype.

33. The model bubbler system consists of a network of copper tubing placed along the axis of the bay and its major tributaries (Figure 10). The tubing is charged with a constant air pressure and releases bubbles into the water column at a constant prescribed flow rate. Throughout any given test the bubble flow rate, air pressure, and bubbler depth in the water are monitored for consistency.

Current Meters

34. In this study, both magnitude and direction of currents were sampled. Current magnitude measurements were made with miniature Price-type meters (Figure 11). The center line of the model cups on the meter was about 0.04 ft above the bottom of the meter frame. The overall width of the meter was about 0.1 ft in the model, representing a horizontal width of about 100 ft in the prototype. Therefore distortion of the horizontal area (model to prototype) resulted in model velocities averaged over a much larger area than those

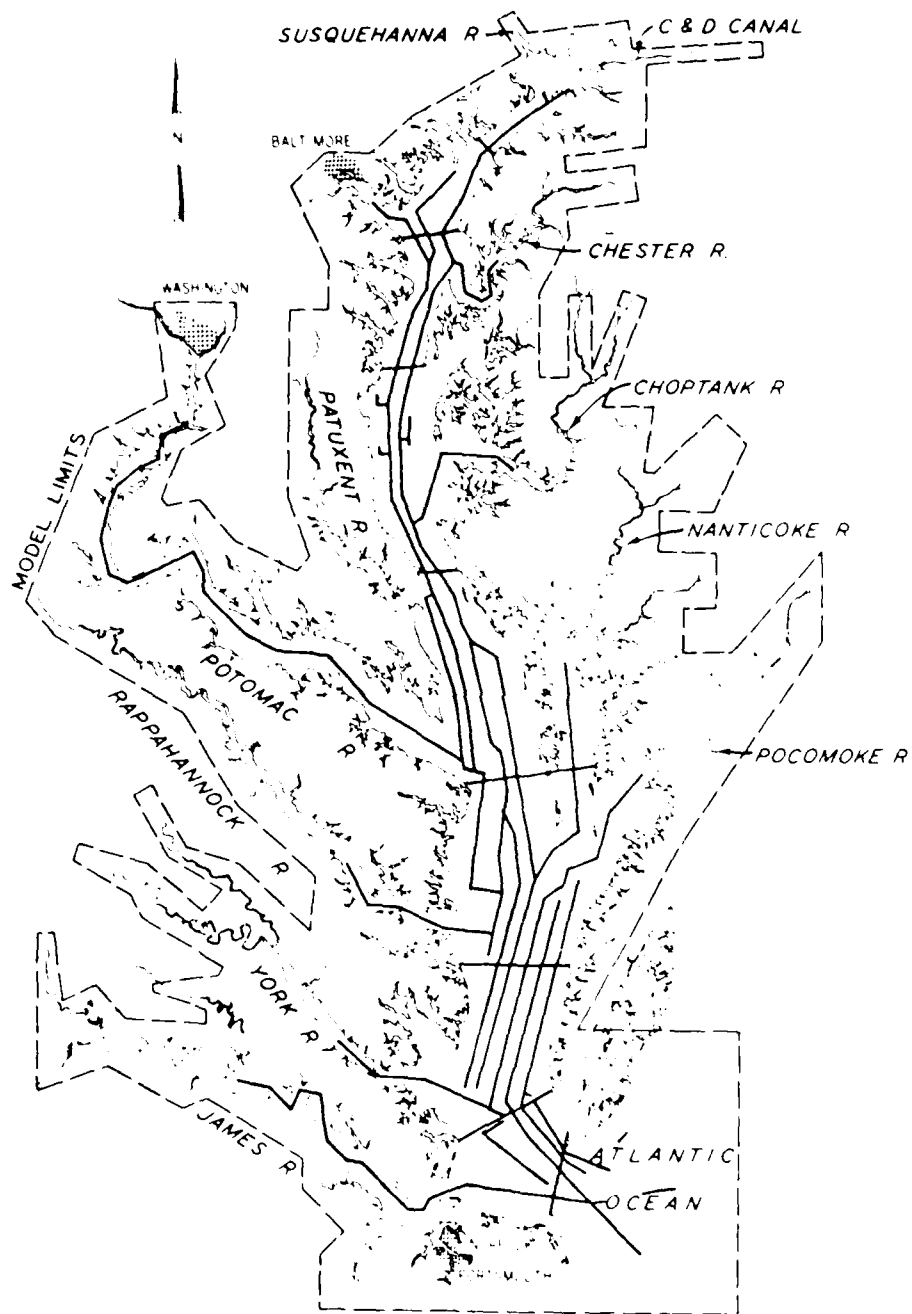


Figure 10. Bubbler system layout

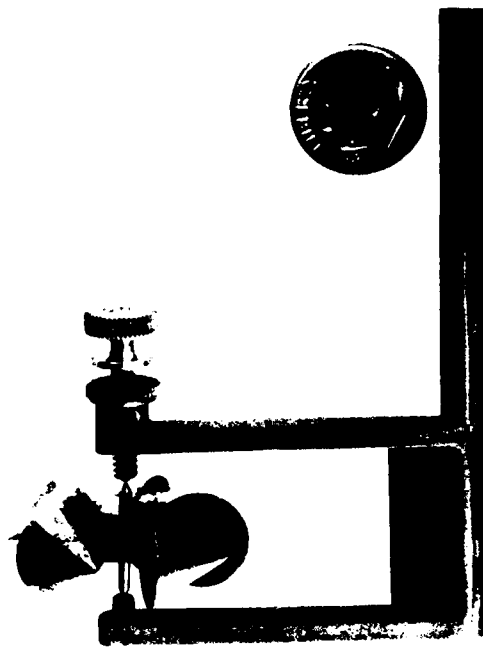


Figure 11. Miniature Price-type
velocity current meter

of the prototype point observations. The same was true for the vertical area since the height of the cups on the meter was equivalent to about 4.0 ft prototype. Current speeds were obtained by counting the number of revolutions the meter made in a 10-sec interval which was equivalent to about 17 min in the prototype. The meters were calibrated frequently to ensure the accuracy of measurements and were capable of measuring actual speeds as low as about 0.03 fps (0.3 fps prototype). Accuracy of these meters was about ± 0.15 fps (prototype).

35. Current directions were recorded hourly to the nearest 10 deg by using a direction vane and direction rose as shown in Figure 12. As was true with the Price-type meters, the size of the vane results in direction readings that are an average value over its 2-ft (prototype) height. In most cases, current direction changes are fairly slow so technicians could maintain reading precision to within 10 deg.

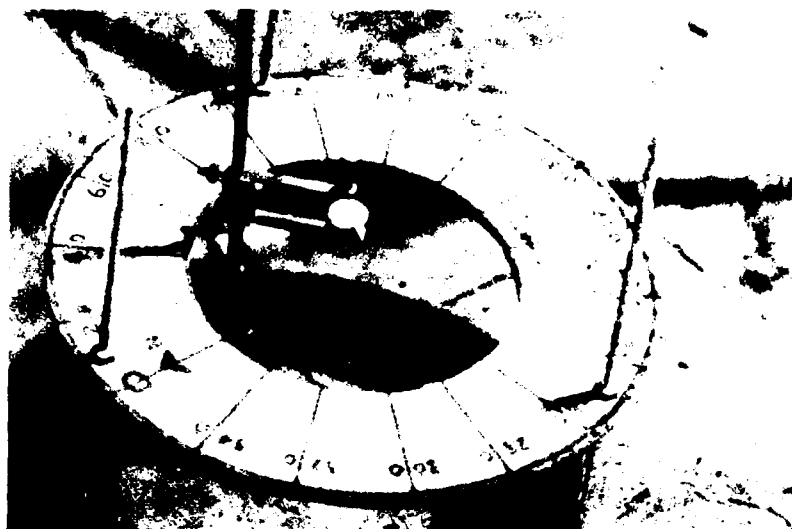


Figure 12. Current direction vane and compass rose

Vacuum Sampling System

36. Salinity samples for this test were taken using a vacuum aspiration system. A series of vacuum pumps provide a continuous vacuum to three valve manifolds. A total of 16 valves control a varying number of cotidal stations arranged such that sampling times are never more than 1/2 hr (prototype) from the desired slack-water sampling time. In each case, the sample is pulled at the same time relative to slack water. The sampling station consists of a sampling probe built from a number of separate copper tubes soldered together to form a multidepth probe. These copper tubes are attached to short lengths of plastic tubing that lead to individual 10-ml test tubes. Vacuum is provided to the tubes by a vacuum/overflow jar that provides an even vacuum to all lines. This system has proven effective in taking a very large number of samples. The filled test tubes are removed manually from the sampling device between sampling times and placed in special racks for later analysis.

Salinity Testing System

37. Beckman RA-5 solumeters are the primary instruments for making conductivity measurements at the model (Figure 13). These meters use a salinity probe shaped like an eyedropper into which a sample is drawn and the salinity

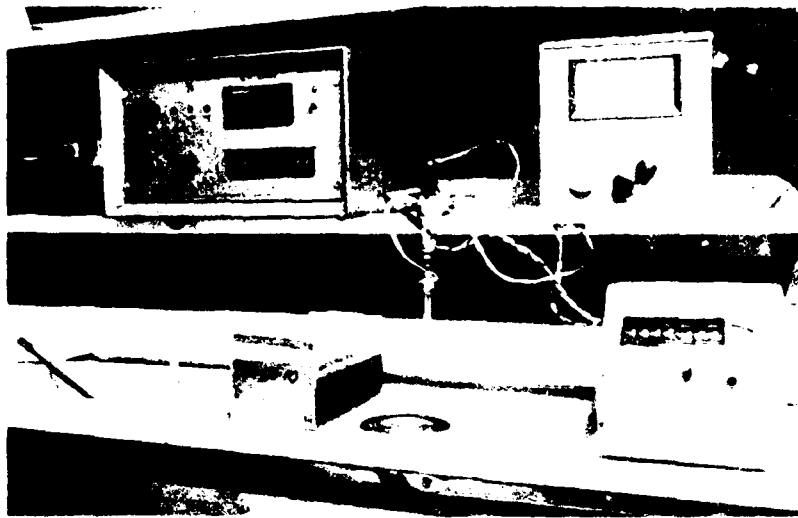


Figure 13. Beckman solometer

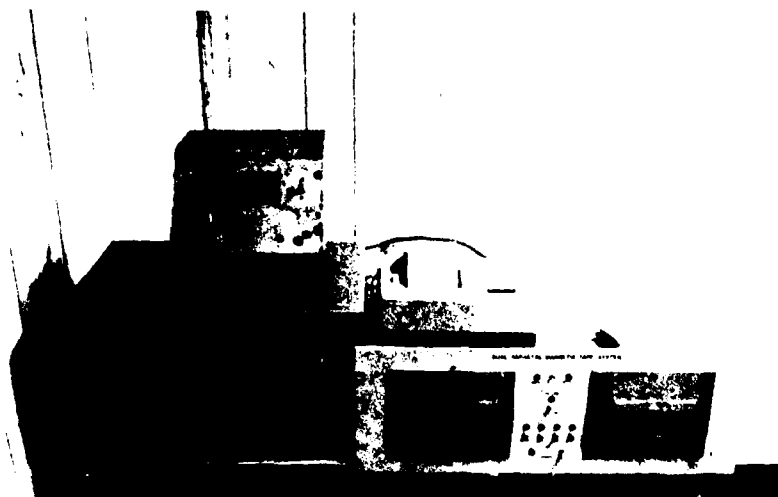


Figure 14. Salinity data logger

is read from an analog meter. Analog meters provide much opportunity for error in reading and transcription, and even the most experienced operators are unable to be more accurate than 2 percent of full scale, which is 0.8 ppt. The solumeters provide a voltage output of 0 to 100 mv which is proportional to 0 to 100 percent of full scale. This voltage is used to drive a digital voltmeter that measures to within ± 0.1 mv giving a resolution of 0.1 percent of full scale or 0.04 ppt. In calibrating the meters, it was found that a given salinity standard could be repeated to within approximately 0.3 percent or 0.12 ppt. This is in an ideal situation where temperatures, conductivity, and probe residence time are carefully controlled. Other tests performed on the meters indicate that most samples can be relied upon to within approximately 0.5 ppt. There are some cases where operator error or electronic problems can cause larger deviations, but these are detectable and can be isolated from the data set or corrected.

38. The data logging system (Figure 14) used for this study enters the values, converted by the digital voltmeters, on cassette tape in ASCII code where it can be processed by the TI 980 minicomputer for storage. With each sample value, pertinent information such as depth, time, tide, and station name is added to the record. This can all be accomplished with a minimum effort on the part of the meter operator. Direct entry of values on cassette tape precludes the need for keypunching and the possibility of misinterpretation with each transfer to a different medium.

PART III: STEADY-STATE TIDE AND VELOCITY TESTS

Test Conditions

39. The purpose of the steady-state tests in the Norfolk Harbor study was to examine the impact of channel deepening on tidal elevations and current velocities in the lower Chesapeake Bay and James River regions. The data collected from these hydraulic model tests were to be used in numerical hydrodynamic models at WES under a separate agreement with the U. S. Army Engineer District, Norfolk, to study sediment transport and shoaling characteristics of the dredged Norfolk shipping channels and adjacent estuary bed areas. The proposed improvements to Norfolk Harbor and its approach channels are described in PART I and are shown in Figure 2.

40. The term "steady state" indicates that the hydraulic model was operated under conditions of constant river inflow and a repetitive cosine tide at the model ocean. The testing scheme consisted of a base condition in which the model bathymetry simulated present prototype conditions with the Norfolk channels molded to depths reported from a U. S. Army Corps of Engineers hydrographic survey in 1980, and a plan condition in which the channels were deepened to their proposed project depths plus 3 ft for overdepth dredging. The tide, velocity,* and direction testing for both base and plan conditions was performed under the following four test scenarios:

Test 1: The model was operated under a repetitive cosine tide varying from +2.40 to -2.40 ft NGVD** at the Atlantic Ocean control station. This approximates a spring tide condition in Chesapeake Bay. The total bay freshwater river inflow was a constant 200,000 cfs which represents a relatively high flooding condition.

Test 2: The total bay discharge remained at 200,000 cfs; however, the repetitive cosine tide varied from +1.50 to -1.50 ft NGVD which approximates a neap tide condition.

Test 3: The total bay discharge was 70,000 cfs which simulates the long-term average flow into the Chesapeake Bay from all of

* Velocity can be rigorously defined as a vector quantity containing speed and direction. It is, however, commonly used as a scalar quantity describing current speed in either a flood or ebb direction. Hereafter, velocity will be used as a description of current speed unless otherwise noted.

** All elevations cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD), though on some figures and plates "ft msl" is used.

its tributaries. The approximate spring tide varying from +2.40 to -2.40 ft was generated at the ocean.

Test 4: The total bay discharge remained at 70,000 cfs and the approximate neap tide varying from +1.50 to -1.50 ft was generated at the ocean.

41. Steady-state discharges for each of the 23 model river inflows are summarized in Table 2. In addition to the river inflows, five sewage treatment plants and the Surry Nuclear Power Plant cooling water diversion were operated throughout the four steady-state tests. Locations of the sewage treatment plants and the Surry plant are shown in Figure 5 with their coordinates and steady-state discharge rates given in Table 1.

42. During both the steady-state and dynamic tests, tides were generated only at the Atlantic Ocean boundary. The model is capable of generating tides at the Delaware Bay end of the C&D Canal but this was not done during the Norfolk study. The Delaware Bay tide source is sufficiently distant from the study area to make its inclusion insignificant and certainly not cost-effective.

43. The source salinity for the entire model study was 32.5 ppt. Control of the source salinity during the steady-state tests was considered good with any minor variations being incapable of causing any observable base versus plan differences in tides or velocities. A complete documentation of all model boundary conditions during these tests is available (Waltz and Morton 1982).

Tide Test Data and Results

44. During steady-state testing, model tide observations were made at the 16 stations shown in Figure 15 and at one in the ocean. The 17 stations are listed in Table 3. Tide elevations were recorded hourly (every 36 sec real-time) over two tide cycles or 24.84 prototype equivalent hours. These tide measurements were made both manually using graduated point gages attached to portable tripod supports and automatically using electronic water-level detectors. Data from the water-level detectors were stored on flexible diskettes via the model control computer.

45. Tide station locations were determined by the requirements of the numerical hydrodynamic models to be used in the sediment transport studies at WES. Major boundaries of the two numerical hydrodynamic models were at range

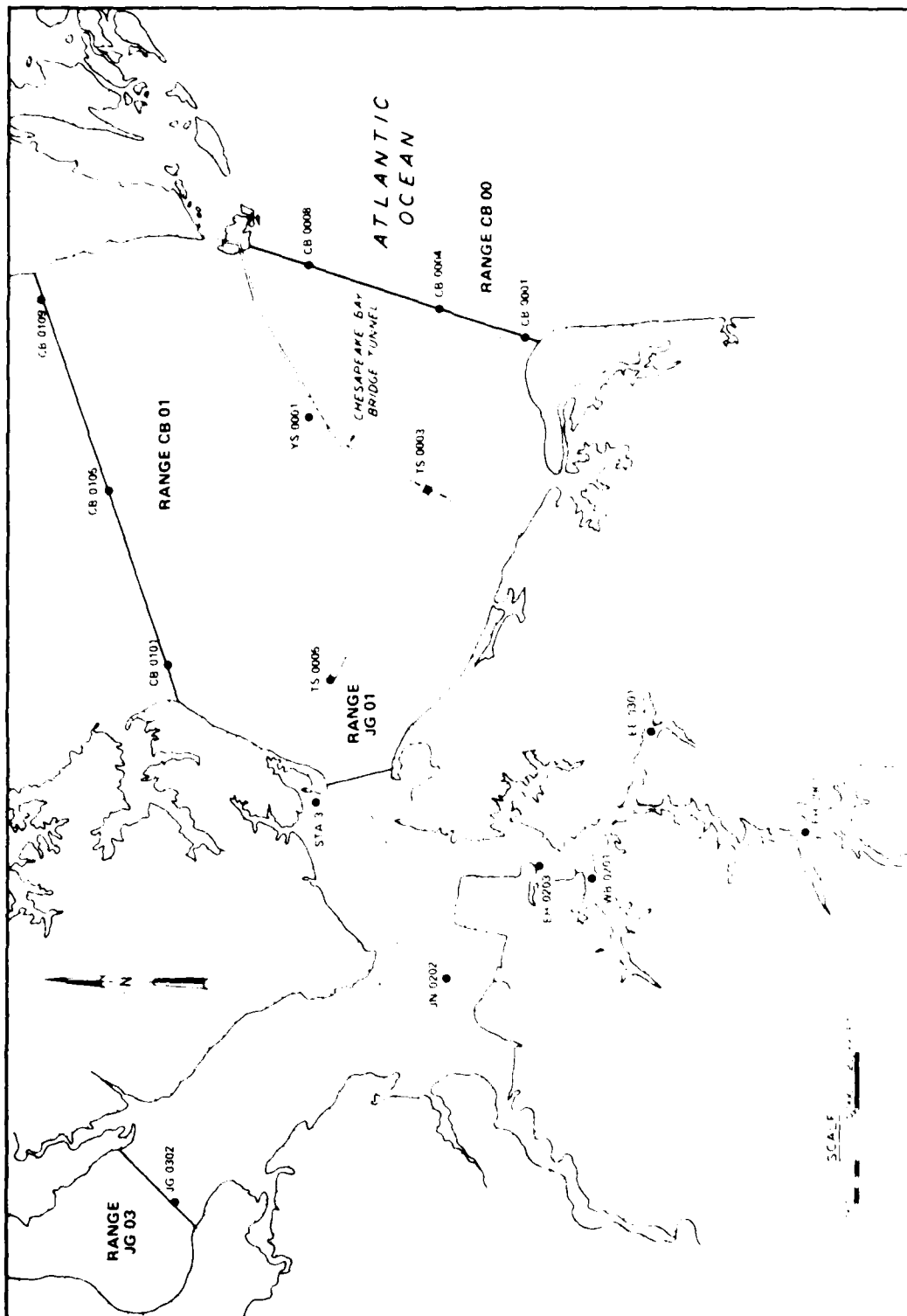


Figure 15. Steady-state manual tide station locations

CB00 on the east, CB01 on the north, range JG01 at the mouth of the James River, and range JG03 at the upstream boundary on the James. To adequately describe cross-sectional water-surface slopes, three tide stations were located across range CB00 at the mouth of Chesapeake Bay, and three stations were positioned across range CB01. Since the James River boundary ranges had relatively short widths, their cross-sectional water-surface slopes were essentially horizontal in the model and could be described by a single tide station.

46. During the base and plan steady-state tests, over 3,400 discrete hourly tide elevation data points were collected from the 17 manual sampling stations. The data set is complete with the exception of sta TS0005 which is missing from base tests 2 and 3. From each station for each test, 25 consecutive hourly tide elevations constituting two complete tidal cycles were fitted to the following expression:

$$h(t) = A_o + a \cos \left(\frac{2\pi\omega t}{360} - \frac{2\pi\theta}{360} \right) \quad (1)$$

where

$h(t)$ = tide height, ft

t = time, hr

A_o = mean water level, ft, of hourly tides

a = amplitude, ft

$\omega = M_2$ constituent angular velocity, 28.984104 deg/hr

θ = phase angle or epoch, deg, from zero lunar hour

47. Resulting cosine-fitted curves for the observed tides are shown in Plates 1-17, and the computed mean water level (A_o), amplitude (a), and phase angle (θ) are listed in Tables 4A-4D along with base to plan comparisons. The value, R^{**2} , shown in Plates 1-112 is a statistic that measures the goodness of fit of the cosine curve through the individual data points with a value of 1.0 being an exact fit.

48. Manual point gages are graduated to 0.001 ft (0.1 ft prototype equivalent) and can be estimated to the nearest 0.0005 ft (0.05 ft prototype). Thus it is reasonable to assume that the accuracy of the manual point gages for a single tide measurement is ± 0.10 ft (prototype) depending upon a number of variables including the keenness of the technician's eye, the delicacy of his or her touch in lowering the point gage to the water surface, and the presence or absence of small water-surface ripples at the instant of measurement.

Accuracy of the computed mean water level and tidal amplitude is therefore also assumed to be ± 0.10 ft (prototype).

49. "Zero-lunar-hour" is the time reference used to ensure that measurements made in the model can be compared with those taken in the prototype. Zero-lunar-hour occurs when the moon is directly over Chesapeake Bay. For the model reverification tests conducted in 1981, the model clock in the ocean tide control hut was set so that zero-lunar-hour occurred at hour 6.6 (191 deg epoch). This same clock setting was also used for both base and plan tests of the Norfolk Harbor study. The procedure for setting the model clock was somewhat subjective. A technician would take a succession of readings at the ocean point gage, the time between readings normally being between 6 and 10 sec (real-time). Upon noticing that the peak of the tidal wave had occurred, the technician would then note the time on the model clock and adjust it to hour 6.6 if necessary. The time lag from the instant of actual tidal peak occurrence to the instant that the technician perceives this peak could be as great as 17 sec (14 deg epoch). In general, no adjustments were made to the clock unless high-water occurrence varied by 0.5 hr or more from the desired hour 6.6.

50. Technicians are cued by a bell timing system which rings for a duration of 10 sec at the start of each prototype hour, and they are instructed to make their tide measurements as near as possible to the beginning of the bell. It is believed that discrepancies in time of measurement could cause as much as an 8-deg error in epoch when considering a discrete tide observation. Hence it is reasonable to assume that the raw model phase angles are accurate to within ± 22 deg.

51. Plan-minus-base amplitude differences for the four tests are summarized in Table 5. Very little change in amplitude was noticed between base and plan tests. From the differences listed in Table 5, one may be able to deduce trends indicating a slight increase in amplitude for the plan condition during Test 1, slight decreases in plan amplitudes during Tests 2 and 3, and essentially no change during Test 4. However, the largest change in amplitude measured in the model was -0.08 ft at sta CB0008 during Test 3. This is within the accuracy limitations of the model; thus any differences listed in Table 5 are considered due to random measurement error inherent in the model and not a result of channel deepening.

52. Plan-minus-base mean water-level differences for all four tests are

summarized in Table 6. Computed mean water-level differences from the manual point gages were nearly uninterpretable due to two problems that existed in the model during testing:

- a. The portable tripods on which the manual point gages were mounted were not stable enough for the degree of accuracy required to interpret base-to-plan mean water-level changes. The procedure for referencing these point gages to a datum involved lowering the point of the gage to a submerged fixed pin whose elevation was known. However, the pressure exerted in touching the point to the pin was apparently great enough in many cases to cause the entire tripod to tilt by as much as 0.30 ft (prototype). This may account for the anomalous values in Table 6.
- b. In the ocean tide hut, the model is controlled by a bubble tube positioner (BTP) and a fixed-point gage housed inside a baffle pit. The main purpose of the baffle pit was to prevent surface waves from interfering with the tide sensing equipment. Prior to the start of the Norfolk Harbor study, this baffle pit was reconstructed using solid barriers to prevent the thin fresh-water lens, which accumulates in the ocean as a result of river inflows, from being sensed by the BTP. This baffle pit, therefore, prevented the horizontal exchange of ocean water on the outside with essentially stagnant water on the inside. Near the completion of the plan test, an experiment was performed in which it was discovered that the water inside the baffle pit was 4.5 ppt less saline than an equivalent column of ocean water on the outside.

53. The model computer controlled the level in the model so that the mean water level at the ocean station within the baffle pit was 0.00 ft. However, the laws of fluid statics state that existence of a 4.5-ppt density difference will cause the plane of the model outside the baffle pit to be 0.14 ft less than the plane within the baffle pit. The only fixed-point gage other than the ocean station that was monitored during the Norfolk Harbor tests was sta 3 at Old Point Comfort on the James River. It is evident in Table 6 that the plan-minus-base mean water-level difference is -0.14 ft at sta 3 just as the aforementioned experiment concluded. No data are available from the base tests to confirm whether a density difference was present in the ocean baffle pit; however, based on the data from sta 3, it is assumed that no such difference existed at that time. Therefore it is reasonable to treat this as a systematic error and apply an approximate additive correction of +0.14 ft to all base-to-plan mean water-level differences (see adjusted mean water-level differences in Table 6).

54. Although the unstable tripods have created an error which cannot be filtered out of the mean water-level data, it is interesting to note that the

overall average of adjusted mean water-level differences in Table 6 was 0.00 ft for Test 1, +0.06 ft for Test 2, +0.01 ft for Test 3, and -0.05 ft for Test 4. The overall mean of all four tests combined showed a difference of 0.00 ft. Based on these averages, a general inference can be made that on the whole, channel deepening caused no changes in mean water levels in this model study.

55. All phase angles listed in Tables 4A-4D have been normalized to a standard ocean station phase of 191 deg and are summarized in Table 7 along with plan-minus-base differences. By normalizing all phase angles to the ocean station, the error in model control of the occurrence of high water at hour 6.6 has been filtered out of all measurements. Any remaining base-to-plan discrepancies in phase can now be attributed either to the time-of-measurement random sampling error, or to the effects of channel deepening, or a combination of both. Plan-minus-base differences in Table 7 are all within the ± 18 deg time-of-measurement error band. Thus the model evidence indicates that all phase differences are due to random sampling errors rather than the result of deepening Norfolk Harbor and its approach channels.

Velocity Tests

56. Current velocities in the Chesapeake Bay model are largely the result of three factors: tides, freshwater discharges, and salinity density gradients. Of these, the most important factor affecting current velocities is the amplitude of the tide which varies throughout the model depending on the local bathymetry. Freshwater discharge plays a variable role depending upon its magnitude and the estuary cross-sectional geometry, the most significant effect being in the upper reaches of tributaries. Existence of a salinity density gradient causes a multilayer flow system to be formed in which the denser bottom water tends to move predominantly in the flood direction (upstream) while the fresher surface layer flows mainly in the ebb direction (downstream).

57. Model velocities were measured at 32 sampling stations during the four steady-state tests. Velocity observations were collected concurrently with the tide elevations discussed in the previous section. In addition, current direction data were collected at 26 of the velocity sampling stations. Six stations (EH 0203, 0501, 0701, 0901, EE 0301, and WB 0201) were located in constricted channel areas where direction measurements were unnecessary. Locations of the velocity stations are shown in Figure 16 and are listed in Table 8.

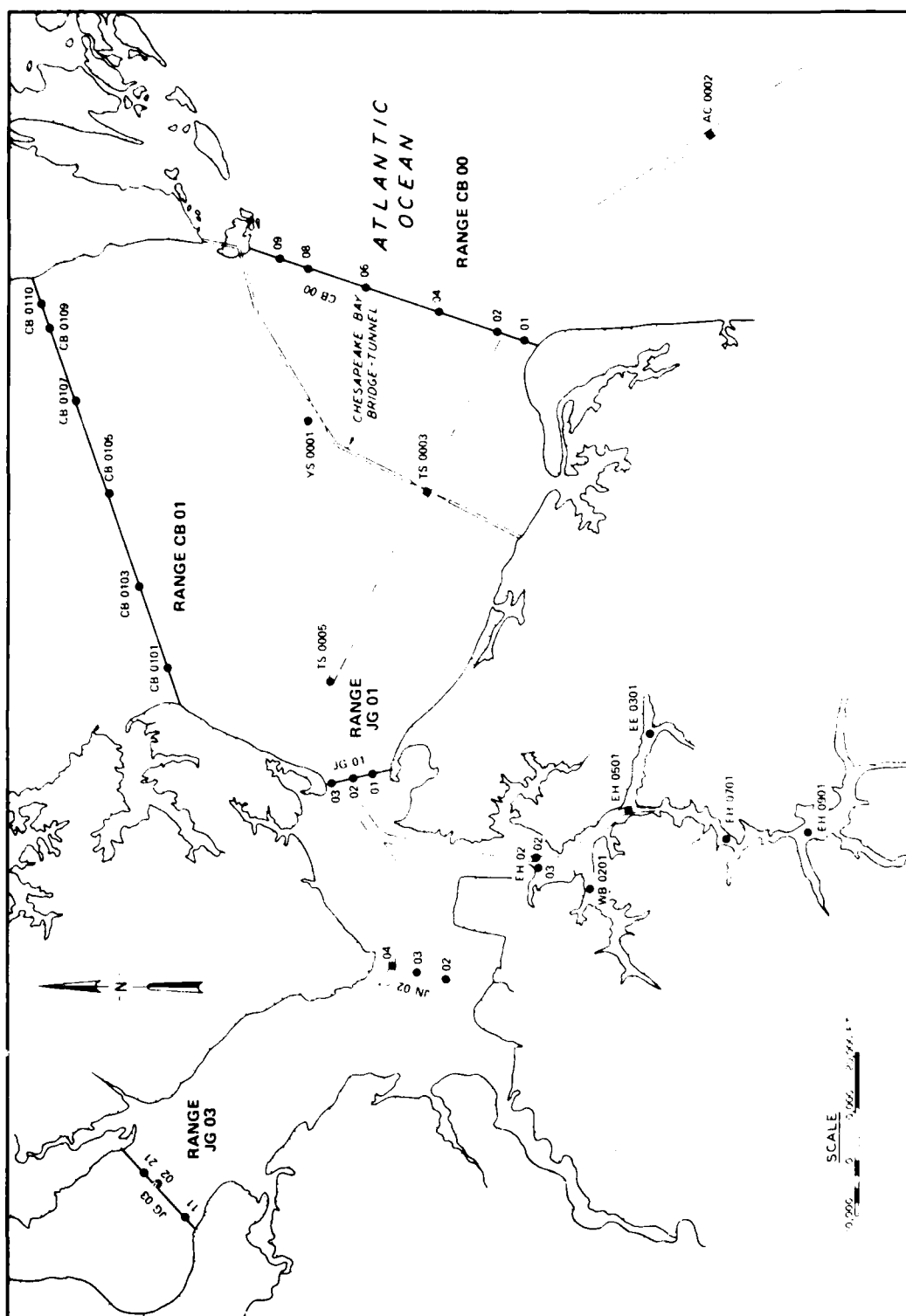


Figure 16. Steady-state velocity stations

58. Station locations were determined primarily by boundary requirements of the numerical hydrodynamic and sediment transport models at WES. Velocities were sampled across ranges CB00, CB01, JG01, and JG03 which defined transverse boundaries in the mathematical models. Additional samples were taken in the Norfolk approach channels and in the Elizabeth River and its tributaries. Depending upon total station depth, velocities and directions were generally sampled at the surface, middle, and bottom. At stations located within the Norfolk approach channels, velocities were collected at coincident depths for both base and plan channel configurations with an additional deeper bottom depth sampled during the plan test (Figure 17).

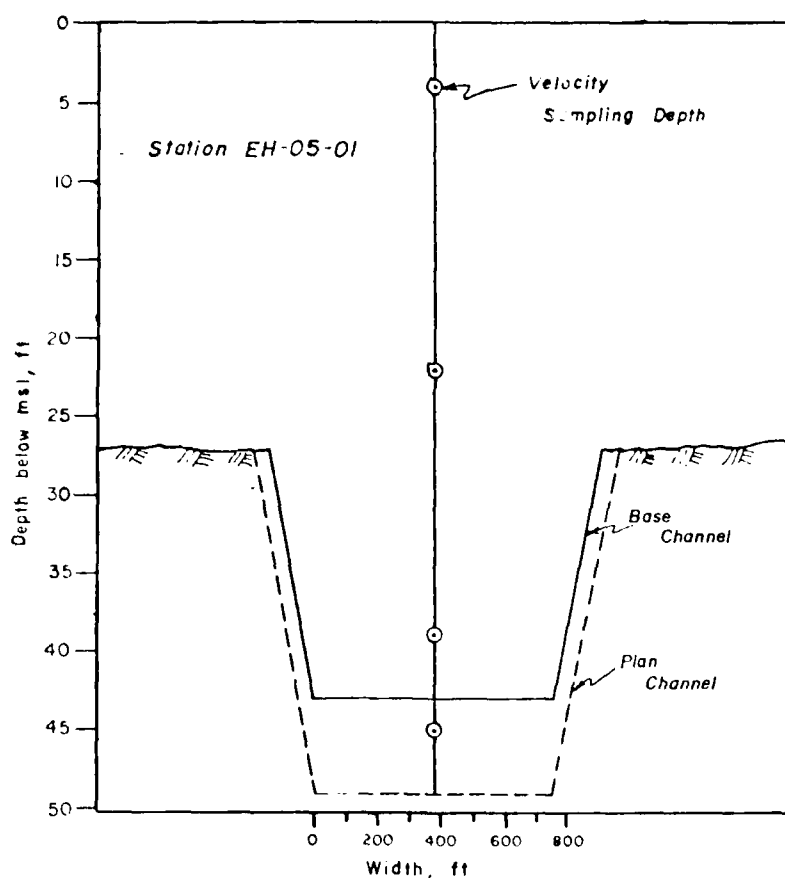


Figure 17. Typical velocity sampling scheme

59. The testing equipment included miniature Price-type velocity meters and a small direction vane, both of which are discussed in PART II. Velocity magnitude and direction measurements were recorded every hour (36 sec

real-time) for two tide cycles at each sampling depth. Each velocity meter had a unique calibration equation which related the current velocity (prototype fps) to the number of revolutions traveled by the meter cups in a 10-sec interval (real-time). Each meter also had a so-called "threshold-of-motion" defined as a critical velocity less than which the meter would cease to turn. At velocities less than critical, the momentum of the moving water was not great enough to overcome the inertial and frictional forces of the meter. The threshold-of-motion varied from meter to meter and was generally 0.30 fps (prototype equivalent) or less.

60. Uncertainty in model velocity measurements results from errors falling into the following three classes:

- a. Boundary condition errors--These are caused by variations in source salinity, tide control, river discharge control, and local perturbations in the flow field.
- b. Instrument errors--These result from imperfections in the manufacture and calibration of the velocity meters. As an example, the mechanical cups of a meter may not be centered symmetrically about its axis causing an irregular rotation even though the actual current may be steady and uniform.
- c. Personal errors--These errors stem from limitations of the human senses of sight, touch, and hearing, all of which are used during velocity testing.

Three of the boundary condition errors (source salinity, tide control, and river discharge) were maintained within acceptable limits throughout the steady-state testing; and the recorded variations will have a negligible effect on the reliability of current velocities. Local perturbations in the flow field are random natural errors and tend to cancel out with a large number of observations. Instrument errors were minimized by screening all available velocity meters in the initial calibration process and choosing for testing purposes only those exhibiting the highest quality. The calibration of each meter was checked at least once a day in the laboratory flume. The calibration equations are accurate to within approximately ± 0.15 fps based on 95 percent confidence interval with 47 degrees of freedom. The most significant personal error introduced into the velocity measurements was in estimating the fractions of a revolution that a meter turns. This can be reasonably estimated to the nearest 0.2 revolutions or about ± 0.15 fps. Thus, considering all the sources of possible error, the accuracy of a discrete model velocity measurement is approximately ± 0.30 fps (prototype equivalent).

61. The frontal dimension of one velocity meter cup is 0.04 ft (actual) in diameter and has an area of 0.001265 sq ft. Due to the distorted scale of the model, this corresponds to an equivalent prototype area of 126.5 sq ft in the shape of an ellipse having a semimajor horizontal axis of 200 ft and a semiminor vertical axis of 2 ft. Because of this scale effect, velocities measured in the model cannot be interpreted as equivalent prototype point velocities; instead, they correspond to prototype velocities averaged over the area of the equivalent ellipse.

Velocity Data Analysis

62. Over 32,000 discrete velocity and direction measurements were recorded during the base and plan tests. At each sampling depth, 25 consecutive hourly velocity observations constituting two tidal cycles were fitted to the following equation using a harmonic least squares curve fitting technique.

$$v(t) = U_o + u \cos \left(\frac{2\pi\omega t}{360} - \frac{2\pi\theta}{360} \right) \quad (2)$$

where

$v(t)$ = current velocity, fps

t = time, hr

U_o = mean velocity, fps of the hourly observations

u = amplitude, fps

ω = M_2 constituent angular velocity, 28.984104 deg/hr

θ = phase angle, deg

The confidence of the computed velocity constants (phase (θ), amplitude (u), and mean (U_o)) is generally greater than that of a discrete measurement since all 25 hourly observations are used in the analysis. The velocity constants are relatively insensitive to a few outliers.

63. Individual velocity observations and cosine-fitted curves for both the base and plan conditions are shown in Plates 18-112. Velocity constants are listed in Tables 9A-9D. Plan-minus-base differences in the velocity constants for the four steady-state tests and summary statistics are given in Tables 10A-10D.

64. The inertial and frictional forces inherent in the velocity meters introduce relatively large instrument errors at low current velocities;

however, as the current speed increases these instrument errors decrease. Thus a higher degree of confidence can be placed in the discrete maximum flood and maximum ebb velocities measured in the model such that plan-to-base comparisons are meaningful. Each set of 25 hourly velocities contained two maximum flood and two maximum ebb velocity measurements. These two maximums were averaged and are listed in Tables 11A-11D under the "MODEL DATA" heading. Also, maximum flood and ebb velocities computed from the harmonic Fourier analysis are given in Tables 11A-11D under the "HARMONIC ANALYSIS" heading. Plan-minus-base maximum flood and ebb differences and summary statistics are given in Tables 12A-12F. Plates 113-144 show the maximum flood and ebb velocity profiles for both the base and plan tests.

65. The concept of flow predominance is useful in analyzing the effects of density-induced currents on velocities. Consider the conventional velocity versus time plot in Figure 18. The shaded area under the ebb portion of the curve is divided by the sum of the areas under the ebb curve and flood curve. The result is called the flow predominance and is defined as the percent of the total flow per tide cycle that is moving in the ebb direction at a given velocity sampling depth. In a partly mixed estuary such as Chesapeake Bay, the bottom flow predominance will be mainly in the flood direction within the salinity wedge, and the surface flow predominance will be in the ebb

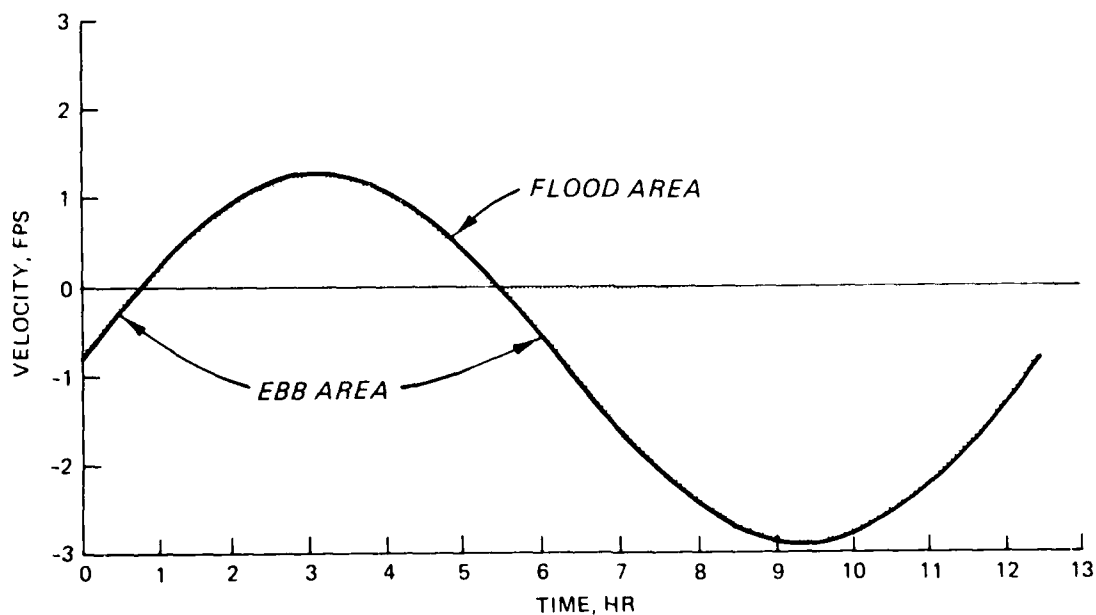


Figure 18. Definition sketch: flow predominance

direction. The flow predominance percentages for the four steady-state tests along with plan-minus-base differences and summary statistics are listed in Tables 13A-13B.

Velocity Test Results

Plan-to-base velocity phase comparisons

66. Current velocity phase is the time (in degrees) of maximum flood velocity referenced to zero-lunar-hour. A complete tidal cycle in the model is 12.4206 model hours (360 deg) in length. The confidence of velocity phasing is approximately ± 20 deg. Frequency-of-occurrence statistics of plan-minus-base phase differences are provided in Table 10B. Nearly 30 percent of the plan and base values were within 5 deg of one another, 67 percent were within 10 deg, nearly 87 percent were within 15 deg, and nearly 97 percent were within the 20-deg confidence band. Table 10A shows that during Test 1 the plan phase occurs 64 deg prior to the base phase at sta JG0103 at depth 83 ft. A velocity meter problem was evident during the base test and this phase value should not be considered. Also, at sta EH0901 and depth 35 ft during Test 2 and at sta EE0301 and depth 21 ft during Test 4 the velocities were so low that threshold-of-motion problems were experienced resulting in anomalous phasing. Only 10 (2.9 percent) phase discrepancies fall outside the 20-deg confidence band with all but one occurring in the Elizabeth River at sta EH0202, EH0203, and EH0501. It appears that the deepened Elizabeth River channel with its larger cross-sectional area reduced velocities sufficiently to cause the velocity meters to occasionally operate within their threshold-of-motion ranges resulting in the anomalous data. Thus any phase differences outside the ± 20 deg confidence band should be viewed with reservation.

67. The conclusion is that channel deepening has caused only minimal phasing differences between base and plan tests. The only sampling depth at which a phase difference trend seemed evident was at sta EH0501, depth 39 ft, which is at the confluence of the Eastern and Southern Branches of the Elizabeth River. Here the plan phase consistently arrived earlier than the base phase.

Plan-to-base velocity amplitude comparisons

68. Current velocity amplitudes are defined as one-half of the range

between the maximum flood and maximum ebb velocities from the cosine fit curve. All 25 hourly velocity observations are taken into account in the amplitude computations, so greater confidence can be placed in the amplitude values than in a discrete velocity observation. Frequency-of-occurrence statistics of plan-minus-base amplitude differences are given in Table 10C. Over 27 percent of the base and plan velocity amplitudes were within 0.10 fps of one another, over 52 percent were within 0.20 fps, over 73 percent were within 0.30 fps, and about 84 percent were within 0.40 fps. There was an overall trend toward decreased amplitudes in the plan test. Of the 347 amplitude difference values, 97 (28 percent) were greater than 0.00 fps while 250 (72 percent) were less than 0.00 fps. The overall mean of the amplitude differences indicated a 0.13-fps decrease in the plan test. This decrease in velocity amplitude in the plan test meets the expectancy associated with deepened channels and the resulting larger cross-sectional areas.

69. Anomalous amplitude values are evident at sta CB0008 and sta JG0103, depths 66 and 83 ft, respectively, during base Test 1 and should not be considered due to meter instrument errors. The largest plan-to-base decreases in amplitude are between 0.80 and 1.00 fps and occur during Test 1 (200,000-cfs discharge with spring tides) at sta JG0102, EH0202, and EH0203. The largest plan-to-base increases in amplitude are 0.56 fps at sta CB0006, depth 4 ft, during Test 1 and 0.51 fps at sta YS0001, depth 25 ft, during Test 2.

70. By inspection of Tables 10A, 10B, and 10C, trends can be seen in the amplitude changes due to channel deepening without regard to a specific freshwater discharge or tide range. On the average, the stations on range CB00 show plan-to-base decreases in amplitude with the exception of CB0004 and CB0006 which show slight increases. An overall decrease in amplitude in the plan test is also evident across range CB01 with the exception of the surface depth at CB0109. Sta AC0002 shows an amplitude decrease at the surface and middle while the bottom amplitudes remained essentially the same in the plan tests. Sta YS0001 shows an amplitude decrease at the surface and averages essentially no change at the middle and bottom. Sta TS0003 indicates a decrease in surface and middle amplitudes and essentially no change at the bottom. Sta TS0005 indicates a decrease at the surface, no change in the middle, and an increase at the bottom. Interestingly, the entrance to the James River at range JG01 shows plan decreases in amplitude at the out-of-channel stations while the deep natural channel sta JG0103 shows an increase in amplitude at

the three lower depths. Apparently, the deepened Norfolk channels have caused a redistribution of the flow pattern at the mouth of the James. The other two James ranges, JN02 and JG03, show slight decreases in amplitude essentially across both ranges. The stations in the Elizabeth River and its tributaries all show decreases in plan amplitudes except the bottom depths at sta EH0501 and EH0901 which indicate essentially no change from base to plan.

Plan-to-base mean velocity comparisons

71. The mean current velocity is simply the mean of the 25 hourly velocity measurements at a given sampling depth. The mean velocity gives an indication of flow predominance, positive being flood predominance and negative being ebb predominance. The frequency-of-occurrence statistics of plan-minus-base mean velocity differences are listed in Table 10D. More than 60 percent of the base and plan mean velocities were within 0.10 fps of one another, over 86 percent were within 0.20 fps, nearly 95 percent were within 0.30 fps, and over 97 percent were within 0.40 fps. The mean of these differences for each of the four steady-state tests was close to 0.00 fps as was the overall mean of the entire data set. This indicates that channel deepening had little impact on the mean current velocities when the entire data set is considered.

72. The average overall plan-minus-base mean velocity differences at each sampling depth for the four tests are given in Table 10D. Inspection of Table 10A shows that sampling points at which the mean velocity increased with channel deepening during all four tests are:

CB0001 Depth 4 ft
TS0003 Depths 4 and 46 ft
JG0103 Depths 22 and 66 ft
JN0204 Depth 48 ft
EH0701 Depth 4 ft

Sampling points showing a decrease in plan mean velocity for all four tests are:

CB0004 Depth 4 ft
TS0005 Depth 50 ft
EH0202 Depth 46 ft

All other stations show either essentially no change from base-to-plan conditions or an increase during one test and a decrease in another.

Plan-to-base maximum flood
and ebb velocity comparisons

73. Since the maximum flood and ebb velocities are normally well outside the threshold-of-motion range, a high degree of confidence can be placed on these measurements making plan-to-base comparisons meaningful. The plan-minus-base maximum flood and ebb velocity differences are presented in two forms: (a) the differences using discrete model measurements are given in Table 12A, and (b) the differences using the peaks of the harmonic cosine-fit curve are given in Table 12B. Anomalous data at sta CB008, all depths, and JG0103, depth 83 ft, during Test 1 were not considered in the analyses.

74. From the frequency-of-occurrence statistics in Tables 12C-12F, the following summary of the overall data set shows the percent occurrence within certain intervals:

Interval	Maximum Flood percent		Maximum Ebb percent	
	Model Data	Cosine- Fit Data	Model Data	Cosine- Fit Data
Plan and base within 0.10 fps	27.9	29.9	21.3	22.3
Plan and base within 0.20 fps	51.5	55.2	42.9	46.3
Plan and base within 0.30 fps	69.3	72.7	61.7	62.3
Plan and base within 0.40 fps	81.9	84.4	73.8	76.6

When considering overall averages from the four tests, the prevailing trend indicates that the maximum flood and ebb velocities decrease by approximately 0.10 fps after channel deepening. The largest average change was during Test 4 (70,000-cfs discharge with neap tide range) where plan maximum flood and ebb velocities decreased about 0.20 fps. The overall maximum flood and ebb velocity magnitudes were reduced slightly because of the increase in cross-sectional area associated with the deeper plan channels.

75. Plates 113-144 show two sets of maximum flood and ebb velocity profiles for each steady-state test at each station. One set is labeled "model data" and represents the actual maximum flood and ebb velocities measured in the model. The other set is labeled "harmonic data" and represents the maximum flood and ebb velocities taken from the harmonic cosine-fit curve resulting from the harmonic analysis of the 25 hourly velocity observations. Most often the model and harmonic profiles are in agreement. However, there are

times when the harmonic profile shows better plan-to-base agreement than does the model data profile (e.g., see the ebb profile for sta TS0005 during Test 2 in Plate 127). Likewise, there are occasions when the model data profile shows slightly better plan-to-base agreement than does the harmonic profile (e.g., see the ebb profile for sta CB0008 during Test 2 in Plate 117). Both sets of velocity profiles were given equal weight and were used as references to formulate the following specific comments:

- a. The maximum flood and ebb velocities at range CB00 for both base and plan conditions were essentially the same with the exception of sta CB0002 which shows lower ebb velocities during the plan Tests 1 and 2 (200,000-cfs discharge), sta CB0004 which showed increased flood and ebb during Test 2 and sta CB0008 which showed reduced flood and ebb during Test 4. Decreases in plan maximum velocities can be seen at sta CB0009.
- b. Across range CB01, the overall trend was for maximum flood and ebb velocities to decrease slightly along the western half of the range and remain essentially the same along the eastern half during the plan test.
- c. At sta AC0002, the effects of the new Atlantic Ocean channel can be clearly seen in Plate 125. The deepened channel with its larger cross-sectional area causes a decrease in plan velocities at the surface and middle depths.
- d. At sta TS0003, the plan maximum ebb velocities tend to decrease at the surface while the flood velocities show little change except during Tests 1 and 4 where there is a decrease of about 0.40 fps at the surface and middle depths. At TS0005, the maximum velocity profiles are essentially the same from base-to-plan conditions except for the middle depth during Test 4 which becomes more flood predominant.
- e. At the mouth of the James River, sta JG0101 and JG0102 both indicate a general decrease in maximum velocities of about 0.20 to 1.00 fps. Sta JG0103 (Plate 131) contains anomalous data at depth 83 ft during base Test 1; however, there is an indication of increased velocities at bottom depths during the spring tide range (Tests 1 and 3) while the entire velocity profile remains unchanged during neap tides (Tests 2 and 4).
- f. At JN0204, which is stationed within the deepened Norfolk Harbor Channel, a decrease of about 0.40 fps occurs generally throughout the entire velocity profile during Test 3 while an increase of about 0.50 fps in surface ebb is apparent during Test 1 with a lower increase for Test 2.
- g. Sta JG0302 is interesting because a 0.20- to 1.00-fps decrease is evident throughout the plan flood and ebb velocity profiles during Tests 3 and 4 (70,000-cfs discharge). However, there is an increase of about 0.35 fps throughout the entire flood and ebb profile during Test 1. Test 2 shows essentially no change.

- h. Sta EH0202 is another good example showing how channel deepening causes a decrease in velocities within the channel (the base velocities during Test 2, however, appear to be within the threshold-of-motion range of the velocity meter and should not be considered). All velocity stations within the deepened Elizabeth River channel show a general decrease in maximum flood and ebb velocities of 0.10 to 0.40 fps throughout the vertical profile.

Plan-to-base flow
predominance comparisons

76. Flow predominance values are given in percent of flow in the ebb direction in Table 13A. Frequency-of-occurrence statistics for plan-minus-base flow predominance differences are given in Table 13B. Overall, about 66 percent of the differences were within 5 percent, over 83 percent were within 10 percent, about 92 percent were within 15 percent, and nearly 97 percent were within 20 percent. The overall mean difference was -0.57 percent. Tests 1 and 2 with the high 200,000-cfs discharge show slightly overall increased ebb predominance during the plan conditions while Tests 3 and 4 with the lower 70,000-cfs discharge indicate that channel deepening will decrease ebb predominance slightly. It should be mentioned, however, that the sampling stations represent a finite number of points and do not portray the entire cross section. Other stations across the section, if they were sampled, might have refuted these observations.

77. A more general conception of flow conditions in the James River and Elizabeth River is shown in Figures 19 and 20 where surface and bottom flow predominance profiles have been plotted along the estuary channels. Plan-versus-base changes are subtle in the James River, normally not varying by more than 5 or 10 percent; however, consistent trends are evident. Plan-versus-base variations in the flow predominance profile are more apparent in the Elizabeth River. However, it must be remembered that velocity meters were operating near the threshold-of-motion range, so less confidence can be placed in the Elizabeth River measurements. Again, consistent trends are evident.

78. Saltwater intrusion is important to estuary sedimentation because saline water causes flocculation of suspended clay particles and density currents tend to move sediments upstream along the bottom. Thus sediments entering the estuary may become trapped instead of moving back out to sea. Frequently, the heaviest shoaling occurs between the high-water and low-water

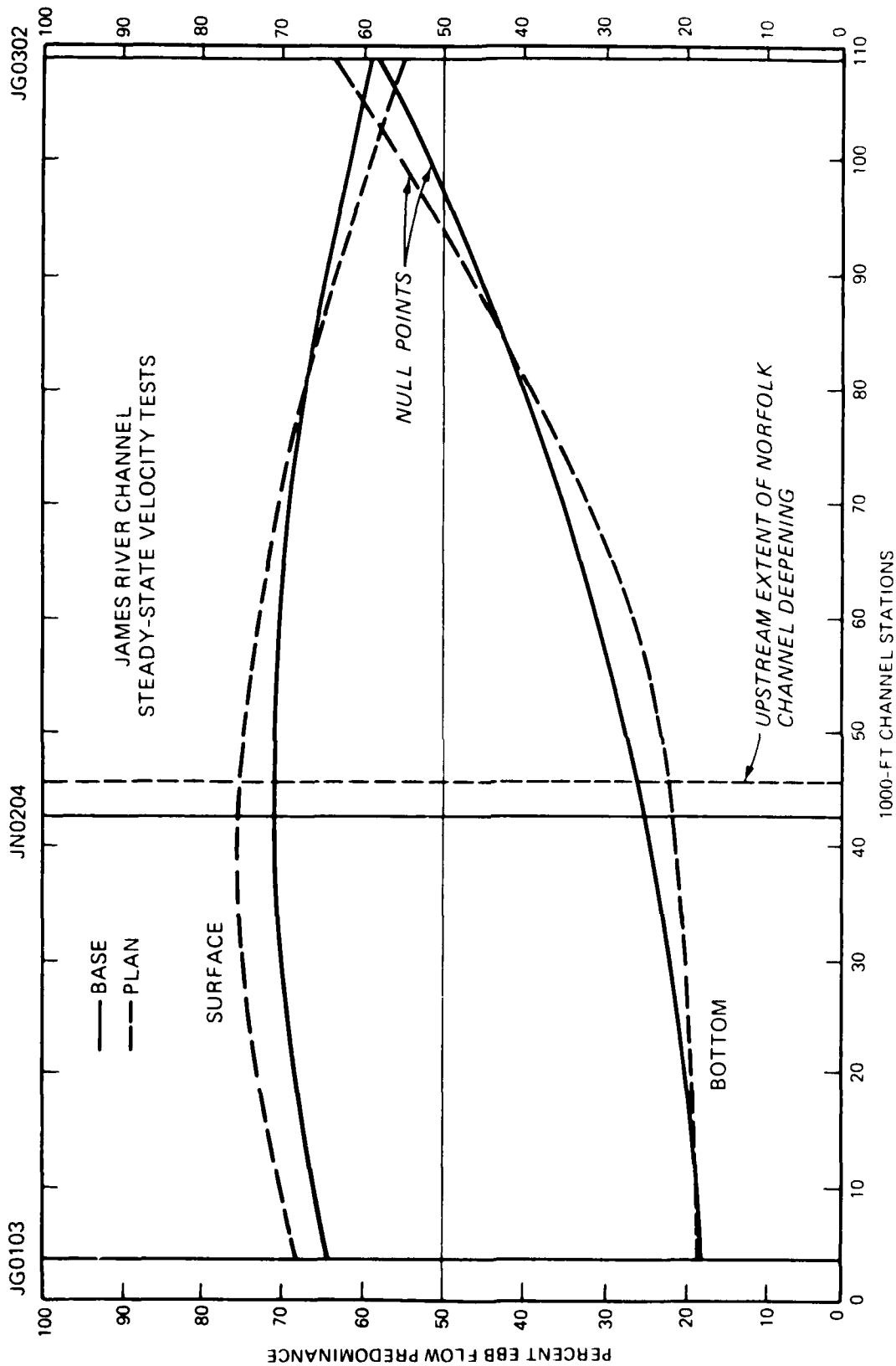


Figure 19. Flow predominance along the lower James River channel

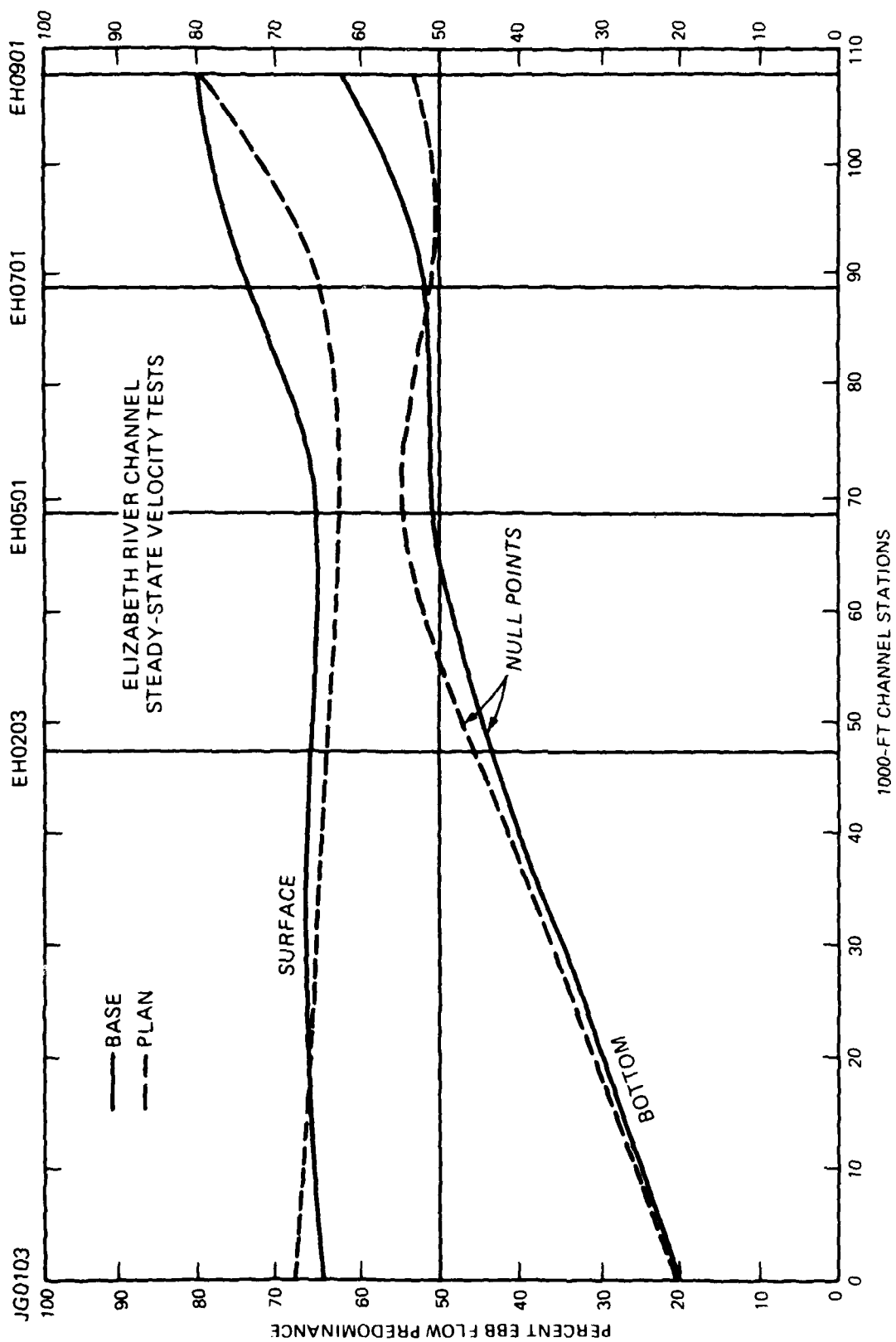


Figure 20. Flow predominance along the Elizabeth River channel

positions of the upstream limit of salinity intrusion. Although shoaling depends largely on the ability of bottom currents to move bed materials upstream, the most likely region in which the heaviest shoaling will occur is the reach bracketing the 50 percent value (or null point) on the bottom flow predominance profile (Schultz and Simmons 1957). In both the James and Elizabeth Rivers, the location of this null point remains basically the same from base-to-plan conditions. Hence, channel deepening should not change the present locations of the heaviest shoaling in the James and Elizabeth Rivers. On the other hand, there are several isolated instances where the plan condition reversed the direction of bottom flow predominance. This should indicate a significant change in local shoaling during those particular flow and tide conditions. However, this model study cannot directly predict whether the magnitude of shoaling will change with channel deepening. It is important to understand that the locations of these heavy shoaling areas cannot be pinpointed exactly in the model and are only "best guess" interpretations of model velocity measurements. In order to determine shoaling locations more accurately, a more dense velocity sampling network would be necessary. The velocity sampling scheme used in this study was primarily determined by the requirements of the numerical hydrodynamic models that will perform a much more rigorous sedimentation and shoaling analysis than was presented herein.

Tide and Velocity Summary

79. Any changes in tide elevations, amplitudes, and phasing due to channel deepening were sufficiently small that they remained undetectable with the measurement techniques used at the hydraulic model.

80. Several subtle velocity variations in the model tests were apparently due to channel deepening. An overall average decrease in velocity amplitude of about 0.13 fps was observed in the plan test. This decrease is consistent with the principle of continuity which states that for a given flow rate the velocity will vary inversely with the cross-sectional area. Similarly, the maximum flood and ebb velocities tend to decrease by approximately 0.10 fps on the average during the plan test. During the high discharge tests, the overall ebb predominance increased slightly. During the 70,000-cfs discharge tests, which represent the long-term average annual flow into Chesapeake Bay, the overall ebb predominance decreased slightly. But it must be

remembered that more than one-third of the velocity stations in this study were located in the channels, so they would feel the impact of salinity intrusion more than the shallow-water stations and would also tend to bias the overall flow predominance mean differences referred to in Table 13B. Hence, no firm conclusions concerning salinity intrusion into the estuary can be made from the velocity data. Deepening the Norfolk channels should not affect the present location of heaviest shoaling in the James and Elizabeth channels, based on the limited number of sampling stations used in this study.

PART IV: DYNAMIC SALINITY TESTING

Test Conditions

81. Dynamic salinity testing for the Norfolk Harbor study was designed so that model response to base and plan geometries could be simulated for a range of naturally occurring prototype conditions. The salinity structure of the prototype, particularly in the lower bay and James River area, is sensitive to a number of boundary conditions that can be simulated in the model. The two most important conditions are the highly variable nature of freshwater input and the cyclical neap-to-spring variations in the tides.

82. The effect of freshwater input on partially mixed estuaries is well documented in the literature. Simply stated, it has been shown in numerous estuaries that increasing freshwater input upstream tends to stratify the estuary given constant tidal conditions, while decreasing inflows provides a homogenizing effect. If the degree of stratification is not altered drastically, an increase in freshwater inflow reduces the upstream extent of salt-water intrusion and vice versa. Tidal influence on salinity structure has also been studied in the past but generally in a steady-state fashion by observing different constant amplitude tides that typify maximum and minimum variations in the tidal record.

83. However, the prototype tide record in Chesapeake Bay, as well as in other estuaries, does not consist of a series of constant amplitude tides. Tides in the Chesapeake show strong neap and spring variations as well as smaller semidiurnal differences in tide heights. The effect of this tidal variability on salinity structure was thought to be important for some time but there has been very little substantiation in the literature. The most notable prototype studies to date discussing this phenomenon are from Haas (1977) and Allen et al. (1980).

84. Haas' study area was the lower York and Rappahannock Rivers in Virginia where he found strong correlations between salinity stratification and the neap-spring tide cycle. Allen's studies were primarily confined to macrotidal estuaries in France, but his observations do support the importance of the neap-spring tide cycle on salinity structure.

85. There have been model studies that have confirmed the importance of the neap-spring cycle on salinity. Physical model studies by Richards and

Gulbrandsen (1982) and Granat and Gulbrandsen (1982) document the existence of structural salinity changes at various stations throughout Chesapeake Bay. These changes seem to be strongest in the lower bay and James River areas.

86. Ample evidence exists, therefore, to suggest that dynamic tidal and freshwater inputs are necessary to approximate prototype responses to base and plan geometries in the Norfolk Harbor areas. The Norfolk Harbor study simulated variable prototype conditions by using a 2-1/2-year weekly stepped hydrograph and a repetitive 28-lunar-day (56 cycle) variable tide. The source salinity for the model study for ease of duplication in both tests was held constant at 32.5 ppt which is appropriate for the historical drought hydrograph used. A more detailed discussion of test boundary conditions follows.

Tides

87. Source (ocean) tides used in the Norfolk Harbor study consisted of a repetitive, 28-lunar-day, 56-cycle tide sequence. The 12 harmonic constituents used to construct the tide were based on coefficients used by NOAA to predict tides at Old Point Comfort, Virginia. Once the desired tide for Old Point Comfort had been determined, it was necessary to adjust the amplitudes and phases to obtain values for the ocean source tide generated some 30 miles offshore. The ocean tide is based on the equation:

$$h(t) = A_o + \sum_{i=1}^{12} \left[a_i \cos \left(\frac{2\pi}{T_i} t - \phi_i \right) \right] \quad (3)$$

where

$h(t)$ = tide height

A_o = mean water level = -0.20 ft NGVD

a_i = constituent amplitude, ft

t = time, hr

T_i = constituent period, hr

ϕ_i = constituent phase, rad

The following are the constituent values:

No.	Constituent	Amplitude, a	Period, T	Phase, ϕ
1	M2	1.426	12.4206	2.3457
2	S2	0.276	12.0000	2.7975
3	N2	0.318	12.6584	1.9627
4	K1	0.204	23.9344	0.0743

(Continued)

No.	Constituent	Amplitude, a	Period, T	Phase, ϕ
5	O1	0.175	25.8194	0.4567
6	V2	0.061	12.6260	2.0553
7	M1	0.007	24.8332	0.3994
8	J1	0.014	23.0985	0.1355
9	Q1	0.024	26.8683	5.9859
10	P1	0.058	24.0659	0.3555
11	L2	0.040	12.1916	2.5059
12	K2	0.071	11.9672	2.6338

Example tide ranges for the source tide include 4.8 ft for tide 1, the largest spring tide, and 2.6 ft for tide 48, a smaller neap tide.

88. Figure 21 is a graphic representation of the 56-cycle tide computed from the above constituents. It contains the spring and neap tide variations and the semidiurnal inequalities noted in prototype tide records. As in the prototype, the tide is propagated up the bay and reaches Reedy Point, Delaware, at the Delaware River end of the C&D Canal approximately 16.16 hr later.

89. Prior to the start of the test, a brief lead-in period of constant tide amplitude is necessary to adjust the ocean tide control amplifier. The range of this lead-in tide reflects the values of tide 1. Once the tide amplifier had been calibrated for the lead-in tide, the variable tide was started and along with a constant discharge condition the model was brought to a state of stable density equilibrium. Upon reaching density equilibrium, the test hydrograph was started and variable tides were maintained throughout the test.

90. The strict control of boundary and initial conditions in a physical model test is of primary importance if any degree of confidence is to be attached to the results. This is especially true for base versus plan testing where model response should be related entirely to designed base versus plan changes (e.g., deepened channels) rather than any fluctuations in boundary conditions.

91. To ensure source tide integrity in both base and plan tests, the ocean tide is monitored continuously by a WLD that is hard-wired to the computer and a strip chart recorder for real-time observation. In addition, manual point gage measurements were taken twice per 56-cycle period on tides 7 and 8 and on tides 35 and 36 to confirm water levels indicated by electronic measurements.

92. The Delaware Bay source tide was not used in these tests for two reasons. First, available prototype data are inadequate to define the amplitudes and periods of the source tide and salinity under variable tidal

ATLANTIC OCEAN SOURCE TIDE FROM 12 CONSTITUENT HARMONIC ANALYSIS

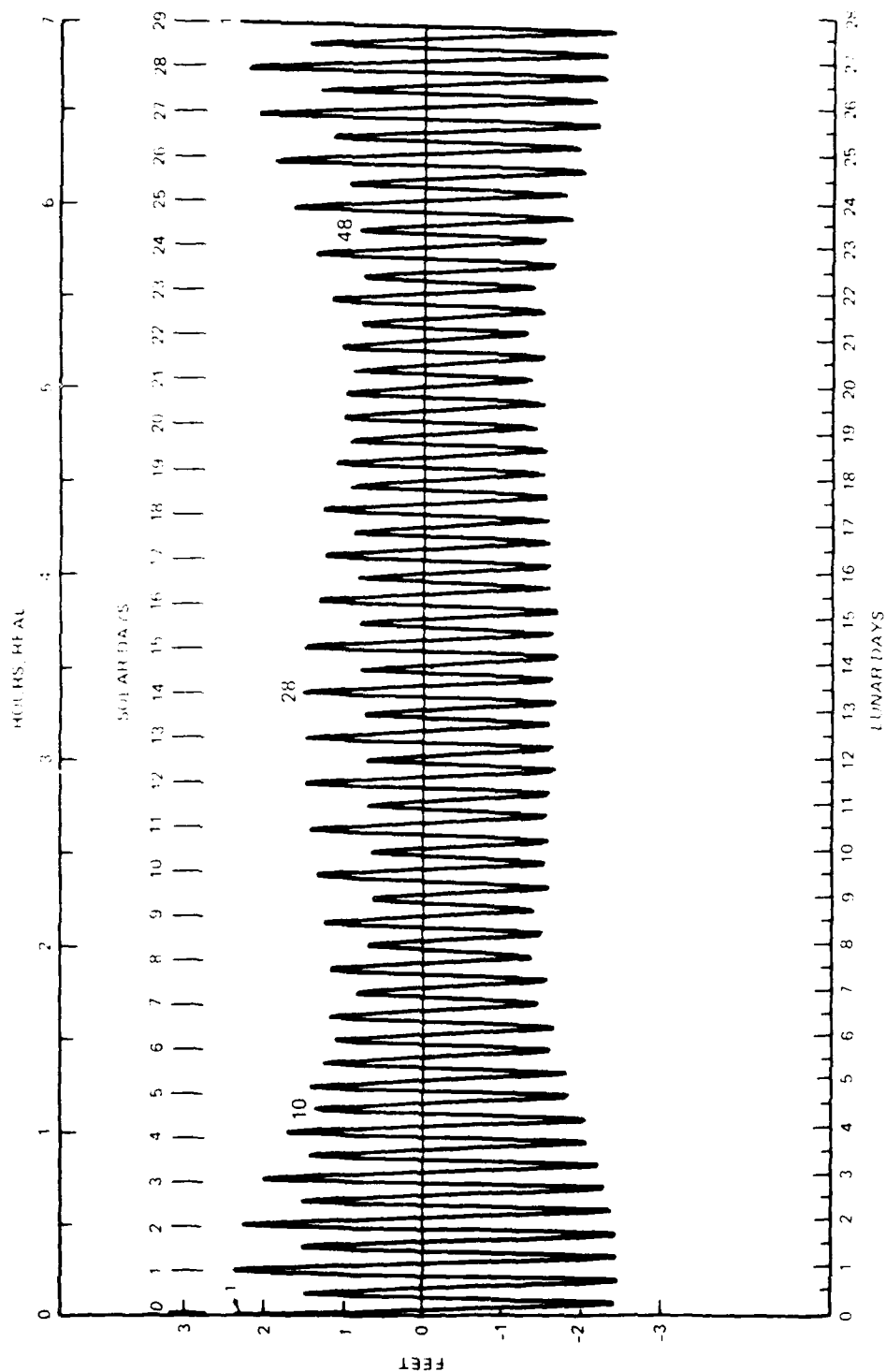


Figure 21. Ocean source variable tide showing tides 1, 10, 28, and 48

conditions in Chesapeake and Delaware Bays. Second, previous testing in the model had shown that the hydrodynamics of the C&D Canal are very sensitive, particularly to variations in mean water-surface elevation, so that even minor discrepancies in boundary control of water-surface elevations have significant impact on canal hydrodynamics and thus on salinities in the Upper Bay. Since boundary control for the source tide in Delaware Bay was not capable of preventing small discrepancies in water-surface elevations, it was decided not to reproduce the source tide for these tests so that any changes in Upper Bay salinities from the base test to the future test would not be erroneously affected by possible discrepancies in boundary control.

Freshwater inflow

93. The Norfolk Harbor test hydrograph consisted of two parts. First, there was a lead-in period (weeks 1-15) of constant discharge that reflected an average total bay discharge of 70,000 cfs. The second period (weeks 16-136) depicted weekly averaged prototype conditions between 24 May 1963 and 17 August 1965. Hydrograph plots for the total bay discharge along with the five rivers closest to the subject area are shown in Plates 145-150.

94. The 15-week constant discharge period was used to observe model stability prior to starting the historical hydrograph and salinity sampling. The ensuing historical hydrograph was used because it was an available data set and had been used largely on other Chesapeake Bay Model tests. As a whole, it reflects a period of relatively low to drought conditions on the bay. This should be considered when analyzing the data. The hydrograph does, however, have sufficiently seasonal variations in discharge to be useful.

Source salinity

95. Source salinity is defined as the salinity of supply water as it enters the headbay at the ocean. This definition was chosen to facilitate sampling and control of salinity. During varying freshwater discharges, the mixing of fresh and salt water in the model ocean causes discontinuous and variable salinities in the vicinity of the headbay. Sampling in this area can yield large changes in salinity over relatively short periods of time, especially during high freshwater discharge periods. The supply sump is a large and nearly homogeneous volume of water (analogous to the prototype ocean) that reacts slowly to a spiked hydrograph; thus it can be measured less often and with greater confidence in a single set of measurements. Salinity samples were taken hourly (4.17 prototype days) in the headbay, in the return sump, and in

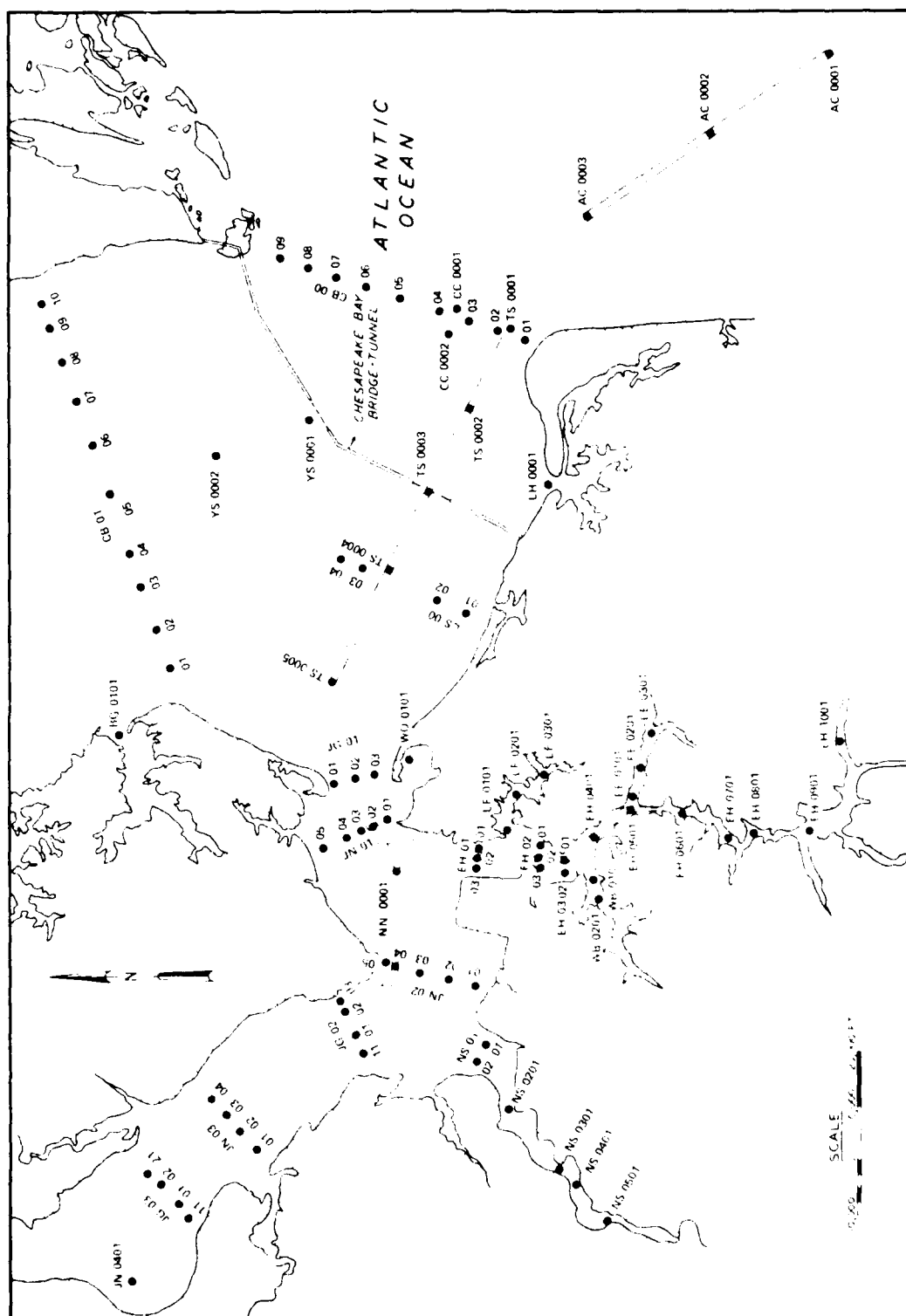
the supply sump throughout each dynamic salinity test. Testing of the three areas together helps project trends in the source salinity, and thus large drops in source salinity can be prevented by adding brine to the return sump when it shows a decline. Source salinity was kept to within ± 0.5 ppt of the desired 32.5 ppt throughout both base and plan tests.

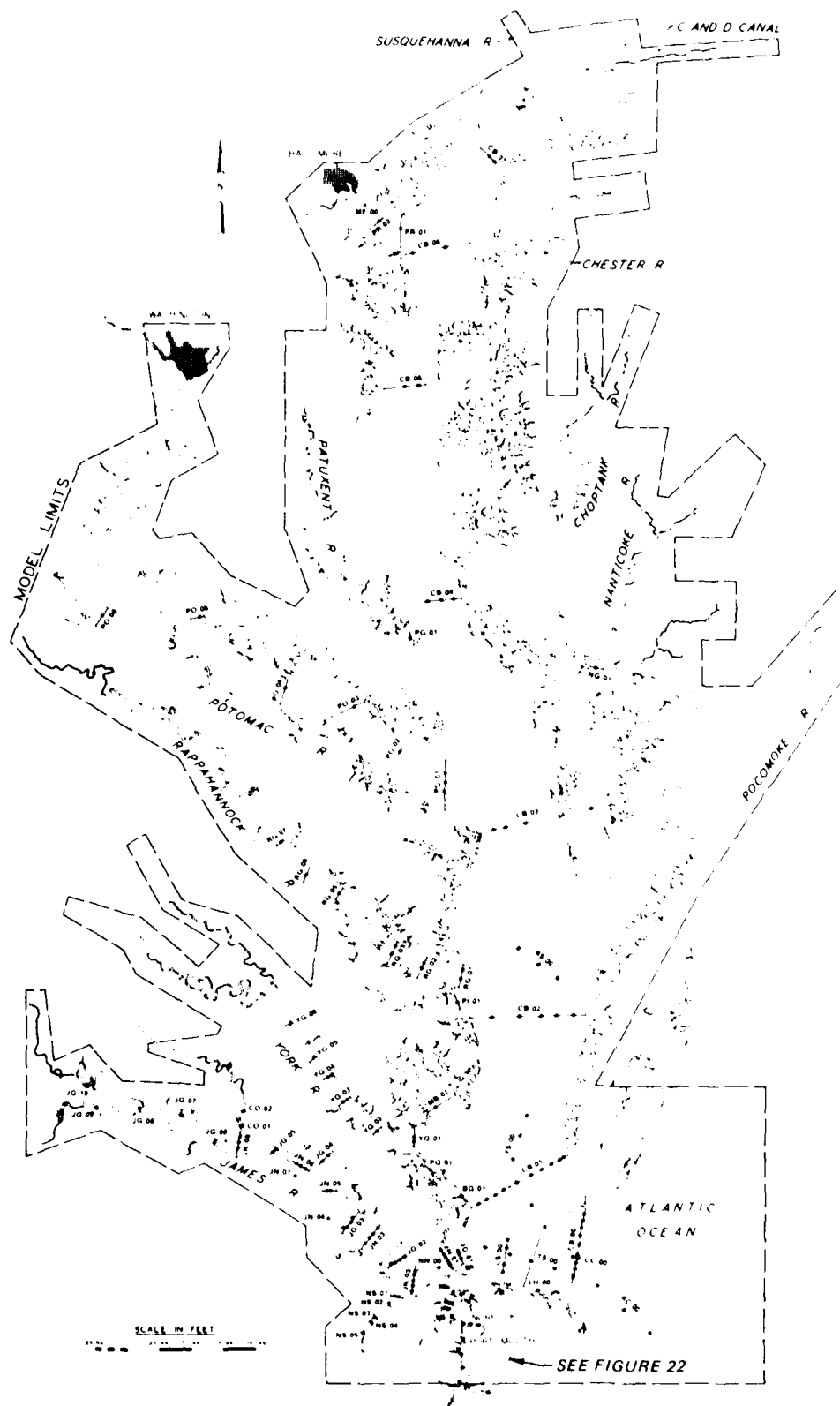
96. Sump control in general was considered good for both tests. There were short-term deviations caused by response to freshwater inflow fluctuations in both tests and did not create perceptible discrepancies in the bay salinities. The supply sump source salinity was checked a total of 269 times coincident to both base and plan tests from lunar day -146 to lunar day 933. The base and plan source salinities were within ± 0.2 ppt of each other 78.9 percent of the time, and within ± 0.5 ppt 97.0 percent of the time. Only 8 of the 269 comparisons were outside the ± 0.5 ppt range and they all occurred during the lead-in period from lunar day -29 to lunar day 3. The largest plan-minus-base difference in sump source salinity was +0.8 ppt at lunar day -9. The overall base test average source salinity was 32.49 ppt and the plan test average was 32.50 ppt.

Salinity sampling

97. It was necessary during testing to monitor the distribution of salinity within the bay to ensure that general expected patterns were developing and that anomalies in the bay were explainable within the context of the test. In order to accomplish this task, a set of 19 stability monitoring stations throughout Chesapeake Bay and the major tributaries was selected to give a general picture of baywide salinity structure. These salinity monitoring stations were not a primary part of the comprehensive testing program but were selected mainly for comparison with other studies performed at the Chesapeake Bay model. The salinity monitoring stations were used to determine when the model had reached the dynamic salinity equilibrium required for test initiation and were a real-time test monitoring aid. Samples were taken at slack after flood at each of the 19 salinity monitoring stations on every tide 3 and every tide 30 throughout the tests. The samples were analyzed immediately and hand-plotted to facilitate rapid analysis. No abnormalities in density structure were observed in either test and, consequently, confidence in their comparability is high.

98. Salinities in the bay were sampled at individual stations at from one to five depths per station (Figures 22 and 23 and Table 14). Approximately





500 samples were taken at each sampled tide. The sampled tides were 1, 10, 28, and 48 at slack after flood which represent high-spring, mean, low-spring, and neap tides, respectively (Figure 21). In all, 57,041 samples were collected in the plan test and 55,331 were collected in the base test. The number of additional samples for the plan test was due to additional sampling in the deepened channel.

Salinity Data Analysis

99. The purpose of the dynamic salinity tests was to determine what impact the deepened channels would have on the salinity distribution within the Chesapeake Bay system. Salinity sampling stations were positioned at 193 locations throughout the model so that the effects on the entire system could be determined. The majority of the stations were located near the project area in the lower bay and James River with care taken in the selection process so that biologically sensitive areas would be covered. Locations of the sensitive areas were provided by the Virginia Institute of Marine Science (VIMS) along with suggestions for nearby sampling locations. Where physically possible, these locations were used.

100. Performing a detailed data analysis on 193 stations and presenting the results in a technical report is an arduous and unnecessary exercise. Data from all 193 stations were inspected for base-to-plan salinity differences and a more reasonable number of stations were selected for a detailed analysis and presentation in this report. Data from 65 stations are presented in this report along with various graphical plots that were used in the data analysis. The stations chosen for inclusion in this report provide an adequate coverage of the entire bay with more stations selected from areas which showed notable base-to-plan salinity changes.

101. Salinity data were primarily analyzed by using several graphical techniques which are included in this report. First, the data were displayed from both tests in multidepth time-histories beneath a total bay discharge freshwater hydrograph (Plates 151-215). The time-histories display the entire data set at 65 stations and are useful for observing changes in the vertical salinity structure resulting from hydrographic and tidal variations.

102. Contained in the same plates are displays of plan-minus-base differences at surface and bottom and plan-minus-base depth-averaged differences, both plotted against the same time scale. When a data point was missing from

one or both tests no difference was listed, thereby resulting in discontinuities in the plotted curves. At stations within the deepened channels, an additional depth was included in the plan test showing the deeper bottom. Bottom differences were calculated using the deepest depth at a station for each test.

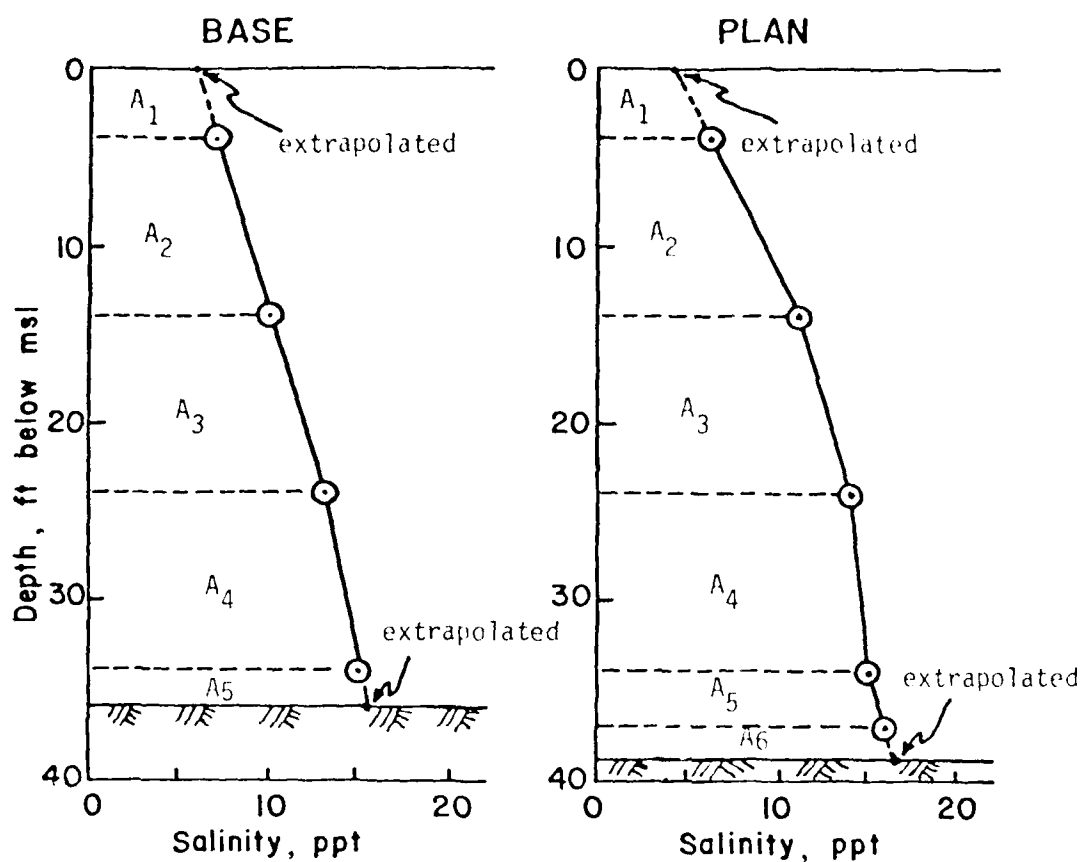
103. Salinity depth-averages were computed to determine the net salinity change integrated over the water column at various locations in the bay resulting from channel deepening. It should be firmly stated that one should not view depth-averaged differences as the single most important indicator of base-to-plan salinity differences. This method does not satisfactorily consider increased vertical stratification that often accompanies channel deepening. For a bottom dwelling organism, this is a crucial consideration. Base and plan depth-averages were computed as shown in Figure 24. There are some errors that are intrinsic to this method. Salinities at the surface and bottom boundaries are computed by extrapolation from the two adjacent depths. This is not accurate in any rigorous sense but it is a reasonable approximation that is applied in a similar fashion in both base and plan tests. When differences are computed, the effects of this error are minimized. In order to avoid the introduction of additional errors, the depth-averaging algorithm only considered those stations having a complete set of salinities for both base and plan tests at a given point in time. In other words, if a salinity value was missing from a certain depth at a given point in time, no depth-averaged salinity difference was computed. This accounts for the gaps in the depth-averaged difference plots (e.g., Plate 152).

104. The previously mentioned methods are adequate for observing base-to-plan differences at one station over time but do not allow a picture of salinity changes in a longitudinal or transverse sense. For this reason, longitudinal isohaline profiles were drawn using data sampled from the four tides of the neap-spring cycle during both high and low discharge periods.

Salinity Results

Model accuracy and repeatability

105. Prior to any discussion of the impacts of channel deepening on salinities in the bay, it is prudent to discuss the accuracy and repeatability of salinity data measured in the model. The term accuracy refers to closeness



$$\overline{\text{SAL}} = \frac{\sum_{i=1}^n A_i}{D}$$

$$\text{or } \overline{\text{SAL}} = \frac{\sum_{i=1}^n \left[\frac{1}{2} (\text{SAL}_i + \text{SAL}_{i+1}) (d_{i+1} - d_i) \right]}{D}$$

where $\overline{\text{SAL}}$ = depth-averaged salinity, ppt

SAL_i = salinity at depth i , ppt

d_i = depth i in feet below msl

D = total station depth, ft

Figure 24. Definition sketch: depth-averaged salinity

of salinity values measured in the model to the "true" values occurring in the prototype given that both model and prototype experience identical boundary conditions. The level of accuracy of the Chesapeake Bay model will never be exactly known because it is virtually impossible to reproduce in the model all the boundary conditions affecting the prototype (wind, rain, ship movement, Coriolis force, etc.). However, by considering the major forces affecting the hydrodynamics of the bay (variable tide, river inflows, and ocean source salinity), an approximation of the level of accuracy is possible.

106. The model has undergone two lengthy verification tests. The initial verification was accomplished in 1978 (Scheffner et al. 1981) and a re-verification in 1981 (Granat et al. in preparation) following extensive concrete repairs prior to the Norfolk Harbor study. Although direct comparability between individual model and prototype data points is not always possible due to different boundary conditions and other differences, these verification tests have shown that the model does a good job of reproducing the seasonal salinity variations resulting from a dynamic freshwater hydrograph and the neap-spring tide cycle. When used to determine base-to-plan salinity differences under similar boundary conditions, the model is accurate to within ± 1 ppt. Certainly not every measured data point will be accurate to within these limits, but the overall accuracy of the estimation of salinity changes resulting from channel deepening will be on that order. Further discussion of the individual inaccuracies that combine to form the ± 1 ppt accuracy level is lengthy and will not be addressed in this report.

107. A closely related and equally important aspect of model testing is the repeatability (or precision) of model results. Here repeatability refers to the closeness to one another of different sets of model salinity measurements taken under the same boundary conditions. Ideally, it would seem rational in both base and plan tests to bring the model to the same state of dynamic salinity equilibrium prior to initiation of testing using the same start-up procedure. In this manner, one can be assured that any base-to-plan salinity differences are the result of channel deepening and not due to some inconsistency in the model start-up procedure. However, there is an interesting dilemma springing from this approach. Will the model, having different base and plan geometric configurations with the deepened channels, be able to reach the same salinity stability under boundary conditions that are in every other way equivalent? A close inspection of base-versus-plan lead-in

salinities and a good deal of model experience are required in order to satisfactorily answer that question.

108. This dilemma is of particular importance to the Norfolk salinity tests. Both the base and plan tests were brought to stability in a similar fashion by initially flooding the model with fresh water and then introducing saline water from the ocean source via a variable tide generated at the ocean. Despite the desired strictness of control in the start-up of both base and plan tests, variations in the rates of fresh- and saltwater introduction were noticed between tests which resulted in different salinity distributions at equivalent points in time. Due to differences in the model start-up procedures and perhaps to a much lesser extent the different model geometries, the model did not reach salinity stability in the same period of time for the plan test as in the base condition. From past experiences with the model, it was decided that an additional day (200 tide cycles) of lead-in time was needed in the plan condition to obtain a state of stability similar to the base condition. After the additional day of lead-in, the overall plan salinities were approximately 0.5 ppt higher than the base salinities. The primary study area in the lower bay and James River areas had very similar base and plan salinities at this time, while areas showing the maximum lead-in differences were distant from the study area in the middle and upper bay. By the end of testing, the overall base-to-plan salinity difference at the stability monitoring stations was near 0.0 ppt. The net effect of differing salinity beginning conditions caused by dissimilar base-to-plan start-up procedures would be to slightly overestimate the magnitude of any increased salinities in the plan test. The areas showing the greatest base-to-plan lead-in differences will be discussed in more detail later in this report.

Neap-spring salinity variations

109. One of the purposes of this model study was to determine what differences in salinity structure could be associated with the proposed channel deepening project. Findings from the study would ultimately be used to determine if the project has any adverse effects on the environment, and if so, perhaps the benefits of the project would be reassessed. Channel deepening often alters the salinity structure of estuaries. In most cases, the net effect would be to increase salinity intrusion on the bottom with increased vertical salinity stratification. Net increases in salt averaged over the water column are sometimes evident as well. It becomes the task of local authorities to

ultimately determine whether or not the noted changes could adversely affect the estuary, most particularly the biota. This test was designed to determine over time the nature and magnitude of salinity variations caused by the channel deepening so that these values could be provided to local authorities for their planning purposes. However, before any degree of concern is placed on salinity differences reported herein, an understanding of the prototype through its physical model representation is needed especially if there are naturally occurring salinity variations which make the magnitude of base-to-plan differences comparatively small.

110. The lower Chesapeake Bay along with the James, York, and Rappahannock Rivers experience tidally induced salinity variations that have been noticed in the prototype (Haas 1979) and confirmed in the Chesapeake Bay model. The neap-spring variations, as they are called, occur when lower amplitude tides (tides 28 and 48) allow stratification in the water column followed by larger range tides (tides 1 and 10) which mix the column again. Intertidal salinity changes of as much as 5 to 8 ppt are common at a single depth along with depth-averaged salt variations of 3 to 5 ppt (Figures 25-27). Extreme variations, such as at sta JG2302 (Figure 25), can result in variations of depth-averaged and bottom salinity changes of 9 ppt and 14 ppt, respectively. Neap-spring changes in the project area appear to be greatest during periods of high discharge when the vertical density gradient is the strongest. A definition sketch showing the relationship between the neap-spring tide cycle and salinity variations is given in Figure 28 (from Richards and Gulbrandsen 1982).

111. The time-histories in Plates 151-215 illustrate that this phenomenon is present throughout the model to various degrees with the strongest variations located in the vicinity of the project area. From each reach of the deepened channels, a representative station was chosen and displayed in Figures 25-27. Sta AC0002 is located in the Atlantic Ocean Channel, TS0004 in the Thimble Shoal Channel, JN0103 in the Norfolk Harbor Channel, and EH0601 upstream in the Elizabeth River. Sta JG2302 in the James River was chosen because it is the most extreme example of variations, and sta CB0404 in the middle bay shows very little if any neap-spring variation.

112. The mechanism responsible for causing neap-spring variations is not suitably described in the literature nor is it sufficiently understood. From the observations of data from various model tests including the Norfolk Harbor study, it appears to occur in areas that contain large vertical density

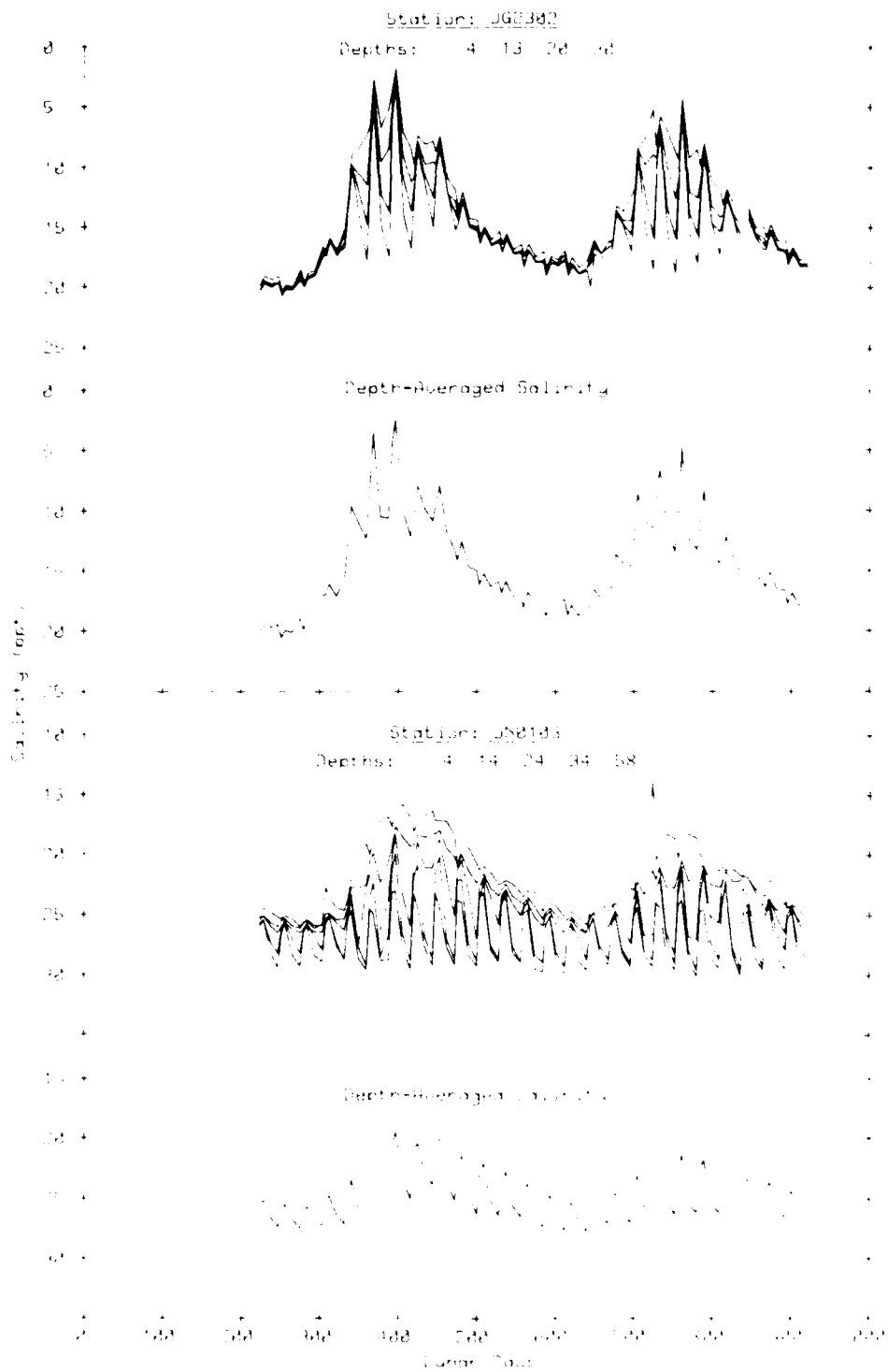


Figure 25. Typical neap-spring and seasonal salinity variations in the lower James River

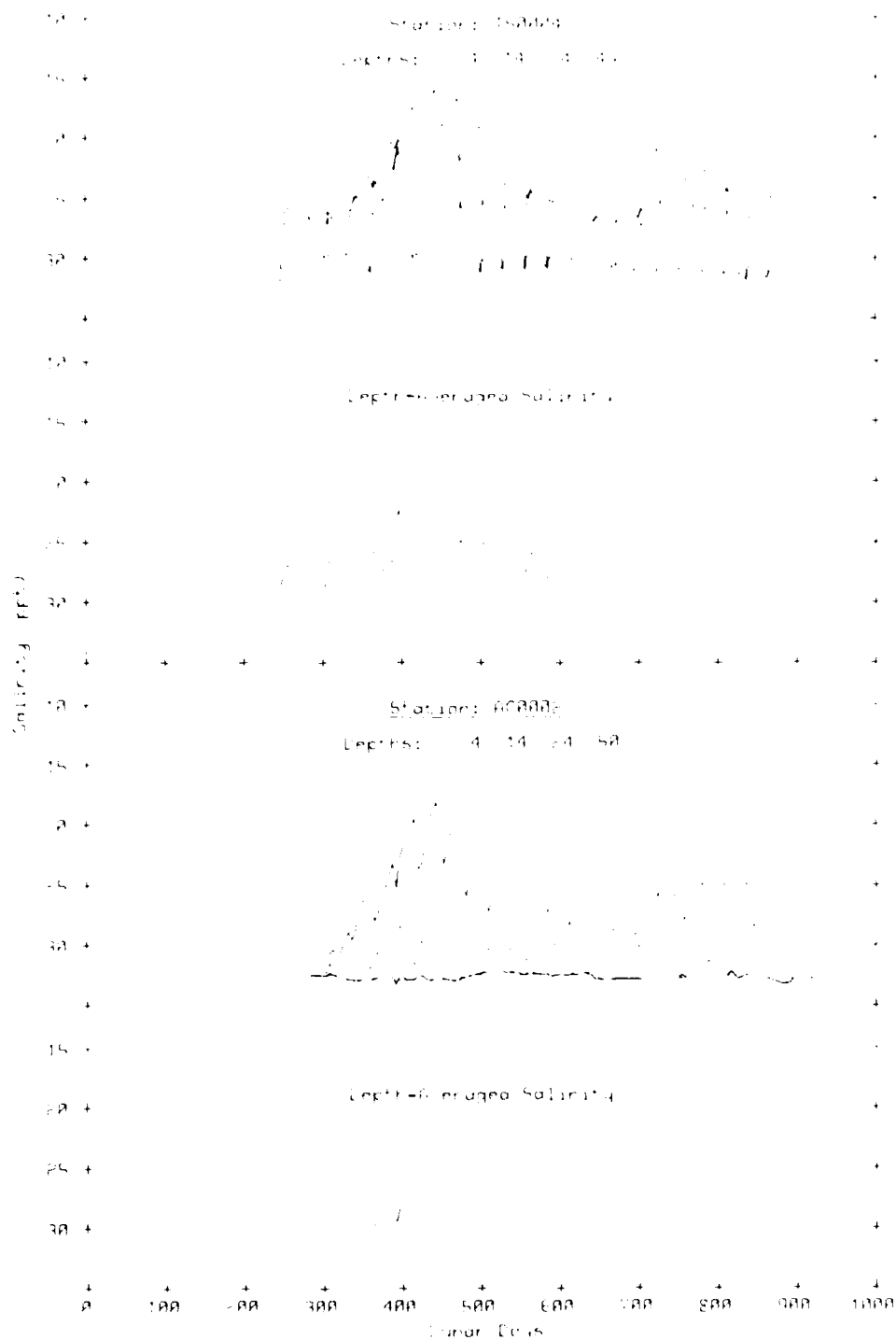


Figure 26. Typical neap-spring and seasonal salinity variations in the lower Chesapeake Bay and Atlantic Ocean

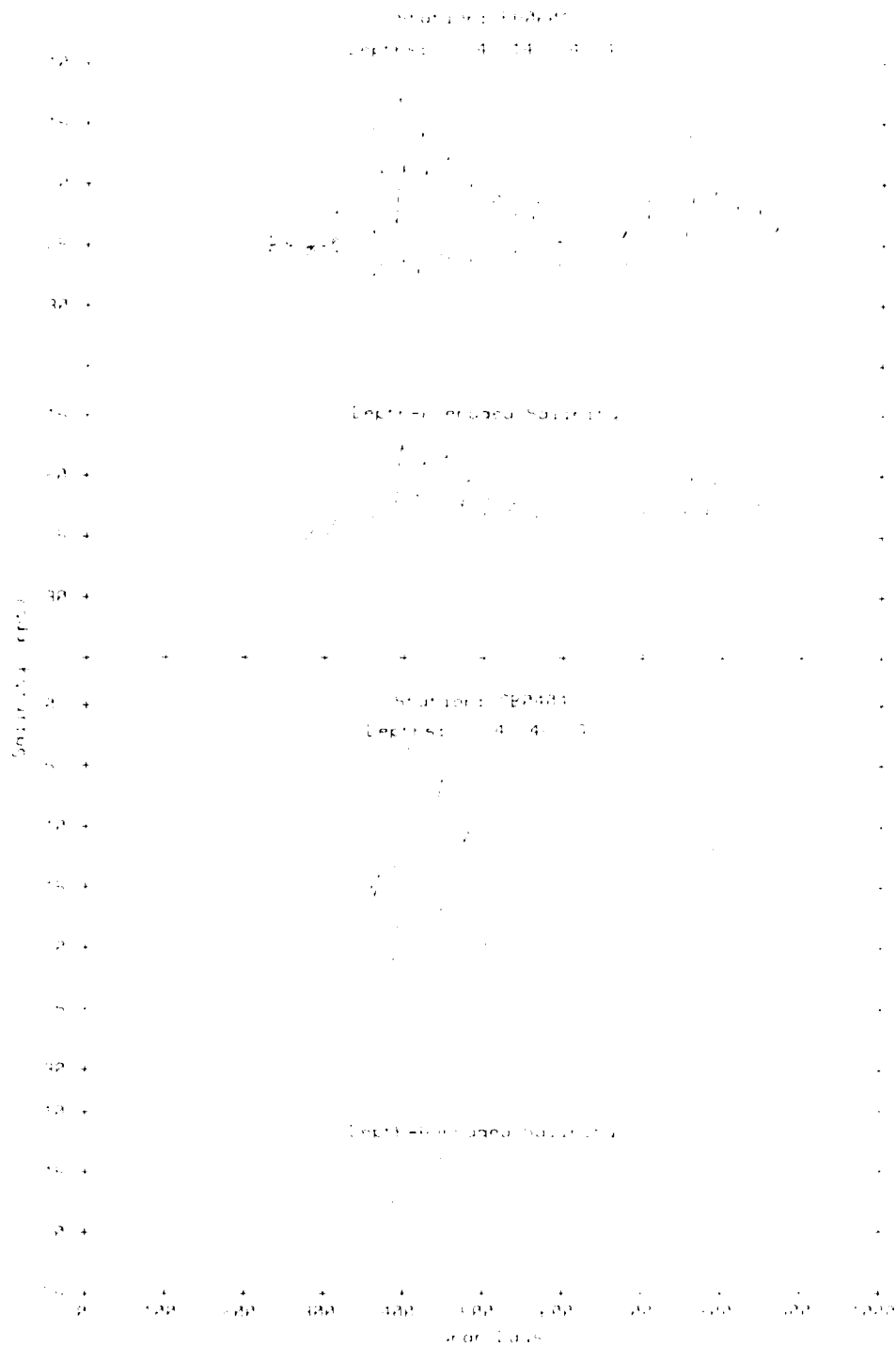
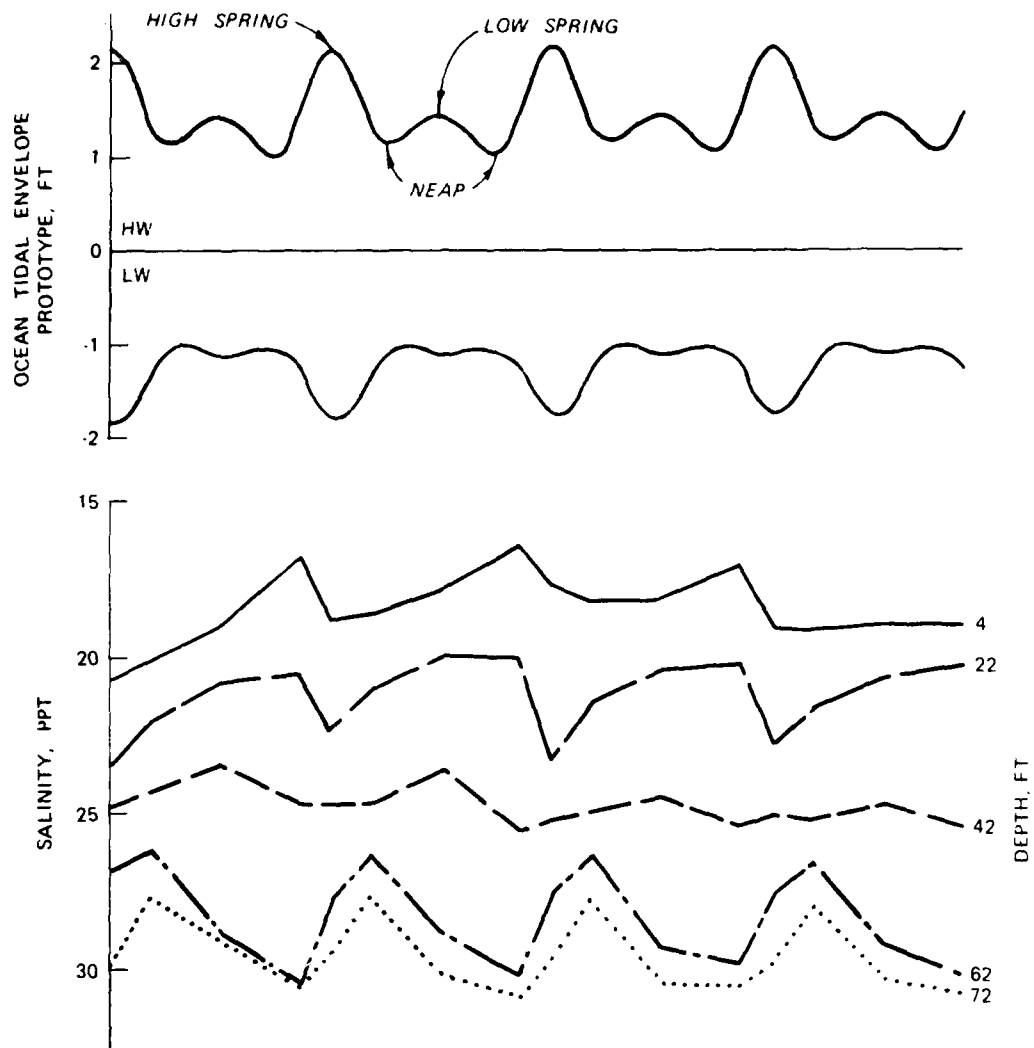


Figure 27. Typical neap-spring and seasonal salinity variations in the Elizabeth River and mid-bay regions



STATION CB-01-09

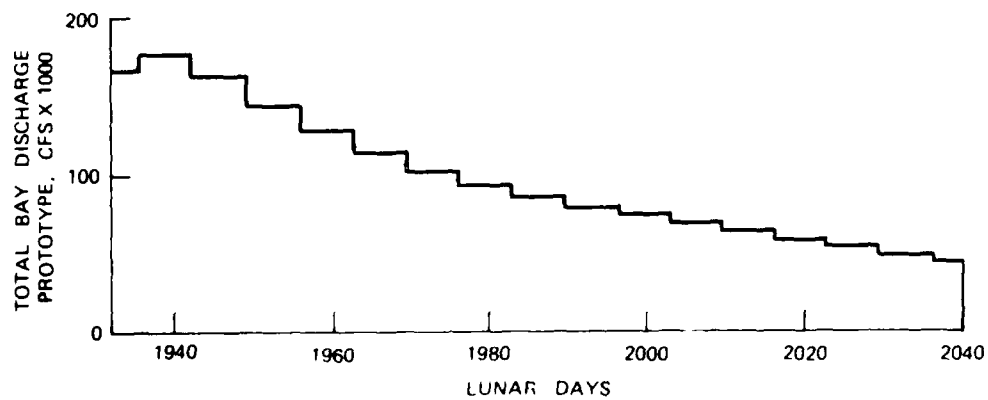


Figure 28. Definition sketch showing salinity response to neap-spring tidal variations

gradients which, of course, are noticed in the lower bay and Virginia rivers. This thesis seems to be supported by the observations that when neap-spring variations occur at a station throughout a time-history, they are greatest during high discharge conditions when the water column is most stratified (Figure 24).

113. The major emphasis in this discussion is that organisms which live in the project area should be adapted to survive neap-spring changes in salinity without significant stress to their populations. Neap-spring salinity changes have existed for ages and will continue to do so unless massive geometric changes and/or flow suppression schemes are implemented by man or nature. Nevertheless, the plan condition in this test was analyzed for structural changes in this neap-spring tide cycle.

Discharge-induced salinity variations

114. Variations in the supply of fresh water to the estuary are also a source of naturally occurring salinity variations. Periods of high discharge during the winter and spring seasons generally freshen the entire water column with an increased vertical salinity stratification. With the approach of the summer and early autumn low-flow periods, the salinity in the entire water column gradually increases and the overall stratification decreases. Longitudinal salinity structure changes induced by freshwater flow variations are very large at times, especially in the higher discharge rivers of the bay. Smaller discharge rivers also experience structural changes related to the hydrograph but to a lesser extent due in part to the fact that tidal flows in and out of the river are large in comparison with freshwater discharge.

115. The James River shows the largest seasonal variations in salinity in the study area. It is one of the higher discharge rivers on the bay (Plate 149), and the range of flow magnitudes between high and low conditions is great. The flushing effect of a high discharge rate can be observed in the James River longitudinal isohaline profiles (Plates 216 and 217). In general over all tidal conditions, the 1-ppt isohaline is located approximately 125,000 ft (23.5 miles) farther downstream during the high-flow period than during the low-flow period. Similarly, the 15-ppt isohaline is about 50,000 ft (9 miles) farther downstream during the high-flow conditions.

116. The Elizabeth River can be classified as a low discharge river (Plate 150). Flows in and out of the river are largely tidal in nature and as a result the Elizabeth is a rather well-mixed estuary with the 20-ppt isohaline

extending upstream to sta EH1001 during the low-flow period (Plate 218). The Elizabeth River does not exhibit the well-defined "wedge" of salinity that was observed moving upstream and downstream in the James River with changes in freshwater flow magnitude. However, the estuary clearly becomes much more stratified during the high-flow period (Plate 219). The 20-ppt isohaline in the vicinity of sta EH1001 is replaced by a 6- or 8-ppt isohaline. During the high-flow period, the surface salinities along the estuary are 8 ppt or more fresher than during the low-flow period, but bottom salinities are only about 1 ppt fresher.

117. The Atlantic Ocean and Thimble Shoal Channels are located in open areas of the bay and ocean and do not have a single, most predominant source of fresh water. They do, however, experience similar longitudinal reactions to the variable hydrograph (Plates 220 and 221) observed in the James and Elizabeth Rivers. In the upper water column near sta TS0005, the 17- to 20-ppt isohaline which is present during high-flow conditions is replaced by a 25- to 26-ppt isohaline in the low-flow period. At the bottom, the 31-ppt isohaline remains in essentially the same position during both high- and low-flow periods at tides 1 and 10. However, at tides 28 and 48 the 31-ppt isohaline intrudes about 50,000 ft farther upstream in the Thimble Shoal Channel during low-flow periods. The strength of neap-spring variations in this region is dominant as was shown in Figure 26.

Base-to-plan salinity differences

118. With an understanding of the dynamic nature of the lower bay under undeepened existing conditions, we can now address changes in salinity structure which may be expected with the proposed channel deepening. Changes that occurred in the deepened plan condition were examined in four ways: (a) plan-minus-base differences at each depth (most importantly the bottom depth), (b) plan-minus-base differences in depth-averages, (c) channel versus shallow-water redistributions of salinity, and (d) plan versus base changes to the neap-spring salinity response. Each of these will be discussed separately. It should again be stated in this discussion of differences that no significant changes due to channel deepening were noticed in the model north of range CB01. Any changes that are displayed in the plates are the result of boundary and initial condition problems in model control and not channel deepening.

119. Plan-minus-base differences at each depth were plotted through

time in Plates 151-215. It would be convenient to generalize on the nature of salinity differences, but it is difficult because each individual station lies in a portion of the estuary where freshwater and tidal flows have different relative strengths as well as different local geometries. Each station should be inspected individually for differences at depth with the realization that there is noise in the data set so no particular significance should be assigned to any one point. Also it should be realized that the degree of model density stability increases with time so data collected in the later portions of the test are more realistic in predicting differences. It is safe to generalize that channel stations showed increased bottom salinities with an overall increase in vertical salinity stratification. Shallow-water areas and channels that were not deepened showed less structural variations and less increased salinity than deepened-channel stations. Figures summarizing those findings will be presented later.

120. Depth-averages were computed to predict what net imports or exports of salt could be expected in the project area. Results from 65 study stations were grouped into five categories describing the average net increase or decrease in depth-averages throughout the test. The following summarizes the observed changes.

			Net Increase, ppt			Net Decrease
			0.51 to	1.01 to	1.51 to	ppt
			1.00	1.50	2.00	0.00 to 0.50
AC0002	JG0601	PG0101	EE0101	EH0202	EH0102	CB0002
CB0109	JN0104	PO0202	EH0401	EH0501		CB0008
CB0208	JN0201	RG0102	EH0901	EH0601		JN0101
CB0303	JN0202	RG0202	EH1001	EH0701		JN0103
CB0404	JN0203	RG0501	JG0203	EH0801		JN0105
CB0505	JN0502	TS0002	JG0302			JN0205
CB0611	JN0603	WB0201	JN0102			LF0101
CB0705	JN0801	WO0101	JN0204			LS0001
CG0101	MF0001	YG0102	JN0303			LS0002
EH0301	NS0101	YG0302	NN0001			LS0003
JG0103	NS0201	YG0501	TS0004			LS0004
JG0402	NS0301					
JG0502	NS0401					

121. As shown in the preceding list, stations upstream of range CB01 as well as the upper James River show little if any changes in their depth-averaged salinity. Channel stations in the Elizabeth and lower James Rivers along with the upper end of Thimble Shoal Channel show noticeable average net salinity increases from 0.5 to 1.7 ppt. Some stations, primarily in

shallow-water areas, actually showed depth-averaged freshening in the plan test although very slight, always less than 0.5 ppt fresher.

122. The freshening of shallow-water areas in the Horseshoe Shoal area is an example of a transverse redistribution of salt in the cross section due to channel deepening. Freshening rarely occurred at any of the stations unless they were adjacent to a deepened channel area. Figure 29 shows depth-averaged differences across the Horseshoe Shoal transect (LS0001-LS0004) with sta TS0004 (Figure 22) being the deepened station. The 1-ppt approximate increase in depth-averaged salinity at sta TS0004 and the slight freshening at sta LS0001, LS0002, LS0003, and LS0004 illustrate this point. During the first high-flow season, the redistribution is particularly strong. Other transects show a similar response to varying degrees in both the bottom differences and depth-averaged differences plots.

123. Bottom differences were one of the most important results of the study. It is on the bottom where certain biota, particularly shellfish, are particularly susceptible to adverse salinity changes. Maps summarizing bottom differences for the various tide and hydrograph conditions are given in Plates 222-236. These plates show that channel deepening increases salinity along the bottom of the channels by up to 4.0 ppt, but shallow-water areas and undeept channels show very little change. In fact, outside of the Elizabeth and lower James channel areas, increases were rarely as great as 1 ppt for any tide or hydrograph condition tested.

124. The bottom differences discussed thus far are viewed at discrete points in time during particular tidal or hydrographic conditions. It is also important to view the change in the bottom variations through time to detect any possible change to the neap-spring salinity response. Changes to the neap-spring response are most important on the bottom for previously stated reasons. They are also easily observable on the bottom.

125. An inspection of the base and plan time-histories in Plates 151-215 will reveal the magnitude of the cyclic neap-spring response on the bottom depths. For example, in Plate 163, sta EH0102 shows a different neap-spring response between base and plan conditions. The base contains an approximate 3- to 4-ppt variation throughout the hydrograph while the plan shows only a 2- to 3-ppt range. This damping of the tidally induced neap-spring response on the bottom is prevalent in the deepened channel areas of the Elizabeth River. From sta EH0102 upstream to EH0801, the damping is fairly consistent with base

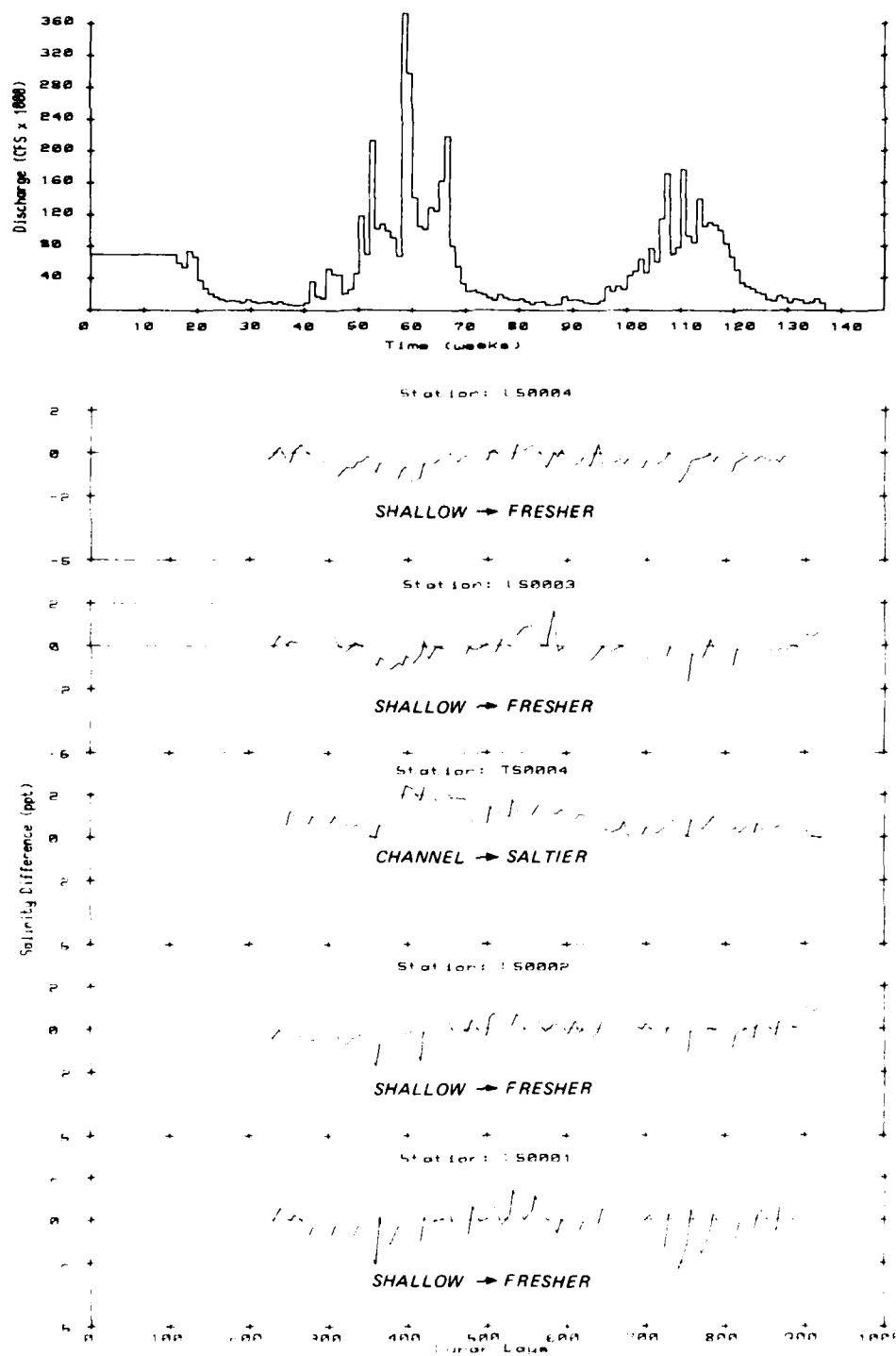


Figure 29. Depth-averaged salinity redistribution across the Horseshoe Shoal transect

ranges varying between 2 and 3 ppt and the plan between 1 and 2 ppt. On the average, a 1-ppt damping was noticed with the exception of sta EH0301 which showed an increased bottom range. This station, however, exists in a portion of the river which was not deepened. Both base and plan tests had their salinity probes located at the same depths. The observation of increased bottom range in the plan condition at sta EH0301 is consistent with the 48-ft depth downstream at sta EH0202 and the 44-ft depth upstream at sta EH0401. Both experienced slight range increases in what were the base bottom depths.

126. Since three channel sections were dredged in the lower bay and James River area it is interesting that only the deepened portions of the Elizabeth River showed any distinguishable changes in the neap-spring salinity response. A possible explanation for this observation stems from the fact that each of the channel sections, Thimble Shoal, lower James River, and the Elizabeth River, lie in radically different portions of the estuary. The James River is a high discharge river with broad transverse dimensions compared with its relatively narrow navigation channel widths. The Thimble Shoal Channel lies in the lower bay where the significant freshwater influences of the James and other rivers are felt plus again it has a narrow navigation channel in a broad cross section. Both are highly dynamic zones of turbulent mixing with strong freshwater and tidal mixing inputs and strong current velocities. The Elizabeth River, by contrast, is a narrow river with negligible freshwater input, weak current velocities, and its deepening represents a larger portion of its total conveyance area. Relatively little mixing is present with successive neap and spring tide cycles having little influence on the bottom current velocities and thereby these salinities.

127. The biological ramifications of a damped neap-spring response are worthy of consideration. A variety of organisms can tolerate increases or decreases in salt concentration provided they are of limited duration. The damped neap-spring response along with the slight increase of bottom salinities could place a number of species in a stressful position. Biologists would have to determine the tolerance levels for each species versus the changes predicted in this report. Normally, shellfish are of the most concern in deepening studies both because of their bands of salinity tolerance and those of their predators. One heartening fact observed in viewing the data is that where changes do occur either by absolute or in a time-varying neap-spring fashion, they inevitably occur in nonactive biological areas in the

deep channels. Shallow-water areas where most shellfish thrive were relatively unaffected by this deepening project especially when compared with the magnitude of natural salinity variations which already occur in the base condition.

PART V: CONCLUSIONS

128. Changes in tidal elevations, amplitudes, and phasing which may be due to the effects of channel deepening were sufficiently small that they were undetectable with the measurement techniques used at the hydraulic model. Model measurement techniques are of sufficient accuracy that significant changes would have been noticed; therefore none are expected.

129. Several subtle velocity variations in the model tests were apparently due to channel deepening. An overall decrease in velocity amplitude of about 0.13 fps was noticed during the plan test. This is consistent with the principles of continuity, but the magnitude of change is close to the accuracy limitations of model instrumentation. Slight increases in flood predominance were noticed under average inflow conditions indicating perhaps that salinity intrusion may move upstream in the study area. This observation is consistent with the observed increased salinities. Overall changes in model velocities could be attributed to the effects of channel deepening but the magnitude of the changes is barely detectable.

130. Variations in the model salinity distribution were noticed that could be attributed to channel deepening. The greatest differences were noticed in the deepened channel areas where increases in the bottom salinities varied between 0 and 4.0 ppt. Channel depth-averaged increases varied between 0 and 2 ppt. Shallow-water areas near the deepened channels experienced much less of a salinity increase. At times there was actually a slight freshening of the shallow waters. Stations elsewhere in the model showed modest increases in depth-averaged salinity but were normally less than 0.5 ppt.

131. The salinity tests documented the locations of stations in the study area that exhibit large (commonly as great as 5 to 8 ppt) salinity changes due to the neap-spring tide cycle. The entire study area experienced these variations that are naturally occurring and not caused by channel deepening. Channel deepening did, however, cause a slight change in the neap-spring salinity response. It was characterized by a damping of the cyclical salinity variations in the bottom depths of the Elizabeth River. Elsewhere, little if any neap-spring changes were detectable.

132. The intention of this report and its accompanying data set is to furnish biologists and planners with the information necessary to assess the impacts of the proposed deepening project on the environment. Almost all

deepening projects cause some degree of environmental change and this project is no exception. Every effort has been made to quantify the extreme natural salinity variability in the project area resulting from hydrographic and tidal variations. Before any value judgments are made pertaining to the benefits of the dredging versus any possible environmental concerns, a good knowledge of the region's natural variability should be obtained. The variations in salinity response caused by channel deepening are small compared with the variations that occur naturally in the region.

REFERENCES

- Allen, G. P., et al. 1980 (Apr). "Effects of Tides on Mixing and Suspended Sediment Transport in Macrotidal Estuaries," Sedimentary Geology, Vol 26, pp 69-90.
- Granat, Mitchell A., and Gulbrandsen, Leif F. 1982 (Feb). "Baltimore Harbor and Channels Deepening Study; Chesapeake Bay Hydraulic Model Investigation," Technical Report HL-82-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Granat, Mitchell A., et al. "Reverification of the Chesapeake Bay Model; Chesapeake Bay Hydraulic Model Investigation" (in preparation), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Haas, Leonard W. 1977. "The Effect of the Spring-Neap Tidal Cycle on the Vertical Salinity Structure of the James, York, and Rappahannack Rivers, U.S.A.," Estuarine and Coastal Marine Science, Vol 5, pp 485-496.
- Richards, David R., and Gulbrandsen, Leif F. 1982 (Jan). "Low Freshwater Inflow Study; Chesapeake Bay Model Investigation," Technical Report HL-82-3, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Scheffner, Norman W., et al. 1981 (Dec). "Verification of the Chesapeake Bay Model; Chesapeake Bay Hydraulic Model Investigation," Technical Report HL-81-14, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Schultz, E. A., and Simmons, H. B. 1957 (Apr). "Fresh Water-Salt Water Density Currents, A Major Cause of Siltation in Estuaries," Technical Bulletin No. 2, Committee on Tidal Hydraulics, Corps of Engineers, U. S. Army.
- U. S. Army Engineer District, Norfolk. 1980 (Jul). "Norfolk Harbor and Channels, Virginia-Deepening and Disposal Feasibility Report," Norfolk, Va.
- Waltz, P. A., and Morton, M. R. 1982. "Norfolk Harbor and Channels Deepening Study; Hydraulic Model Boundary Control and Data Presentation Report," Acres American, Inc., and Tetra Tech, Inc.; Report on file at U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., and U. S. Army Engineer District, Baltimore, Baltimore, Md.

Table 1
Sewage Treatment Plans (STP) and Other Diversions

<u>I.D.</u>	<u>Name</u>	<u>Tributary</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Discharge cfs</u>
A	James River STP	James River	37°04'35"	76°32'20"	26
B	Boat Harbor STP	James River	36°37'30"	76°24'48"	34
C	Army Base STP	Elizabeth River	36°55'20"	76°20'10"	23
D	Lamberts Point Outfall	Elizabeth River	36°52'58"	76°24'00"	50
E	Chesapeake - Elizabeth STP	Little Creek	36°56'35"	76°10'17"	40
-	Surry Nuclear Cooling Intake	James River	37°09'33"	76°40'15"	3740*
-	Surry Nuclear Cooling Outfall	James River	37°10'09"	76 42'11"	3740*
TOTAL					173*

*The discharge of 3740 cfs for the Surry Nuclear Power Plant cooling diversion was not added to the model, but was instead circulated from the downstream side of Hog Island to the upstream side to simulate prototype conditions. Hence, the 3740 cfs is not included in the total.

Table 2
Freshwater Discharges
Steady-State Velocity and Tide Tests

Inflow Number	Tributary	Discharge, cfs	
		Tests 1 & 2	Tests 3 & 4
1	Nansemond River	1,063	372
2	Chickahominy River	826	289
3	Appamattox River	2,763	967
4	James River	20,711	7,249
5	York River	7,597	2,659
6	Rappahannock River	8,120	2,842
7	Wicomico River (Potomac)	1,177	412
8	Occoquan Creek	6,771	2,370
9	Anacostia River	1,663	582
10	Potomac River	21,997	7,699
11	Patuxent River	2,517	881
12	Severn River	660	231
13	Patapsco River	1,751	613
14	Gunpowder River	2,291	802
15 & 22	Susquehanna River	106,335	37,217
16	Bohemia River	1,103	386
17	Chester River	1,434	502
18	Wye River	543	190
19	Choptank River	2,334	817
20	Nanticoke River	4,626	1,619
21	Pocomoke River	2,849	907
23	Elizabeth River	869	314
	Total Bay Discharge	200,000	70,900

Table 3

Tide Station Locations
Steady-State Tide Tests

<u>Station</u>	<u>Body of Water</u>	<u>Latitude</u>	<u>Longitude</u>
OCEAN	Atlantic Ocean	36°58'54"	75°33'27"
Sta 3	James River (Old Pt. Comfort)	37°00'18"	76°18'50"
CB0001	Chesapeake Bay	36°56'17"	76°00'23"
CB0004	Chesapeake Bay	37°00'14"	75°59'30"
CBC008	Chesapeake Bay	37°03'13"	75°58'37"
CB0101	Chesapeake Bay	37°06'00"	76°14'36"
CB0105	Chesapeake Bay	37°08'51"	76°08'48"
CB0109	Chesapeake Bay	37°11'42"	76°02'07"
JG0302	James River	37°03'21"	76°35'35"
JN0202	James River	36°55'42"	76°25'44"
EH0203	Elizabeth River	36°53'09"	76°20'13"
EH0901	Elizabeth River	36°45'05"	76°17'46"
EE0301	East Branch Elizabeth River	36°50'13"	76°14'40"
WB0201	West Branch Elizabeth River	36°51'18"	76°21'15"
TS0003	Thimble Shoal Channel	36°58'24"	76°06'30"
TS0005	Thimble Shoal Channel	37°00'18"	76°13'54"
YS0001	York Spit Channel	37°02'43"	76°04'23"

Table 4A

TEST 1

Steady-State Tides: 200,000 cfs; +2.4 ft cosine tide

STATION	BASE			PLAN			PLAN - BASE					
	PHASE	AMP	A(0)	R**2	PHASE	AMP	A(0)	R**2	PHASE	AMP	A(0)	B/P: R
OCEAN	206	2.30	-0.04	0.990	213	2.32	-0.11	0.994	7	0.02	-0.06	0.992
STA. 3	249	1.70	0.10	0.992	254	1.74	0.04	0.995	5	-0.03	-0.14	0.996
CS0001	217	2.24	-0.07	0.989	226	2.23	-0.02	0.991	9	-0.01	0.05	0.988
CS0004	217	2.13	0.03	0.983	227	2.16	-0.10	0.987	10	0.02	-0.22	0.987
CS0008	210	2.03	0.21	0.986	229	2.05	-0.17	0.990	11	0.02	-0.37	0.983
CS0101	239	1.59	0.21	0.986	247	1.65	0.05	0.991	0	0.06	-0.16	0.992
CS0105	239	1.55	0.23	0.989	247	1.56	0.02	0.990	0	0.01	-0.20	0.991
CS0109	244	1.40	0.32	0.981	249	1.46	-0.01	0.994	5	0.05	-0.33	0.997
JG0302	294	1.50	0.37	0.980	301	1.48	0.44	0.981	7	-0.02	0.00	0.993
JN0202	262	1.07	0.13	0.991	260	1.06	0.00	0.990	6	-0.00	-0.05	0.993
EH0203	257	1.93	0.41	0.993	262	1.96	0.11	0.988	5	0.03	-0.30	0.996
EH0501	259	2.12	0.03	0.962	266	2.12	0.01	0.967	7	-0.00	-0.02	0.993
EE0301	260	2.03	0.23	0.980	265	2.02	0.10	0.981	5	-0.00	-0.13	0.996
LB0201	262	1.97	0.10	0.990	267	2.00	0.03	0.980	5	0.03	-0.15	0.997
TS0003	224	1.99	0.02	0.971	234	2.01	0.03	0.989	10	0.02	0.01	0.985
TS0005	235	1.05	0.11	0.995	243	1.09	-0.09	0.994	0	0.04	-0.20	0.991
YS0001	228	1.79	0.06	0.997	235	1.85	-0.13	0.997	7	0.06	-0.19	0.992

(Continued)

(Sheet 1 of 4)

Table 4B

TEST 2

Steady-State Tides: 200,000 cfs, ± 1.5 ft cosine tides

STATION	BASE			PLAN			PLAN - BASE					
	PHASE	AMP	A(0)	R**2	PHASE	AMP	A(0)	R**2	PHASE	AMP	A(0)	B/P: R
OCEAN	205	1.46	-0.05	0.994	195	1.40	-0.02	0.987	-10	-0.06	0.03	0.983
STA. 3	247	1.11	0.19	0.993	236	1.13	0.03	0.990	-11	0.02	-0.16	0.981
CB0001	220	1.40	-0.04	0.989	206	1.39	0.15	0.989	-14	-0.00	0.10	0.970
CB0004	219	1.37	-0.00	0.987	209	1.33	-0.09	0.974	-10	-0.04	-0.08	0.986
CB0008	224	1.32	0.06	0.980	210	1.32	-0.08	0.985	-14	-0.01	-0.14	0.969
CB0101	240	1.11	0.10	0.990	230	1.11	-0.03	0.979	-10	-0.00	-0.13	0.983
CB0105	246	1.00	0.06	0.978	229	0.99	-0.13	0.980	-17	-0.02	-0.19	0.961
CB0109	245	1.00	0.09	0.991	233	0.94	0.05	0.982	-12	-0.06	-0.04	0.979
JG0302	294	1.02	0.26	0.983	281	1.01	0.19	0.986	-13	-0.02	-0.07	0.973
JN0202	259	1.16	0.11	0.986	245	1.17	0.06	0.985	-14	0.01	-0.06	0.975
EH0203	255	1.25	0.20	0.992	241	1.28	0.14	0.987	-14	0.02	-0.06	0.975
EH0901	260	1.36	0.16	0.981	247	1.32	0.05	0.982	-13	-0.03	-0.11	0.974
EE0301	257	1.32	0.22	0.979	248	1.31	0.11	0.983	-9	-0.01	-0.11	0.989
LB0201	258	1.31	0.30	0.980	247	1.30	0.05	0.992	-11	-0.00	-0.25	0.980
TS0003	227	1.28	-0.07	0.985	216	1.23	0.08	0.979	-11	-0.04	0.15	0.981
TS0005	***	*****	*****	*****	223	1.23	-0.03	0.987	***	*****	*****	*****
YS0001	228	1.19	0.08	0.981	218	1.17	0.00	0.984	-10	-0.02	-0.07	0.984

(Continued)

(Sheet 2 of 4)

Table 4C

TEST 3

Steady-State Tides: 70,000 cfs, +2.4 ft cosine tide

STATION	BASE			R**2	PLAN			R**2	BASE - PLAN			
	PHASE	AMP	A(0)		PHASE	AMP	A(0)		PHASE	AMP	A(0)	B/P: R
OCEAN	193	2.31	-0.11	0.990	189	2.27	-0.08	0.991	-4	-0.04	0.04	0.998
STA. 3	233	1.84	0.05	0.990	229	1.83	-0.06	0.990	-4	-0.01	-0.11	0.998
CB0001	203	2.23	-0.12	0.984	202	2.28	-0.23	0.975	-1	0.05	-0.12	1.000
CB0004	211	2.11	-0.16	0.989	205	2.15	-0.06	0.991	-6	0.03	0.10	0.993
CB0008	209	2.10	-0.02	0.991	201	2.02	-0.17	0.988	-8	-0.08	-0.15	0.990
CB0101	224	1.67	0.10	0.988	222	1.68	-0.09	0.982	-2	0.00	-0.28	0.999
CB0105	224	1.51	0.04	0.994	215	1.52	-0.07	0.992	-9	0.00	-0.11	0.987
CB0109	228	1.45	-0.05	0.990	221	1.44	-0.26	0.988	-7	-0.02	-0.21	0.991
JG0302	280	1.53	0.26	0.969	277	1.54	-0.00	0.942	-3	0.01	-0.26	0.999
JN0202	245	1.87	0.08	0.992	239	1.87	0.09	0.990	-6	-0.00	0.00	0.995
EH0203	244	1.99	0.21	0.989	241	2.02	0.15	0.991	-3	0.02	-0.07	0.999
EH0301	246	2.19	0.18	0.958	242	2.14	0.00	0.960	-4	-0.05	-0.18	0.997
EE0301	240	2.13	-0.08	0.981	237	2.09	-0.07	0.981	-3	-0.04	0.01	0.999
LB0201	246	2.05	0.28	0.989	245	2.03	-0.02	0.992	-1	-0.01	-0.30	1.000
TS0003	213	2.06	0.00	0.994	210	2.00	-0.13	0.990	-3	-0.06	-0.13	0.999
TS0005	***	*****	*****	*****	221	1.84	0.01	0.987	**	*****	*****	*****
YS0001	212	1.80	-0.11	0.970	207	1.74	-0.19	0.992	-5	-0.06	-0.09	0.996

(Continued)

(Sheet 3 of 4)

Table 4D

TEST 4

Steady-State Tides: 70,000 cfs, +1.5 ft cosine tide

STATION	BASE			PLAN			PLAN - BASE		
	PHASE	AMP	A(0)	R**2	PHASE	AMP	A(0)	R**2	B/P: R
OCEAN	197	1.46	-0.04	0.994	187	1.46	-0.06	0.986	-10 0.986
STA. 3	241	1.20	0.15	0.990	226	1.17	-0.02	0.984	-15 0.968
C60001	200	1.39	0.10	0.991	201	1.42	-0.03	0.993	-7 0.991
C60004	205	1.38	0.14	0.987	203	1.33	-0.09	0.976	-2 0.999
C60008	209	1.35	-0.03	0.983	204	1.32	-0.16	0.989	-5 0.996
C60101	230	1.03	0.30	0.976	223	1.10	-0.06	0.991	-7 0.992
C60105	231	1.08	0.19	0.981	222	1.03	-0.13	0.987	-9 0.989
C60109	233	0.93	0.17	0.980	227	0.96	-0.11	0.991	-6 0.995
JG0302	281	1.09	0.33	0.983	277	1.07	0.22	0.993	-4 0.998
JN0202	252	1.25	0.12	0.994	244	1.26	-0.05	0.985	-8 0.990
EH0203	245	1.28	0.12	0.986	237	1.31	0.06	0.993	-8 0.992
EH0901	250	1.43	0.08	0.983	240	1.42	0.01	0.984	-10 0.986
EE0301	252	1.42	0.20	0.989	241	1.39	0.02	0.986	-11 0.983
LB0201	250	1.34	0.13	0.993	243	1.36	-0.14	0.989	-7 0.991
TS0003	217	1.28	0.14	0.987	210	1.30	-0.10	0.986	-7 0.993
TS0005	228	1.25	0.07	0.985	215	1.23	-0.13	0.985	-13 0.975
YS0001	222	1.20	0.09	0.989	211	1.20	0.01	0.979	-11 0.984

(Sheet 4 of 4)

Table 5

Plan-Minus-Base Amplitude Differences
Steady-State Tide Tests

<u>Station</u>	<u>Test 1 ft</u>	<u>Test 2 ft</u>	<u>Test 3 ft</u>	<u>Test 4 ft</u>	<u>Four Test Average ft</u>
OCEAN	0.02	-0.06	-0.04	-0.01	-0.02
Sta 3	-0.03	0.02	-0.01	-0.03	-0.01
CB0001	-0.01	0.00	0.05	0.03	0.02
CB0004	0.02	-0.04	0.03	-0.05	-0.01
CB0008	0.02	-0.01	-0.08	-0.03	-0.02
CB0101	0.06	0.00	0.00	0.07	0.03
CB0105	0.01	-0.02	0.00	-0.05	-0.01
CB0109	0.05	-0.06	-0.02	0.03	0.00
JG0302	-0.02	-0.02	0.01	-0.02	-0.01
JN0202	0.00	0.01	0.00	0.01	0.00
EH0203	0.03	0.02	0.02	0.02	0.02
EH0901	0.00	-0.03	-0.05	-0.01	-0.02
EE0301	0.00	-0.01	-0.04	-0.03	-0.02
WB0201	0.03	0.00'	-0.01	0.02	0.01
TS0003	0.02	-0.04	-0.06	0.02	-0.01
TS0005	0.04	N/A	N/A	-0.03	0.00
YS0001	0.06	-0.02	-0.06	0.00	0.00
Mean	0.018	-0.013	-0.015	-0.004	-0.003
Std Dev	0.027	0.023	0.037	0.033	0.032

Table 6
Plan-Minus-Base Mean Water Level Differences
Steady-State Tide Tests

Station	Unadjusted MWL Differences, ft					Adjusted MWL Differences, ft				
	Test 1	Test 2	Test 3	Test 4	Average	Test 1	Test 2	Test 3	Test 4	Average
OCEAN	-0.06	0.03	0.04	-0.02	0.00	-0.06	0.03	0.04	-0.02	0.00
Sta 3	-0.14	-0.16	-0.11	-0.17	-0.14	0.00	-0.02	0.03	-0.03	0.00
CB0001	0.05	0.18	-0.12	-0.14	-0.01	0.19*	0.32*	0.02	0.00	0.13
CB0004	-0.22	-0.08	0.10	-0.23	-0.11	-0.18	0.06	0.24*	-0.09	0.03
CB0008	-0.37	-0.14	-0.15	-0.13	-0.20	-0.23*	0.00	-0.01	0.01	-0.06
CB0101	-0.16	-0.13	-0.28	-0.36	-0.23	-0.02	0.01	-0.14*	-0.22*	-0.09
CB0105	-0.20	-0.18	-0.11	-0.32	-0.20	-0.06	-0.05	0.03	-0.18*	-0.06
CB0109	-0.33	-0.04	-0.21	-0.29	-0.22	-0.19*	0.10	-0.07	-0.15*	-0.08
JG0302	0.08	-0.07	-0.26	-0.11	-0.09	-0.06	0.07	-0.12*	0.03	0.05
JN0202	-0.05	-0.06	0.00	-0.17	-0.07	0.09	0.08	0.14*	-0.03	0.05
EH0203	-0.30	-0.06	-0.07	-0.06	-0.12	-0.16*	0.08	0.07	0.08	0.02
EH0901	-0.02	-0.11	-0.18	-0.06	-0.09	0.12*	0.03	-0.04	0.08	0.05
EE0301	-0.13	-0.11	0.01	-0.17	-0.10	0.01	0.03	0.15*	-0.03	0.04
WB0201	-0.15	-0.25	-0.30	-0.27	-0.24	-0.01	-0.11*	-0.16*	-0.13*	-0.10
TS0003	0.01	0.15	-0.13	-0.24	-0.05	0.15*	0.30*	0.01	0.10	0.09
TS0005	-0.20	N/A	N/A	-0.20	-0.20	-0.06	N/A	N/A	-0.06	-0.06
YS0001	-0.19	-0.07	-0.09	-0.08	-0.11	-0.05	0.07	0.05	0.06	0.03
Mean (excluding OCEAN)	-0.14	-0.08	-0.13	-0.19	-0.14	0.00	0.06	0.01	-0.05	0.00

* Possible anomalous value due to unstable tripod.

Table 7

Steady-State Tides

Phase Angles Normalized to the Ocean

Station	**** Test 1 ****			**** Test 2 ****			**** Test 3 ****			**** Test 4 ****		
	Base deg	Plan deg	Diff deg	Base deg	Plan deg	Diff deg	Base deg	Plan deg	Diff deg	Base deg	Plan deg	Diff deg
OCEAN	191 ⁰	191 ⁰	0 ⁰	191 ⁰	191 ⁰	0 ⁰	191 ⁰	191 ⁰	0 ⁰	191 ⁰	191 ⁰	0 ⁰
Sta 3	234	232	-2	233	232	-1	231	231	0	235	230	-5
CB0001	202	204	2	206	202	-4	201	204	3	202	205	3
CB0004	202	205	3	205	205	0	209	207	-2	198	206	3
CB0008	203	207	4	210	206	-4	207	203	-4	203	208	5
CB0101	224	225	1	226	226	0	222	224	2	224	227	3
CB0105	224	225	1	232	225	-7	222	217	-5	225	226	1
CB0109	229	227	-2	231	229	-2	226	223	-3	227	231	4
JG0302	279	279	0	280	277	-3	278	279	1	275	281	6
JN0202	247	246	-1	245	241	-4	243	241	-2	246	248	2
EH0203	242	240	-2	241	237	-4	242	243	1	239	241	2
EH0901	244	244	0	246	243	-3	244	244	0	244	244	0
EE0301	245	243	-2	243	244	1	238	239	1	246	245	-1
WB0201	247	245	-2	244	243	-1	244	247	3	244	247	3
TS0003	209	212	3	213	212	-1	211	212	1	211	214	3
TS0005	220	221	1	N/A	219	N/A	N/A	223	N/A	222	219	-3
YS0001	213	213	0	214	214	0	210	209	-1	216	215	-1

Note: N/A = not available.

Table 8
Velocity Station Locations
Steady-State Velocity Tests

Station	Body of Water	Sampling Depths (ft below msl)	Latitude	Longitude
CB0001	Chesapeake Bay	4, 18, 32	36°56'12"	76°00'18"
CB0002	Chesapeake Bay	4,20,35,54,71	36°57'30"	76°00'05"
CB0004	Chesapeake Bay	4, 16, 28	37°00'06"	75°59'30"
CB0006	Chesapeake Bay	4, 15	37°02'00"	75°59'06"
CB0008	Chesapeake Bay	4, 24, 43	37°03'18"	75°58'48"
CB0009	Chesapeake Bay	4, 16	37°04'37"	75°58'36"
CB0101	Chesapeake Bay	4, 13	37°05'58"	76°14'43"
CB0103	Chesapeake Bay	4, 14, 24	37°07'05"	76°12'15"
CB0105	Chesapeake Bay	4, 20, 37	37°08'36"	76°08'59"
CB0107	Chesapeake Bay	4, 15, 27	37°10'36"	76°04'37"
CB0109	Chesapeake Bay	4, 39, 75	37°11'48"	76°02'01"
CB0110	Chesapeake Bay	4, 15	37°12'08"	76°01'32"
AC0002	Atlantic Ocean Channel	4,27,49,54*	36°54'06"	75°54'33"
TS0003	Thimble Shoal Channel	4,26,56,51*	36°58'21"	76°06'39"
TS0005	Thimble Shoal Channel	4,27,50,55*	37°00'24"	76°14'39"
YS0001	York Spit Channel	4, 25, 45	37°02'33"	76°04'31"
JG0101	James River	4, 11	36°58'54"	76°17'36"
JG0102	James River	4, 26, 48	36°59'36"	76°17'54"
JG0103	James River	4,22,44,66,83	37°00'00"	76°18'12"
JG0311	James River	4, 11	37°03'06"	76°36'16"
JG0302	James River	4, 16, 27	37°03'30"	76°35'36"
JG0321	James River	4	37°04'11"	76°36'15"
JN0202	James River	4, 12	36°55'23"	76°25'46"
JN0203	James River	4, 20	36°56'24"	76°25'22"
JN0204	James River	4,26,48,55*	36°57'04"	76°25'07"
EH0202	Elizabeth River	4,25,46,55*	36°53'15"	76°20'04"
EH0203	Elizabeth River	4, 22, 40	36°53'14"	76°20'16"
EH0501	Elizabeth River	4,22,39,45*	36°50'34"	76°17'41"
EH0701	Elizabeth River	4,19,35,40*	36°47'05"	76°18'13"
EH0901	Elizabeth River	4, 19, 35	36°45'18"	76°17'44"
EE0301	East Branch Elizabeth River	4, 21	36°50'13"	76°14'48"
WB0201	West Branch Elizabeth River	4, 13	36°51'14"	76°21'20"

* Additional depths samples during plan test only.

TEST 1

200,000 cfs, +2.4 ft Ocean Tide Amplitude

STATION	DEPTH FT	>>>>>>> BASE			TEST <<<<<<<			>>>>>>> PLAN			TEST <<<<<<<			>>PLAN-MINUS-BASE<<<		
		PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS
C80001	4	205.	2.84	-1.11	0.940	207.	2.73	-0.85	0.952	3.	-0.10	0.27				
C80001	18	196.	2.63	-0.68	0.980	198.	2.50	-0.71	0.941	1.	-0.12	-0.03				
C80001	32	170.	1.99	-0.55	0.791	165.	1.94	-0.46	0.947	-4.	-0.05	0.09				
C80002	4	205.	2.10	-0.72	0.938	213.	1.93	-0.70	0.956	8.	-0.17	0.02				
C80002	20	204.	2.51	-0.31	0.895	214.	1.94	-0.57	0.929	9.	-0.57	-0.26				
C80002	35	206.	2.55	0.34	0.915	204.	2.50	0.43	0.962	-2.	-0.05	0.09				
C80002	54	202.	2.72	0.29	0.913	197.	2.45	0.38	0.977	-4.	-0.27	0.08				
C80002	71	194.	2.29	0.30	0.911	189.	1.70	0.20	0.934	-5.	-0.59	-0.10				
C80004	4	206.	2.03	-0.62	0.945	209.	2.20	-0.63	0.928	3.	0.17	-0.01				
C80004	16	203.	2.36	-0.29	0.963	209.	2.42	-0.28	0.956	6.	0.06	0.02				
C80004	28	187.	2.13	0.29	0.952	189.	2.08	0.36	0.965	3.	-0.05	0.08				
C80006	4	206.	3.38	-0.10	0.928	211.	3.94	-0.85	0.969	5.	0.56	-0.74				
C80006	15	204.	2.62	-0.18	0.952	209.	3.09	-0.33	0.955	4.	0.47	-0.16				
C80008	4	213.	0.97	-0.20	0.956	214.	3.49	-0.74	0.979	0.	2.53	-0.53				
C80008	24	203.	0.86	-0.08	0.963	203.	3.03	-0.30	0.981	0.	2.17	-0.22				
C80008	43	189.	0.60	0.06	0.942	191.	2.30	-0.09	0.950	2.	1.70	-0.14				
C80009	4	191.	4.87	-0.39	0.956	193.	4.52	-0.42	0.962	2.	-0.35	-0.03				
C80009	16	187.	4.64	-0.31	0.977	191.	3.94	-0.21	0.986	4.	-0.71	0.10				
C80101	4	252.	2.31	-0.44	0.965	256.	2.21	-0.48	0.975	4.	-0.11	-0.03				
CEJ101	13	250.	1.60	-0.17	0.960	260.	1.84	-0.25	0.960	11.	0.25	-0.08				
C80103	4	278.	1.85	-0.29	0.885	273.	1.79	-0.32	0.958	-5.	-0.07	-0.03				
C80103	14	267.	1.93	-0.24	0.969	270.	1.86	-0.26	0.970	3.	-0.07	-0.02				
C80103	24	250.	1.05	-0.16	0.950	261.	1.34	-0.14	0.914	11.	-0.30	0.02				
C80105	4	283.	2.06	-0.13	0.945	274.	1.96	-0.10	0.926	-10.	-0.11	0.03				
C80105	20	253.	2.06	0.26	0.939	256.	1.99	0.23	0.941	3.	-0.07	-0.04				
C80105	37	228.	1.22	0.25	0.913	274.	1.50	0.47	0.925	5.	0.28	0.22				
C80107	4	279.	2.35	-0.37	0.945	268.	2.24	-0.33	0.945	-11.	-0.11	0.04				
C80107	15	280.	2.35	0.07	0.978	267.	2.07	0.13	0.939	-13.	-0.29	0.06				
C80107	27	265.	1.58	0.41	0.928	258.	1.47	0.39	0.876	-9.	-0.12	-0.61				
C80109	4	259.	2.12	-0.62	0.945	268.	2.17	-0.71	0.971	3.	0.05	-0.09				
C80109	39	243.	1.72	0.52	0.892	251.	1.74	0.31	0.943	7.	0.02	-0.22				
C80109	75	182.	0.96	0.63	0.769	194.	0.72	0.44	0.782	12.	-0.24	-0.19				

(Continued)

(Sheet 1 of 12)

Table 9A (Concluded)

[illegible]

TEST 2

200,000 cfs, 11.5 ft Ocean Tide Amplitude

[illegible]

(Continued)

(Sheet 4 of 12)

Table 9B (concluded)

STATION	DEPTH FT	>>>>>>>> BASE			TEST <<<<<<<<<			>>>>>>>> PLAN			TEST <<<<<<<<<			>>>>>>>> PLAN-MINUS-BASE<<<<<<<<<		
		PHASE DEG	AMP FPS	MEAN FPS	PHASE DEG	AMP FPS	MEAN FPS	PHASE DEG	AMP FPS	MEAN FPS	PHASE DEG	AMP FPS	MEAN FPS	PHASE DEG	AMP FPS	MEAN FPS
JG0321	4	269.	1.65	-0.34	0.970	268.	1.74	-0.37	0.977	-1.	0.09	-0.02				
JN0202	4	230.	0.84	-0.02	0.895	222.	0.90	-0.14	0.865	-9.	0.06	-0.11				
JN0202	12	198.	0.62	0.03	0.794	202.	0.62	-0.01	0.870	4.	-0.00	-0.04				
JN0203	4	225.	1.42	-0.59	0.932	221.	1.23	-0.53	0.896	-4.	-0.18	0.07				
JN0203	20	203.	0.87	-0.05	0.871	213.	0.90	-0.12	0.703	10.	0.04	-0.06				
JN0204	4	220.	1.89	-0.67	0.960	238.	2.18	-0.71	0.895	18.	0.29	-0.04				
JN0204	26	227.	1.70	0.16	0.949	226.	1.67	0.17	0.887	-1.	-0.02	0.01				
JN0204	48	195.	1.57	1.13	0.868	209.	1.62	1.22	0.711	14.	0.05	0.09				
JN0204	55	****	*****	*****	0.968	208.	1.55	1.22	0.688	*****	*****	*****				
EH0202	4	164.	1.08	-0.25	0.804	171.	0.95	-0.21	0.770	-12.	-0.13	0.04				
EH0202	25	180.	0.32	0.14	0.442	189.	0.74	0.24	0.202	9.	0.42	0.10				
EH0202	46	249.	0.11	-0.02	0.115	267.	0.58	-0.04	0.453	19.	0.47	-0.03				
EH0202	55	*****	*****	*****	0.115	250.	0.30	-0.06	0.164	*****	*****	*****				
EH0203	4	154.	0.95	-0.33	0.904	153.	0.61	-0.13	0.749	-0.	-0.34	0.20				
EH0203	22	149.	0.61	0.28	0.540	159.	0.50	0.27	0.606	10.	-0.03	-0.02				
EH0203	40	63.	0.13	0.02	0.214	49.	0.22	-0.05	0.163	-13.	0.09	-0.08				
EH0501	4	186.	0.26	-0.01	0.531	209.	0.37	-0.03	0.422	23.	0.11	-0.02				
EH0501	22	213.	0.35	-0.05	0.464	209.	0.24	0.01	0.262	-4.	-0.11	0.06				
EH0501	39	175.	0.64	-0.25	0.839	118.	0.36	-0.12	0.383	-57.	-0.28	0.3				
EH0501	45	*****	*****	*****	0.839	131.	0.43	-0.12	0.512	*****	*****	*****				
EH0701	4	225.	0.39	-0.28	0.711	220.	0.30	-0.12	0.686	-5.	-0.09	0.16				
EH0701	19	190.	0.67	-0.24	0.677	179.	0.59	-0.12	0.754	-11.	-0.08	0.12				
EH0701	35	164.	0.50	0.37	0.410	150.	0.45	-0.11	0.810	-5.	0.33	-0.15				
EH0701	40	*****	*****	*****	0.410	261.	0.26	-0.13	0.795	*****	*****	*****				
EH0901	4	216.	0.64	-0.30	0.960	231.	0.62	-0.26	0.806	6.	-0.01	0.04				
EH0901	19	202.	0.37	0.09	0.570	197.	0.29	-0.06	0.520	-5.	-0.08	-0.15				
EH0901	35	136.	0.02	-0.01	0.007	207.	0.03	0.01	0.004	63.	0.00	0.02				
EE0301	4	196.	0.11	0.10	0.631	198.	0.45	0.07	0.545	13.	-0.15	-0.04				
EE0301	21	184.	0.83	-0.02	0.176	174.	0.22	-0.16	0.363	-10.	-0.62	-0.13				
WB0201	4	164.	1.04	0.12	0.689	175.	1.02	0.06	0.952	10.	-0.02	-0.05				
WB0201	13	152.	0.82	0.08	0.836	155.	0.57	-0.03	0.728	3.	-0.15	-0.10				

(Sheet 6 of 12)

AD-A134 563

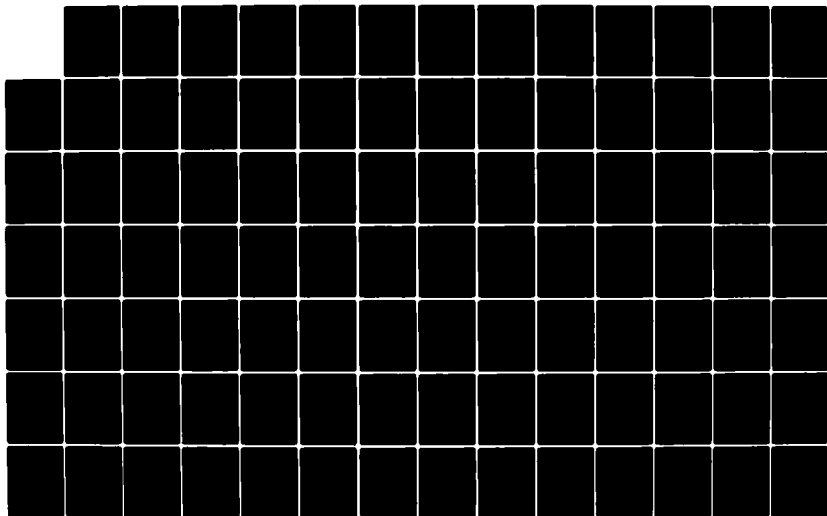
NORFOLK HARBOR AND CHANNELS DEEPENING STUDY REPORT 1
PHYSICAL MODEL RESUL..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS HYDRA..

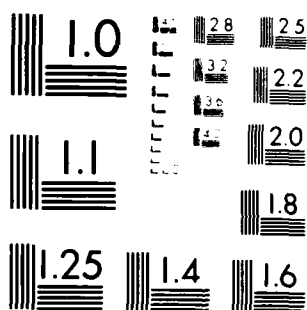
24

UNCLASSIFIED

D R RICHARDS ET AL. JUN 83 WES/TR/HL-83-13 F/G 13/2

NL





MICROCOPY RESOLUTION TEST CHART
 NATIONAL BUREAU OF STANDARDS-1963-A

TEST 3

+70,000 cfs, -2.4 ft Ocean Tide Amplitude

[illegible]

(Continued)

(Sheet 7 of 12)

Table 9C (Continued)

Table 9C (Concluded)

STATION	DEPTH FT	>>>>>>>> BASE TEST <<<<<<<<						>>>>>>>> PLAN TEST <<<<<<<<						>>PLAN-MINUS-BASE<<<																							
		PHASE			AMP			MEAN			R-SQUARE			PHASE			AMP			MEAN			R-SQUARE			PHASE			AMP			MEAN			R-SQUARE		
		DEG	FPS		FPS			FPS			R-SQ			DEG	FPS		FPS			R-SQ			DEG	FPS		FPS			R-SQ			DEG	FPS		FPS		
JG0321	4	238.	2.27	-0.38	0.949							243.	2.08	-0.34	0.958							5.	-0.19	0.04													
JN0202	4	194.	1.64	-0.06	0.962							197.	1.38	0.03	0.868							3.	-0.26	0.09													
JN0202	12	194.	1.37	0.05	0.942							193.	1.25	0.05	0.902							-0.	-0.13	-0.00													
JN0203	4	221.	1.63	-0.40	0.864							223.	1.72	-0.48	0.879							3.	0.09	-0.08													
JN0203	20	195.	1.44	-0.04	0.934							212.	1.43	-0.13	0.934							17.	-0.00	-0.09													
JN0204	4	204.	3.43	-0.75	0.936							223.	3.01	-0.86	0.926							19.	-0.42	0.11													
JN0204	26	197.	3.06	-0.05	0.975							207.	2.50	0.08	0.979							9.	-0.56	0.13													
JN0204	48	211.	2.65	0.18	0.967							203.	2.25	0.25	0.961							19.	-0.41	0.07													
JN0204	55	****	*****	*****	0.967							201.	2.00	0.23	0.924							*****	*****	*****													
EH0202	4	173.	1.39	-0.17	0.884							166.	0.99	-0.06	0.749							-7.	-0.40	0.11													
EH0202	25	159.	1.33	-0.02	0.923							152.	1.03	-0.00	0.894							-7.	-0.30	0.02													
EH0202	46	161.	1.25	0.16	0.860							142.	1.11	-0.09	0.729							-19.	-0.13	-0.24													
EH0202	55	****	*****	*****	0.860							116.	0.93	0.04	0.871							*****	*****	*****													
EH0203	4	175.	1.48	-0.09	0.866							165.	0.97	-0.19	0.723							-10.	-0.51	-0.09													
EH0203	22	168.	1.34	-0.00	0.871							158.	1.13	0.07	0.901							-10.	-0.21	0.08													
EH0203	40	163.	1.36	0.11	0.884							149.	1.11	0.29	0.845							-14.	-0.25	0.18													
EH0501	4	178.	0.94	-0.30	0.776							184.	0.66	0.09	0.249							6.	-0.28	0.39													
EH0501	22	180.	0.98	0.01	0.935							161.	0.53	-0.09	0.468							-19.	-0.45	-0.11													
EH0501	39	194.	0.85	0.13	0.791							147.	0.88	0.14	0.750							-46.	0.02	0.00													
EH0501	45	****	*****	*****	0.791							151.	0.96	0.15	0.668							*****	*****	*****													
EH0701	4	180.	1.20	-0.20	0.622							179.	0.65	0.00	0.724							-1.	-0.55	0.21													
EH0701	19	177.	1.32	-0.02	0.707							164.	0.79	-0.04	0.586							-14.	-0.53	-0.02													
EH0701	35	166.	1.22	-0.01	0.694							153.	0.82	-0.05	0.668							-14.	-0.40	-0.04													
EH0701	40	****	*****	*****	0.694							147.	0.68	-0.02	0.577							*****	*****	*****													
EH0901	4	183.	0.86	-0.32	0.370							168.	0.77	-0.21	0.479							5.	-0.09	0.10													
EH0901	19	161.	0.64	0.01	0.498							145.	0.53	0.07	0.415							-16.	-0.11	0.05													
EH0901	35	137.	0.46	-0.03	0.667							132.	0.46	-0.03	0.217							-5.	0.00	0.00													
EE0301	4	173.	0.71	0.00	0.626							166.	0.82	0.09	0.795							-8.	0.12	0.09													
EE0301	21	162.	0.47	0.11	0.594							172.	0.41	0.11	0.515							10.	-0.06	-0.00													
EE0201	4	172.	1.40	0.06	0.904							166.	1.52	0.33	0.875							-7.	0.04	0.27													
EB0201	13	171.	1.35	0.13	0.894							174.	1.45	0.20	0.926							3.	0.09	0.07													

(Sheet 9 of 12)

TEST 4

70,000 cfs, ⁺1.5 ft Ocean Tide Amplitude

STATION	DEPTH FT	>>>>>>>> BASE <<<<<<<<						>>>>>>>> PLAN TEST <<<<<<<<						>>>>>>>> PHASE MINUS-BASE<<<																							
		PHASE			AMP			TEST			R-SQUARE			PHASE			AMP			TEST			R-SQUARE			PHASE			AMP			TEST			R-SQUARE		
		DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS	DEG	FPS	FPS						
C800001	4	224.	1.50	-0.91	0.810		219.	1.31	-0.41	0.848		-5.	-0.19	0.51		C800001	18	209.	1.56	-0.38	0.947		196.	1.18	-0.21	0.878		-13.	-0.38	0.17							
C800001	32	172.	1.52	-0.28	0.829		154.	1.22	-0.03	0.857		-18.	-0.30	0.25		C800001	4	231.	1.49	-0.41	0.976		221.	1.22	-0.43	0.970		-10.	-0.27	-0.02							
C800002	20	212.	1.61	0.05	0.962		219.	1.37	0.09	0.944		7.	-0.24	0.04		C800002	35	212.	1.53	0.27	0.957		215.	1.48	0.31	0.945		3.	-0.13	0.03							
C800002	54	202.	1.64	0.29	0.965		211.	1.48	0.27	0.942		9.	-0.16	-0.02		C800002	71	209.	1.23	0.34	0.929		200.	1.18	0.27	0.923		-9.	-0.05	-0.07							
C800002	4	245.	1.51	-0.59	0.920		229.	1.47	-0.60	0.895		-17.	-0.04	-0.01		C800004	16	235.	1.58	-0.04	0.975		219.	1.58	-0.02	0.954		-16.	0.01	0.02							
C800004	28	219.	1.27	0.11	0.955		199.	1.18	0.16	0.957		-21.	-0.09	0.05		C800004	4	230.	2.30	-0.55	0.963		220.	2.06	-0.42	0.959		-10.	-0.23	0.13							
C800006	15	210.	1.70	-0.08	0.883		213.	1.63	0.04	0.960		2.	-0.07	0.11		C800006	4	217.	2.43	-0.14	0.785		220.	2.05	-0.14	0.955		3.	-0.37	-0.00							
C800008	24	204.	2.24	-0.21	0.918		209.	1.88	-0.05	0.934		5.	-0.35	0.16		C800008	43	198.	2.02	0.15	0.854		204.	1.52	0.05	0.930		-5.	-0.50	-0.10							
C800008	4	207.	3.46	-0.25	0.977		202.	3.22	-0.23	0.944		-5.	-0.24	0.02		C800008	16	193.	3.07	0.06	0.964		195.	3.00	0.04	0.976		2.	-0.07	-0.01							
C800009	4	241.	1.64	-0.02	0.896		255.	1.06	-0.03	0.614		15.	-0.59	-0.01		C800009	4	241.	1.64	-0.02	0.896		255.	1.06	-0.03	0.614		15.	-0.59	-0.01							
C80101	13	243.	1.22	-0.04	0.871		237.	1.03	-0.03	0.899		-5.	-0.19	0.02		C80101	13	243.	1.22	-0.04	0.871		237.	1.03	-0.03	0.899		-5.	-0.19	0.02							
C80103	4	270.	1.18	-0.33	0.922		263.	0.97	-0.31	0.795		-8.	-0.22	0.03		C80103	4	270.	1.18	-0.33	0.922		263.	0.97	-0.31	0.795		-8.	-0.22	0.03							
C80103	14	267.	1.06	-0.26	0.898		254.	0.97	-0.24	0.789		-13.	-0.08	0.02		C80103	14	267.	1.06	-0.26	0.898		254.	0.97	-0.24	0.789		-13.	-0.08	0.02							
C80103	24	229.	1.10	0.05	0.886		230.	0.95	-0.01	0.843		0.	-0.15	-0.06		C80103	24	229.	1.10	0.05	0.886		230.	0.95	-0.01	0.843		0.	-0.15	-0.06							
C80105	4	257.	1.45	-0.09	0.967		254.	1.22	-0.01	0.960		-2.	-0.23	0.07		C80105	4	257.	1.45	-0.09	0.967		254.	1.22	-0.01	0.960		-2.	-0.23	0.07							
C80105	20	242.	1.39	0.30	0.945		232.	1.17	0.30	0.932		-10.	-0.21	0.00		C80105	20	242.	1.39	0.30	0.945		232.	1.17	0.30	0.932		-10.	-0.21	0.00							
C80105	37	229.	1.32	0.29	0.918		214.	1.07	0.24	0.921		-14.	-0.25	-0.05		C80105	37	229.	1.32	0.29	0.918		214.	1.07	0.24	0.921		-14.	-0.25	-0.05							
C80107	4	247.	1.56	-0.11	0.963		251.	1.36	0.03	0.954		3.	-0.20	0.14		C80107	4	247.	1.56	-0.11	0.963		251.	1.36	0.03	0.954		3.	-0.20	0.14							
C80107	15	248.	1.56	0.08	0.953		249.	1.42	0.13	0.943		1.	-0.13	0.05		C80107	15	248.	1.56	0.08	0.953		249.	1.42	0.13	0.943		1.	-0.13	0.05							
C80107	27	234.	1.27	0.31	0.942		234.	0.71	0.21	0.848		-3.	-0.56	-0.10		C80107	27	234.	1.27	0.31	0.942		234.	0.71	0.21	0.848		-3.	-0.56	-0.10							
C80109	4	253.	1.23	-0.21	0.977		251.	1.20	-0.14	0.918		0.	-0.03	0.07		C80109	4	253.	1.23	-0.21	0.977		251.	1.20	-0.14	0.918		0.	-0.03	0.07							
C80109	39	243.	1.19	0.10	0.848		239.	1.15	0.14	0.762		-4.	-0.04	0.04		C80109	39	243.	1.19	0.10	0.848		239.	1.15	0.14	0.762		-4.	-0.04	0.04							
C80109	75	199.	0.90	0.11	0.635		194.	0.67	-0.08	0.801		-4.	-0.23	-0.19		C80109	75	199.	0.90	0.11	0.635		194.	0.67	-0.08	0.801		-4.	-0.23	-0.19							

(Continued)

(Sheet 10 of 12)

Table 9D (Continued)

STATION	DEPTH FT	>>>>>> BASE			TEST <<<<<<<			>>>>>> PLAN			TEST <<<<<<<			>>PLAN-MINUS-BASE<<		
		PHASE DEG	AMP FPS	FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	FPS	MEAN FPS	R-SQUARE	PHASE (DEG)	AMP (FPS)	MEAN (FPS)		
C80110	4	244.	1.78	-0.27	0.939		245.	1.60		-0.36	0.881		1.	-0.18	-0.09	
C80110	15	238.	1.44	-0.04	0.978		234.	1.53		-0.07	0.957		-4.	0.10	-0.03	
AC0002	4	211.	0.63	-0.25	0.830		210.	0.55		-0.08	0.783		-1.	0.08	0.17	
AC0002	27	213.	0.70	0.18	0.928		212.	0.49		0.16	0.740		-1.	-0.20	-0.02	
AC0002	49	191.	0.51	0.12	0.841		201.	0.47		0.17	0.661		10.	-0.03	0.05	
AC0002	54	****	****	****	0.841		203.	0.54		0.14	0.802		****	****	****	
TS0003	4	216.	1.96	-0.40	0.949		197.	1.18		-0.16	0.699		-19.	-0.78	0.24	
TS0003	26	221.	1.83	0.27	0.957		205.	1.30		0.26	0.887		-16.	-0.53	-0.01	
TS0003	46	226.	1.60	0.19	0.900		212.	1.28		0.51	0.911		-13.	-0.32	0.32	
TS0003	51	****	****	****	0.900		213.	1.28		0.47	0.915		****	****	****	
TS0005	4	227.	1.79	-0.89	0.989		229.	1.77		-0.64	0.848		2.	-0.02	0.25	
TS0005	27	214.	1.50	0.00	0.921		205.	1.57		0.79	0.847		-9.	0.07	0.79	
TS0005	50	216.	0.94	1.58	0.640		223.	1.03		1.29	0.851		7.	0.09	-0.28	
TS0005	55	****	****	****	0.640		216.	1.01		1.18	0.818		****	****	****	
YS0001	4	234.	2.37	0.00	0.911		227.	2.18		0.09	0.848		-6.	-0.20	0.09	
YS0001	25	229.	2.23	0.77	0.964		220.	2.14		0.75	0.943		-9.	-0.09	-0.02	
YS0001	45	227.	1.76	0.79	0.815		220.	1.76		0.76	0.981		-7.	0.00	-0.04	
JG0101	4	183.	2.31	-0.24	0.943		176.	2.04		-0.21	0.878		-7.	-0.27	0.04	
JG0101	11	183.	1.90	-0.16	0.940		179.	1.74		-0.17	0.935		-3.	-0.17	-0.01	
JG0102	4	207.	2.79	-0.51	0.970		200.	2.36		-0.40	0.895		-7.	-0.44	0.12	
JG0102	26	206.	2.40	-0.25	0.936		195.	2.01		-0.21	0.943		-11.	-0.39	0.04	
JG0102	48	191.	2.42	-0.27	0.918		174.	1.99		-0.29	0.862		-17.	-0.42	-0.02	
JG0103	4	205.	2.29	-0.45	0.968		210.	2.22		-0.63	0.923		5.	-0.07	-0.17	
JG0103	22	207.	1.94	-0.24	0.934		199.	1.94		-0.21	0.943		-8.	-0.00	0.02	
JG0103	44	190.	1.86	0.20	0.880		181.	1.95		0.31	0.874		-9.	0.09	0.11	
JG0103	66	172.	1.63	0.44	0.667		164.	1.69		0.60	0.793		-8.	0.06	0.16	
JG0103	83	156.	1.08	0.36	0.673		141.	1.02		0.58	0.630		-15.	-0.06	0.22	
JG0311	4	258.	1.69	-0.33	0.972		243.	1.60		-0.03	0.860		-15.	-0.30	0.30	
JG0311	11	259.	1.47	-0.16	0.932		252.	1.45		-0.05	0.939		-7.	-0.03	0.12	
JG0302	4	250.	2.15	-0.18	0.968		242.	1.47		0.15	0.955		-8.	-0.69	0.32	
JG0302	16	249.	1.77	0.09	0.958		245.	1.13		0.02	0.886		-4.	-0.64	-0.07	
JG0302	27	251.	1.22	0.08	0.922		248.	0.60		-0.09	0.635		-3.	-0.62	-0.17	

(Continued)

(Sheet 11 of 12)

Table 9D (Concluded)

STATION	DEPTH FT	>>>>>>>			TEST <<<<<<<			>>>>>>>			PLAN TEST <<<<<<<			>>PLAN-MINUS-BASE<<<		
		PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS	R-SQUARE	PHASE DEG	AMP FPS	MEAN FPS
JG0321	4	256.	2.16	-0.33	0.976	254.	1.91	-0.24	0.900	-2.	-0.25	0.09				
JN0202	4	186.	1.36	-0.12	0.865	199.	0.77	-0.06	0.876	13.	-0.59	0.07				
JN0202	12	199.	0.99	0.05	0.963	190.	0.56	0.02	0.880	-9.	-0.43	-0.03				
JN0203	4	245.	1.82	-0.69	0.919	229.	1.29	-0.48	0.947	-15.	-0.53	0.21				
JN0203	20	214.	1.17	-0.12	0.915	208.	0.96	-0.11	0.730	-5.	-0.21	0.00				
JN0204	4	234.	2.02	-0.69	0.942	223.	1.61	-0.58	0.939	-11.	-0.40	0.11				
JN0204	26	214.	1.94	0.09	0.981	207.	1.75	0.07	0.957	-7.	-0.19	-0.03				
JN0204	48	197.	1.38	0.65	0.938	198.	1.63	0.98	0.944	1.	0.24	0.32				
JN0204	55	****	*****	*****	0.938	196.	1.44	0.98	0.892	*****	*****	*****				
EH0202	4	190.	1.00	-0.22	0.780	174.	0.78	-0.19	0.701	-16.	-0.23	0.03				
EH0202	25	175.	1.05	0.15	0.812	170.	0.54	0.17	0.625	-4.	-0.50	0.02				
EH0202	46	143.	0.72	0.18	0.621	96.	0.11	0.06	0.116	-46.	-0.61	-0.12				
EH0202	55	****	*****	*****	0.621	101.	0.08	0.02	0.047	*****	*****	*****				
EH0203	4	182.	0.81	-0.22	0.906	159.	0.80	-0.26	0.817	-23.	-0.02	-0.04				
EH0203	22	171.	0.92	0.11	0.773	161.	0.71	0.04	0.811	-10.	-0.21	-0.08				
EH0203	40	127.	0.81	0.20	0.723	101.	0.17	0.02	0.178	-26.	-0.64	-0.17				
EH0501	4	169.	0.38	-0.08	0.579	198.	0.18	-0.09	0.443	29.	-0.20	-0.04				
EH0501	22	185.	0.35	0.07	0.441	211.	0.06	0.03	0.060	25.	-0.29	-0.04				
EH0501	39	186.	0.31	0.00	0.393	170.	0.51	-0.09	0.769	-16.	0.20	-0.10				
EH0501	45	****	*****	*****	0.393	150.	0.47	-0.05	0.816	*****	*****	*****				
EH0701	4	202.	0.36	-0.11	0.568	194.	0.19	-0.03	0.335	-8.	-0.17	0.08				
EH0701	19	167.	0.77	-0.16	0.741	165.	0.69	-0.16	0.813	-2.	-0.08	-0.00				
EH0701	35	146.	0.73	-0.04	0.780	152.	0.36	0.06	0.593	7.	-0.37	0.10				
EH0701	40	****	*****	*****	0.780	142.	0.29	0.06	0.457	*****	*****	*****				
EH0901	4	177.	0.40	-0.13	0.583	194.	0.27	-0.15	0.334	17.	-0.13	-0.02				
EH0901	19	157.	0.39	-0.02	0.589	167.	0.29	-0.07	0.298	10.	-0.11	-0.06				
EH0901	35	173.	0.17	0.00	0.445	157.	0.32	0.05	0.255	-16.	0.15	0.05				
EE0301	4	182.	0.61	0.15	0.754	179.	0.36	0.02	0.485	-3.	-0.25	-0.13				
EE0301	21	147.	0.29	0.22	0.532	175.	0.14	0.09	0.196	28.	-0.14	-0.13				
WB0201	4	172.	1.31	0.00	0.919	171.	1.05	0.10	0.885	-1.	-0.26	0.02				
WB0201	13	165.	1.14	0.09	0.938	158.	0.91	0.07	0.900	-7.	-0.33	-0.02				

(Sheet 12 of 12)

Table 10A

Steady-State Velocity Tests

Plan-Minus-Base Phase, Amplitude, and Mean Differences

STATION	DEPTH FT	TEST 1 *****			TEST 2 *****			TEST 3 *****			TEST 4 *****		
		PHASE DIFF DEG	AMP. FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. FPS	MEAN DIFF FPS
EB0001	4	3.	-0.10	0.27	18.	-0.05	0.12	5.	-0.27	0.26	-5.	-0.19	0.51
EB0001	18	1.	-0.12	-0.03	7.	0.09	-0.03	2.	-0.16	0.15	-13.	-0.38	0.17
EB0001	32	-4.	-0.05	0.09	10.	0.13	-0.12	-3.	-0.26	0.11	-18.	-0.30	0.25
EB0002	4	8.	-0.17	0.02	18.	0.03	0.69	11.	-0.06	0.15	-10.	-0.27	-0.02
EB0002	20	9.	-0.57	-0.26	9.	-0.18	0.14	11.	0.11	-0.05	7.	-0.24	0.04
EB0002	35	-2.	-0.05	0.09	10.	-0.24	0.13	6.	0.10	-0.02	3.	-0.13	0.03
EB0002	54	-4.	-0.27	0.08	12.	-0.19	-0.02	5.	0.00	-0.12	9.	-0.16	-0.02
EB0002	71	-5.	-0.59	-0.10	-4.	-0.23	-0.02	7.	0.29	-0.01	-9.	-0.05	-0.07
EB0004	4	3.	0.17	-0.01	8.	0.32	-0.38	5.	-0.43	-0.04	-17.	-0.04	-0.01
EB0004	16	6.	0.06	0.02	6.	0.32	-0.10	6.	-0.13	-0.14	-16.	0.01	0.02
EB0004	28	3.	-0.05	0.08	12.	0.46	0.02	-10.	0.14	-0.05	-21.	-0.09	0.05
EB0006	4	5.	0.56	-0.74	3.	0.13	-0.18	7.	-0.27	-0.07	-10.	-0.23	0.13
EB0006	15	4.	0.47	-0.16	11.	-0.13	0.01	1.	0.05	0.12	2.	-0.07	0.11
EB0008	4	0.	2.53	-0.53	14.	0.17	-0.18	15.	0.14	0.03	3.	-0.37	-0.00
EB0008	24	0.	2.17	-0.22	16.	-0.03	-0.29	9.	0.20	0.05	5.	-0.35	0.16
EB0008	43	2.	1.70	-0.14	-2.	0.07	0.05	10.	-0.23	0.12	5.	-0.50	-0.10
EB0009	4	2.	-0.35	-0.03	-10.	-0.36	0.05	6.	-0.67	0.29	-5.	-0.24	0.02
EB0009	16	4.	-0.71	0.10	-5.	-0.15	-0.03	8.	-0.34	0.16	2.	-0.07	-0.01
EB0101	4	4.	-0.11	-0.03	12.	-0.39	-0.03	-6.	-0.18	0.06	15.	-0.59	-0.01
EB0101	13	11.	0.25	-0.08	6.	-0.21	0.07	-4.	-0.08	-0.03	-5.	-0.19	0.02
EB0103	4	-5.	-0.07	-0.03	-2.	-0.37	0.08	-5.	-0.22	-0.02	-8.	-0.22	0.03
EB0103	14	3.	-0.07	-0.02	-0.	-0.39	0.09	-5.	-0.19	-0.03	-13.	-0.08	0.02
EB0103	24	11.	-0.30	0.02	-2.	-0.46	-0.05	-11.	-0.43	0.02	0.	-0.15	-0.06
EB0105	4	-10.	-0.11	0.03	4.	-0.52	0.33	16.	-0.30	-0.01	-2.	-0.23	0.07
EB0105	20	3.	-0.07	-0.04	-9.	-0.47	0.58	12.	-0.01	-0.04	-10.	-0.21	0.00
EB0105	37	6.	0.28	0.22	-5.	-0.25	-0.03	4.	-0.39	-0.06	-14.	-0.25	-0.05
EB0107	4	-11.	-0.11	0.04	16.	-0.22	0.07	10.	0.24	-0.04	3.	-0.20	0.14
EB0107	15	-13.	-0.29	0.06	1.	-0.04	0.00	3.	0.13	-0.14	1.	-0.13	0.05
EB0107	27	-9.	-0.12	-0.01	11.	-0.30	-0.03	10.	-0.07	0.03	-0.	-0.56	-0.10
EB0109	4	9.	0.05	-0.09	-2.	0.15	-0.07	18.	0.23	-0.54	-3.	-0.03	0.07
EB0109	39	7.	0.02	-0.22	9.	-0.06	-0.12	3.	-0.02	0.05	-4.	-0.04	0.04
EB0109	75	12.	-0.24	-0.19	20.	0.03	0.08	14.	-0.30	0.06	-4.	-0.23	-0.19

(Continued)

(Sheet 1 of 6)

Table 10A (Continued)

STATION	DEPTH FT	TEST 1			TEST 2			TEST 3			TEST 4		
		PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS
CB0110	4	3.	-0.13	-0.11	-5.	-0.14	-0.10	12.	-0.30	-0.02	1.	-0.18	-0.09
CB0110	15	4.	0.00	-0.04	-5.	0.04	-0.15	9.	-0.16	0.06	-4.	0.10	-0.03
AC0002	4	1.	-0.20	-0.00	11.	-0.19	-0.04	6.	-0.40	0.28	-1.	-0.08	0.17
AC0002	27	19.	-0.24	0.09	-10.	-0.18	-0.01	4.	-0.24	-0.01	-1.	-0.20	-0.02
AC0002	49	-10.	-0.06	-0.04	7.	-0.02	-0.07	8.	0.13	-0.01	10.	-0.03	0.05
AC0002	54	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
TS0003	4	-10.	-0.43	0.02	-15.	-0.18	0.09	-11.	-0.22	0.16	-19.	-0.78	0.24
TS0003	26	-13.	-0.31	0.00	-14.	0.02	-0.08	-10.	-0.36	0.18	-16.	-0.53	-0.01
TS0003	46	-13.	-0.06	0.18	-6.	0.25	0.06	-6.	0.25	0.10	-13.	-0.32	0.32
TS0003	51	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
TS0005	4	-4.	-0.12	-0.01	10.	-0.19	0.11	5.	-0.29	0.08	2.	-0.02	0.25
TS0005	27	-10.	-0.35	0.07	15.	0.35	0.25	-1.	-0.17	-0.15	-9.	0.07	0.79
TS0005	50	-13.	0.17	-0.20	17.	0.13	-0.04	8.	0.49	-0.29	7.	0.09	-0.28
TS0005	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
YS0001	4	-2.	-0.41	-0.16	6.	-0.31	-0.09	13.	0.12	0.22	-6.	-0.20	0.09
YS0001	25	-10.	-0.22	-0.16	15.	0.51	0.67	17.	-0.14	0.14	-9.	-0.09	-0.02
YS0001	45	-9.	0.07	-0.01	12.	-0.25	-0.25	10.	0.12	0.25	-7.	0.00	-0.04
JG0101	4	-11.	0.24	-0.36	6.	-0.20	-0.07	7.	-0.31	0.10	-7.	-0.27	0.04
JG0101	11	-19.	-0.22	-0.13	-5.	-0.26	-0.09	12.	-0.11	-0.09	-3.	-0.17	-0.01
JG0102	4	6.	-0.83	0.14	4.	0.10	-0.25	-1.	-0.67	0.20	-7.	-0.44	0.12
JG0102	26	2.	-0.30	0.03	-2.	-0.06	-0.09	0.	-0.44	0.08	-11.	-0.39	0.04
JG0102	48	6.	-0.95	0.15	5.	0.07	0.12	-2.	-0.16	-0.00	-17.	-0.42	-0.02
JG0103	4	9.	-0.00	-0.07	11.	0.15	-0.15	7.	-0.32	-0.13	5.	-0.07	-0.17
JG0103	22	6.	0.19	0.14	4.	-0.16	0.16	8.	-0.45	0.08	-8.	-0.00	0.02
JG0103	44	12.	-0.01	-0.11	10.	0.06	0.05	17.	0.23	0.12	-9.	0.09	0.11
JG0103	66	5.	0.80	0.15	-4.	0.06	0.03	14.	0.37	0.08	-8.	0.06	0.16
JG0103	83	-64.	1.00	0.46	8.	-0.10	-0.10	9.	0.21	-0.07	-15.	-0.06	0.22
JG0311	4	5.	0.11	0.10	6.	0.36	-0.05	-6.	-0.20	0.26	-15.	-0.30	0.30
JG0311	11	7.	-0.04	0.02	17.	0.37	0.04	-5.	0.08	0.00	-7.	-0.03	0.12
JG0302	4	8.	0.39	-0.12	-4.	-0.03	0.07	10.	-0.37	0.12	-8.	-0.69	0.32
JG0302	16	8.	0.34	-0.00	-13.	-0.19	-0.02	8.	-0.22	0.06	-4.	-2.64	-0.07
JG0302	27	9.	0.29	-0.07	-0.	9.13	-0.10	6.	-0.00	-0.07	-3.	-0.62	-0.17

(Continued)

(Sheet 2 of 6)

Table 10A (Concluded)

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS	PHASE DIFF DEG	AMP. DIFF FPS	MEAN DIFF FPS
JG0321	4	7.	-0.46	0.04	-1.	0.09	-0.02	5.	-0.19	0.04	-2.	-0.25	0.09
JN0202	4	-9.	0.21	-0.15	-9.	0.06	-0.11	3.	-0.26	0.09	13.	-0.59	0.07
JN0202	12	-3.	-0.48	0.06	4.	-0.00	-0.04	-0.	0.13	-0.00	-9.	-0.43	-0.03
JN0203	4	10.	-0.17	0.00	-4.	-0.18	0.07	3.	0.09	-0.08	-15.	-0.53	0.21
JN0203	20	-2.	-0.04	-0.08	10.	0.04	-0.06	17.	-0.00	-0.09	-5.	-0.21	0.00
JN0204	4	14.	0.26	-0.63	18.	0.29	-0.04	19.	-0.42	-0.11	-11.	-0.40	0.11
JN0204	26	6.	-0.17	0.05	-1.	-0.02	0.01	9.	-0.56	0.13	-7.	-0.19	-0.03
JN0204	48	-2.	0.04	0.21	14.	0.05	0.09	-8.	-0.41	0.07	1.	0.24	0.32
JN0204	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0202	4	5.	-0.12	0.07	-12.	-0.13	0.04	-7.	-0.40	0.11	-16.	-0.23	0.03
EH0202	25	-2.	-0.05	0.12	9.	0.42	0.10	-7.	-0.30	0.02	-4.	-0.50	0.02
EH0202	46	10.	-0.99	-0.20	19.	0.47	-0.03	-19.	-0.13	-0.24	-46.	-0.61	-0.12
EH0202	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0203	4	5.	-0.02	-0.02	-0.	-0.34	0.20	-10.	-0.51	-0.09	-23.	-0.02	-0.04
EH0203	22	7.	-0.09	0.16	10.	-0.03	-0.02	-10.	-0.21	0.08	-10.	-0.21	-0.08
EH0203	40	11.	-0.85	-0.15	-13.	0.09	-0.08	-14.	-0.25	0.18	-26.	-0.64	-0.17
EH0501	4	-10.	-0.14	0.01	23.	0.11	-0.02	6.	-0.28	0.39	29.	-0.20	-0.02
EH0501	22	-2.	0.07	-0.15	-4.	-0.11	0.06	-19.	-0.45	-0.11	25.	-0.29	-0.04
EH0501	39	-25.	0.12	-0.22	-57.	-0.28	0.13	-46.	0.02	0.00	-16.	0.20	-0.10
EH0501	45	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0701	4	-10.	-0.45	0.22	-5.	-0.09	0.16	-1.	-0.55	0.21	-8.	-0.17	0.08
EH0701	19	-11.	-0.08	0.03	-11.	-0.08	0.12	-14.	-0.53	-0.02	-2.	-0.08	-0.00
EH0701	35	-12.	-0.26	0.09	-5.	0.33	-0.15	-14.	-0.40	-0.04	7.	-0.37	0.10
EH0701	40	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0901	4	11.	-0.24	0.26	6.	-0.01	0.04	5.	-0.08	0.10	17.	-0.13	-0.02
EH0901	19	-17.	-0.24	0.12	-5.	-0.08	-0.15	-16.	-0.11	0.05	10.	-0.11	-0.06
EH0901	35	13.	-0.15	0.00	68.	0.00	0.02	-5.	0.00	0.00	-16.	0.15	0.05
EE0301	4	-1.	0.23	0.04	13.	-0.15	-0.04	-8.	0.12	0.09	-3.	-0.25	-0.13
EE0301	21	4.	-0.15	-0.02	-10.	-0.62	-0.13	10.	-0.06	-0.00	28.	-0.14	-0.13
WB0201	4	-10.	0.12	-0.18	10.	-0.92	-0.05	-7.	0.04	0.27	-1.	-0.26	0.02
WB0201	13	-8.	0.21	-0.06	3.	-0.15	-0.10	3.	0.09	0.07	-7.	-0.33	-0.02

(Sheet 3 of 6)

Table 10B

Steady-State Velocity Tests

Plan-Minus-Base Phase Differences: Summary Statistics

CLASS INTERVAL	*** TEST 1 *** FREQ. RELATIVE FREQ.	*** TEST 2 *** FREQ. RELATIVE FREQ.	*** TEST 3 *** FREQ. RELATIVE FREQ.	*** TEST 4 *** FREQ. RELATIVE FREQ.	*** OVERALL *** FREQ. RELATIVE FREQ.
GREATER THAN 30 DEG	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
25 < DIFF < 30 DEG	0 0.000	0 0.000	0 0.000	3 0.034	3 0.009
20 < DIFF < 25 DEG	0 0.000	1 0.011	0 0.000	0 0.000	1 0.003
15 < DIFF < 20 DEG	1 0.011	10 0.115	7 0.080	1 0.011	19 0.054
10 < DIFF < 15 DEG	8 0.092	16 0.184	10 0.114	3 0.034	37 0.106
5 < DIFF < 10 DEG	21 0.241	17 0.195	28 0.318	8 0.091	74 0.211
0 < DIFF < 5 DEG	21 0.241	7 0.080	11 0.125	10 0.114	49 0.140
-5 < DIFF < 0 DEG	11 0.126	19 0.218	8 0.091	17 0.193	55 0.157
-10 < DIFF < -5 DEG	12 0.138	9 0.103	14 0.159	23 0.261	58 0.166
-15 < DIFF < -10 DEG	10 0.115	7 0.080	6 0.068	8 0.091	31 0.089
-20 < DIFF < -15 DEG	2 0.023	0 0.000	3 0.034	11 0.125	16 0.046
-25 < DIFF < -20 DEG	1 0.011	0 0.000	0 0.000	2 0.023	3 0.009
-30 < DIFF < -25 DEG	0 0.000	0 0.000	0 0.000	1 0.011	1 0.003
LESS THAN -30 DEG	0 0.000	1 0.011	1 0.011	1 0.011	3 0.009
NUMBER IN SAMPLE	87	87	88	88	350
MEAN DIFFERENCE (DEG)	0.19	3.15	2.11	-4.68	0.18
STANDARD DEVIATION (DEG)	8.77	11.37	10.49	11.32	10.92

(Sheet 4 of 6)

Table 10C

Steady-State Velocity Tests

Plan-Minus-Base Amplitude Differences: Summary Statistics

CLASS INTERVAL	*** TEST 1 *** FREQ. RELATIVE FREQ.	*** TEST 2 *** FREQ. RELATIVE FREQ.	*** TEST 3 *** FREQ. RELATIVE FREQ.	*** TEST 4 *** FREQ. RELATIVE FREQ.	*** OVERALL *** FREQ. RELATIVE FREQ.
GREATER THAN 0.8 FPS	0	0	0	0	0
0.7 < DIFF < 0.8 FPS	0	0	0	0	0
0.6 < DIFF < 0.7 FPS	0	0	0	0	0
0.5 < DIFF < 0.6 FPS	1	1	0	0	2
0.4 < DIFF < 0.5 FPS	1	3	1	0	5
0.3 < DIFF < 0.4 FPS	2	6	1	0	9
0.2 < DIFF < 0.3 FPS	8	3	6	2	19
0.1 < DIFF < 0.2 FPS	6	9	10	1	26
0.0 < DIFF < 0.1 FPS	7	14	8	7	36
-0.1 < DIFF < 0.0 FPS	16	15	9	18	58
-0.2 < DIFF < -0.1 FPS	16	17	14	14	61
-0.3 < DIFF < -0.2 FPS	10	9	16	21	56
-0.4 < DIFF < -0.3 FPS	4	7	8	8	27
-0.5 < DIFF < -0.4 FPS	5	2	9	4	20
-0.6 < DIFF < -0.5 FPS	2	1	4	7	14
-0.7 < DIFF < -0.6 FPS	0	1	2	5	8
-0.8 < DIFF < -0.7 FPS	1	0	0	1	2
LESS THAN -0.8 FPS	4	0	0	0	4
NUMBER IN SAMPLE	83	80	83	83	347
MEAN DIFFERENCE (FPS)	-0.12	-0.04	0.07	-0.02	-0.13
STANDARD DEVIATION (FPS)	0.33	0.24	0.24	0.21	0.25

(Sheet 5 of 6)

Table 100

Steady-State Velocity Tests

Plan-Minus-Base Mean Velocity Differences: Summary Statistics

CLASS INTERVAL	*** TEST 1 *** FREQ. RELATIVE FREQ.	*** TEST 2 *** FREQ. RELATIVE FREQ.	*** TEST 3 *** FREQ. RELATIVE FREQ.	*** TEST 4 *** FREQ. RELATIVE FREQ.	*** OVERALL *** FREQ. RELATIVE FREQ.
GREATER THAN 0.8 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
0.7 < DIFF < 0.8 FPS	0 0.000	0 0.000	0 0.000	1 0.011	1 0.003
0.6 < DIFF < 0.7 FPS	0 0.000	2 0.023	0 0.000	0 0.000	2 0.006
0.5 < DIFF < 0.6 FPS	0 0.000	1 0.011	0 0.000	1 0.011	2 0.006
0.4 < DIFF < 0.5 FPS	1 0.011	0 0.000	0 0.000	0 0.000	1 0.003
0.3 < DIFF < 0.4 FPS	0 0.000	1 0.011	1 0.011	4 0.045	6 0.017
0.2 < DIFF < 0.3 FPS	5 0.057	1 0.011	8 0.091	5 0.057	19 0.054
0.1 < DIFF < 0.2 FPS	9 0.102	11 0.125	17 0.193	11 0.125	48 0.136
0.0 < DIFF < 0.1 FPS	27 0.307	23 0.261	25 0.284	27 0.307	102 0.290
-0.1 < DIFF < 0.0 FPS	22 0.250	33 0.375	27 0.307	30 0.341	112 0.318
-0.2 < DIFF < -0.1 FPS	15 0.170	12 0.136	7 0.080	8 0.091	42 0.119
-0.3 < DIFF < -0.2 FPS	5 0.057	3 0.034	2 0.023	1 0.011	11 0.031
-0.4 < DIFF < -0.3 FPS	1 0.011	1 0.011	0 0.000	0 0.000	2 0.006
-0.5 < DIFF < -0.4 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
-0.6 < DIFF < -0.5 FPS	1 0.011	0 0.000	1 0.011	0 0.000	2 0.006
-0.7 < DIFF < -0.6 FPS	1 0.011	0 0.000	0 0.000	0 0.000	1 0.003
-0.8 < DIFF < -0.7 FPS	1 0.011	0 0.000	0 0.000	0 0.000	1 0.003
LESS THAN -0.8 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
NUMBER IN SAMPLE	88	88	88	88	352
MEAN DIFFERENCE (FPS)	-0.03	0.01	0.04	0.04	0.02
STANDARD DEVIATION (FPS)	0.18	0.17	0.14	0.15	0.16

(Sheet 6 of 6)

TEST 1

Maximum Flood and Ebb Velocities

[illegible]

(Continued)

(Sheet 1 of 12)

Table 11A (Continued)

STATION	DEPTH FT	MODEL DATA				HARMONIC ANALYSIS			
		BASE TEST		PLAN TEST		BASE TEST		PLAN TEST	
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS
CB0110	4	2.30	2.08	2.18	2.97	2.12	3.12	1.87	3.11
CB0110	15	1.56	2.36	1.70	2.47	1.69	2.34	1.65	2.38
AC0002	4	0.42	2.02	0.18	1.80	0.24	1.94	0.03	1.75
AC0002	27	1.24	1.05	1.00	0.75	1.21	0.95	1.06	0.62
AC0002	49	1.36	0.77	1.38	0.84	1.40	0.70	1.31	0.68
AL0002	54	*****	*****	1.32	0.68	*****	*****	1.23	0.64
TS0003	4	2.52	4.10	2.15	3.35	2.49	3.44	2.08	2.99
TS0003	26	3.52	2.43	2.90	2.12	3.10	2.50	2.79	2.19
TS0003	45	3.33	2.46	3.48	2.26	3.09	2.26	3.21	2.02
TS0003	51	*****	*****	3.22	2.26	*****	*****	3.13	2.13
TS0005	4	2.10	4.26	1.91	4.58	1.97	4.19	1.84	4.08
TS0005	27	2.23	2.68	1.94	2.61	2.18	2.63	1.90	2.21
TS0005	50	3.55	0.23	3.51	0.43	3.69	0.48	3.66	0.11
TS0005	55	*****	*****	3.26	0.00	*****	*****	3.24	0.31
YS0001	4	4.13	3.49	3.81	3.23	3.71	3.56	3.14	3.30
YS0001	25	4.51	2.31	4.10	2.02	3.96	2.59	3.57	2.53
YS0001	45	3.24	1.64	3.33	1.67	3.48	1.63	3.5	1.71
JG0101	4	2.26	2.07	2.12	3.25	2.56	2.84	2.4	3.44
JG0101	11	2.30	3.20	1.99	2.91	2.53	2.98	2.19	2.89
JG0102	4	3.10	4.80	2.53	3.82	3.57	4.83	2.88	3.86
JG0102	26	2.90	4.03	2.80	3.60	3.05	4.05	2.78	3.72
JG0102	48	2.84	3.84	2.26	2.97	3.17	3.68	2.38	2.58
JG0103	4	2.67	4.64	2.58	4.19	2.93	4.33	2.86	4.40
JG0103	22	2.24	3.70	2.68	3.55	2.61	3.72	2.94	3.77
JG0103	44	2.83	3.83	2.84	3.39	3.21	3.29	3.09	3.40
JG0103	66	2.34	1.63	2.58	2.97	1.86	1.31	2.81	1.96
JG0103	83	0.34	0.45	1.78	2.00	0.13	0.16	1.59	0.70
JG0311	4	1.75	2.68	2.13	2.60	1.94	2.77	2.15	2.78
JG0311	11	1.68	2.45	1.81	2.46	1.80	2.58	1.78	2.53
JG0302	4	1.86	2.31	2.24	2.67	1.99	2.45	2.26	2.95
JG0302	16	1.51	2.21	1.96	2.45	1.71	2.24	2.05	2.59
JG0302	27	1.35	1.67	1.71	2.14	1.45	1.80	1.66	2.15

(Continued)

(Sheet 2 of 12)

Table 11A (Concluded)

STATION	DEPTH	>>>>>>>>>> MODEL DATA <<<<<<<<<<<<						>>>>>>>>> HARMONIC ANALYSIS <<<<<<<<<<<<					
		**** BASE TEST ****			**** PLAN TEST ****			**** BASE TEST ****			**** PLAN TEST ****		
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS		
JG0321	4	2.01	3.25	1.77	2.72	2.25	3.28	1.83	2.78				
JN0202	4	1.04	1.13	1.06	1.55	1.05	1.04	1.11	1.41				
JN0202	12	1.13	1.46	0.66	0.88	1.19	1.32	0.77	0.78				
JN0203	4	1.33	2.33	1.19	2.02	1.39	2.41	1.23	2.23				
JN0203	20	1.27	1.52	1.01	1.62	1.21	1.49	1.10	1.53				
JN0204	4	2.64	3.05	1.92	4.28	2.13	3.14	1.76	4.03				
JN0204	26	2.58	2.58	2.47	2.53	2.74	2.64	2.62	2.42				
JN0204	48	2.55	1.81	2.91	1.48	2.50	1.77	2.85	1.61				
JN0204	55	*****	*****	2.72	1.12	*****	*****	2.86	0.96				
EH0202	4	1.32	1.98	1.27	1.51	1.01	1.64	0.95	1.46				
EH0202	25	1.21	1.14	1.24	1.17	1.03	1.16	1.10	0.99				
EH0202	46	1.65	1.18	0.45	0.56	1.40	1.15	0.21	0.36				
EH0202	55	*****	*****	0.65	0.42	*****	*****	0.29	0.23				
EH0203	4	1.28	1.88	0.98	1.68	0.86	1.36	0.83	1.36				
EH0203	22	1.41	1.38	1.35	1.14	1.09	1.07	1.17	0.82				
EH0203	40	1.98	1.21	1.08	0.45	1.64	0.95	0.64	0.25				
EH0501	4	0.52	1.07	0.61	0.84	0.56	0.86	0.43	0.71				
EH0501	22	0.75	0.91	0.57	0.75	0.68	0.52	0.60	0.74				
EH0501	39	0.68	0.75	0.52	0.97	0.63	0.47	0.53	0.81				
EH0501	45	*****	*****	0.66	0.75	*****	*****	0.61	0.63				
EH0701	4	0.86	1.61	0.78	0.78	0.90	1.27	0.66	0.60				
EH0701	19	0.75	1.78	0.75	1.71	0.70	0.88	0.65	0.78				
EH0701	35	0.73	1.75	0.72	1.12	0.61	1.02	0.64	0.66				
EH0701	40	*****	*****	0.62	0.62	*****	*****	0.63	0.59				
EH0901	4	0.49	2.20	0.61	1.55	0.56	1.74	0.57	1.24				
EH0901	19	0.36	1.26	0.44	0.35	0.31	0.57	0.19	0.21				
EH0901	35	0.26	0.59	0.18	0.18	0.21	0.25	0.06	0.09				
EE0301	4	1.13	0.93	1.25	1.40	0.78	0.79	1.05	0.99				
EE0301	21	0.69	0.42	0.36	0.42	0.37	0.28	0.20	0.14				
WB0201	4	2.24	1.51	2.55	1.74	1.99	1.56	1.93	1.86				
WB0201	13	1.93	1.14	2.08	1.31	1.63	1.13	1.78	1.45				

(Sheet 3 of 12)

TEST 2

Maximum Flood and Ebb Velocities

[illegible]

(Continued)

(Sheet 4 of 12)

Table 11B (Continued)

STATION	DEPTH FT	>>>>>>>>>> MODEL DATA <<<<<<<<<<<<						>>>>>>>>> HARMONIC ANALYSIS <<<<<<<<<<<<					
		**** BASE TEST ****			**** PLAN TEST ****			**** BASE TEST ****			**** PLAN TEST ****		
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS		
C80110	4	1.70	1.70	1.37	1.77	1.31	1.98	1.07	1.93				
C80110	15	1.57	1.17	1.40	1.35	1.18	1.14	1.07	1.33				
AC0002	4	0.38	0.93	0.11	0.95	0.36	0.75	0.14	0.60				
AC0002	27	0.90	0.38	0.85	0.29	0.76	0.47	0.57	0.30				
AC0002	49	0.87	0.38	0.95	0.39	0.77	0.34	0.68	0.39				
AC0002	54	*****	*****	0.78	0.29	*****	*****	0.51	0.32				
TS0003	4	1.46	2.06	1.51	1.75	1.11	2.09	1.02	1.81				
TS0003	26	1.99	1.59	2.22	1.58	2.05	1.31	1.99	1.41				
TS0003	46	1.89	1.33	2.16	1.44	1.88	1.01	2.19	1.19				
TS0003	51	*****	*****	2.09	1.27	*****	*****	2.00	1.02				
TS0005	4	0.00	2.82	0.00	2.00	0.29	2.29	0.21	1.98				
TS0005	27	1.24	1.49	1.61	1.77	1.04	1.19	1.64	1.29				
TS0005	50	2.79	0.53	2.75	1.22	2.82	0.19	2.91	0.37				
TS0005	55	*****	*****	2.78	0.95	*****	*****	2.82	0.36				
YS0001	4	2.40	1.66	2.13	1.63	1.57	2.03	1.17	1.81				
YS0001	25	2.47	1.60	3.09	1.41	2.09	1.52	3.27	1.36				
YS0001	45	3.15	1.29	2.72	1.11	3.34	1.21	2.84	1.21				
JG0101	4	1.82	3.39	1.56	2.94	1.93	3.06	1.56	2.93				
JG0101	11	1.72	2.33	1.28	2.11	1.67	2.27	1.31	2.10				
JG0102	4	1.99	3.13	2.02	3.62	2.03	3.22	1.89	3.57				
JG0102	26	2.11	2.23	2.09	2.67	1.98	2.05	1.83	2.09				
JG0102	48	1.43	1.08	1.17	1.58	1.20	0.95	1.39	0.89				
JG0103	4	1.61	3.23	1.68	3.57	1.92	3.08	1.92	3.38				
JG0103	22	1.45	2.40	1.74	2.26	1.81	2.10	1.80	1.78				
JG0103	44	1.55	1.29	1.68	1.55	1.51	0.93	1.64	1.16				
JG0103	66	1.77	1.45	1.87	1.35	1.88	0.89	1.97	0.92				
JG0103	83	1.20	0.84	1.15	0.86	1.39	0.47	1.18	0.47				
JG0311	4	1.13	1.78	1.59	2.08	1.17	1.68	1.49	2.09				
JG0311	11	0.81	1.52	1.37	1.68	0.90	1.37	1.31	1.69				
JG0302	4	1.50	2.11	1.44	2.20	1.48	2.08	1.53	1.97				
JG0302	16	1.51	1.54	1.19	1.44	1.32	1.53	1.12	1.36				
G0302	27	0.67	0.92	0.43	1.25	0.40	0.84	0.43	1.06				

(Continued)

(Sheet 5 of 12)

Table 11B (Concluded)

TEST 3

Maximum Flood and Ebb Velocities

STATION	DEPTH	>>>>>>>>> MODEL DATA <<<<<<<<<<<<<<<						>>>>>>>>> HARMONIC ANALYSIS <<<<<<<<<<<<<<<																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
		**** BASE TEST ****			**** PLAN TEST ****			**** BASE TEST ****			**** PLAN TEST ****																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	FT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</

(Continued)

(Sheet 7 of 12)

Table 11C (Continued)

STATION	DEPTH	>>>>>>>>> MODEL DATA <<<<<<<<<<<<						>>>>>>>>> HARMONIC ANALYSIS <<<<<<<<<<<<					
		BASE TEST *****			PLAN TEST *****			BASE TEST *****			PLAN TEST *****		
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS		
	FT												
		2.06	3.00	2.19	2.64	2.18	3.14	1.86	2.86				
C80110	4			1.96	2.19	1.98	2.67	1.87	2.44				
C80110	15	2.00	2.45	0.25	1.44	0.29	1.94	0.10					
AC0002	4	0.62	1.87	0.81	0.81	1.36	1.02	1.11	0.79				
AC0002	27	1.36	1.20	1.37	0.98	1.31	0.72	1.43	0.86				
AC0002	49	1.27	0.79	1.25	0.75	*****	*****	1.26	0.80				
AC0002	54	*****	*****	2.81	3.18	2.54	3.42	2.48	3.05				
TS0003	4	2.81	3.64	3.32	2.50	3.14	2.64	2.97	2.09				
TS0003	26	3.49	2.58	3.38	2.84	2.87	2.19	3.22	2.33				
TS0003	46	2.74	2.52	3.25	2.67	*****	*****	2.91	2.28				
TS0003	51	*****	*****	2.02	3.49	2.15	3.59	1.95	3.22				
TS0005	4	2.20	3.78	2.21	2.50	2.39	2.53	2.07	2.50				
TS0005	27	2.72	2.62	3.01	0.49	2.78	0.35	2.98	0.42				
TS0005	50	2.85	0.90	2.54	0.43	*****	*****	2.62	0.10				
TS0005	55	*****	*****	4.65	2.98	3.63	3.18	3.96	3.09				
YS0001	4	4.26	2.76	4.21	2.41	3.79	2.68	3.80	2.40				
YS0001	25	4.57	2.15	4.08	1.88	3.14	2.08	3.51	1.94				
YS0001	45	3.55	1.83	2.02	2.60	2.70	2.74	2.48	2.33				
JG0101	4	2.38	3.14	1.96	2.47	2.37	2.19	2.17	2.17				
JG0101	11	2.02	2.62	2.63	3.10	3.16	4.19	2.69	3.32				
JG0102	4	2.94	4.24	2.32	3.19	2.85	3.67	2.50	3.15				
JG0102	26	2.51	3.99	2.60	3.16	2.92	3.31	2.76	3.15				
JG0102	48	2.67	3.43	2.64	3.49	3.10	3.64	2.65	3.46				
JG0103	4	2.93	3.59	2.33	2.64	2.83	3.07	2.46	2.53				
JG0103	22	2.68	2.87	2.39	2.81	2.43	2.45	2.78	2.57				
JG0103	44	2.20	2.36	2.57	3.21	2.66	1.87	3.11	2.16				
JG0103	66	2.23	2.68	2.29	1.48	1.63	0.52	1.78	0.81				
JG0103	83	2.23	1.33	2.29	1.48	1.63	0.52	1.78	0.81				
JG0311	4	1.63	3.14	1.96	2.34	1.78	2.85	1.84	2.39				
JG0311	11	1.48	2.15	1.99	2.12	1.69	2.15	1.77	2.23				
JG0302	4	2.09	2.72	1.84	2.30	2.25	2.83	2.00	2.34				
JG0302	16	2.02	2.31	1.75	2.10	2.06	2.36	1.89	2.08				
JG0302	27	1.71	1.52	1.45	2.04	1.71	1.77	1.64	1.84				

(Continued)

(Sheet 8 of 12)

Table 11C (Concluded)

TEST 4

Maximum Flood and Ebb Velocities

[illegible]

(Continued)

(Sheet 10 of 12)

Table 11D (Continued)

STATION	DEPTH FT	>>>>>>>>>> MODEL DATA <<<<<<<<<<<<						>>>>>>>>> HARMONIC ANALYSIS <<<<<<<<<<<<					
		**** BASE TEST ****			**** PLAN TEST ****			**** BASE TEST ****			**** PLAN TEST ****		
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS		
CB0110	4	1.51	2.09	1.58	1.78	1.51	2.06	1.24	1.96				
CB0110	15	1.42	1.58	1.38	1.71	1.40	1.48	1.47	1.60				
AC0002	4	0.29	0.94	0.59	0.76	0.37	0.88	0.46	0.63				
AC0002	27	0.94	0.55	0.83	0.38	0.88	0.51	0.65	0.34				
AC0002	49	0.72	0.33	0.83	0.38	0.62	0.39	0.64	0.30				
AC0002	54	*****	*****	0.79	0.42	*****	*****	0.68	0.40				
TS0003	4	1.77	2.27	1.59	1.49	1.56	2.36	1.02	1.34				
TS0003	26	2.27	1.62	1.80	1.31	2.11	1.56	1.56	1.04				
TS0003	46	1.96	1.47	1.83	1.06	1.78	1.41	1.79	0.77				
TS0003	51	*****	*****	1.70	1.06	*****	*****	1.75	0.80				
TS0005	4	0.95	2.72	1.00	2.71	0.90	2.68	1.13	2.40				
TS0005	27	1.74	1.55	2.40	0.93	1.50	1.50	2.36	0.78				
TS0005	50	2.87	0.00	2.33	0.00	2.52	0.64	2.32	0.26				
TS0005	55	*****	*****	2.33	0.00	*****	*****	2.18	0.17				
YS0001	4	2.73	2.49	2.91	2.02	2.38	2.37	2.27	2.09				
YS0001	25	2.93	1.36	2.87	1.34	3.00	1.45	2.89	1.39				
YS0001	45	2.73	1.23	2.50	1.17	2.55	0.96	2.52	1.00				
JG0101	4	2.09	2.58	1.52	2.52	2.07	2.56	1.83	2.25				
JG0101	11	1.65	1.95	1.42	2.00	1.74	2.06	1.56	1.91				
JG0102	4	2.28	3.44	1.94	2.91	2.28	3.31	1.96	2.76				
JG0102	26	2.24	2.81	1.78	2.39	2.15	2.66	1.80	2.22				
JG0102	48	2.21	2.90	1.42	2.68	2.14	2.69	1.70	2.29				
JG0103	4	1.77	2.91	1.79	3.32	1.83	2.74	1.59	2.84				
JG0103	22	1.67	2.15	1.54	2.33	1.70	2.18	1.72	2.15				
JG0103	44	2.02	2.28	2.09	2.16	2.06	1.67	2.26	1.65				
JG0103	66	2.09	1.86	2.12	1.51	2.07	1.19	2.29	1.09				
JG0103	83	1.51	0.88	1.51	0.76	1.44	0.72	1.60	0.43				
JG0311	4	1.50	2.27	1.48	1.89	1.57	2.22	1.57	1.62				
JG0311	11	1.16	1.77	1.23	1.64	1.31	1.64	1.40	1.49				
JG0302	4	2.02	2.49	1.48	1.38	1.98	2.33	1.62	1.32				
JG0302	16	1.92	1.69	1.07	1.10	1.86	1.68	1.15	1.11				
JG0302	27	1.23	1.16	0.62	0.94	1.29	1.14	0.51	0.69				

(Continued)

(Sheet 11 of 12)

Table 11D (Concluded)

Table 12A

Maximum Flood and Ebb Velocities: Plan-Minus-Base Differences

Computed from Observed Model Data

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	DIFFERENCE	MAX FLOOD VELOCITY (FPS)	MAX EBB VELOCITY FPS	DIFFERENCE	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	DIFFERENCE	MAX FLOOD VELOCITY FPS	MAX EBB VELOCITY FPS	DIFFERENCE
C80001	4	0.16	-0.37		0.33	-0.14		0.10	-0.07		0.61	-0.07	
C80001	18	0.11	+0.07		0.12	+0.07		0.28	-0.12		-0.12	-0.31	
C80001	32	-0.07	+0.00		-0.06	+0.33		-0.46	-0.28		-0.19	-0.23	
C80002	4	-0.15	-0.32		0.43	-0.34		0.22	-0.28		-0.42	-0.23	
C80002	20	-1.31	-0.03		0.28	-0.27		0.32	+0.22		-0.11	-0.44	
C80002	35	-0.21	-0.20		-0.09	-0.21		0.20	+0.24		0.10	-0.32	
C80002	54	-0.36	-0.32		-0.04	-0.21		0.23	+0.13		-0.10	-0.11	
C80002	71	-0.47	-0.55		-0.13	-0.11		0.28	+0.71		-0.13	-0.05	
C80004	4	0.19	+0.16		-0.02	+0.66		-0.47	-0.06		-0.04	+0.10	
C80004	16	-0.07	+0.27		0.13	+0.42		-0.30	+0.18		0.08	+0.15	
C80004	28	0.07	+0.11		0.60	+0.27		0.18	+0.21		-0.08	-0.28	
C80006	4	-0.52	+1.41		-0.26	+0.35		-0.12	-0.49		-0.08	-0.38	
C80006	15	0.43	+0.79		-0.27	-0.19		0.18	-0.13		-0.14	+0.01	
C80008	4	2.03	+3.09		-0.05	+0.21		0.25	-0.17		-0.16	-0.88	
C80008	24	1.83	+2.49		-0.39	+0.16		-0.00	+0.51		-0.16	-0.44	
C80000	43	1.33	+2.13		-0.01	-0.04		0.10	-0.25		-0.52	-0.71	
C80009	4	-0.62	+0.44		-0.17	-0.50		-0.04	-0.93		0.01	-0.11	
C80009	16	-0.90	-0.60		-0.21	-0.26		-0.30	+0.03		-0.12	-0.01	
C80101	4	-0.12	-0.07		-0.20	-0.21		-0.13	-0.02		-0.31	-0.74	
C80101	13	0.50	+0.19		0.04	-0.11		0.02	+0.07		-0.14	-0.27	
C80103	4	0.10	-0.60		-0.18	-0.24		-0.27	+0.12		-0.06	-0.14	
C80103	14	0.07	+0.04		-0.25	-0.17		-0.14	-0.10		0.05	-0.15	
C80103	24	-0.37	-0.22		-0.24	-0.17		-0.20	-0.49		-0.20	-0.00	
C80105	4	0.08	-0.01		0.10	-0.96		-0.20	-0.37		-0.09	-0.38	
C80105	20	-0.15	-0.19		0.26	-1.15		-0.14	+0.22		-0.16	-0.21	
C80105	37	0.24	+0.07		-0.31	-0.25		-0.43	-0.23		-0.25	-0.14	
C80107	4	-0.20	-0.28		-0.22	-0.26		0.13	+0.49		-0.08	-0.45	
C80107	15	-0.23	-0.09		-0.16	-0.19		-0.16	+0.19		0.07	-0.25	
C80107	27	-0.28	+0.18		-0.35	-0.35		-0.06	+0.13		-0.67	-0.37	
C80109	4	-0.20	+0.13		0.19	-0.00		-0.26	+1.35		0.19	-0.09	
C80109	39	-0.14	+0.26		-0.31	-0.11		-0.07	-0.05		-0.02	-0.02	
C80109	75	-0.45	-0.03		0.05	-0.03		-0.12	-0.00		-0.53	+0.06	

(Continued)

(Sheet 1 of 10)

Table 12A (Continued)

STATION	DEPTH FT	TEST 1 *****			TEST 2 *****			TEST 3 *****			TEST 4 *****		
		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS
CB0110	4	-0.11	+0.09	-0.33	+0.07	0.13	-0.36	0.07	-0.30				
CB0110	15	0.14	+0.11	-0.16	+0.17	-0.04	-0.26	-0.04	+0.13				
AC0002	4	-0.24	-0.20	-0.27	+0.02	-0.36	-0.43	0.30	-0.18				
AC0002	27	-0.24	-0.50	-0.06	-0.09	-0.12	-0.39	-0.12	-0.17				
AC0002	49	0.02	+0.07	0.08	+0.01	0.11	+0.19	0.11	+0.05				
AC0002	54	*****	*****	*****	*****	*****	*****	*****	*****				
TS0003	4	-0.39	-0.74	0.05	-0.31	-0.00	-0.46	-0.46	-0.78				
TS0003	26	-0.62	-0.30	0.23	-0.01	-0.17	-0.09	-0.47	-0.32				
TS0003	46	0.15	-0.20	0.27	+0.11	0.64	+0.32	-0.13	-0.41				
TS0003	51	*****	*****	*****	*****	*****	*****	*****	*****				
TS0005	4	-0.19	+0.32	0.00	-0.82	-0.18	-0.29	0.04	-0.00				
TS0005	27	-0.29	-0.07	0.37	+0.28	-0.51	+0.11	0.66	-0.62				
TS0005	50	-0.03	+0.20	-0.04	+0.69	0.16	+0.49	-0.54	-0.00				
TS0005	55	*****	*****	*****	*****	*****	*****	*****	*****				
YS0001	4	-0.32	-0.26	-0.27	-0.03	0.39	+0.22	0.18	-0.47				
YS0001	25	-0.41	-0.29	0.63	-0.19	-0.36	+0.26	-0.06	-0.02				
YS0001	45	0.10	+0.03	-0.43	-0.18	0.53	+0.05	-0.23	-0.06				
JG0101	4	-0.14	+0.38	-0.26	-0.45	-0.36	-0.55	-0.57	+0.14				
JG0101	11	-0.31	-0.29	-0.44	-0.22	-0.06	-0.15	-0.23	+0.05				
JG0102	4	-0.57	-0.98	0.03	+0.49	-0.31	-1.14	-0.34	-0.53				
JG0102	26	-0.11	-0.44	-0.02	+0.43	-0.19	-0.80	-0.47	-0.43				
JG0102	48	-0.58	-0.86	-0.26	+0.49	-0.07	-0.27	-0.79	-0.22				
JG0103	4	-0.09	-0.45	0.07	+0.34	-0.30	-0.09	0.02	+0.40				
JG0103	22	0.43	-0.16	0.29	-0.14	-0.35	-0.24	-0.13	+0.18				
JG0103	44	0.01	-0.44	0.13	+0.25	0.20	+0.45	0.07	-0.12				
JG0103	66	0.25	+1.33	0.10	-0.10	0.34	+0.53	0.04	-0.35				
JG0103	83	1.44	+1.55	-0.05	+0.01	0.86	+0.15	-0.80	-0.12				
JG0311	4	0.38	-0.08	0.45	+0.30	0.23	-0.80	-0.02	-0.38				
JG0311	11	0.13	+0.01	0.56	+0.16	0.41	-0.03	0.07	-0.13				
JG0302	4	0.38	+0.36	-0.06	+0.09	-0.25	-0.42	-0.54	-1.11				
JG0302	16	0.36	+0.24	-0.32	-0.10	-0.27	-0.21	-0.86	-0.60				
JG0302	27	0.36	+0.47	-0.24	+0.33	-0.26	+0.52	-0.61	-0.23				

(Continued)

(Sheet 2 of 10)

Table 12A (Concluded)

STATION	DEPTH FT	***** TEST 1 *****				***** TEST 2 *****				***** TEST 3 *****				***** TEST 4 *****			
		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS
JG0321	4	-0.24	-0.52	0.08	+0.13	-0.23	+0.13	-0.23	+0.13	-0.23	+0.13	-0.23	+0.13	-0.23	+0.13	-0.23	+0.13
JN0202	4	0.02	+0.41	-0.06	+0.11	-0.10	+0.11	-0.10	+0.11	-0.10	+0.11	-0.10	+0.11	-0.10	+0.11	-0.10	+0.11
JN0202	12	-0.48	-0.58	-0.13	-0.16	0.04	-0.16	0.04	-0.16	0.04	-0.16	0.04	-0.16	0.04	-0.16	0.04	-0.16
JN0203	4	-0.13	-0.31	-0.19	+0.03	-0.18	+0.03	-0.18	+0.03	-0.18	+0.03	-0.18	+0.03	-0.18	+0.03	-0.18	+0.03
JN0203	20	-0.26	+0.10	0.00	+0.46	-0.15	+0.46	-0.15	+0.46	-0.15	+0.46	-0.15	+0.46	-0.15	+0.46	-0.15	+0.46
JN0204	4	-0.72	+1.24	0.24	+0.57	-0.53	+0.57	-0.53	+0.57	-0.53	+0.57	-0.53	+0.57	-0.53	+0.57	-0.53	+0.57
JN0204	26	-0.12	-0.05	0.03	+0.25	-0.48	+0.25	-0.48	+0.25	-0.48	+0.25	-0.48	+0.25	-0.48	+0.25	-0.48	+0.25
JN0204	48	0.36	-0.33	0.43	-0.26	-0.55	-0.26	-0.55	-0.26	-0.55	-0.26	-0.55	-0.26	-0.55	-0.26	-0.55	-0.26
JN0204	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0202	4	-0.05	-0.47	-0.22	-0.19	-0.09	-0.19	-0.09	-0.19	-0.09	-0.19	-0.09	-0.19	-0.09	-0.19	-0.09	-0.19
EH0202	25	0.03	+0.02	0.35	+0.38	-0.30	+0.38	-0.30	+0.38	-0.30	+0.38	-0.30	+0.38	-0.30	+0.38	-0.30	+0.38
EH0202	45	-1.20	-0.63	0.62	+0.21	-0.44	+0.21	-0.44	+0.21	-0.44	+0.21	-0.44	+0.21	-0.44	+0.21	-0.44	+0.21
EH0202	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0203	4	-0.30	-0.20	-0.21	-0.40	-0.62	-0.40	-0.62	-0.40	-0.62	-0.40	-0.62	-0.40	-0.62	-0.40	-0.62	-0.40
EH0203	22	-0.07	-0.24	-0.05	-0.07	-0.20	-0.07	-0.20	-0.07	-0.20	-0.07	-0.20	-0.07	-0.20	-0.07	-0.20	-0.07
EH0203	40	-0.90	-0.76	-0.00	+0.39	-0.10	+0.39	-0.10	+0.39	-0.10	+0.39	-0.10	+0.39	-0.10	+0.39	-0.10	+0.39
EH0501	4	0.09	-0.24	0.25	+0.25	0.30	+0.25	0.30	+0.25	0.30	+0.25	0.30	+0.25	0.30	+0.25	0.30	+0.25
EH0501	22	-0.18	-0.16	-0.00	-0.11	-0.49	-0.11	-0.49	-0.11	-0.49	-0.11	-0.49	-0.11	-0.49	-0.11	-0.49	-0.11
EH0501	39	-0.16	+0.22	-0.12	-0.25	-0.03	-0.25	-0.03	-0.25	-0.03	-0.25	-0.03	-0.25	-0.03	-0.25	-0.03	-0.25
EH0501	45	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0701	4	-0.08	-0.83	0.22	-0.38	-0.33	-0.38	-0.33	-0.38	-0.33	-0.38	-0.33	-0.38	-0.33	-0.38	-0.33	-0.38
EH0701	19	-0.00	-0.08	-0.03	-0.17	-0.45	-0.17	-0.45	-0.17	-0.45	-0.17	-0.45	-0.17	-0.45	-0.17	-0.45	-0.17
EH0701	35	-0.01	-0.62	0.17	+0.27	-0.47	+0.27	-0.47	+0.27	-0.47	+0.27	-0.47	+0.27	-0.47	+0.27	-0.47	+0.27
EH0701	40	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0901	4	0.12	-0.65	0.00	+0.03	-0.00	+0.03	-0.00	+0.03	-0.00	+0.03	-0.00	+0.03	-0.00	+0.03	-0.00	+0.03
EH0901	19	0.08	-0.91	-0.40	+0.30	0.22	+0.30	0.22	+0.30	0.22	+0.30	0.22	+0.30	0.22	+0.30	0.22	+0.30
EH0901	35	-0.08	-0.41	0.22	-0.03	0.07	-0.03	0.07	-0.03	0.07	-0.03	0.07	-0.03	0.07	-0.03	0.07	-0.03
EH0301	4	0.11	+0.48	-0.30	-0.02	-0.04	-0.02	-0.04	-0.02	-0.04	-0.02	-0.04	-0.02	-0.04	-0.02	-0.04	-0.02
EH0301	21	-0.34	-0.00	-0.97	-0.42	-0.04	-0.42	-0.04	-0.42	-0.04	-0.42	-0.04	-0.42	-0.04	-0.42	-0.04	-0.42
WB0201	4	0.30	+0.23	-0.17	-0.18	-0.08	-0.18	-0.08	-0.18	-0.08	-0.18	-0.08	-0.18	-0.08	-0.18	-0.08	-0.18
WB0201	13	0.14	+0.17	-0.18	+0.09	-0.24	+0.09	-0.24	+0.09	-0.24	+0.09	-0.24	+0.09	-0.24	+0.09	-0.24	+0.09

(Sheet 3 of 10)

Table 12B

Maximum Flood and Ebb Velocities: Plan-Minus-Base Differences
Computed from Least-Squares Cosine Curve Fitted to Model Data

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	
CB0001	4	0.16	-0.37	0.06	-0.17	0.12	-0.01	-0.53	0.32	-0.70			
CB0001	18	-0.15	-0.09	0.07	0.12	0.12	-0.01	-0.31	-0.21	-0.55			
CB0001	32	0.04	-0.14	0.00	0.25	0.25	-0.15	-0.38	-0.05	-0.55			
CB0002	4	-0.15	-0.19	0.72	-0.66	-0.66	0.09	-0.20	-0.29	-0.25			
CB0002	20	-0.83	-0.31	-0.03	-0.32	-0.32	0.06	0.15	-0.20	-0.27			
CB0002	35	0.04	-0.14	-0.12	-0.37	-0.37	0.08	0.13	-0.10	-0.17			
CB0002	54	-0.18	-0.35	-0.21	-0.17	-0.17	-0.11	0.12	-0.18	-0.14			
CB0002	71	-0.69	-0.49	-0.25	-0.21	-0.21	0.27	0.30	-0.12	0.01			
CB0004	4	0.16	0.19	-0.06	0.71	0.71	-0.47	-0.38	-0.04	-0.03			
CB0004	16	0.07	0.04	0.22	0.42	0.42	-0.27	0.02	0.03	-0.01			
CB0004	28	0.02	-0.13	0.48	0.44	0.44	0.09	0.20	-0.05	-0.14			
CB0006	4	-0.18	1.30	-0.05	0.31	0.31	-0.34	-0.19	-0.10	-0.36			
CB0006	15	0.31	0.63	-0.12	-0.14	-0.14	0.17	-0.07	0.04	-0.18			
CB0008	4	1.99	3.06	-0.01	0.35	0.35	0.17	0.11	-0.38	-0.37			
CB0008	24	1.95	2.39	-0.32	0.26	0.26	0.25	0.14	-0.19	-0.51			
CB0008	43	1.56	1.84	0.12	0.02	0.02	-0.12	-0.35	-0.60	-0.41			
CB0009	4	-0.37	-0.32	-0.31	-0.41	-0.41	-0.39	-0.96	-0.23	-0.26			
CB0009	16	-0.61	-0.81	-0.17	-0.12	-0.12	-0.17	-0.50	-0.08	-0.05			
CB0010	4	-0.14	-0.07	-0.42	-0.36	-0.36	-0.11	-0.24	-0.59	-0.56			
CB0010	13	0.17	0.32	-0.14	-0.28	-0.28	-0.10	-0.05	-0.17	-0.21			
CB0010	4	-0.10	-0.04	-0.29	-0.45	-0.45	-0.23	-0.20	-0.19	-0.24			
CB0010	14	-0.09	-0.05	-0.30	-0.49	-0.49	-0.22	-0.17	-0.06	-0.11			
CB0010	24	-0.29	-0.32	-0.50	-0.41	-0.41	-0.41	-0.45	-0.21	-0.05			
CB0010	4	-0.08	-0.13	-0.19	-0.85	-0.85	-0.31	-0.29	-0.15	-0.30			
CB0010	20	-0.10	-0.03	0.12	-1.05	-1.05	-0.95	0.02	-0.21	-0.21			
CB0010	37	0.50	0.06	-0.29	-0.22	-0.22	-0.46	-0.33	-0.30	-0.19			
CB0010	4	-0.06	-0.15	-0.15	-0.29	-0.29	0.20	0.29	-0.05	-0.35			
CB0010	15	-0.22	-0.35	-0.04	-0.04	-0.04	-0.01	0.27	-0.09	-0.13			
CB0010	27	-0.13	-0.10	-0.33	-0.28	-0.28	-0.04	-0.09	-0.55	-0.45			
CB0010	4	-0.03	0.14	0.08	0.23	0.23	-0.31	0.75	0.04	-0.10			
CB0010	39	-0.19	0.24	-0.17	0.06	0.06	0.03	-0.07	-0.00	-0.08			
CB0010	75	-0.43	-0.05	0.11	-0.04	-0.04	-0.24	-0.35	-0.42	-0.04			

(Continued)

Sheet 1 of 10

Table 12B (Continued)

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	
CB0110	4	-0.24	-0.01	-0.24	-0.05	-0.32	-0.28	-0.27	-0.09	-0.27	-0.09	-0.27	-0.09
CB0110	15	-0.04	0.04	-0.11	0.19	-0.11	-0.22	0.07	0.13	0.07	0.13	0.07	0.13
AC0002	4	-0.20	-0.19	-0.23	-0.15	-0.11	-0.68	0.09	-0.25	0.09	-0.25	0.09	-0.25
AC0002	27	-0.15	-0.33	-0.19	-0.17	-0.25	-0.23	-0.23	-0.18	-0.23	-0.18	-0.23	-0.18
AC0002	49	-0.09	-0.02	-0.10	0.05	0.12	0.13	0.02	-0.09	0.02	-0.09	0.02	-0.09
AC0002	54	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
TS0003	4	-0.41	-0.45	-0.08	-0.27	-0.06	-0.38	-0.54	-1.02	-0.54	-1.02	-0.54	-1.02
TS0003	26	-0.31	-0.31	-0.06	0.10	-0.17	-0.54	-0.54	-0.52	-0.54	-0.52	-0.54	-0.52
TS0003	46	0.11	-0.24	0.31	0.19	0.35	0.15	0.00	-0.64	0.00	-0.64	0.00	-0.64
TS0003	51	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
TS0005	4	-0.13	-0.12	-0.08	-0.31	-0.21	-0.38	0.23	-0.27	0.23	-0.27	0.23	-0.27
TS0005	27	-0.27	-0.42	0.60	0.10	-0.32	-0.03	0.86	-0.72	0.86	-0.72	0.86	-0.72
TS0005	50	-0.03	-0.38	0.09	0.18	0.20	0.07	-0.20	-0.37	-0.20	-0.37	-0.20	-0.37
TS0005	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
YS0001	4	-0.57	-0.25	-0.40	-0.22	0.34	-0.09	-0.11	-0.29	-0.11	-0.29	-0.11	-0.29
YS0001	25	-0.39	-0.06	1.18	-0.17	0.00	-0.28	-0.11	-0.07	-0.11	-0.07	-0.11	-0.07
YS0001	45	0.05	0.08	-0.50	-0.00	0.37	-0.14	-0.03	0.04	-0.03	0.04	-0.03	0.04
JG0101	4	-0.13	0.60	-0.27	-0.13	-0.21	-0.41	-0.24	-0.31	-0.24	-0.31	-0.24	-0.31
JG0101	11	-0.34	-0.09	-0.36	-0.17	-0.19	-0.02	-0.18	-0.15	-0.18	-0.15	-0.18	-0.15
JG0102	4	-0.69	-0.97	-0.14	0.35	-0.47	-0.87	-0.32	-0.55	-0.32	-0.55	-0.32	-0.55
JG0102	26	-0.27	-0.32	-0.15	0.04	-0.35	-0.52	-0.35	-0.43	-0.35	-0.43	-0.35	-0.43
JG0102	48	-0.79	-1.10	0.19	-0.05	-0.16	-0.16	-0.44	-0.41	-0.44	-0.41	-0.44	-0.41
JG0103	4	-0.07	0.07	0.00	0.30	-0.45	-0.19	-0.24	0.10	-0.24	0.10	-0.24	0.10
JG0103	22	0.33	0.05	-0.00	-0.32	-0.38	-0.54	0.02	-0.03	0.02	-0.03	0.02	-0.03
JG0103	44	-0.12	0.11	0.34	0.23	0.35	0.12	0.20	-0.02	0.20	-0.02	0.20	-0.02
JG0103	66	0.95	0.65	0.09	0.03	0.45	0.29	0.22	-0.09	0.22	-0.09	0.22	-0.09
JG0103	83	1.46	0.54	-0.20	-0.00	0.15	0.28	0.16	-0.28	0.16	-0.28	0.16	-0.28
JG0311	4	0.22	0.01	0.32	0.41	0.06	-0.46	0.00	-0.60	0.00	-0.60	0.00	-0.60
JG0311	11	-0.02	-0.06	0.41	0.32	0.09	0.08	-0.36	-1.01	-0.36	-1.01	-0.36	-1.01
JG0302	4	0.27	0.51	0.05	-0.10	-0.25	-0.48	-0.71	-0.57	-0.71	-0.57	-0.71	-0.57
JG0302	16	0.34	0.35	-0.21	-0.17	-0.17	-0.28	-0.78	-0.45	-0.78	-0.45	-0.78	-0.45
JG0302	27	0.21	0.34	0.03	0.23	-0.07	0.06						

(Continued)

(Sheet 5 of 10)

Table 12B (Concluded)

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS	MAX FLOOD VELOCITY DIFFERENCE FPS	MAX EBB VELOCITY DIFFERENCE FPS
JG0321	4	-0.42	-0.49	0.06	0.11	0.17	-0.15	-0.23	-0.16	-0.34	-0.16	-0.34	-0.65
JH0202	4	0.06	0.37	-0.05	0.17	0.04	-0.17	-0.35	-0.52	-0.65	-0.52	-0.65	-0.40
JH0202	12	-0.42	-0.54	-0.05	0.04	0.04	-0.13	-0.12	-0.46	-0.40	-0.46	-0.40	-0.74
JH0203	4	-0.16	-0.18	-0.12	-0.25	0.10	0.01	0.17	-0.32	-0.74	-0.32	-0.74	-0.21
JH0203	20	-0.12	0.04	-0.03	0.10	0.33	-0.10	0.09	-0.21	-0.21	-0.21	-0.21	-0.52
JH0204	4	-0.37	0.89	0.25	0.33	-0.03	-0.52	-0.31	-0.29	-0.52	-0.29	-0.52	-0.16
JH0204	26	-0.11	-0.22	-0.02	-0.03	-0.03	-0.43	-0.69	-0.22	-0.16	-0.22	-0.16	-0.08
JH0204	48	0.25	-0.16	0.15	-0.04	-0.04	-0.34	-0.47	0.56	-0.08	0.56	-0.08	*****
JH0204	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0202	4	-0.05	-0.19	-0.09	-0.17	-0.17	-0.30	-0.51	-0.20	-0.25	-0.20	-0.25	-0.53
EH0202	25	0.07	-0.16	0.53	0.32	0.32	-0.28	-0.31	-0.48	-0.53	-0.48	-0.53	-0.49
EH0202	46	-1.19	-0.79	0.44	0.49	0.49	-0.38	0.11	-0.74	-0.49	-0.74	-0.49	*****
EH0202	55	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0203	4	-0.03	-0.00	-0.14	-0.54	-0.54	-0.60	-0.42	-0.06	0.03	-0.06	0.03	-0.13
EH0203	22	0.07	-0.25	-0.04	-0.01	-0.01	-0.14	-0.29	-0.29	-0.13	-0.29	-0.13	-0.47
EH0203	40	-1.01	-0.70	0.01	0.18	0.18	-0.07	-0.43	-0.82	-0.47	-0.82	-0.47	-0.19
EH0501	4	-0.13	-0.15	0.10	0.13	0.13	0.12	-0.67	-0.22	-0.19	-0.22	-0.19	-0.26
EH0501	22	-0.08	0.23	-0.05	-0.17	-0.17	-0.55	-0.34	-0.33	-0.26	-0.33	-0.26	0.30
EH0501	39	-0.11	0.34	-0.15	-0.41	-0.41	0.03	0.02	0.11	0.30	0.11	0.30	*****
EH0501	45	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0701	4	-0.24	-0.67	0.07	-0.26	-0.26	-0.34	-0.76	-0.09	-0.25	-0.09	-0.25	-0.07
EH0701	19	-0.05	-0.11	0.04	-0.20	-0.20	-0.55	-0.50	-0.08	-0.07	-0.08	-0.07	-0.47
EH0701	35	-0.17	-0.35	0.18	0.46	0.46	-0.44	-0.36	-0.27	-0.47	-0.27	-0.47	*****
EH0701	40	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
EH0901	4	0.02	-0.50	0.03	-0.05	-0.05	0.02	-0.19	-0.16	-0.11	-0.16	-0.11	-0.05
EH0901	19	-0.12	-0.36	-0.23	0.08	0.08	-0.06	-0.16	-0.16	-0.05	-0.16	-0.05	0.10
EH0901	35	-0.15	-0.16	0.03	-0.01	-0.01	0.03	-0.30	0.20	0.10	0.20	0.10	-0.33
EH0901	4	0.27	0.23	-0.19	-0.12	-0.12	0.21	0.03	-0.33	-0.33	-0.33	-0.33	-0.82
EH0901	21	-0.17	-0.16	-0.75	-0.09	-0.09	-0.06	-0.66	-0.27	-0.82	-0.27	-0.82	-0.28
EH0901	4	-0.06	0.50	-0.03	0.03	0.03	0.51	-0.13	-0.24	-0.28	-0.24	-0.28	-0.35
EH0901	13	0.15	0.27	-0.25	-0.05	-0.05	0.15	0.13	-0.35	-0.35	-0.35	-0.35	-0.32

(Sheet 6 of 10)

Table 12C

Maximum Flood Velocities: Plan-Minus-Base Differences
Plan-Minus-Base Differences: Summary Statistics (Model Data)

CLASS INTERVAL	*** TEST 1 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 2 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 3 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 4 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** OVERALL *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.
GREATER THAN 0.8 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
0.7 < DIFF < 0.8 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
0.6 < DIFF < 0.7 FPS	0 0.000	2 0.023	1 0.011	2 0.023	5 0.014
0.5 < DIFF < 0.6 FPS	0 0.000	2 0.023	1 0.011	0 0.000	3 0.009
0.4 < DIFF < 0.5 FPS	3 0.036	3 0.034	1 0.011	0 0.000	7 0.020
0.3 < DIFF < 0.4 FPS	6 0.071	3 0.034	4 0.045	2 0.023	15 0.043
0.2 < DIFF < 0.3 FPS	2 0.024	9 0.102	8 0.091	1 0.011	20 0.057
0.1 < DIFF < 0.2 FPS	9 0.107	6 0.058	9 0.102	3 0.034	27 0.078
0.0 < DIFF < 0.1 FPS	11 0.131	9 0.102	5 0.057	13 0.148	38 0.109
-0.1 < DIFF < 0.0 FPS	10 0.119	19 0.216	15 0.170	15 0.170	59 0.170
-0.2 < DIFF < -0.1 FPS	14 0.167	10 0.114	14 0.159	17 0.193	55 0.158
-0.3 < DIFF < -0.2 FPS	8 0.095	15 0.170	9 0.102	10 0.114	42 0.121
-0.4 < DIFF < -0.3 FPS	7 0.093	6 0.068	9 0.102	7 0.080	29 0.083
-0.5 < DIFF < -0.4 FPS	4 0.048	3 0.034	8 0.091	6 0.068	21 0.068
-0.6 < DIFF < -0.5 FPS	3 0.036	0 0.000	3 0.034	6 0.068	12 0.034
-0.7 < DIFF < -0.6 FPS	2 0.024	0 0.000	1 0.011	4 0.045	7 0.020
-0.8 < DIFF < -0.7 FPS	1 0.012	0 0.000	0 0.000	1 0.011	2 0.006
LESS THAN -0.8 FPS	4 0.048	1 0.011	0 0.000	1 0.011	6 0.017
NUMBER IN SAMPLE	84	88	88	88	348
MEAN DIFFERENCE (FPS)	-0.13	-0.02	-0.03	-0.17	-0.10
STANDARD DEVIATION (FPS)	0.34	0.27	0.27	0.28	0.29

(Sheet 7 of 10)

Table 120

Maximum Ebb Velocities: Plan-Minus-Base Differences
 Plan-Minus-Base Differences: Summary Statistics (Model Data)

CLASS INTERVAL	*** TEST 1 *** MAXIMUM EBB FREQ. RELATIVE FREQ.	*** TEST 2 *** MAXIMUM EBB FREQ. RELATIVE FREQ.	*** TEST 3 *** MAXIMUM EBB FREQ. RELATIVE FREQ.	*** TEST 4 *** MAXIMUM EBB FREQ. RELATIVE FREQ.	*** OVERALL *** MAXIMUM EBB FREQ. RELATIVE FREQ.
GREATER THAN 0.8 FPS	4 0.048	3 0.034	5 0.057	4 0.045	16 0.046
0.7 < DIFF < 0.8 FPS	2 0.024	0 0.000	0 0.000	4 0.045	6 0.017
0.6 < DIFF < 0.7 FPS	3 0.035	0 0.000	2 0.023	3 0.034	8 0.023
0.5 < DIFF < 0.6 FPS	5 0.060	0 0.000	3 0.034	2 0.023	10 0.029
0.4 < DIFF < 0.5 FPS	5 0.060	4 0.045	7 0.080	10 0.114	26 0.075
0.3 < DIFF < 0.4 FPS	6 0.071	4 0.045	7 0.060	12 0.136	29 0.084
0.2 < DIFF < 0.3 FPS	11 0.131	11 0.125	10 0.115	13 0.148	45 0.130
0.1 < DIFF < 0.2 FPS	4 0.048	17 0.193	11 0.126	11 0.125	43 0.124
0.0 < DIFF < 0.1 FPS	9 0.107	9 0.102	10 0.115	11 0.125	39 0.112
-0.1 < DIFF < 0.0 FPS	11 0.131	10 0.114	5 0.057	9 0.102	35 0.101
-0.2 < DIFF < -0.1 FPS	8 0.095	6 0.060	10 0.115	7 0.080	31 0.099
-0.3 < DIFF < -0.2 FPS	5 0.060	8 0.091	8 0.092	0 0.000	21 0.061
-0.4 < DIFF < -0.3 FPS	3 0.036	8 0.091	1 0.011	1 0.011	13 0.037
-0.5 < DIFF < -0.4 FPS	4 0.048	5 0.057	3 0.034	1 0.011	13 0.037
-0.6 < DIFF < -0.5 FPS	0 0.000	1 0.011	3 0.034	0 0.000	4 0.012
-0.7 < DIFF < -0.6 FPS	0 0.000	2 0.023	0 0.000	0 0.000	2 0.006
-0.8 < DIFF < -0.7 FPS	1 0.012	0 0.000	1 0.011	0 0.000	2 0.006
LESS THAN -0.8 FPS	3 0.036	0 0.000	1 0.011	3 0.030	4 0.012

NUMBER IN SAMPLE 34
 MEAN DIFFERENCE (FPS) 0.09
 STANDARD DEVIATION (FPS) 0.45

37
 0.13
 0.30

39
 0.15
 0.30

(Sheet 8 of 10)

Table 12E

Maximum Flood Velocities: Plan-Minus-Base Differences
 Plan-Minus-Base Differences: Summary Statistics (From Harmonic Analysis)

CLASS INTERVAL	*** TEST 1 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 2 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 3 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** TEST 4 *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.	*** OVERALL *** MAXIMUM FLOOD FREQ. RELATIVE FREQ.
GREATER THAN 0.8 FPS	1 0.012	1 0.011	0 0.000	1 0.011	3 0.009
0.7 < DIFF < 0.8 FPS	0 0.000	1 0.011	0 0.000	0 0.000	1 0.003
0.6 < DIFF < 0.7 FPS	0 0.000	0 0.000	0 0.000	0 0.000	0 0.000
0.5 < DIFF < 0.6 FPS	0 0.000	2 0.023	0 0.000	1 0.011	3 0.009
0.4 < DIFF < 0.5 FPS	1 0.012	3 0.034	1 0.011	0 0.000	5 0.014
0.3 < DIFF < 0.4 FPS	3 0.036	3 0.034	5 0.057	1 0.011	12 0.034
0.2 < DIFF < 0.3 FPS	5 0.060	2 0.023	4 0.045	3 0.034	14 0.040
0.1 < DIFF < 0.2 FPS	5 0.060	6 0.060	7 0.080	3 0.034	21 0.060
0.0 < DIFF < 0.1 FPS	9 0.107	16 0.182	12 0.136	10 0.114	47 0.135
-0.1 < DIFF < 0.0 FPS	15 0.179	18 0.205	11 0.125	13 0.148	57 0.164
-0.2 < DIFF < -0.1 FPS	21 0.250	15 0.170	16 0.182	15 0.170	67 0.193
-0.3 < DIFF < -0.2 FPS	7 0.083	11 0.125	10 0.114	19 0.216	47 0.135
-0.4 < DIFF < -0.3 FPS	5 0.060	5 0.057	11 0.125	8 0.091	29 0.083
-0.5 < DIFF < -0.4 FPS	4 0.048	3 0.034	7 0.080	4 0.045	18 0.052
-0.6 < DIFF < -0.5 FPS	1 0.012	1 0.011	3 0.034	5 0.057	10 0.029
-0.7 < DIFF < -0.6 FPS	3 0.036	0 0.000	1 0.011	1 0.011	5 0.014
-0.8 < DIFF < -0.7 FPS	1 0.012	1 0.011	0 0.000	3 0.034	5 0.014
LESS THAN -0.8 FPS	3 0.036	0 0.000	0 0.000	1 0.011	4 0.011
NUMBER IN SAMPLE	84	88	88	88	348
MEAN DIFFERENCE (FPS)	-0.13	-0.03	-0.11	-0.18	-0.11
STANDARD DEVIATION (FPS)	0.31	0.28	0.24	0.27	0.28

(Sheet 9 of 10)

Table 12F
Maximum Ebb Velocities: Plan-Minus-Base Differences
Plan-Minus-Base Differences: Summary Statistics (From Harmonic Analysis)

CLASS INTERVAL	*** TEST 1 ***		*** TEST 2 ***		*** TEST 3 ***		*** TEST 4 ***		*** OVERALL ***	
	MAXIMUM EBB FREQ. RELATIVE	FREQ.	MAXIMUM EBB FREQ. RELATIVE	FREQ.	MAXIMUM EBB FREQ. RELATIVE	FREQ.	MAXIMUM EBB FREQ. RELATIVE	FREQ.	MAXIMUM EBB FREQ. RELATIVE	FREQ.
GREATER THAN 0.8 FPS	2	0.024	0	0.000	0	0.000	0	0.000	2	0.005
0.7 < DIFF. < 0.8 FPS	0	0.000	1	0.011	1	0.011	0	0.000	2	0.006
0.6 < DIFF. < 0.7 FPS	2	0.024	0	0.000	0	0.000	0	0.000	2	0.006
0.5 < DIFF. < 0.6 FPS	3	0.035	0	0.000	0	0.000	0	0.000	3	0.009
0.4 < DIFF. < 0.5 FPS	0	0.000	5	0.057	0	0.000	0	0.000	5	0.014
0.3 < DIFF. < 0.4 FPS	5	0.059	6	0.068	1	0.011	1	0.011	13	0.037
0.2 < DIFF. < 0.3 FPS	4	0.047	6	0.058	5	0.057	0	0.000	15	0.043
0.1 < DIFF. < 0.2 FPS	4	0.047	11	0.125	11	0.125	2	0.023	28	0.080
0.0 < DIFF. < 0.1 FPS	8	0.094	8	0.091	9	0.102	4	0.045	29	0.083
-0.1 < DIFF. < 0.0 FPS	12	0.141	12	0.136	9	0.102	16	0.182	49	0.140
-0.2 < DIFF. < -0.1 FPS	17	0.200	15	0.170	8	0.091	16	0.182	56	0.160
-0.3 < DIFF. < -0.2 FPS	4	0.047	9	0.102	12	0.136	16	0.182	41	0.117
-0.4 < DIFF. < -0.3 FPS	12	0.141	5	0.057	12	0.136	8	0.091	37	0.106
-0.5 < DIFF. < -0.4 FPS	5	0.059	6	0.068	9	0.091	8	0.091	27	0.077
-0.6 < DIFF. < -0.5 FPS	1	0.012	1	0.011	6	0.068	10	0.114	18	0.052
-0.7 < DIFF. < -0.6 FPS	1	0.012	1	0.011	3	0.034	3	0.034	8	0.023
-0.8 < DIFF. < -0.7 FPS	2	0.024	0	0.000	1	0.011	2	0.023	5	0.014
LESS THAN -0.8 FPS	3	0.035	2	0.023	2	0.023	2	0.023	9	0.026
NUMBER IN SAMPLE	95		88		89		88		349	
MEAN DIFFERENCE (FPS)	-0.08		-0.05		-0.18		-0.27		-0.15	
STANDARD DEVIATION (FPS)	0.38		0.30		0.30		0.24		0.32	

Table 13A

Flow Predominance (Percent of Flow in Ebb Direction)

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		FLOW BASE	PREDOMINANCE PLAN	DIFF %	FLOW BASE	PREDOMINANCE PLAN	DIFF %	FLOW BASE	PREDOMINANCE PLAN	DIFF %	FLOW BASE	PREDOMINANCE PLAN	DIFF %
CB0001	4	79.4	74.1	-5.2	85.4	82.4	-3.0	76.8	72.1	-4.6	90.6	74.1	-16.5
CB0001	10	70.7	72.4	1.7	67.5	67.8	0.3	68.7	65.0	-3.8	69.5	65.0	-4.5
CB0001	32	71.8	69.1	-2.7	53.2	59.7	6.5	69.5	67.5	-2.0	65.5	53.3	-12.3
CB0002	4	76.4	77.5	1.1	88.1	54.6	-33.4	64.4	60.2	-4.2	71.6	76.6	5.1
CB0002	20	60.9	73.1	12.2	44.2	35.1	-9.1	48.5	49.8	1.4	48.6	45.9	-2.7
CB0002	35	41.0	38.2	-2.9	39.0	29.0	-10.1	43.0	44.0	1.0	37.5	34.4	-3.2
CB0002	54	43.0	39.5	-3.5	38.4	37.4	-0.9	40.7	44.3	3.6	37.9	37.2	-0.7
CB0002	71	41.4	42.5	1.2	37.3	35.6	-1.7	47.8	48.6	0.9	30.4	33.7	3.3
CB0004	4	73.8	72.6	-1.2	76.5	85.7	9.2	58.0	60.5	2.5	79.0	80.0	1.0
CB0004	16	60.9	60.2	-0.8	49.9	54.7	4.9	50.3	55.0	4.7	52.8	52.1	-0.7
CB0004	28	41.0	38.0	-3.0	47.1	47.2	0.1	50.0	52.4	2.4	44.2	40.9	-3.3
CB0006	4	53.7	67.5	13.8	79.2	83.0	3.8	61.1	63.3	2.2	69.0	66.6	-2.4
CB0006	15	56.5	59.6	3.0	56.7	56.3	-0.3	62.1	58.7	-3.4	54.8	49.5	-5.3
CB0008	4	67.2	67.2	0.0	75.4	78.8	3.4	64.3	63.0	-1.3	55.6	56.5	1.0
CB0008	24	58.1	58.9	0.8	47.4	58.7	11.3	58.2	56.5	-1.7	58.6	53.5	-5.2
CB0008	43	44.3	54.3	10.0	34.3	32.4	-2.0	53.5	50.2	-3.3	45.7	48.7	3.0
CB0009	4	57.7	58.6	0.9	58.7	50.4	-8.3	57.5	53.4	-4.1	56.9	57.0	0.0
CB0009	16	56.7	55.7	-1.0	50.1	50.9	0.7	53.6	50.7	-2.8	50.0	50.4	0.3
CB0101	4	65.3	67.0	1.7	67.8	73.2	5.4	60.2	58.3	-1.9	51.7	52.6	0.9
CB0101	13	58.7	60.7	2.0	60.9	57.7	-3.2	58.5	60.3	1.9	53.4	52.8	-0.6
CB0103	4	62.2	63.9	1.7	76.3	80.5	4.2	60.3	62.1	1.8	71.6	74.1	2.5
CB0103	14	59.7	60.9	1.2	76.5	80.5	4.1	53.8	55.3	1.5	68.9	69.0	0.1
CB0103	24	57.9	58.4	0.4	56.7	68.1	11.4	54.7	55.2	0.5	47.4	51.8	4.5
CB0105	4	54.6	54.0	-0.6	68.4	55.1	-13.3	50.7	50.7	-0.0	55.0	51.3	-3.7
CB0105	20	40.3	41.3	1.0	58.3	22.9	-35.4	42.8	44.1	1.2	34.1	31.5	-2.5
CB0105	37	35.0	27.0	-8.0	28.8	25.8	-3.0	32.7	30.7	-2.0	33.9	34.1	0.2
CB0107	4	62.1	61.5	-0.6	66.3	64.6	-1.7	55.2	56.0	0.7	56.2	48.6	-7.6
CB0107	15	47.5	45.1	-2.4	50.7	50.6	-0.1	40.3	45.6	5.3	46.3	43.0	-3.2
CB0107	27	30.2	29.6	-0.6	36.8	33.2	-3.6	37.7	35.8	-1.9	31.9	28.8	-3.1
CB0109	4	72.4	74.5	2.1	80.4	80.9	0.5	61.1	77.3	16.2	53.6	59.4	4.2
CB0109	39	27.5	36.7	9.2	77.0	42.1	-34.9	33.1	30.8	-2.3	44.1	41.2	-2.8
CB0109	75	8.6	10.7	2.1	61.9	56.0	-5.9	0.0	0.0	0.0	42.2	60.9	18.7

(Continued)

(Sheet 1 of 4)

Table 13A (Continued)

STATION	DEPTH FT	***** TEST 1 *****			***** TEST 2 *****			***** TEST 3 *****			***** TEST 4 *****		
		FLOW BASE %	PREDOMINANCE PLAN %	DIFF %	FLOW BASE %	PREDOMINANCE PLAN %	DIFF %	FLOW BASE %	PREDOMINANCE PLAN %	DIFF %	FLOW BASE %	PREDOMINANCE PLAN %	DIFF %
CB0110	4	65.4	63.4	4.0	65.8	71.9	6.1	65.0	67.1	2.1	62.6	67.9	5.3
CB0110	15	63.2	64.6	1.4	48.7	58.6	10.0	62.5	61.2	-1.3	52.9	54.3	1.4
AC0002	4	96.5	99.8	3.3	76.5	91.2	14.7	95.2	95.5	0.3	80.1	62.8	-17.3
AC0002	27	42.1	31.0	-11.1	33.1	28.0	-5.1	40.4	38.7	-1.7	31.1	27.0	-4.0
AC0002	49	25.7	27.3	1.6	22.5	30.4	8.0	29.9	32.5	2.7	33.3	24.4	-8.9
AC0002	54	*****	27.3	*****	*****	33.3	*****	*****	34.5	*****	*****	31.7	*****
TS0003	4	63.5	65.0	1.5	73.7	72.0	-1.7	62.6	59.3	-3.3	66.8	61.8	-5.0
TS0003	26	42.3	41.5	-0.8	33.7	37.9	4.2	44.3	37.9	-6.4	39.4	35.9	-3.5
TS0003	46	38.3	33.3	-5.0	27.8	28.6	0.8	40.7	38.9	-1.8	41.8	22.0	-19.8
TS0003	51	*****	36.1	*****	*****	26.4	*****	*****	41.7	*****	*****	23.7	*****
TS0005	4	77.1	78.3	1.2	96.3	97.1	0.9	70.1	69.8	-0.3	85.1	77.2	-7.9
TS0005	27	58.2	56.8	-1.4	56.3	41.7	-14.6	53.6	58.7	5.1	51.1	15.8	-35.3
TS0005	50	0.0	0.0	0.0	1.5	3.8	2.3	0.0	4.9	4.9	0.0	0.0	0.0
TS0005	55	*****	0.0	*****	*****	3.8	*****	*****	0.7	*****	*****	0.0	*****
YS0001	4	48.8	52.5	3.7	61.0	67.3	6.4	46.1	41.2	-4.8	50.8	47.7	-3.1
YS0001	25	34.0	37.2	3.2	38.0	20.3	-18.5	38.0	33.6	-4.4	24.9	24.9	-0.1
YS0001	45	23.2	24.3	1.1	17.4	21.0	3.6	35.5	29.1	-6.4	18.3	19.7	1.4
JG0101	4	55.2	64.4	9.2	70.1	73.7	3.6	52.0	48.9	-3.1	59.6	59.3	-0.3
JG0101	11	57.6	62.1	4.5	63.1	68.7	5.6	48.3	51.3	3.0	58.0	59.2	1.3
JG0102	4	62.8	62.3	-0.4	68.2	73.8	5.6	62.2	59.5	-2.6	65.3	64.2	-1.1
JG0102	26	62.1	62.4	0.3	52.6	56.4	3.8	61.0	60.2	-0.8	59.4	59.4	0.0
JG0102	48	57.2	54.5	-2.7	42.0	34.6	-7.4	56.4	56.7	0.3	60.2	62.7	2.5
JG0103	4	65.9	67.2	1.2	68.8	71.7	2.8	57.7	61.6	3.8	66.4	72.2	5.8
JG0103	22	64.7	60.7	-4.0	57.1	50.8	-6.3	54.5	52.5	-2.0	60.8	59.9	-0.9
JG0103	44	52.2	54.8	2.6	33.3	34.0	0.7	51.8	48.3	-3.5	43.3	39.3	-4.0
JG0103	66	38.2	37.8	-0.4	24.9	24.7	-0.2	38.0	37.6	-0.3	30.8	25.1	-5.7
JG0103	83	58.4	22.7	-35.7	16.1	19.9	3.8	15.3	23.7	8.4	26.4	12.0	-14.4
JG0311	4	64.0	60.0	-4.0	64.1	63.3	-0.8	68.3	60.8	-7.5	53.6	51.9	-11.9
JG0311	11	64.1	63.5	-0.6	66.4	60.0	-6.4	60.0	59.6	-0.4	59.0	53.1	-5.9
JG0302	4	58.3	60.5	2.2	63.2	60.2	-2.9	59.8	56.9	-2.9	56.9	42.7	-14.2
JG0302	16	60.7	59.2	-1.5	55.9	58.3	2.3	55.1	54.3	-0.8	45.4	49.2	2.8
JG0302	27	58.7	60.1	1.4	76.3	80.7	4.3	52.2	55.0	2.9	45.6	62.5	17.0

(Continued)

(Sheet 2 of 4)

Table 13A (Concluded)

Table 13B

Flow Predominance (Percent of Flow in Ebb Direction)

Plan-Minus-Base Summary Statistics

CLASS INTERVAL	*** TEST 1 *** FREQ. RELATIVE FREQ.	*** TEST 2 *** FREQ. RELATIVE FREQ.	*** TEST 3 *** FREQ. RELATIVE FREQ.	*** TEST 4 *** FREQ. RELATIVE FREQ.	*** OVERALL *** FREQ. RELATIVE FREQ.
GREATER THAN 40%	0 0.000	1 0.011	0 0.000	0 0.000	1 0.003
33% < DIFF < 40%	0 0.000	2 0.023	0 0.000	0 0.000	2 0.006
20% < DIFF < 30%	2 0.023	0 0.000	0 0.000	0 0.000	2 0.006
15% < DIFF < 20%	1 0.011	1 0.011	2 0.023	4 0.045	8 0.023
10% < DIFF < 15%	4 0.045	4 0.045	1 0.011	3 0.034	12 0.034
5% < DIFF < 10%	5 0.057	14 0.159	4 0.045	6 0.068	29 0.082
0% < DIFF < 5%	36 0.409	27 0.307	27 0.307	24 0.273	114 0.324
-5% < DIFF < 0%	27 0.307	21 0.239	43 0.489	28 0.318	119 0.338
-10% < DIFF < -5%	7 0.080	8 0.091	7 0.080	9 0.102	31 0.088
-15% < DIFF < -10%	3 0.034	6 0.060	3 0.034	7 0.080	19 0.054
-20% < DIFF < -15%	2 0.023	1 0.011	0 0.000	5 0.057	8 0.023
-30% < DIFF < -20%	0 0.000	0 0.000	0 0.000	1 0.011	1 0.003
-40% < DIFF < -30%	1 0.011	2 0.023	1 0.011	1 0.011	5 0.014
LESS THAN -40%	0 0.000	1 0.011	0 0.000	0 0.000	1 0.003
NUMBER IN SAMPLE	88	88	88	88	352
MEAN DIFFERENCE (%)	0.37	0.22	-0.94	-1.92	-0.57
STANDARD DEVIATION (%)	8.19	12.46	6.31	8.91	9.25

(Sheet 4 of 4)

Table 14

SALINITY STATION LOCATIONS
DYNAMIC HYDROGRAPH TESTS

Station	Body of Water	Sampling Depths ft below msl	Latitude	Longitude
AC0001	Atlantic Channel	4,14,24,50	35°49'54"	75°48'52"
AC0002	Atlantic Channel	4,14,24,50,57*	36°54'06"	75°54'33"
AC0003	Atlantic Channel	4,14,24,50,57*	36°55'10"	75°56'12"
BG0101	Back River (Virginia)	3,10	37°06'36"	76°17'30"
CB0001	Chesapeake Bay	5,13,23,33	36°56'12"	76°00'18"
CB0002	Chesapeake Bay	4,12,22,32,68	36°57'30"	76°00'05"
CB0003	Chesapeake Bay	4,22,32	36°58'48"	75°59'43"
CB0004	Chesapeake Bay	4,22,30	37°00'06"	75°59'30"
CB0005	Chesapeake Bay	4,12,17	37°01'12"	75°59'18"
CB0006	Chesapeake Bay	5,12	37°02'00"	75°59'06"
CB0007	Chesapeake Bay	5,13,18	37°02'54"	75°58'54"
CB0008	Chesapeake Bay	5,23,43	37°03'18"	75°58'43"
CB0009	Chesapeake Bay	4,16	37°04'37"	75°58'36"
CB0101	Chesapeake Bay	5,15	37°05'58"	76°14'43"
CB0102	Chesapeake Bay	4,12,18	37°06'37"	76°13'18"
CB0103	Chesapeake Bay	5,15,28	37°07'05"	76°12'15"
CB0104	Chesapeake Bay	4,13,30	37°07'37"	76°11'07"
CB0105	Chesapeake Bay	4,23,37	37°08'36"	76°08'59"
CB0106	Chesapeake Bay	4,12,22	37°09'14"	76°06'33"
CB0107	Chesapeake Bay	4,12,27	37°10'36"	76°04'37"
CB0108	Chesapeake Bay	4,14,28	37°11'12"	76°03'03"
CB0109	Chesapeake Bay	4,12,22,42,72	37°11'48"	76°02'01"
CB0110	Chesapeake Bay	4,17	37°12'08"	76°01'32"
CB0202	Chesapeake Bay	4,12,27	37°30'16"	76°12'48"
CB0204	Chesapeake Bay	4,12,32	37°30'08"	76°08'12"
CB0206	Chesapeake Bay	4,22,42	37°30'15"	76°04'42"
CB0208	Chesapeake Bay	4,32,52	37°30'21"	76°02'26"
CB0210	Chesapeake Bay	3,11,26	37°30'28"	75°59'38"
CB0301	Chesapeake Bay	4,22,35	37°54'02"	76°11'42"
CB0303	Chesapeake Bay	4,22,62	37°54'18"	76°10'03"
CB0306	Chesapeake Bay	4,22,37	37°54'46"	76°07'16"
CB0310	Chesapeake Bay	3,11,57	37°56'30"	75°56'30"
CB0401	Chesapeake Bay	4,22,32	38°23'14"	76°22'16"
CB0404	Chesapeake Bay	4,42,92	38°23'20"	76°20'13"
CB0407	Chesapeake Bay	4,16	38°23'29"	76°18'15"

(Continued)

* Additional depths sampled during plan test only.

(Sheet 1 of 6)

Table 14 (Continued)

Station	Body of Water	Sampling Depths (ft below msl)	Latitude	Longitude
CB0502	Chesapeake Bay	4,22,32	38°50'32"	76°26'12"
CB0505	Chesapeake Bay	4,52,102	38°50'35"	76°23'50"
CB0611	Chesapeake Bay	4,28,53	39°08'03"	76°24'06"
CB0604	Chesapeake Bay	4,22,37	39°08'20"	76°19'23"
CB0703	Chesapeake Bay	4,12,29	39°19'57"	76°12'02"
CB0705	Chesapeake Bay	3,23,43	39°19'22"	76°11'24"
CC0001	Cape Henry Channel	4,23,52	36°59'05"	76°00'11"
CC0002	Cape Henry Channel	4,24,47	36°59'48"	76°00'54"
CG0101	Choptank River	4,22,62	38°38'10"	76°09'36"
CO0101	Chickahominy River	4,20	36°16'13"	76°52'47"
CO0201	Chickahominy River	4,10	36°18'42"	76°52'42"
EE0101	E. Br. Elizabeth River	4,16,28	36°50'27"	76°16'56"
EE0201	E. Br. Elizabeth River	4,14,24	36°50'24"	76°16'00"
EE0301	E. Br. Elizabeth River	4,14,24	36°50'13"	76°14'48"
EH0101	Elizabeth River	4,12	36°55'30"	76°20'08"
EH0102	Elizabeth River	4,14,24,48,58*	36°55'30"	76°20'21"
EH0103	Elizabeth River	4,14	36°55'30"	76°20'33"
EH0201	Elizabeth River	4	36°53'09"	76°19'53"
EH0202	Elizabeth River	4,14,24,48,58*	36°53'15"	76°20'04"
EH0203	Elizabeth River	4,24,43	36°53'14"	76°20'16"
EH0301	Elizabeth River	4,14,24,48	36°52'25"	76°19'59"
EH0302	Elizabeth River	4,14,24	36°52'23"	76°20'12"
EH0401	Elizabeth River	4,14,24,44,48*	36°51'31"	76°18'50"
EH0501	Elizabeth River	4,14,24,42,48*	36°50'34"	76°17'41"
EH0601	Elizabeth River	4,14,24,42,48*	36°48'50"	76°17'28"
EH0701	Elizabeth River	4,14,24,36,43*	36°47'05"	76°18'13"
EH0801	Elizabeth River	4,14,24,36,41*	36°46'36"	76°17'45"
EH0901	Elizabeth River	4,14,24,36	36°45'18"	76°17'44"
EH1001	Elizabeth River	3,13	36°43'53"	76°16'49"

(Continued)

(Sheet 2 of 6)

Table 14 (Continued)

Station	Body of Water	Sampling Depths ft below msl	Latitude	Longitude
JG0101	James River	3,13	36°58'54"	76°17'36"
JG0102	James River	3,23,43	36°59'36"	76°17'54"
JG0103	James River	3,13,23,43,72	37°00'00"	76°18'12"
JG0211	James River	4,14	36°58'17"	76°28'20"
JG0201	James River	3,12	36°58'48"	76°27'54"
JG0202	James River	3,12,22	36°58'54"	76°27'12"
JG0203	James River	3,23,43	36°59'12"	76°26'54"
JG0311	James River	4,14	37°03'06"	76°36'16"
JG0301	James River	3,12,18	37°02'54"	76°35'54"
JG0302	James River	4,13,20,30	37°03'30"	76°35'36"
JG0321	James River	4	37°04'11"	76°36'15"
JG0401	James River	2,19	37°11'54"	76°40'18"
JG0402	James River	4,13,28	37°12'30"	76°39'12"
JG0501	James River	3,7,20	37°12'54"	76°48'00"
JG0502	James River	3,20,39	37°13'06"	76°47'36"
JG0601	James River	3,13,22	37°14'06"	76°56'48"
JG0701	James River	4,14,29	37°17'06"	77°02'36"
JG0801	James River	5,15,25	37°18'06"	77°08'48"
JG0901	James River	4,16,29	37°19'06"	77°16'24"
JG1001	James River	4,13,24	37°22'48"	77°20'18"
JN0101	James River	4,12,20	36°58'06"	76°19'48"
JN0102	James River	4,14,24,44,57*	36°58'17"	76°20'03"
JN0103	James River	4,14,24,34,58	36°58'30"	76°20'16"
JN0104	James River	4,14,24,44	36°58'52"	76°20'41"
JN0105	James River	4,12	36°59'33"	76°21'25"
JN0201	James River	4,12	36°55'09"	76°25'56"
JN0202	James River	4,14	36°55'23"	76°25'46"
JN0203	James River	4,14,23	36°56'24"	76°25'22"
JN0204	James River	4,14,24,50,58*	36°57'04"	76°25'07"
JN0205	James River	4,14,22	36°57'28"	76°24'41"
JN0301	James River	4	37°00'33"	76°32'44"
JN0302	James River	4,18	37°01'17"	76°31'55"
JN0303	James River	4,18,32	37°01'43"	76°31'26"
JN0304	James River	4	37°02'33"	76°30'33"

(Continued)

(Sheet 3 of 6)

Table 14 (Continued)

Station	Body of Water	Sampling Depths ft below msl	Latitude	Longitude
JN0401	James River	4,14,24	37°04'21"	76°39'53"
JN0501	James River	4,14	37°07'29"	76°39'05"
JN0502	James River	4,17,31	37°07'33"	76°38'32"
JN0601	James River	4,10	37°10'30"	76°42'32"
JN0602	James River	4,10	37°10'50"	76°43'10"
JN0603	James River	4,14,28	37°11'15"	76°43'53"
JN0701	James River	4	37°09'39"	76°44'02"
JN0801	James River	4,14,25	37°12'55"	76°52'41"
JN0802	James River	4,12	37°13'28"	76°52'42"
JN0803	James River	4,14,24	37°14'36"	76°52'43"
LF0101	Lafayette River	4	36°54'04"	76°19'11"
LF0201	Lafayette River	4,16	36°54'13"	76°17'40"
LF0301	Lafayette River	4,10	36°53'16"	76°16'42"
LH0001	Lynhaven Bay	4,20	36°55'09"	76°05'18"
LS0001	Horseshoe Shoal	4,18	36°57'26"	76°12'37"
LS0002	Horseshoe Shoal	4,14,23	36°58'53"	76°12'08"
LS0003	Horseshoe Shoal	4,14,24	37°00'20"	76°11'44"
LS0004	Horseshoe Shoal	4,18	37°01'30"	76°11'21"
MB0102	Mobjack Bay	3,20	37°18'42"	76°20'48"
MF0001	Fort McHenry Channel	4,22,52	39°13'48"	76°32'32"
NG0101	Nanticoke River	4,14,24	38°14'50"	75°55'39"
NN0001	Newport News Channel	4,14,32,50,58*	36°57'35"	76°21'16"
NS0101	Nansemond River	4,17	36°54'12"	76°27'32"
NS0102	Nansemond River	4	36°54'23"	76°28'16"
NS0201	Nansemond River	4,12,20	36°53'18"	76°29'17"
NS0301	Nansemond River	4,12,19	36°52'03"	76°30'37"
NS0401	Nansemond River	4,10	36°50'31"	76°32'00"
NS0501	Nansemond River	4	36°49'11"	76°32'22"
PG0101	Patuxent River	3,22,39	38°18'43"	76°25'17"

(Continued)

(Sheet 4 of 6)

Table 14 (Continued)

Station	Body of Water	Sampling Depths (ft below msl)	Latitude	Longitude
PI0101	Piankatank River	4,12,20	37°31'54"	76°18'24"
P00102	Potomac River	3,22,38	37°58'30"	76°19'42"
P00103	Potomac River	3,22,40	37°59'30"	76°19'54"
P00104	Potomac River	3,31,49	38°00'52"	76°20'00"
P00202	Potomac River	3,22,60	38°04'04"	76°27'11"
P00301	Potomac River	3,32,57	38°09'28"	76°34'39"
P00402	Potomac River	4,22,41	38°12'08"	76°45'42"
P00601	Potomac River	3,22,62	38°21'20"	76°59'12"
P00802	Potomac River	5,19	38°21'38"	77°14'59"
PQ0101	Poquosson River	3,10	37°10'12"	76°23'09"
PR0103	Patapsco River	14,32,48	39°10'45"	76°26'33"
PR0202	Patapsco River	15,33,50	39°11'58"	76°30'10"
RG0101	Rappahannock River	3,13,26	37°34'54"	76°17'36"
RG0102	Rappahannock River	3,20,33	37°36'06"	76°17'06"
RG0201	Rappahannock River	3,13,26	37°36'25"	76°23'41"
RG0202	Rappahannock River	3,14,25,52	37°36'55"	76°23'54"
RG0301	Rappahannock River	3,13,26,59	37°37'54"	76°28'36"
RG0302	Rappahannock River	3,13,20	37°38'42"	76°28'12"
RG0501	Rappahannock River	3,13,25	37°45'54"	76°37'12"
RG0601	Rappahannock River	2,19	37°48'36"	76°42'36"
RG0701	Rappahannock River	2,19	37°52'30"	76°46'18"
RS0001	Rappahannock Shoal Ch.	4,24,52	37°34'51"	76°03'32"
RS0002	Rappahannock Shoal Ch.	4,24,52	37°37'00"	76°05'48"
RS0003	Rappahannock Shoal Ch.	4,23,52	37°39'12"	76°08'02"
TS0001	Thimble Shoal Channel	4,14,24,49	36°56'49"	76°00'11"
TS0002	Thimble Shoal Channel	4,14,24,49,58*	36°57'40"	76°04'45"
TS0003	Thimble Shoal Channel	4,14,24,49,54*	36°58'21"	76°06'39"
TS0004	Thimble Shoal Channel	4,14,24,49,58*	36°59'47"	76°11'53"
TS0005	Thimble Shoal Channel	4,14,24,49,58*	37°00'24"	76°14'39"

(Continued)

(Sheet 5 of 6)

Table 14 (Concluded)

Station	Body of Water	Sampling Depths ft below msl	Latitude	Longitude
WB0101	W. Br. Elizabeth River	4,14	36°51'34"	76°20'07"
WB0201	W. Br. Elizabeth River	4,16	36°51'14"	76°21'20"
W00101	Willoughby Bay	4,10	36°57'27"	76°16'57"
YG0101	York River	4,24,34	37°14'12"	76°25'00"
YG0102	York River	5,25,54	37°14'30"	76°25'00"
YG0201	York River	4,14,44,59	37°14'18"	76°30'12"
YG0301	York River	3,13	37°19'00"	76°36'24"
YG0302	York River	3,11,27	37°19'18"	76°35'54"
YG0401	York River	3,11	37°22'12"	76°39'00"
YG0402	York River	12,16,25	37°22'24"	76°38'36"
YG0501	York River	4,14,26	37°24'48"	76°41'06"
YG0601	York River	4,14,24	37°29'18"	76°45'24"
YS0001	York Spit Channel	4,24,49	37°02'33"	76°04'31"
YS0002	York Spit Channel	4,22,49	37°06'24"	76°07'16"
YS0003	York Spit Channel	4,22,49	37°11'03"	76°09'19"
YS0004	York Spit Channel	4,22,49	37°14'12"	76°08'08"
YS0005	York Spit Channel	4,24,52	37°17'12"	76°06'59"

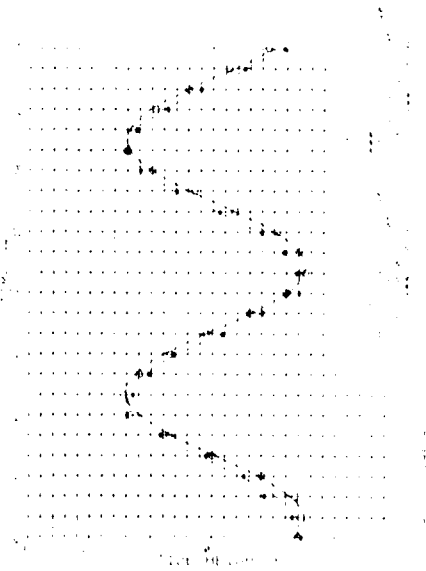
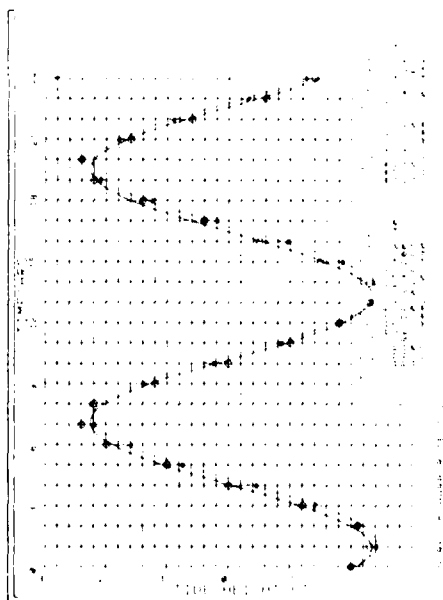
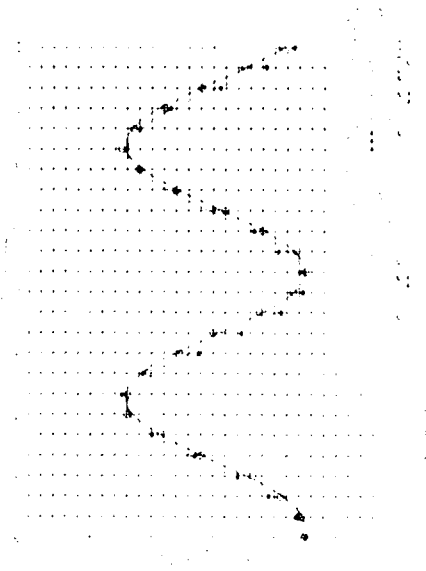
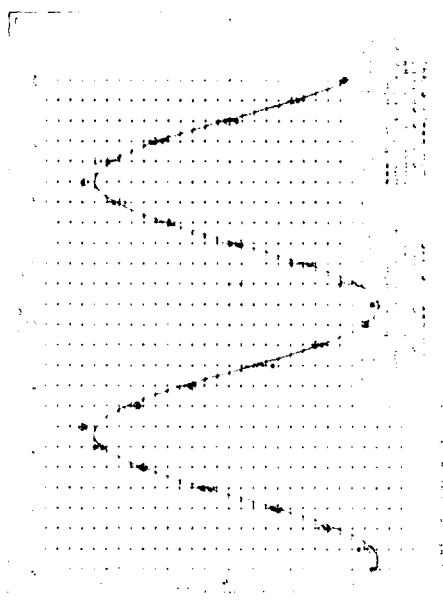


PLATE 1

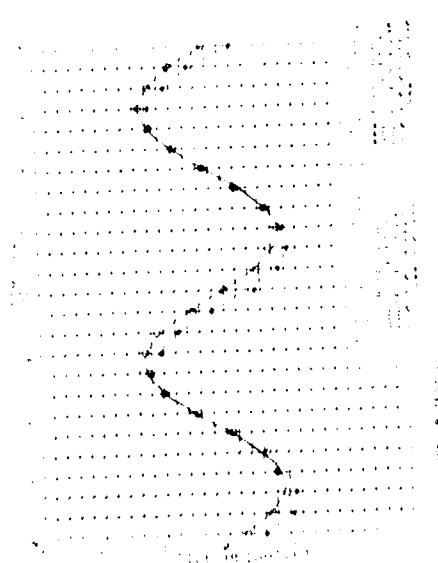
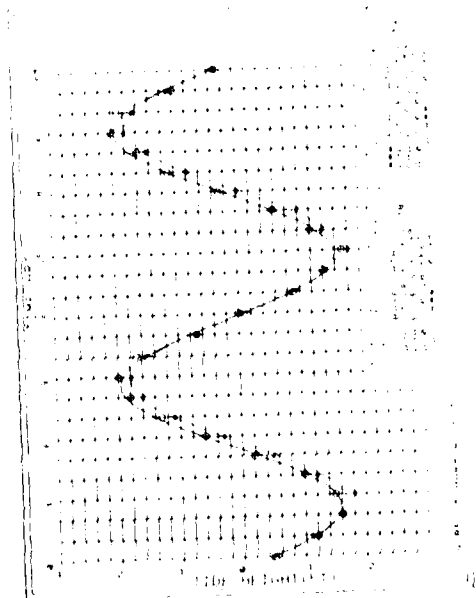
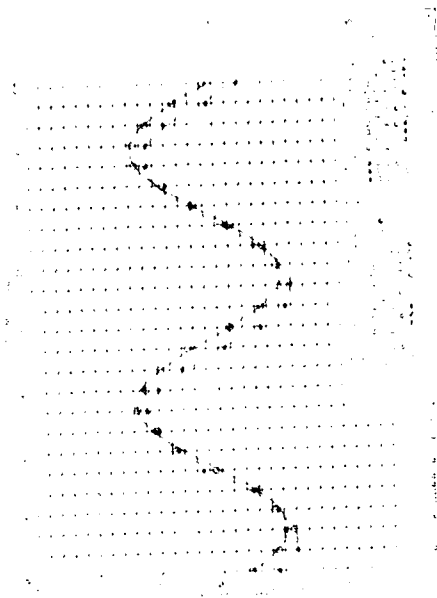
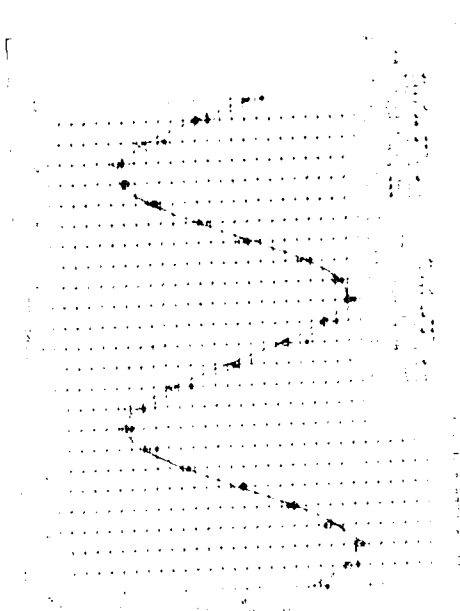


PLATE 2

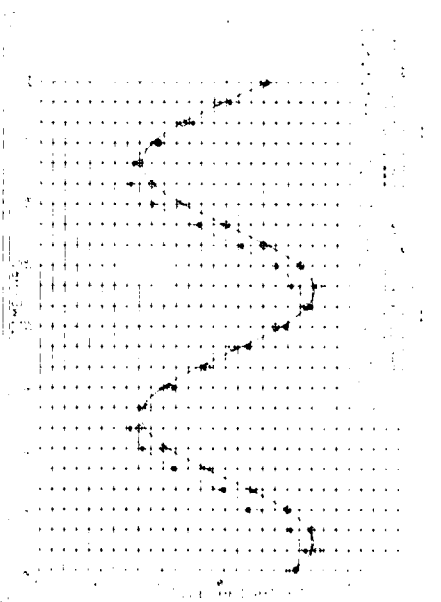
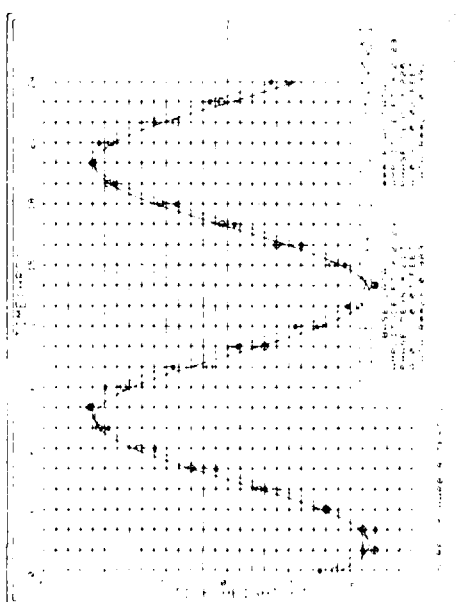
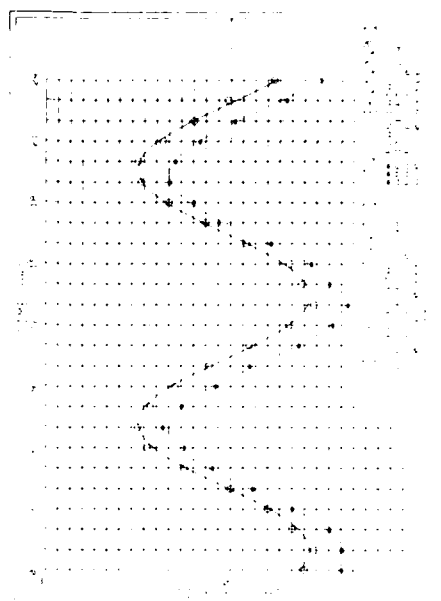
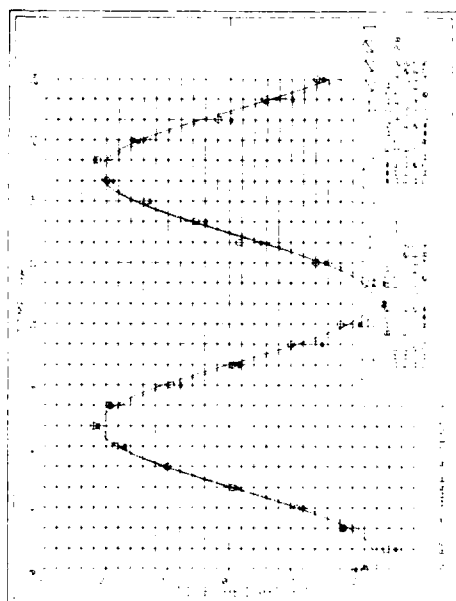


PLATE 3

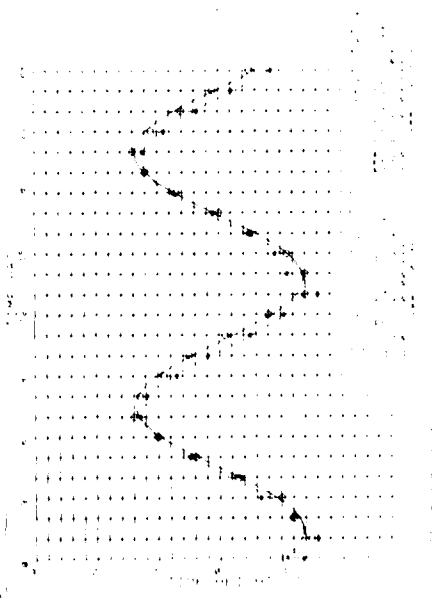
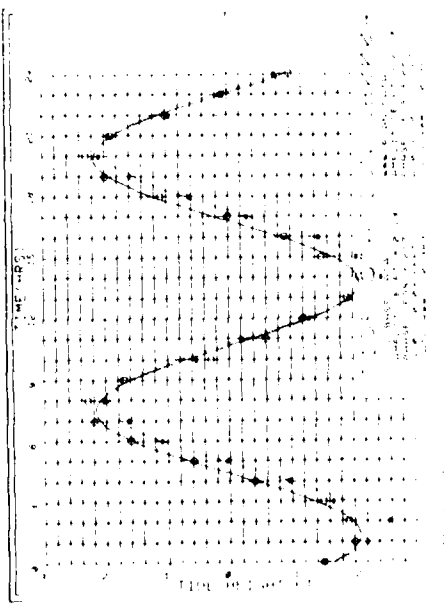
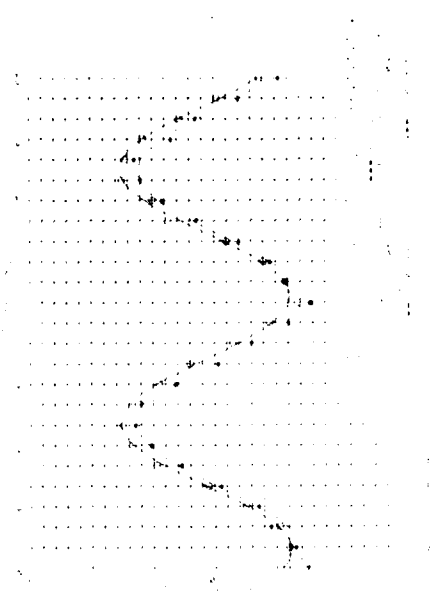
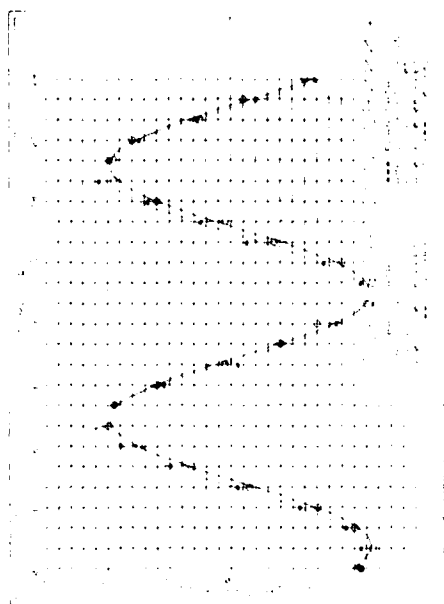


PLATE 4

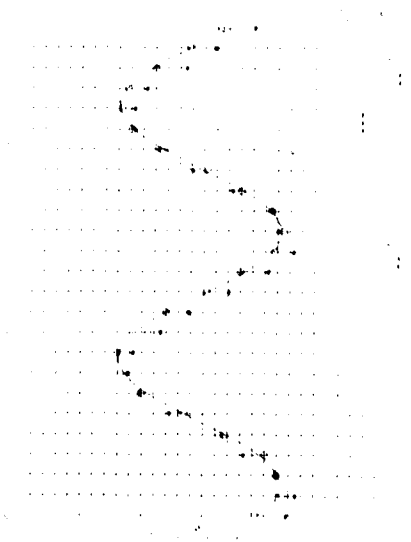
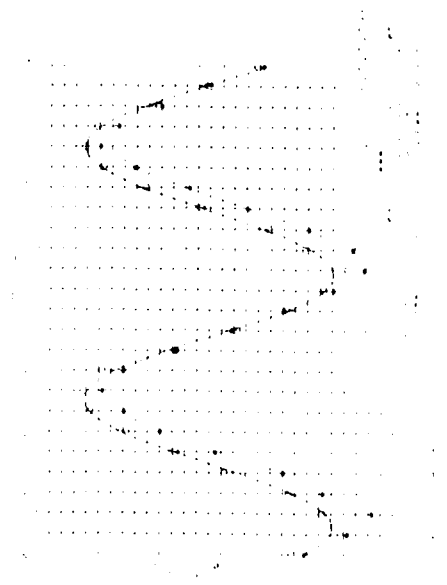
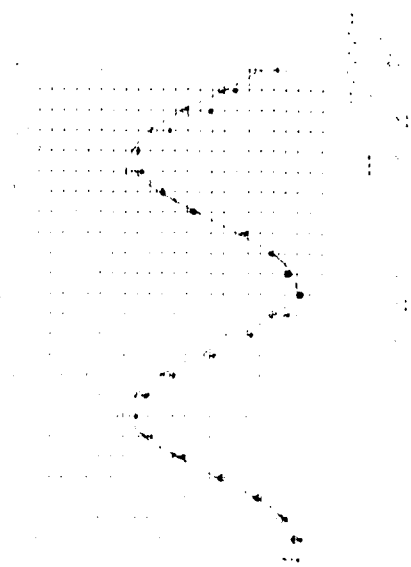
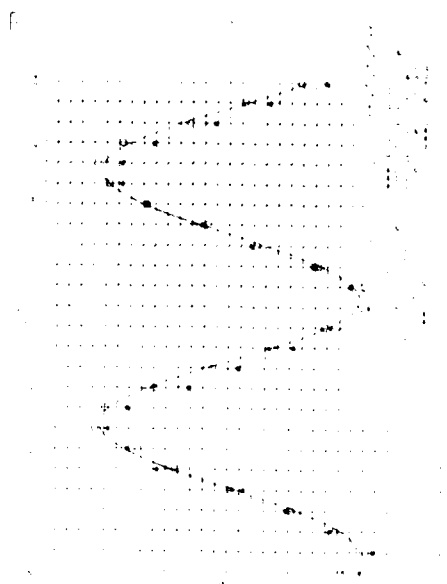


PLATE 5

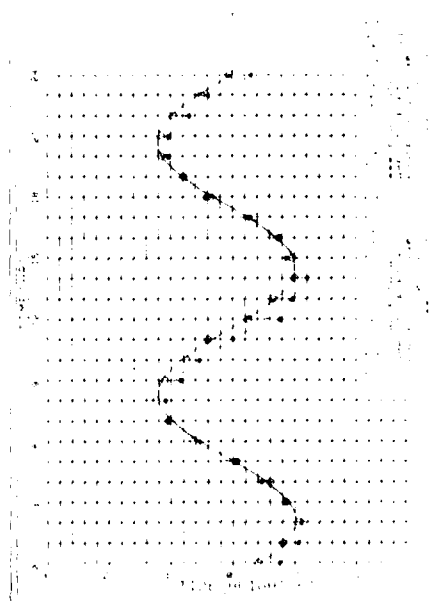
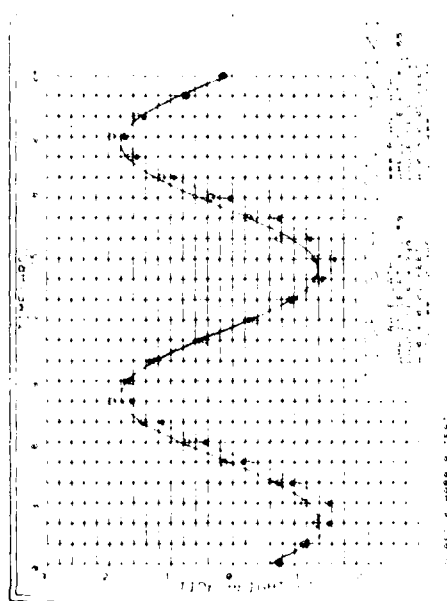
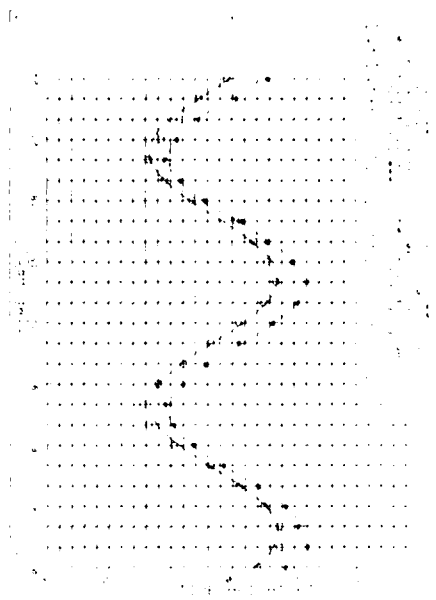
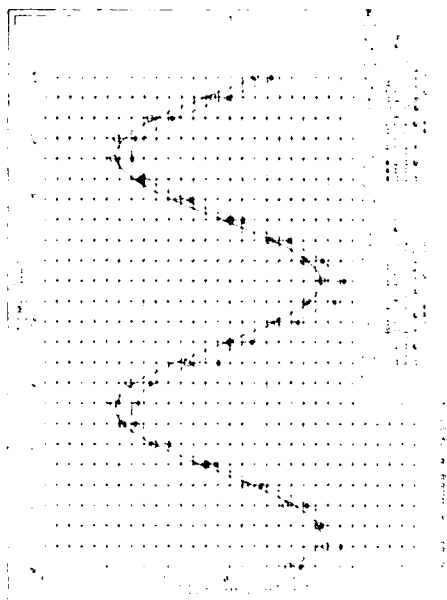
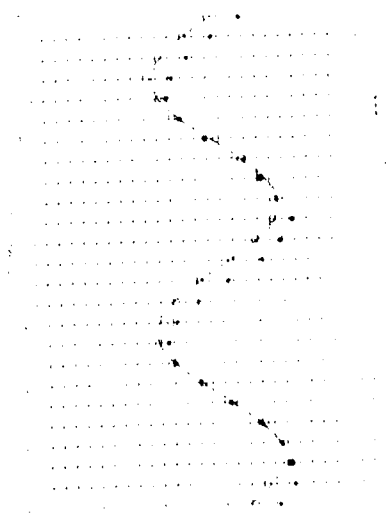
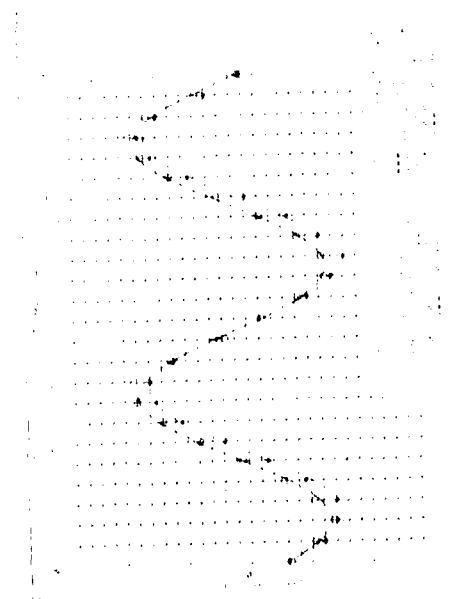
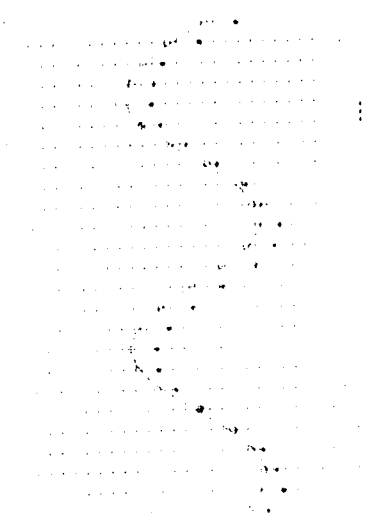
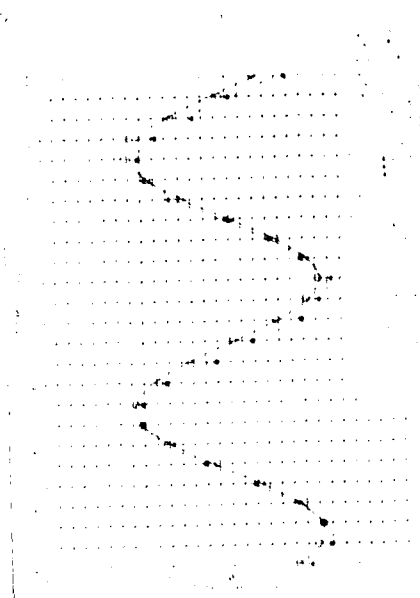


PLATE 6



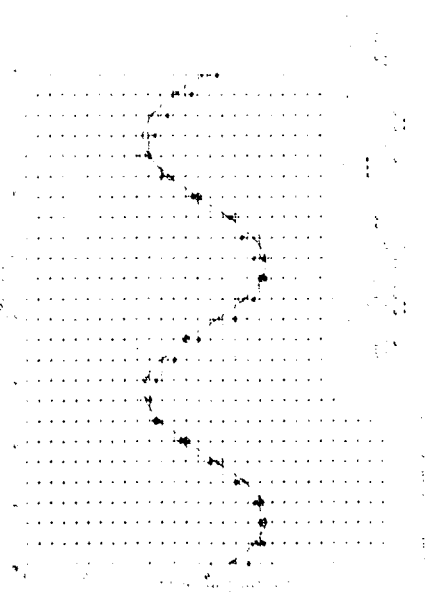
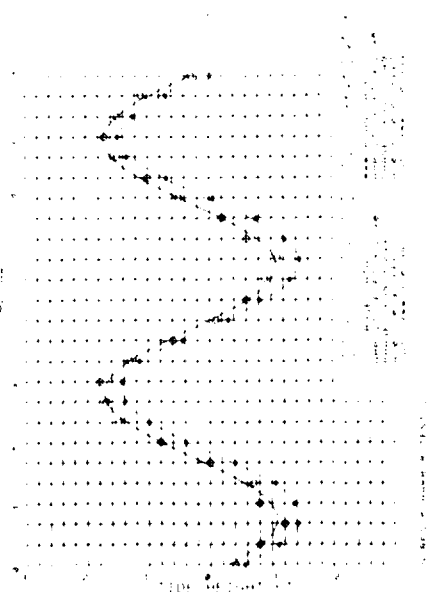
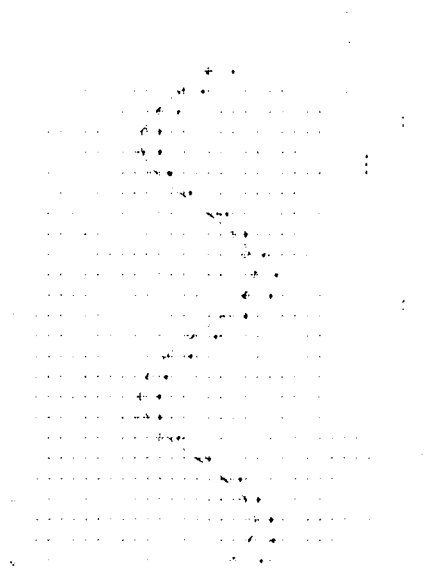
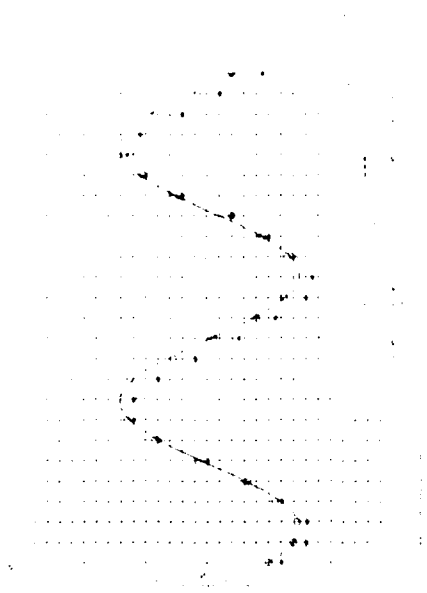
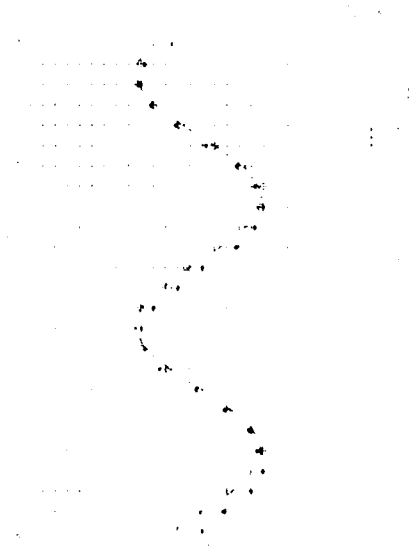
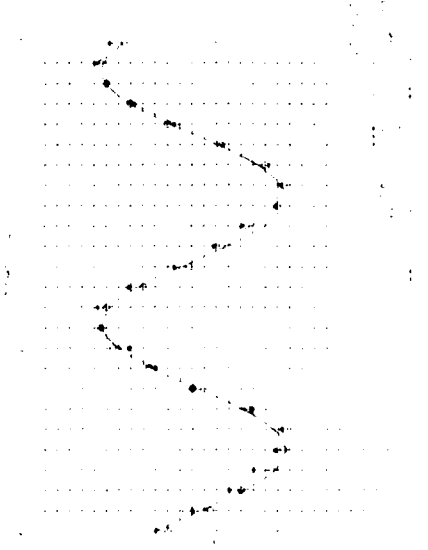
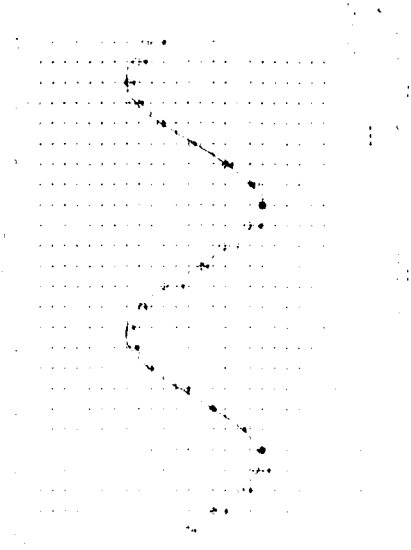
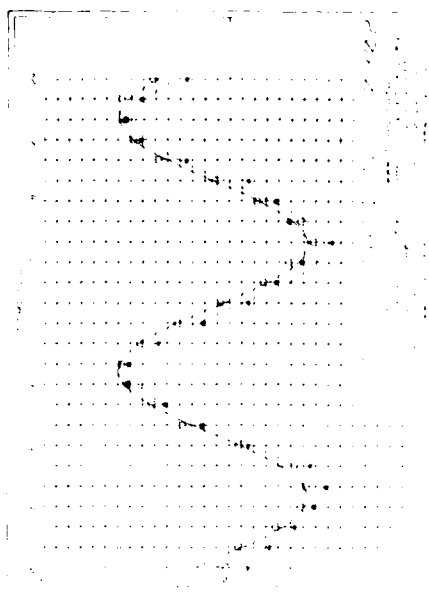


PLATE 8



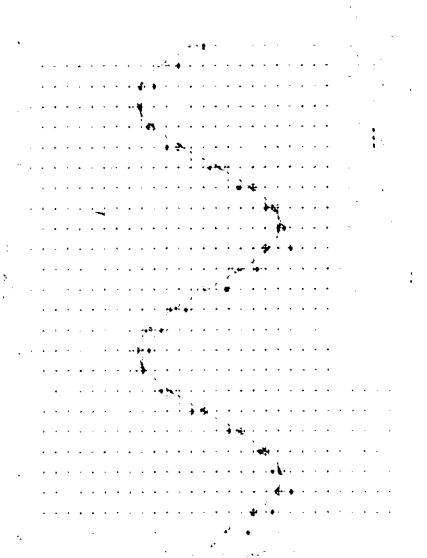
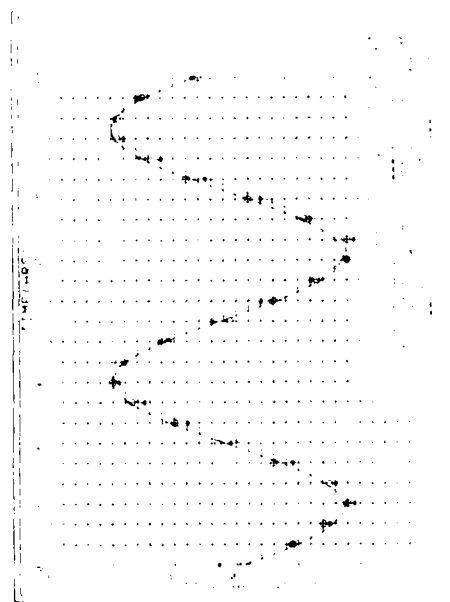
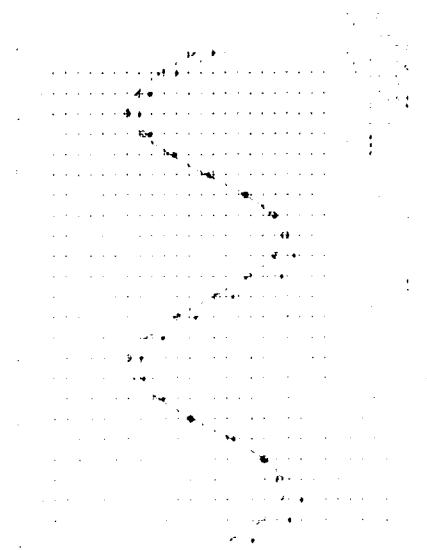
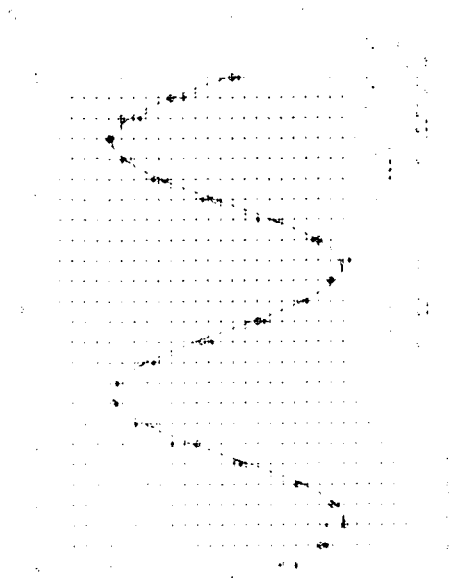
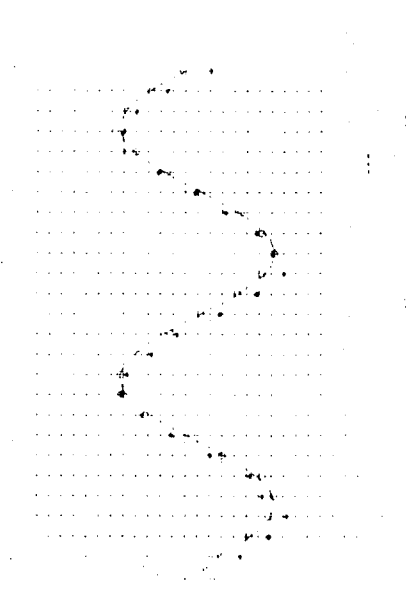
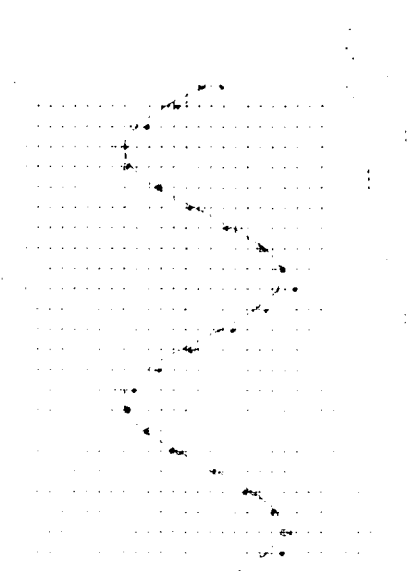
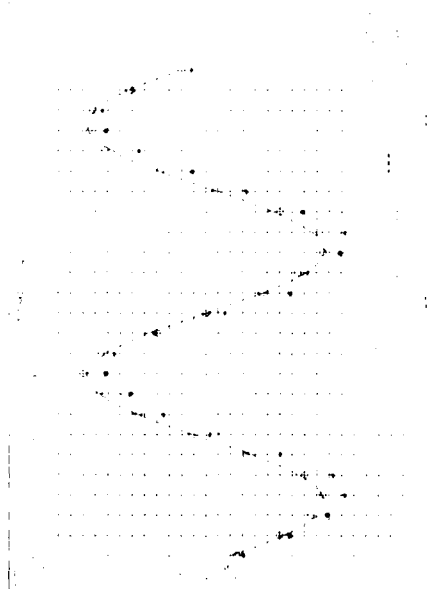


PLATE 10



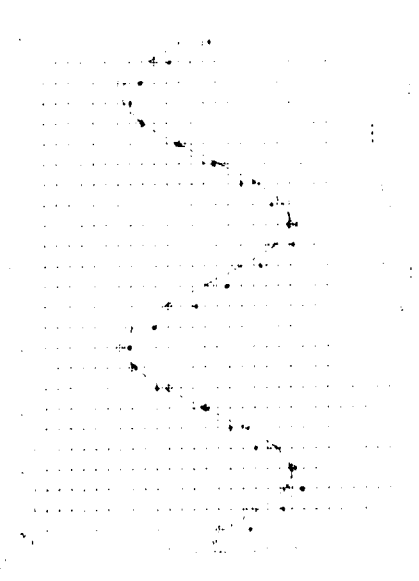
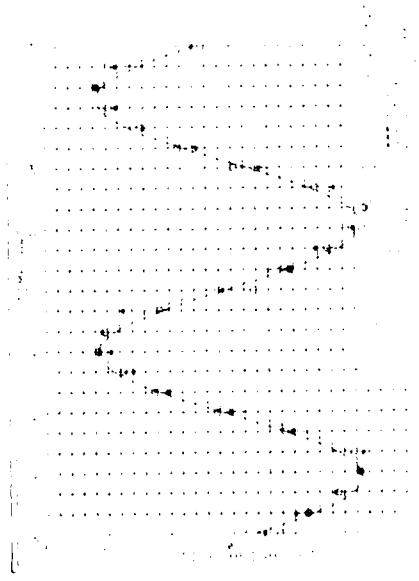
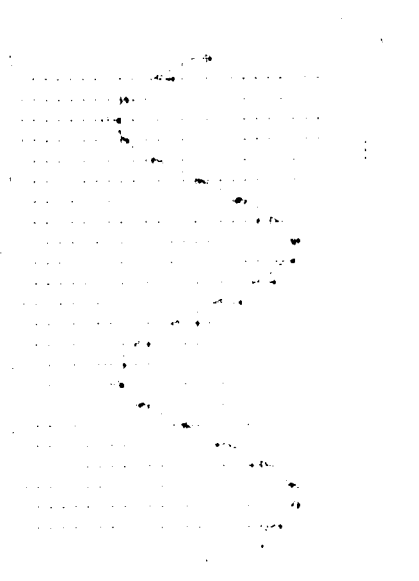
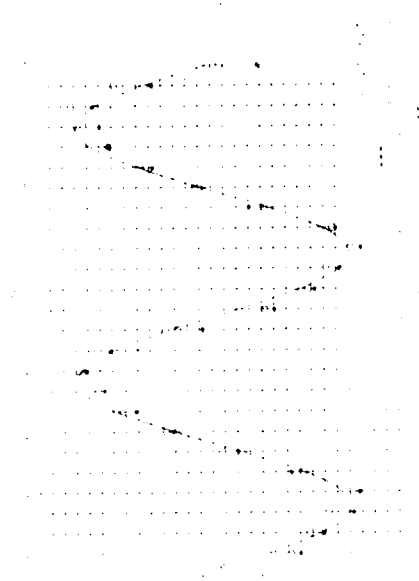


PLATE 12

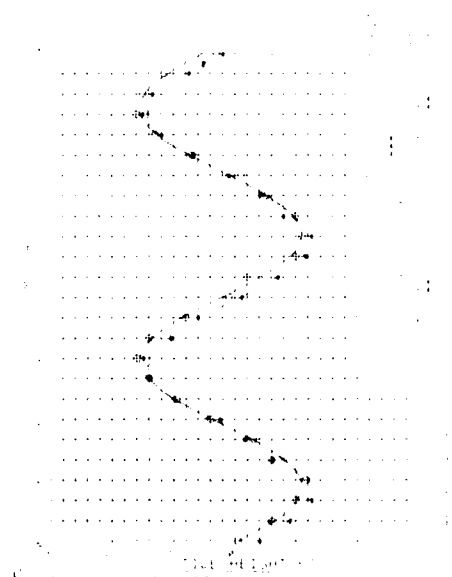
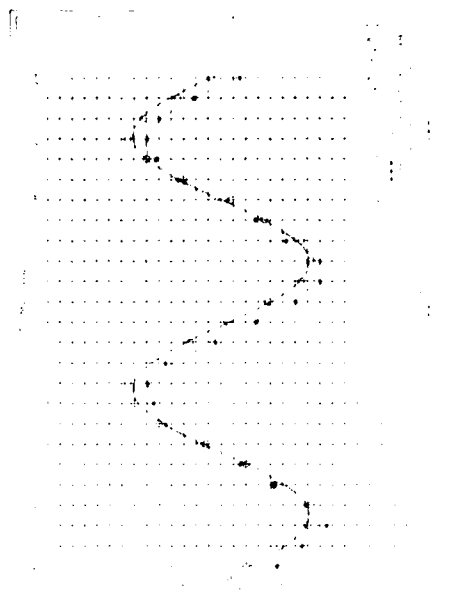
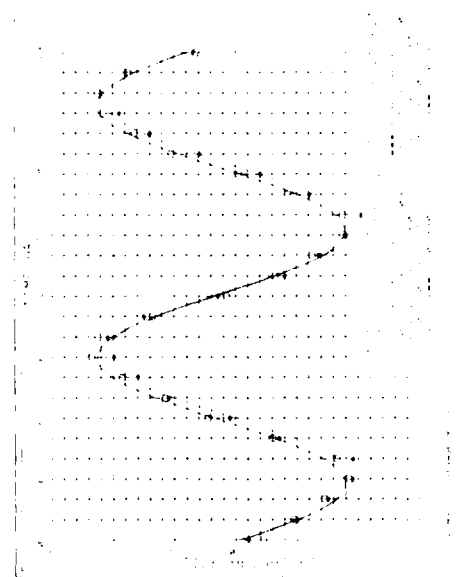
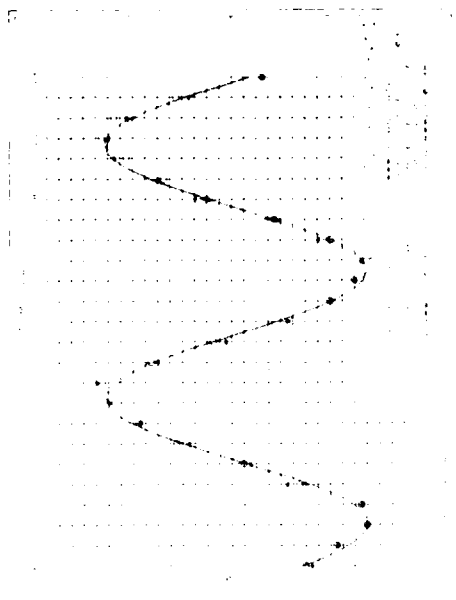


PLATE 13

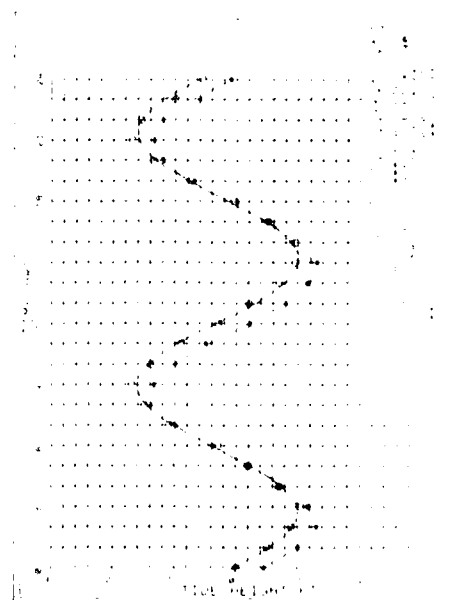
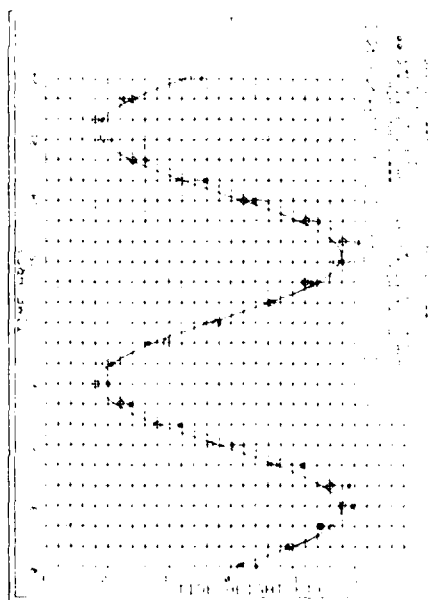
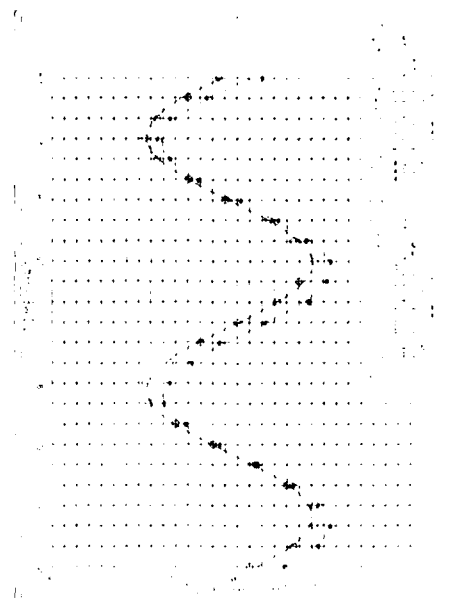
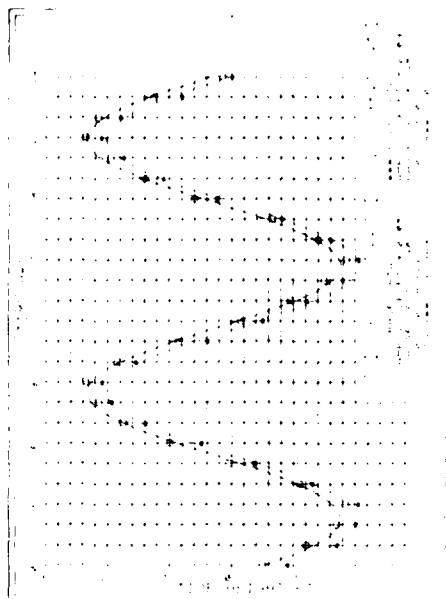
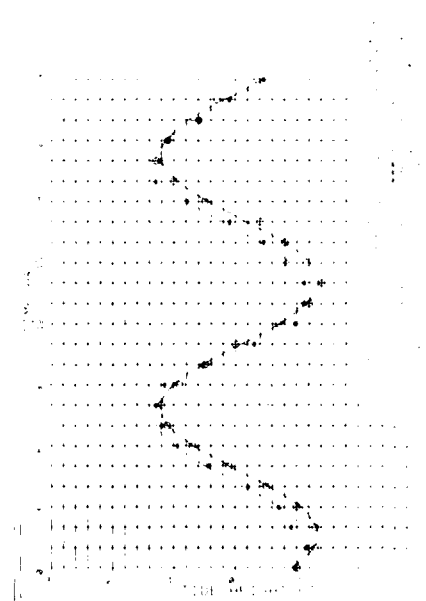
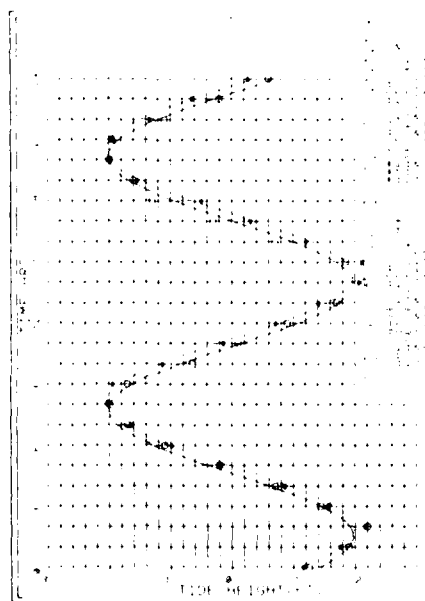
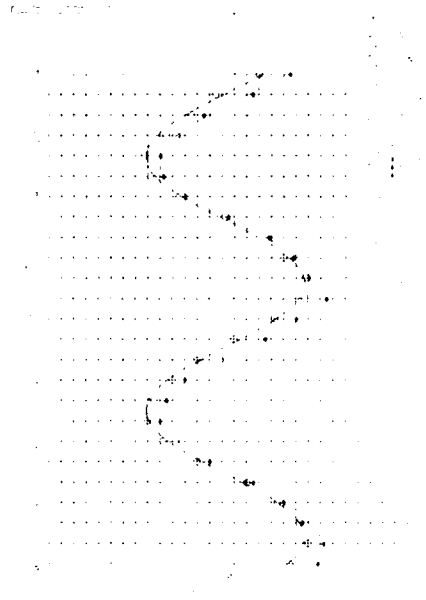
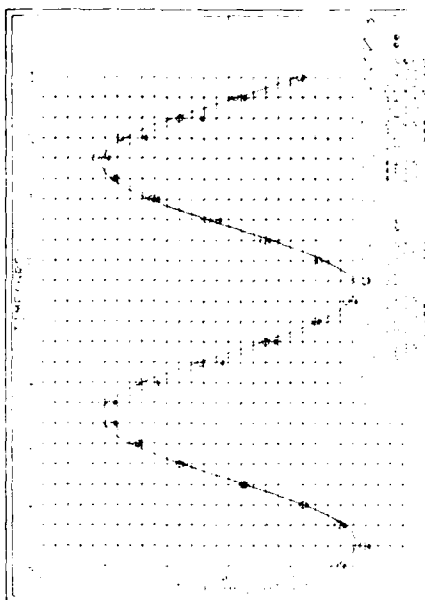


PLATE 14



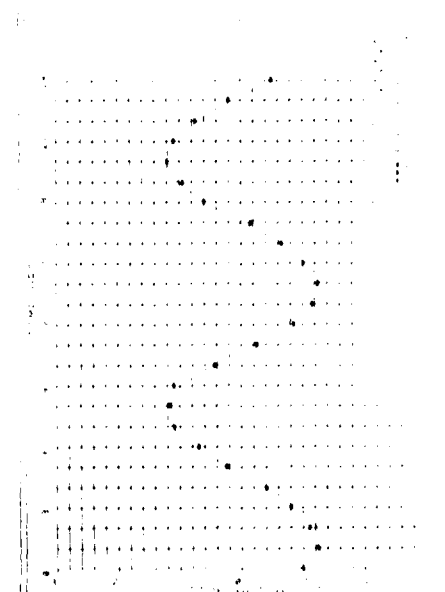
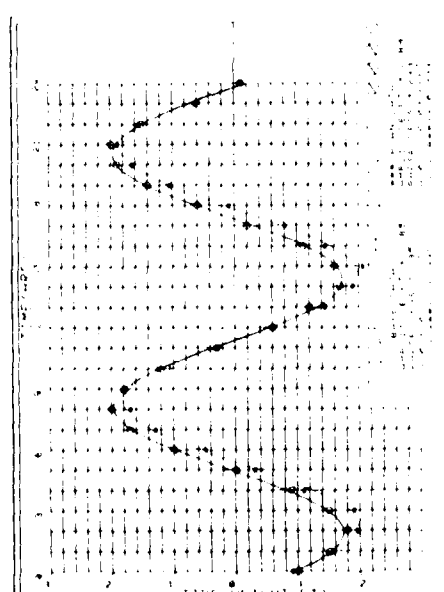
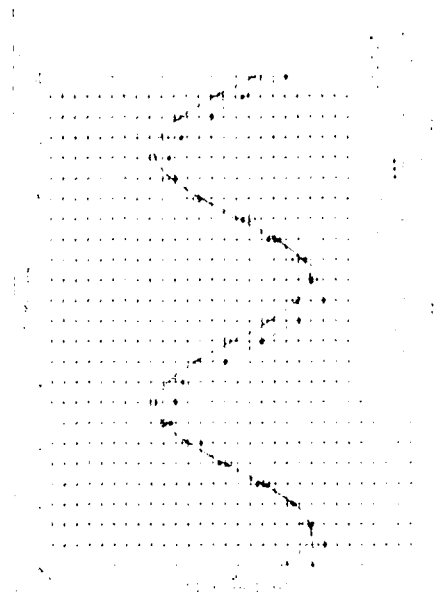
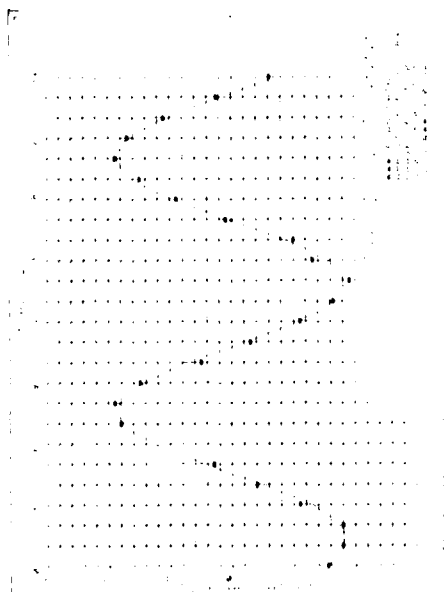
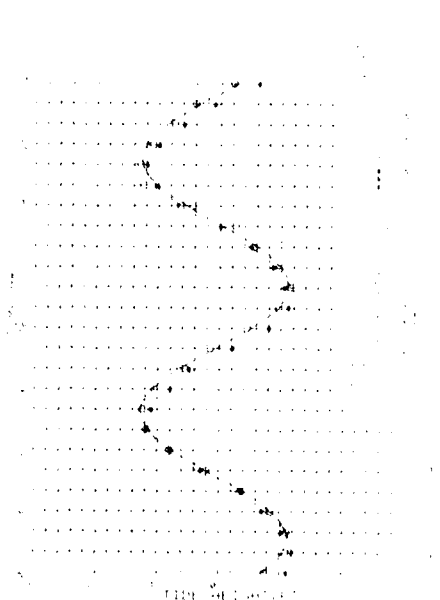
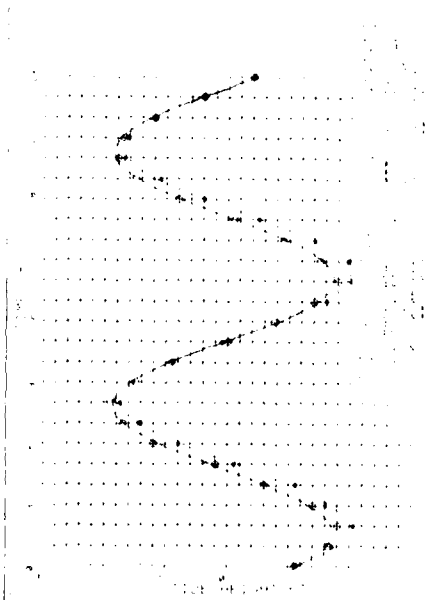
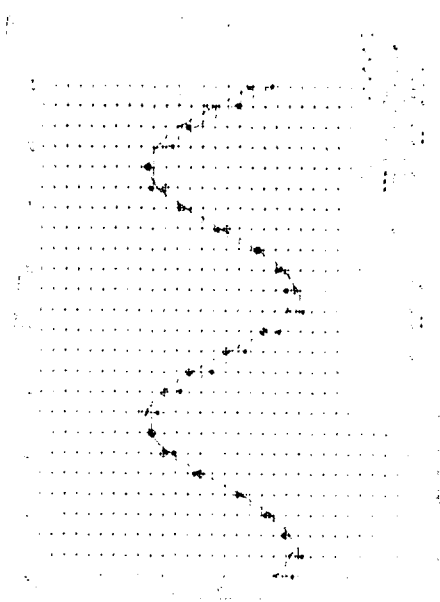
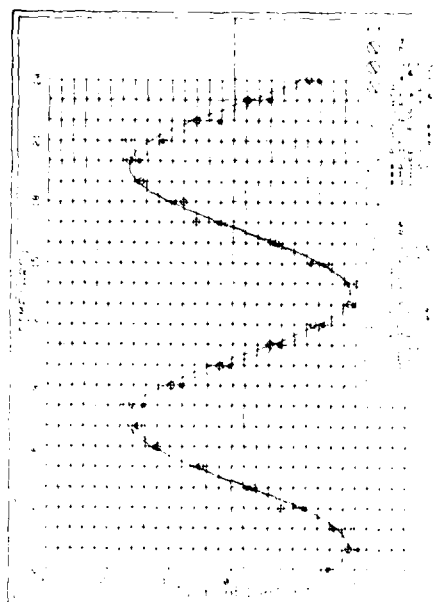


PLATE 16



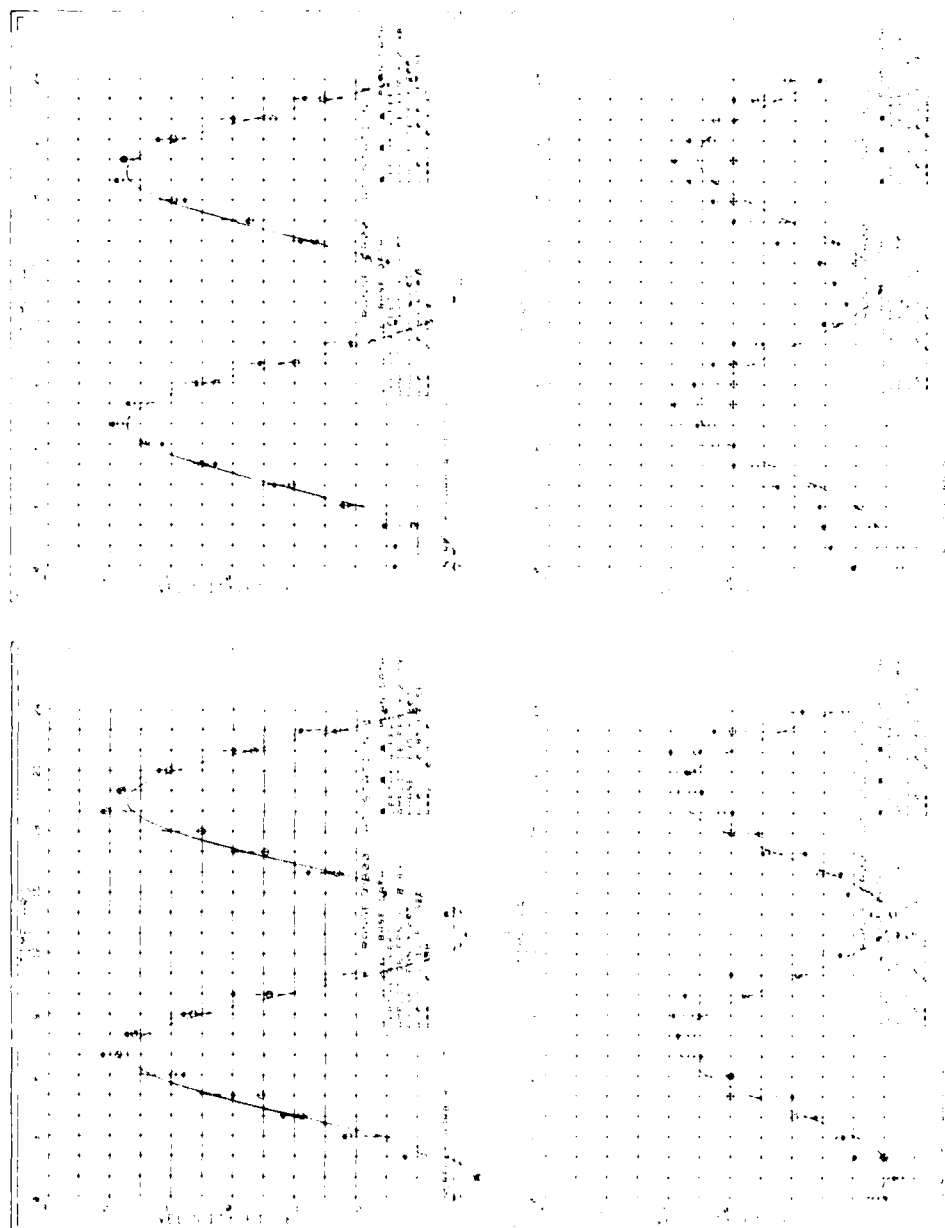
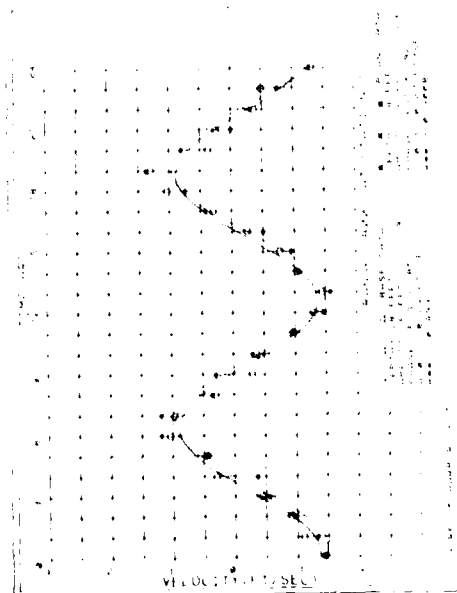
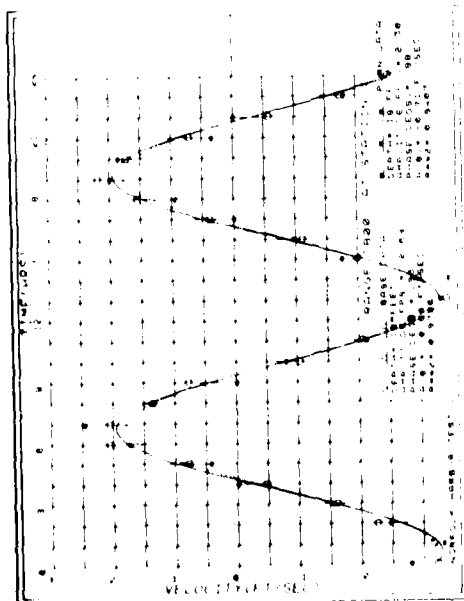
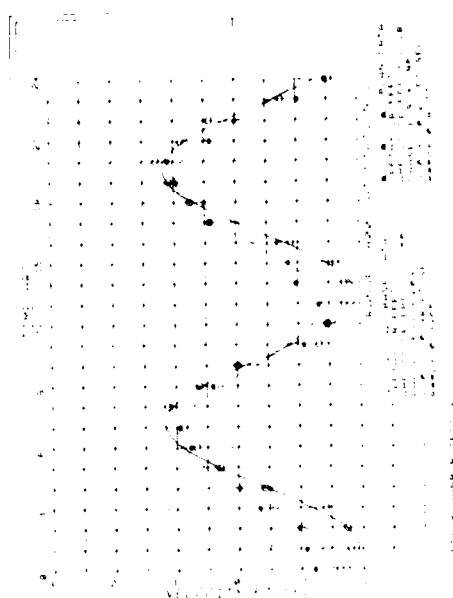
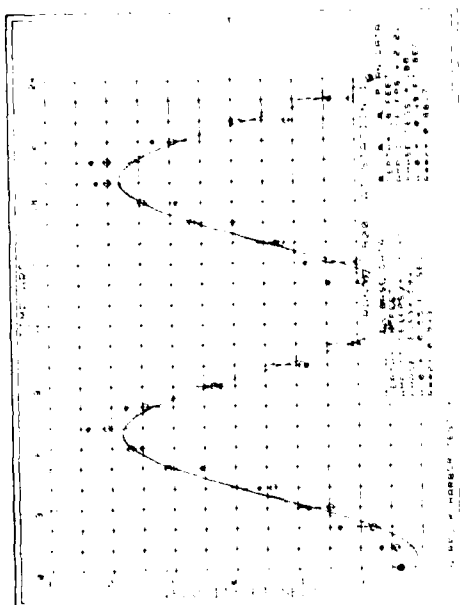


PLATE 18



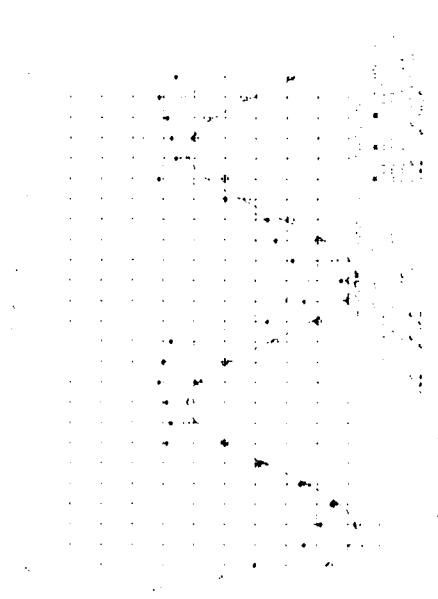
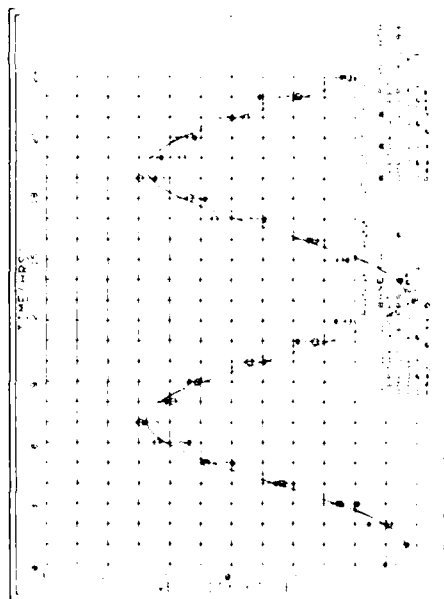
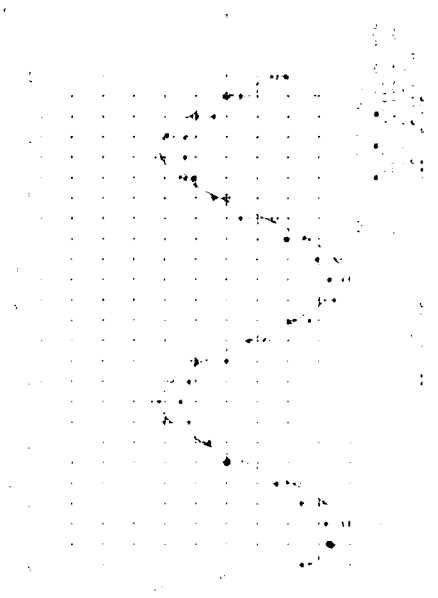
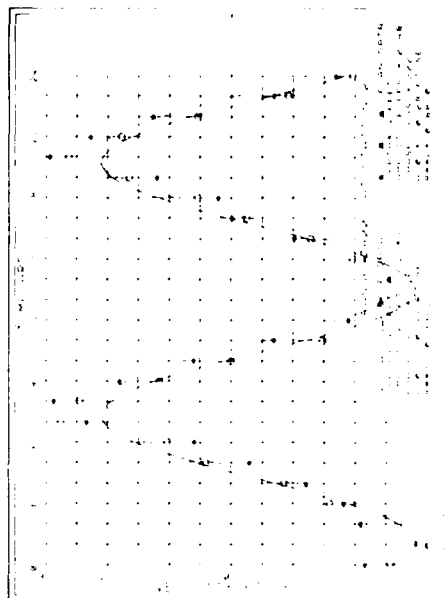


PLATE 21

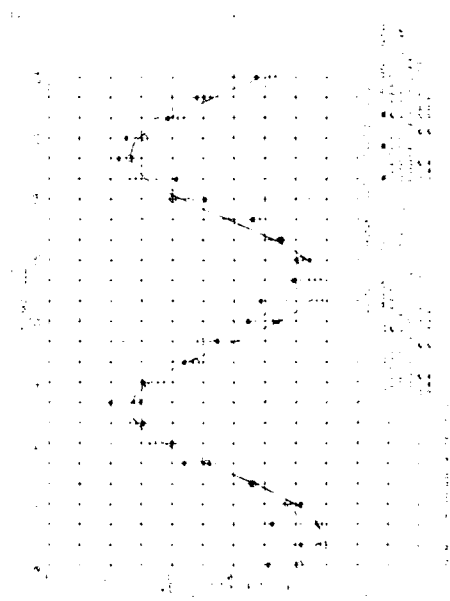
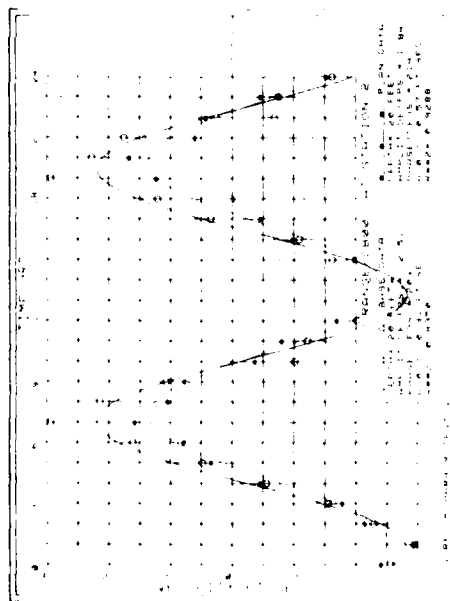
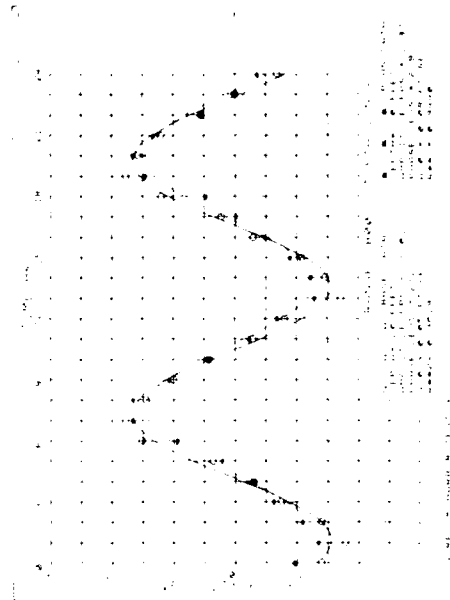
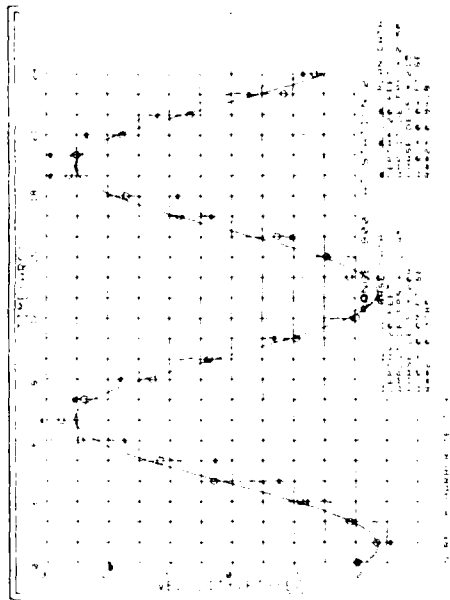


PLATE 22

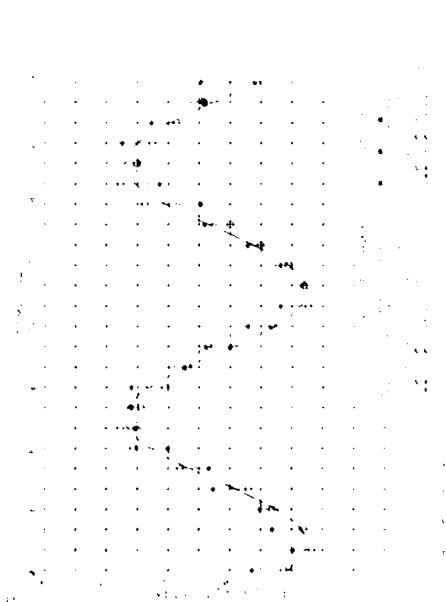
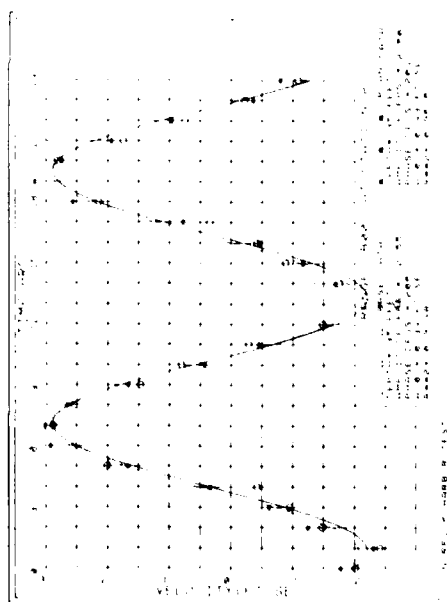
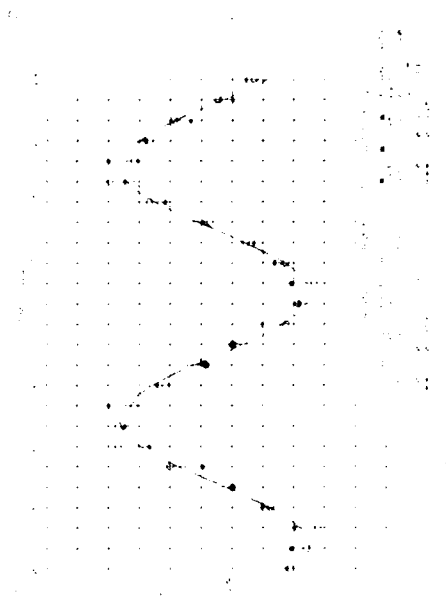
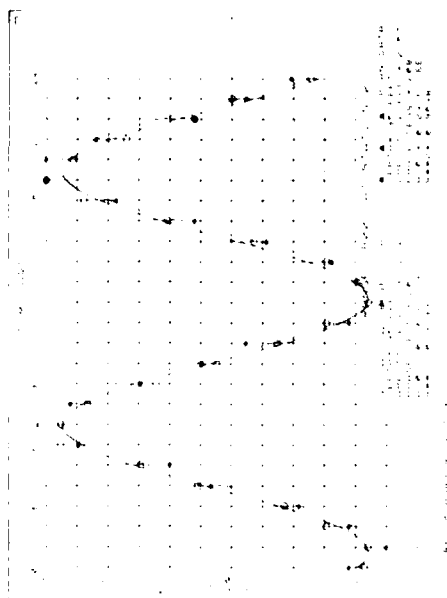


PLATE 23

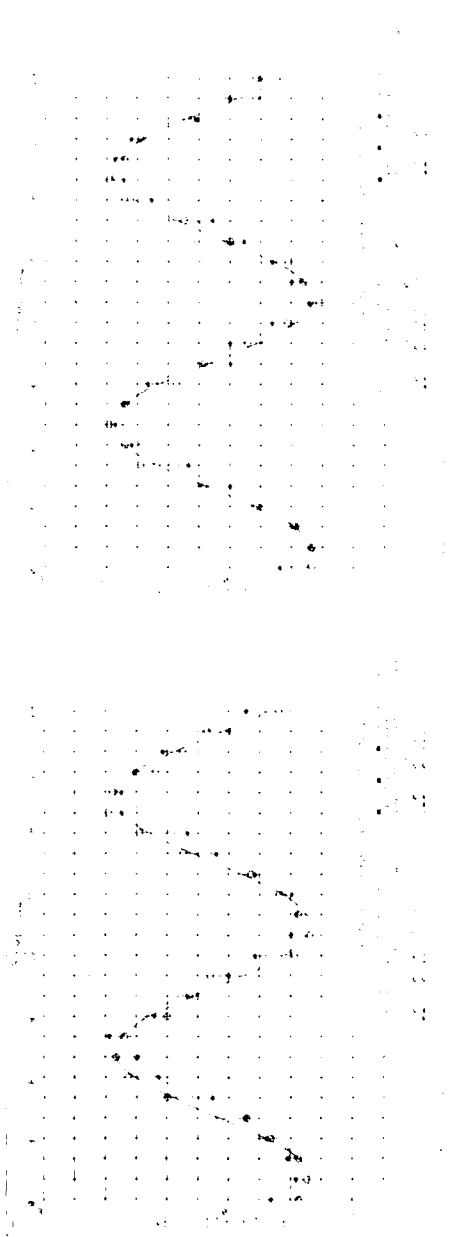
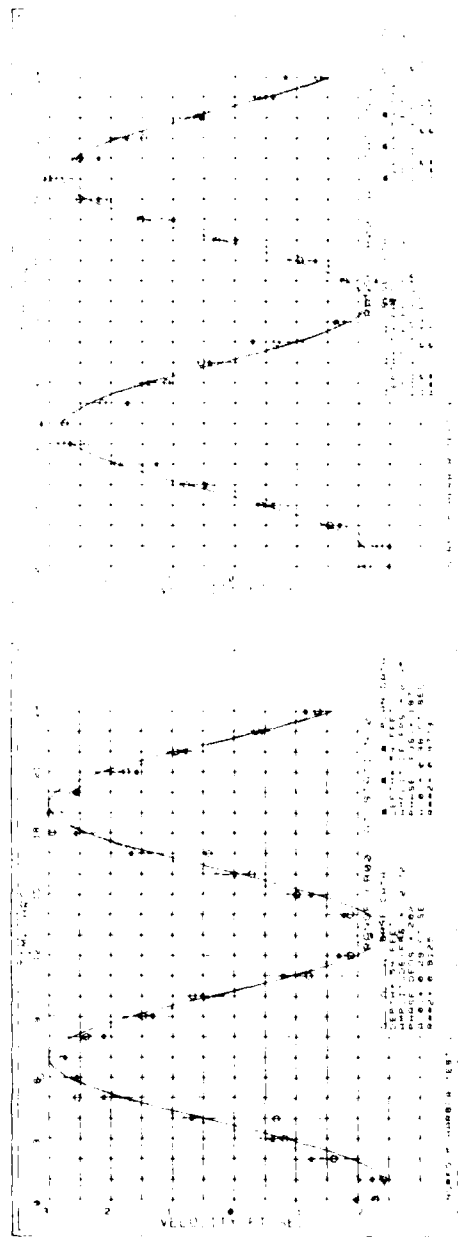


PLATE 24

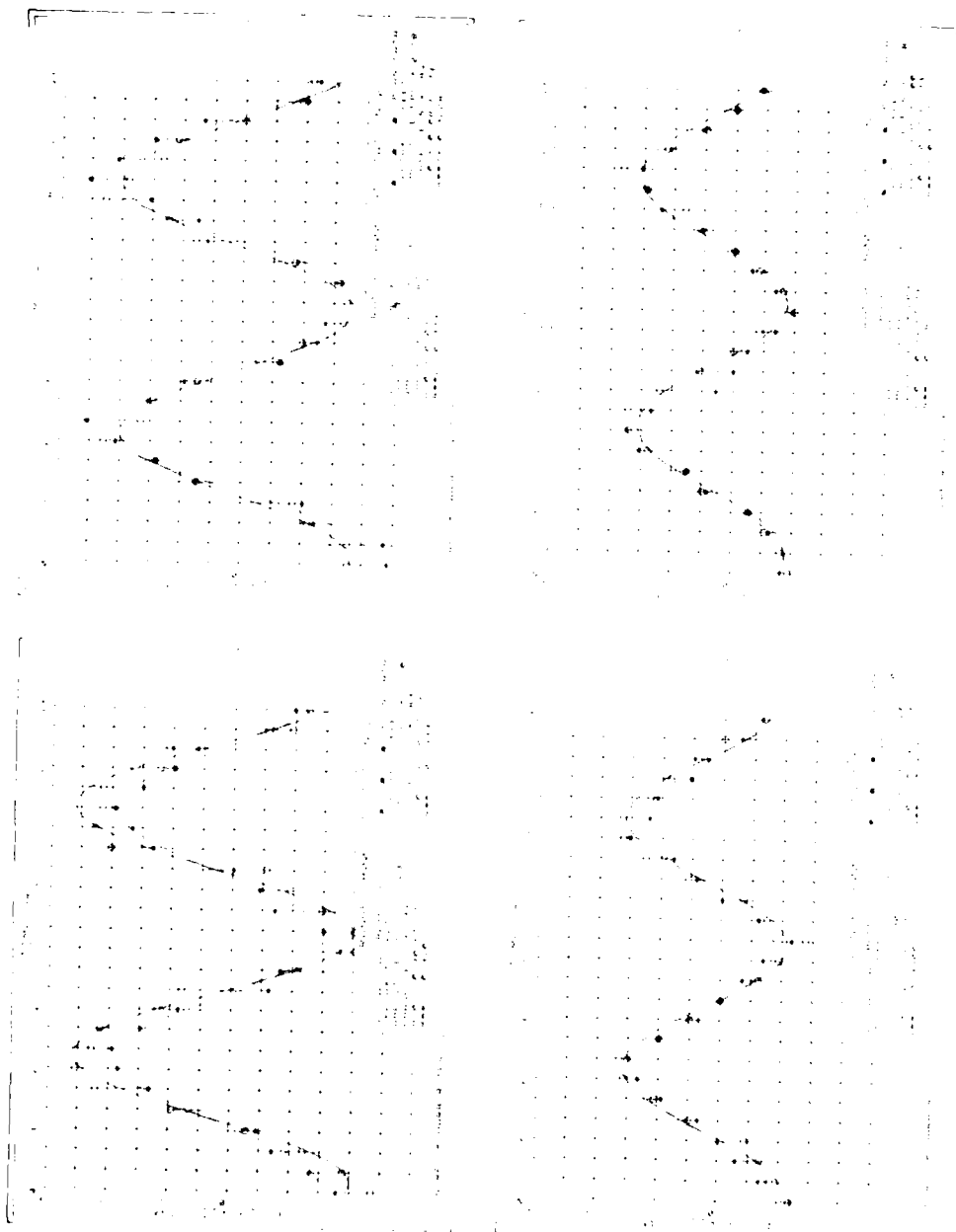


PLATE 25

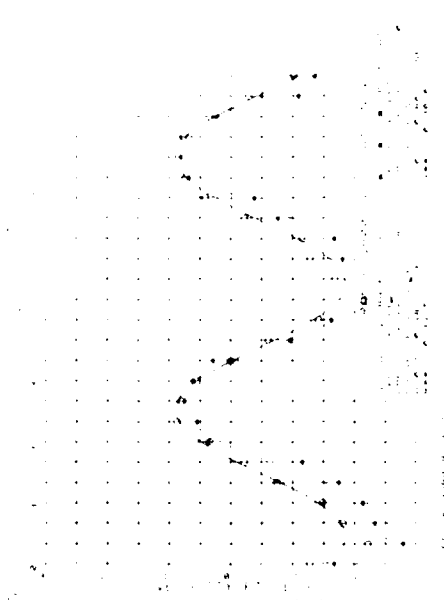
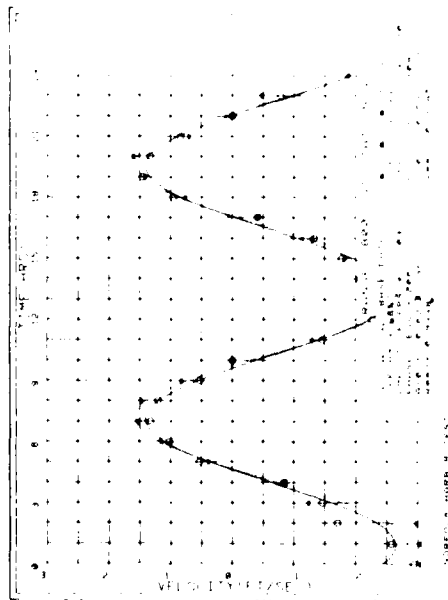
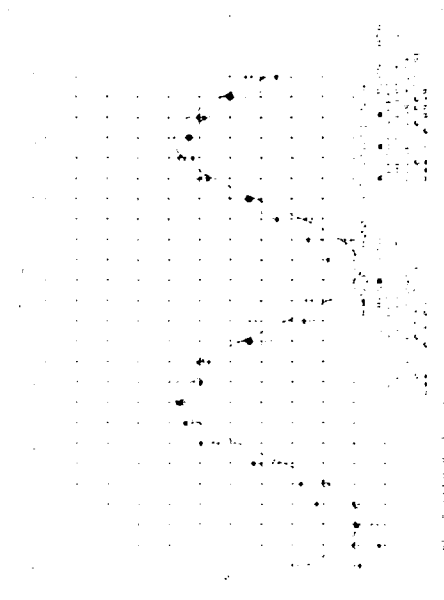
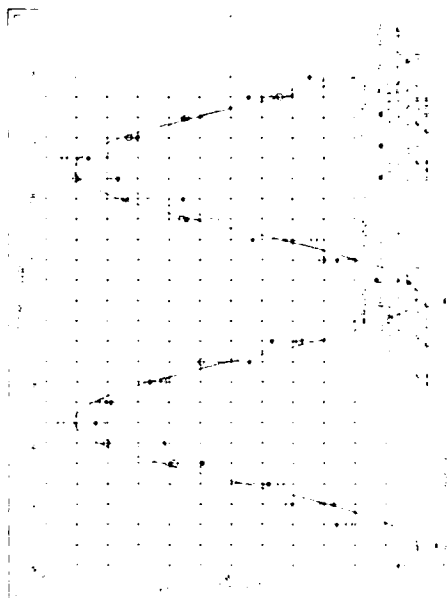


PLATE 26

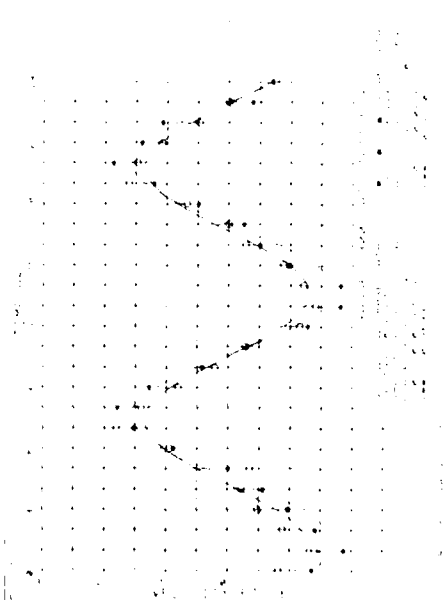
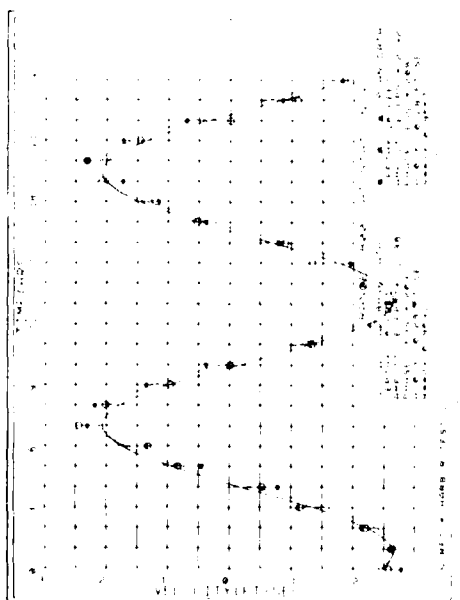
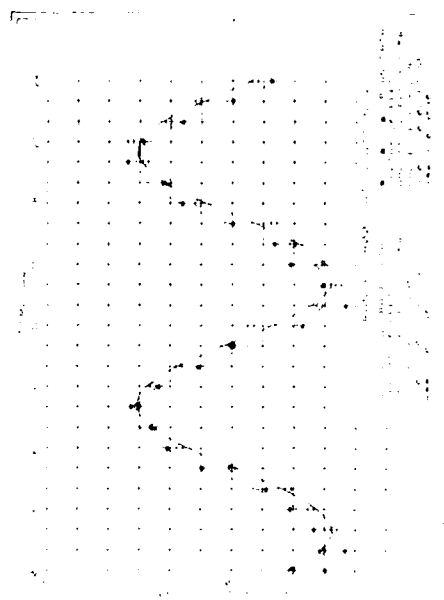
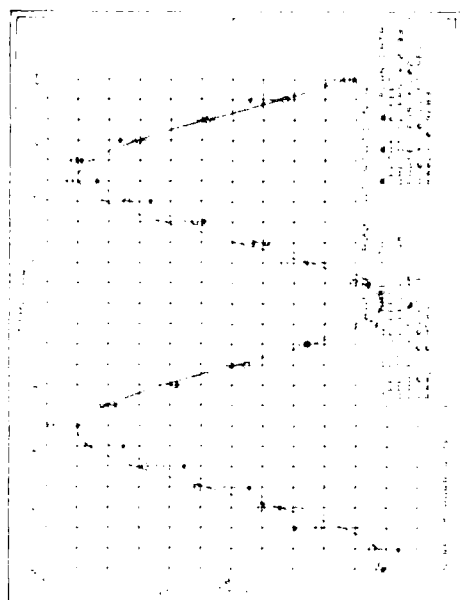


PLATE 27

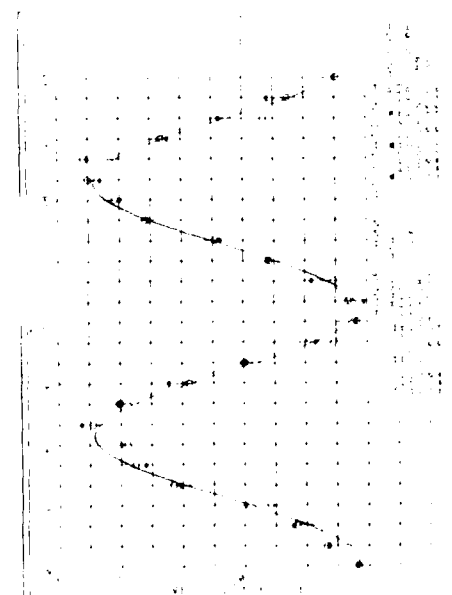
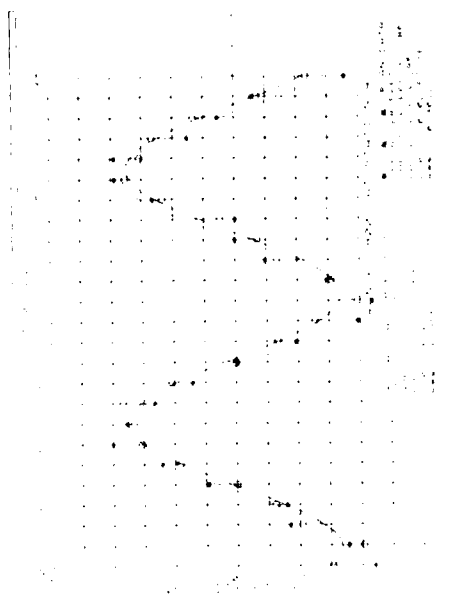


PLATE 28

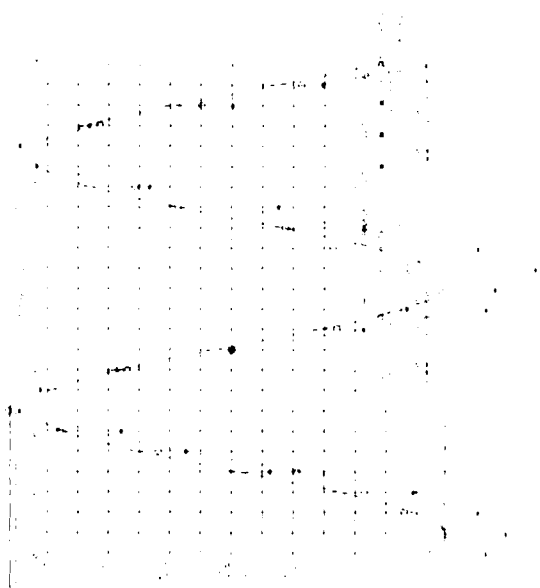
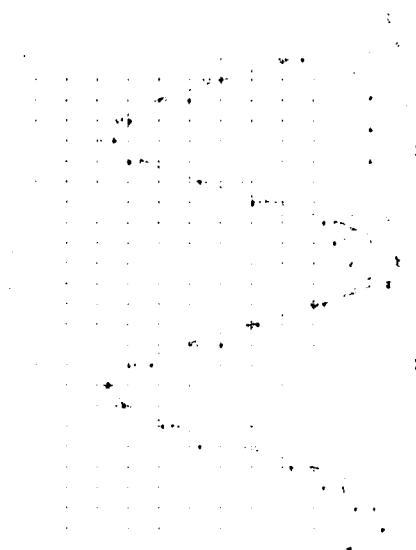
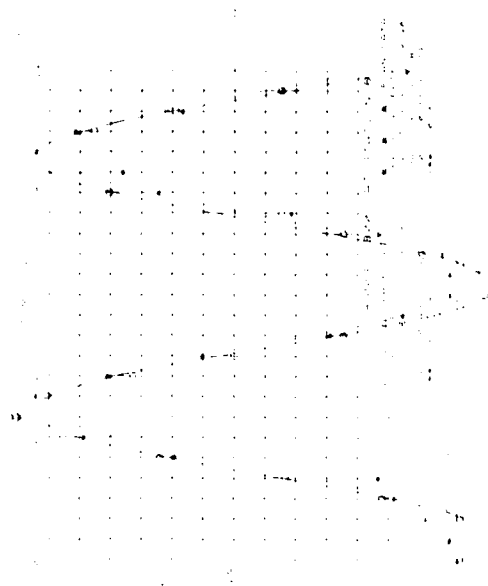


PLATE 29

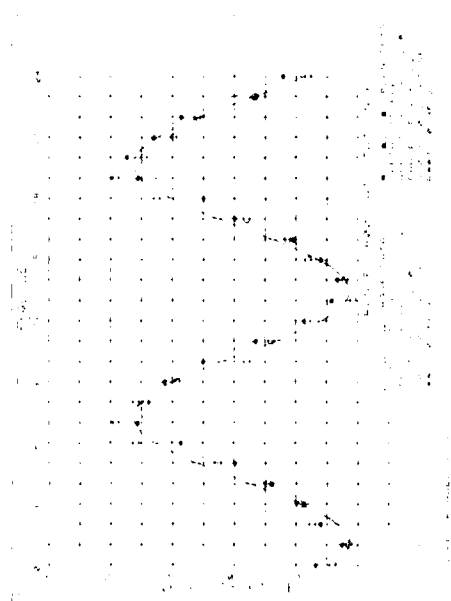
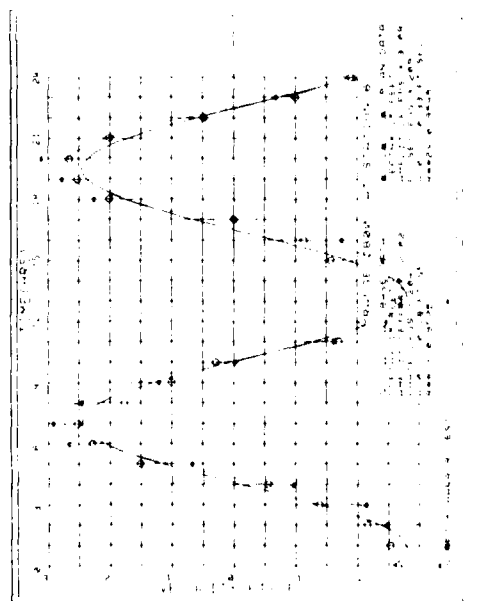
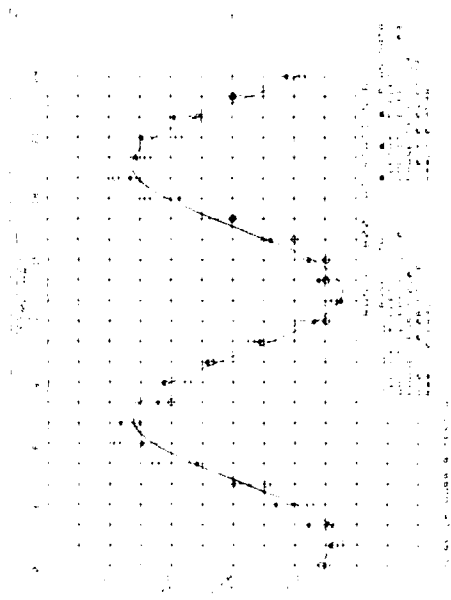
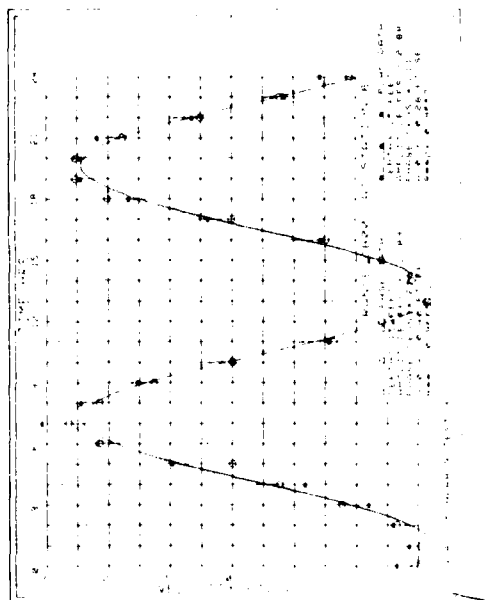


PLATE 30

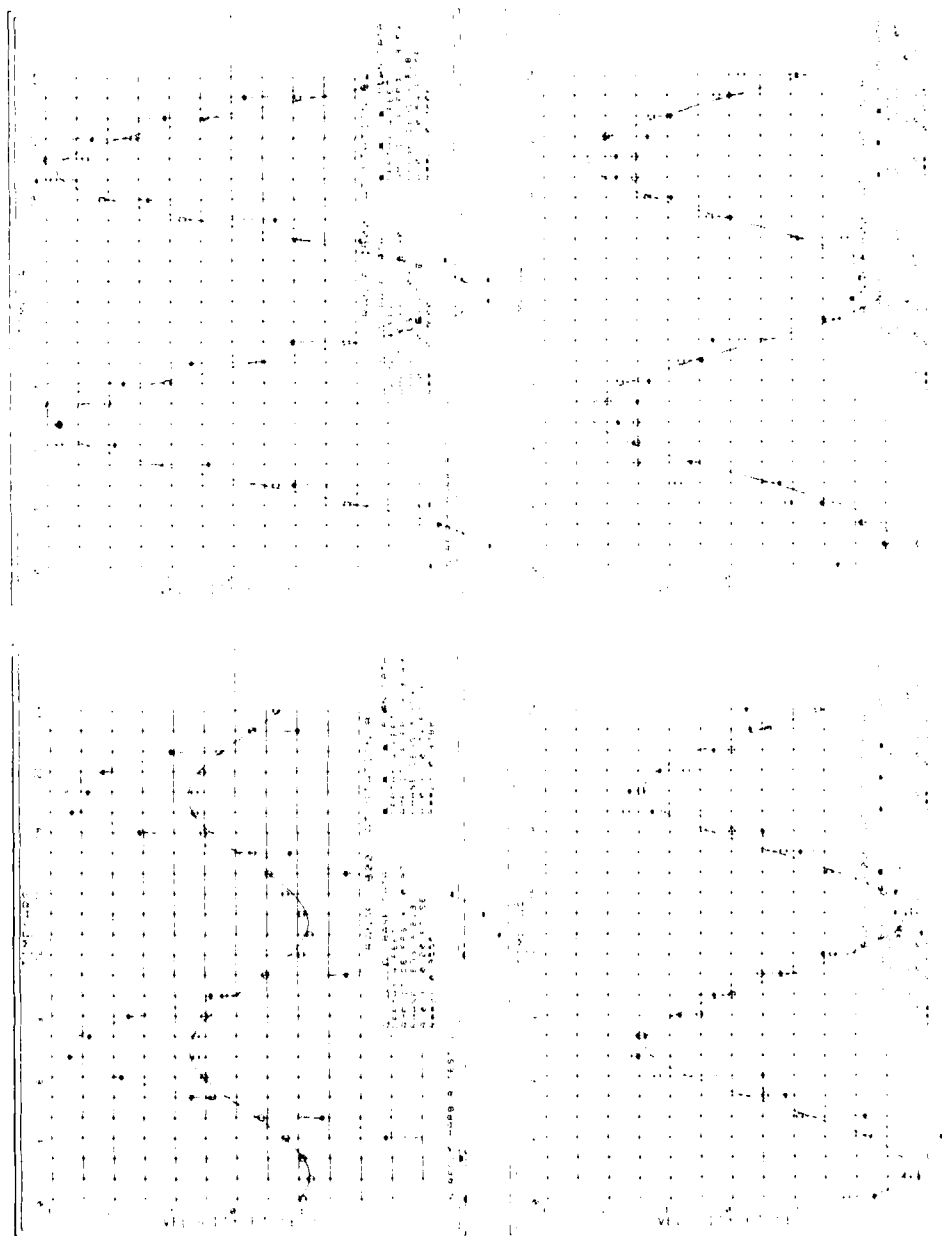


PLATE 31

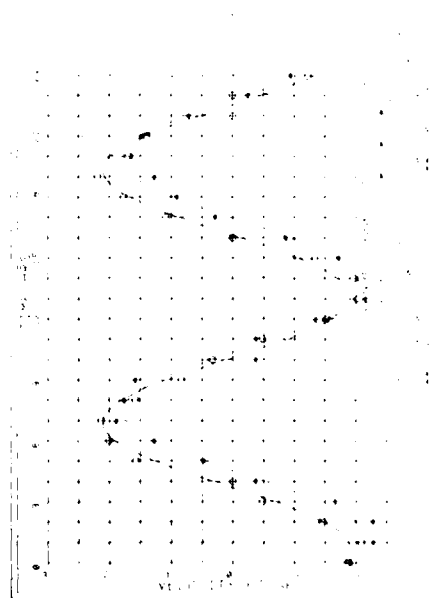
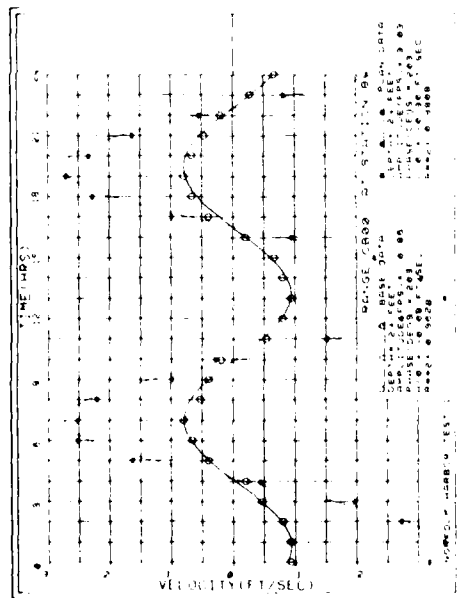
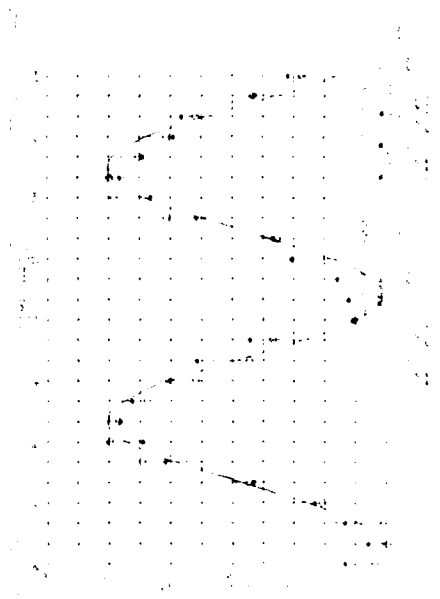
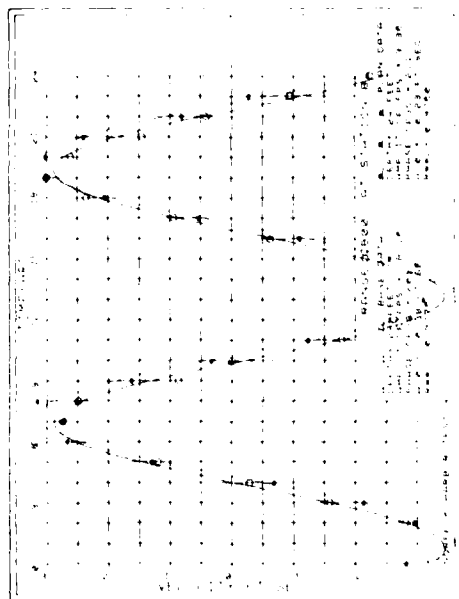
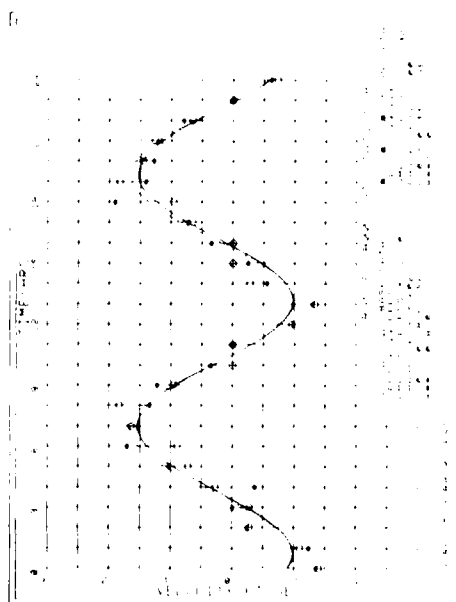
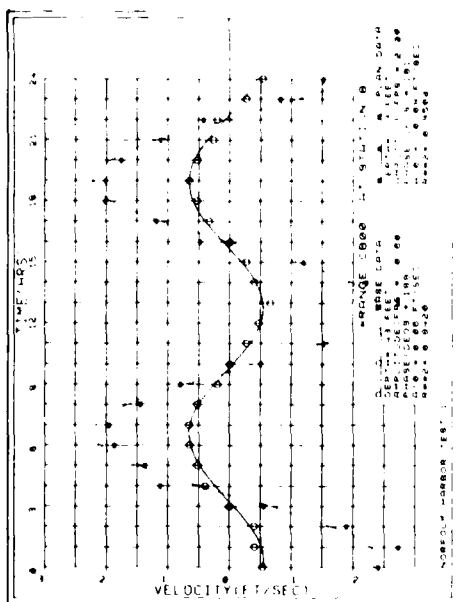
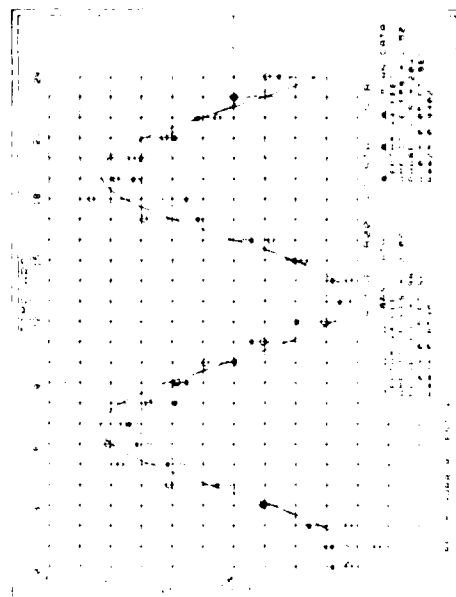
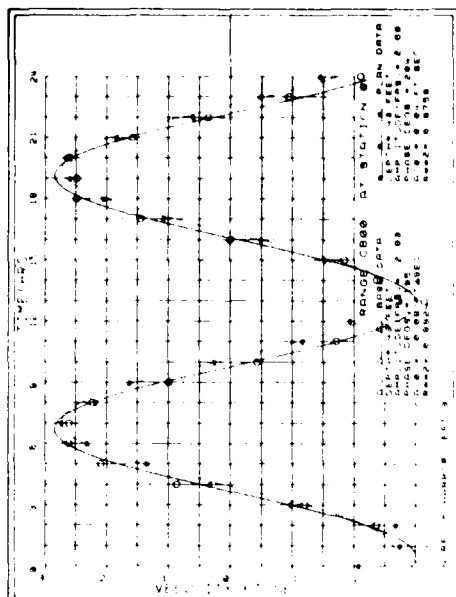


PLATE 32



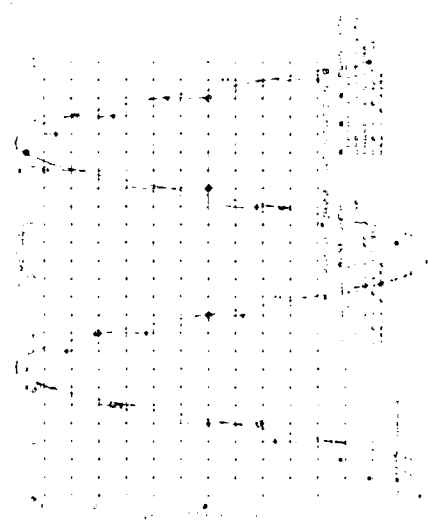
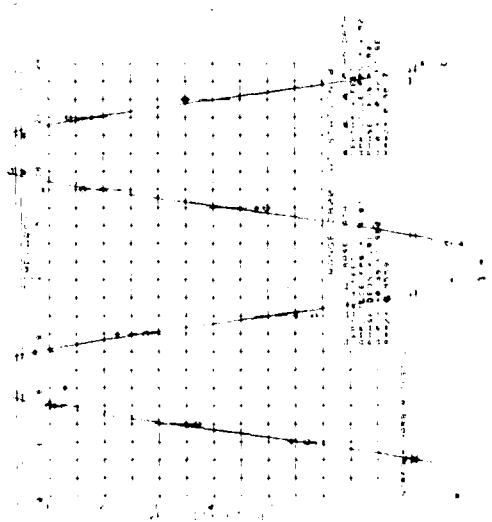
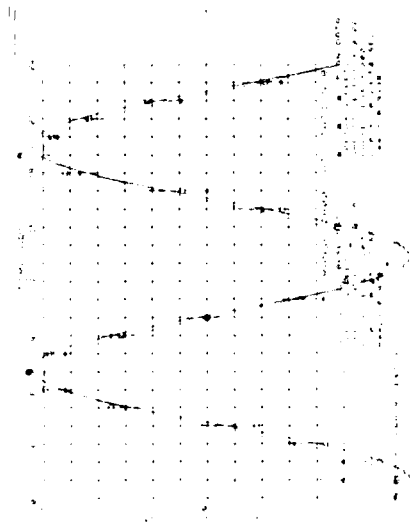
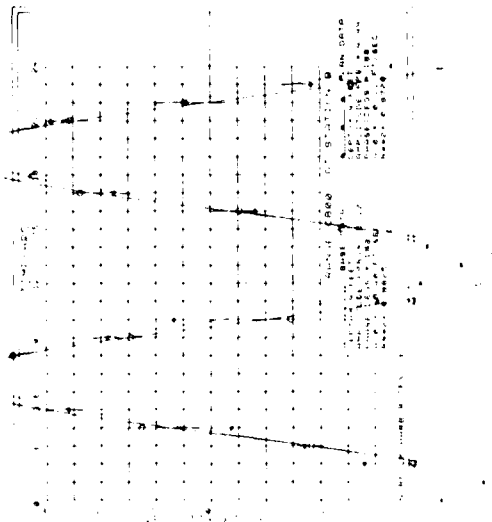


PLATE 34

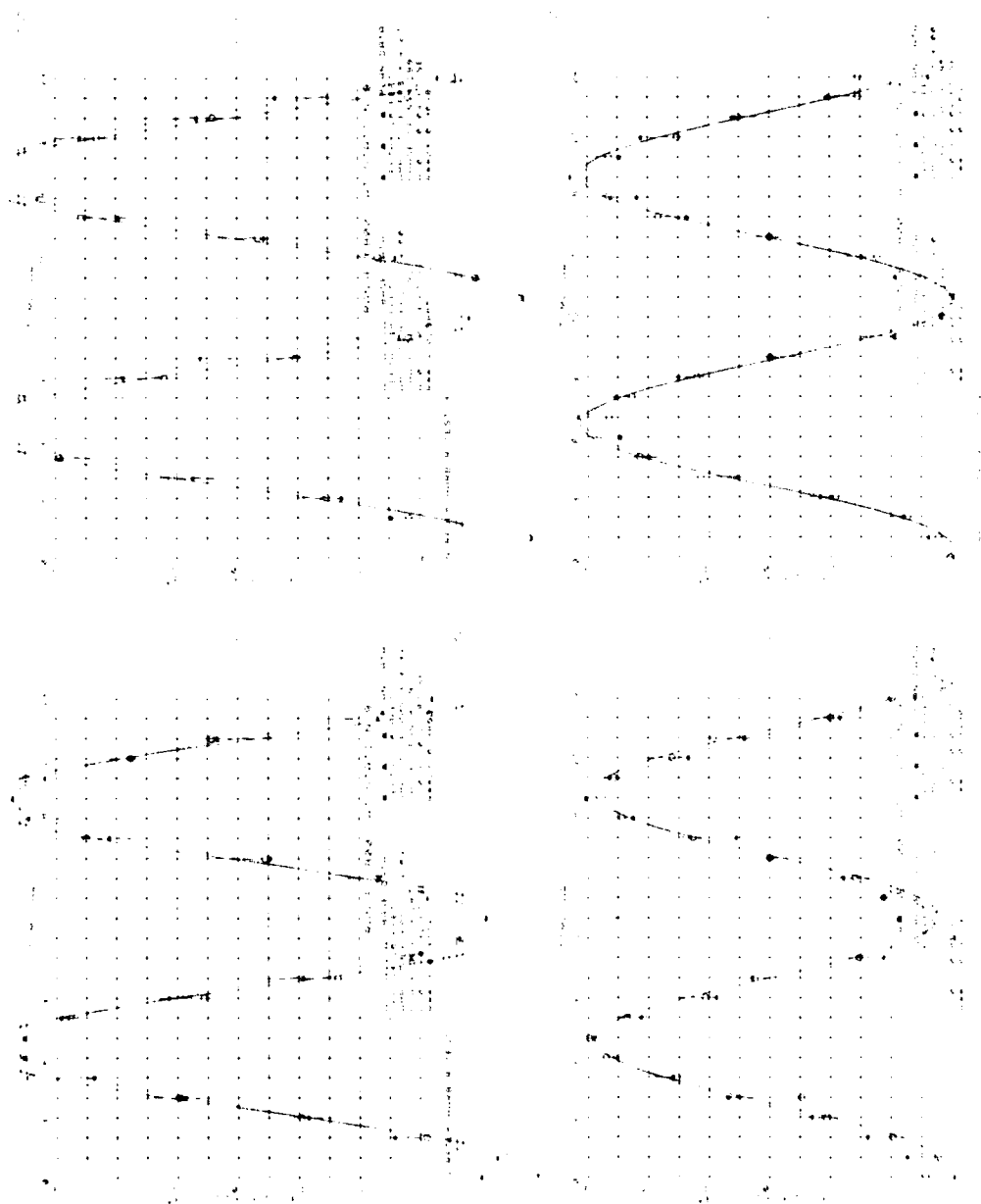


PLATE 35

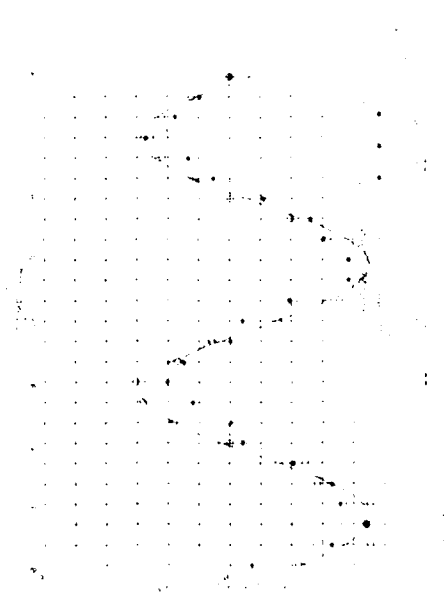
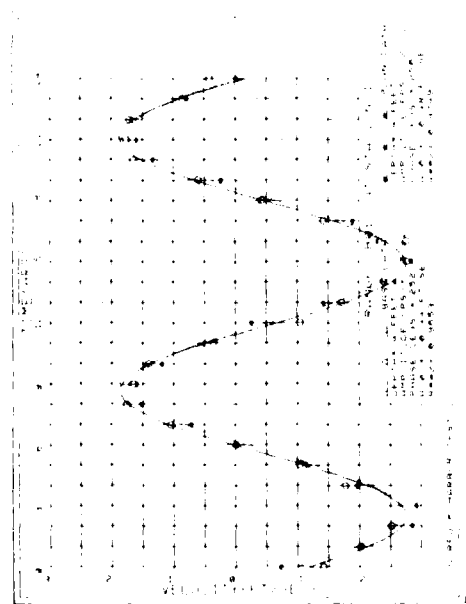
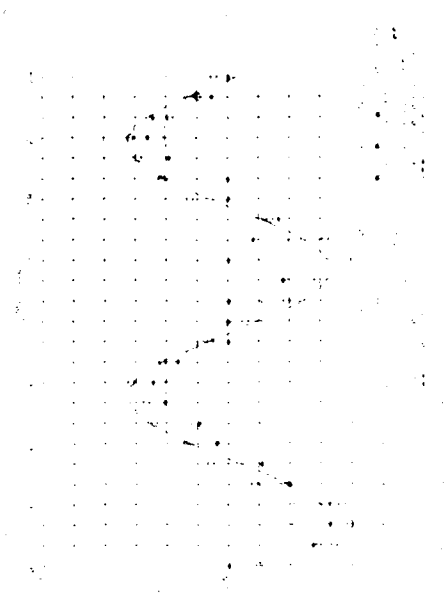
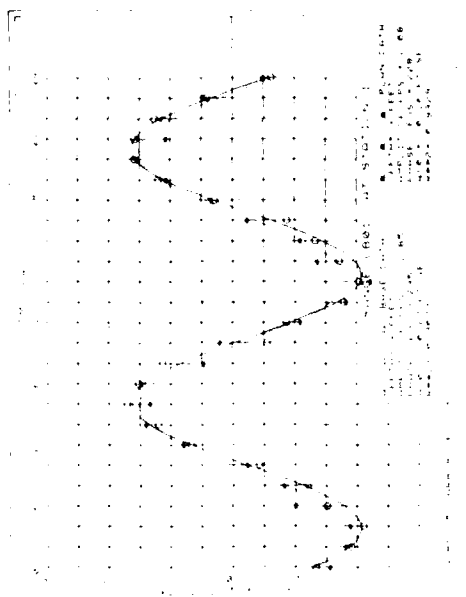


PLATE 36

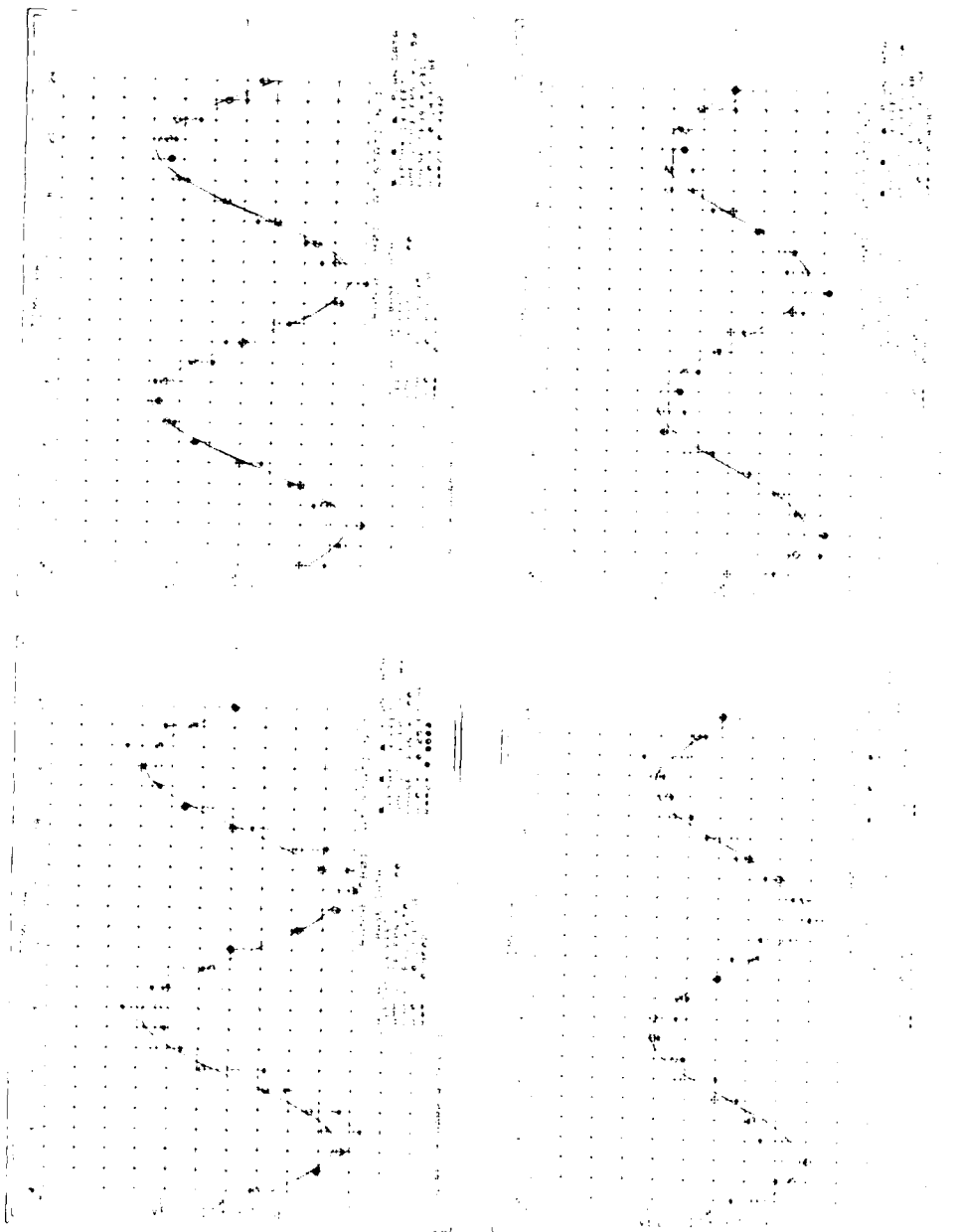


PLATE 37

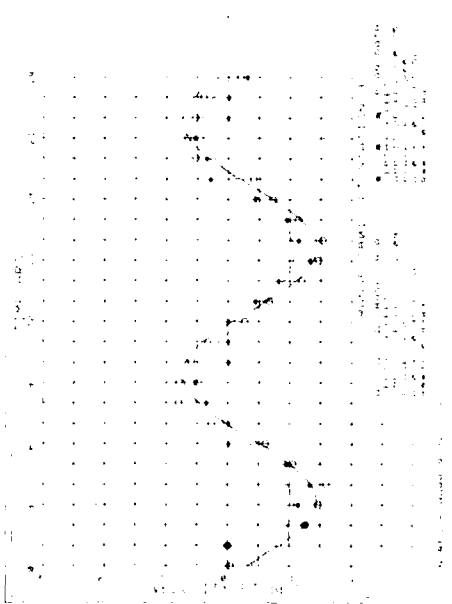
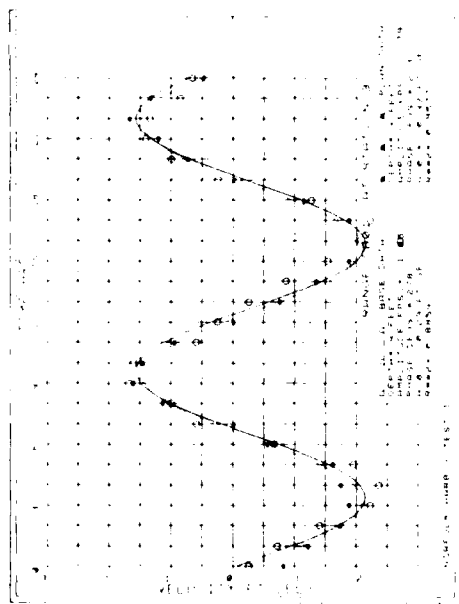
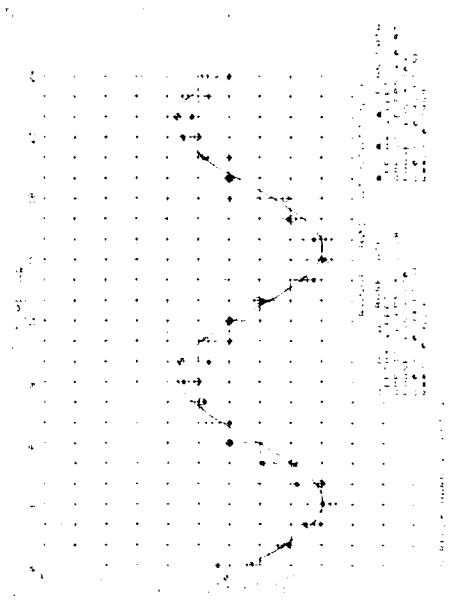
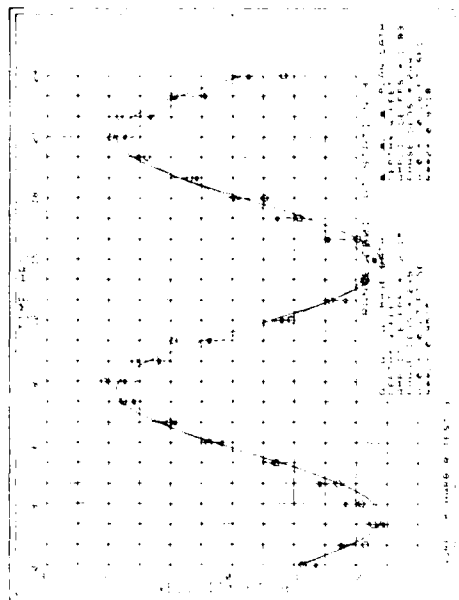
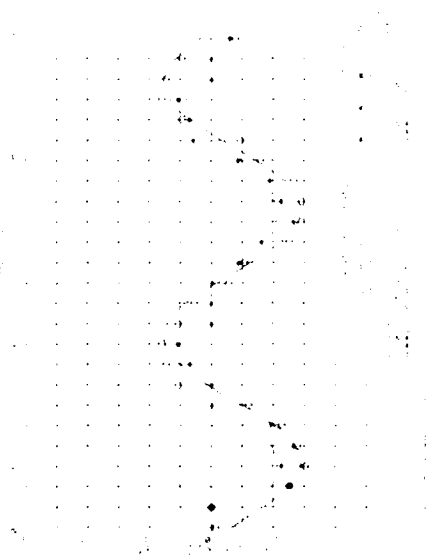
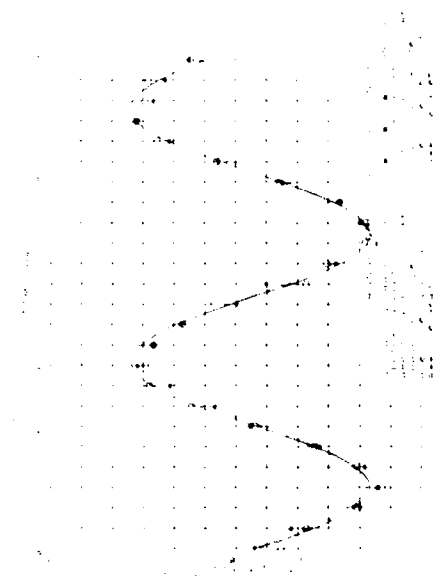
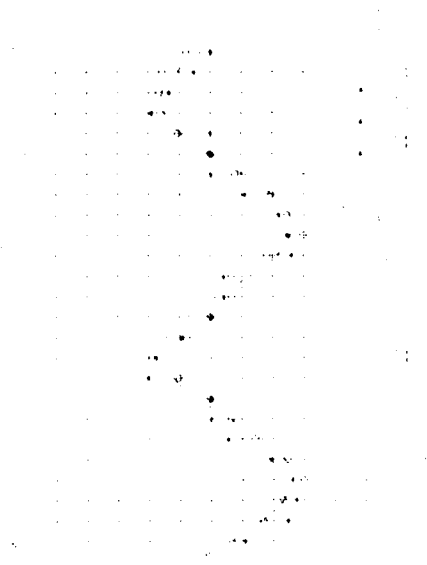


PLATE 38



FLATE 39

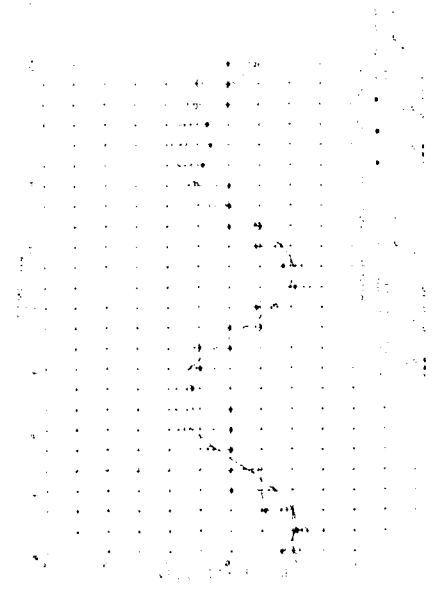
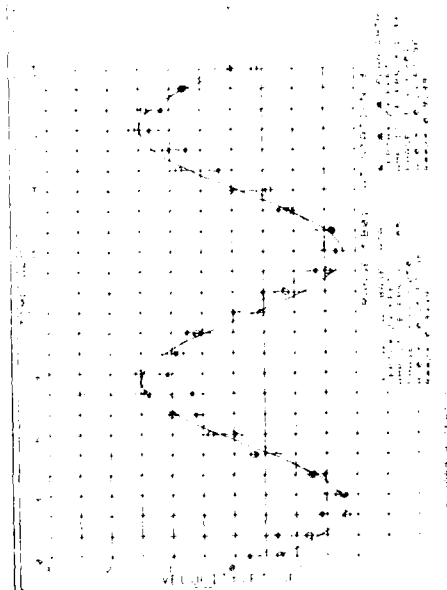
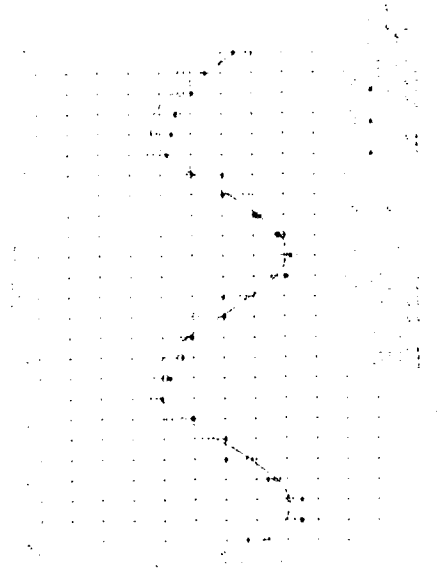
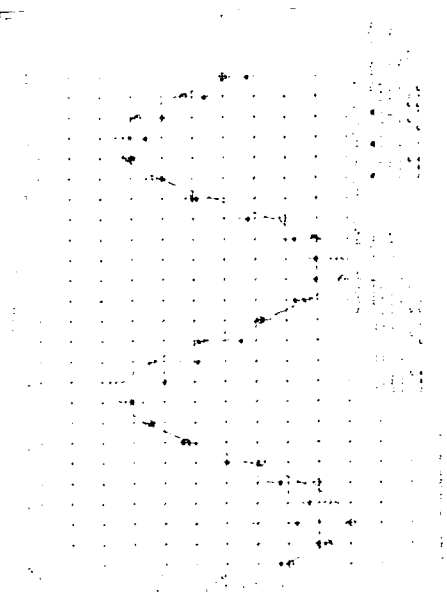


PLATE 40

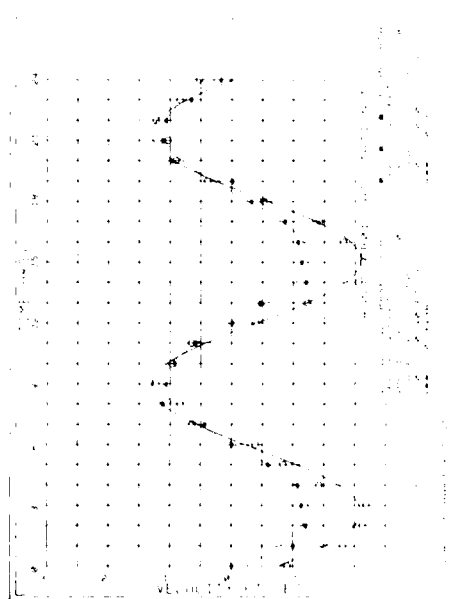
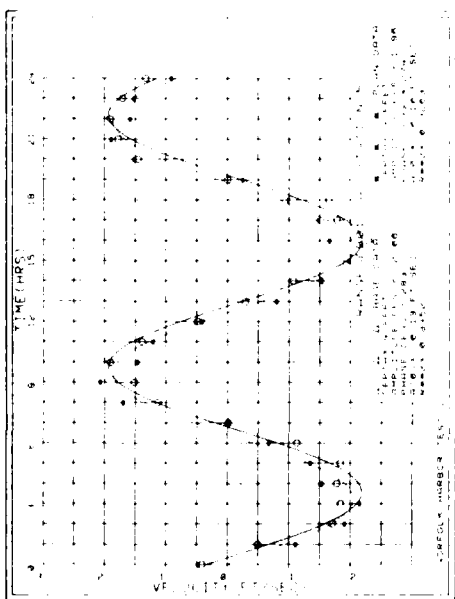
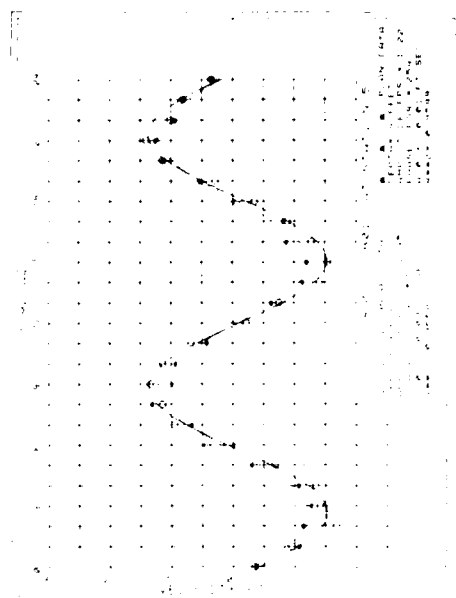
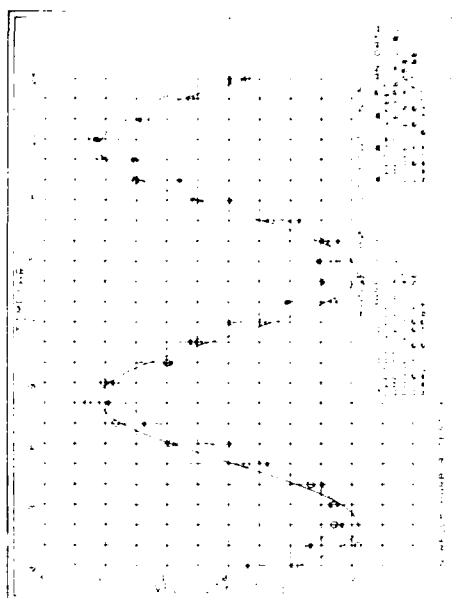
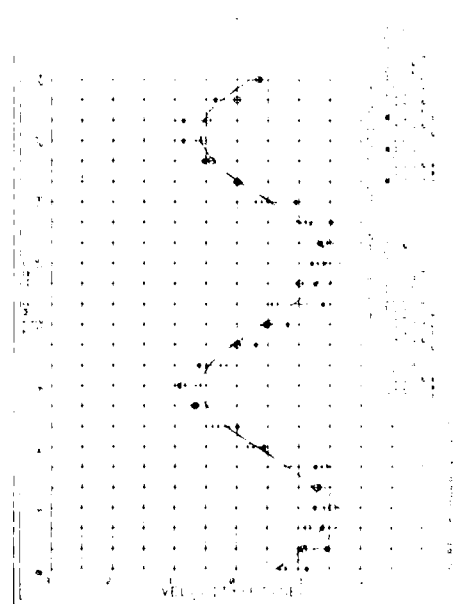
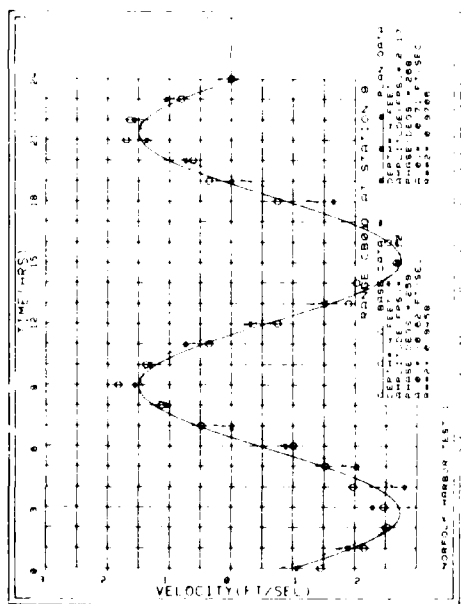
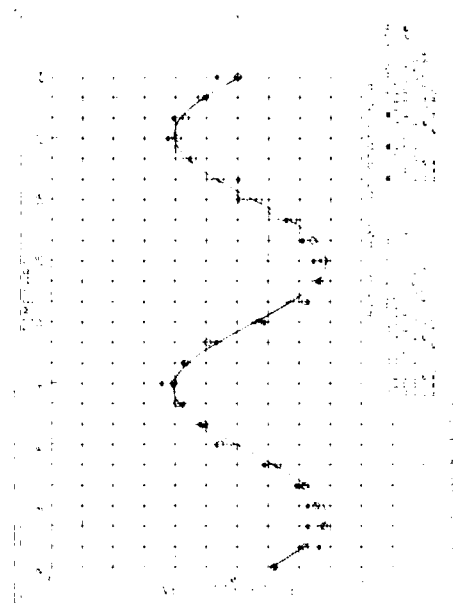
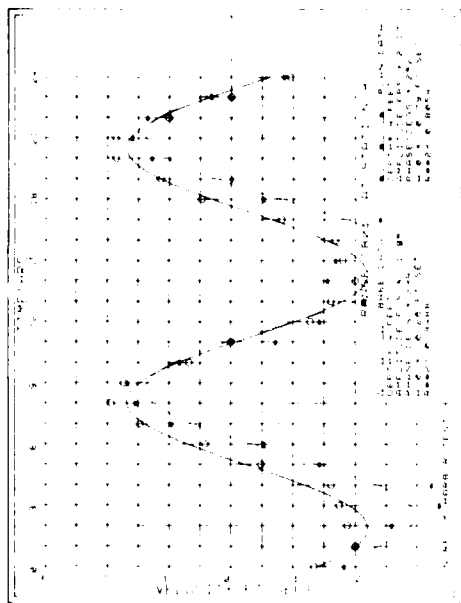


PLATE 41



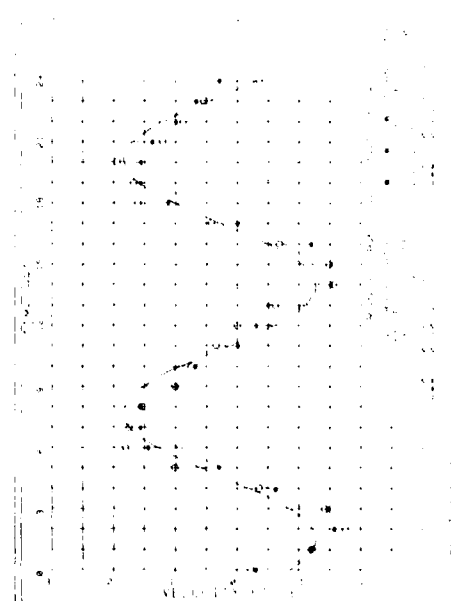
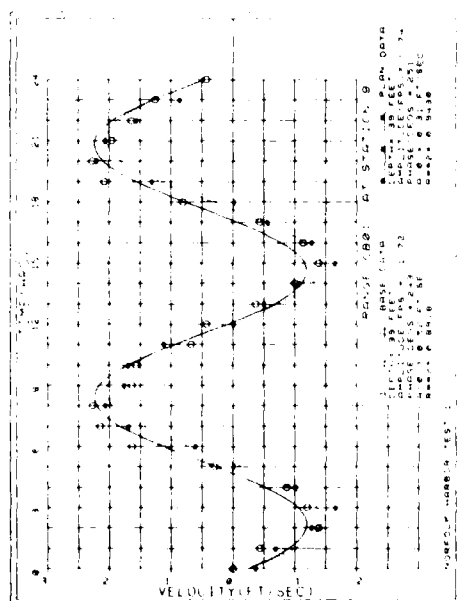
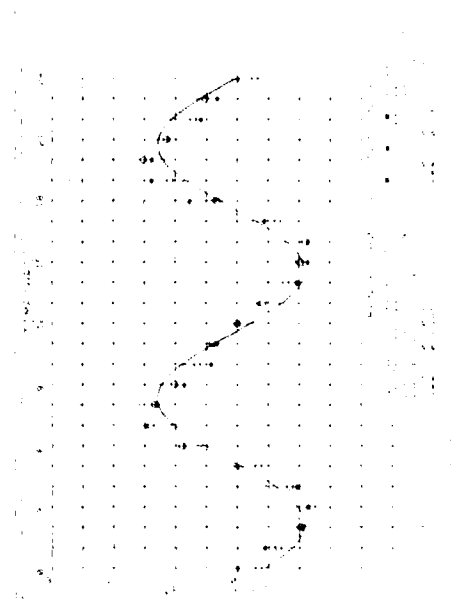
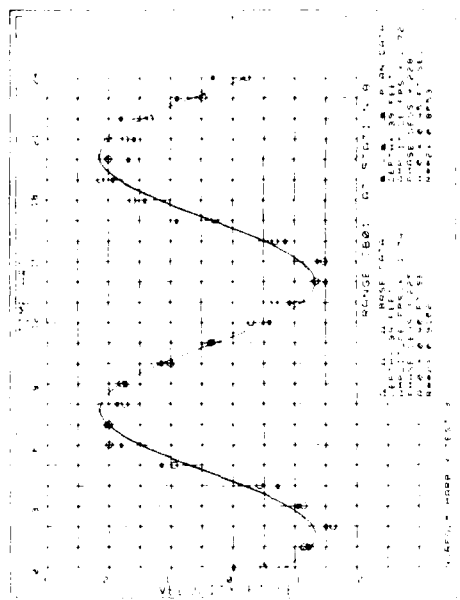
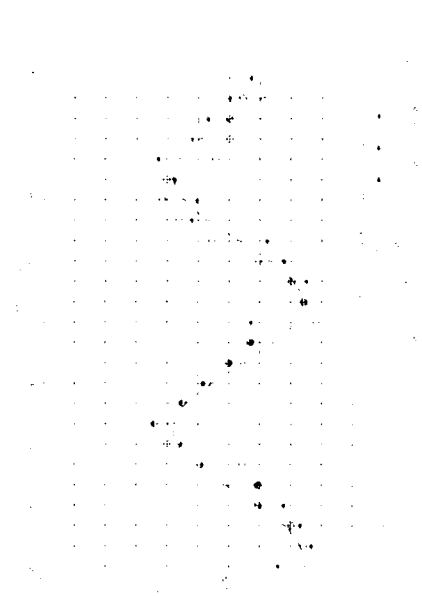
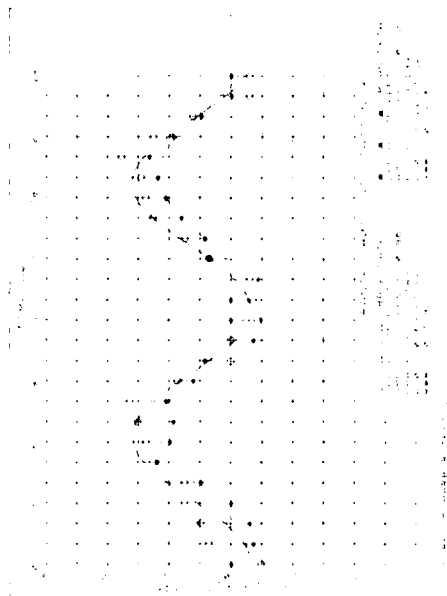
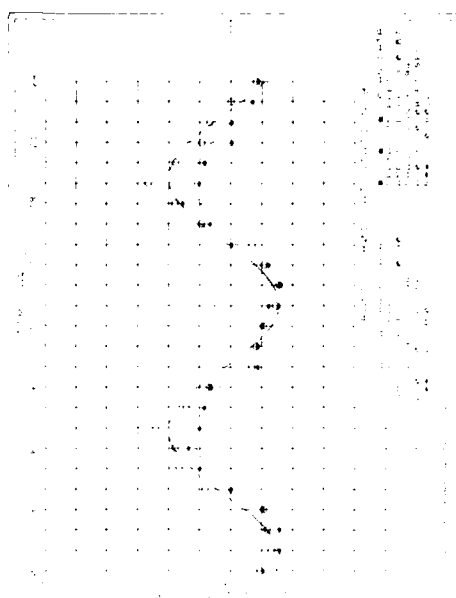
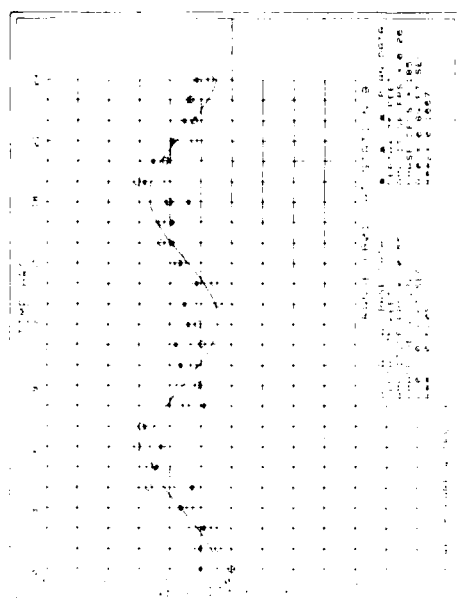


PLATE 48



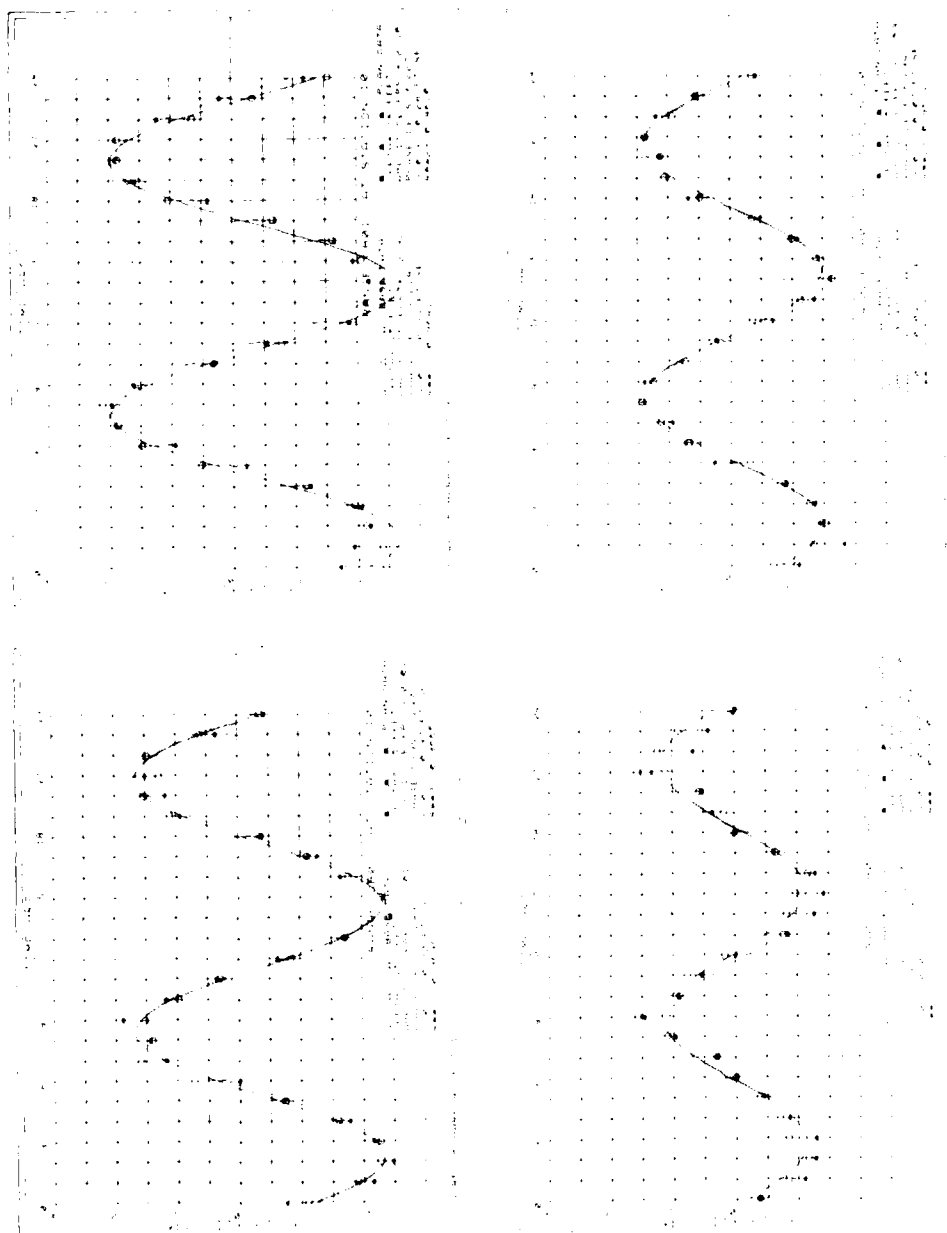


PLATE 50

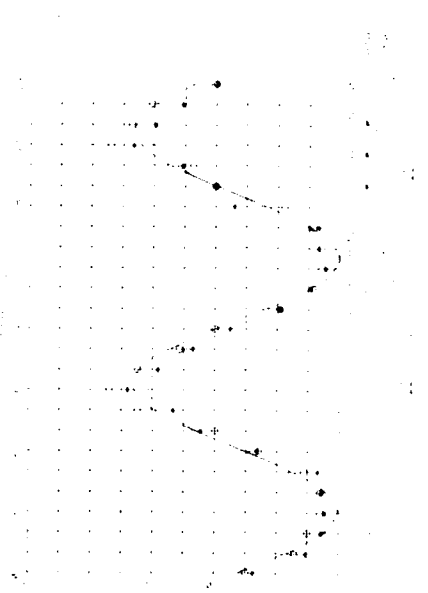
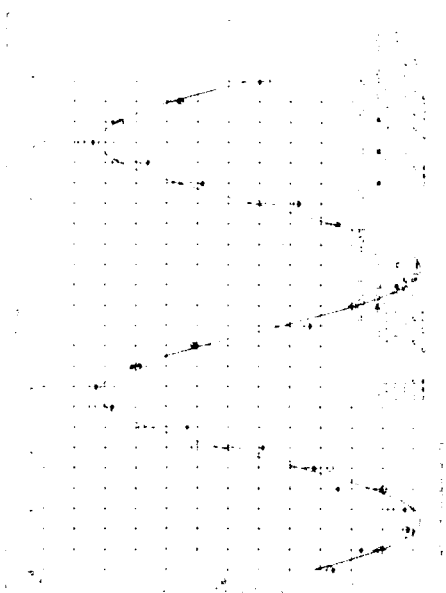
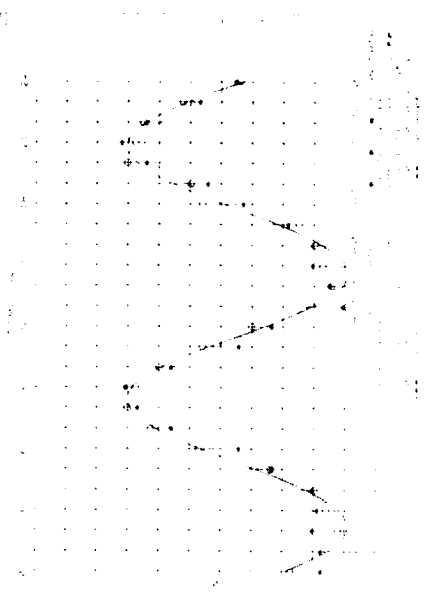


PLATE 31

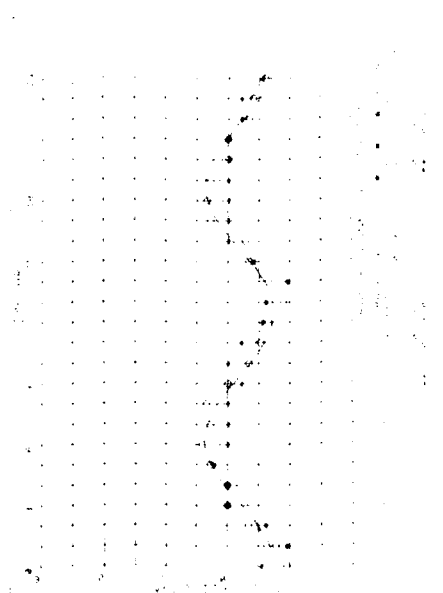
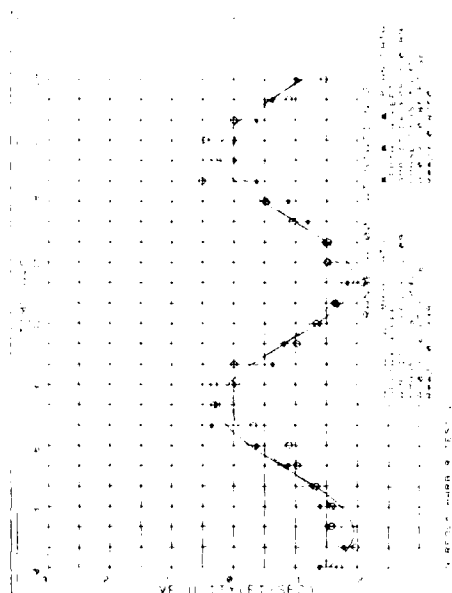
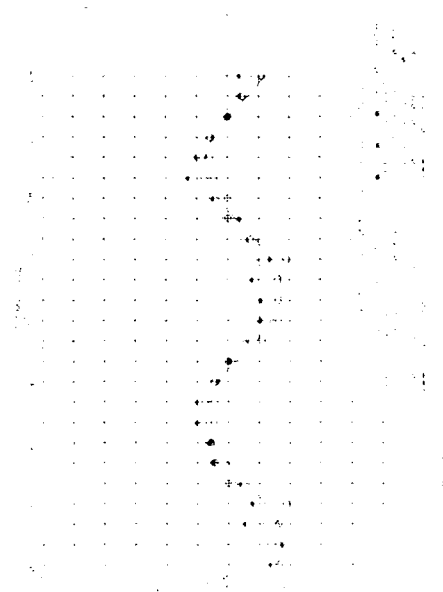
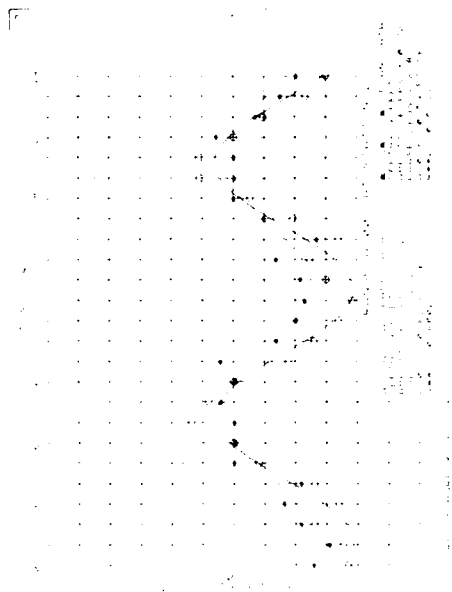


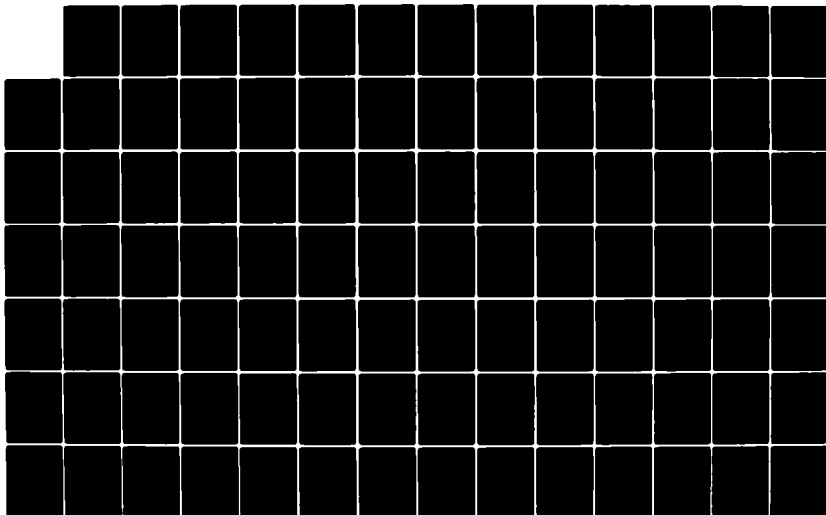
PLATE 52

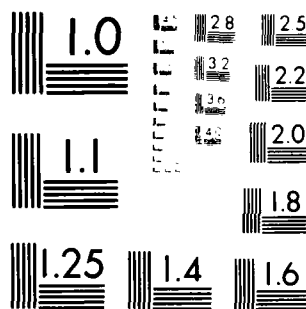
AD-A134 563 . NORFOLK HARBOR AND CHANNELS DEEPENING STUDY REPORT 1
PHYSICAL MODEL RESUL..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS HYDRA..

3/4

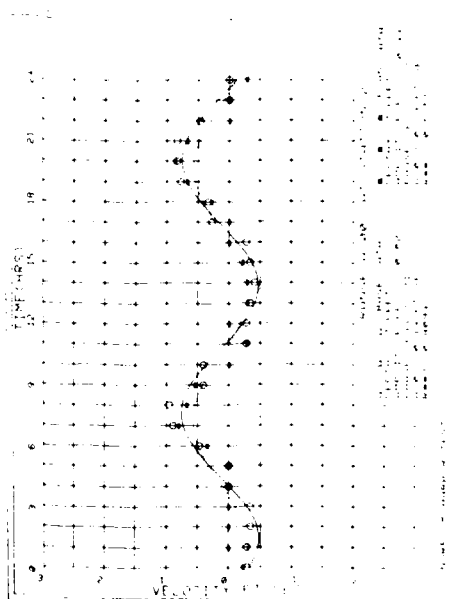
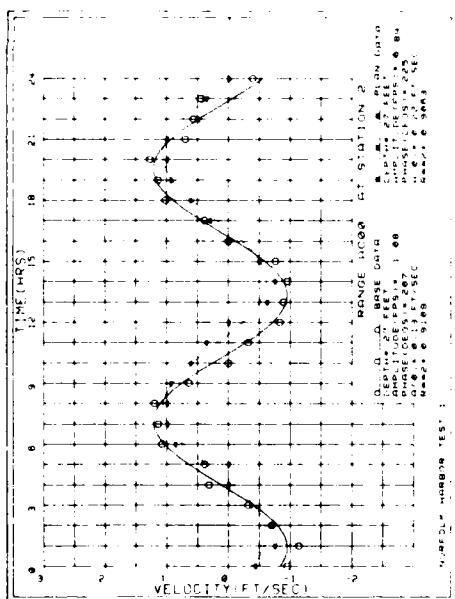
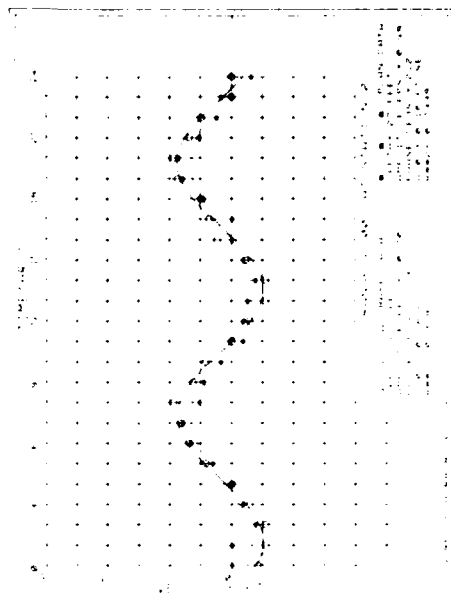
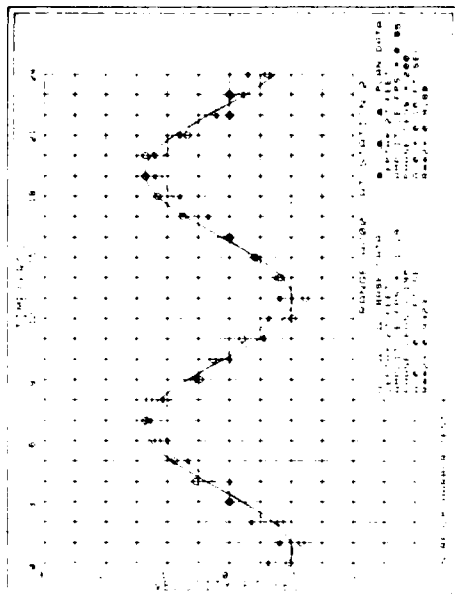
UNCLASSIFIED D R RICHARDS ET AL. JUN 83 WES/TR/HL-83-13 F/G 13/2

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



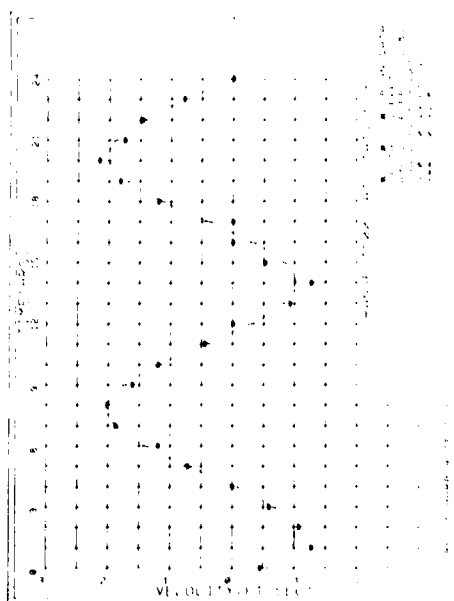
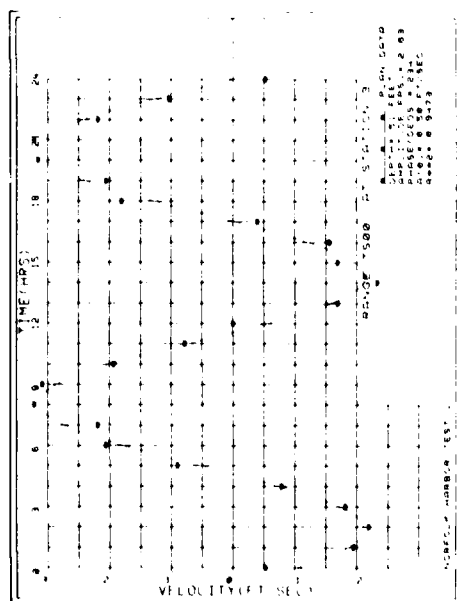
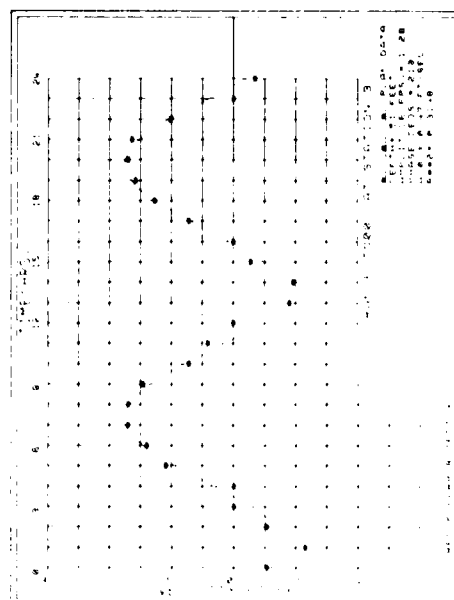
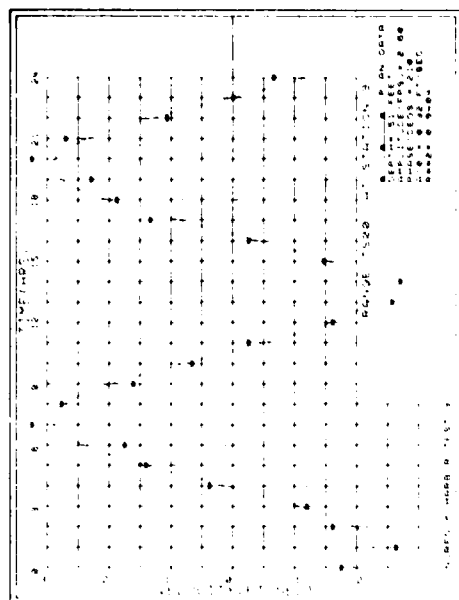


PLATE 59

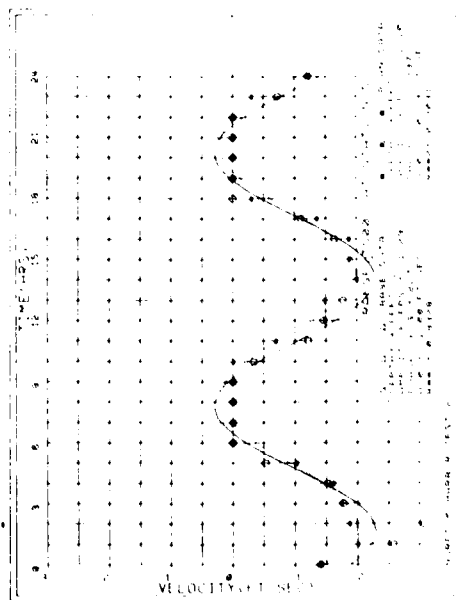
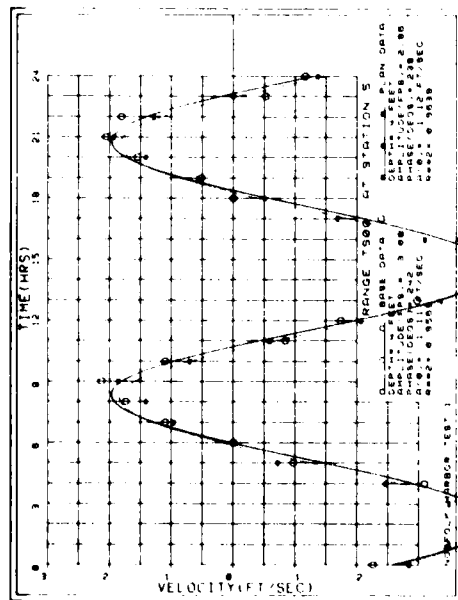
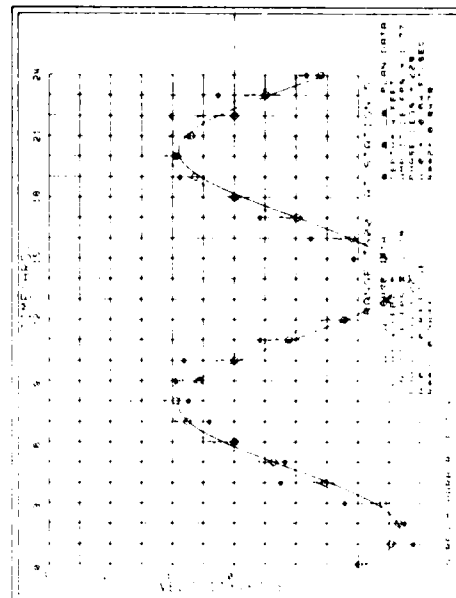
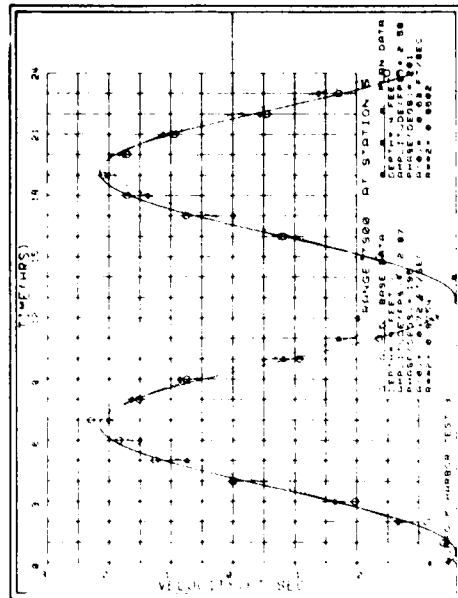


PLATE 60

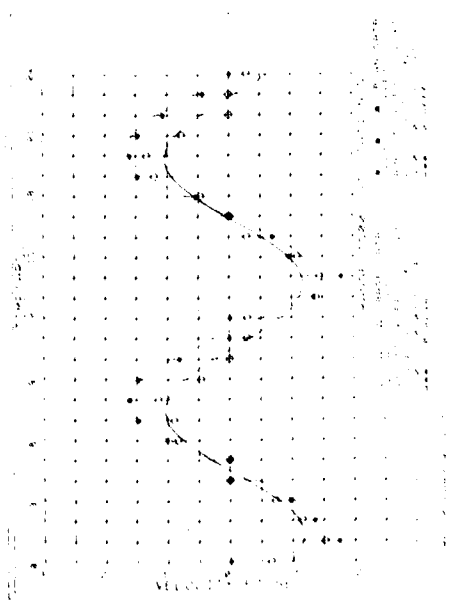
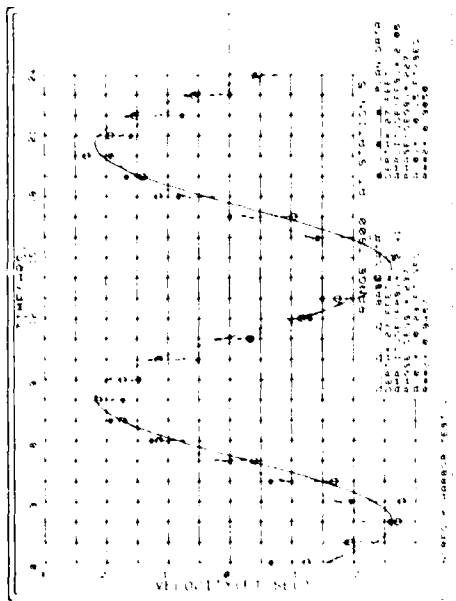
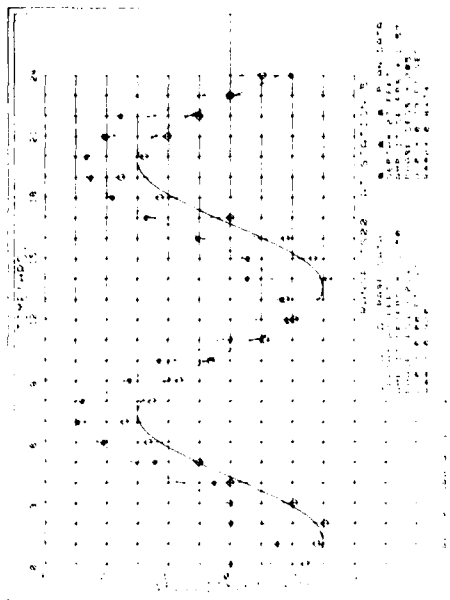
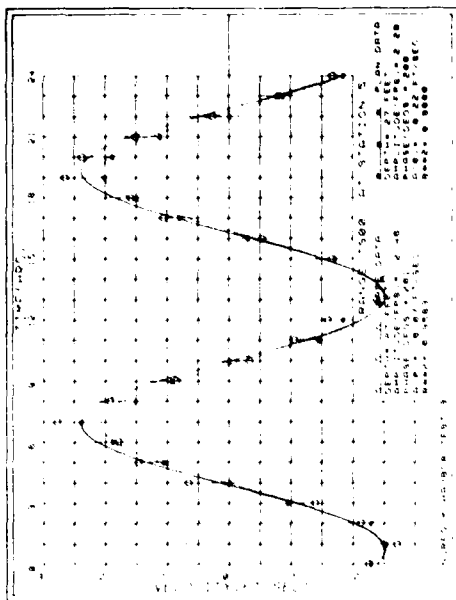
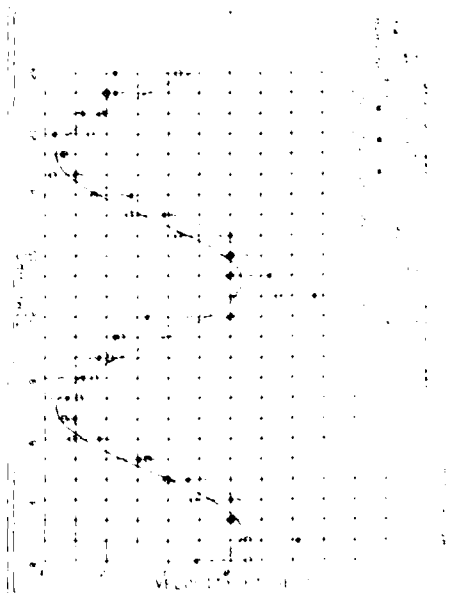
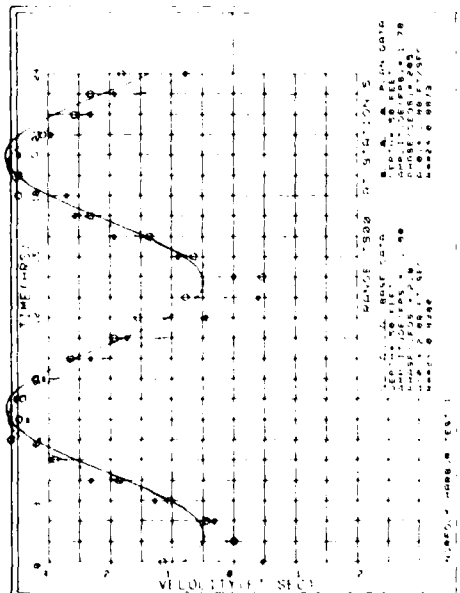
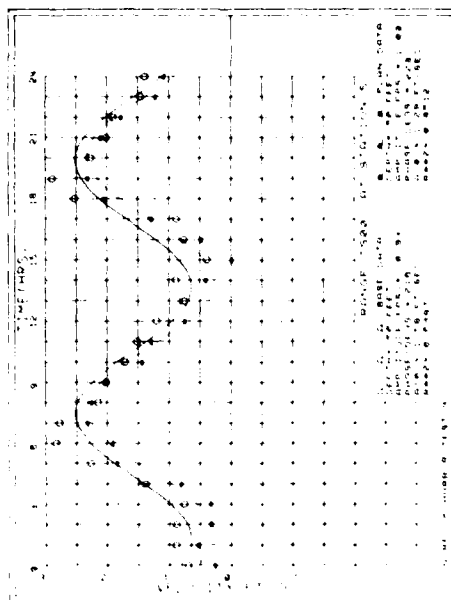
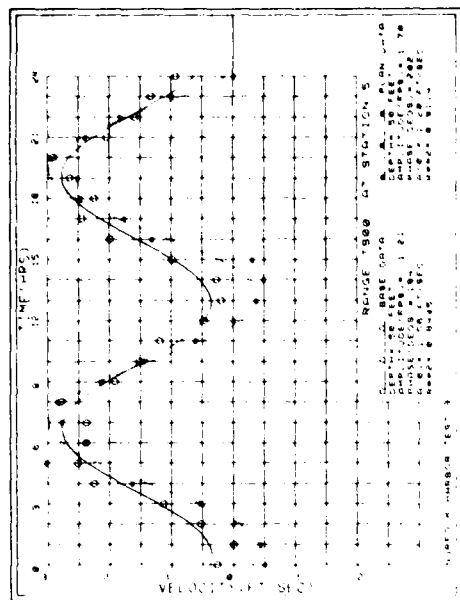


PLATE 61



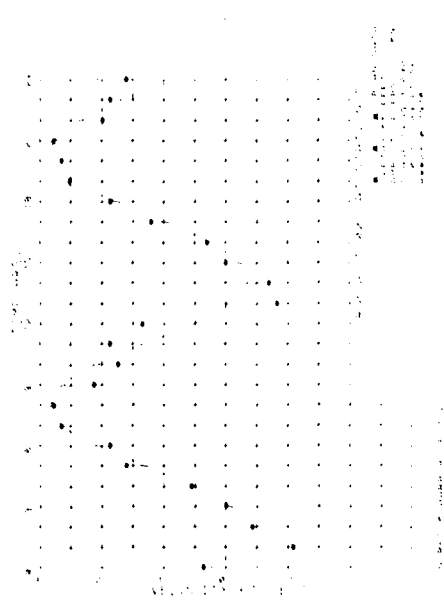
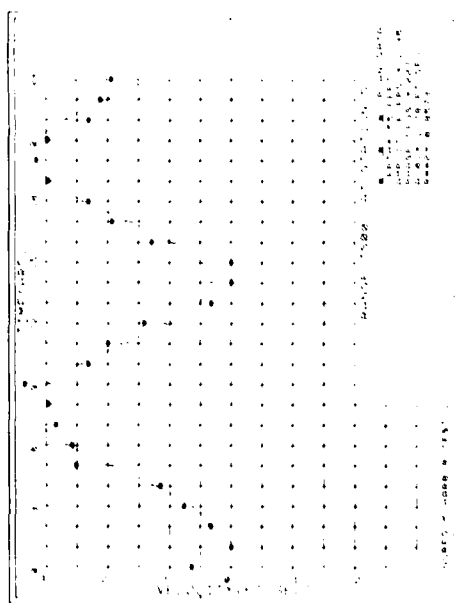
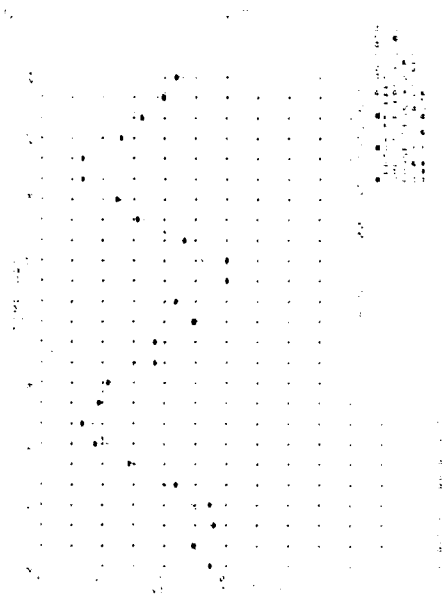
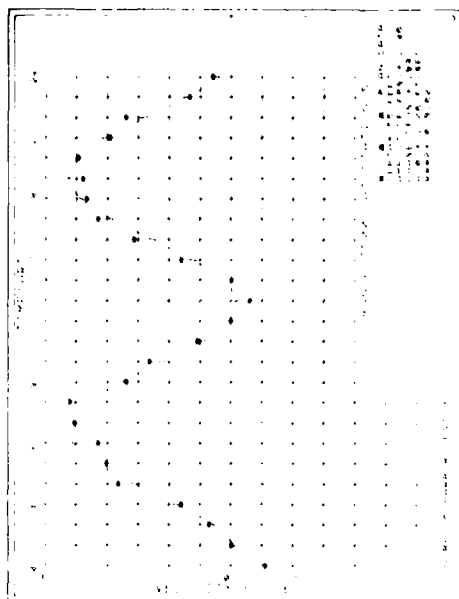


PLATE 63

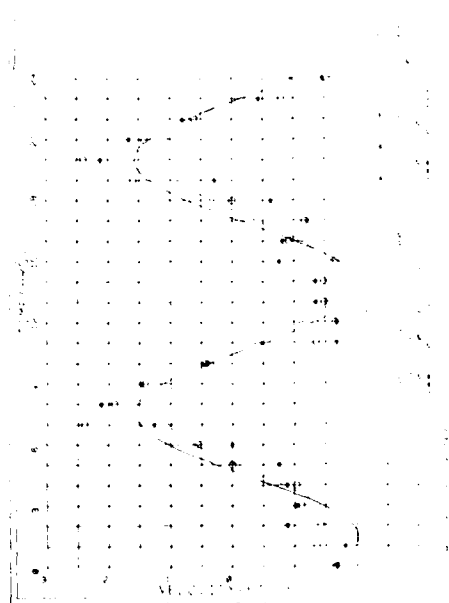
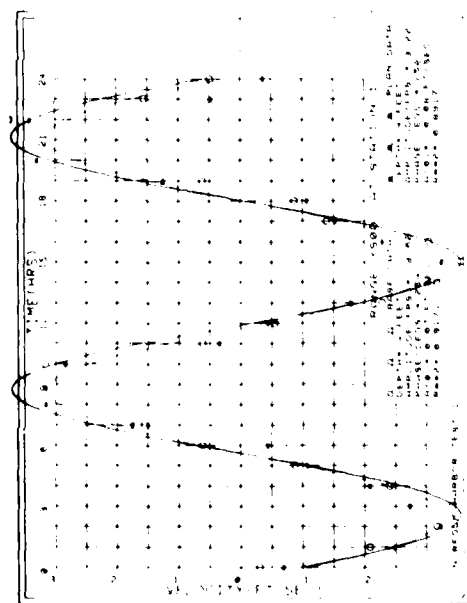
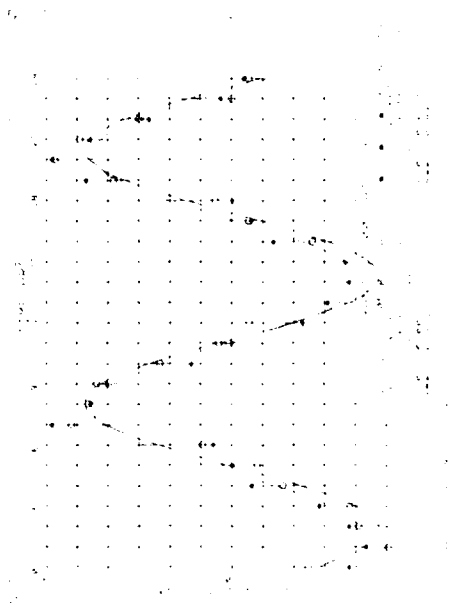
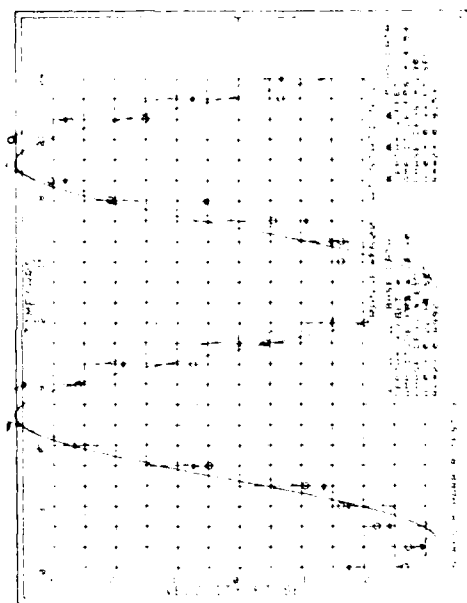


PLATE 64

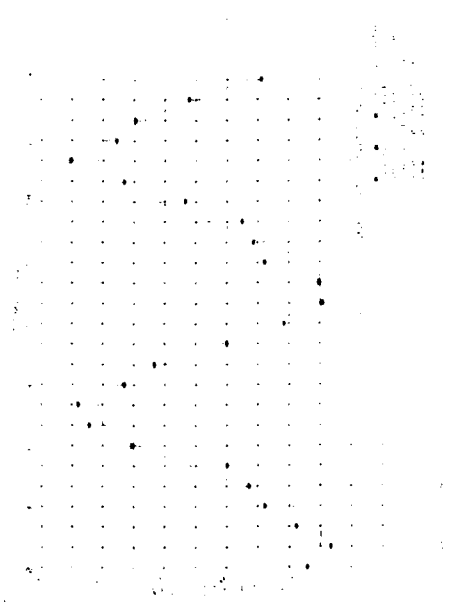
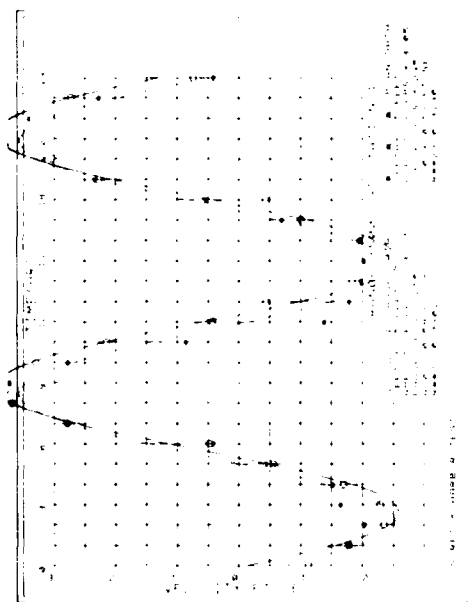
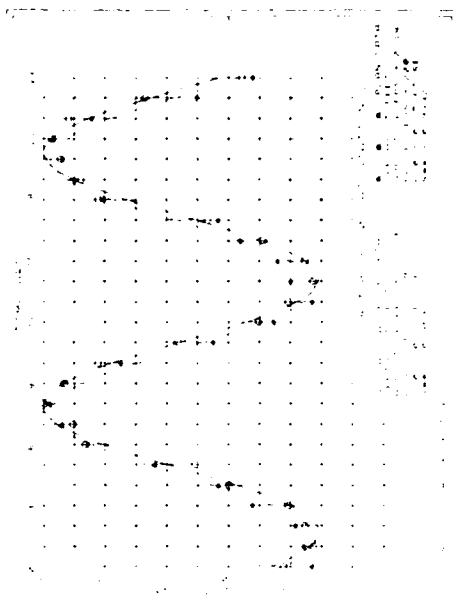
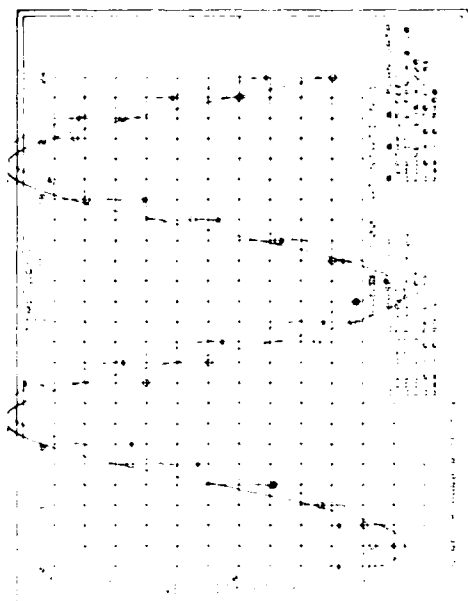


PLATE 65

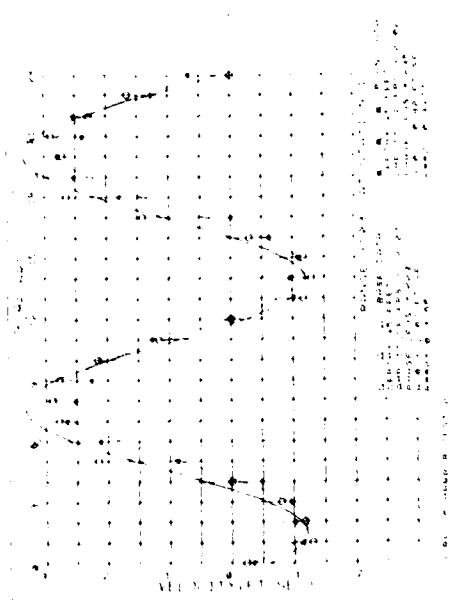
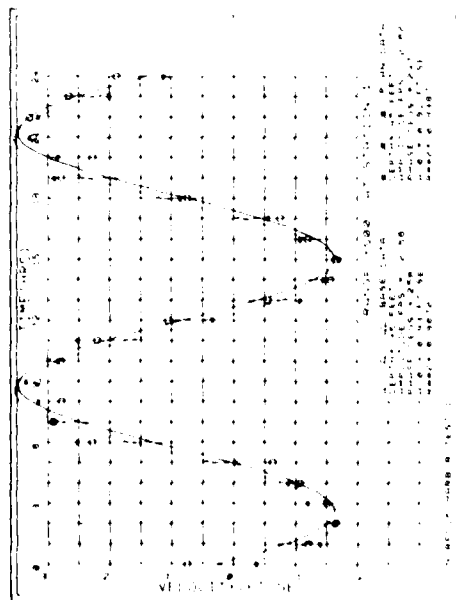
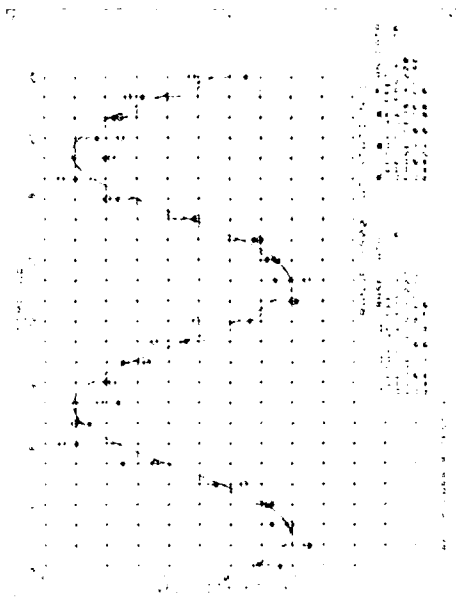
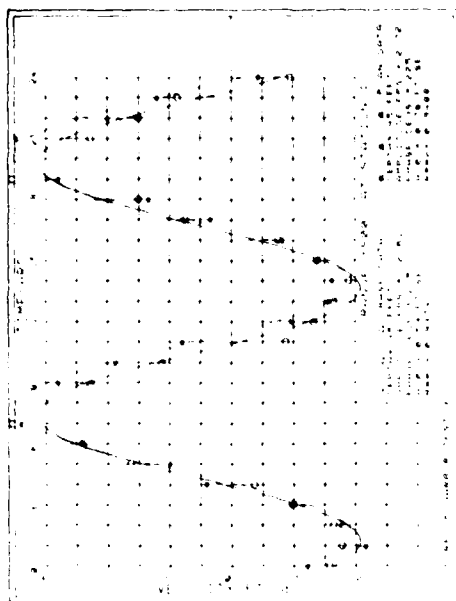


PLATE 66

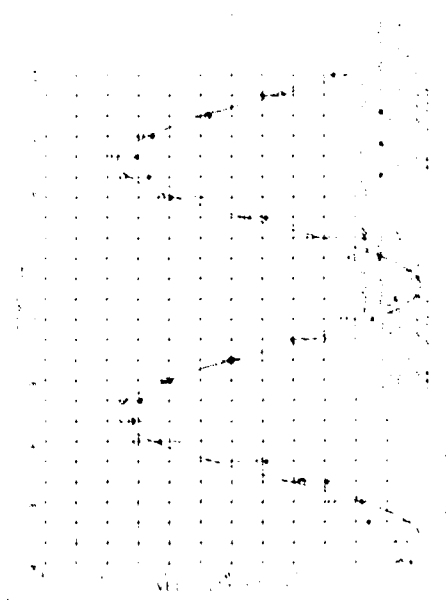
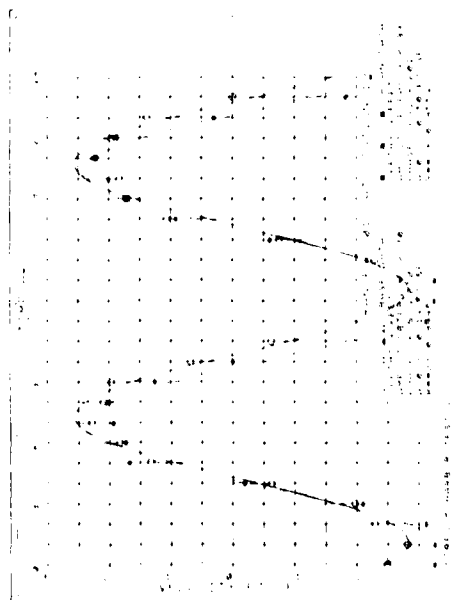
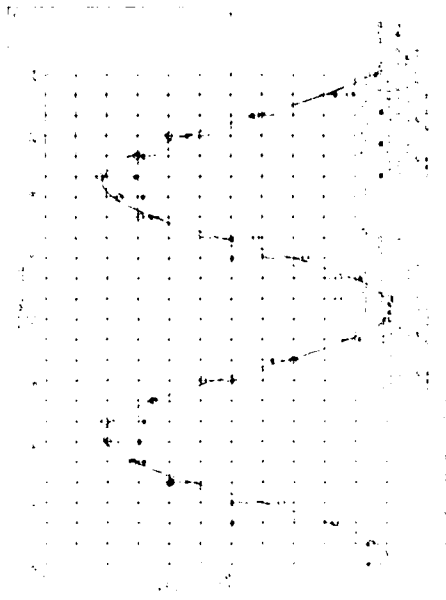
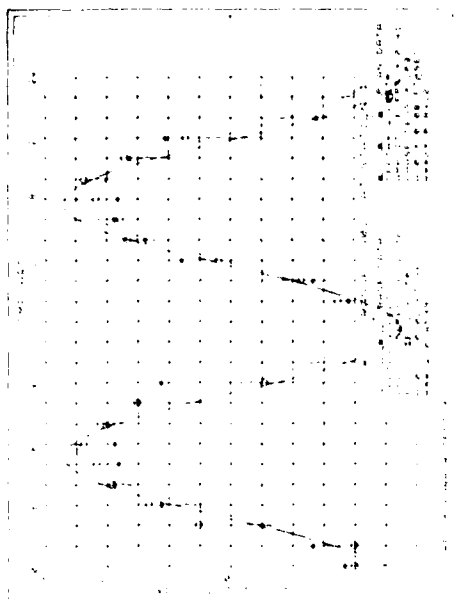


PLATE 67

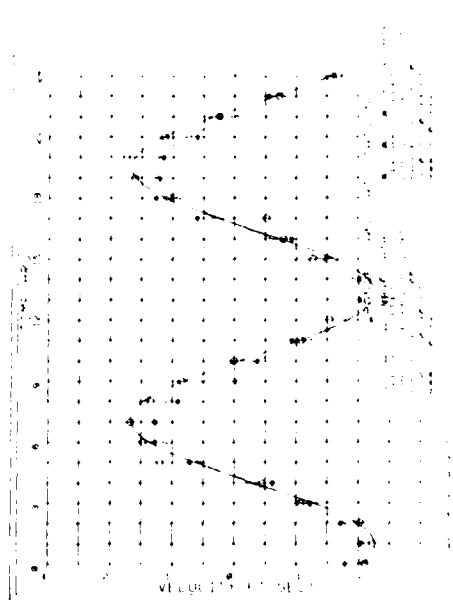
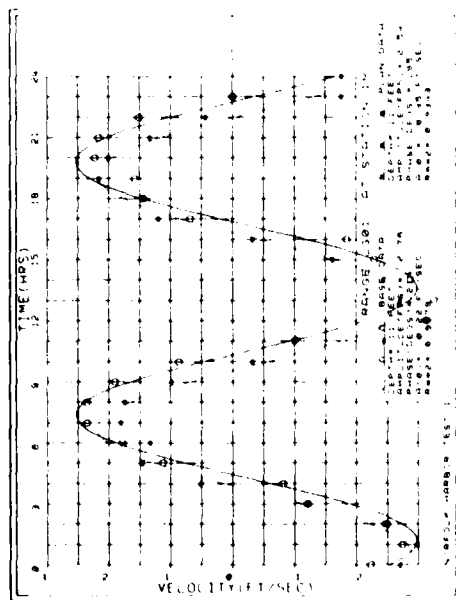
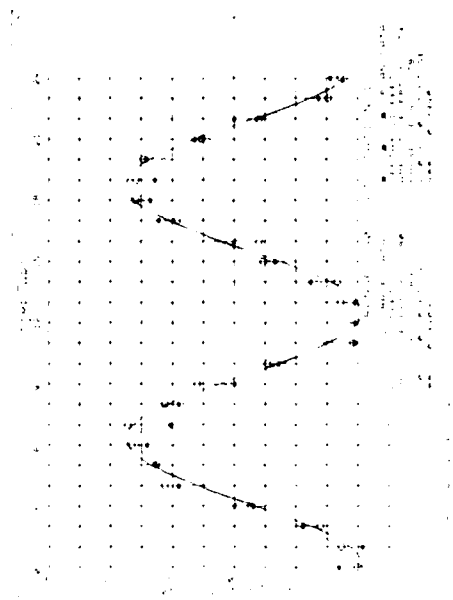
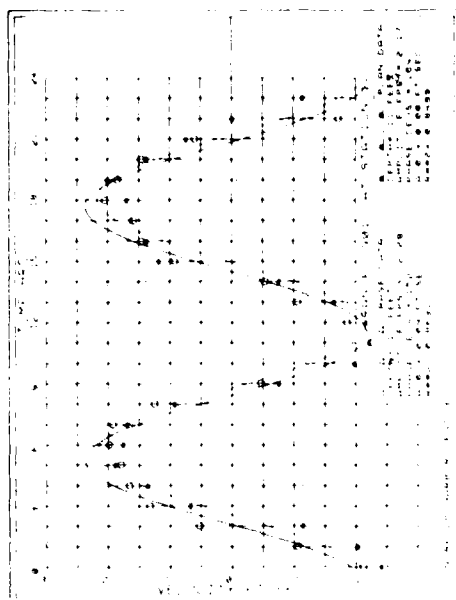


PLATE 68

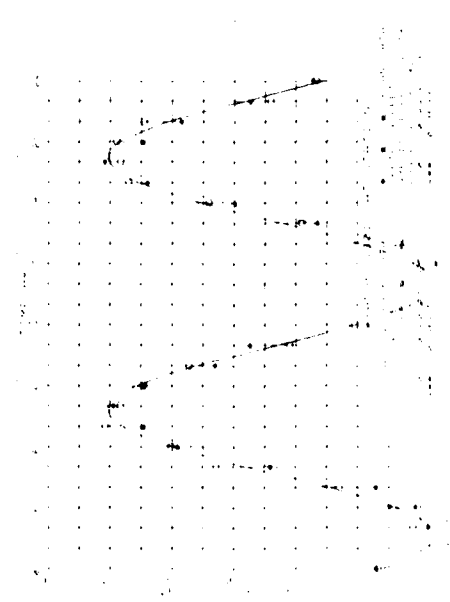
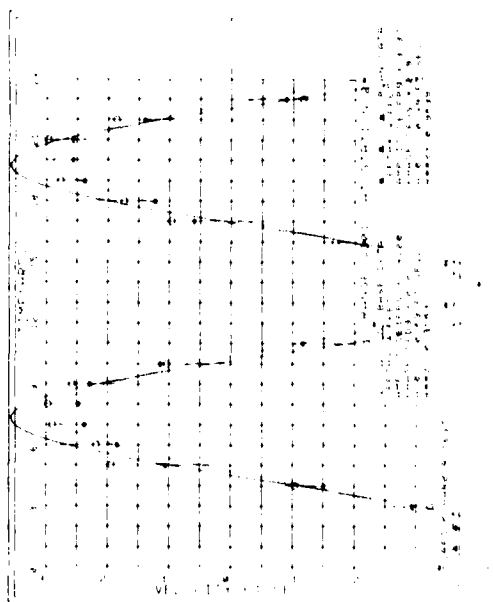
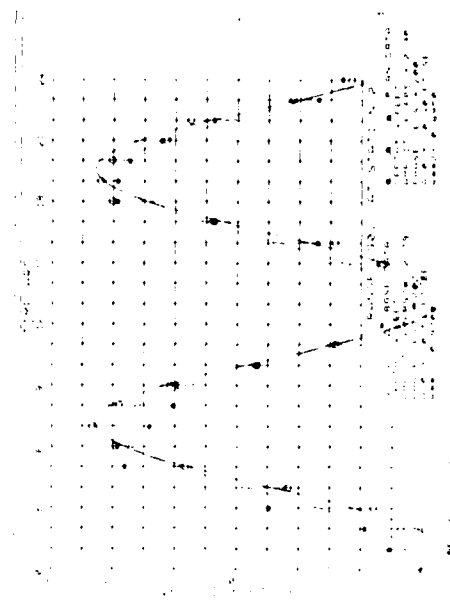
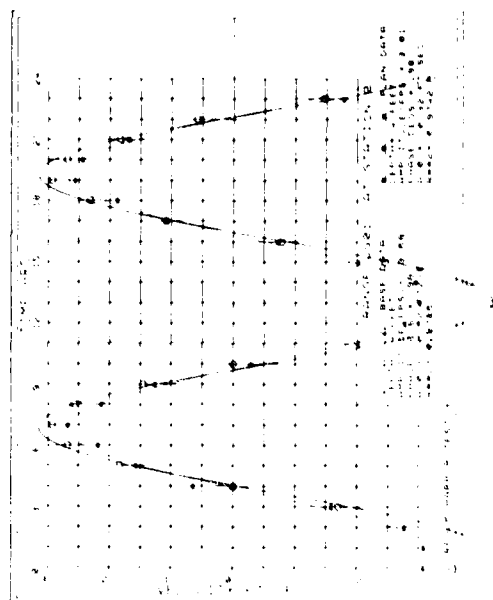
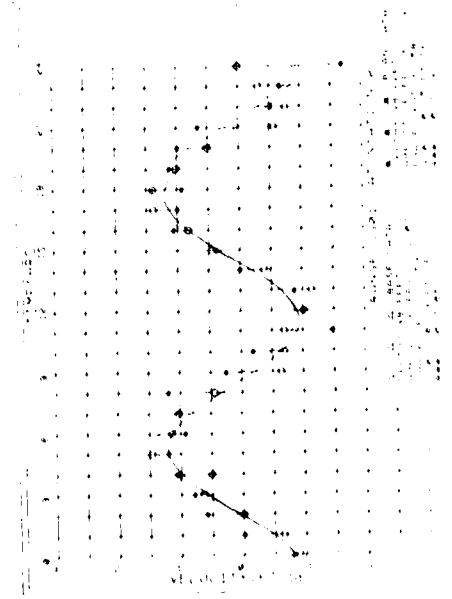
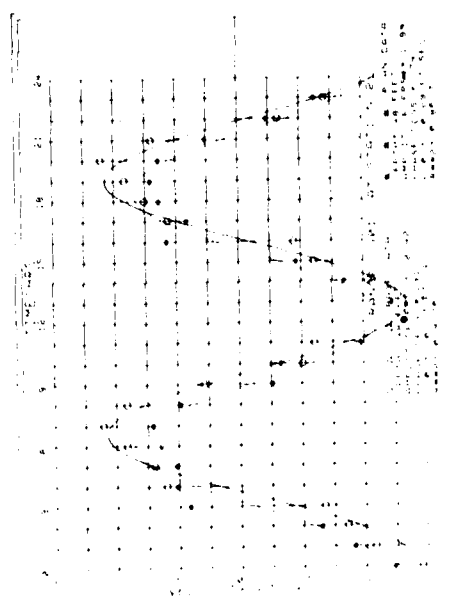
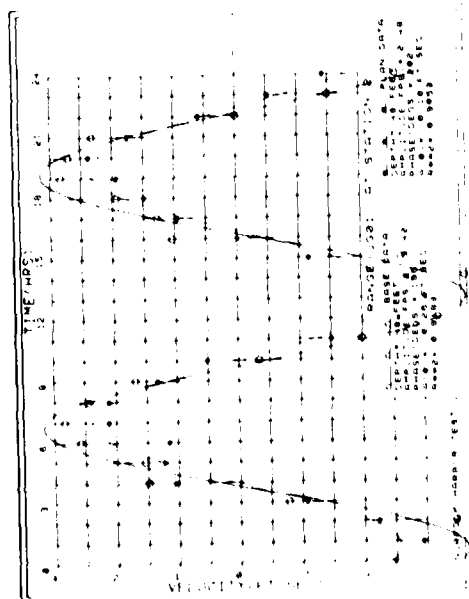
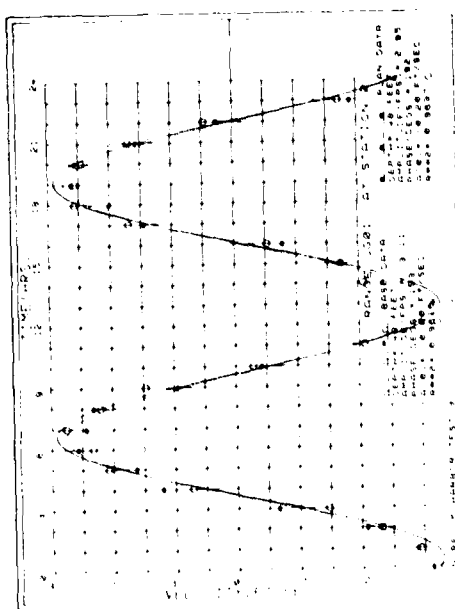


PLATE 69



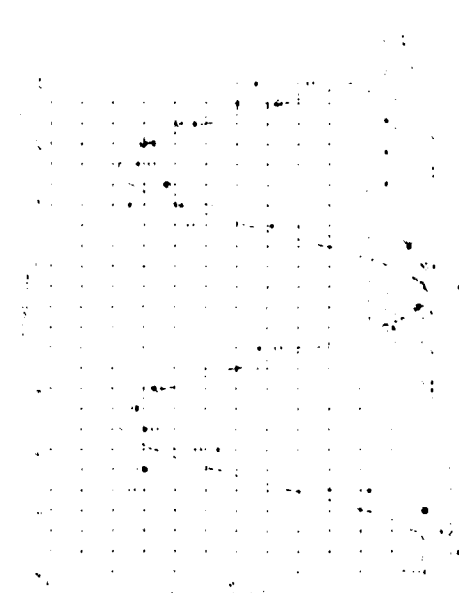
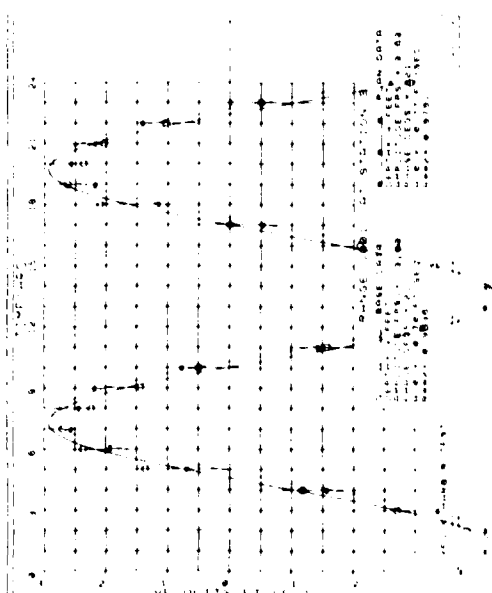
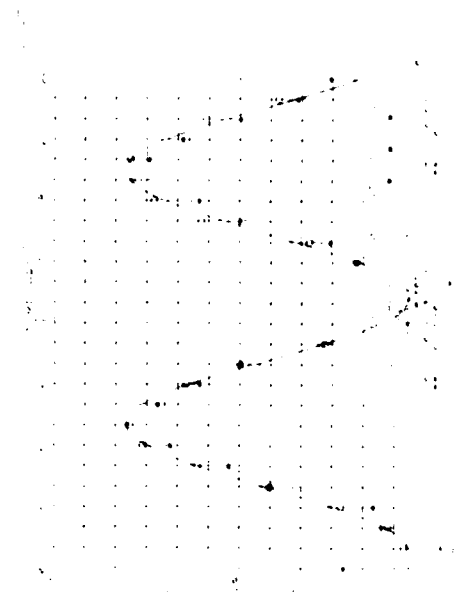
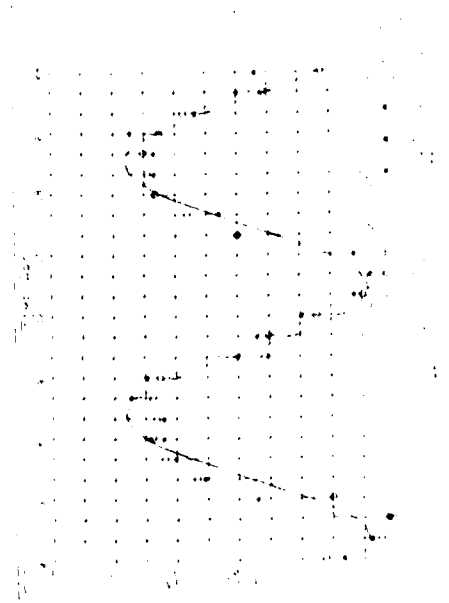
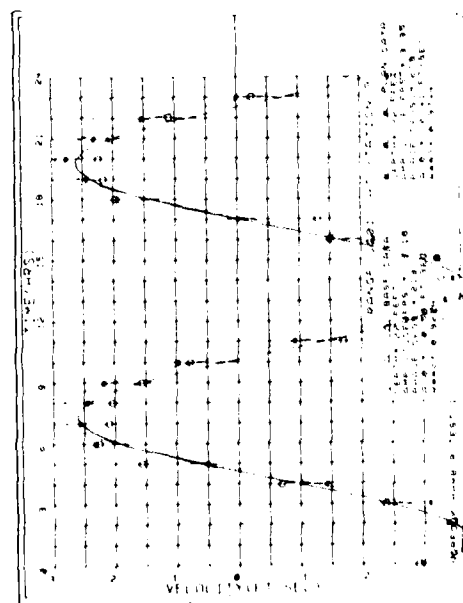
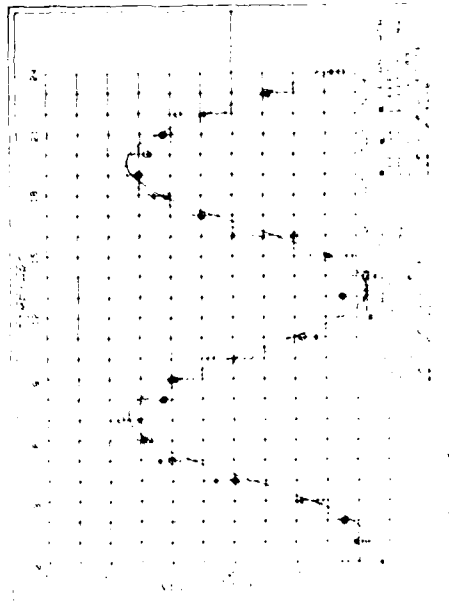
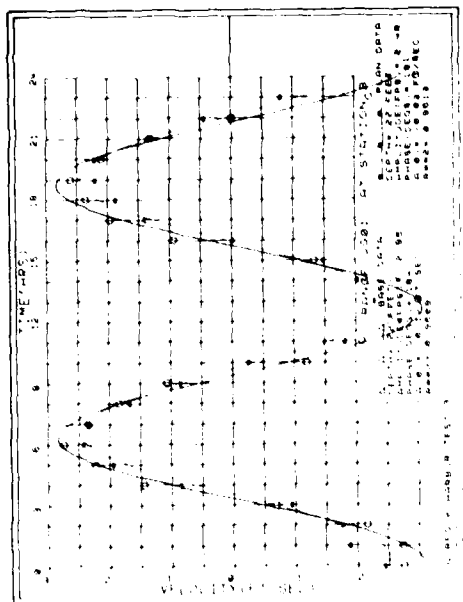


PLATE 72



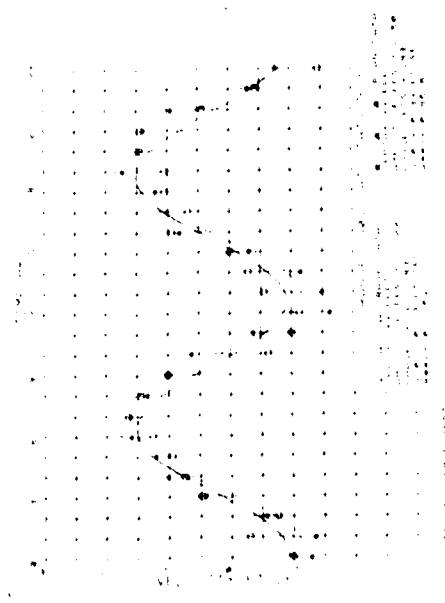
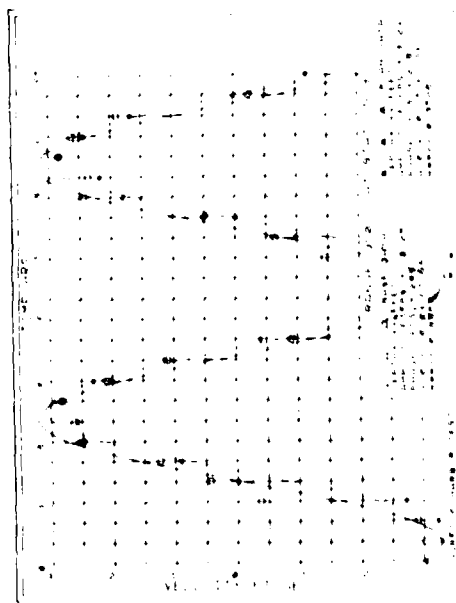
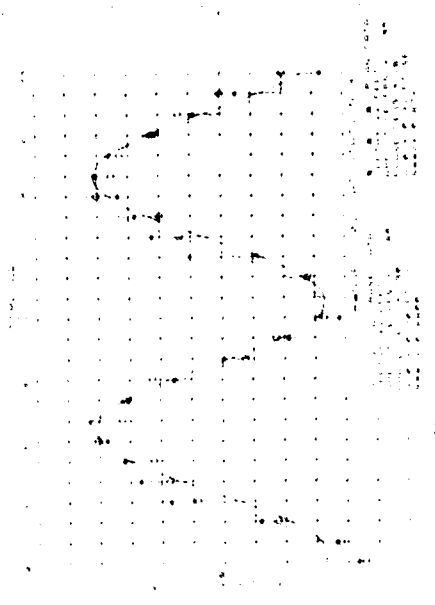
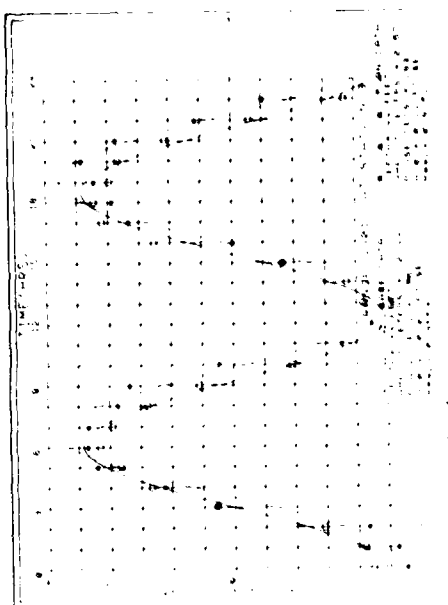
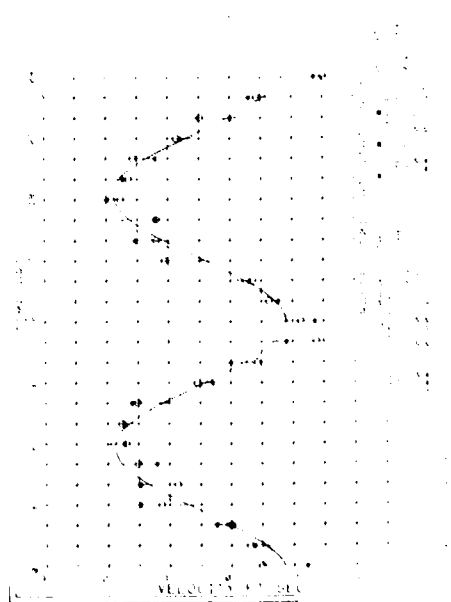
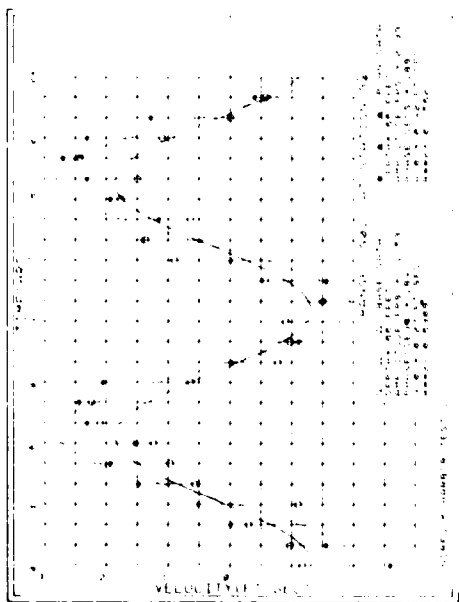
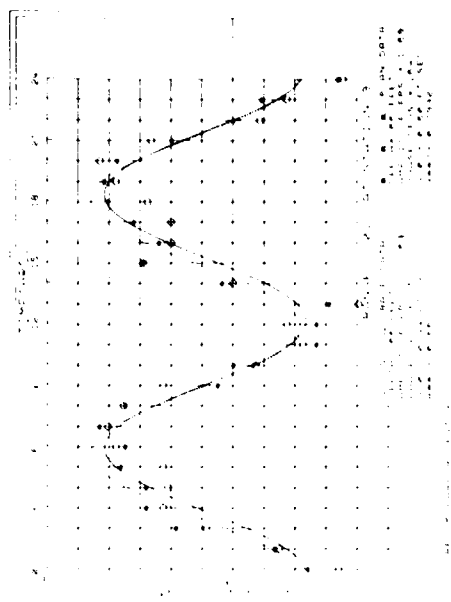
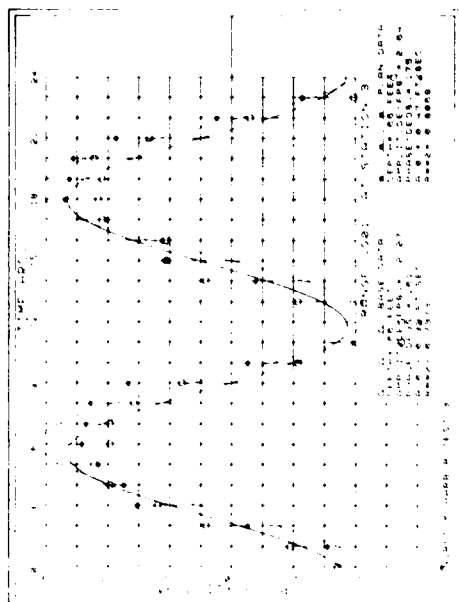
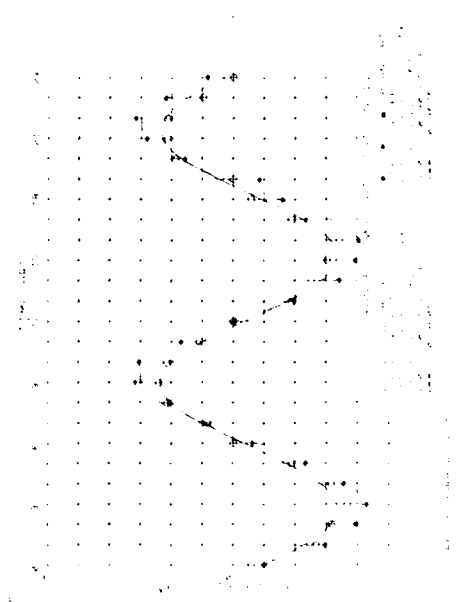
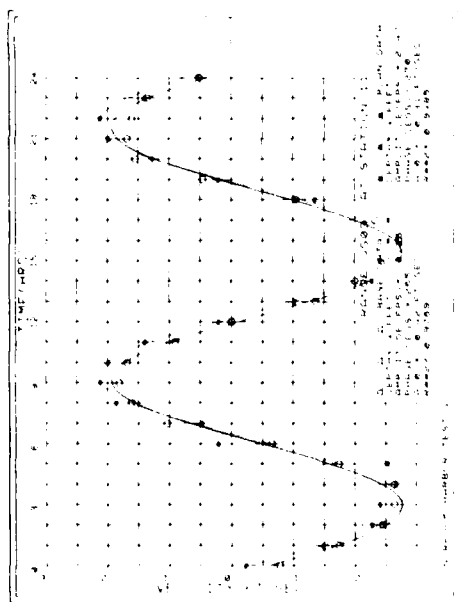
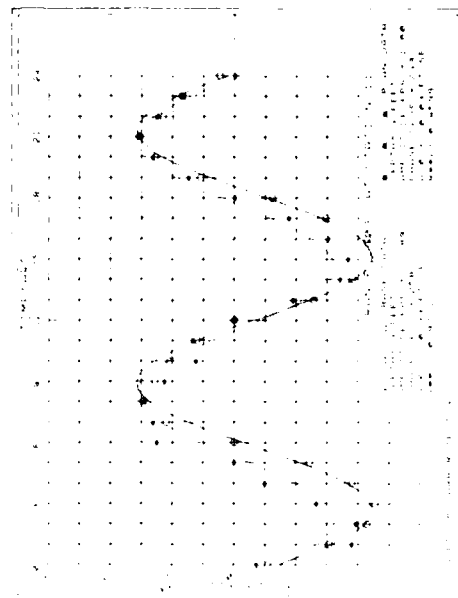
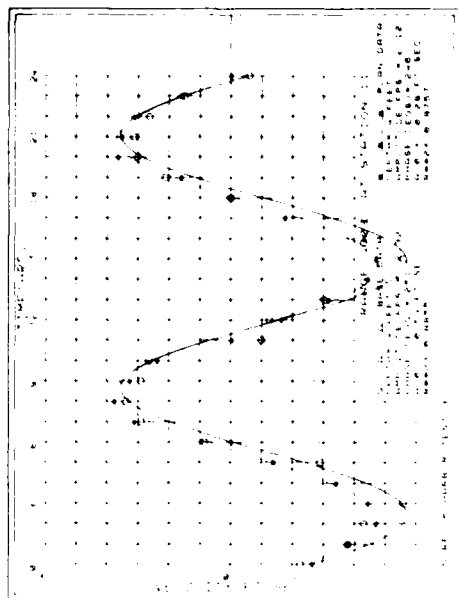


PLATE 74





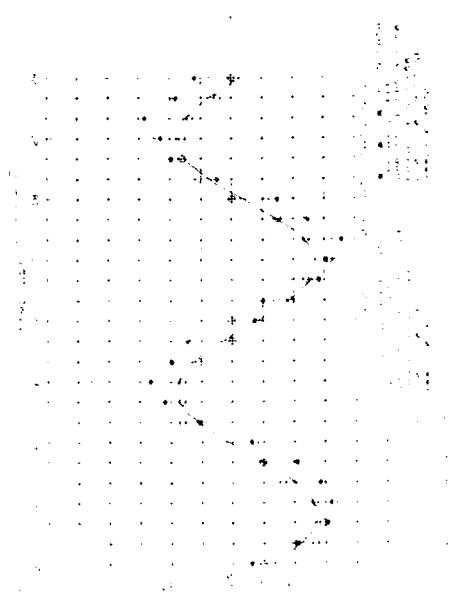
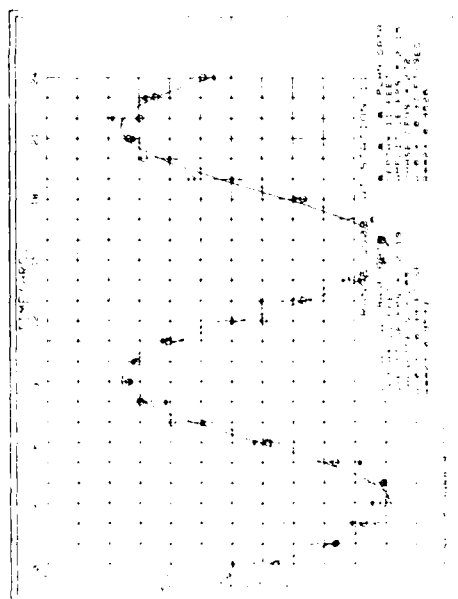
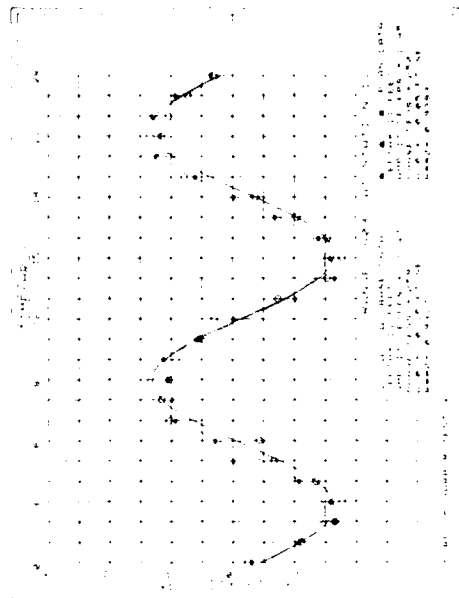
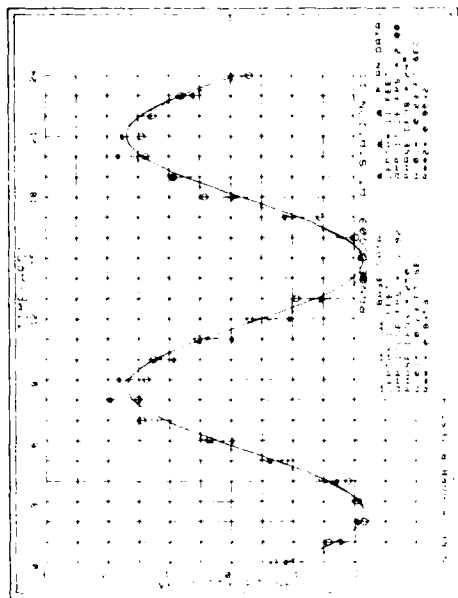


PLATE 78

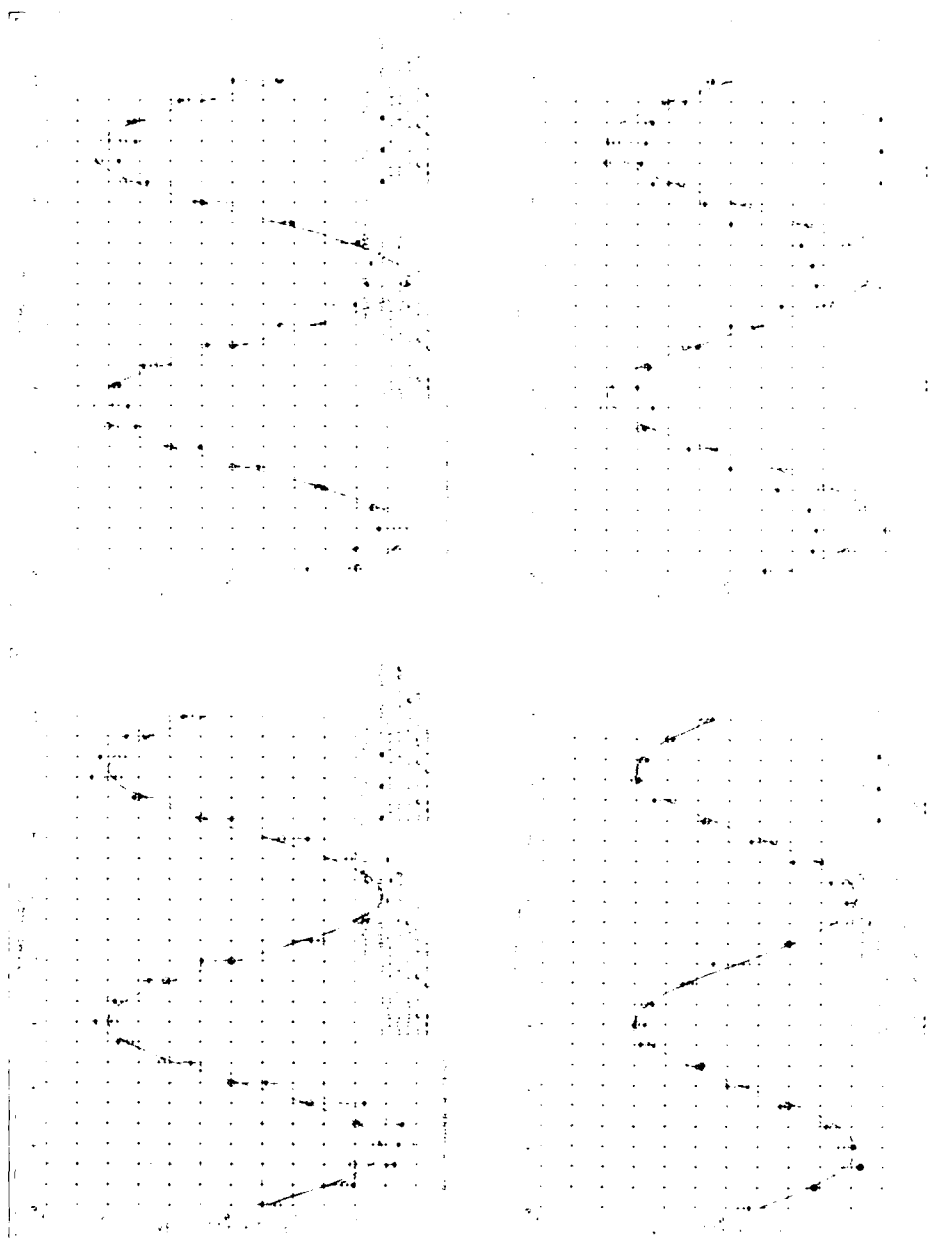


PLATE 79

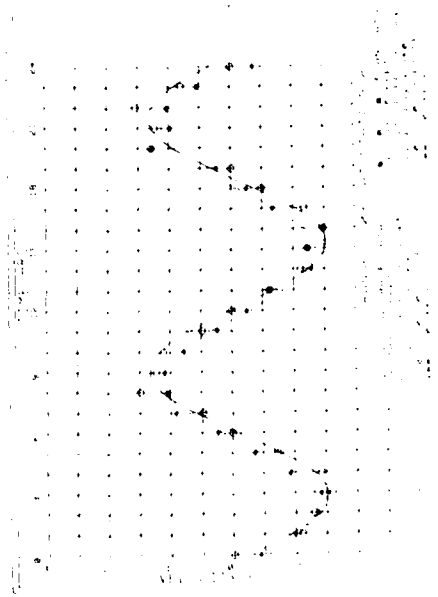
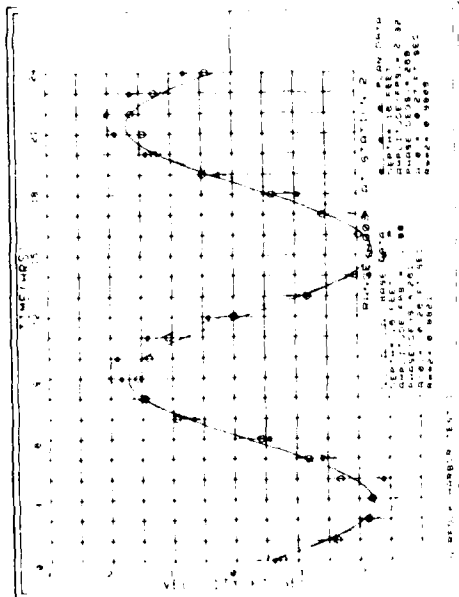
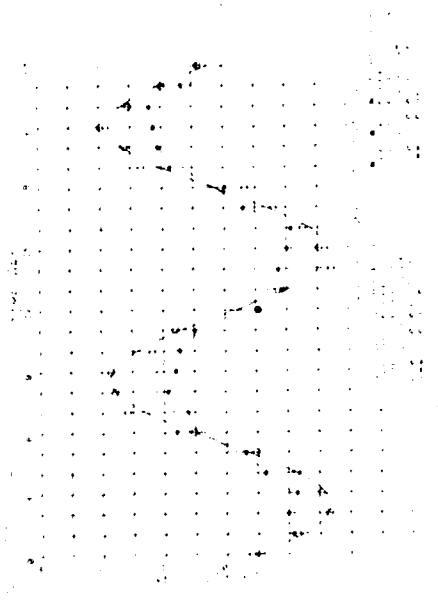
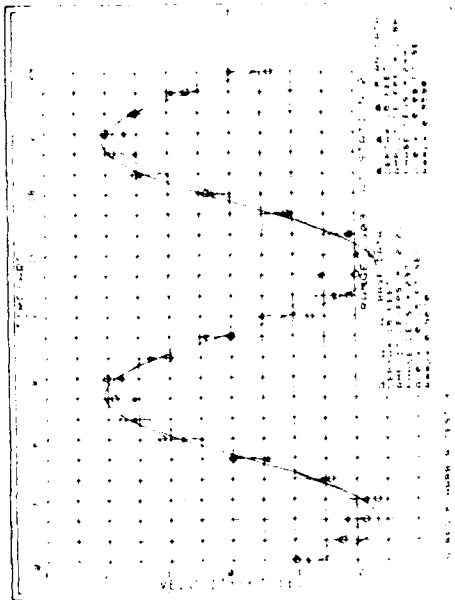
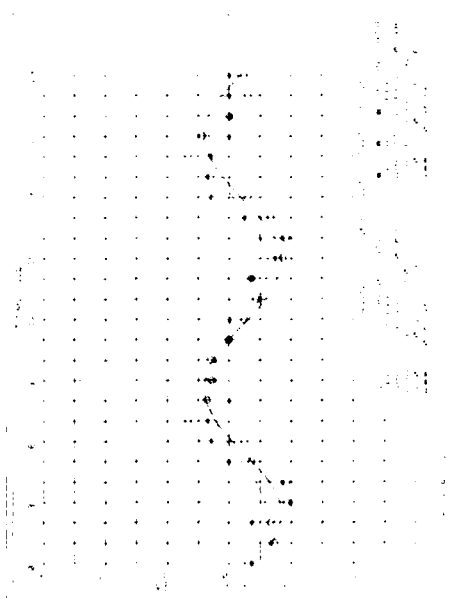
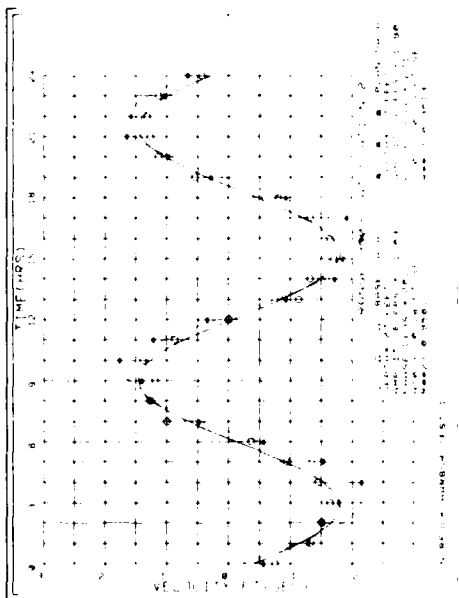
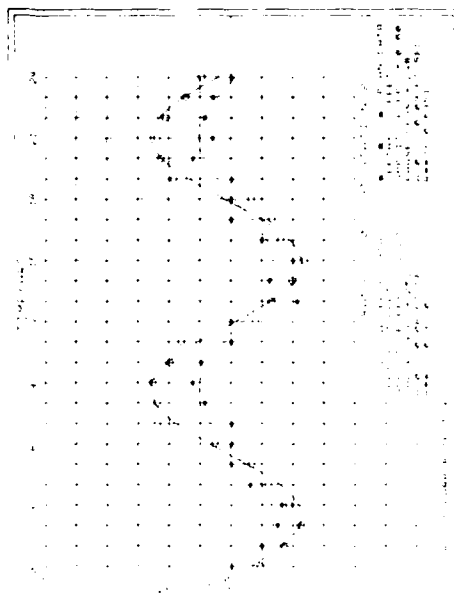
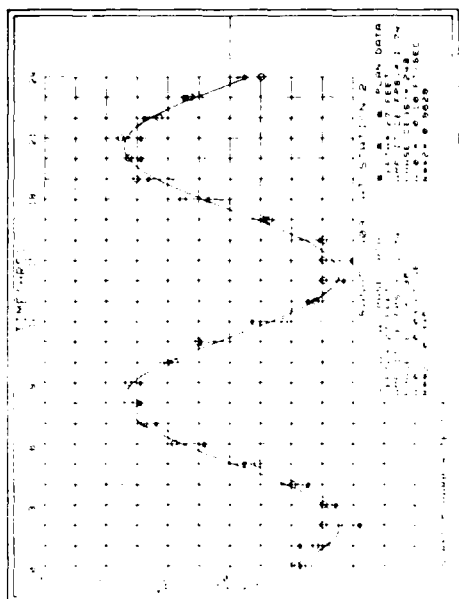


PLATE 80



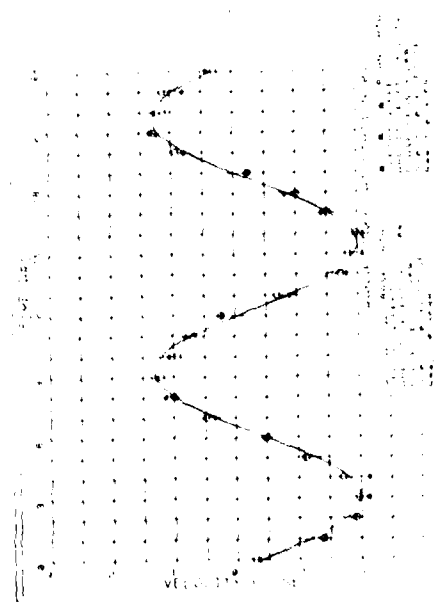
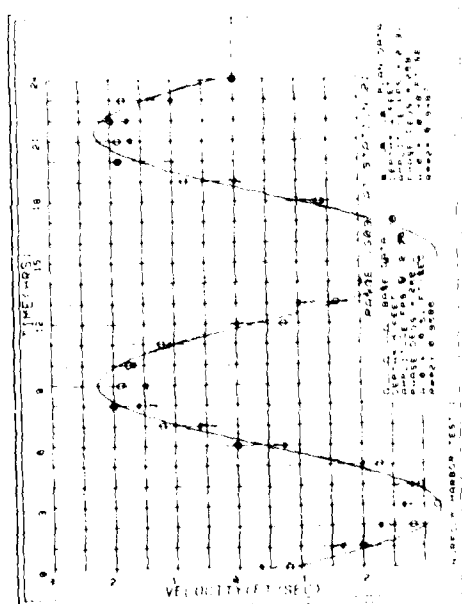
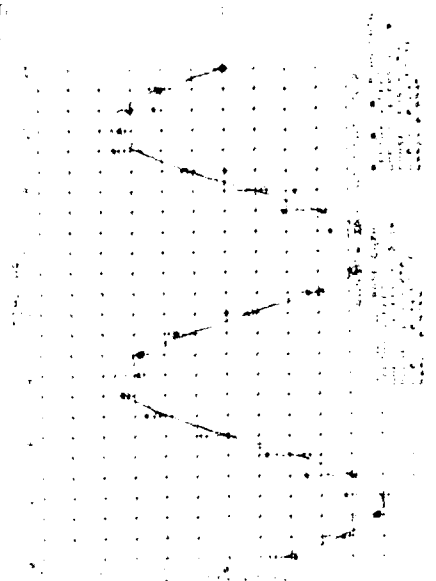
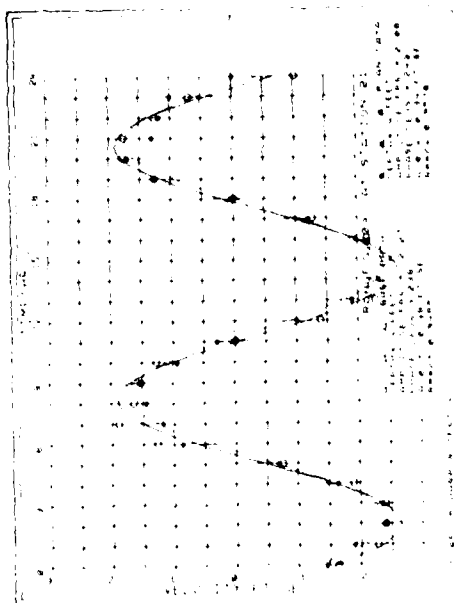


PLATE 82

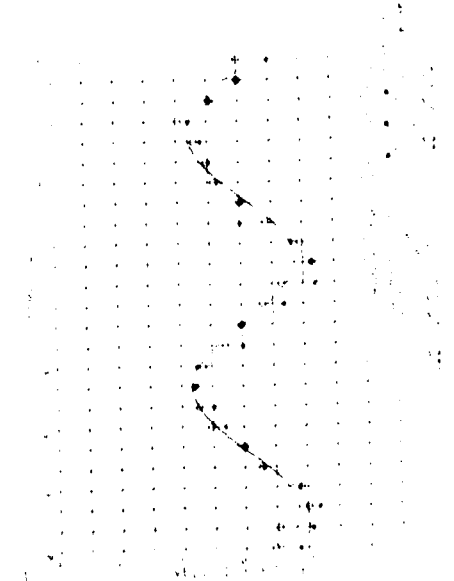
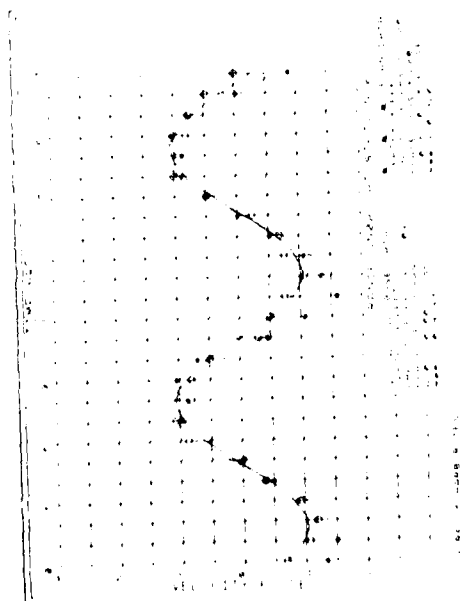
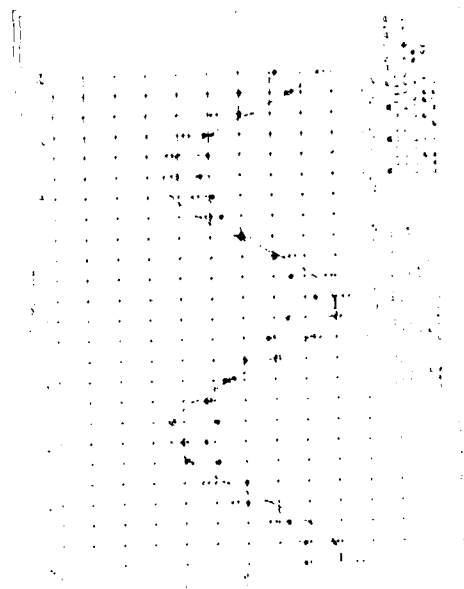
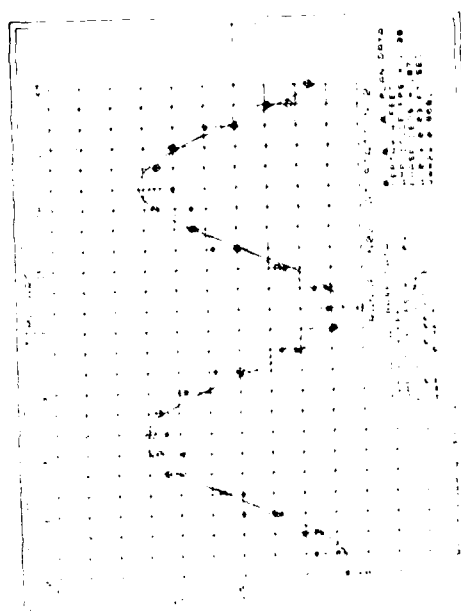


PLATE 83

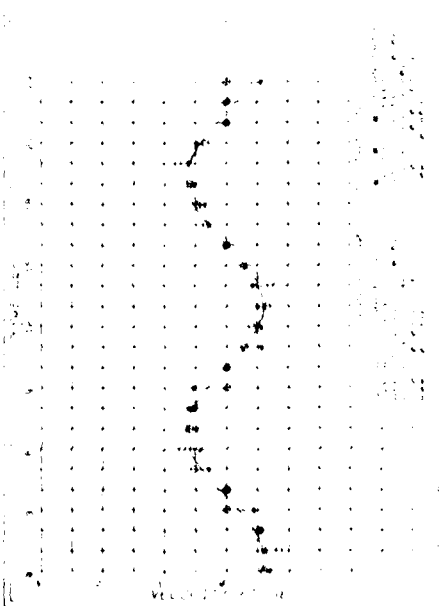
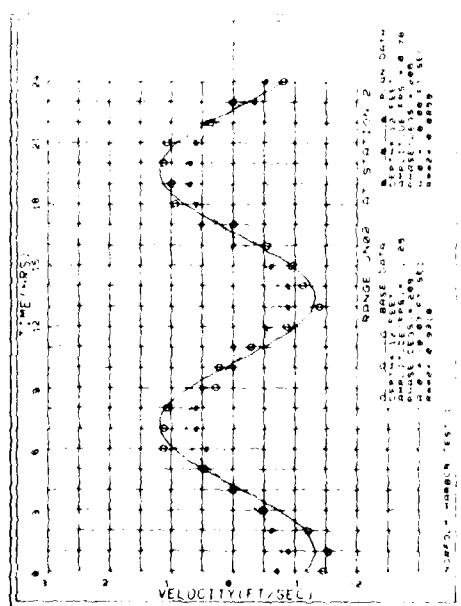
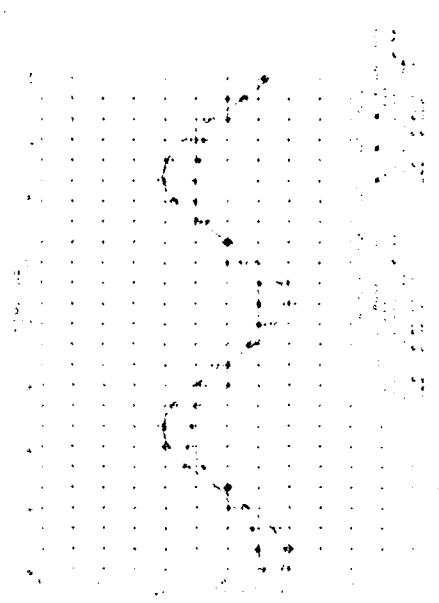
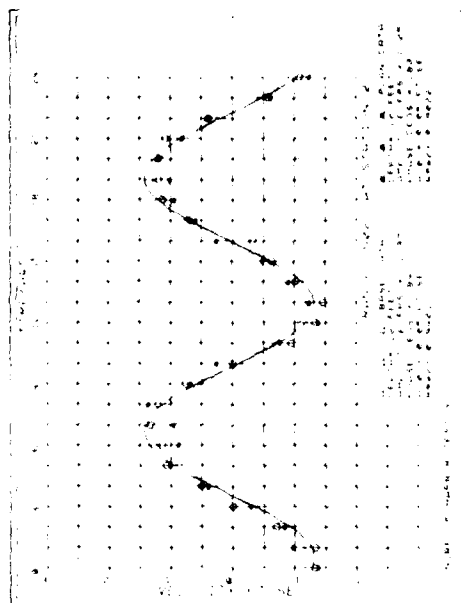


PLATE 84

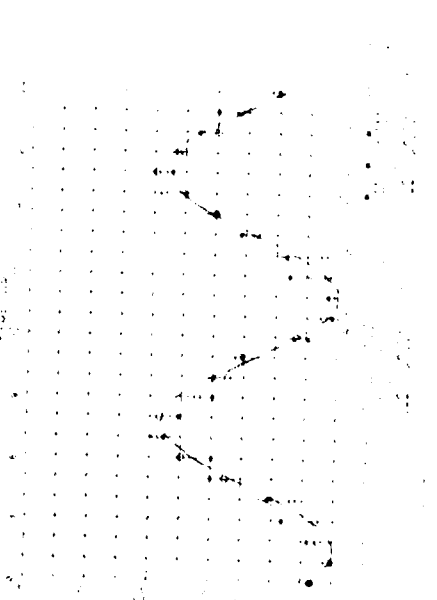
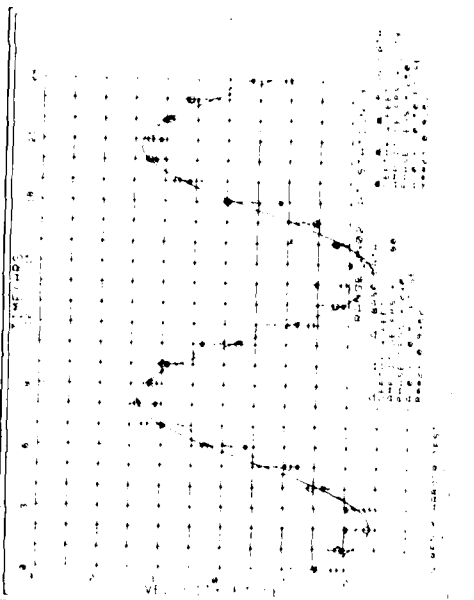
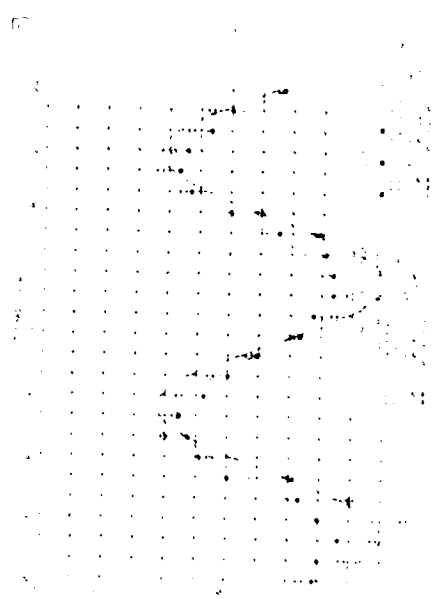
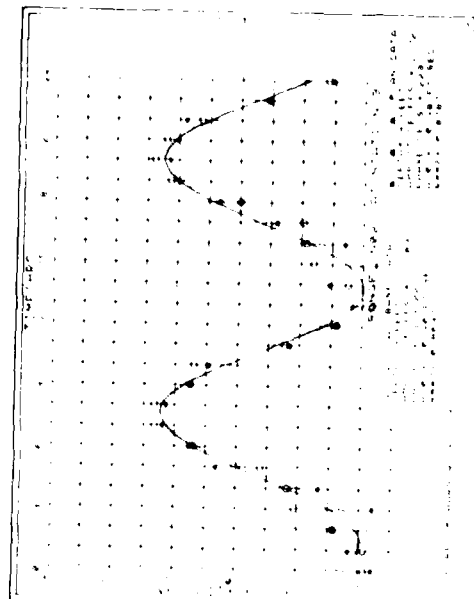


PLATE 85

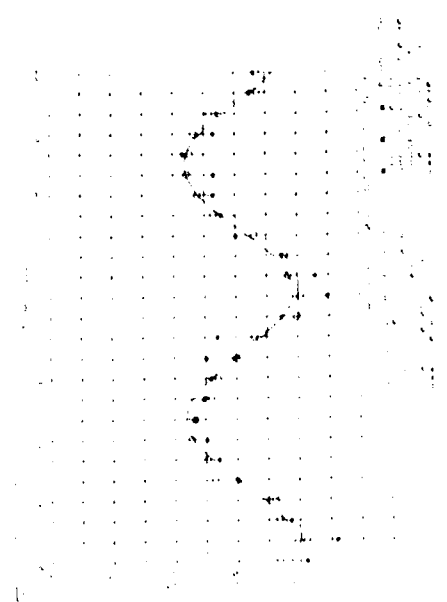
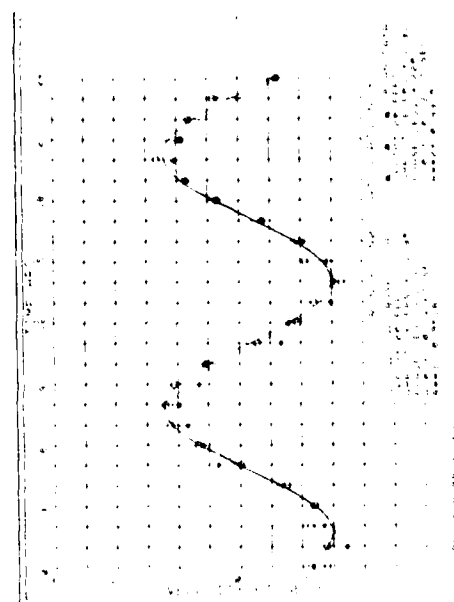
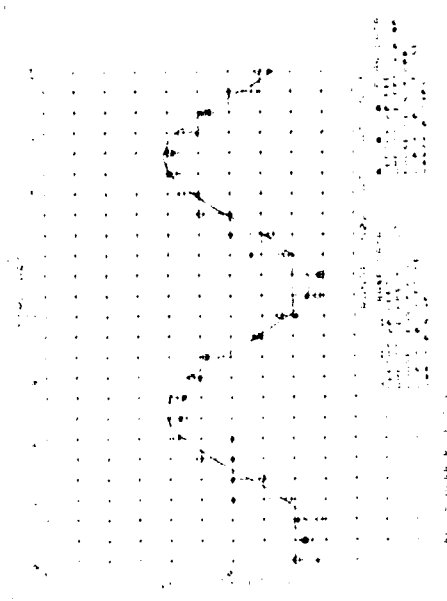
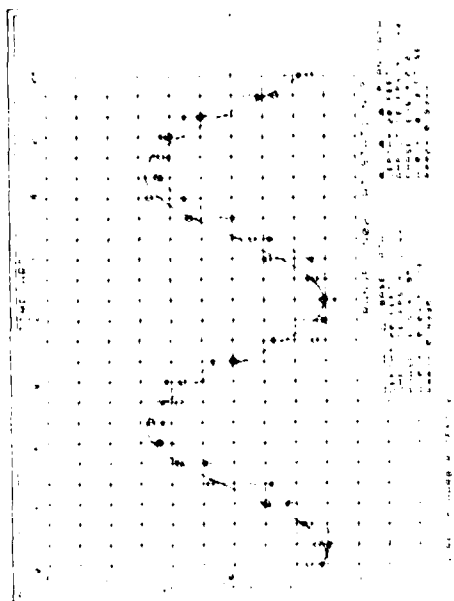


PLATE 86

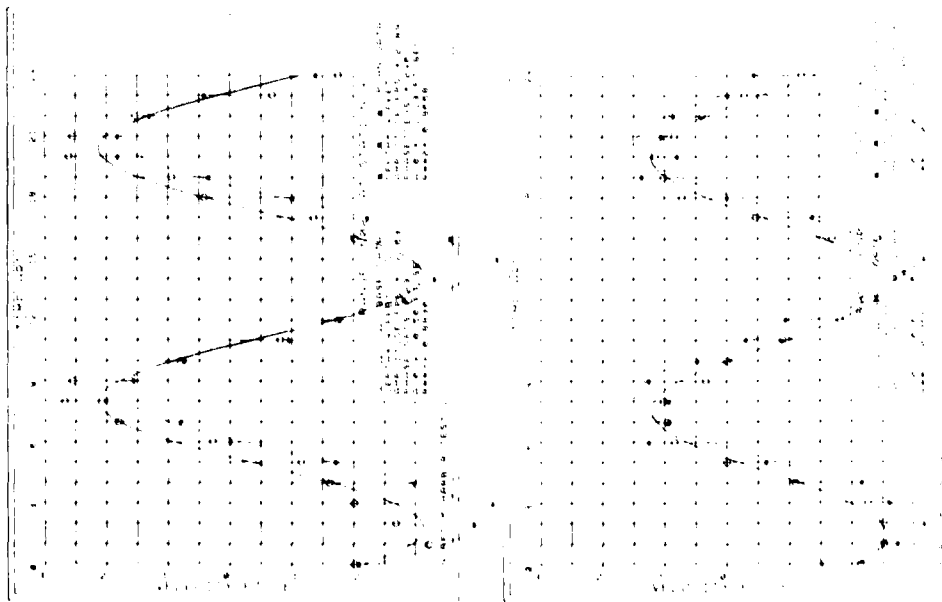
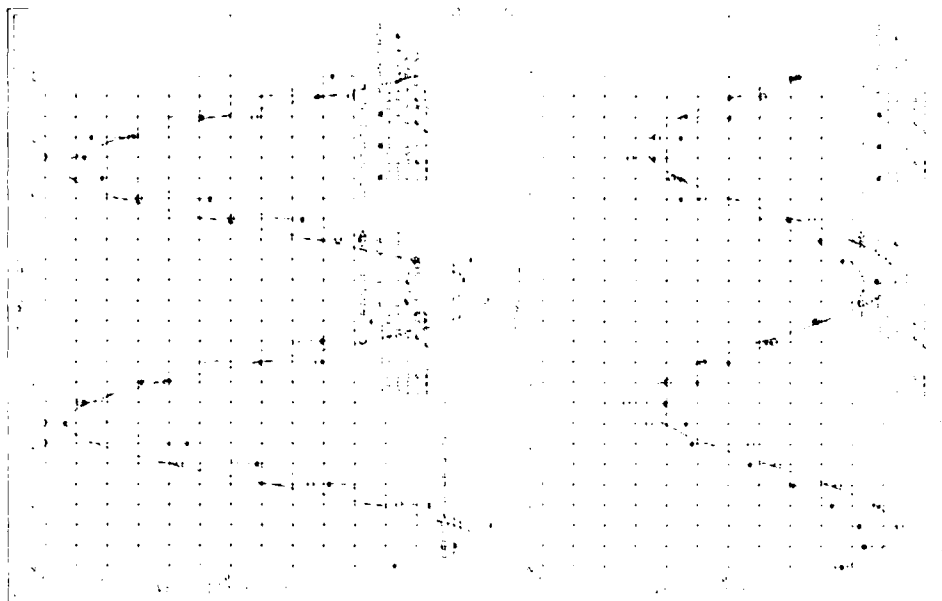


PLATE 87

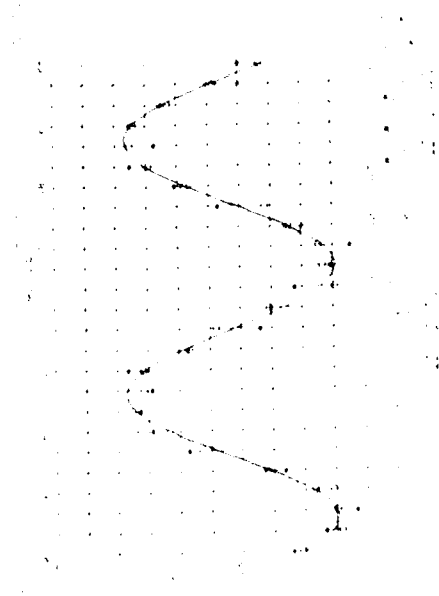
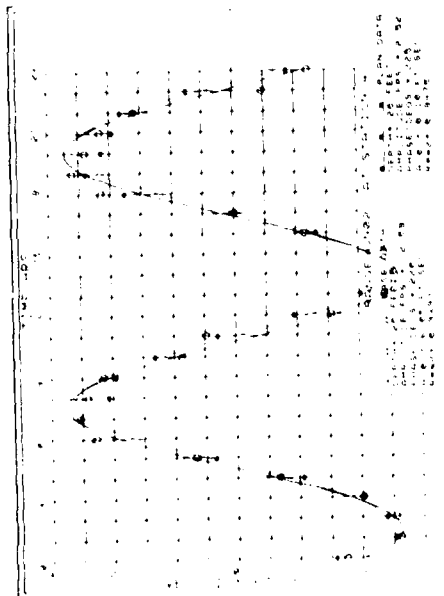
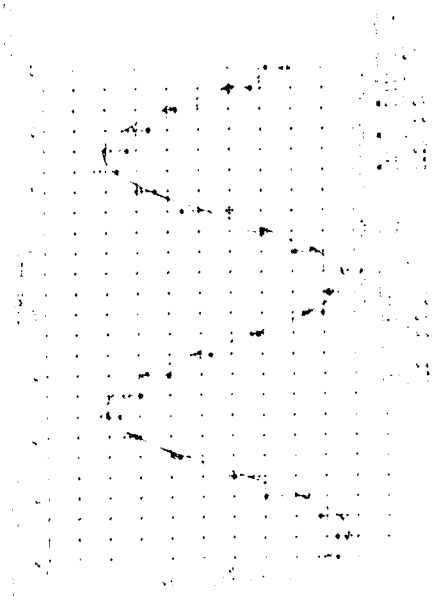
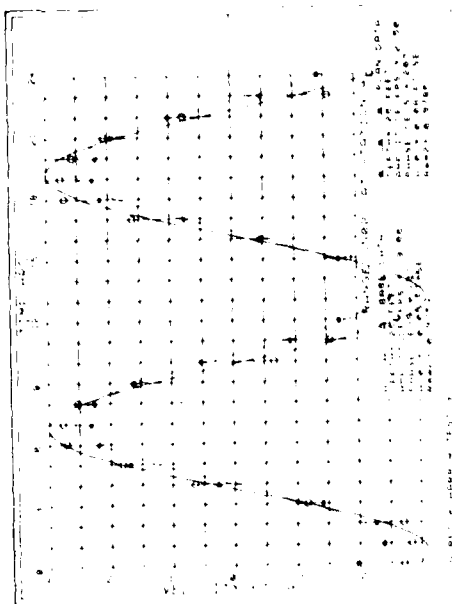


PLATE 88

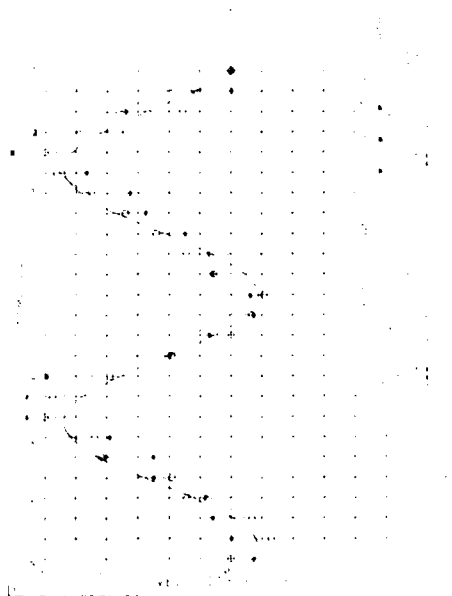
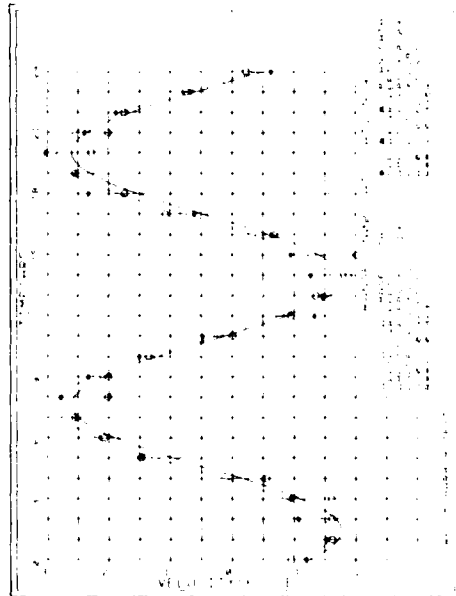
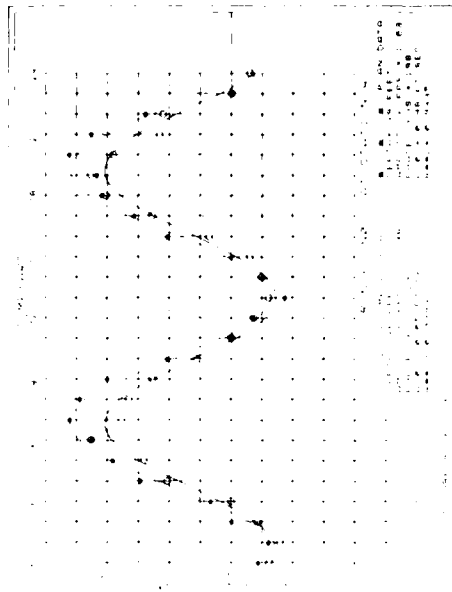
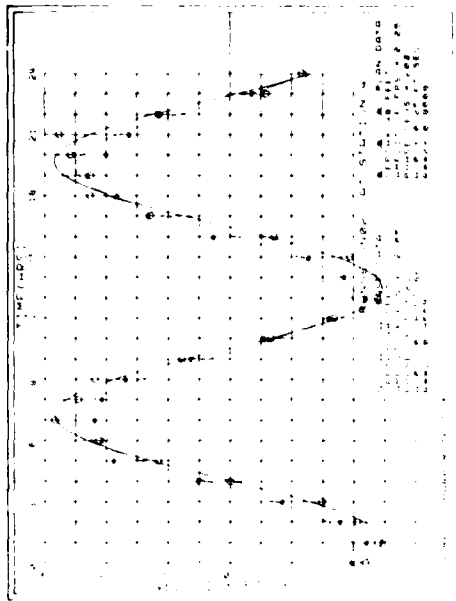


PLATE 89

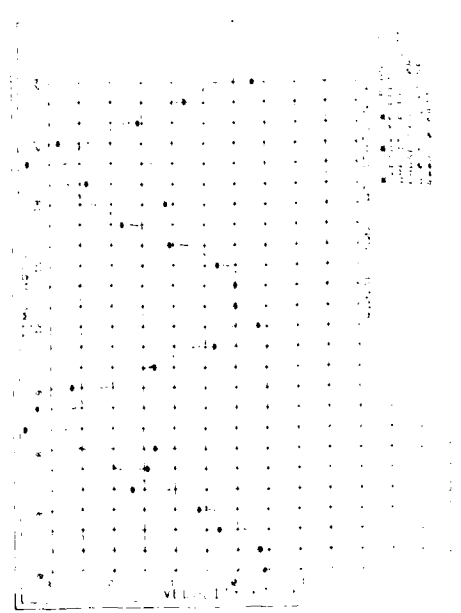
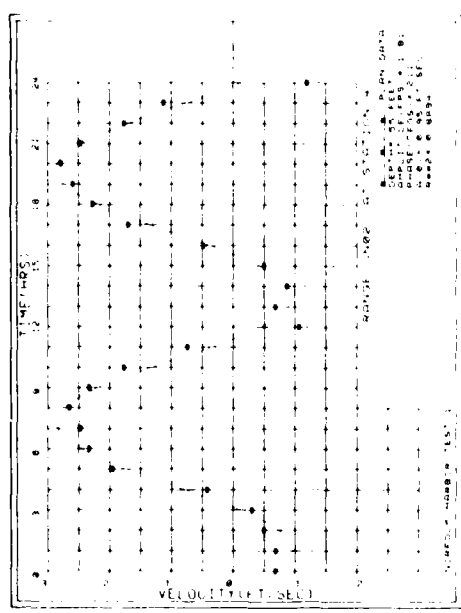
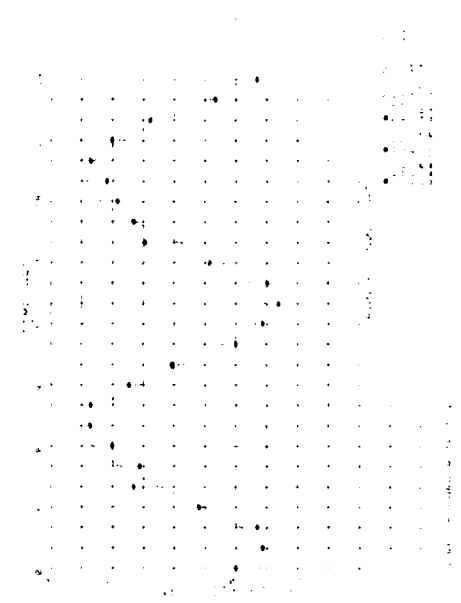
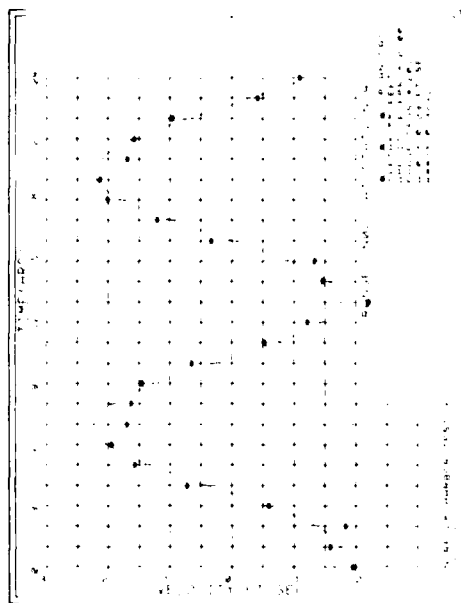


PLATE 90

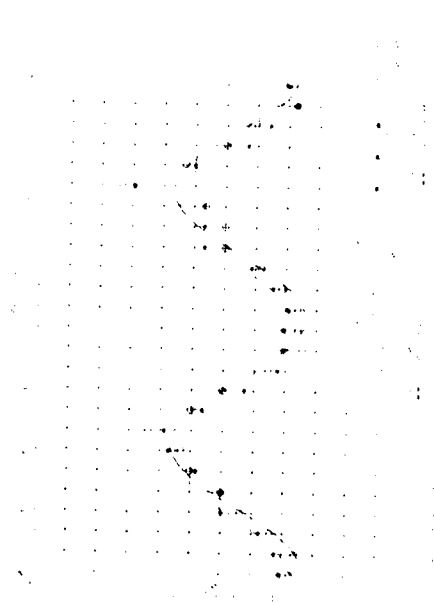
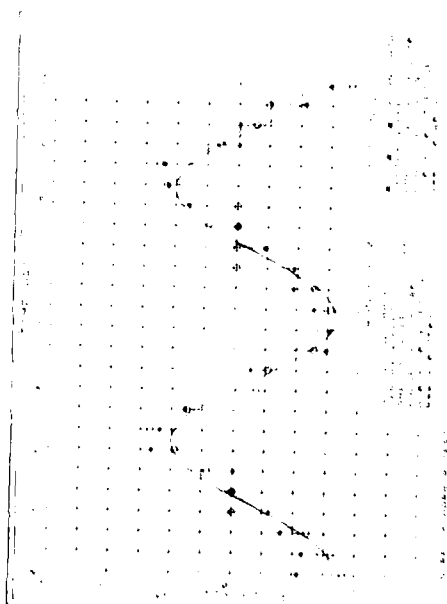
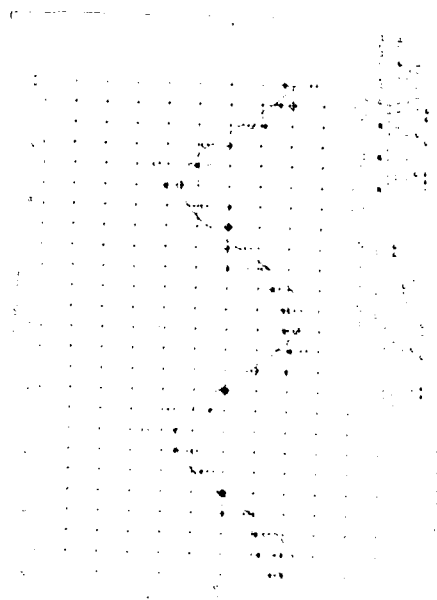
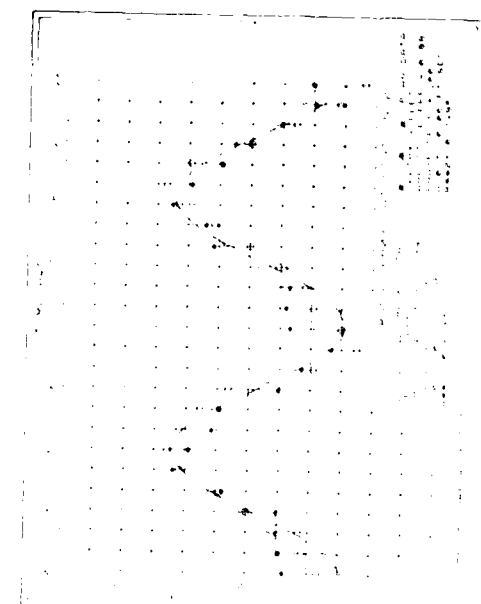


PLATE 91

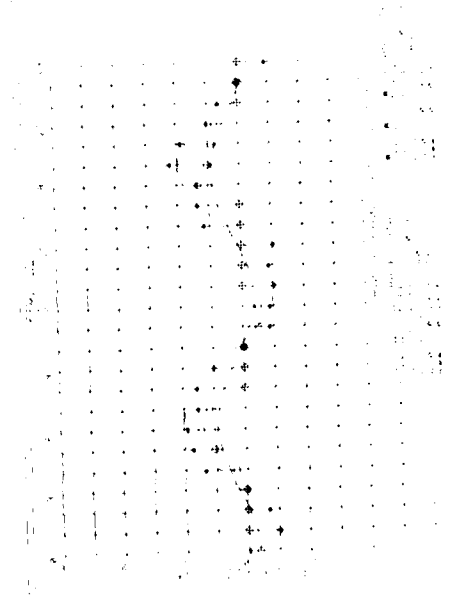
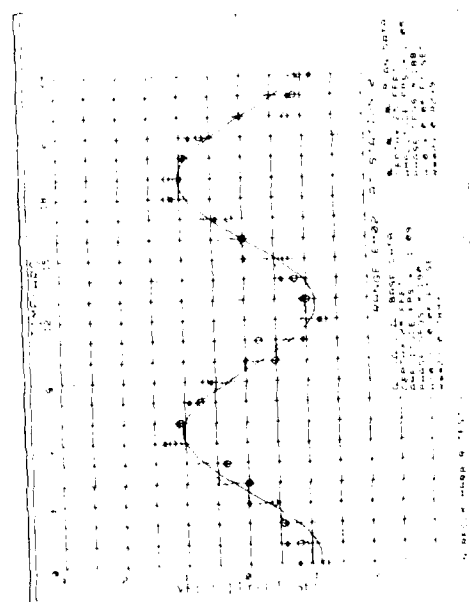
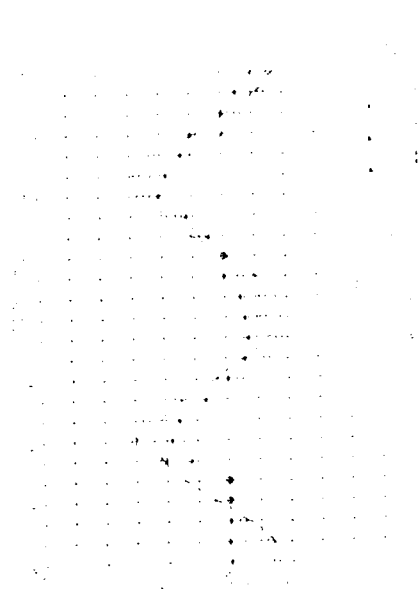
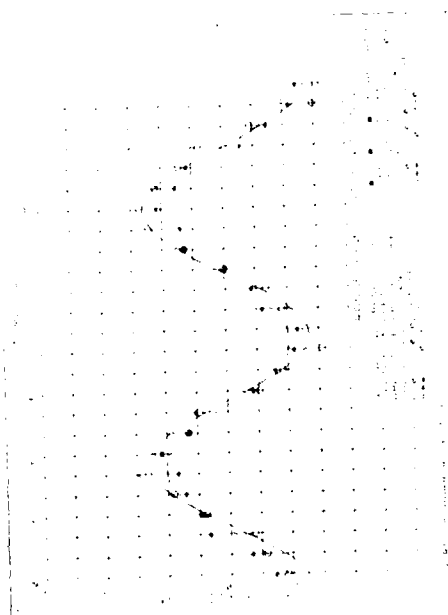
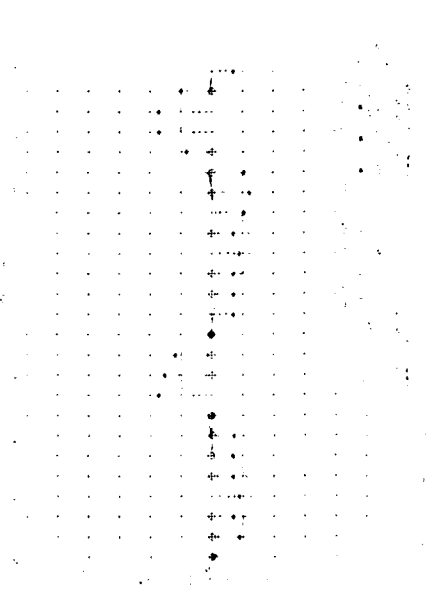
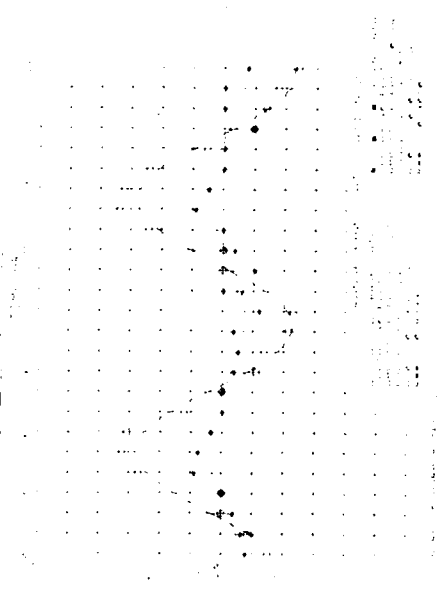
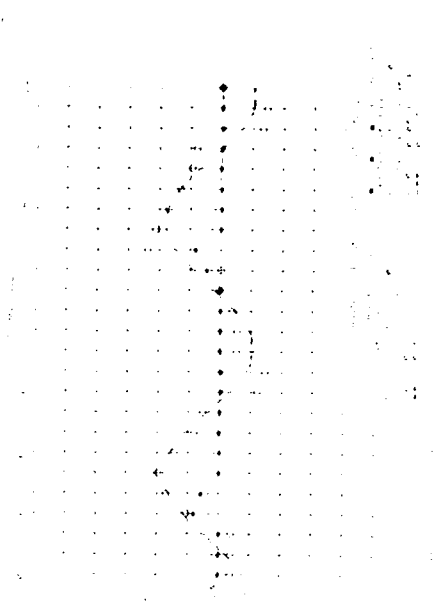
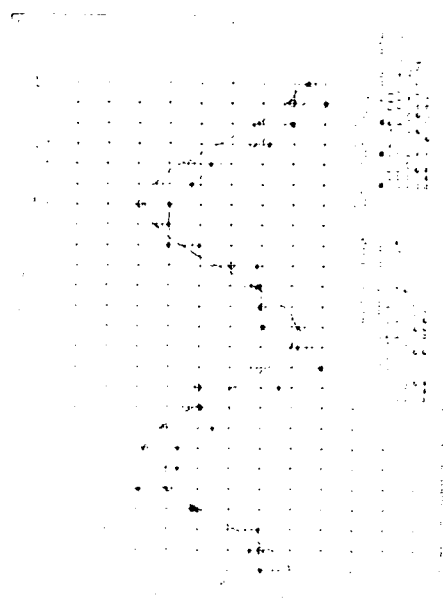


PLATE 92



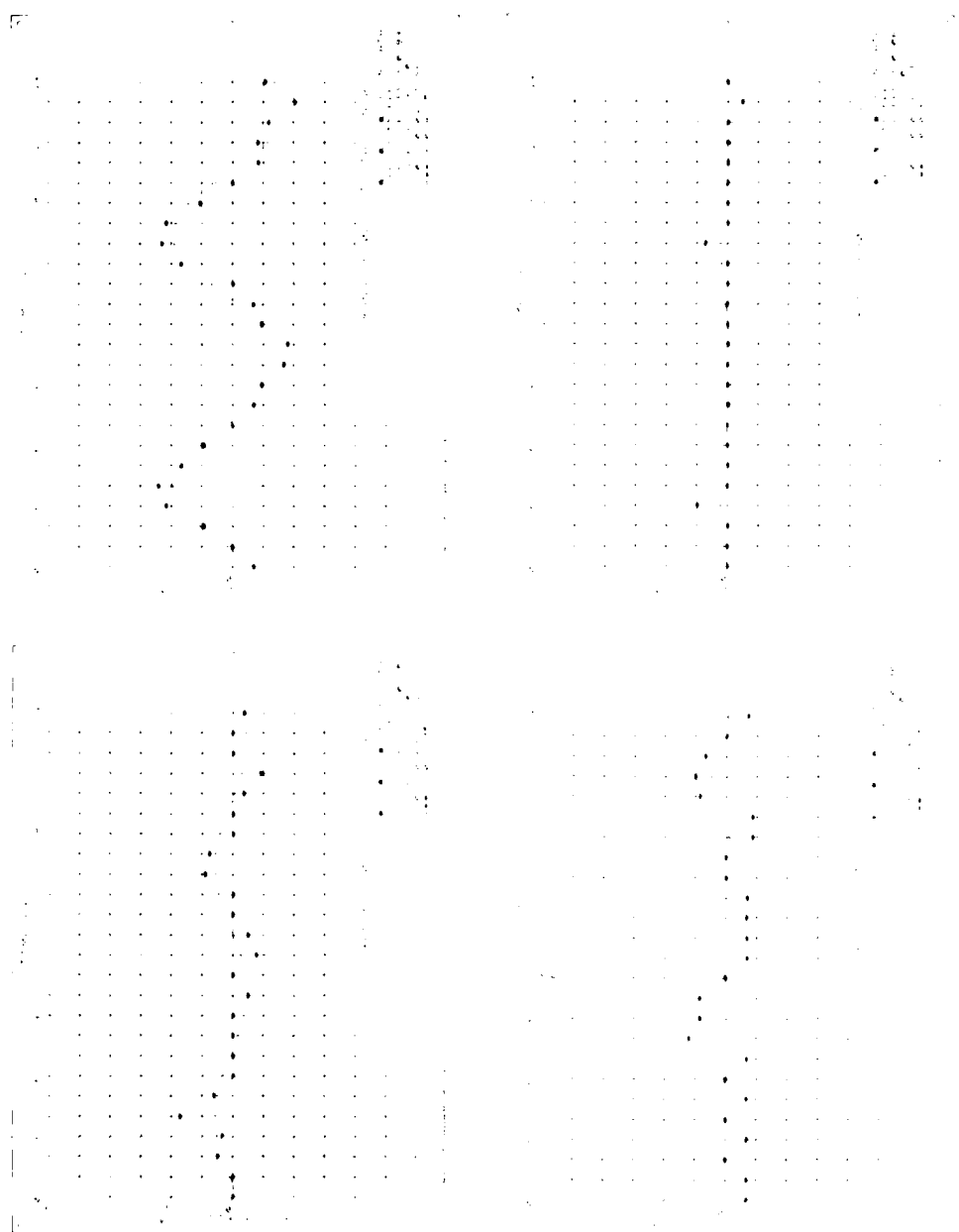


PLATE 94

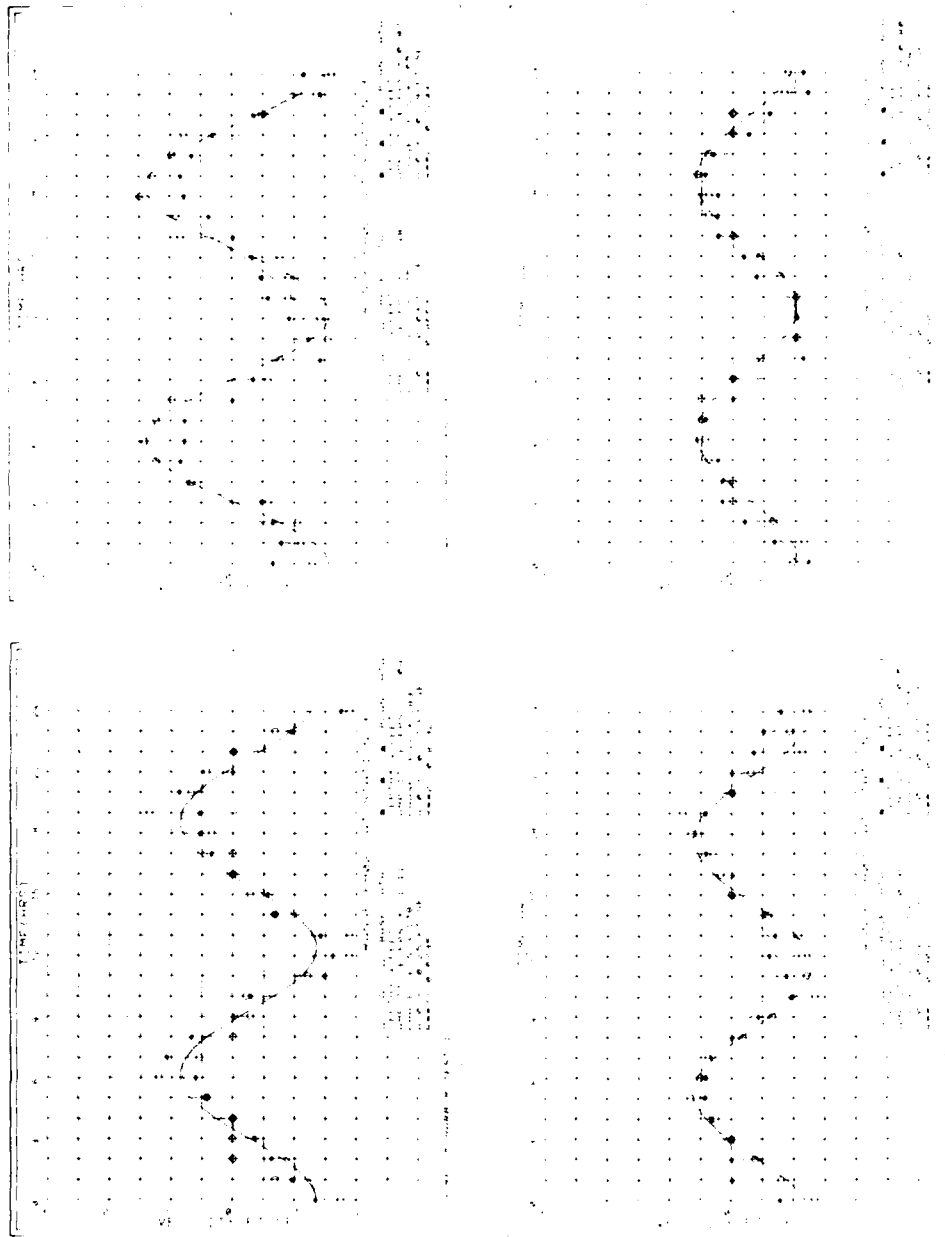


PLATE 95

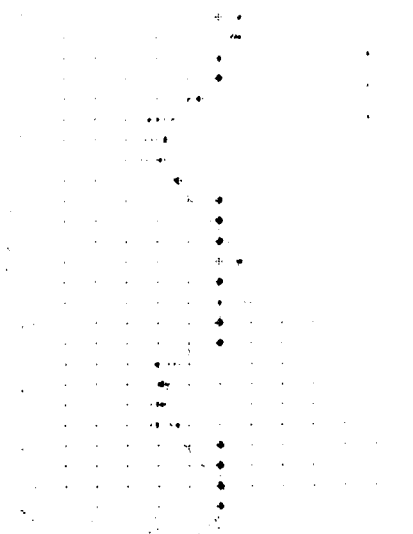
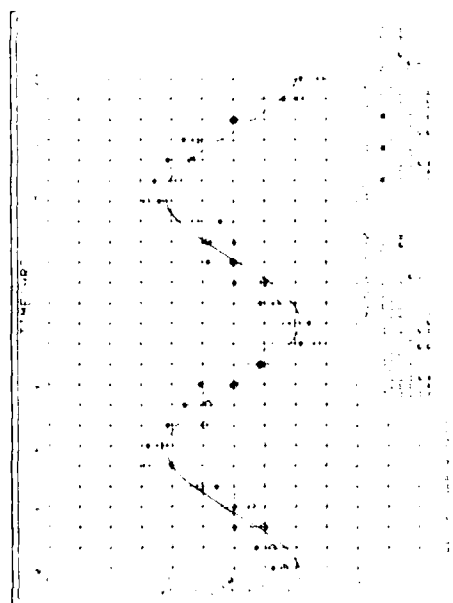
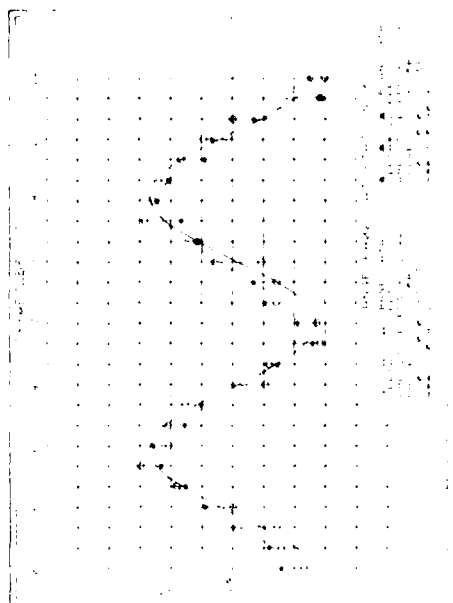


PLATE 96

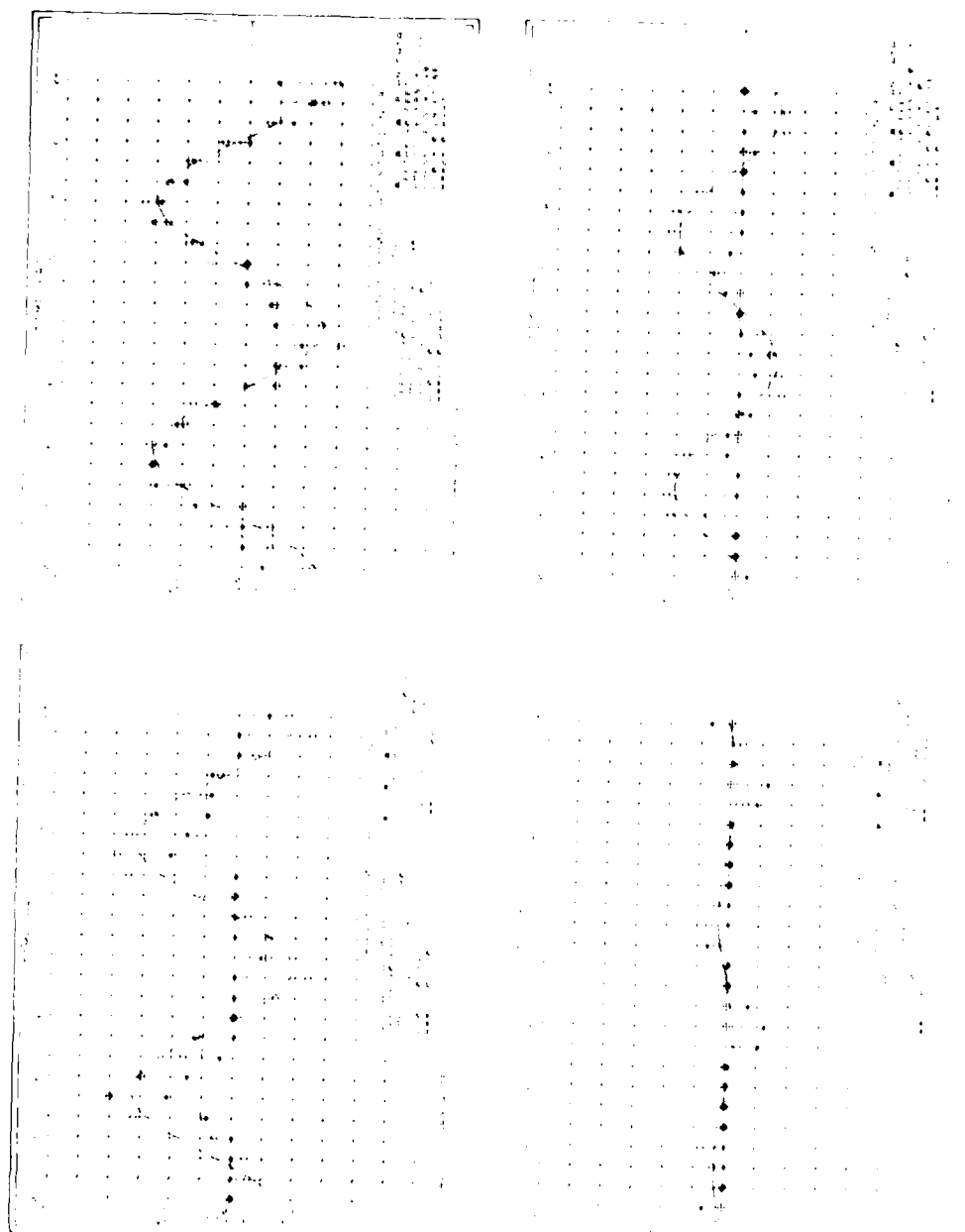


PLATE 97

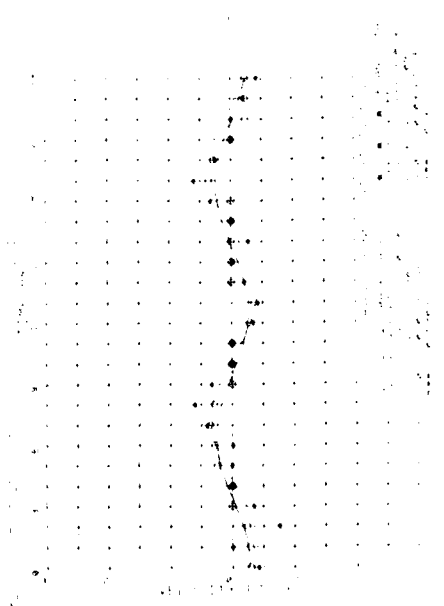
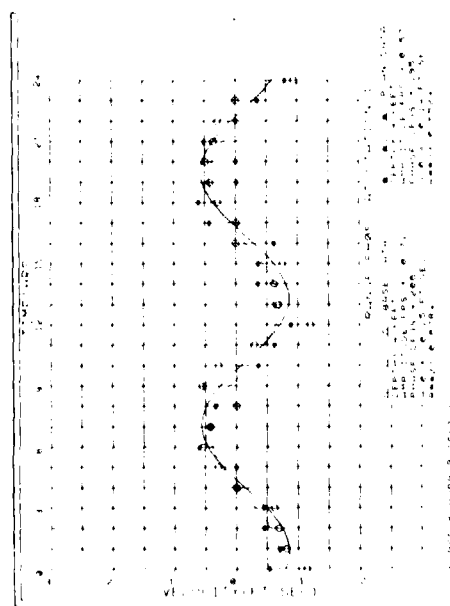
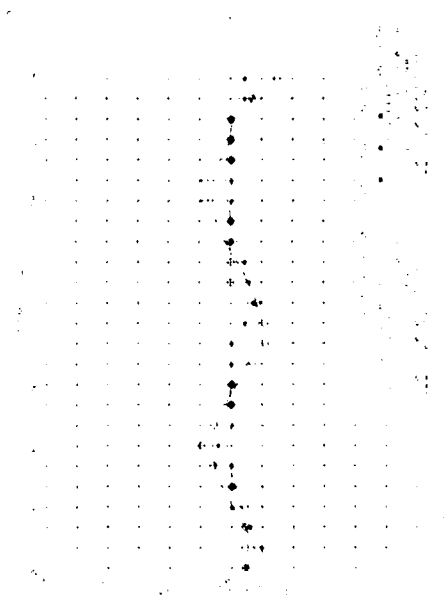
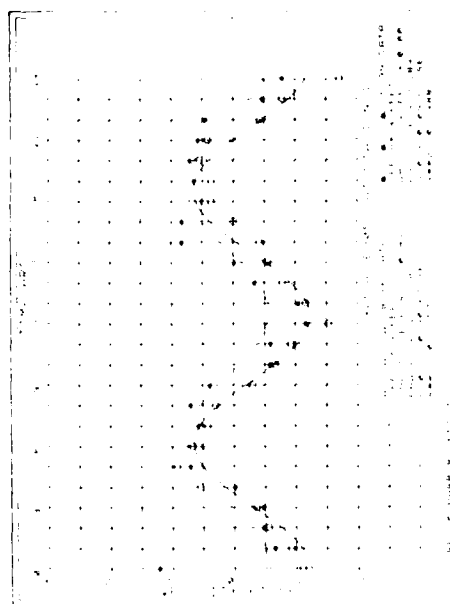
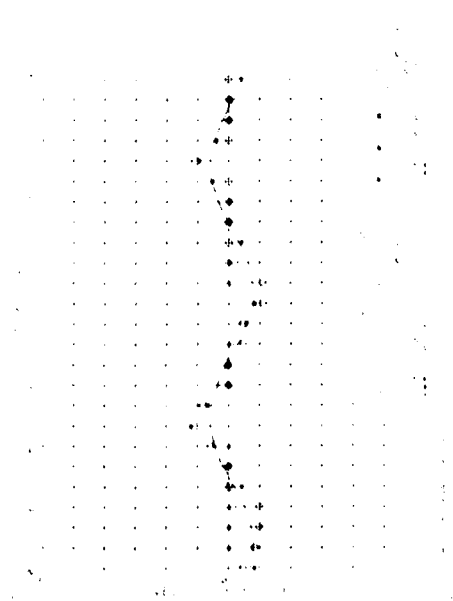
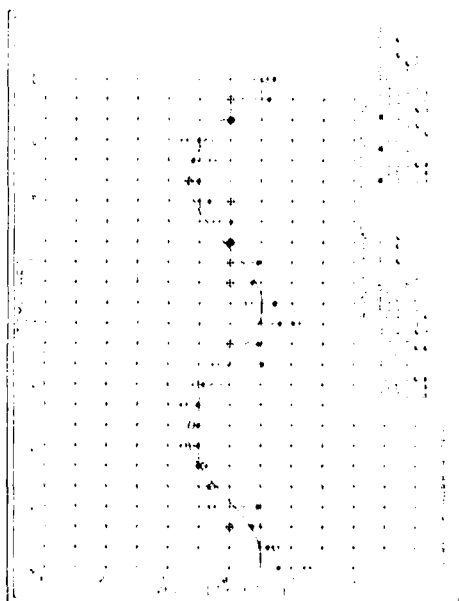
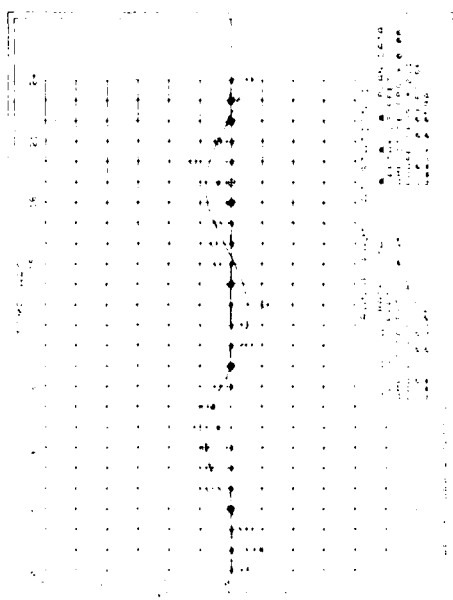
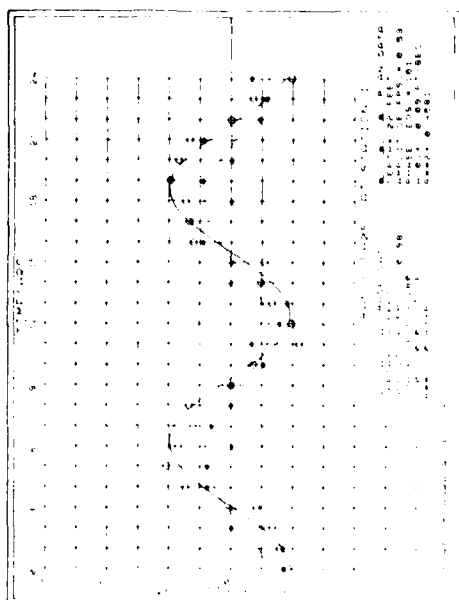


PLATE 98



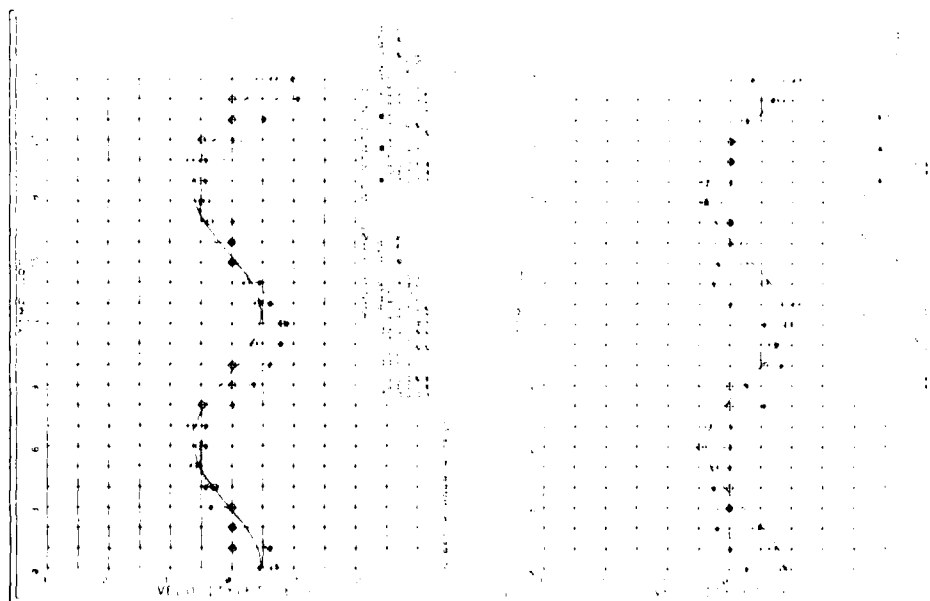
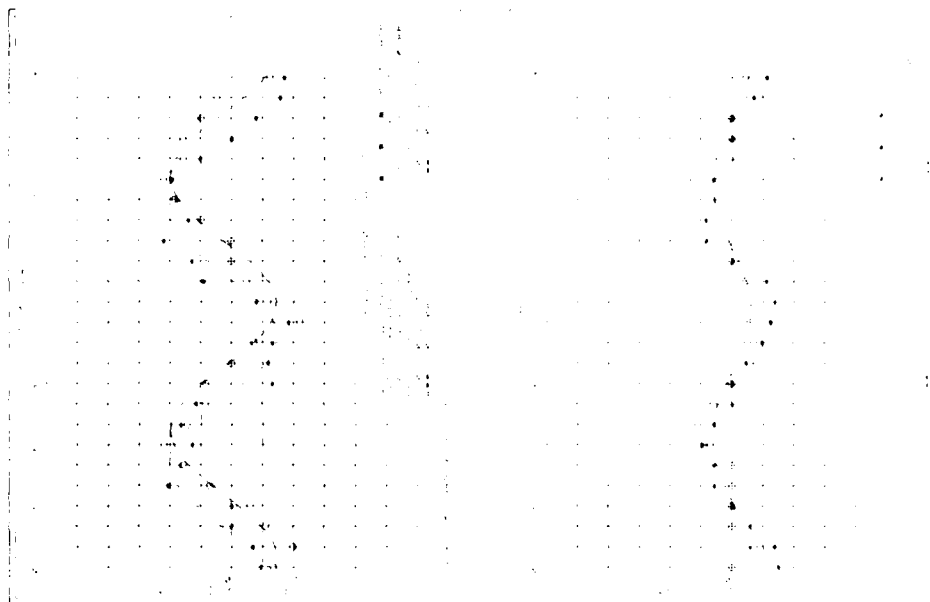
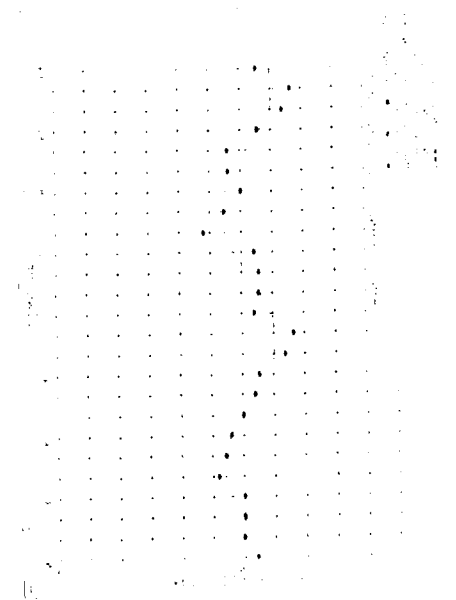
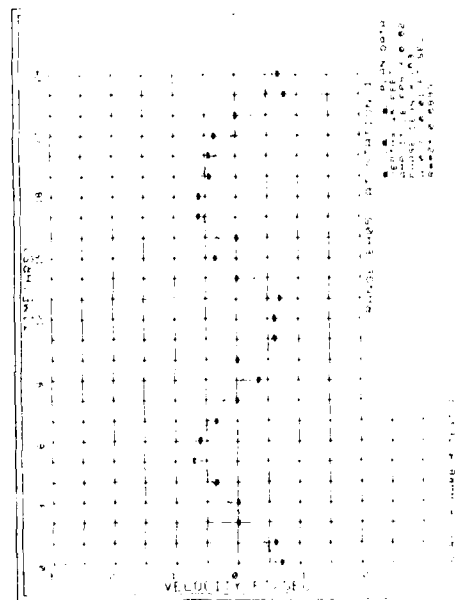
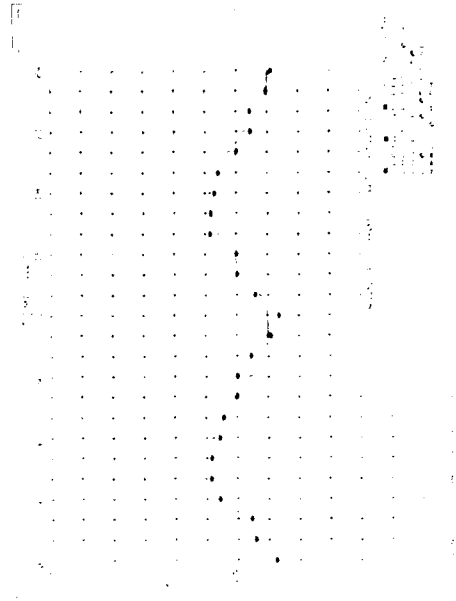
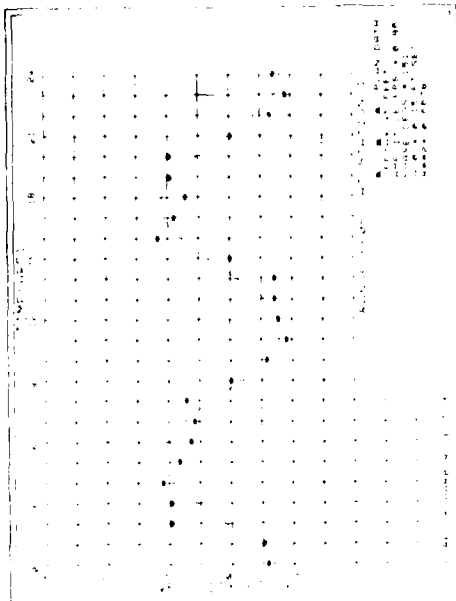


PLATE 100



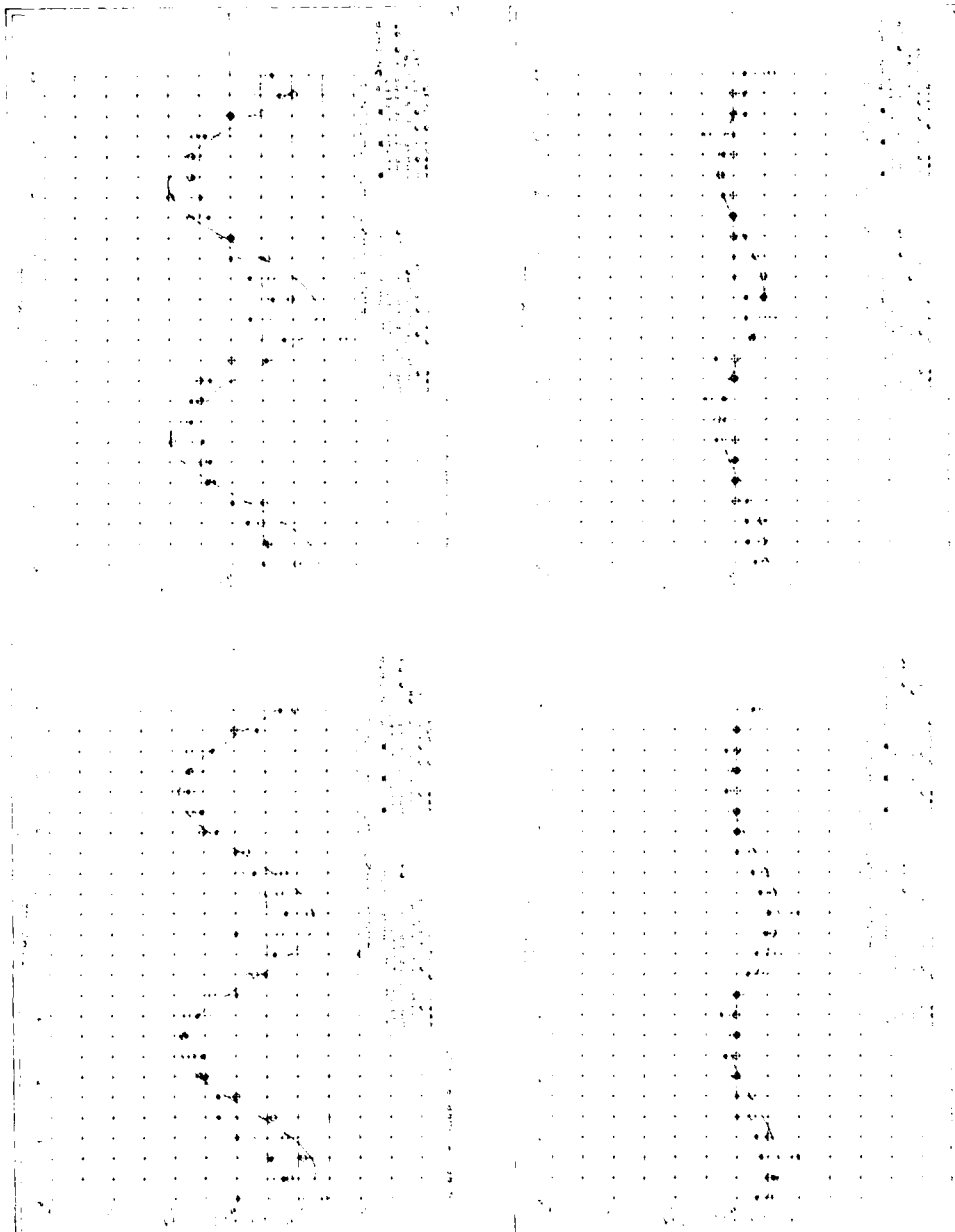
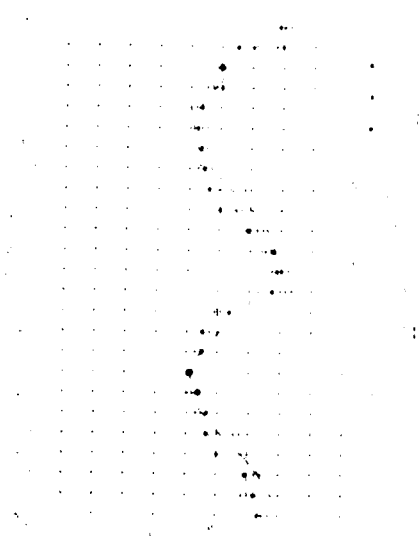
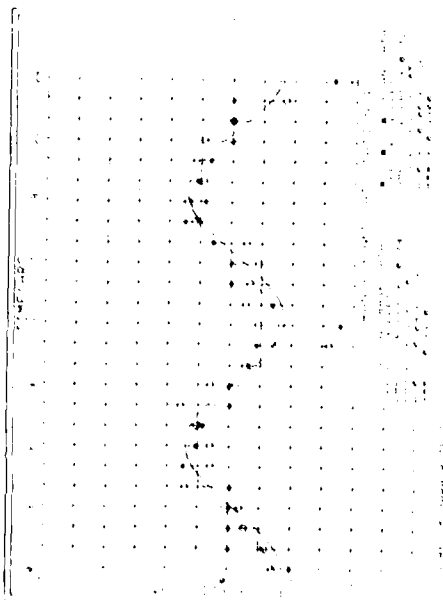
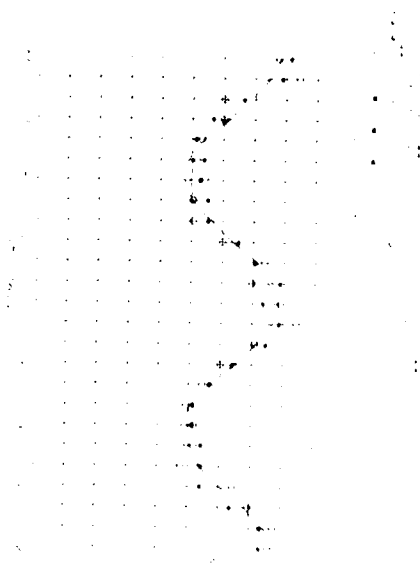
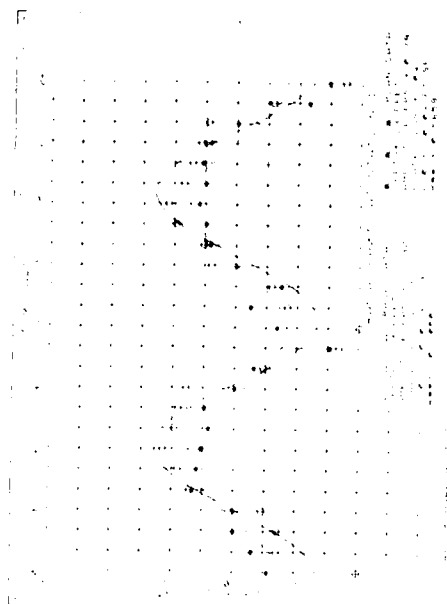
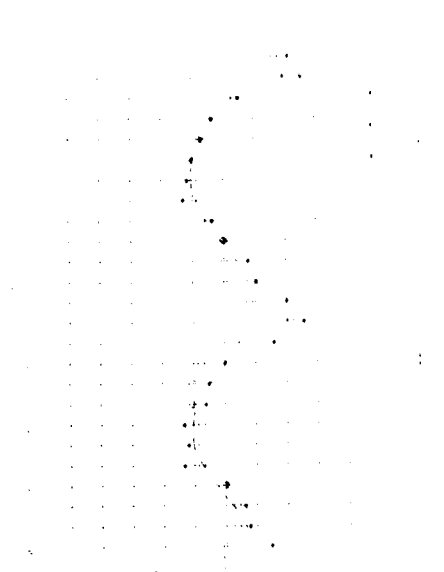
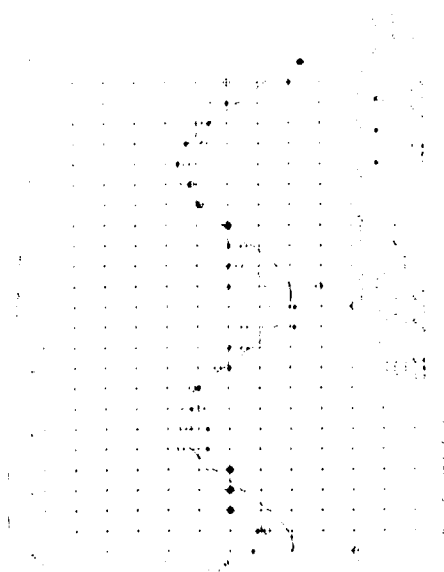
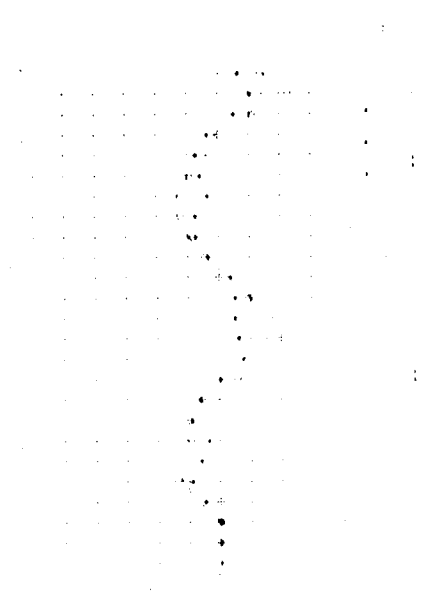
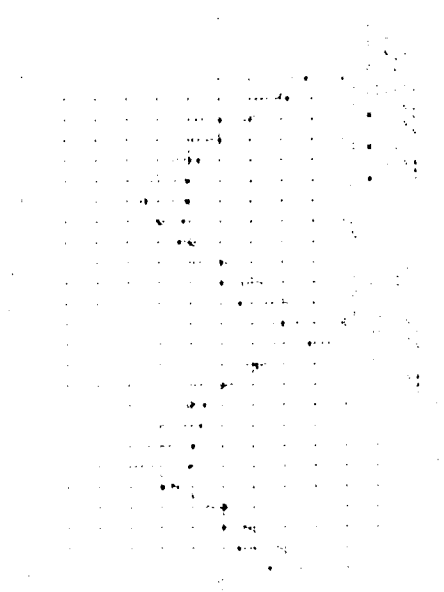


PLATE 102





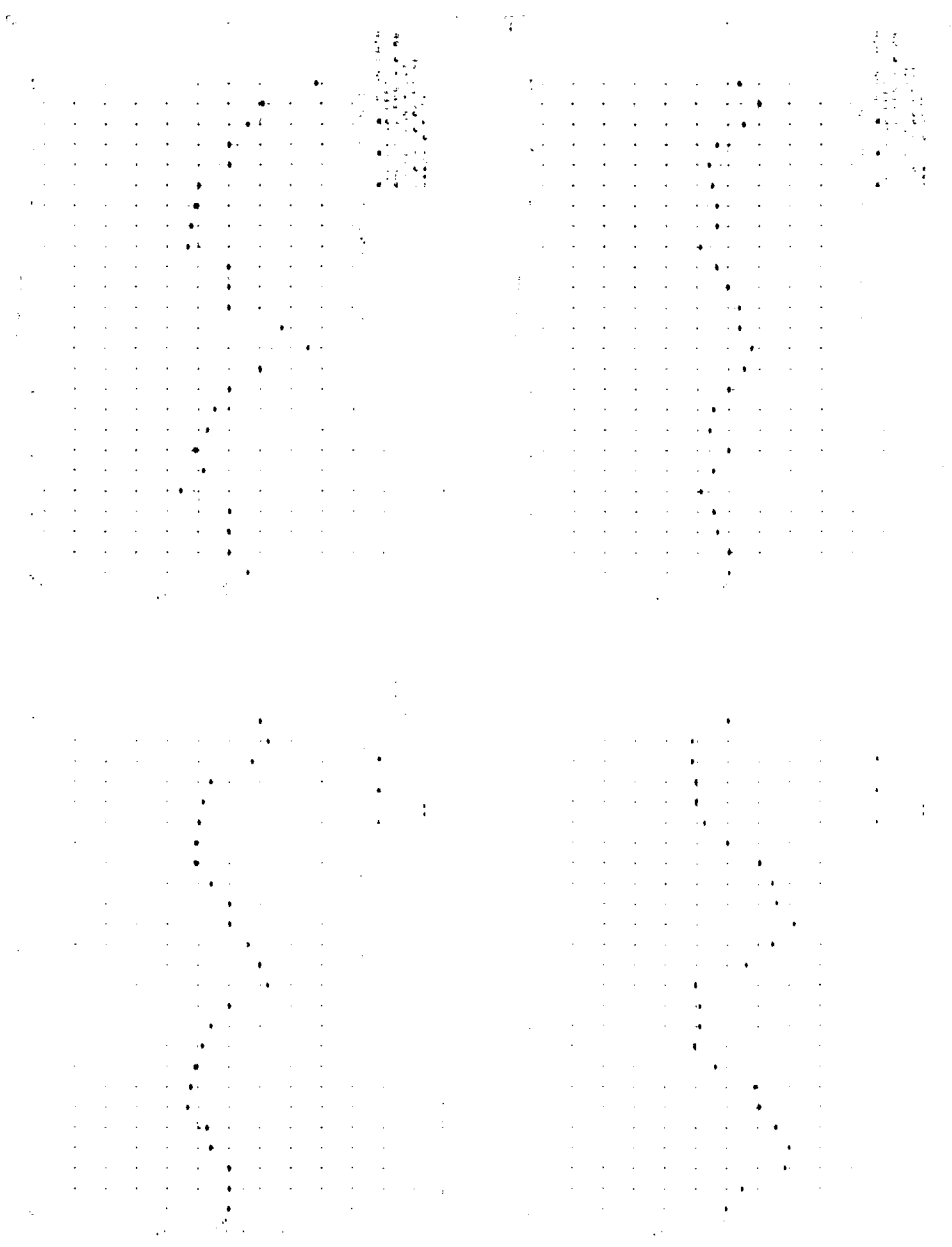


PLATE 105

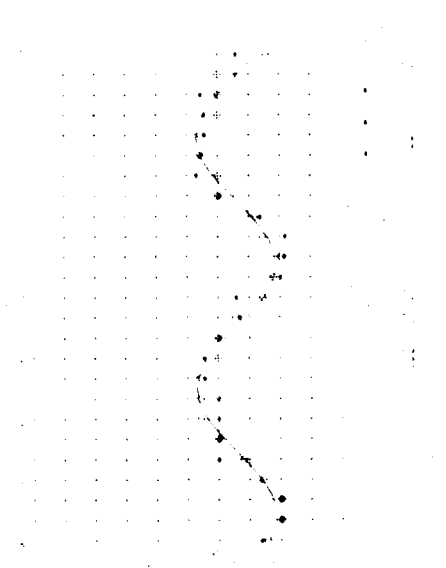
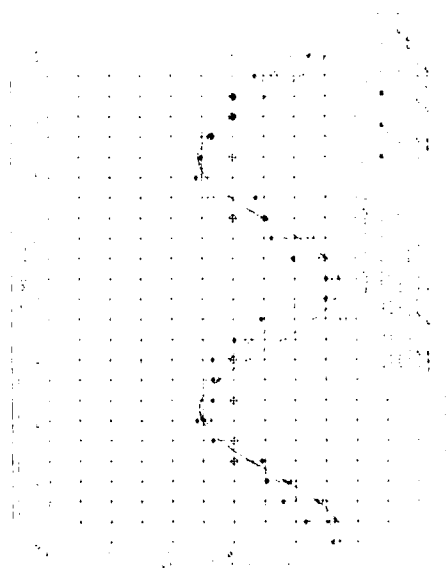
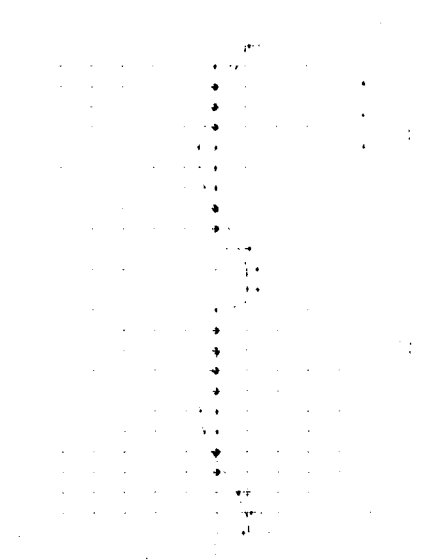
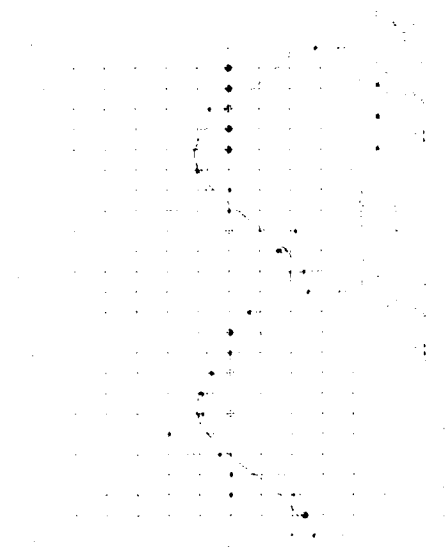
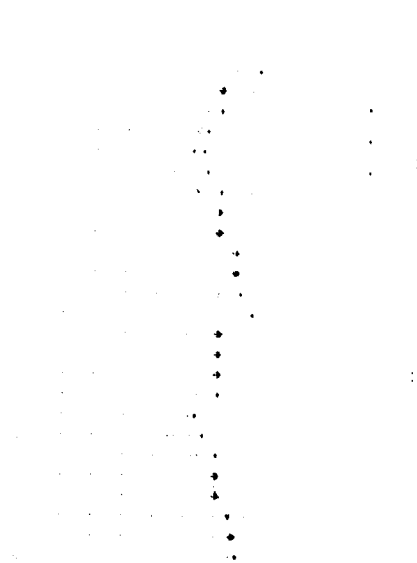
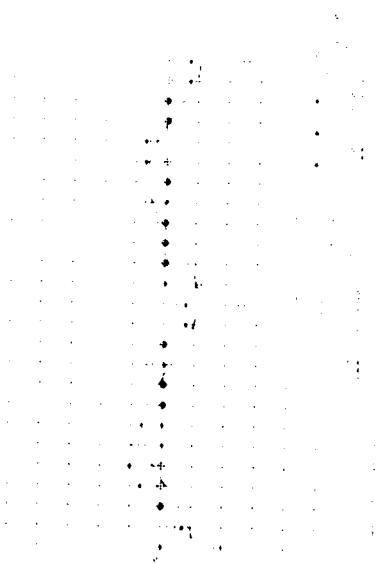
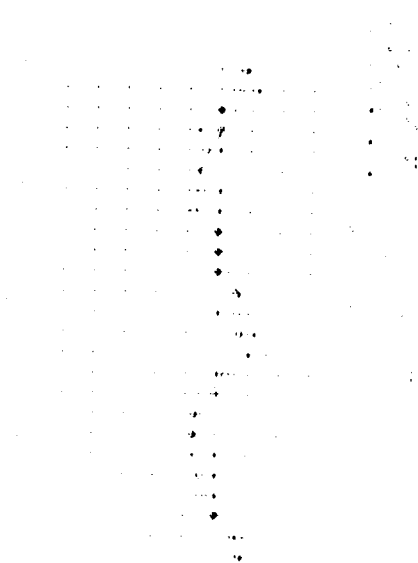
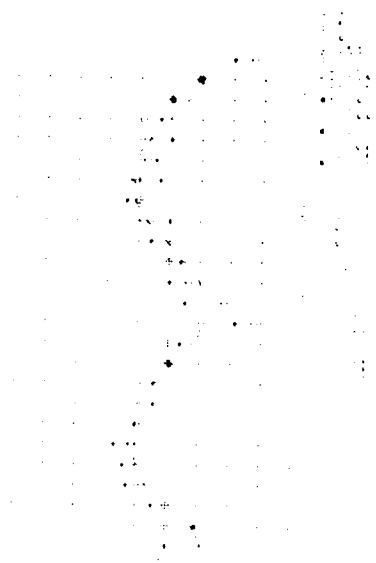
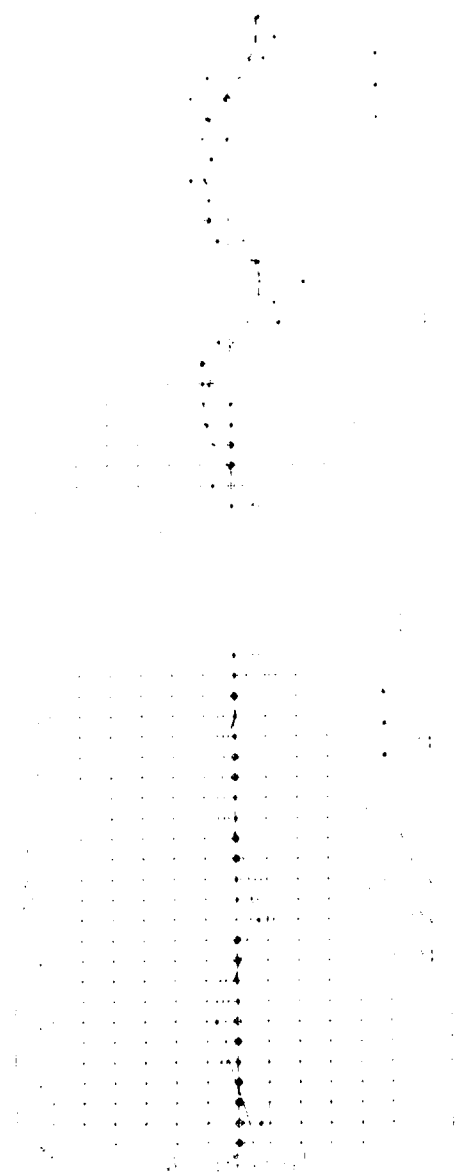
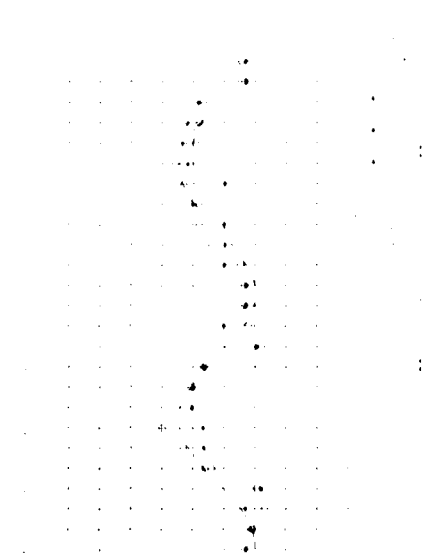
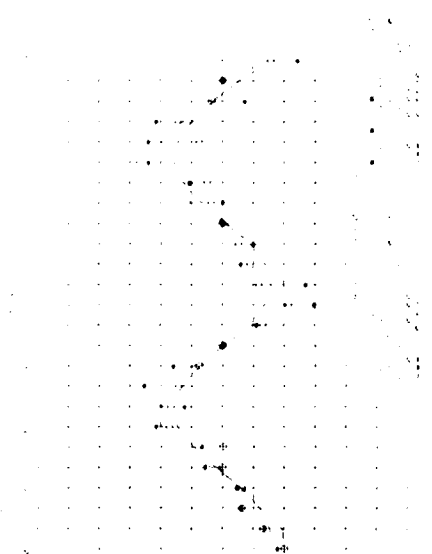
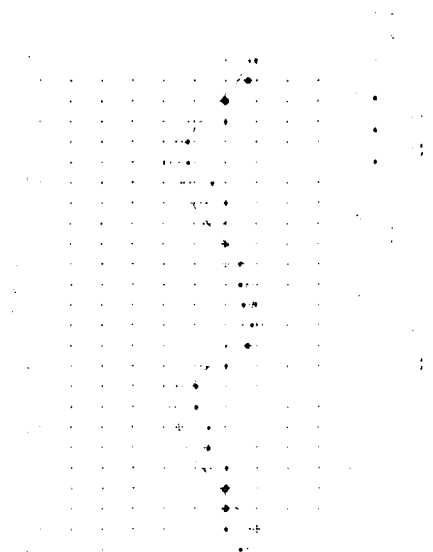
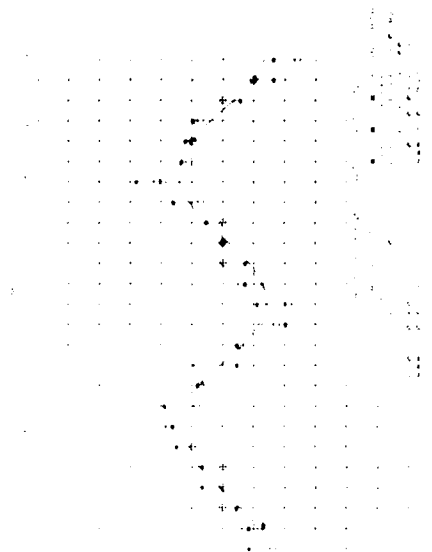


PLATE 106







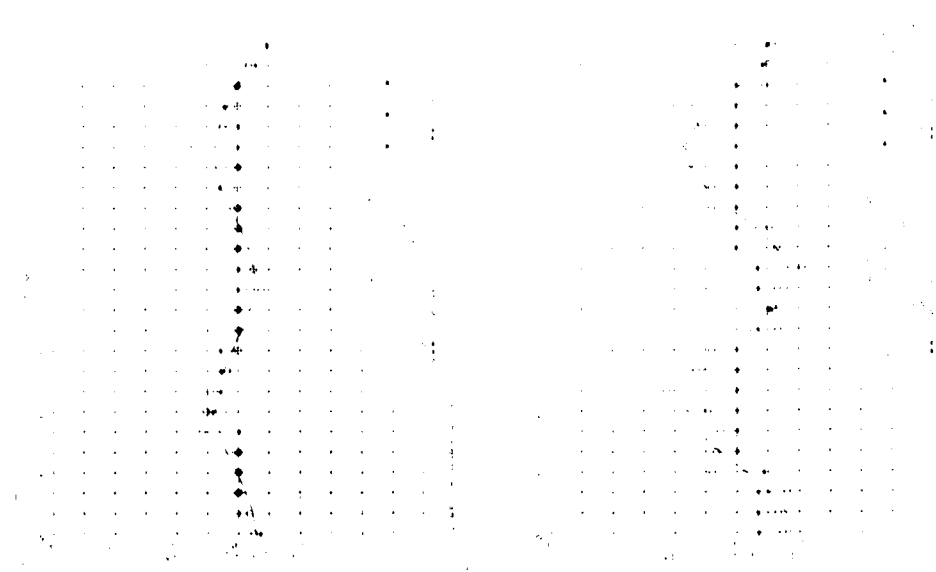
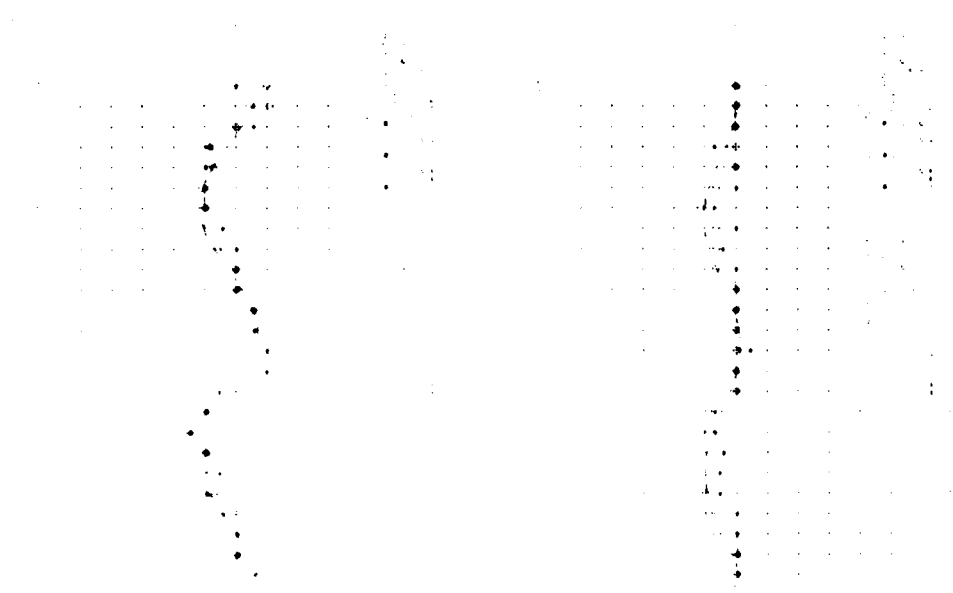
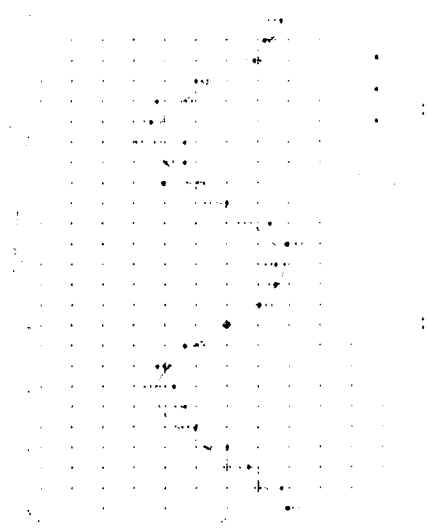
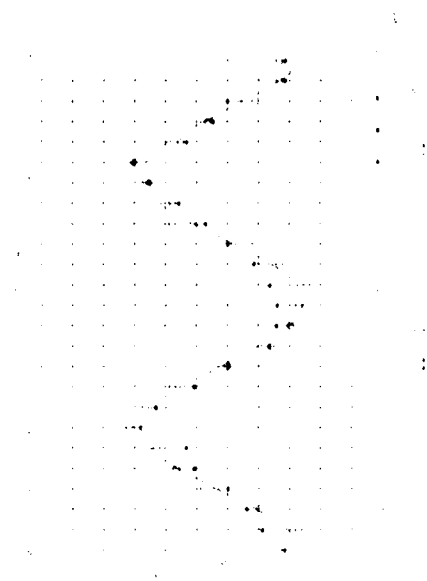
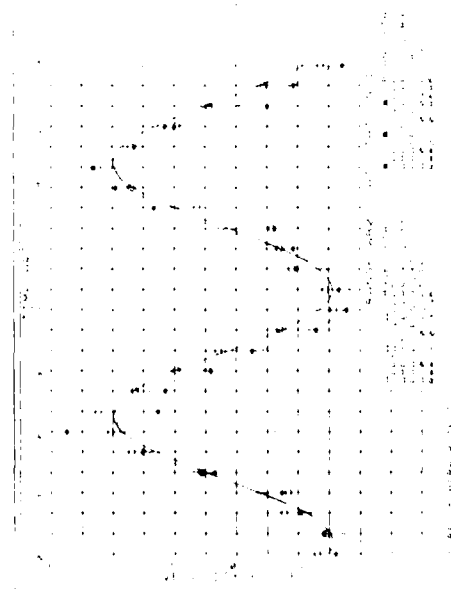
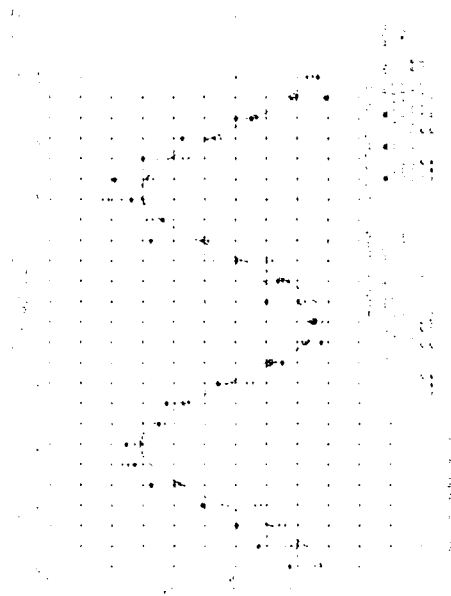


PLATE 110



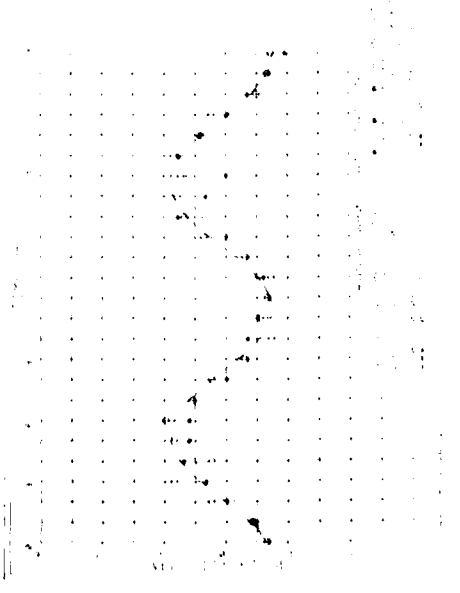
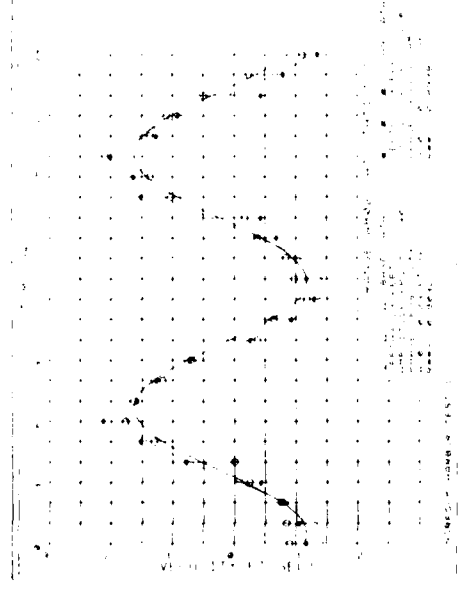
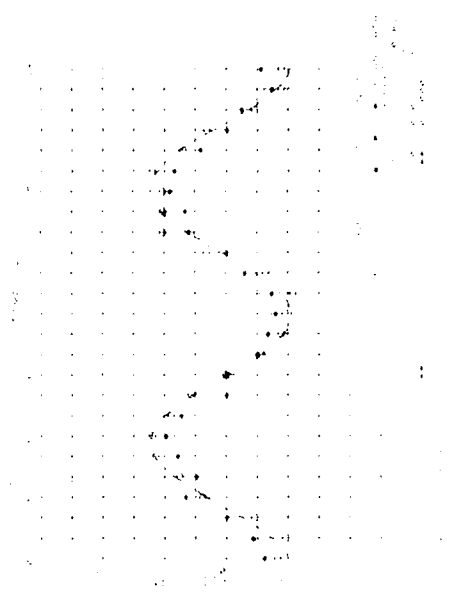
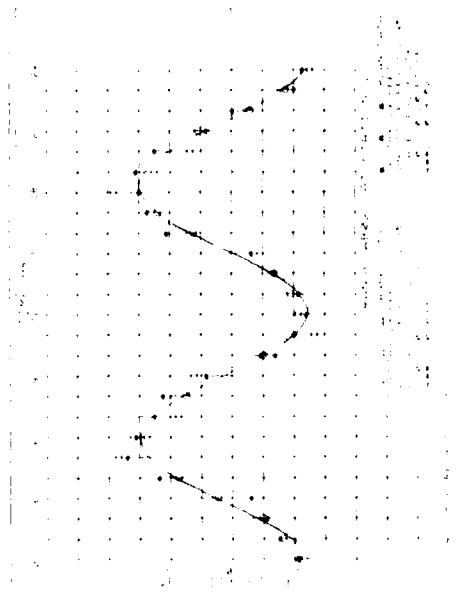
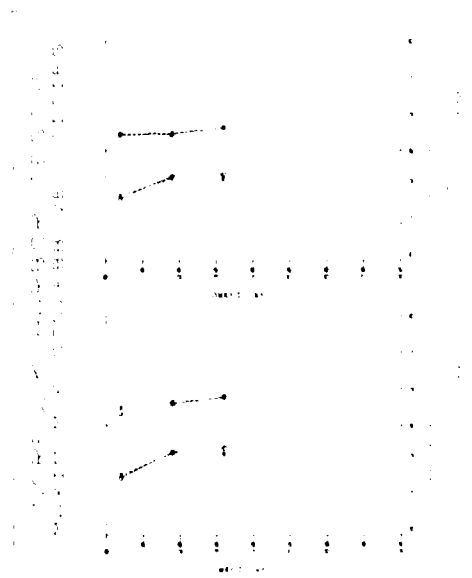
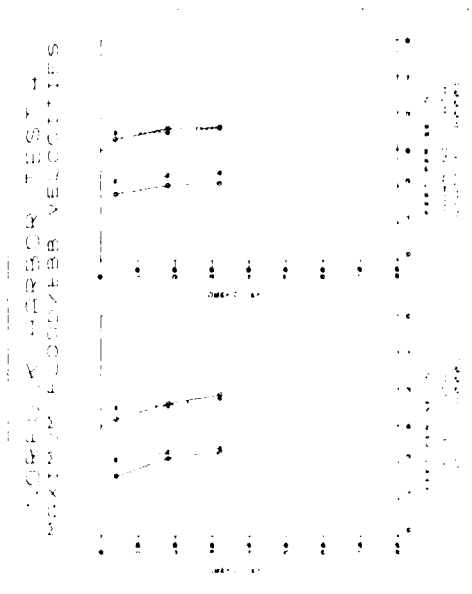
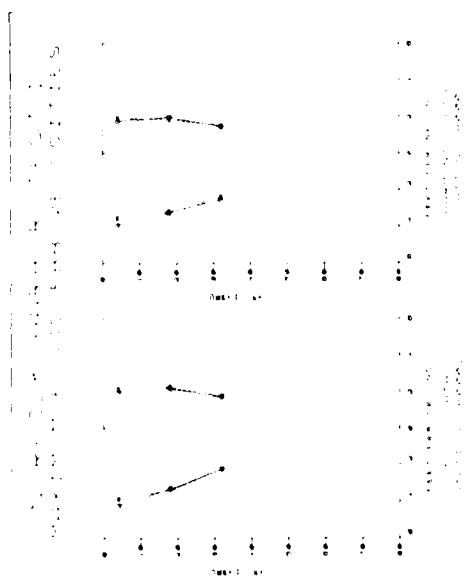
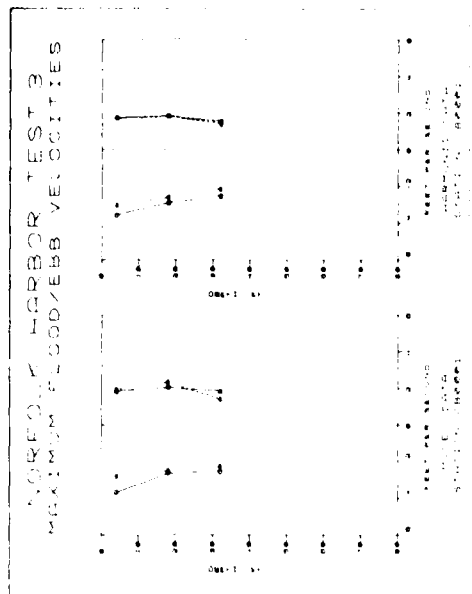
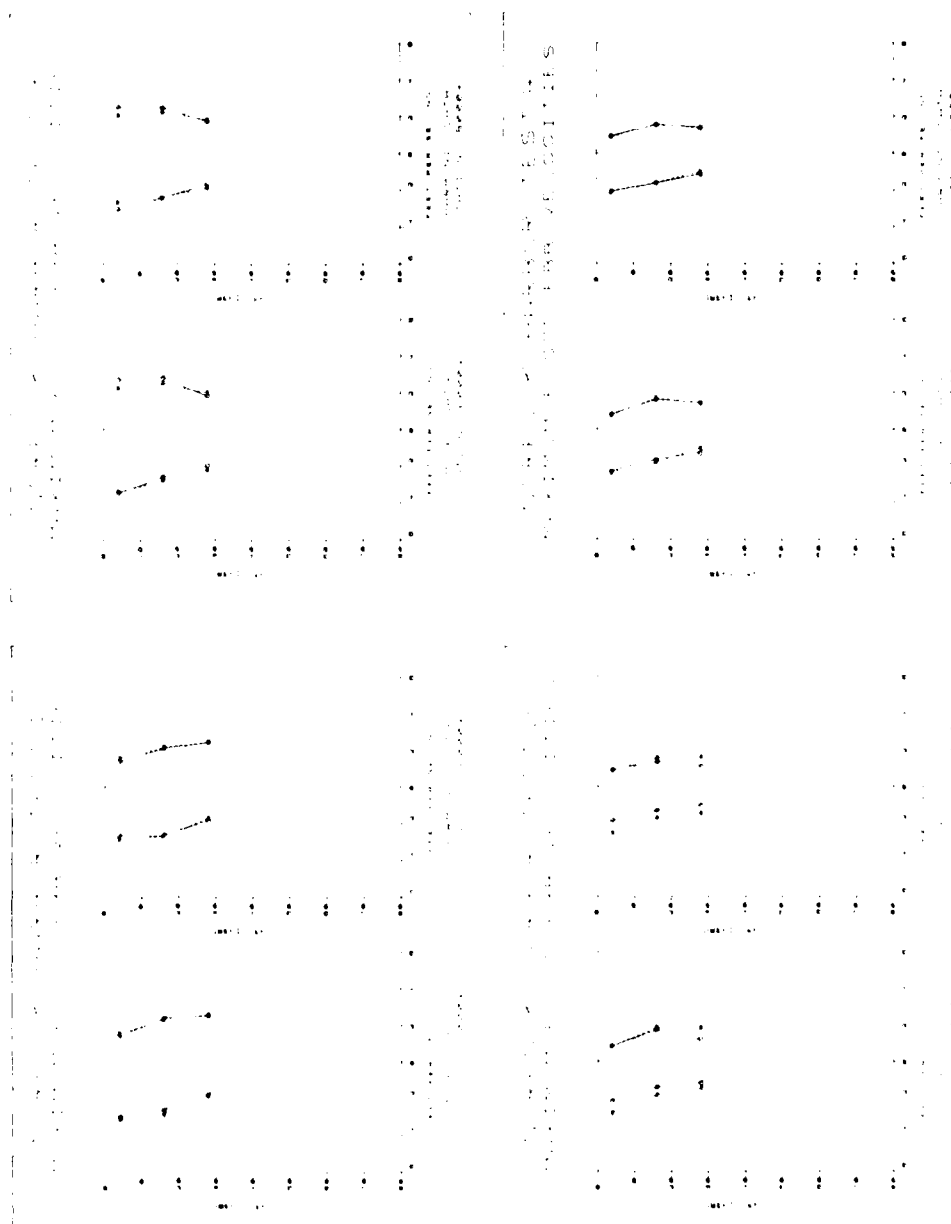


PLATE 112



0 10 20 30 40 50 60 70 80 90 100
PLAN



SE
SC
SQ
S
C
Q
S

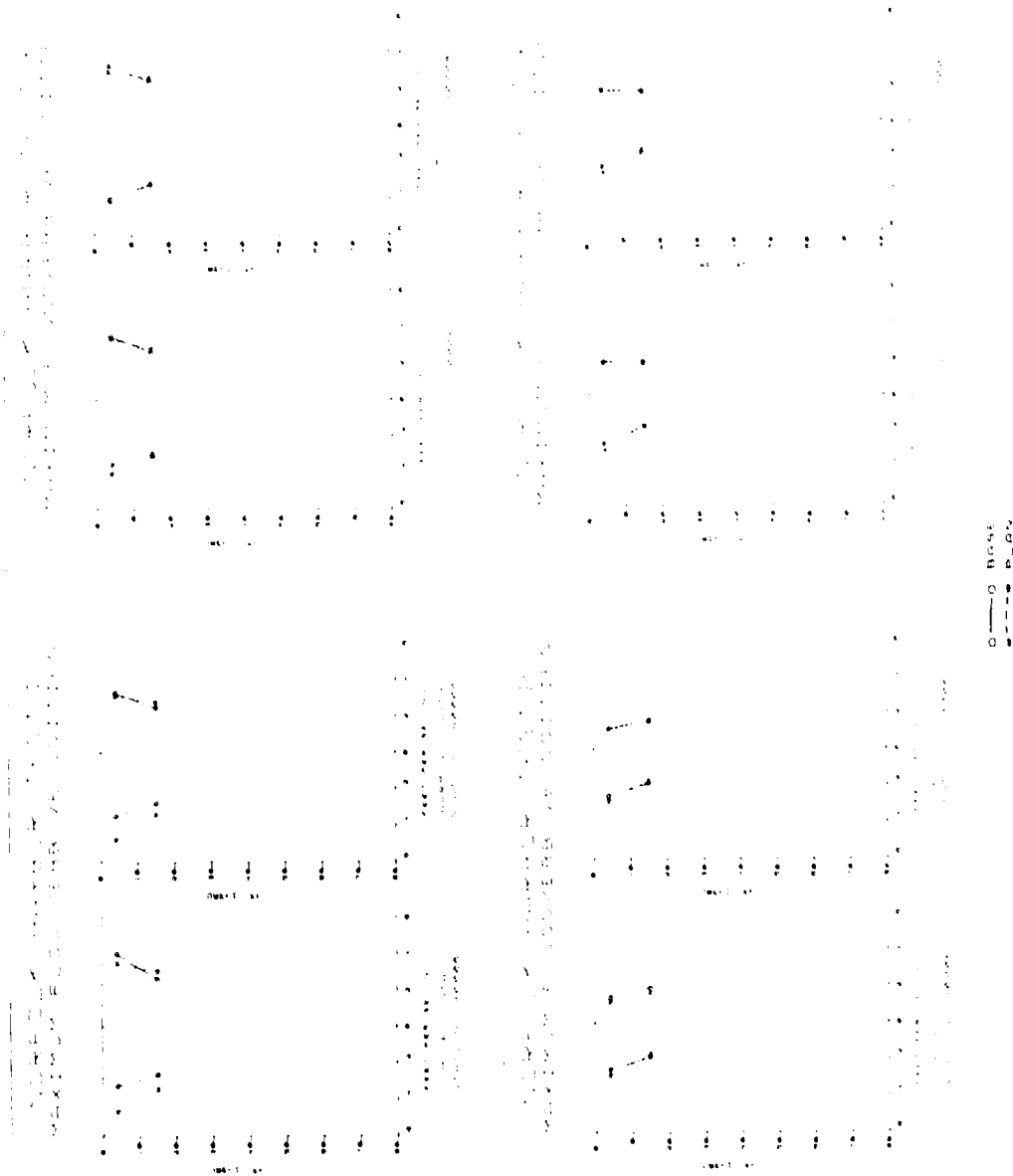


PLATE 116

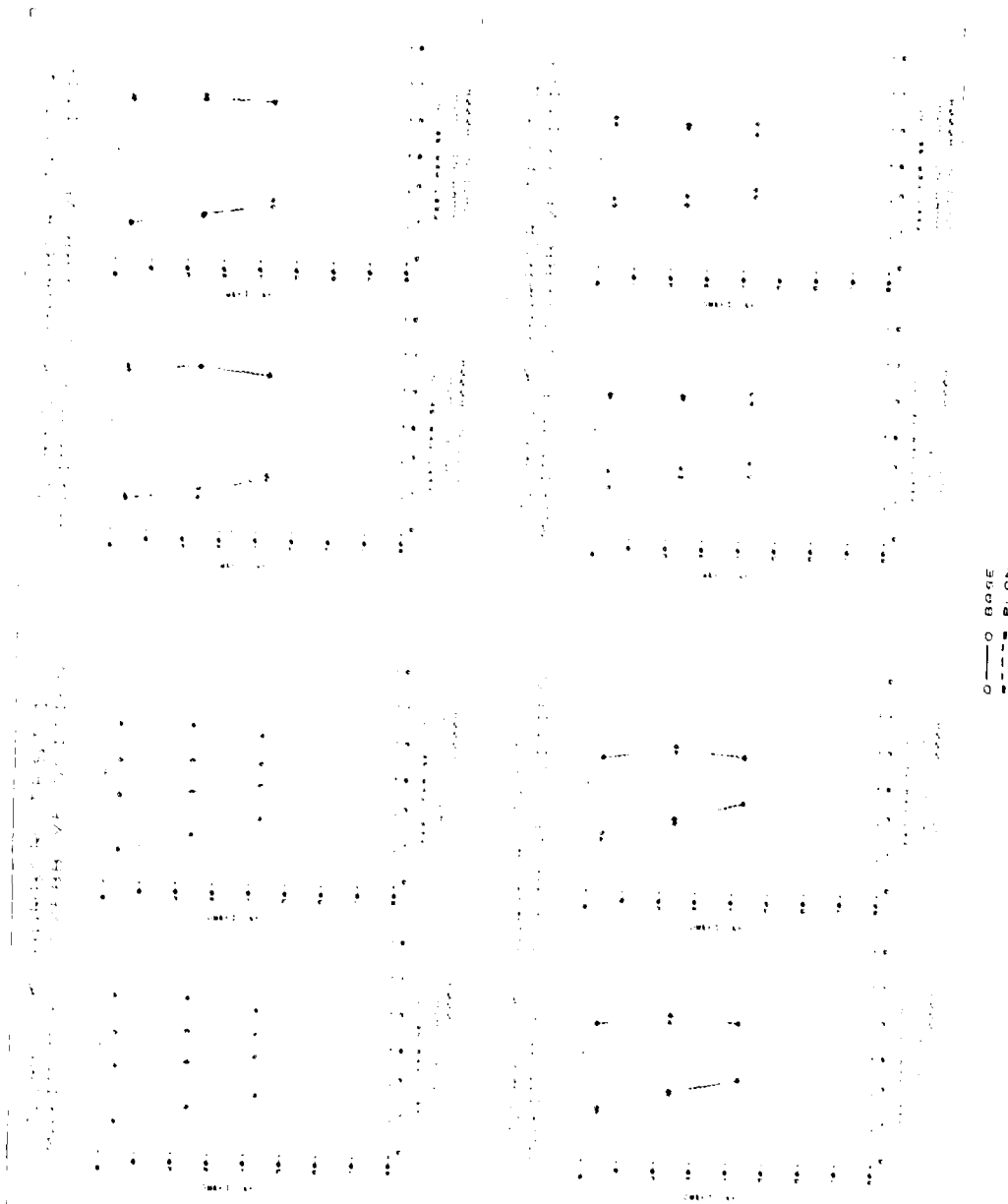
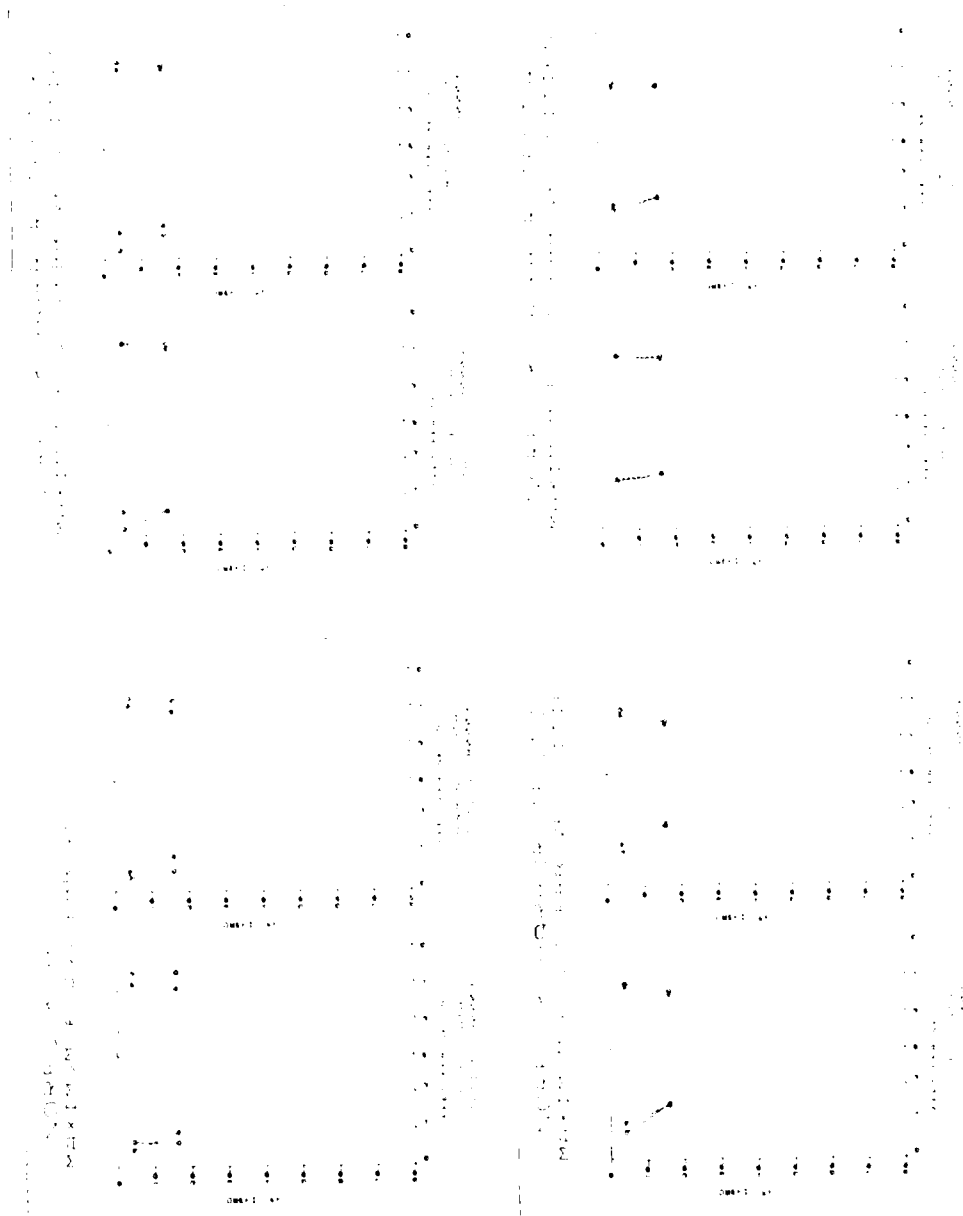
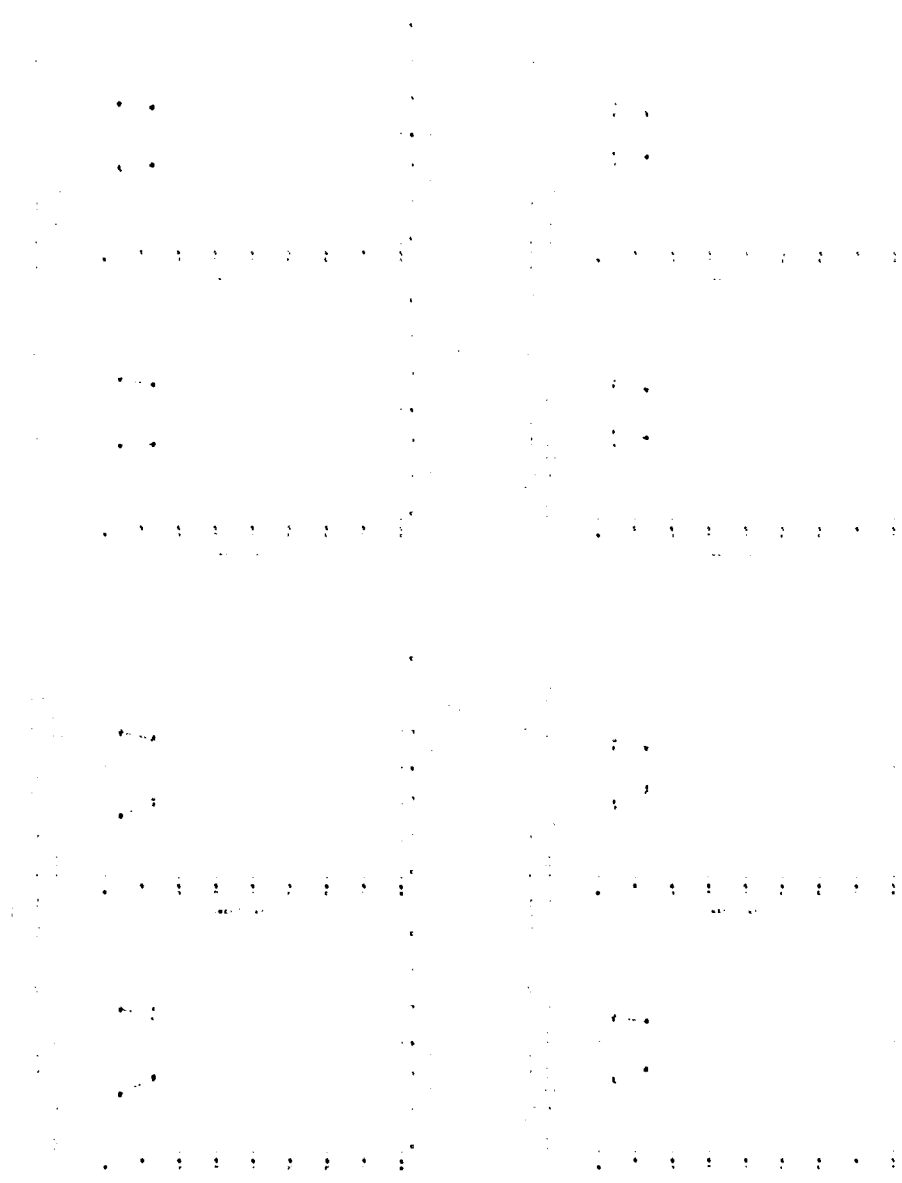


PLATE 117



0 BASE
0 PLON

PLATE 118



0 1 2 3 4 5 6 7 8 9

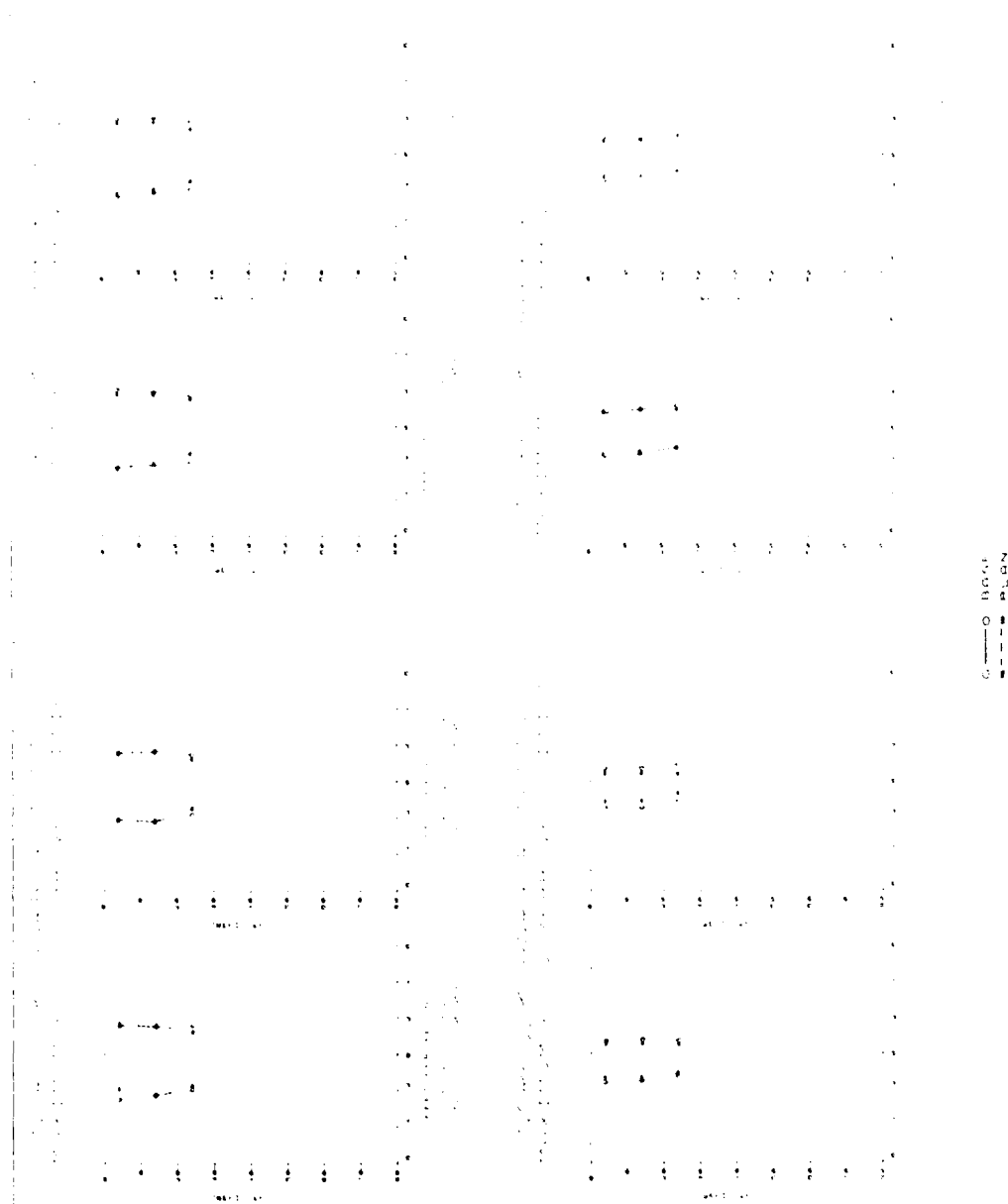


PLATE 120

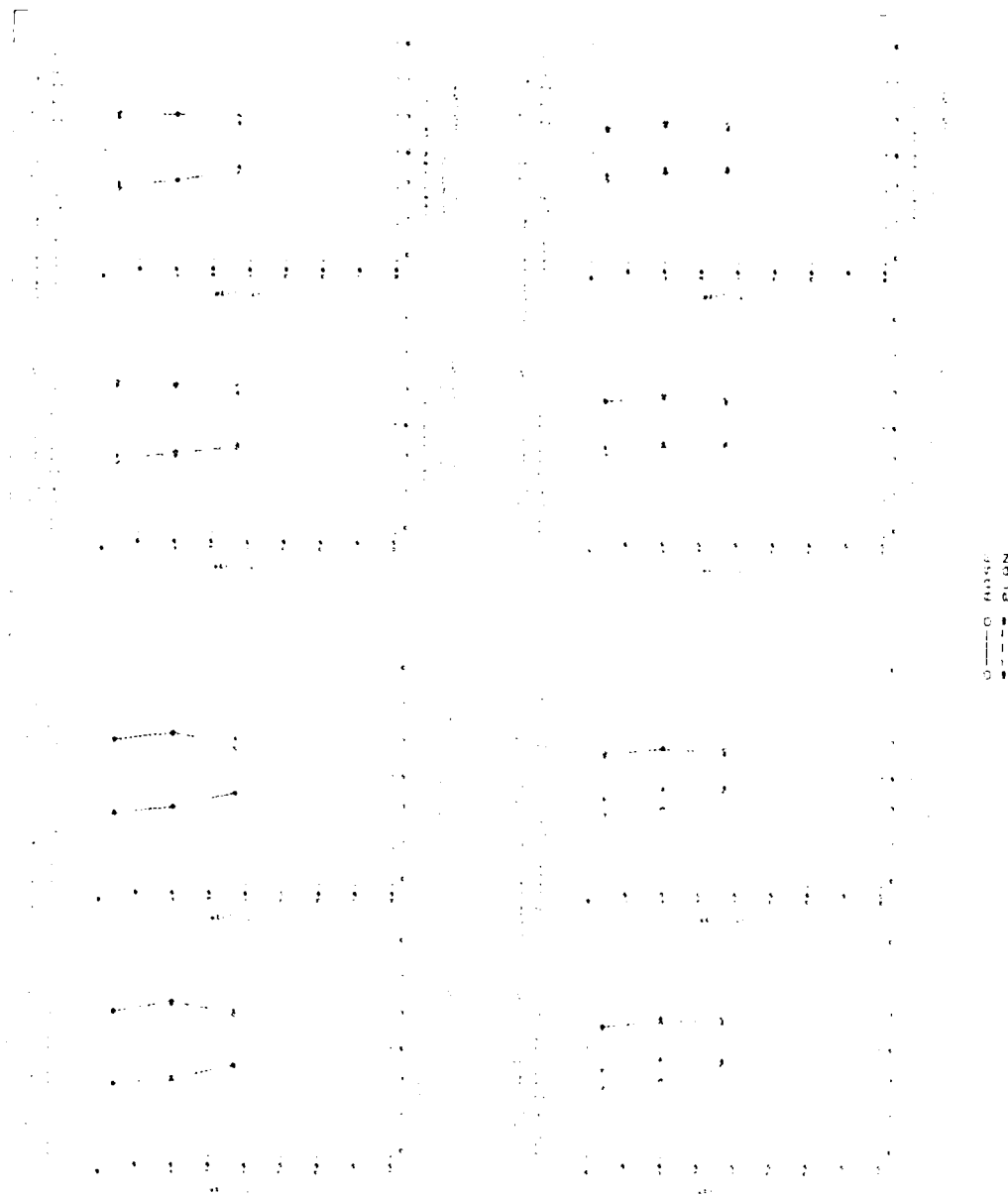
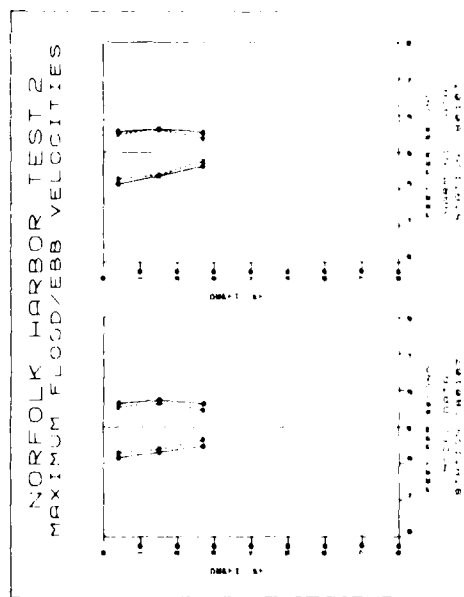
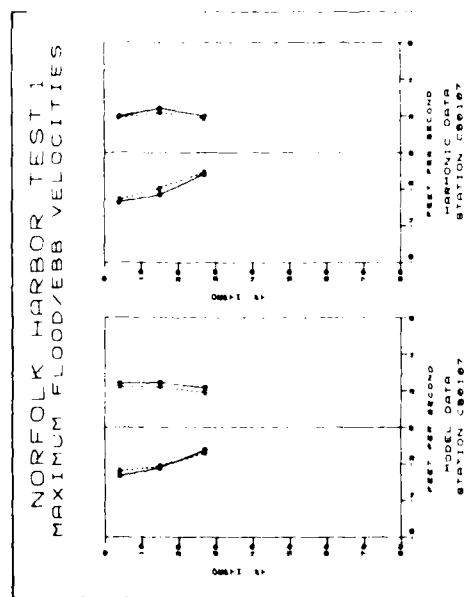
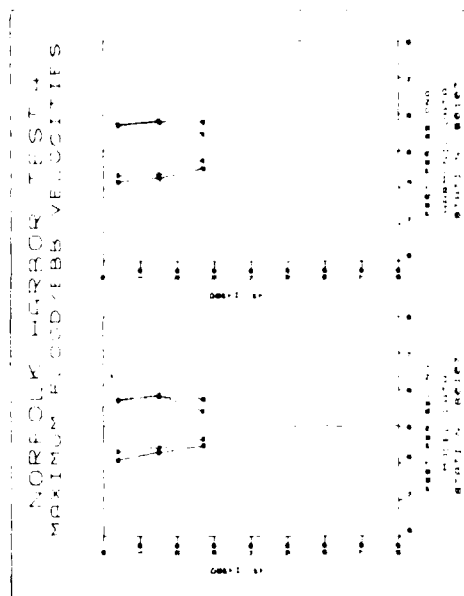
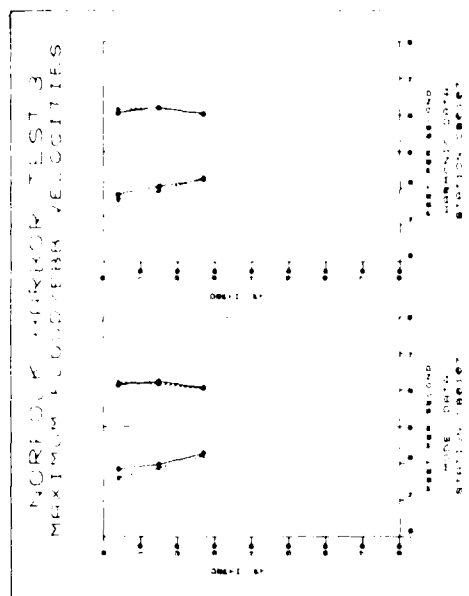


PLATE 121



0.00000000
PLAN

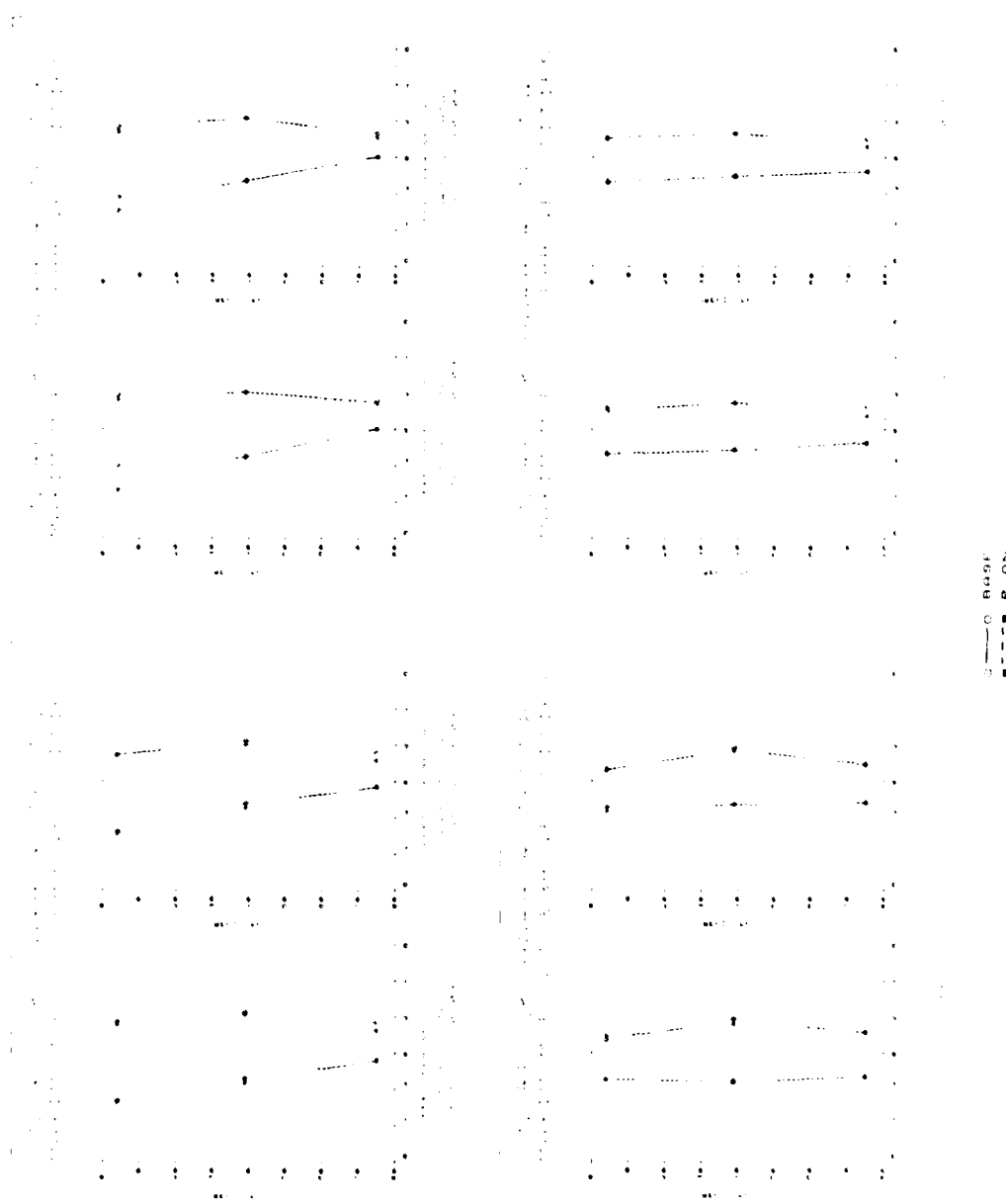
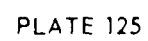


PLATE 123





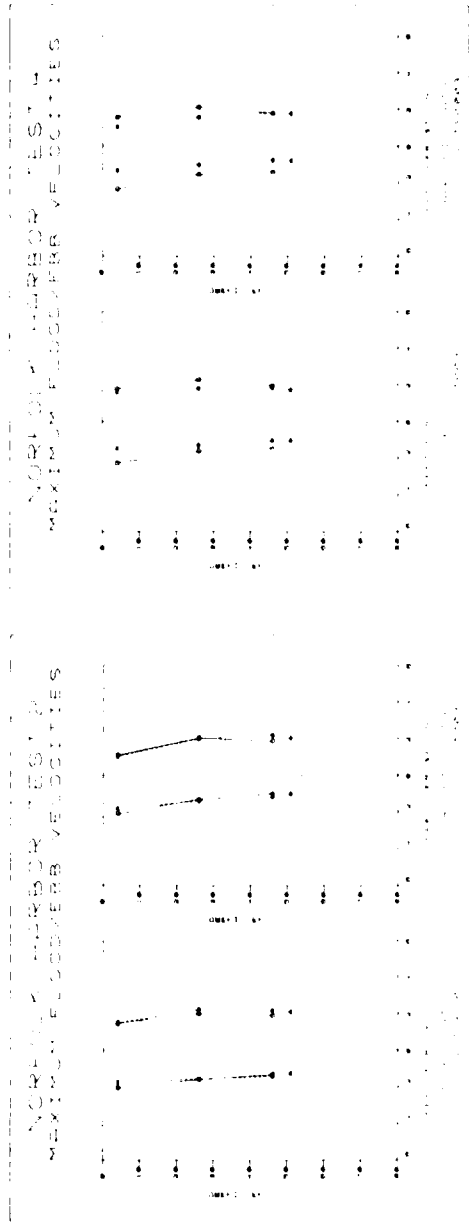
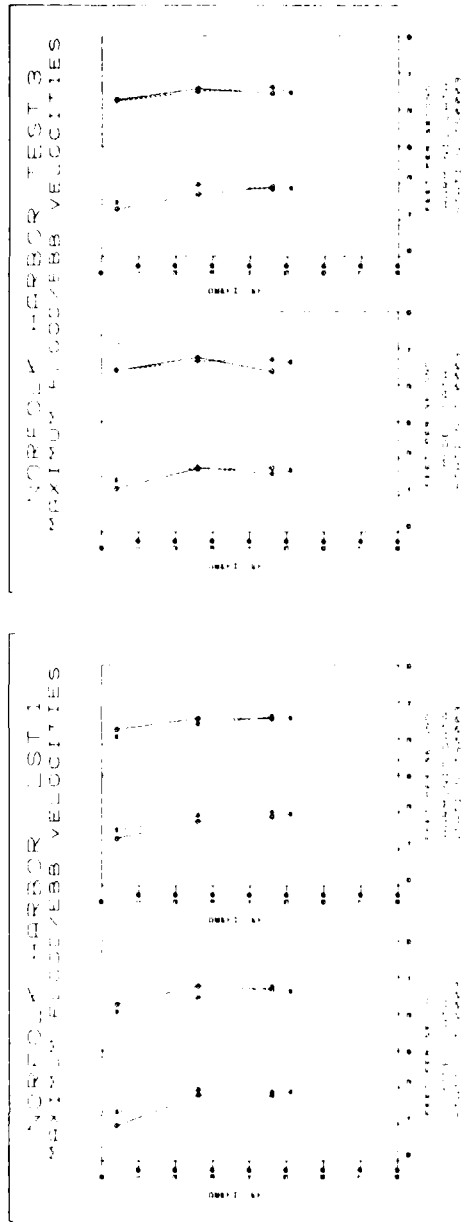
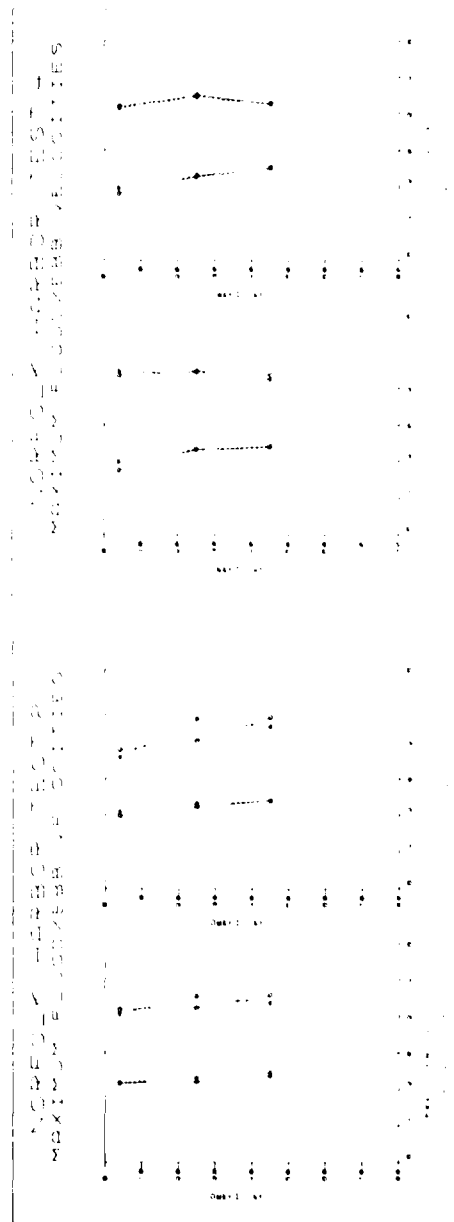
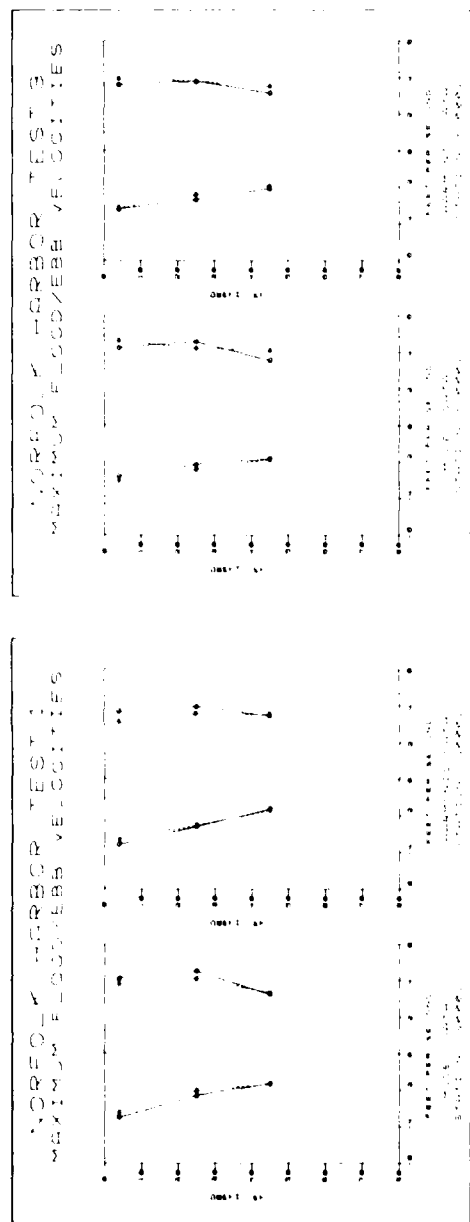


PLATE 126



0 1 2 3 4 5 6 7 8 9 10

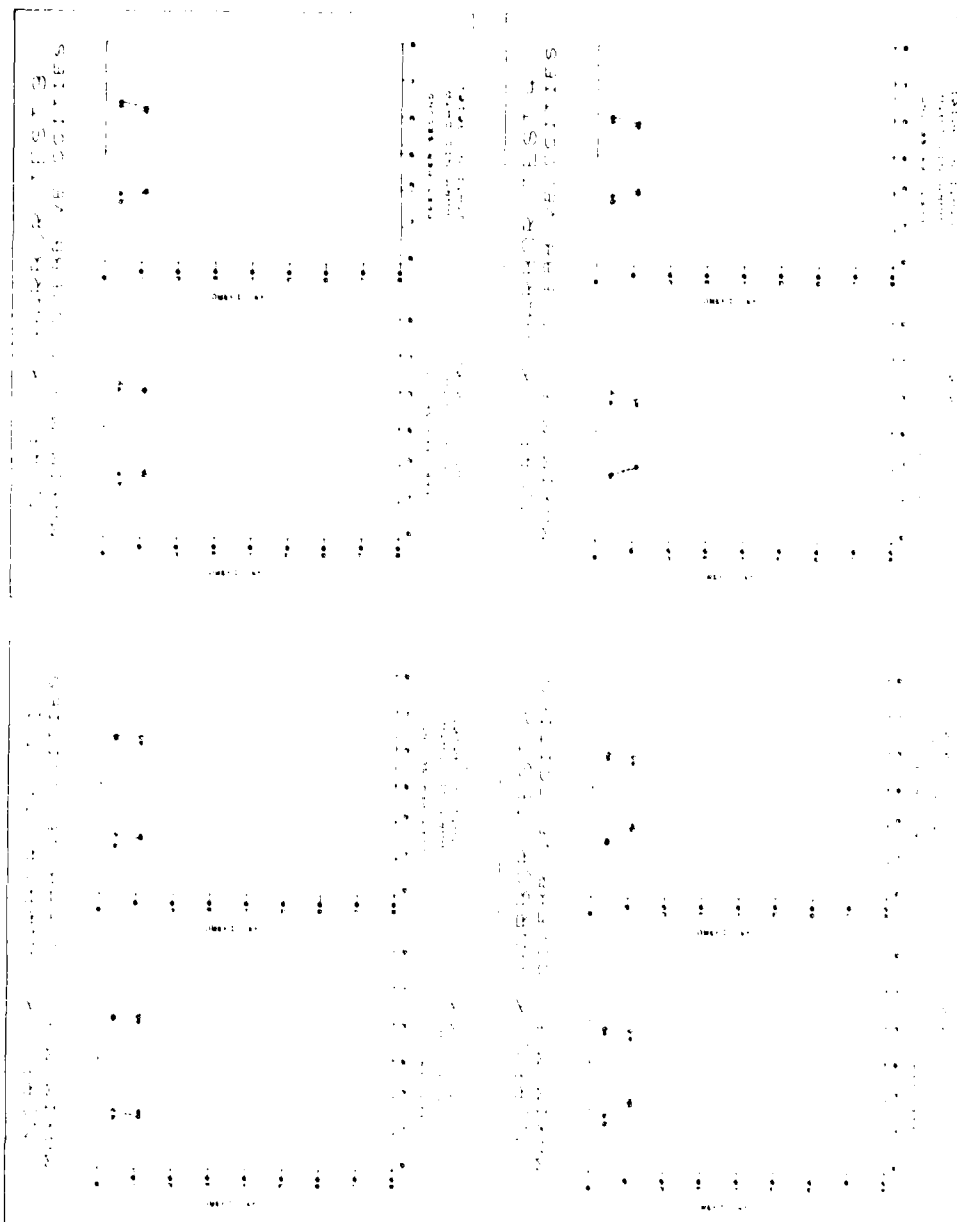


PLATE 129

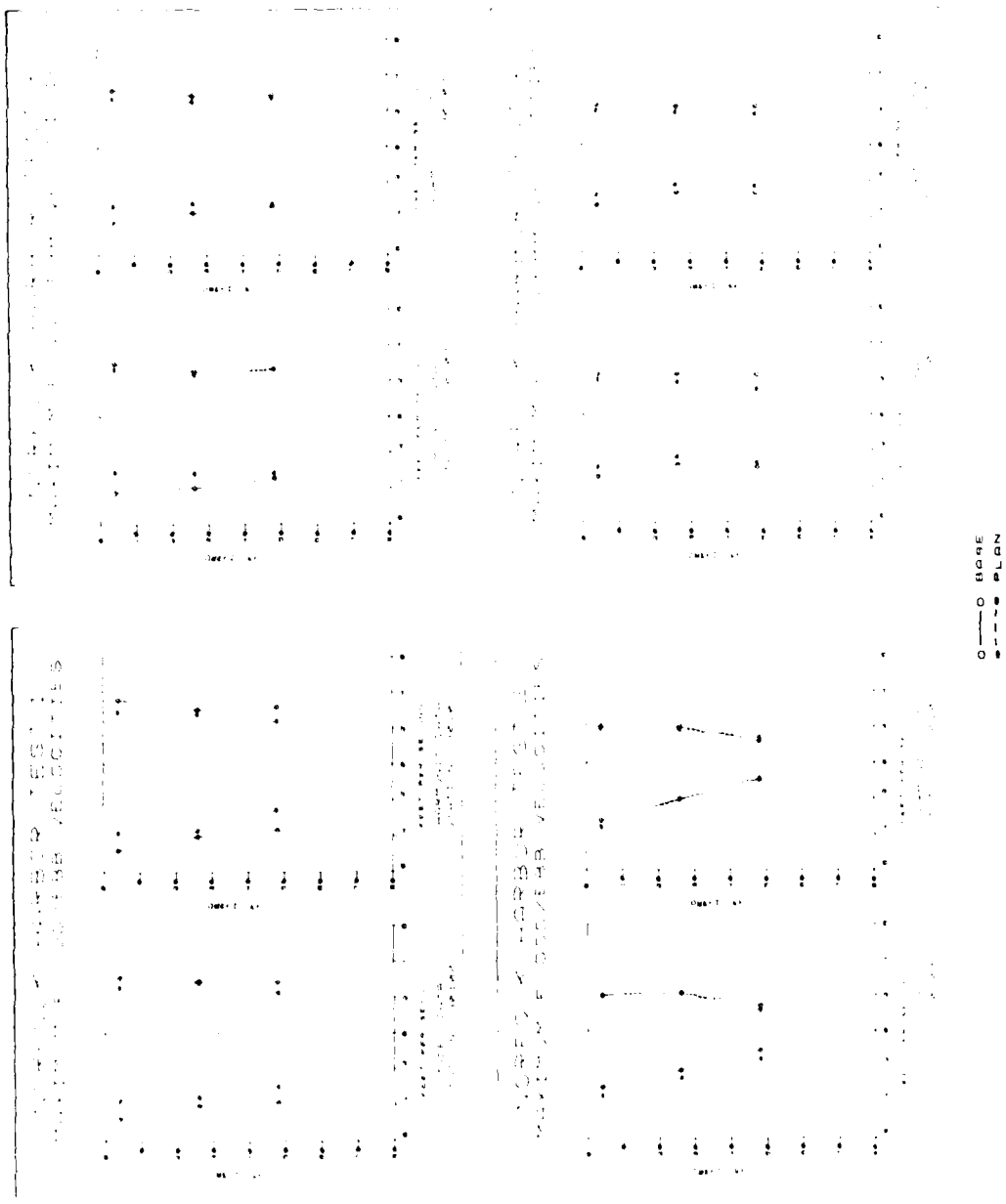
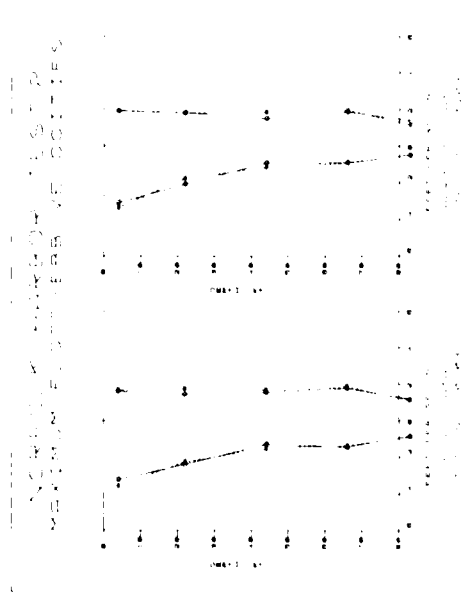
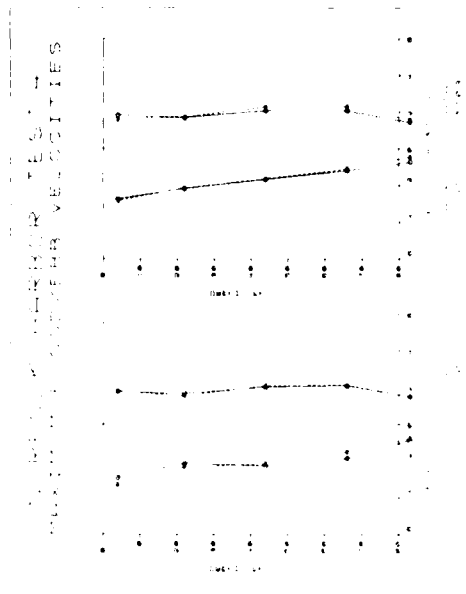
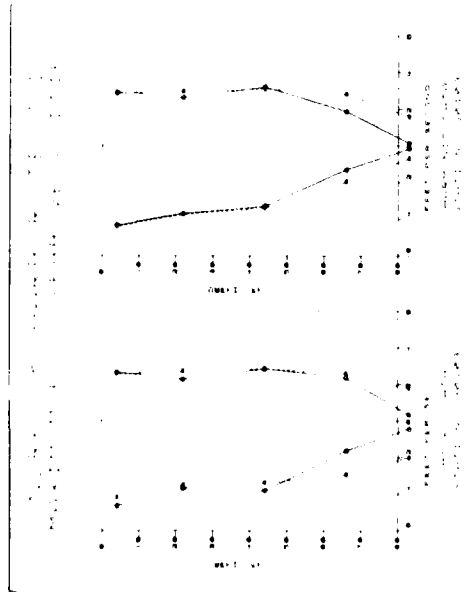
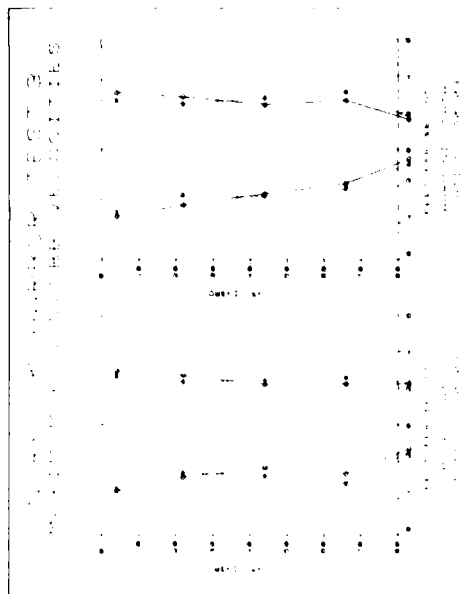


PLATE 130



0 1 2 3 4 5 6 7 8 9 10

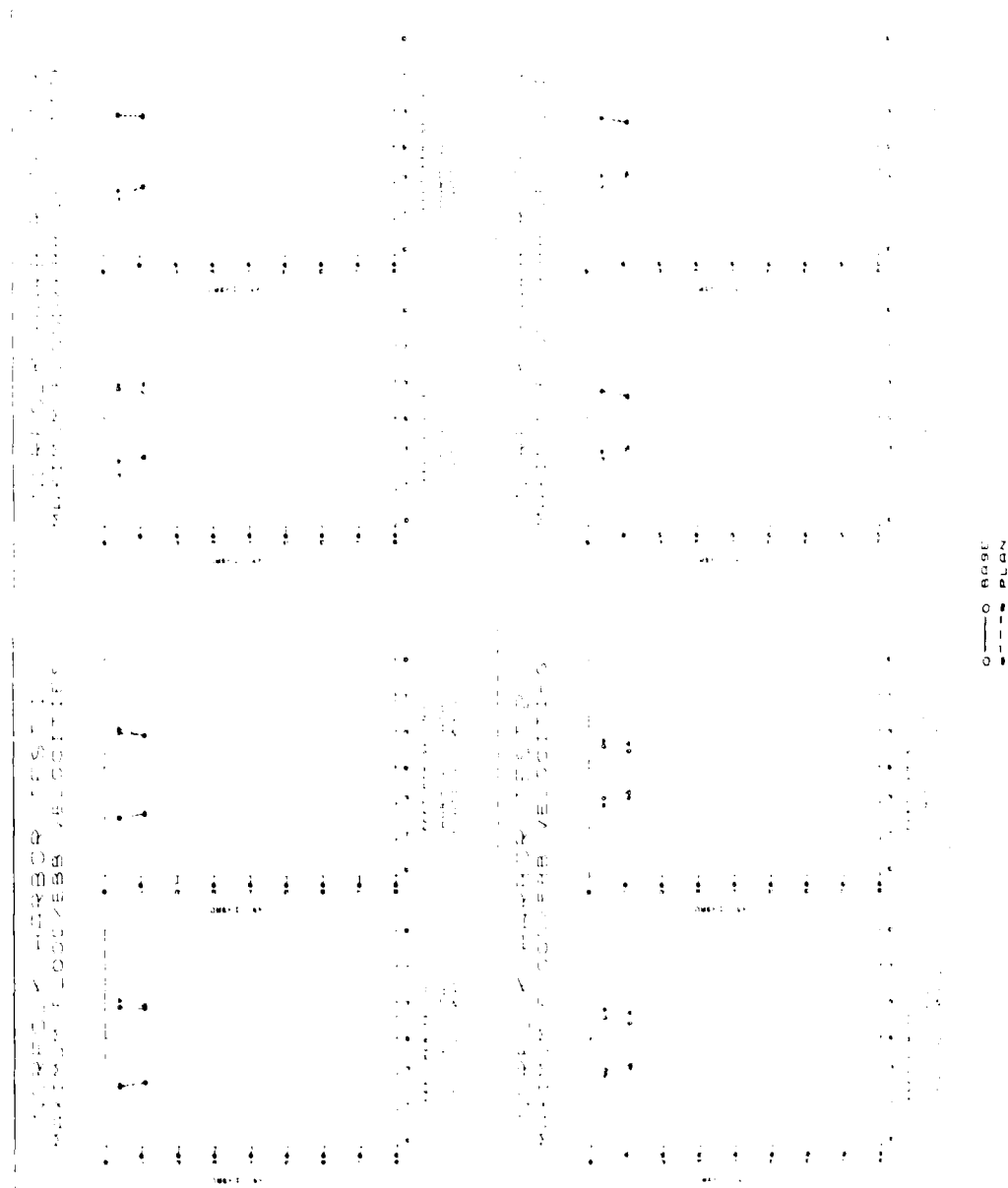


PLATE 132

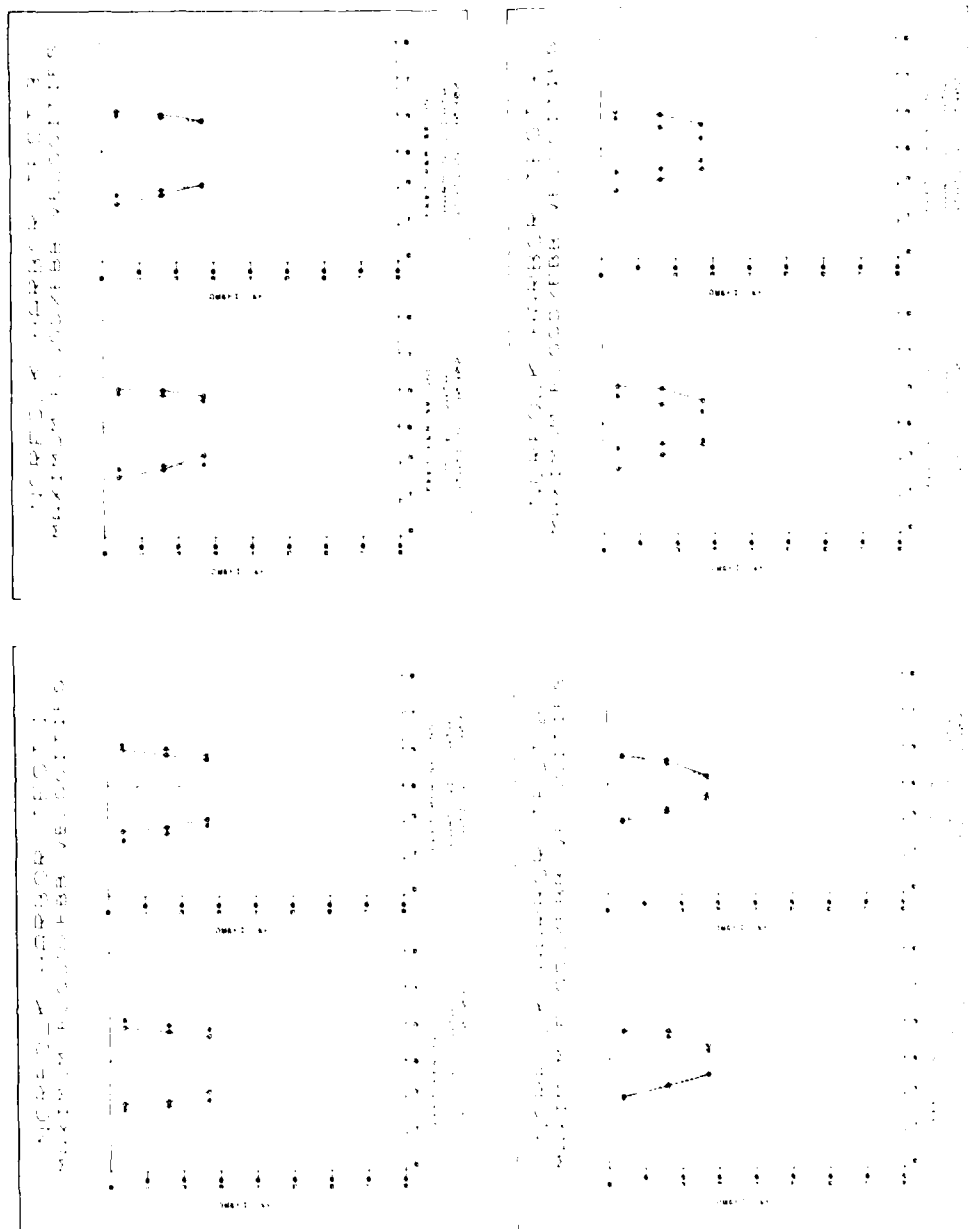
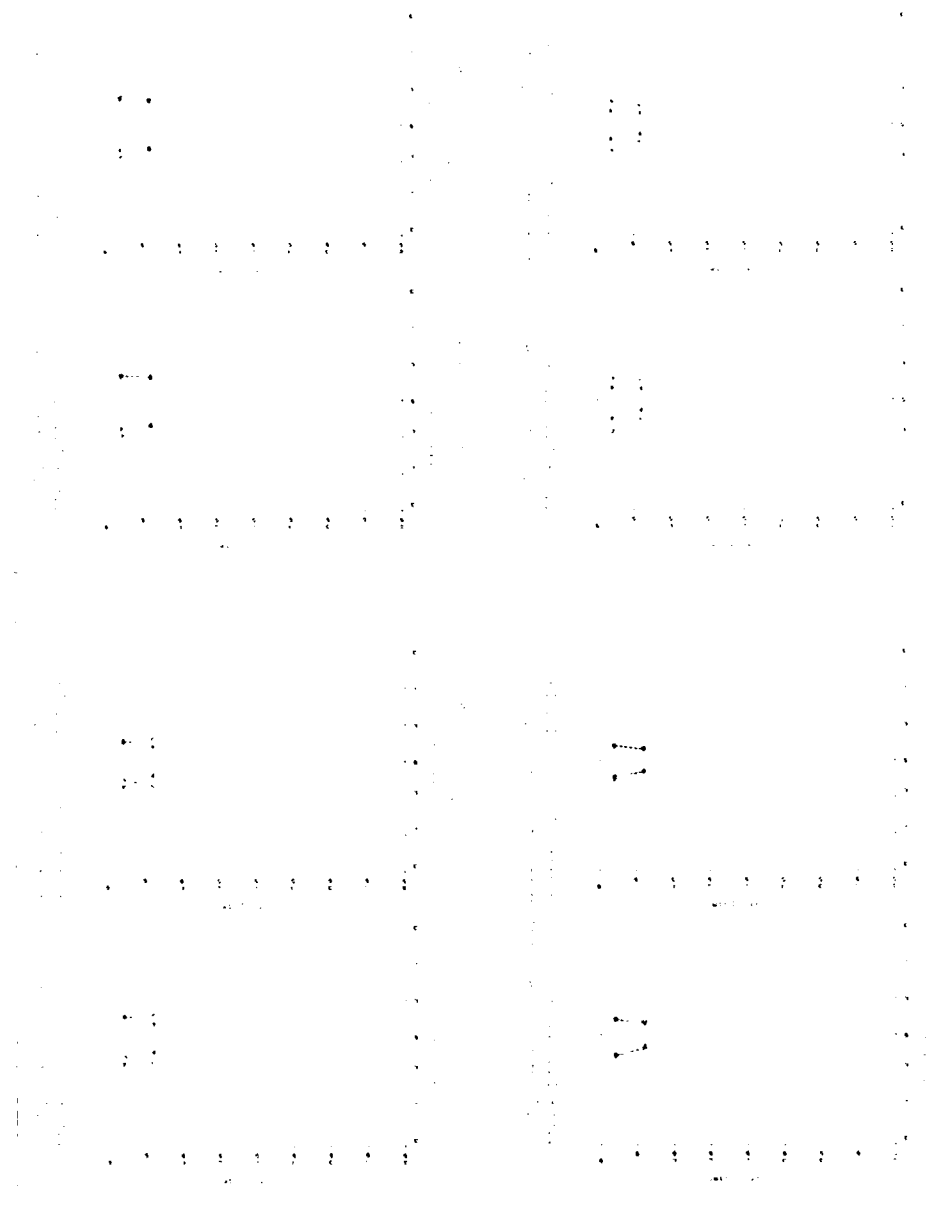


PLATE 133



0 1 2 3 4 5 6 7 8 9
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

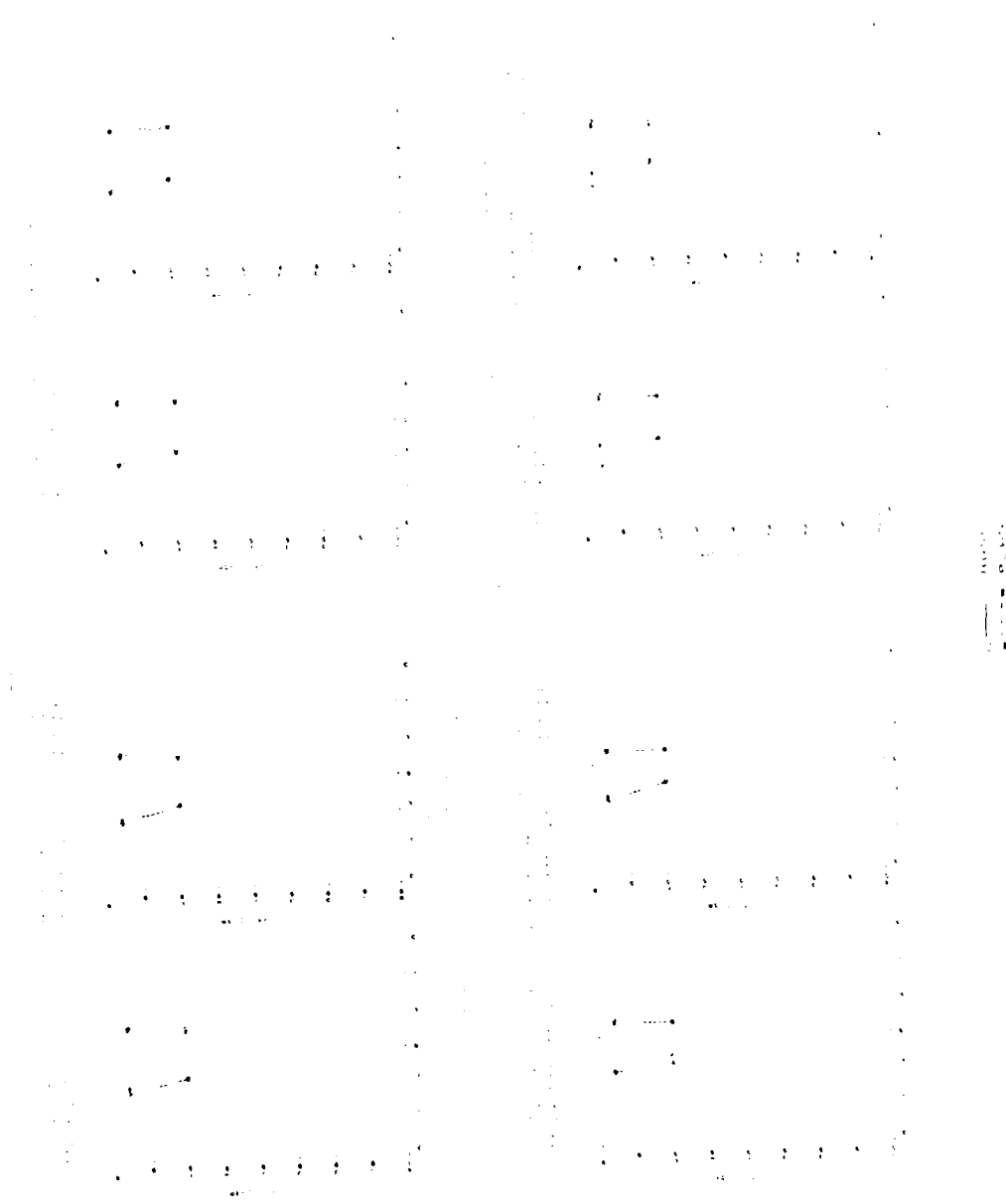
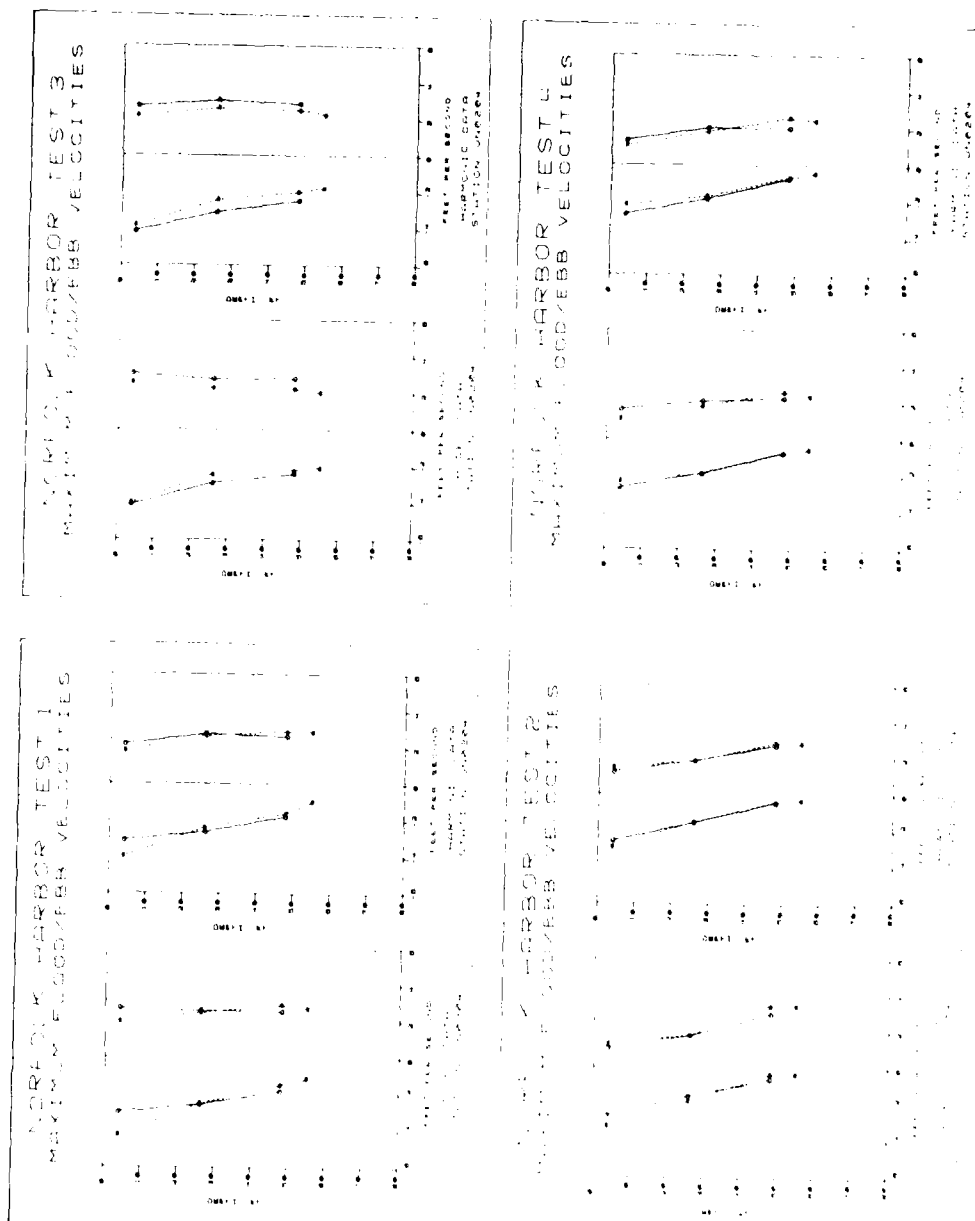


PLATE 136



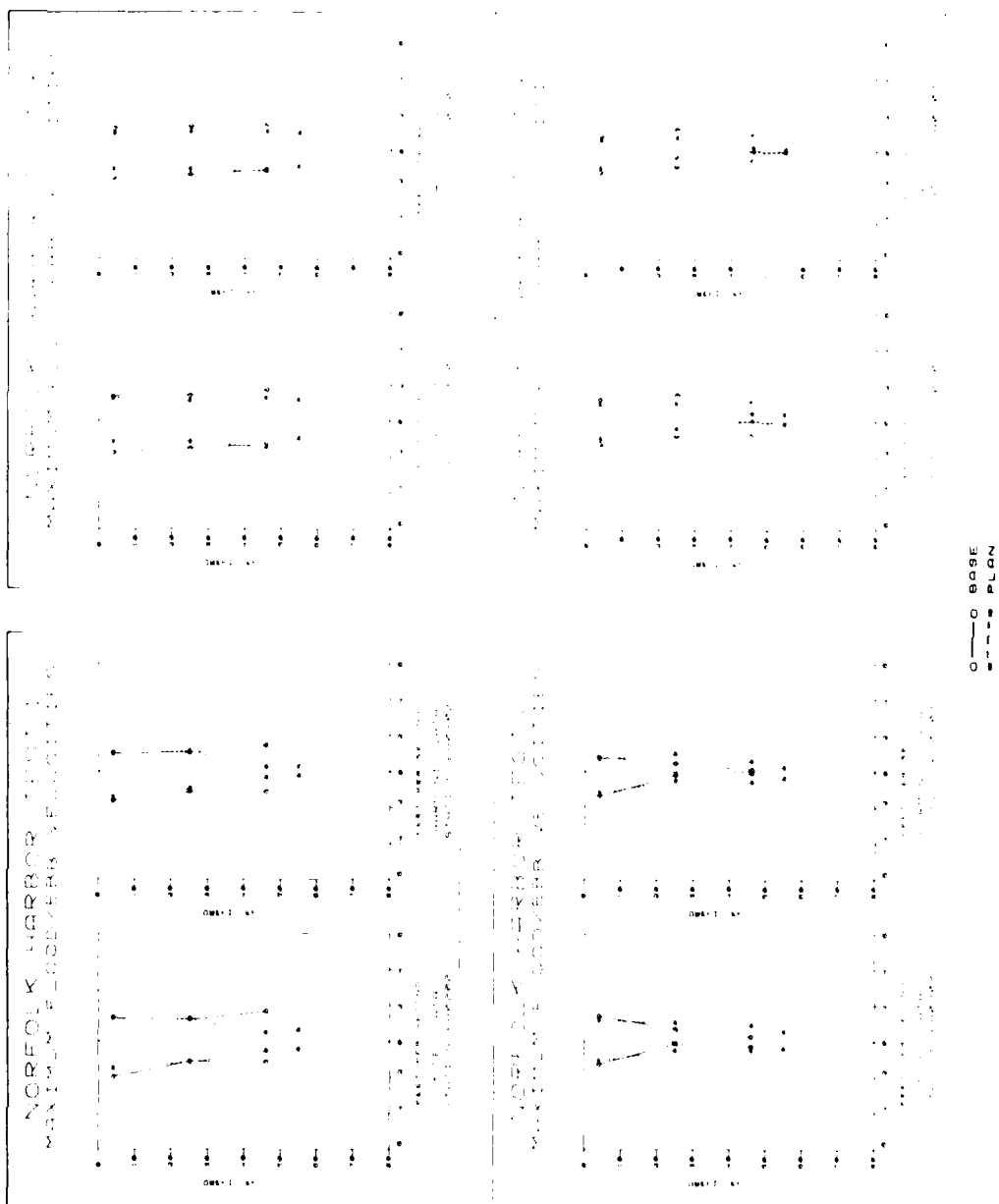
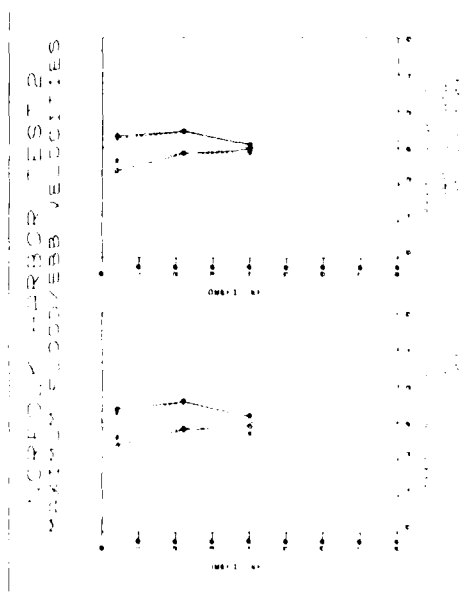
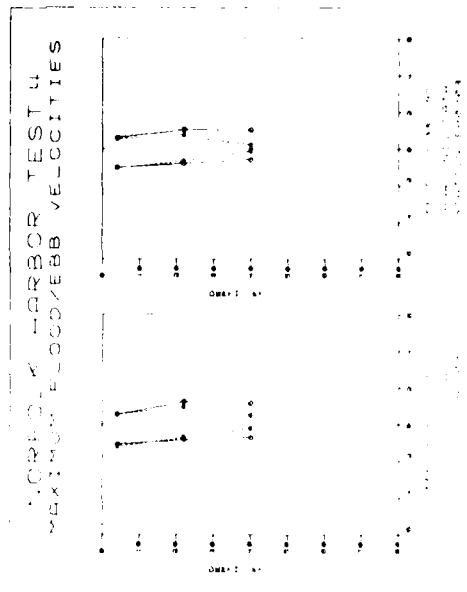
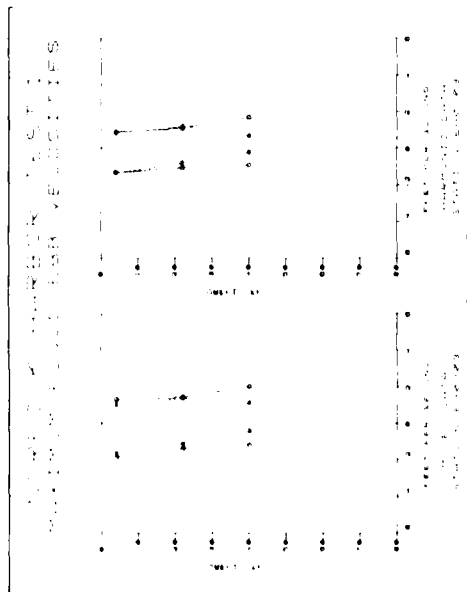
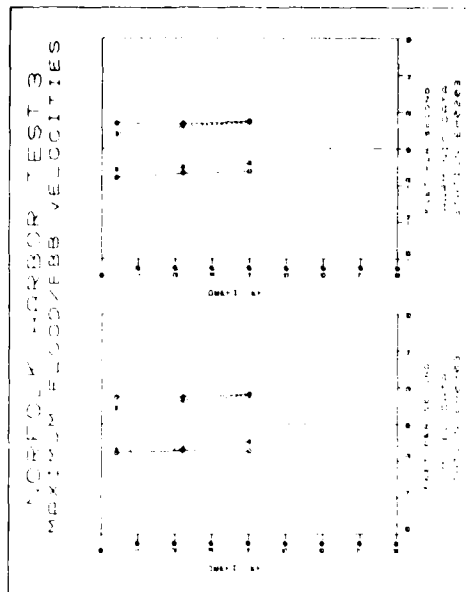
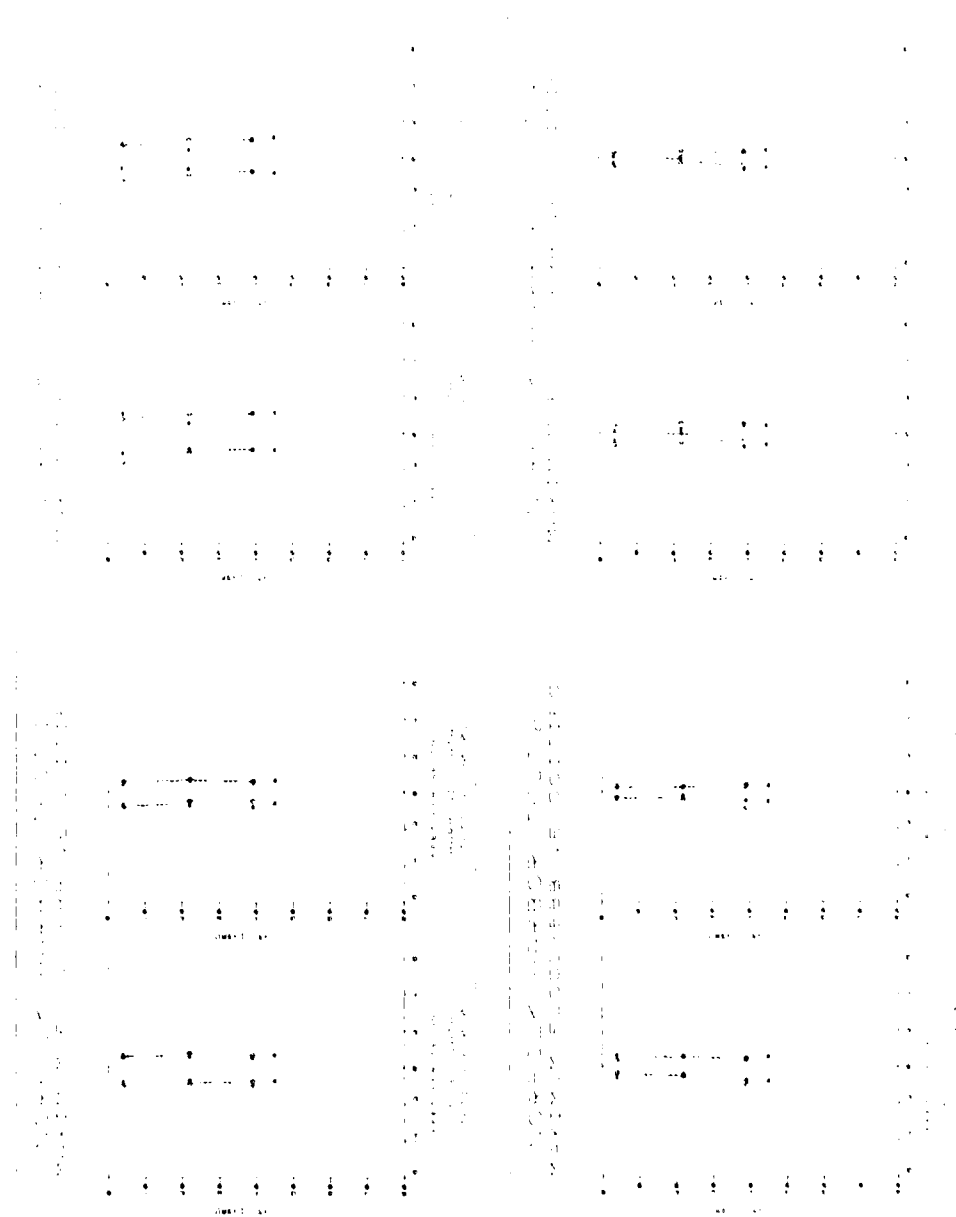


PLATE 138



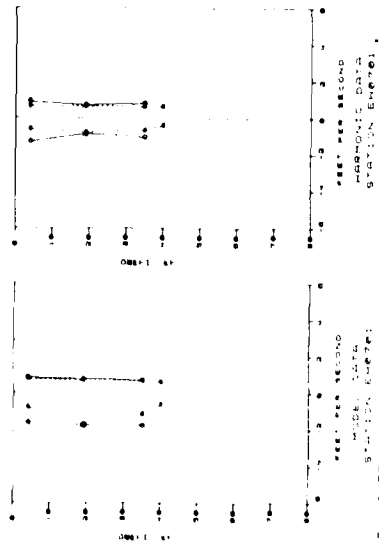
0 BASE
- PLAN



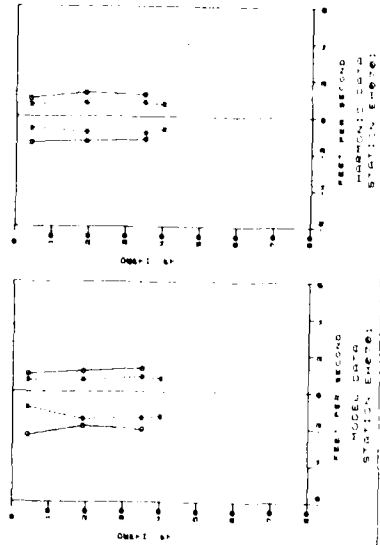
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100

PLATE 140

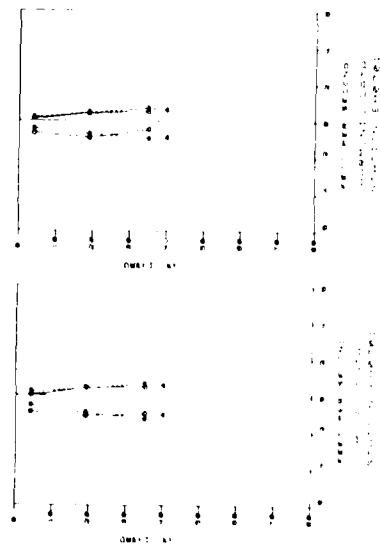
NORFOLK HARBOR TEST 1 MAXIMUM FLOOD/EBB VELOCITIES



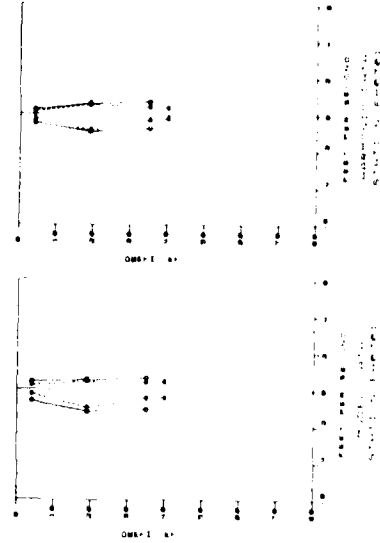
NORFOLK HARBOR TEST 3 MAXIMUM FLOOD/EBB VELOCITIES



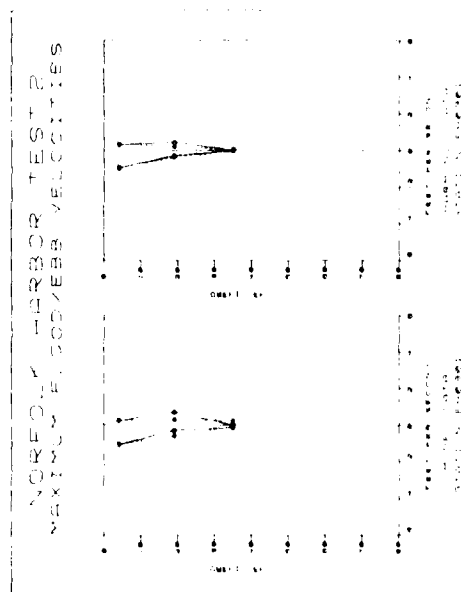
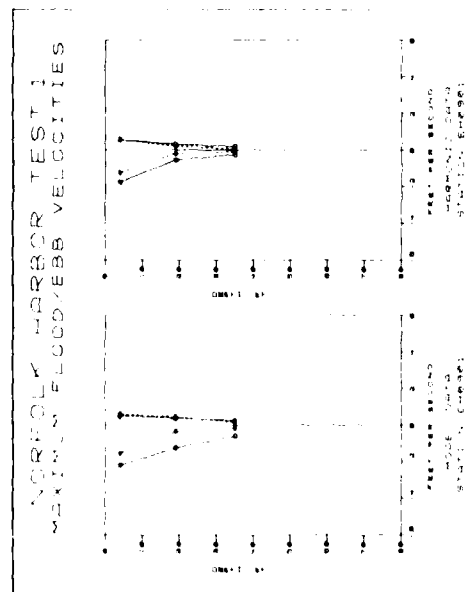
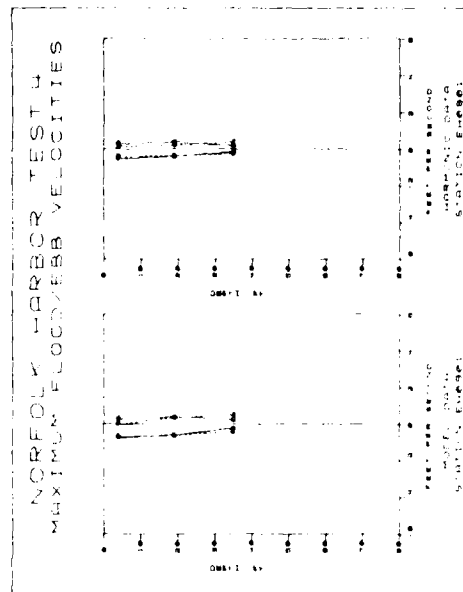
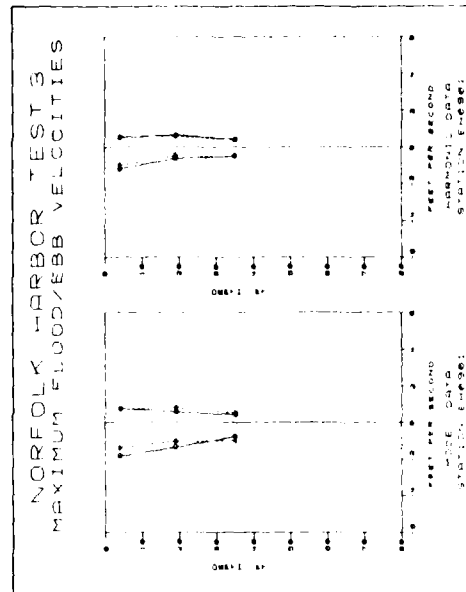
NORFOLK HARBOR TEST 2 MAXIMUM FLOOD/EBB VELOCITIES



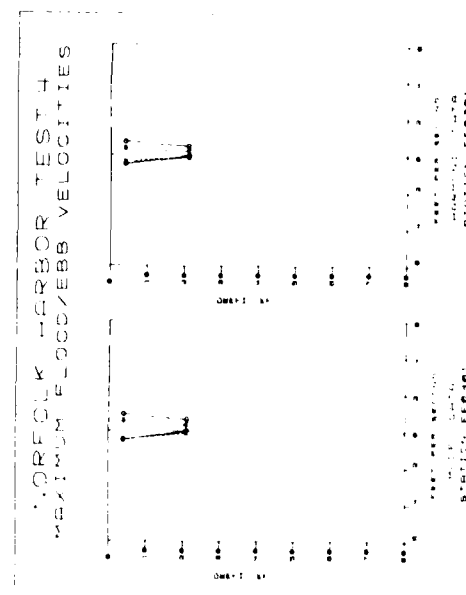
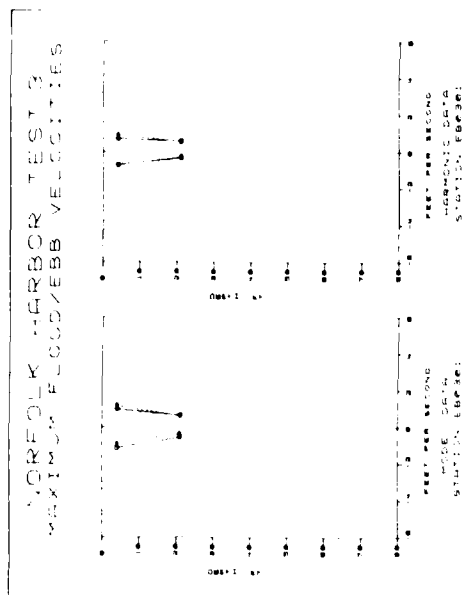
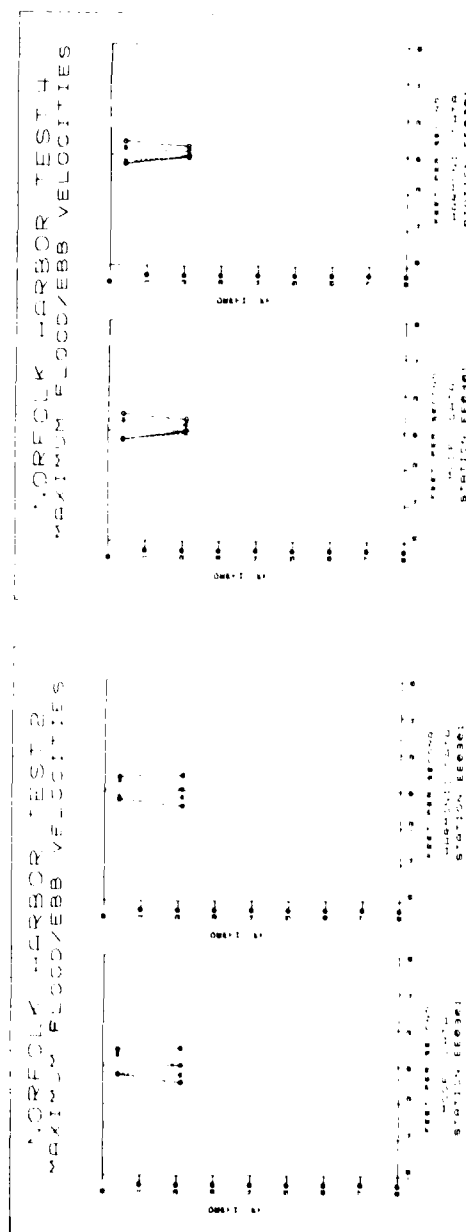
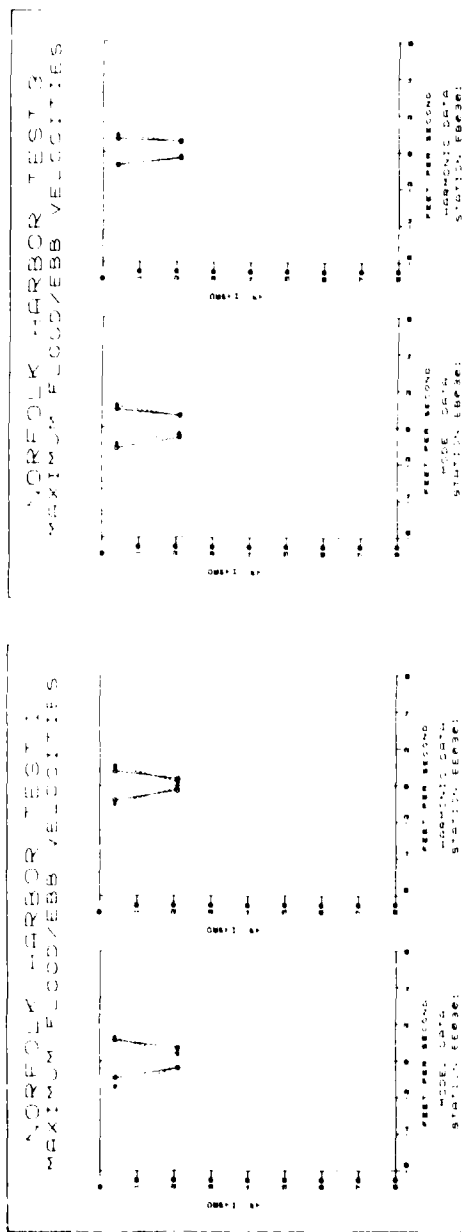
NORFOLK HARBOR TEST 4 MAXIMUM FLOOD/EBB VELOCITIES



0 BASE
PLAN



— OBS
--- PLOW



0 BASE
10 PLUG

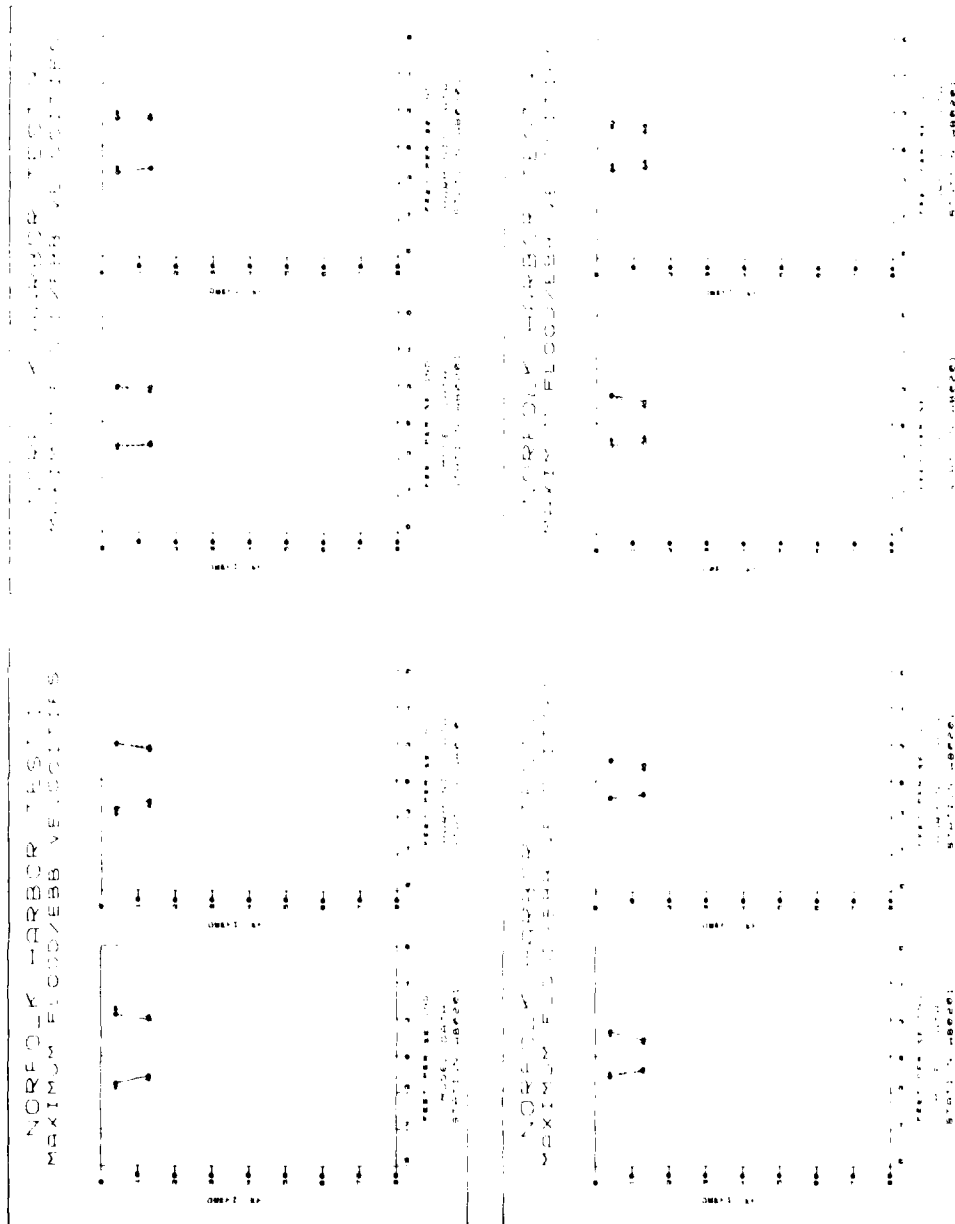
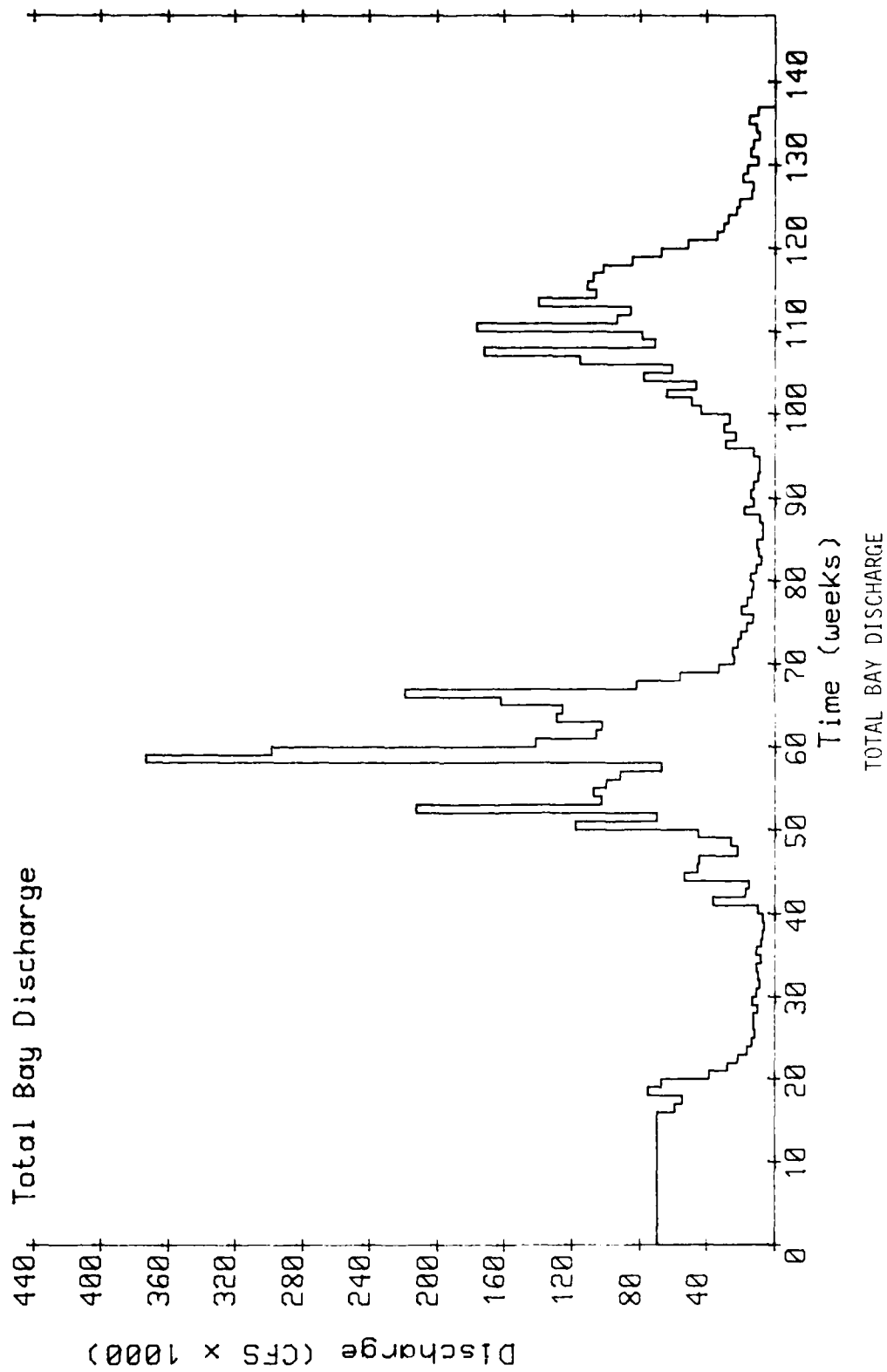
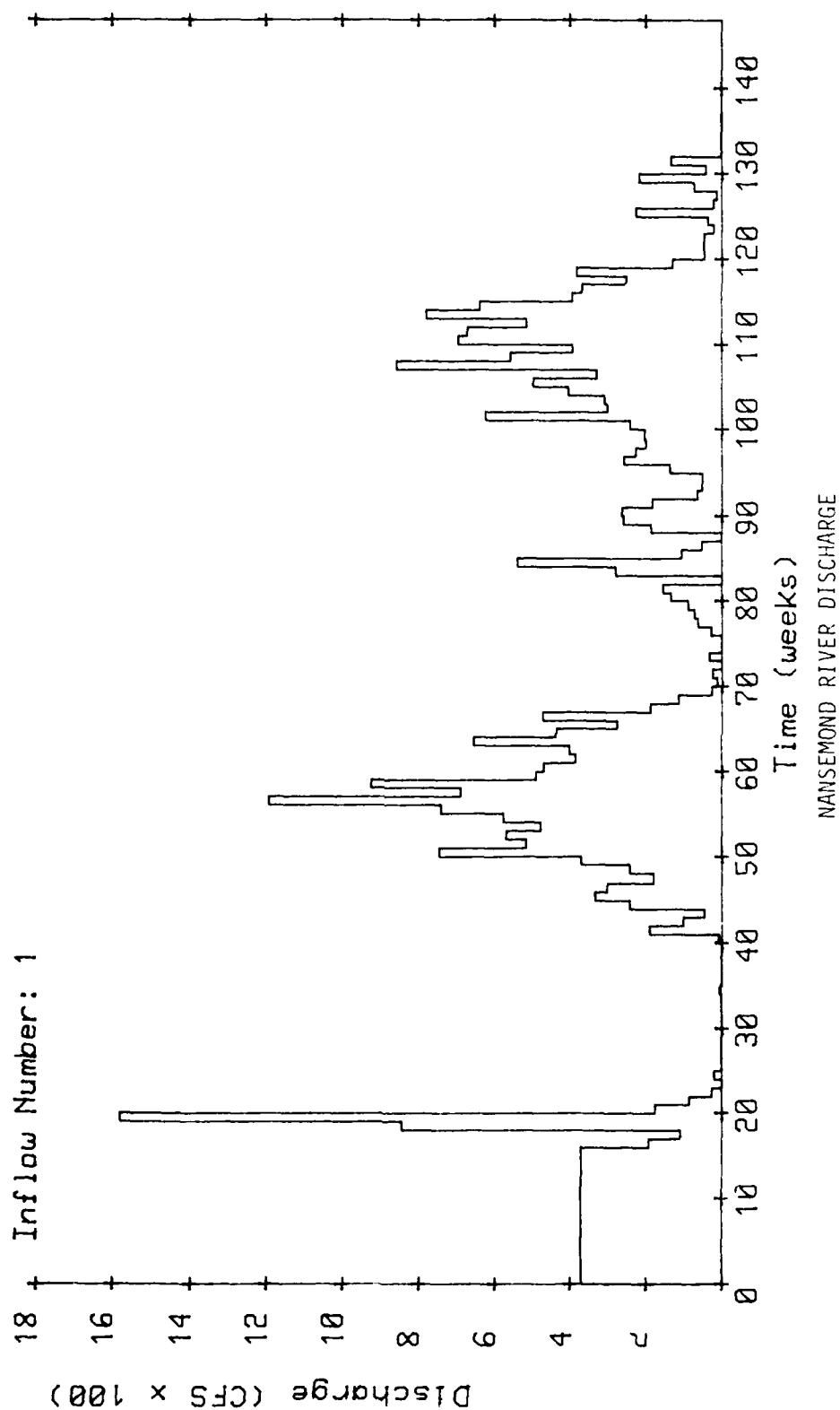
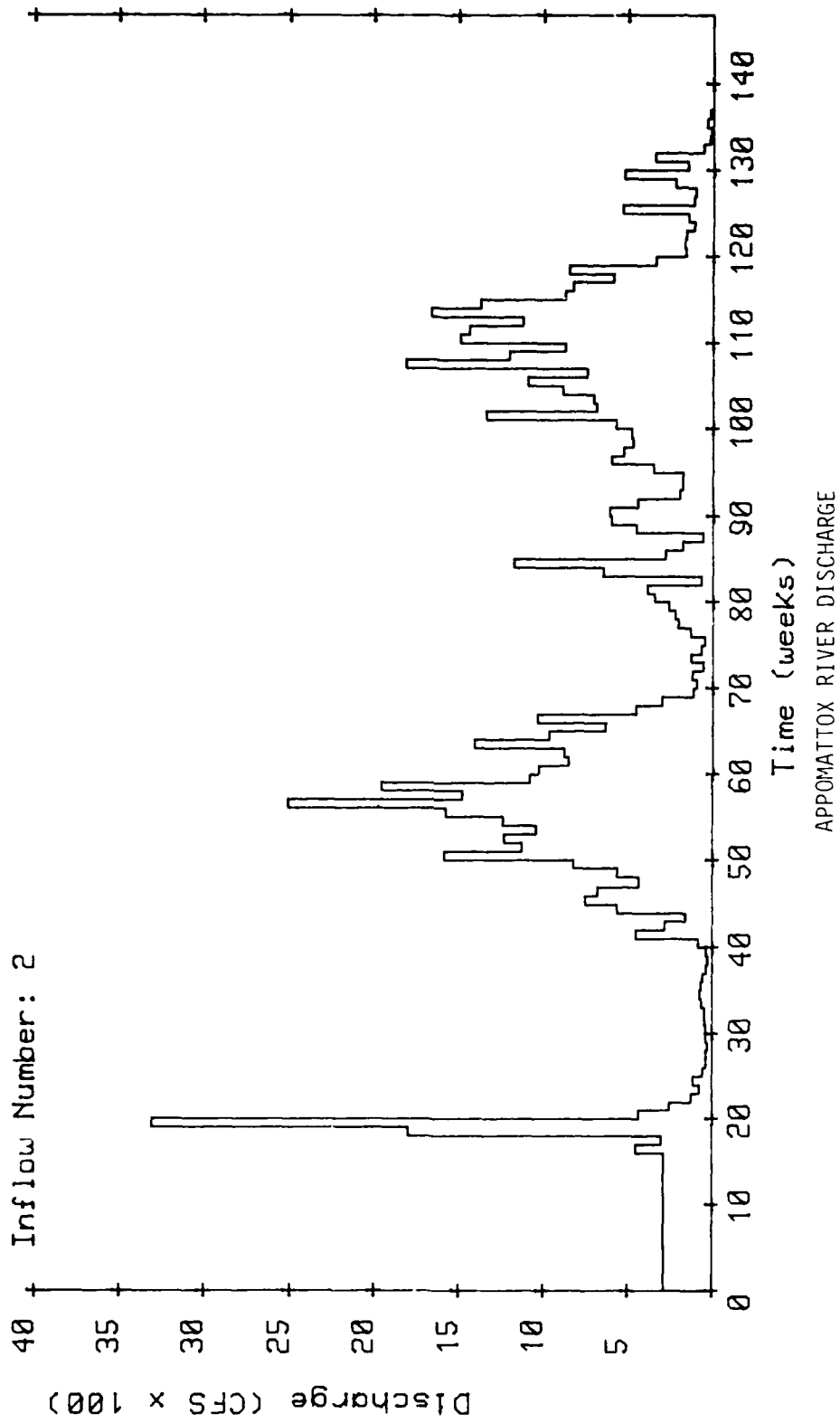


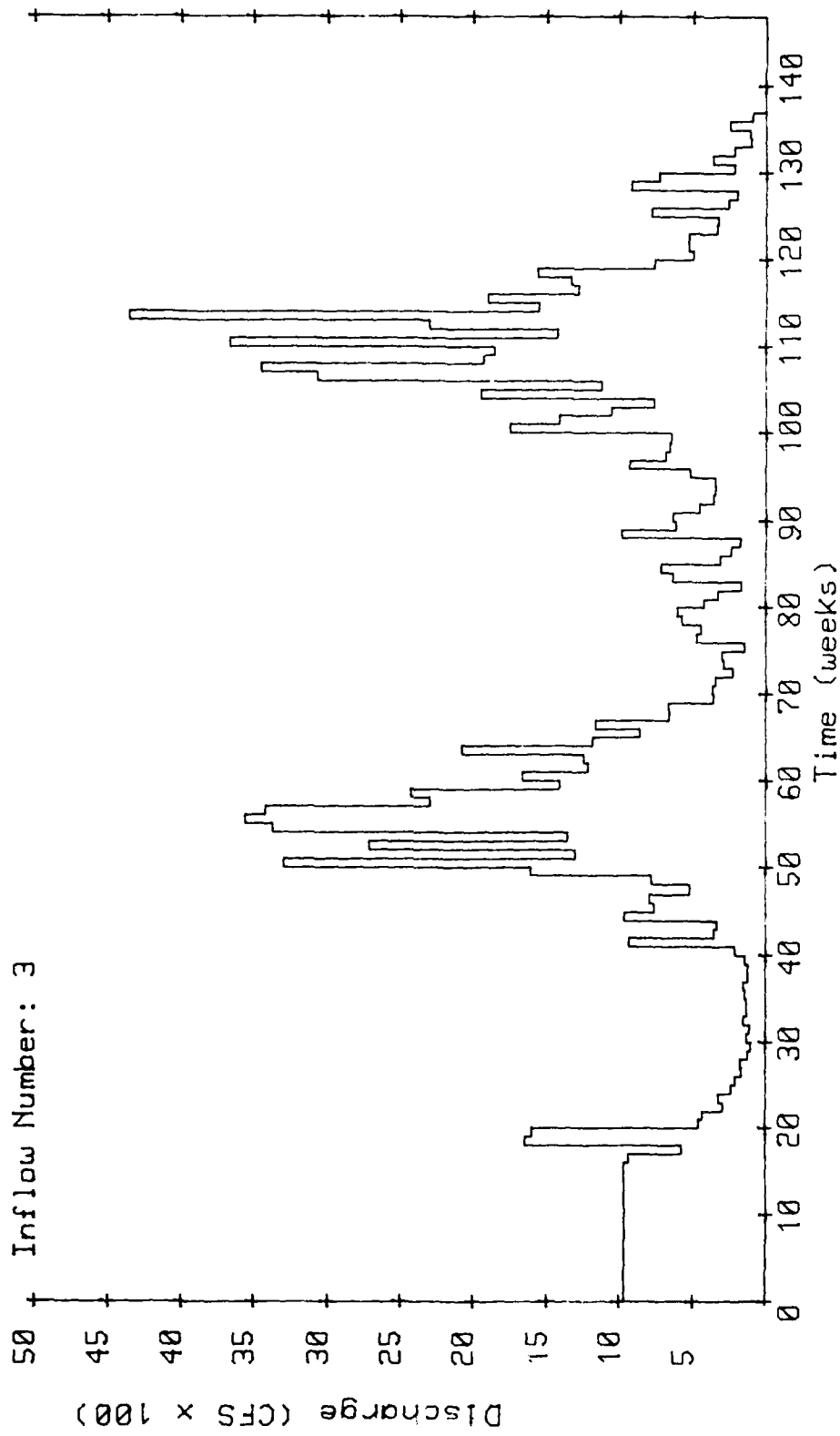
PLATE 144

0 1 2 3 4 5 6 7 8 9









AD-A134 563

NORFOLK HARBOR AND CHANNELS DEEPENING STUDY REPORT 1
PHYSICAL MODEL RESULTS (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS HYDRA.

W4

UNCLASSIFIED

D R RICHARDS ET AL. JUN 83 WES/TR/HL-83-13 F/G 13/2

NL

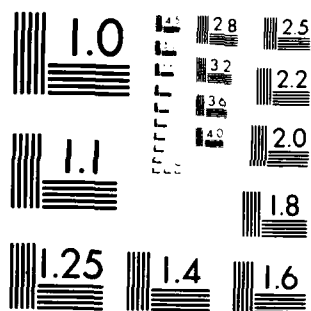
END

DATE

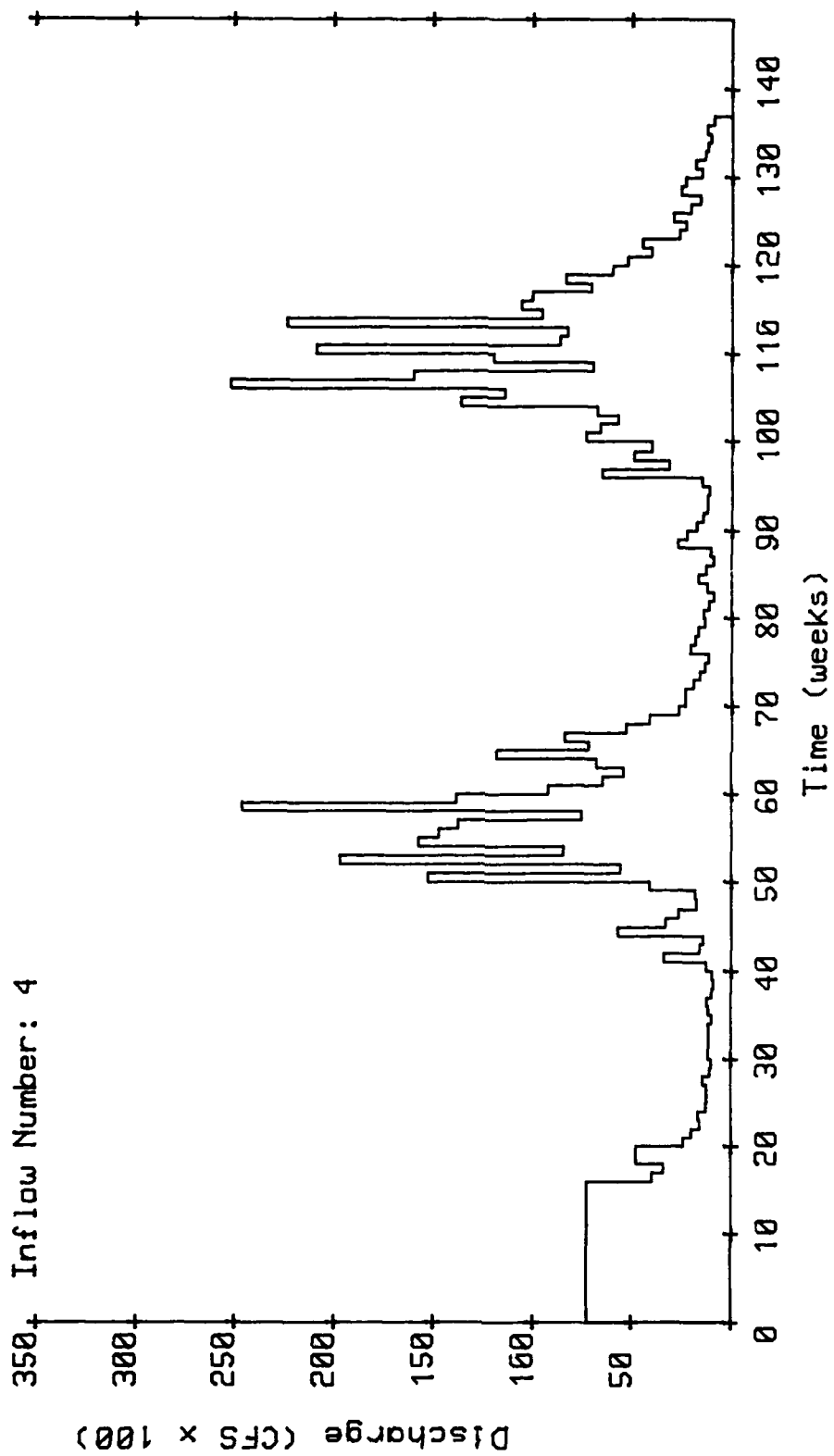
FILED

11-83

DTIC

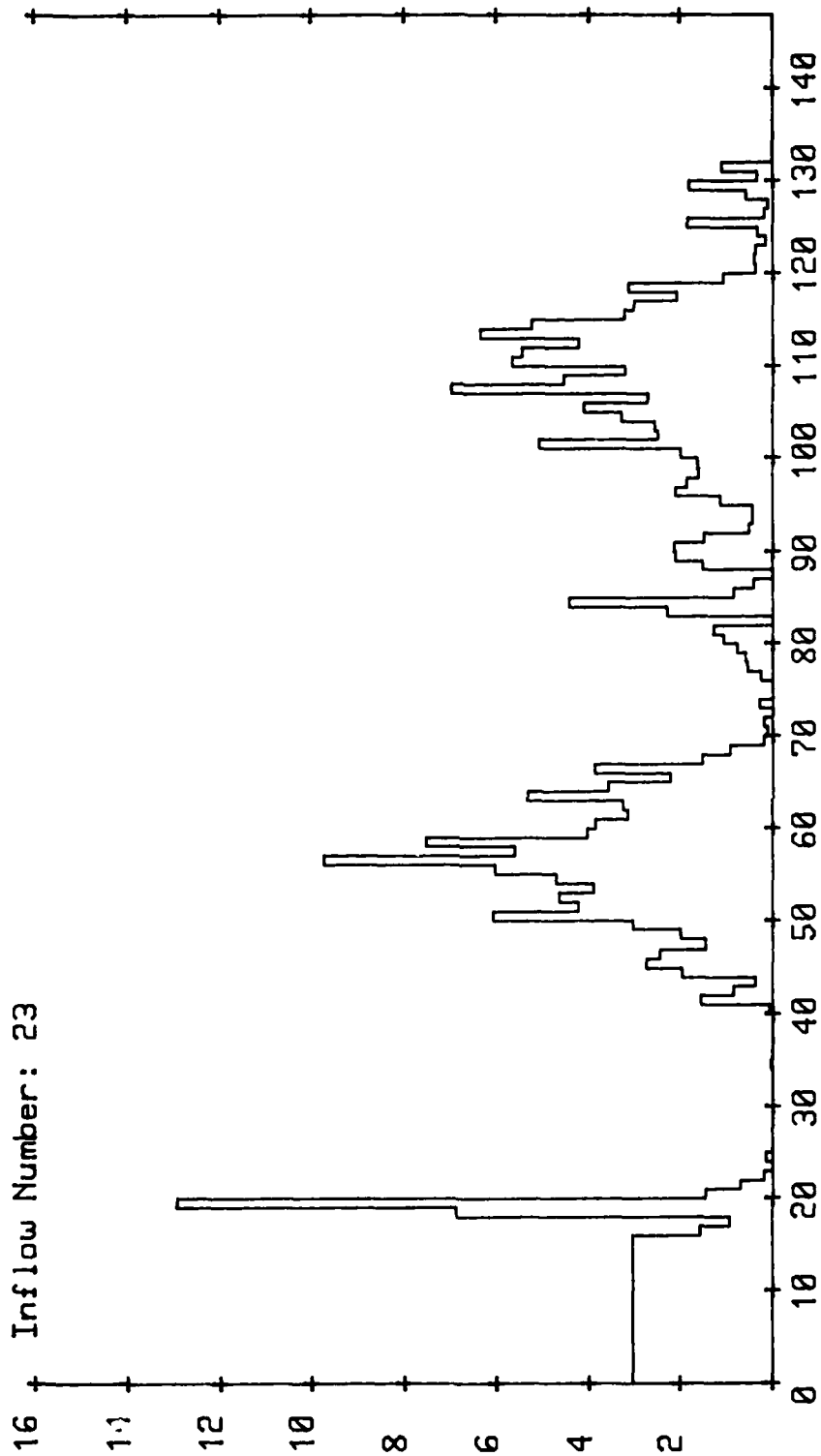


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



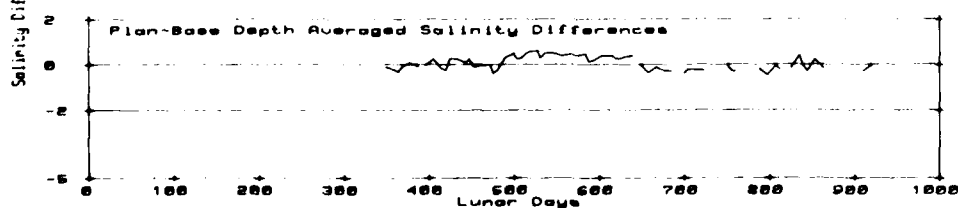
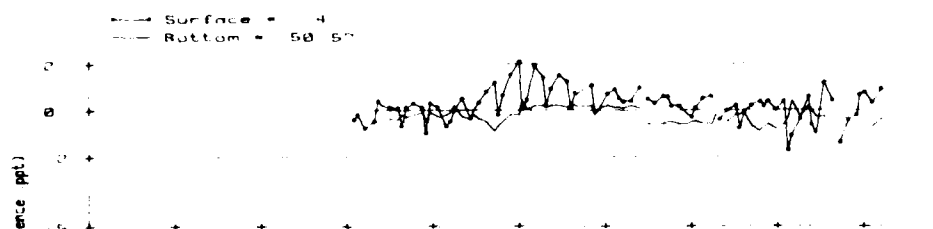
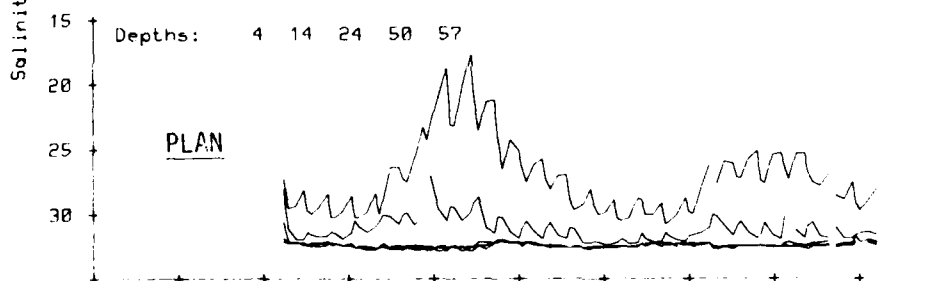
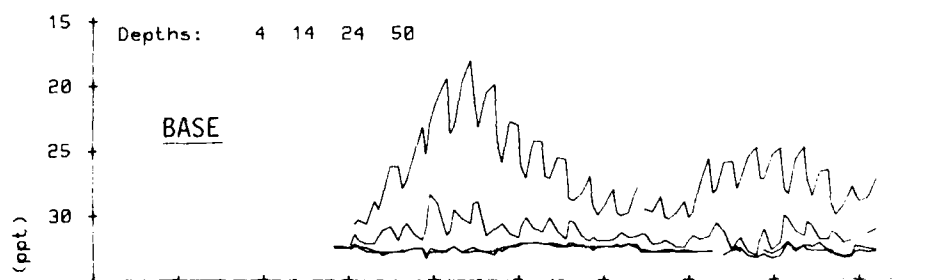
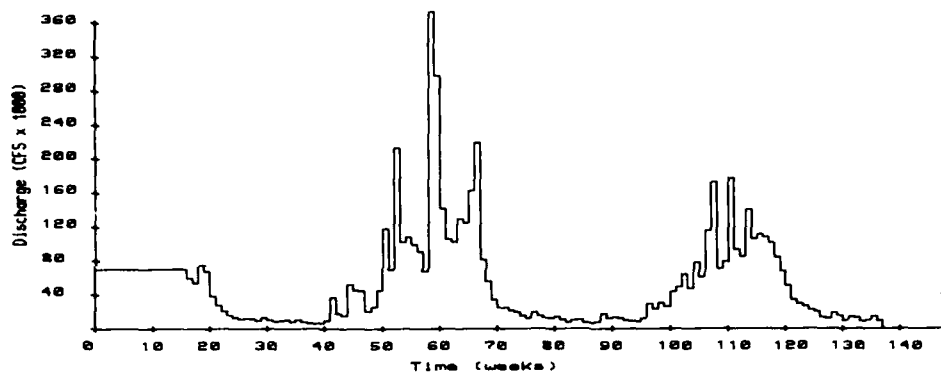
Inflow Number: 23

Discharge (CFS x 100)

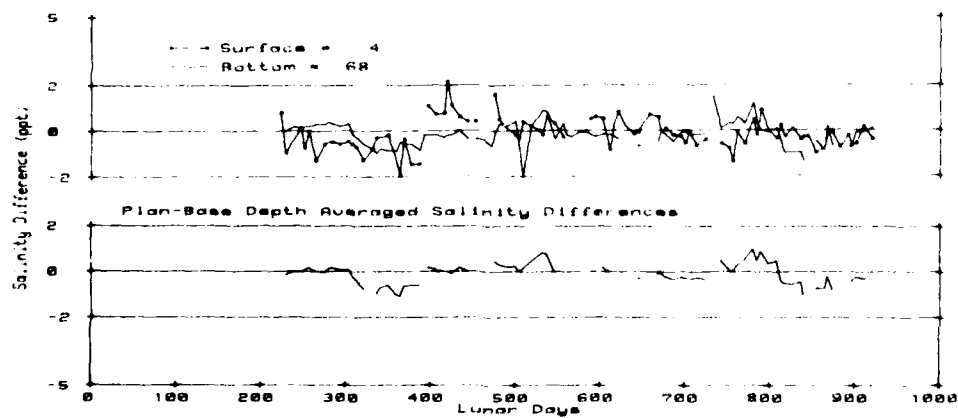
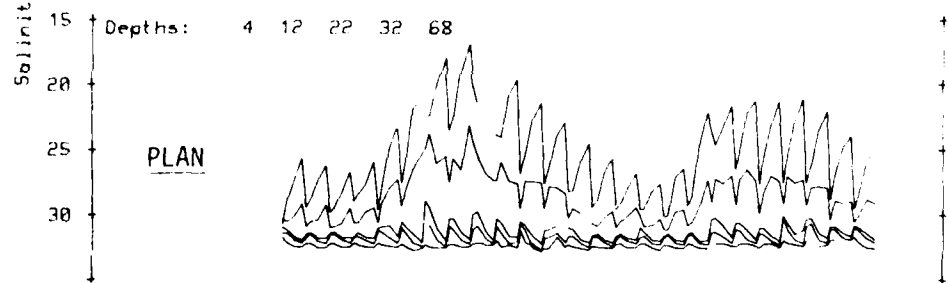
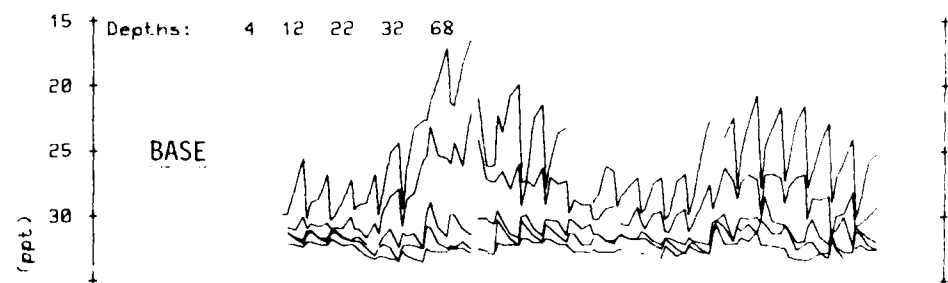
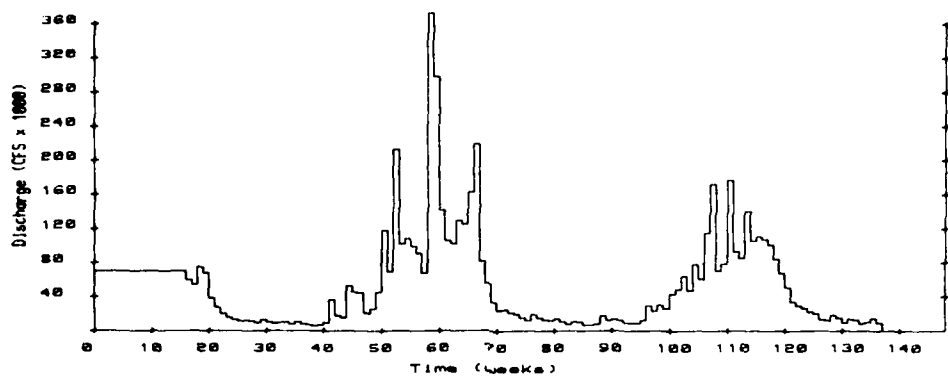


Time (weeks)

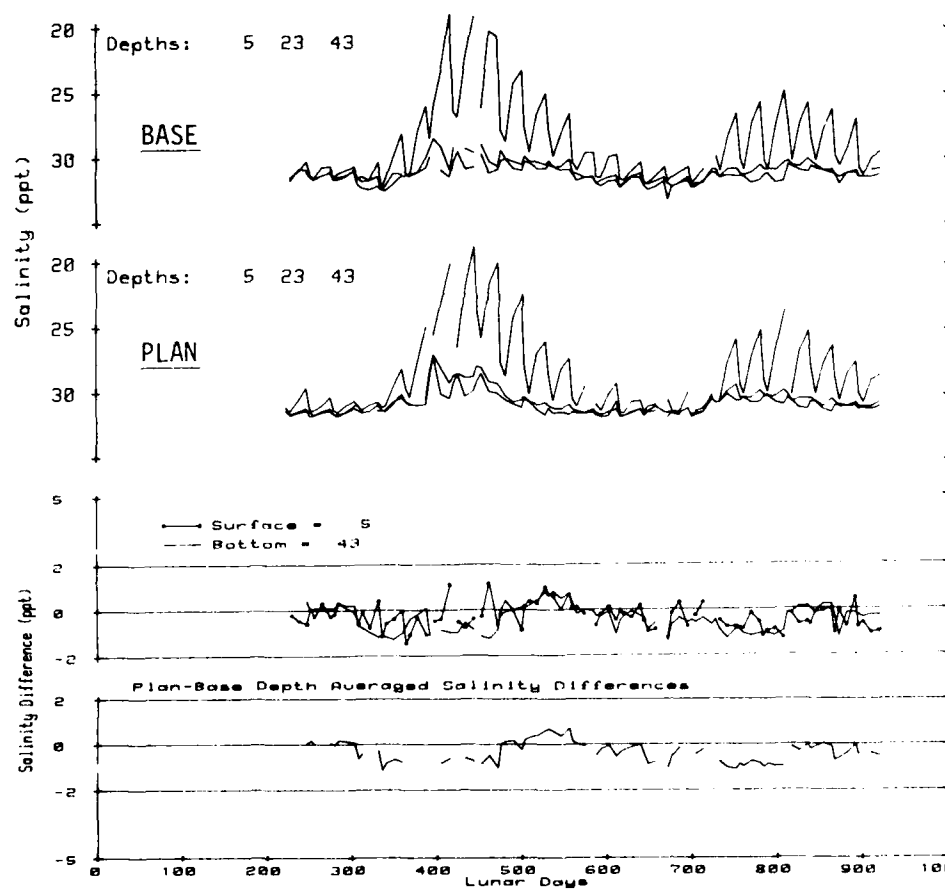
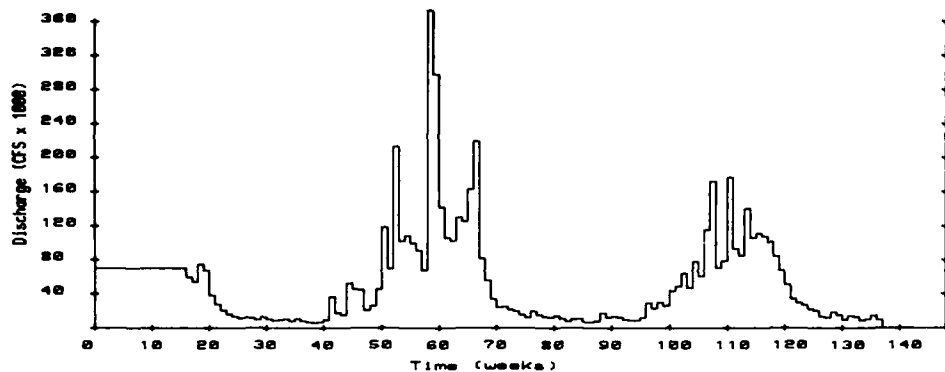
ELIZABETH RIVER DISCHARGE



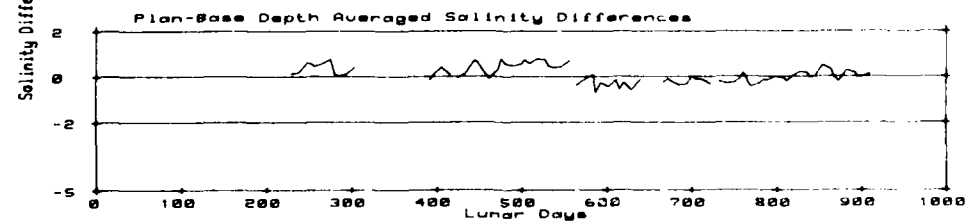
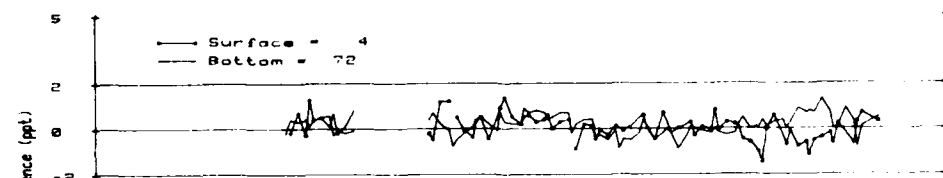
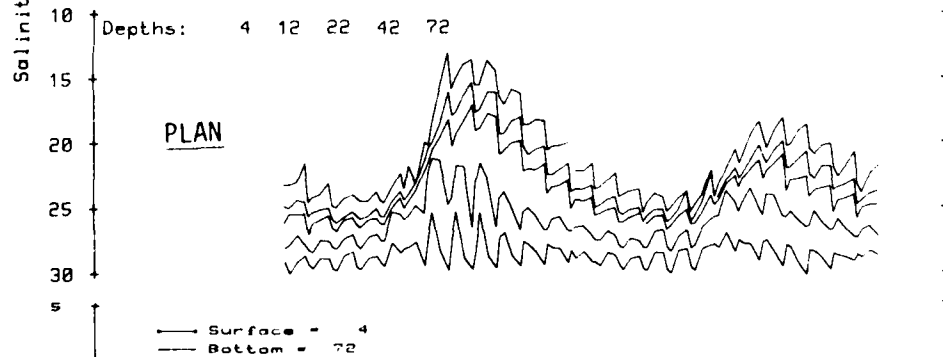
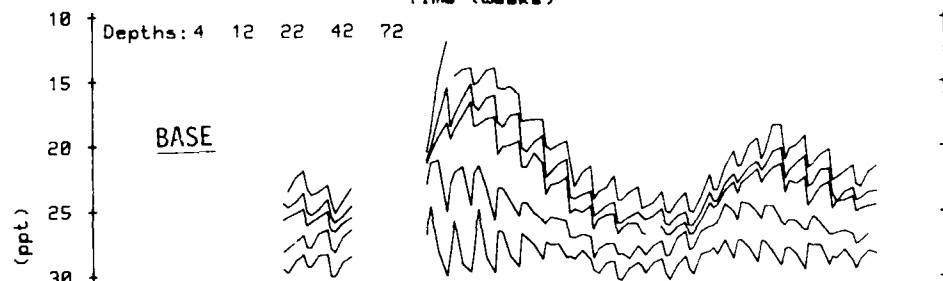
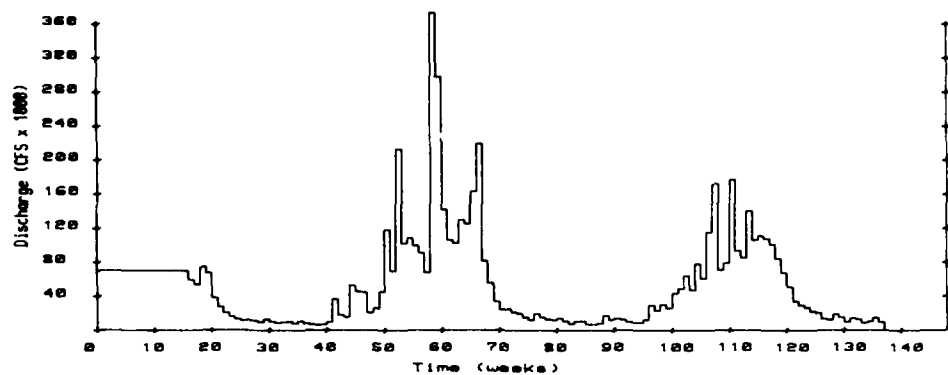
Station AC 0002



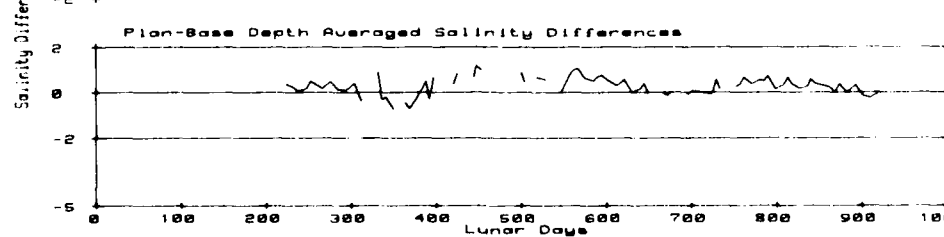
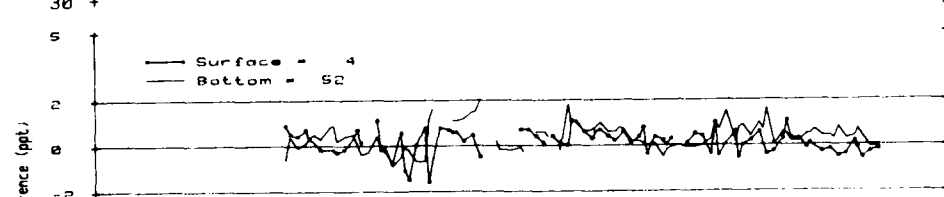
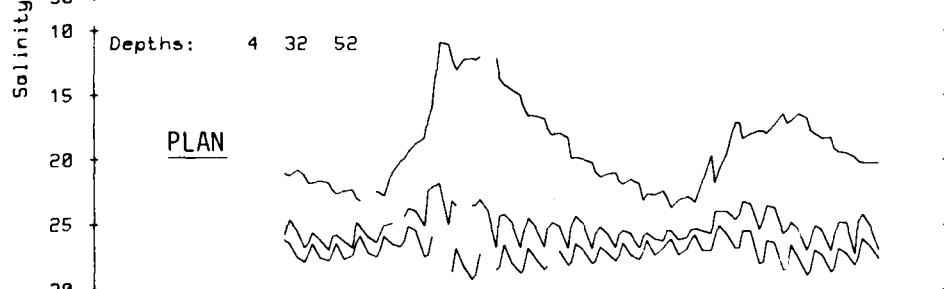
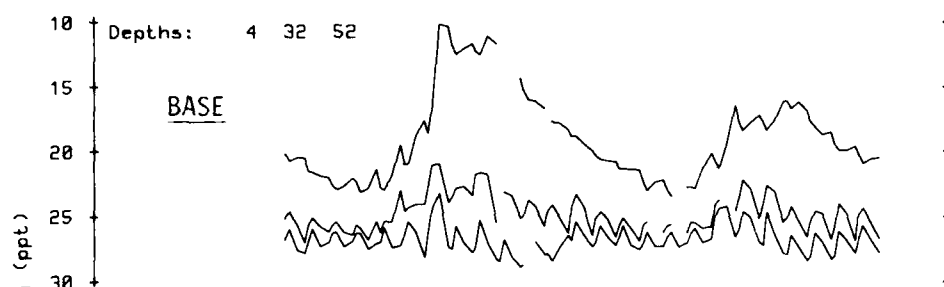
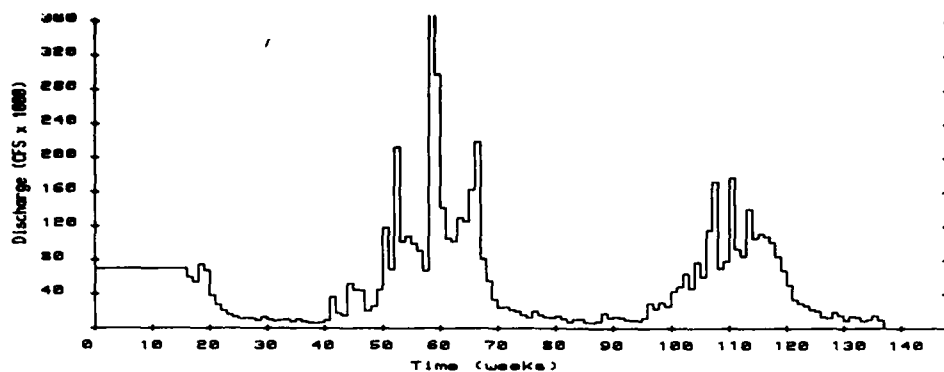
Station CB 0002



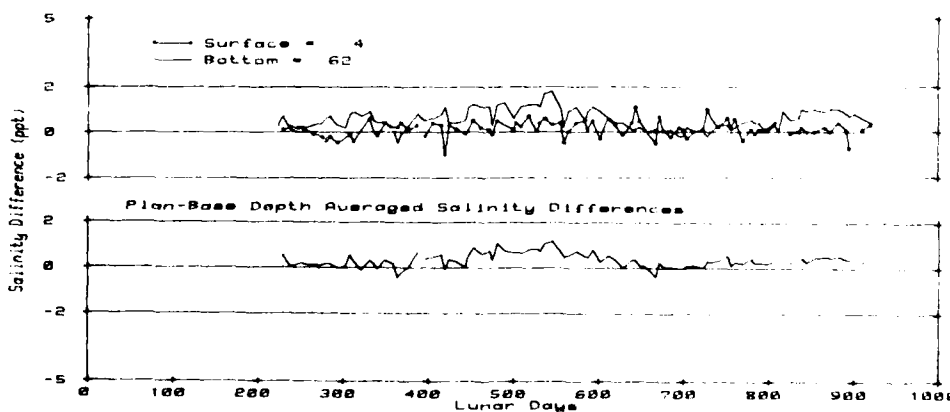
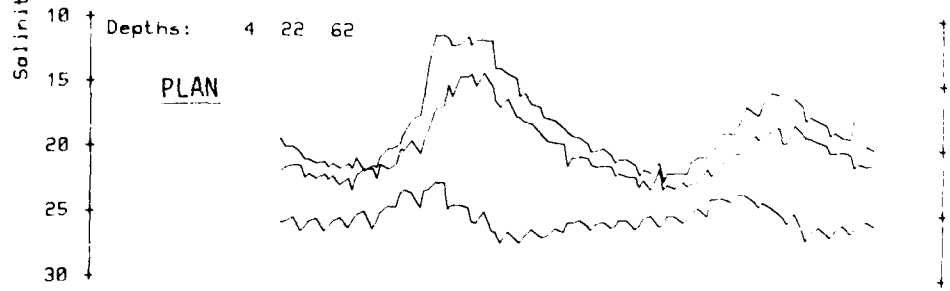
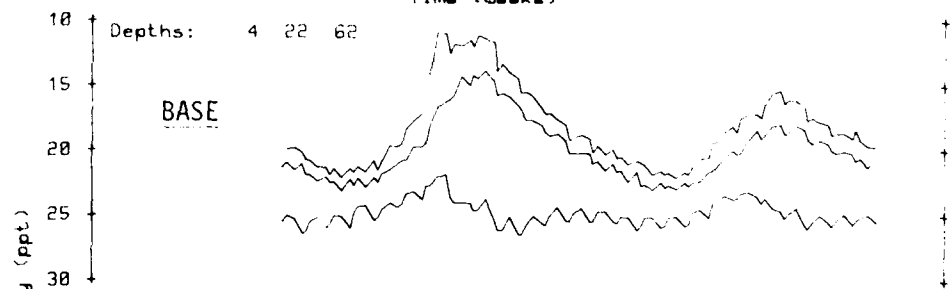
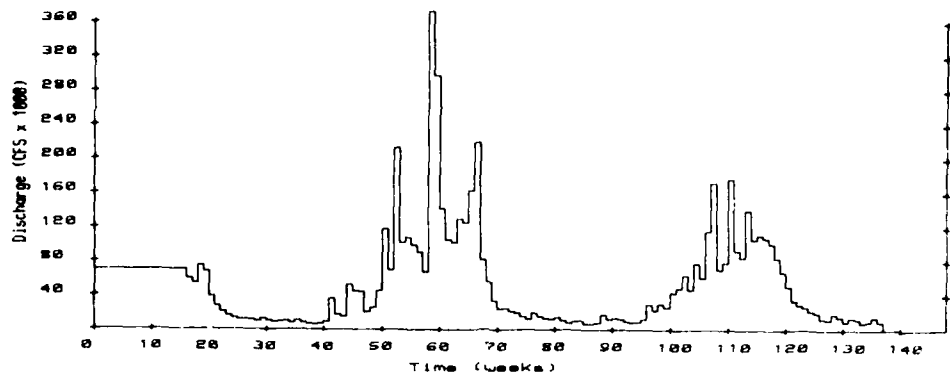
Station CB 0008



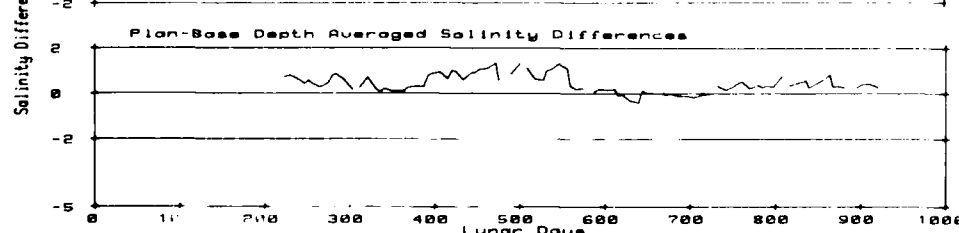
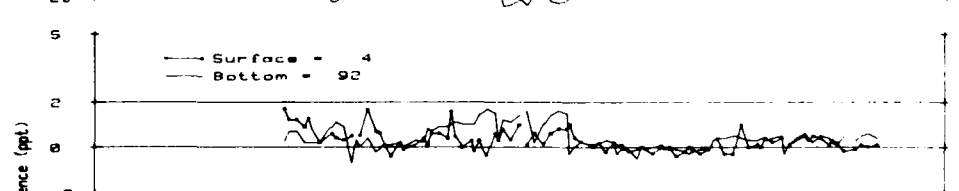
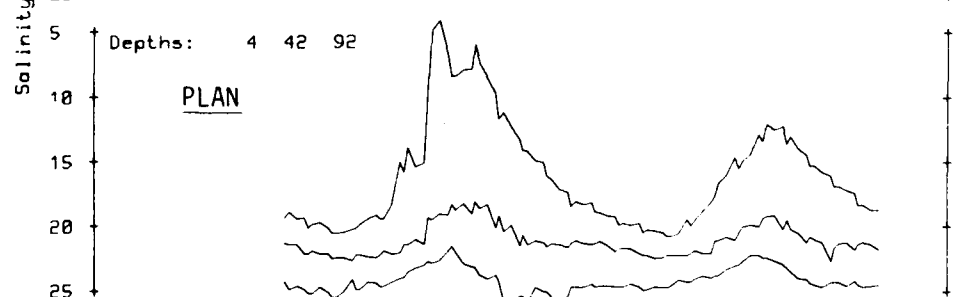
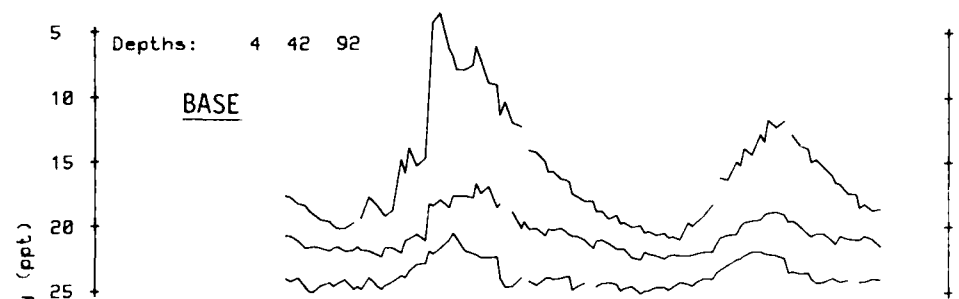
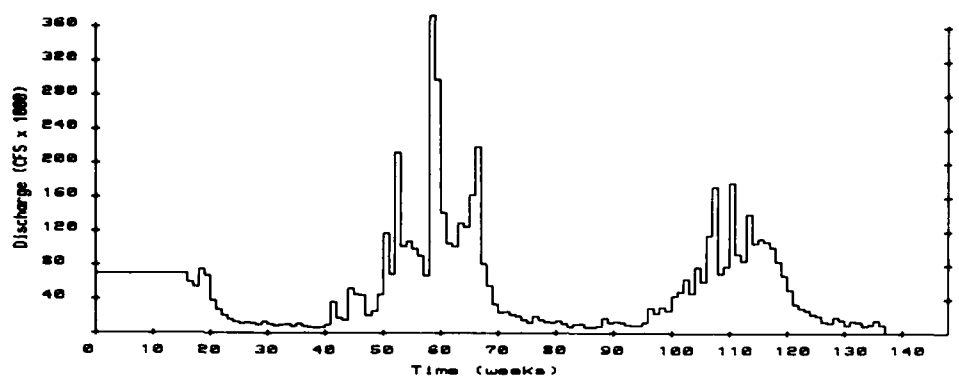
Station CB 0109



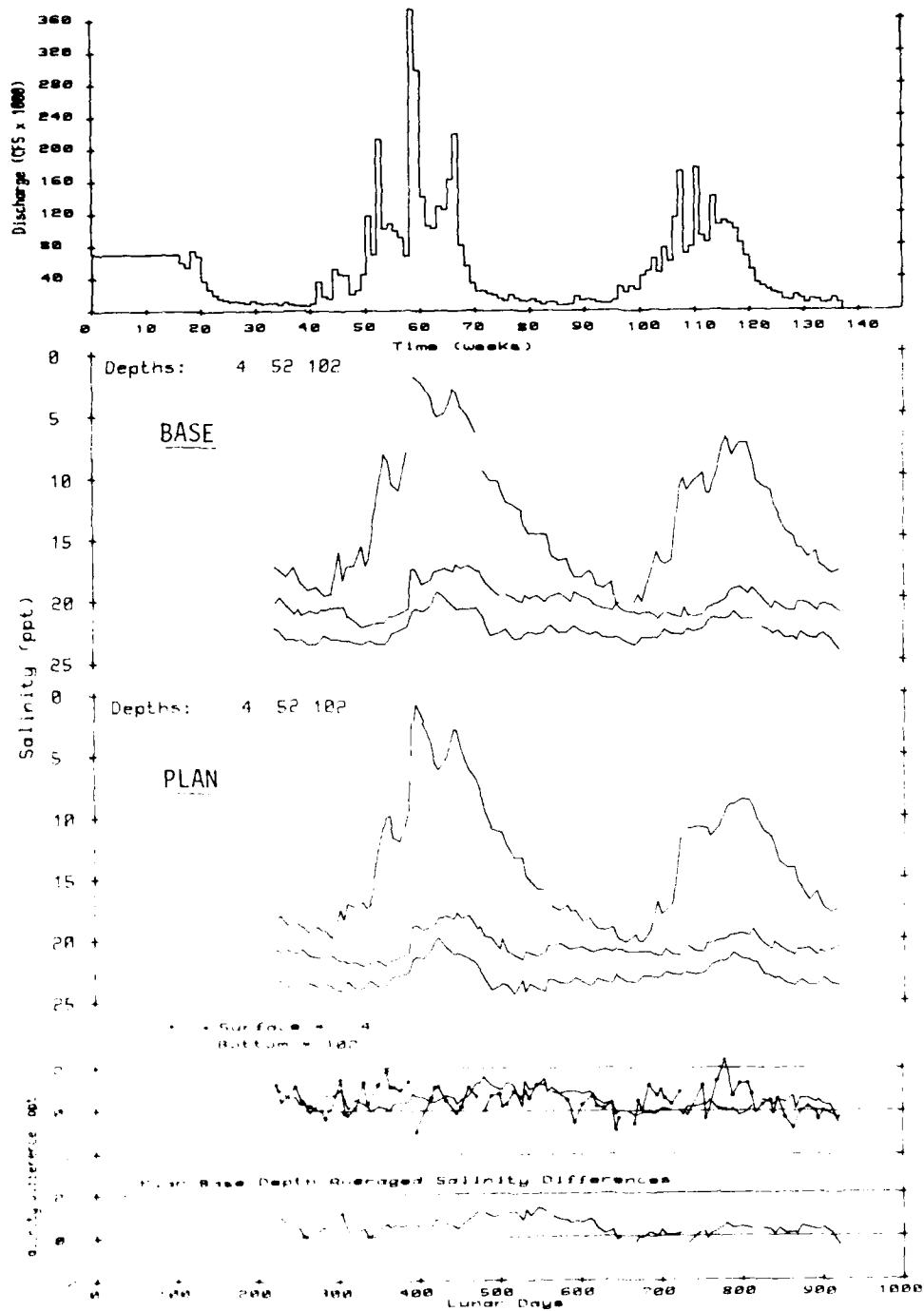
Station CB 0208



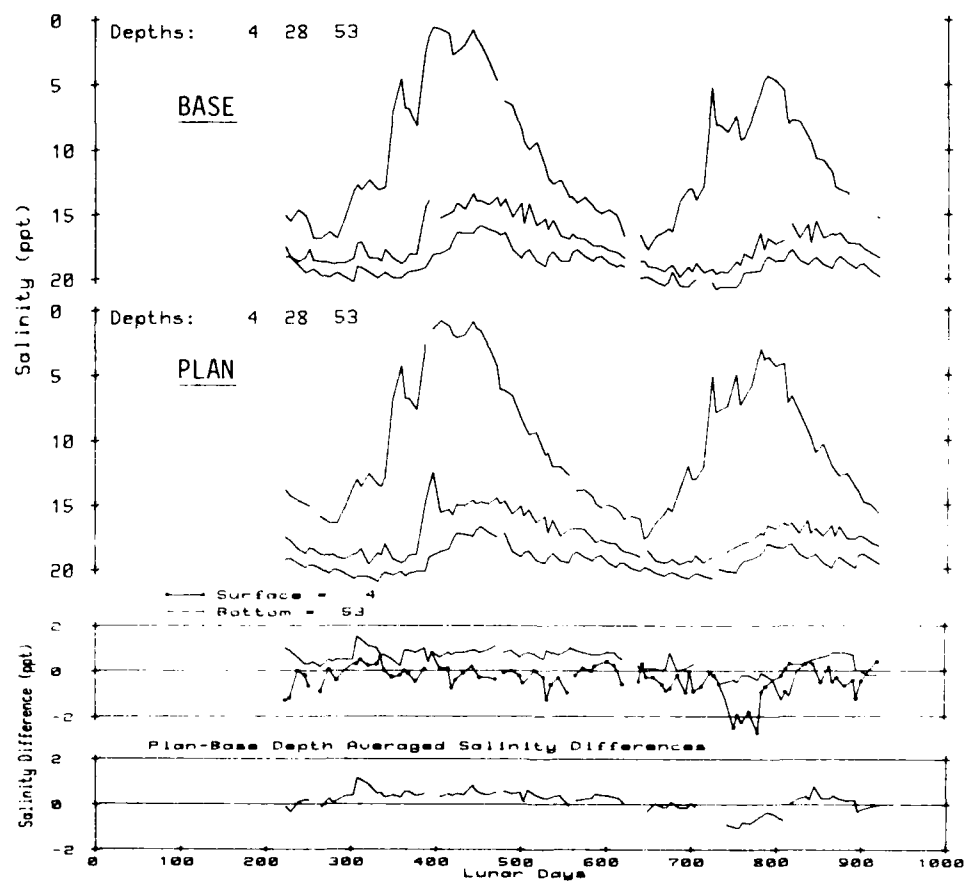
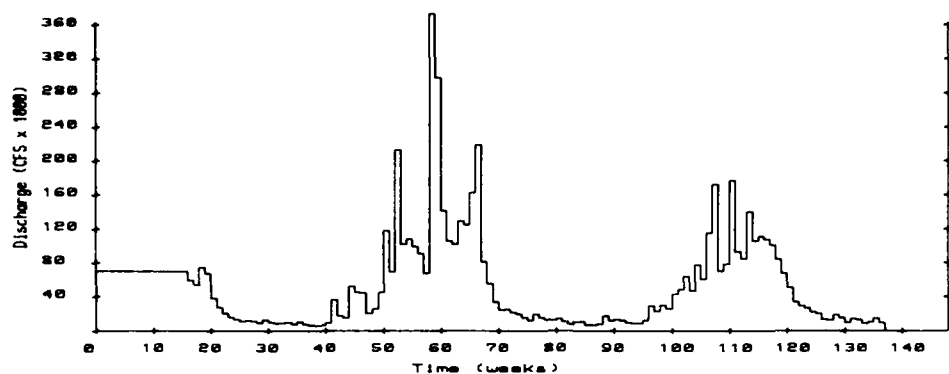
Station CB 0303



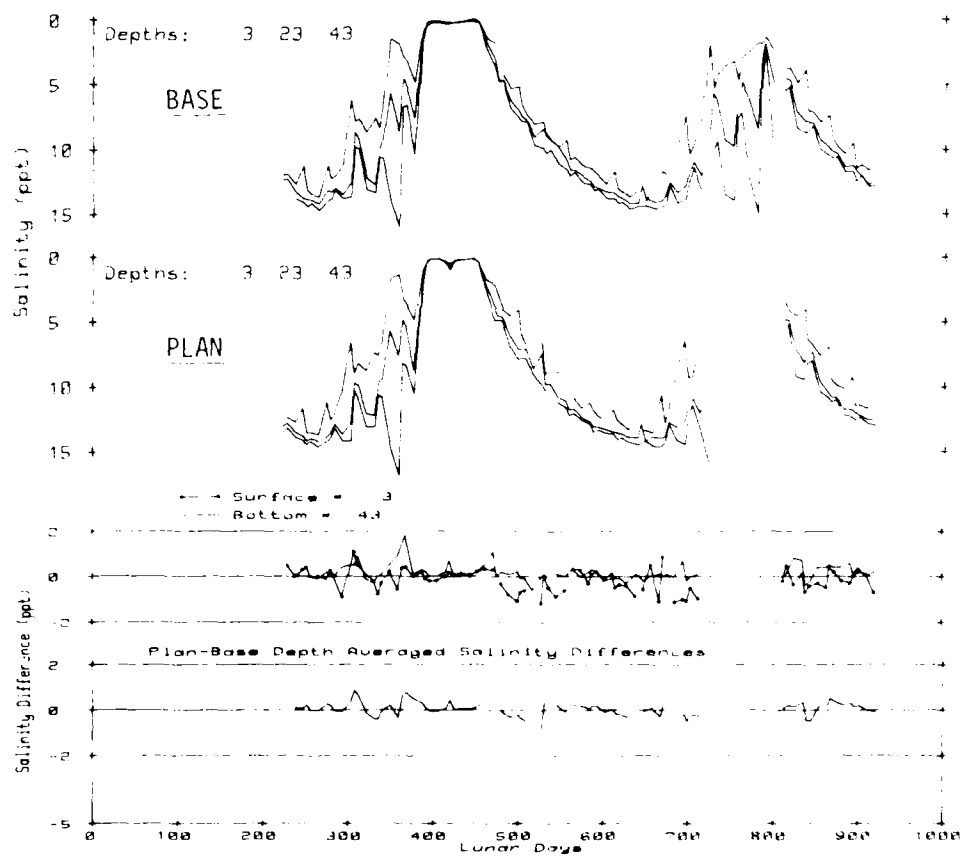
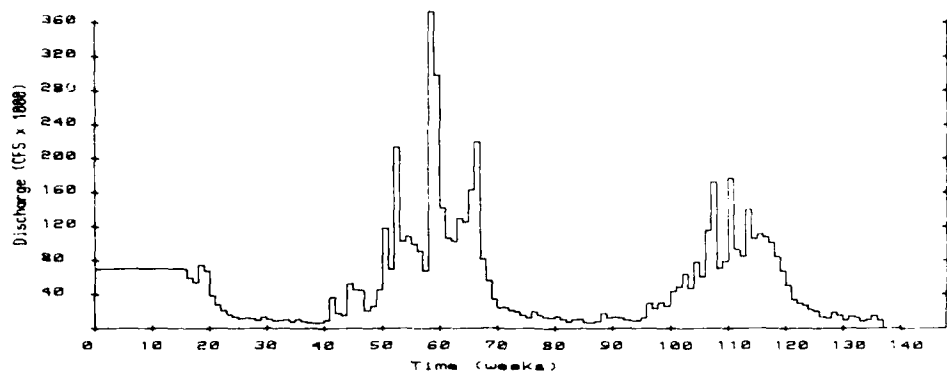
Station CB 0404



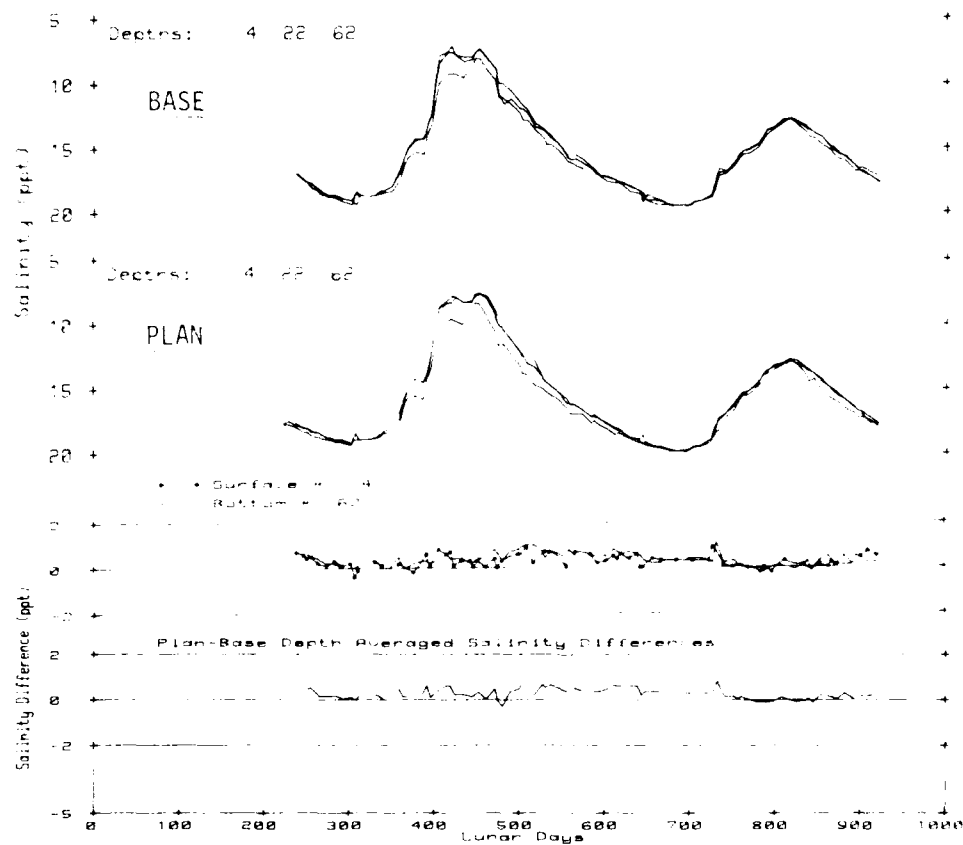
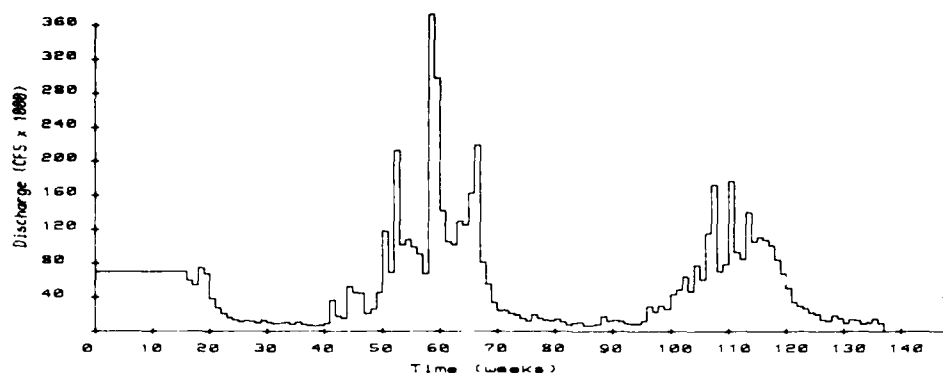
Station CB 0505



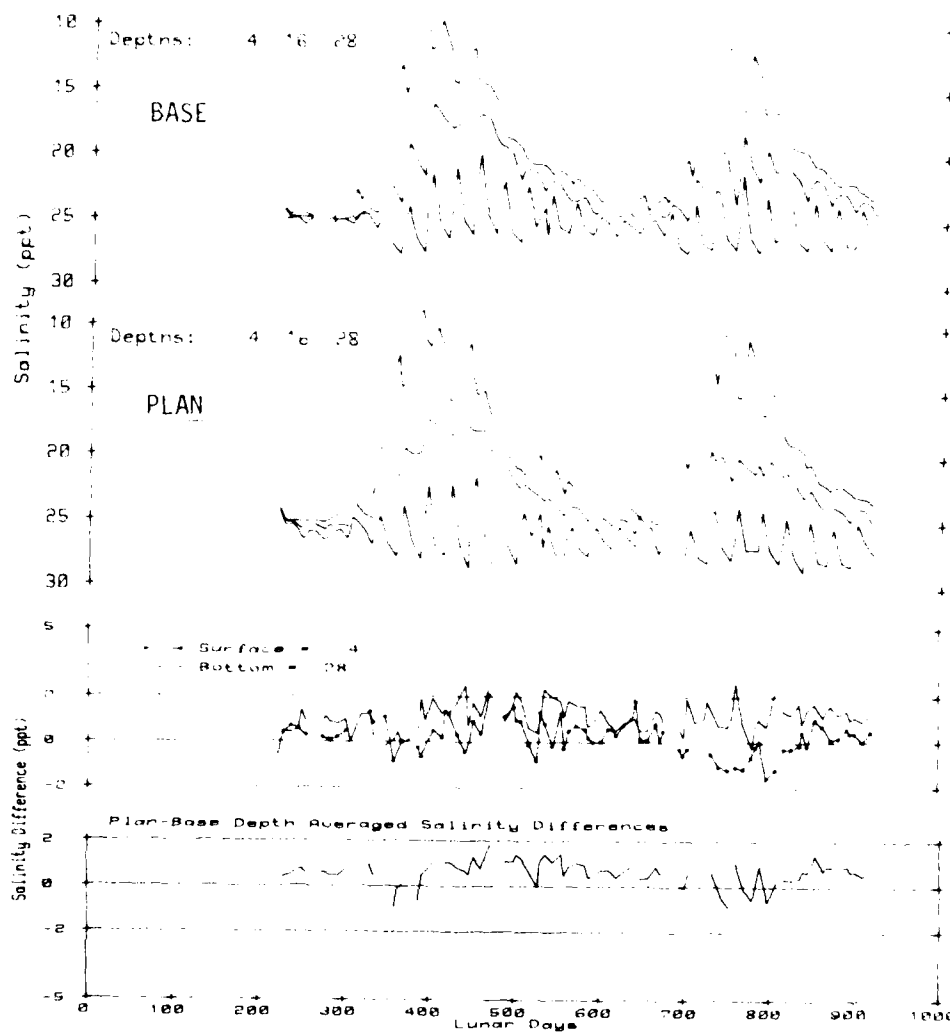
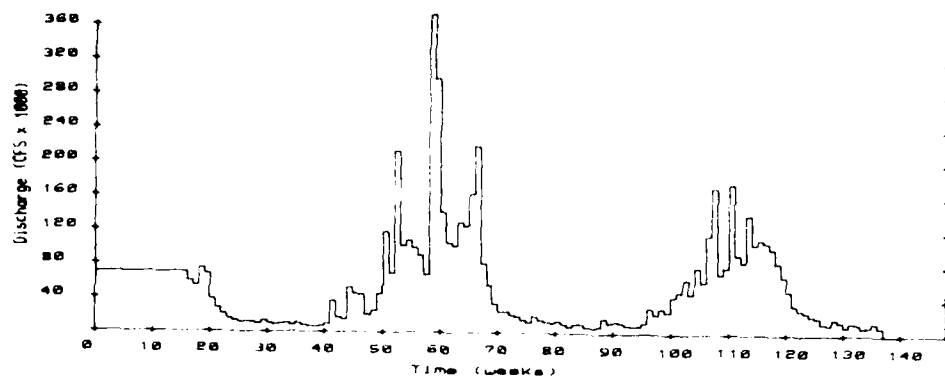
Station CB 0611



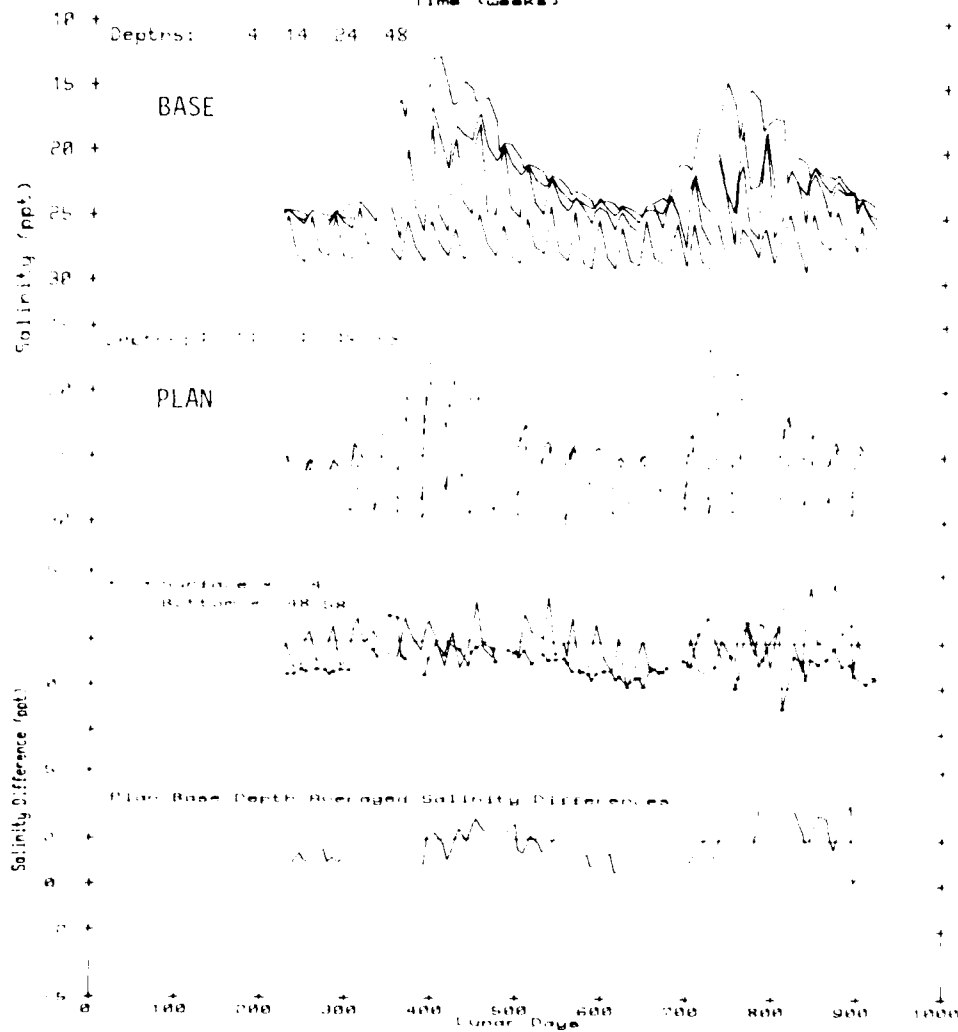
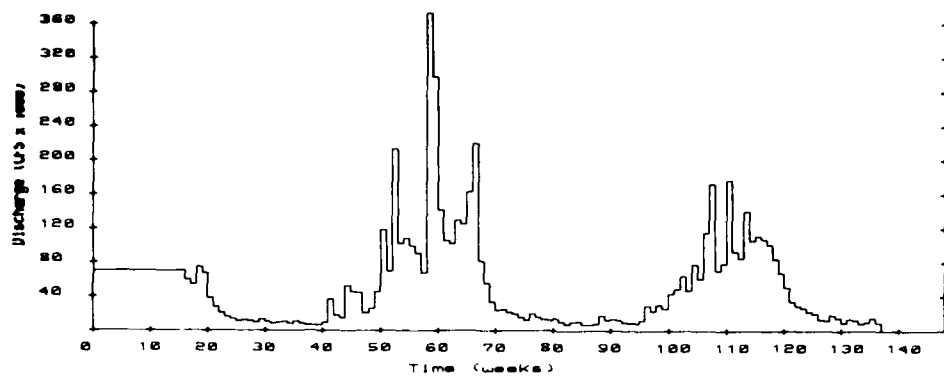
Station CB 0703



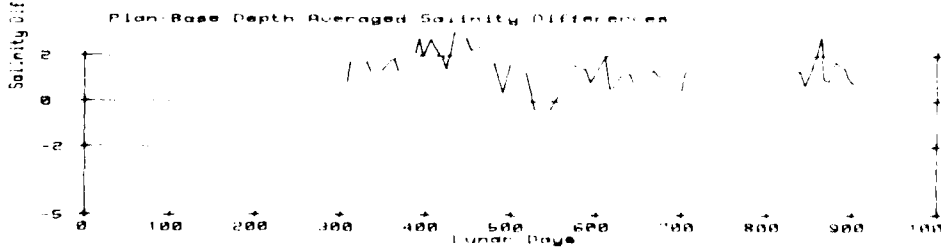
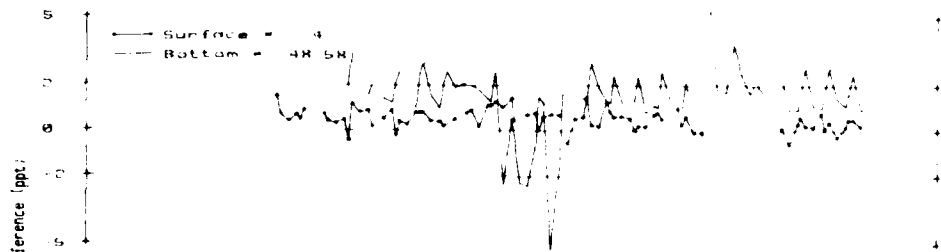
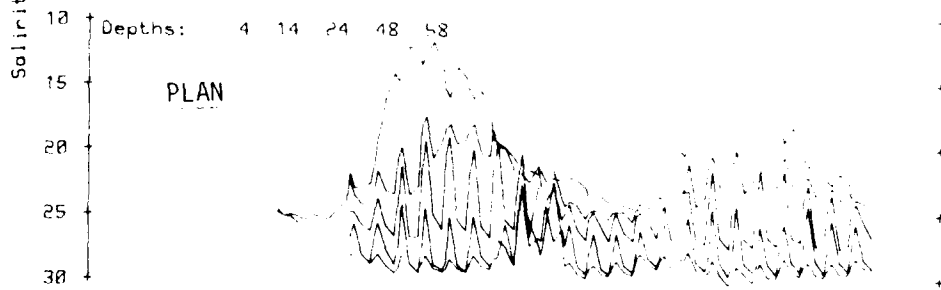
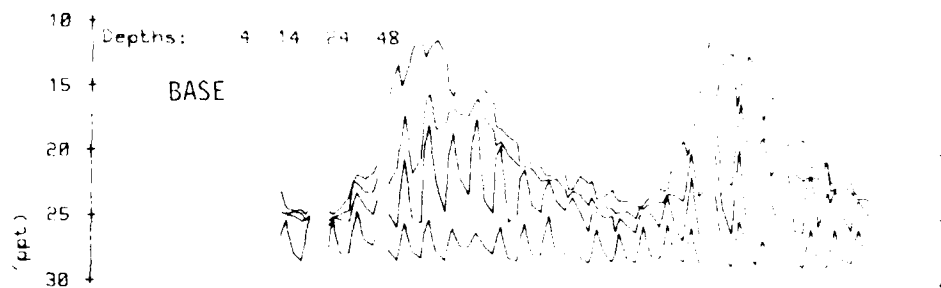
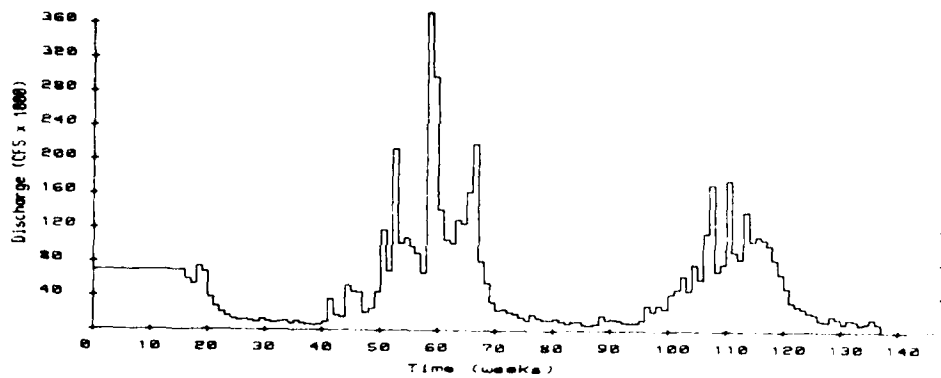
Station CG 2101

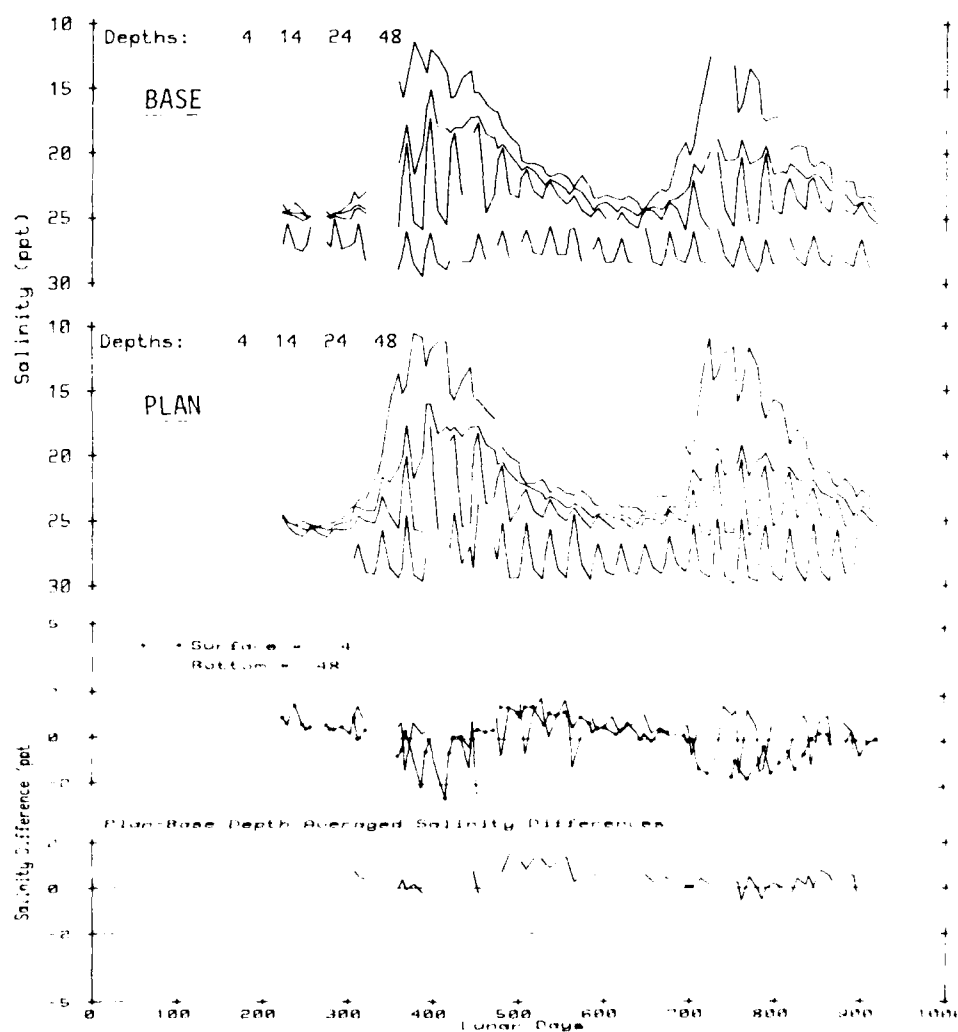
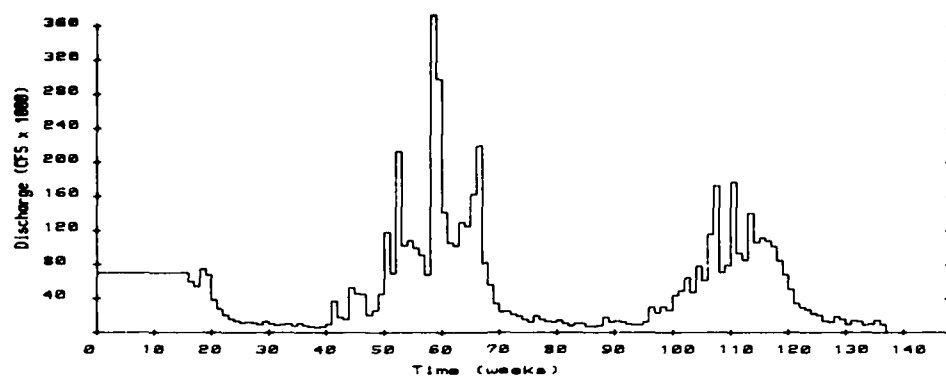


Station EE 0101

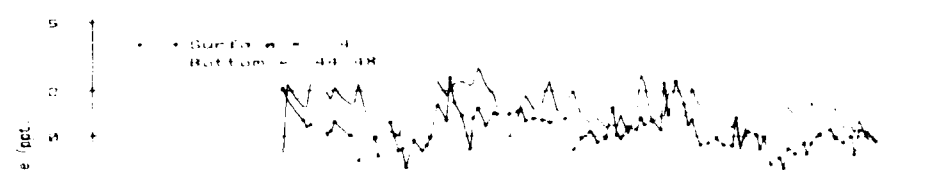
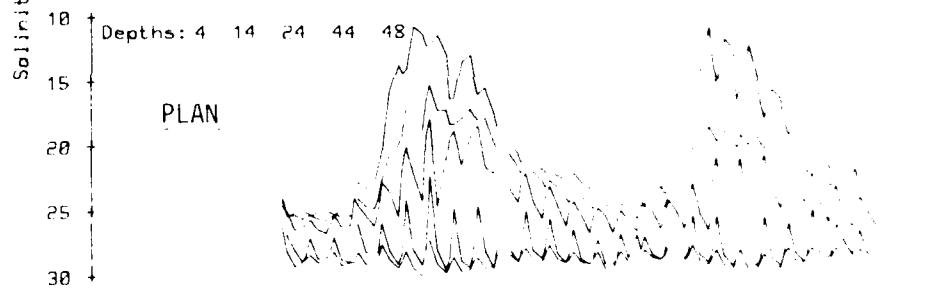
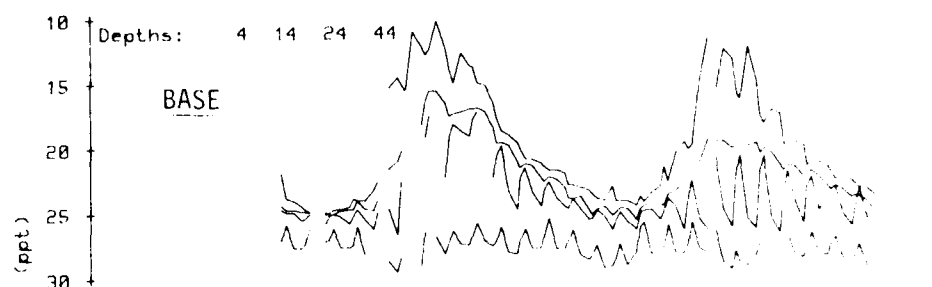
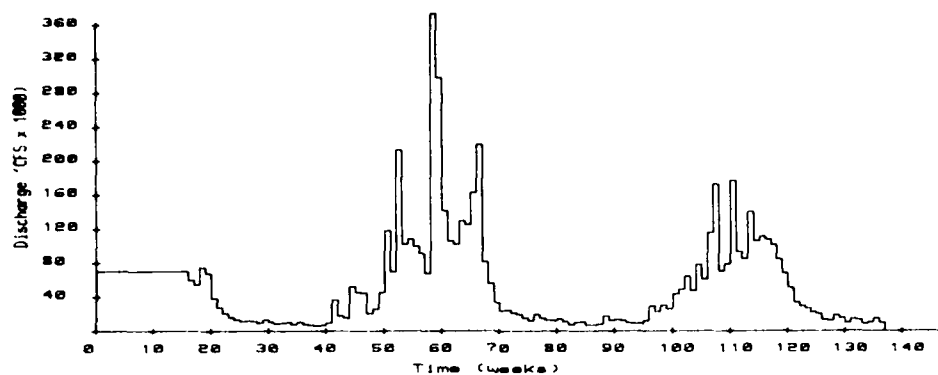


Station EH 0102

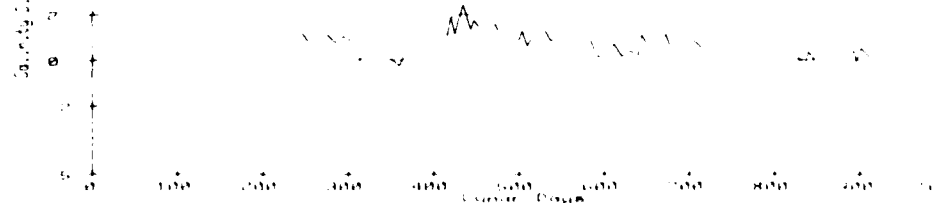




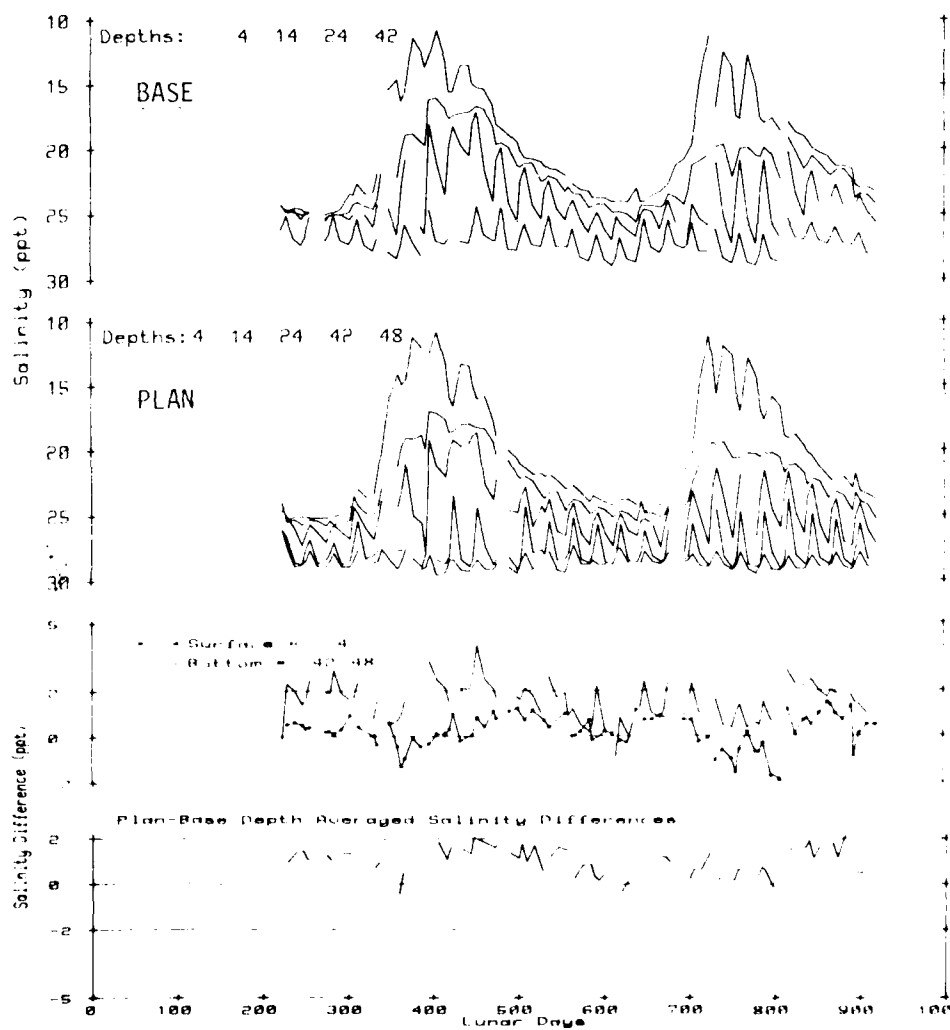
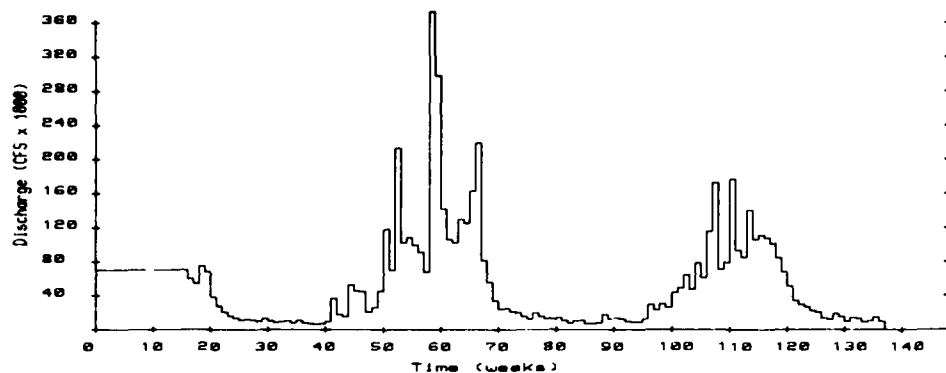
Station EH 0301



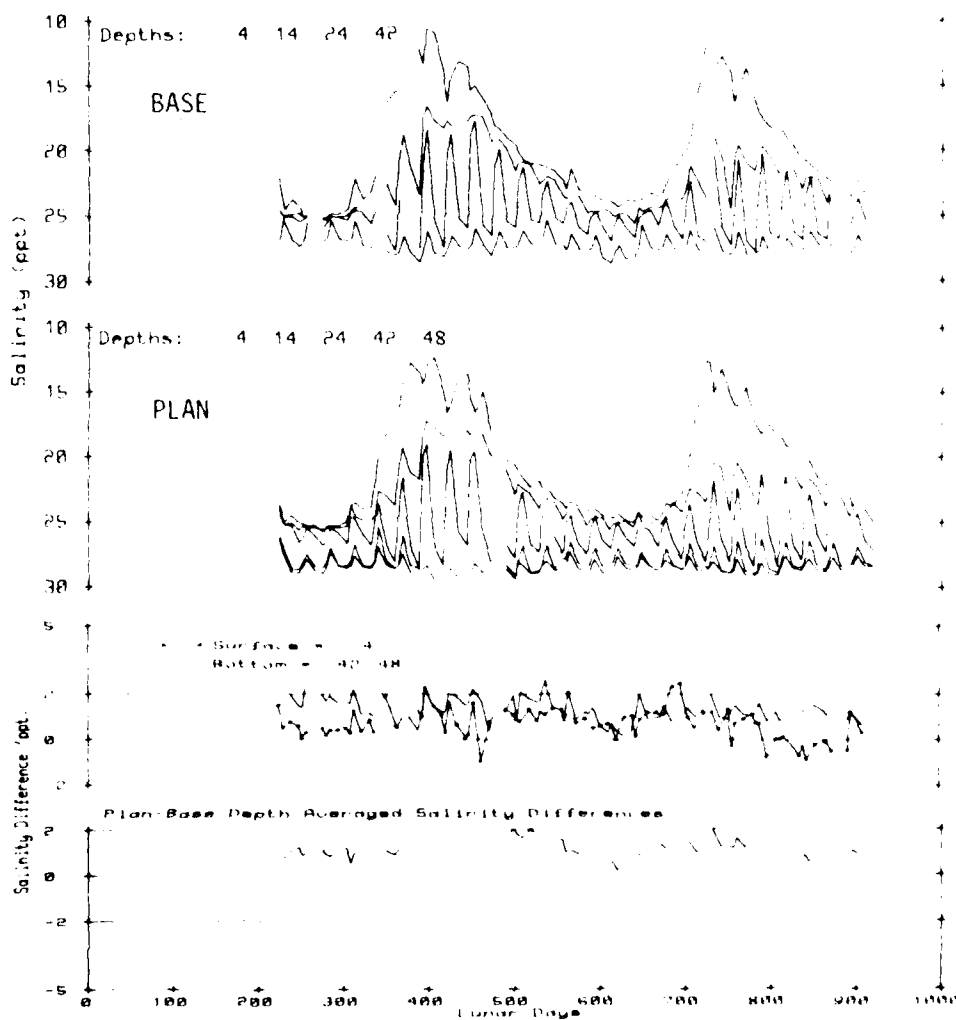
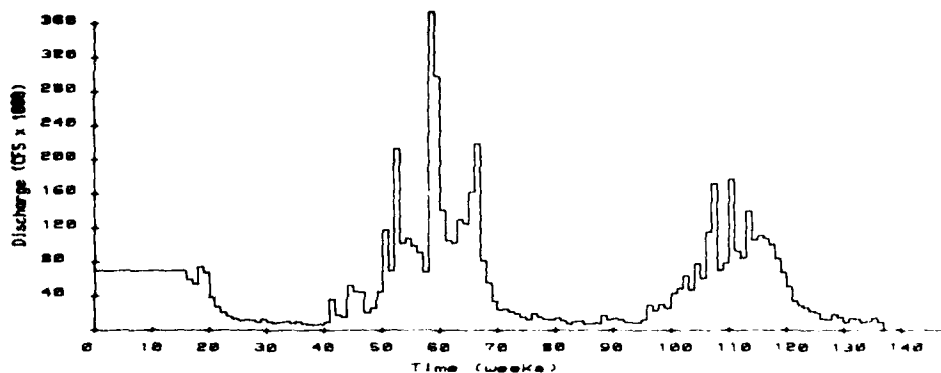
Plan Base Depth Averaged Solinity Differences



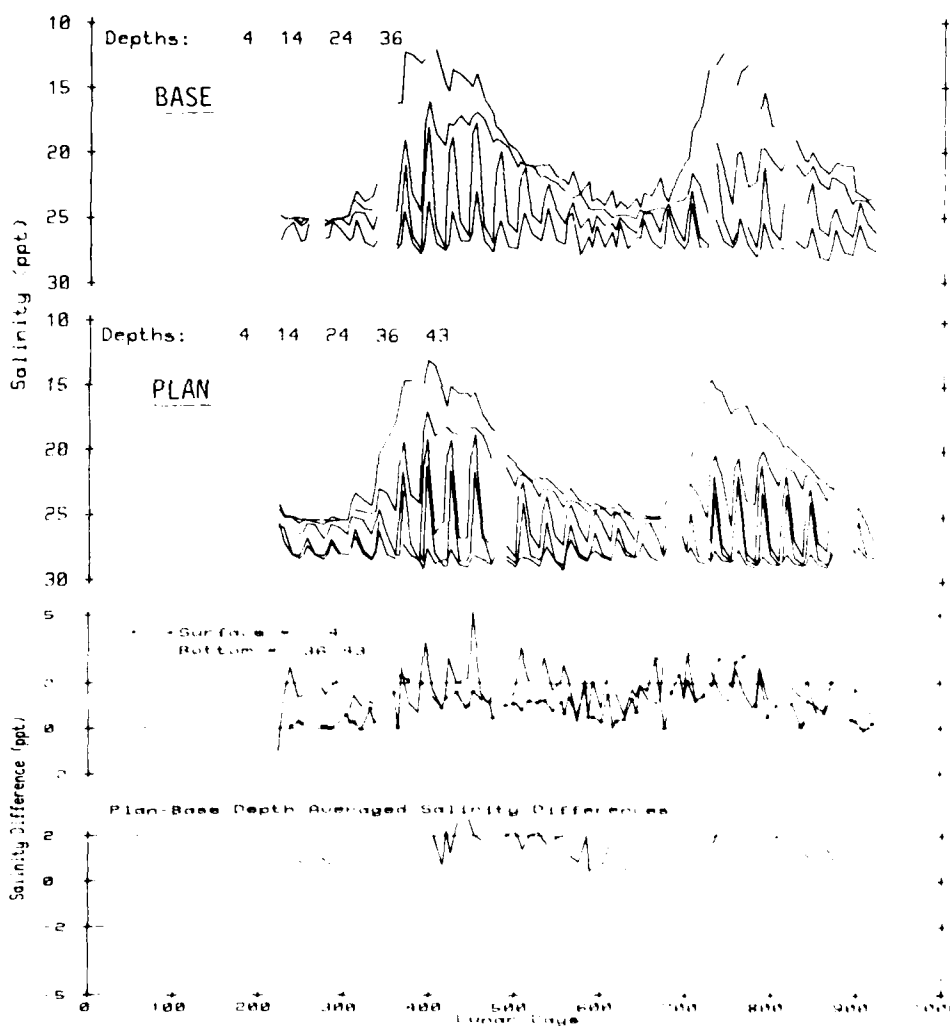
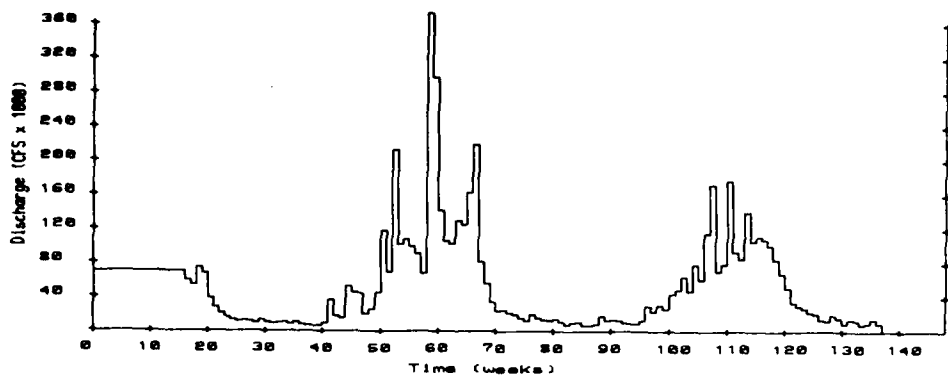
Station EH 0401



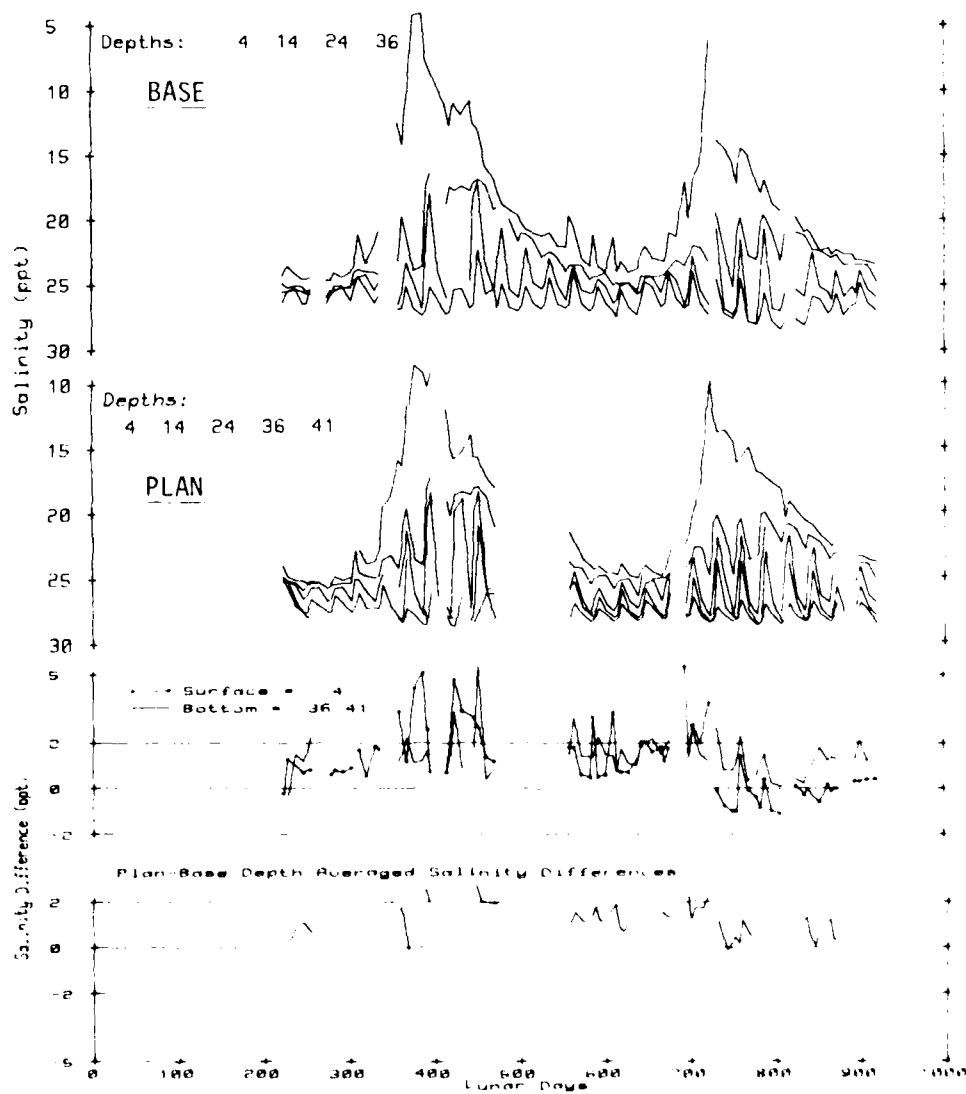
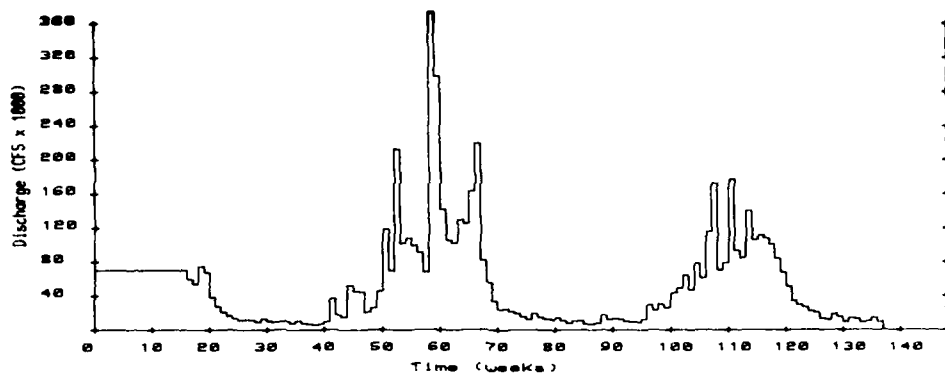
Station EH 0501



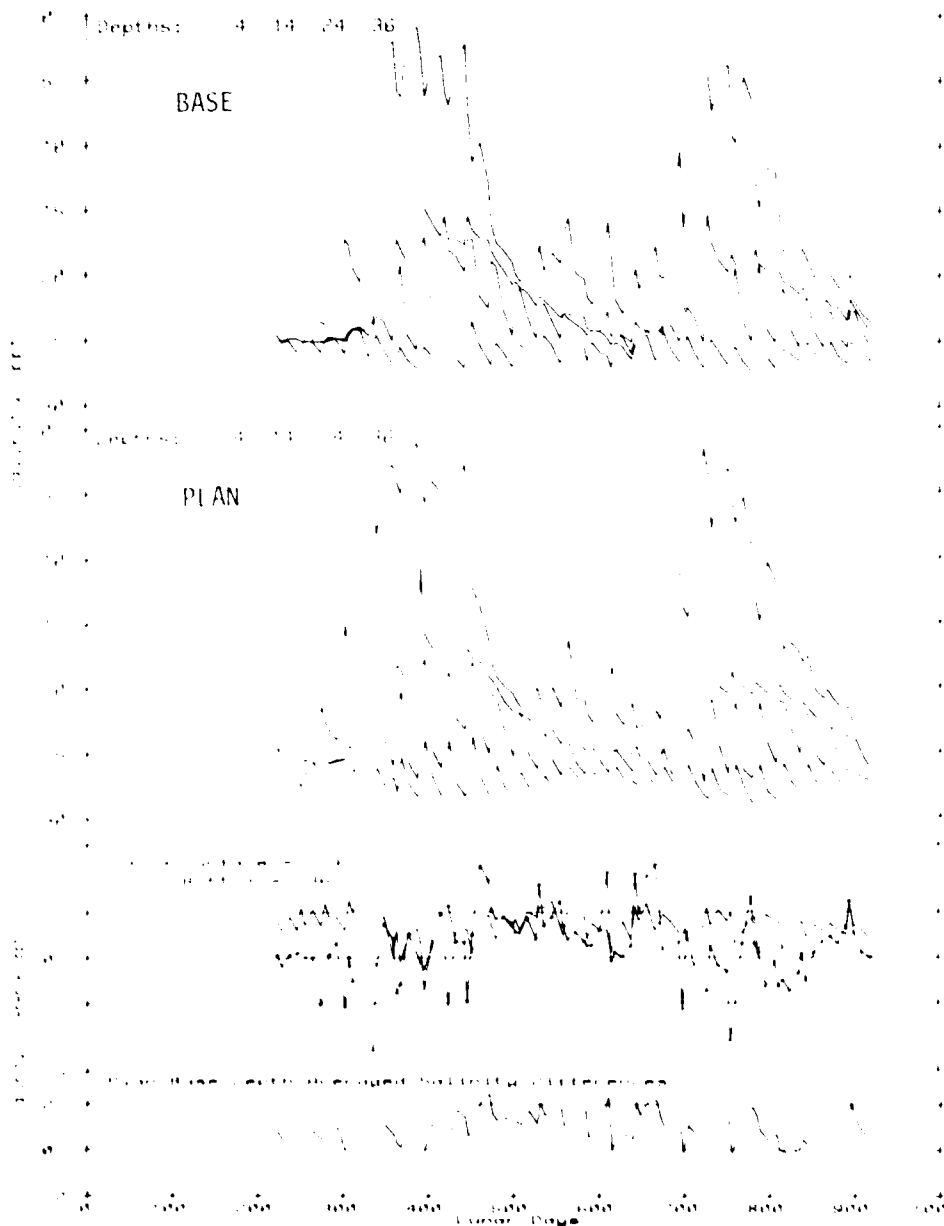
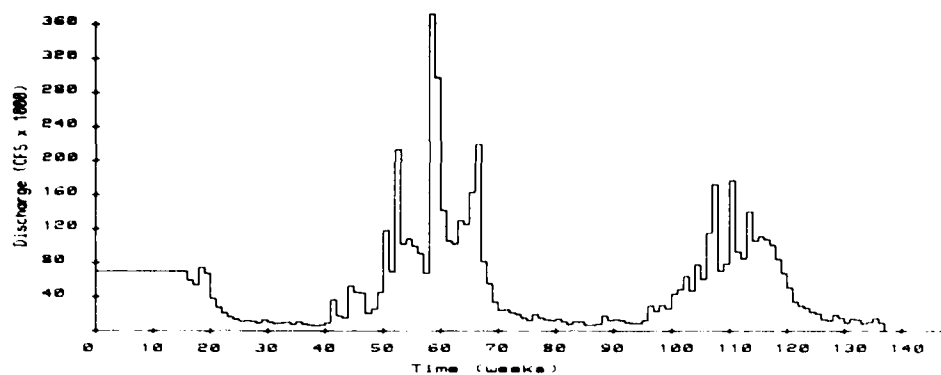
Station EH 0601



Station EH 0701

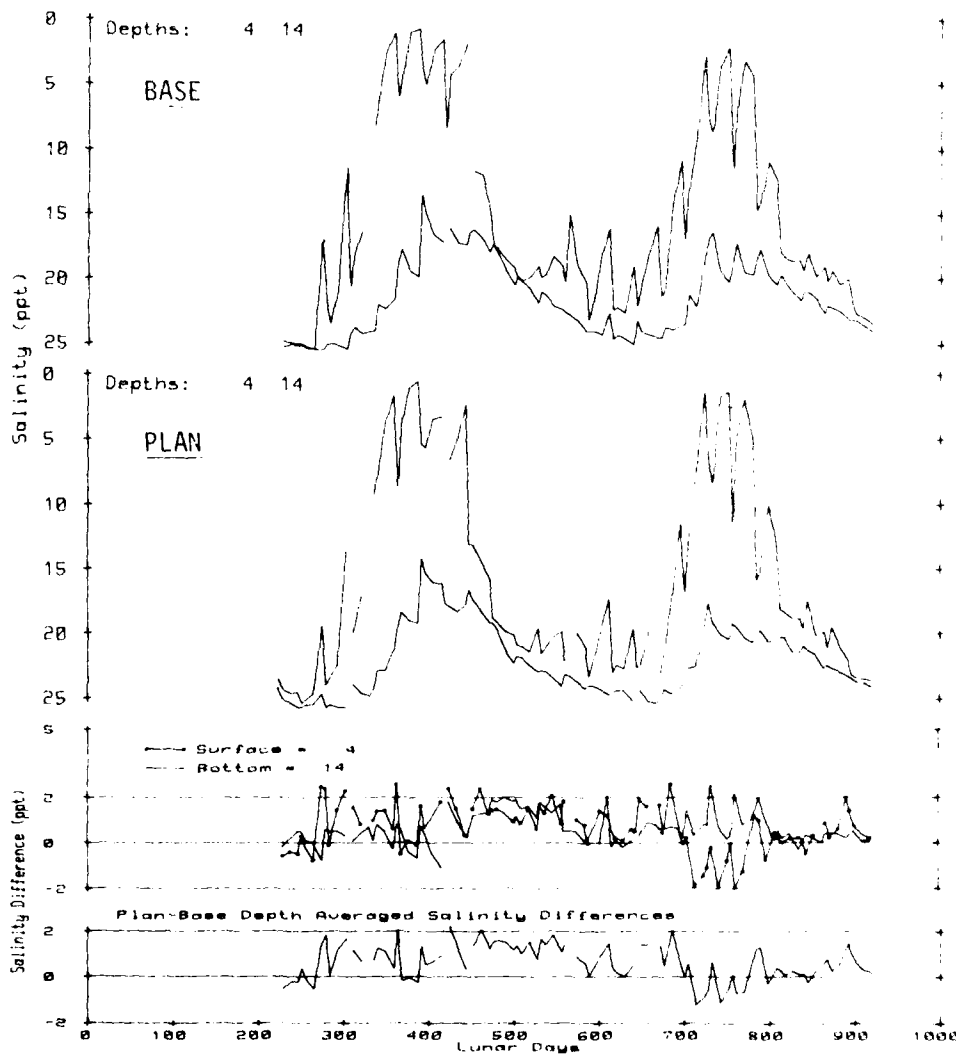
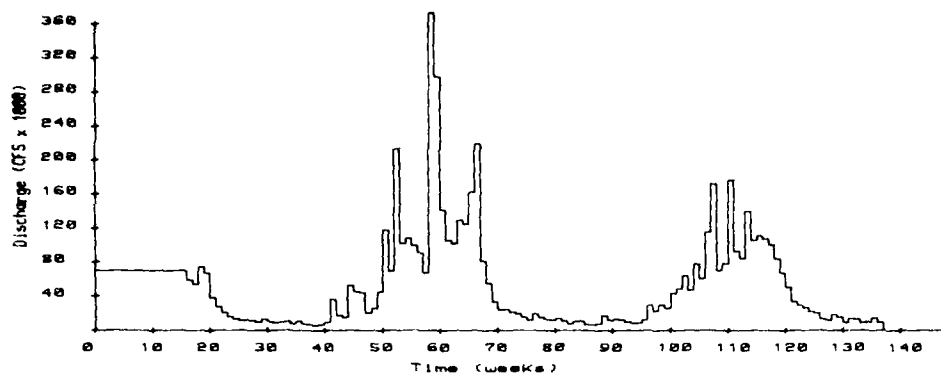


Station FH 0801

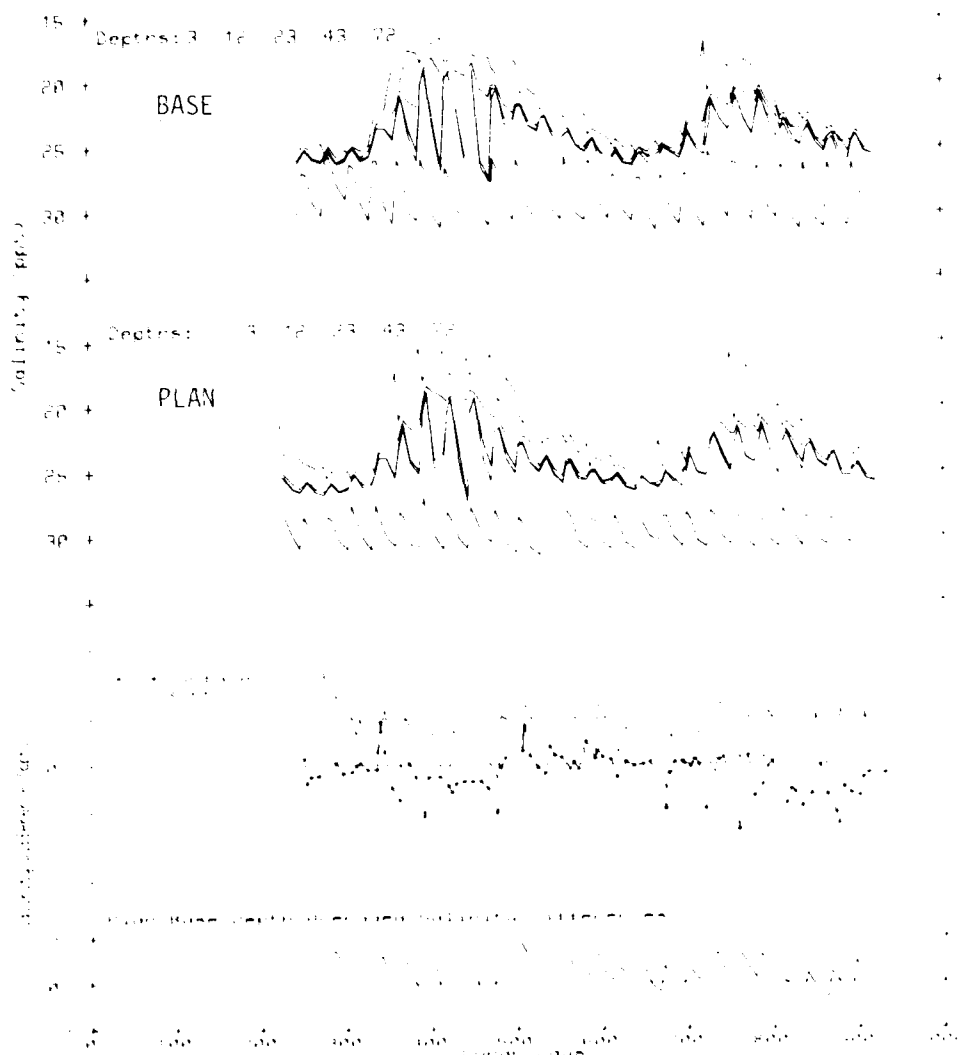
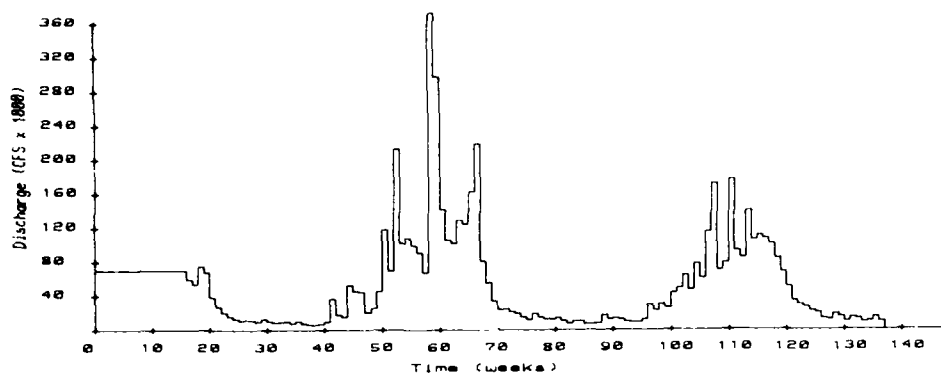


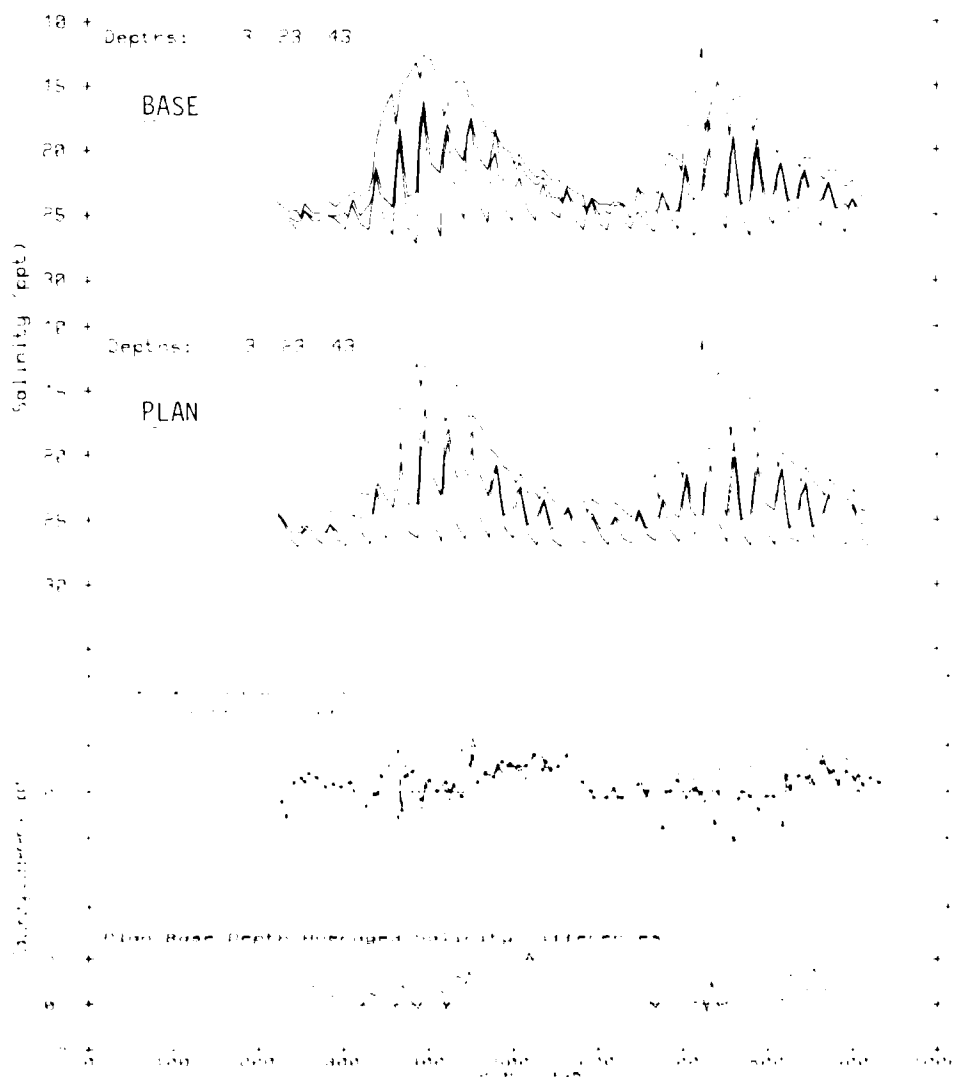
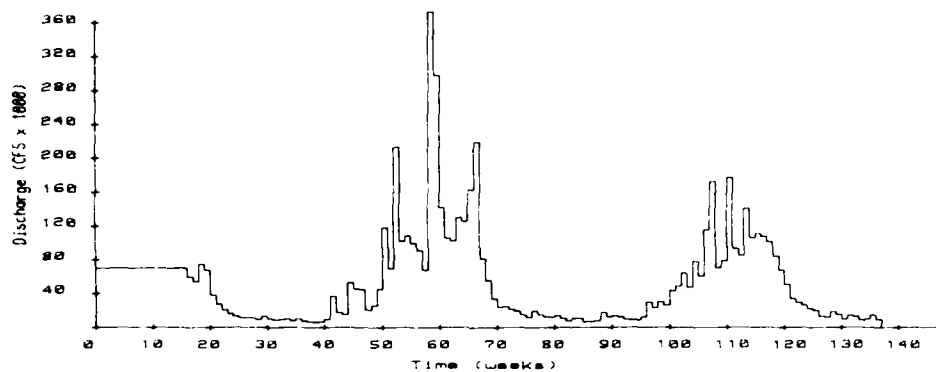
Station EH 0901

PLATE 171

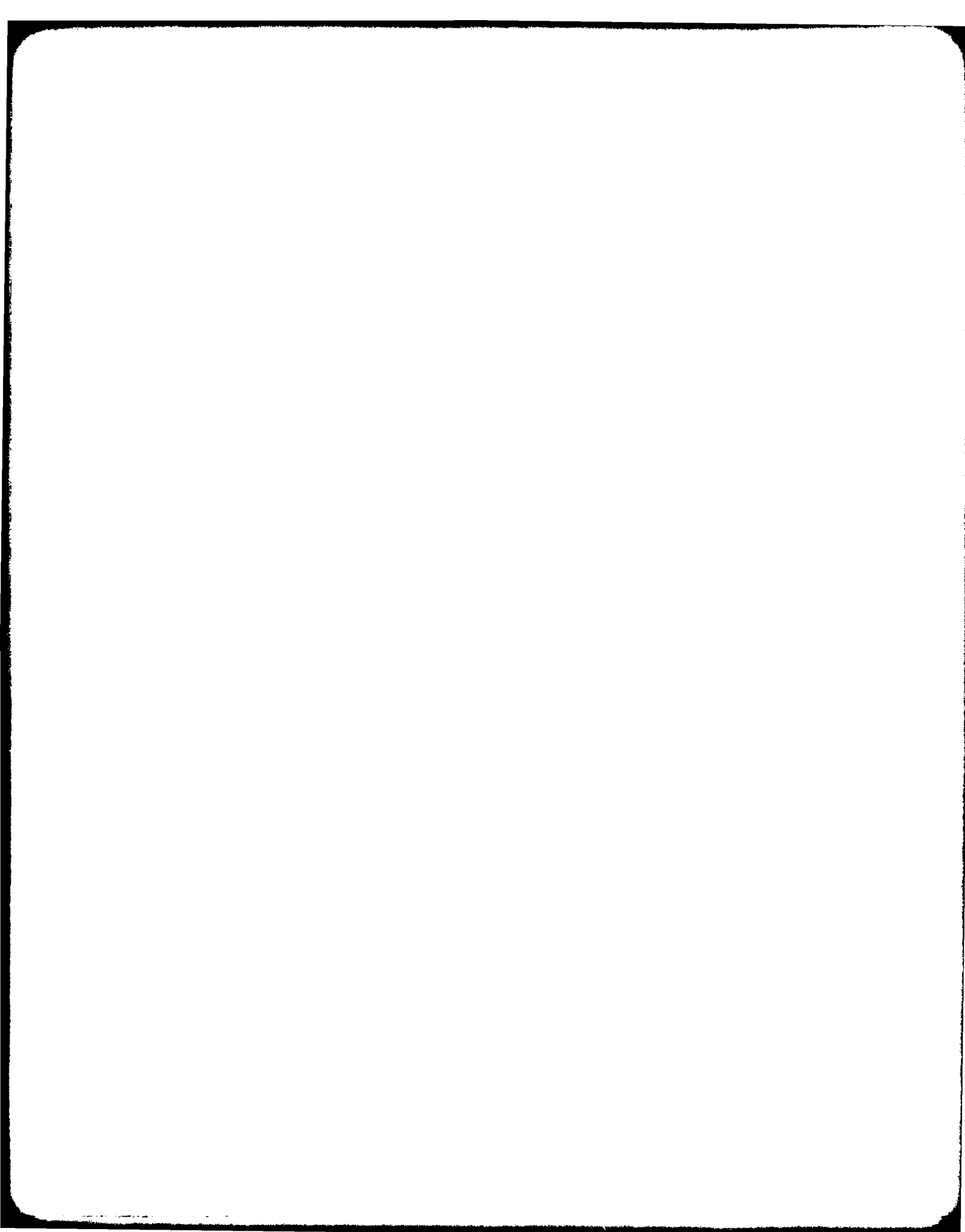


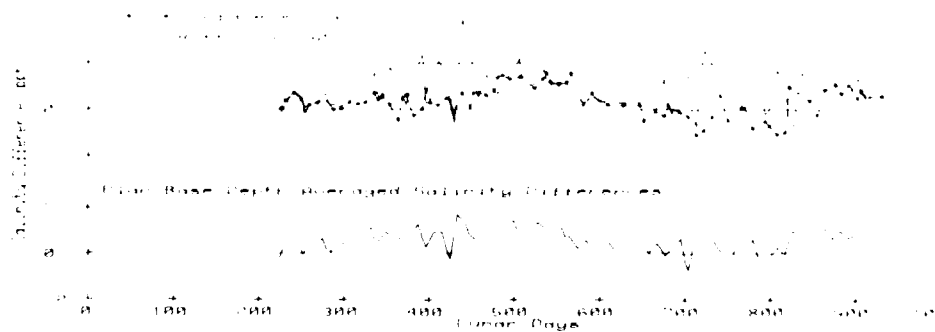
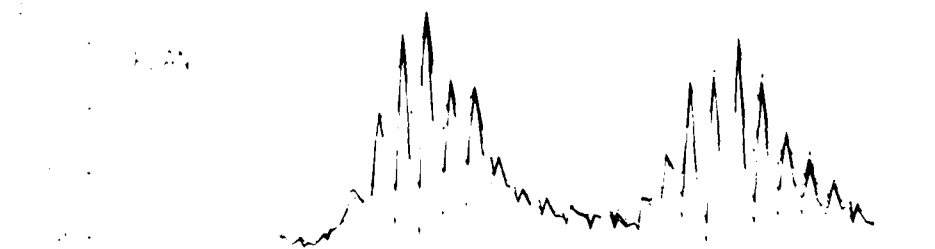
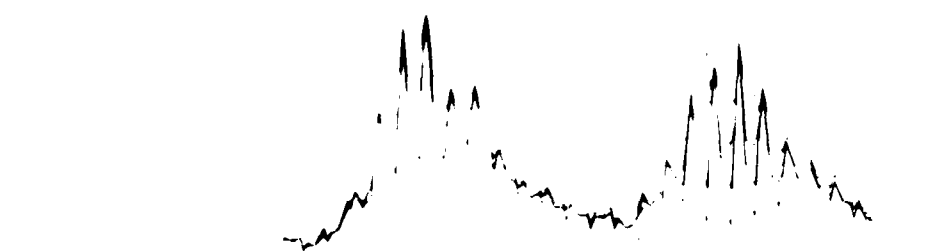
Station EH 1001





Station JG 0203

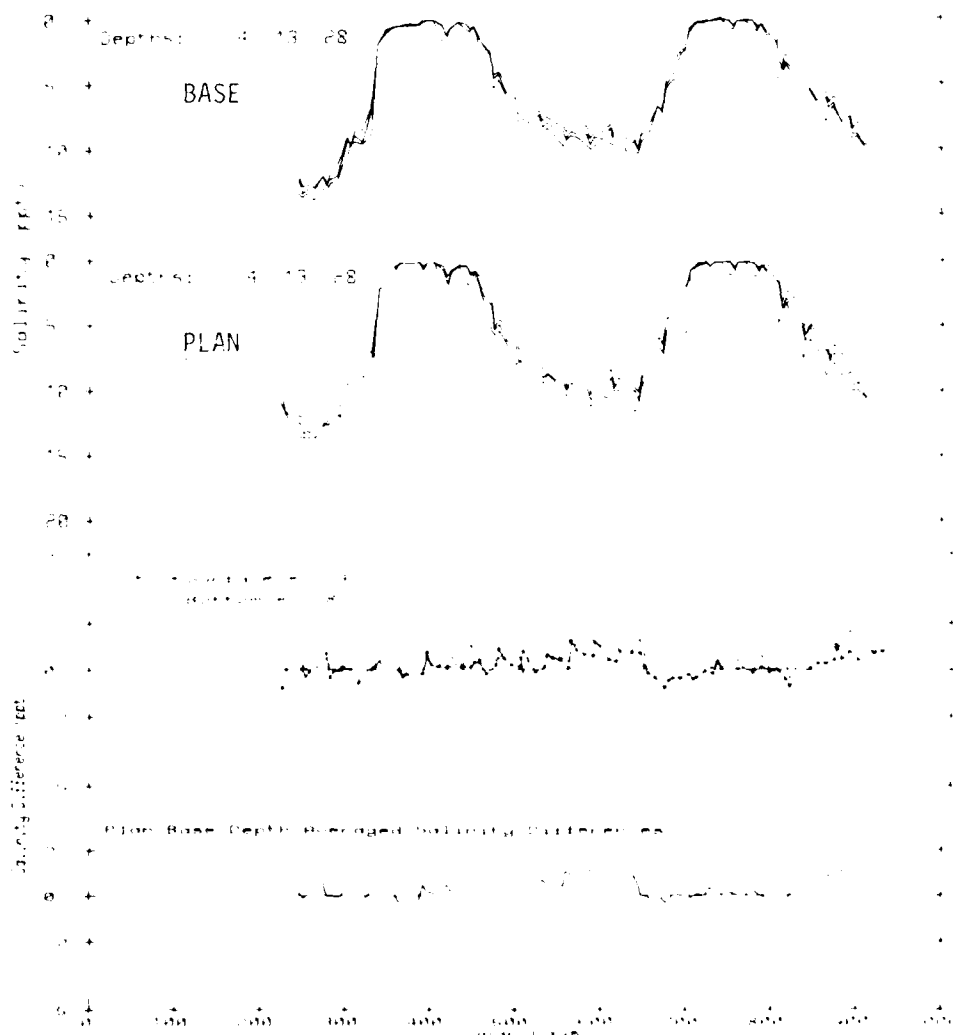
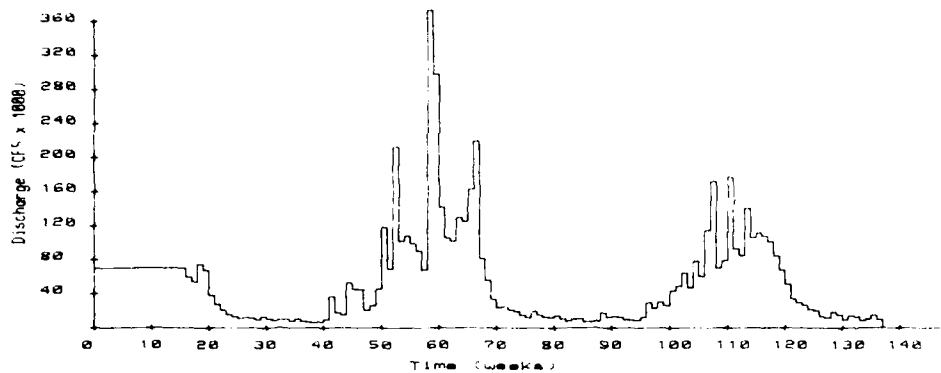




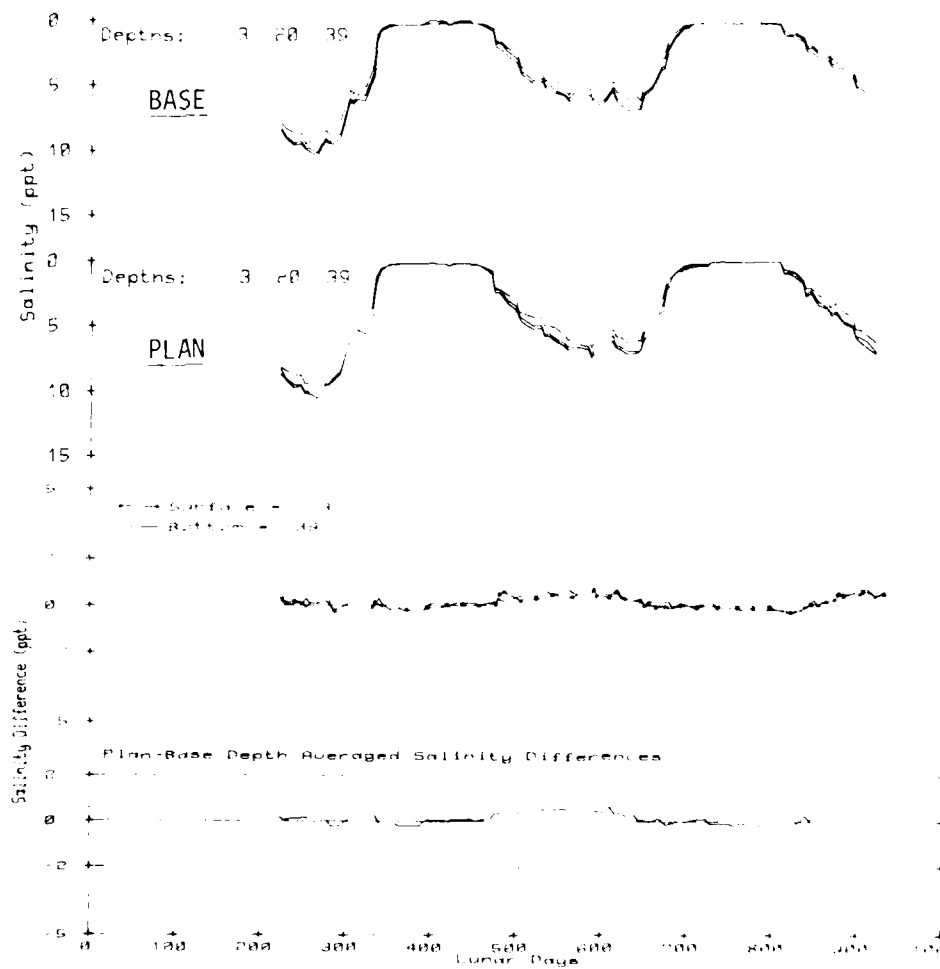
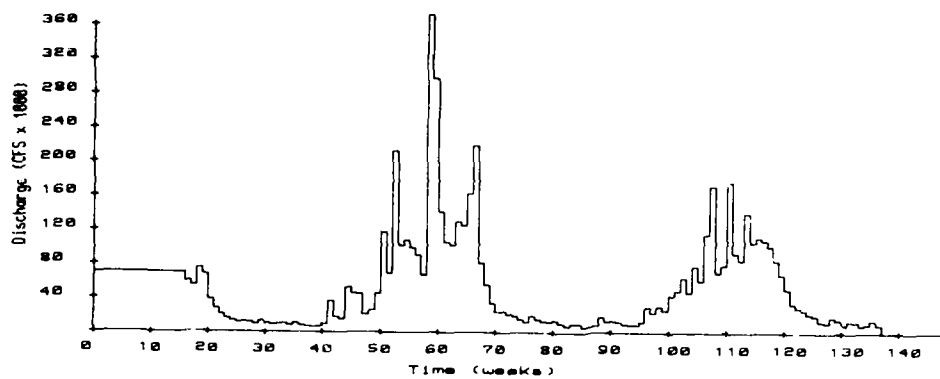
Station JG 0302

PLATE 175

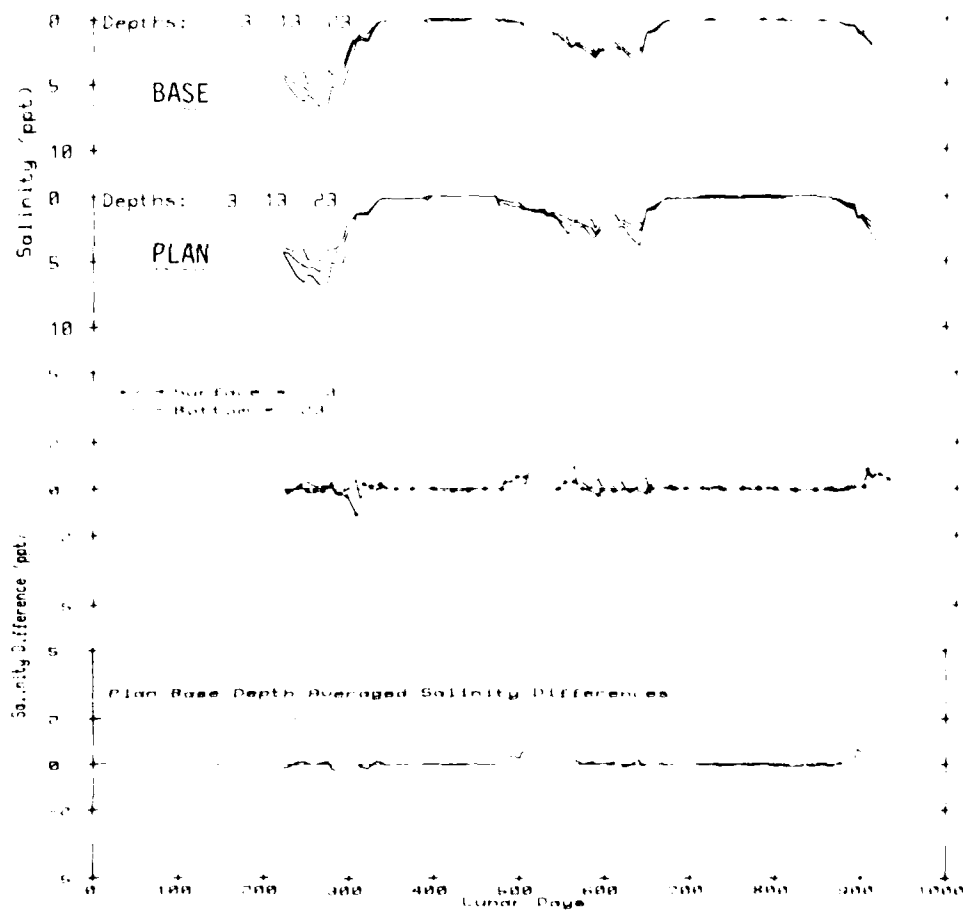
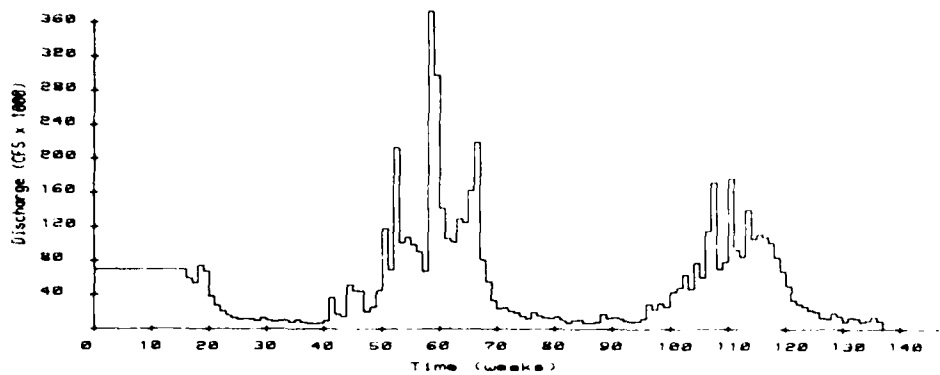
PRECEDING PAGE BLANK-NOT FILMED



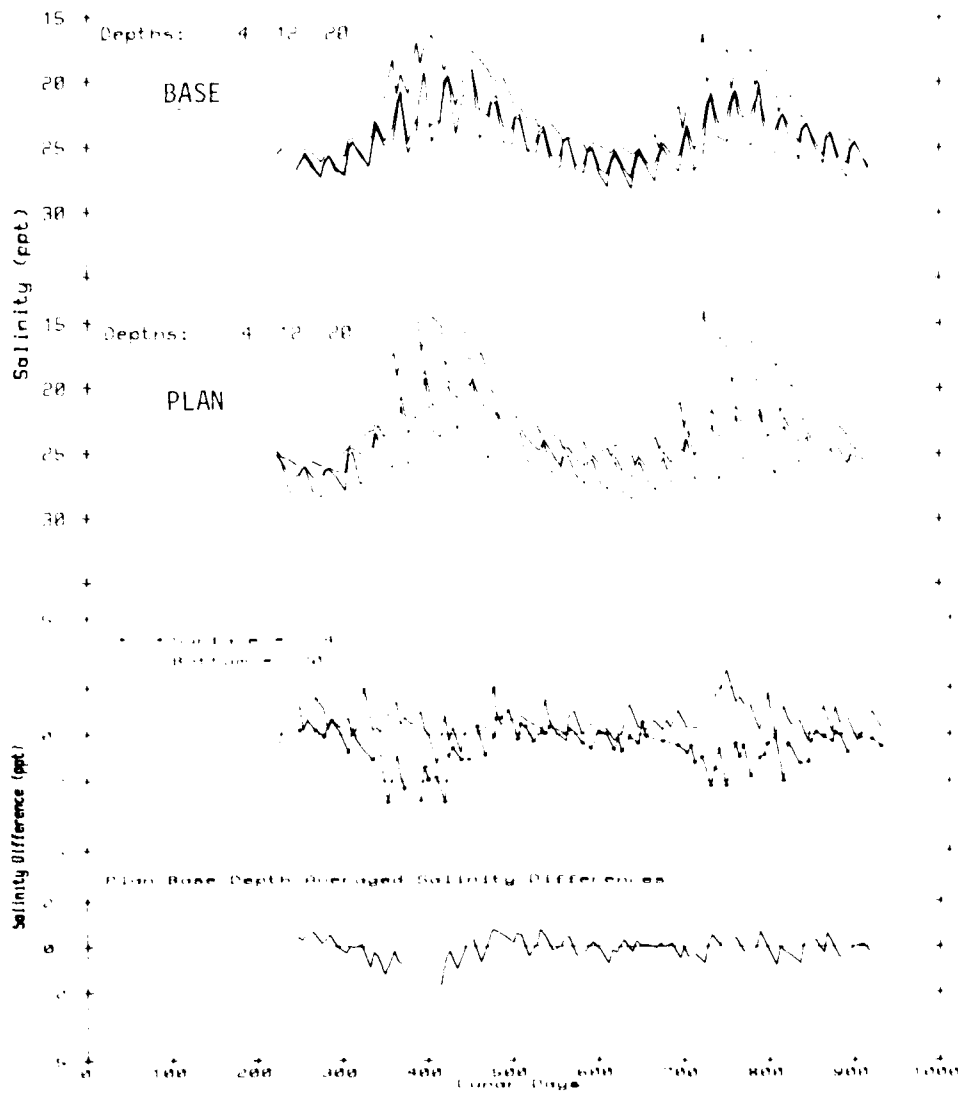
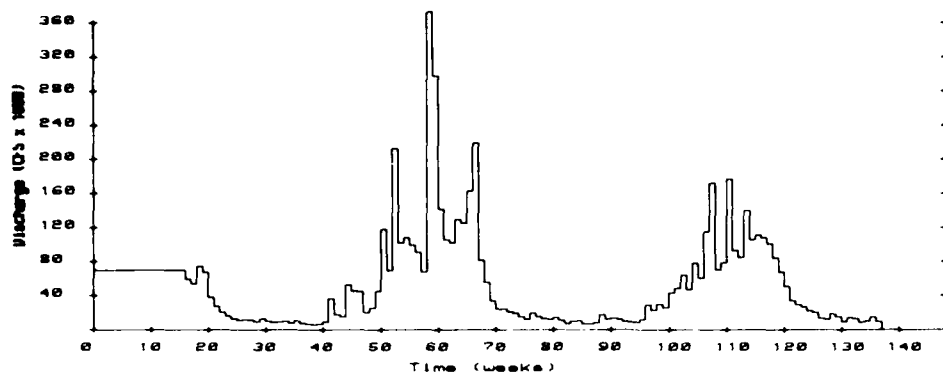
Station JG 0402



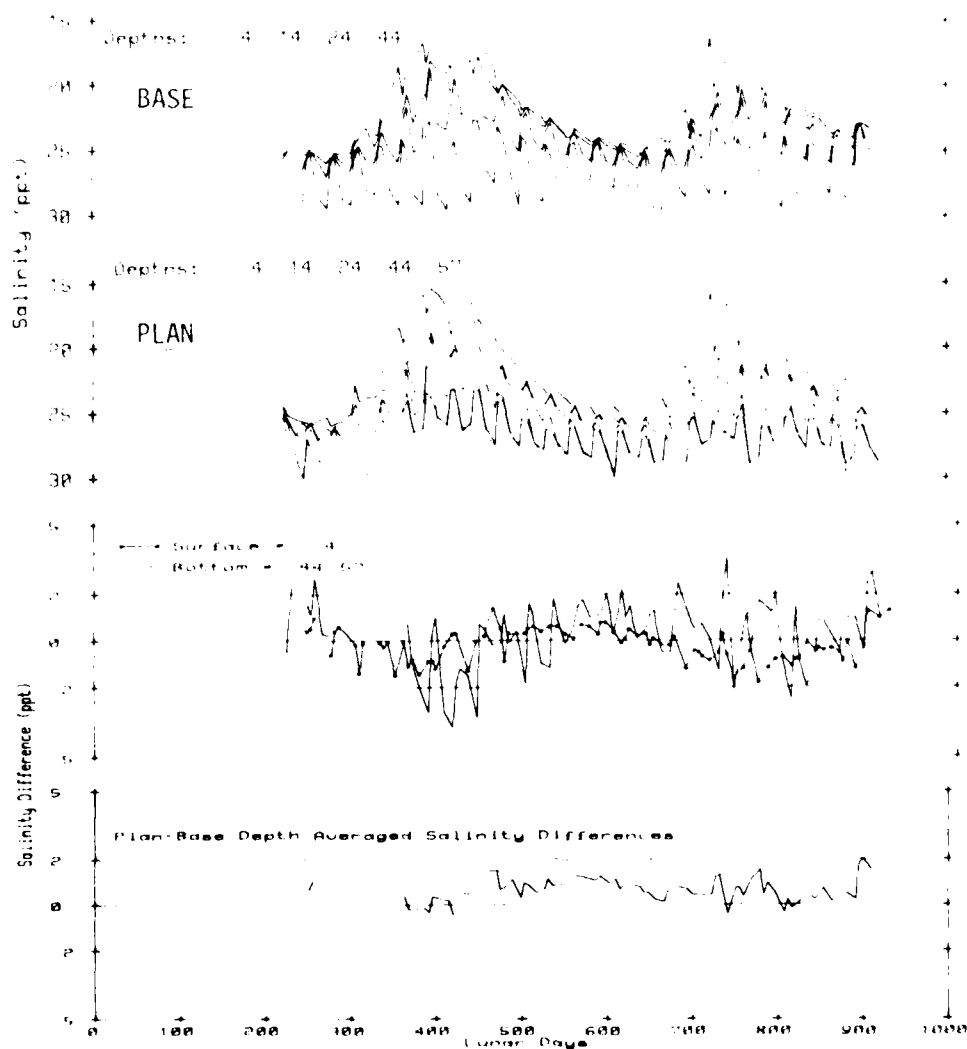
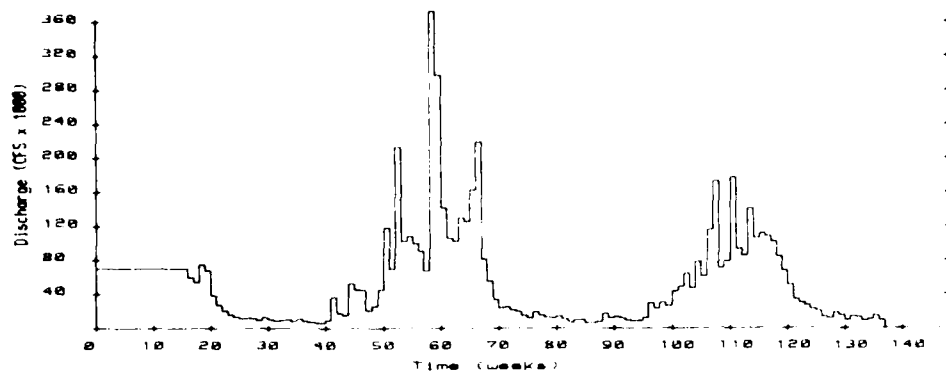
Station JG 0502



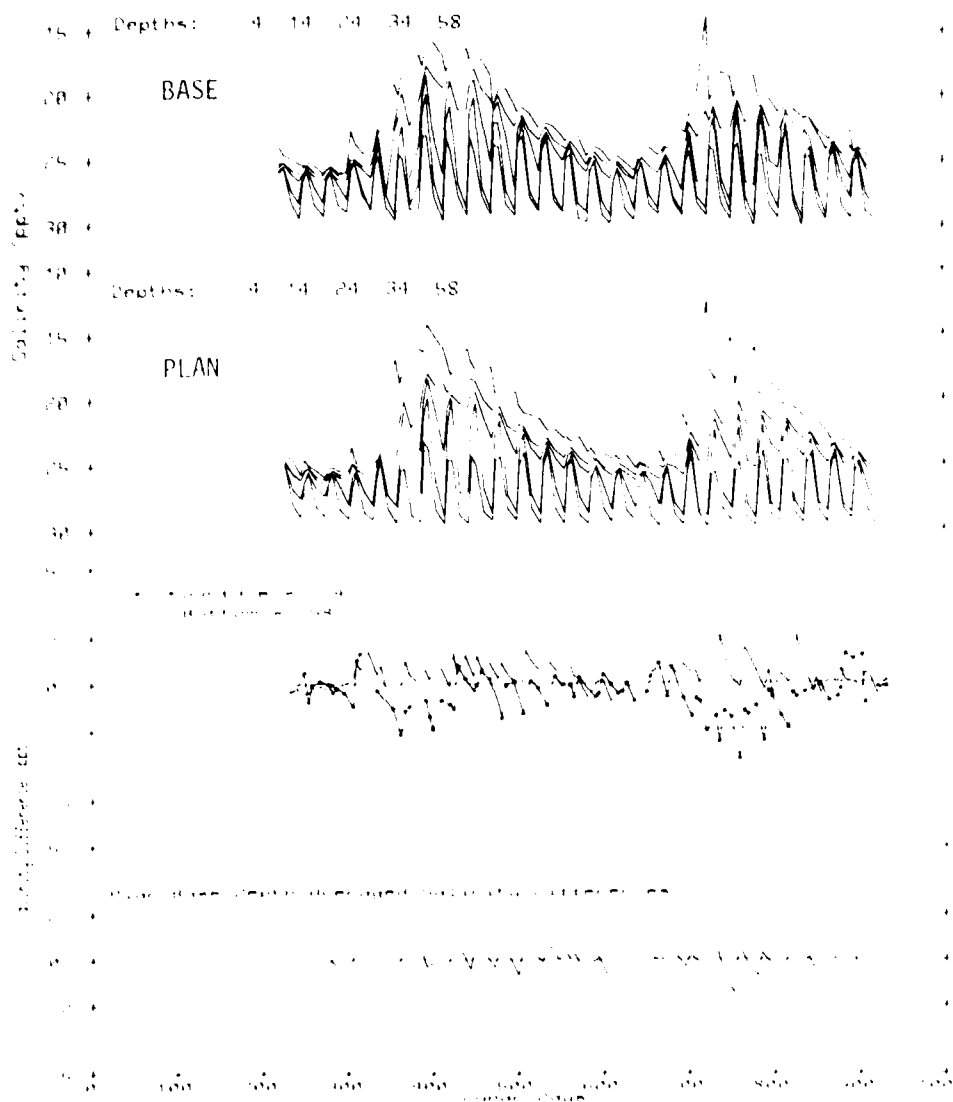
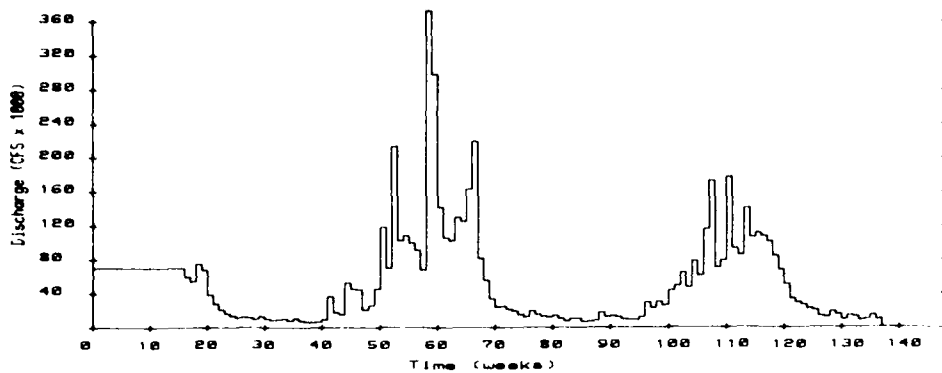
Station JG 0601



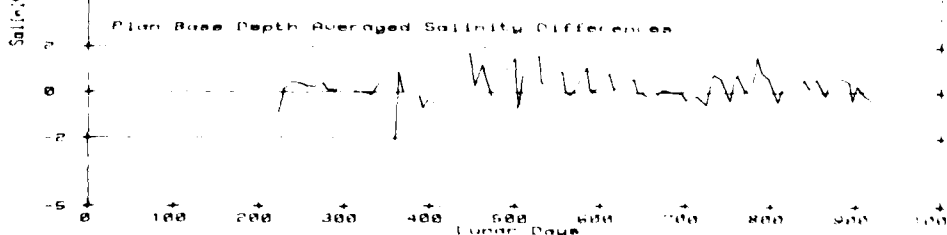
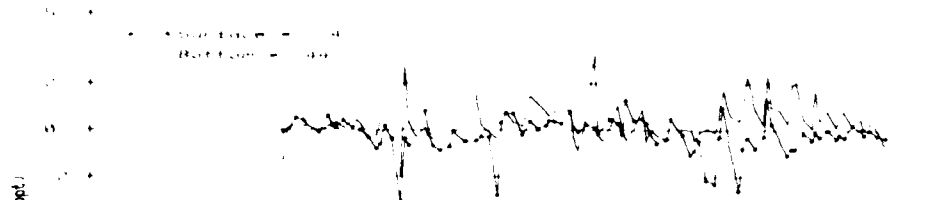
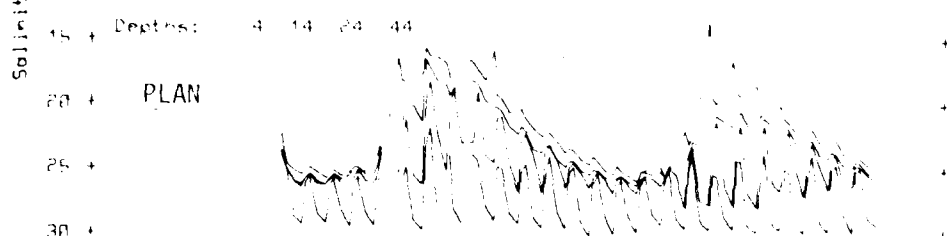
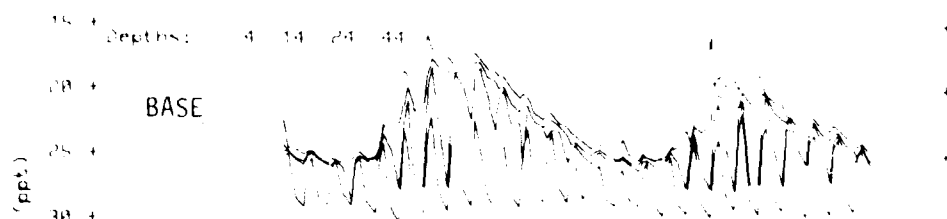
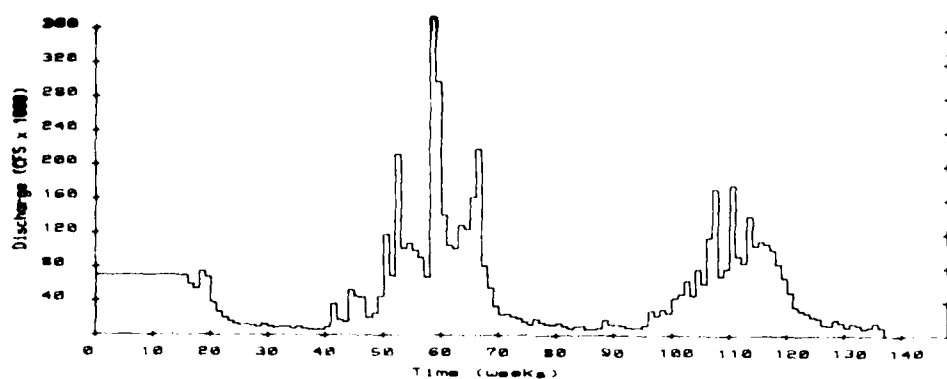
Station JN 0101



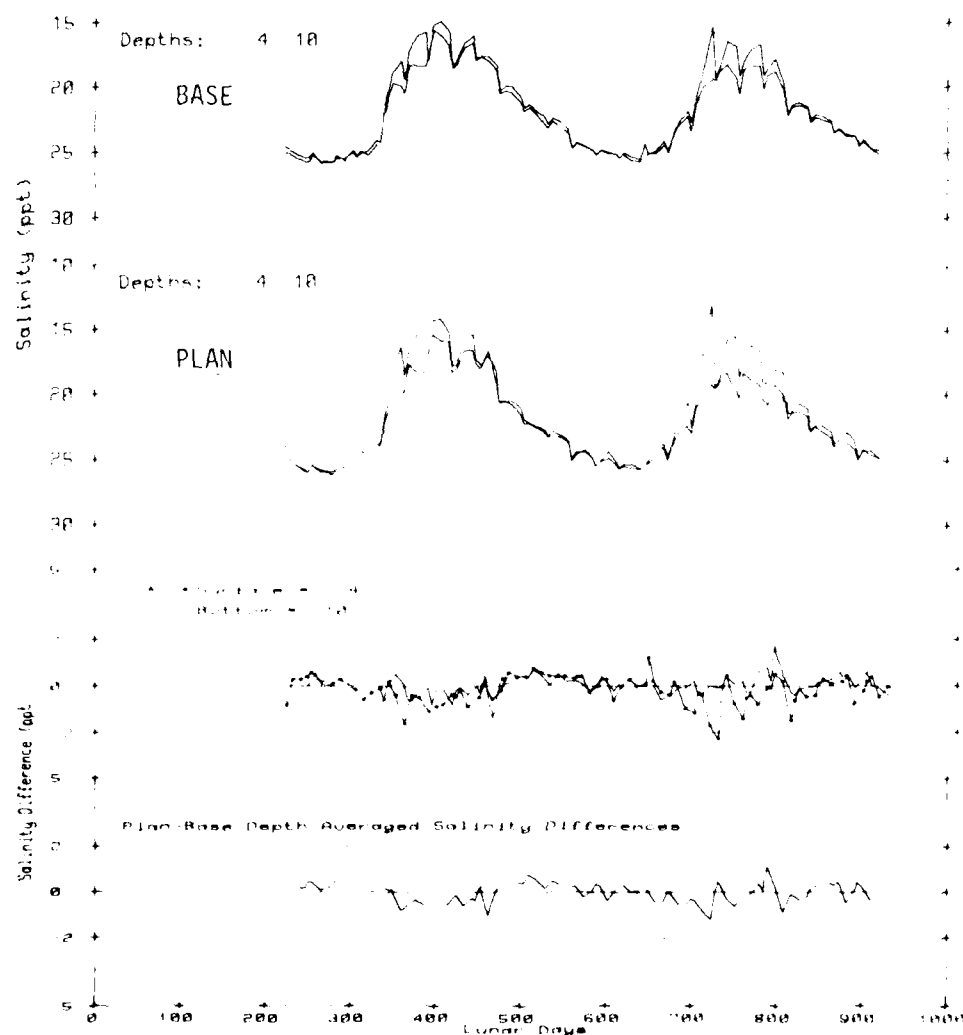
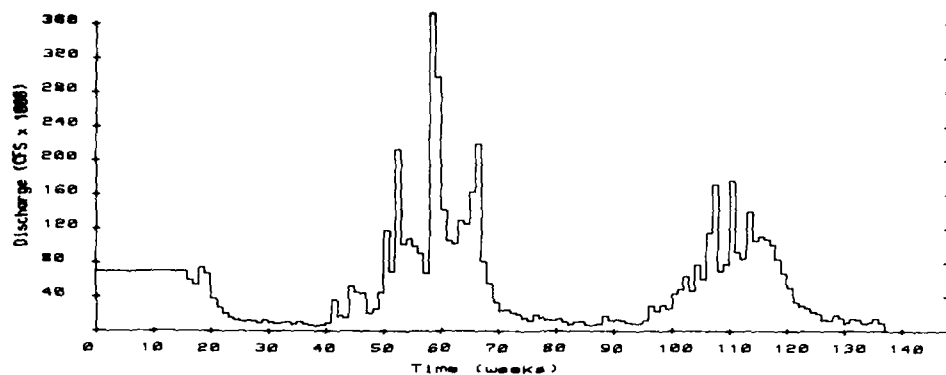
Station JN 0102



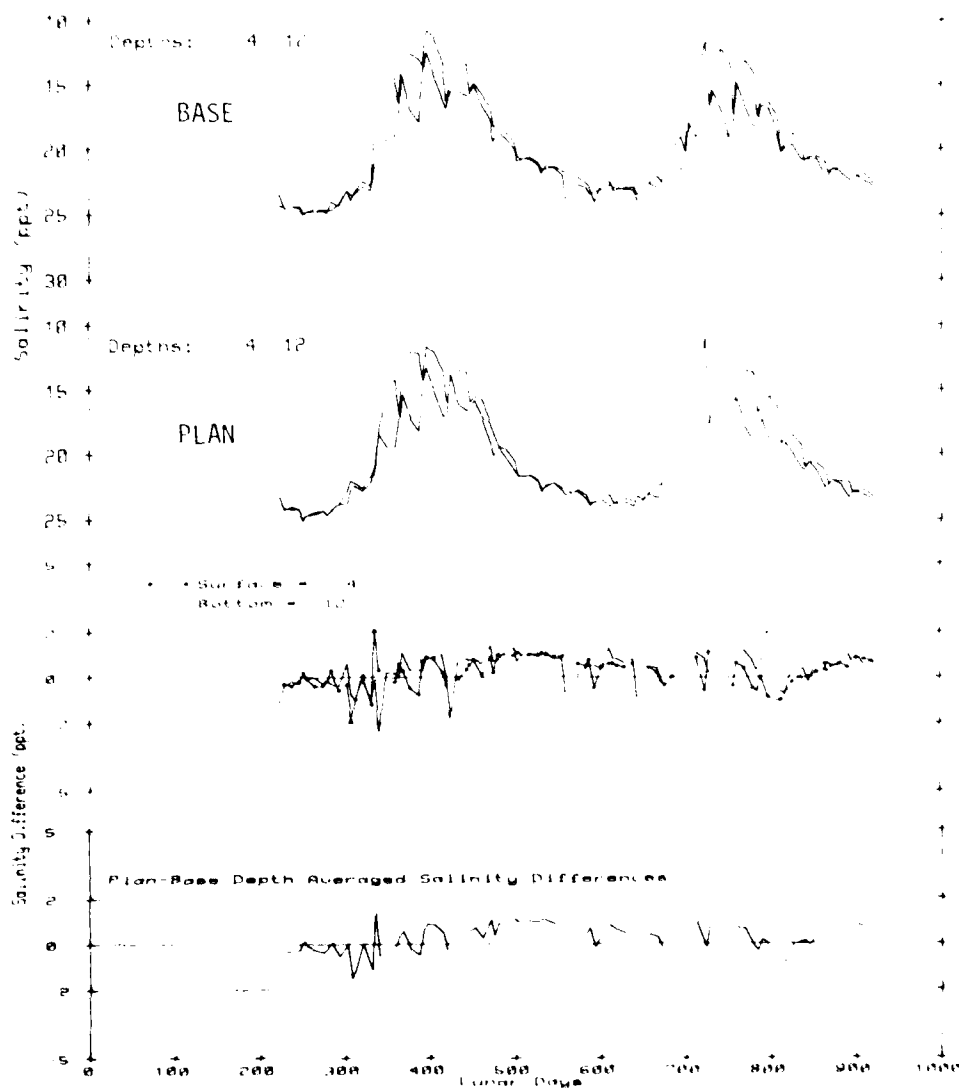
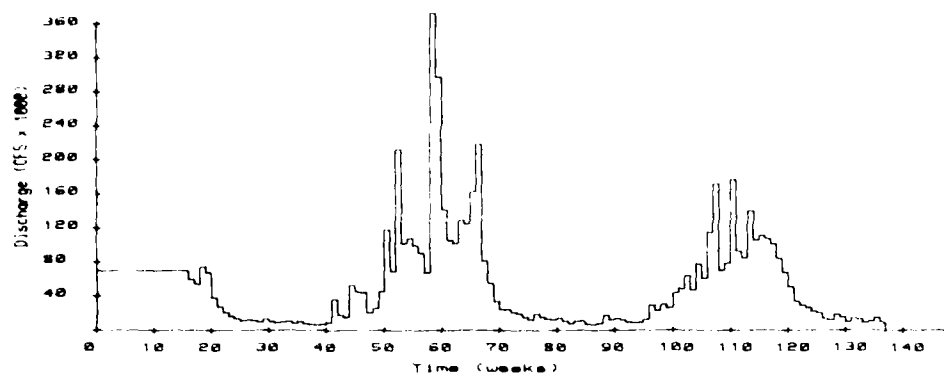
Station JN 0103



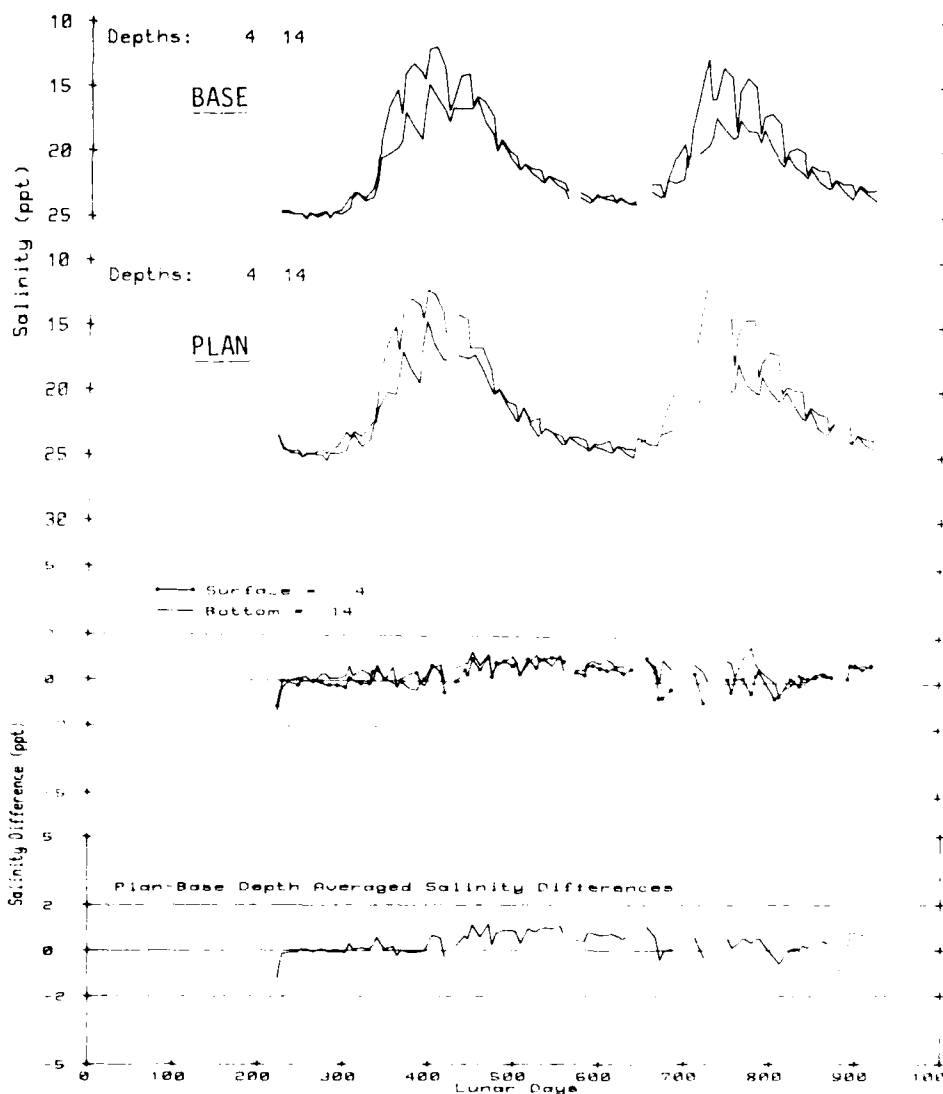
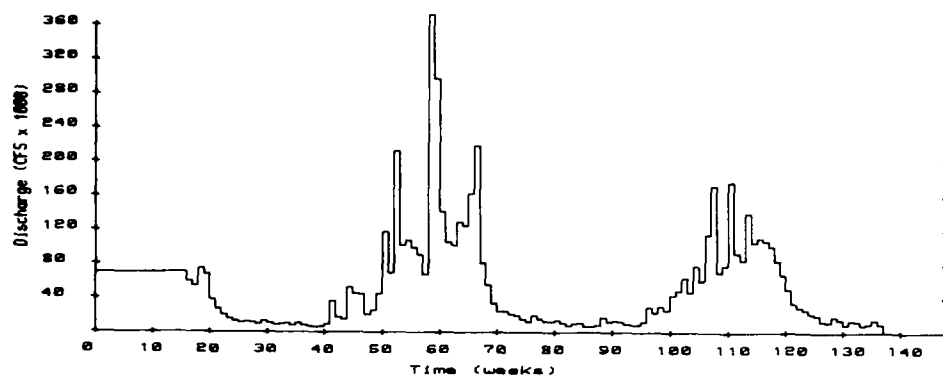
Station JN 0104



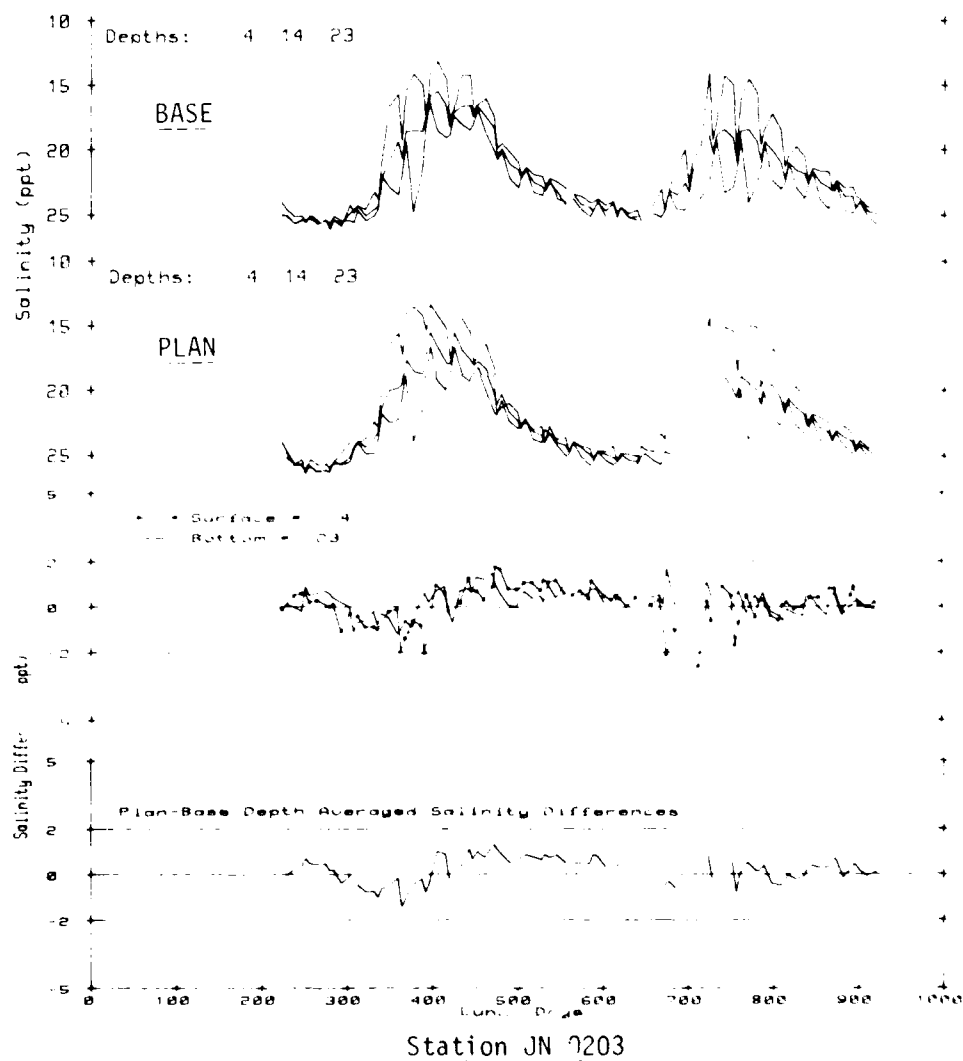
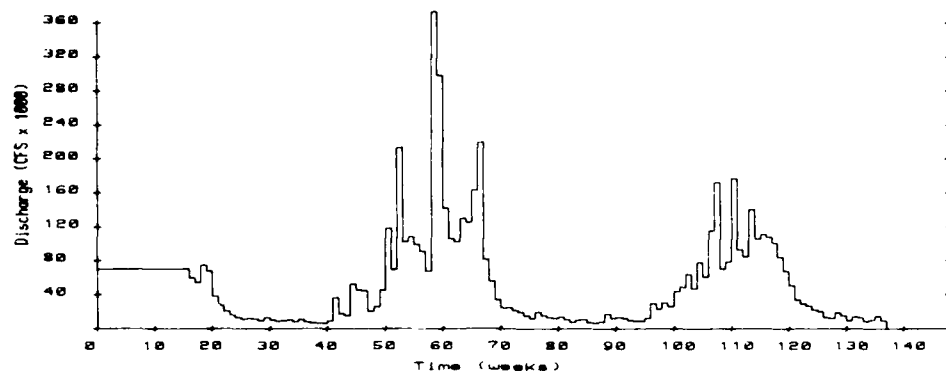
Station JN 0103

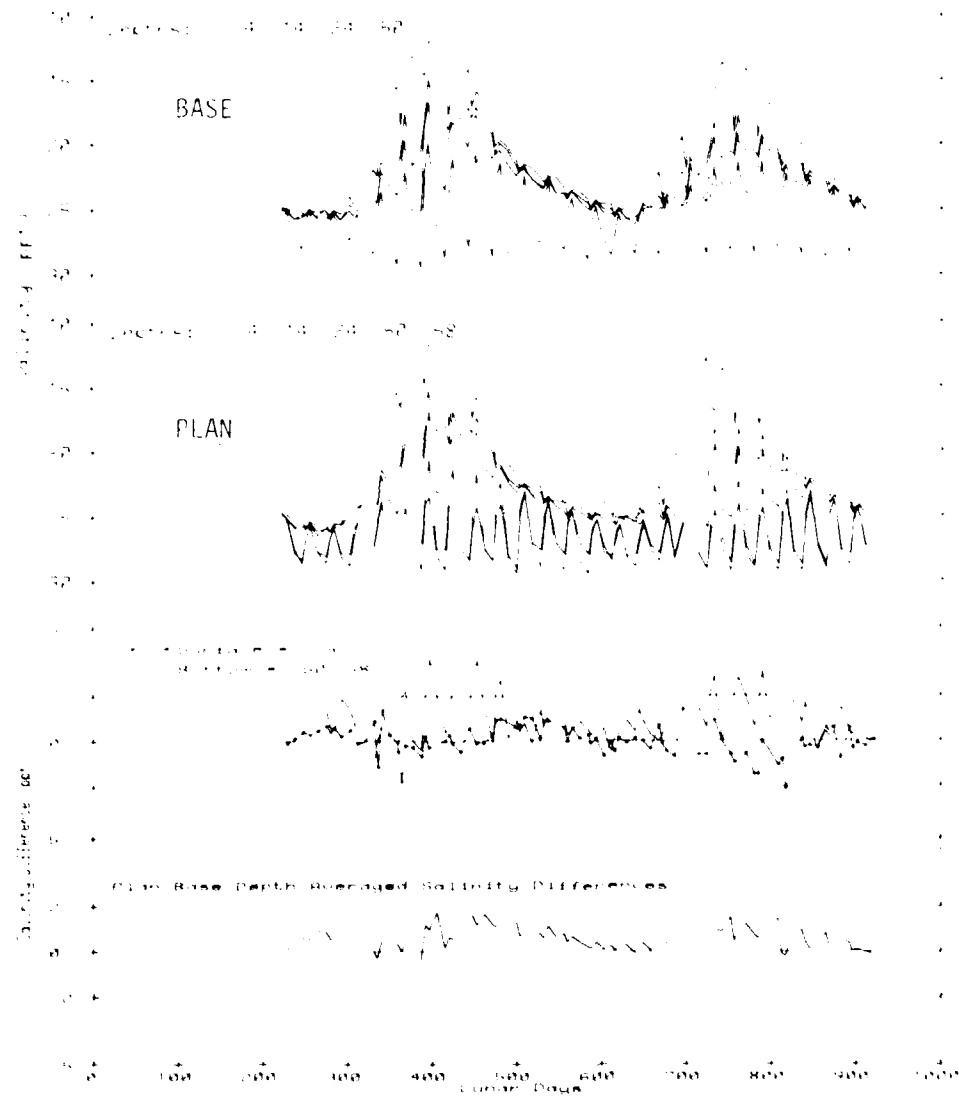
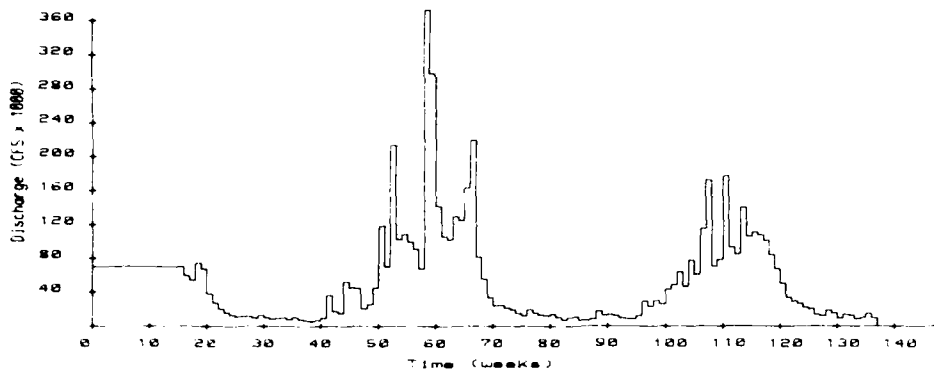


Station JN 0201

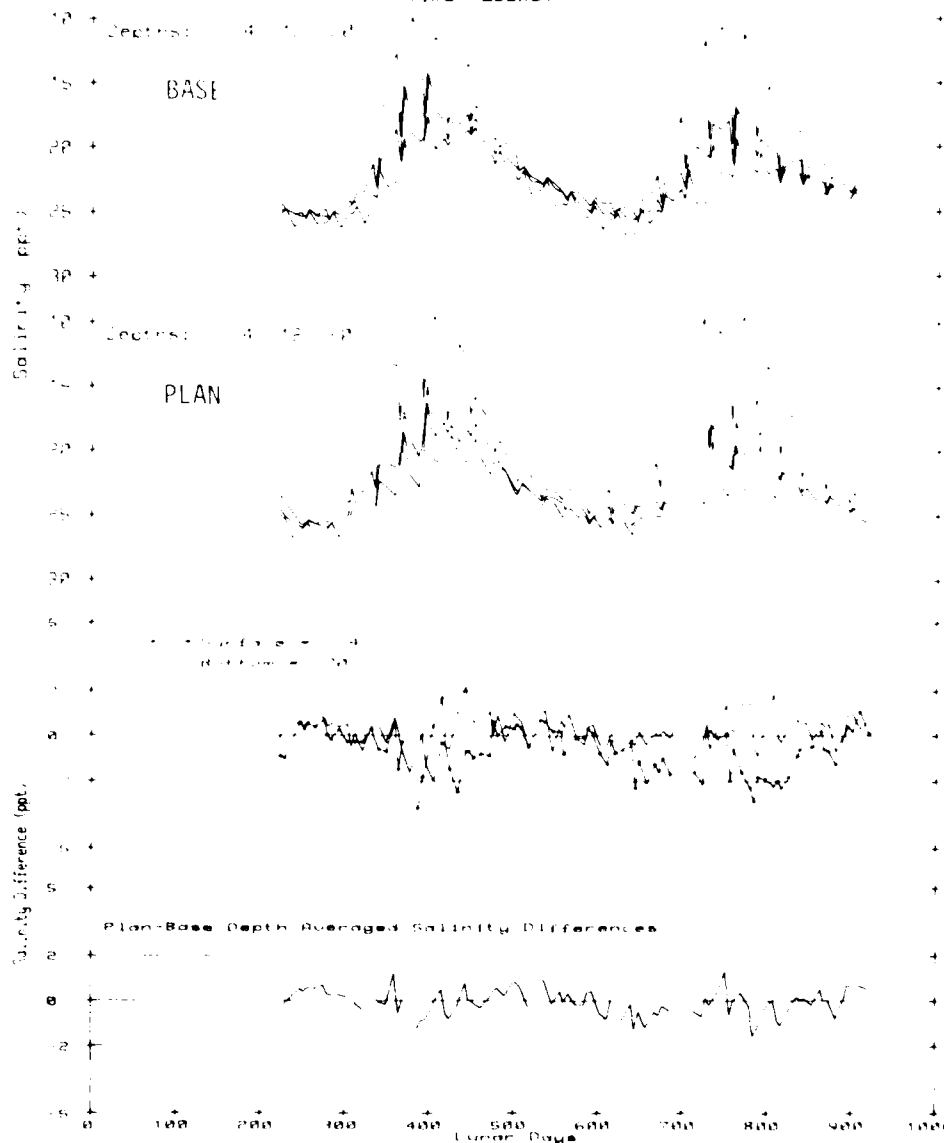
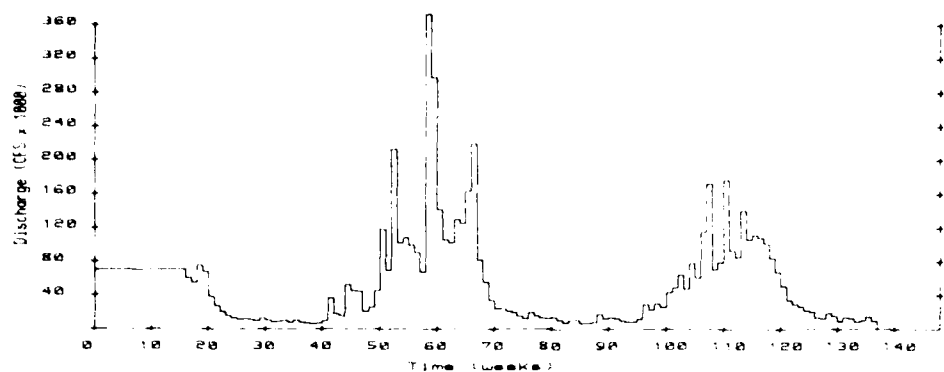


Station JN 0202

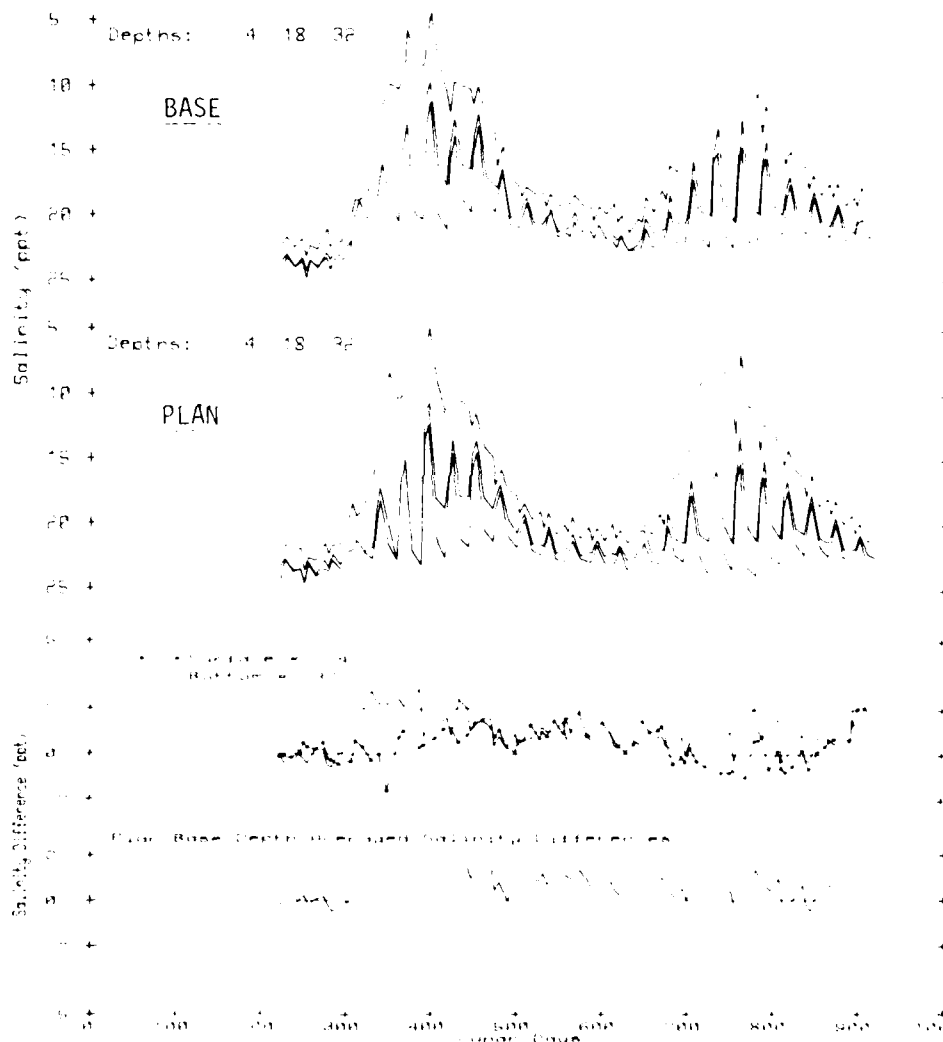
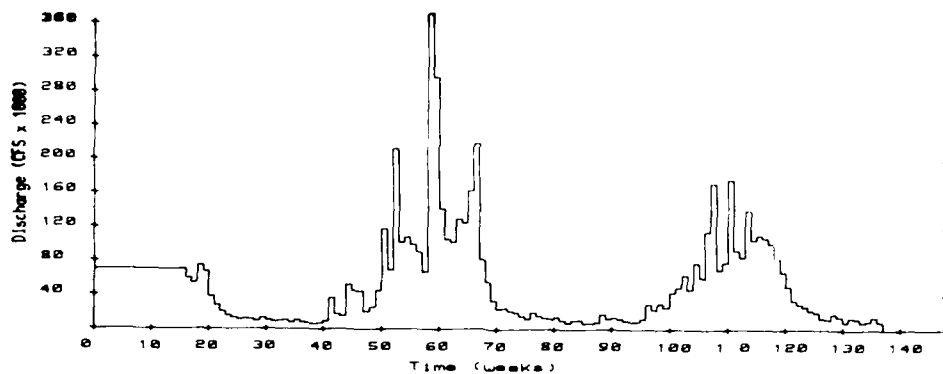




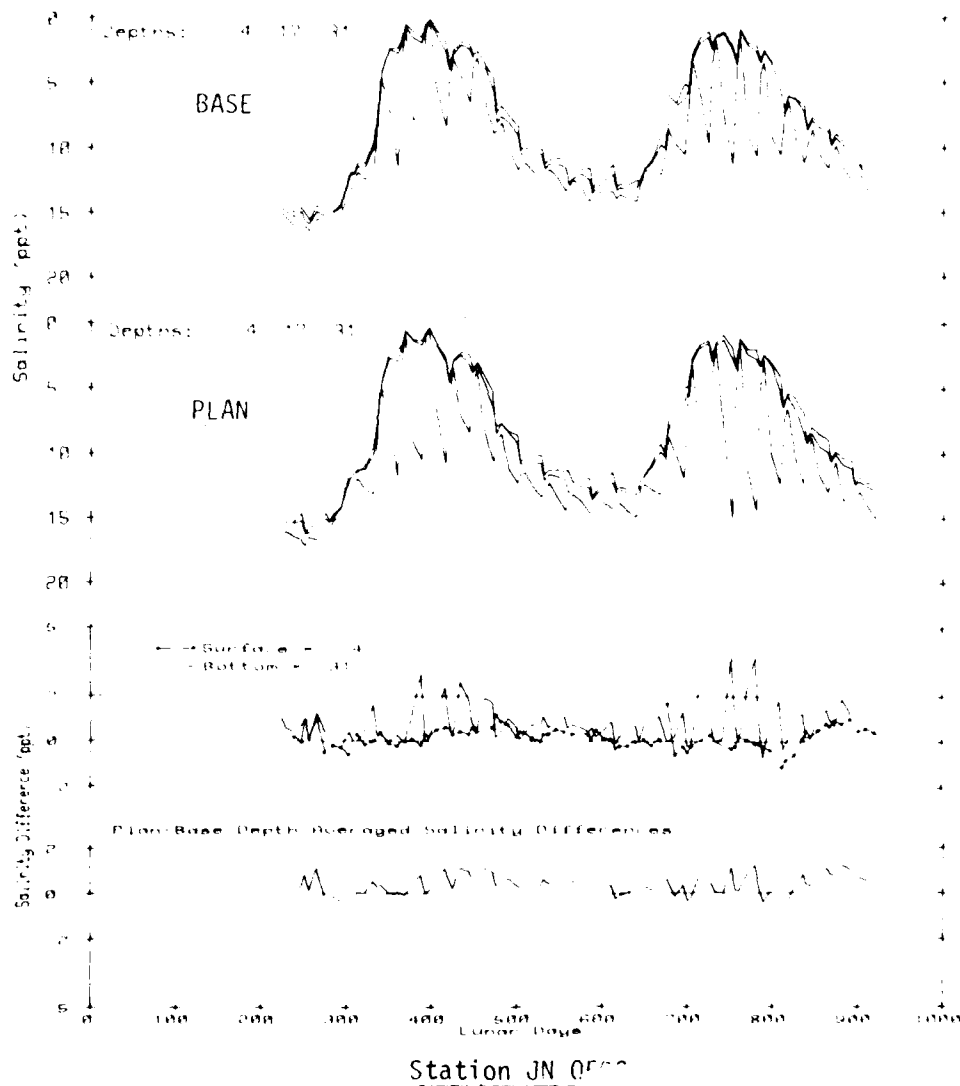
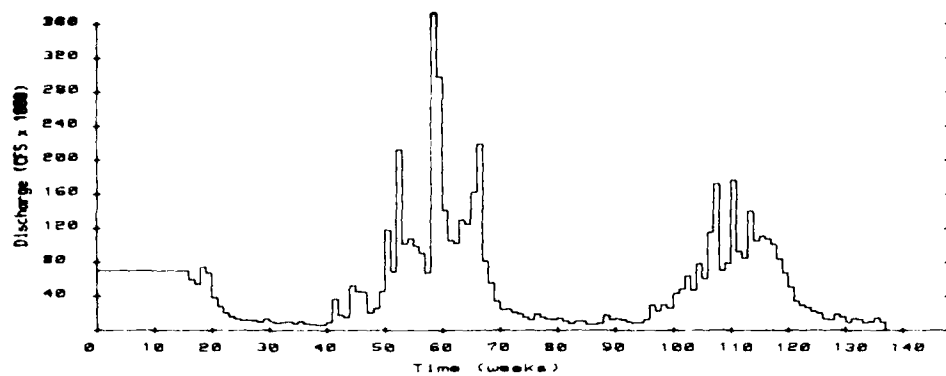
Station JN 0204

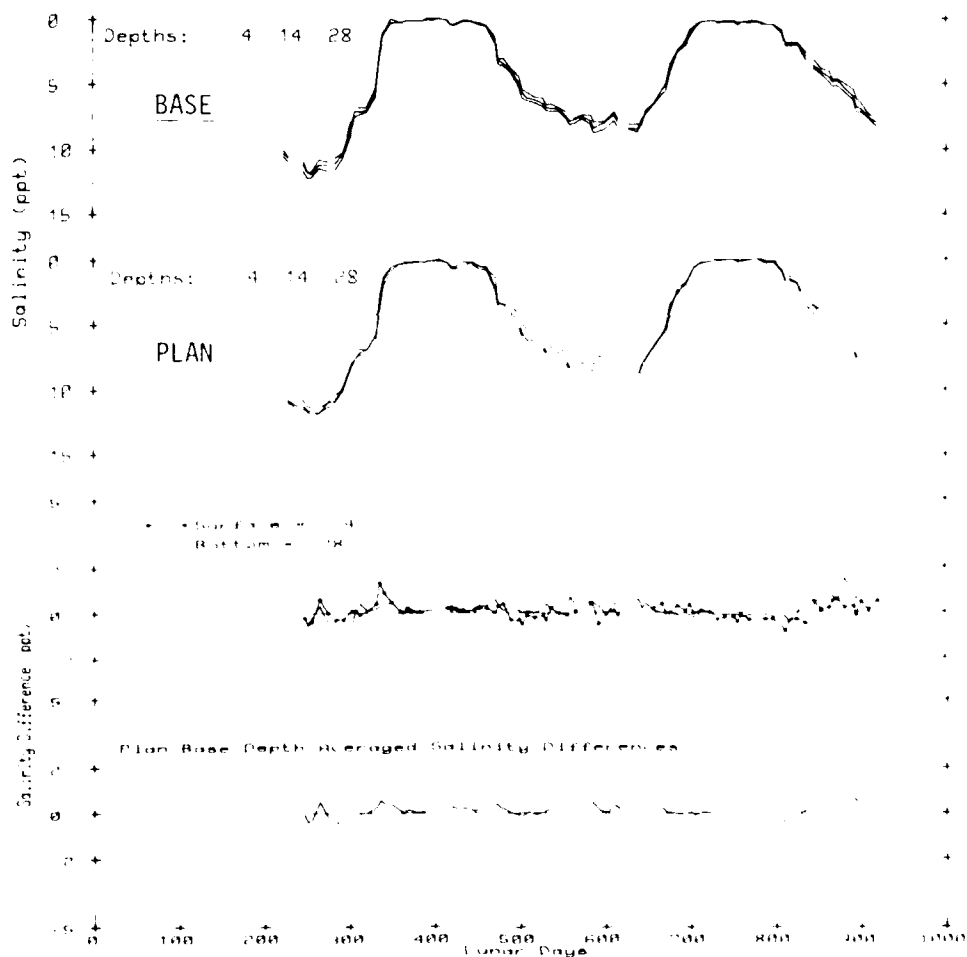
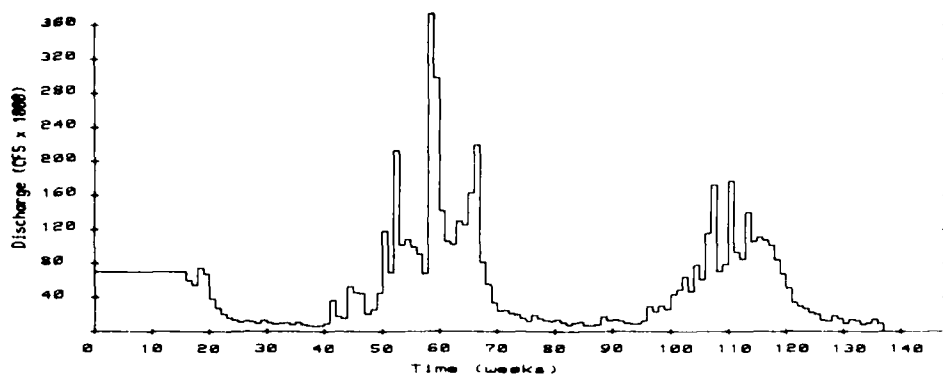


Station JN 0205

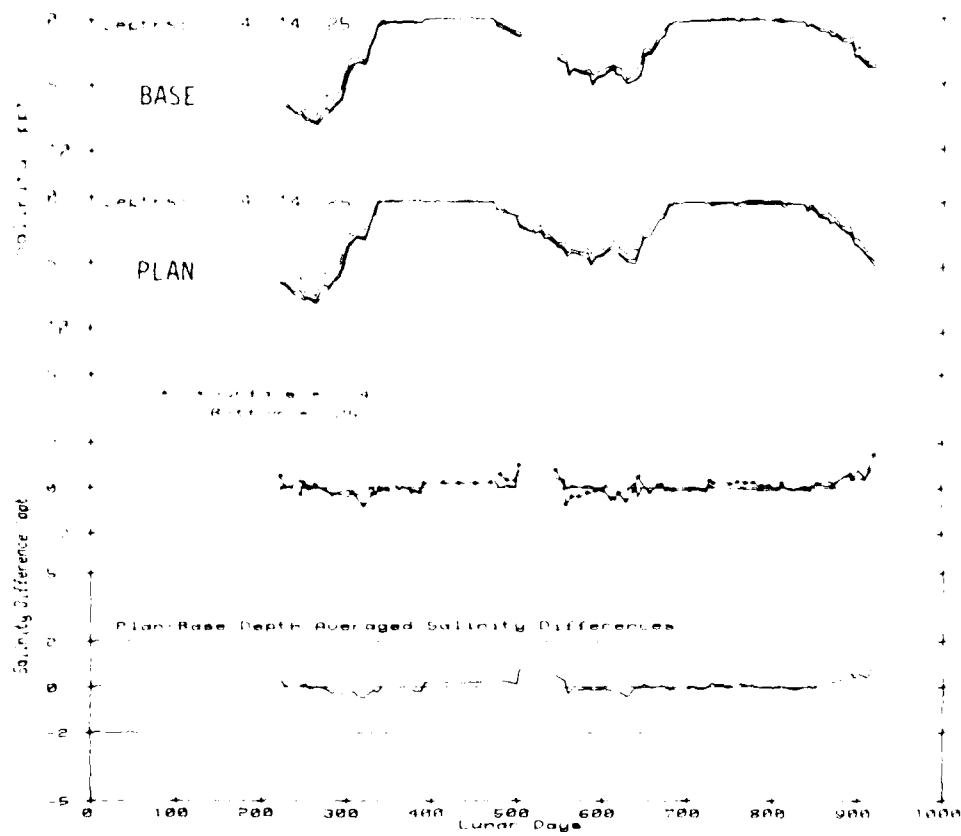
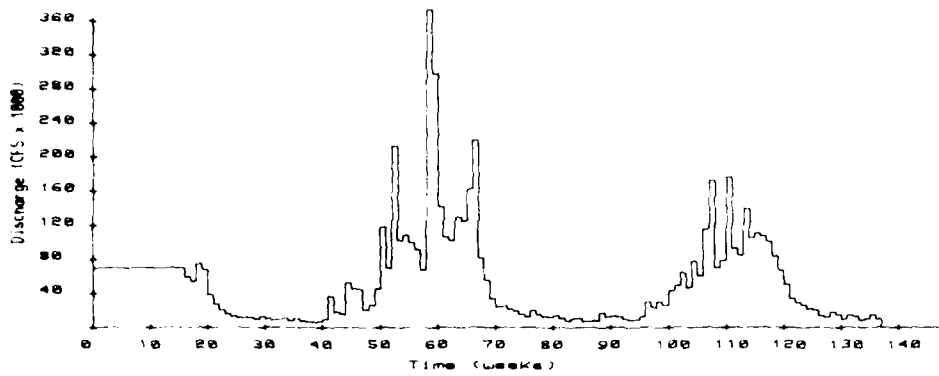


Station JN 0303

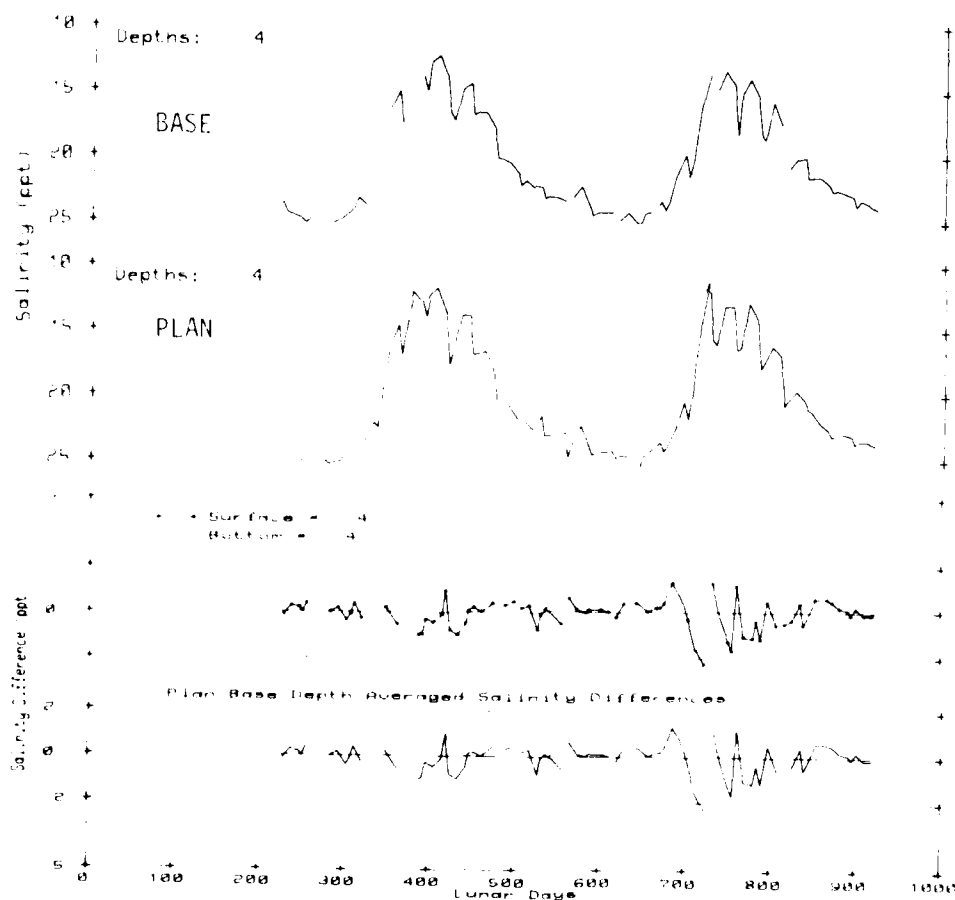
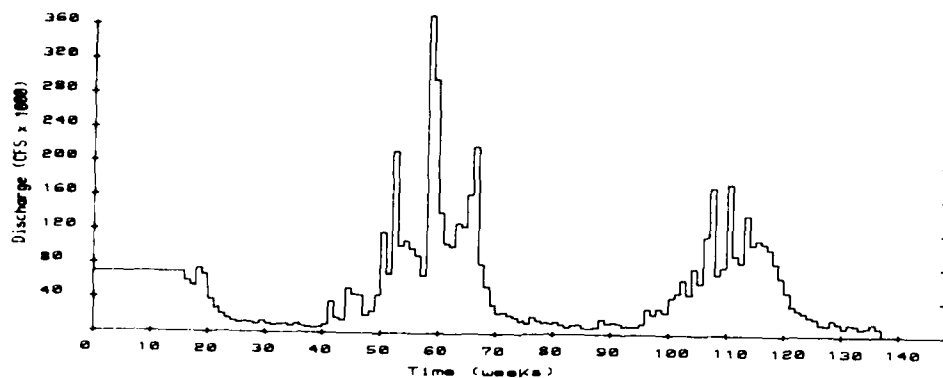




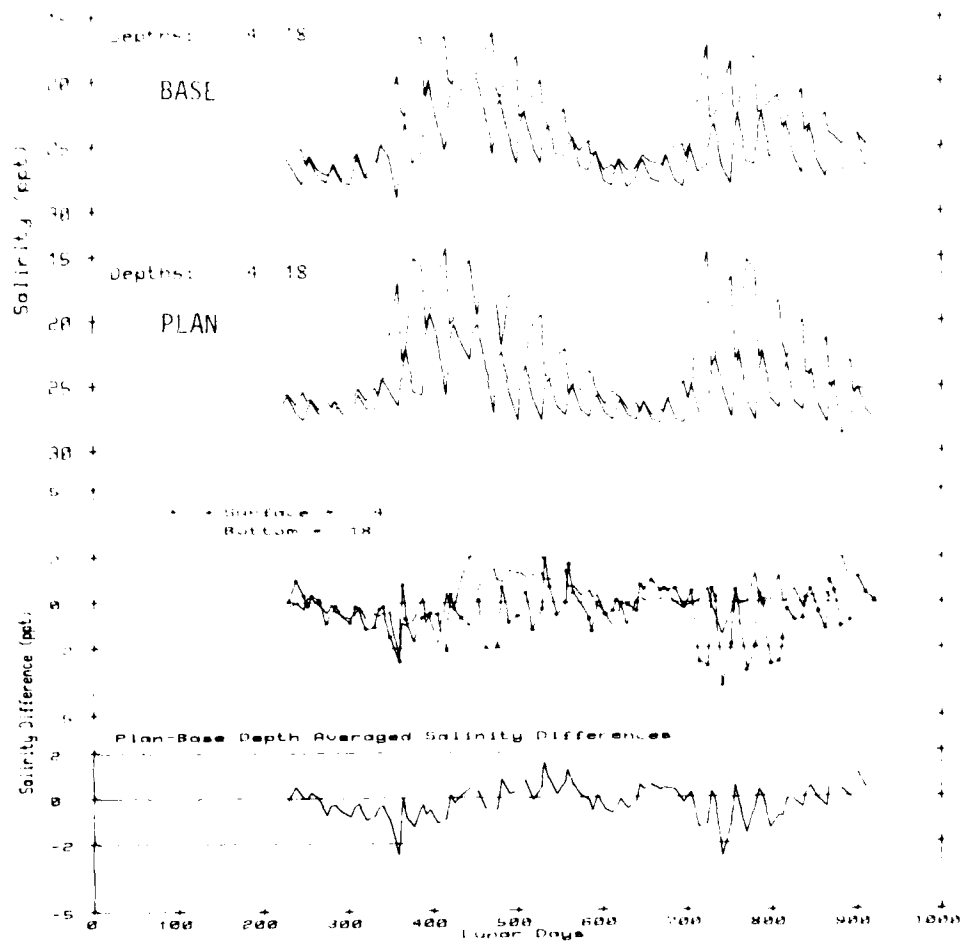
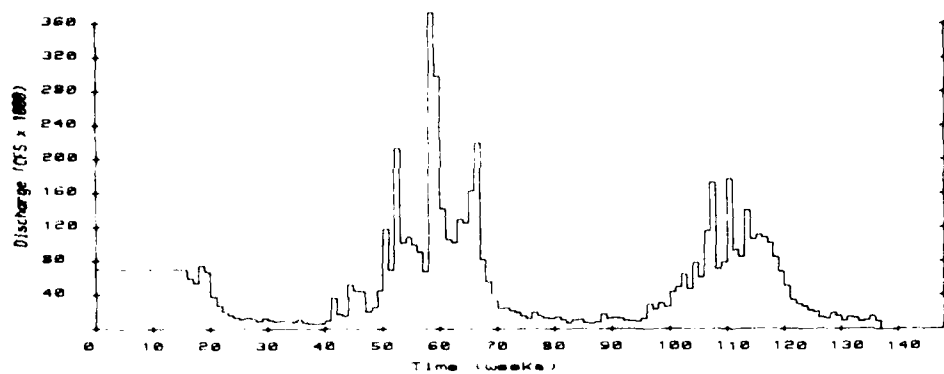
Station JN 0603



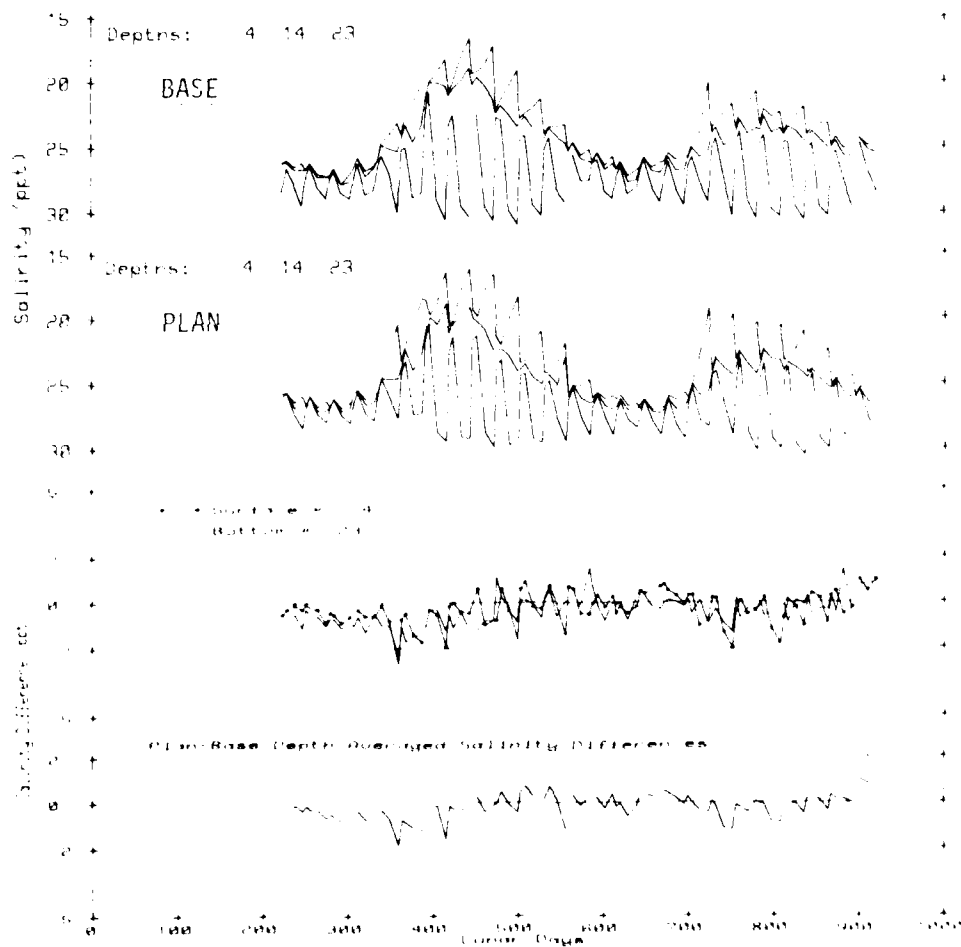
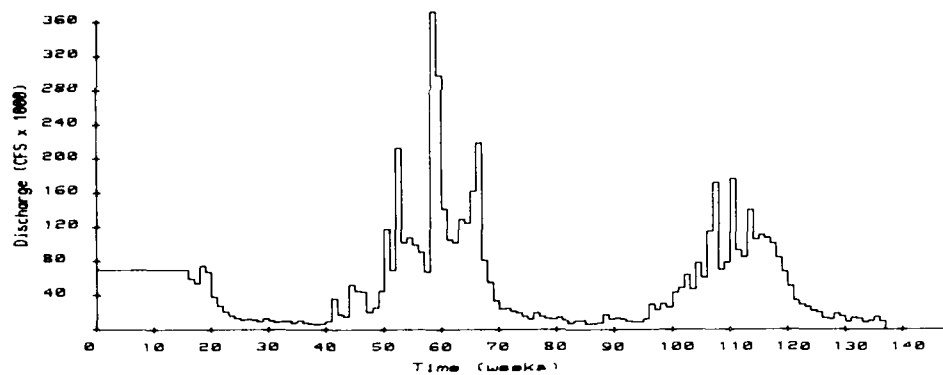
Station JN 0801



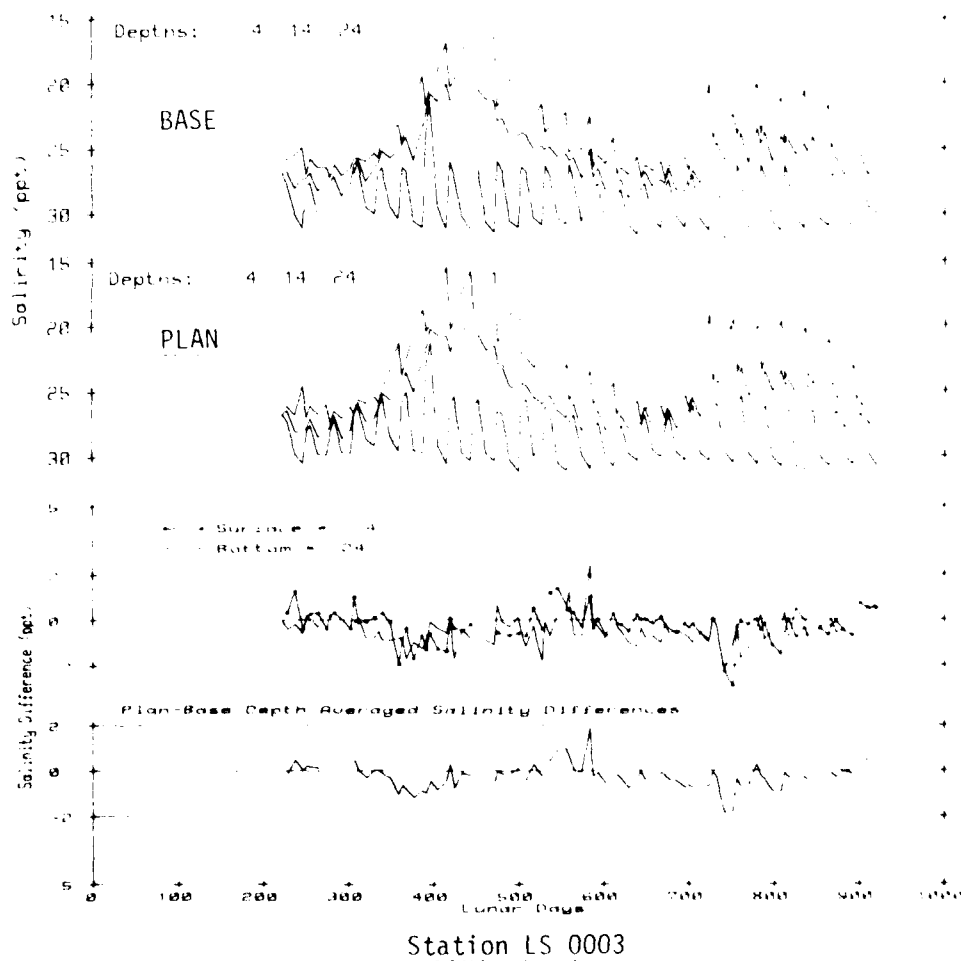
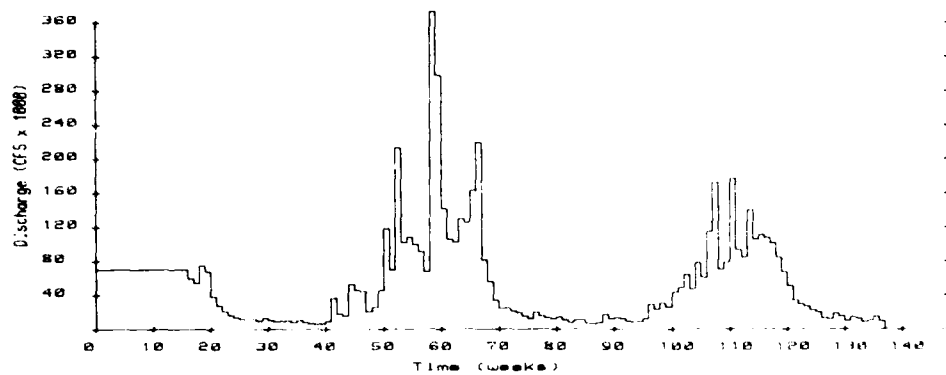
Station LF 0101

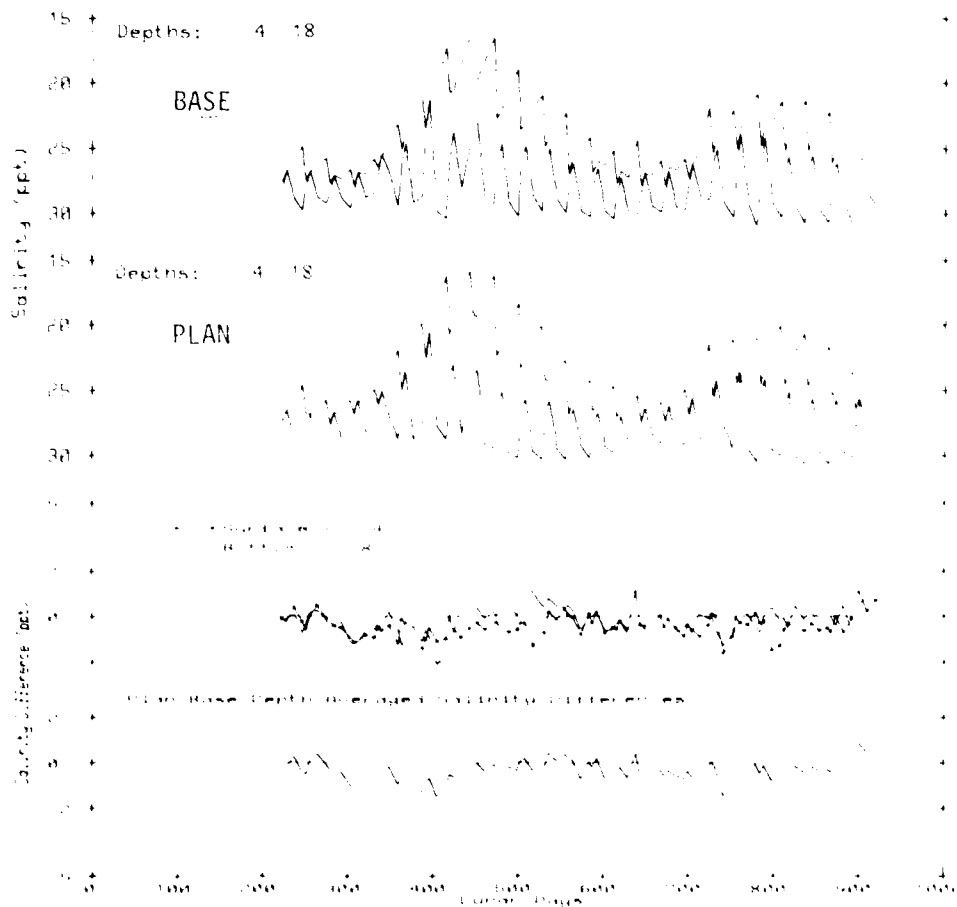
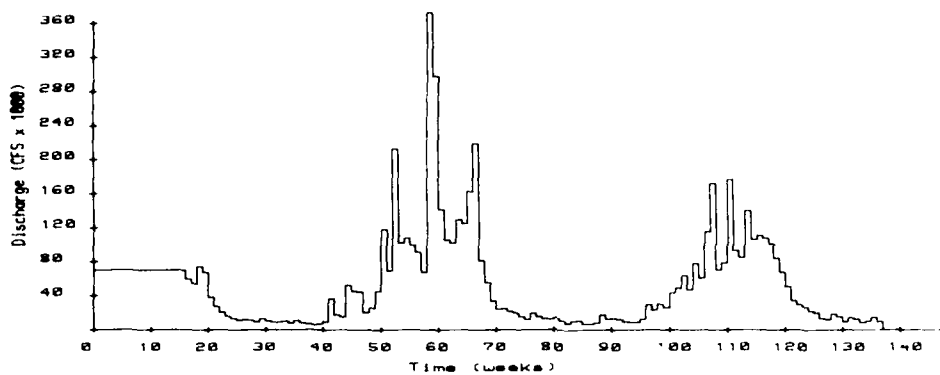


Station LS 0001

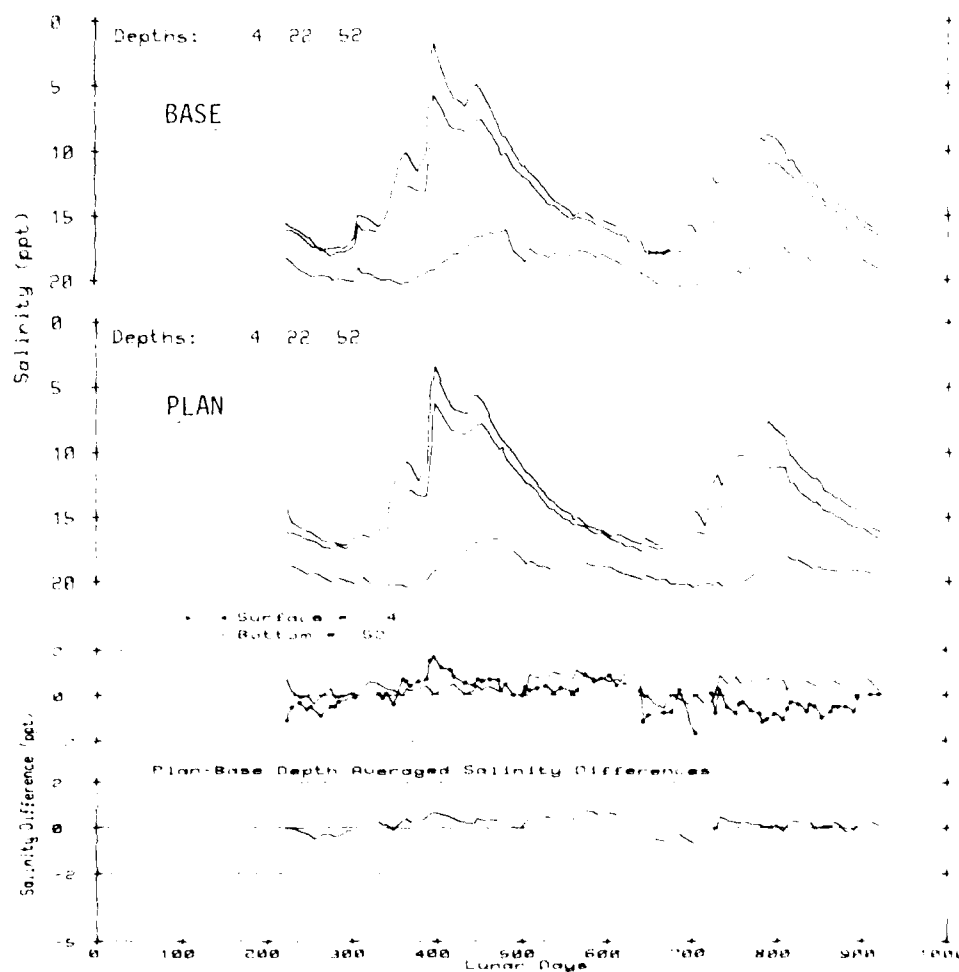
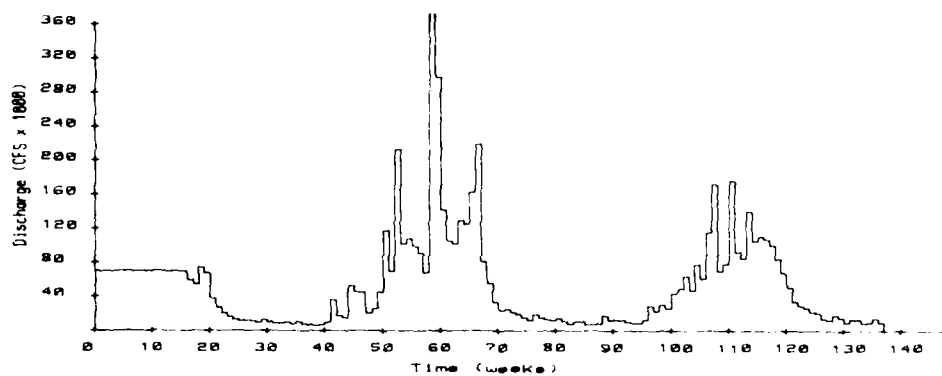


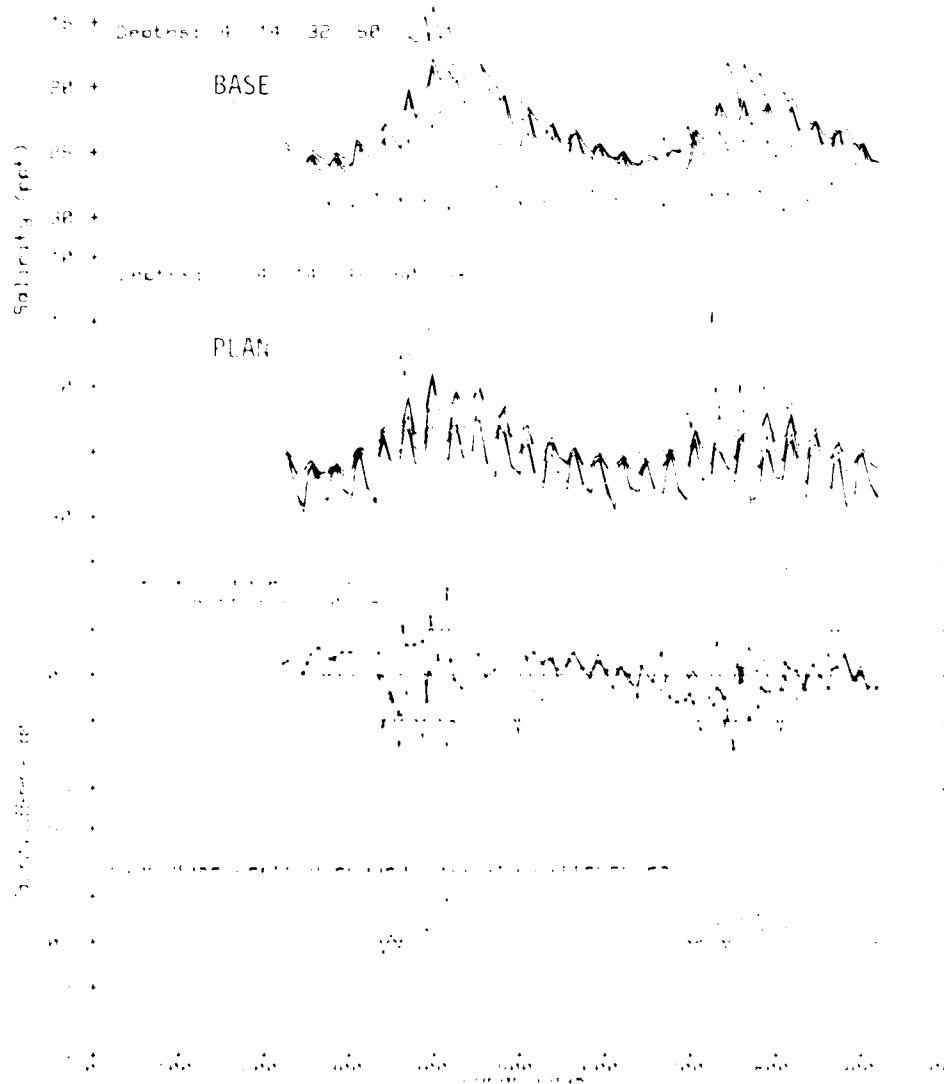
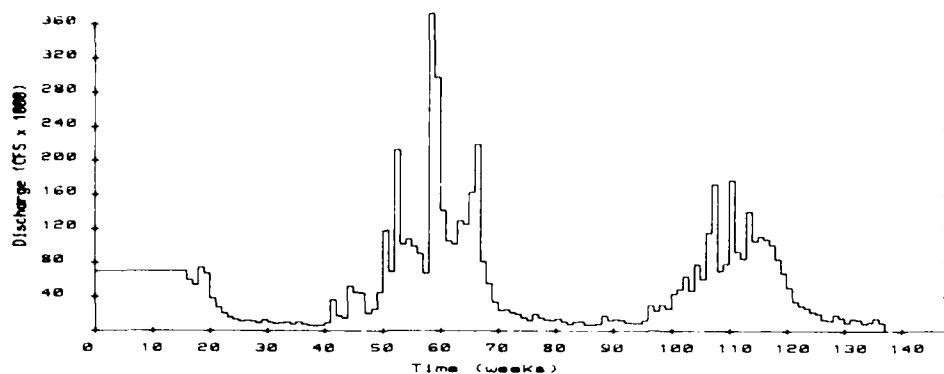
Station LS_0002



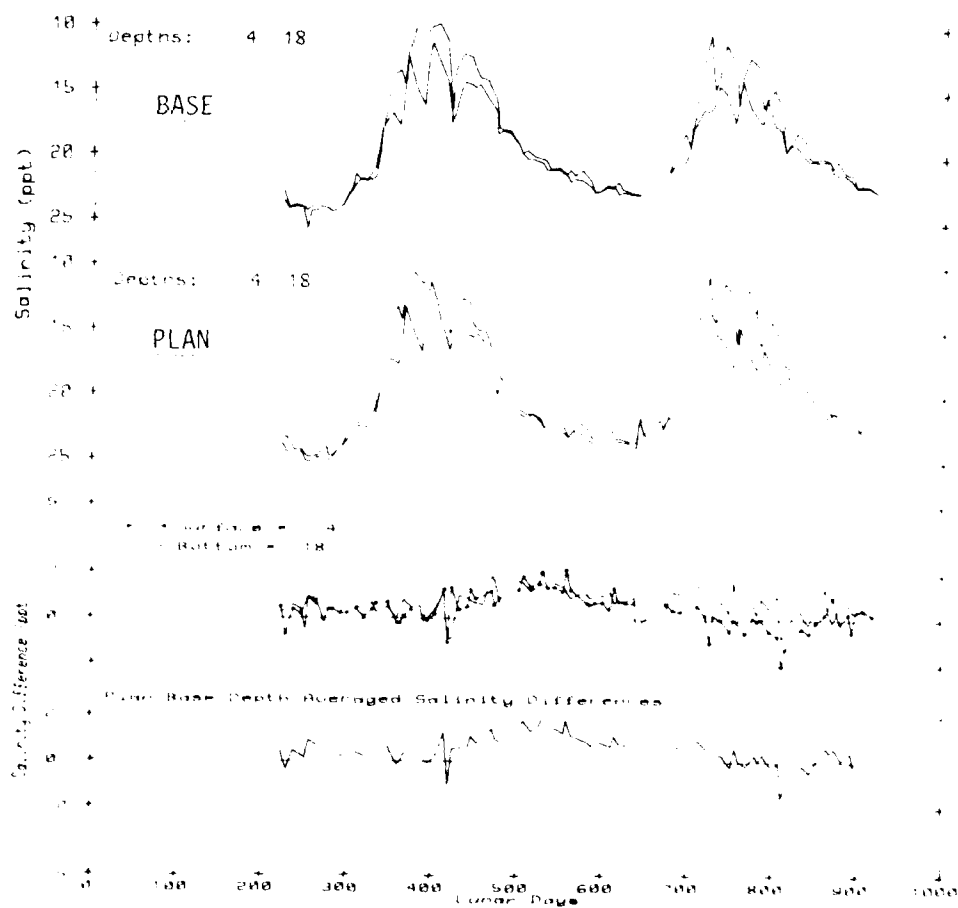
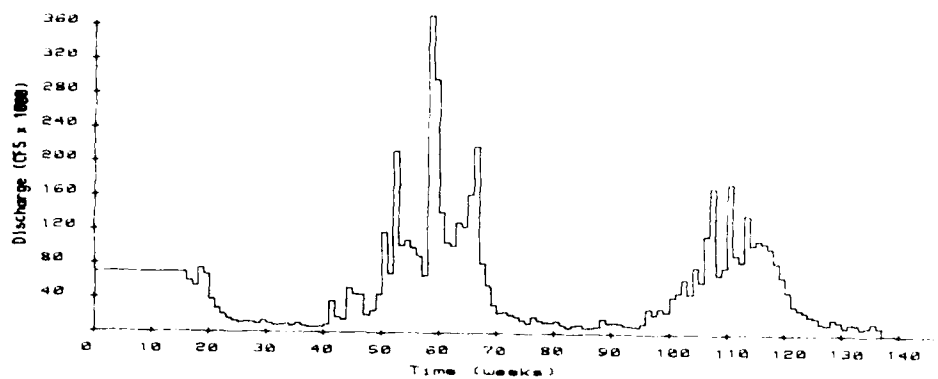


Station IS 0004

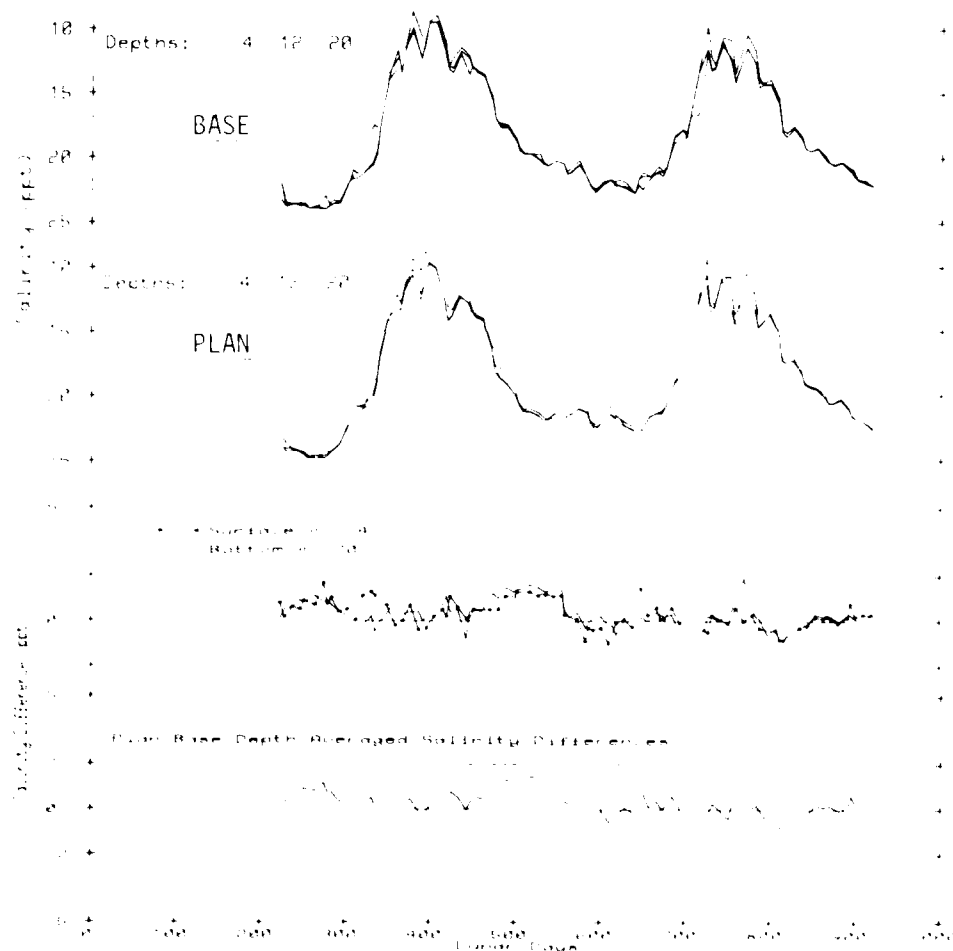
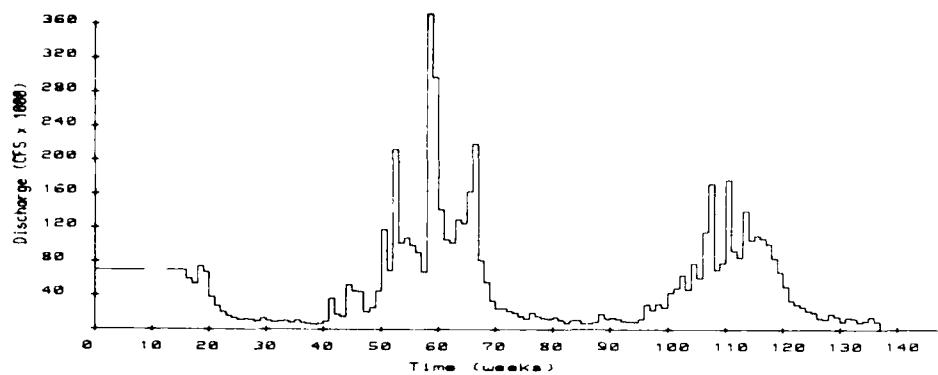




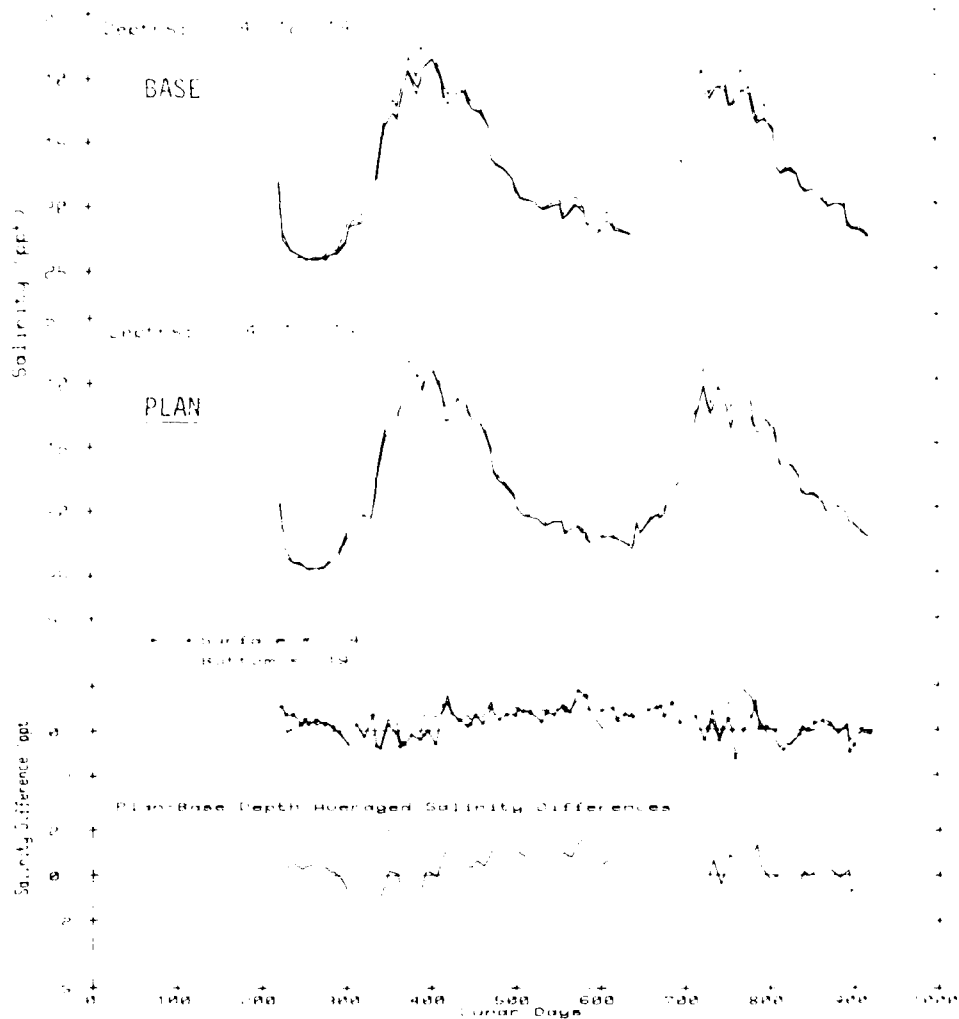
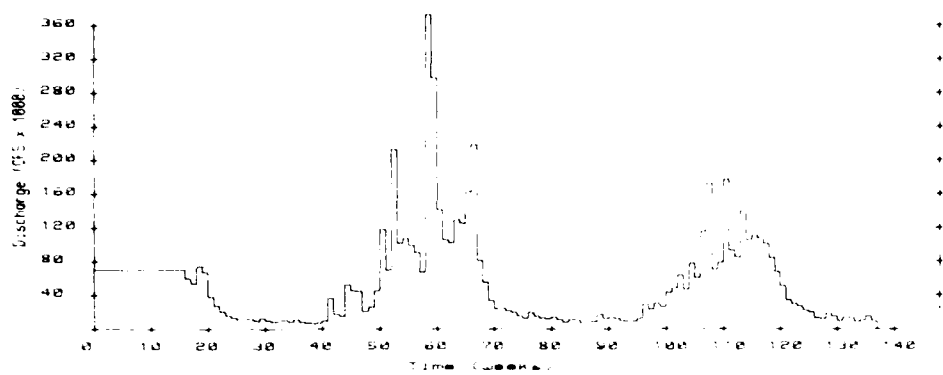
Station NN 0001



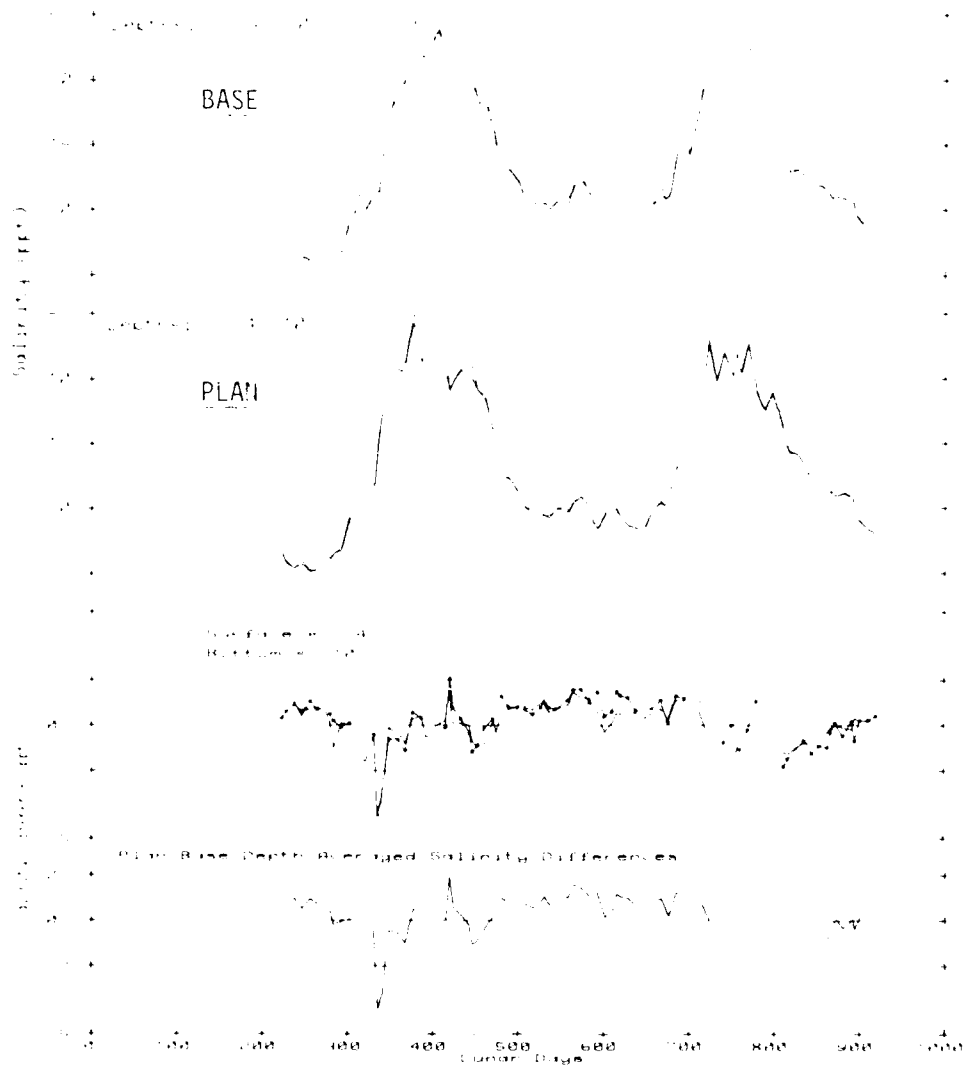
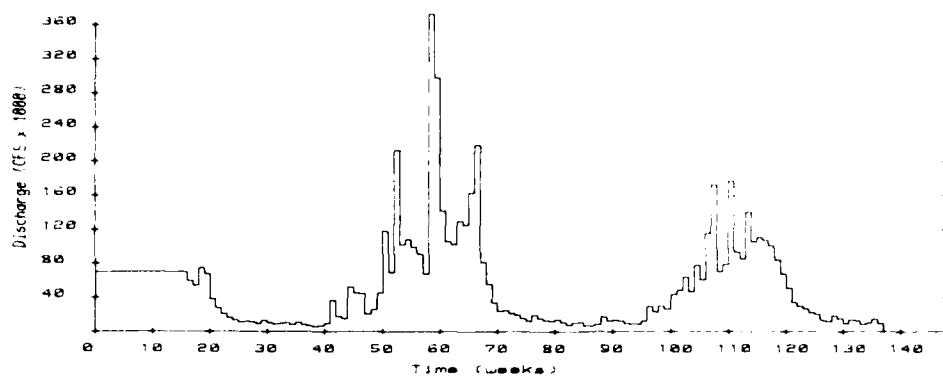
Station NS 0101



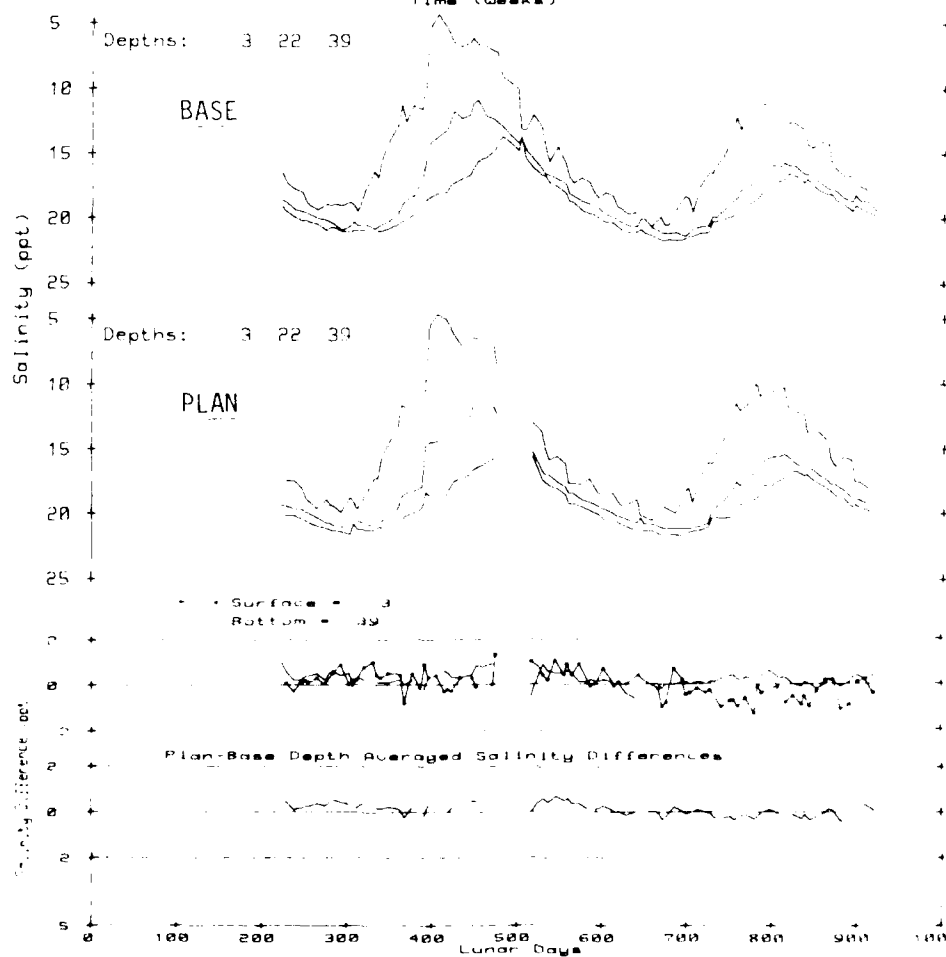
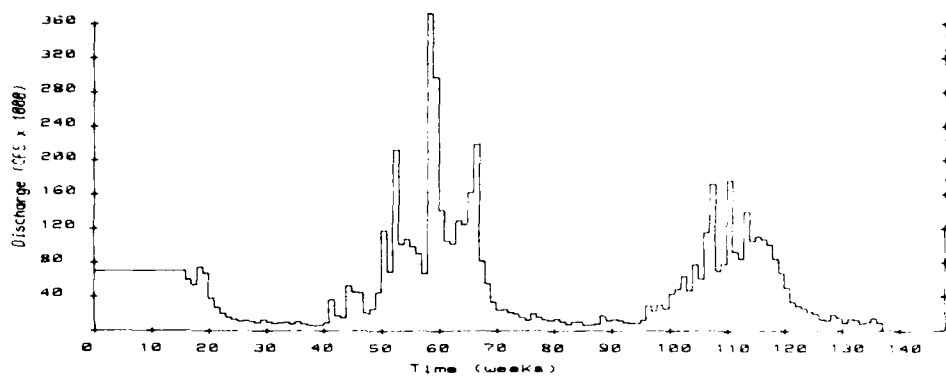
Station NS 0201



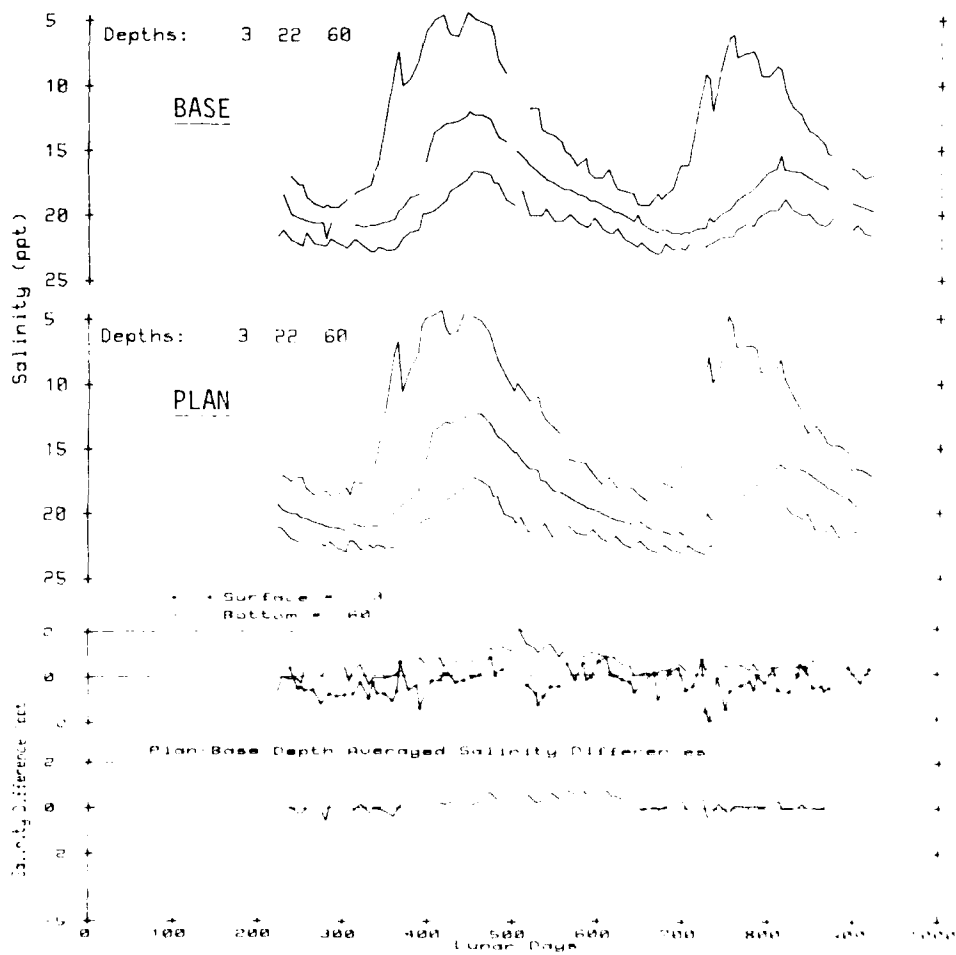
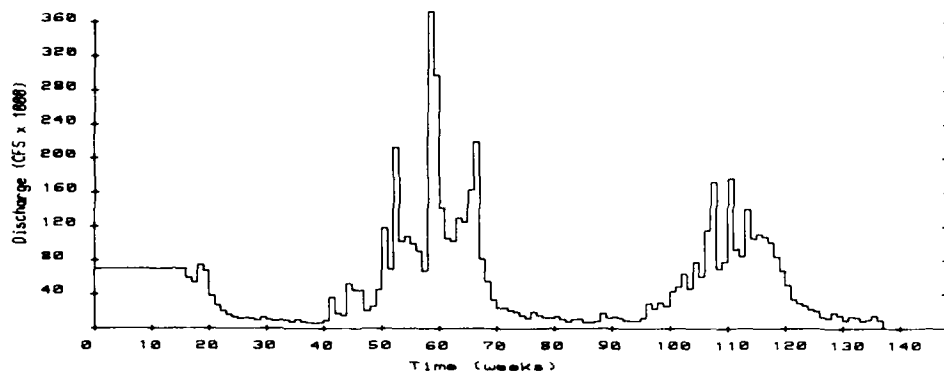
Station NS 0301



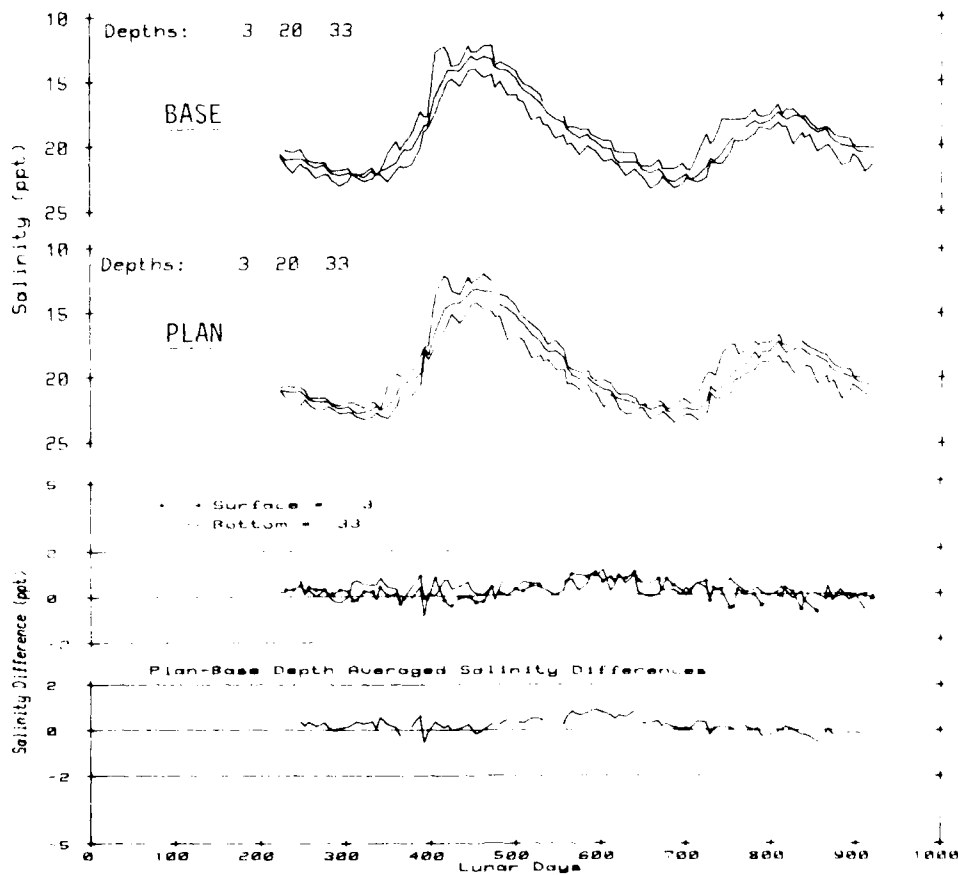
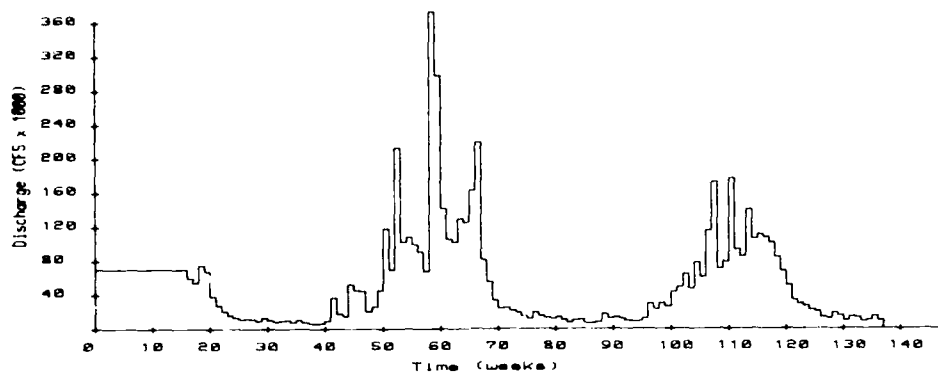
Station NS 0401



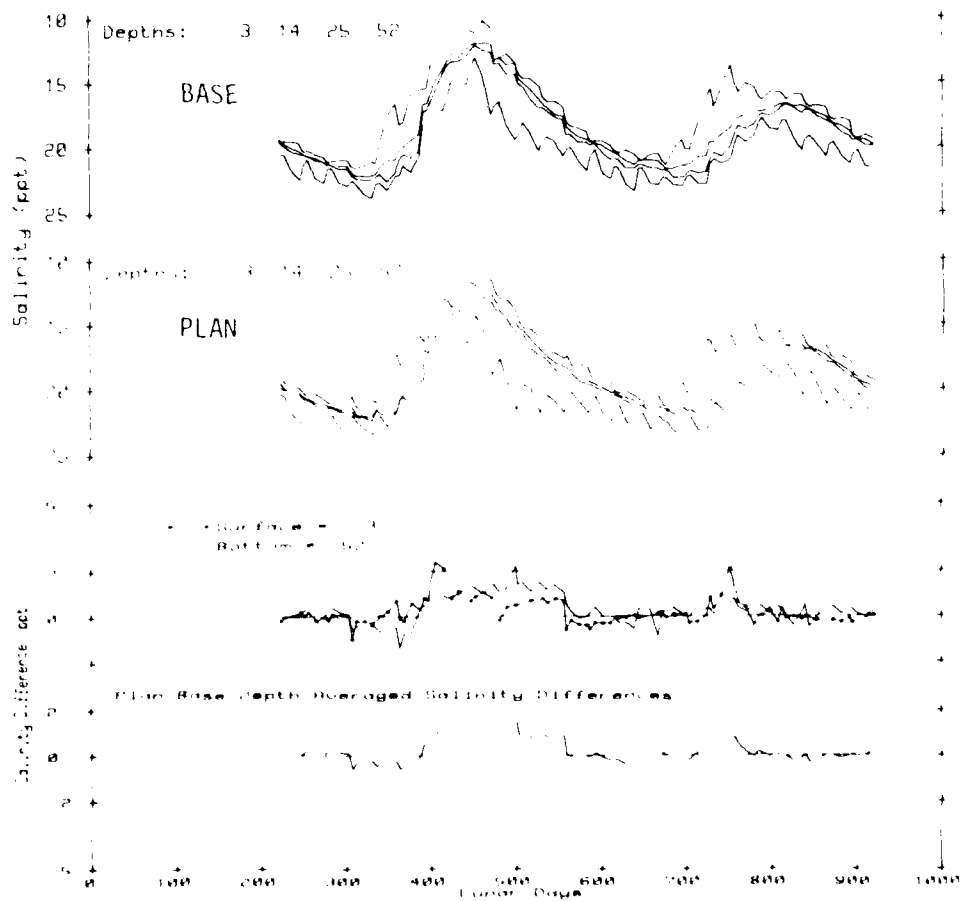
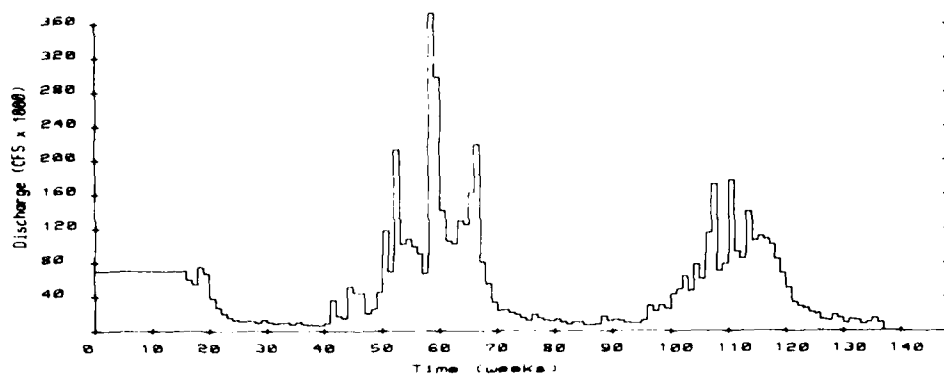
Station PG 0101



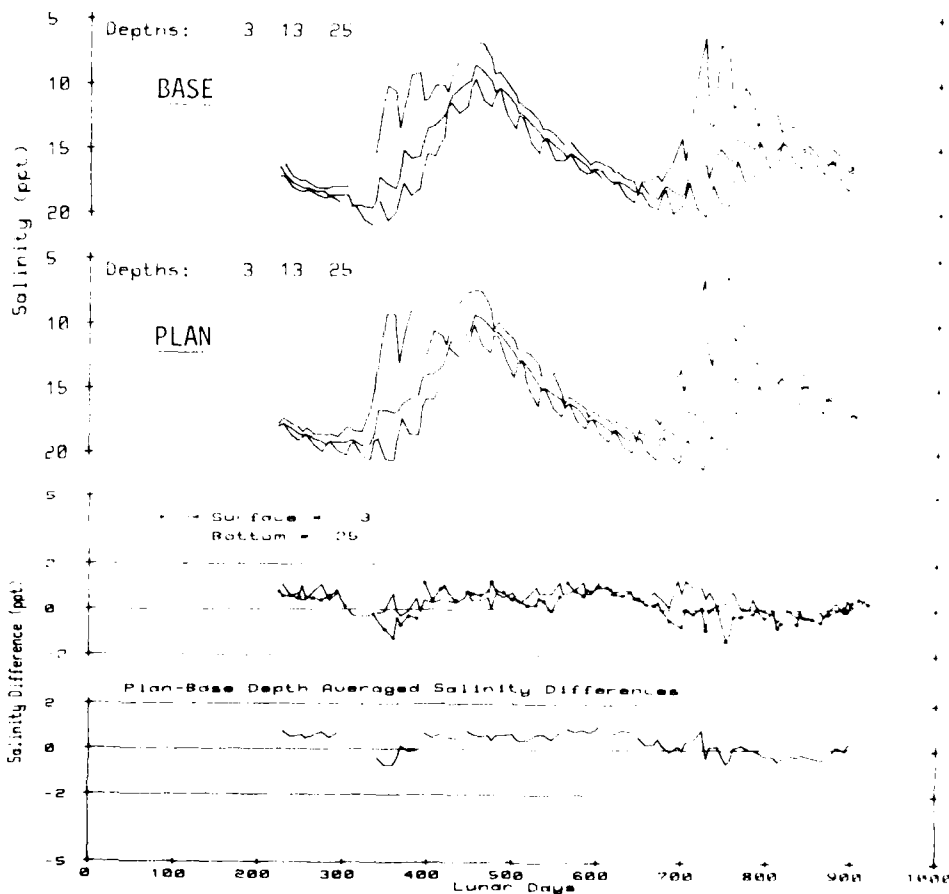
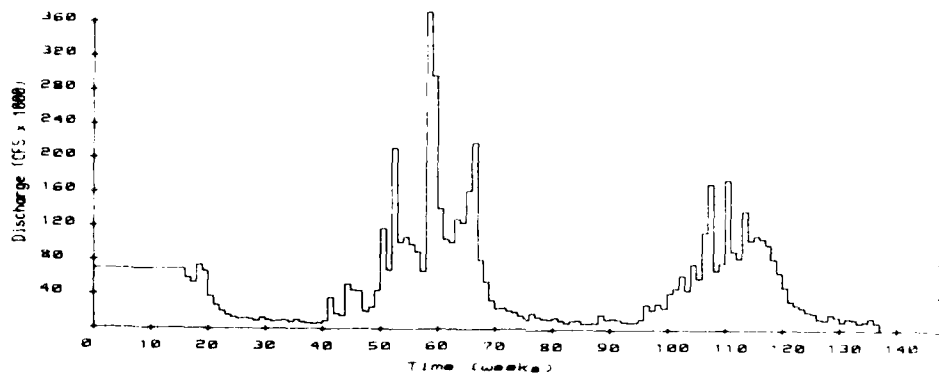
Station PO 0202



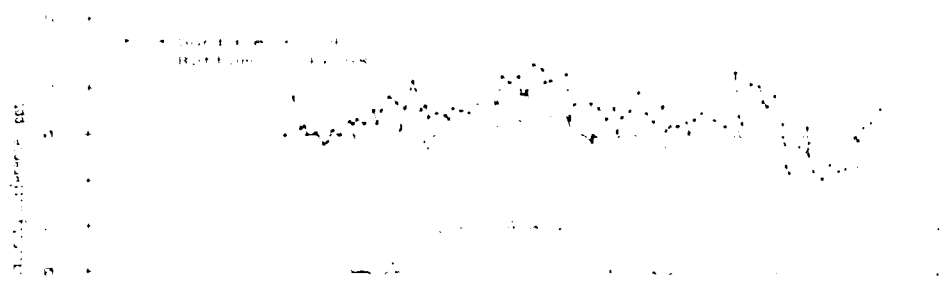
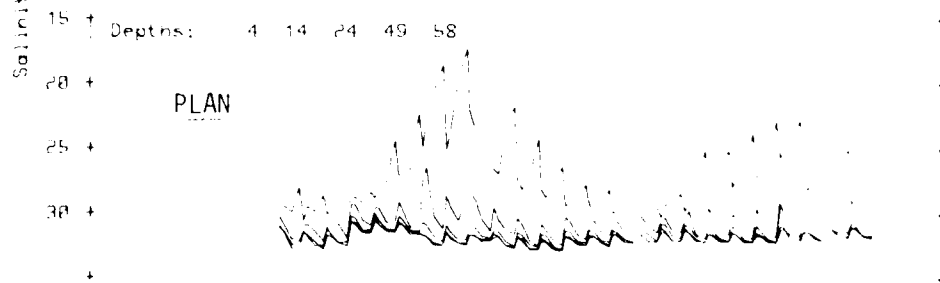
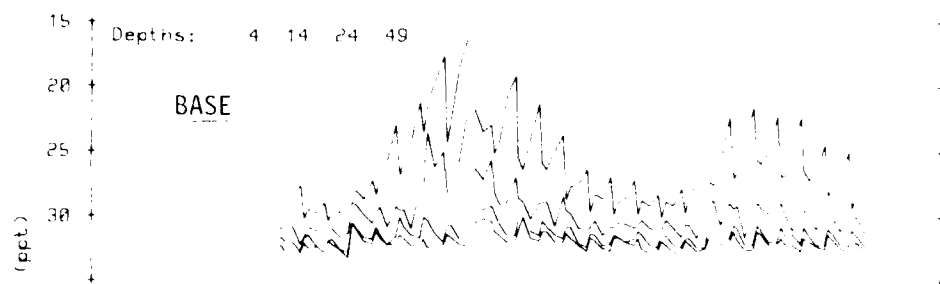
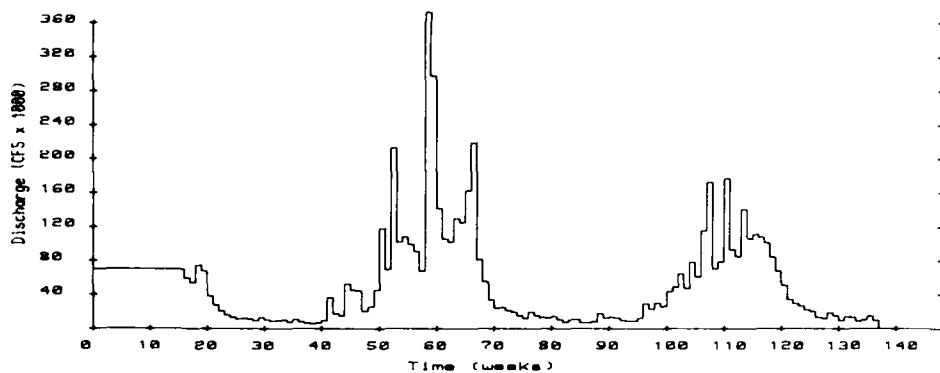
Station RG 0102



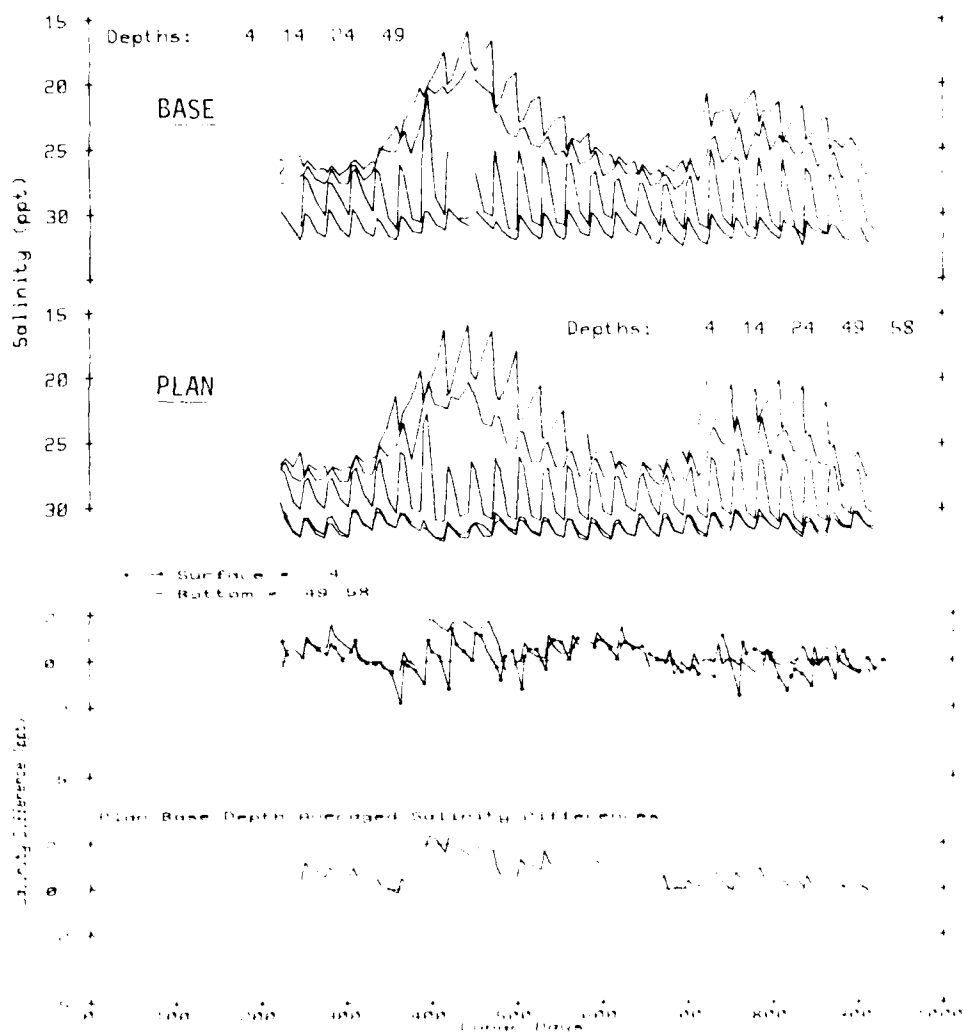
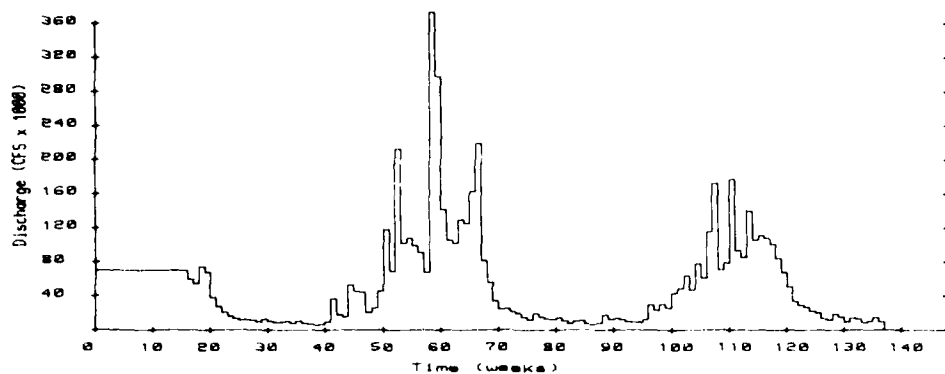
Station RG 0202



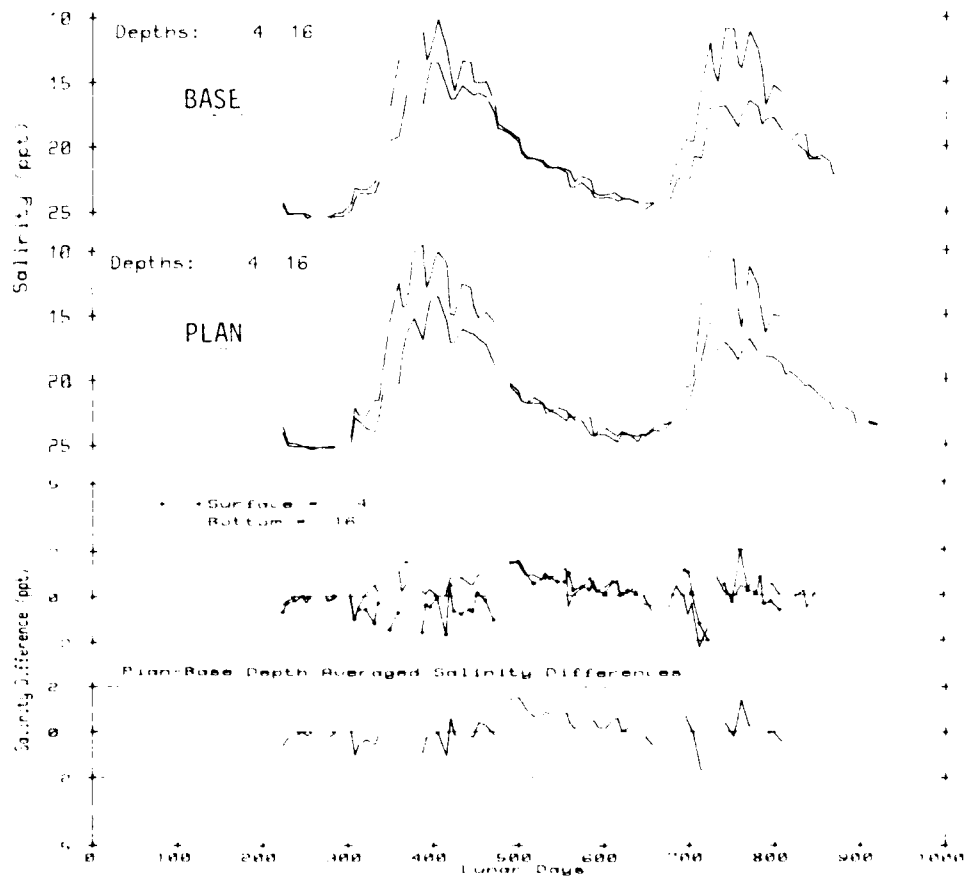
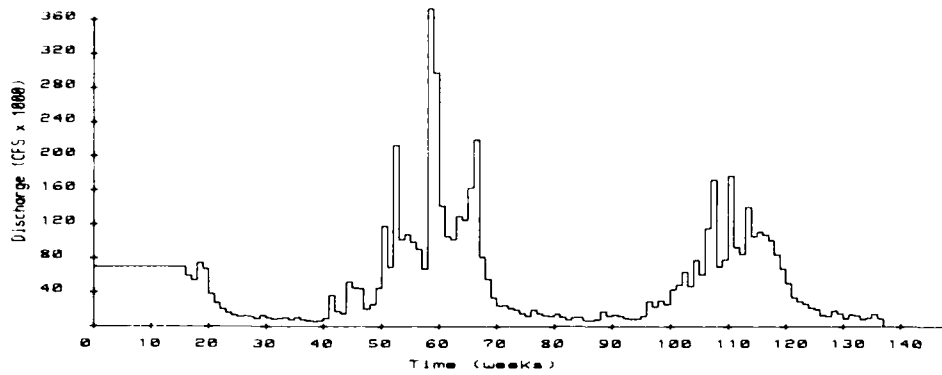
Station RG 0501



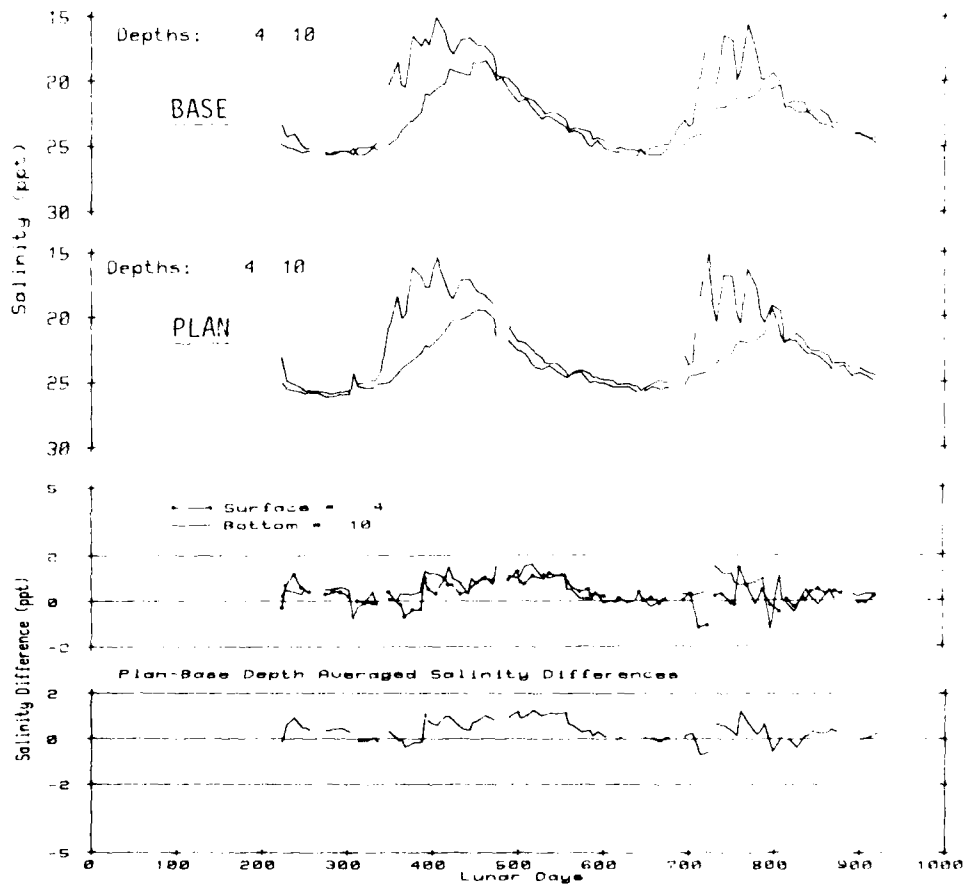
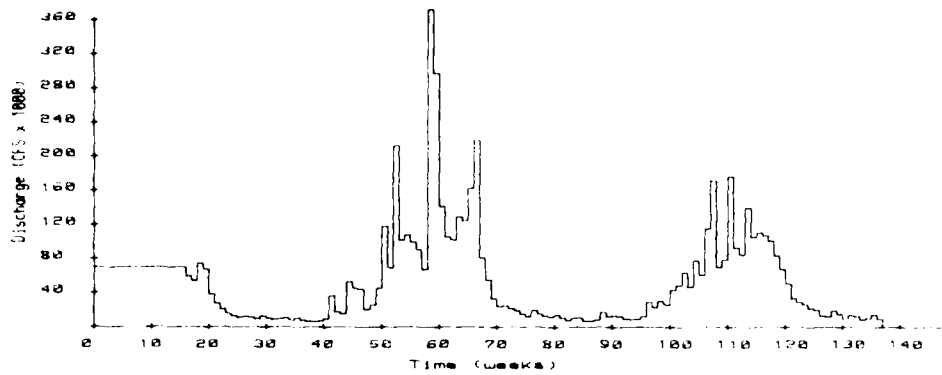
Station 15 0002



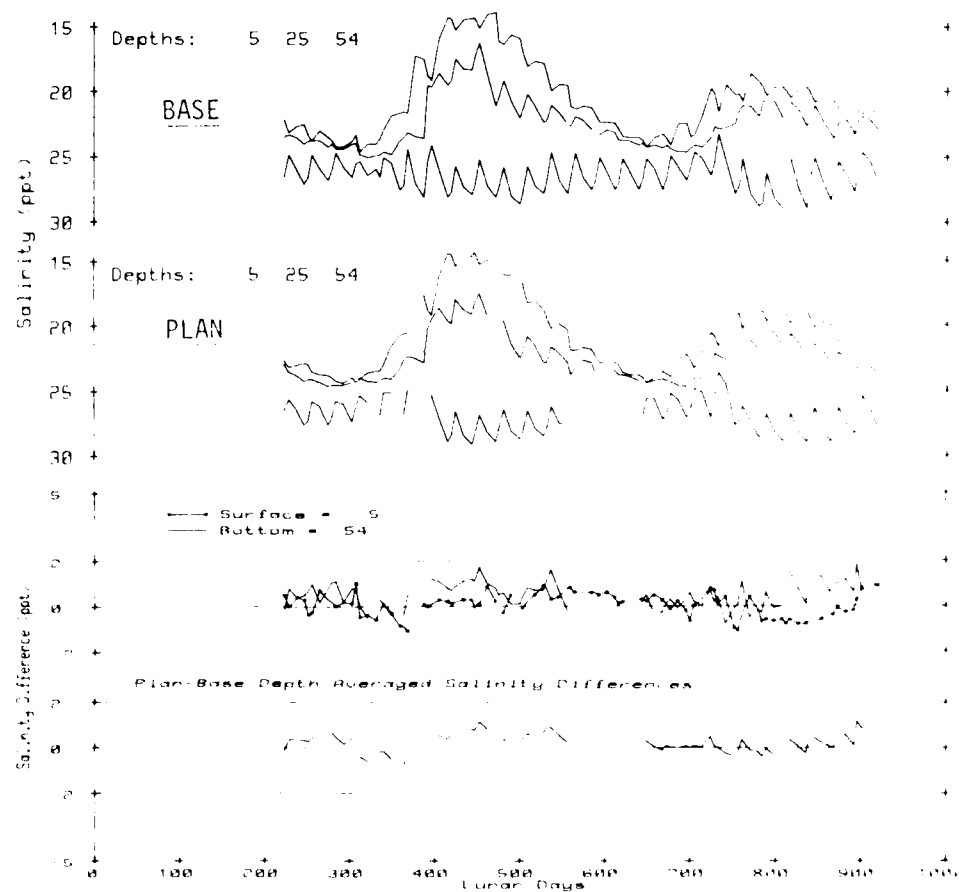
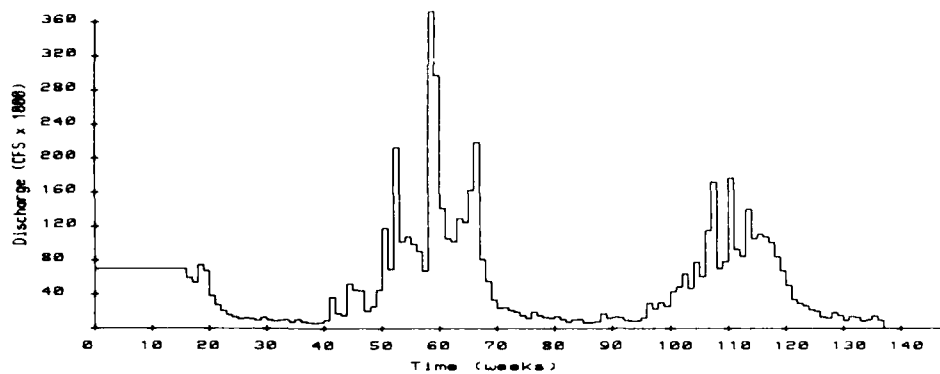
Station TS 0004



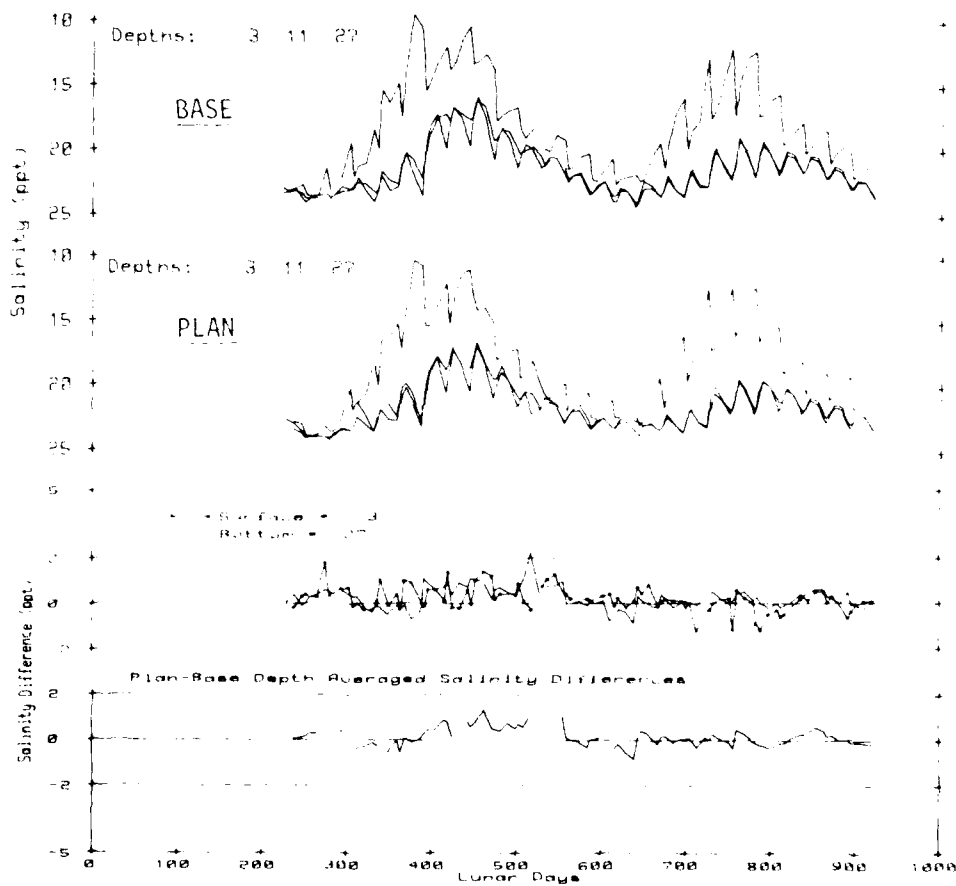
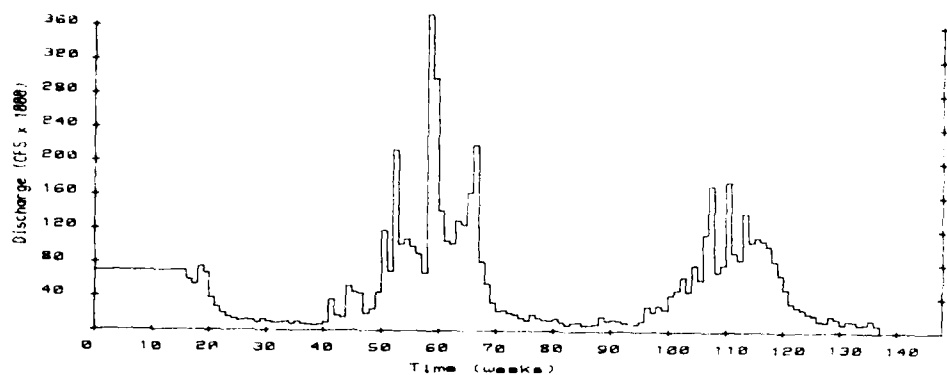
Station WB 0201



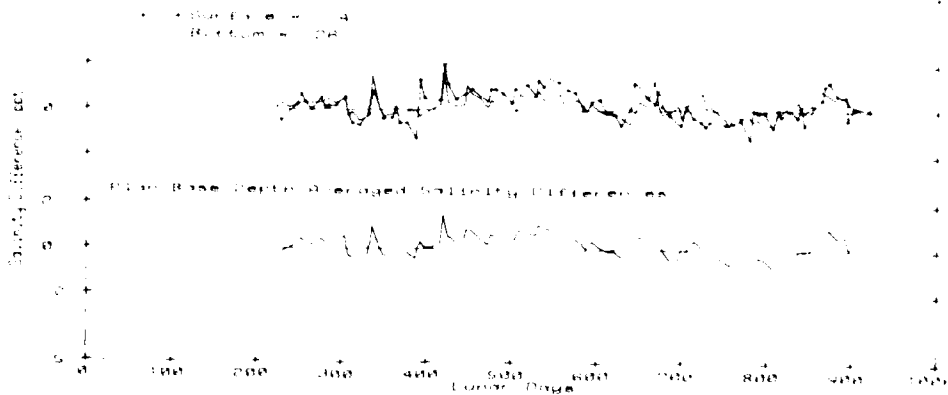
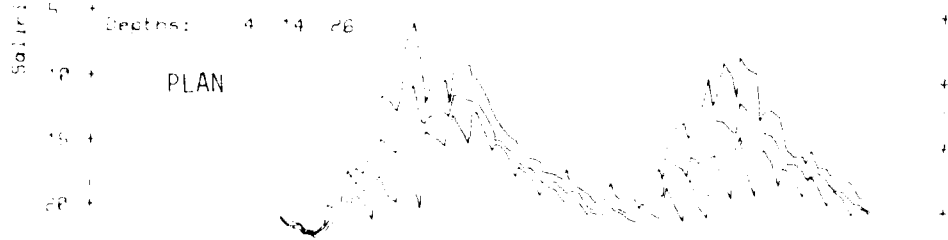
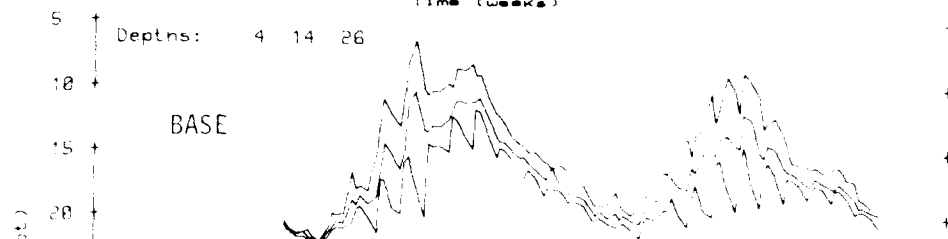
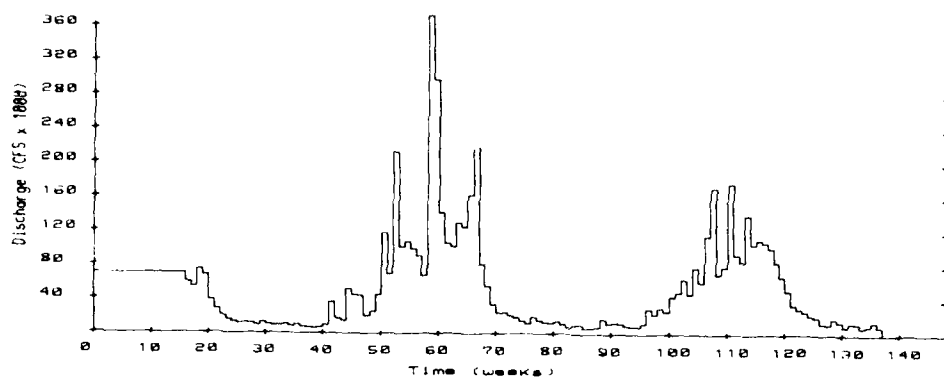
Station W0 0101



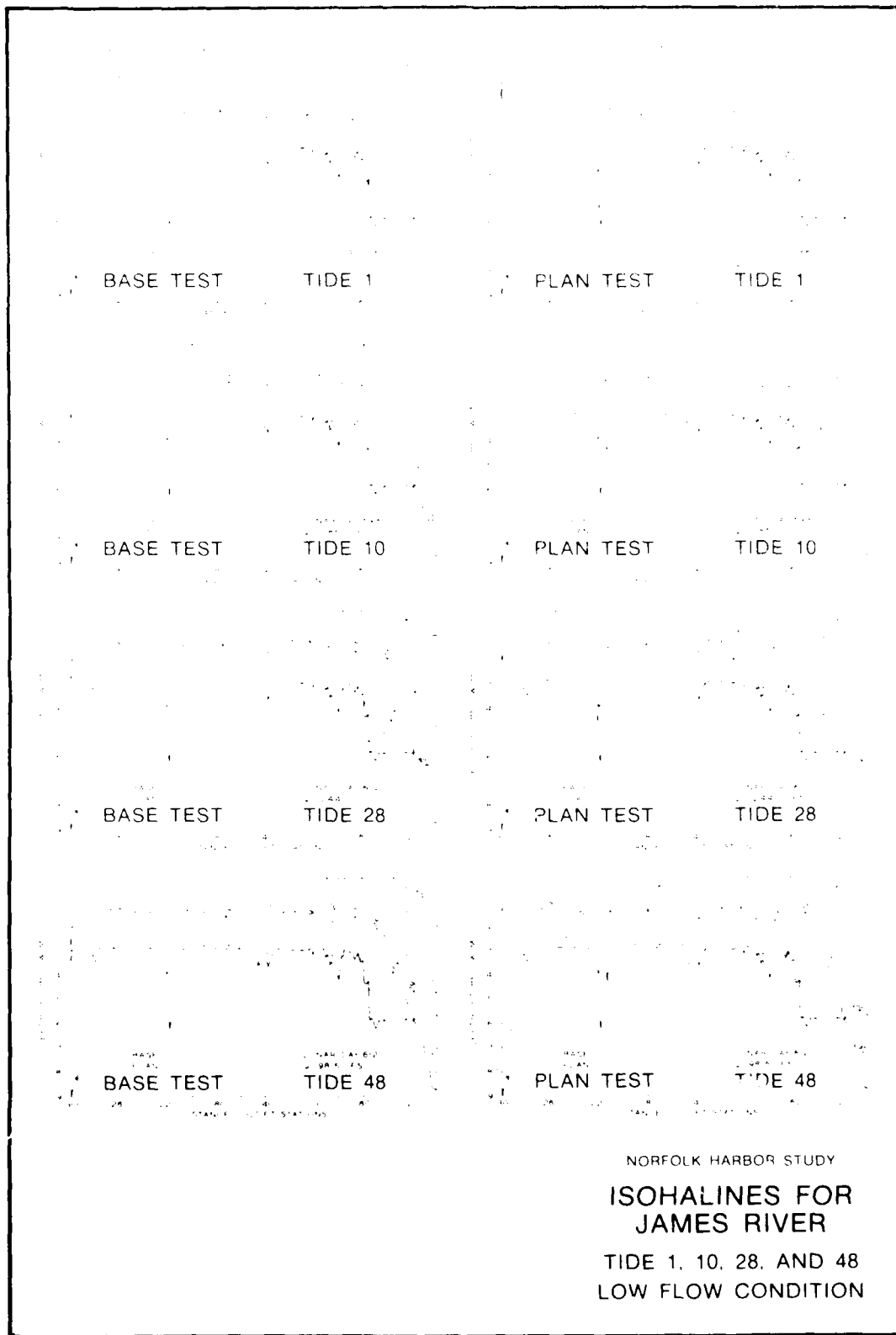
Station YG 0102



Station YG 0302



Station YG 0501



BASE TEST

TIDE 1

PLAN TEST

TIDE 1

BASE TEST

TIDE 10

PLAN TEST

TIDE 10

BASE TEST

TIDE 28

PLAN TEST

TIDE 28

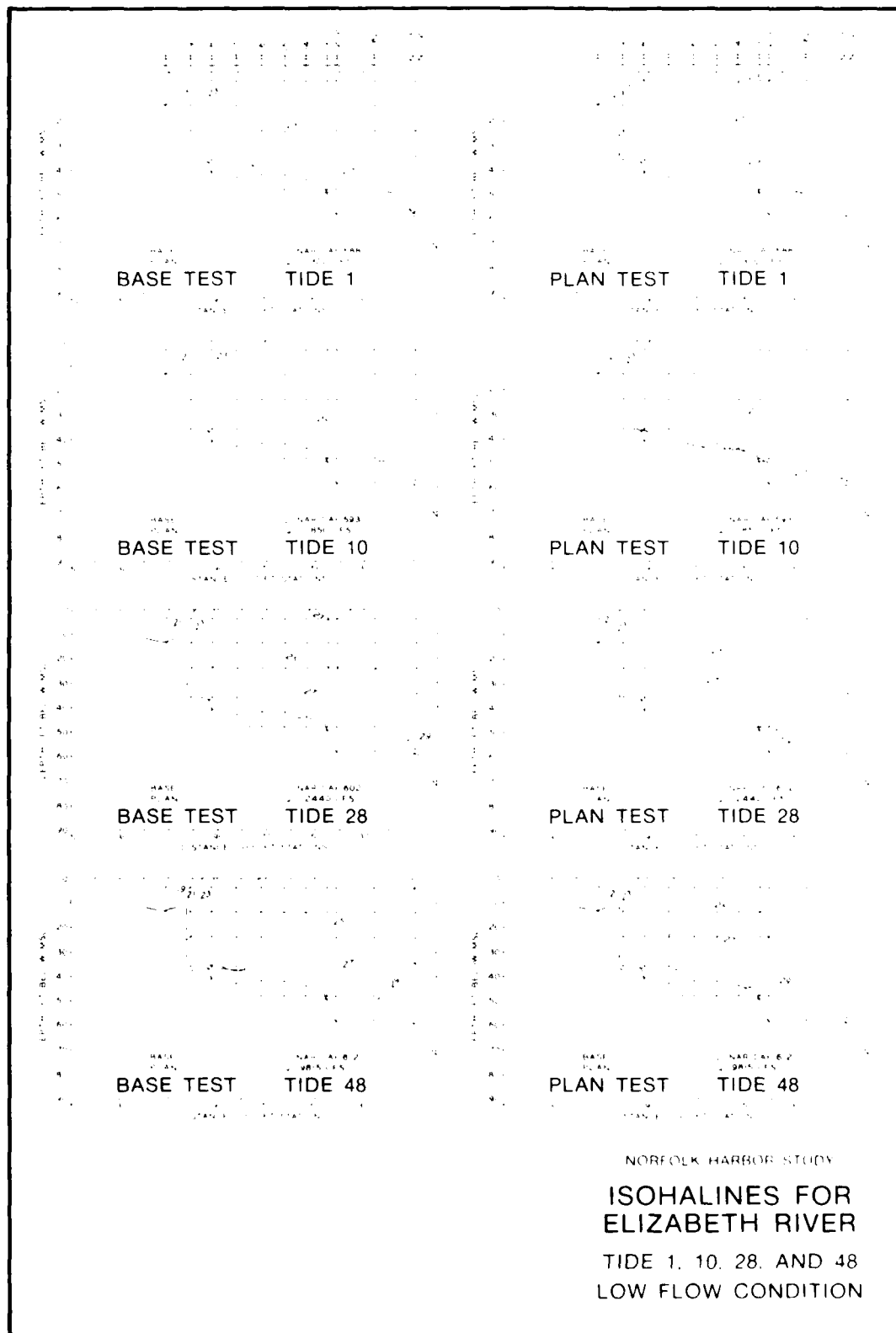
BASE TEST

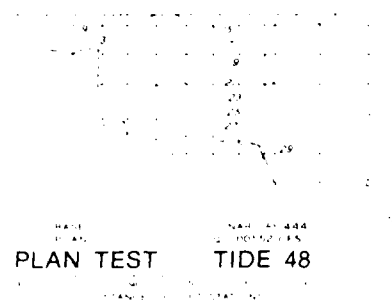
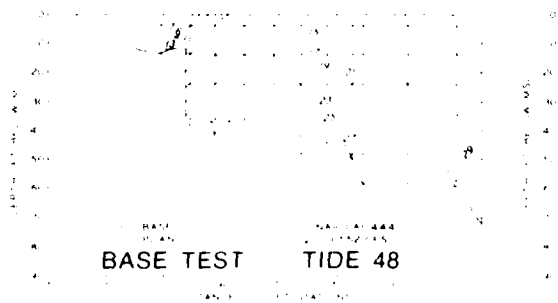
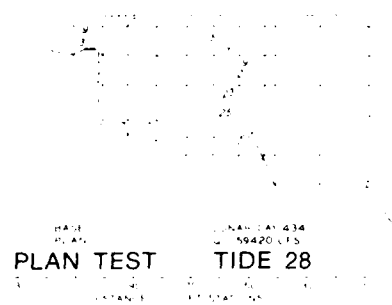
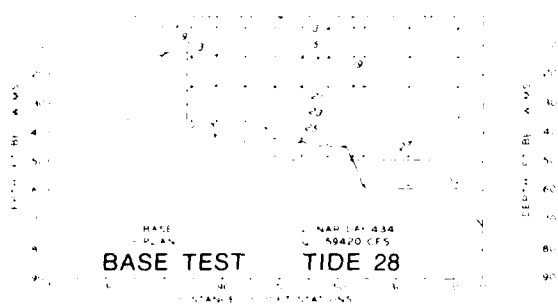
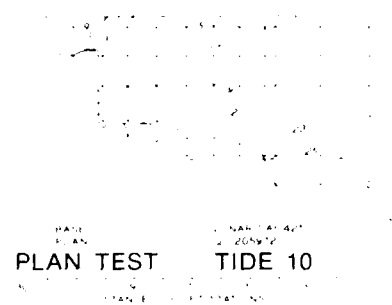
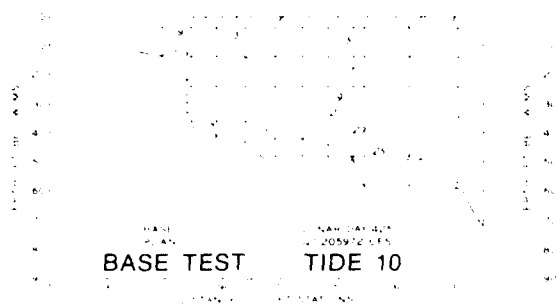
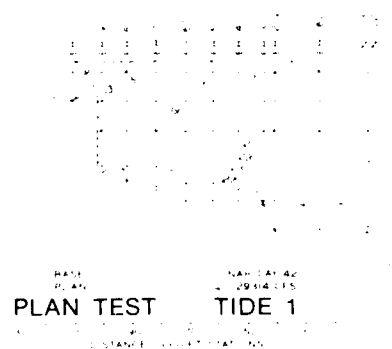
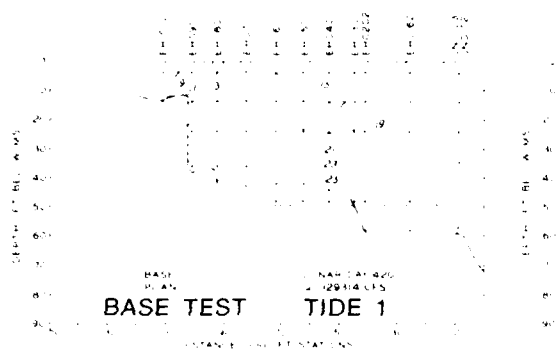
TIDE 48

PLAN TEST

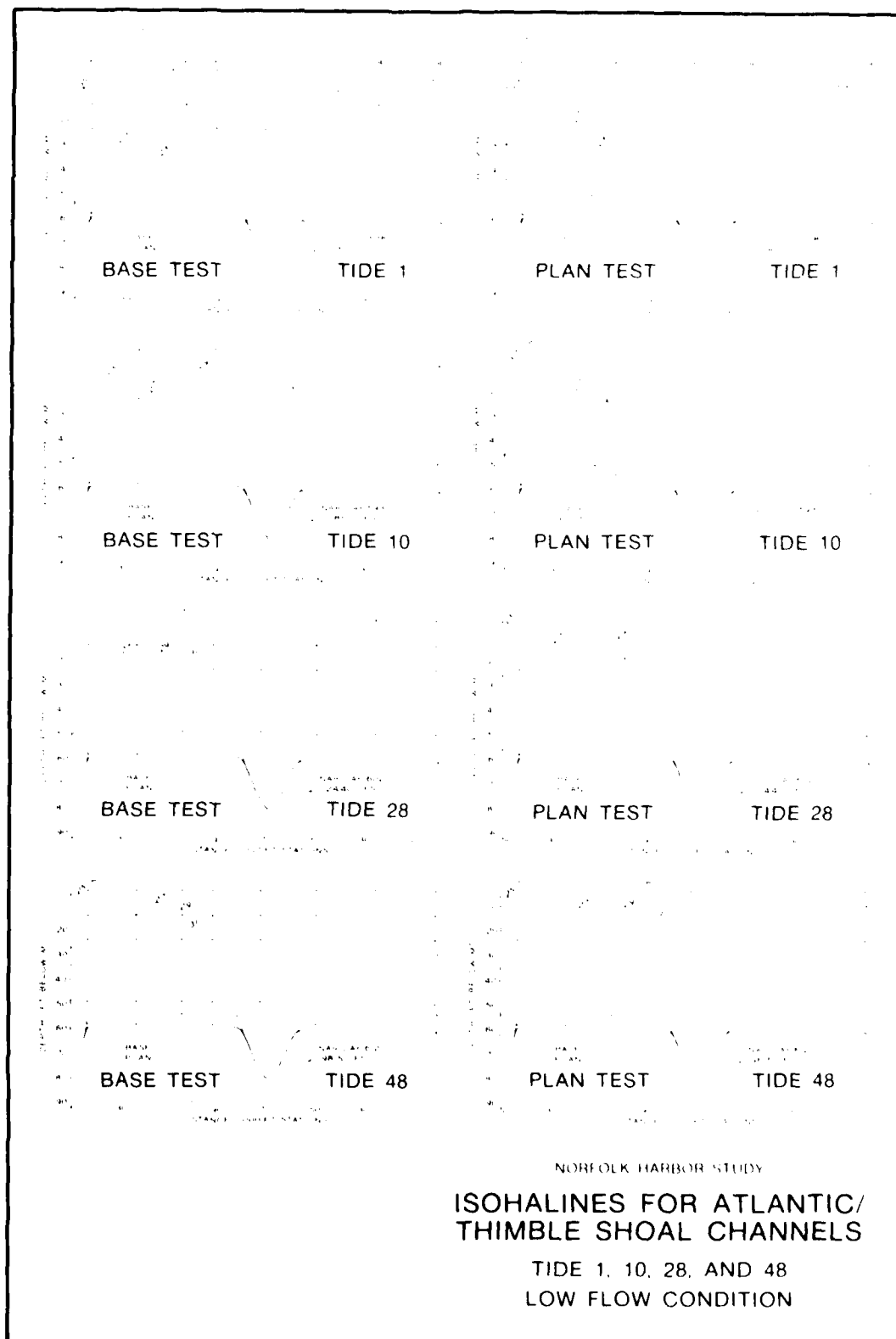
TIDE 48

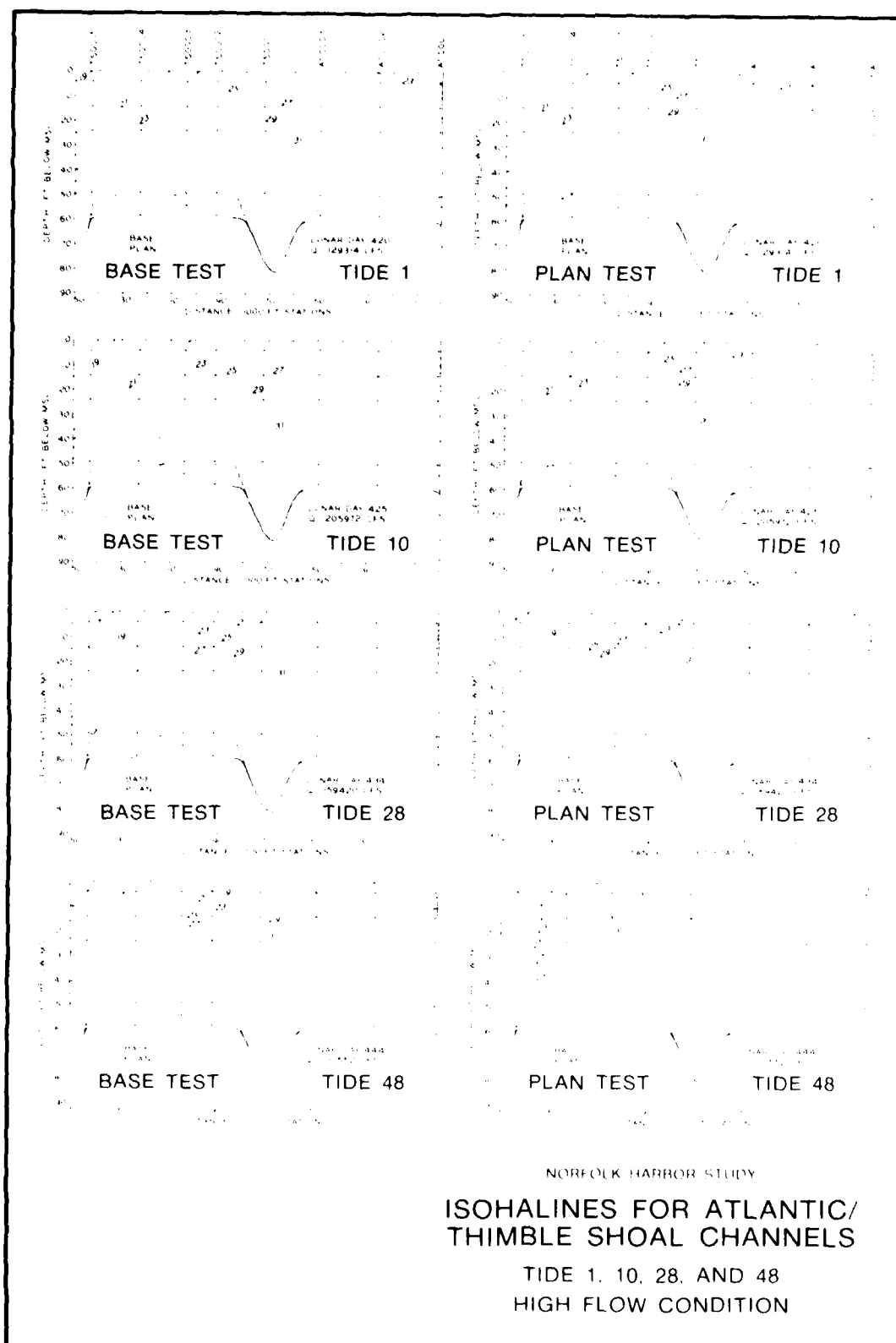
NORFOLK HARBOR STUDY
ISOHALINES FOR
JAMES RIVER
TIDE 1, 10, 28, AND 48
HIGH FLOW CONDITION





NORFOLK HARBOR STUDY
ISOHALINES FOR
ELIZABETH RIVER
TIDE 1, 10, 28, AND 48
HIGH FLOW CONDITION





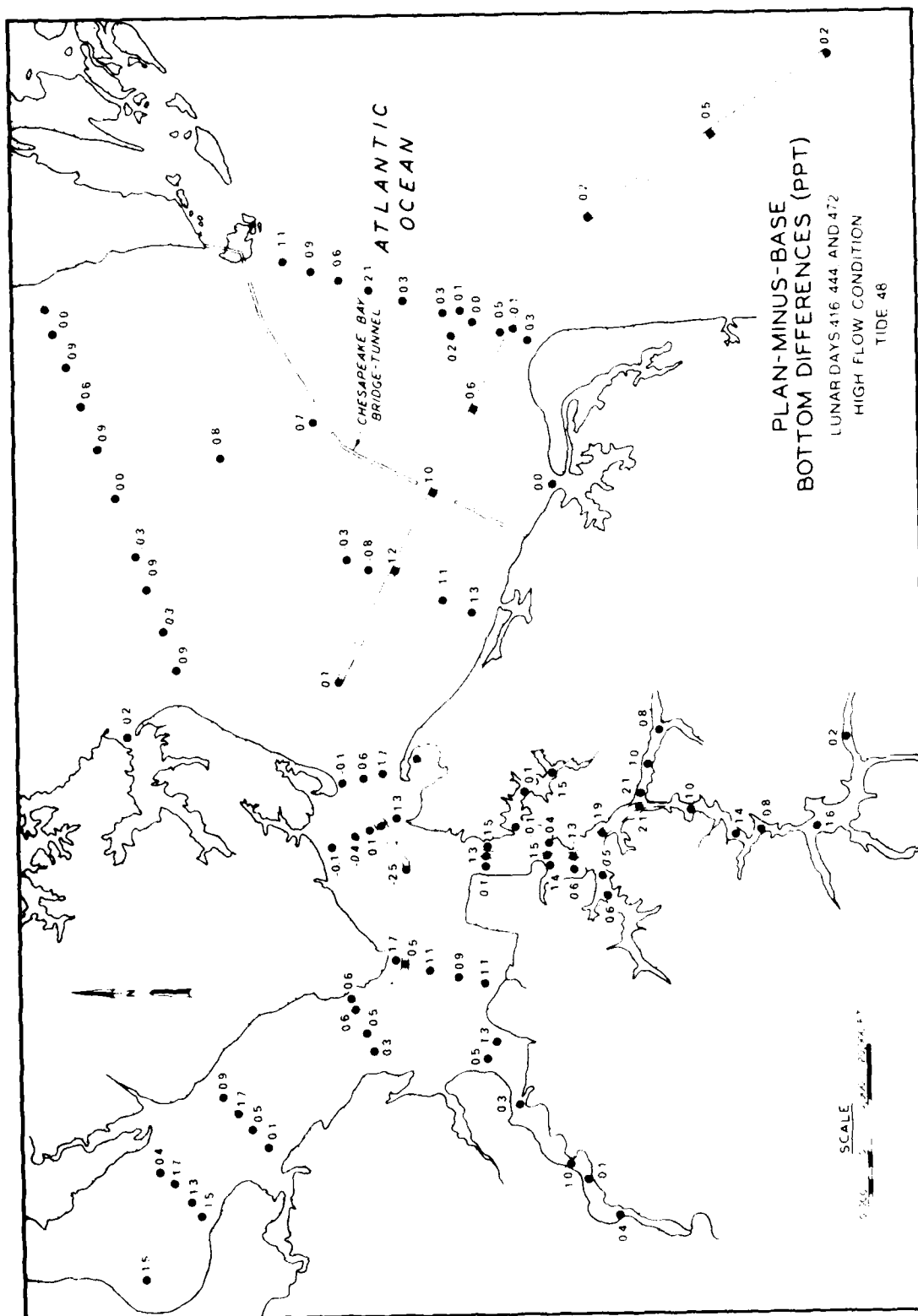
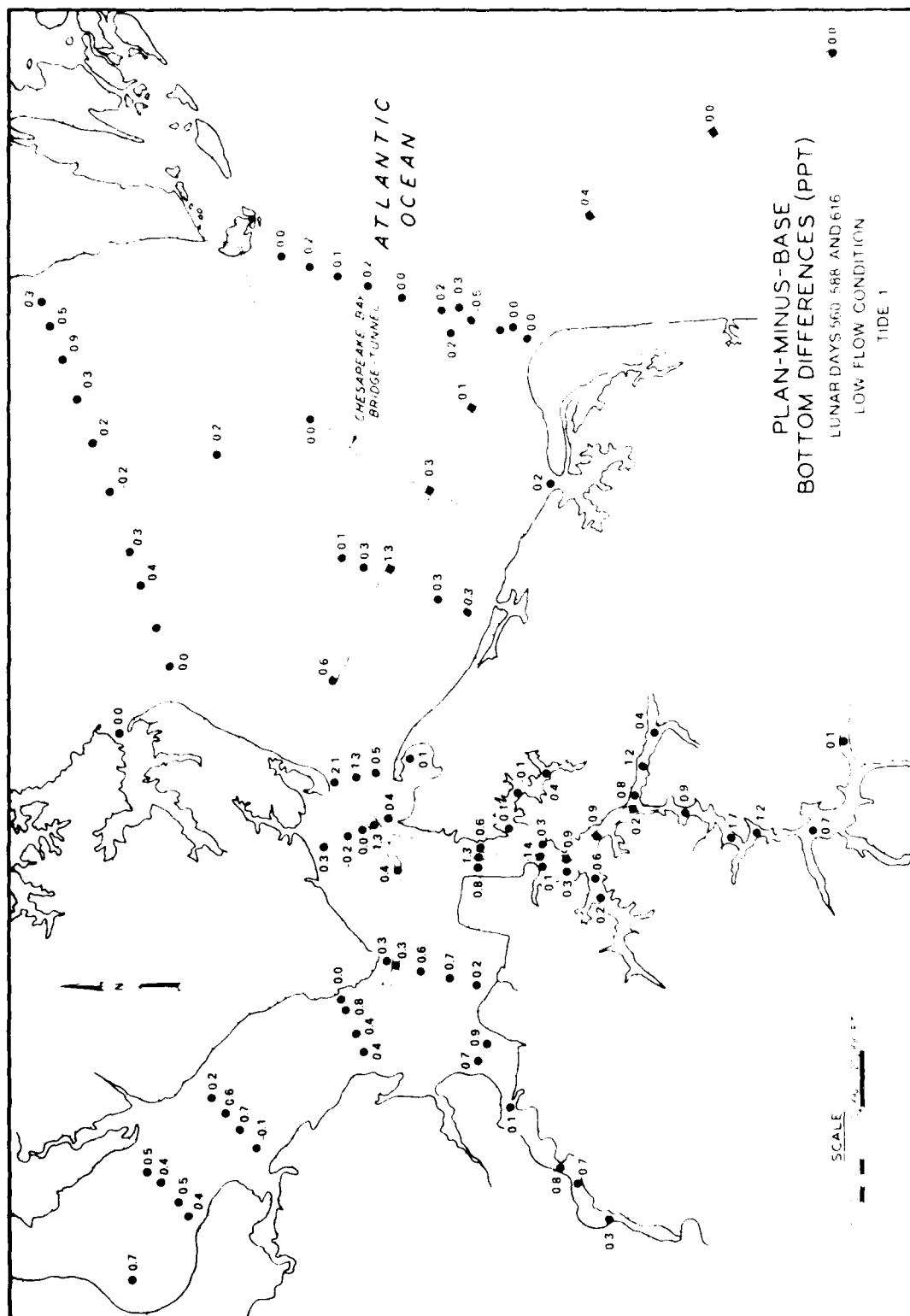


PLATE 226



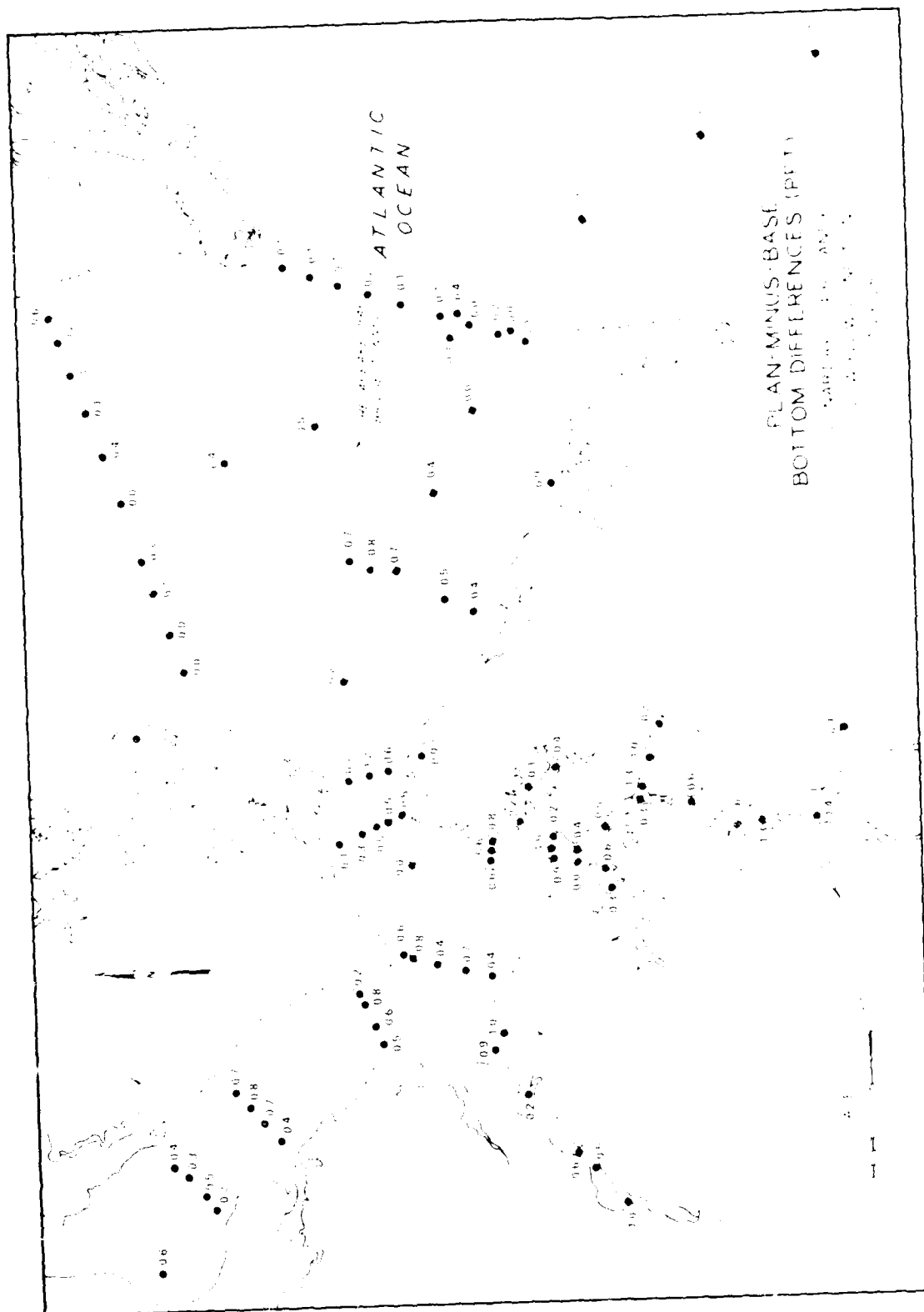
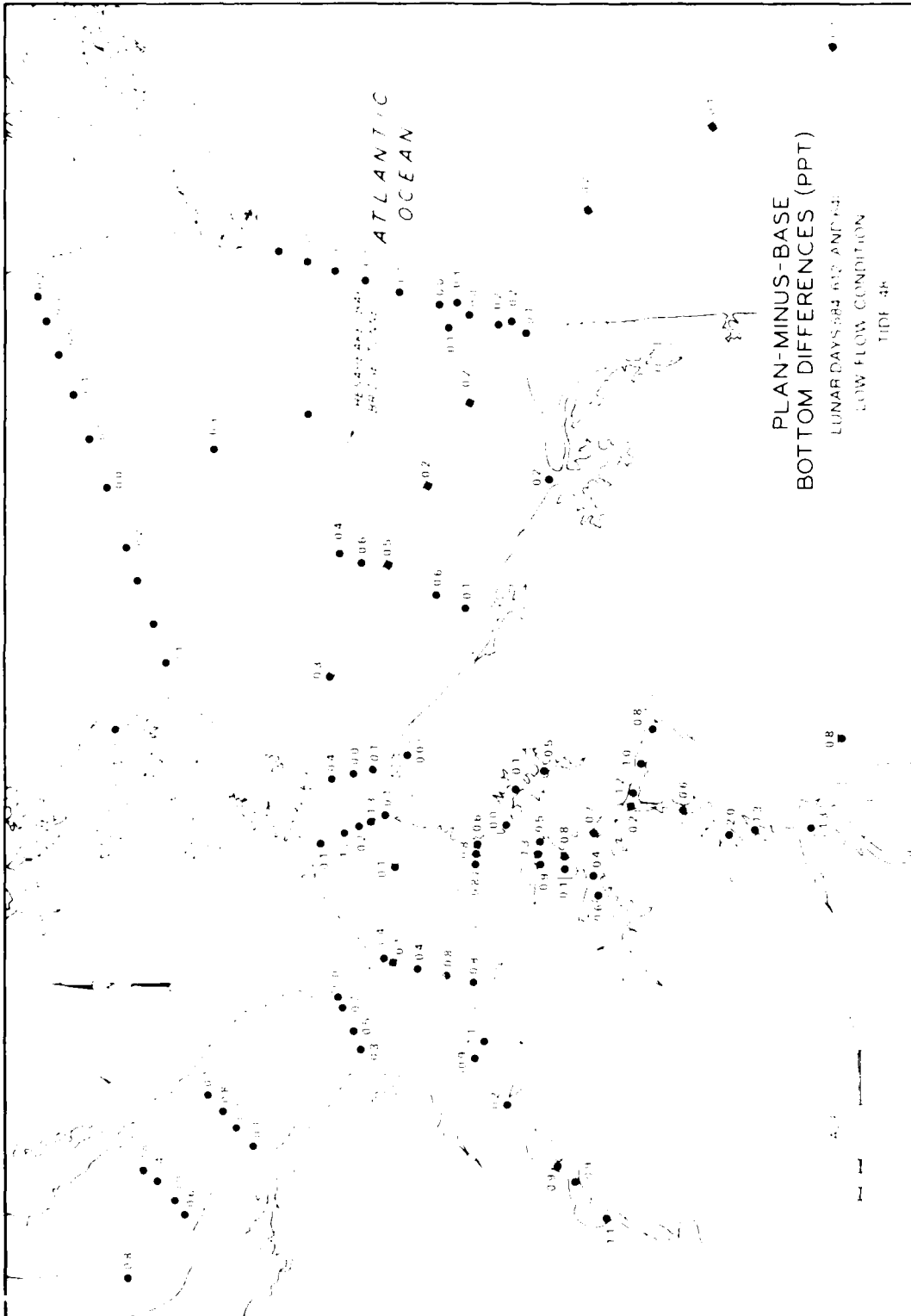


PLATE 230



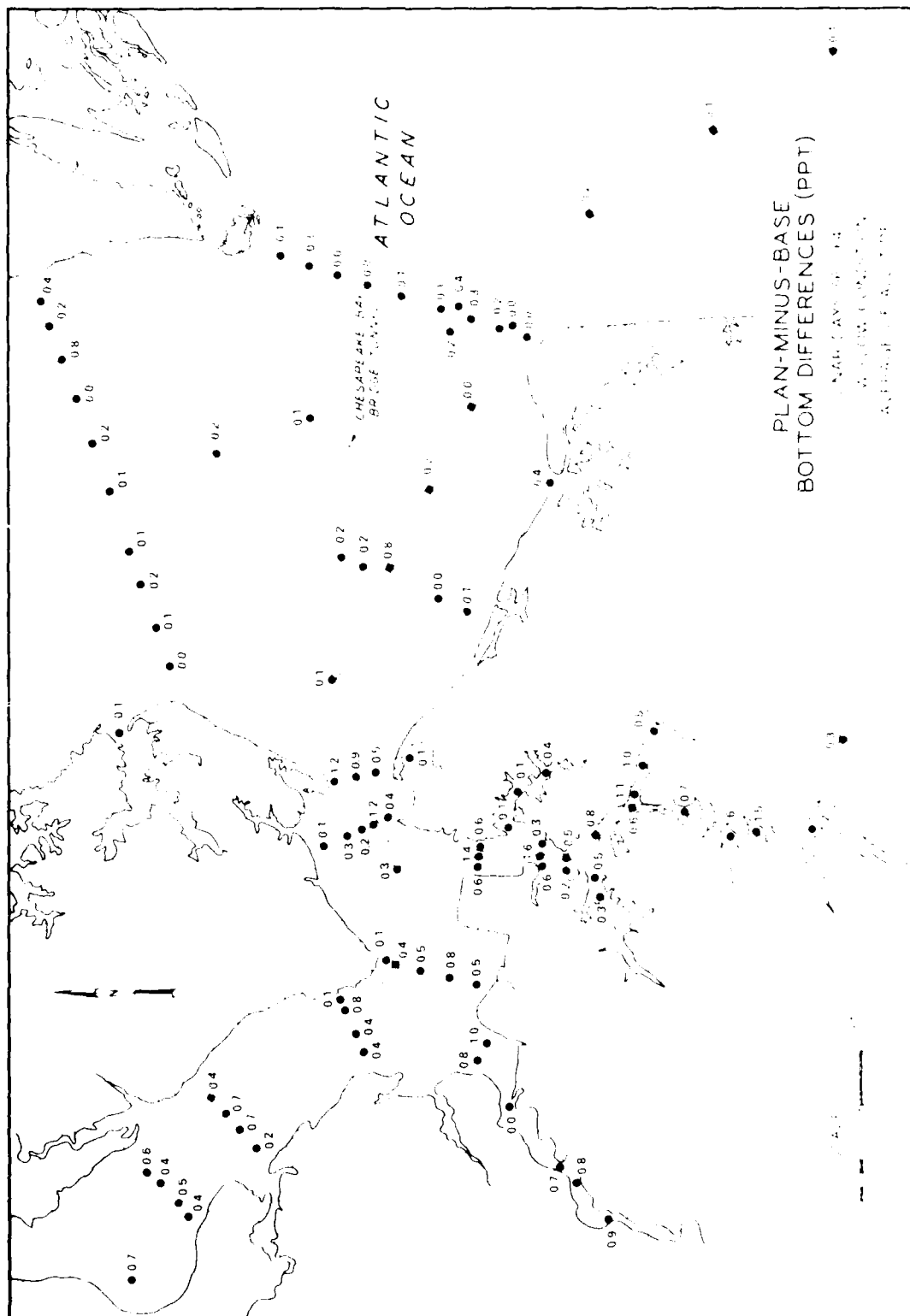
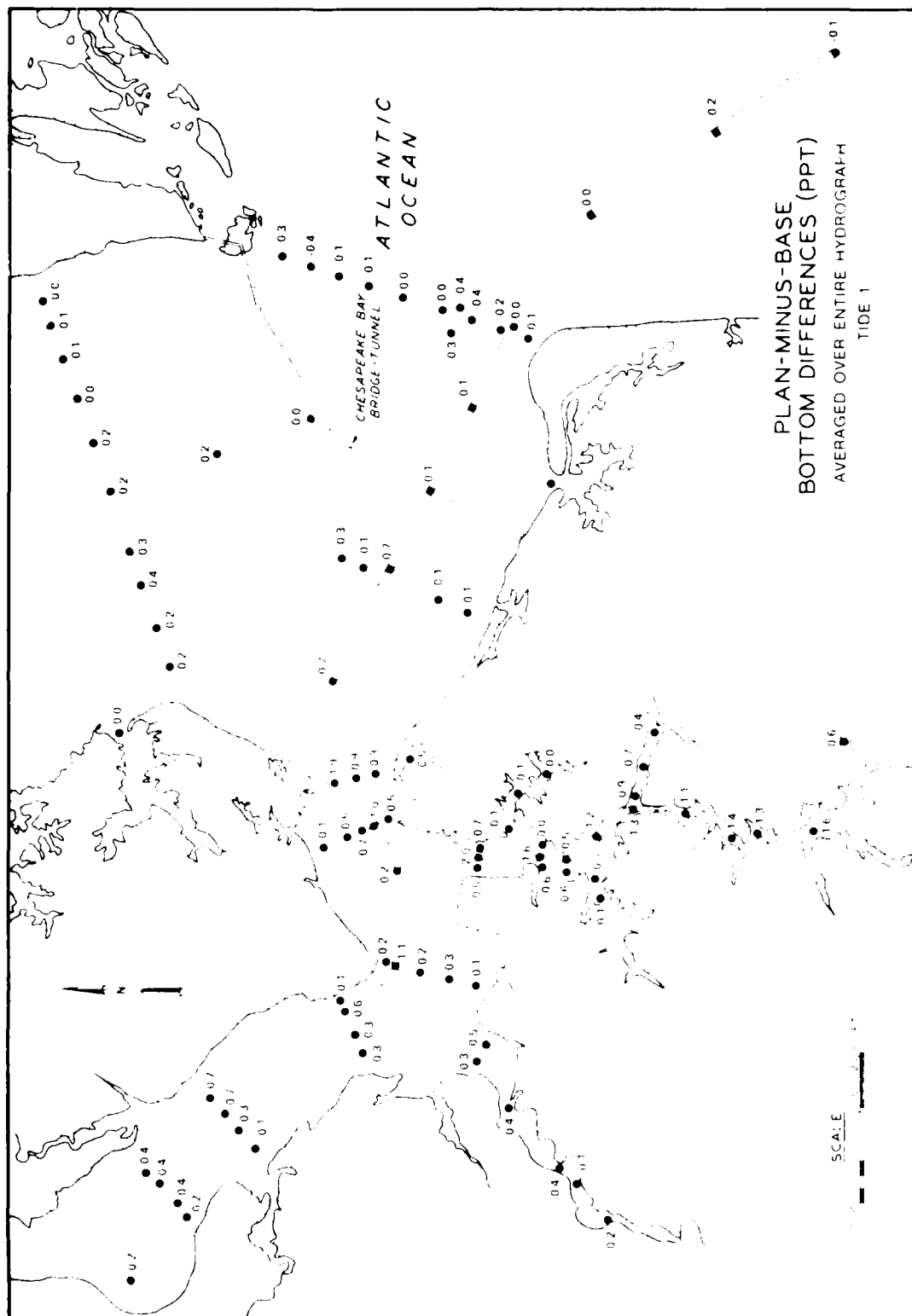


PLATE 232



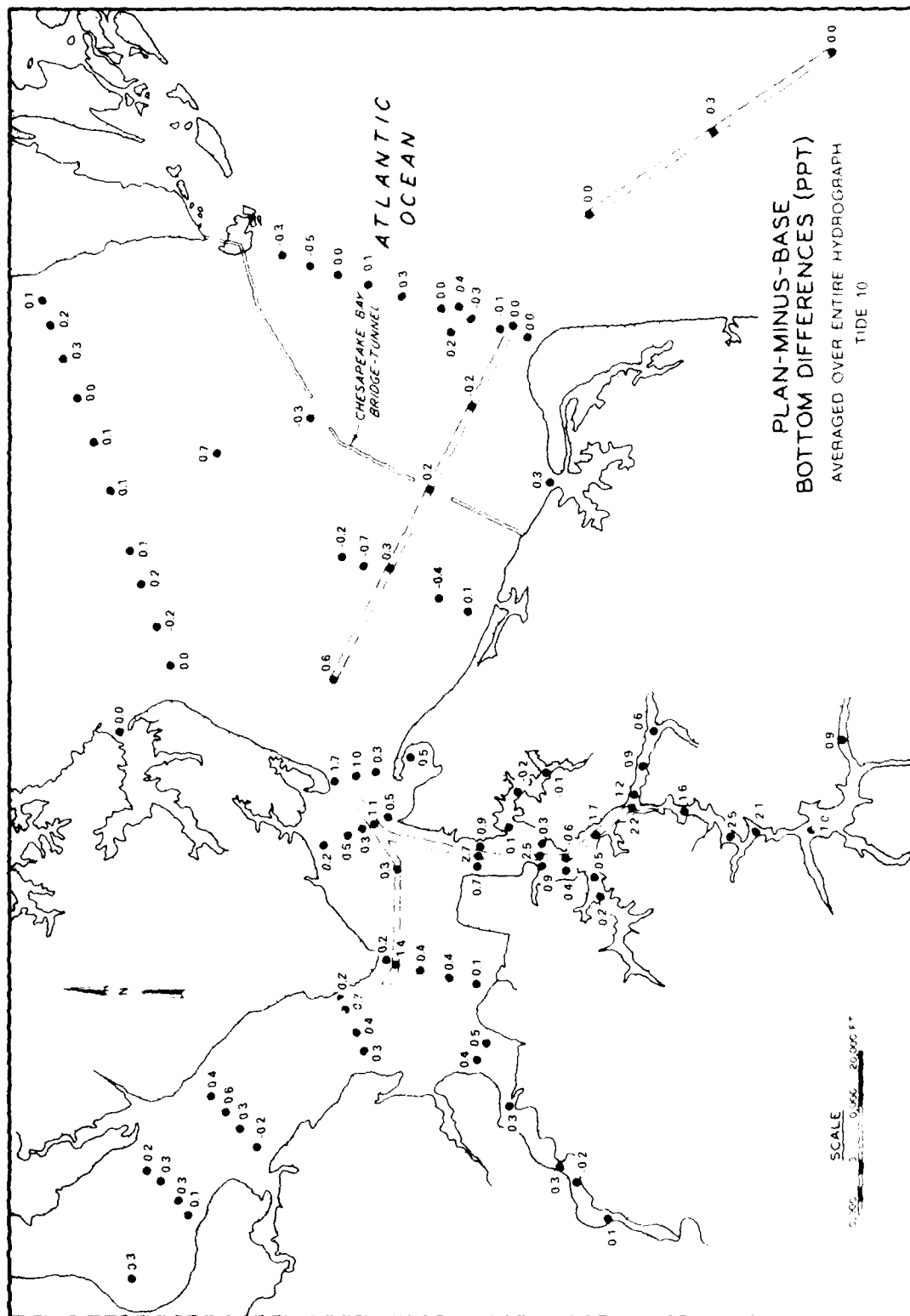
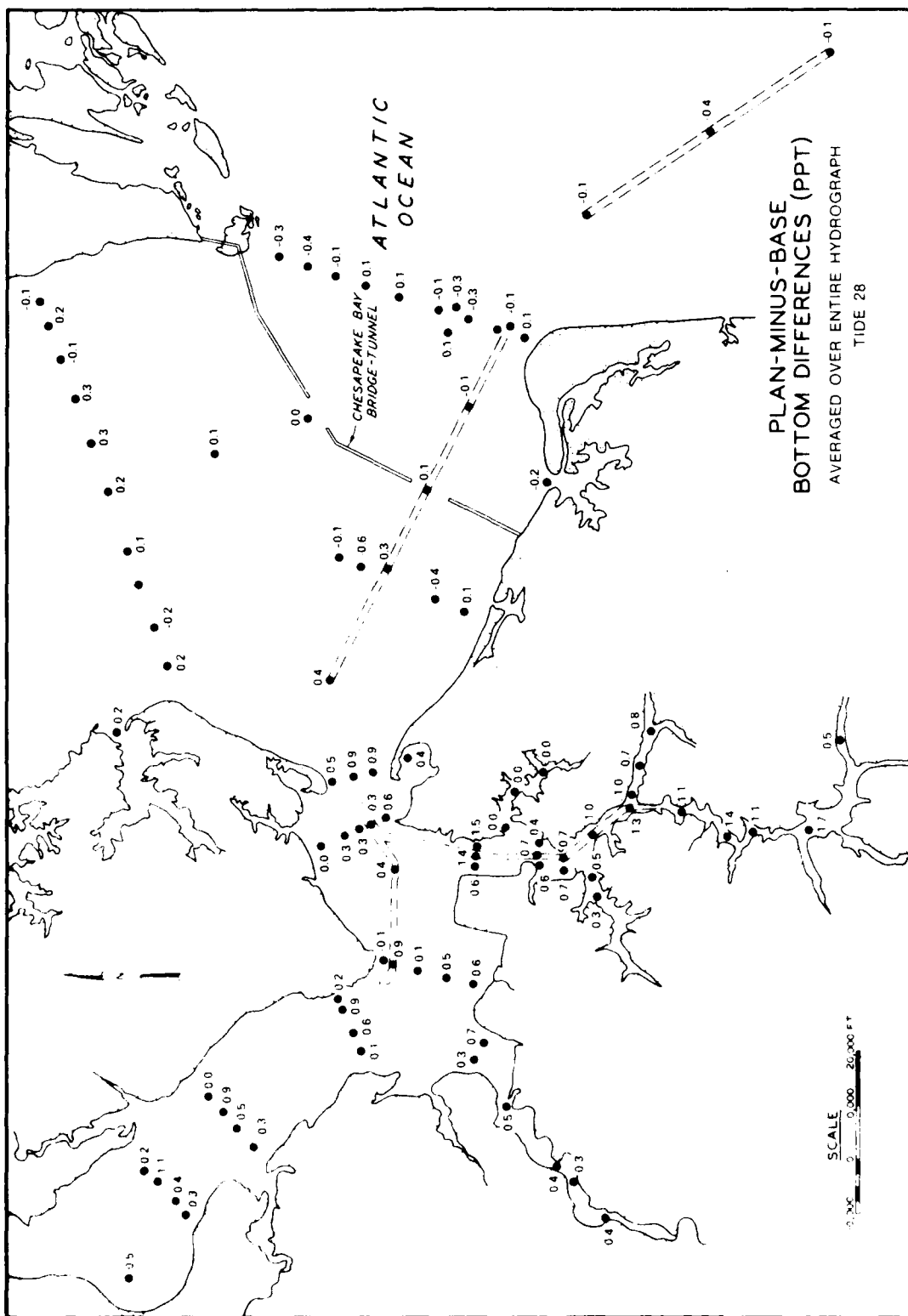


PLATE 234



ATE
MED
8