Technical Report CHL-98-13
May 1998

US Army Corps
of Engineers
Waterways Experiment
Station

Ship Navigation Simulation Study, Alafia River, Tampa Bay, Florida

by Edward F. Thompson, Moira T. Fong,
Peggy S. Van Norman, Ben Brown

Prepared for U.S. Army Engineer District, Jacksonville

Technical Report CHL-98-13
May 1998

Ship Navigation Simulation Study, Alafia River, Tampa Bay, Florida

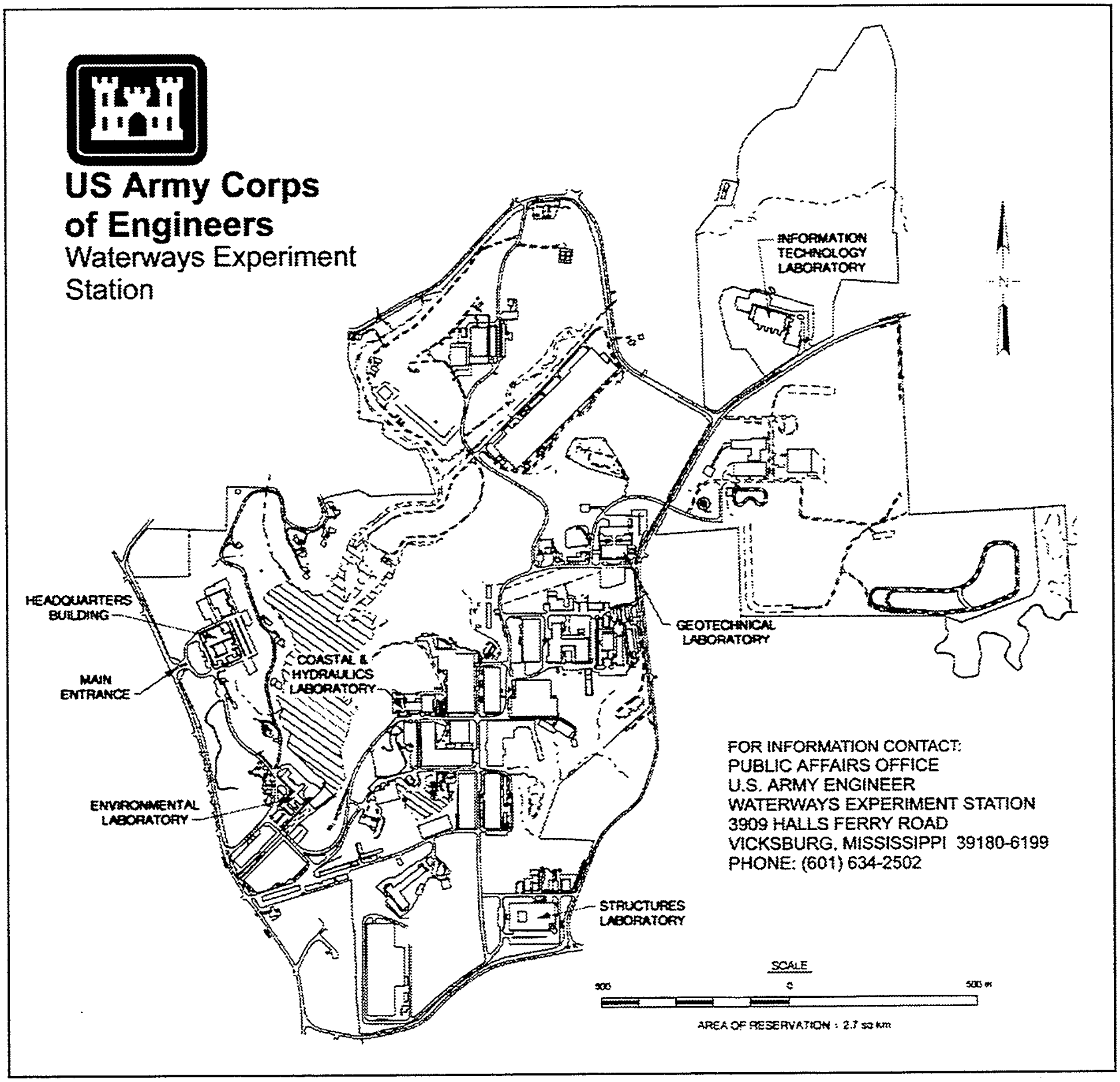
by Edward F. Thompson, Moira T. Fong,
Peggy S. Van Norman, Ben Brown

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Engineer District, Jacksonville
P.O. Box 4970, Jacksonville, FL 32232-0019



Waterways Experiment Station Cataloging-in-Publication Data

Ship navigation simulation study, Alafia River, Tampa Bay, Florida / by Edward F. Thompson ... [et. al] ; prepared for U.S. Army Engineer District, Jacksonville.
82 p. : ill. ; 28 cm. — (Technical report ; CHL-98-13)
Includes bibliographic references.
1. Ships — Maneuverability — Computer simulation. 2. Channels (Hydraulic engineering) — Florida. 3. Navigation — Florida. 4. Alafia River (Fla.) I. Thompson, Edward F. II. United States. Army. Corps of Engineers. Jacksonville District. III. U.S. Army Engineer Waterways Experiment Station. IV. Coastal and Hydraulics Laboratory (U.S. Army Engineer Waterways Experiment Station) V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; CHL-98-13.
TA7 W34 no.CHL-98-13

Contents

List of Figures

List of Tables

Preface

This investigation was performed by the Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Waterways Experiment Station (WES) for the U.S. Army Engineer District, Jacksonville (SAJ). The study was conducted with the WES research ship simulator during the period June - December 1997. SAJ provided survey data of the prototype area.

The investigation was conducted by Dr. Edward F. Thompson of the Coastal Hydrodynamics Branch, Navigation and Harbors Division (NHD), CHL; Ms. Moira T. Fong, Instrumentation Support Division, Information Technology Laboratory, WES, on assignment to the Navigation Branch, NHD, CHL; Ms. Peggy S. Van Norman, Navigation Branch, NHD, CHL; and Mr. Ben Brown, Tidal Hydraulics Branch, Estuary and Hydroscience Division, CHL; under the direct supervision of Dr. Martin C. Miller, Chief of the Coastal Hydrodynamics Branch; Mr. Dennis W. Webb and Dr. Sandra K. Martin, Acting Chiefs, Navigation Branch; and Dr. Robert T. McAdory, Chief of the Tidal Hydraulics Branch. General supervision was provided by Dr. James R. Houston, Director, CHL; Mr. Richard A. Sager and Mr. Charles C. Calhoun, Jr., Assistant Directors, CHL; Mr. C. E. Chatham, Chief, NHD; and Mr. William H. McAnally, Chief, EHD. Mr. Webb provided valuable consultation throughout the investigation. Ms. Shann Martin, Contract Student, Navigation Branch, assisted in the study.

Acknowledgment is made to Mr. Mike Choate, SAJ, for cooperation and assistance at various times throughout the investigation. Special thanks go to the Tampa Bay Pilots Association for participating in the study.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Robin R. Cababa, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
cubic feet	0.02832	cubic meters
knots (international)	0.5144444	meters per second
miles (U. S. nautical)	1.852	kilometers
miles (U. S. statute)	1.609347	kilometers

1 Introduction

Background

The Alafia River mouth is located along the eastern shore of Hillsborough Bay, about 8 miles[1] southeast of Tampa, Florida (Figure 1). Alafia River Harbor, adjacent to a major Cargill Fertilizer, Inc., processing facility, is located approximately 0.5 mile upstream from open water in Hillsborough Bay. The constricted channel between markers "13" and "14" and the turning basin (marker "15") is referred to as the *land cut*.

The existing federally maintained project consists of a turning basin adjacent to Alafia River Harbor dock facilities and a channel connecting the turning basin to Hillsborough Bay Channel Cut C, the primary north-south shipping channel in Hillsborough Bay. Total length of the federal project is 3.6 miles. Channel depth is 30 ft below mean low water (mlw) datum. Channel width is 200 ft. The turning basin is 700 ft wide and 1200 ft long.

Alafia River Harbor is used mainly for shipment of phosphate rock and bulk phosphate products. Vessels typically enter the harbor in ballast and load bulk materials until the vessel draft reaches the limit allowed in Alafia River Channel or until the vessel is fully loaded. Vessels turn in the turning basin at the start of the outbound run, in a loaded condition.

Mean tidal range in the area is 1.8 ft. Tidal currents in the area are not considered to be a problem, but outflow from Alafia River after heavy rains can cause strong currents (on the order of 1 knot) through the turning basin and land cut. Wind can impact navigation in the area, especially for light-loaded vessels. Wind is often from a northerly direction, giving a significant cross-channel component tending to force vessels in Alafia River Channel toward the south.

The U.S. Army Engineer District, Jacksonville (SAJ), requested the U.S. Army Engineer Waterways Experiment Station (WES) to investigate navigation performance of two proposed plans for upgrading the Alafia River Channel and turning basin. The WES study is described in this report and study results are presented.

---

[1] A table of factors for converting non-SI units of measurement to SI units is provided on page vii.

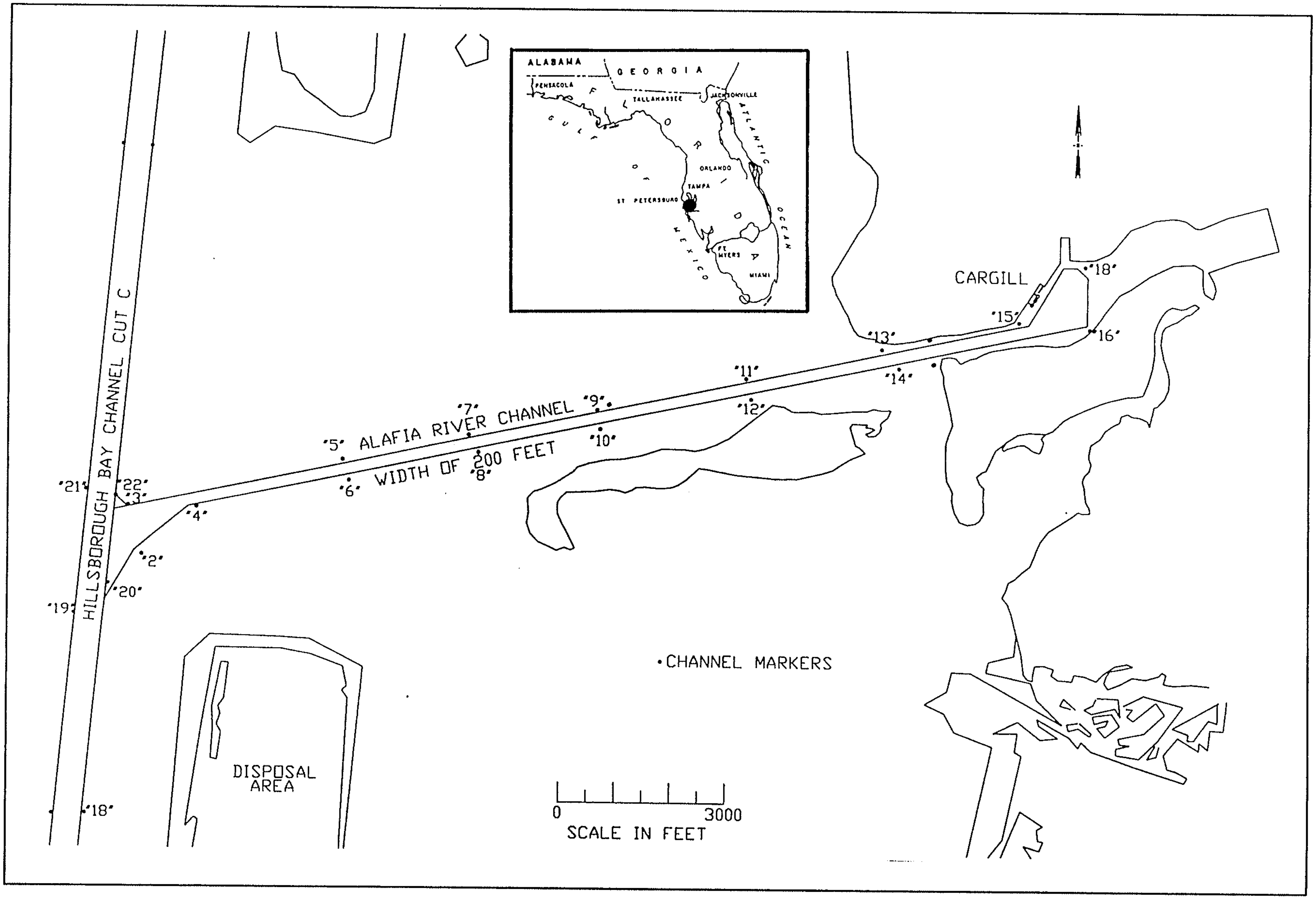


Figure 1. Existing Alafia River Channel and turning basin

Existing Conditions and Navigation Problems

The existing Alafia River Channel is relatively narrow. Vessels sometimes experience difficulty with wind. Pilots report that a wind of 20-25 knots can make the channel hazardous for typical present usage. With a long, wide-beam vessel and wind-induced crabbing, clearance between the vessel and channel boundaries can be greatly reduced. Bank effects are a concern, particularly between markers "11" and "15", where water depths adjacent to the channel are very shallow. Currents in the turning basin and land cut can interfere with navigation when the Alafia River has a strong outflow.

Vessels are accompanied by one or two tugs when they transit the Alafia River Channel. Tug assistance is necessary for docking, undocking, and turning in the turning basin. Tug assistance may be required in turning at the juncture of Hillsborough Bay Channel Cut C and Alafia River Channel. Some tug assistance may also be required along the Alafia River Channel if the vessel should experience problems. Thus, Alafia River Channel needs to accommodate not only the deep-draft vessel, but also one or two tugs typically positioned along the bow.

The existing Alafia River Channel has an authorized depth of 30 ft, while Hillsborough Bay Channel Cut C has an authorized depth of 43 ft (Table 1). The larger vessels loading at Alafia are forced to carry a partial load because of the restrictive depth in Alafia River Channel. Existing range markers include northbound and southbound ranges in Hillsborough Bay Channel Cut C and outbound ranges in Alafia River Channel.

Table 1
Existing and Proposed Project Dimensions

Configuration	Depth, ft	Width, ft	Turning Basin Size, ft
Hillsborough Bay Channel Cut C	43[1]	500	...
Existing Alafia River Channel	30[1]	200	700 × 1200
Plan 1	41[2]	250	1162 (diameter)
Plan 2	41[2]	250	1000 (diameter)

[1] Depths referenced to mean low water datum.
[2] Depths referenced to mean lower low water datum.

Proposed Improvements

In order to address these navigation concerns and to allow larger, deeper draft vessels to call at Alafia Harbor, SAJ has proposed two channel and turning basin alternatives (Plan 1 and Plan 2). Both plans have a widened and deepened Alafia River Channel (Table 1). The two plans differ mainly in location and layout of the turning basin. Depths for proposed alternatives are referenced to mllw datum to reflect present practice. The mllw datum is 0.43 ft below mlw at this location. Special features of each plan are:

a. Plan 1 (Figures 2 and 3). Alafia River Channel is widened to 250 ft and deepened to 41 ft mllw. The turning basin is expanded to the maximum circular size allowable at the present location without intruding on land areas, a diameter of 1162 ft. A widener on the north side of the turn from Alafia River Channel into Hillsborough Bay Channel Cut C was also included in Plan 1 to give some information on the navigation benefits of this feature. Navigation aids were moved and added as needed to mark the new channel and turning basin.

b. Plan 2 (Figures 4 and 5). Alafia River Channel is widened to 250 ft and deepened to 41 ft mllw as in Plan 1. The turning basin and dock are relocated outside the land cut. The turning circle is 1000 ft in diameter. It is tangent to the south boundary of Alafia River Channel and extends north. The new dock is north of the channel and just east of the turning basin. A dredged 240-ft wide berthing area adjacent to the dock is included. Navigation aids were moved and added as needed to mark the new channel and turning basin.

Purpose and Scope

In order to evaluate the proposed plans for channel and turning basin improvement, a real-time simulation investigation was conducted. The purpose of the study was to determine the effects of proposed improvements on navigation and to assist in optimizing channel width and turning basin configuration required to efficiently navigate the study area.

The study described in this report was performed by WES Coastal and Hydraulics Laboratory (CHL). The approach consisted of the following tasks:

a. Develop data required in navigation simulation.

b. Validate the navigation simulation of Alafia River Channel and turning basin.

c. Conduct real-time navigation simulations of existing and proposed plans for Alafia River Channel and turning basin.

d. Evaluate effectiveness of proposed plans for meeting navigation requirements.

These tasks are discussed in the following chapters. Conclusions and recommendations are given in Chapter 5. That chapter is followed by an appendix with detailed information on flow modeling done in support of the navigation simulation study.

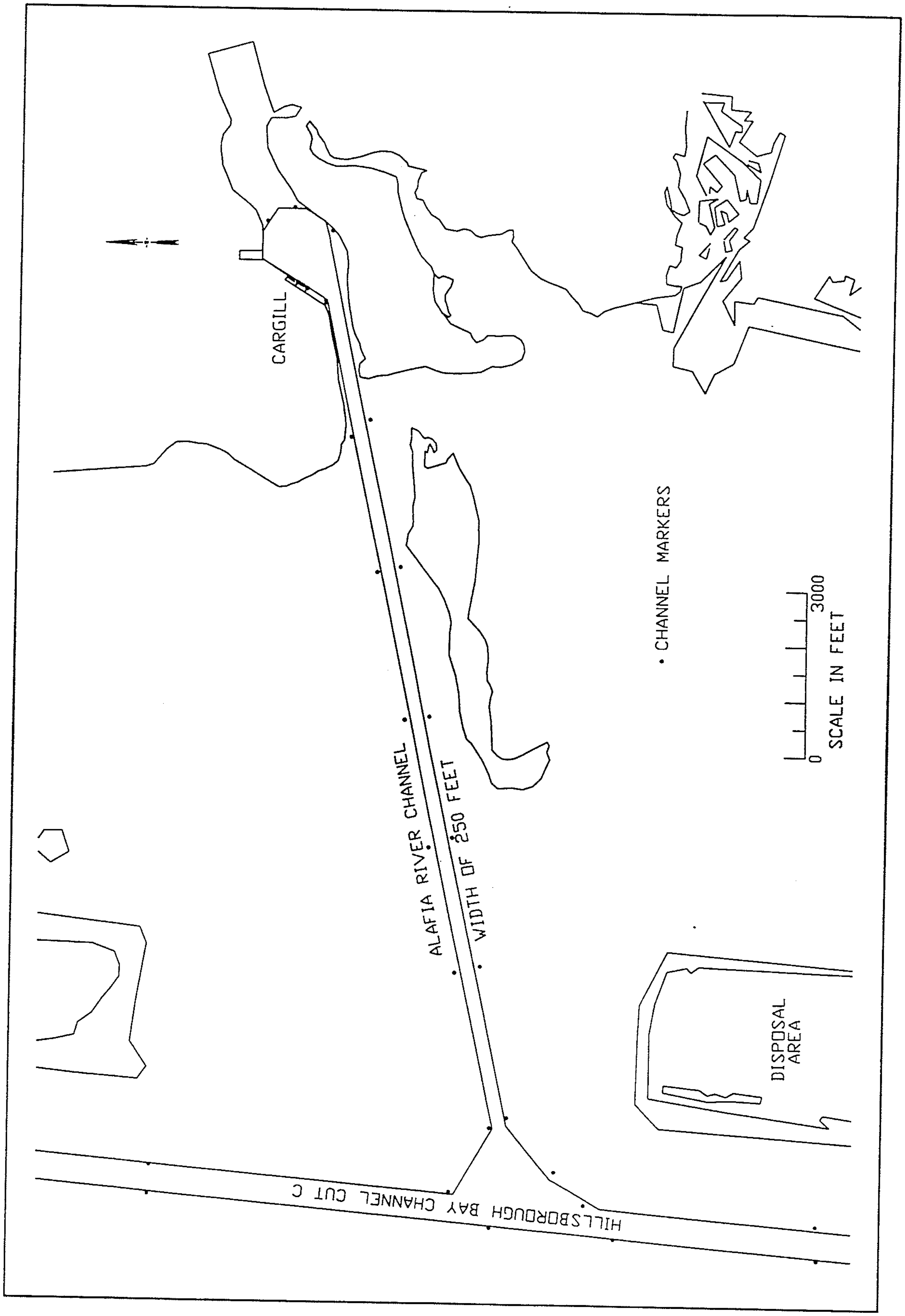


Figure 2. Plan 1 channel and turning basin configuration

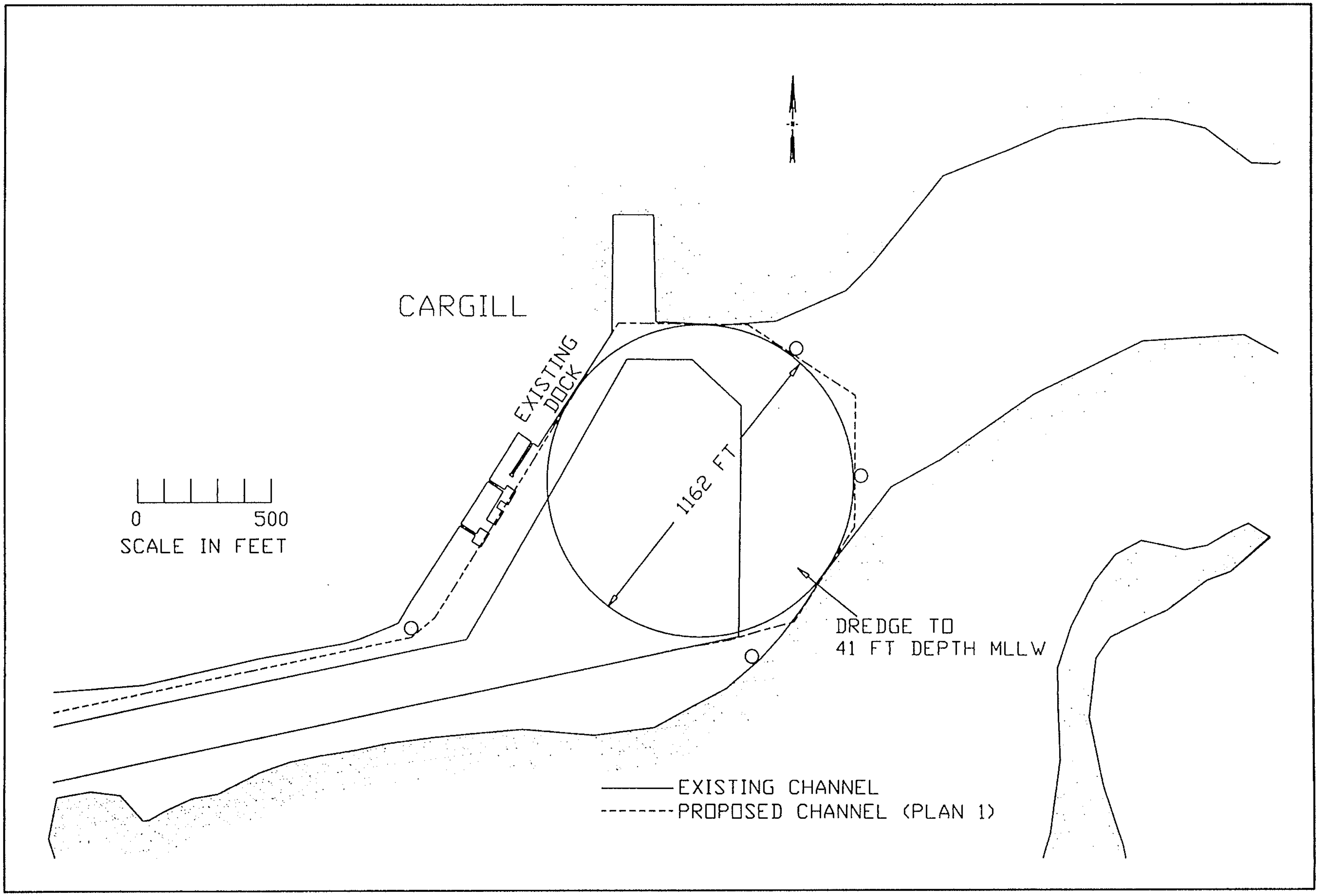


Figure 3. Plan 1 turning basin detail

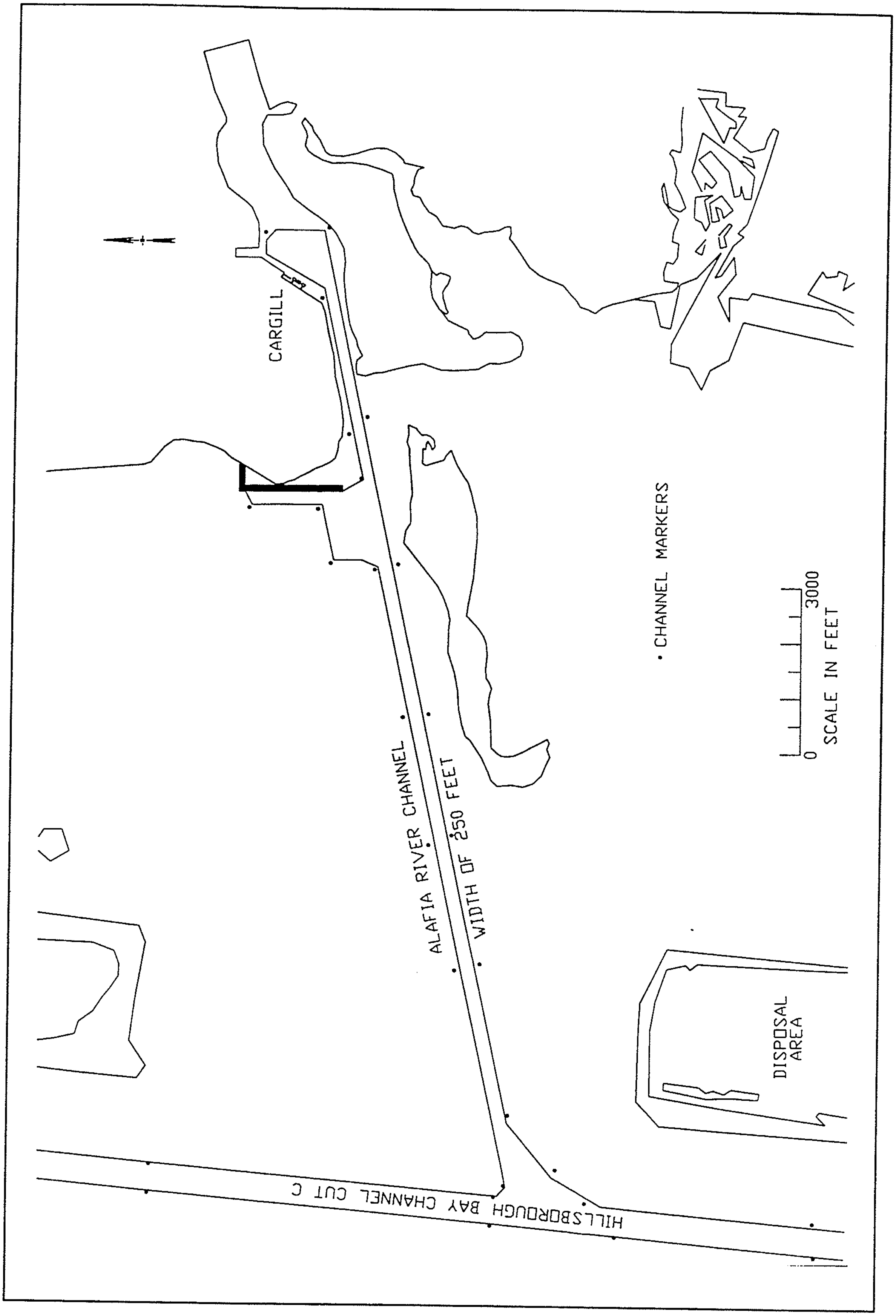


Figure 4. Plan 2 channel and turning basin configuration

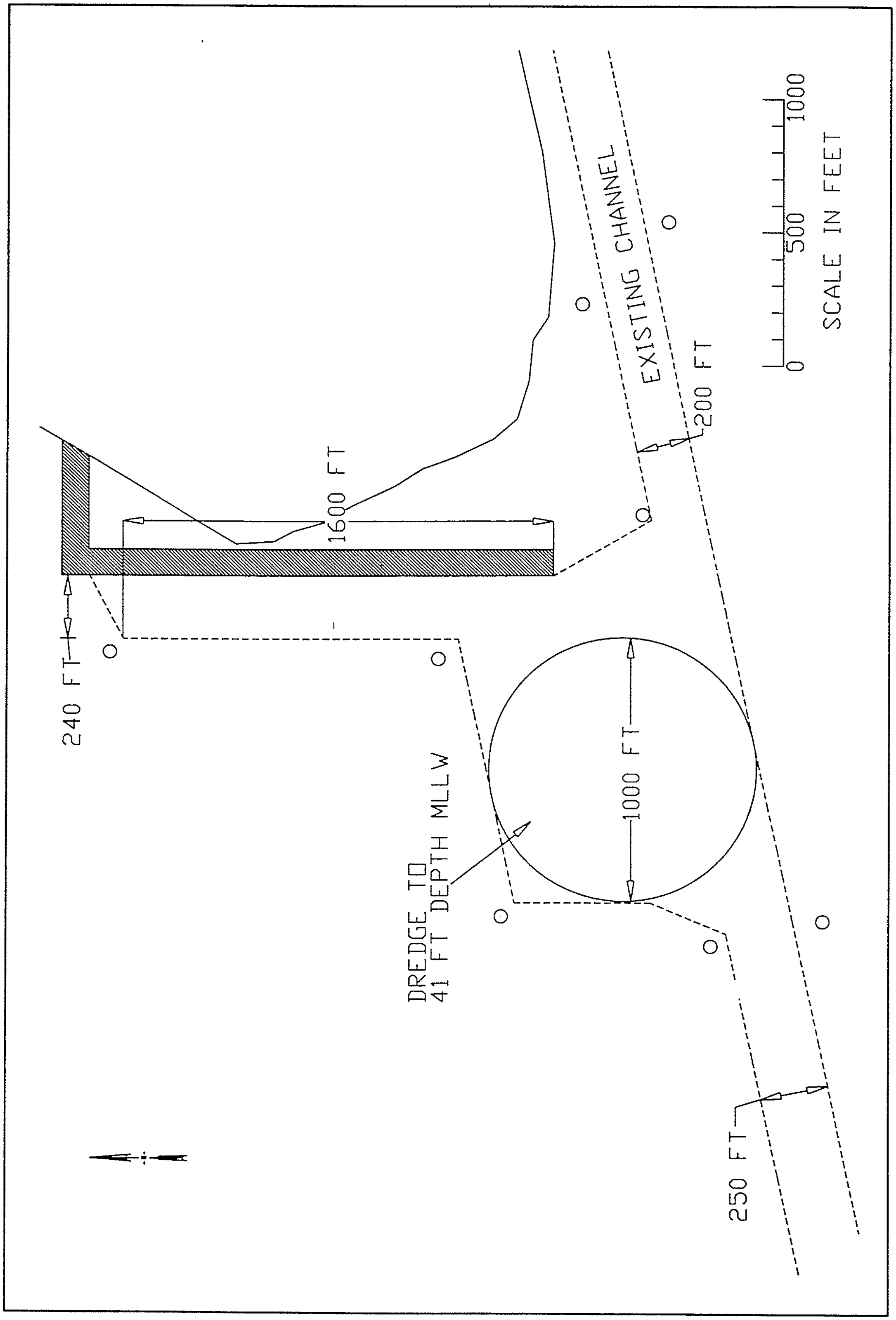


Figure 5. Plan 2 turning basin detail

2 Data Development

Description of Simulator

It is beyond the scope of this report to describe other than briefly the WES ship simulator.[1] The purpose of the WES ship simulator is to provide the essential factors necessary in a controlled computer environment to allow the inclusion of the man-in-the-loop, i.e., local ship pilots, in the navigation channel design process. The simulator is operated in real-time by a pilot at a ship's wheel placed in front of a screen upon which a computer-generated visual scene is projected. The visual scene is updated as the hydrodynamic portion of the simulator program computes a new ship's position and heading resulting from manual input from the pilot (rudder, engine throttle, bow and stern thruster, and tug commands) and external forces. The external force capability of the simulator includes effects of wind, waves, currents, banks, shallow water, ship/ship interaction, and tugboats. In addition to the visual scene, pilots are provided simulated radar and other navigation information such as water depth, relative ground and water speed of the vessel, magnitude of lateral vessel motions, relative wind speed and direction, and ship's heading.

Required Data

Data required for the simulation study included channel geometry, bottom topography, channel currents for proposed as well as existing conditions, numerical models of experiment ships, and visual data of the physical scene in the study area. Dredging survey sheets provided by SAJ were used for establishing channel alignments. Current data were obtained from a TABS-2 finite element numerical model of upper Hillsborough Bay and the Alafia River Channels and turning basins developed for navigation (Appendix A). Two reconnaissance trips were carried out for the purpose of gathering data and observing actual shipping operations in the study area. Still photographs and video footage were taken during reconnaissance transits to aid in generation of the simulated visual scene. A hand-held Global Positioning System (GPS) device was used to accurately

---

[1] "Hydraulic Design of Deep Draft Navigation Channels," PROSPECT (Proponent Sponsored Engineer Corps Training) course notes, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 19-23 June 1989.

establish the locations of several key points in the harbor. Discussions with pilots were also held so that WES engineers could become more familiar with concerns and problems experienced during channel operations.

Experiment File

The experiment file contains initial conditions (ship speed and heading, rudder angle, and engine setting) for the simulation and geographical coordinates for channel alignment. The channel is defined in terms of cross sections located to coincide with changes in channel alignment and current direction and magnitude. Information used for development of the Alafia River Channel and turning basin database was obtained from SAJ's project surveys. Plane coordinates on the survey sheets are based on a transverse Mercator projection for the west zone of Florida. The same coordinate system was used for the simulator database. Also included in the experiment file are bank steepness and overbank depth (water depth at the top of the side slope) adjacent to the channel. These data are used by the computer to calculate bank effect forces on vessels in the simulations. Specifications of other external forces such as wind are also included in this file.

For the Alafia River Channel and turning basin project, simulator channel cross sections were placed approximately 500 ft apart in straight, uniform channel areas. Since the channels were fairly uniform, simulator cross sections did not vary in spacing along much of the channel. Cross section spacing was reduced considerably in bends, turning basins, and dock areas to insure good representation of changes in geometry and currents. The simulator program handles transition between cross sections on an interpolative basis.

Water depths for the simulator were based on authorized project depths. For the simulated existing channel, water depth represented the existing condition taken from the July 1997 project condition survey furnished by SAJ. Bank slopes and overbank depths were also obtained from the July 1997 project condition survey. These data are used in calculating ship hull bank forces. Bank forces occur when a ship travels close to a submerged bank (also, wall or docked ship). The resulting effect is characterized by ship movement toward the bank and bow-out rotation away from the bank.

Scene File

The scene data base comprises several data files containing geometrical information enabling the graphics computer to generate a simulated scene of the study area. The computer hardware and software used for visual scene generation are separate from the main computer of the ship simulator. The main computer provides motion and orientation information to a stand-alone graphics computer for correct vessel positioning in the scene, which is then viewed by the pilot. Operators view the scene as if they are standing on the bridge of a ship looking toward the ship's bow in the foreground. View direction can be changed during simulation for the purpose of looking at objects outside of the relatively narrow straight-ahead view. For example, this capability is critical for inbound vessels in

Alafia River Channel because the only available range markers are behind the vessel.

Aerial photographs, reconnaissance photographs, navigation charts, and dredging survey charts provided basic data for generation of the visual scene. All land masses in the vicinity of the navigation channel were included in the scene. Land based features such as trees and buildings were included in sufficient detail to provide pilots with familiar visual cues and to provide realism. All aids to navigation in the vicinity of the study area were included. In addition to the man-made and topographical features in the vicinity, the visual scene included a perspective view of the bow of the ship from the pilot's viewpoint. The visual scene did not include tug representations. Visual databases for all design ships were developed at WES for use in the simulation.

Radar File

The radar file contains coordinates defining the border between land and water and significant man-made objects, such as docked ships and aids to navigation. These data are used by another graphics computer that connects the coordinates with straight lines and displays them on a terminal. The objects viewed comprise visual information that simulates shipboard radar. The main information sources for this database were project drawings and dredging survey sheets supplied by SAJ.

Ship Files

The ship files contain characteristics and hydrodynamic coefficients for the vessels to be modeled. These data are the computer's definition of the ship. Coefficients govern the reaction of the ship to external forces, such as wind, current, banks, and underkeel clearance, and internal controls, such as rudder and engine revolutions per minute (rpm) commands. The numerical bulk carrier model for Alafia River Channel and turning basin simulations was developed originally by Tracor Hydronautics, Inc., of Laurel, MD.[1] The numerical ITB model was developed similarly under contract with WES, by Designers and Planners, Inc., of Arlington, VA, using the same technical experts. These ships were chosen based on SAJ's economic analysis of future shipping business and operations.

---

[1] V. Ankudinov. (1988). "Hydrodynamic and mathematical models for ship maneuvering simulations of "LASH" barge carrier and two bulk carriers in support of the Pascagoula Harbor study," Technical Report 87005.0623-1, Prepared under Contract No. DACW3987-D-0029 by Tracor Hydronautics, Laurel, MD, for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Current File

The current file contains current magnitude and direction and water depth for each of eight points across each of the cross sections defining channel alignment. Current information for a ship simulation study is usually obtained from physical or numerical models. In this study, current information was generated with a numerical model of upper Hillsborough Bay (Appendix A). Current information in the proposed channel and turning basin configurations was based on numerical modeling with the plan bathymetry.

Experiment Conditions

The experiment scenarios, design vessels, and environmental conditions were selected in order to evaluate existing and proposed channels in the "maximum credible adverse situation," that is, the worst conditions under which the harbor would maintain normal operations. This approach provides a built-in safety factor when analyzing the results. The existing channel was included in order to provide a base with which to compare simulations of the proposed channels, and to provide a basis for comparison of conditions by pilots involved in the study. Experiment conditions are summarized in Table 2 and discussed in the following paragraphs.

Wind

A 15-knot wind from the north was imposed on all simulations in Alafia River Channel and turning basin. Ballasted vessels transiting Alafia River Channel are especially vulnerable to beam forces exerted by this representative moderately strong wind.

Currents

Channel and turning basin currents were derived from a TABS-2 model study conducted at WES (Appendix A). Although currents outside the turning basin and land cut were small, simulations were run with both ebb and flood tide in areas where they could have design significance. Alafia River discharge and the effect of ship damming during turning in the inner turning basin were included in the modeling. An Alafia River discharge of 4000 cfs at the U.S. Highway 41 bridge (less than one mile upstream from the dock), representing an average two-year maximum event, was used in all simulations. Only ebb tide, which reinforced Alafia River flow, was used in turning simulations for the inner turning basin.

Design vessels

Design vessels for the simulation of Alafia River Channel and turning basin were a 740-ft × 106-ft bulk carrier and a 760-ft × 78-ft Integrated Tug Barge (ITB). The bulk carrier, when inbound, was in ballast at a draft of 25 ft. The bulk carrier, when outbound, was loaded to a draft of 29 ft for the existing condition and 39 ft for proposed conditions. The ITB, when inbound, was in ballast at a draft of 12 ft. The fully loaded ITB has a draft of 32 ft, but this vessel was not used for design experiments. The ITB has twin screws, which were included in the simulation. The length given for the bulk carrier is the length between perpendiculars. The bulk carrier length overall was 775 ft. Comparable design vessels were used in a previous real-time navigation simulation study of Big Bend Channel, Hillsborough Bay, Florida, conducted by WES for SAJ.

Table 2
Experiment Conditions

Configuration	Environment			Vessel		
	Wind Speed, knot	Wind Direction	Tidal Current	Type	Travel Direction	Draft, ft
Existing	15	From North	Flood & ebb	Bulk carrier	Inbound	25
				Bulk carrier	Outbound	29
				ITB	Inbound	12
Plans 1 and 2	15	From North	Flood & ebb	Bulk carrier	Inbound	25
				Bulk carrier	Outbound	39
				ITB	Inbound	12

Note: Alafia River discharge of 4000 cfs applied at U.S. Highway 41 bridge in all simulations.

3 Navigation Study

Validation

Simulation was validated with the assistance of two pilots licensed for Tampa Bay. The following information was verified and fine tuned during validation:

a. Wind effects.

b. Bank conditions.

c. Currents.

d. Ship engine and rudder response.

e. Visual scene and radar image of the study area.

(1) Location of all aids to navigation.

(2) Location and orientation of the docks.

(3) Location of buildings visible from the vessel.

Validation began by the pilots conducting real-time simulation runs through the entire study area in the existing condition with no wind or currents. Vessel handling, bank effects, visual accuracy and realism were all scrutinized. Problem areas were identified, prototype data were re-examined, and the model was adjusted as needed to achieve realism. This process of experimenting and adjusting was repeated until pilots were satisfied that the simulated vessel response was similar to that of an actual vessel in the prototype. Then external forces of wind and current were added and verified by the same procedure. Simulation of the turning maneuver in the existing turning basin for the loaded bulk carrier could not be verified. This maneuver was attempted but clearly was impractical for the design vessel in the existing confined turning basin. Turning was also attempted with a smaller ship, representative of vessels presently calling at Alafia. However, current forces due to ship damming were based on the larger, design ship; and the turning simulation was not sufficiently realistic. Instead, simulation of the turning maneuver was subjected to a validation procedure when simulations of the Plan 1 proposed condition began.

Experiment Scenarios and Procedure

In order to completely analyze the proposed channels and turning basins, inbound and outbound simulation runs were undertaken using the bulk carrier. Only inbound runs were included using the ITB. Some of the inbound and outbound runs were abbreviated to focus simulator time on the turning basin and dock and the juncture of Alafia River Channel and Hillsborough Bay Channel Cut C, areas of greatest concern for navigation.

Inbound Scenarios

Inbound runs began in Hillsborough Bay Channel Cut C, south of Alafia River Channel, and transited the Alafia River Channel. In most cases, inbound vessels proceeded to the dock, but a turning maneuver and backing into the dock was included in some of the Plan 2 condition runs. Examples of the visual scene during an inbound bulk carrier simulation of the Plan 1 condition are shown for approach to the land cut (Figure 6) and approach to the dock (Figure 7).

Outbound Scenarios

Bulk carriers turned at the start of outbound Plan 1 condition runs and in some of the Plan 2 condition runs. Bulk carriers in existing condition outbound runs started in the turning basin near the land cut (since they could not turn in the existing turning basin). Because of the need for special current modeling in the turning basin to account for ship damming effects, the outbound Plan 1 condition run was divided into two simulation runs: turning in the turning basin, and transit from the land cut to Hillsborough Bay Channel Cut C.

Special Scenarios

Two special scenarios were included for limited simulation. Navigation of the sharp turn into and from Hillsborough Bay Channel Cut C, north of the Alafia River Channel was studied. Also, the potential navigation benefits of adding inbound ranges for Alafia River Channel were investigated in several simulation runs.

Procedure

Experiments were conducted in random order. This approach was designed to prevent prejudicing results. For example, if all existing conditions were run prior to running plans, the pilots' acquired proficiency at operating the simulator could make the plans appear to have an exaggerated effect on improving navigation.

During each run, characteristic parameters of the ship were automatically recorded every 5 seconds. These parameters included position of the ship's center of gravity, speed, rpm of the engine, heading, drift angle, rate of turn, rudder angle, and port and starboard clearances.

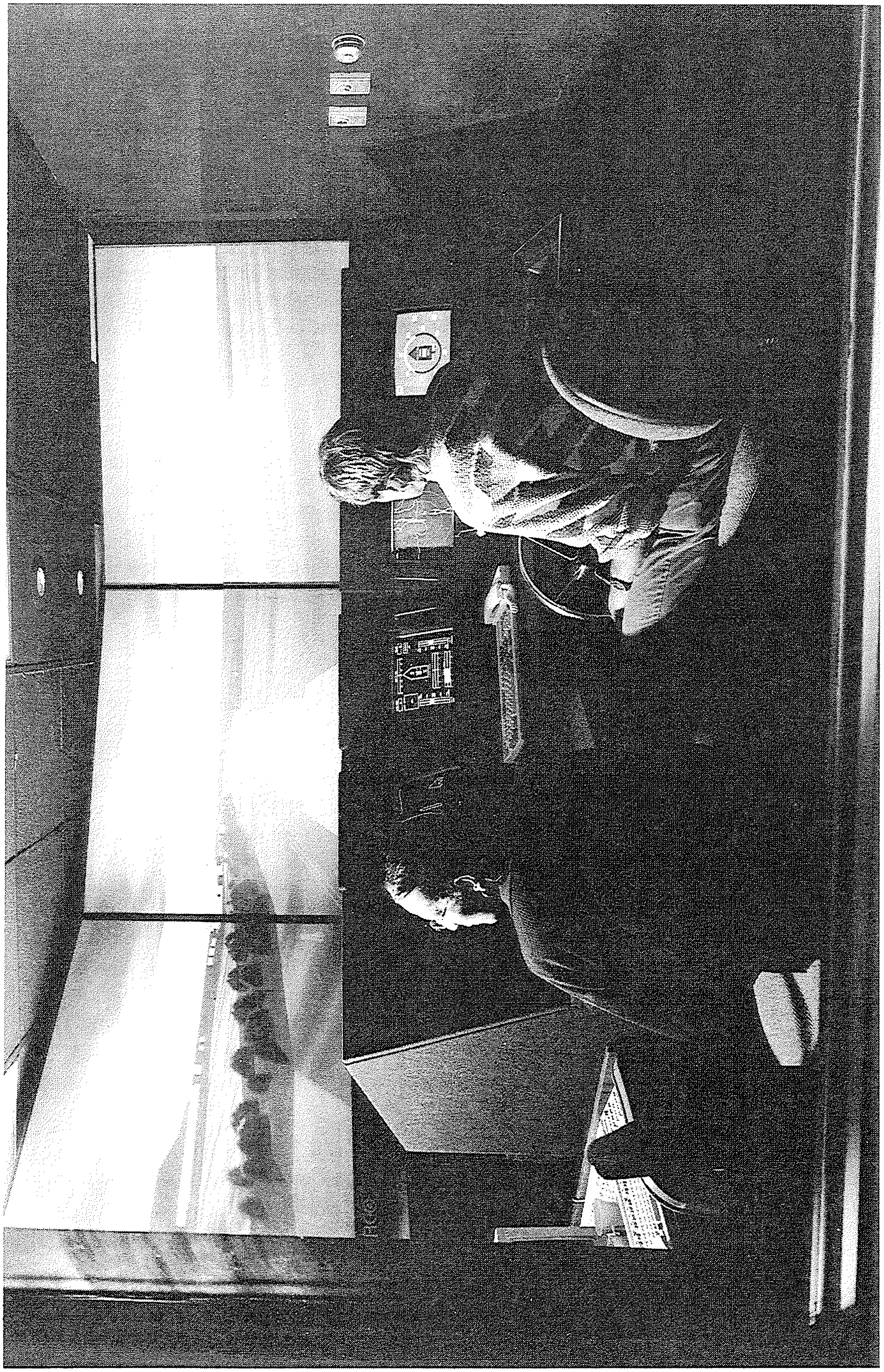


Figure 6. Visual scene, approach to land cut, inbound bulk carrier

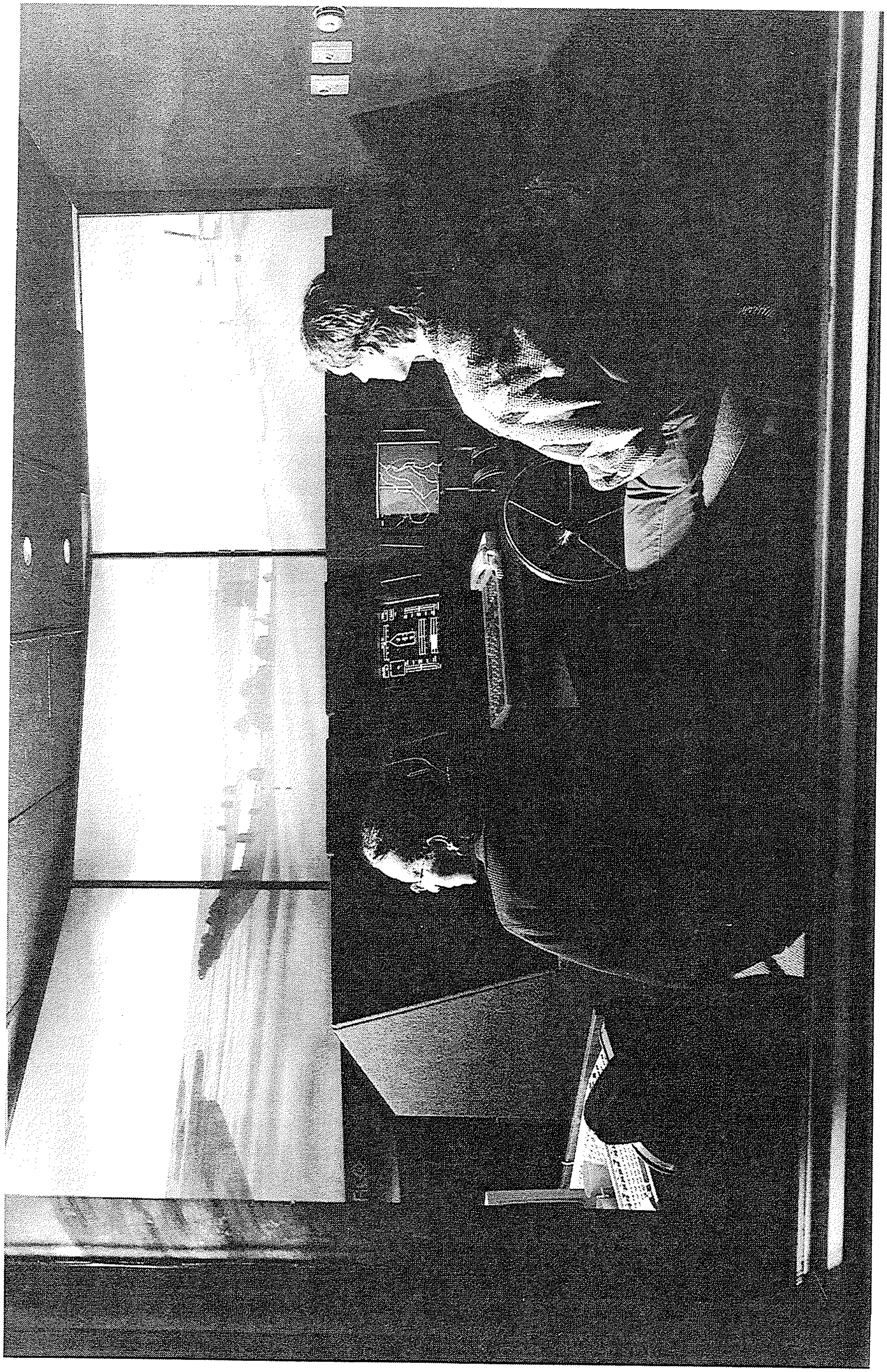


Figure 7. Visual scene, approach to dock, inbound bulk carrier

4 Study Results

A total of six professional pilots from the Tampa Bay Pilots Association conducted real-time simulator experiments for Alafia River Channel and turning basin. All experiments were performed at the WES ship/tow simulator. Simulations occurred in October and November 1997 (Table 3). Two pilots participated in each week of simulations. During each simulation run, the pilot had full control over the vessel's rudder and engines and the actions of assist tugs. One pilot conned the vessel and operated steering and engine controls while the other provided tug assistance as requested. Track plots of real-time simulations conducted at the WES ship/tow simulator are presented in Plates 1-29. Most track plots are composites showing up to seven different runs superimposed.

Table 3
Experiment and Validation Schedule

Activity	Begin Date	End Date
Validation	29 Sep 97	3 Oct 97
Sim. Week 1	13 Oct 97	17 Oct 97
Sim. Week 2	27 Oct 97	31 Oct 97
Sim. Week 3	10 Nov 97	14 Nov 97

Track Plot Analysis

Inbound

Existing Conditions, Inbound, Bulk Carrier. Track plots of inbound bulk carriers transiting the existing channel are shown in Plates 1-2. These results are an accurate representation of operating procedures the pilots presently employ. Pilots used the ranges to stay in the center of Hillsborough Bay Channel Cut C until the turn into Alafia River Channel. They used the alignment of buoys "20", "2", and "4" as a cue in beginning the turn. Track plots reveal that the vessels were generally well-positioned during the turn under ebb tide conditions but tended to swing wide under flood tide conditions. Two tracks swung outside the northern channel boundary, one by as much as a beam width. One of the vessels ran across buoy "3" but the vessels did not ground. After the turn, pilots used the aft range markers and Alafia River Channel buoys to align vessels in the center of Alafia River Channel.

Vessels experienced some crabbing due to the north wind. With a vessel of this length and beam, even a small crabbing angle significantly reduces clearance between the vessel and channel boundaries. After passing markers "9" and "10", vessels tended to have some difficulty staying within the confines of the authorized channel. After passing markers "11" and "12", vessels began to experience strong bank effects due to the very shallow overbank depth on either side of the channel. Pilots could reduce bank effects by slowing the vessel, but then wind-induced vessel crabbing increased. Pilots found it difficult to successfully balance wind and bank effects and maintain control of the vessel. In one run shown, the vessel grounded on the north side of the channel at the land cut entrance. Clearance for one or two tugs at the bow would also be a major concern with this vessel in the existing channel.

As vessels reduced speed in the land cut and approach to the turning basin, they tended to be set to the south by wind. The vessel stern passed outside the southern channel boundary in every run as the vessels turned to approach the dock. Successful runs were terminated when the vessels were in a position to make the final, tug-assisted approach to the dock.

Plan 1 Conditions, Inbound, Bulk Carrier. Track plots of inbound bulk carriers approaching Alafia River Channel from the south and turning into the proposed Plan 1 channel are shown in Plate 3. Only flood tide simulations were run for this condition. As in the existing channel, vessels tended to swing wide and pass near or beyond the northern channel boundary as they entered Alafia River Channel. The widener on the north side of the Alafia River Channel entrance helped to give vessels more maneuvering space than they have in the existing channel. Two vessels passed over the relocated buoy "3" used to mark the north side of the entrance to Alafia River Channel. In one of these runs, the pilot commented that, in retrospect, the vessel should have reduced speed more going into the turn. Runs were terminated after vessels successfully completed the turn.

Plan 2 Conditions, Inbound, Bulk Carrier. Track plots of inbound bulk carriers transiting the proposed Plan 2 channel are shown in Plates 4-7. The conditions represented include ebb tide without vessel turning, ebb tide with vessel turning, and flood tide. Flood tide runs focussed on the turn from Hillsborough Bay Channel Cut C into Alafia River Channel, but one full run to the dock was also included. Vessels approaching from the south generally negotiated the turn into Alafia River Channel successfully. Vessels tended to swing wide on this turn, especially during flood tide. Despite small excursions outside the authorized channel boundary in four runs, no vessels were in danger of grounding.

After the turn into Alafia River Channel, transits went smoothly up to near markers "9" and "10", where several runs passed slightly outside the channel boundaries. After these markers, pilots were required to reduce speed on approaching the turning basin. The speed reduction made vessels more vulnerable to the north wind, and they were generally set to the south. In most runs, the vessel's aft starboard quarter and stern passed outside the south channel boundary as the vessel turned into the turning basin. Distances outside the channel were up to one beam width, which would put the vessel rudder and propeller in jeopardy of contact with channel side slopes and very shallow waters flanking the dredged channel. Pilots maintained higher speed coming into the turning basin than they would have preferred in an effort to counter the wind effect. Several pilots commented that slowing a vessel of this size in a 250-ft wide channel with a north wind is nearly impossible.

After vessels successfully cleared the south channel bank and entered the turning basin, the bow-in run to the dock was straightforward. One vessel hit the south end of the dock because of an error in tug implementation which would not be encountered in the prototype.

In runs where vessels were turned to have bow out at the dock, turns generally went smoothly until the vessel stern approached the northeast corner of the turning basin and, in four runs, passed slightly beyond the turning basin boundary toward the undredged area just north of the turning basin. This shallow area would endanger the turning vessel's rudder and propeller. Pilots commented that considerable tug assistance was required to stop the vessel in the turning basin and position it for turning. The combination of vessel speed needed to counter wind effects in the channel and short stopping distance in the turning basin made this maneuver potentially dangerous.

Only the south berth along the proposed Plan 2 dock was used in simulations. Utilizing the more northerly berth would involve slow, tug-powered movement of vessels in a very confined area, a maneuver which is beyond vessel navigation concerns.

Existing Conditions, Inbound, ITB. Track plots of inbound ITB's transiting the existing channel are shown in Plates 8-9. The ITB is more responsive to wind forces than the bulk carrier. Track plots indicate a tendency for pilots to underestimate or overcompensate for wind forces on the simulated vessel during the turn into Alafia River Channel. Vessels passed outside the authorized channel in several runs, but this shallow draft ballasted vessel was in no danger of grounding.

The ITB crabbed noticeably and tended to be set to the south during transit along the Alafia River Channel. The vessel passed outside the channel boundary by a small amount in a number of instances, but no groundings occurred. As vessels reduced speed in the land cut and turning basin approach, they were strongly influenced by wind forces. The set to the south would have resulted in likely grounding and rudder/propeller damage on the shallow banks south of the land cut channel and turning basin in two of the runs. After clearing the south edge of the turning basin, vessels proceeded comfortably to the dock.

Plan 1 Conditions, Inbound, ITB. Track plots of inbound ITB's approaching Alafia River Channel from the south and turning into the proposed Plan 1 channel are shown in Plate 10. Only flood tide simulations were run for this condition. The vessels successfully negotiated the turn in all simulation runs.

Plan 2 Conditions, Inbound, ITB. Track plots of inbound ITB's transiting the proposed Plan 2 channel are shown in Plates 11-14. Only ebb tide conditions were considered. Simulation runs which included turning are shown separately from those in which the vessels proceeded directly to a bow-in position at the dock. Pilots were free to devise their turning maneuvers within the confines of the dredged area. The two general approaches used can be classified as clockwise and counter-clockwise turns. Close-up track plots are shown for each of these approaches.

The turn from Hillsborough Bay Channel Cut C into Alafia River Channel was generally successful. A few runs passed slightly outside the northern boundary at the beginning of Alafia River Channel with no danger of grounding. One run passed well north of the channel, but the pilot recovered and continued the run. Vessels stayed within or slightly outside the Alafia River Channel boundaries until they passed markers "9" and "10". At this point, the vessels reduced speed to approach the turning basin and tended to be set to the south. In three runs, the vessel passed more than one beam width outside the channel and likely would have grounded. Once the stern cleared the south channel boundary, vessels easily proceeded to a bow-in position along the dock. In turning runs, turning proceeded smoothly until the vessel stern approached the northeast corner of the turning basin. At this point, the vessel stern had little or no clearance in five of the runs.

Outbound

Existing Conditions, Outbound, Bulk Carrier. Track plots of outbound bulk carriers transiting the existing channel are shown in Plates 15-16. Both ebb and flood tide conditions are shown. Ebb tide runs covered the full length of Alafia River Channel and turn south into Hillsborough Bay Channel Cut C. Flood tide runs focussed on only the turn from Alafia River Channel south into Hillsborough Bay Channel Cut C. Vessels experienced strong bank effects between the turning basin and around markers "9" and "10". Vessels went outside the south channel boundary in three runs, which would represent grounding for this loaded vessel. Several pilots commented that the 200-ft channel width is inadequate for this vessel. Beyond markers "9" and "10", pilots kept the vessels within the authorized channel, except for a few small exceptions. Pilots took full advantage of the clear forward view of the range markers to keep vessels on course. Turning south into Hillsborough Bay Channel Cut C went smoothly except for two flood tide runs which overshot the west channel boundary by up to one beam width.

Plan 1 Conditions, Outbound, Bulk Carrier. Track plots of outbound bulk carriers transiting the proposed Plan 1 channel are shown in Plates 17-20. Conditions shown include full transit from the turning basin through the south turn into Hillsborough Bay Channel Cut C during ebb tide, the turn from Alafia River Channel south into Hillsborough Bay Channel Cut C during flood tide, and close-up views of turning in the turning basin in clockwise and counter-clockwise directions during ebb tide. Vessels stayed strictly within the channel boundaries over its entire length in every simulation run except for two small exceptions, both during flood tide runs. In one case, the vessel passed slightly over the north boundary of Alafia River Channel as it began turning into Hillsborough Bay Channel Cut C. In the other case, the vessel clipped the south side of Alafia River Channel at buoy "2", about the same location.

Pilots found that turning in the turning basin with the large vessel, ebb tide, and a significant river outflow was difficult in the simulation. To turn in the counterclockwise fashion that pilots presently use at Alafia, they required full power from two large capacity tugs to push the vessel up river from the dock and then further push the stern up river to turn the vessel. Even with this level of tug assistance, the vessel could be turned only slowly at best. If the tugs were to be overpowered by the current while the vessel was in a broadside position, the vessel would drift downstream toward the entrance to the land cut, where it would increasingly dam the river current. The vessel could then become uncontrollable in this confined area. Several simulation runs had to be aborted when this scenario began to develop. One pilot commented that he would only turn this vessel on flood tide (and presumably low river flow) because, with strong outflow through the turning basin, there is not enough time or space to recover if anything goes wrong.

Alternatively, pilots found that keeping the vessel toward the north of the turning basin and executing a clockwise turn worked well. The initial turn from the dock was slow but controlled. When the bow had rotated to about pointing east, it was protruding into the main current flows through the turning basin. Current forces assisted in turning the bow through the rest of the turn and the vessel could accelerate into the land cut channel.

The seven simulation runs in which vessels successfully turned clockwise in the turning basin stayed within the turning basin boundaries except for one run in which the vessel bow crossed over the south boundary of the turning basin. Two of the three simulation runs in which vessels successfully turned counterclockwise in the turning basin stayed within the basin boundaries. The exception was a run in which the vessel stern passed up to about one beam width beyond the south boundary, which would have resulted in grounding.

Plan 2 Conditions, Outbound, Bulk Carrier. Track plots of outbound bulk carriers transiting the proposed Plan 2 channel are shown in Plates 21-23. All the simulation runs represent ebb tide. Full transit runs represent vessels leaving the dock with bow out and continuing through the turn south into Hillsborough Bay Channel Cut C. Runs with vessels oriented bow-in at the dock were conducted only for evaluating turning scenarios in the turning basin. Both clockwise and counterclockwise turns were simulated, at the pilots' discretion. The turning runs ended when vessels completed the turn and were positioned to begin the transit of Alafia River Channel.

Vessels leaving the dock passed slightly outside the dredged berthing area and turning basin as they rotated away from the dock in half of the simulation runs, despite considerable care by the pilots. After clearing the berthing area, vessels on full transit runs successfully proceeded within the channel boundaries for the rest of the simulation. Two turning runs (one clockwise and one counterclockwise) clipped the corner of Alafia River Channel at marker "11" as the turn was completed. Clockwise turns were more consistently successful than counterclockwise turns. Clockwise turns moved vessels into a favorable position for aligning with Alafia River Channel and proceeding outbound. Two of the four counterclockwise turns were successfully executed, but the other two positioned the vessels too far toward the north and west part of the turning basin. Those vessels were faced with a sharp turn into Alafia River Channel and ended the runs aground on the south side of the channel near marker "12".

Supplementary Experiments

North Turn into Hillsborough Bay Channel Cut C, Bulk Carrier. Track plots of outbound bulk carriers turning north from Alafia River Channel into Hillsborough Bay Channel Cut C are shown in Plates 24-26. The north turn during ebb tide was subjected to limited simulation for the existing condition and the proposed Plan 1 and Plan 2 conditions. A turn widener was added in Plan 1 to provide information about its impact on navigation. In the existing channel, vessels had difficulty making the turn while staying in the channel. Vessels crossed over the south channel boundary in all three runs and the west boundary of Hillsborough Bay Channel Cut C in one run, hitting buoy "21". The vessel passed over buoy "4" in one run and came very close to it in the other two runs. In another run, the vessel nearly hit buoy "2". The three simulation runs in Plan 1 were all fully successful, with no deviations outside the channel. One pilot commented that positioning the start of the widener and buoy "3" opposite buoy "4" would be more effective than the simulated condition. Of three simulation runs in Plan 2, one vessel stayed fully in the channel and two passed along or slightly across the south channel boundary.

Inbound Range Experiments, Bulk Carrier. Track plots of a few selected bulk carrier maneuvers performed with the aid of inbound range markers are shown in Plates 27-29. The inbound bulk carrier in Plan 2 approaching from the south and turning into Alafia River Channel centered in the channel immediately after completing the turn. The pilot conducting this run commented on the usefulness of inbound range markers. The level of precision exhibited in completing the turn, in comparison to the same maneuver done with existing ranges, appears to confirm that inbound ranges have a positive impact.

Two turns in the Plan 1 turning basin were also executed with the inbound range markers in place. One pilot chose to turn in a clockwise direction and the other pilot turned counterclockwise. Both turns were successful and both pilots commented that the inbound ranges were helpful for this maneuver. Pilots presently rely on the outbound ranges to judge Alafia River Channel alignment when entering and leaving the turning basin, but these are quite distant from the turning basin. They can be difficult to see and to use for sufficiently accurate alignment of a large vessel in the turning basin.

Vessel Control Analysis

Inbound Bulk Carrier, Rudder Angle and Engine Speed. Rudder angle and engine speed used by inbound bulk carriers is shown in Plate 30 for a typical run. Rudder angle and engine speed follow an expected pattern. Engine speed drops as the vessel approaches the turn into Alafia River Channel, increases after the turn and remains high along Alafia River Channel until the vessel begins to approach the land cut or Plan 2 turning basin.

Inbound Bulk Carrier, Speed. Ship speed used by inbound bulk carriers is shown in Plate 31 for a typical run. Maximum speed achieved by the vessel in Alafia River Channel is comparable in the existing and Plan 2 conditions, around 10 knots.

Inbound ITB, Rudder Angle and Engine Speed. Rudder angle and engine speed used by inbound ITB's is shown in Plate 32 for a typical run. Engine speed drops briefly as the vessel approaches the turn into Alafia River Channel, increases quickly after the turn and remains high along Alafia River Channel until the vessel arrives at the land cut or Plan 2 turning basin.

Inbound ITB, Speed. Ship speed used by inbound ITB's is shown in Plate 33 for a typical run. Maximum speed achieved by the vessel in Alafia River Channel is comparable in the existing and Plan 2 conditions, around 10 knots.

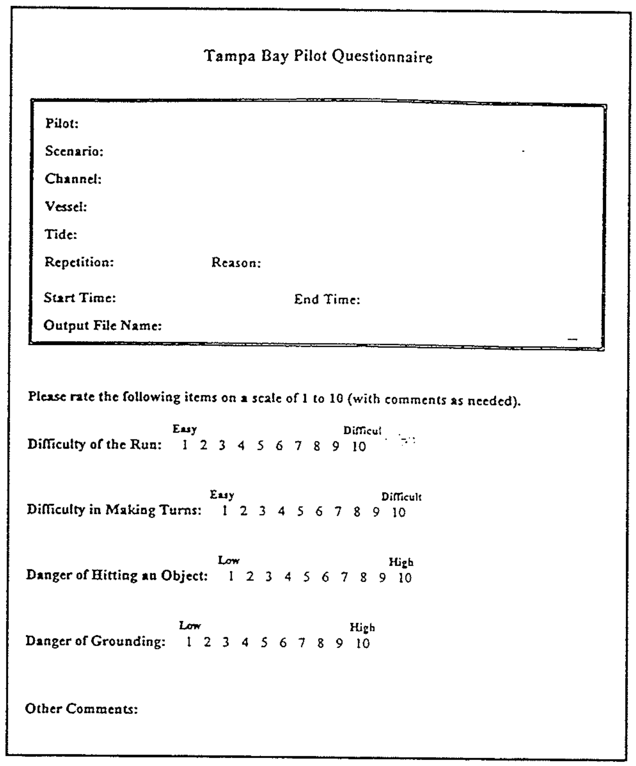
Outbound Bulk Carrier, Rudder Angle and Engine Speed. Rudder angle and engine speed used by outbound bulk carriers is shown in Plate 34 for a typical run. Engine speed holds around half ahead through much of Alafia River Channel, drops as the vessel approaches the turn into Hillsborough Bay Channel Cut C, and increases to full ahead in or soon after the turn.

Outbound Bulk Carrier, Speed. Ship speed used by outbound bulk carriers is shown in Plate 35 for a typical run. Maximum speed achieved by the vessel in Alafia River Channel is comparable in the existing, Plan 1, and Plan 2 conditions, 6-7 knots.

Pilots' Ratings

Questionnaire

Immediately after each simulation run, pilots completed a questionnaire designed to document the run (Figure 8). As part of the questionnaire, pilots were asked to rate several potential difficulties or dangers encountered during the run on a scale from 1 to 10, with 10 being the most difficult or dangerous. The questionnaire also provided space for comments, and pilots furnished comments on many runs.


Tampa Bay Pilot Questionnaire

Pilot:
Scenario:
Channel:
Vessel:
Tide:
Repetition: Reason:
Start Time: End Time:
Output File Name:

Please rate the following items on a scale of 1 to 10 (with comments as needed).

Difficulty of the Run: Easy 1 2 3 4 5 6 7 8 9 10 Difficult

Difficulty in Making Turns: Easy 1 2 3 4 5 6 7 8 9 10 Difficult

Danger of Hitting an Object: Low 1 2 3 4 5 6 7 8 9 10 High

Danger of Grounding: Low 1 2 3 4 5 6 7 8 9 10 High

Other Comments:

Figure 8. Questionnaire for individual simulation runs

After the final week of simulations, numerical ratings from the questionnaires were averaged to give a rating for each scenario representing the collective judgement of all pilots who ran that scenario. Results from scenarios with a sufficient number of runs to give meaningful averages and comparisons are presented in the following section. Due to space limitations on the plots, questions are designated by number rather than content. For reference in interpreting the plots, questions are stated in Table 4.

Table 4
Questions for Rating Individual Simulation Runs

Question Number	Question
1	What is the level of difficulty of the run?
2	What is the level of difficulty in making turns?
3	What is the danger of hitting an object?
4	What is the danger of grounding?

Average Ratings

Inbound Bulk Carrier. Average pilot ratings for inbound bulk carriers are shown for the full ebb tide run from Hillsborough Bay Channel Cut C headed north, turning into Alafia River Channel, and continuing to the dock, with no turning at the dock (Figure 9). The most significant differences are the increased difficulty in turning in Plan 2 (Question 2) and the decreased danger of grounding in Plan 2 (Question 4) relative to the existing condition. The turning difficulty in Plan 2 arises from the layout of the proposed turning basin, as discussed earlier. The decreased danger of grounding in Plan 2 is due to elimination of the land cut portion of the existing Alafia River Channel.

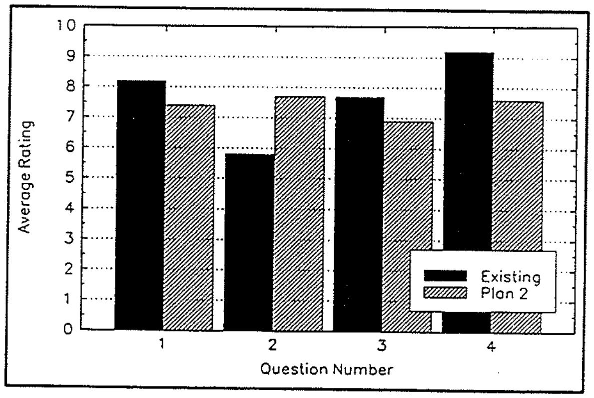


Figure 9. Pilot ratings, inbound bulk carrier, ebb tide, full run to the dock without turning

Average pilot ratings for the first part of the flood tide run, stopping after the turn into Alafia River Channel, are shown in Figure 10. The Plan 1 condition, with widener on the north side of the turn and a wider Alafia River Channel, noticeably reduces turning difficulty over the existing condition.

Inbound ITB. Average pilot ratings for inbound ITB's are shown for the full ebb tide run from Hillsborough Bay Channel Cut C headed north, turning into Alafia River Channel, and continuing to the dock, with no turning at the dock (Figure 11). The ITB is narrower and more maneuverable than the bulk carrier. Pilots favored Plan 2 over the existing condition in terms of all four questions for this vessel. The 250-ft wide channel in Plan 2 was particularly helpful, since the ballasted ITB crabbed significantly in the simulations.

Outbound Bulk Carrier. Average pilot ratings for outbound bulk carriers are shown for the full ebb tide run from the dock and turning basin (without turning) through the turn south into Hillsborough Bay Channel Cut C (Figure 12). The most significant differences are the decreased difficulty of the run and decreased danger of hitting an object or grounding in Plans 1 and 2 relative to the existing condition. Differences can be attributed mainly to the 250-ft wide Alafia River Channel in Plans 1 and 2.

Average pilot ratings for the latter part of the flood tide run, starting near buoys "5" and "6" and continuing through the turn south into Hillsborough Bay Channel Cut C, are shown in Figure 13. The Plan 1 condition appears to offer a slight improvement over the existing condition for this maneuver.

Turning Bulk Carrier. Average pilot ratings for turning bulk carriers in the turning basin are shown for ebb tide conditions (Figure 14). For loaded outbound vessels, Plan 2 is favored over Plan 1. The differences can be attributed mainly to currents in the turning basin, which are very weak in Plan 2 and relatively strong in Plan 1. Inbound bulk carriers had difficulty turning in Plan 2 because of wind and short stopping distance, and that is reflected in the pilot ratings.

Supplementary Experiments. Average pilot ratings for outbound bulk carriers starting near buoys "5" and "6" and turning north into Hillsborough Bay Channel Cut C are shown for ebb tide conditions (Figure 15). The Plan 1 condition, with widener on the north side of the turn, shows a clear, but small, advantage over the existing condition and Plan 2.

Pilot ratings for simulation runs with inbound ranges added are shown in Figures 16 and 17. Only three runs were performed with inbound ranges in place (two runs turning in the Plan 1 turning basin and one run of the inbound turn into Alafia River Channel), so average ratings for inbound range runs have limited statistical significance. However, pilots clearly found the inbound ranges useful.

Final Questionnaire

After finishing all simulation runs, pilots completed a final questionnaire to give their opinions on the project as well as on the simulation. Some of the comments made by the pilots on the project follow:

1. Do you feel that the proposed 250 ft wide, 41 ft deep Alafia Channel is adequate?

"Yes. However, light draft Panamax beam ships will be difficult with 25 knots or better beam wind."

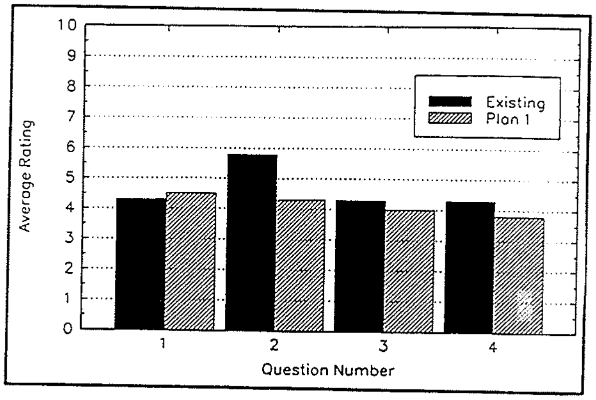


Figure 10. Pilot ratings, inbound bulk carrier, flood tide, turn into Alafia River Channel

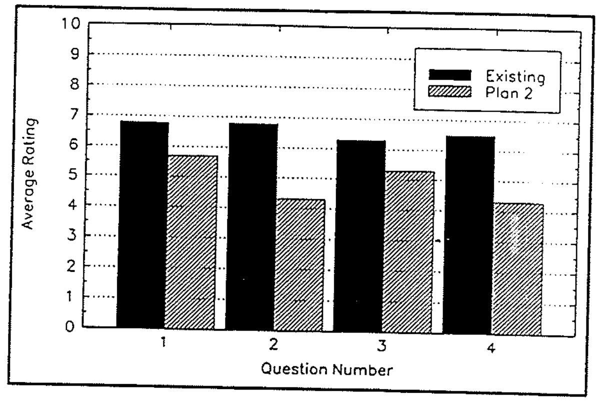


Figure 11. Pilot ratings, inbound ITB, ebb tide, full run to dock without turning

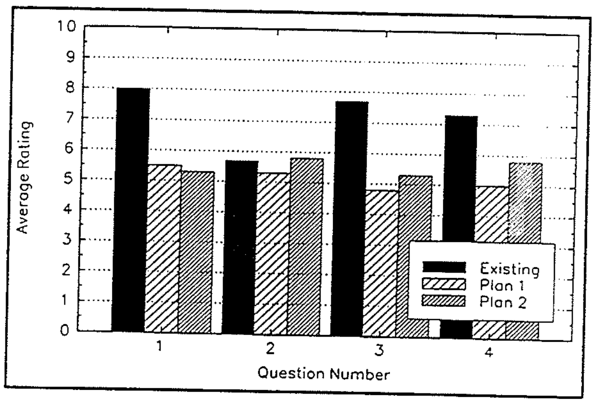


Figure 12. Pilot ratings, outbound bulk carrier, ebb tide, full run to Hillsborough Bay Channel Cut C without turning

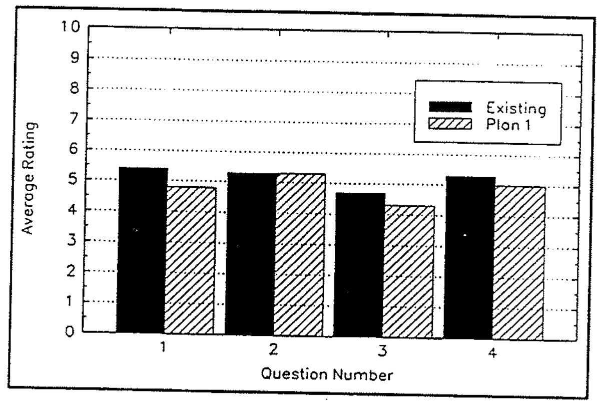


Figure 13. Pilot ratings, outbound bulk carrier, flood tide, south turn into Hillsborough Bay Channel Cut C

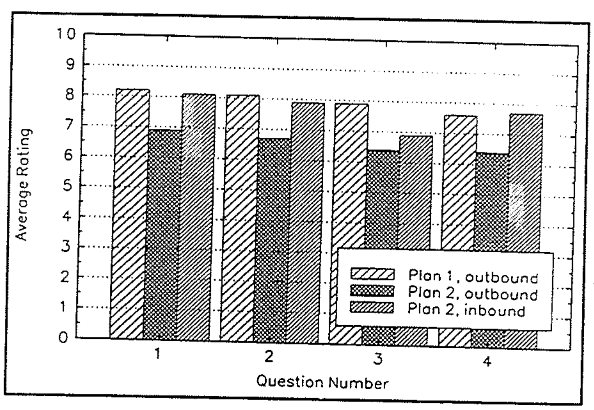


Figure 14. Pilot ratings, bulk carrier, ebb tide, turn in turning basin

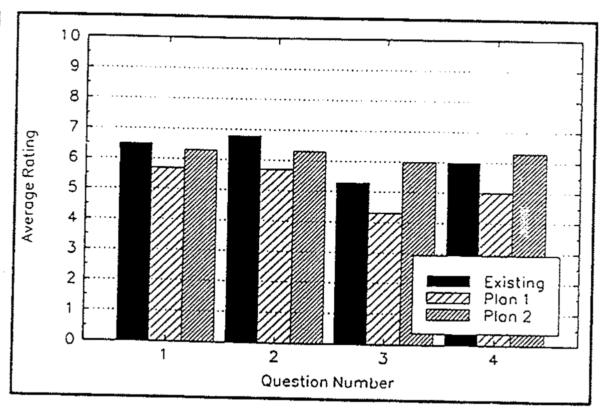


Figure 15. Pilot ratings, outbound bulk carrier, ebb tide, north turn into Hillsborough Bay Channel Cut C

"Based on the simulation and using what I thought were acceptable handling characteristic of the vessels involved, I thought a 250 ft x 41 ft channel would be adequate."

"I believe the proposed project is marginal for vessels of Panamax size. Under ideal conditions, this size vessel can be handled with reasonable safety. Under conditions of moderate to strong cross winds, there will be little if any margin for error especially when the vessel needs to slow down to make a turn. Inbound ranges would become essential for this project as any Panamax vessel that did not have visibility directly astern from within the wheelhouse would put too much distance between the pilot and quartermaster for issuing commands and monitoring the steering."

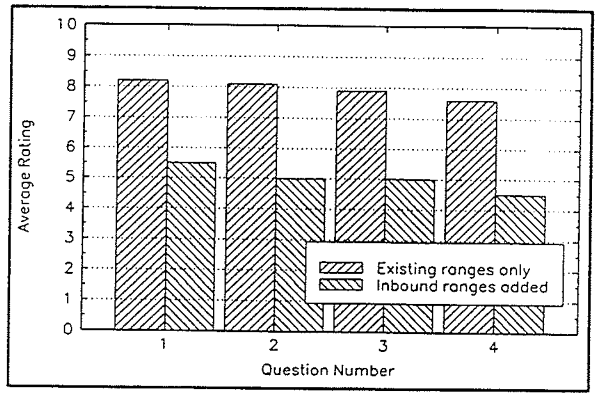


Figure 16. Pilot ratings, outbound bulk carrier, ebb tide, turn in Plan 1 turning basin, inbound range experiments

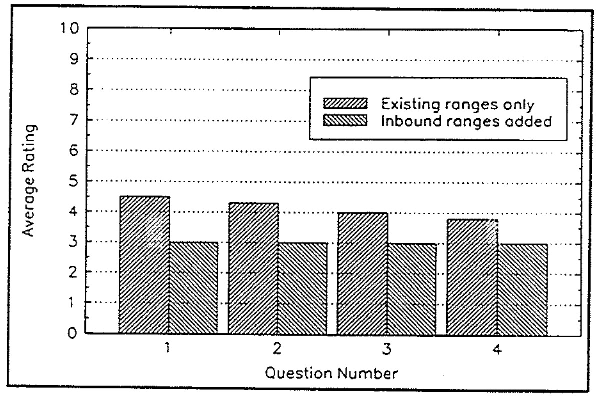


Figure 17. Pilot ratings, inbound bulk carrier, Plan 2 turn from south into Alafia River Channel, inbound range experiment

"250 ft would be marginal at best. Wind conditions during speed reductions are a primary concern. Historically, the channel requires routine dredging; 250 ft would soon become 200 ft again."

"300 ft would be more appropriate for the proposed ships."

"A 300-ft channel would be much safer."

2. Do you feel that the proposed expansion of the existing turning basin to 1162-ft diameter is adequate?

"Yes. The 1162-ft diameter proposal seems a bit extreme for the types of Panamax bulk carrier we are used to seeing in the phosphate trade. The typical 730 ft LOA ship could be turned in 900-ft diameter with little cross current. 730 ft x 1.2 = 876 ft; a turning basin of 1000 ft should also be considered."

"I have grave concerns for this proposal. I am not confident that the damming effect of a vessel of such size and draft as those tested was adequately simulated. This is not to say the simulation was worthless but rather that it is extremely difficult to judge whether the simulation's imposed influence on the ship model will be the same in real life. I am also concerned that shoaling will be a constant problem along the headland portion of the basin as it is in the existing turning basin. I am also concerned for the stability of the southeast bank as the proposed turning basin will abut the river bank."

"Available room appears adequate. Required tug assistance during ebb conditions would be a major factor."

3. Do you feel that the proposed 1000-ft diameter turning basin relocated west of the land cut is adequate?

"I do not feel the positioning of this basin north of the channel is the best design. A design that places the basin symmetrically around the channel would be much better."

"The proposed 1000-ft diameter turning basin is of poor design as it does not allow for a convenient turn that is in relation to the dock nor does it provide for a safe turn of large vessels. During simulation, it appears that a considerable amount of the northwest corner of the turning basin was not utilized both in docking (because the turn was too sharp to the north) and undocking (because it is easier to turn on left wheel from the proposed berth). This dead area could be left in its original state and the northeast corner of the basin could be expanded more to the north. Turning inbound into the turning basin from the Alafia channel is almost impossible to do safely with any kind of north wind on a light ship. This maneuver may actually be impossible with a loaded ship. Simulation showed that the stern was in danger of grounding. The fact that a vessel slowing down tends to move the pivot point forward on a ship means that additional space is needed to the south in order for the stern to swing safely during the turn into the basin. It would not be possible to turn large ships into the basin at Big Bend during strong southwest winds if it were not for the small area of the basin which lies north of the Big Bend Channel edge."

"No, insufficient room for vessels this size. Basin design should be modified. NW corner remains wasted space."

"This needs to be reshaped, either a cut out to the south of the channel for the stern to swing into or rounding out (cutting off) the southwest corner to allow a more gradual turn into the turning basin."

4. Do you feel that the proposed 240-ft by 1600-ft berthing area west of the land cut is adequate?

"The ship docked to the north will be blocked in by a ship at the south. Panamax beam 106 ft + tug 110 ft = 216 ft. This does not leave much room astern of the tug and between the ship and berth."

"The 240-ft width is marginal when you consider a ship beam of 106 ft, a tug of about 110 ft, then when you back on the tug line, add the line and stretch, not much room left."

"The proposed 240-ft wide berthing area is very tight, especially on the south end. With tugs of 110-ft length and ships of 106-ft beam, there is very little room for error, especially when shaping up to take the vessel from the basin into this slip. Depending on the construction of this wharf, if vessels are not able to slide up the face of the dock, there is a good chance that the dock or the tug will be damaged when weather conditions are unfavorable."

"Cut off the corner in the vicinity of the NE buoy."

"No. 240 ft is barely enough for a typical tug (100 ft - 110 ft) to be at a 90 degree angle to the ship (105 ft). 300 ft would be much safer."

"This needs to be wider to allow more room for tugs working alongside."

5. Do you feel that the proposed widening of the turn between the Alafia Channel and the north reach of Hillsborough Bay Channel Cut C is adequate?

"Any improvement would be welcome. We presently are making this very difficult turn (108 degrees) with quite large ships."

"I believe that this widener is essential if vessels of the size used in the exercise are to be turned to the north. I would also say that all buoys used to delineate both the north and south wideners should be lighted buoys."

"Yes, provided adequate tug assistance according to vessel size."

"Yes. This also makes the inbound turn smoother, having a gated buoy pair (#3 and #4) at the entrance."

6. Do you have any additional comments on the overall project?

"900-ft and/or 1000-ft turning circles can be achieved with little new dredging in the existing turning basin. The new turning basin west of the land cut should be symmetrical around the channel. It seems that there is room south to do this."

"I think that the simulation was very realistic, but some attention may be needed to simulate hard rudder and a "kick" ahead on the ship's engine. It should have the effect of "lifting" the stern more than that simulated."

"I believe that the sophistication of the simulation as to hydrodynamic effects has vastly improved since the last time I attended the Corp's facility. I was also very pleased to see the simulation runs were adjusted to test those areas of the proposed project which were viewed by the pilots to be the most troubling. Although this flexibility testing makes comparison studied more difficult, I believe

it more readily addresses the real question as to whether certain aspects of the project's design are adequate."

"1) All simulation done during daytime. All elements of ship handling obviously become more difficult at night; 2) Significantly more vessel information (rate of turn, speed through water, lateral motion, radar representation) than commonly available to pilot in actual practice."

"The shape of the new turning basin and berthing area is difficult to maneuver - the turns are too sharp."

"A set of inbound ranges would be very helpful."

Two pilots provided sketches of alternative designs for the Plan 2 turning basin (Figure 18).

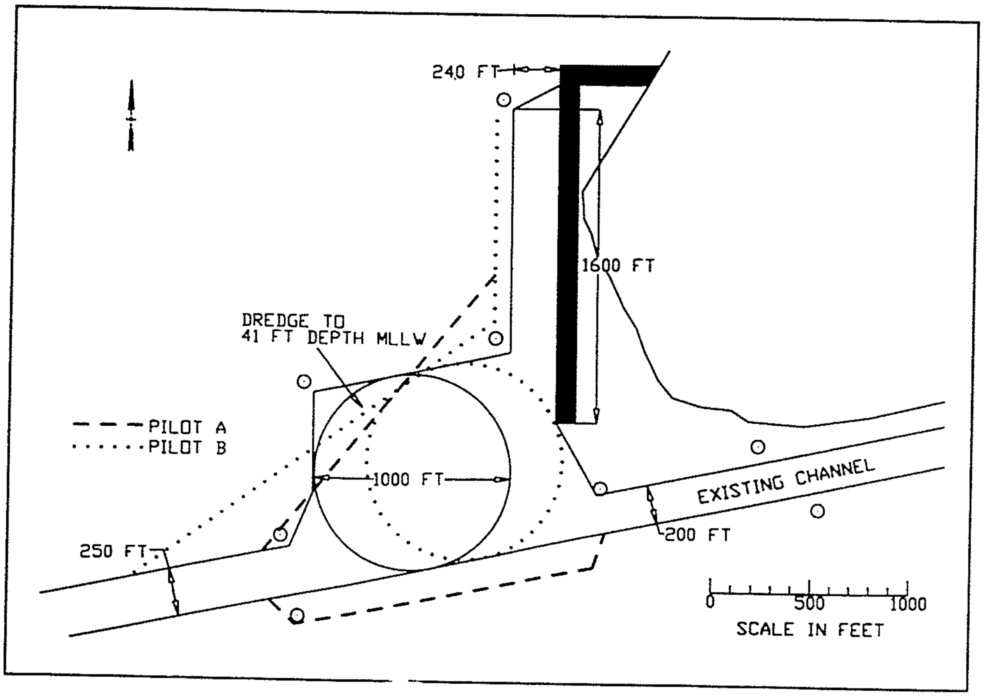


Figure 18. Pilot suggestions for Plan 2 turning basin configuration

5 Conclusions and Recommendations

Based on the real-time ship simulator study conducted by WES with relatively large ships and difficult environmental conditions, the following conclusions may be drawn:

a. The existing channel and turning basin are not adequate for the simulated conditions. Pilots found the confined channel from markers "11" and "12" to marker "15" to be especially difficult. Turning in the existing turning basin is geometrically possible, but not practical for the simulated conditions. Several attempts were made to simulate turning of the bulk carrier in the existing turning basin, one was successful, but the pilots would not consider attempting this scenario in reality.

b. The 250-ft Alafia River Channel in the proposed plans is adequate. Pilots were generally able to make the runs, but clearance for tugs could be a concern.

c. The Plan 1 turning basin is large enough for turning. Most turns in the simulation were successful. Currents significantly affected the ship during turning. The average two-year maximum river outflow simulated seems to be approaching a maximum condition for this maneuver. When the turning ship is in a position to dam the river during high outflow, forces due to the river flow can potentially overpower the tugs.

d. The proposed plan to move the turning basin and dock outside the land cut (as in Plan 2) has advantages for navigation including:

(1) Shortened travel distance from Hillsborough Bay Channel Cut C to the dock.

(2) Elimination of confined land cut from navigation route.

(3) Large reduction in magnitude of currents (tidal and Alafia River outflow) in navigation and turning area.

e. The proposed Plan 2 turning basin layout is difficult for navigation, but it could be significantly improved with some suggested modifications. Transition from the southwest corner of the turning basin into Alafia River Channel, the southern edge of the turning basin, and transition from the northeast corner of the turning basin to the berthing area are all areas which created vessel clearance problems.

f. The proposed widener for the north turn from Alafia River Channel into Hillsborough Bay Channel Cut C helped significantly to improve navigation around this difficult turn.

g. The addition of inbound range markers in Alafia River Channel improves navigation precision on inbound runs and turning in the turning basin. This conclusion is based on a very limited number of simulations, but pilot comments and ship track plots clearly indicate that inbound ranges are beneficial to navigation.

Based on the real-time ship simulation study conducted at WES, the following recommendations are made:

a. *Channel width and depth.* The proposed channel width was adequate in simulations. However, the proposed channel provides only marginal clearance for tugs. Addition of inbound ranges would significantly improve the pilots' ability to maintain channel position. Proposed channel depth was acceptable in simulations.

b. *Turning basin location.* Both the Plan 1 and Plan 2 turning basin locations will meet project needs.

c. *Turning basin layout.* The Plan 1 turning basin layout is effective, recognizing that large ships may occasionally have to restrict usage during times of very strong river outflow. To make Plan 2 effective, it is strongly recommended that the Plan 2 turning basin layout be modified to ease navigation as shown in Figure 18.

d. *Berthing area width.* A widened berthing area in Plan 2 is recommended if the dock is to accommodate two wide-beam ships simultaneously. This design parameter was not studied in simulation maneuvers, but pilots clearly stated that the 240-ft width was insufficient. For a ship to exit the north berth and pass a ship in the south berth, a space of two beam widths (2x106 ft) plus clearance between ships (50 ft) plus tug operating space (50 ft), a total of at least 312 ft is needed. With typical tug dimensions of 35-ft beam and 110-ft length, the 50 ft tug allowance used in calculation is considered a minimum.

e. *Widener on north turn into Hillsborough Bay Channel Cut C.* A widener on the north turn from Alafia River Channel into Hillsborough Bay Channel Cut C is recommended. The layout used in Plan 1 would be more effective if modified to have the widener begin at the same location along

Alafia River Channel as the existing widener on the south side of the channel.

f. Inbound ranges. Consideration of inbound range markers in Alafia River Channel as an addition to any plan for channel improvement is recommended.

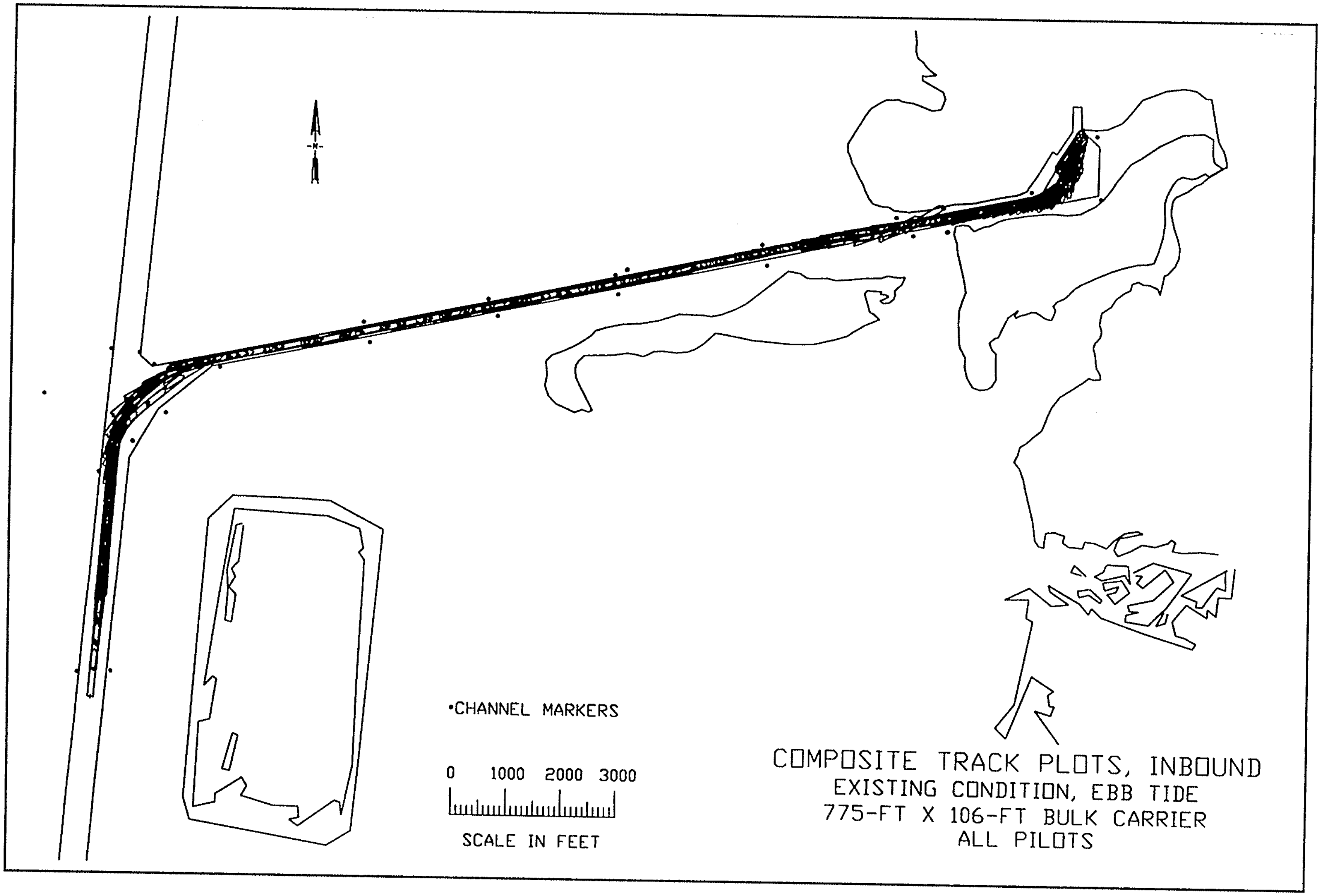
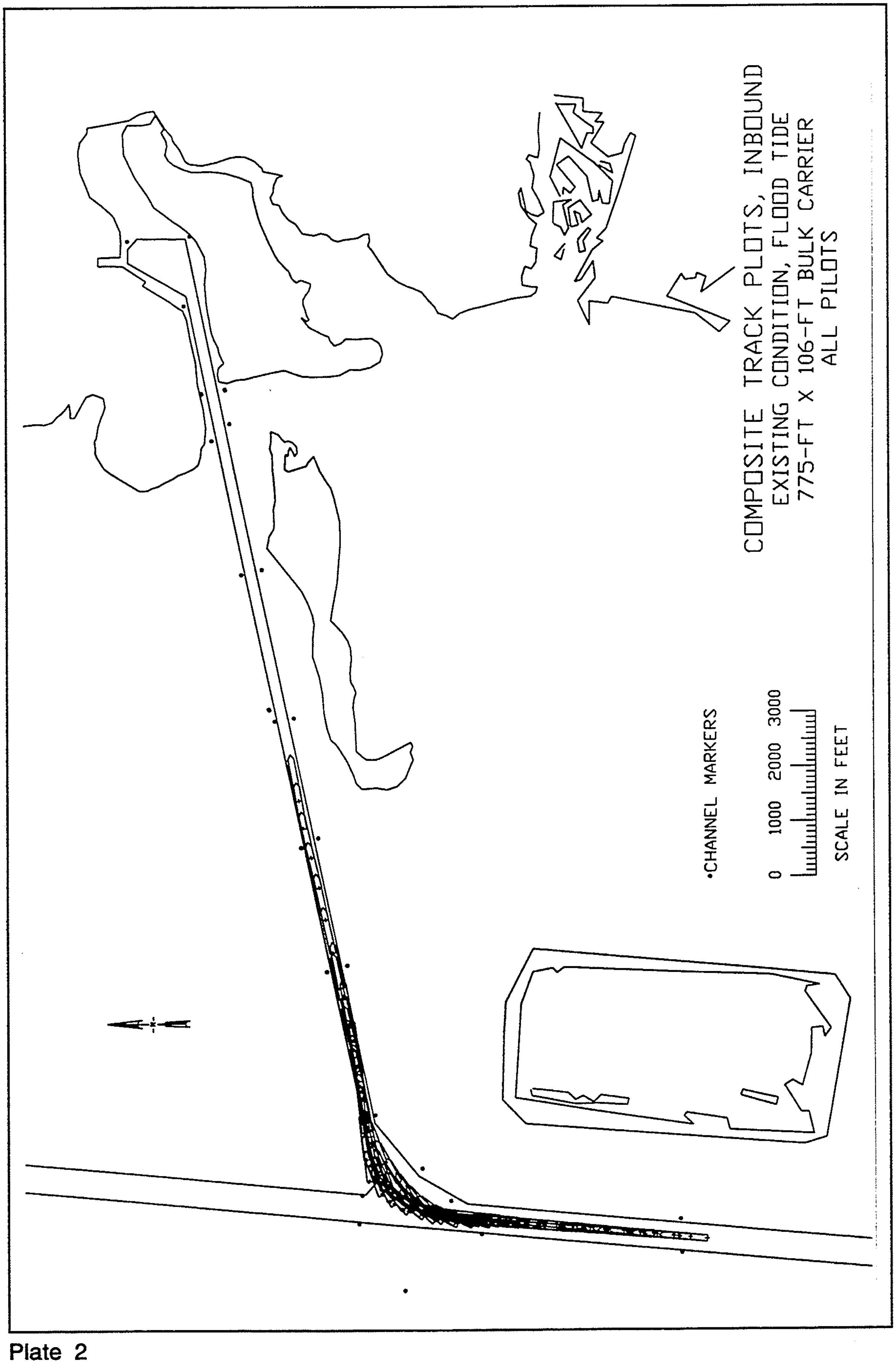

•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET
N
COMPOSITE TRACK PLOTS, INBOUND
EXISTING CONDITION, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS

Plate 1



COMPOSITE TRACK PLOTS, INBOUND
EXISTING CONDITION, FLOOD TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

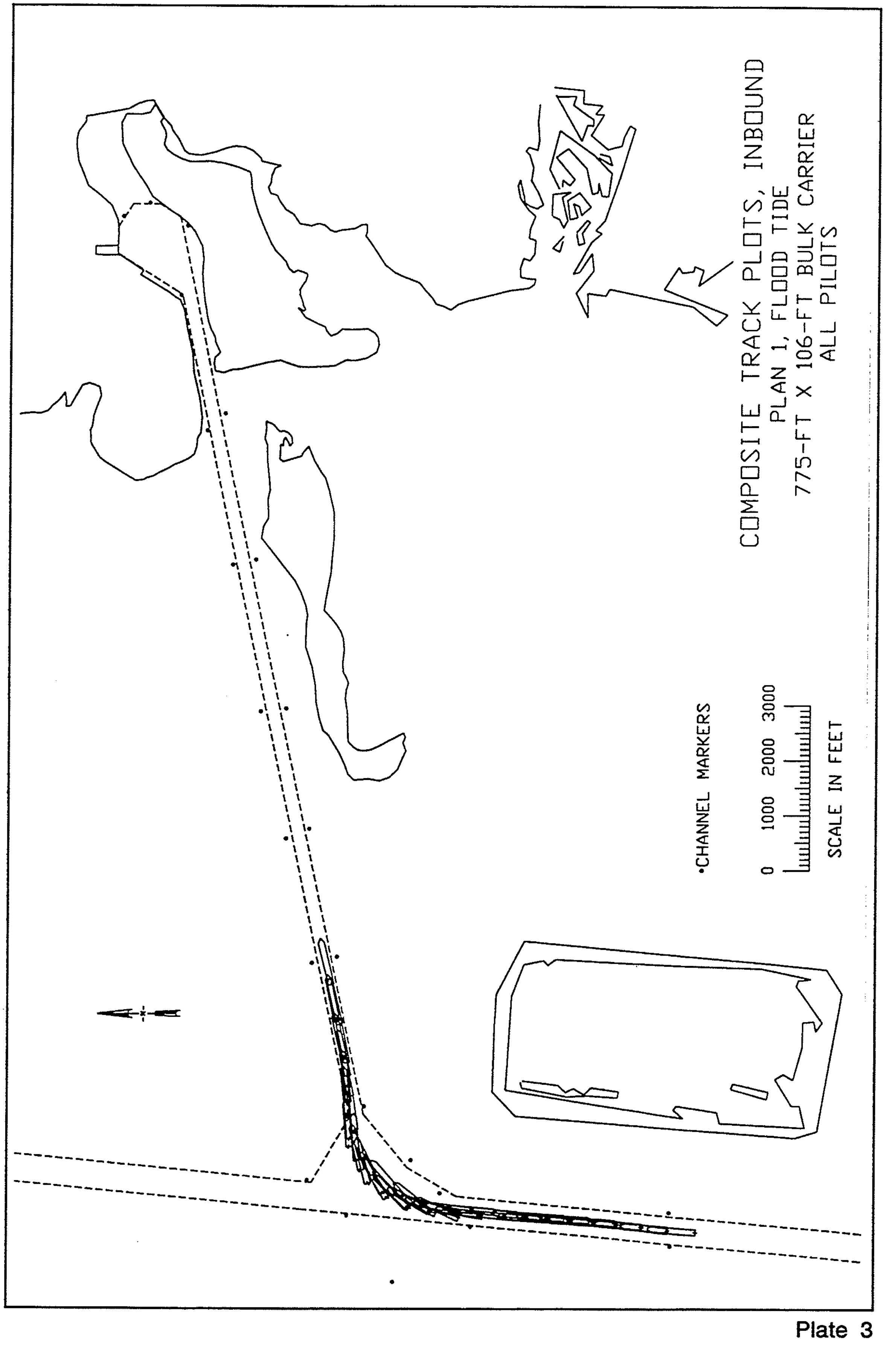

COMPOSITE TRACK PLOTS, INBOUND
PLAN 1, FLOOD TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 3

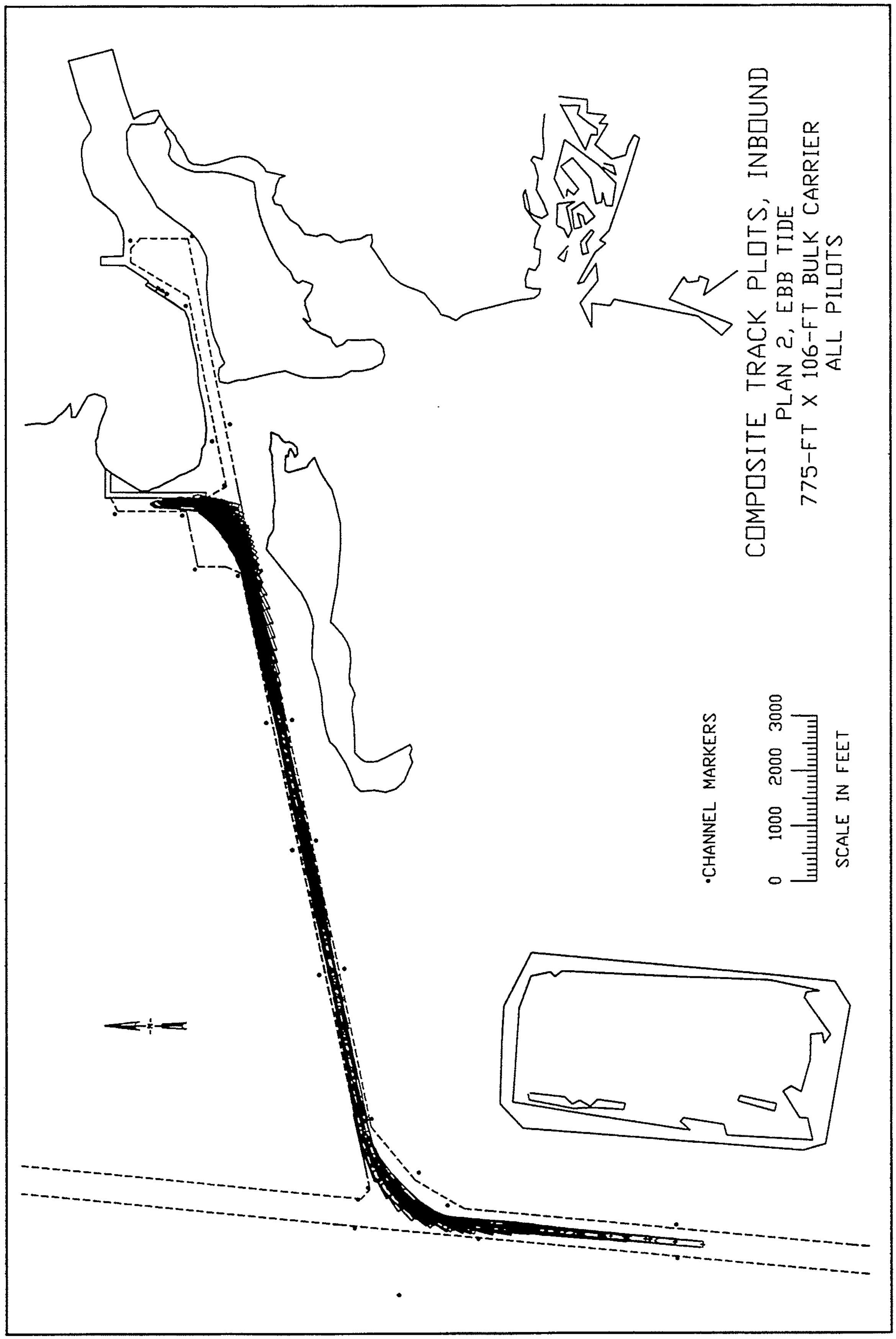
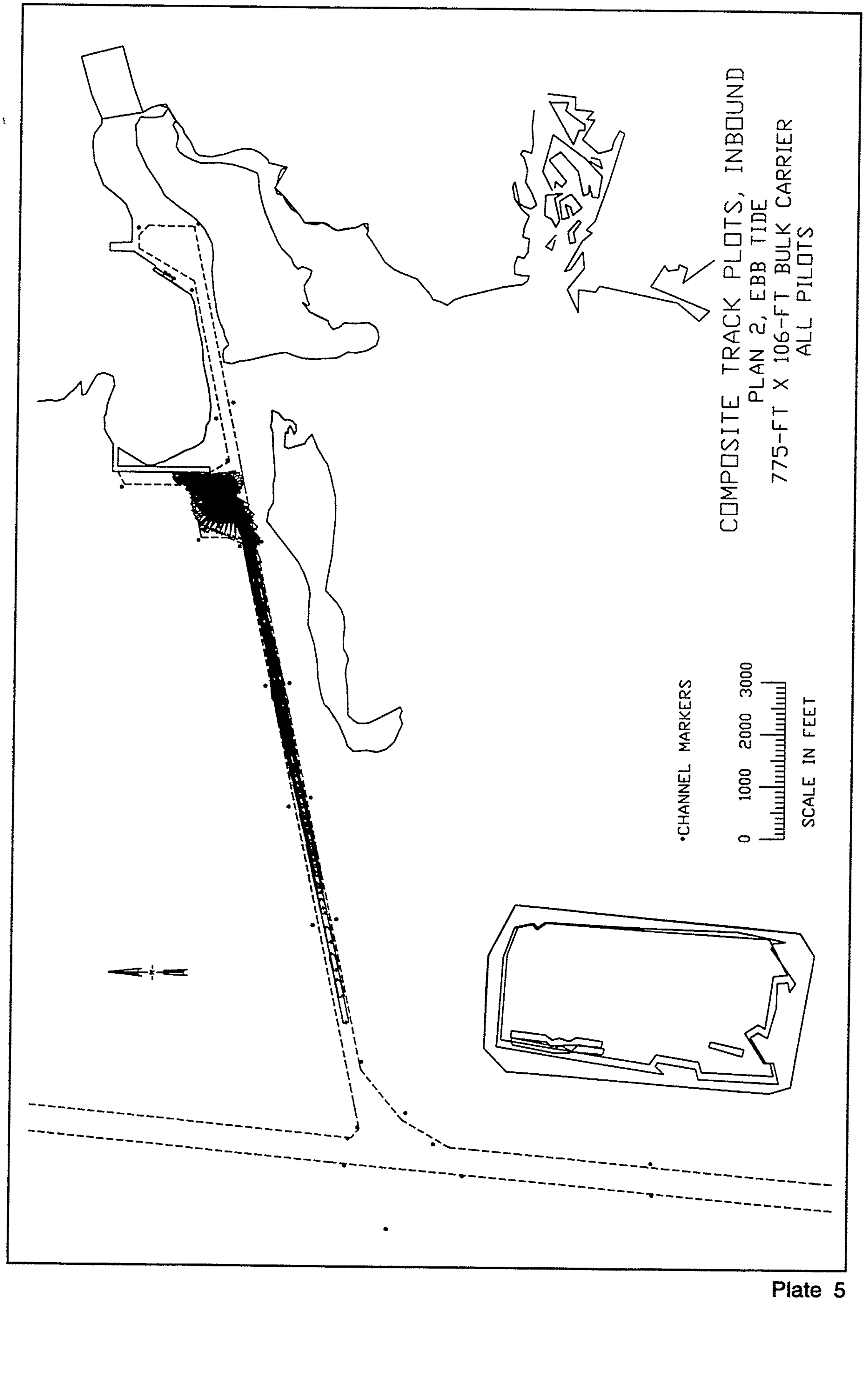

COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 4


COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

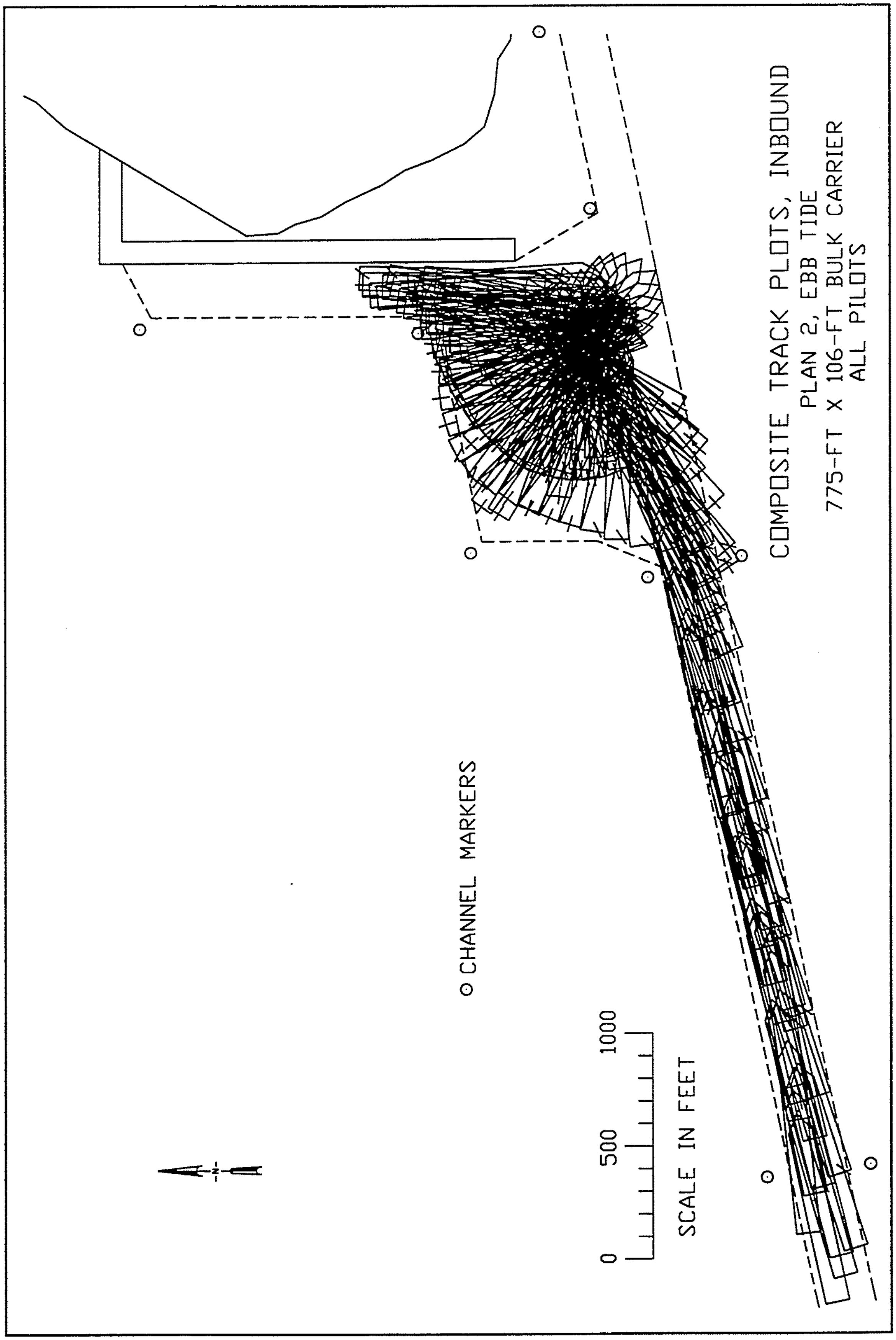
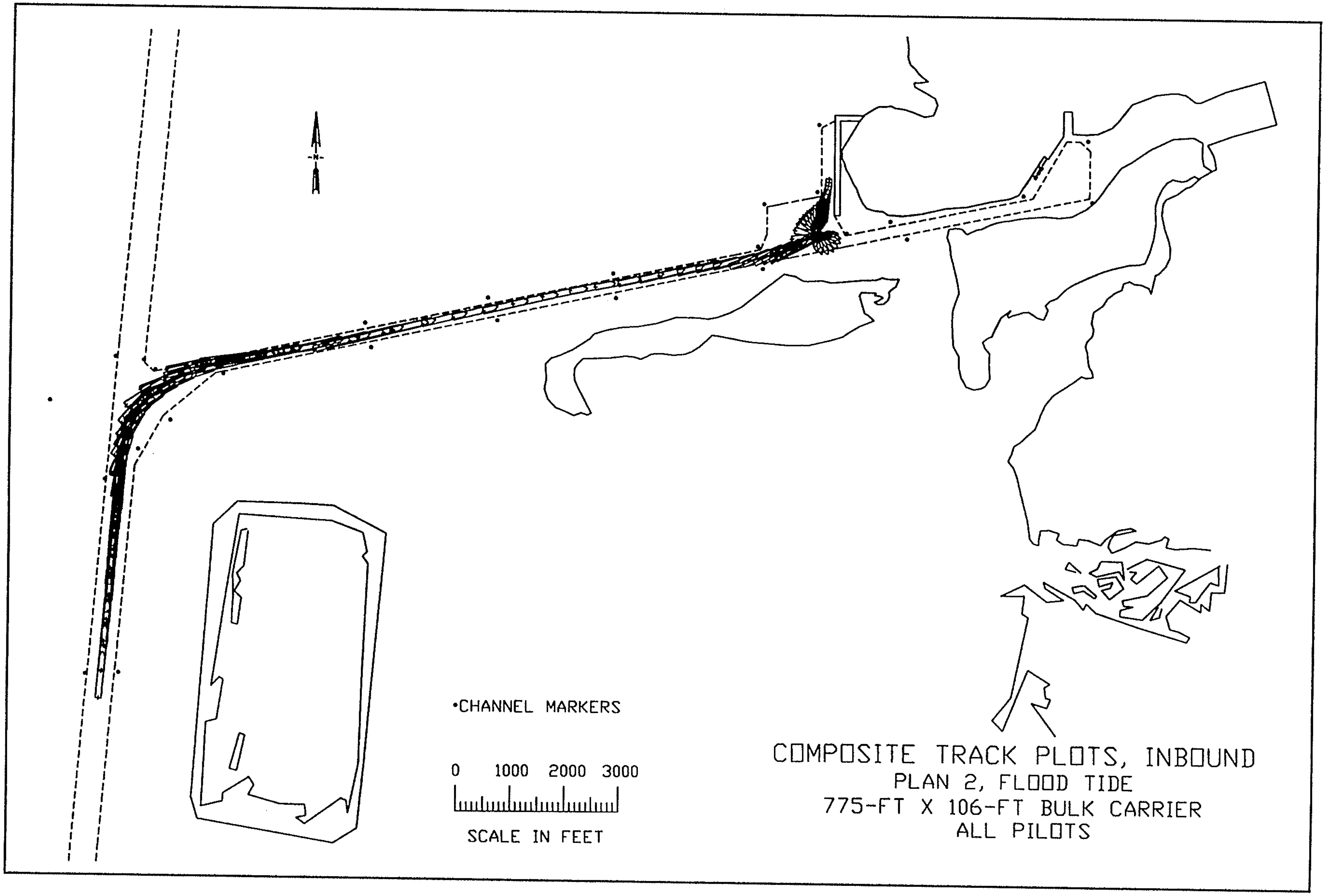

COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
CHANNEL MARKERS
0
500
1000
SCALE IN FEET
N

Plate 6


N
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET
COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, FLOOD TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS

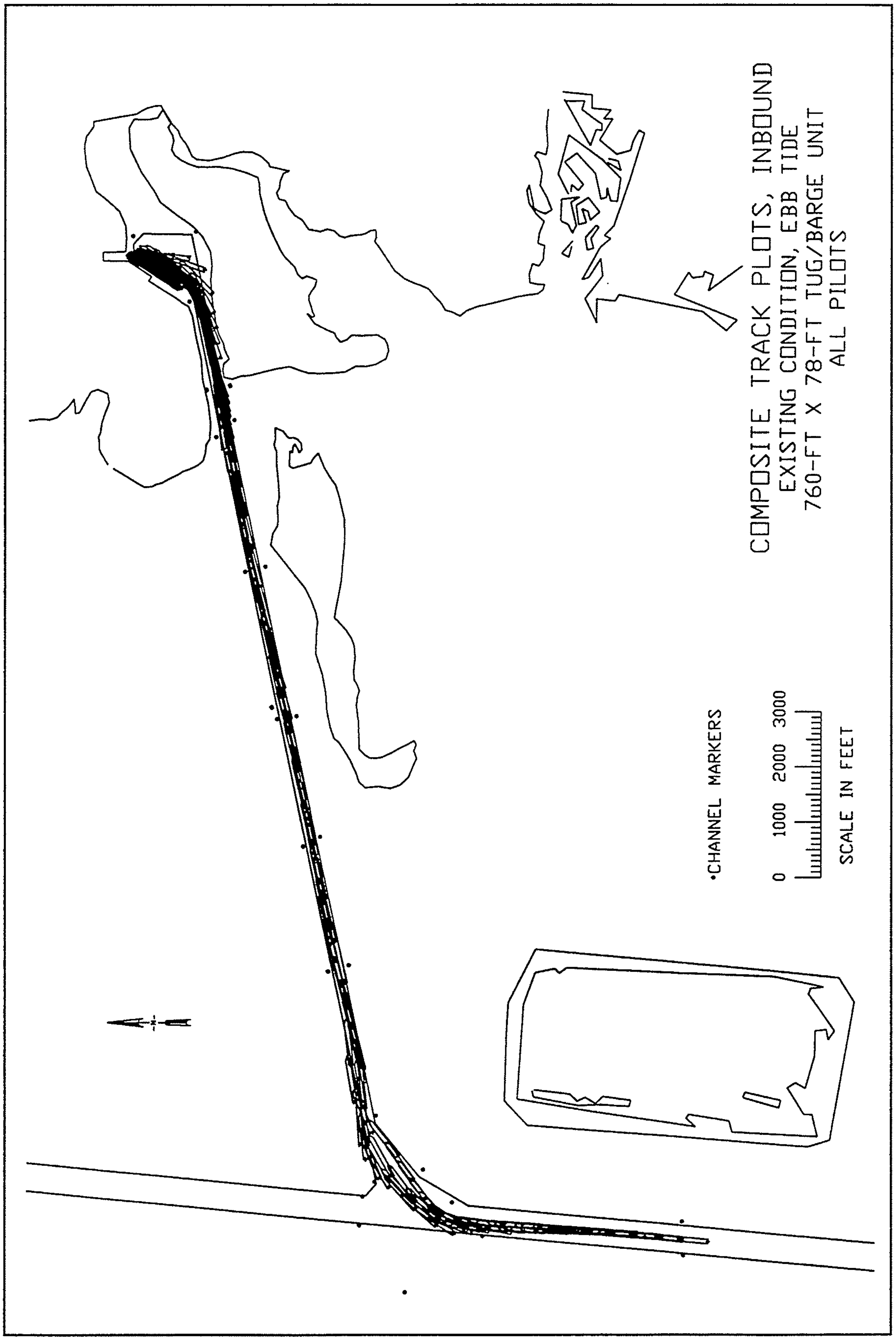
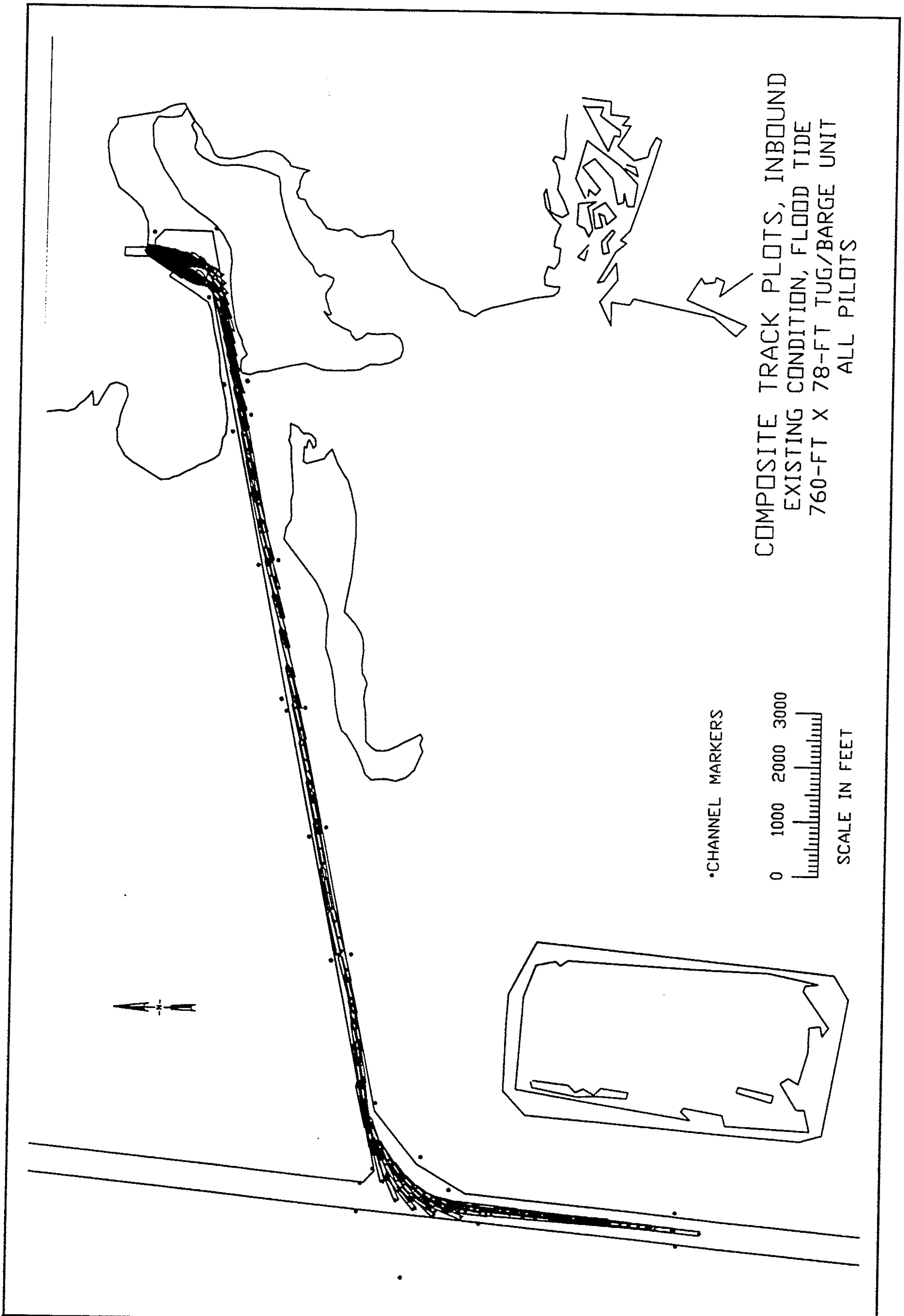

COMPOSITE TRACK PLOTS, INBOUND
EXISTING CONDITION, EBB TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 8


COMPOSITE TRACK PLOTS, INBOUND
EXISTING CONDITION, FLOOD TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

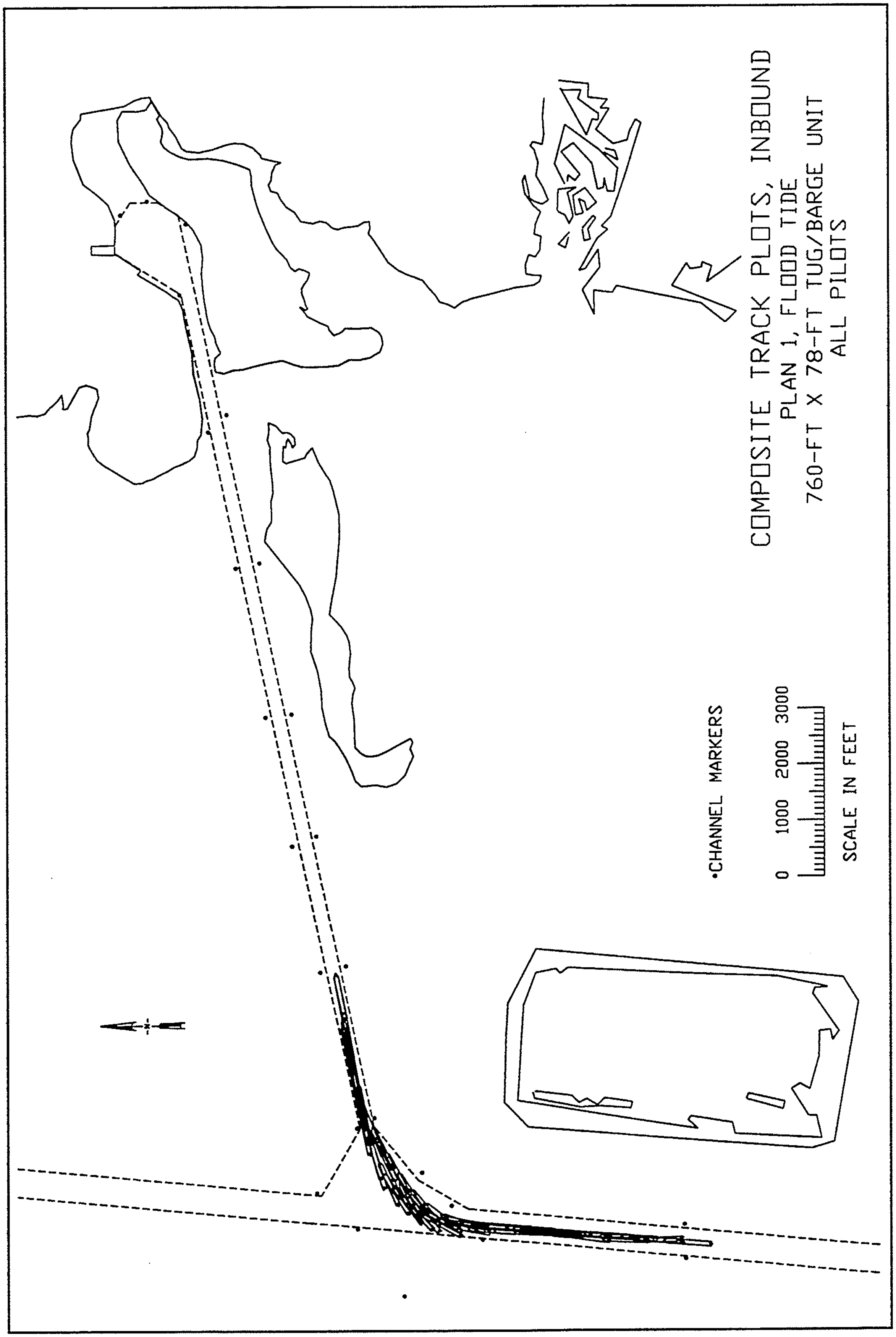
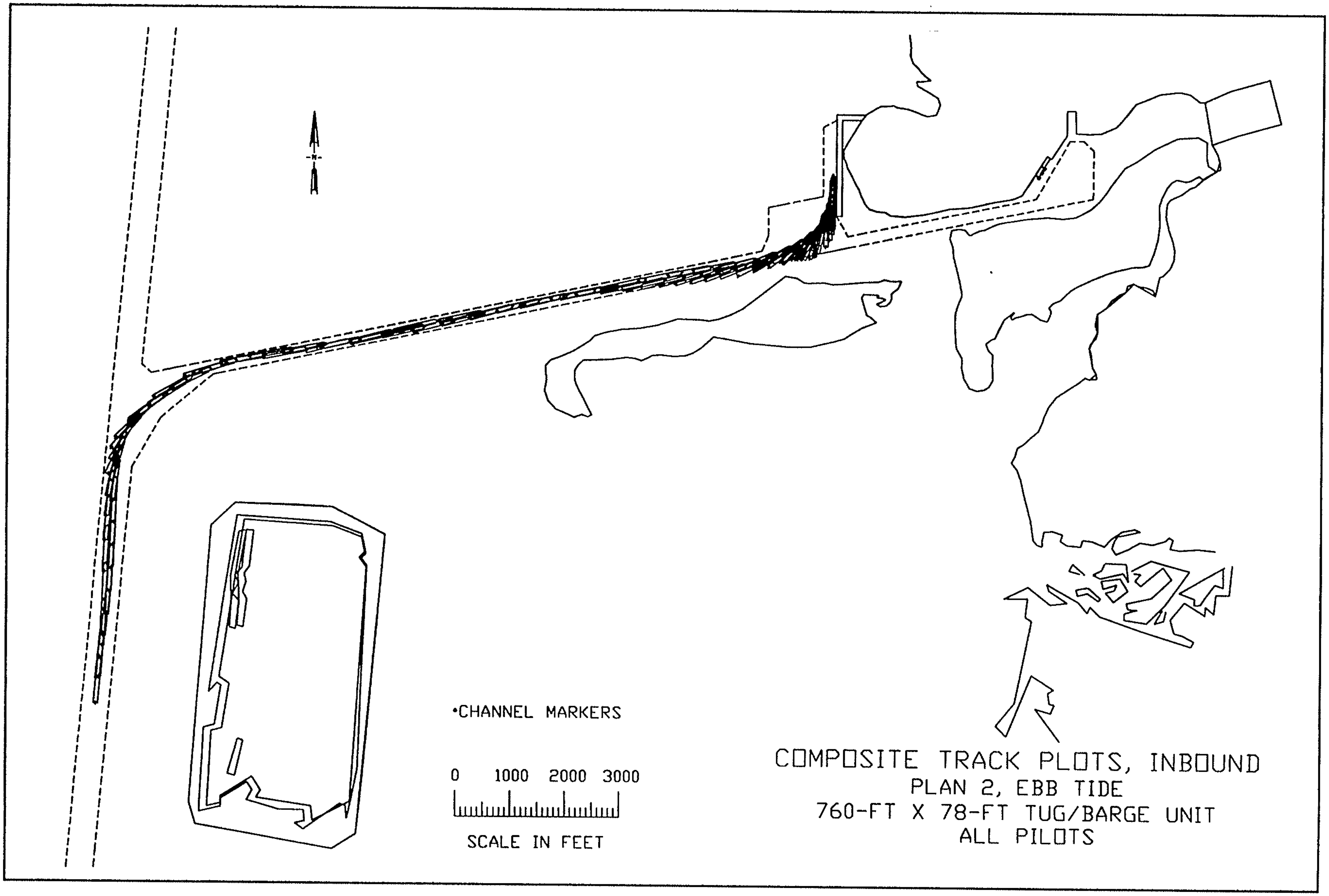

COMPOSITE TRACK PLOTS, INBOUND
PLAN 1, FLOOD TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 10


N
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET
COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS

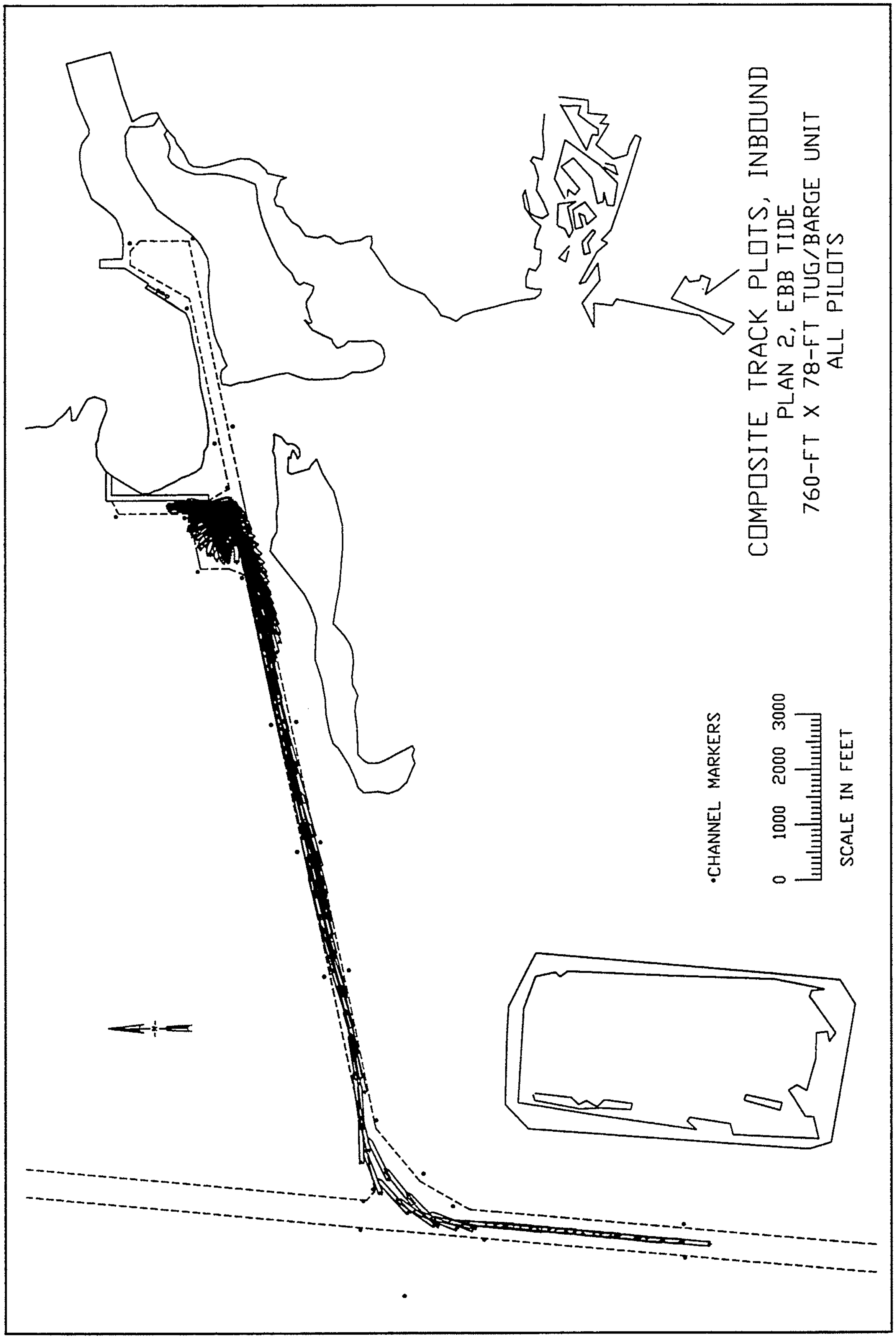
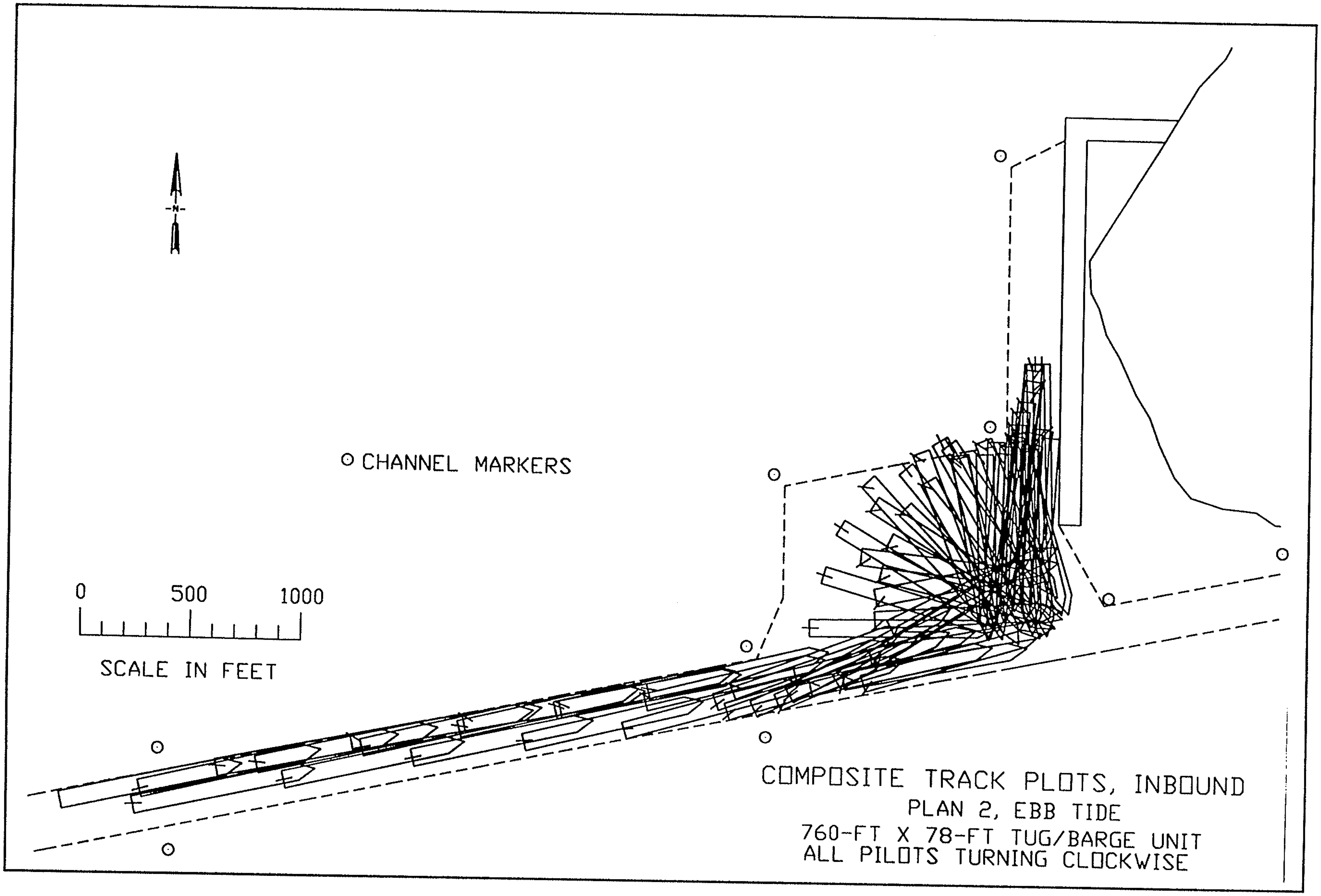

COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 12



COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS TURNING CLOCKWISE

Plate 13

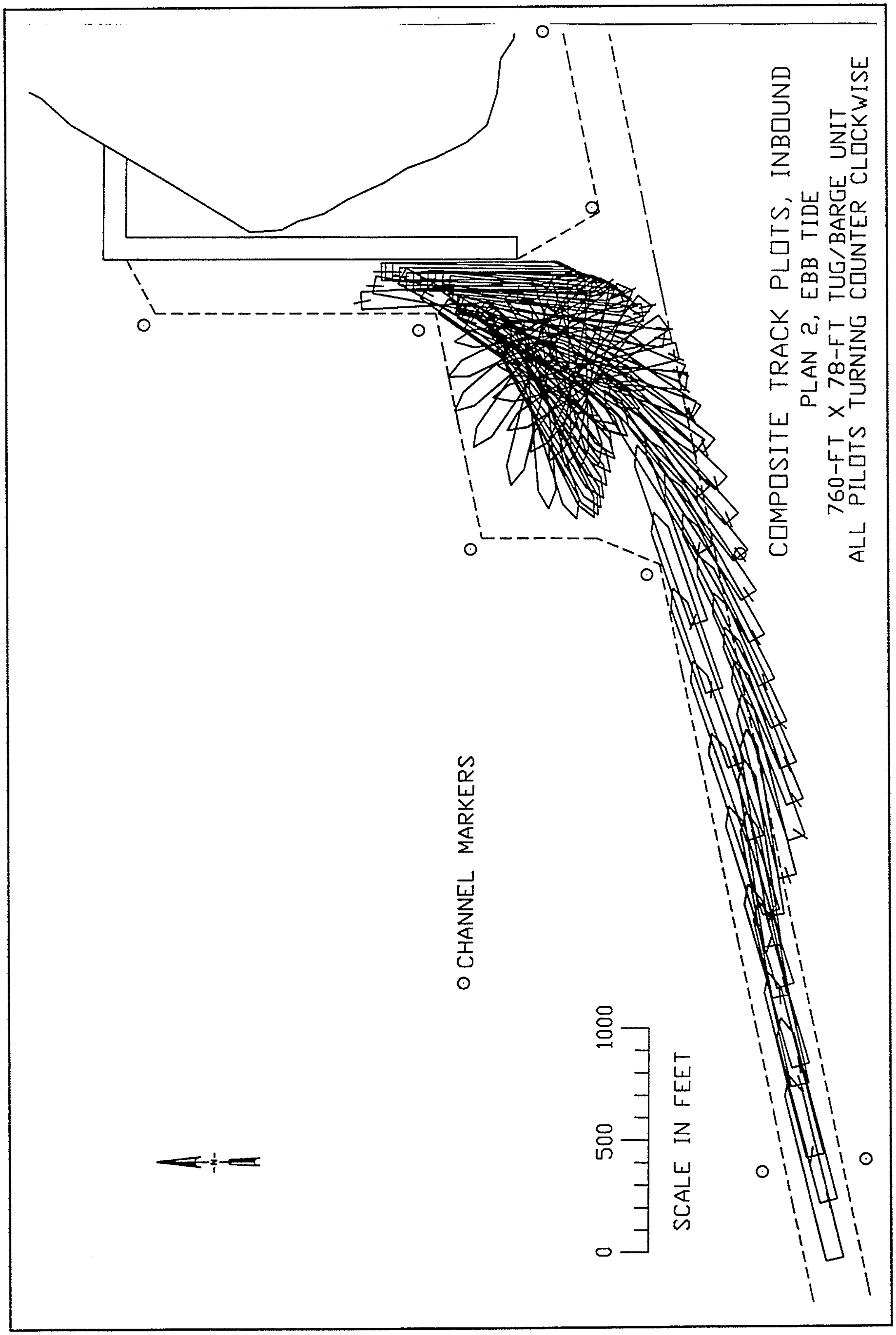
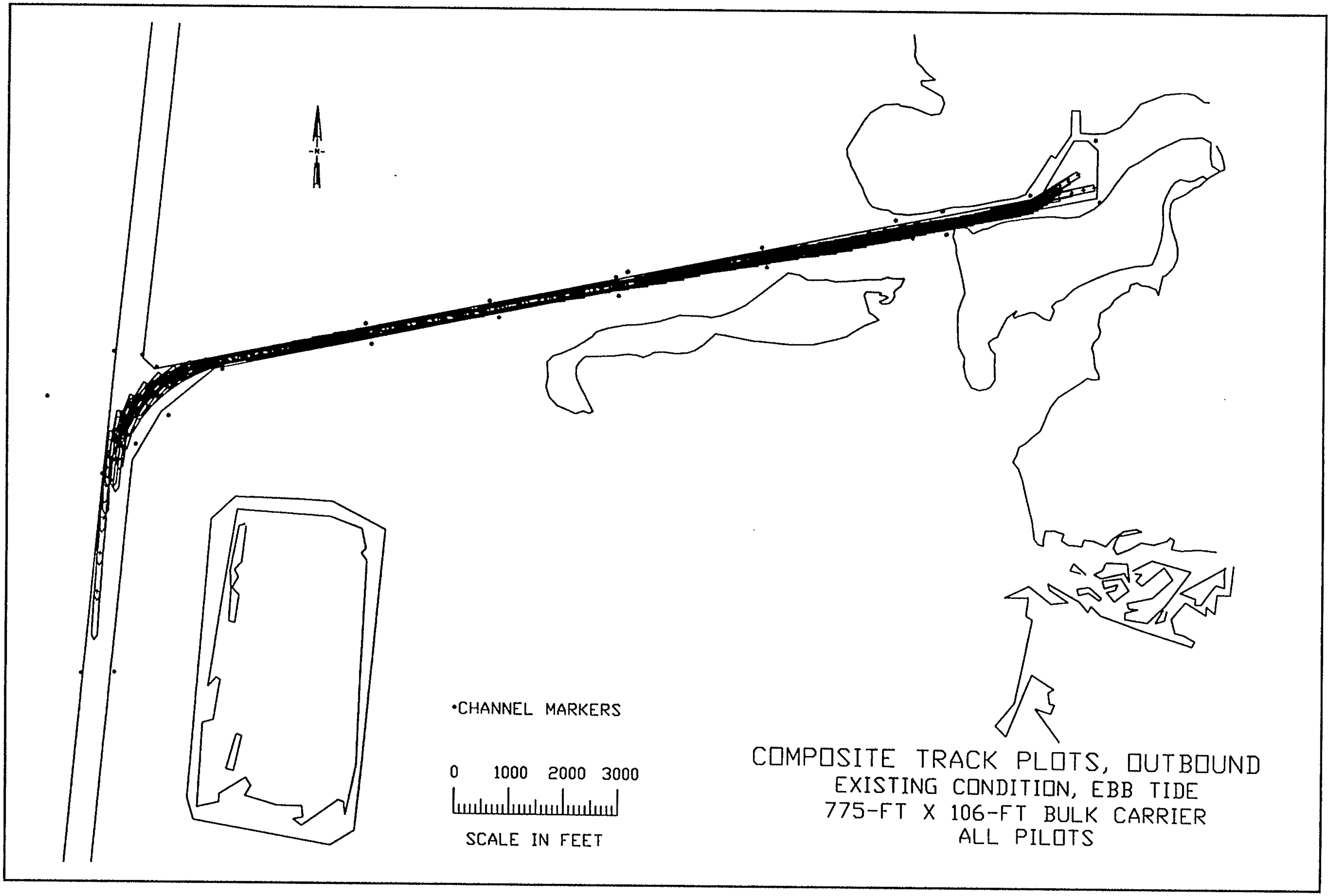
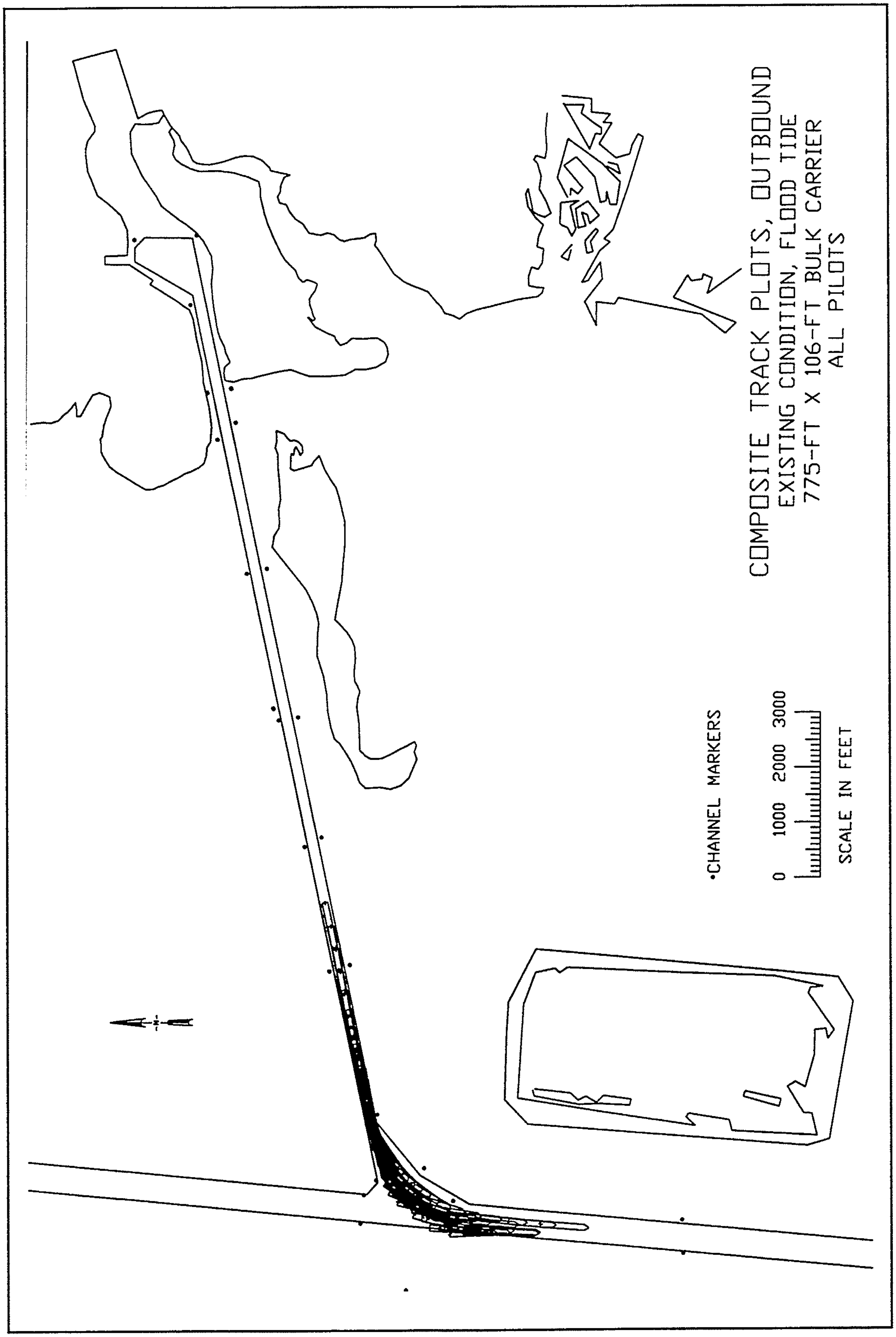

COMPOSITE TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
760-FT X 78-FT TUG/BARGE UNIT
ALL PILOTS TURNING COUNTER CLOCKWISE
CHANNEL MARKERS
SCALE IN FEET
0
500
1000

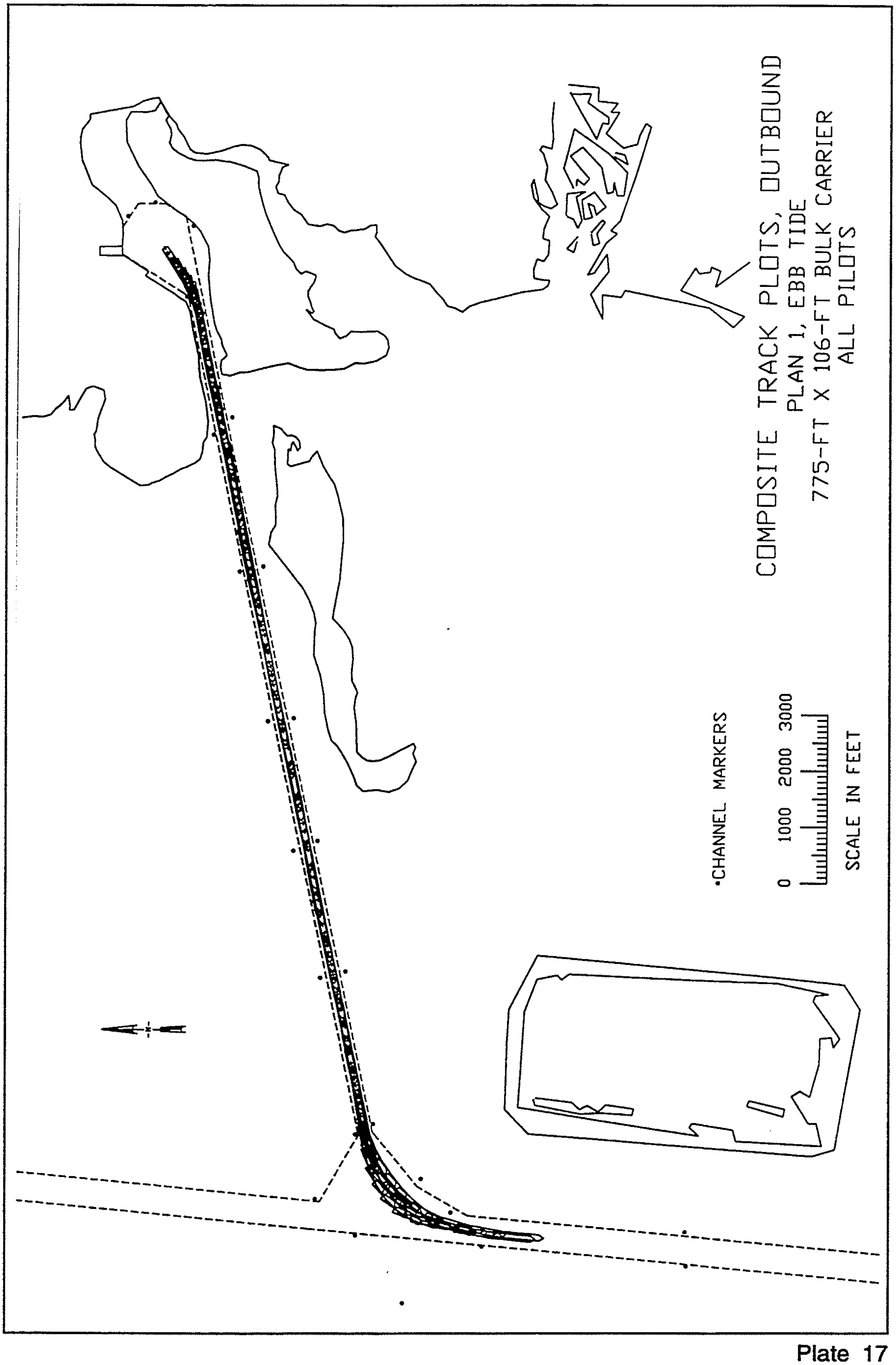
Plate 14


N
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET
COMPOSITE TRACK PLOTS, OUTBOUND
EXISTING CONDITION, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS



COMPOSITE TRACK PLOTS, OUTBOUND
EXISTING CONDITION, FLOOD TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 16


COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

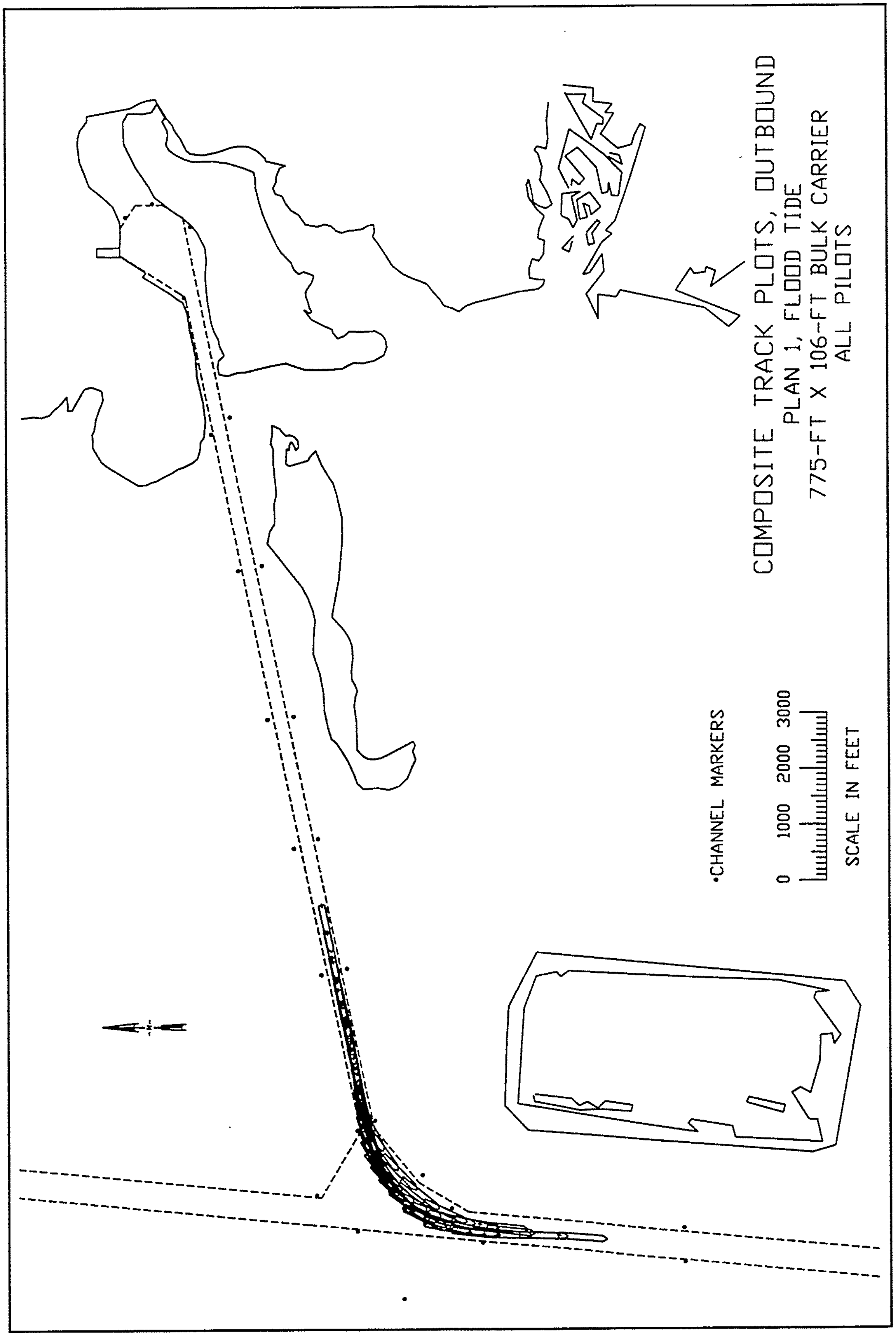
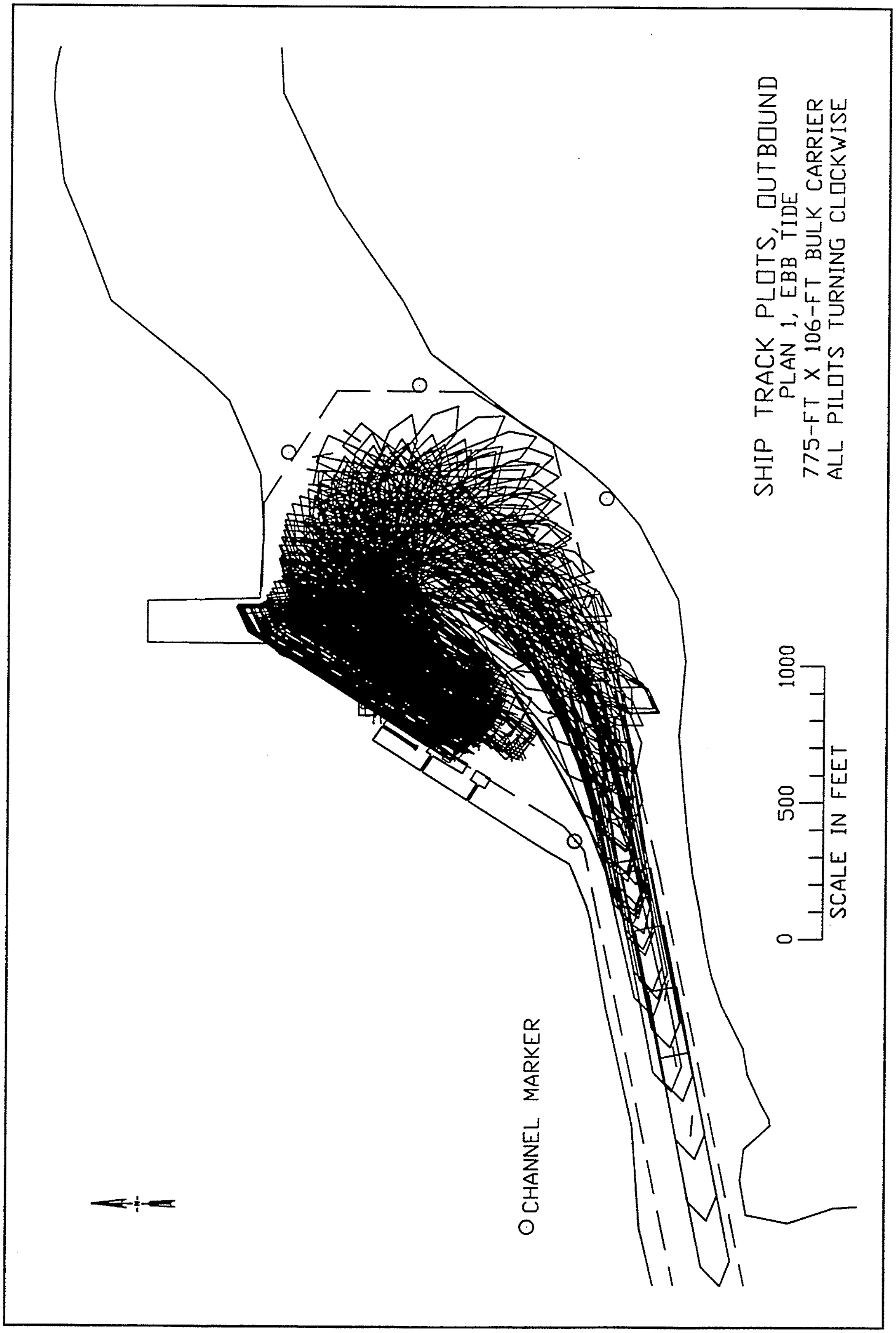

COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 1, FLOOD TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 18


SHIP TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS TURNING CLOCKWISE
0
500
1000
SCALE IN FEET
CHANNEL MARKER

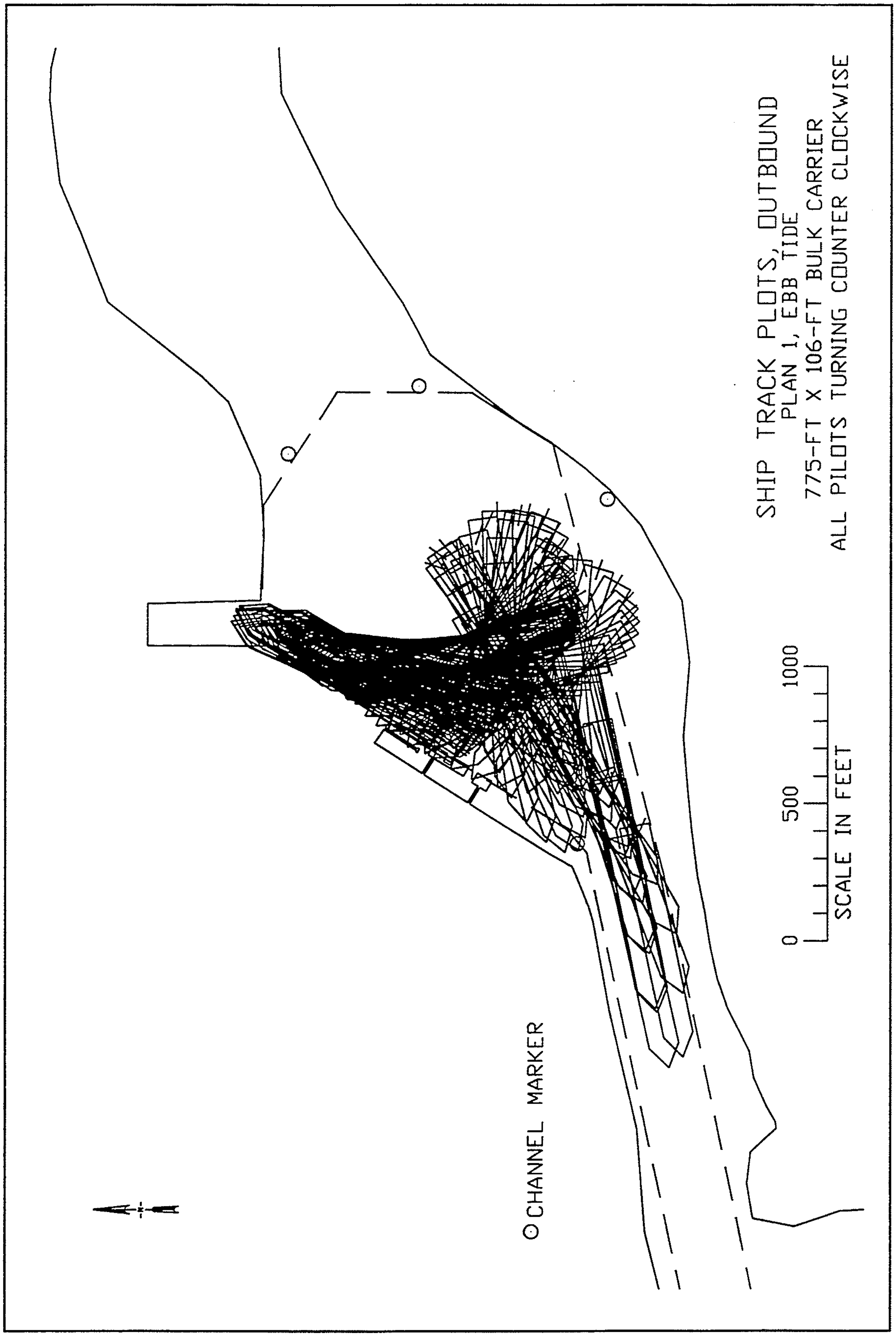
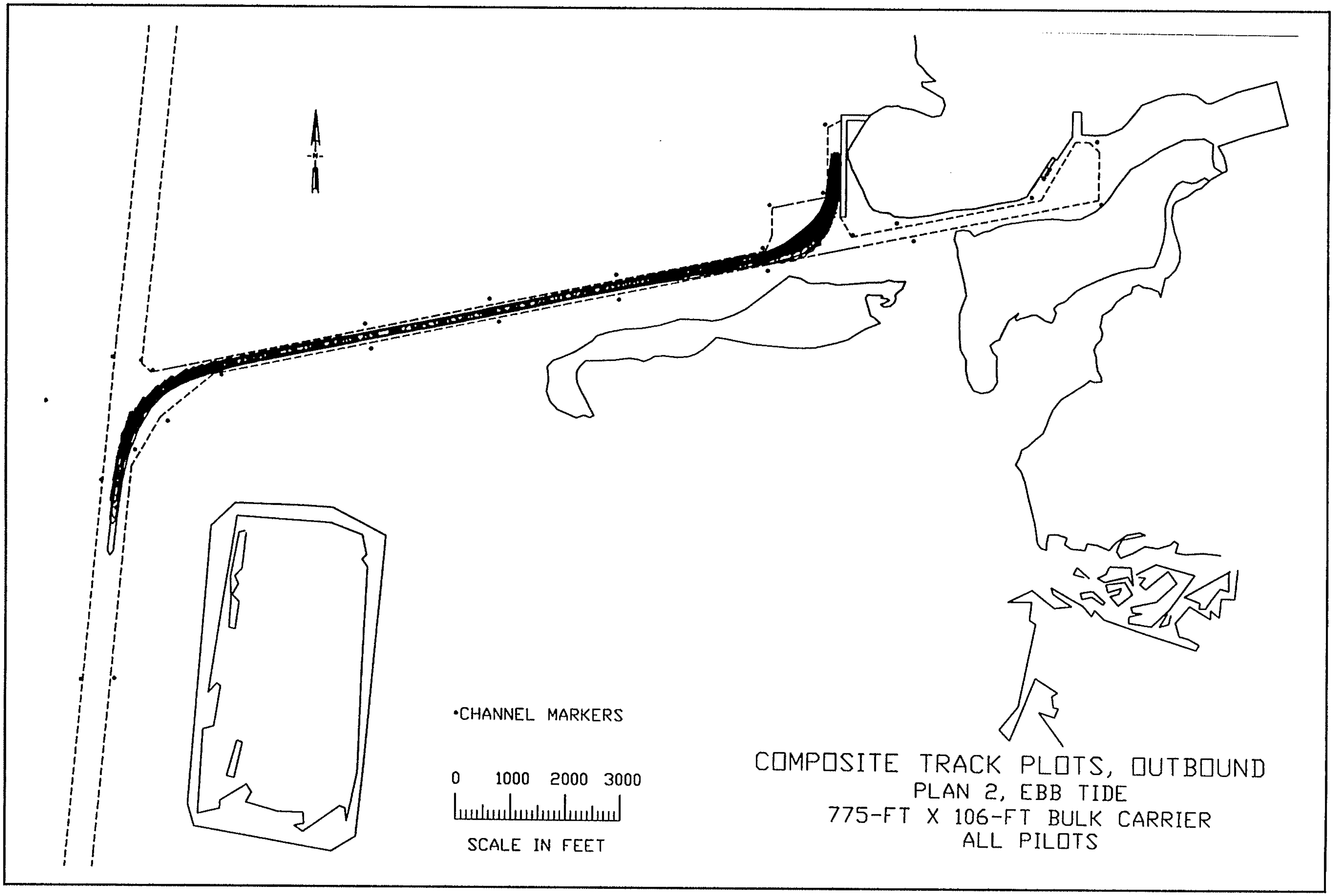

SHIP TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS TURNING COUNTER CLOCKWISE
0
500
1000
SCALE IN FEET
CHANNEL MARKER

Plate 20


N
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET
COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS

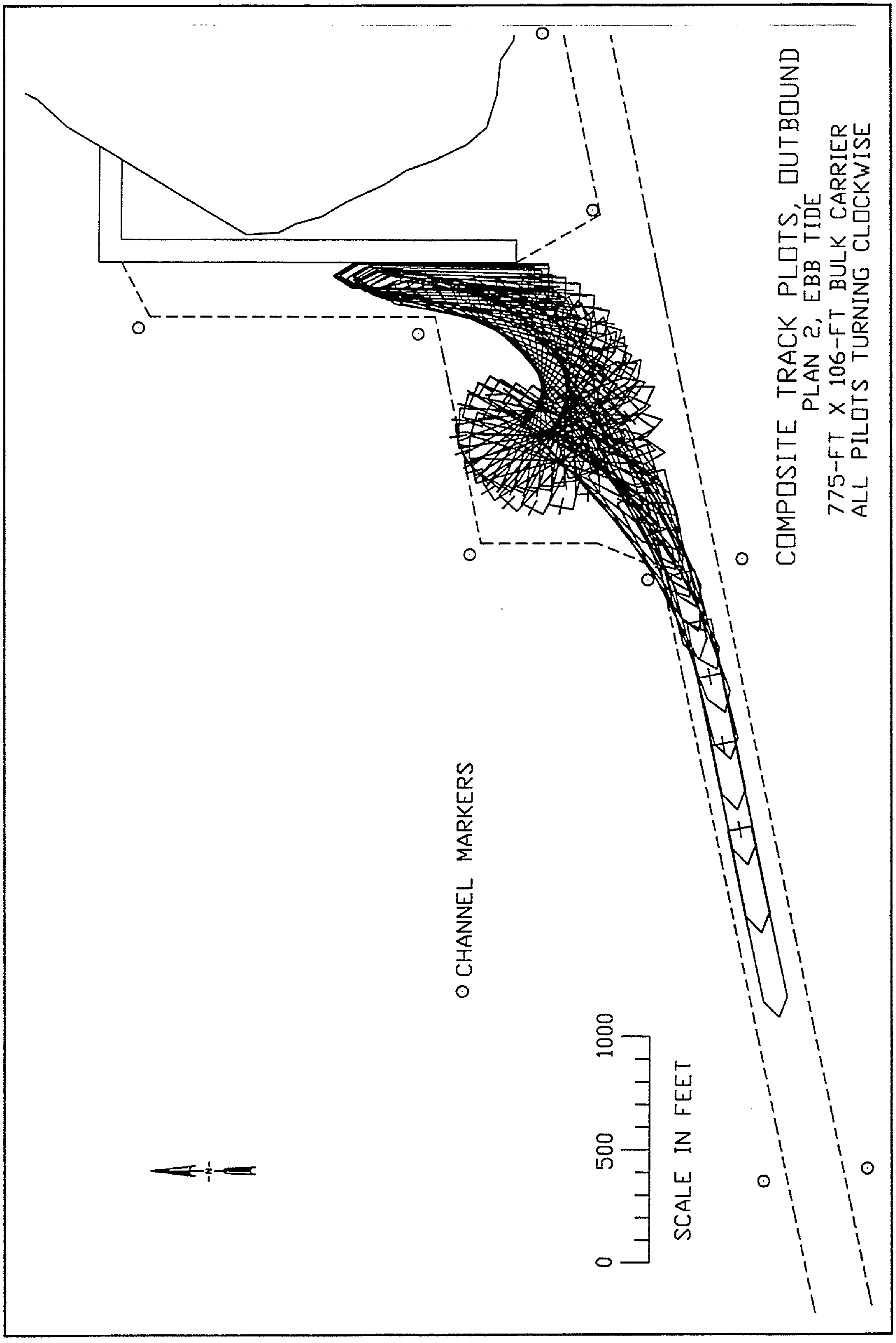
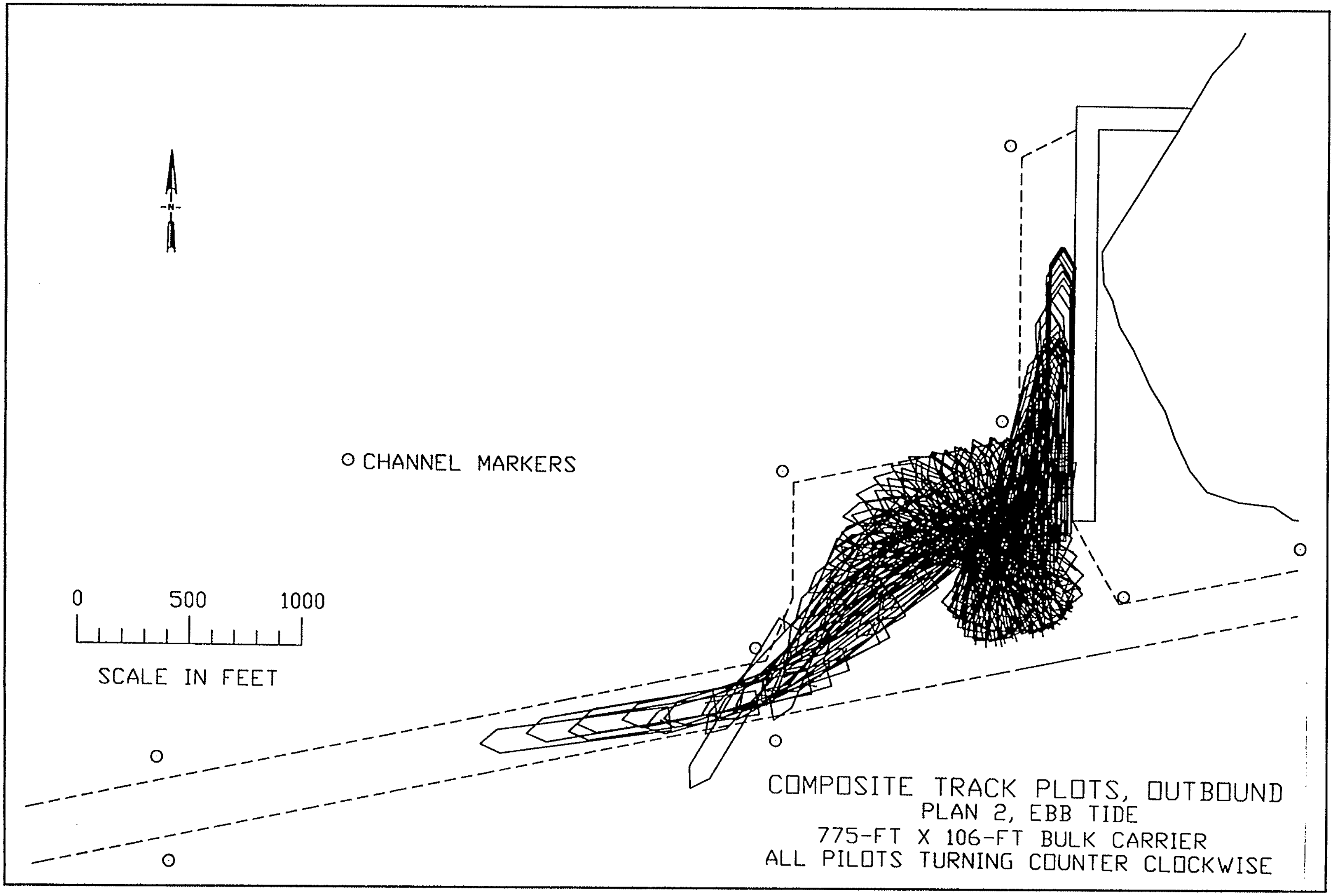

COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS TURNING CLOCKWISE
CHANNEL MARKERS
SCALE IN FEET
0
500
1000
N

Plate 22


N
O CHANNEL MARKERS
0
500
1000
SCALE IN FEET
COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS TURNING COUNTER CLOCKWISE

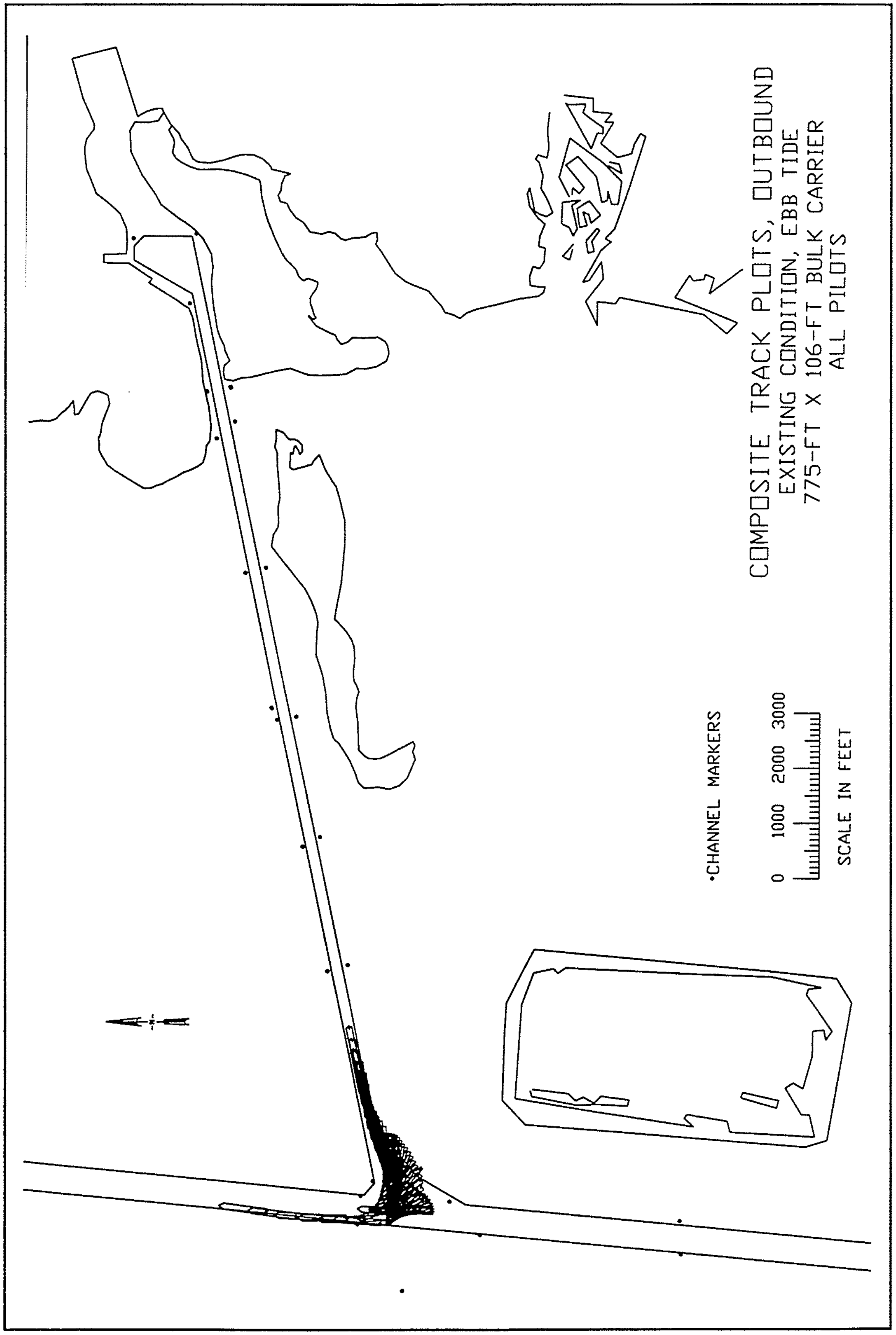
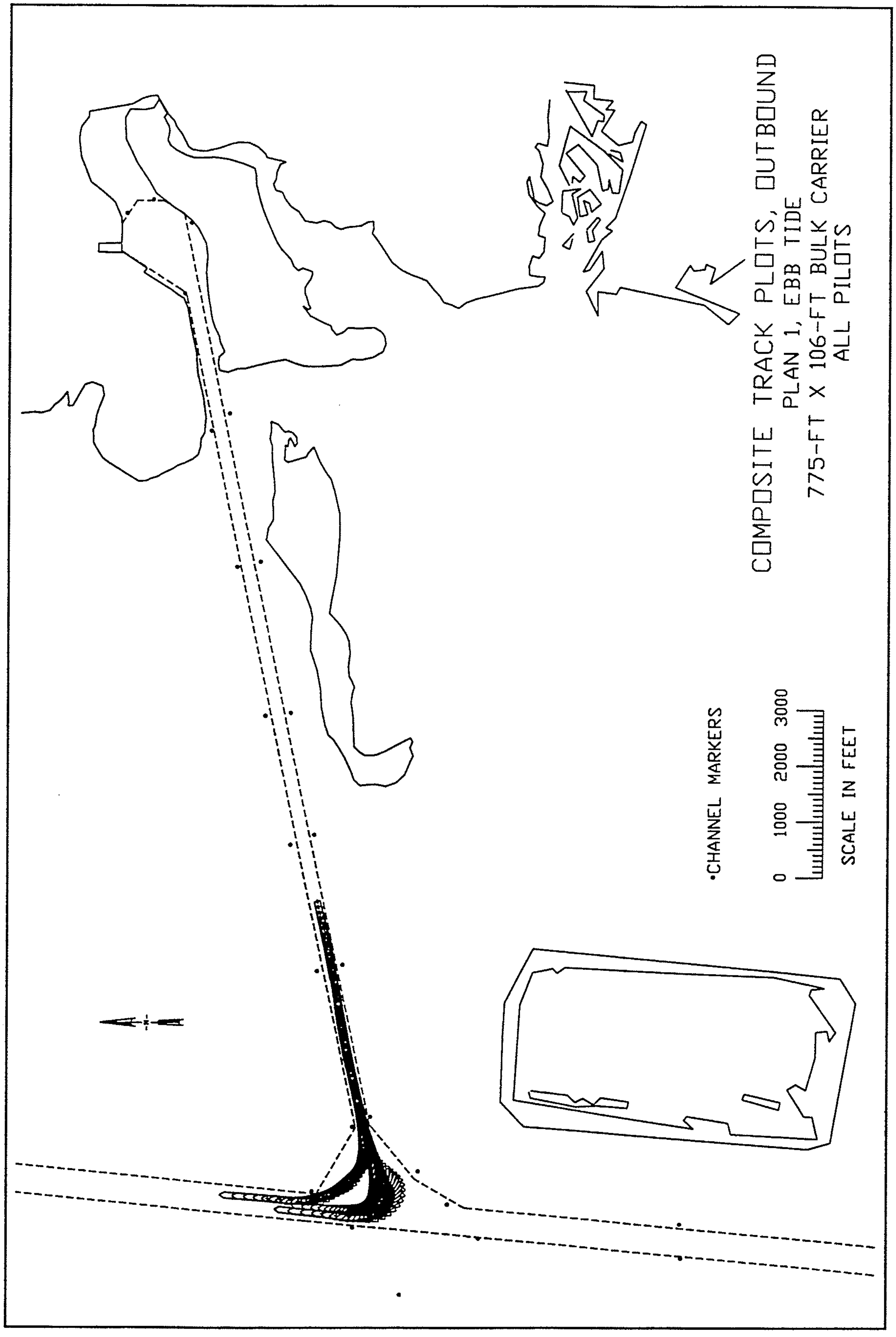

COMPOSITE TRACK PLOTS, OUTBOUND
EXISTING CONDITION, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 24



COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

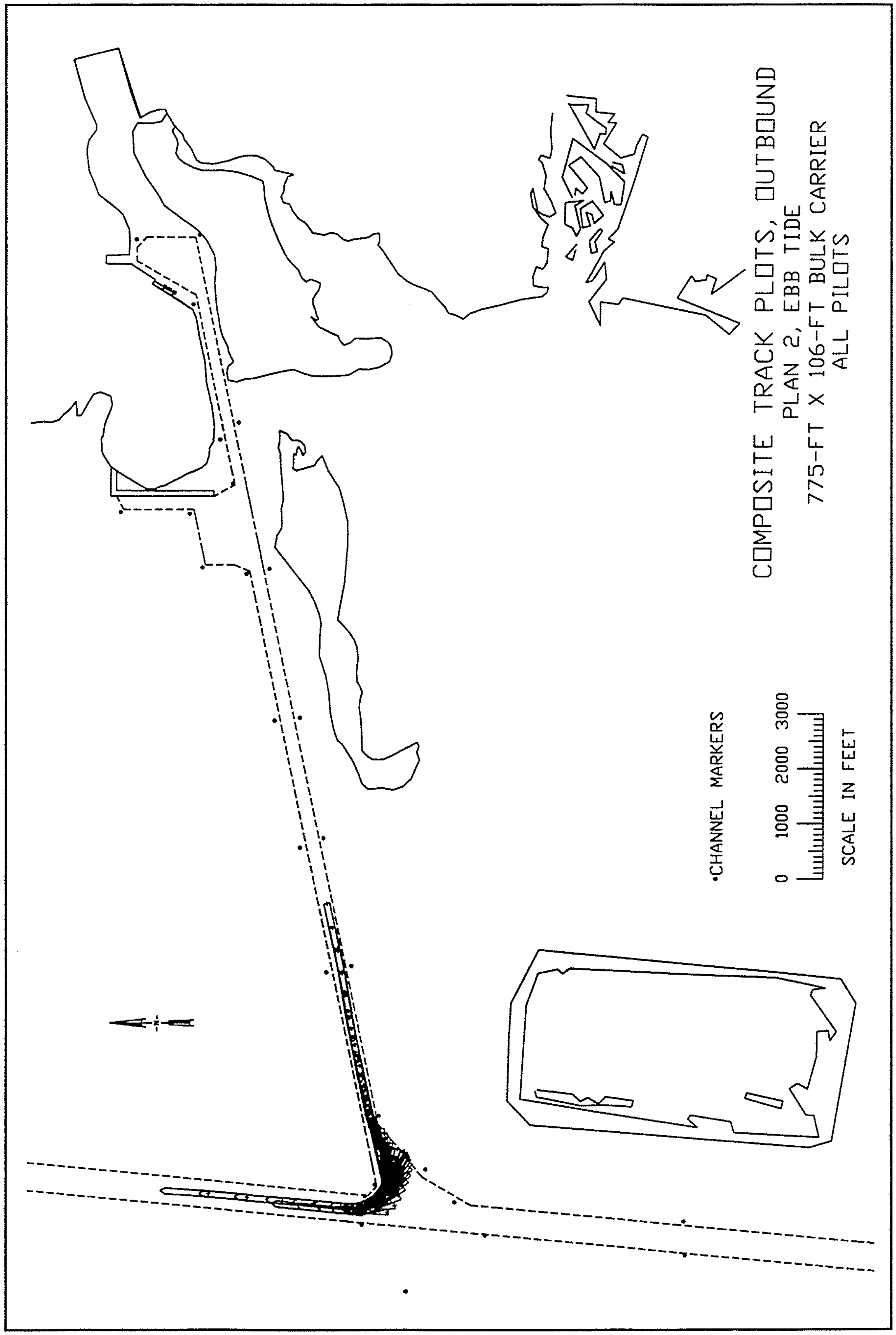
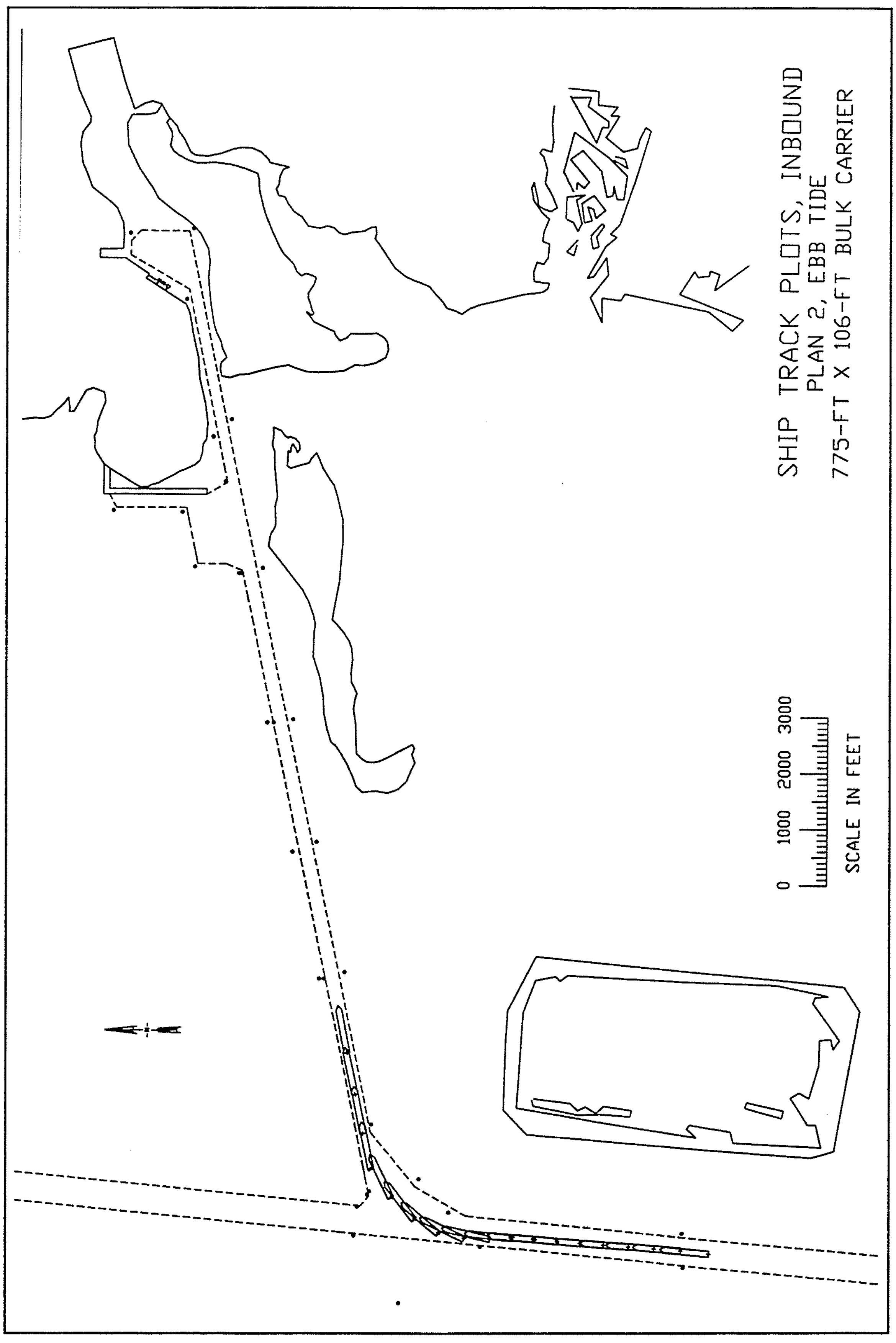

COMPOSITE TRACK PLOTS, OUTBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
ALL PILOTS
•CHANNEL MARKERS
0 1000 2000 3000
SCALE IN FEET

Plate 26


SHIP TRACK PLOTS, INBOUND
PLAN 2, EBB TIDE
775-FT X 106-FT BULK CARRIER
0 1000 2000 3000
SCALE IN FEET

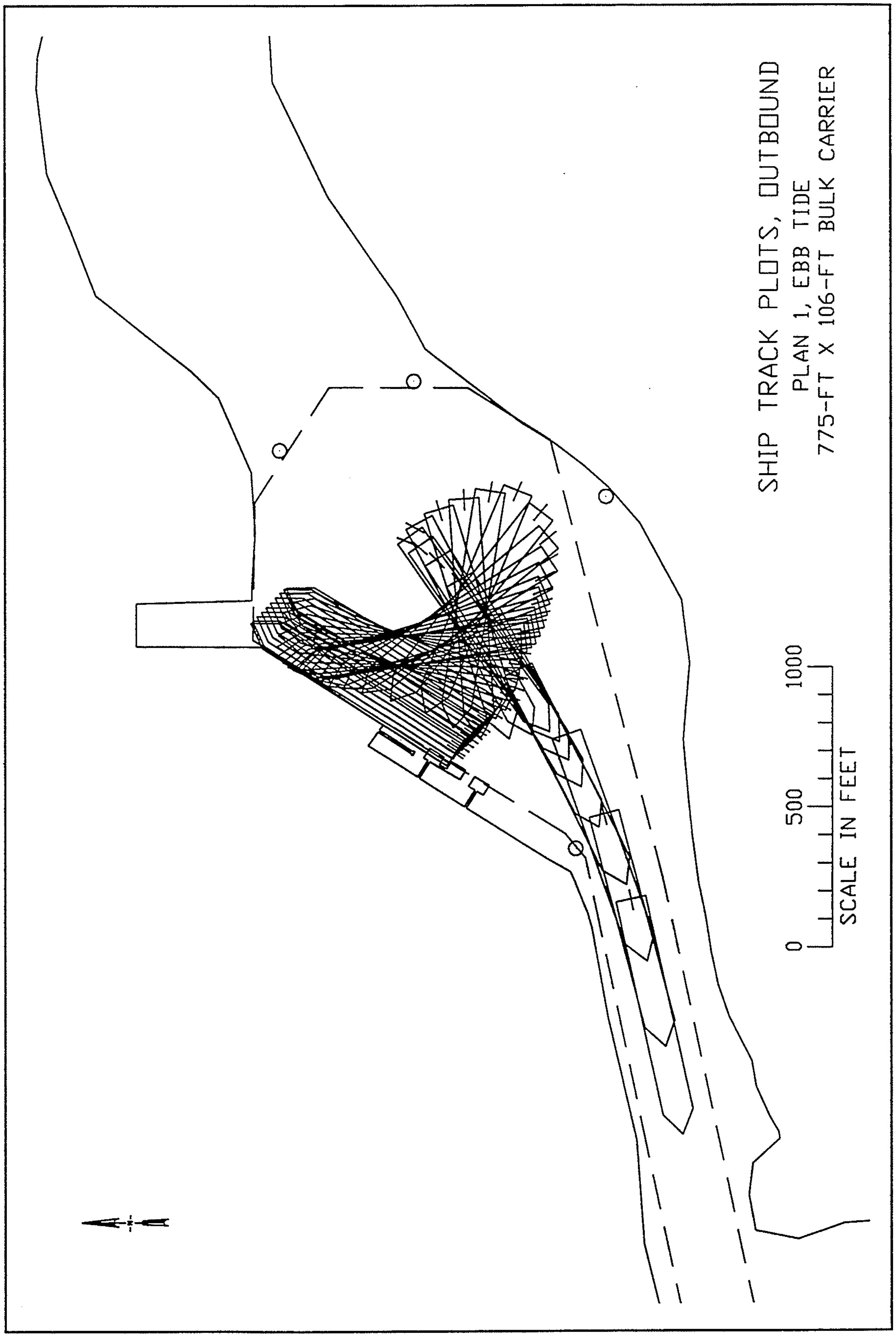
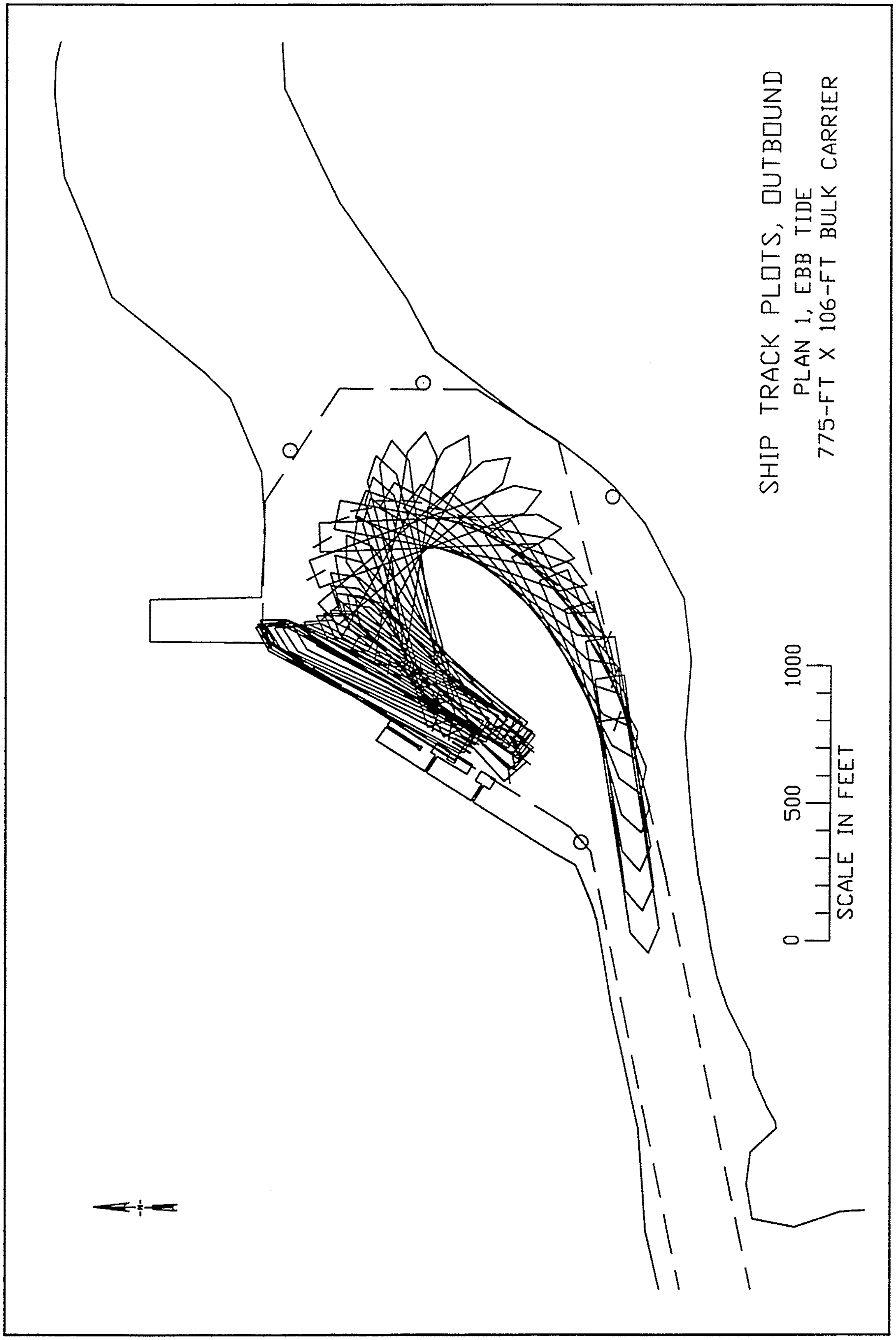
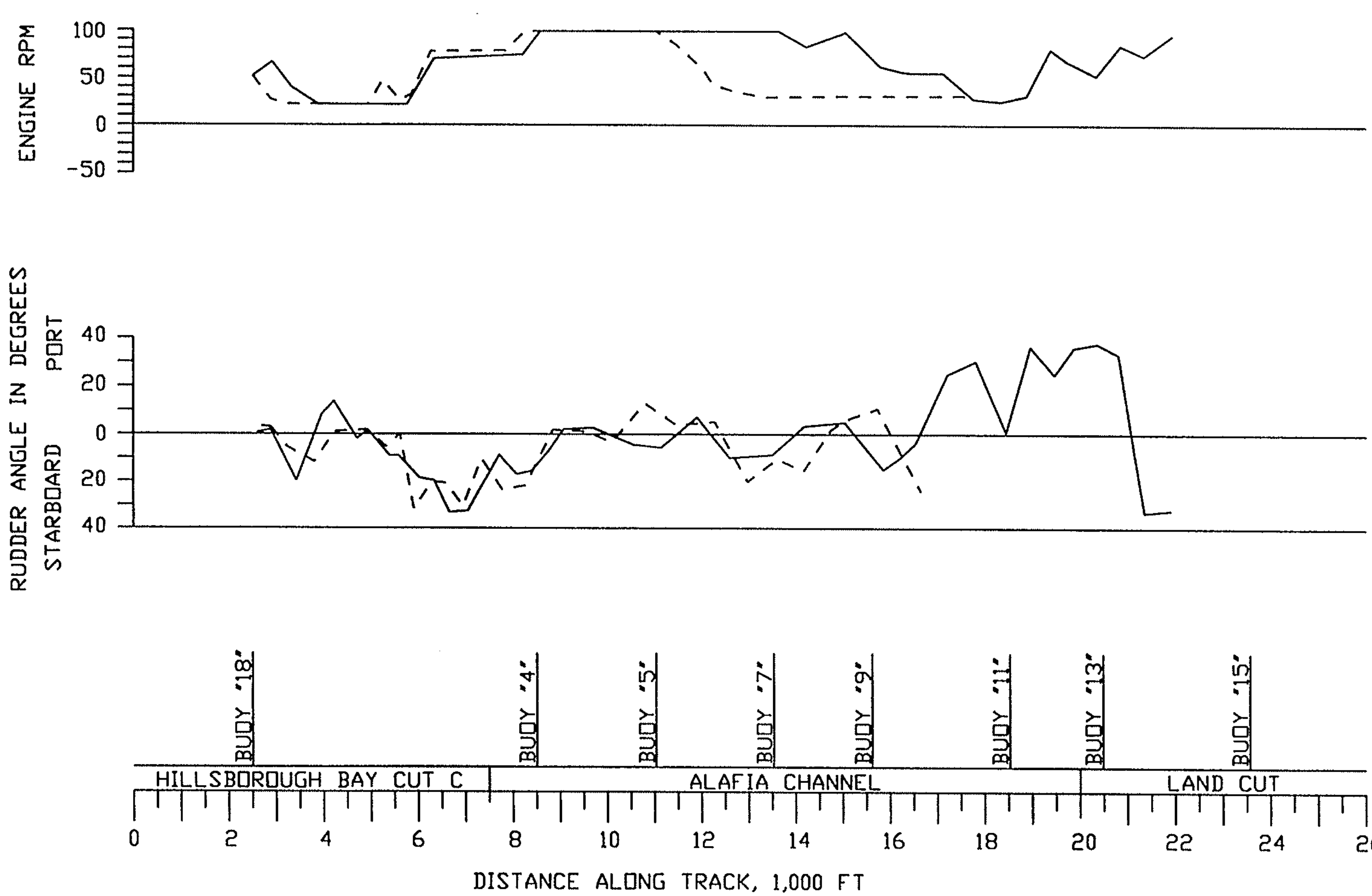

SHIP TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
0
500
1000
SCALE IN FEET

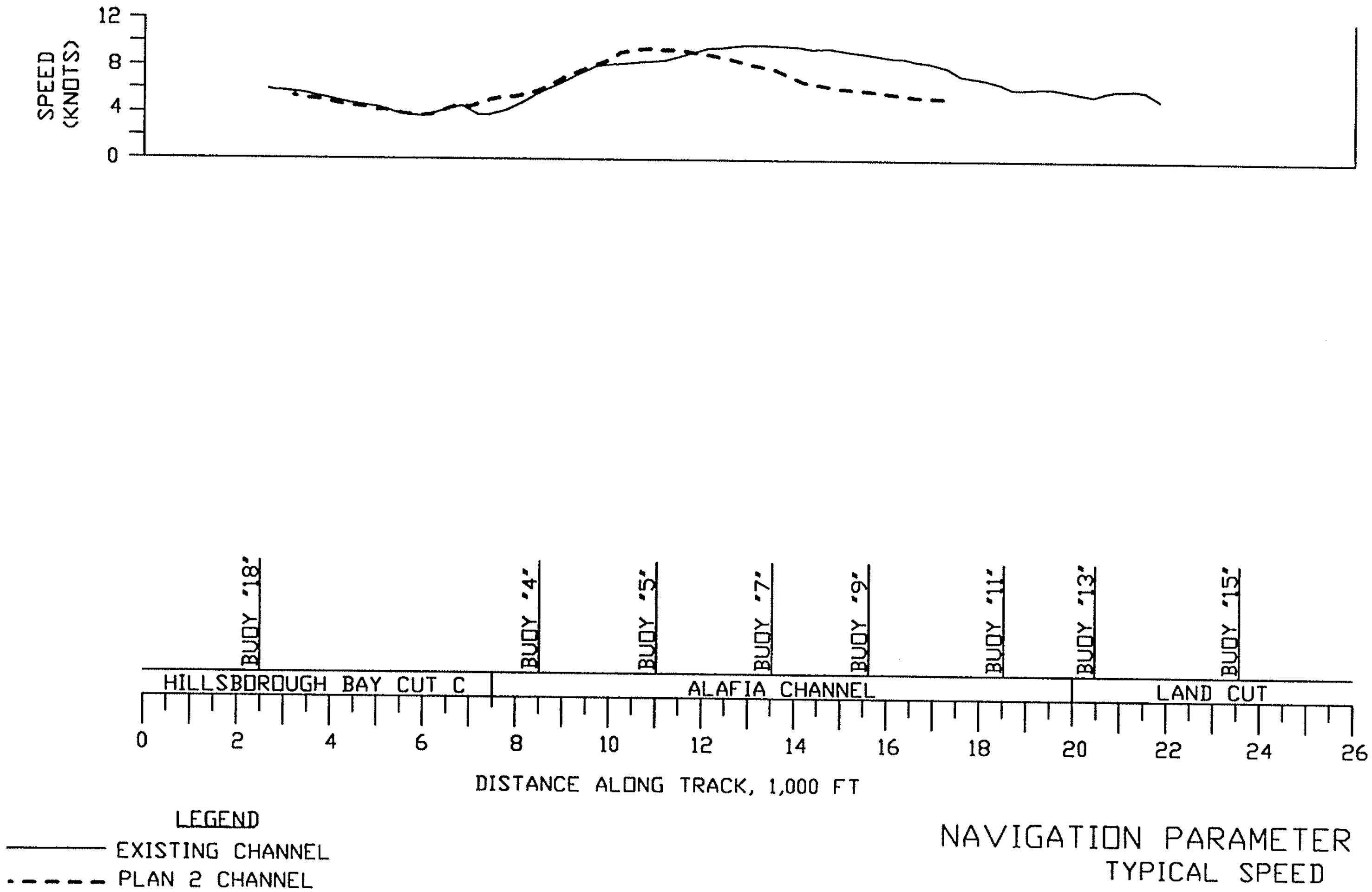
Plate 28


SHIP TRACK PLOTS, OUTBOUND
PLAN 1, EBB TIDE
775-FT X 106-FT BULK CARRIER
0
500
1000
SCALE IN FEET

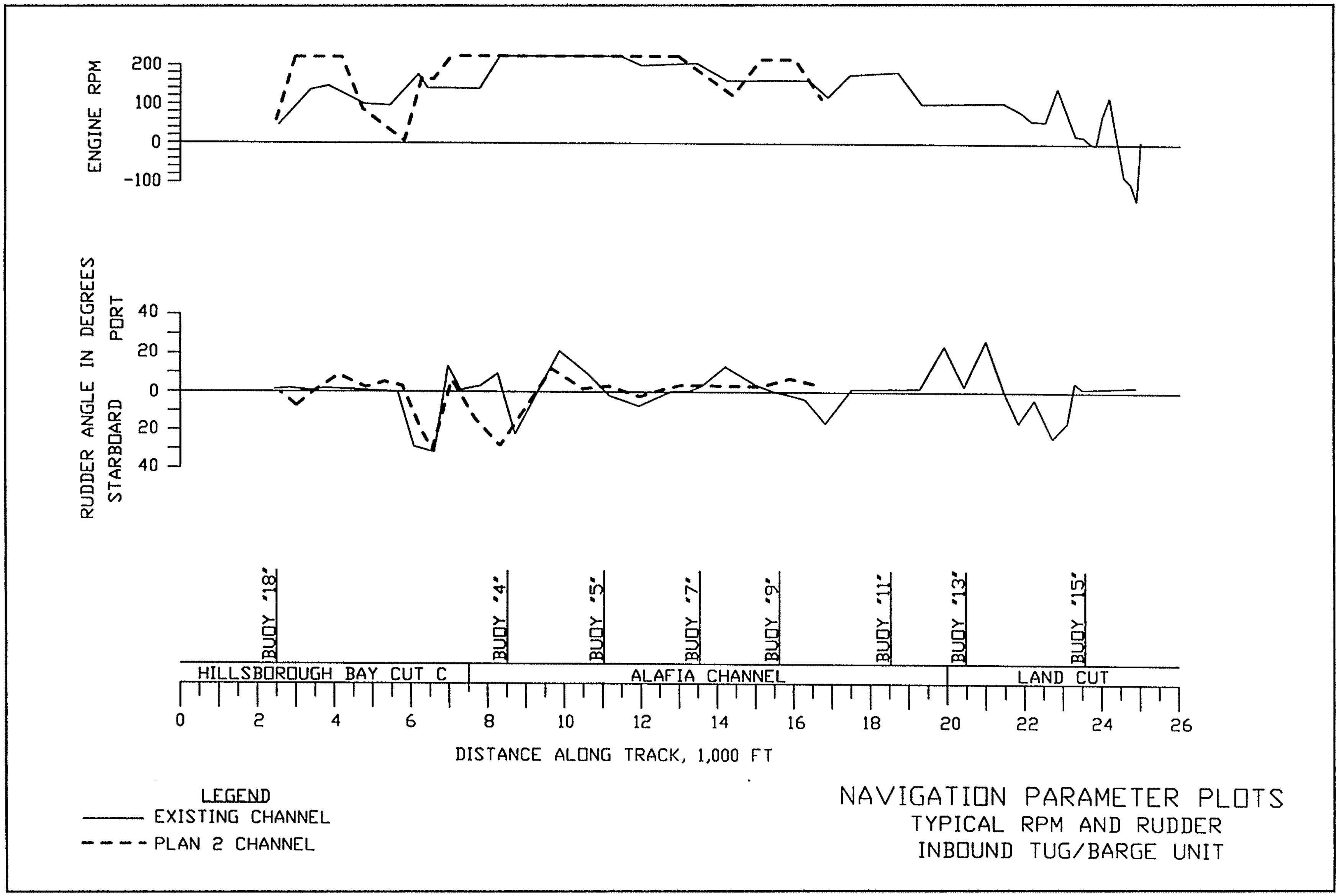


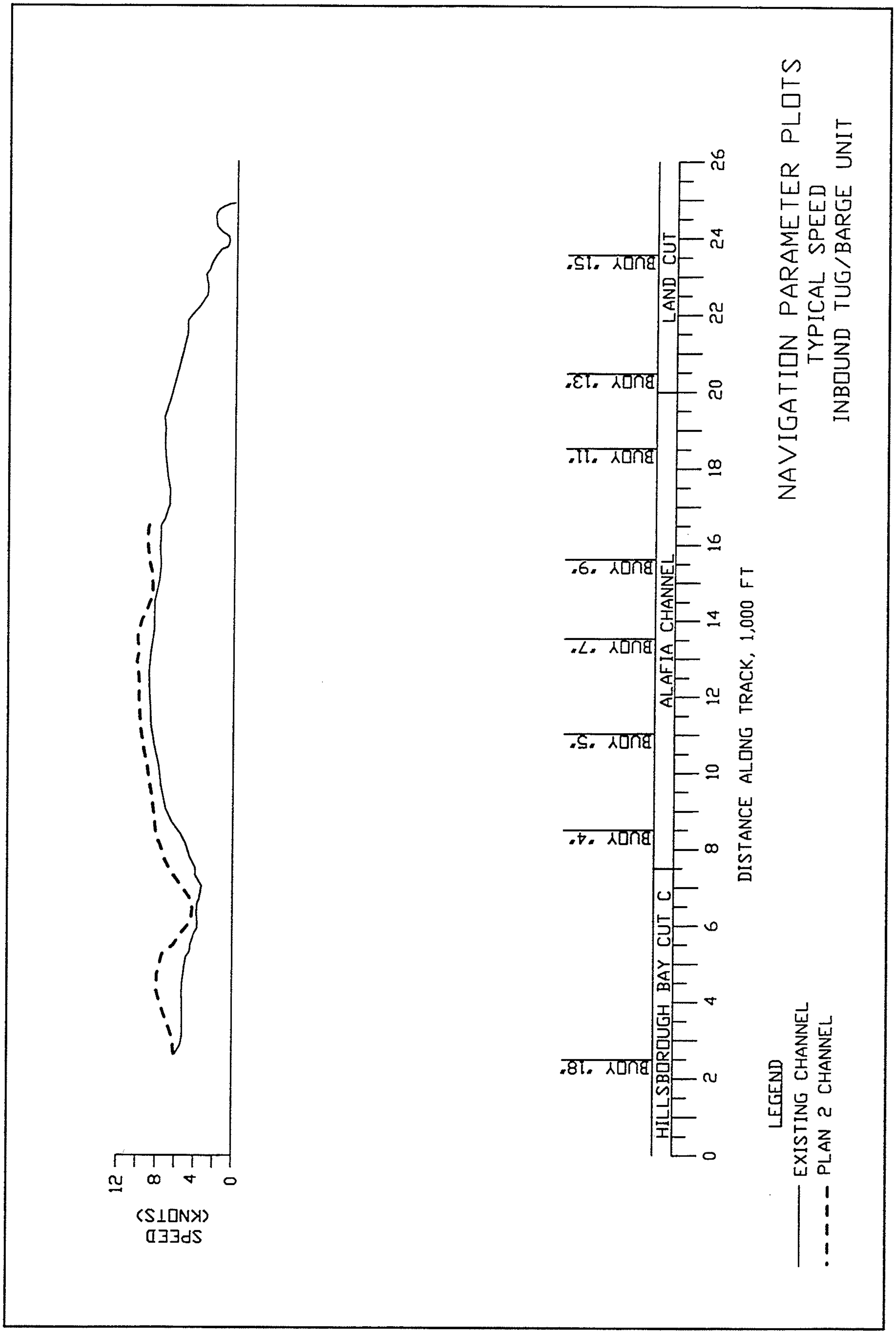
LEGEND
—— EXISTING CHANNEL
- - - - PLAN 2 CHANNEL

NAVIGATION PARAMETER PLOTS
TYPICAL RPM AND RUDDER
INBOUND BULK CARRIER



NAVIGATION PARAMETER PLOTS
TYPICAL SPEED
INBOUND BULK CARRIER


ENGINE RPM
200
100
0
-100
RUDDER ANGLE IN DEGREES
PORT
STARBOARD
40
20
0
20
40
BUOY "18"
BUOY "4"
BUOY "5"
BUOY "7"
BUOY "9"
BUOY "11"
BUOY "13"
BUOY "15"
HILLSBOROUGH BAY CUT C
ALAFIA CHANNEL
LAND CUT
0
2
4
6
8
10
12
14
16
18
20
22
24
26
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING CHANNEL
PLAN 2 CHANNEL
NAVIGATION PARAMETER PLOTS
TYPICAL RPM AND RUDDER
INBOUND TUG/BARGE UNIT



NAVIGATION PARAMETER PLOTS
TYPICAL SPEED
INBOUND TUG/BARGE UNIT
SPEED (KNOTS)
0
4
8
12
DISTANCE ALONG TRACK, 1,000 FT
0
2
4
6
8
10
12
14
16
18
20
22
24
26
HILLSBOROUGH BAY CUT C
ALAFIA CHANNEL
LAND CUT
BUOY "18"
BUOY "4"
BUOY "5"
BUOY "7"
BUOY "9"
BUOY "11"
BUOY "13"
BUOY "15"
LEGEND
EXISTING CHANNEL
PLAN 2 CHANNEL

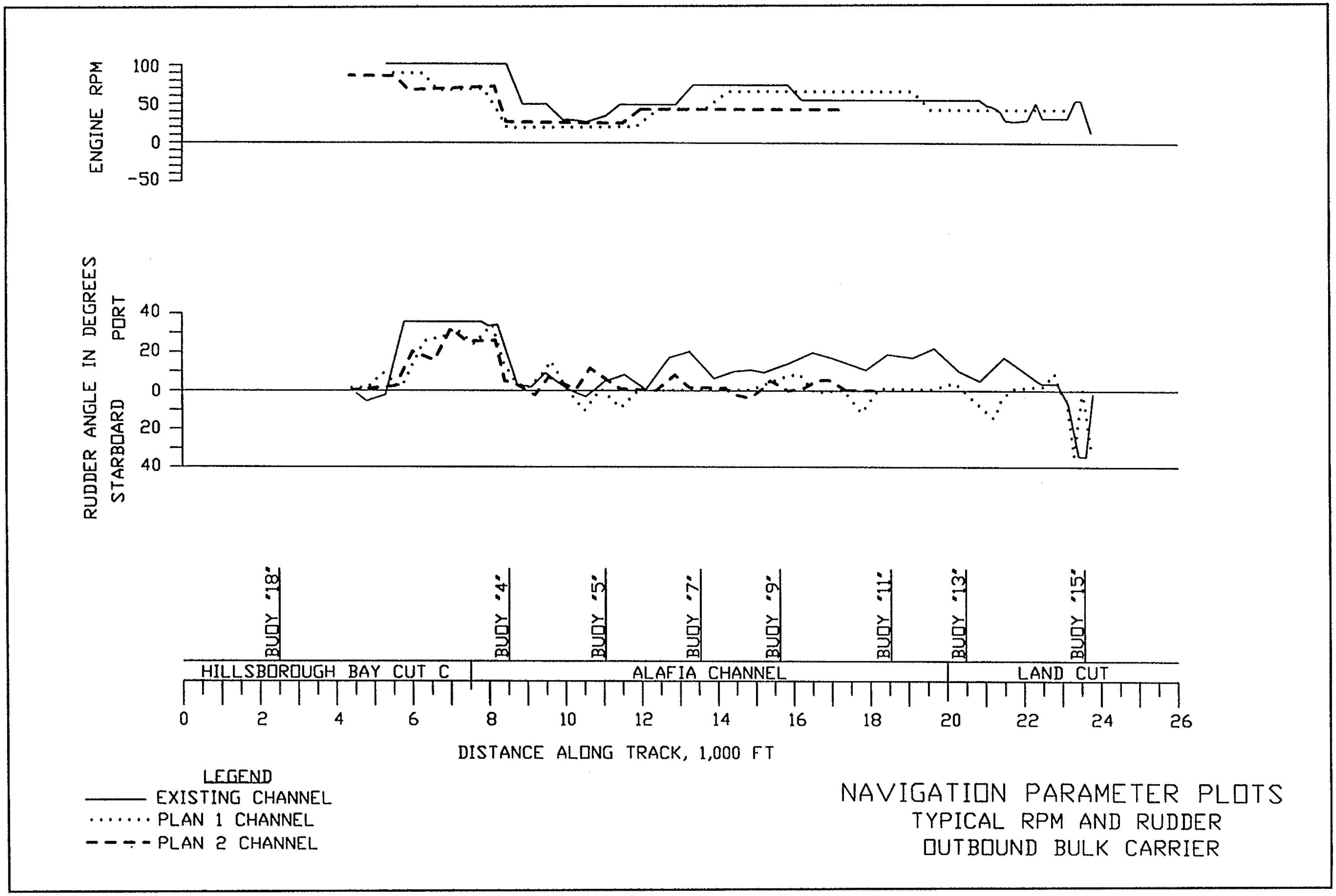
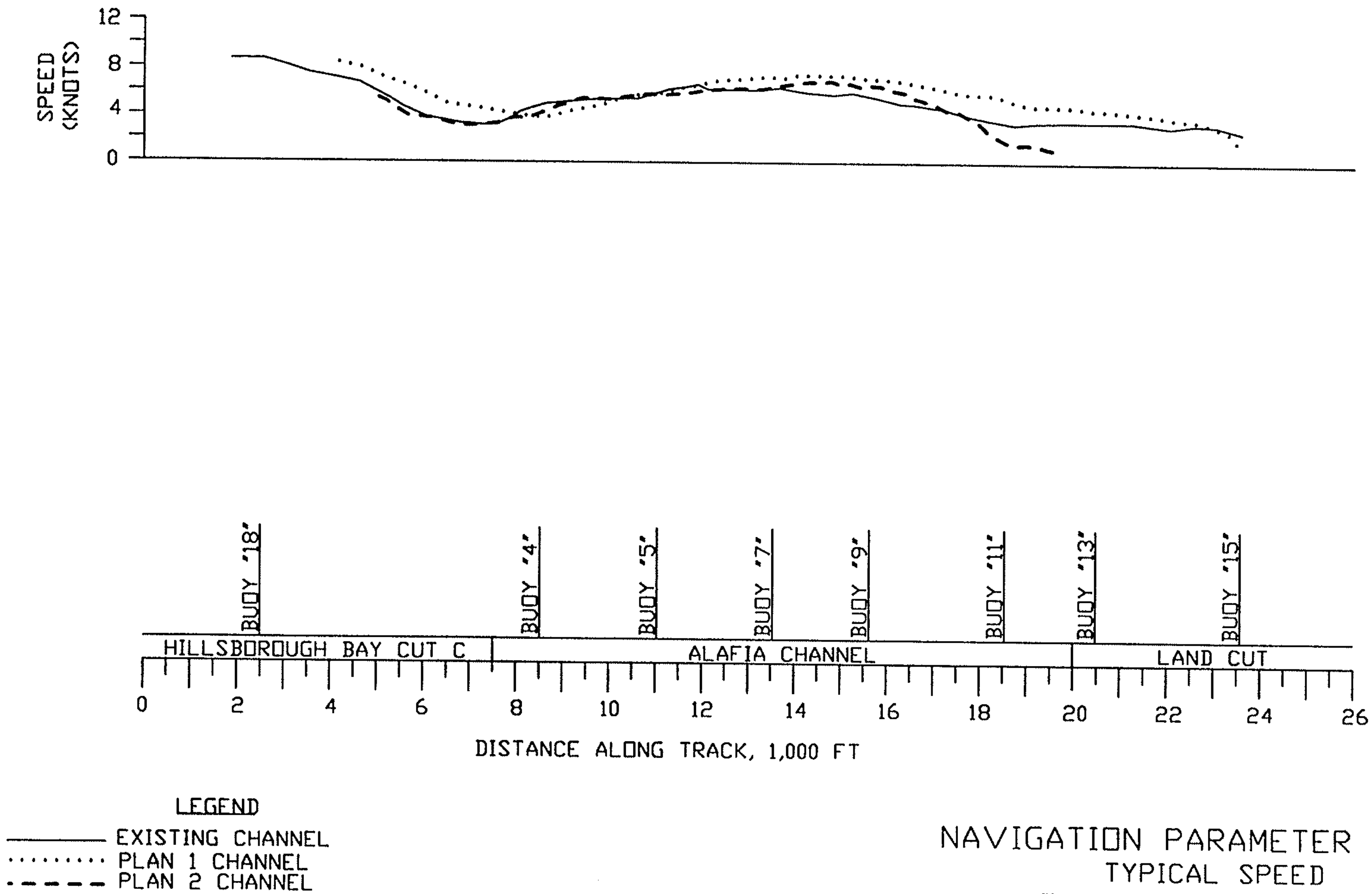

ENGINE RPM
100
50
0
-50
RUDDER ANGLE IN DEGREES
PORT
STARBOARD
40
20
0
20
40
BUOY "18"
BUOY "4"
BUOY "5"
BUOY "7"
BUOY "9"
BUOY "11"
BUOY "13"
BUOY "15"
HILLSBOROUGH BAY CUT C
ALAFIA CHANNEL
LAND CUT
0 2 4 6 8 10 12 14 16 18 20 22 24 26
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING CHANNEL
PLAN 1 CHANNEL
PLAN 2 CHANNEL
NAVIGATION PARAMETER PLOTS
TYPICAL RPM AND RUDDER
OUTBOUND BULK CARRIER

Plate 34



NAVIGATION PARAMETER PLOTS
TYPICAL SPEED
OUTBOUND BULK CARRIER

Appendix A
Flow Modeling

Numerical Model

The WES numerical modeling system, "Open-Channel Flow and Sedimentation, TABS-2",[1] was used in the evaluation of the impact of channel deepening and turning basin modification at Alafia River, Hillsborough Bay, Florida. The hydrodynamic predictions were used in the ship simulator evaluation of the proposed channel improvements. The numerical model used was "A Two-Dimensional Model for Free Surface Flows (RMA-2V)." The code employs the finite element method to solve the depth-integrated governing equations.

Computational Meshes

Alafia River Channel lies in the Hillsborough Bay portion of the Tampa Bay complex. To capture tidal flows in the area, the computational mesh covered much of Hillsborough Bay, extending across the full width and from the north end of the bay nearly to Big Bend Channel, where Hillsborough Bay begins opening into Tampa Bay (Figure A1). Depths were taken from National Oceanic and Atmospheric Administration charts except in the Alafia River Channel, where SAJ surveys were used.

Discharge from the Alafia River can dominate tidal flows in the existing turning basin and land cut. Strong Alafia River flows represent a design condition in this area, particularly during the turning maneuver. A river discharge of 4000 cfs at the Highway 41 bridge, representing an average two-year maximum flow condition, was included in all of the model runs. Example flow fields during flooding and ebbing tides are shown in Figures A2 and A3.

---

[1] William A. Thomas and William H. McAnally, Jr. (1985). "User's Manual for the Generalized Computer Program System: Open-Channel Flow and Sedimentation, TABS-2; Main Text and Appendices A Through O," Instruction Report HL-85-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A special concern in the Alafia River turning basin is the damming effect of a large loaded ship turning in a very confined basin. When the simulated bulk carrier is turned nearly perpendicular to the main flow direction, it blocks most of the cross section and causes significant distortion of flow speeds and directions. The effect of river flow damming caused by the loaded bulk carrier during turning in the existing and Plan 1 conditions was represented by a special set of numerical model runs. The ship was represented as a fixed island, assuming flows around the ends of the loaded ship will be much greater than flows in the very narrow gap under the ship. Current information was generated with the ship positioned at 45-deg intervals of rotation in the turning basin. For ship positions in between the modeled positions, currents were interpolated.

Validation

Validation of the flow model was based on two sources of information. First, pilots report currents through the confined Alafia Channel between markers "13" and "15" occasionally reach speeds of around one knot. This condition would occur during ebb currents coupled with strong river outflow, similar to conditions included in the navigation simulation. Second, the United States Geological Survey (USGS) has published ebb and flood tide flow fields produced by a validated numerical model of Hillsborough Bay.[1] These fields serve as a general validation of WES tidal flows computed for Hillsborough Bay.

Appropriate flow results from the WES model were compared to the available validation information. The WES model was adjusted as needed to achieve validation.

---

[1] Carl R. Goodwin. (1991). "Tidal-Flow, Circulation, and Flushing Changes Caused by Dredge and Fill in Hillsborough Bay, Florida," Open-File Report 88-76, U.S. Geological Survey, Tallahassee, Florida.

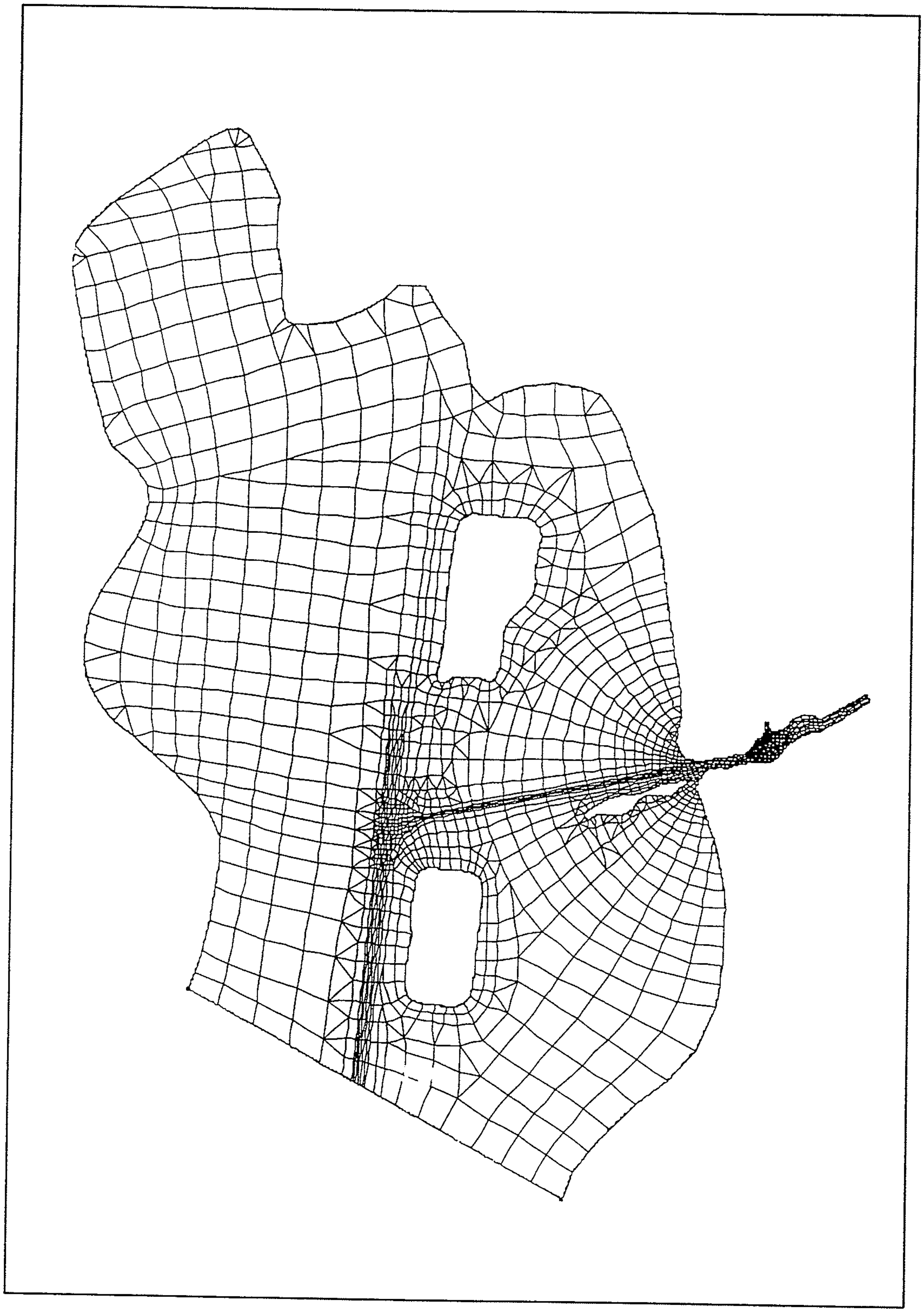


Figure A1. WES flow model mesh

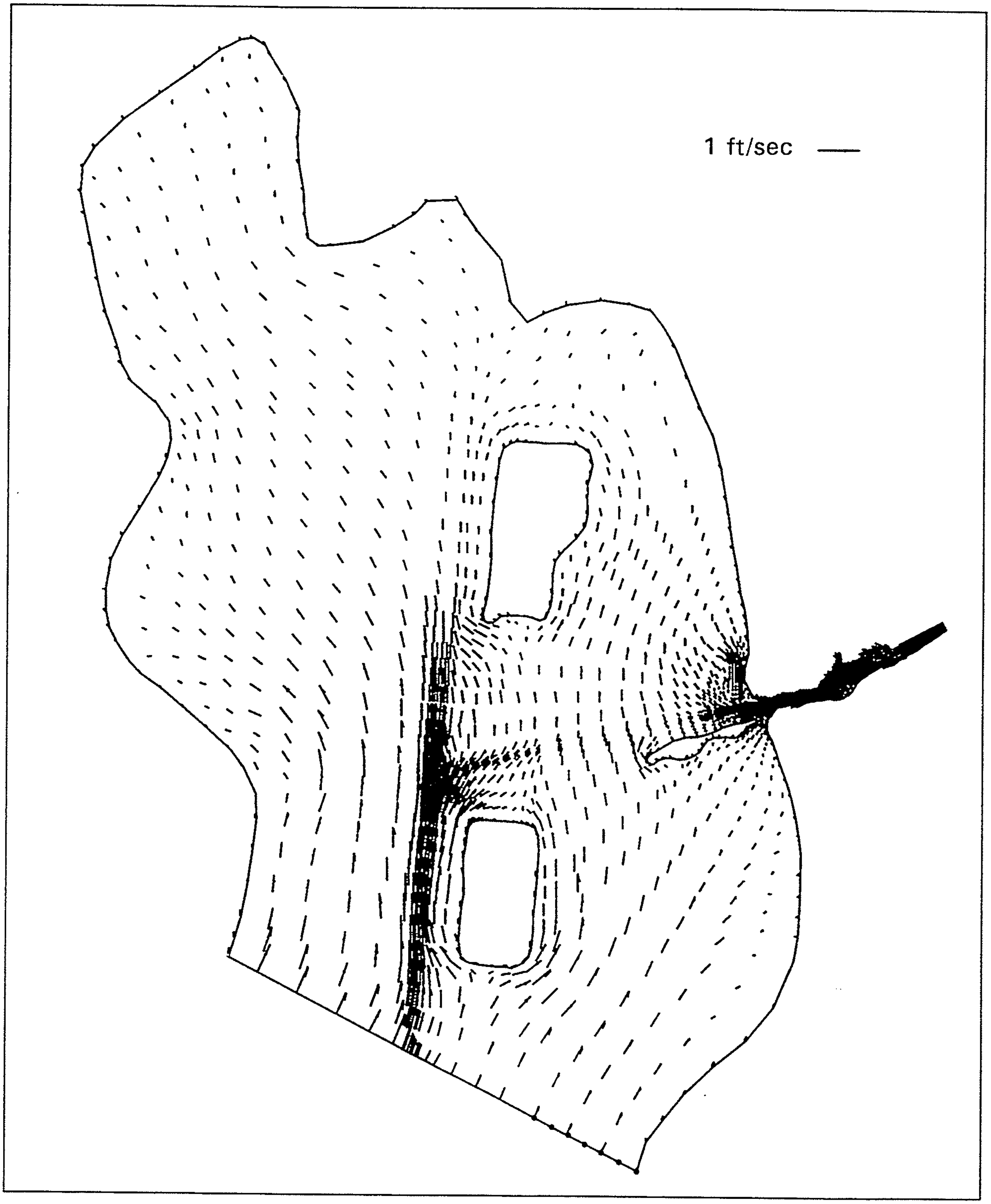


Figure A2. Flow field during flood current with Alafia River discharge

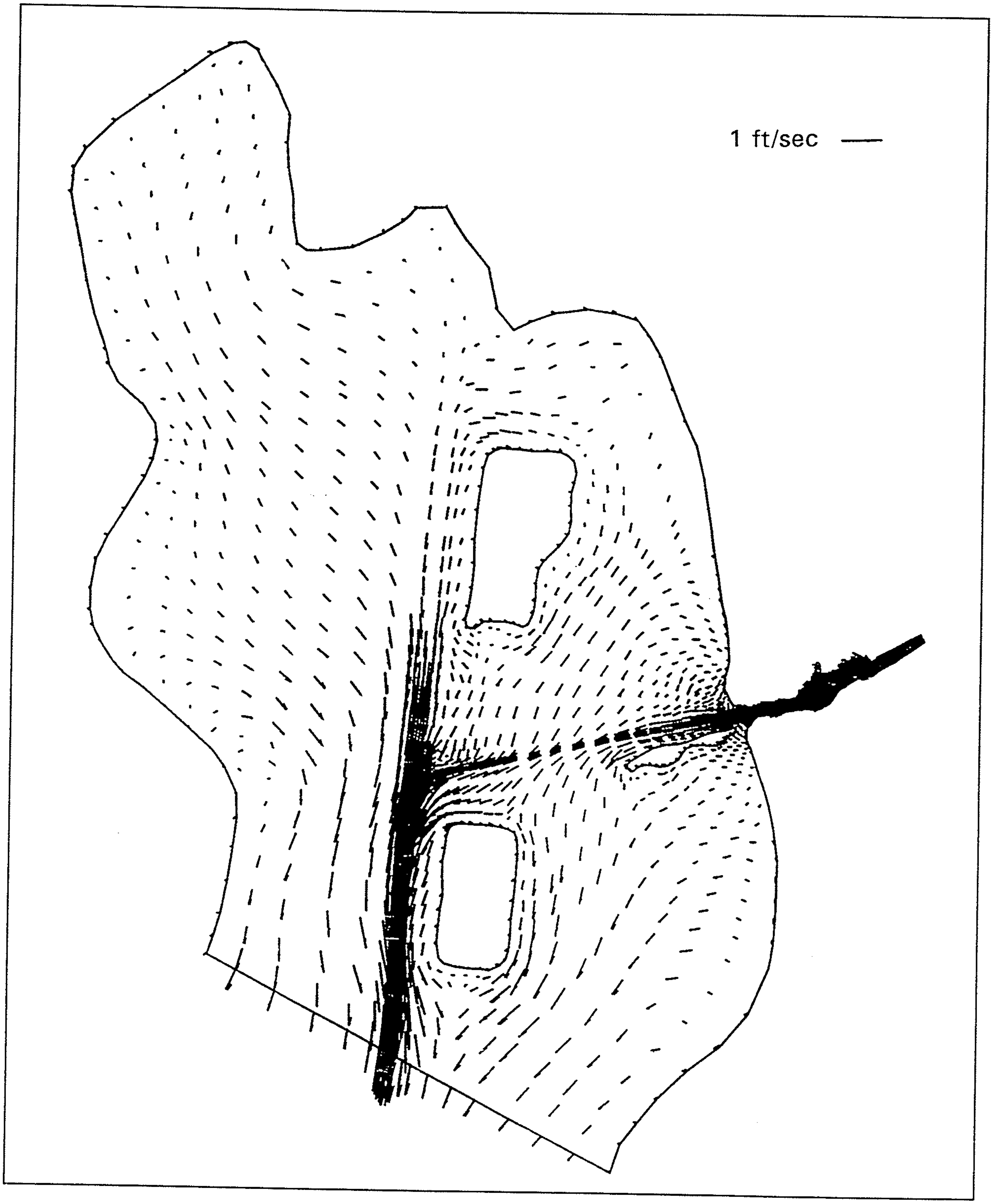


Figure A3. Flow field during ebb current with Alafia River discharge

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 1998

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Ship Navigation Simulation Study, Alafia River, Tampa Bay, Florida

5. FUNDING NUMBERS

6. AUTHOR(S)
Edward F. Thompson, Moira T. Fong, Peggy S. Van Norman, Ben Brown

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report CHL-98-13

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District, Jacksonville
P.O. Box 4970
Jacksonville, FL 32232-0019

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A real-time ship simulation investigation of the proposed design for deepening and widening the Alafia River Channel and turning basin, Tampa Bay, Florida, was conducted. Existing and proposed channel depths are 30 ft and 41 ft, respectively. The purpose of the study was to determine effects of proposed improvements on navigation with larger design ships and to assist in optimizing channel width and turning basin configuration required to efficiently navigate the study area. A numerical model of the existing channel from Hillsborough Bay Channel Cut C to the harbor area was developed. The model was verified by two members of the Tampa Bay Pilots Association. Numerical models of two plans were also developed. The investigation was conducted in Vicksburg, MS, on the U.S. Army Engineer Waterways Experiment Station ship simulator.

14. SUBJECT TERMS
Alafia River Channel
Channel design
Deepwater channel navigation
Real-time simulator study
Ship navigation simulation

15. NUMBER OF PAGES
82

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		