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September 1994

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Waterways Experiment Station

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Ship Navigation Simulation Study, Sacramento River Deepwater Ship Channel Project, Phase II, Sacramento, California

by Dennis W. Webb

Prepared for U.S. Army Engineer District, Sacramento

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3909 Halls Ferry Road
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Final report

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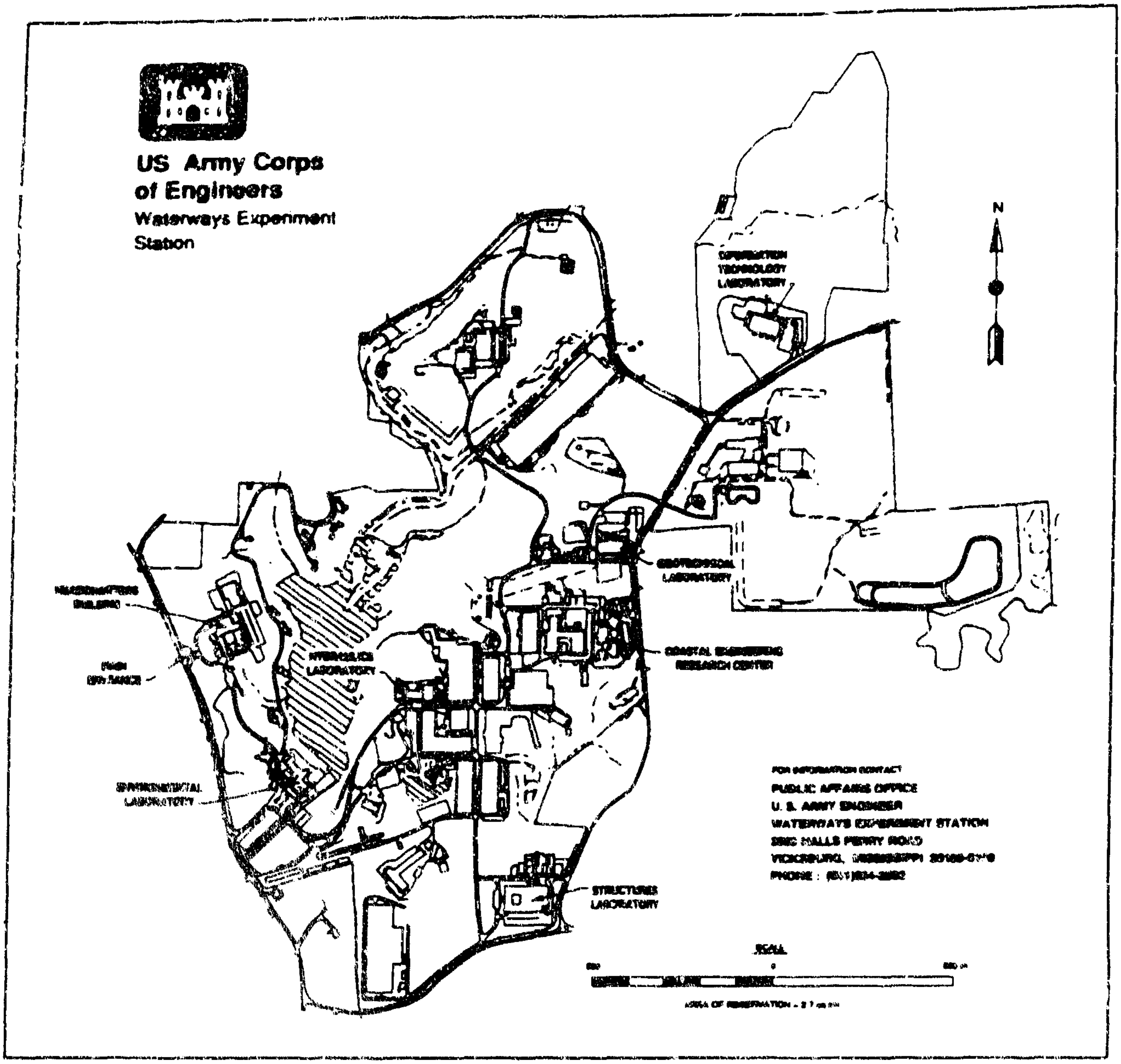

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Contents

Preface

This investigation was performed by the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) for the U.S. Army Engineer District, Sacramento (SPK). The study was conducted with the WES research ship simulator. SPK provided survey data of the prototype area. Current modeling was conducted by Resource Management Associates, based on field data collected by the Estuarine Processes Branch, Estuaries Division, Hydraulics Laboratory. The study was conducted during the period February 1988-June 1988.

The investigation was conducted by Mr. Dennis W. Webb and Dr. Larry L. Daggett of the Navigation Branch, Waterways Division, Hydraulics Laboratory, under the general supervision of Messrs. Frank A. Herrmann, Jr., Director of the Hydraulics Laboratory; R. A. Sager, Assistant Director, Hydraulics Laboratory; and Marden B. Boyd, Chief of the Waterways Division (now retired).

Acknowledgment is made to Messrs. Mike Campbell, Eric Polson, and Fred Garcia, Engineering Division, SPK, for the cooperation and assistance at various times throughout the investigation. Special thanks should go the San Francisco Bar Pilots Association for access to an outbound ship and for furnishing professional pilots to conduct ship simulator tests on the WES ship simulator.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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
acre-feet	1,233.489	cubic meters
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
knots (international)	0.5144444	meters per second
mile (US statute)	1.609347	kilometers
square miles	2.589998	square kilometers

1 Introduction

The Sacramento River Deep Water Ship Channel is located in the Sacramento - San Joaquin Delta region of northern California. The 46.5 mile long channel lies within Contra Costa, Solana, Sacramento, and Yolo Counties and serves the marine terminal facilities at the Port of Sacramento (see Figure 1). The Sacramento River Deep Water Ship Channel joins the 35-feet deep San Fransico to Stockton, California (John F. Baldwin and Stockton Ship Channels) navigation project at New York Slough, thereby affording access from the Port of Sacramento to Bay Area harbors and the Pacific Ocean.

The existing Sacramento Deep Water Ship Channel Project was authorized by the River and Harbor Act (Public Law 525, 79th Congress, 2nd Session) approved July 24, 1946. The principal features of the project as authorized by Public Law 525 include the Deep Water Ship Channel, Harbor and Canal. The harbor consists of a turning basin of the same depth as the ship channel (30 feet), 1000 feet wide and 1200 feet long at Washington Lake. The barge canal, 11 feet deep and 120 feet wide with lock and draw bridge, connects the harbor and Sacramento River. The Deep Water Ship Channel is 30 feet deep and 200 to 300 feet wide from deep water in Suisun Bay to Washington Lake, including flood control intercepting works and drainage culverts. The project has been in operation for oceangoing vessels since June 1963.

Most of the water from the 64,000-square mile Central Valley watershed, or roughly one-third of the entire state of California, drains through the Sacramento - San Joaquin Delta. The water originates as run-off from winter rains in the valley and foothills and spring snowmelt from the Sierra mountains. Three-quarters of the total annual flow occurs between January and May, with January and February being the peak which produces 80 percent of the total run-off; the San Joaquin (15 percent); and other minor tributaries (5 percent). Before large scale water diversions began, the mean annual outflow from the Delta was more than 30 million acre-feet. The construction of many federal, state, and local water projects with the watershed has cut the flow to its present level of about 16 million acre-feet per year.

Water elevations in the area are influenced by hydrological and geological phenomena. Rapid melting of snow packs and rains in the tributary areas may greatly influence the waterways in the area. the combination of heavy run-off and tidal action may produce flood stages. Tidal action is an important factor in the development of any plan to improve the navigability of waterways in the study area. Tidal ranges for an average tide and low advective outflow are 4.5 feet at Collinsville, 4.75 feet at Junction Point, and 6.0 feet at the Port of Sacramento.

Proposed Channel Improvement

The proposed channel improvement for the Sacramento River Deep Water Ship Channel involved modification to three portions of the project reach:

a. New York Slough to the junction of Cache Slough, Steamboat Slough, and the Sacramento River (Channel Mile 15.0): This portion of the channel was planned to be deepened from 30 to 35 feet, and the width increased from 300 to 350 feet.

b. The junction of Cache Slough, Steamboat Slough, and the Sacramento River to the entrance to the manmade channel (Channel Mile 18.6): The width would remain 300 feet along this reach, and the depth would be increased from 30 to 35 feet.

c. The entrance to the manmade channel to the Port of Sacramento: This portion would be deepened from 30 to 35 feet, and the width increased from 200 to 250 feet.

Channel slopes were planned to be 1 vertical on 4 horizontal in the reach between New York Slough and Channel Mile 18.6 and 1 vertical on 3 horizontal from Channel Mile 18.6 to the Port of Sacramento.

The selected plan as discussed above and as presented in the March 1986 General Design Memorandum was to deepen the existing one-way channel between New York Slough and the Port of Sacramento to 35 feet below -2 NGVD (an approximation of MLLW) and to widen the channel according to the tabulation on Table 1.

Table 1
Sacramento River Deep Water Ship Channel, California Channel Dimensions - GDM

	Existing (ft)		GDM (ft)	
Reach	Width	Slope	Width	Slope
New York Slough to Mile 15.0	300	1V:4H	350	1V:4H
Mile 15.0 to Mile 18.6	300	1V:3H	300	1V:3H
Mile 18.6 to Port of Sacramento	200	1V:3H	250	1V:3H

Purpose and Scope of Investigation

The purpose of the ship simulator investigation was to determine the effect of deepening the Sacramento Deep Water Ship Channel on navigation conditions. It was also to determine if elimination of widening in the straight reaches of the man-made portion of the channel would be engineeringly feasible while maintaining adequate navigation efficiency and safety.

The basic plan for the ship simulator investigation was to conduct the study in two phases. The first phase included the man-made channel portion from river mile 18.6 to 43 (Sacramento Harbor). The second phase included the lower portion from river 20 to mile 12, slightly downstream of the Rio Vista Bridge, Rio Vista, California. This report will only present the results of the Sacramento Deep Water Ship Channel Ship Simulation - Phase II (Figure 2). Phase I study results were presented in Nguyen and Daggett.[1]

[1] R. H. T. Nguyen and L. L. Daggett (1990). "Ship navigation simulator study, Sacramento River Deepwater Ship Channel Project, Sacramento, California, Report 1, Phase I," Technical Report HL-90-11, Volumes I and II, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

2 Data Development

In order to simulate the study area, it is necessary to develop information relative to five types of input data:

a. Channel data base contains dimensions for the existing channel and the proposed channel modification. It includes the channel cross-sections, slope angle, overbank depth, initial conditions and autopilot trackline and speed definition.

b. Visual Scene data base which is composed of three dimensional images of principle features of the simulated area, including the aids-to-navigation, buildings, and bridges.

c. Radar data base contains the features for the plan view of the study area.

d. Ship data file contains characteristics and hydrodynamic coefficients for the test vessels.

e. Current pattern data in the channel includes the magnitude, direction, and depth of the current for each cross-section defined in the channel data base.

Channel

The information used to develop the channel data base came from the District-furnished hydrographic survey charts. This was the latest information available concerning depths, dimensions, and bank lines of the channel. State planar coordinates as shown on the annual survey were used for the definition of the data.

The ship simulator model uses eight equally spaced points to define each cross-section. At each of these points, a depth, current magnitude and direction are required. For each cross section, the width, right and left bank slopes are required. This data was obtained from the hydrographic survey data provided by the Sacramento District for use in the main program for calculating bank suction forces. The cross-section layout for the simulation of the

Sacramento River Deep Water Ship Channel - Phase II were placed as shown in Figure 3.

A typical cross-section is shown in Figure 4. This cross-section was taken from the Phase II simulation in the Cache Slough reach and is shown as if the viewer is looking downstream. Notice that the steep edge on the right, or western, side of the channel has a shallow overbank depth (2 feet) and a steep side slope (1 vertical on 3 horizontal). The left, or eastern, side of the cross-section has overbanks that are nearly as deep as the channel itself, and a nearly flat slope. These overbank depths and side slopes are used to calculate bank suction. The shallower the overbank and the steeper the side slope, the greater the computed bank force. The hydrodynamic module that computes bank force requires that the overbank depth be less than the channel bottom. It is important to note that the overbank depth is only used to calculate the bank force and does not necessarily mean that the vessel grounds in that area. A small difference (1 to 2 ft) in channel bottom and overbank depth produces negligible bank forces and moments.

The channel depths at each of the eight points were provided by the math model that computed the current magnitudes and directions.

Visual Scene

The Visual Scene data base was created from the same maps and charts noted in the discussion of the channel source. Aerial and still photographs and pilot's comments obtained aboard a transiting ship during a reconnaissance trip to Sacramento constituted another source of information for the scene. These allowed inclusion of the significant physical features and also helped determine which, if any, features the pilots use for informal ranges and location sightings.

All aids-to-navigation such as buoys, channel markers, the bridge, buildings, and tanks were included in the visual scene.

The visual scene is generated in three dimensions: North-South, East-West, and vertical elevation. As in the development of the channel data base, the state planar coordinate system was used. As the ship progresses through the channel, the three dimensional picture is constantly transformed into a two dimensional perspective graphic image representing the relative size of the objects in the scene as a function of the vessel's position and orientation and the relative direction and position on the bridge for viewing. The graphics hardware used for the Sacramento project is a stand-alone computer (Silicon Graphics - Iris 2300) which is connected with the main computer to obtain information for updating the viewing position and orientation. This information includes parameters such as vessel heading, rate-of- turn, forward and lateral velocity, and position. Also, the viewing angle is passed to the graphics computer for the look- around feature on the simulator console which encompasses only a forty degree arc. This feature simulates the pilot's ability to see any object with a turn of his head. The pilot's position on the bridge can also be changed from the center of the bridge to any position wing to wing to simulate the pilot walking across the bridge to obtain a better view, e.g. along the edge of the ship from the bridge wing.

It may be noted that the creation of a scenario for the project area is very demanding in terms of engineering judgment. The goal of the scenario is to provide all the required data without excessive visual clutter, bearing in mind the finite memory storage and computational resources available on the minicomputer.

Radar

The radar data base is used by the Geneisco graphic image generator to create a simulated radar for use by the test pilots. The radar data base contains X and Y coordinates which define the border between land and water. The file also contains coordinates for any structure which is built or extends into the water such a bridges and aids-to-navigation. In short, this data defines what a pilot would actually see on a shipboard radar. The radar image is a continuously updated view of the vessel's portion relative to the surrounding area. Three different ranges of 0.5 mile, 0.75 mile, and 1.5 miles were programmed in order for the pilot to choose the scale needed.

Currents

A current data base contains current magnitude and direction at eight points across the channel at each of the cross sections defined in the channel. Channel bottom depths are also given at each these eight points and are included in the channel definition.

Current data were modeled by Resource Management Associates (RMA). The modeling techniques used by RMA are covered in King and Rachiele.[1]

Both ebb and flood tides were used for outbound runs. Time limitations on testing allowed for only one tide condition to be tested on inbound runs. Based on conversations with the pilots, flood tides were chosen as the current condition for inbound runs because they presented the "worst case scenario". After completing their required tests, a few pilots had time to run slack tide for inbound or outbound. The slack tide tests were conducted in order to test the effects of fresh water inflow as the dominant source of current. These slack tide currents, while less in magnitude than the ebb tide, had different current

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[1] Ian P. King and Richard R. Rachiele. (1988). "Simulation of the Sacramento River Deep Water Channel," RMA 8801, prepared by Resource Management Associates, Lafayette, CA, for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

patterns that were dampened out when combined with strong tidal driven currents.

Test Ship

The ship data base consists of the ship characteristics and coefficients used in the hydrodynamic program for calculating forces on the bulk carrier used in the testing program. In addition, the bow of the ship would also be seen in the visual scene by the pilot from the ship bridge. Therefore, a visual image of the ship bow had to be created.

The design ship used in the simulation was the Asian Banner which was 610 ft long, has a 93-ft beam and was loaded to a 30-ft draft with 2-ft underkeel clearance for the existing condition and to 35-ft draft with 2-ft underkeel clearance for the proposed channel. A description of the ship model is included in Ankudinov.[1]

Wind

The wind data was supplied by the San Francisco Bar Pilots association. The predominate wind was determined to be from the southwest direction. A wind magnitude of 30 knots was used for all navigation tests. Winds of this magnitude occur frequently during the summer. The simulated wind does not gust and is assumed to be at a constant magnitude and direction throughout the study area.

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[1] V Ankudinov (1988) "Hydrodynamic and mathematical models for ship maneuvering simulation of the bulk carrier *Asian Banner* in deep and shallow waters, and bank effects module in support of WES Sacramento Channel Study," Technical Report 87005.02-1, prepared under Contract No. DACW39-87-D-0029 by Tracor Hydronautics, Inc., Laurel, MD, for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

3 Navigation Study

Validation

Validation of the simulation was conducted over a four day period with the assistance of a pilot from the San Fransico Bar Pilots Association. The following information is verified and fine tuned during validation.

a. The channel definition.

(1) bank conditions.

(2) currents.

b. Wind forces.

c. The visual scene and radar image of the study area.

(1) Location of all aids to navigation.

(2) Location and orientation of the Rio Vista Bridge.

(3) Location and orientation of the Ryer Island Ferry.

(4) Location of buildings visible from vessel.

The vessel model in unrestricted still water had been validated previously during the phase I study, ref 1.

To validate the reaction of the vessel to bank forces, several simulation runs were made with the vessel transiting the entire study area. Special attention was given by the pilot to the response of the ship to the bank forces. Problem areas were isolated, and the prototype data for these areas was examined. The values for the overbank depth, the side slope, or the bank force coefficient were then adjusted. Simulation runs were then undertaken through the problem areas, and if necessary, further adjustment was made. This process was repeated until the pilot was satisfied that the simulator response to the bank force was similar to that of an actual vessel passing through the same reach in the prototype

The reaction of the vessel to current forces was verified by conducting several simulation runs over the entire study area. The pilot was instructed to pay attention to the current effects. The pilot was satisfied that the vessel response to the currents was similar to responses he had experienced in real life.

To validate the reaction of the vessel to wind force, several simulation runs were undertaken with the pilot paying special attention to the reaction of the vessel to the wind. The wind drag coefficient was adjusted until the pilot was satisfied.

A check of the visual scene and radar image of the study area occurred during validation of the other parameters. If the pilot noticed something missing or misplaced, this was checked against prototype information and corrected.

Test Conditions

The study consisted of two test cases. The first case was the base condition. The base condition was the existing authorized 30-ft channel. The second case was the plan, or the 35-ft channel deepened where necessary, but not widened.

The testing schedule for the investigation consisted of the following channel-tide-wind-heading conditions.

Outbound Runs:

- Existing 30-ft channel, ebb tide, no wind.
- Proposed 35-ft channel, ebb tide, no wind.
- Existing 30-ft channel, ebb tide, wind.
- Proposed 35-ft channel, ebb tide, wind.
- Existing 30-ft channel, flood tide, no wind.
- Proposed 35-ft channel, flood tide, no wind.
- Existing 30-ft channel, flood tide, wind.
- Proposed 35-ft channel, flood tide, wind.
- Existing 30-ft channel, slack tide, no wind.[1]
- Proposed 35-ft channel, slack tide, no wind.[1]

Inbound Runs:

- Existing 30-ft channel, flood tide, no wind.
- Proposed 35-ft channel, flood tide, no wind.
- Existing 30-ft channel, flood tide, wind.[1]

[1] These runs were conducted only on a "time available" basis after the pilot had finished his required runs.

Proposed 35-ft channel, flood tide, wind.[1]
Proposed 35-ft channel, slack tide, no wind.[1]

Six pilots participated in the testing program. All pilots were members of the San Fransico Bar Pilots Association and were familiar with piloting in the study area. The pilots came to WES in pairs for testing. The pilots alternated test runs to avoid fatigue.

Prior to collecting the data from the actual test runs, a daily familiarization trial run was required from each of the pilots. These warm-up runs are not included in test analysis.

To avoid prejudicing the statistical analysis performed on the data collected, the test conditions were not given in the same order for each pilot. The random order of testing was necessary because results from the last tests conducted may show better maneuverability only because the pilot is more familiar with the simulator.

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

The simulator tests were evaluated based on pilot ratings, ship tracks and statistical analysis of various ship control parameters recorded during testing. The following section will discuss these three methods of analysis.

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[1] These runs were conducted only on a "time available" basis after the pilot had finished his required runs.

4 Study Results

Pilots' Ratings

To determine what the pilots thought about the simulator and the proposed channel deepening, two questionnaires were prepared to document their comments and rate the runs. One was given to the pilots after each run and a final debriefing questionnaire was given after each pilot had completed his entire testing program. Pilots were asked to provide ratings for three areas in the simulation (Figure 5). Area A was from mile 20, in the Sacramento River Deep Water Ship Channel, to mile 15 just north of the Ryer Island Ferry. Area B was from mile 15 through the junction of Cache Slough, Steamboat Slough, and the Sacramento River to north of the Rio Vista Bridge. Area C was from north of the bridge to mile 11.5. Analysis of the runs conducted on a "time available" basis has been omitted due to the small sample size.

Area A

A plot of the pilots' ratings for Area A (Figure 6) shows that the pilots considered the proposed 35-ft channel to be an "easier" run than the existing 30-ft channel for outbound runs with ebb tide, with or without wind. The pilots rated all four factors—difficulty, attention required, danger of grounding, and danger of hitting an object—lower for the proposed 35-ft channel. For an outbound run with flood tide and no wind, the pilots rated the existing 30-ft channel as safer than the proposed 35-ft channel in all four categories. For the outbound runs with flood tide and wind, the pilots rated the proposed channel as being safer than the existing channel. For this condition, the pilots stated that the existing channel required slightly more attention, with more of a danger of grounding or of hitting an object than the proposed channel. The pilots felt that the inbound run with flood tide and no wind was more difficult for the proposed channel than the existing channel.

Area B

A plot of the pilots' ratings for Area B (Figure 7) shows that the pilots preferred the proposed 35-ft channel to the existing 30-ft channel for outbound runs with ebb tide, with or without wind. For the no wind run the pilots rated the proposed channel and the existing channel as almost equal for attention required and danger of grounding, but rated the proposed channel as less difficult and having less of a danger of hitting an object. For the runs with wind, the pilots rated all four factors—difficulty, attention required, danger of grounding, and danger of hitting—as considerably lower for the proposed 35-ft channel. For an outbound run with flood tide and no wind, the pilots rated the proposed 35-ft channel as being more difficult than the existing 30-ft channel in all four categories. For the outbound run with flood tide and wind, the pilots rated both channels as being equal in the amount of attention required, but rated the existing channel as being slightly more difficult, with more of a danger of grounding or of hitting an object than the proposed channel. The pilots felt that the inbound run with flood tide and no wind was more difficult for the proposed channel than the existing channel.

Area C

A plot of the pilots' ratings for Area C (Figure 8) shows that the pilots rated the proposed 35-ft channel and the existing 30-ft channel as almost equal for outbound runs with ebb tide without wind. For the no wind run the pilots rated the proposed channel and the existing channel as almost equal for attention required and danger of grounding, and rated the proposed channel as less difficult and with less of a danger of hitting an object. For the runs with wind, the pilots rated all four factors—difficulty, attention required, danger of grounding, and danger of hitting—as considerably lower for the proposed 35-ft channel. For an outbound run with flood tide and no wind, the pilots rated the proposed 35-ft channel as being more difficult, requiring more attention, and having a greater danger of grounding than the existing 30-ft channel. Both channels were rated as equal for the danger of hitting an object. For the outbound run with flood tide and wind, the pilots rated both channels as being equal in the danger of grounding but rated the existing channel as being slightly more difficult, but rated the proposed channel as requiring more attention but having less danger of hitting an object. The pilots rated the inbound run with flood tide and no wind as being equally difficult for both the proposed and existing channel, but rated the proposed channel as requiring more attention and having a greater danger of grounding and hitting an object.

Final Questionnaire

After completing all test runs, each pilot 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 are included with this report.

How will deepening the channel affect ship maneuverability and safety?
"It will be a lot easier on making turns and giving us more room in case of bank suction."

"I could not detect any change in effects on the vessel in the deepened channel. However, my experience in the Stockton Channel leads me to believe that deeper vessels in a deeper channel are more sluggish."

"I don't think it will make any difference."

"This would increase safety, even for lighter ships, because there would be more water in the channel, providing for a higher ratio of available water to ship displacement. This would lessen the bank and bottom suction effects on all vessels. There appears to be little additional difficulty in navigating ships at the deeper 35' draft."

"If the ration of underkeel clearance to vessel's draft is increased then maneuverability is increased. If maneuverability is increased, so is safety."

"I would not expect - with increased depth and increased draft - that maneuverability and safety would be greatly different from what they are now. Assuming 250' on the turns at the entrance to the canal, and another 50' increase immediately west of the Rio Vista Bridge."

Is there any difference in the bank force between the existing and the 35' channel?

"I tried on all runs to stay in the proposed channel and did not feel any difference in the bank force."

"I could not detect any. However, in reality, I believe there would be."

"Some"

"In theory, 30' deep channel and 30' draft vessels would experience less bank effect that 35' deep channel and 35' draft vessels."

"I would expect the bank cushion and bank suction forces to increase with the deepening of the channel."

Is there any difference in the effect of the current between the existing and the 35' channel?

"No"

"Current effects were greater with the deeper vessels in the deeper channel."

"Somewhat more"

"There seemed to be no additional adverse effects with current in a 35' channel."

"I could not feel much difference."

"With the movement of more water through the 35 ft channel, I would expect the current to be a little stronger."

Do you have any concerns about a ship with a draft deeper than 30' navigating the deepened (35') channel?

"No. At the present we are taking drafts of 32', but are using the high tides."

"It is my experience with deeper draft vessels in Stockton that there is a reduction in the responsiveness, and deeper vessels are more sluggish."

"No"

"I don't think there would be any major problems bringing 35' draft ships up or down the channel."

"I feel that vessels of 35' draft could safely transit the 35' channel if the channel was widened from BKN 49B to one mile above LT 51 and if the 31' spit just below LT43 (on NOAA chart) was removed."

"No, providing deeper drafts than 32 ft can be taken step by step."

Composite Ship Track Plots

A complete set of the composite ship track plots for the two channel test conditions is presented at the end of this report on Plates 1-76. The model area was divided into 5 areas for the purpose of plotting and studying the tracklines (Figure 9). When plotted, each area overlaps its adjacent areas. For all track plots included in this report, as well as the discussion of those track plots, aids-to-navigation will be referred to as follows:

G-11 = green light number 11
R-12 = red light number 12
C-13 = can buoy number 13
N-14 = nun buoy number 14

Area A is the beginning of outbound runs, and the end of inbound runs. This area is defined as beginning between G-53 and R-54 and ending just downstream of G-51 and R-52 (Figure 10). Although the actual run began upstream of lights G-53 and R-54, data was not collected prior to this point. This is to allow the pilots to gain complete control of the vessel before data collection. This area mainly serves as an approach to Area B for outbound runs. Area B extends from 2000 ft north of G-51 and R-52 to just south of G-45 and R-46 (Figure 11). This area includes the junction of the Ship Channel, Yolo-Bypass Cache Slough and Miner Slough. Area C is defined as the area from between G-45 and R-46 at end of Area B to approximately 1500 ft north of the Ryer Island ferry (Figure 12). Area D extends from 2000 ft north of the Ryer Island Ferry to 1000 ft north of R-36 (Figure 13). Area E is defined as beginning about 3000 ft north of R-36 to about 1000 ft south of R-28 (Figure 14).

Outbound Runs - Flood Tide - Without Wind

Track plots for outbound runs, flood tide, without wind, for both existing and proposed channels are shown in Plates 1-10. Examination of the track plots for Area A, Plates 1 and 6, reveals that once the pilot gained control of the vessel to start their run, they experienced no problems until leaving the man-made channel at G-49A in Area B, Plates 2 and 7. The pilots transited this reach by swinging their vessels west immediately after leaving the man-made channel south of G-49A. This tactic is acceptable under existing conditions because the 30-ft contour line shows that the water is deeper than 30 ft in this area, even through it is outside the authorized and maintained channel. However, the 35-ft contour line shows that the ships would have grounded into the shoal area south of Cache Slough. The track plots from G-49 to the end of Area B, show the runs for the 35-ft channel are more consistent and stayed within the defined channel better than the runs for the 30-ft channel. The exception to this occurred when one pilot of a 35-ft draft ship left the channel to the west between G-49 and G-47. After completing his run, the pilot stated that he had done this out of curiosity as to the bank forces in this reach.That portion of his run will have to be ignored since he was performing in an unrealistic manner.

Track plots of Area C, Plates 3 and 8, show that the runs for the deeper draft ship are more tightly grouped and nearer the defined channel than those of the 30-ft draft ship. Due to the deep water on the eastern side of the channel, none of the runs came close to grounding even through the ships went beyond the authorized channel. Use of this deep water reflects current piloting practices.

Track plots of Area D, Plates 4 and 9, show the runs coming together north of R-40 in order to pass through the Ryer Island Ferry slip. After passing the ferry, all runs took a set to the east at G-39. Most of the runs left the authorized channel for the both existing and proposed conditions and grounded in the shoal area just north of the mouth of Steamboat Slough. After this grounding, pilots of the 30-ft draft ships were able to keep their vessels in deep water (greater than 30 ft) for the rest of Area D, and all were within the defined channel at the end of the area. Although the deeper draft ships followed very closely the track lines of the 30-ft draft ships, the deeper draft caused the vessels to ground on the east side of the channel across from G-37, as well as south of G-39. All runs were within the defined channel at the end of the area. It should be noted that there are no aids-to-navigation to mark the east edge of the channel or the shoals at Steamboat Slough or the Sacramento River. This will effect all test results in this study.

Track plots of Area E, Plates 5 and 10, are nearly identical for both existing and proposed channel conditions. All runs passed through the center of the bridge and left the channel on the east side near R-28.

Outbound Runs - Flood Tide - With Wind

Track plots for outbound runs, flood tide, with wind, for both existing and proposed channels are shown in Plates 11-20. Examination of these plots for Area A, Plates 11 and 16, reveals that once the pilot gained control of the vessel to start their run, the lighter draft vessels were pushed to the eastern channel edge by the strong wind from the South-West. The deeper draft ships, having less freeboard, were able to stay within the channel limits in Area A.

Examination of the track plots for Area B, Plates 12 and 17, shows that the runs left the channel south of G-49A by a lesser amount than those tests conducted without wind. However, several runs of the 35-ft draft ship clipped the shoal area at the mouth of Cache Slough. For the remainder of the run through Area B, the deeper draft runs were more tightly grouped and less effected by the wind that the runs of the 30-ft draft ships. Some of the lighter vessels left the authorized channel north of R-46, but still stayed within the 30-ft contour lines.

Track plots for Area C, Plates 13 and 18, show the pilots using the deep water between R-44 and R-42. The pilots of the lighter ship were more affected by the wind and were inconsistent in getting back into the authorized channel at the end of Area C.

The track plots for Area D, Plates 14 and 19, show the lighter draft ships were not in as good a position to pass through the ferry has they had been for the no wind condition. There were near groundings below R-40 for some of these cases. After passing through the ferry, the 35-ft draft ships once again had a problem with the shoals near Steamboat Slough and the Sacramento River junction.

Track plots of Area E, Plates 15 and 20, are nearly identical for both existing and proposed channel conditions. All runs passed through the center of the bridge and left the channel on the east side near R-28.

Outbound Runs - Ebb Tide - Without Wind

Track plots for outbound runs, ebb tide, without wind, for both existing and proposed channels are shown in Plates 21-30. Examination of these plots for Areas A and B, Plates 21, 22, 25, and 26, reveals that once the pilot gained control of the vessel to start their run, they experienced no problems until leaving the man-made channel at G-49A in Area B. As in tests conducted with flood tide, the pilots transited this reach by swinging their vessels west immediately after leaving the man-made channel south of G-49A. Although some of the runs left the authorized and maintained channel in doing so, both the deeper and lighter draft vessels were able to stay in water deep enough to avoid grounding. For the remainder of the run through Area B, runs for the 35-ft draft ship were more consistent and were better able to stay within the channel. Although several of the runs for the 30-ft draft ship stayed out of the western edge of the channel until G-47, none of these runs came close to an actual grounding. This is a normal operating practice.

The track plots for Area C, Plates 23 and 27, show the pilots using the deep water on the eastern side of the channel as usual. One run for the 35-ft draft ship went between 200 and 300 ft further east than the other runs, but was still able to stay between to 35-ft contours. Normal piloting practice seems to be to operate outside the authorized and maintained channel.

The track plots for Area D, Plates 24 and 28, show the runs for the deeper draft vessels begin more tightly grouped than those for the 30-ft draft ships. Both the 30- and the 35-ft draft ships grounded on the shoal near the mouth of Steamboat Slough. As in test conditions previously discussed, the 35-ft draft ship grounded on the shoal across from G-37 at the junction of the Sacramento River.

Track plots for Area E, Plates 25 and 29, show the runs not grouped as tightly as those runs for the flood tide. Several runs for both 30- and 35-ft draft ships grounded across from R-36. All runs safely transited the bridge, but several pilots had problems making the turn between R-28 and G-29 for both the existing and proposed conditions.

Outbound Runs - Ebb Tide - With Wind

Track plots for outbound runs, ebb tide, with wind, for both existing and proposed channels are shown on Plates 31-41. During the runs in Area A, Plates 31 and 36, pilots of both 30- and 35-ft draft vessels were set to the east by the wind. By examining the track plots, it appears that the pilots of the deeper draft ships suffered more of a set than those of the 30-ft draft ship. However, the plots are deceiving and this is not so. One pilot got out of position in the channel and had a very difficult time getting back against the wind. If his run is omitted, Plate 37, the remainder of the runs show that the deeper draft vessels were less affected by the wind than the lighter draft ships.

Examination of the track plots for Area B, Plates 32 and 38, shows that the pilots were unable to go west of the channel south of G-49A due to the wind forces acting on the ship. The 30-ft draft ships were pushed out of the channel on the west side near R-48, but they did not come close to the 30-ft contour. If the run for the pilot mentioned in the discussion for Area A is ignored, the 35-ft draft vessel runs were consistently less affected by the wind than the 30-ft draft ships. The pilot who got out of position, had his ship back in the channel prior to the end of Area B.

Track plots for Area C, Plates 33 and 39, show the pilots using the deep water throughout reach for both the 30- and the 35-ft draft ships. One 35-ft draft ship came close to leaving the channel on the west side north of G-43. The runs of the lighter ships had problems on the east side of the channel near and south of R-42. One 30-ft draft ship grounded in this reach.

The track plots for Area D, Plates 34 and 40, show that both draft ships came much closer to R-40 for the tests conducted with wind than they did for those without wind. Since the ships were already further to the west going through the ferry, both draft ships had runs which grounded on the shoal near the mouth of Steamboat Slough. The 35-ft draft ship, as in previous conditions, had groundings at the shoal near the mouth of the Sacramento River junction and across from G-37.

Track plots of Area E, Plates 35 and 41, show the runs of the 30-ft draft ships leaving the channel on both sides near R-36. The 35-ft vessel runs managed to stay within the channel on the west side. However, one of the runs consistently stayed out of the channel on the east side from the beginning of the area up until the bridge. None of the runs struck the bridge.

Outbound Runs - Slack Tide - Without Wind

Track plots for outbound runs, slack tide, without wind, for both existing and proposed channels are shown in Plates 42-51. Examination of these plots for Areas A and B, Plates 42, 43, 47 and 48, reveals that once the pilot gained control of the vessel to start the run, they experienced no problems until leaving the man-made channel at G-49A in Area B.

Track plots for Area C, Plates 44 and 49, show the pilots using the deep water between R-44 and R-42 for both the 30- and the 35-ft draft ships. None of the runs came close to grounding in this reach.

The track plots for Area D, Plates 45 and 50, show that both draft ships left the defined channel and entered the shoal area near the mouth of Steamboat Slough. The 35-ft draft ship suffered more of a set to the west than did the 30-ft draft ship. The 35-ft draft ship grounded on the shoal near the mouth of the Sacramento River junction. The lighter draft ship, although out of the channel in this area, did not ground.

Track plots of Area E, Plates 46 and 51, show both draft ships being in the center of the channel by R-36. After passing through the bridge, the 30-ft draft ships made the final turn too soon and grounded near R-28. The deeper draft ships, although on the east side of the defined channel, did not ground.

Inbound Runs - Flood Tide - Without Wind

In order that the discussion will follow the direction of the transit, track plots for all inbound runs will be shown in reverse order of areas, starting with Area E.

Track plots for inbound runs, flood tide, without wind, for both existing and proposed channels are shown in Plates 52-61. Examination of these runs for Area E, Plates 52 and 57, reveals that the pilots started the run on the east side of the channel south of R-28. This starting point was chosen after consultation with the pilots. The pilots stated that at this point they would be hugging the east side of the channel in preparation for the turn into the bridge. Runs for both 30- and 35-ft draft ships left the channel on the west side north of G-29 and grounded.

Track plots for Area D, Plates 53 and 58, show the inbound runs grounding on the same shoal areas as the outbound runs. The main problem areas were the shoals near the mouths of the Sacramento River and Steamboat Slough. As with the outbound runs, a portion of the shoal at the mouth of the Sacramento River had more than 30 ft of water over it, but less than 35 ft. Therefore, the deeper draft ships had more of a problem in this reach.

Examination of track plots for Area C, Plates 54 and 59, reveals that as with the outbound runs, the pilots utilized the deep water on the east side of the channel. All of the runs for the 30-ft draft ships stayed within the 30-ft contour. The runs of the 35-ft vessels also used the deep water to the east. There were no problems except for one pilot who swung west too early, and grounded opposite R- 44.

The track plots for Area B and A, Plates 55, 56, 60 and 61, show that runs for both existing and proposed conditions left the west edge of the defined channel north of G-45. Runs for both 30- and 35-ft draft ships stayed within their respective contours and did not ground in this reach. Just north of G-49, the pilots begin their approach to the man-made canal by swinging their ships west near the entrance to Cache Slough. The 30-ft vessels made it through Cache Slough, but grounded near G-49A. Several of the 35-ft draft vessels grounded on the shoal in Cache Slough as well as grounding near G- 49A. The pilots had better control of the 35-ft ship than of the 30-ft ship, after entering the man-made canal. Track plots of the lighter vessel show the pilots weaving back and forth after entering the canal.

Inbound Runs - Flood Tide - With Wind

Track plots for inbound runs, flood tide, with wind, for both existing and proposed channels are shown in Plates 62-71. Examination of the track plots for Area E, Plates 62 and 67, reveals that the pilots were able to stay within the defined channel through the bridge. Near R-36, one of the deeper draft ships left the defined channel on the east side, and grounded. One of the lighter ships also left the channel on the east side. However, this occurred further north than the 35-ft ship and the pilot was able to stay within the 30-ft contour.

Track plots for Area D, Plates 63 and 68, show the same problem areas as before. The lighter vessel only had one grounding incident, near R-36A. The deeper draft ships had a grounding near R-36A and near the mouths of the Sacramento River and Steamboat Slough.

Area C, Plates 64 and 69, was free of incident for both 30- and 35-ft draft ships; although the normal practice of operating outside the authorized channel continued.

Track plots for Area B, Plates 65 and 70, show that there were no groundings for the lighter ship. The 35-ft draft ships again grounded in the Cache Slough shoal and near G-49A.

After entering the man-made canal in Area A, Plates 66 and 71, the pilots had better control over the deeper draft ships.

Inbound Runs - Slack Tide - Without Wind

Track plots for inbound runs, slack tide, without wind, for the proposed channel only are shown in Plates 72-76. All runs under this condition were able to stay within the defined channel throughout Area E. Only one run of this condition was conducted.

As in the previously discussed runs, the ships grounded near the mouths of the Sacramento River and Steamboat Slough. Throughout Area C, Plate 74, this run managed to stay very close to the authorized channel limits. Plots of Area B, Plate 75, show a smooth trackline as the vessels swung to the west edge of the channel near 49. After entering the defined channel, this run experienced no problems.

Statistical Analysis

During each run, the control, positioning, and orientation parameters of the ship were recorded every 10 seconds. These parameters included position, speed, revolutions per minute (rpm) of the propeller, rudder angle, rate of turn, heading, drift angle, and port and starboard clearances. Since the simulator performances of nearly 70 percent of the active pilots handling ships on the Sacramento channel were recorded during the testing, it was decided that statistical analysis could be based on parameter means rather than concentration on individual runs.

Due to the small sample size of inbound runs with wind and all slack tide runs, these test conditions are omitted from statistical analysis.

All statistical parameters are plotted against distance along track. The distance along track is calculated by projecting the position of the ship center of gravity perpendicularly to the centerline of the channel. The distance along track is measured from the beginning of the centerline. For this study, plots of the centerline, as well as the distance from the beginning of the centerline are shown in Figures 10-14.

For all parameters except clearance, the statistical analysis is presented as a mean of means within a sample channel section. A 500 foot channel section was used. This means that for each individual run each parameter was averaged over 500 ft, and that these means were averaged over all runs under a given condition, thus a mean of the means. The standard deviation of the means was calculated for each run, and these standard deviations were averaged over all runs under a given condition.

Statistical analysis of clearance is presented as a mean of the minimum during a sample channel section. This means that the minimum clearance for port and starboard is found for each channel section of each run. These minimums are then averaged over all runs for each test condition.

Due to the fact that deep water was available for the pilot's use well out of the defined channel, clearance values were not calculated to the channel edge, but to the edge of navigable water. Therefore, clearances for the existing 30-ft channel were calculated to the 30-ft contour and clearances for the proposed 35-ft channel were calculated to the 35-ft contour.

Outbound Runs - Flood Tide - Without Wind

Statistical parameter plots of outbound runs for flood tide without wind are shown in Plates 77-83.

Minimum port clearance. Examination of the port clearance plot (Plate 77) shows two problem areas for the proposed channel. Between the Ryer Island Ferry and light 37 the mean minimums go negative twice. This is in the vicinity of the Steamboat Slough and Sacramento River Junction. The sharp jump between the two areas of groundings reflects the shape of the contour lines in this area. The existing runs show a positive mean minimum for the entire run because of the difference in the contour lines.

Minimum starboard clearance. The plot of the starboard clearance (Plate 78) shows that although the runs for the proposed channel generally had less clearance than those for the existing channel, there was enough clearance in both channels to allow an adequate margin of safety. Since in the area between Ryer Island and light 37, the starboard clearance is greater than 100 ft there was adequate room of the ship to move to the west and eliminate the negative port clearance noted above.

Rudder angle, RPM, speed, and maneuvering factor. The plot of the mean rudder angle (Plate 79) shows little difference for runs in either channel. What difference there is can be attributed to the heavy ship requiring more rudder to turn. Neither channel condition required anywhere near the maximum rudder available. The plots of the RPM and speed (Plates 80 and 81) show the heavier ship requiring 10 to 15 percent more RPM to move the ship at approximately the same speed as the lighter vessel. The maneuvering factor (Plate 82) shows the same trends as the rudder angle plot. Both 30- and 35-ft draft vessels did not use nearly all the maneuvering capability available.

Drift angle. Examination of the drift angle plot (Plate 83) shows that the 35-ft draft vessels had less drift angle than the 30-ft draft ships after leaving the man-made channel at light 49A until the straight reach south of Ryer Island Ferry at light 37. This shows that the deeper draft ship was able to handle the turns easier.

Outbound Runs - Flood Tide - With Wind

Statistical parameter plots of outbound runs for flood tide with wind are shown in Plates 84-90.

Minimum port clearance. The plot of the port clearance (Plate 84) reveals little difference from that for the outbound - flood tide - with wind condition. Once again there are two problem areas for the proposed channel. between the Ryer Island Ferry and light 37. As for the runs conducted without wind, the difference between port clearance for existing and plan is the difference in the contour lines.

Minimum starboard clearance. The plot of the starboard clearance (Plate 85) shows that although the runs for the proposed channel generally had less clearance than those for the existing channel, there was enough clearance in both channels to allow an adequate safety margin as in the no wind condition.

Rudder angle, RPM, speed, and maneuvering factor. The plot of the mean rudder angle (Plate 86) shows that about twice the rudder was required near light 43 for the 35-ft draft vessel than for the 30-ft draft vessel. However, at no point in the run was more than 50 percent of the rudder required. The plots of the RPM and speed (Plates 87 and 88) show the 35-ft draft ship usually requiring more engine speed than the 30-ft ship, but with not as much difference as for those runs without wind. The maneuvering factor (Plate 89) shows the same trends as the rudder angle plot. Both draft vessels did not use even 40% of the maneuvering available.

Drift angle. The drift angle plot (Plate 90) shows that the 35-ft draft vessels had about half of the drift angle of the 30-ft draft ships. This shows that the deeper draft ship with less freeboard was less affected by the wind.

Outbound Runs - Ebb Tide - Without Wind

Statistical parameter plots of outbound runs for ebb tide without wind are shown in Plates 91-97.

Minimum port clearance. Examination of the port clearance plot (Plate 91) shows that both 30- and 35-ft draft vessels have a negative mean minimum port clearance near the Ryer Island Ferry. The mean minimum is about 60 ft less for the 30-ft draft ship than for the 35-ft draft vessel. The port clearance for the 35-ft draft ship near light 37 is negative.

Minimum starboard clearance. The plot of the starboard clearance (Plate 92) shows that although the runs for the proposed channel generally had less clearance than those for the existing channel, there was enough clearance in both channels to allow an adequate safety margin.

Rudder angle, RPM, speed, and maneuvering factor. Examination of the plot of the mean rudder angle (Plate 93) shows that the 30-ft draft ship required more rudder leaving the man-made channel at light 49A, and the 35-ft draft ship required more rudder between lights 43 and 42. Neither channel condition required anywhere near the maximum rudder available. The plots of the RPM and speed (Plates 94 and 95) show the lighter ship traveling about 1 knot faster for approximately the same RPM as the 35-ft draft vessel. The maneuvering factor (Plate 96) shows the same trends as the rudder angle plot. Both draft vessels did not use nearly all the maneuvering available.

Drift angle. Examination of the drift angle plot (Plate 97) shows that the 35-ft draft vessels had less of a drift angle than the 30-ft draft ships after leaving the man made channel at light 49A until the straight reach south of Ryer Island Ferry at light 37. This shows that the deeper draft ship was able to handle the turns easier.

Outbound Runs - Ebb Tide - With Wind

Statistical parameter plots of outbound runs for ebb tide with wind are shown in Plates 98-104.

Minimum port clearance. The port clearance plot (Plate 98) shows that the 35-ft draft vessel has a negative mean minimum port clearance and the 30-ft draft vessel has a zero mean minimum port clearance, near the Ryer Island Ferry. There is zero port clearance for the 35-ft draft ship near light 37.

Minimum starboard clearance. The plot of the starboard clearance (Plate 99) shows that although the runs for the proposed channel generally had less clearance than those for the existing channel, there was enough clearance in both channels to allow an adequate margin of safety.

Rudder angle, RPM, speed, and maneuvering factor. Examination of the plot of the mean rudder angle (Plate 100) reveals little difference in the rudder required for either the 30- or the 35-ft draft vessel, except in the bend near lights 44 and 43. The 35-ft draft vessel used as much a 20 percent left rudder, while the lighter ship used an average 20 percent right rudder. The plots of the RPM and speed (Plates 101 and 102) show the results similar to those runs tested without wind, except that more RPM is required for approximately the same speed. The maneuvering factor (Plate 103) shows the same trends as the rudder angle plot. Neither vessel used more than 20 percent of the available maneuvering capability.

Drift angle. Examination of the drift angle plot (Plate 104) shows that both vessels had more of a problem with the wind while running with the current than they did running against the current (Plate 90). In the critical areas, light 43 to light 40, and near light 37, the 30-ft draft vessels had nearly twice the drift angle of the 35-ft draft ships.

Inbound Runs - Flood Tide - Without Wind

Statistical parameter plots of inbound runs for flood tide without wind are shown in Plates 105-111.

Minimum port clearance. For inbound runs, the port side of the channel is the east side of the channel, the same as the starboard side for outbound runs. The plot of the port clearance (Plate 105) shows that although the runs for the proposed channel generally had less clearance than those for the existing channel, there was enough clearance in both channels to allow an adequate margin of safety.

Minimum starboard clearance. Examination of the starboard clearance plot (Plate 106) shows two problem areas for the proposed channel. Between the Ryer Island Ferry and light 37 the mean minimums go negative in two locations. The existing channel runs show a positive mean minimum for the entire run because of the difference in the effective channel.

Rudder angle, RPM, speed, and maneuvering factor. Examination of the plot of the mean rudder angle (Plate 107) reveals the pilots used approximately the same rudder for runs in either channel until near light 49 when they get ready to enter the man-made ship channel. The deeper draft ship required less rudder than the lighter ship to line up to enter the channel, and to stabilize after entering the channel. Neither channel condition required anywhere near the maximum rudder available. The plots of the RPM and speed (Plates 108 and 109) show the heavier ship requiring either the same or up to 15 percent more RPM to move the ship at a slower speed than the lighter vessel. The maneuvering factor (Plate 110) shows the same trends as the rudder angle plot. Both draft vessels did not use nearly all the maneuvering capability available.

Drift angle. Examination of the drift angle plot (Plate 111) shows that neither the 30- or 35-ft draft ship had much of a drift angle until after light 37. For the remainder of the run, the 35-ft draft vessels had less of a drift angle than the 30-ft draft ships. This shows that the deeper draft ship was able to handle the turns easier.

New Buoy Location Testing

Preliminary results, based primarily on ship track plots and pilot ratings, showed that the primary problem with transiting this reach with 35-ft draft ships was that the pilots are not currently restricting their 30-ft draft ships to the authorized channel. There are numerous areas where this tactic is acceptable for both draft ships in that there is adequate water depth available to avoid grounding. However, several areas have shoals where water depths are between 30 and 35 ft. Bringing a 35-ft draft ship into these areas will result in groundings. Also, if any of the areas that are used outside the authorized channel shoal, they will become unavailable since the Corps of Engineers does not have any authority to dredge these areas.

Widening the channel in some of these areas would be a very expensive undertaking. Also, it was not known if the ships had to leave the defined channel in these areas because of navigation conditions (current, wind, bank forces, etc.) or if it was just due to currently accepted ship handling practices through this reach due to the amount of deep water out of the defined channel and a lack of adequate marking of the areas shallower than the channel depth. It was decided to conduct an abbreviated testing program with several existing buoys relocated, and new buoys added to the test area. This was done in order to see that if by better defining the channel limits and by changing the pilot strategy to minimize the use of areas outside the defined channel, could the pilot keep his vessel in the defined channel. The radar and visual scene data-bases were modified to reflect these new aids-to-navigation.

The new buoy locations were supplied by SPK and were chosen after consultations between WES, SPK, the San Francisco Bar Pilots Association, and the local Coast Guard district office. The new buoy locations are show in Figure 15. Buoys R-36 and R-36A were moved closer to the edge of the channel and north. This was done to help the pilot stay within the channel and out of the shoals near the mouths of the Sacramento River and Steamboat Slough. R- 28 was moved to help the pilots remain in the channel following the turn south of the Rio Vista Bridge on outbound runs. Aids 34A and 33 were added to help define the approach to the bridge. The pilots believed that they could stay within the defined channel for the remainder of the test reach using existing aid-to- navigation, provided that they made an effort to do so.

Due to time limitations, and the fact that the pilots' leaving the channel is primarily a problem only for the deeper draft ship, only the proposed channel conditions were tested. All runs for this testing program were conducted with wind conditions.

After completion of the original testing schedule, addition currents were computed by Resource Management Associates for extreme freshwater inflow. This extreme flood produced a flow of 200,000 cfs at Rio Vista with approximately 120,000 cfs coming out of Cache Slough. Runs using a current database from these conditions were also conducted as part of the testing program. The modeling techniques used by RMA are covered in King and Rachiele.[1]

Test Conditions

The testing schedule for the investigation consisted of the following tide-heading conditions.

Outbound Runs:
- Proposed 35-ft channel, flood tide original freshwater inflow.
- Proposed 35-ft channel, ebb tide original freshwater inflow.
- Proposed 35-ft channel, ebb tide with maximum freshwater inflow.
- Proposed 35-ft channel, slack tide with maximum freshwater inflow.

Inbound Runs:
- Proposed 35-ft channel, flood tide original freshwater inflow.
- Proposed 35-ft channel, ebb tide original freshwater inflow.
- Proposed 35-ft channel, ebb tide with maximum freshwater inflow.
- Proposed 35-ft channel, slack tide with maximum freshwater inflow.

The slack tide tests were short runs used only to examine the effects of the vessel encountering the high current velocities coming out of Cache Slough.

Data collection during the simulator run, as well as the pilot rating questionnaire, was performed as in the earlier tests.

Pilot Ratings

Since only one run was made of each condition, results from the pilots ratings are presented in a tabular form. Pilot rating areas are the same as shown in Figure 5.

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[1] Op cit.

Table 2
Sacramento River Deep Water Ship Channel, California
Pilot Ratings

Condition	Area A				Area B				Area C			
	Dif.	Att.	Grd.	Hlt.	Dif.	Att.	Grd.	Hlt.	Dif.	Att.	Grd.	Hlt.
Out flood	7	9	8	5	7	9	8	8	7	6	6	8
Out ebb	6	7	8	5	6	7	8	8	6	6	6	8
Out max ebb	9	9	9	7	9	9	9	9	8	9	7	9
In flood	6	7	8	6	6	7	8	8	6	7	6	8
In ebb	7	7	8	7	8	9	9	7	7	6	8	8
In max ebb	9	8	8	6	9	9	9	7	7	7	8	8

These ratings show that the pilot considered the runs with the high freshwater inflow to be more dangerous than the others.

Composite Ship Track Plots

A complete set of the composite ship track plots for this testing program is presented on Plates 112-137. The areas plotted are the same as those shown in Figure 9.

Outbound Run - Flood Tide - With Wind

Track plots for outbound run, flood tide, with wind, are shown in Plates 112-115. Examination of these plots for Area B, Plate 112, reveals that even though the pilot was attempting to stay within the defined channel, he left the channel on the west side near G-49A and touched the edge of the shoal area there. The pilot re-entered the defined channel near G-49, and was able to stay within its limits for the remainder of the Area B.

Track plots of Area C, Plate 113, show that the pilot left the channel on the east side as all pilots had done in the earlier tests. The western edge of the channel is not well marked in this reach. However, the water is deep enough to navigate through the area.

Track plots of Area D and E, Plates 114 and 115, show the pilot was able to keep his ship within the defined channel from the ferry slip through the remainder of run. The pilot made the final turn in good position.

Outbound Run - Ebb Tide - With Wind

Track plots for the outbound run, ebb tide, with wind, are shown in Plates 116-119. Examination of these plots for Area B, Plate 116, reveals that the pilot was better able to stay within the defined channel after leaving the man-made canal than for the flood condition. The vessel left the channel south of G-49A, but stayed within the 35-ft contour line.

Track plots of Area C, Plate 117, show that the pilot left the channel on the east side as he had done in the outbound flood tide tests.

Track plots of Areas D and e, Plates 118 and 119, show the pilot had more difficulty running with the current than he had for the flood condition. The vessel left the channel on the east side and hit the shoal area near the mouth of Steamboat Slough. After getting back in the defined channel, the pilot was able to utilize the new buoy locations in order keep his ship within the defined channel for the remainder of run. The pilot made the final turn in good position.

Outbound Run - Max Ebb Tide - With Wind

Track plots for the outbound run, ebb tide with high freshwater inflow from Cache Slough, and with wind, are shown in Plates 120-123. Examination of these plots for Area B, Plate 120, reveals that the pilot was able to stay within the defined channel in Area B. This is due to the fact that the high flow out of Cache Slough pushed the vessel east near G-49A.

Track plots of Area C, Plate 121, show that the pilot left the channel on the east side as he had done in the outbound flood tide tests.

Track plots of Areas D and E, Plates 122 and 123, show the vessel left the channel on the east side and hit the shoal area near the mouth of Steamboat Slough. After getting back in the defined channel, the pilot was able to utilize the new buoy locations in order keep his ship within the defined channel for the remainder of run. The pilot made the final turn in good position.

Outbound Run - Slack Tide - With Wind

The track plot for the outbound run, slack tide, with wind, is shown on Plate 124. This plot reveals that even though the vessel left the defined channel near G-49A, the high fresh water flow out of Cache Slough pushed the ship rapidly to the east. The pilot described leaving the man-made channel under this condition as a "wild ride".

Inbound Run - Flood Tide - With Wind

Track plots for the inbound run, flood tide, with wind, are shown in Plates 125-128. Examination of these plots reveals that the pilot was able to stay within the defined channel from the beginning of the run until near G-49A when he swung west into the shoal near the mouth of Cache Slough in an attempt to line up to enter the man-made canal.

Inbound Run - Ebb Tide - With Wind

Track plots for the inbound run, ebb tide, with wind, are shown in Plates 129-132. Examination of these plots for Areas E and D, Plates 129 and 130, reveals that the pilot was able to stay within the defined channel through the Ryer Island Ferry. The vessel came close to the east channel edge just south of the ferry, but managed to stay within the channel.

Track plots of Area C, Plate 131, show that the pilot left the channel on the east edge of the channel.

Track plots for Area B, Plate 132, reveals that the pilot was able to stay within the defined channel. The ship came close to the west edge of the channel near G-49A when he swung west toward the shoal near the mouth of Cache Slough in an attempt to line up to enter the man-made canal, but the ship did not leave the channel.

Inbound Run - Max Ebb Tide - With Wind

Track plots for the inbound run, ebb tide with high freshwater inflow from Cache Slough, with wind, are shown in Plates 133-136. Examination of these plots reveals that the pilot left the defined channel and hit the shoal area near the mouth of Steamboat Slough. The vessel crossed to the west side of the channel after passing between the ferry slips. The pilot managed to stay within the defined channel for the remainder of test reach, although he apparently experienced some control difficulties as he approached the junction with the man-made channel.

Inbound Run - Slack Tide - With Wind

The track plot for the inbound run, slack tide with high freshwater inflow, and with wind, are shown on Plate 137. This plot shows that the pilot was bringing the vessel to the west in order to enter the man-made canal when the vessel was hit by the strong cross currents out of Cache Slough. Upon entering the man-made channel, the vessel swung to either side of the channel as the pilot fought to bring it back under control.

5 Recommendations

Based on the results of the simulation study we recommend widening the authorized channel in two different problem areas. The first area of recommended widening is junction of Cache Slough, Miner Slough, and the man-made Ship Channel. This widening between navigation aids G-49 and G-49A is shown on Figure 16. This 300-ft widener will aid in providing safe navigation of the entrance to the man-made Ship Channel for both inbound and outbound runs. Outbound transits will be aided by not requiring the pilots to begin the turn to the east while the vessel is still in the man-made Ship Channel. The widener will allow inbound transits to swing west, north of G-49, and enter the man-made ship channel on a straight course. Pilots are currently able to do both of these maneuvers in the existing 30-ft channel, would not be able to do so in the 35-ft channel.

The second area of recommended widening is south of Ryer Island Ferry. This widening is necessary to remove the shoal at the mouth of Steamboat Slough, Figure 17. This will provide safe navigation for both inbound and outbound transits and will allow the pilots to continue the ship-handling techniques that are currently being used in the 30-ft channel.

In addition to the two areas of widening, a new authorized channel definition might be considered in the reach previously defined as simulation test Area C. For nearly all test conditions, the pilots left the defined channel in the Cache Slough Reach from the mouth of Miner Slough to the ferry. This is due to the operation practices of the local pilots, who realize that the water outside of the defined channel is deep enough for safe navigation. Despite a conscious effort to stay within the defined channel in this reach, the test pilot often left the defined channel. This is not a difficult reach to navigate, and the pilots always had additional maneuvering capability available in this reach during simulation testing. It is not necessary to widen this area, but if possible, the channel might be redefined to ensure that the deep water outside of the presently authorized channel will always be available. This proposed new channel definition is shown on Figure 18. These new channel limits will require little if any dredging.

It is also recommended that the added and relocated aids-to-navigation scheme, as shown in Figure 15, be included in the project.

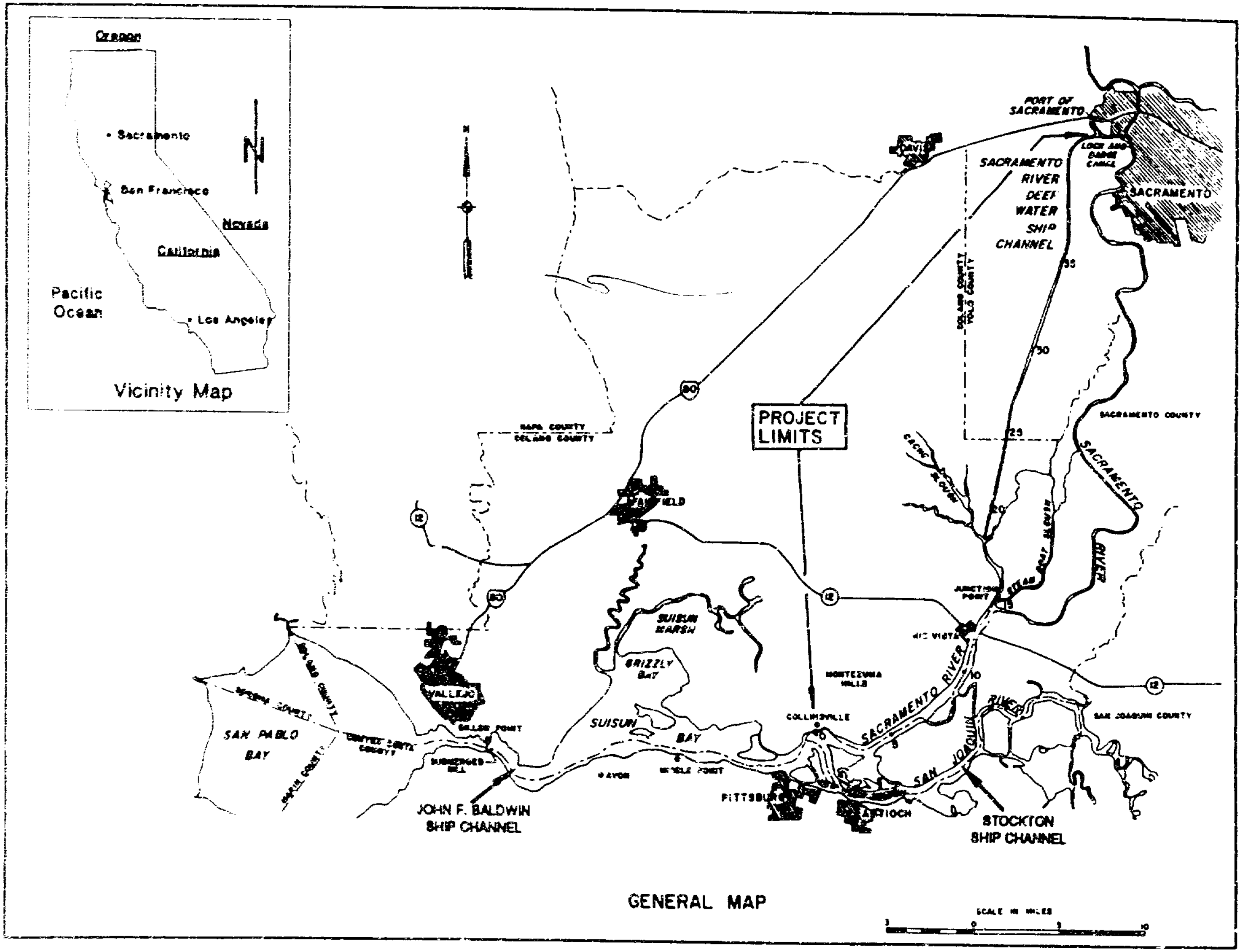


Figure 1. Project location, Sacramento River Deepwater Ship Channel

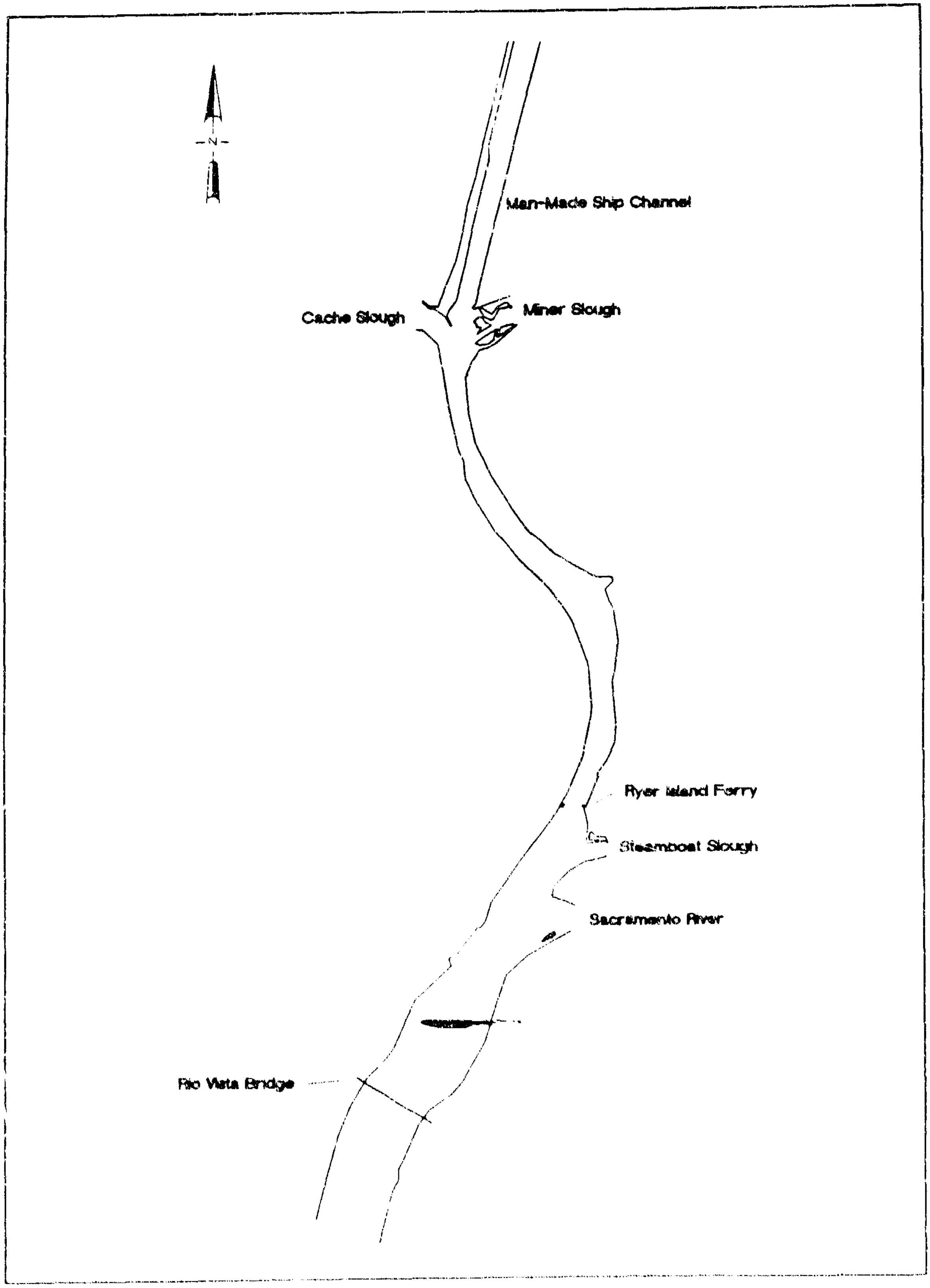


Figure 2. Simulation limits

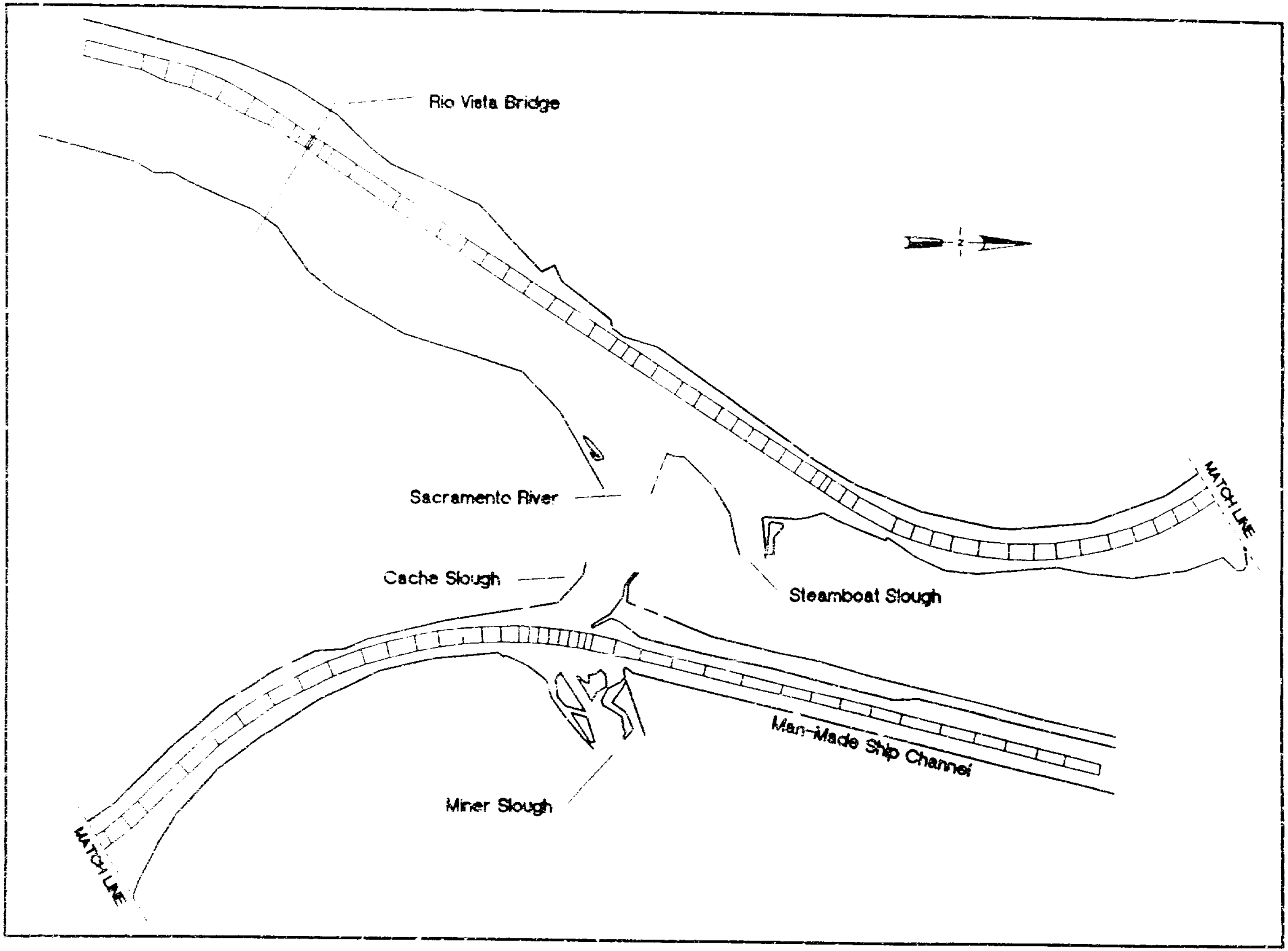


Figure 3. Cross-section layout

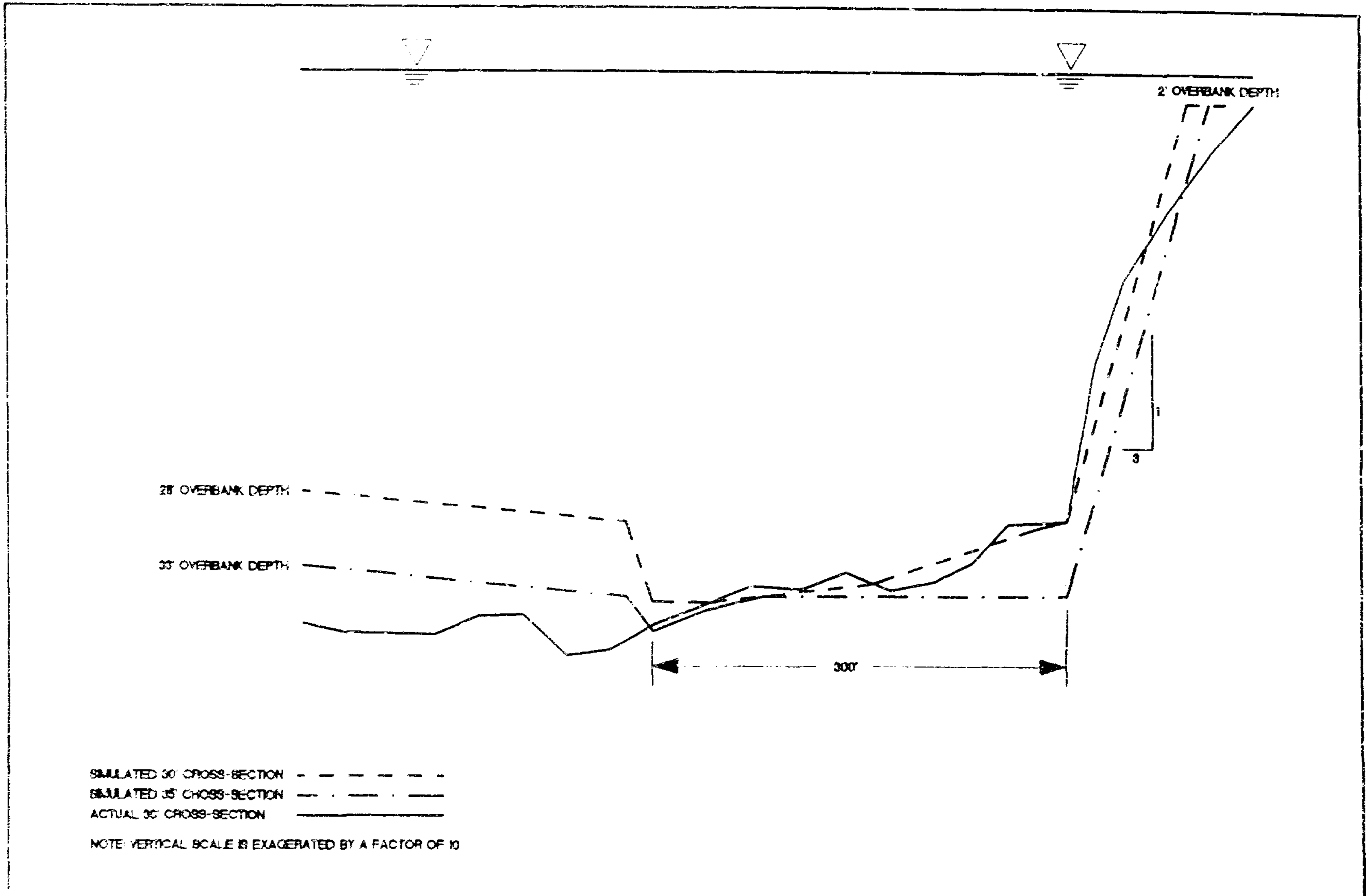


Figure 4. Typical cross section

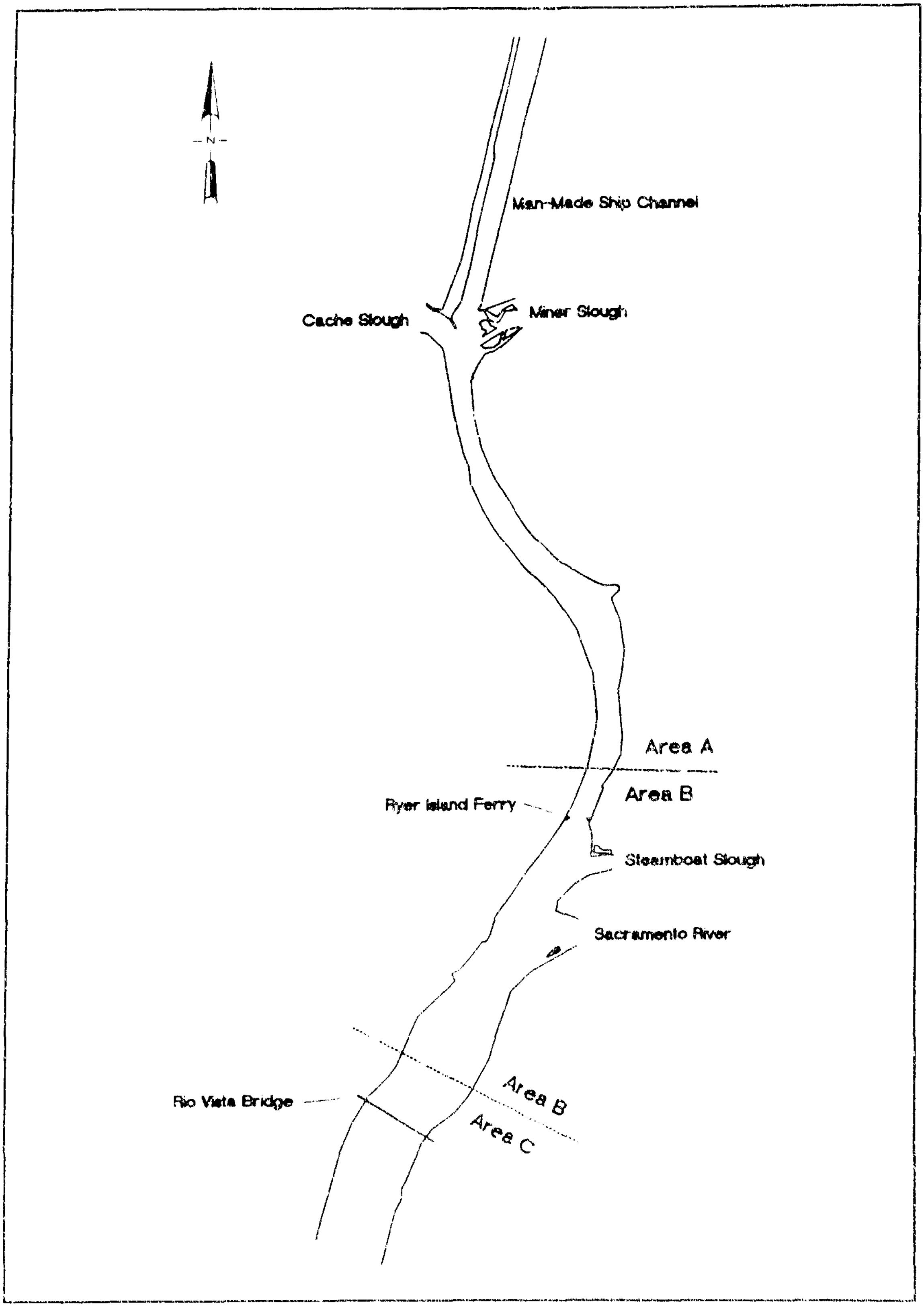


Figure 5. Pilot rating areas

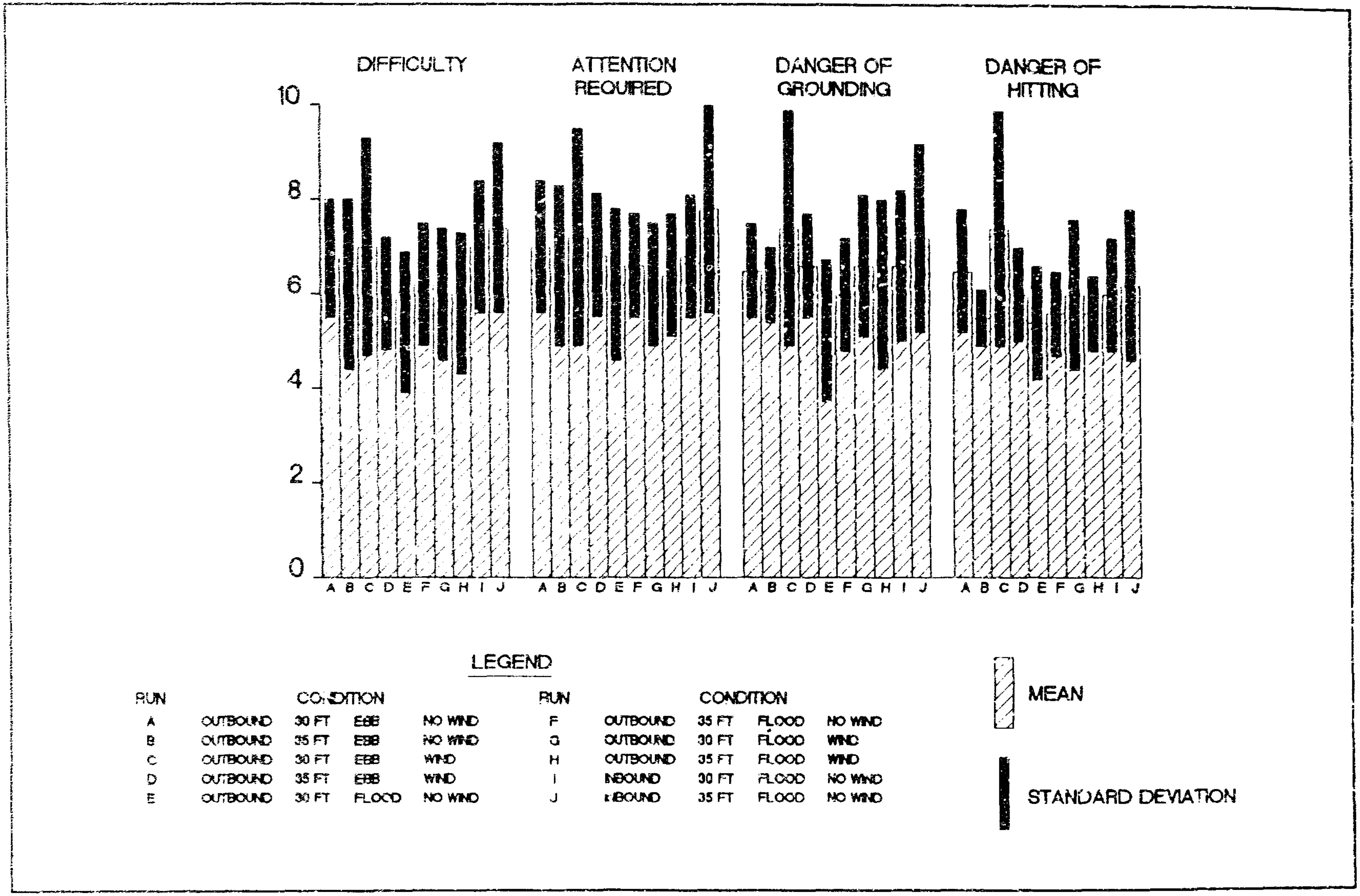


Figure 6. Pilot ratings, Area A

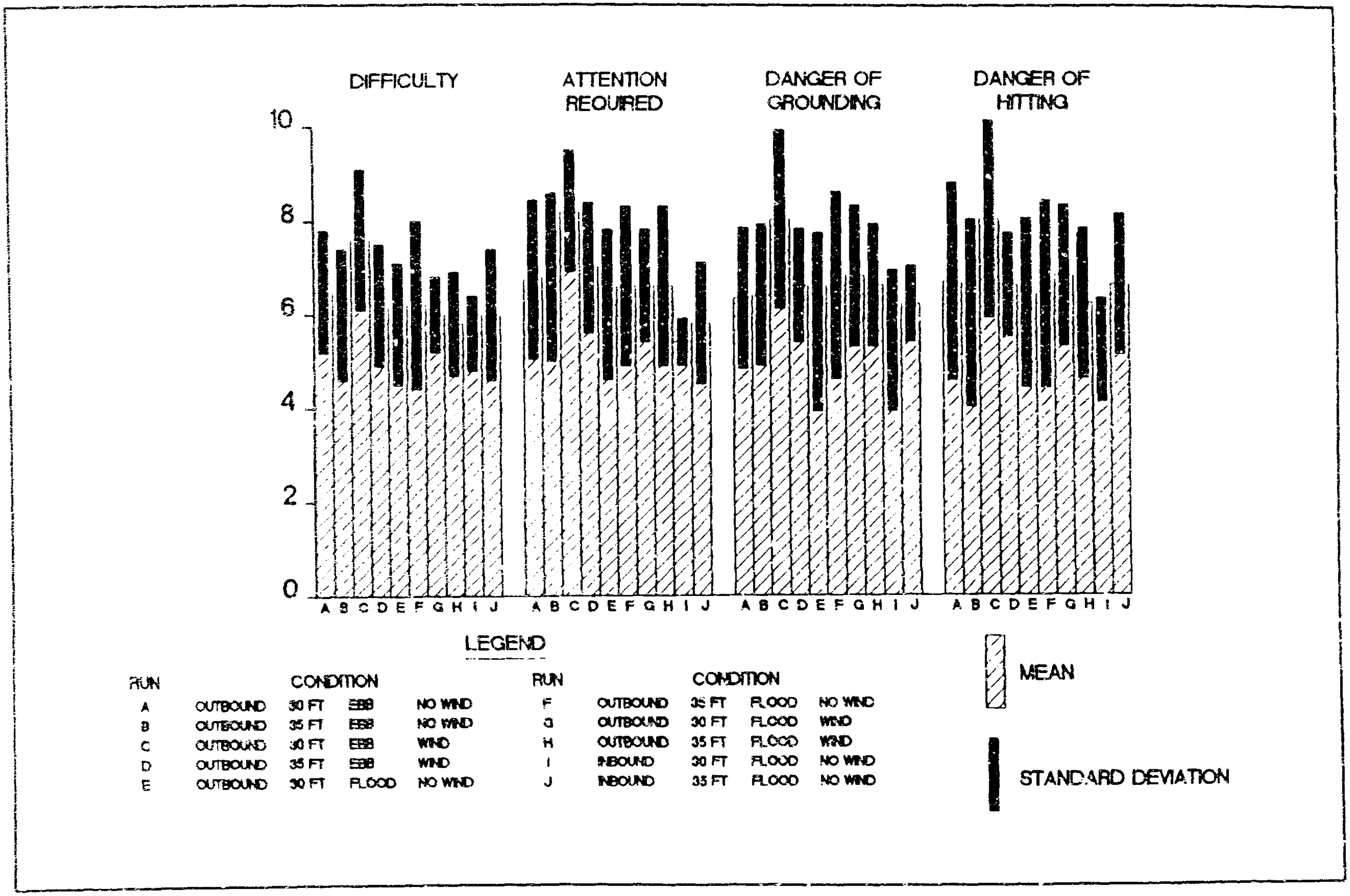


Figure 7. Pilot ratings, Area B

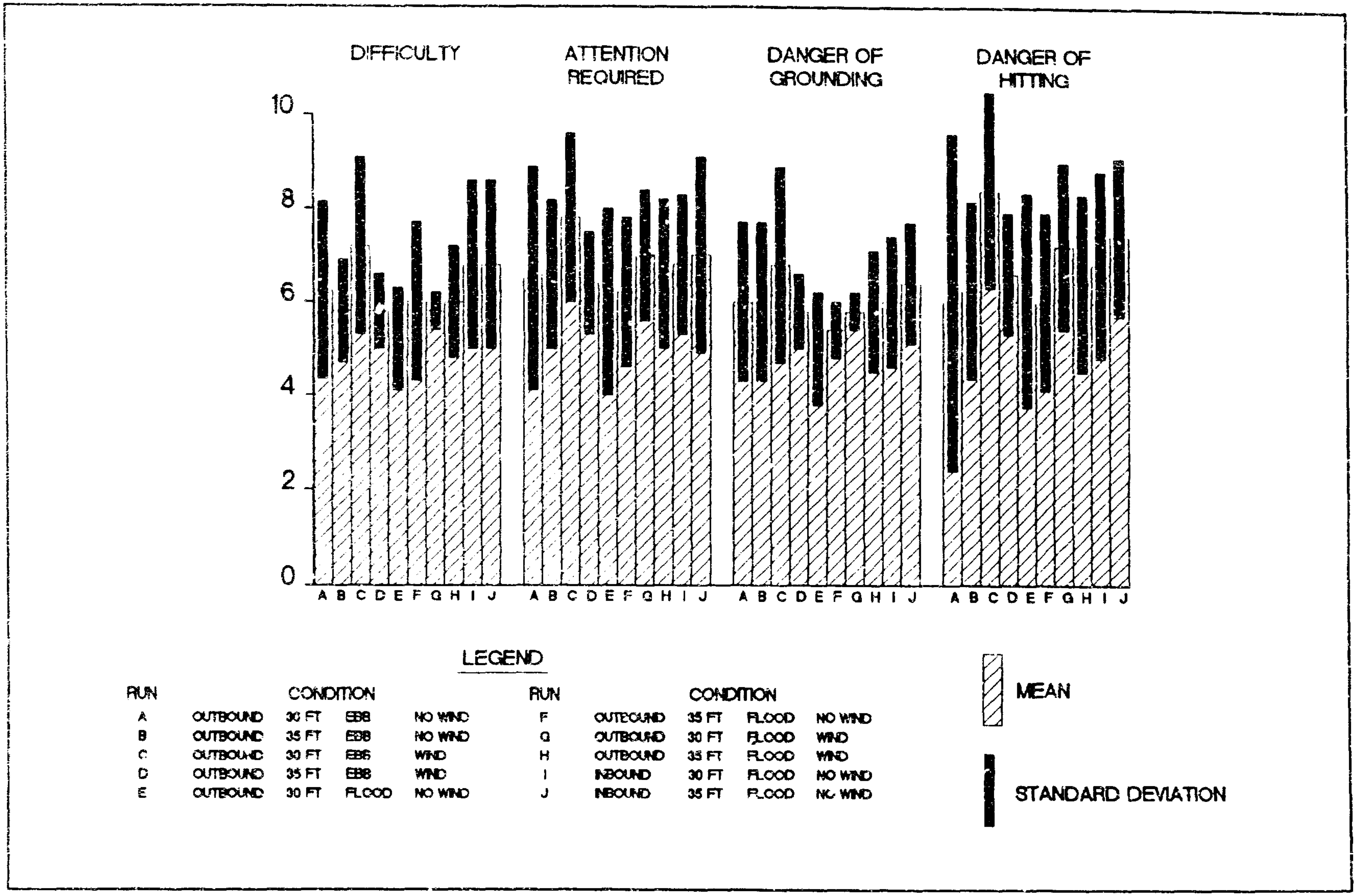


Figure 8. Pilot ratings, Area C

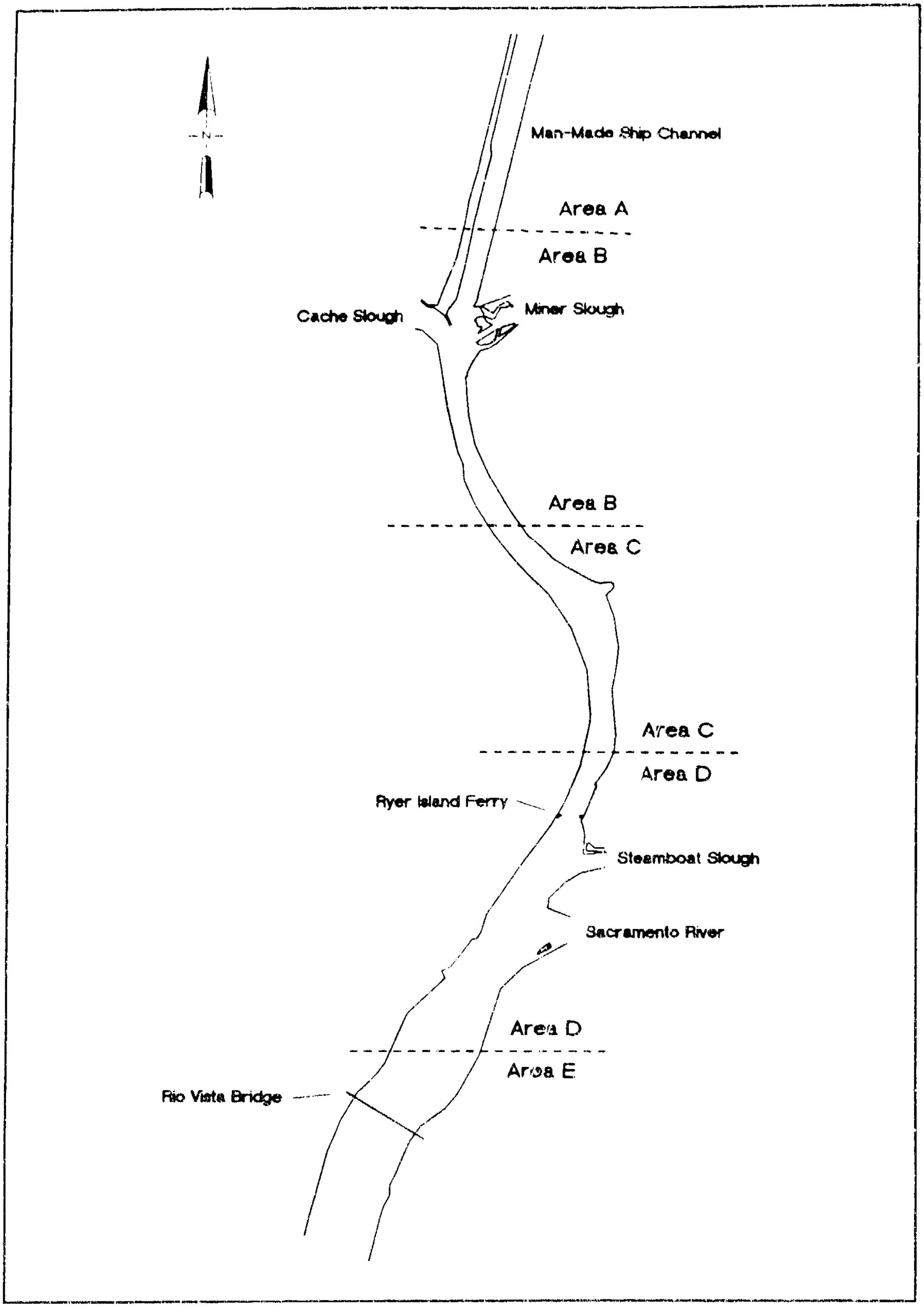


Figure 9. Track plot areas

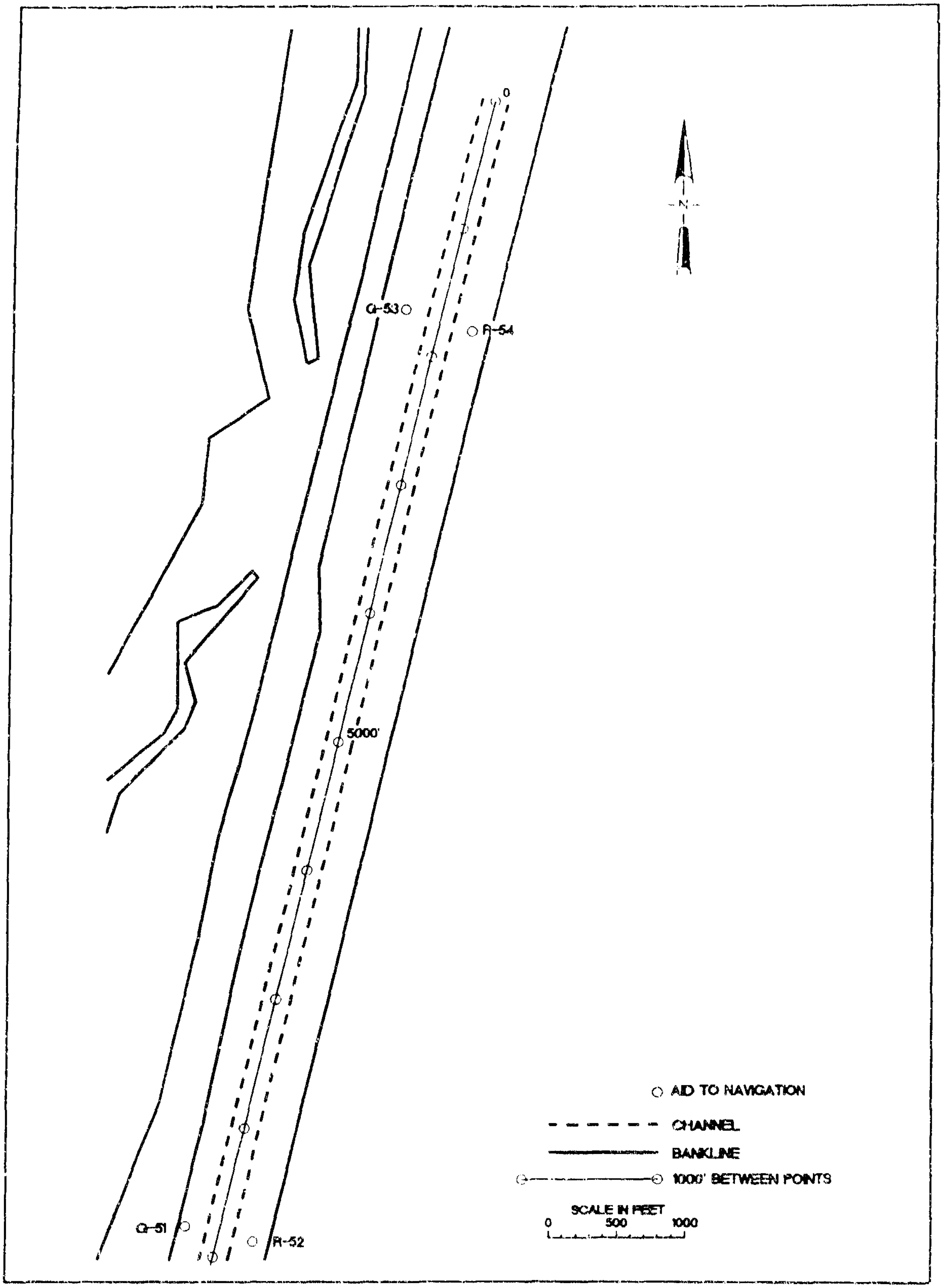


Figure 10. Distance along track, Area A

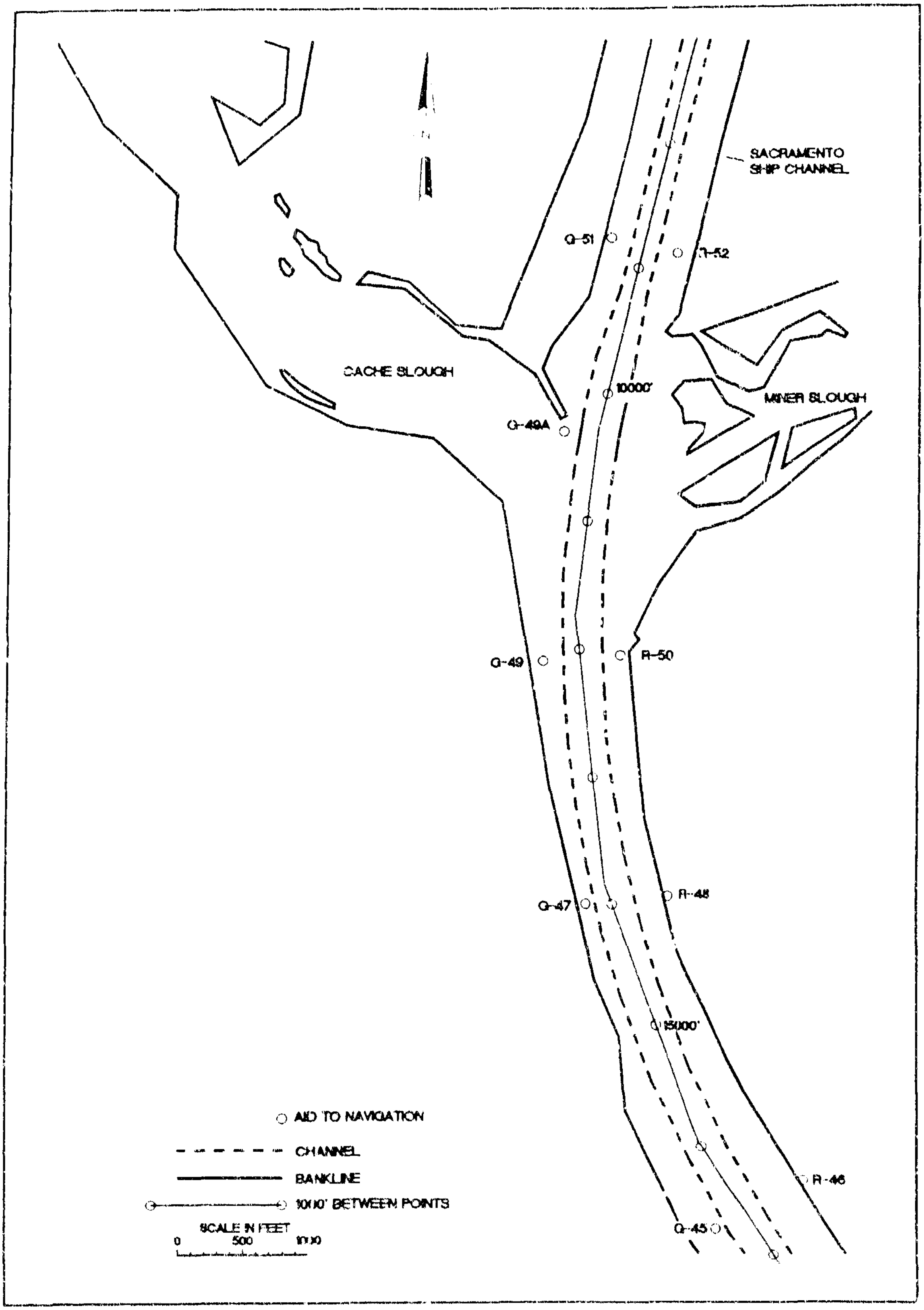


Figure 11. Distance along track, Area B

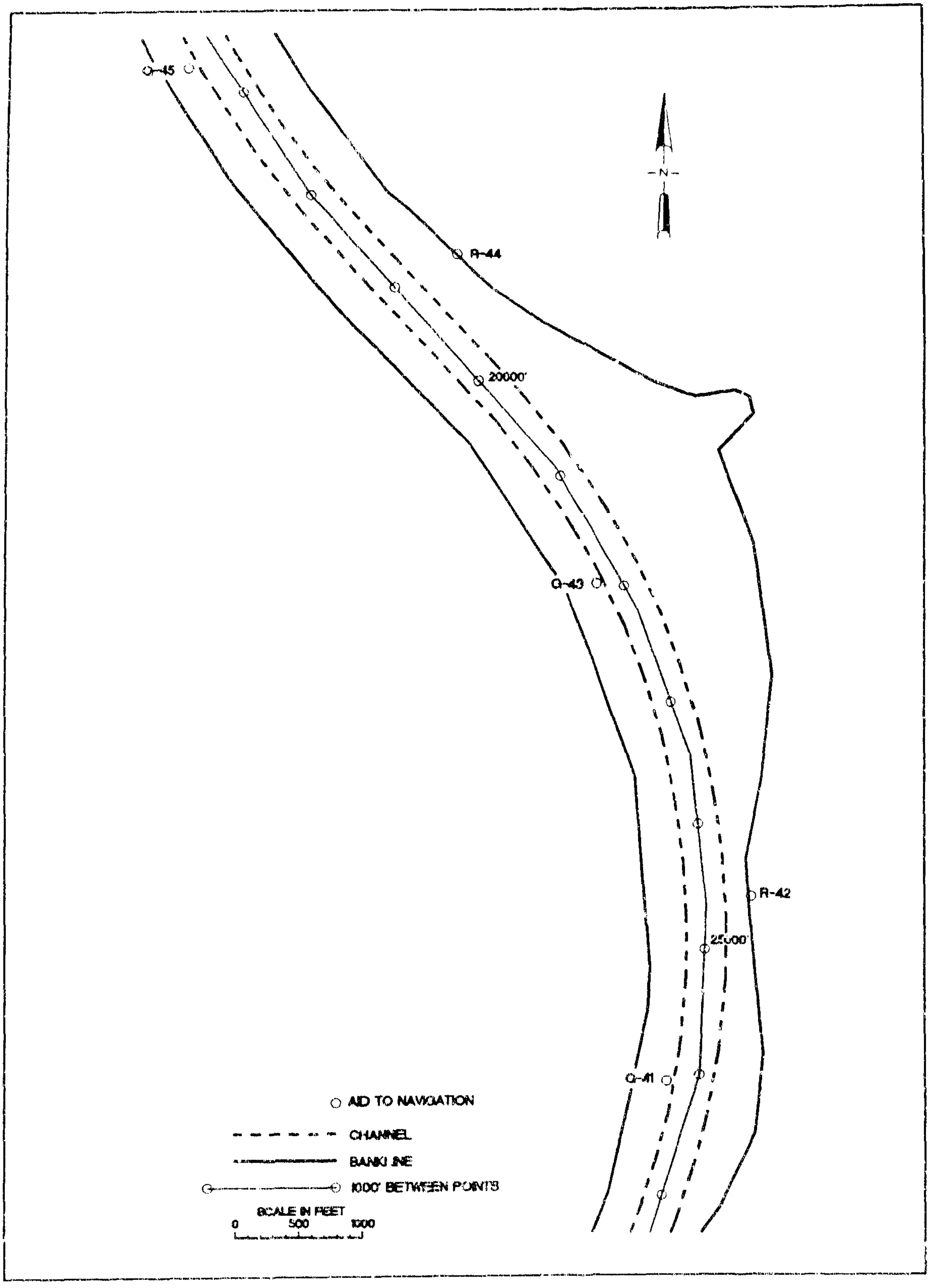


Figure 12. Distance along track, Area C

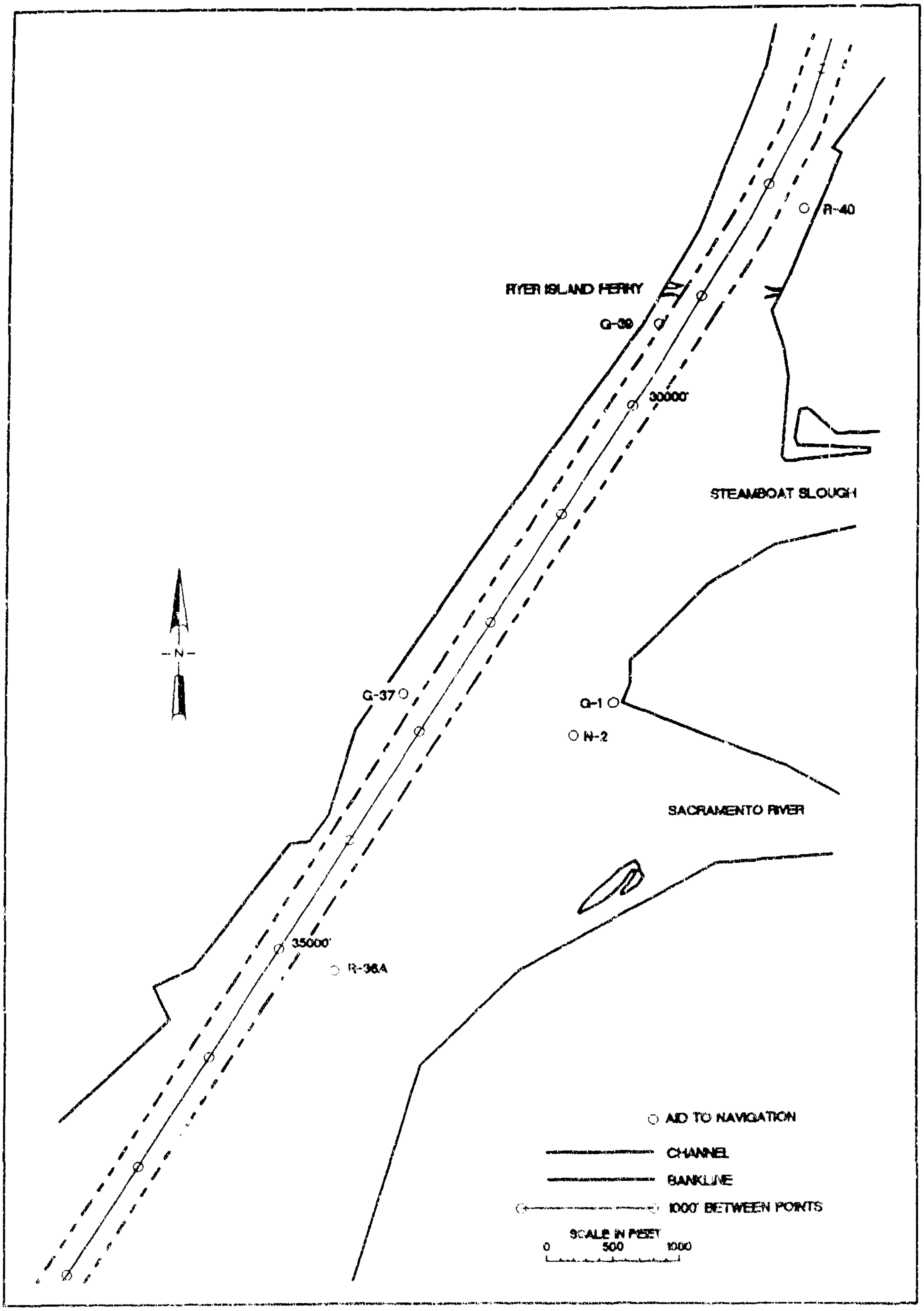


Figure 13. Distance along track, Area D

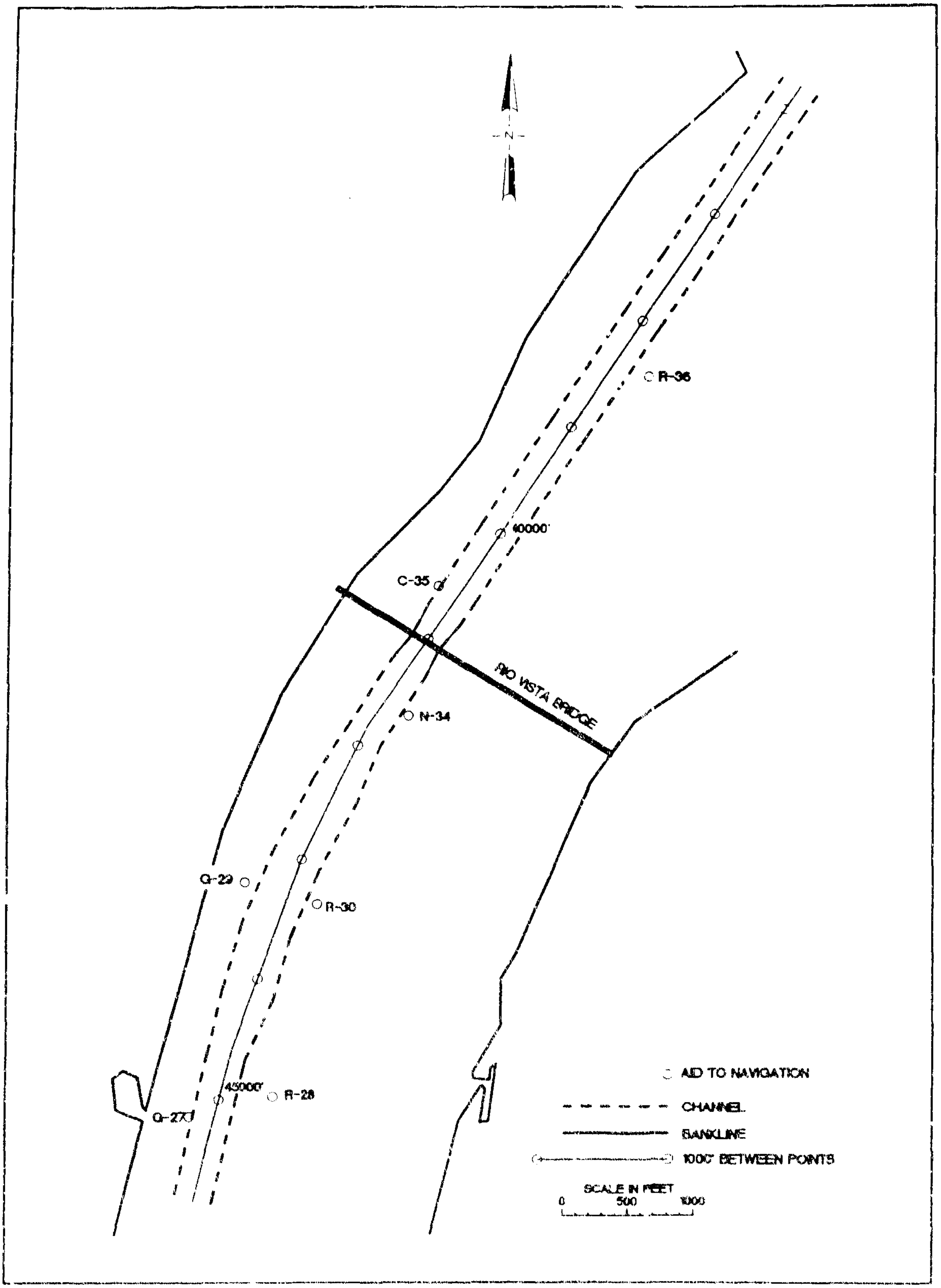


Figure 14. Distance along track, Area E

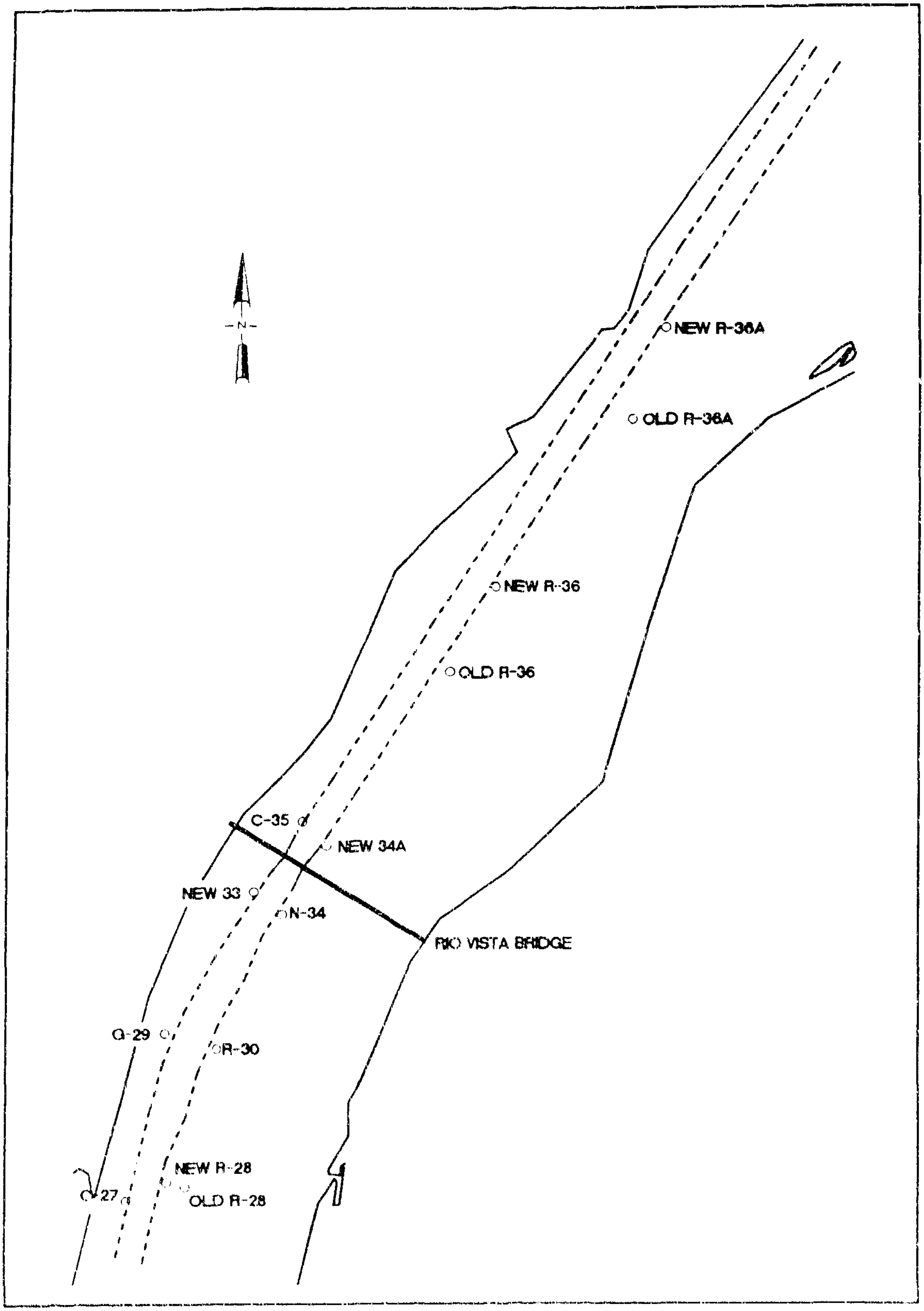


Figure 15. New buoy locations

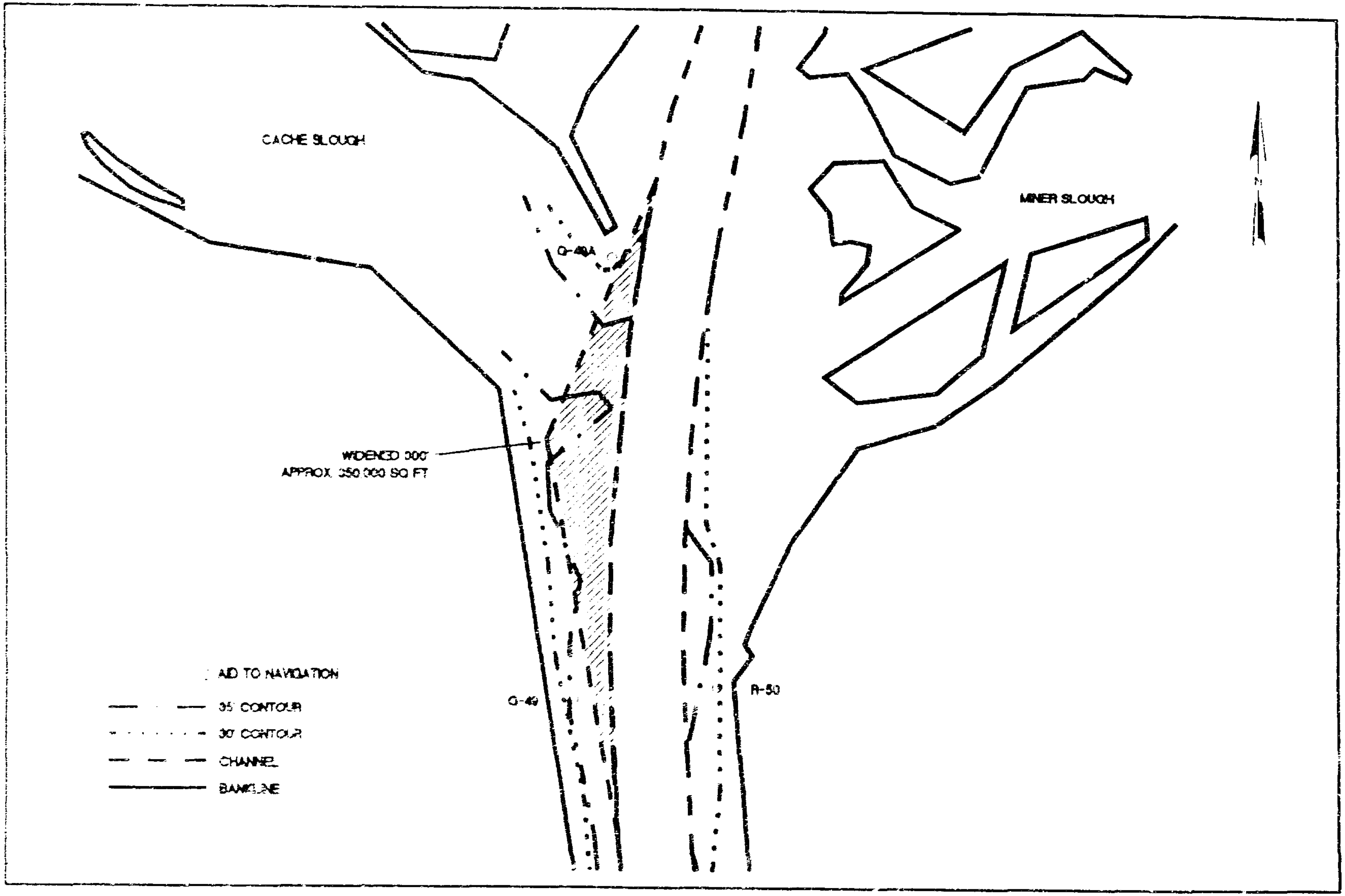


Figure 16. Recommended widening, Junction of Cache Slough, Miner Slough, and Ship Channel

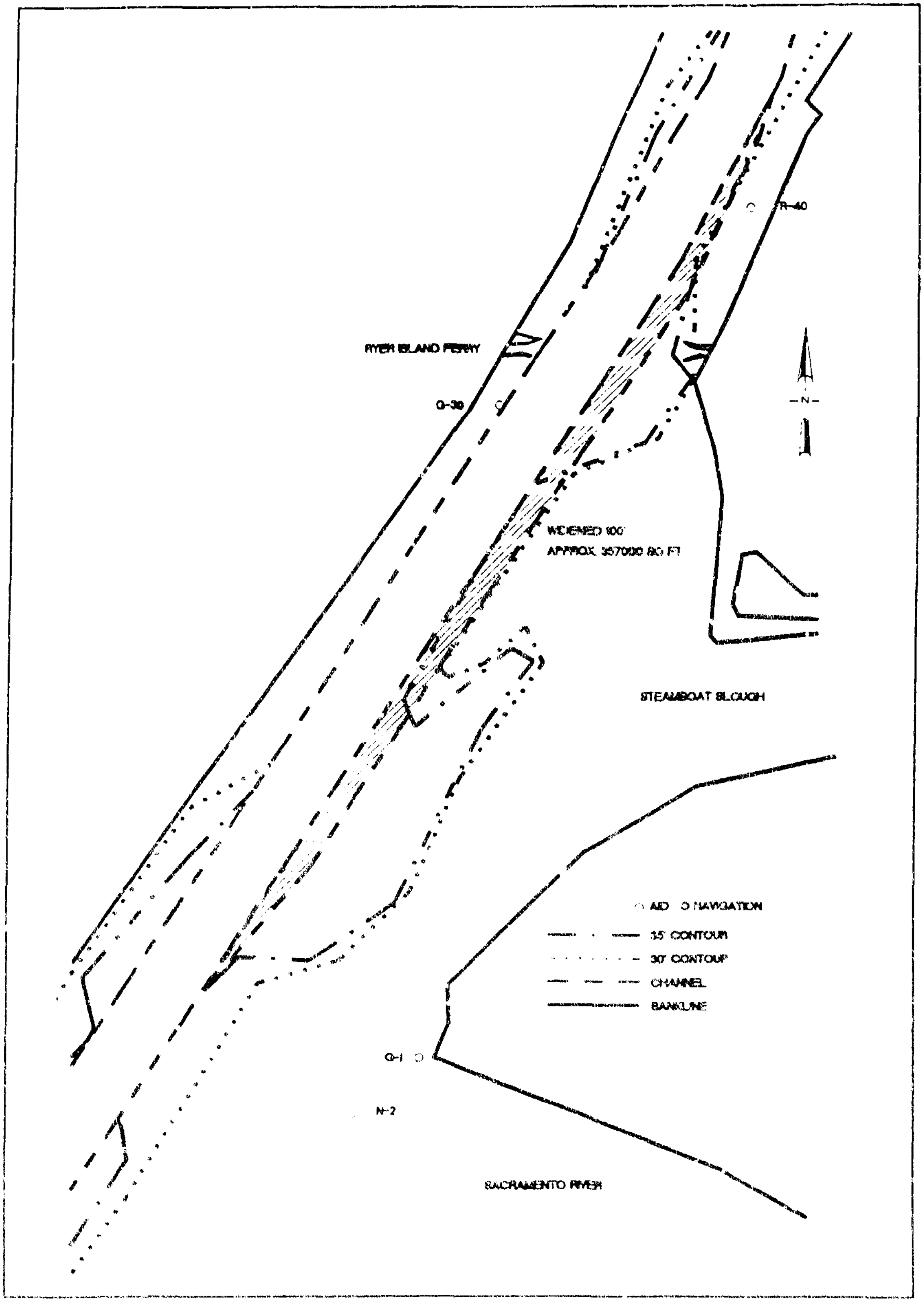


Figure 17. Recommended widening, Junction of Steamboat Slough and Ship Channel

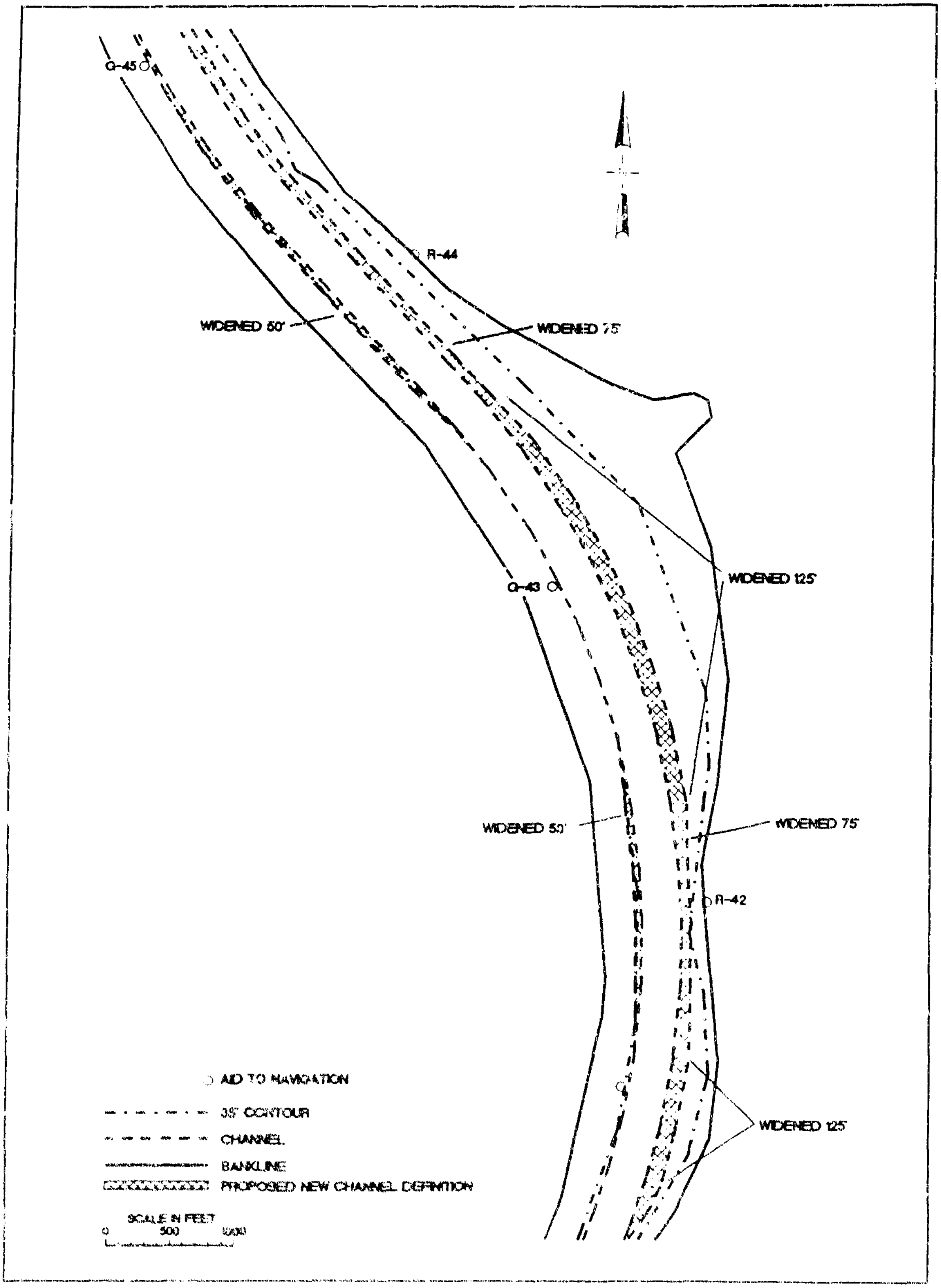
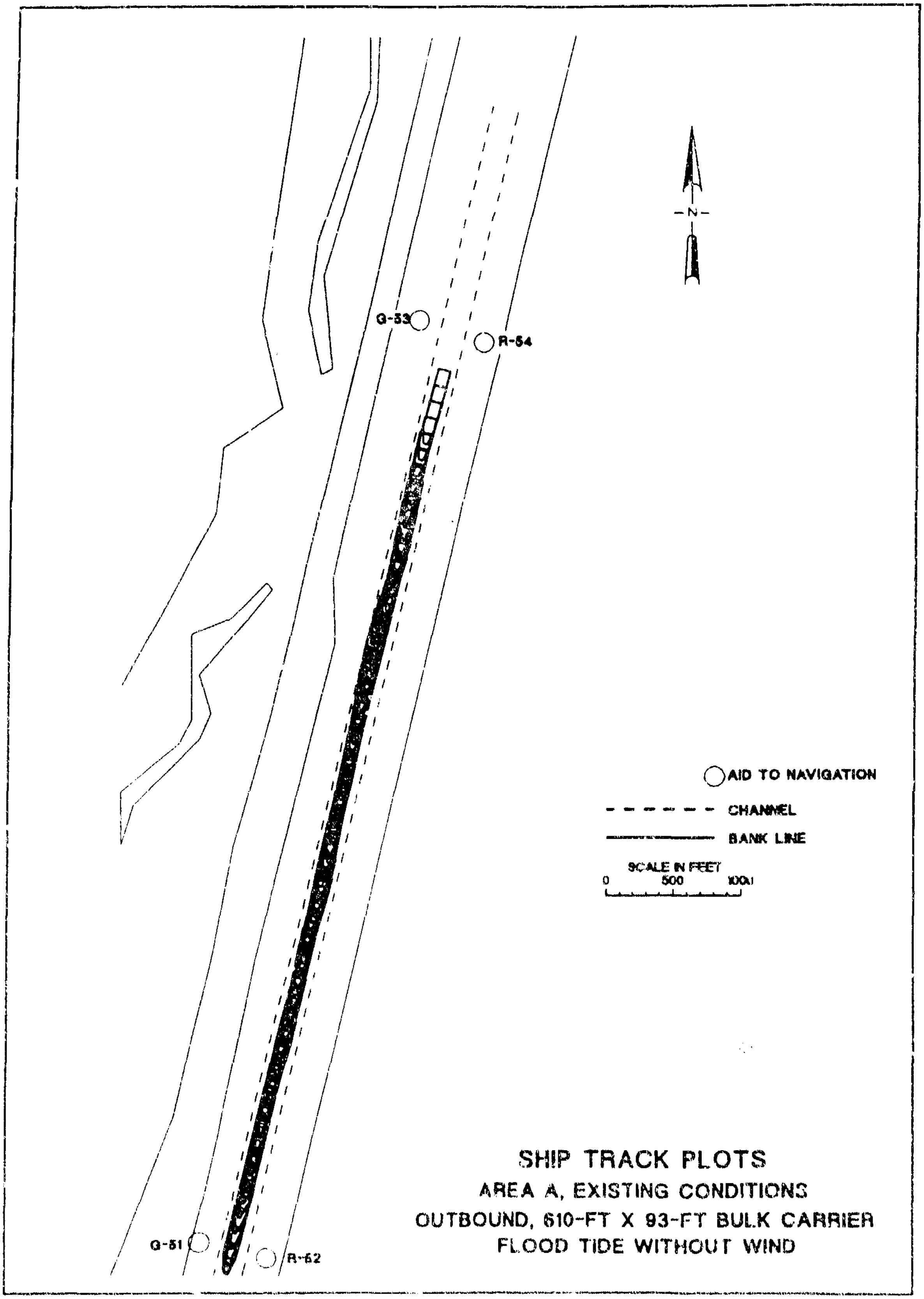
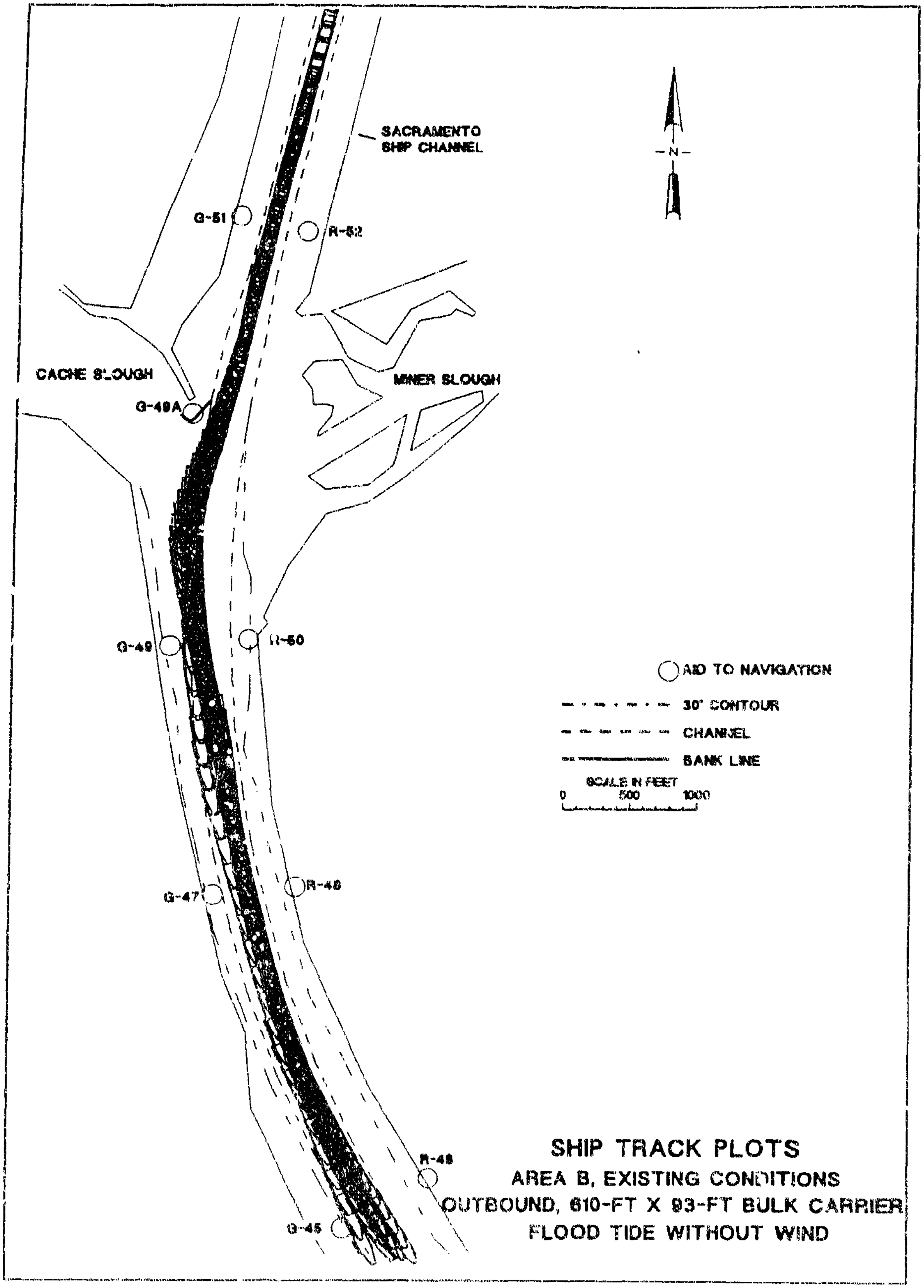


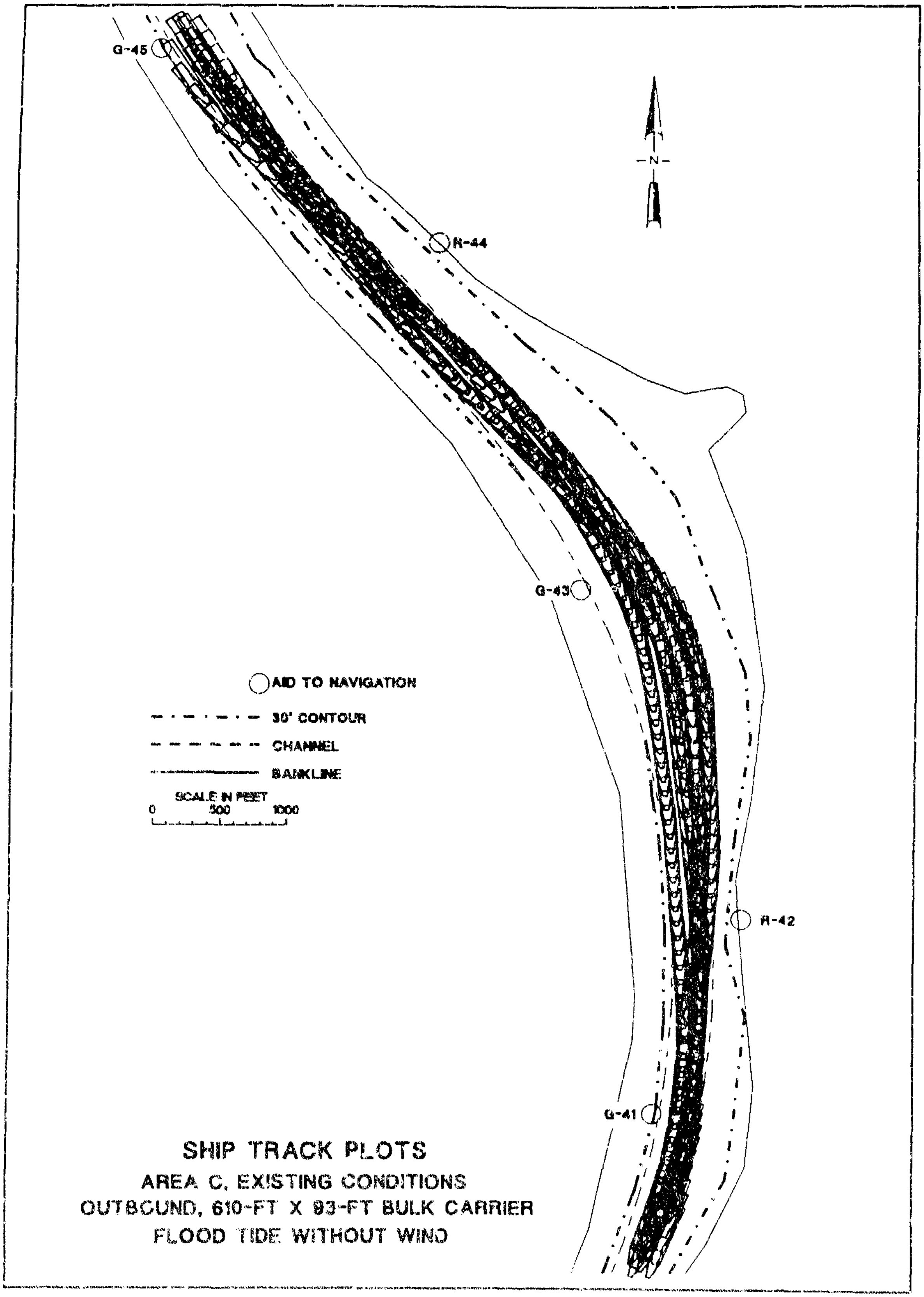
Figure 18. Recommended widening with proposed new channel definition

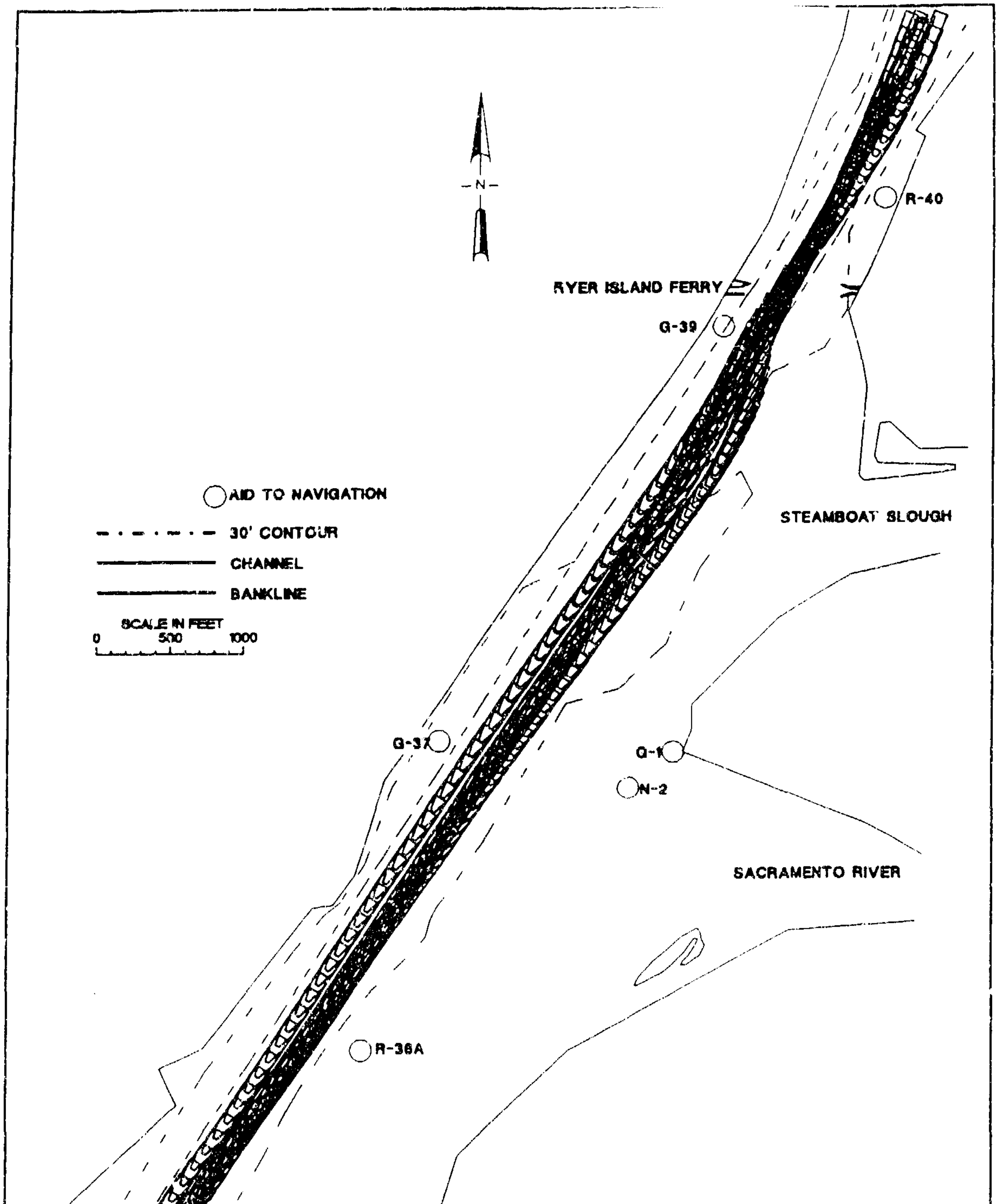

G-53
R-54
N
AID TO NAVIGATION
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND
G-51
R-52



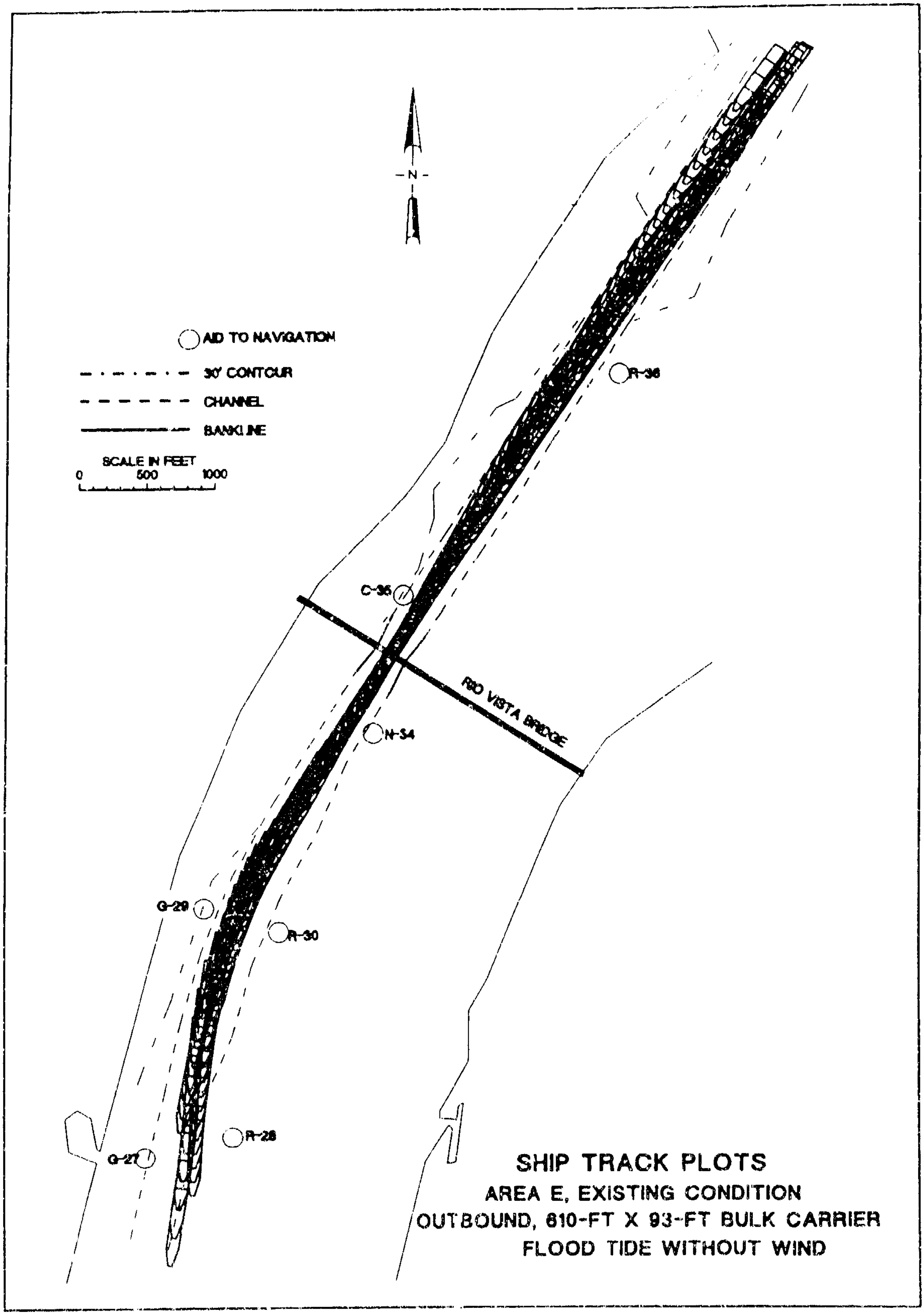
SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

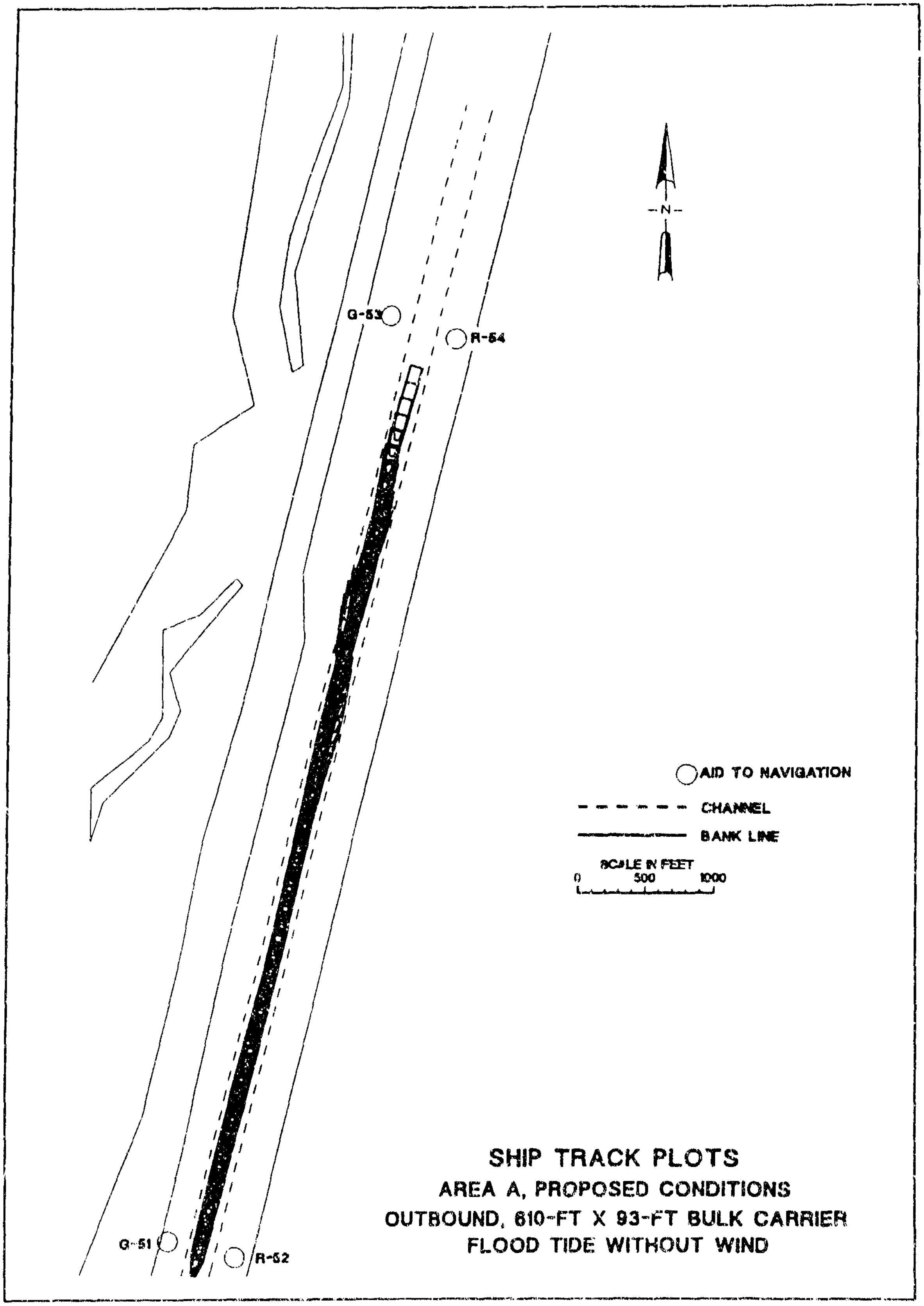
Plate 2


G-45
R-44
N
G-43
AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0 500 1000
R-42
G-41
SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

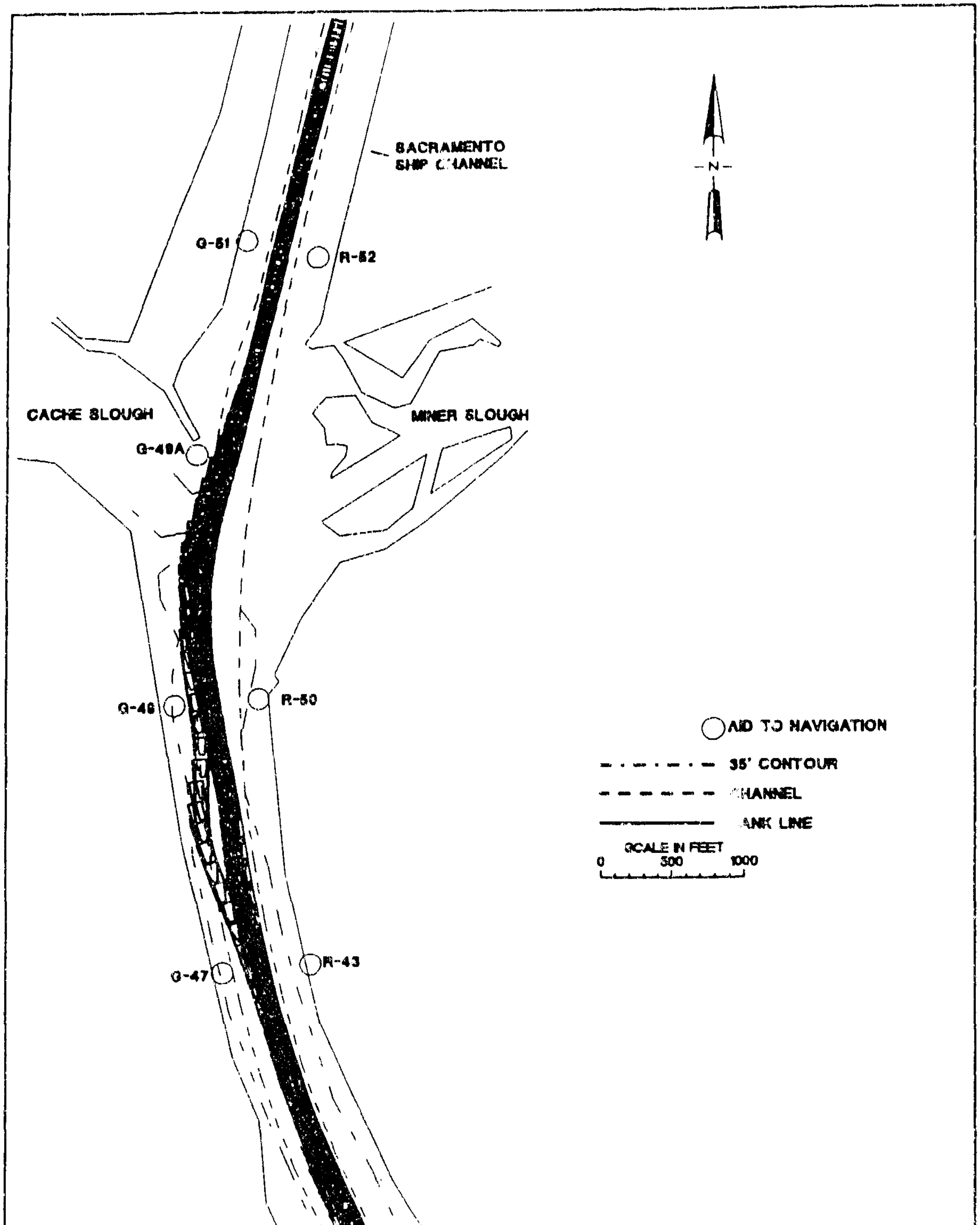


SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

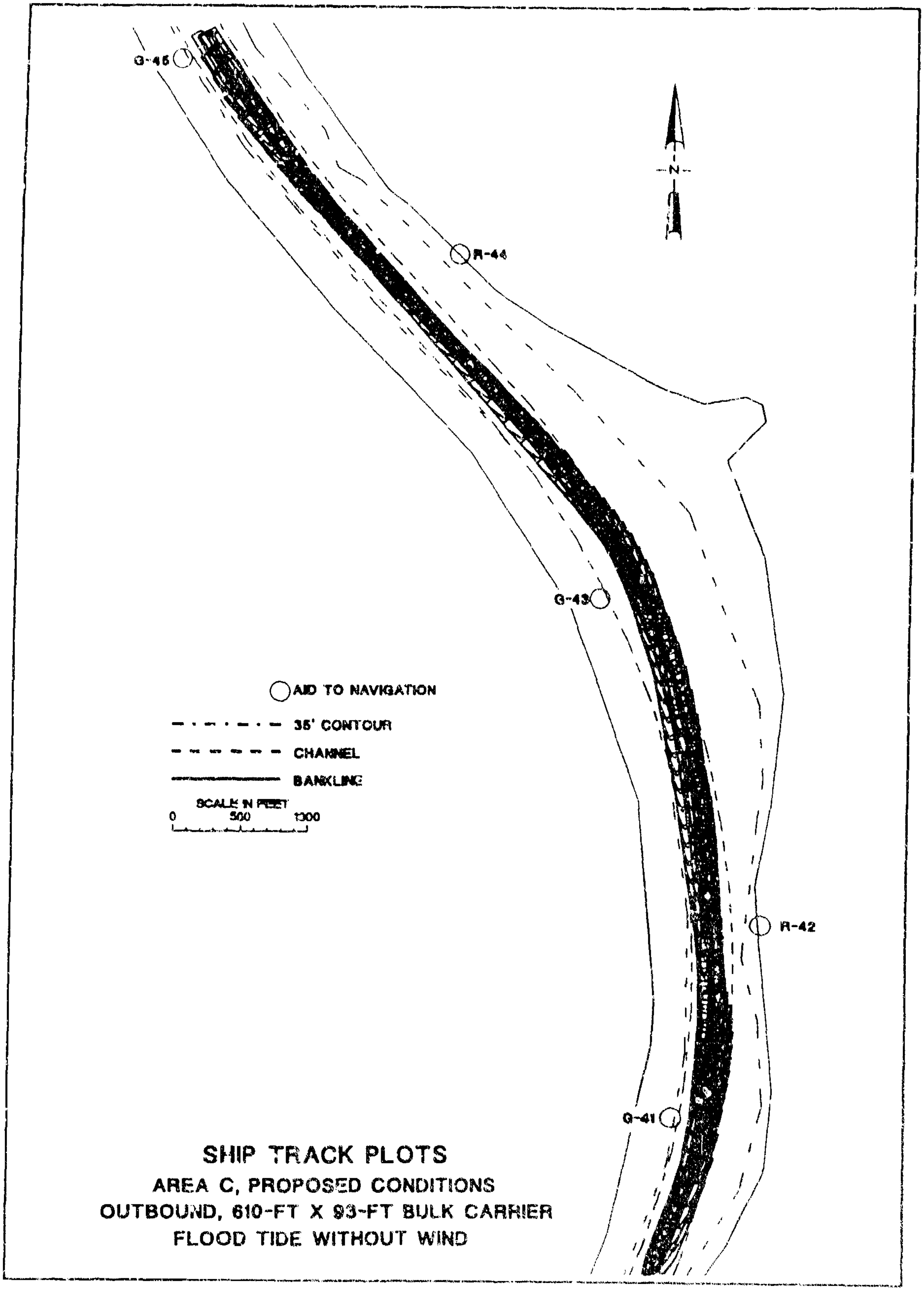

AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0 500 1000
N
R-36
C-35
RIO VISTA BRIDGE
N-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



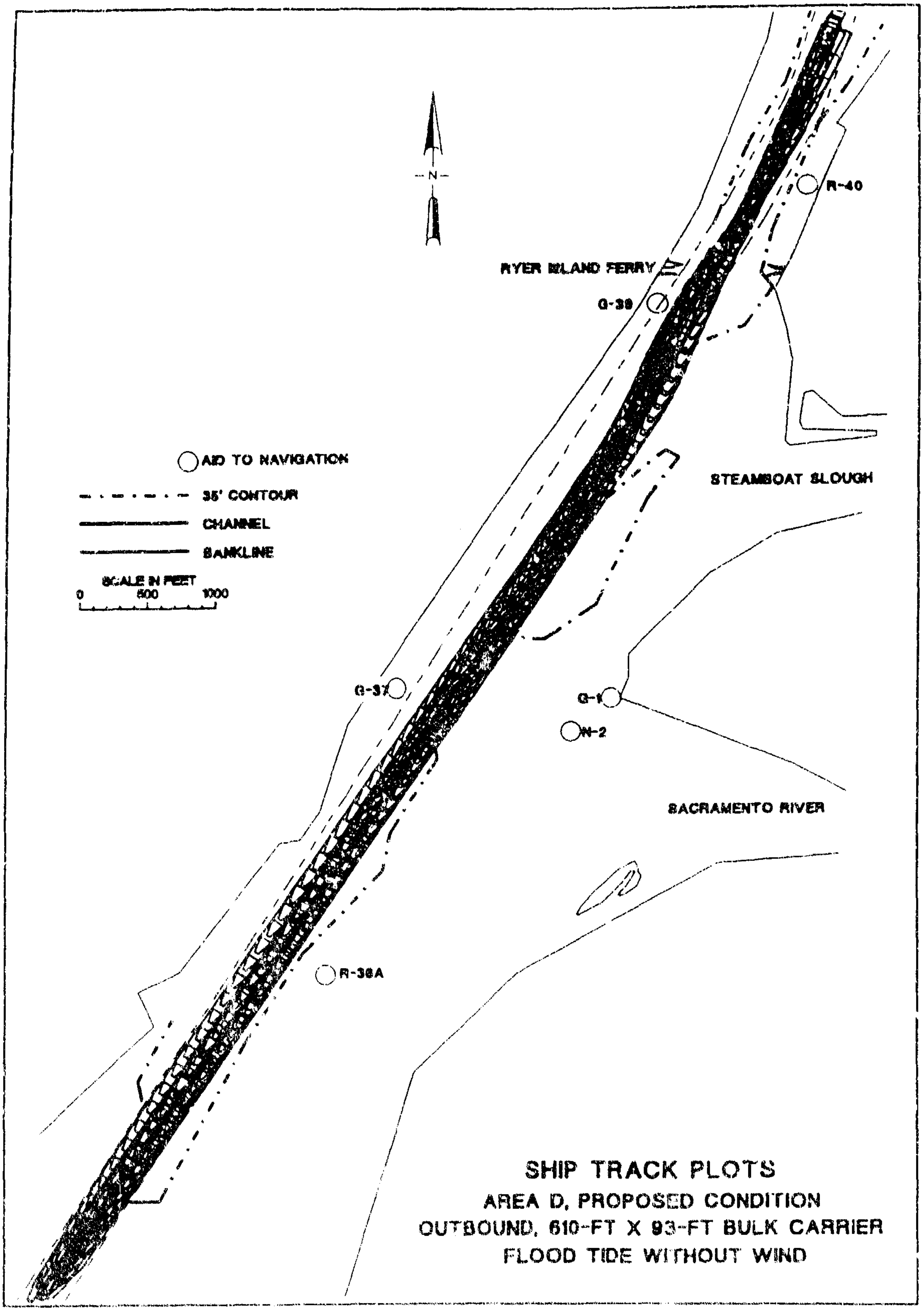
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

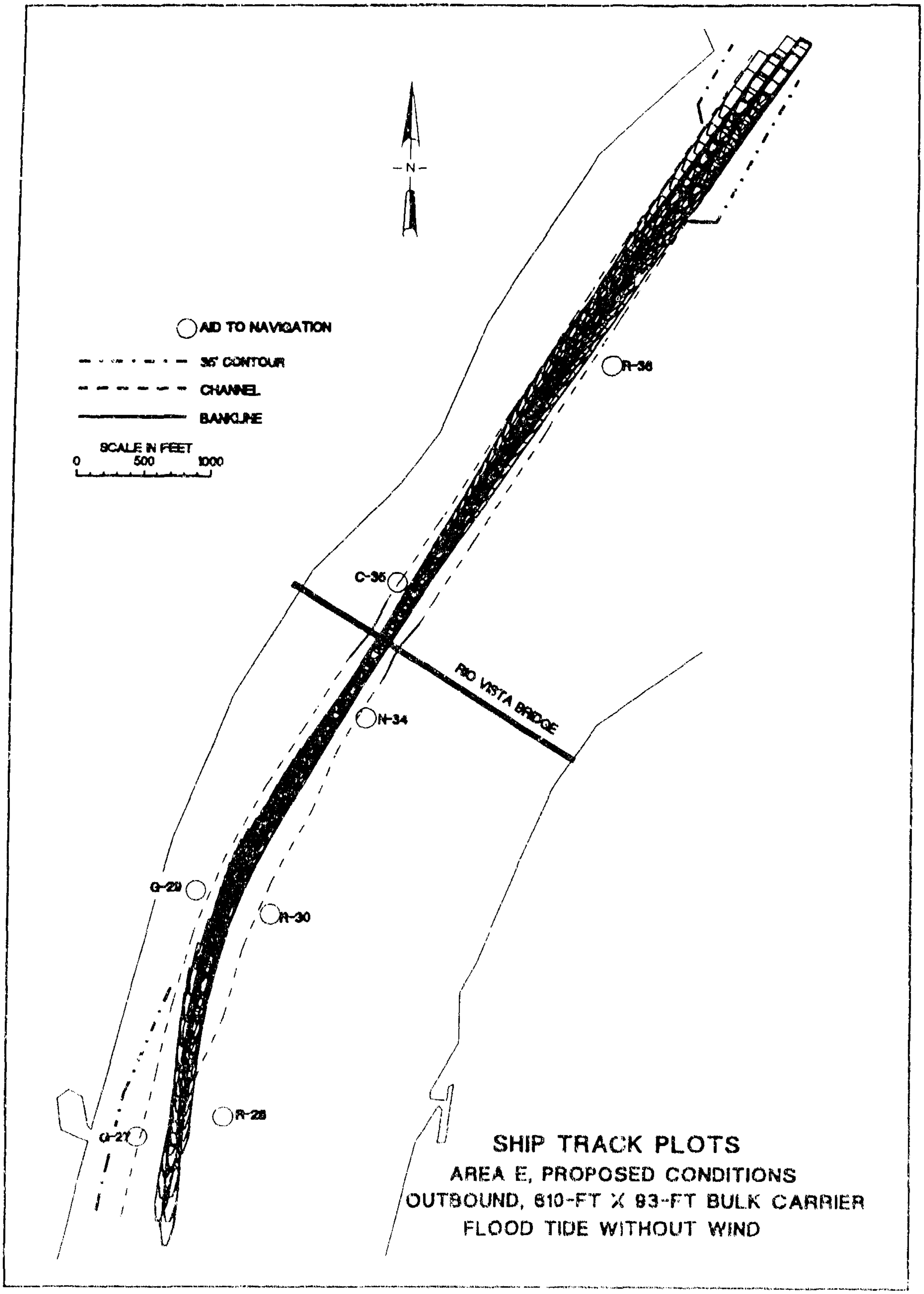


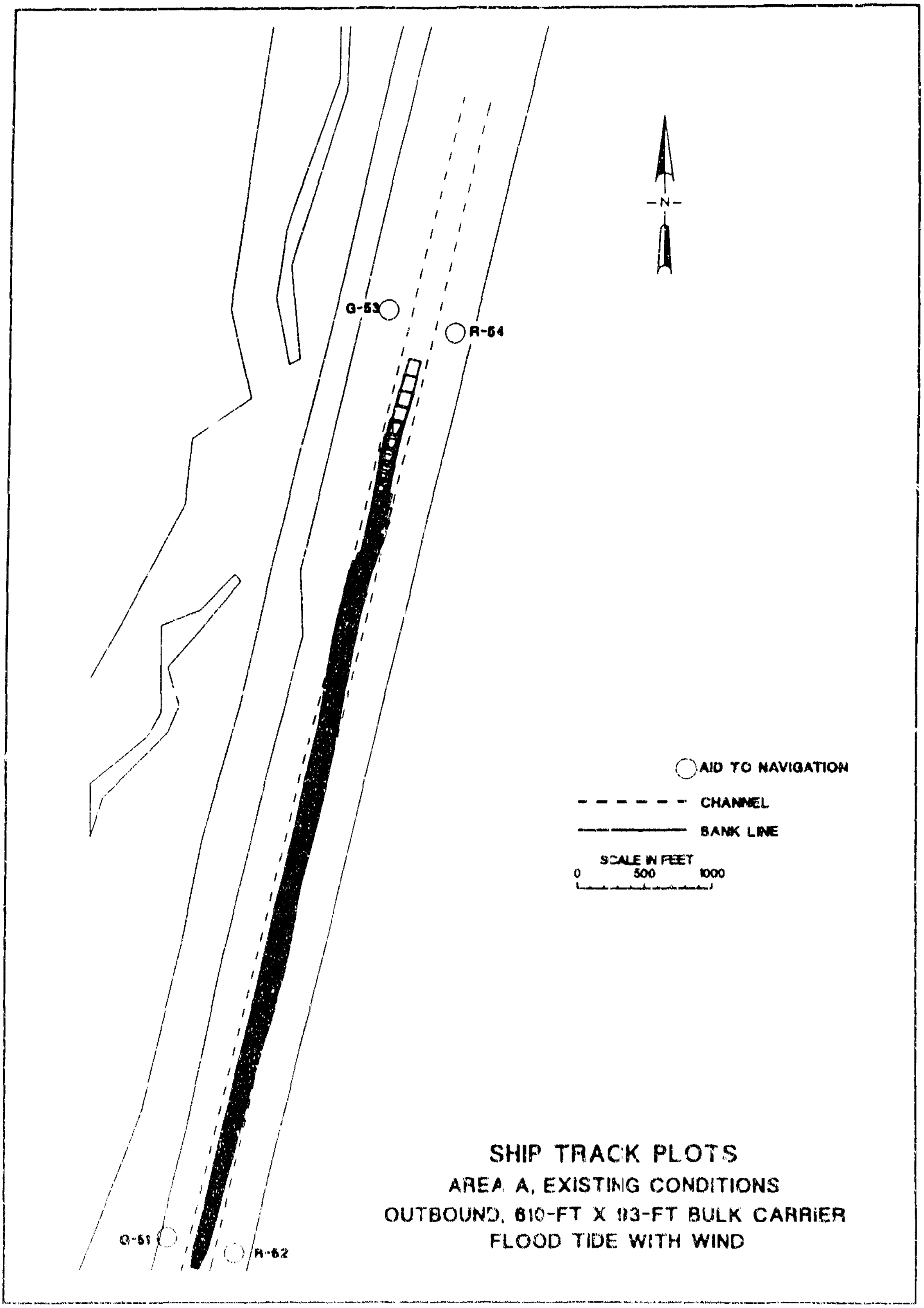
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



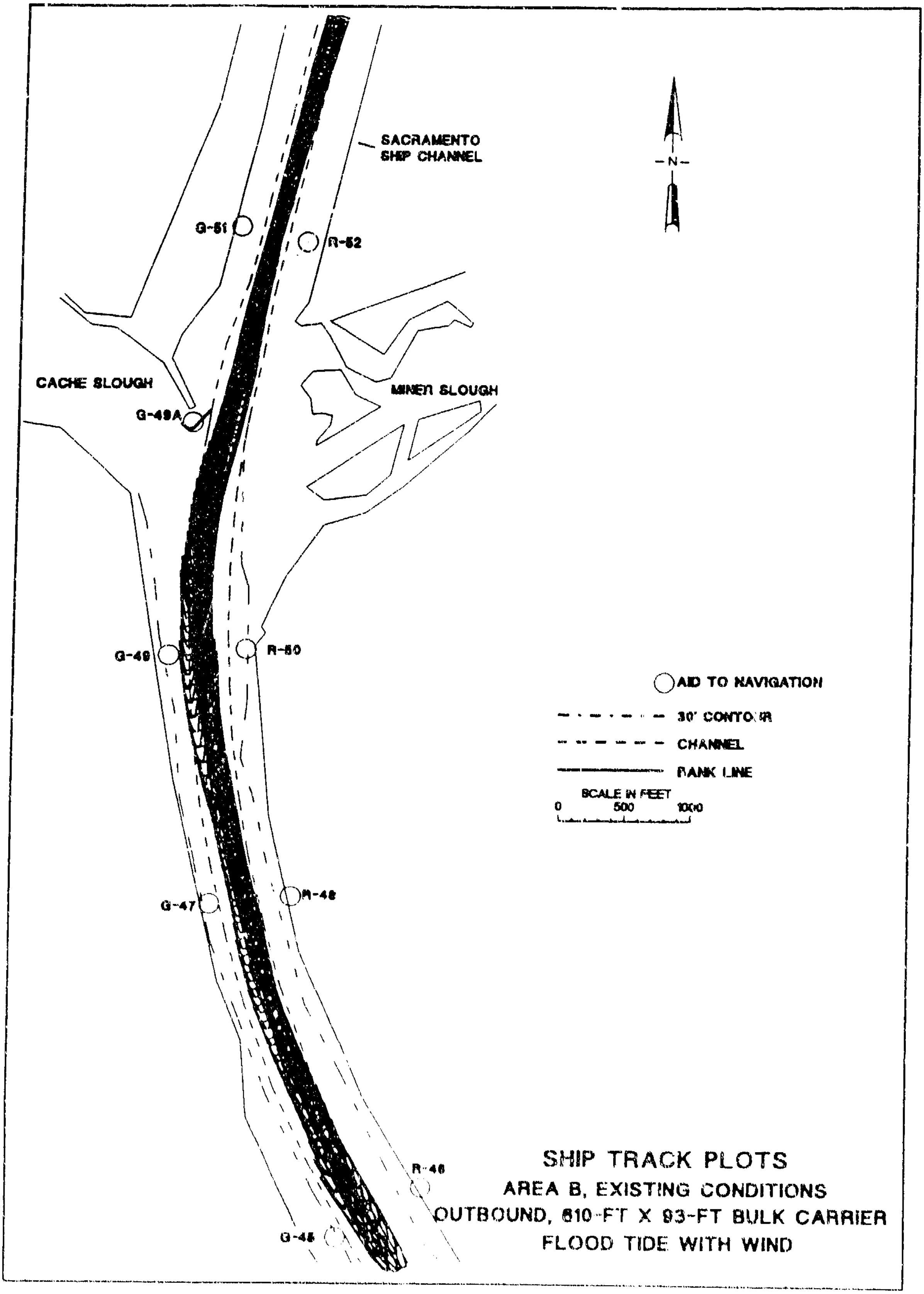
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND


RYER ISLAND FERRY
G-39
R-40
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
STEAMBOAT SLOUGH
G-37
G-1
N-2
SACRAMENTO RIVER
R-38A
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

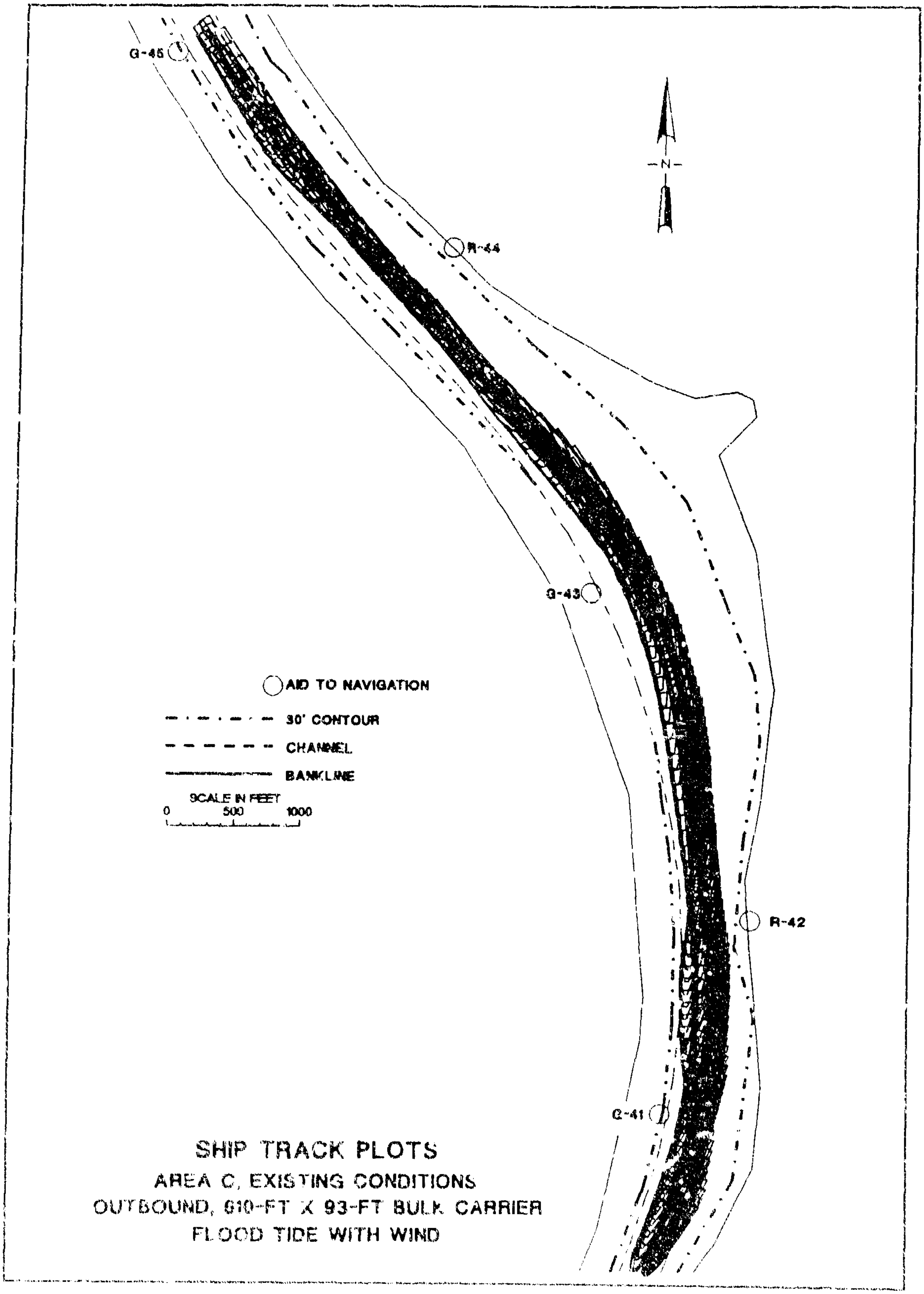

N
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
C-35
RIO VISTA BRIDGE
N-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

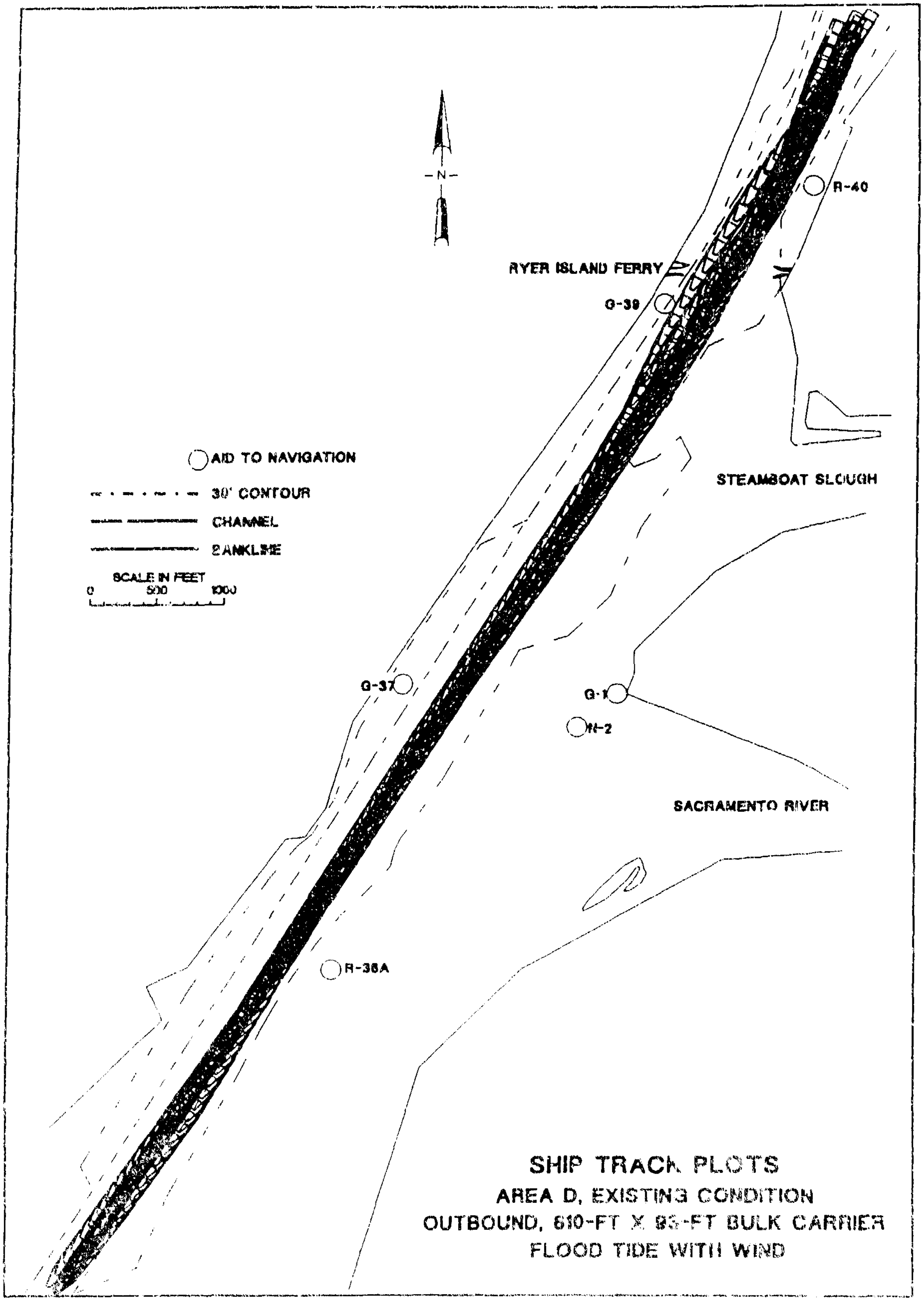
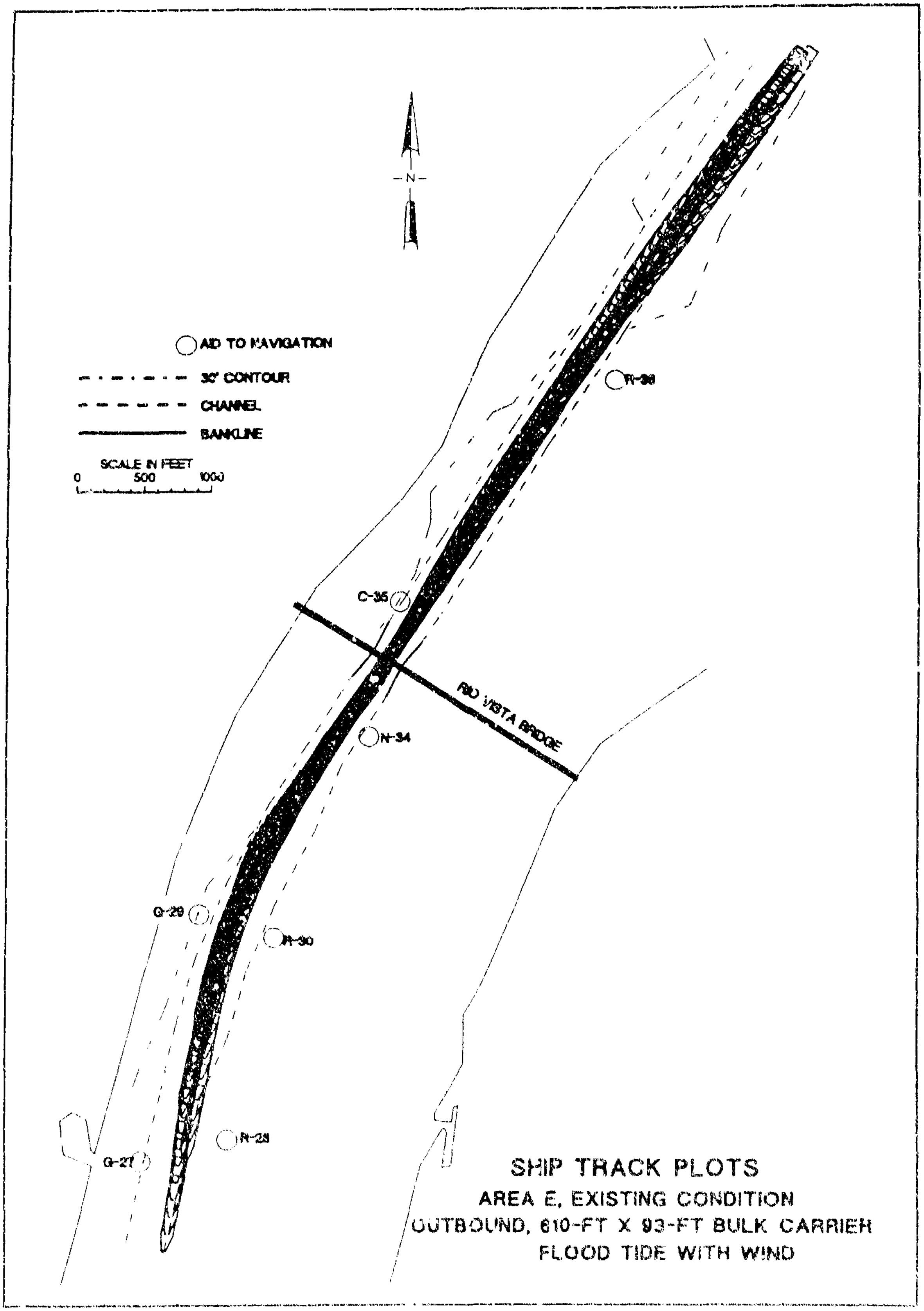
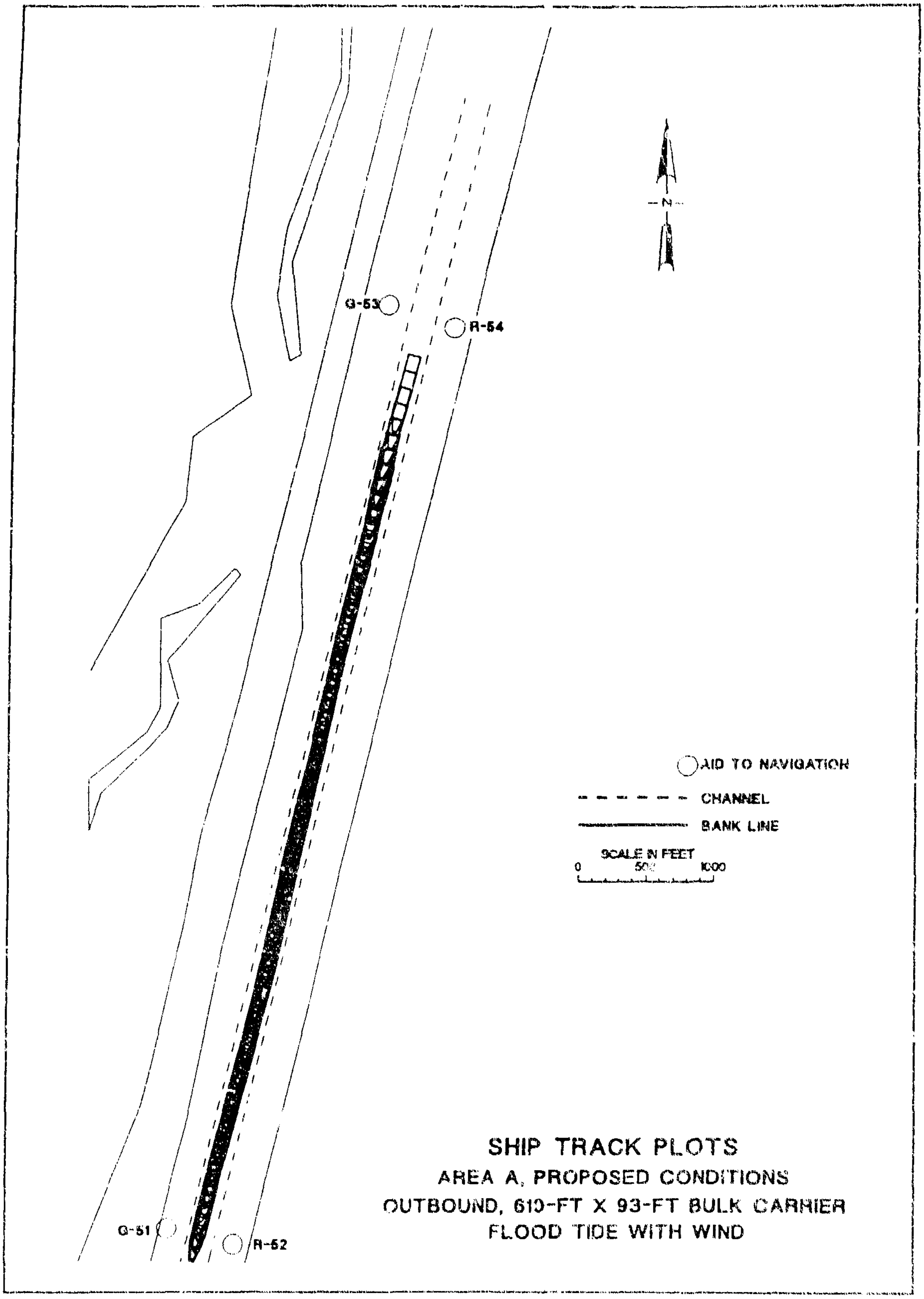

N
R-40
RYER ISLAND FERRY
G-39
AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0 500 1000
STEAMBOAT SLOUGH
G-37
G-1
R-2
SACRAMENTO RIVER
R-38A
SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

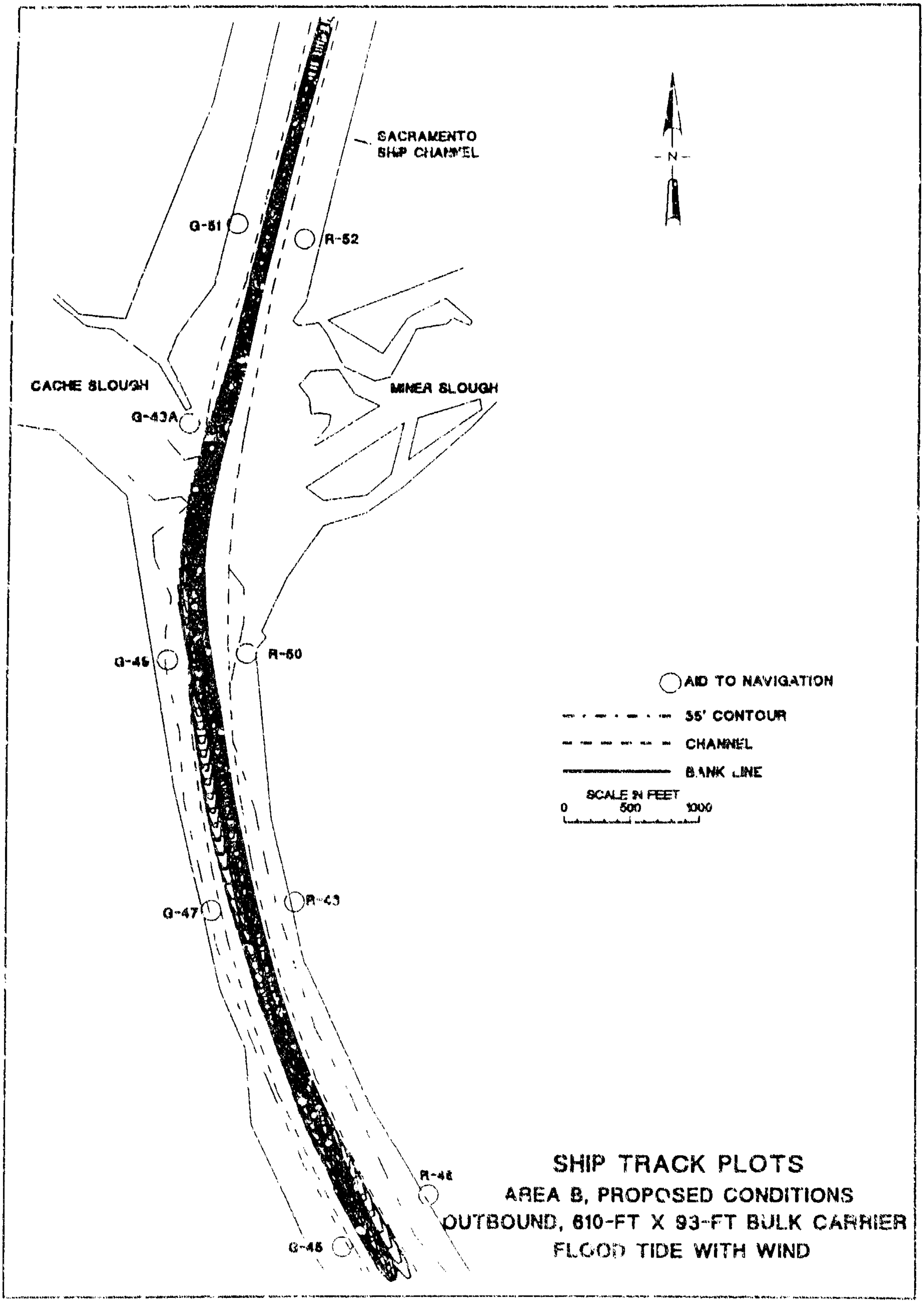
Plate 14


N
AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
C-35
RIO VISTA BRIDGE
N-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

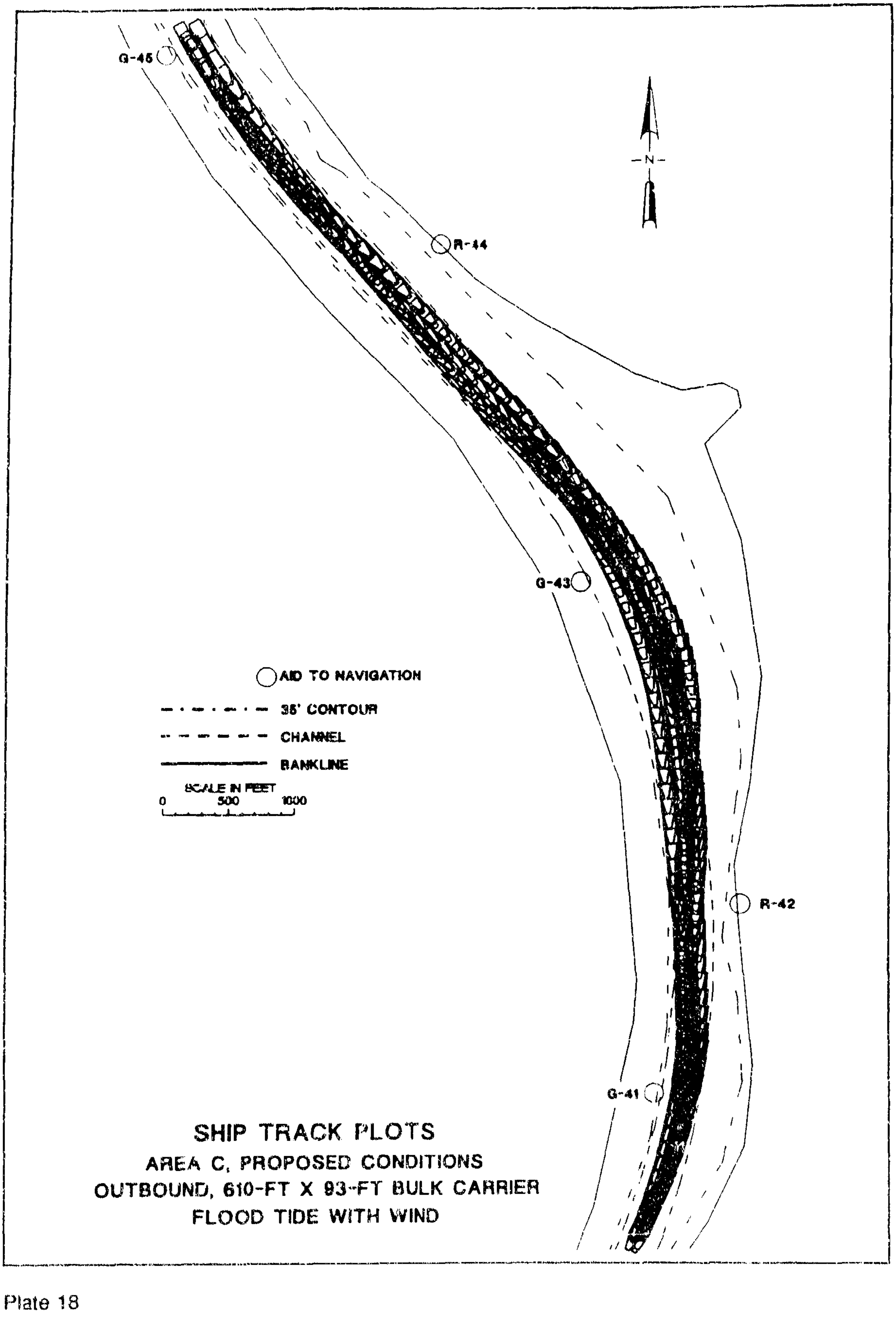


SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

Plate 16

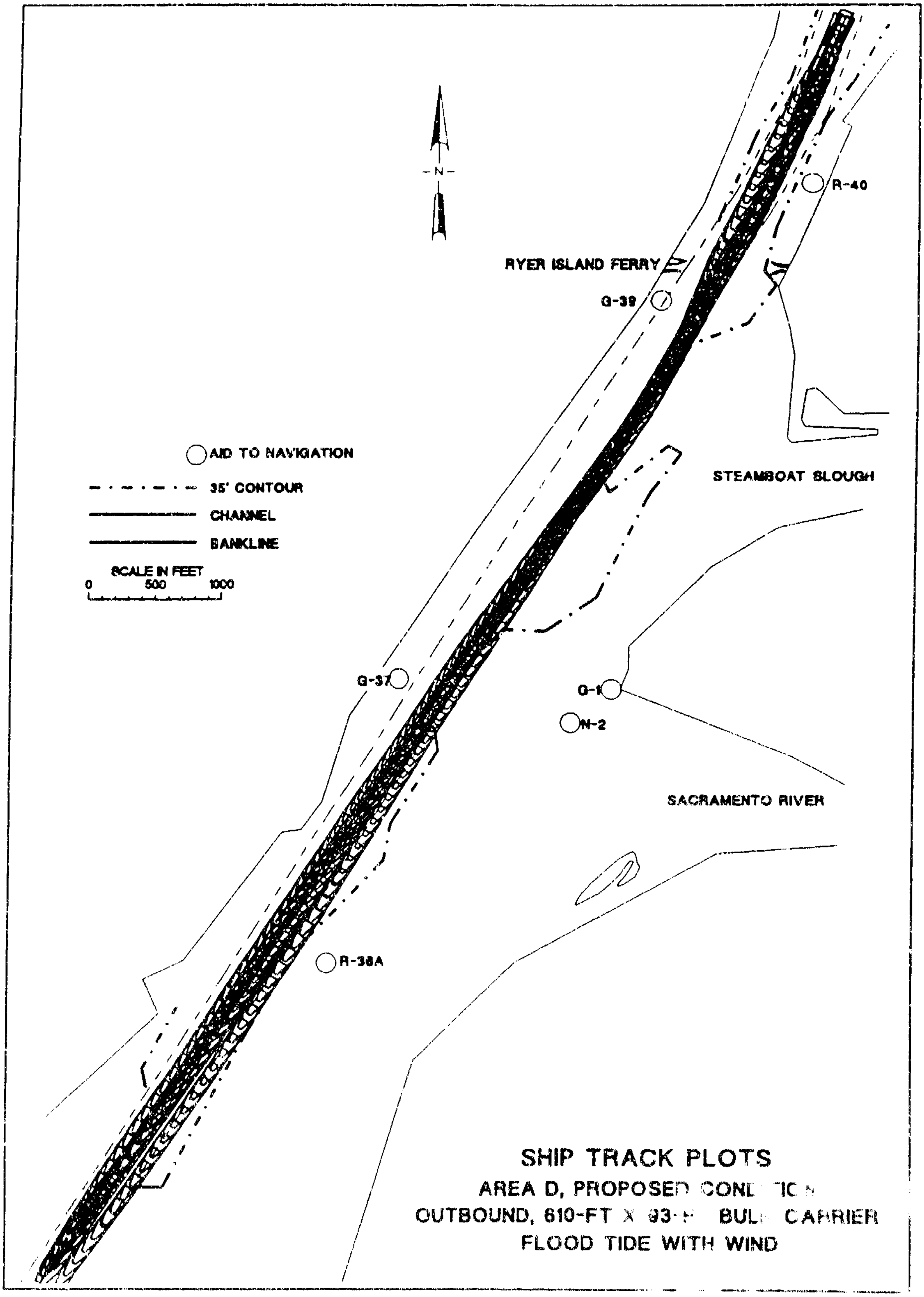


SACRAMENTO
SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-43A
G-45
R-50
AID TO NAVIGATION
55' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
G-47
R-48
G-45
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

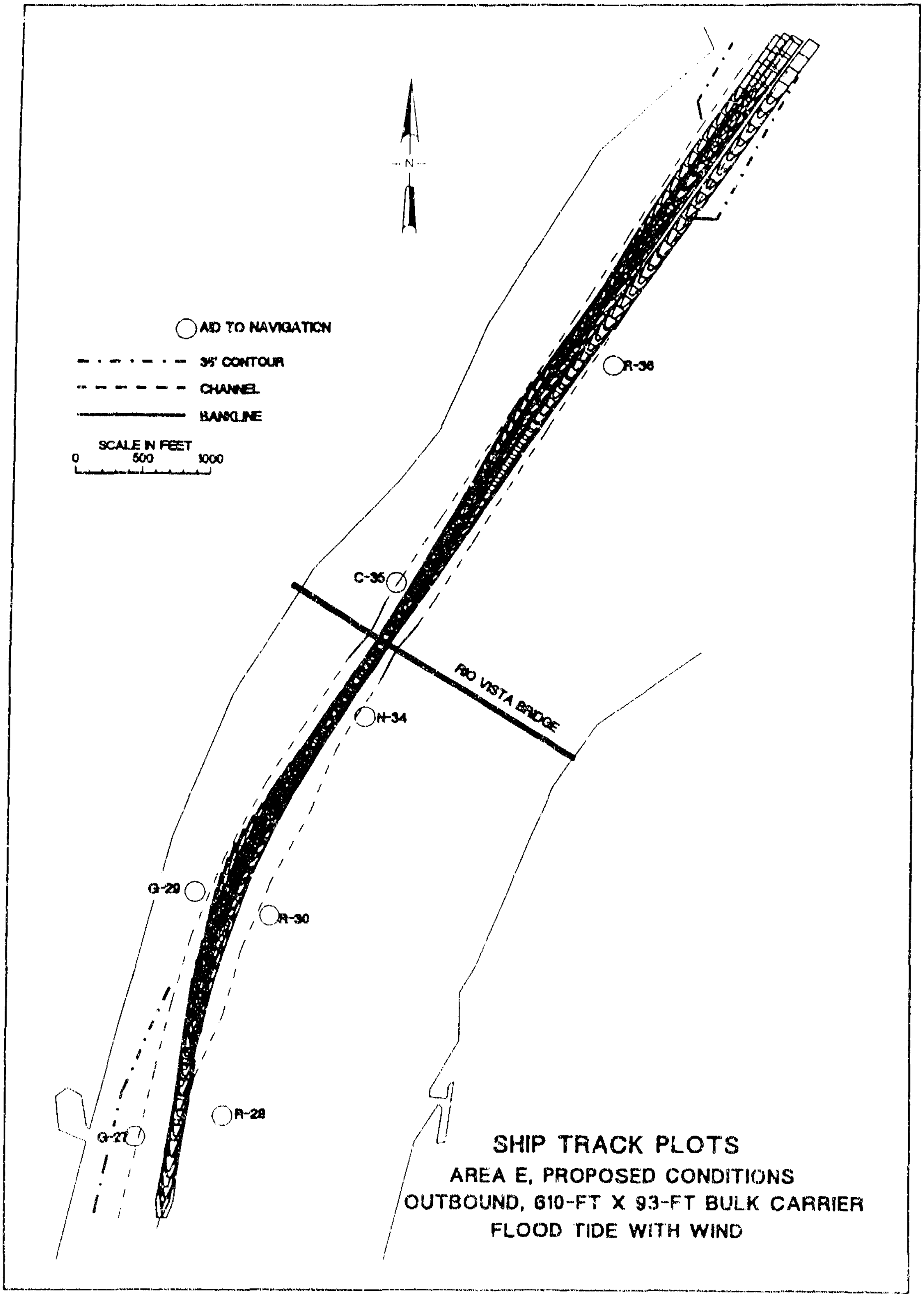


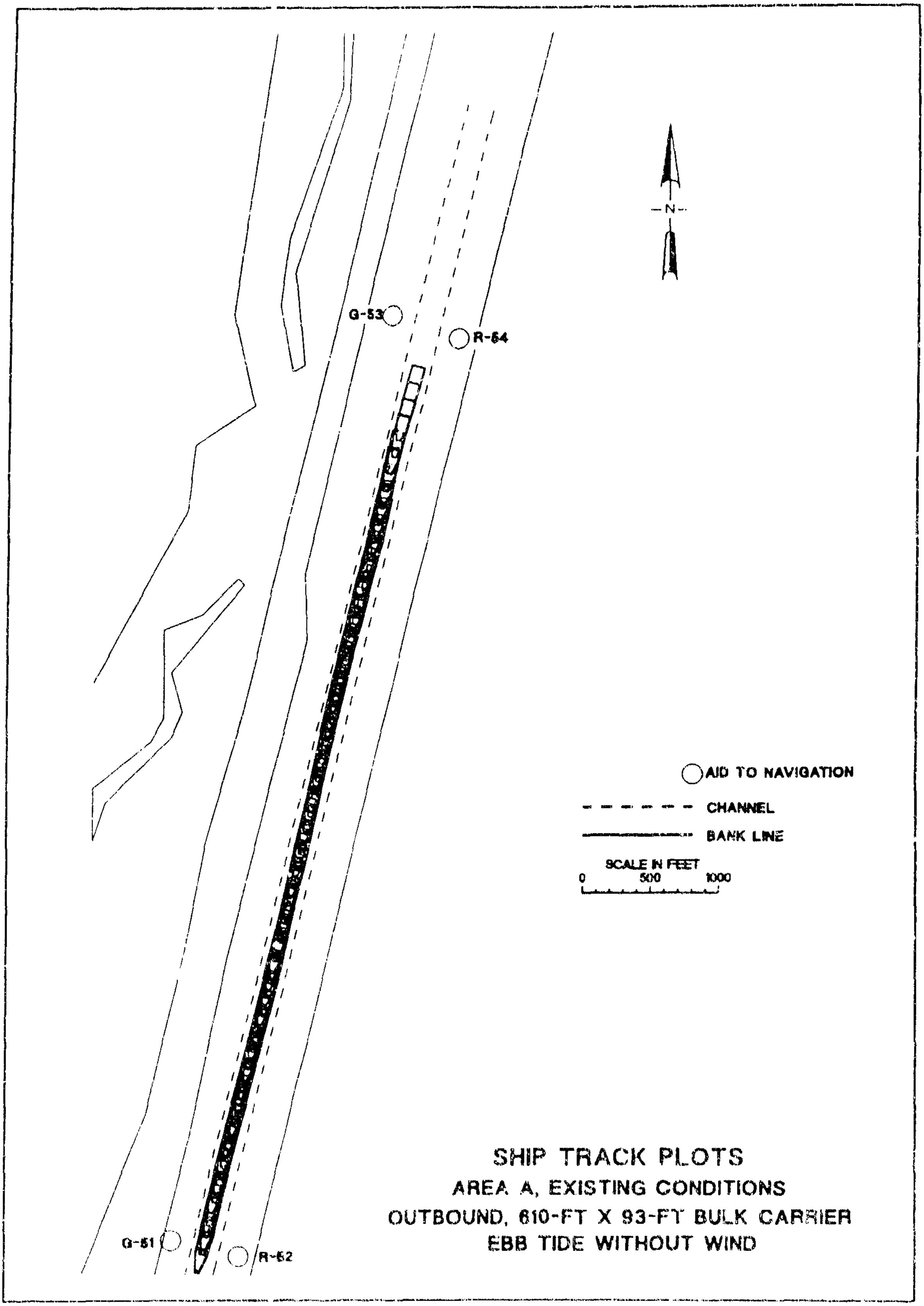
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

Plate 18

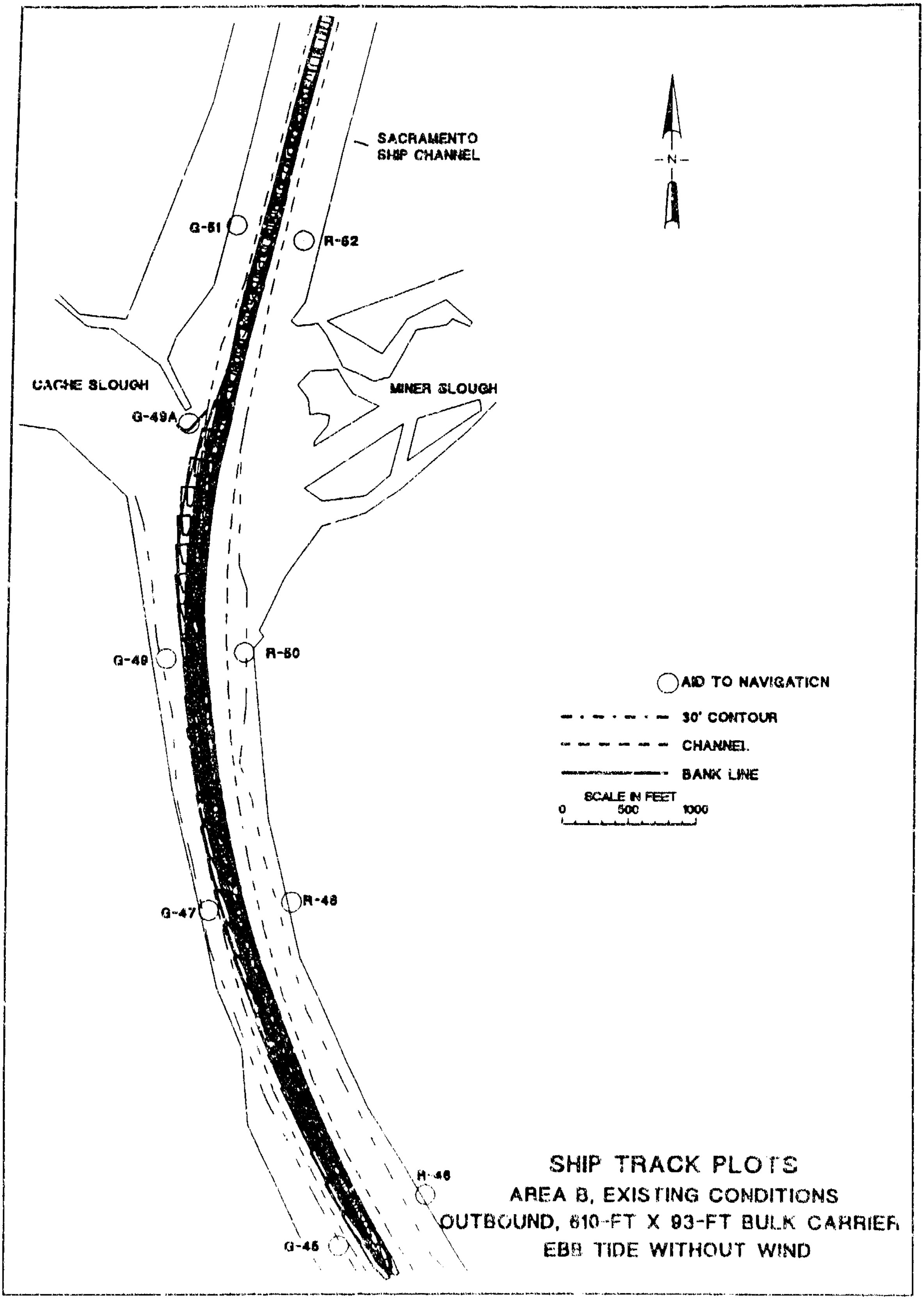


SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND


N
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
C-35
RIO VISTA BRIDGE
R-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

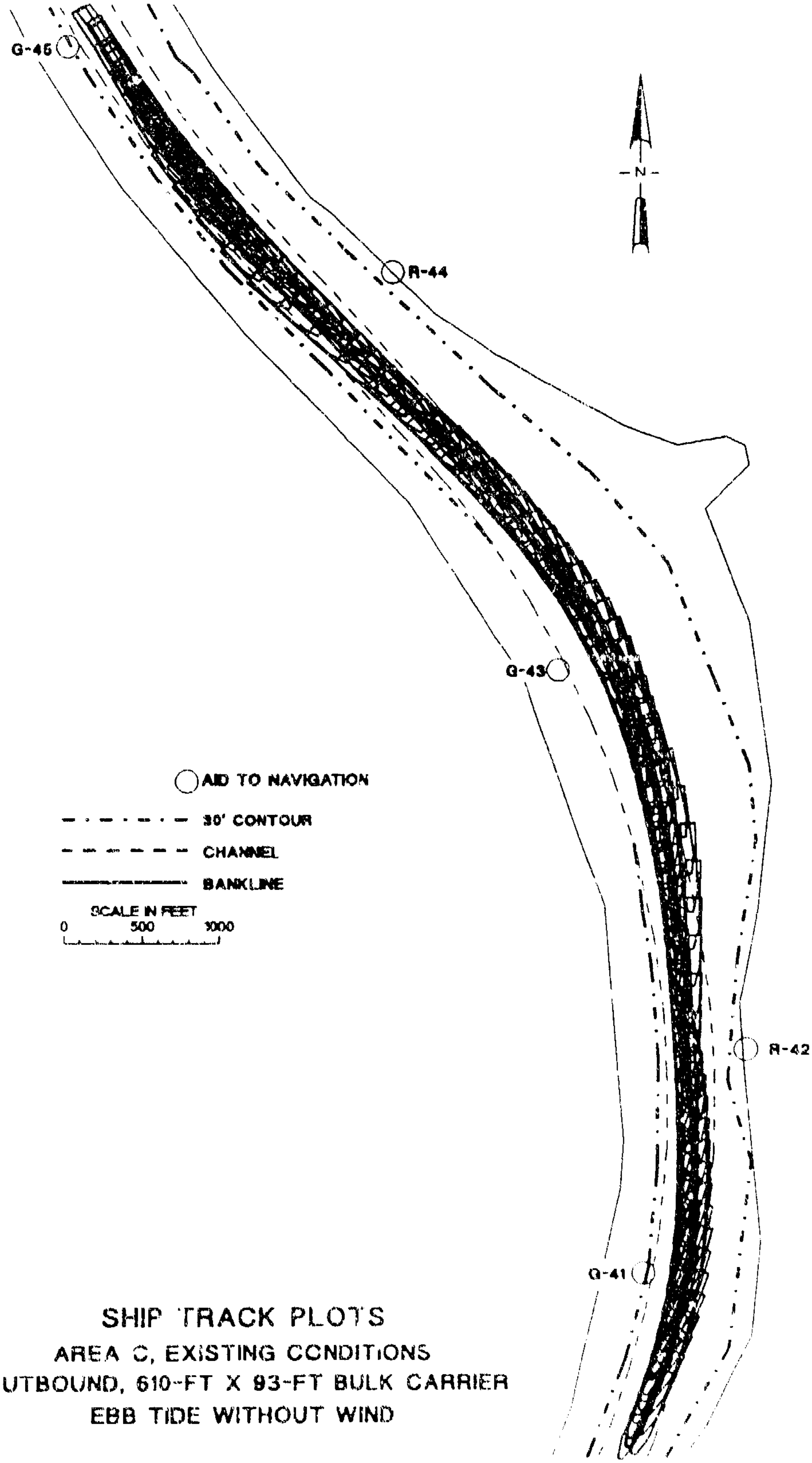


SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

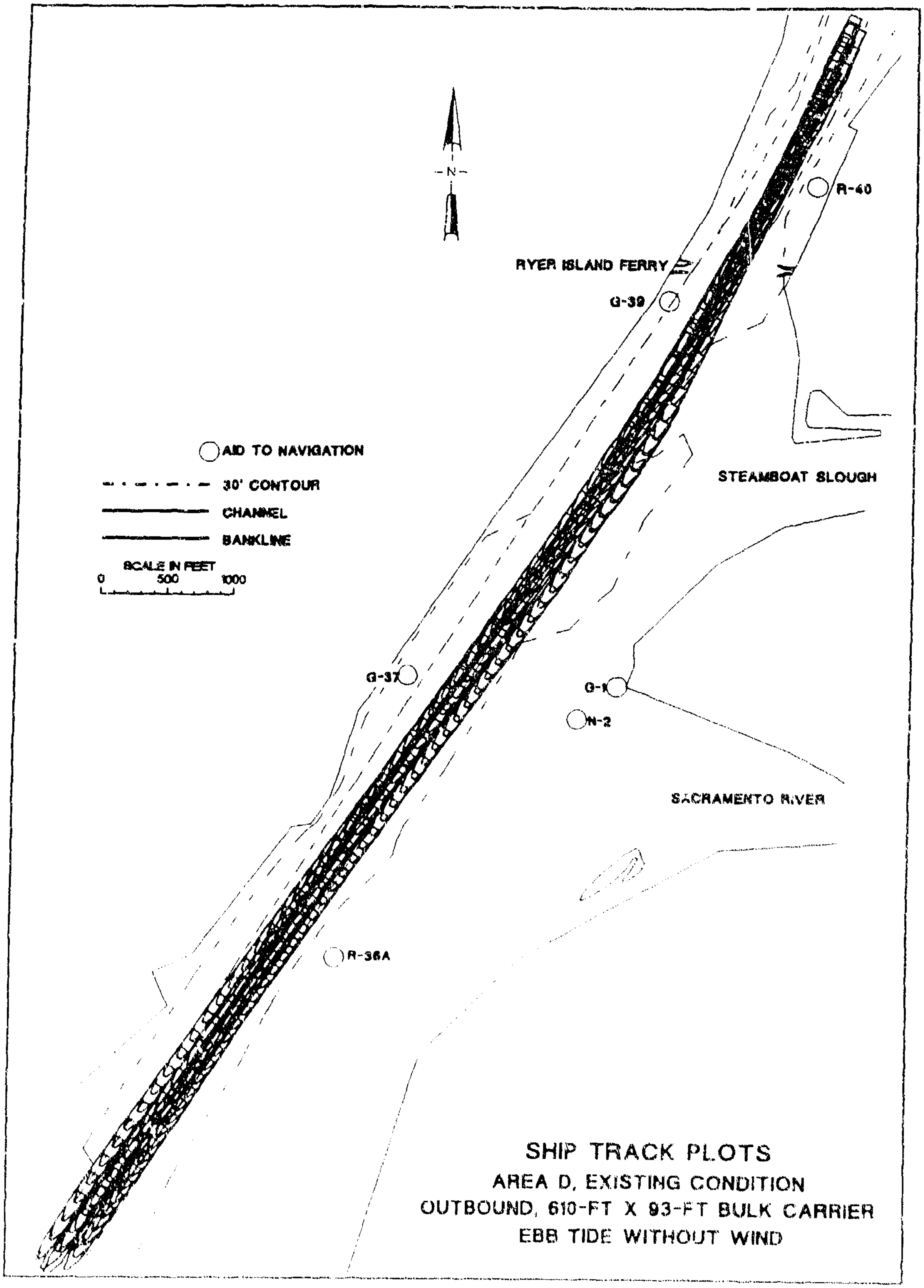


SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

Plate 22

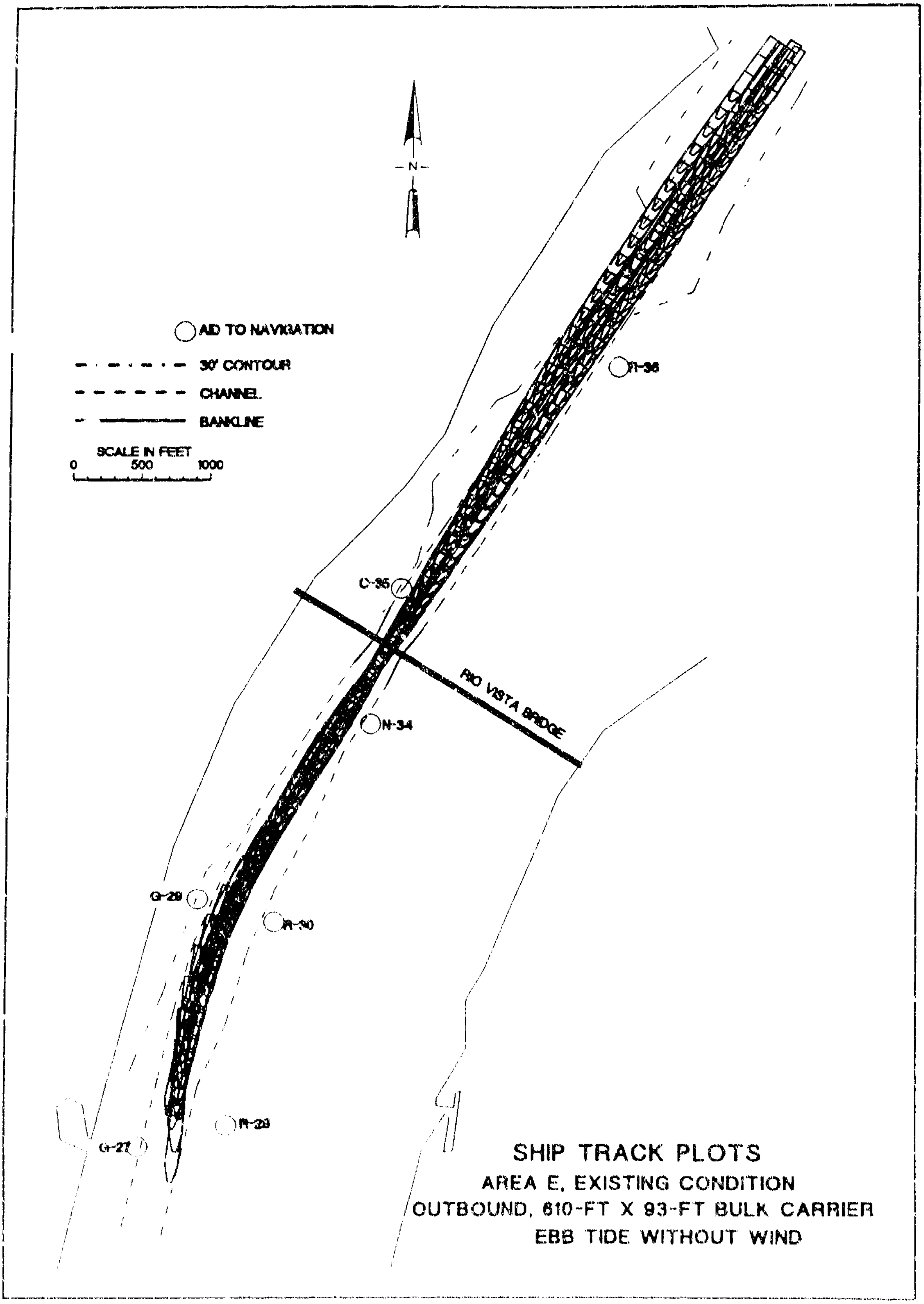


SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

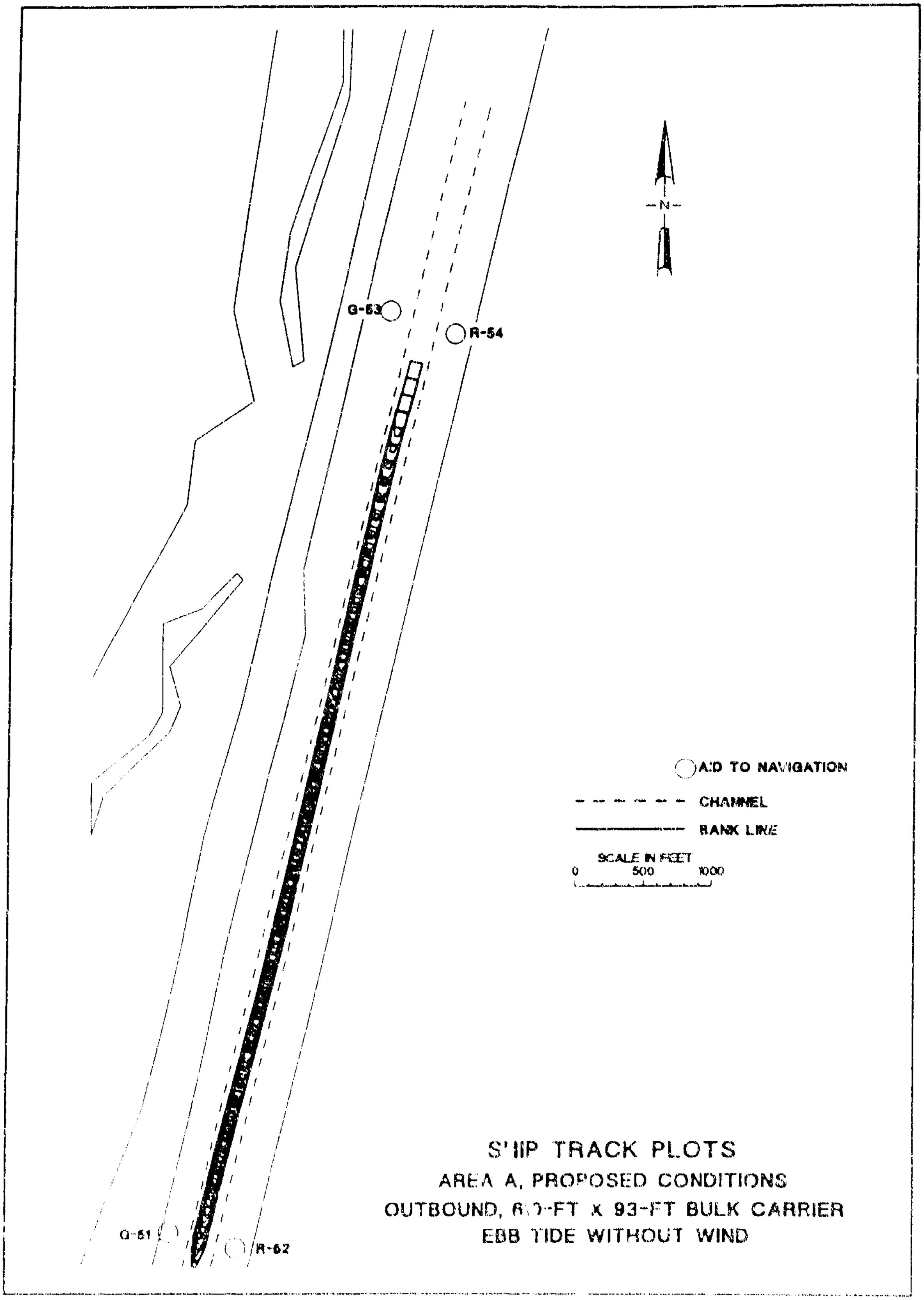


SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

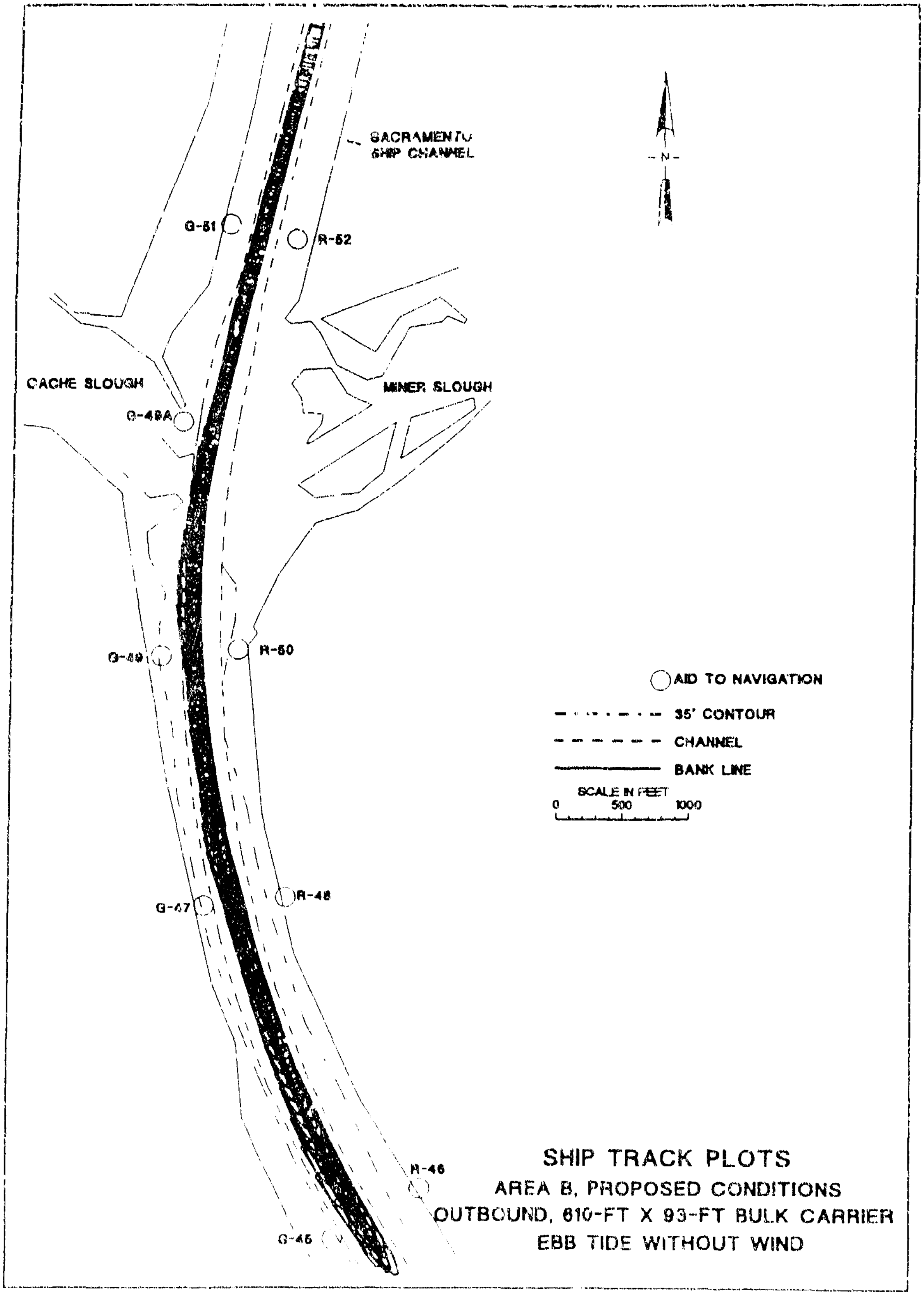
Plate 24



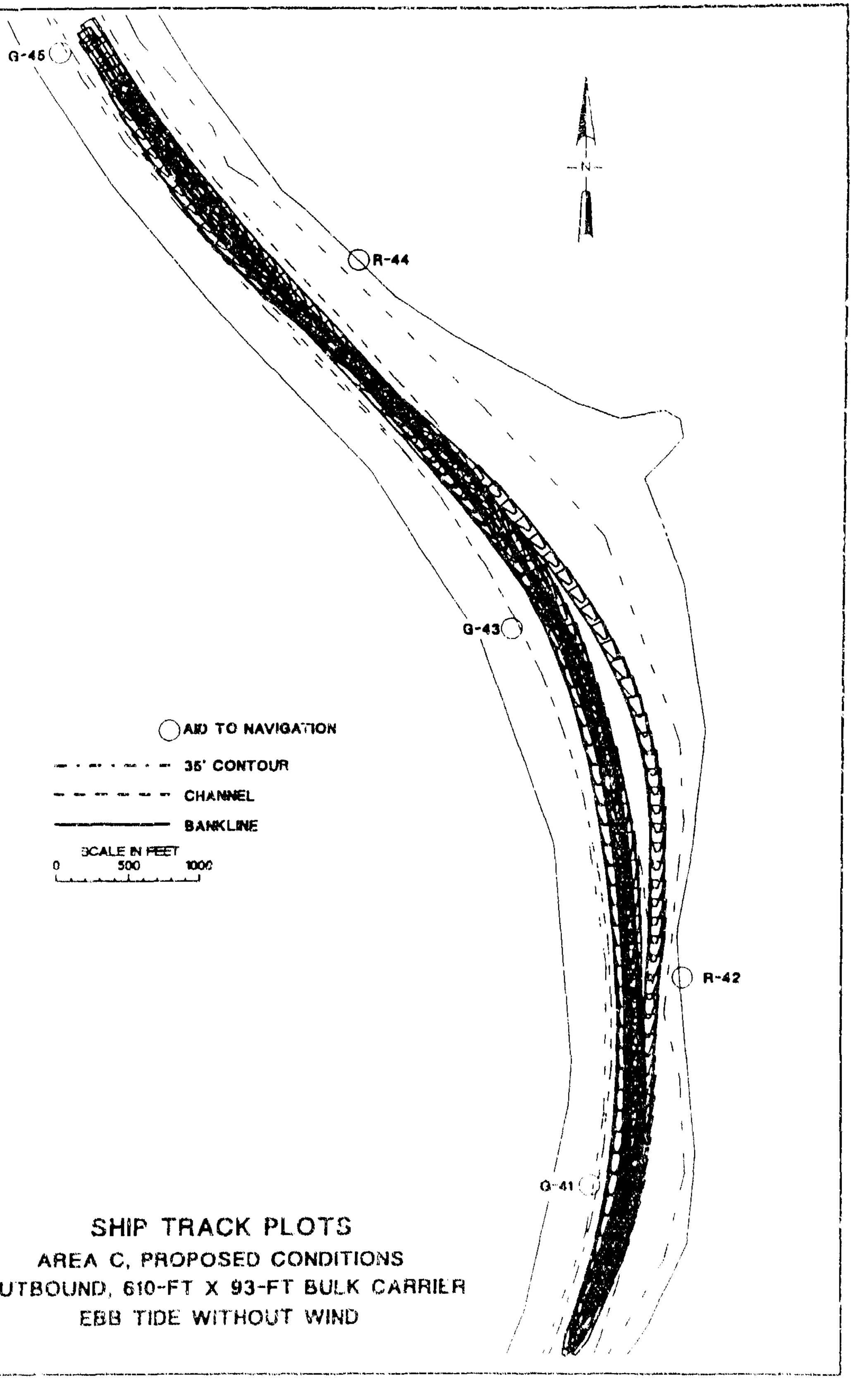
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND



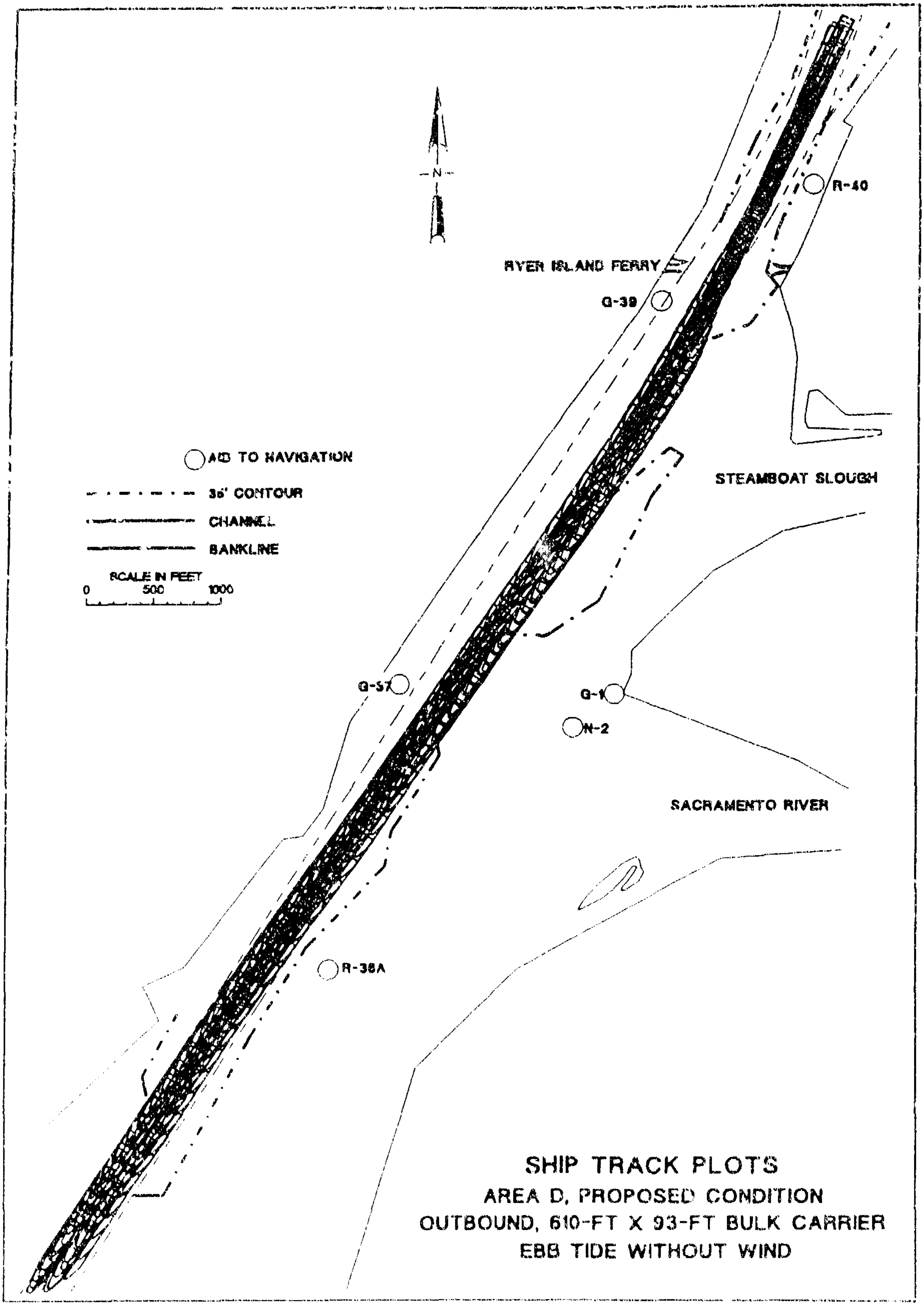
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 6[illegible]0-FT x 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

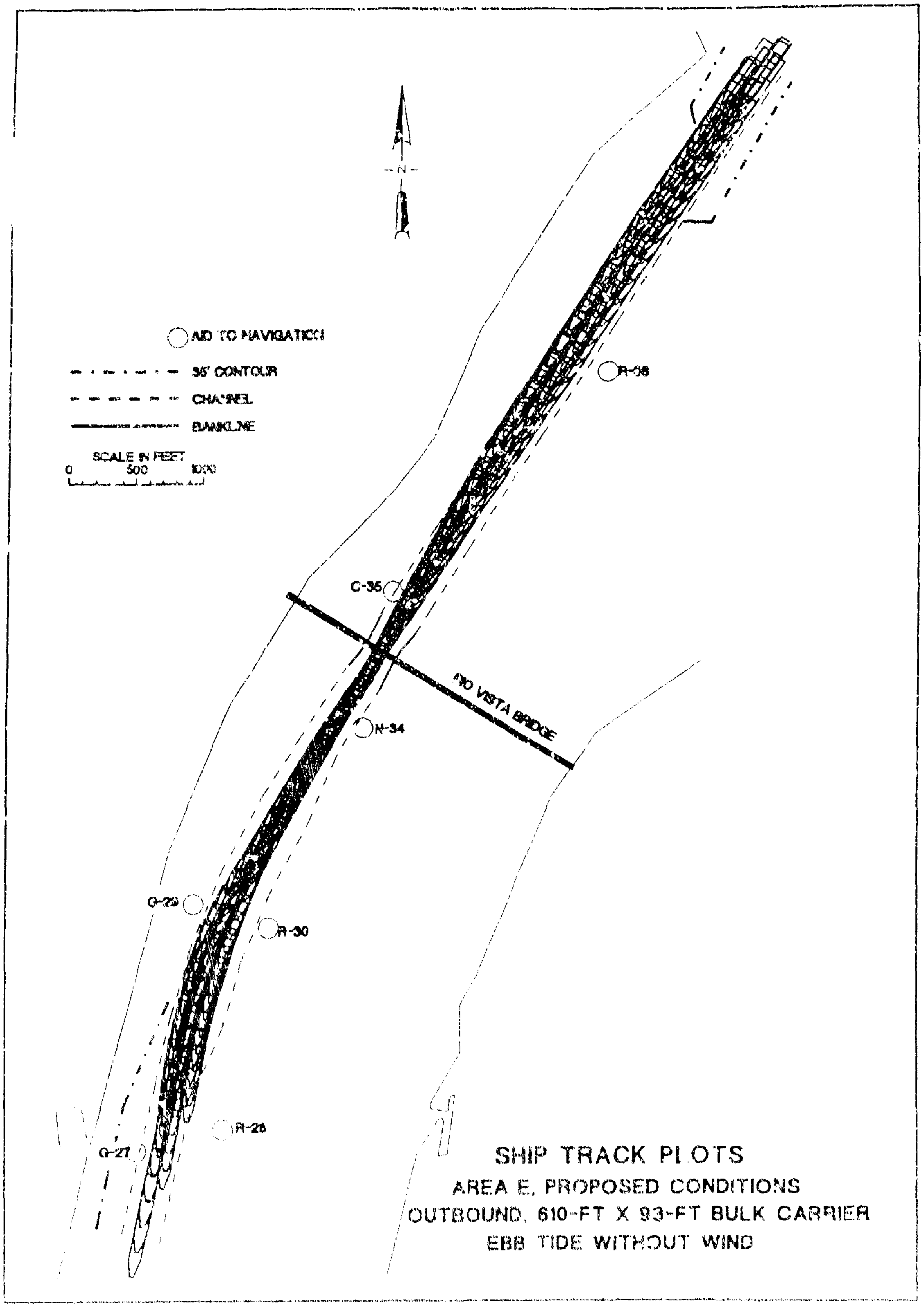
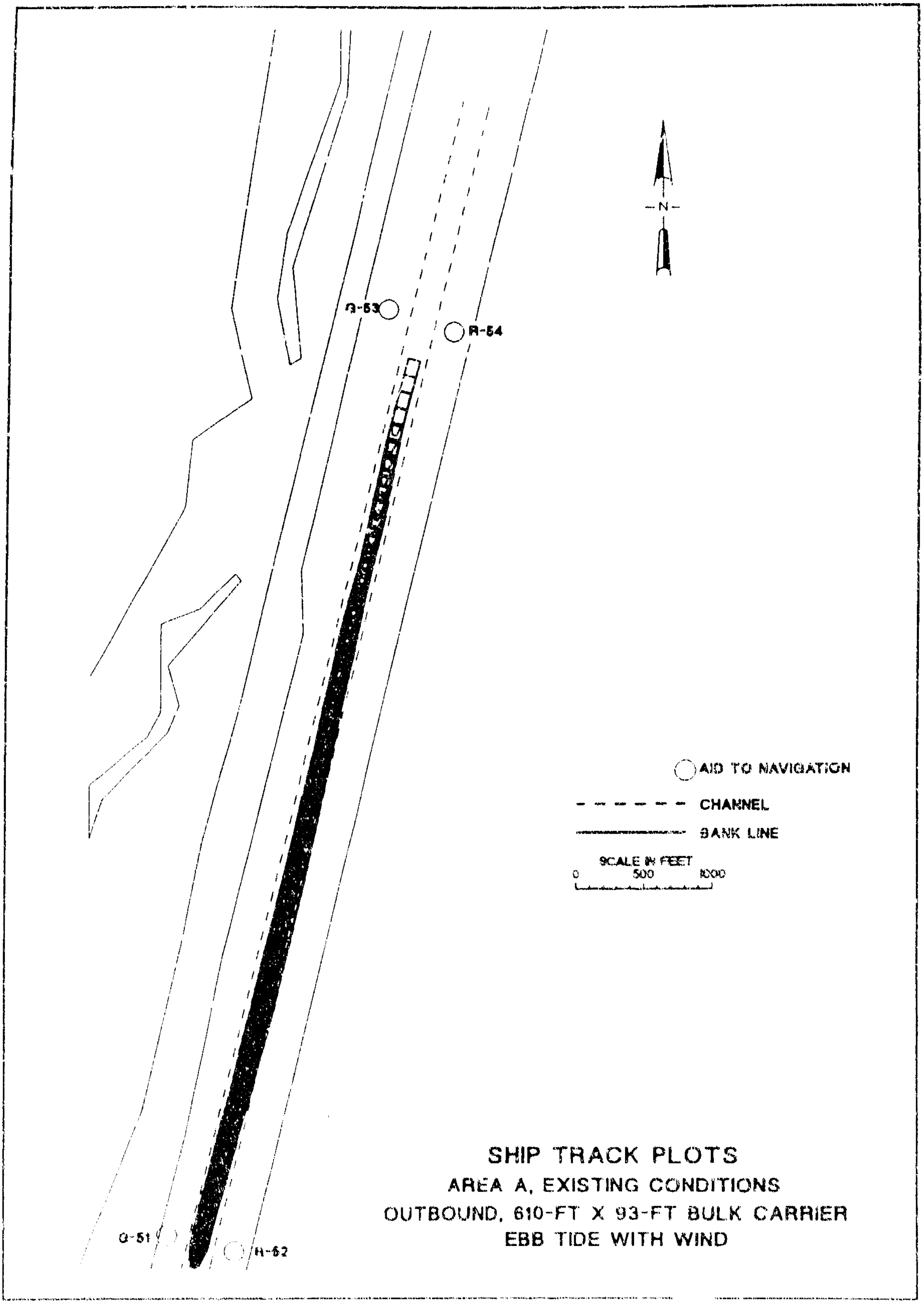
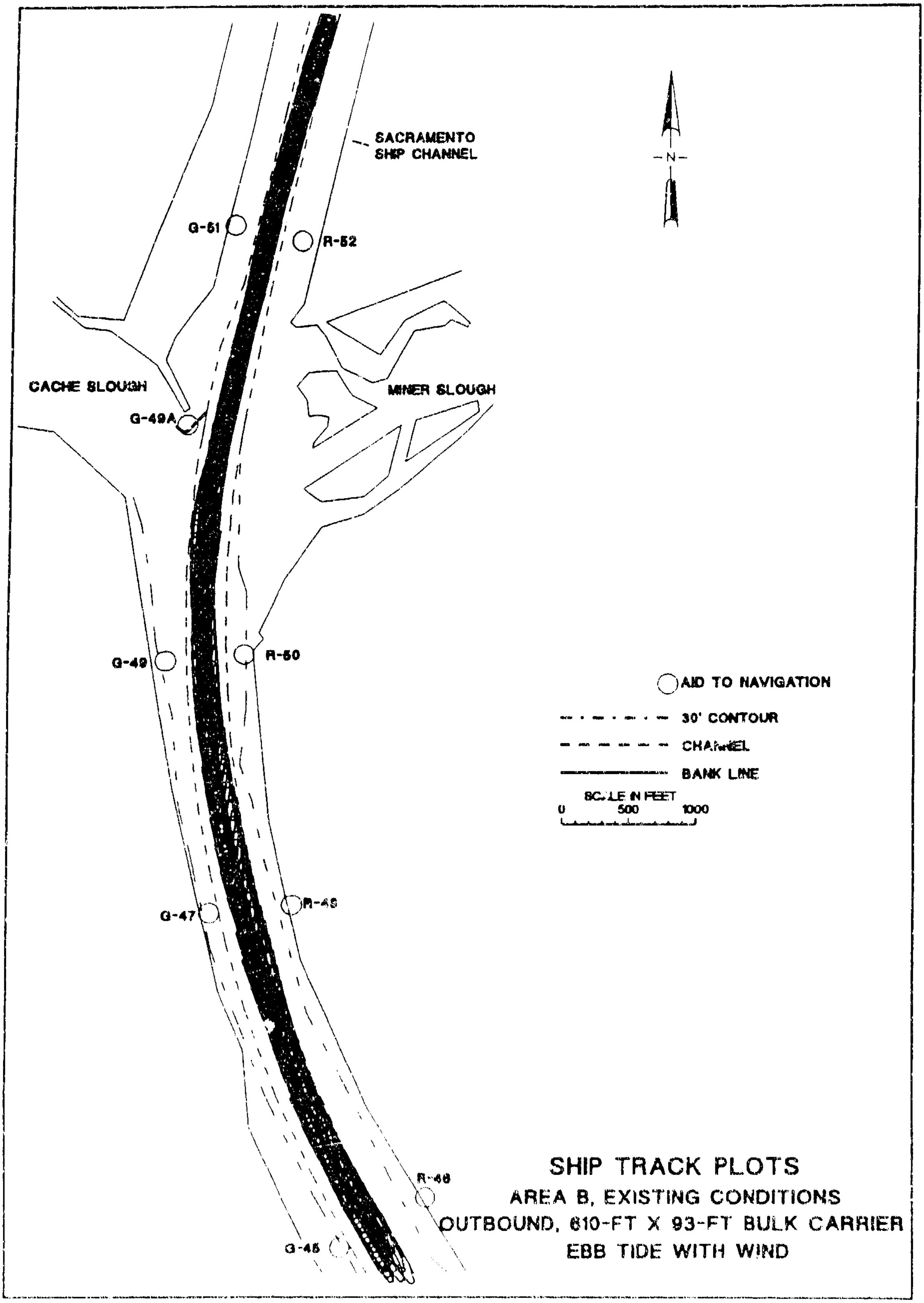

AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0 500 1000
R-36
C-35
RIO VISTA BRIDGE
R-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITHOUT WIND

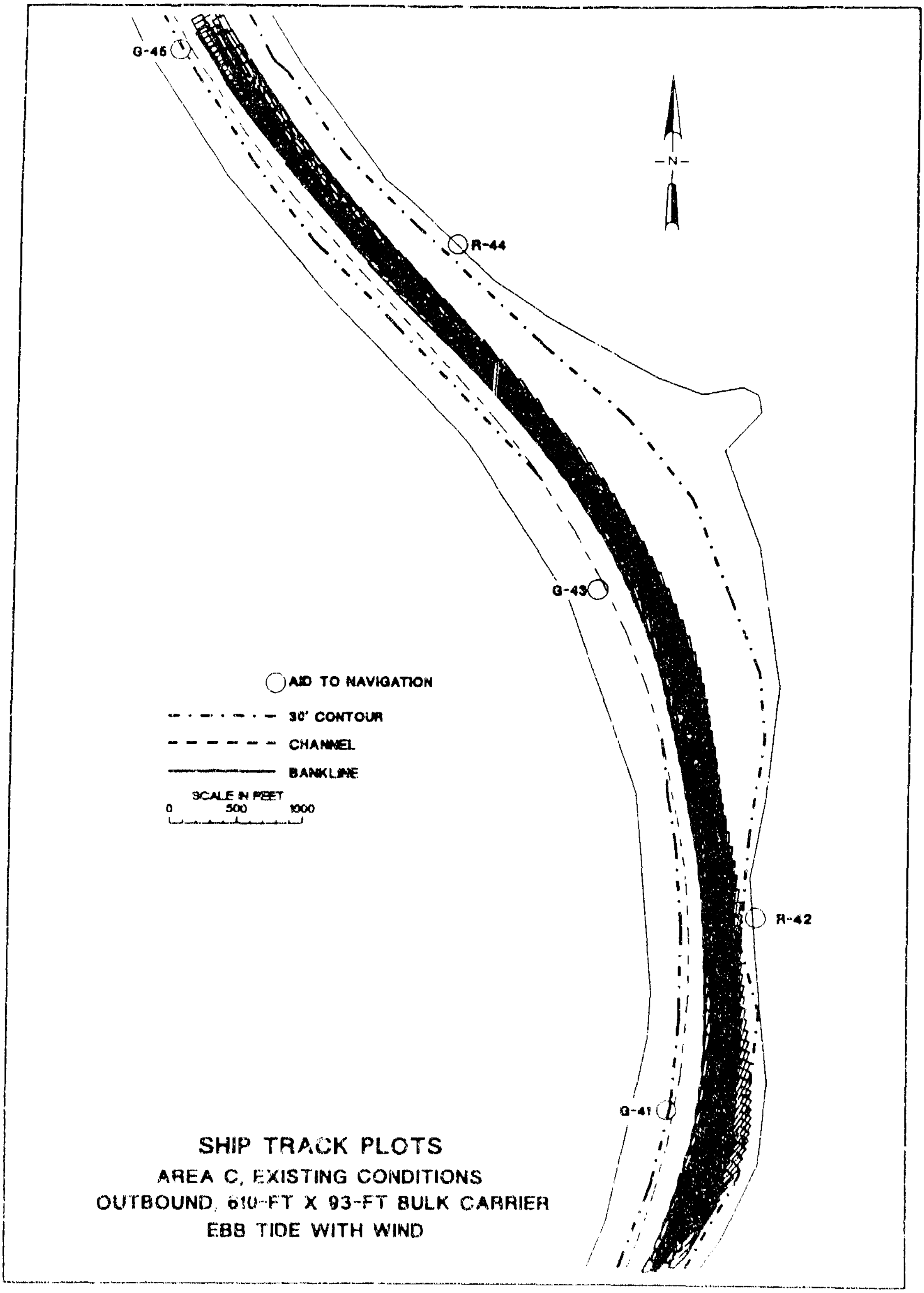
Plate 30



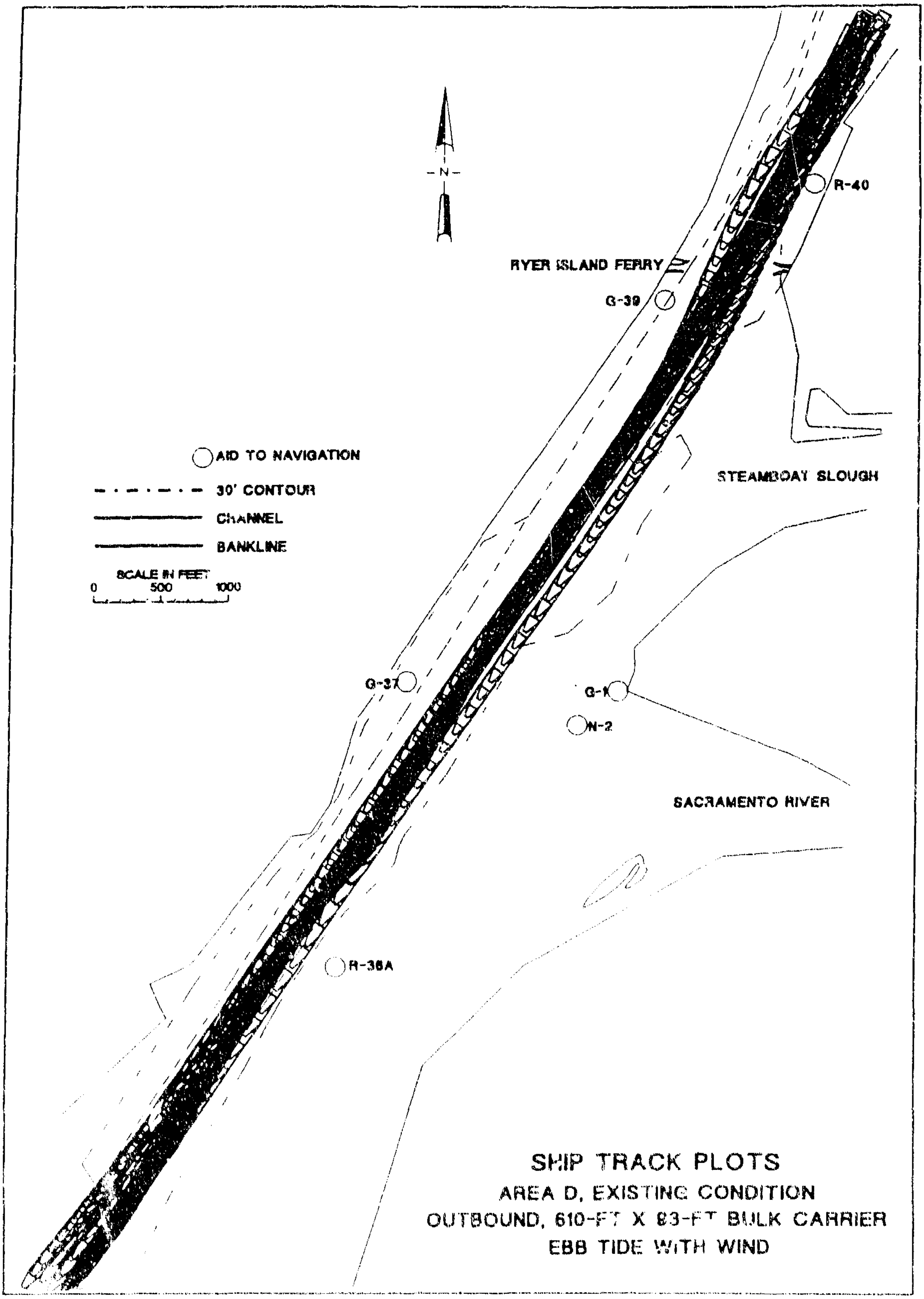
SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND



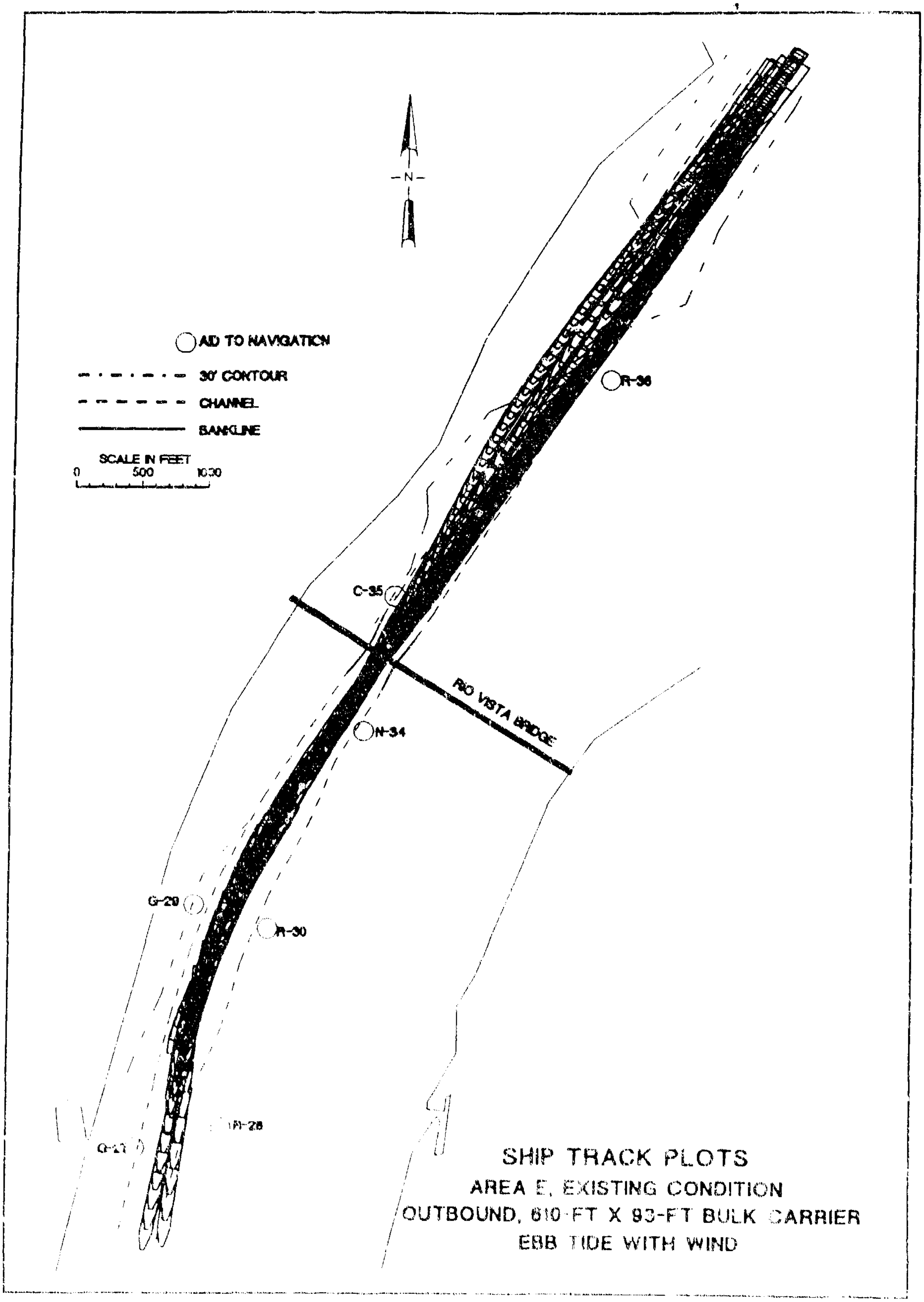
SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

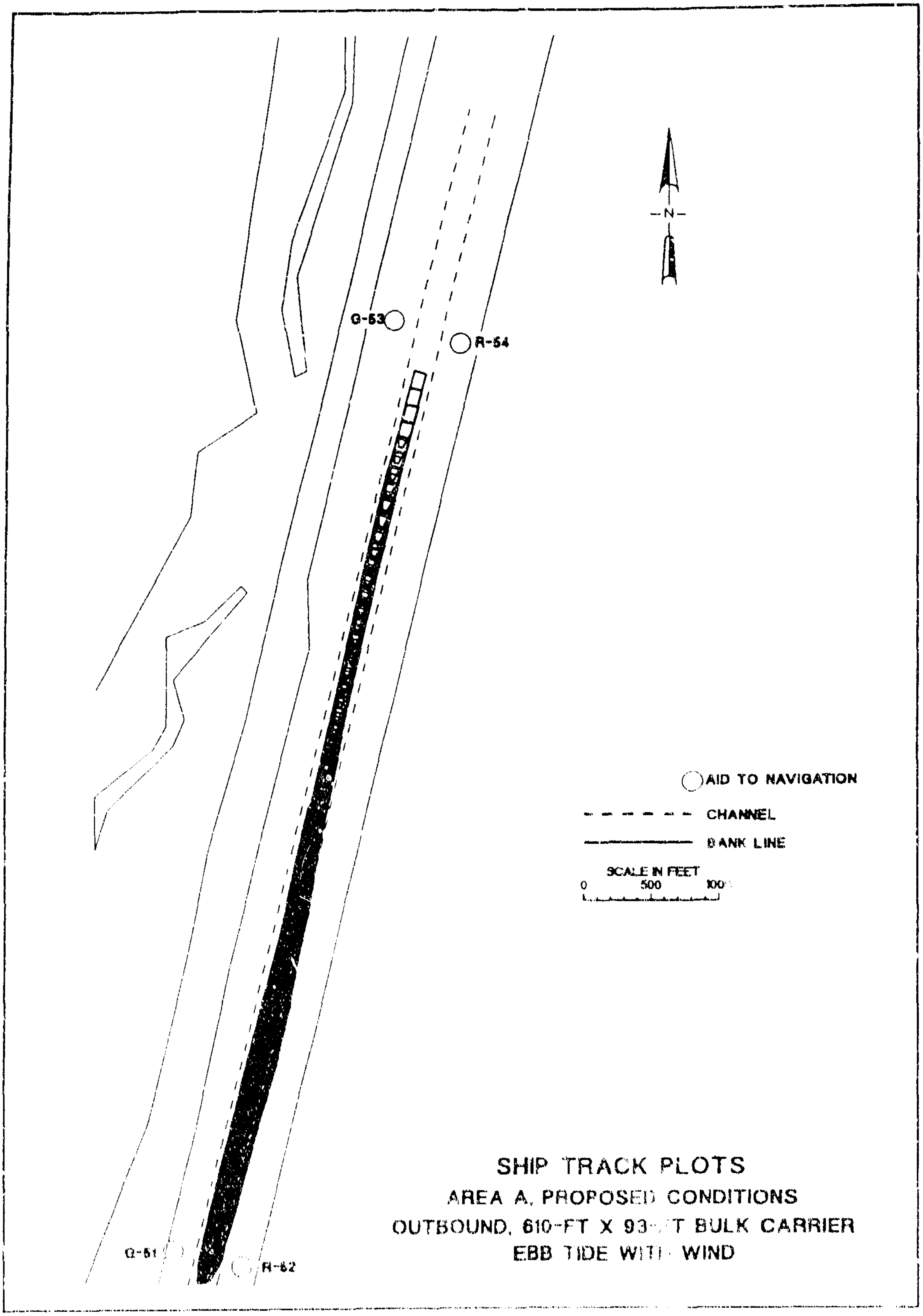


SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND



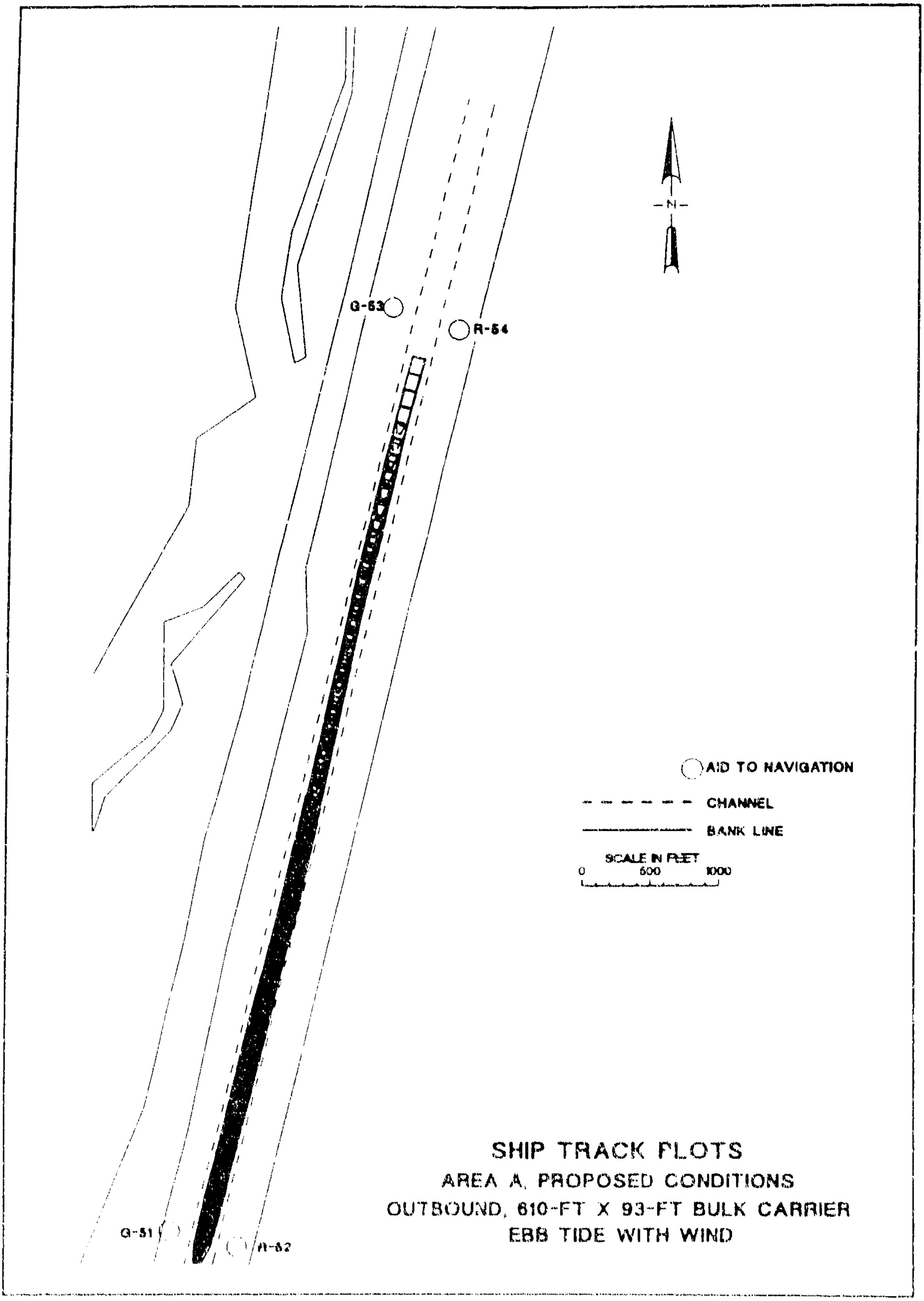
SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
OUTBOUND, 610-FT X 83-FT BULK CARRIER
EBB TIDE WITH WIND


AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
C-35
RIO VISTA BRIDGE
N-34
G-29
R-30
R-28
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
OUTBOUND, 610-FT X 83-FT BULK CARRIER
EBB TIDE WITH WIND

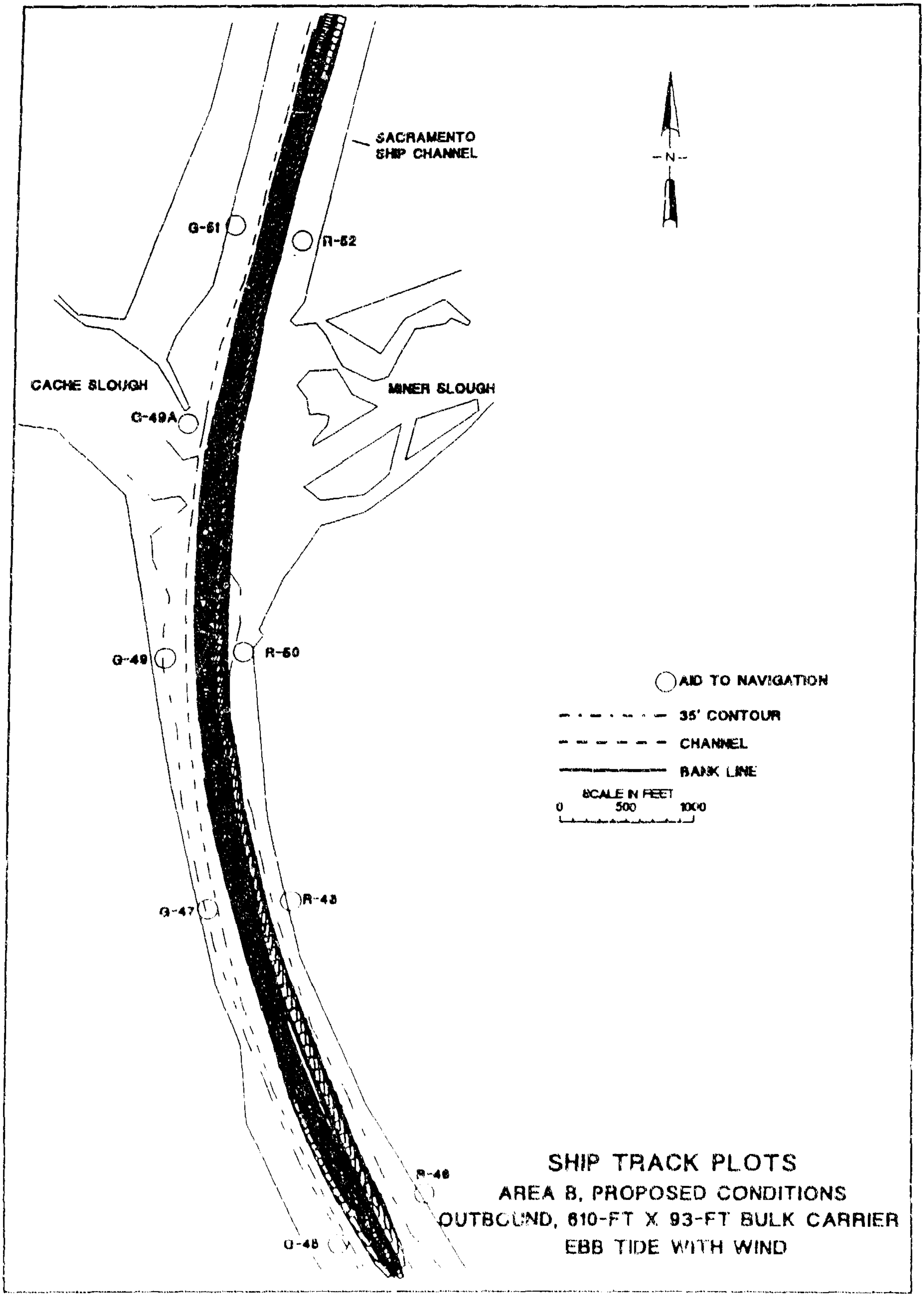


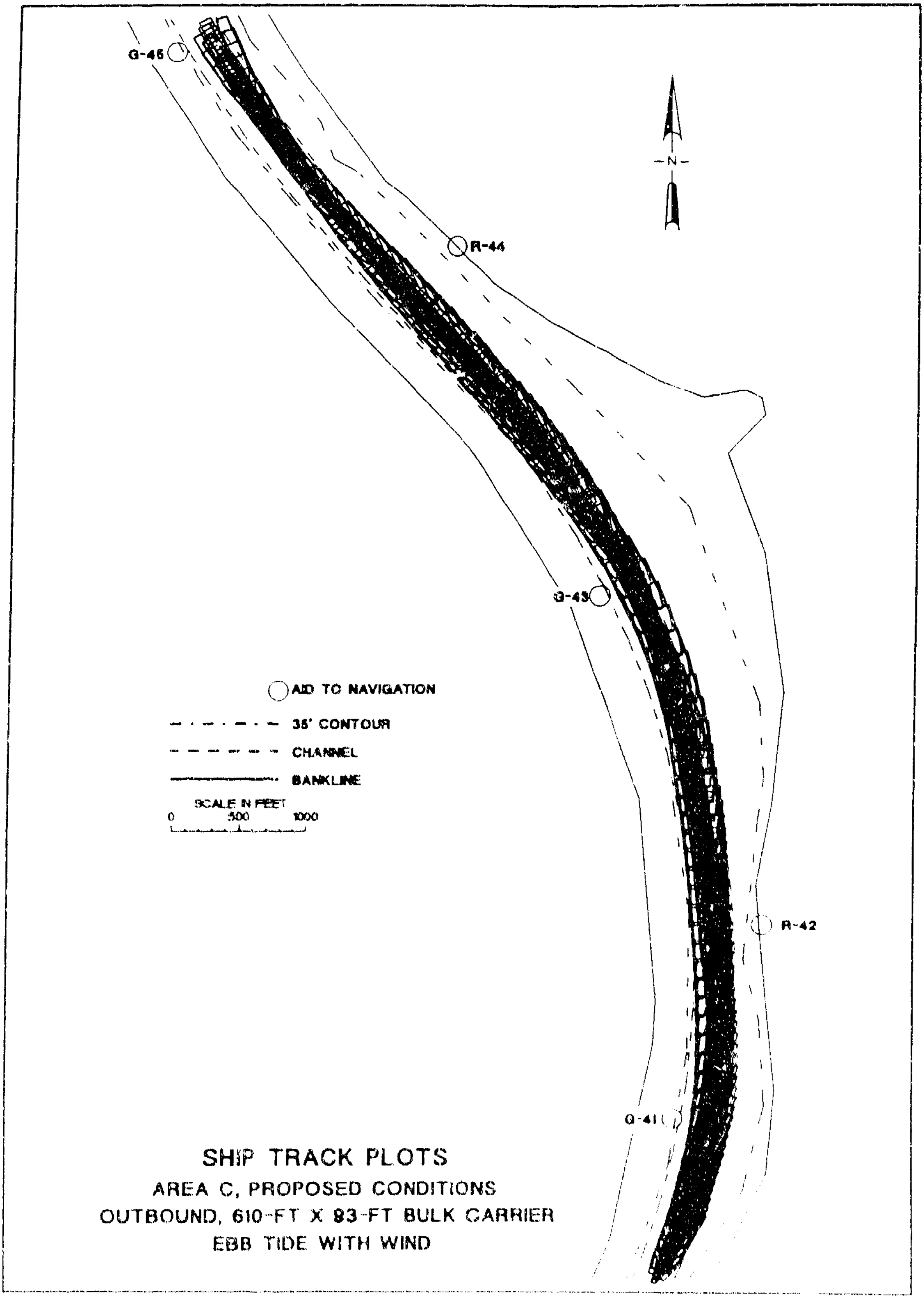
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

Plate 36



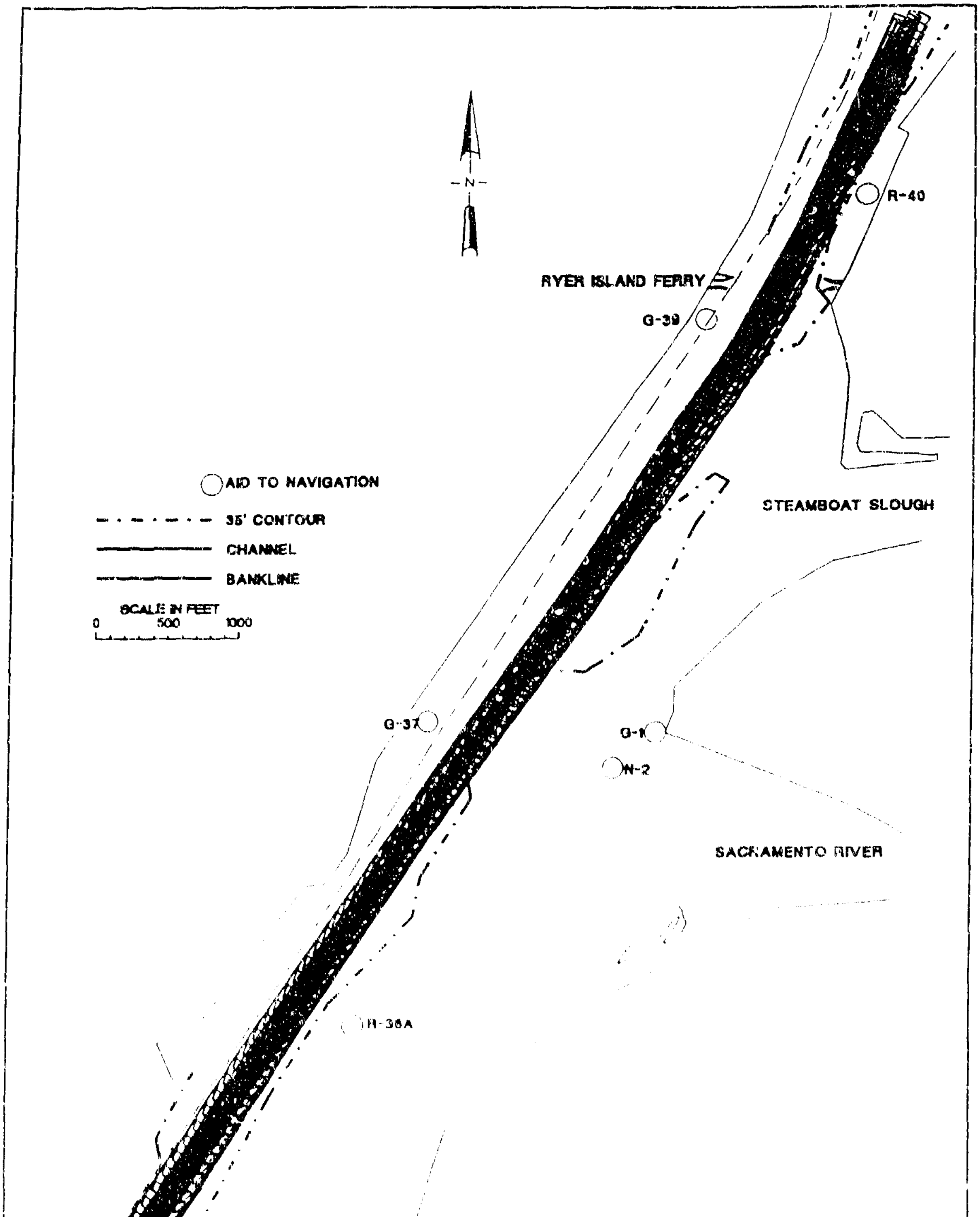
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND


SACRAMENTO SHIP CHANNEL
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
G-49
R-50
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0 500 1000
G-47
R-48
R-46
G-45
SHIP TRACK PLOTS
AREA 8, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND



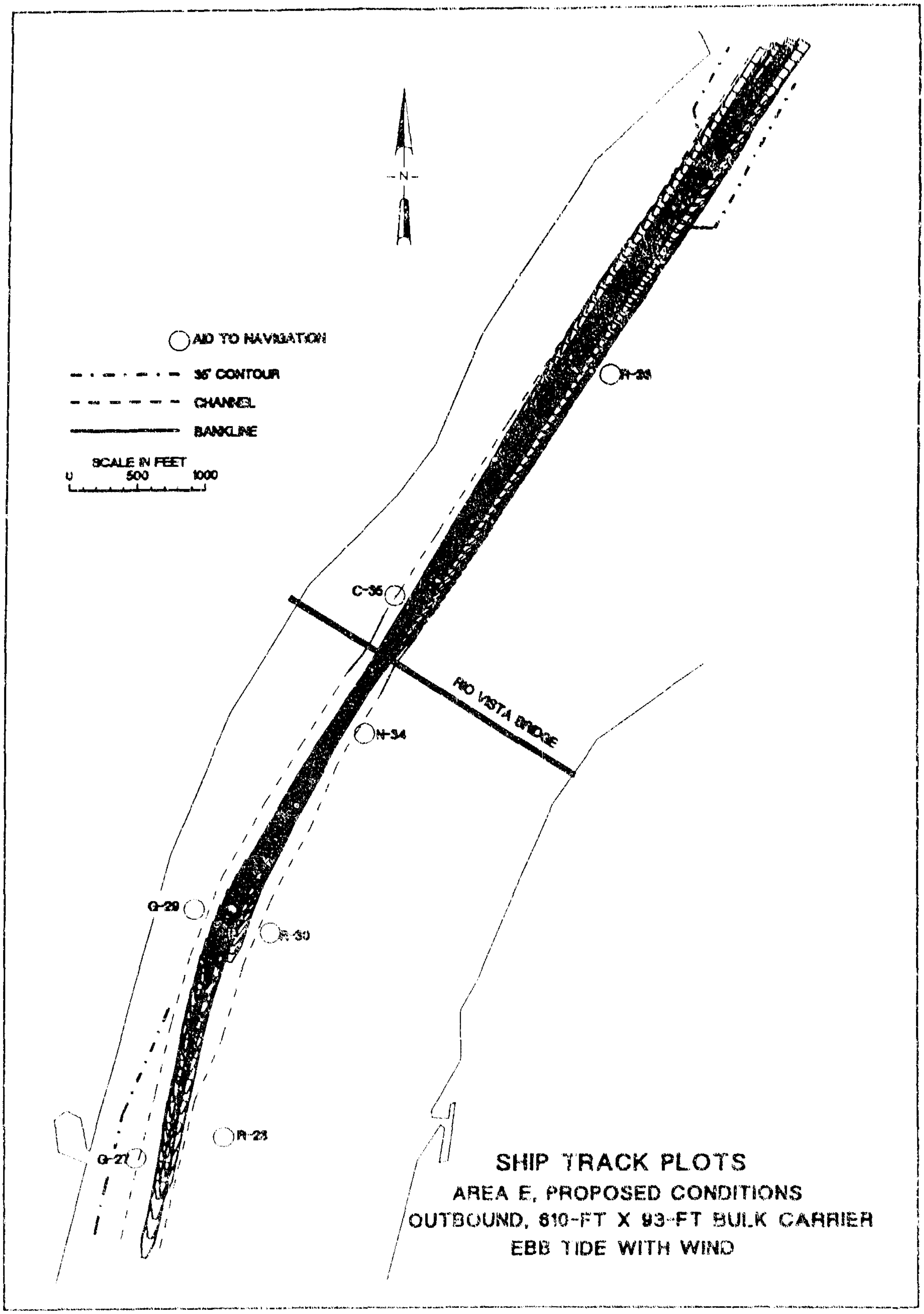
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

Plate 39

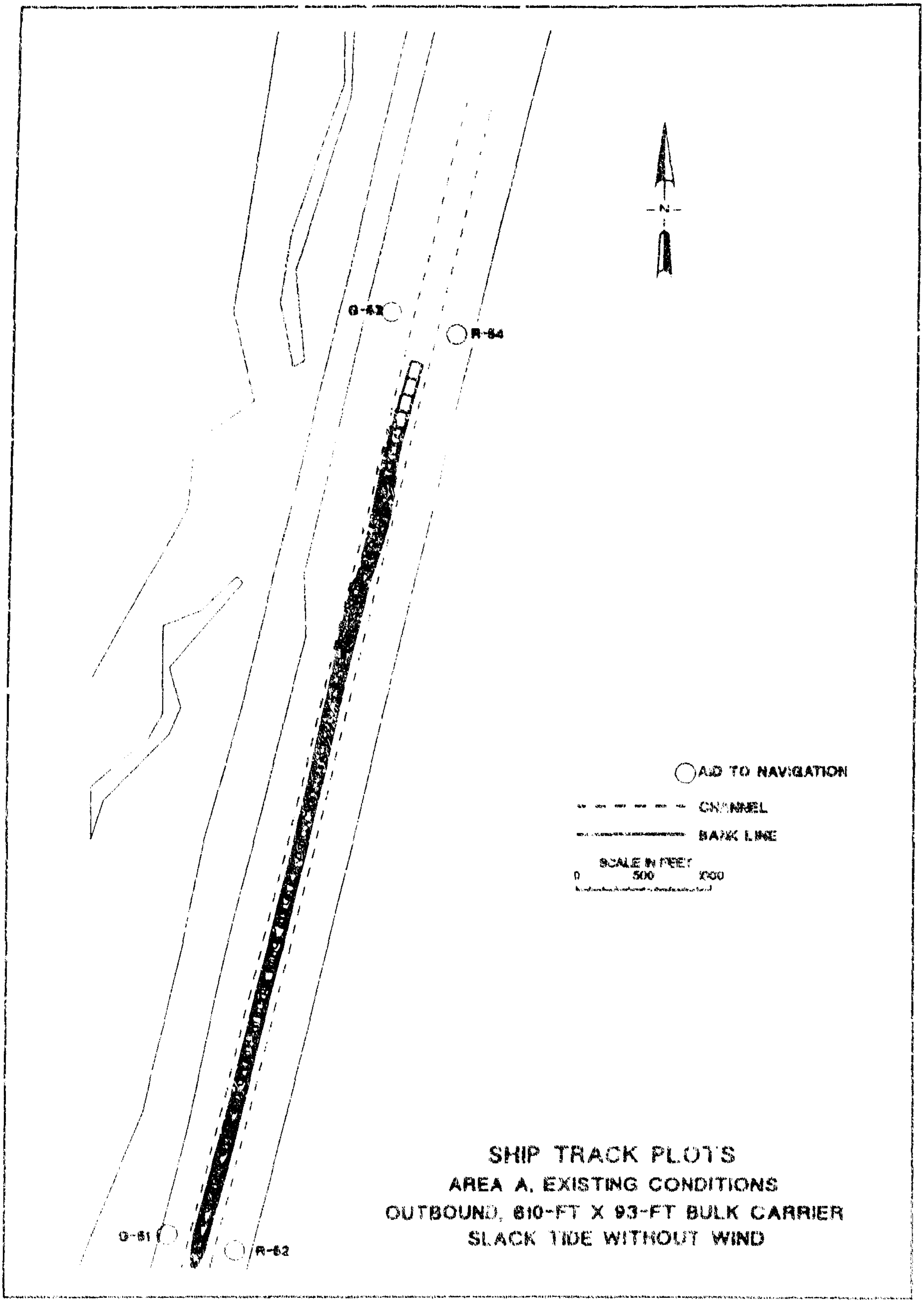


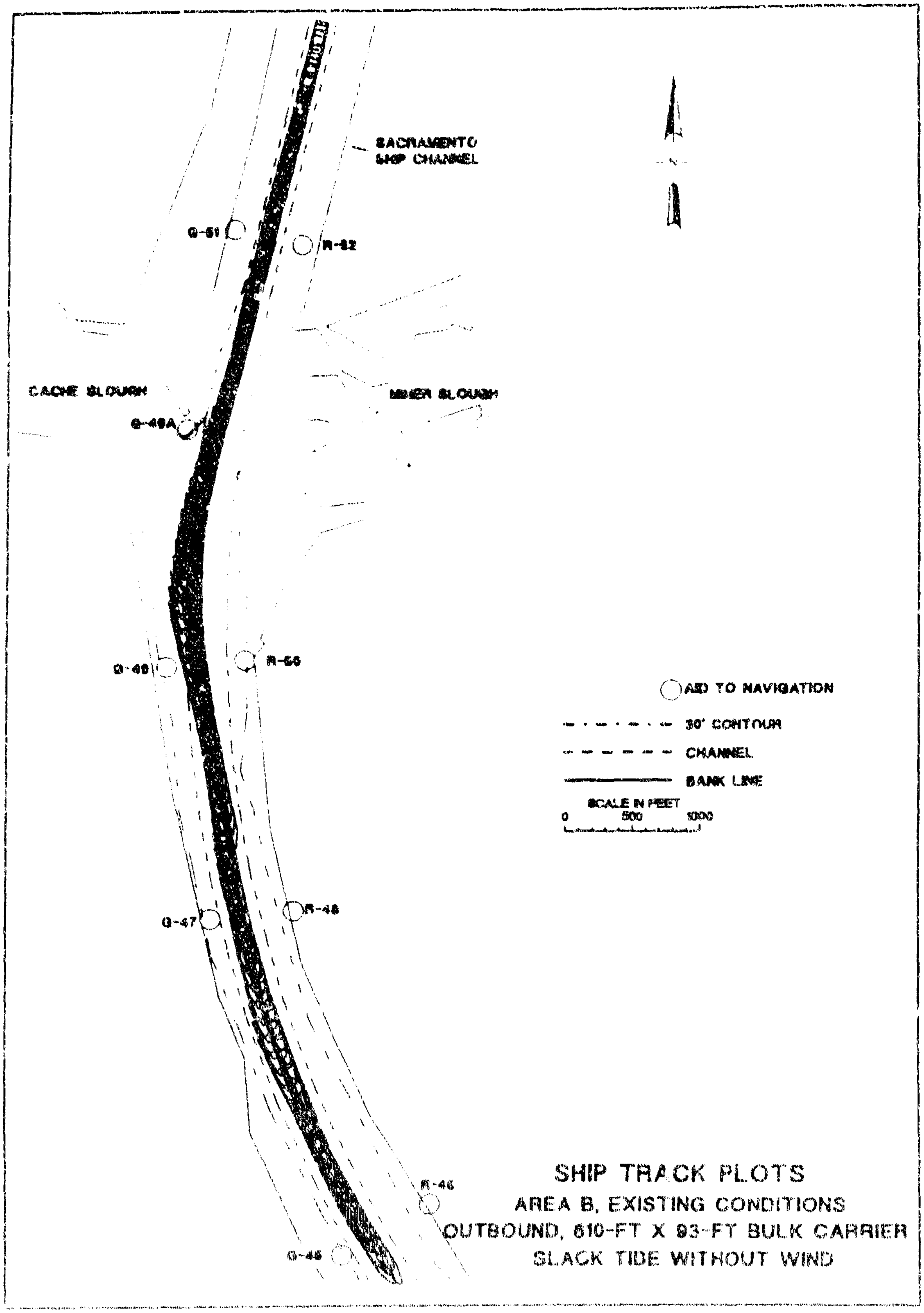
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

Plate 40

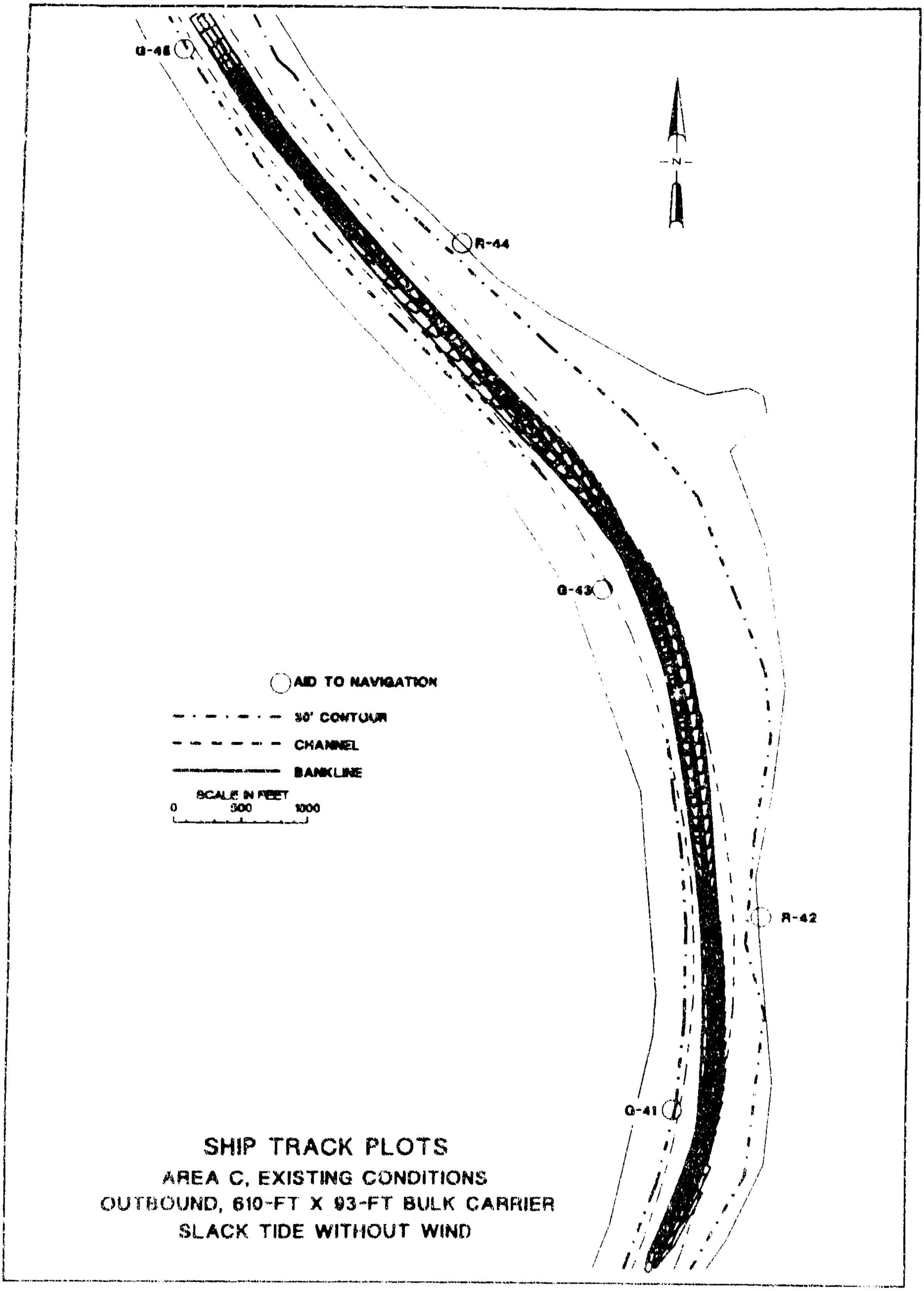


SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

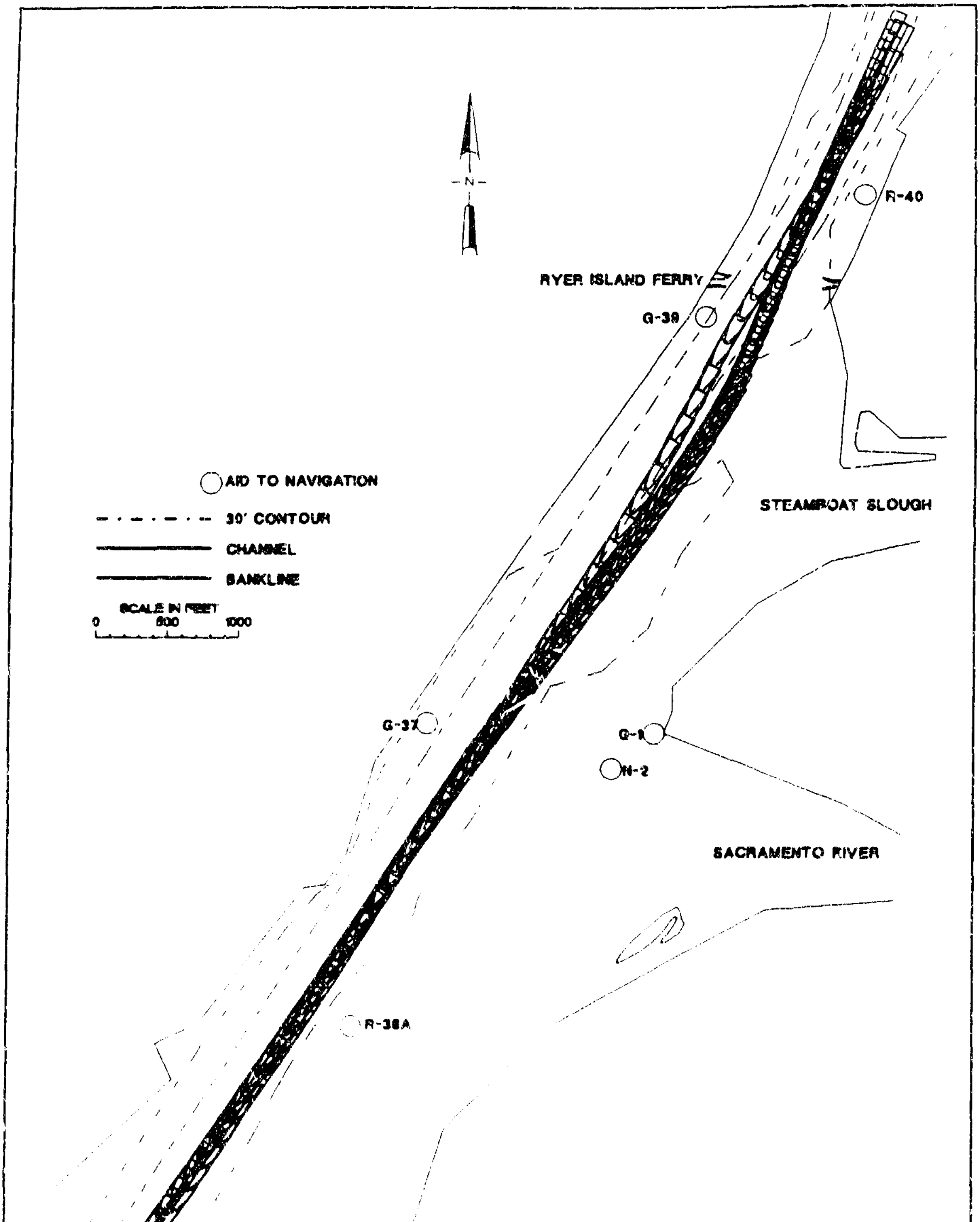

N
G-62
R-64
G-61
R-62
AID TO NAVIGATION
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
OUTBOUND, 810-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



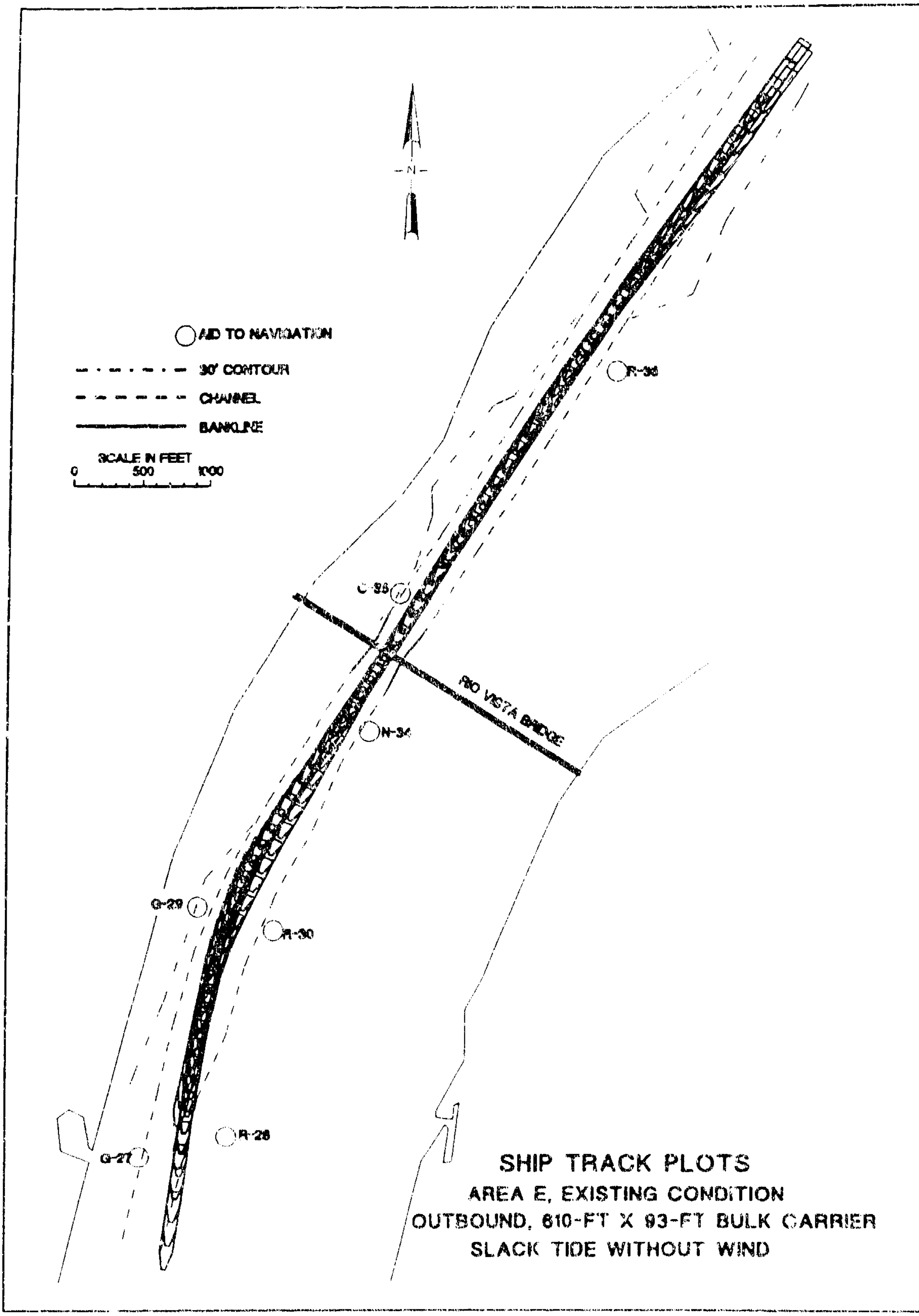
SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



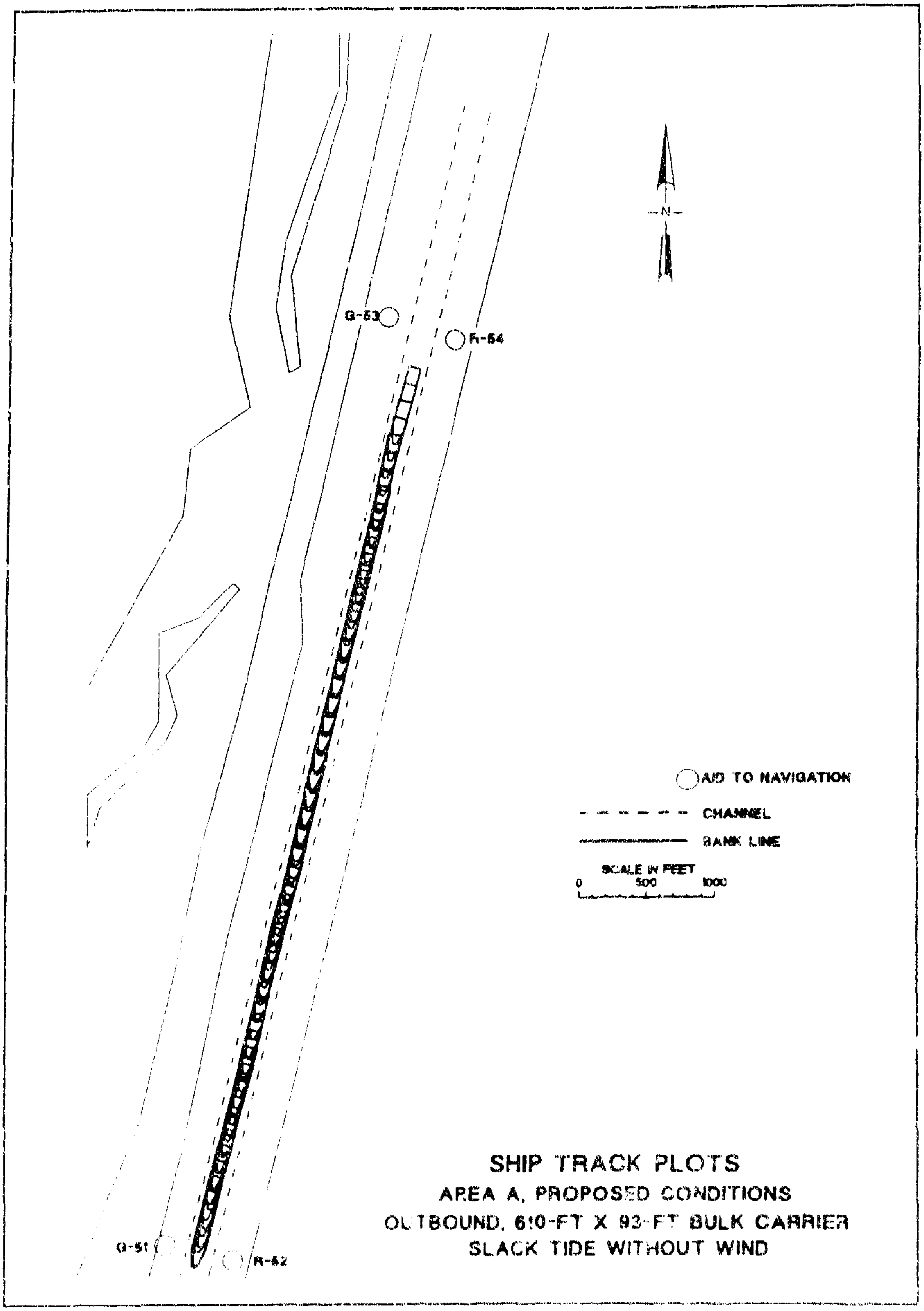
SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



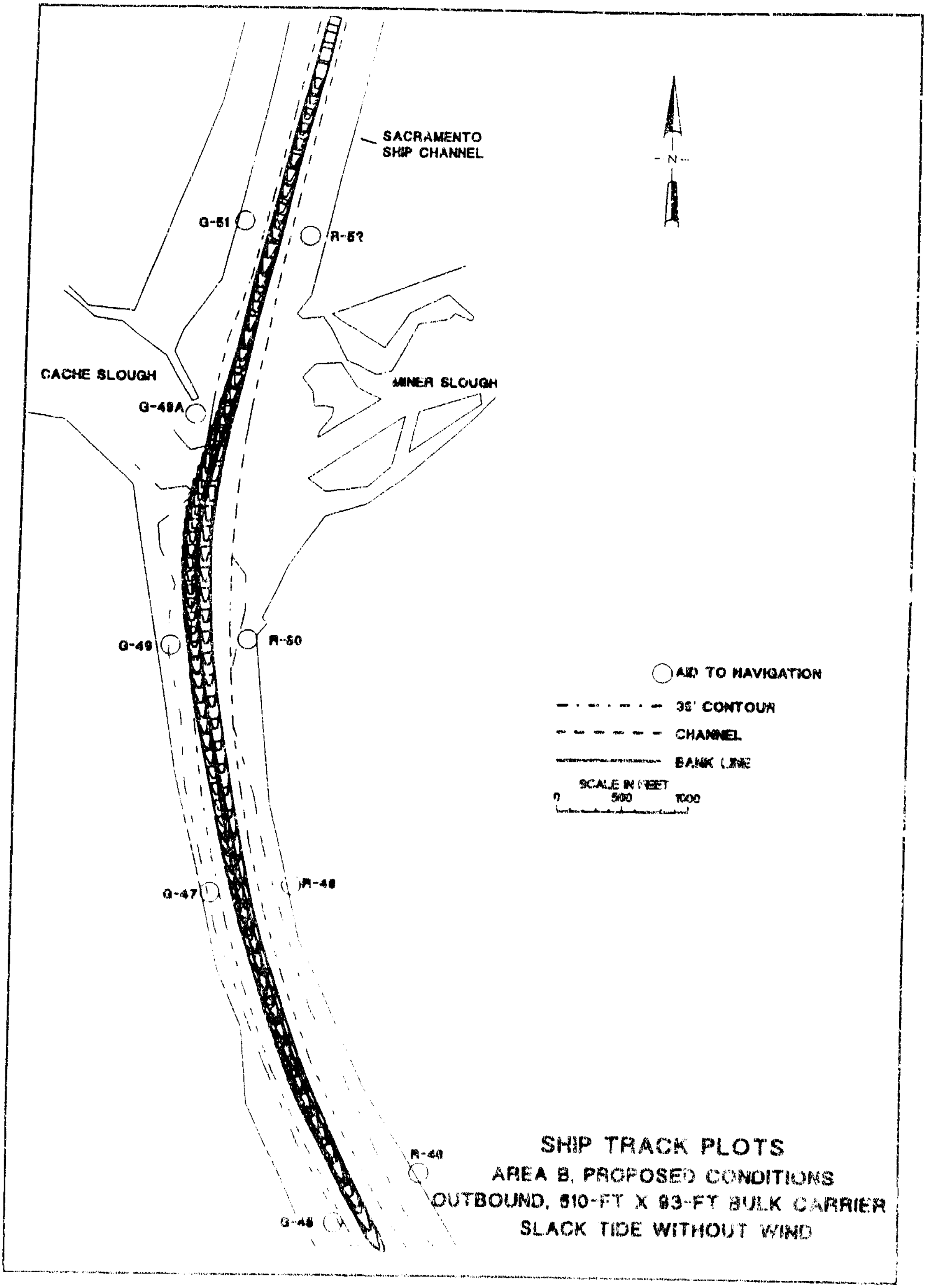
SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



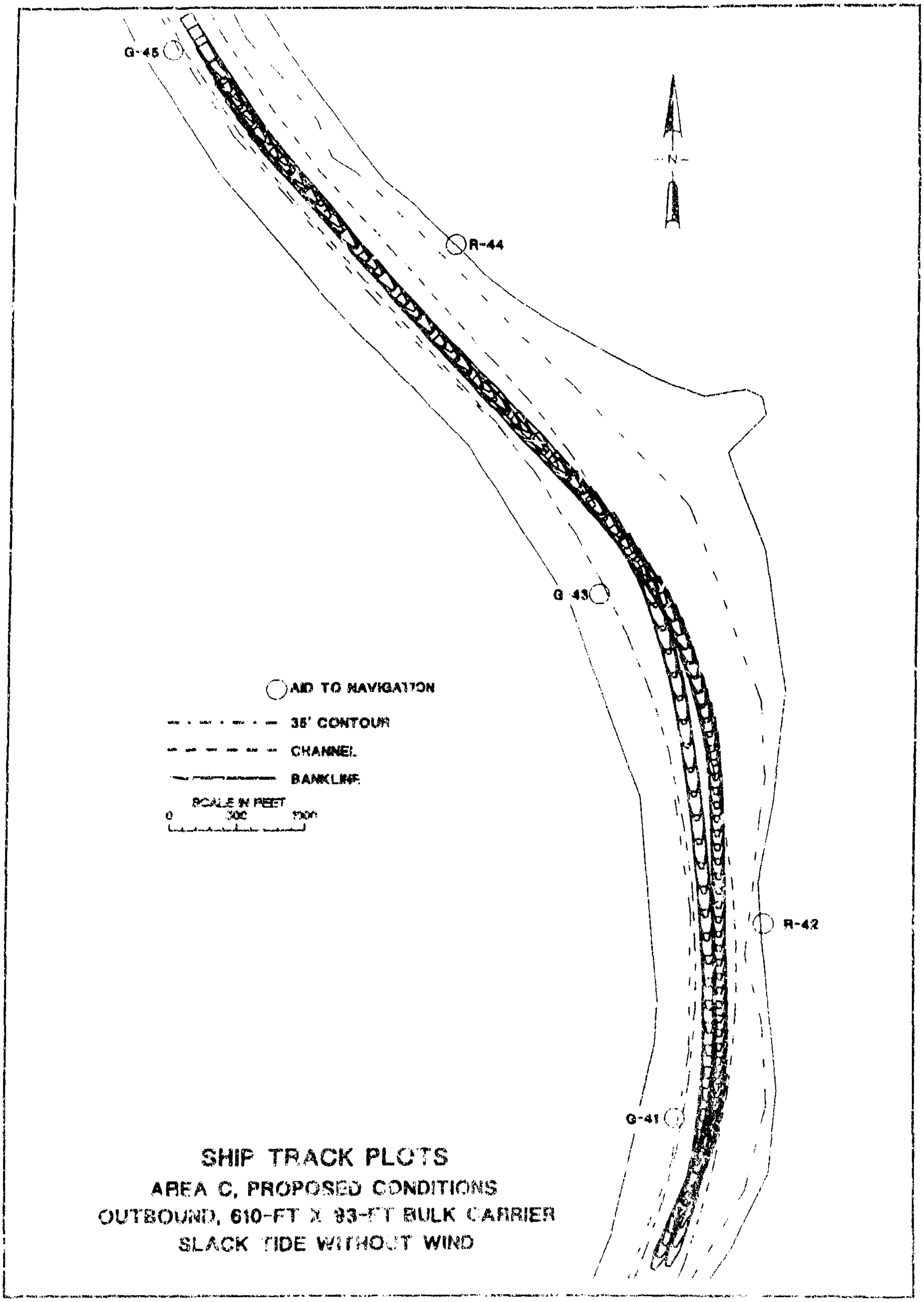
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND

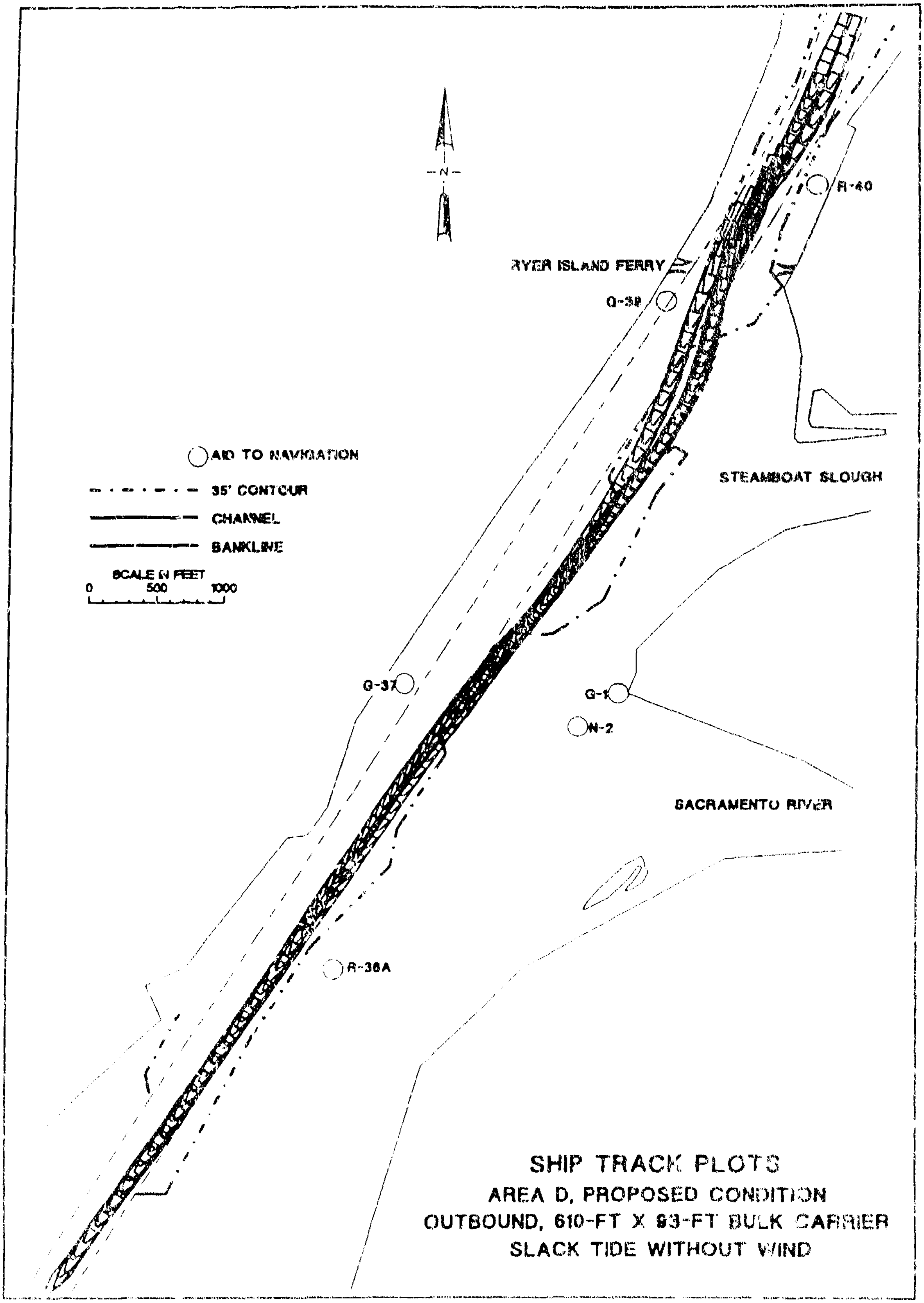


SACRAMENTO
SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
G-49
R-50
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
G-47
R-48
R-40
G-45
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



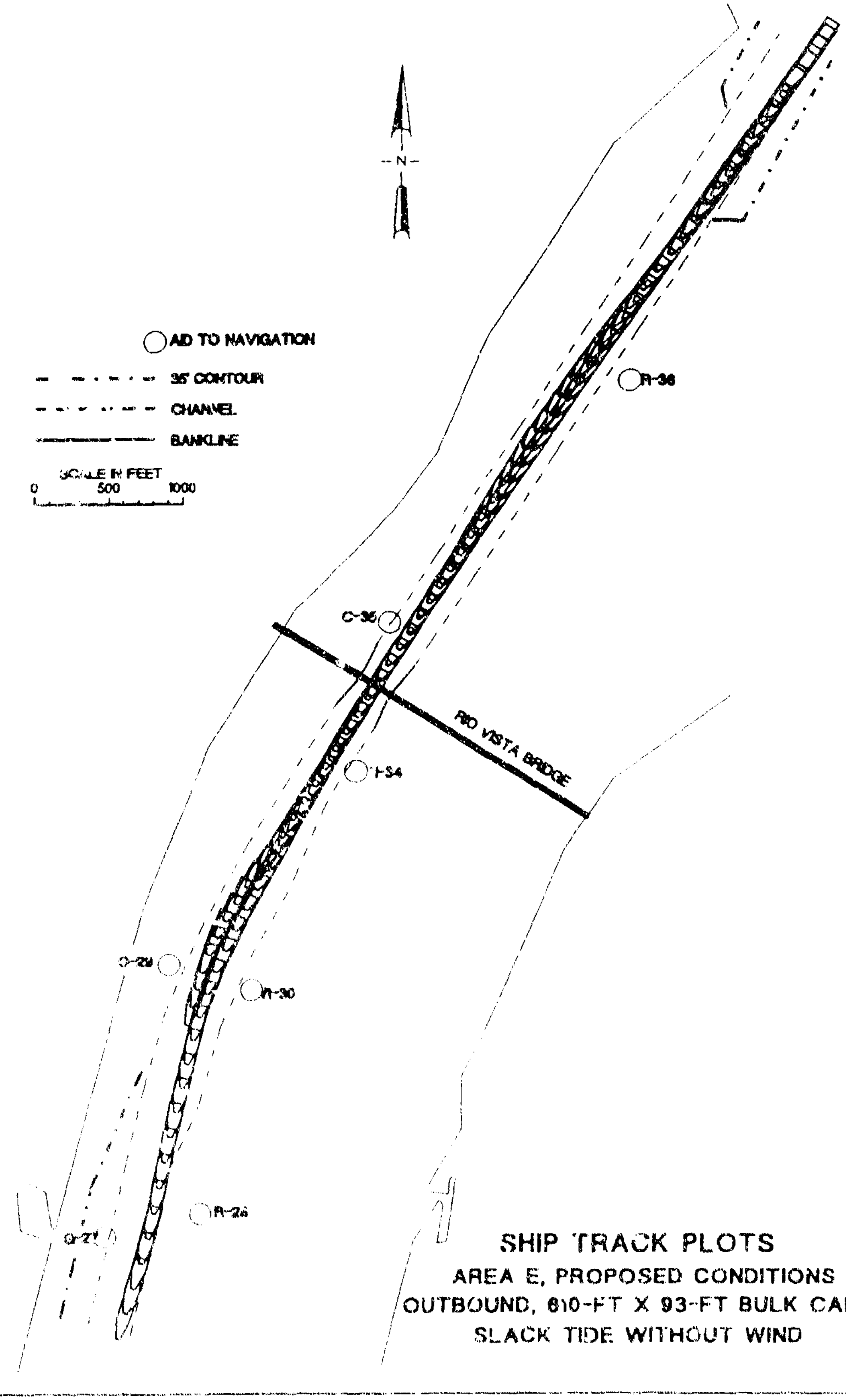
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND

Plate 49

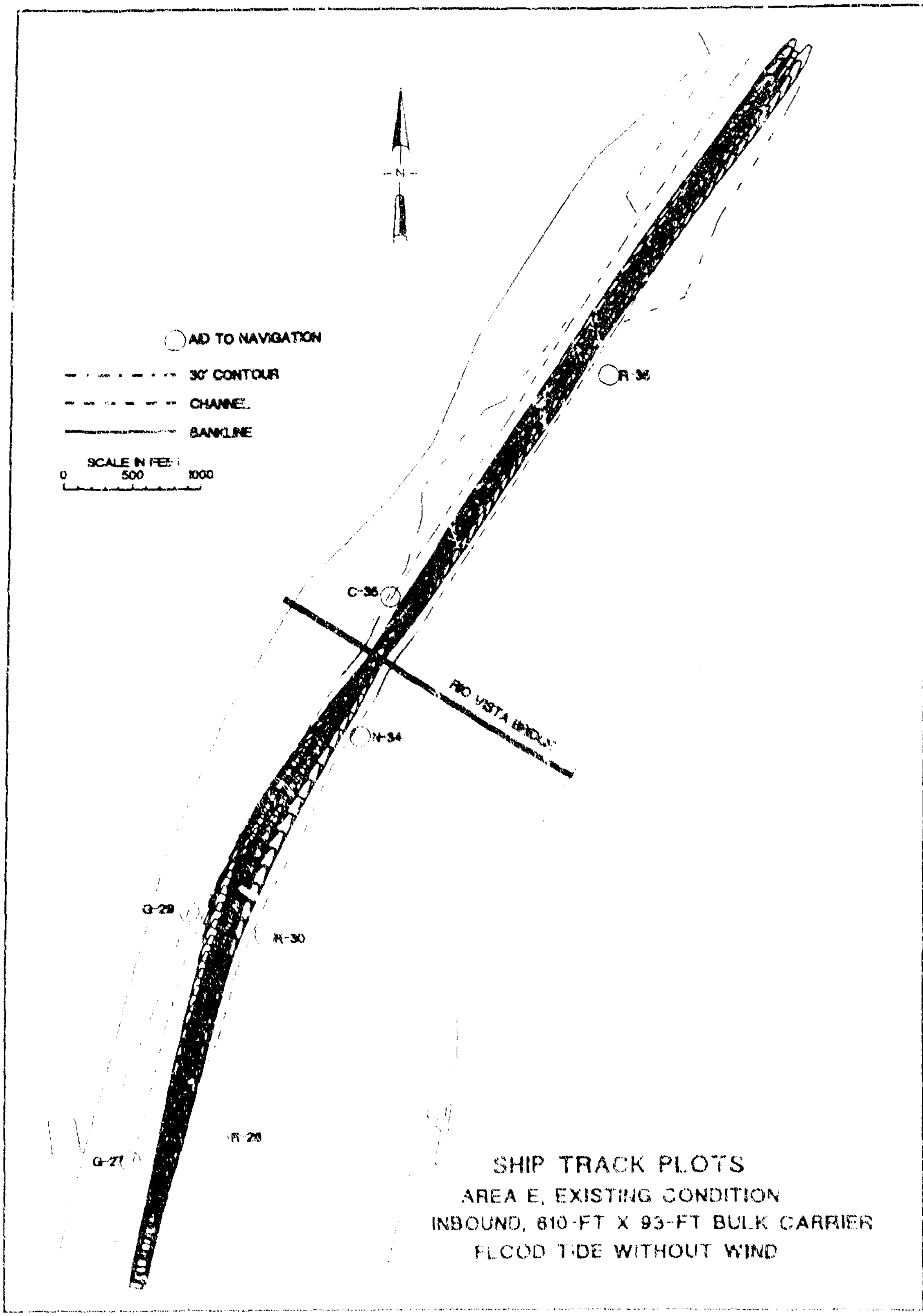


SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND

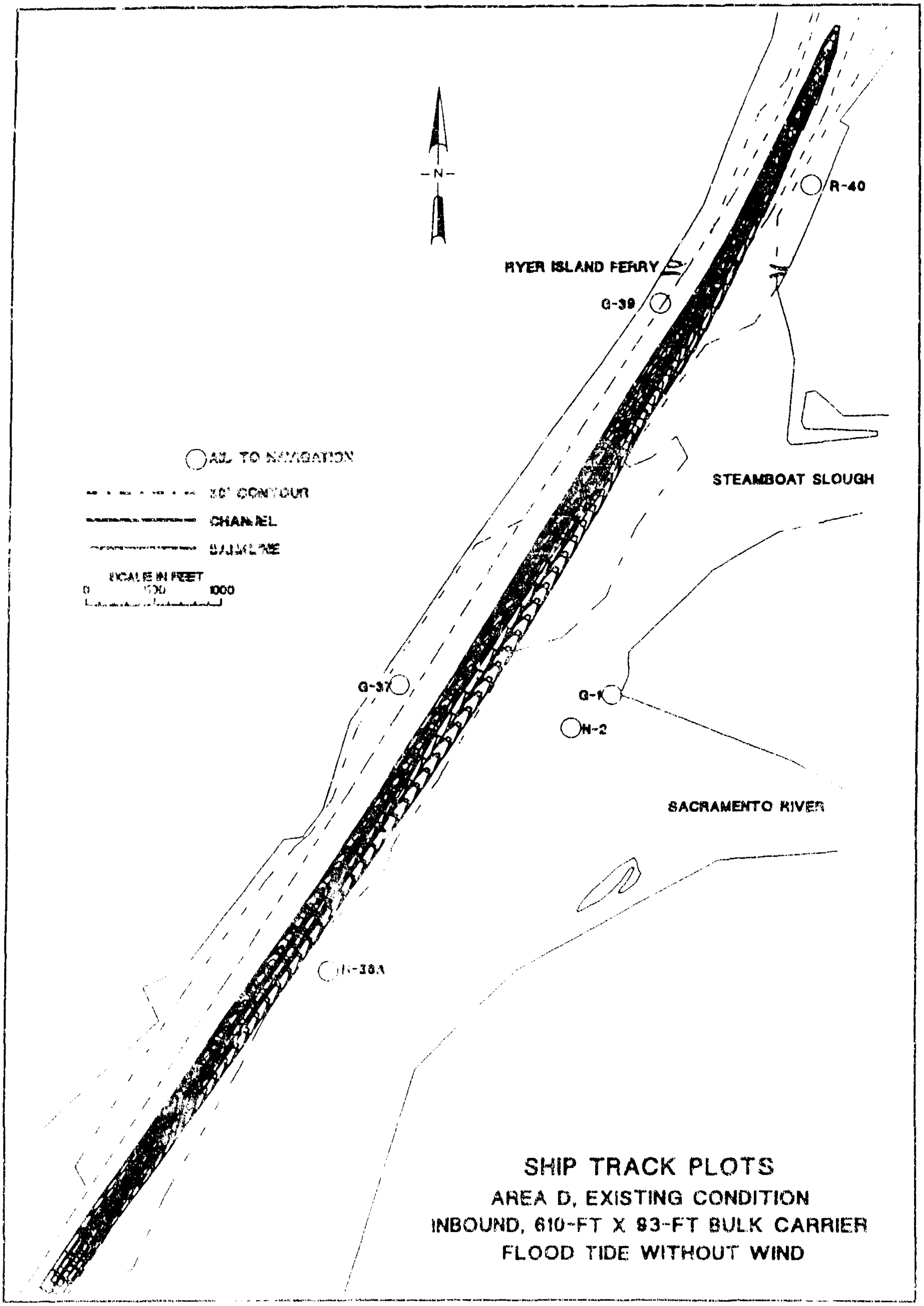
Plate 50



SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
INBOUND, 610-FT X 83-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

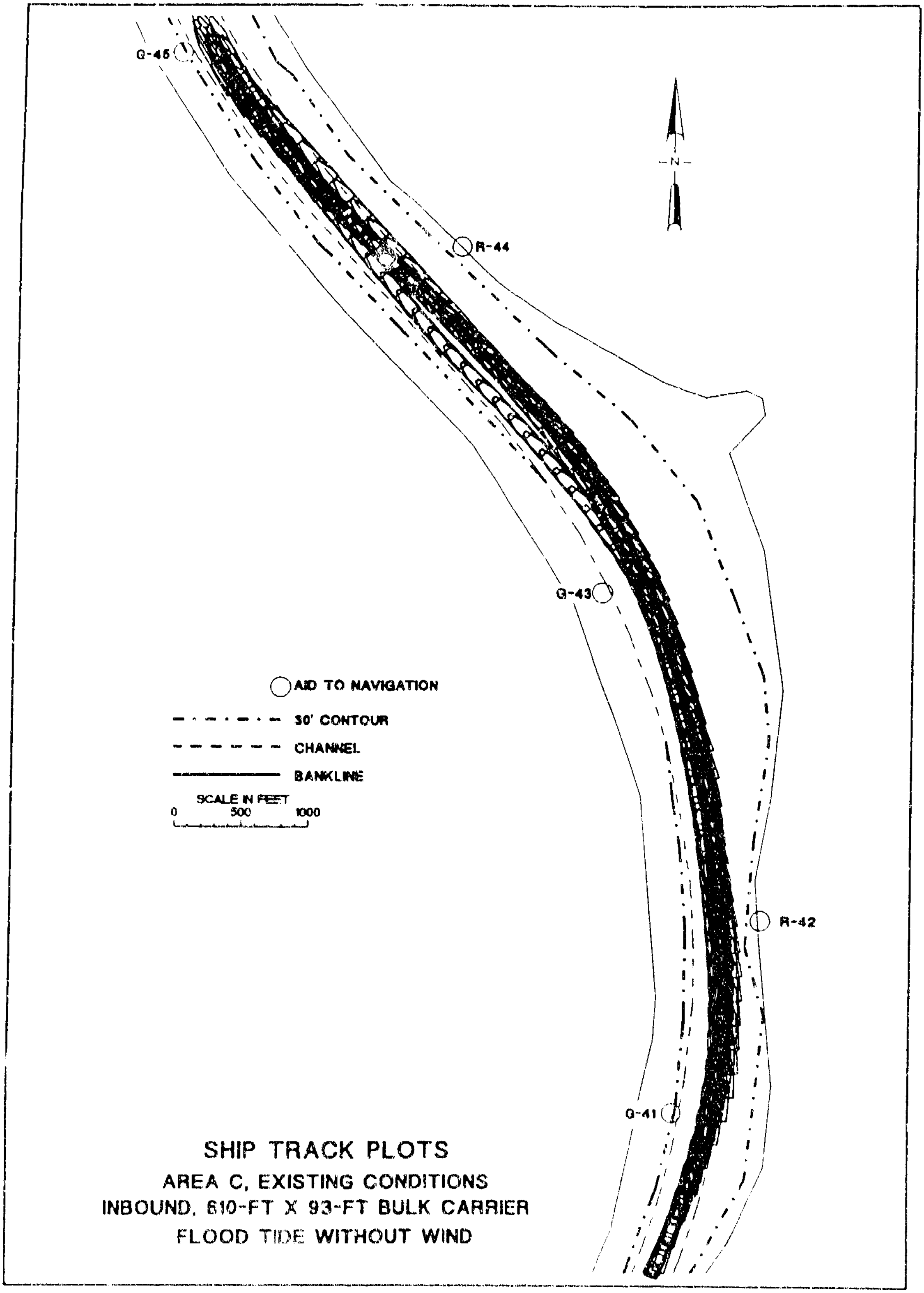
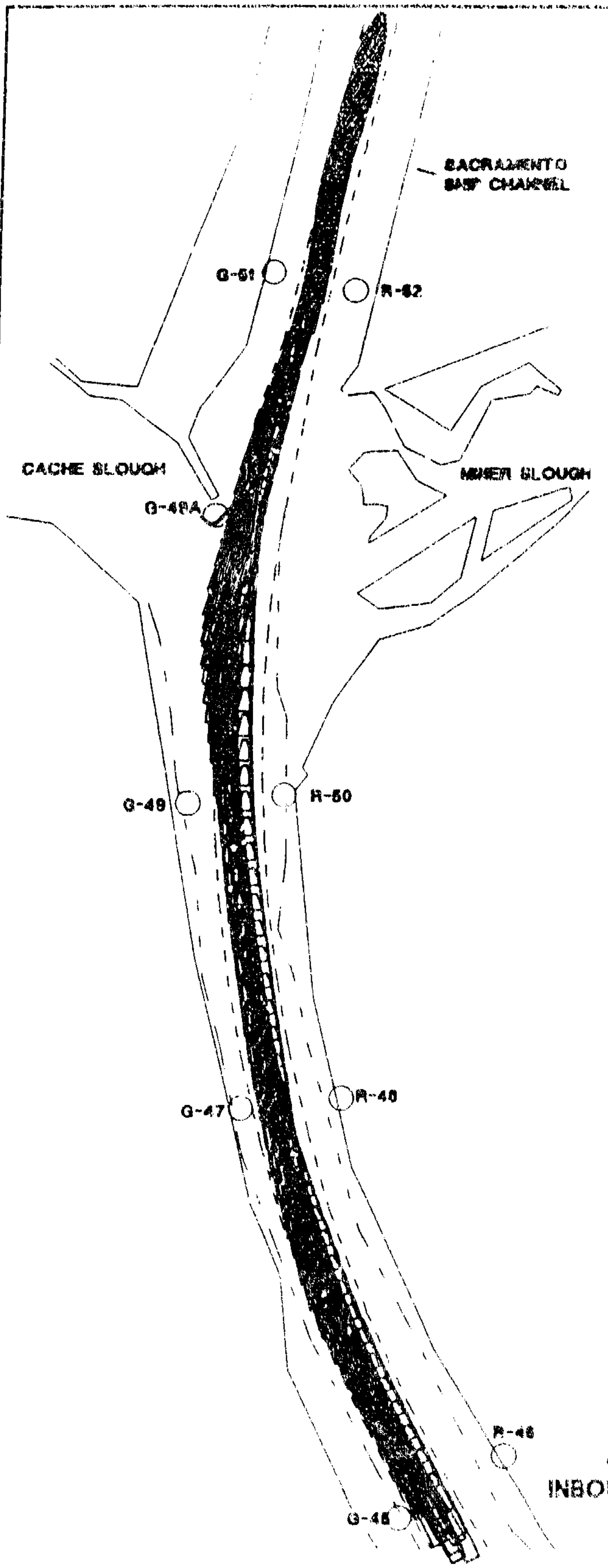

G-45
R-44
N
G-43
AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-42
G-41
SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

Plate 54



SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

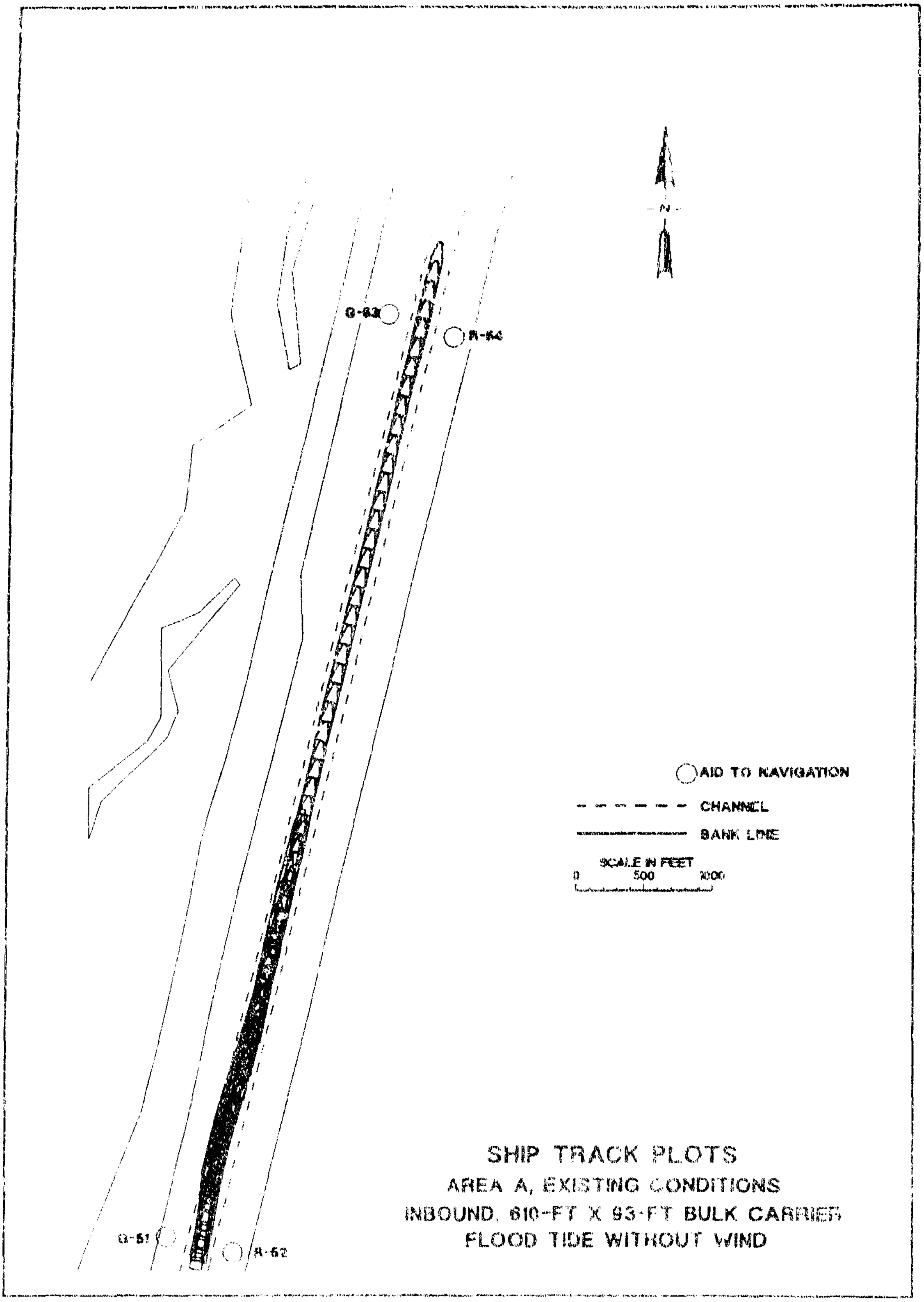
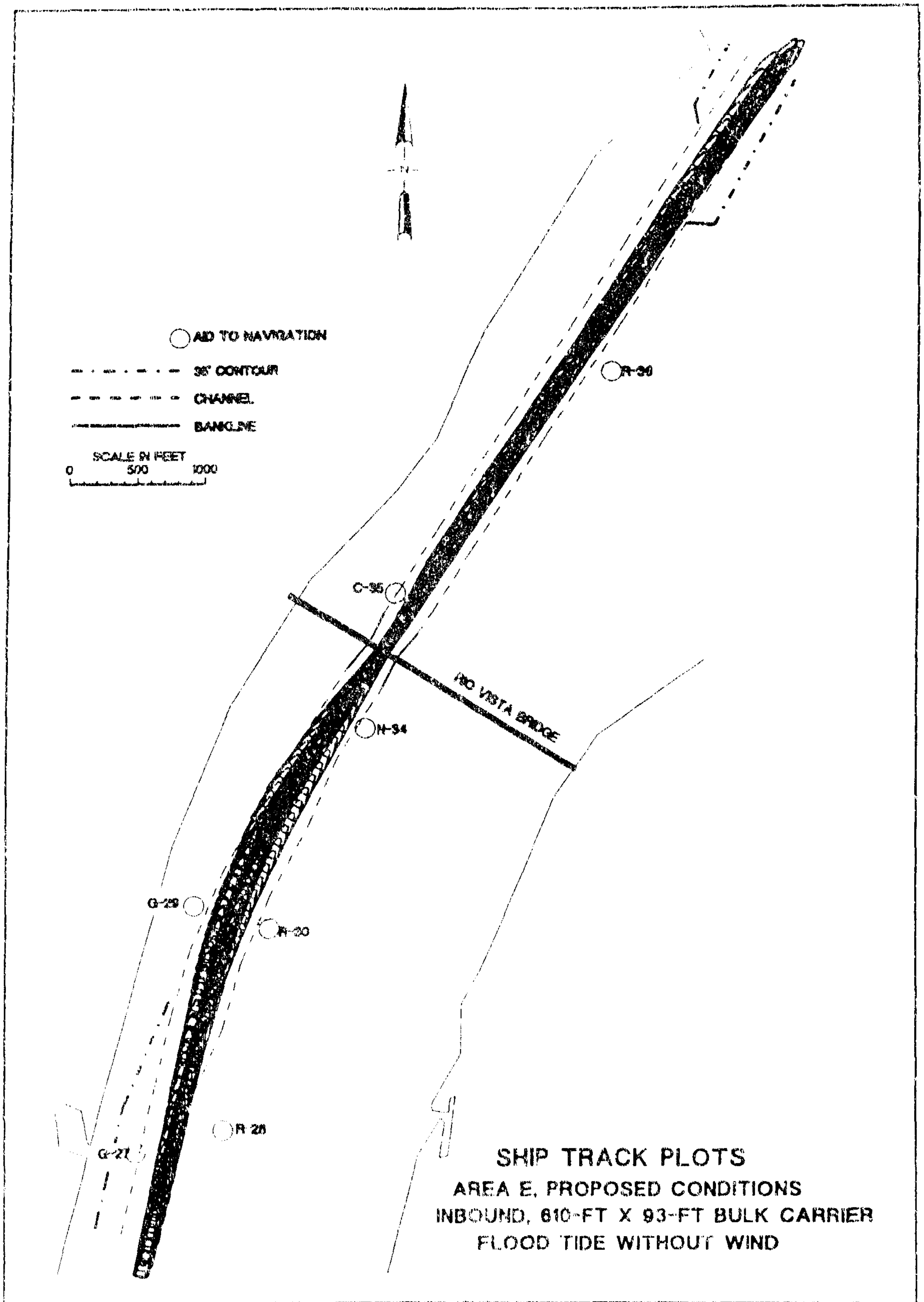

N
G-53
R-54
AID TO NAVIGATION
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND
G-51
R-52

Plate 56


AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
C-35
RIO VISTA BRIDGE
R-34
G-29
R-30
R 28
G-27
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

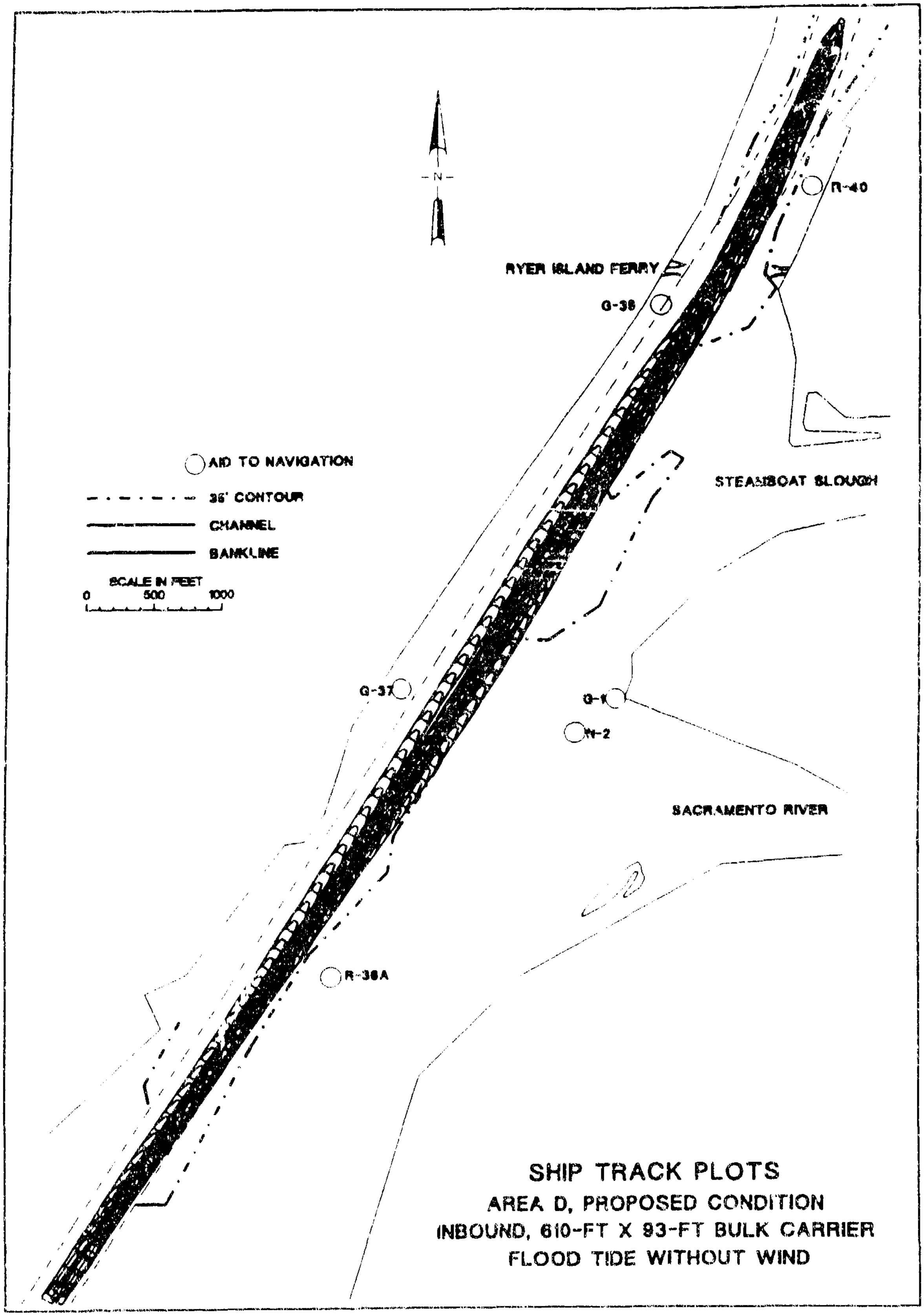
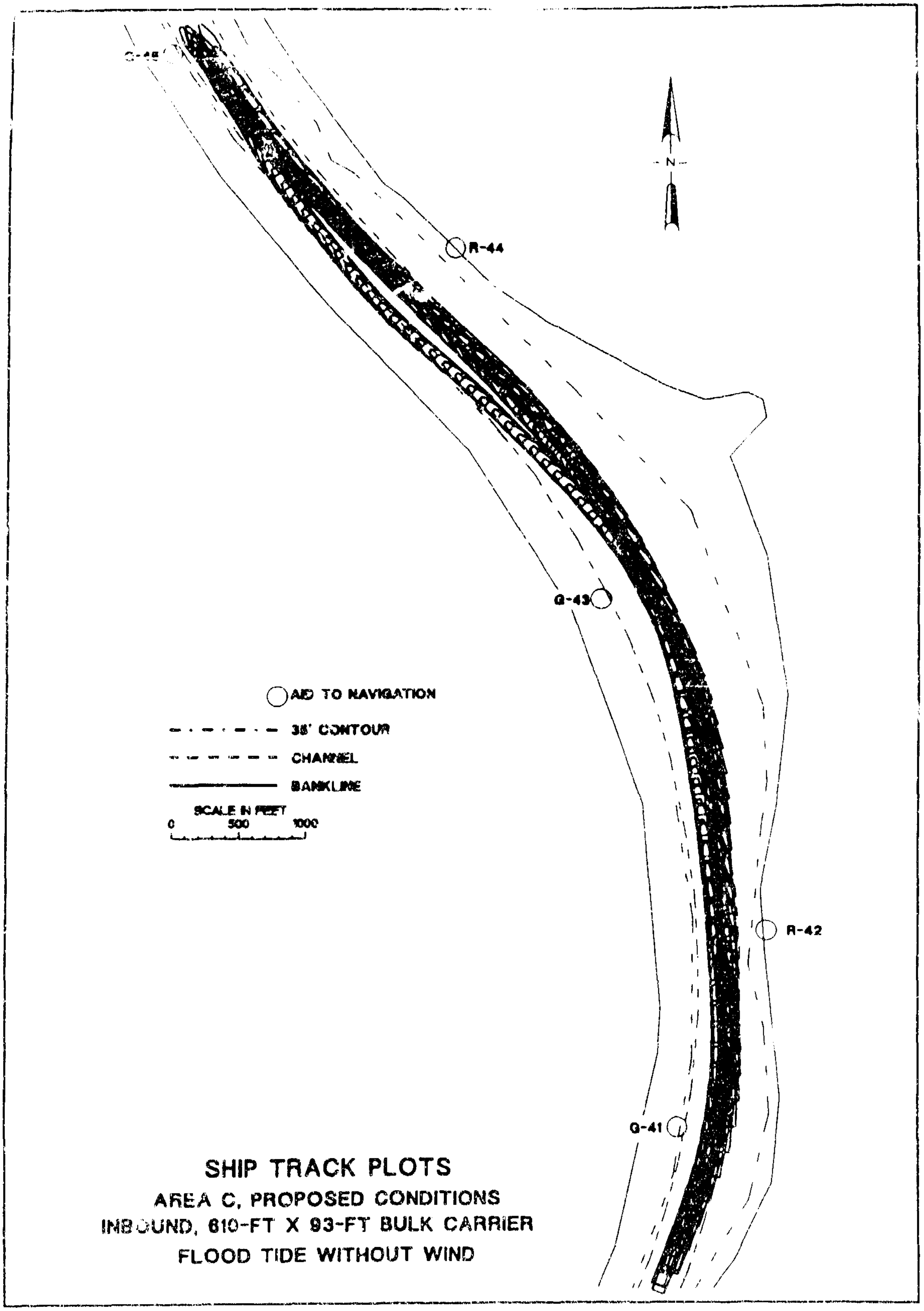

RYER ISLAND FERRY
G-38
R-40
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
STEAMBOAT SLOUGH
G-37
G-1
N-2
SACRAMENTO RIVER
R-36A
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND

Plate 58

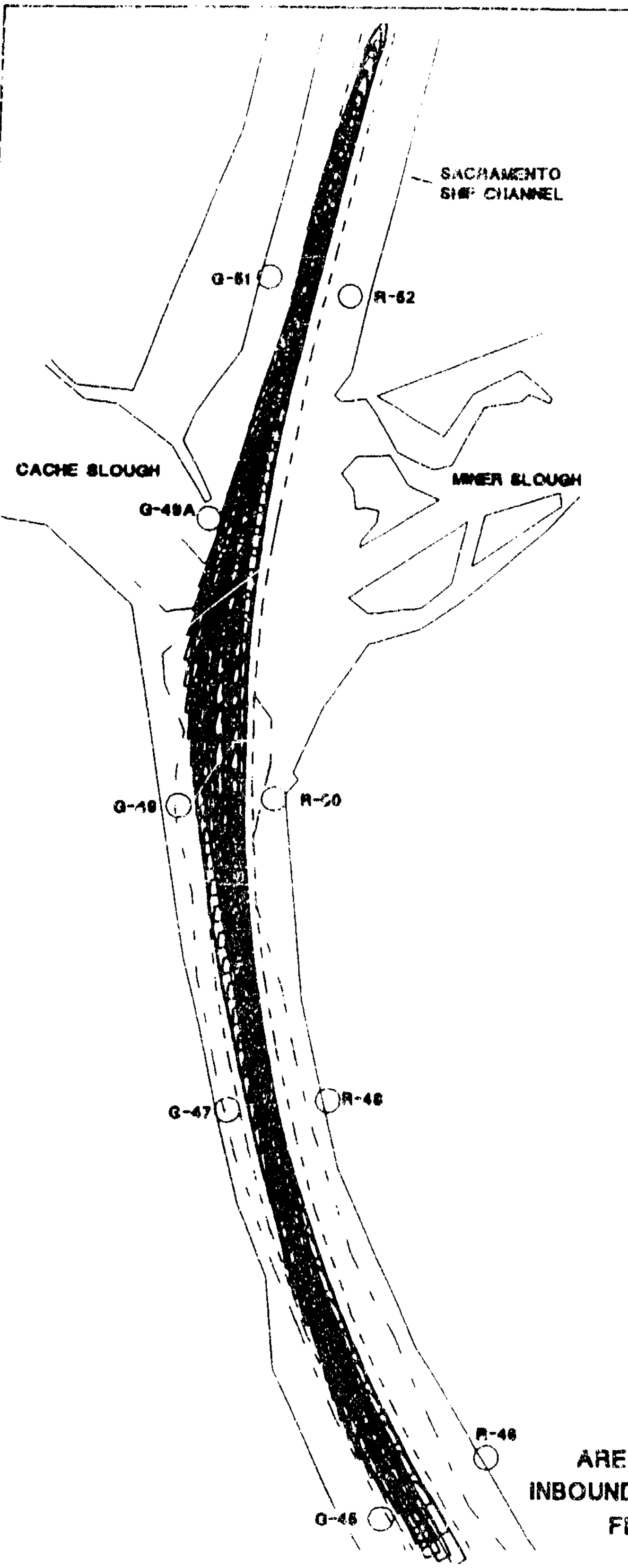


SHIP TRACK PLOTS

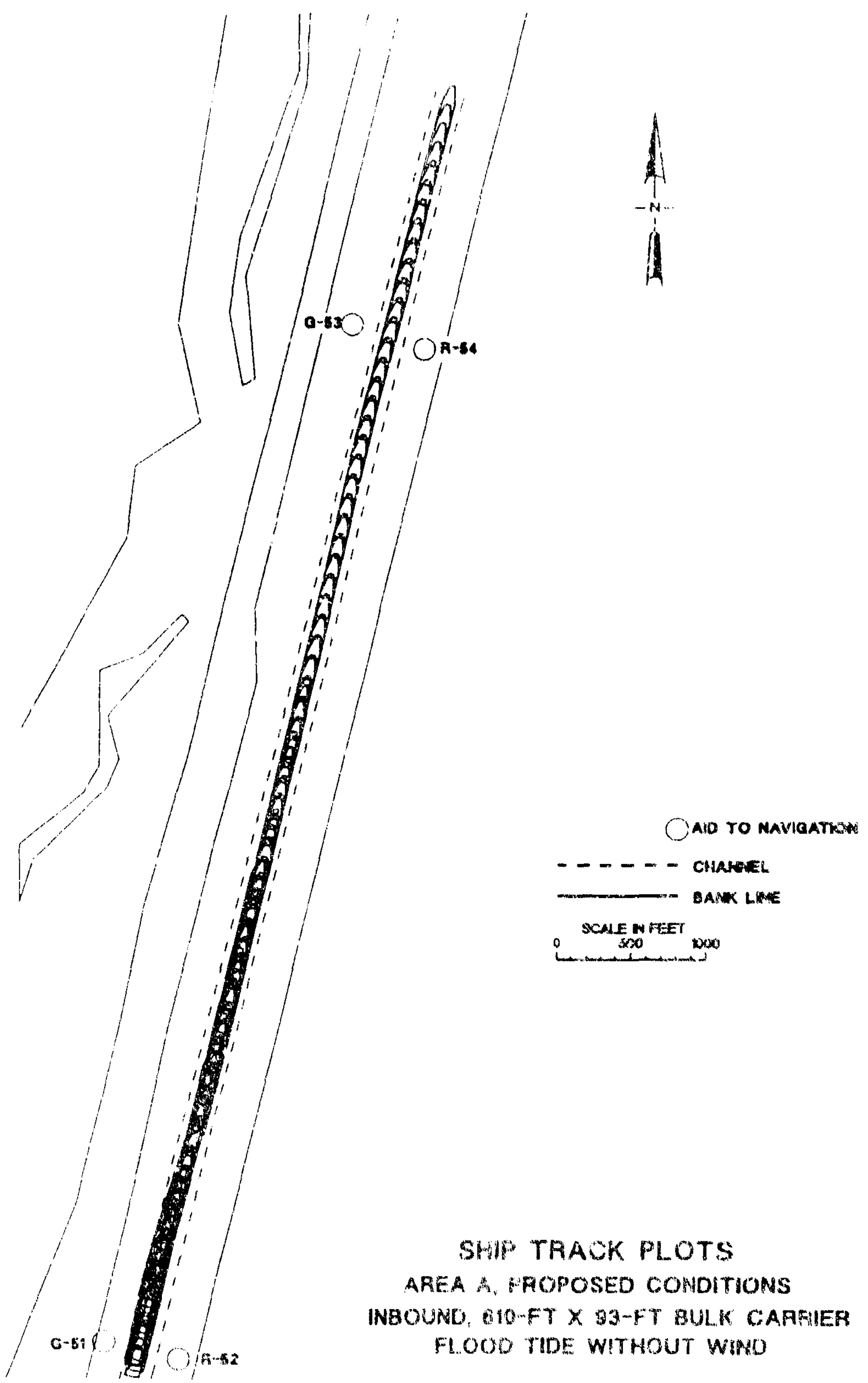
AREA C, PROPOSED CONDITIONS

INBOUND, 610-FT X 93-FT BULK CARRIER

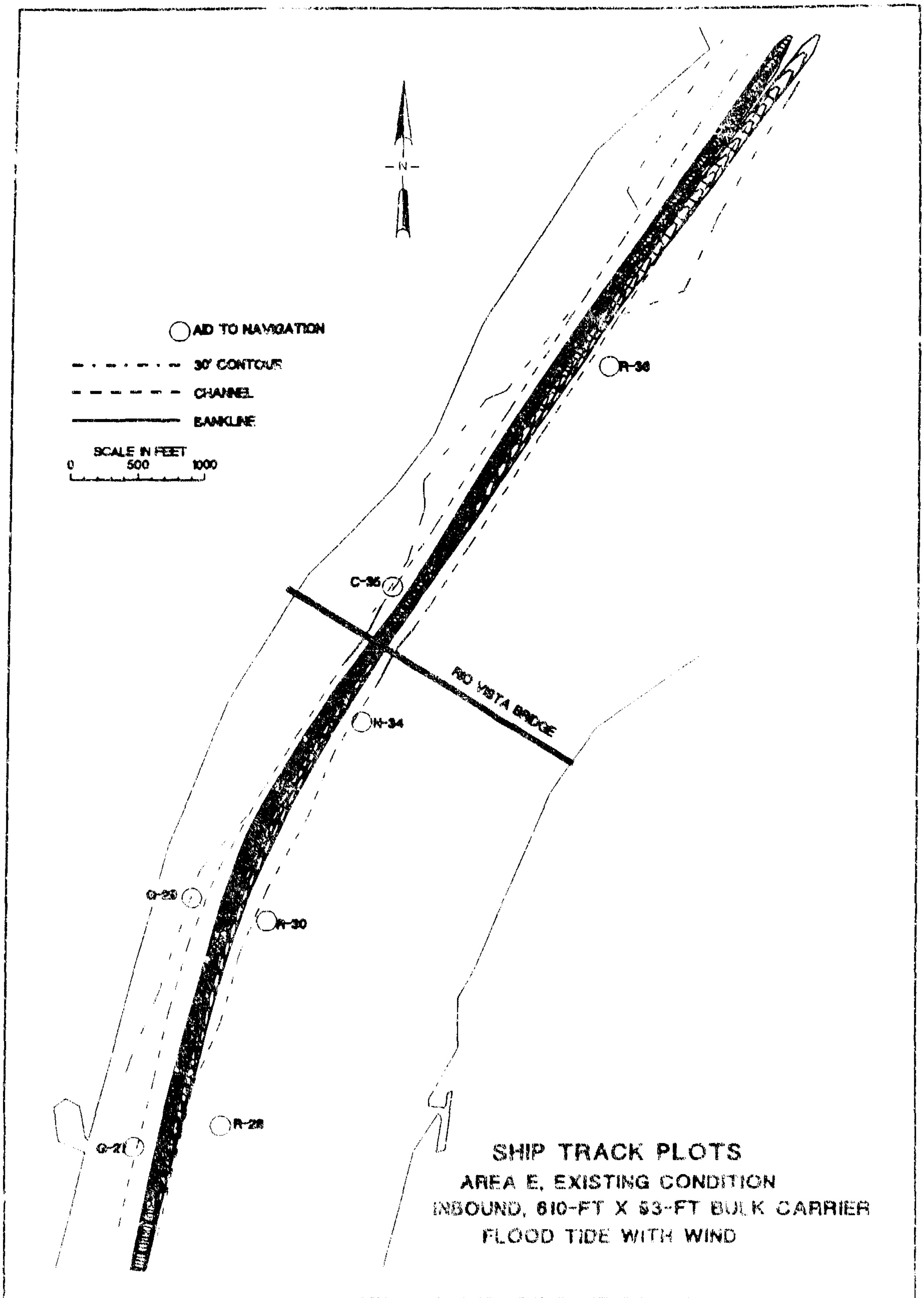
FLOOD TIDE WITHOUT WIND



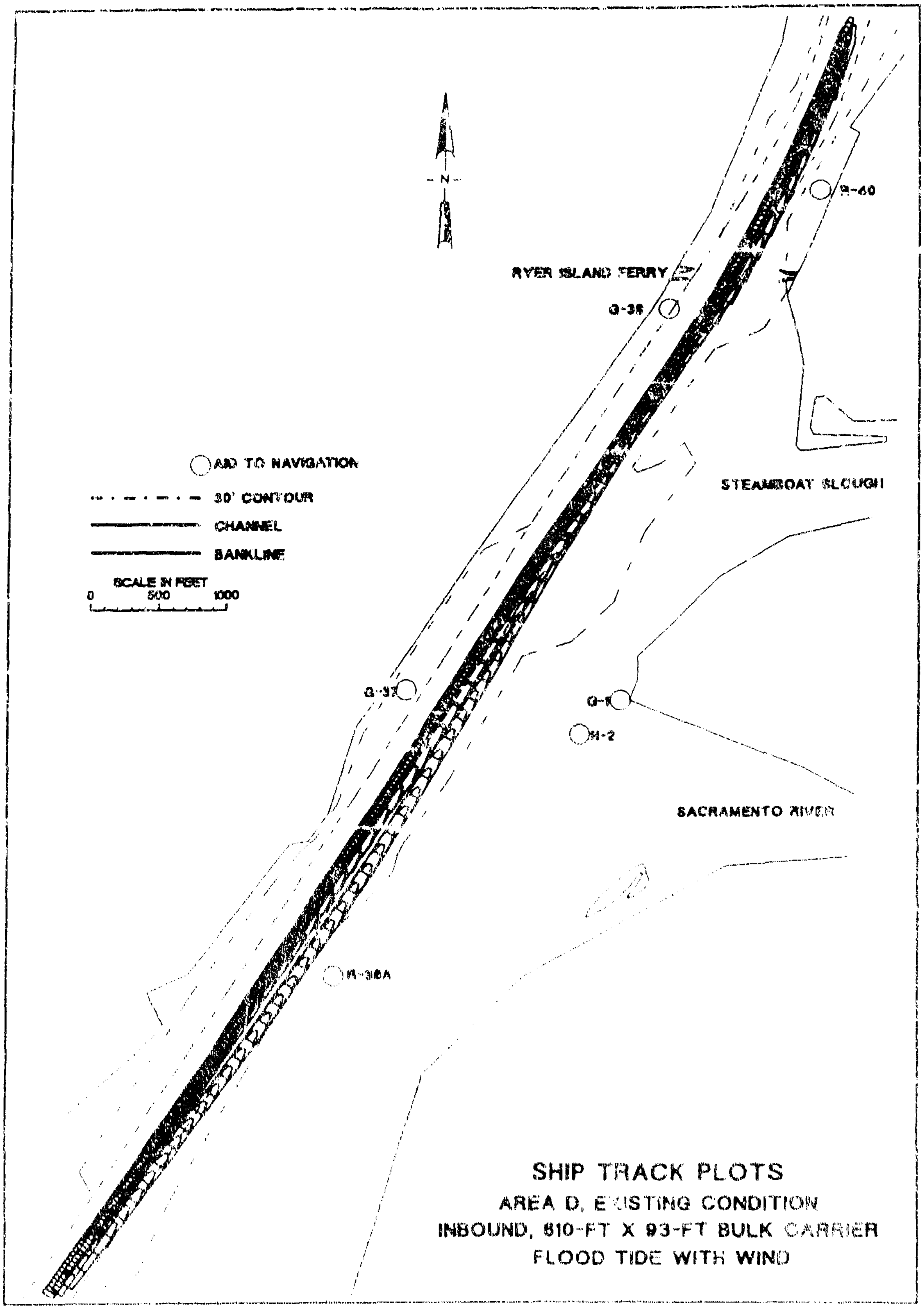
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



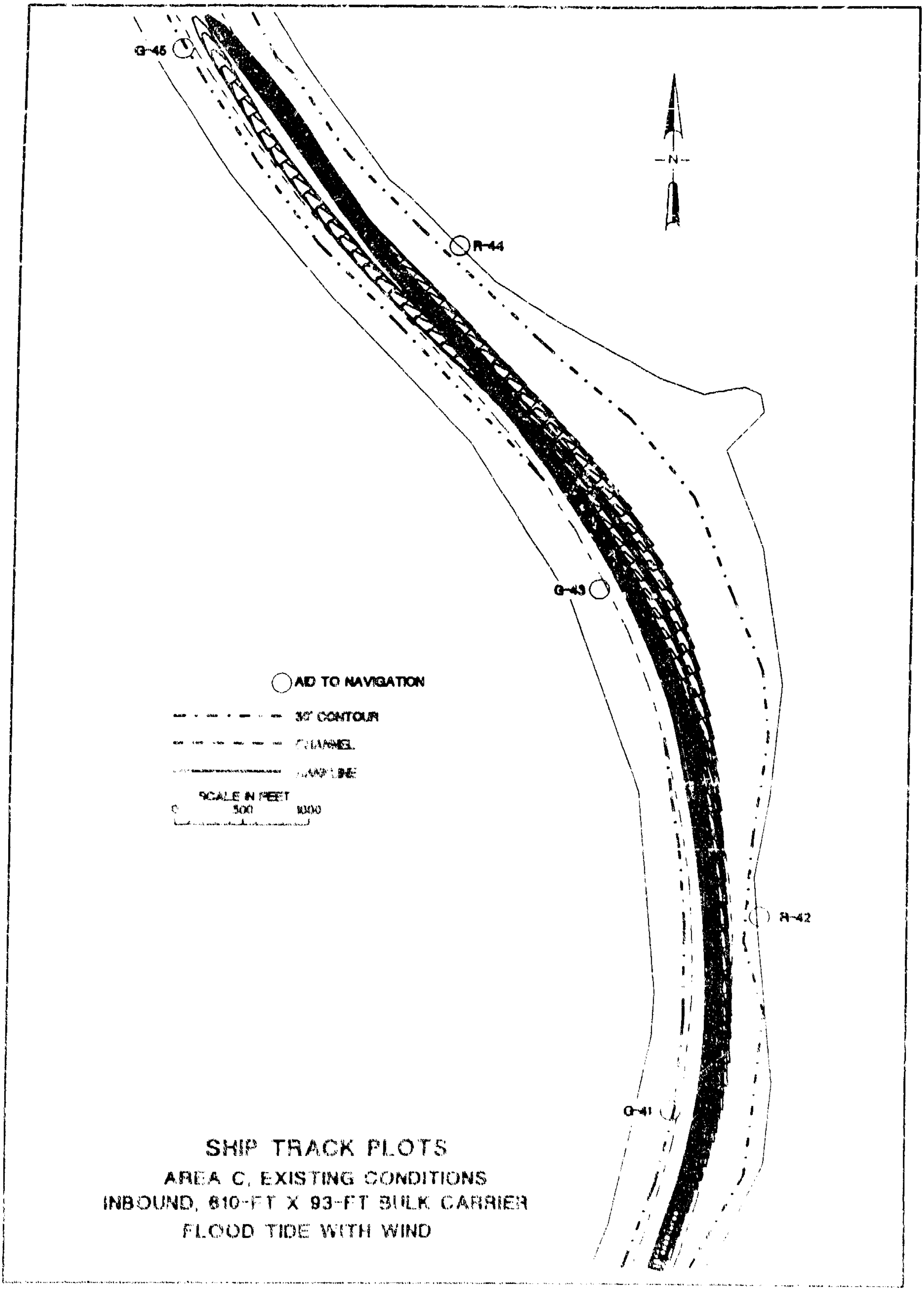
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITHOUT WIND



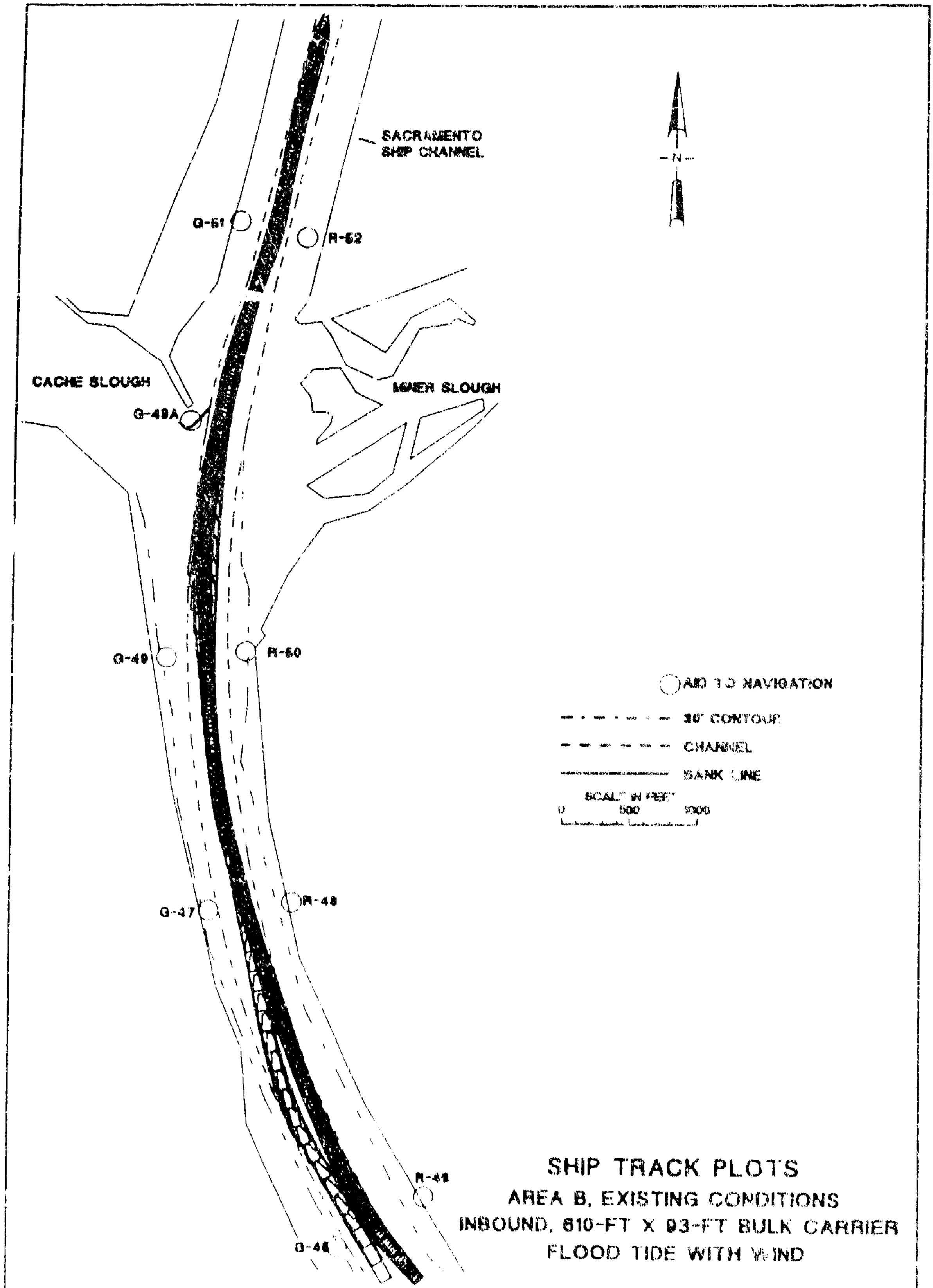
SHIP TRACK PLOTS
AREA E, EXISTING CONDITION
INBOUND, 610-FT X 83-FT BULK CARRIER
FLOOD TIDE WITH WIND

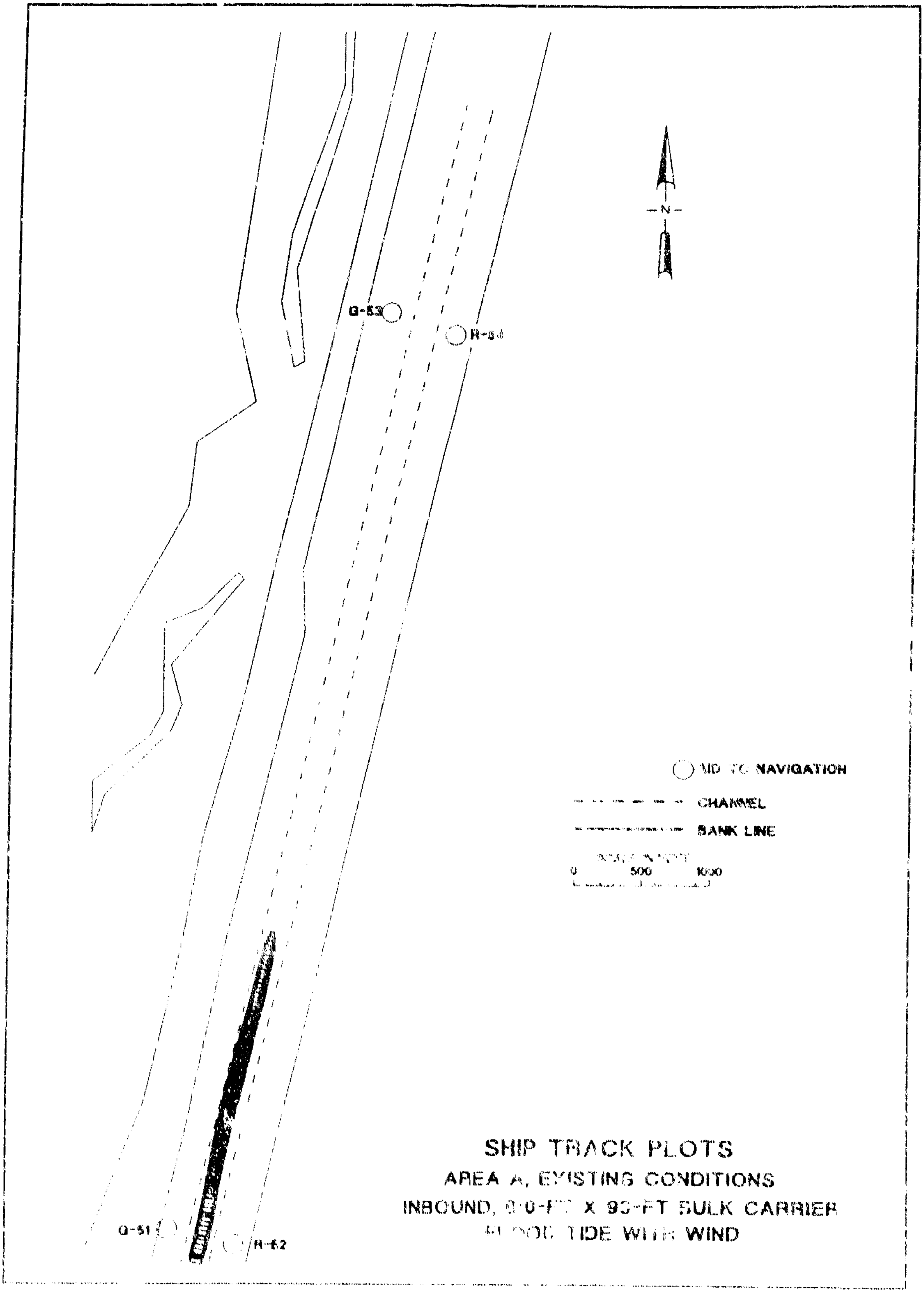


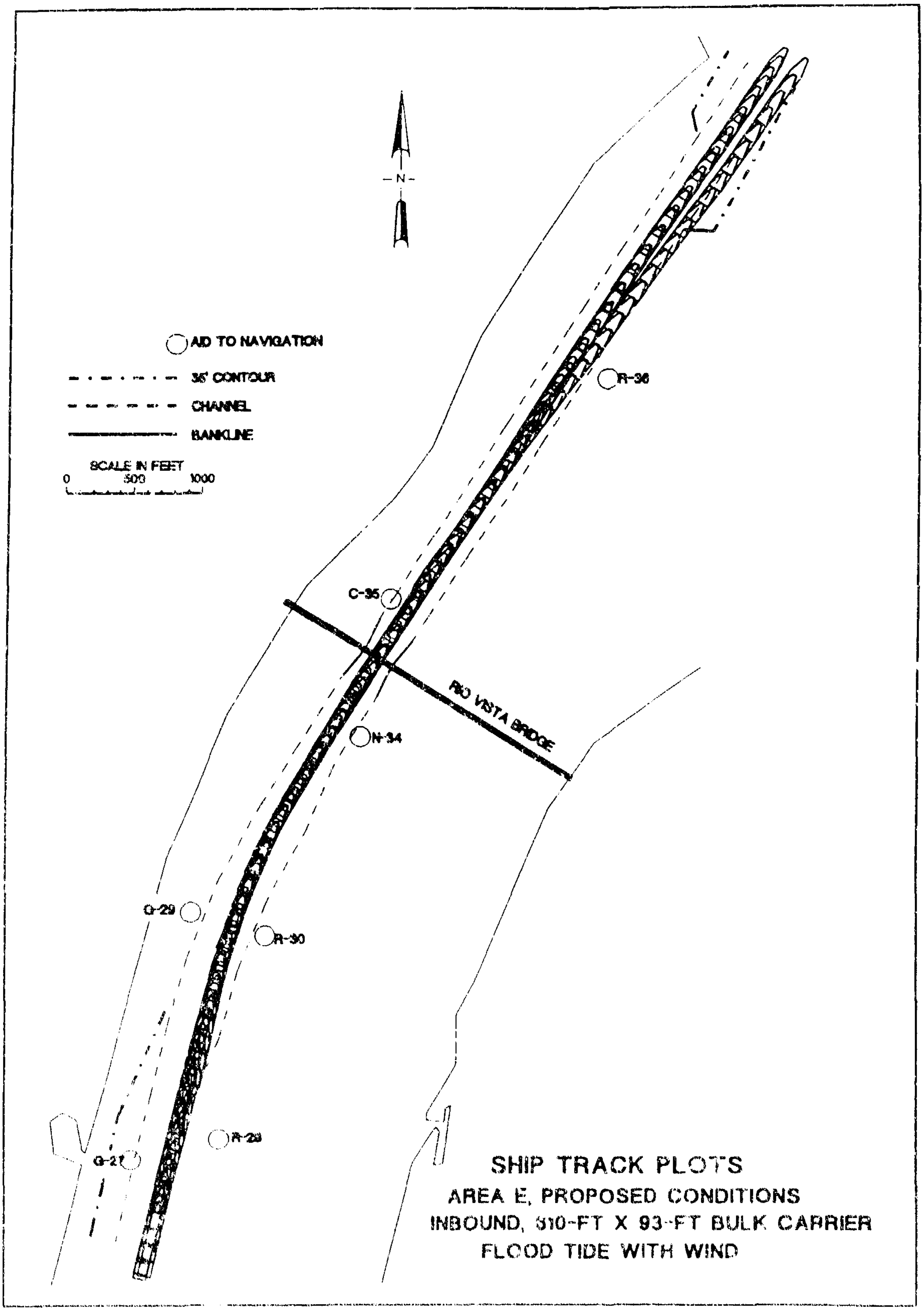
SHIP TRACK PLOTS
AREA D, EXISTING CONDITION
INBOUND, 810-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



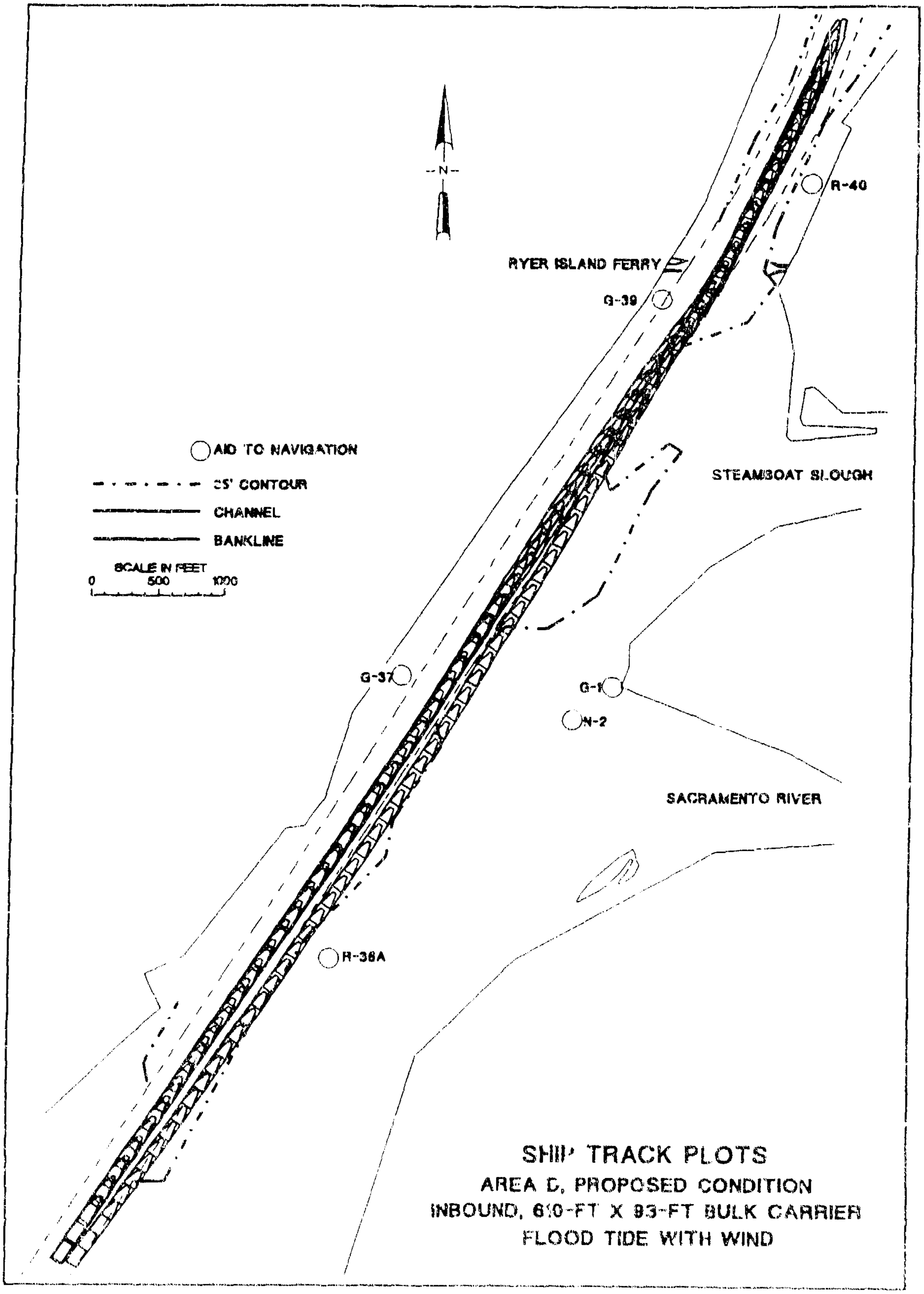
SHIP TRACK PLOTS
AREA C, EXISTING CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND


SACRAMENTO SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
G-49
R-50
AID TO NAVIGATION
30' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
G-47
R-48
R-46
G-46
SHIP TRACK PLOTS
AREA B, EXISTING CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND


G-53
R-54
N
AID TO NAVIGATION
CHANNEL
BANK LINE
0
500
1000
G-51
R-52
SHIP TRACK PLOTS
AREA A, EXISTING CONDITIONS
INBOUND, X 95-FT BULK CARRIER
TIDE WITH WIND

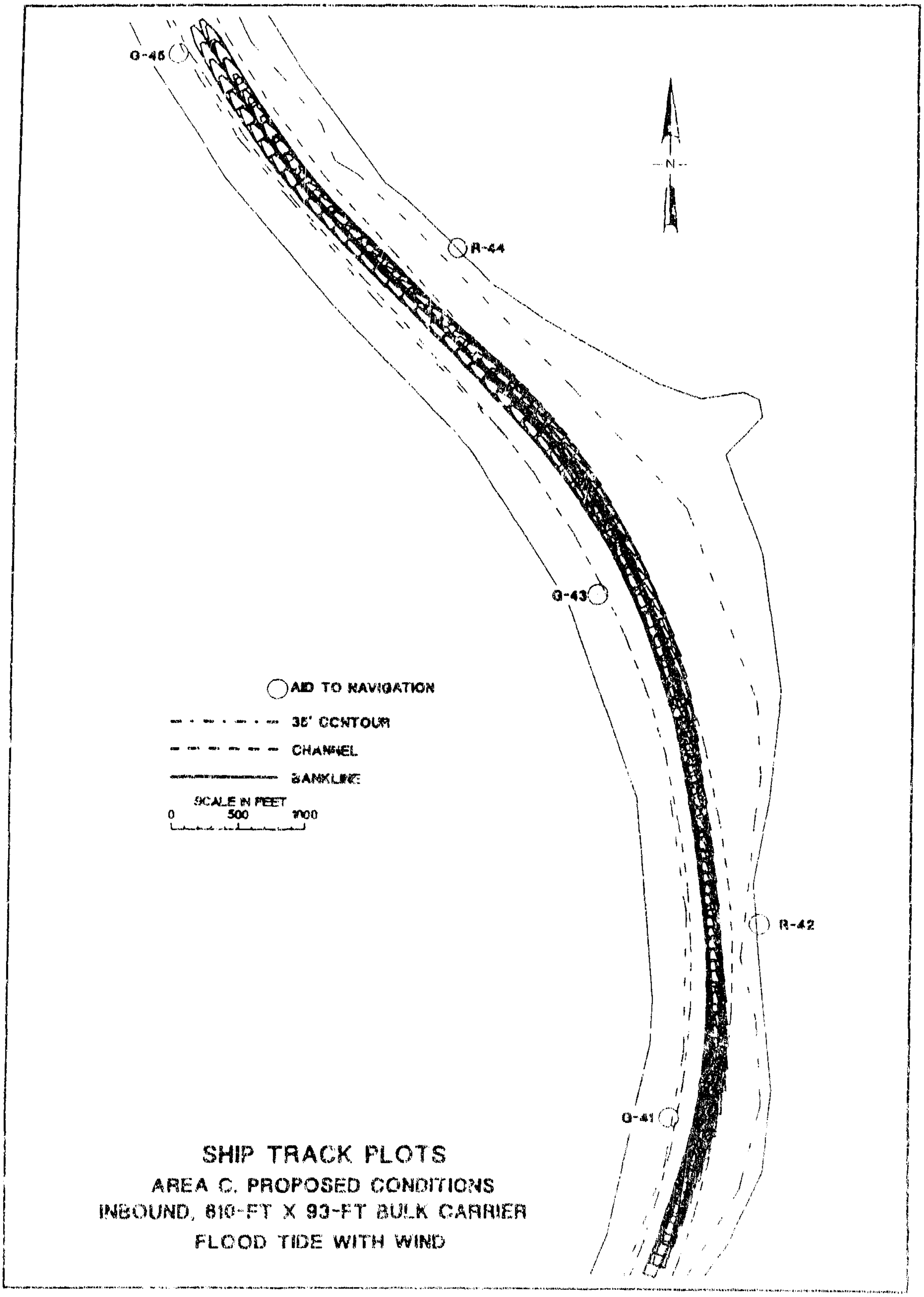


SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
INBOUND, 510-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

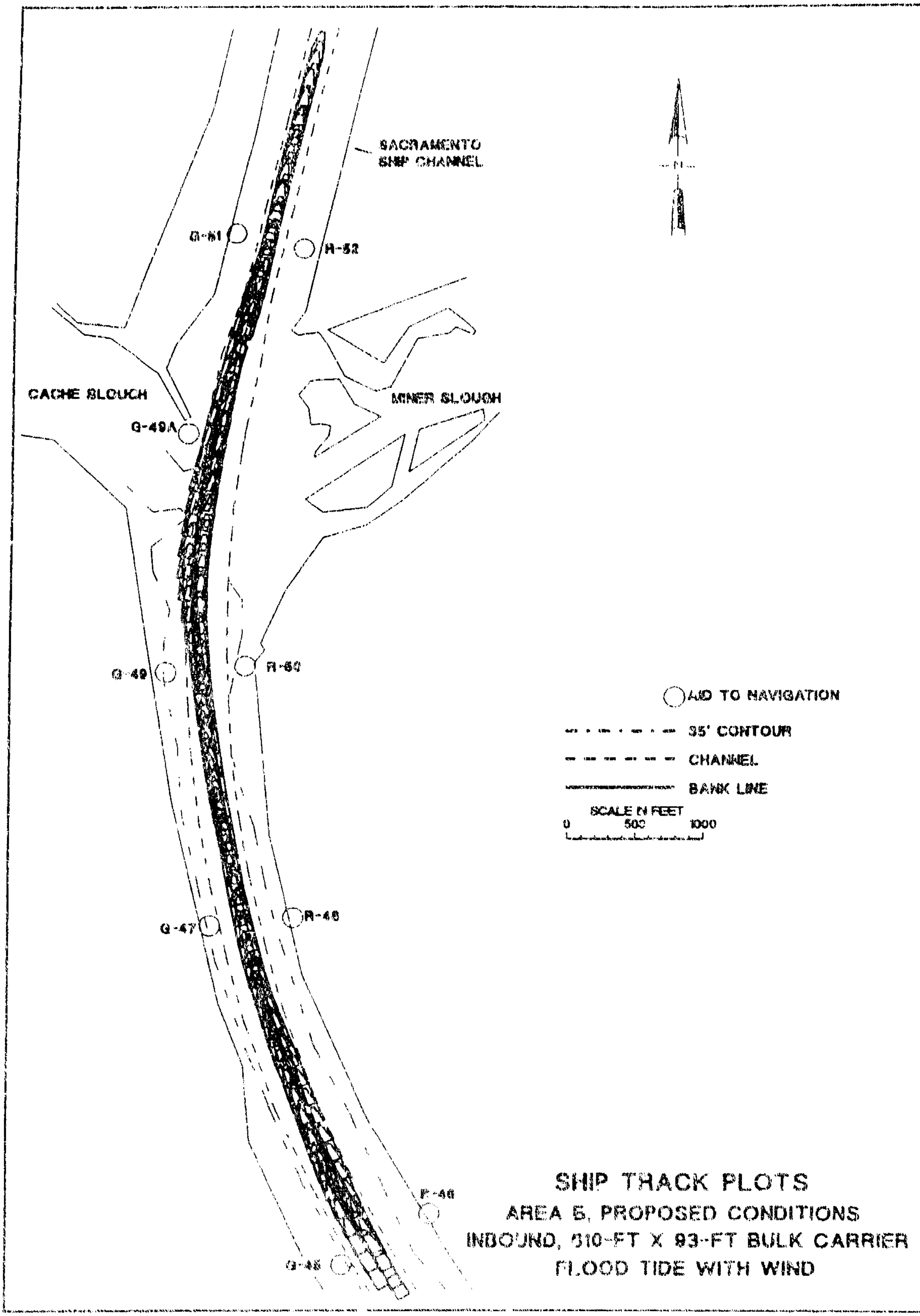


SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

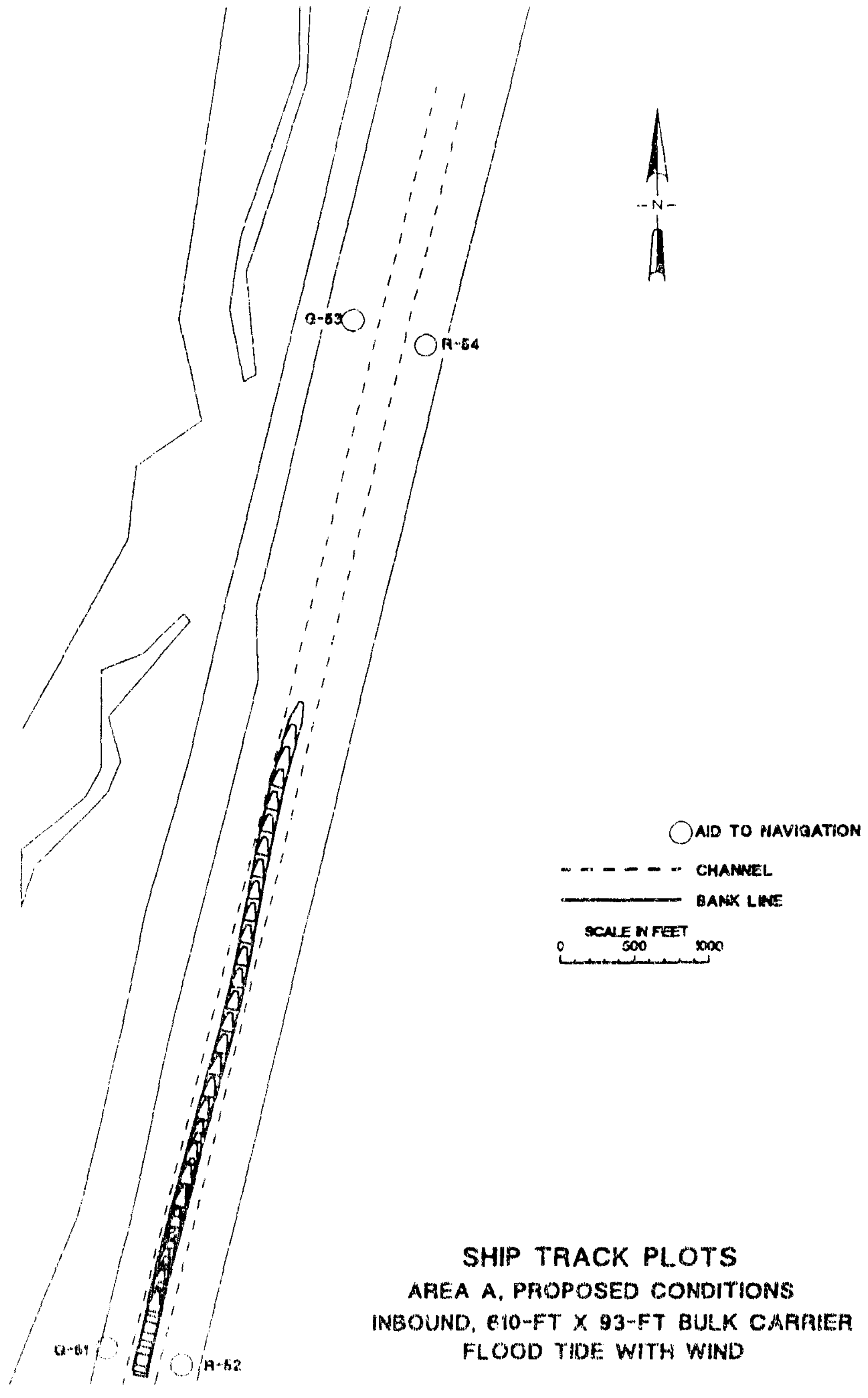
Plate 68



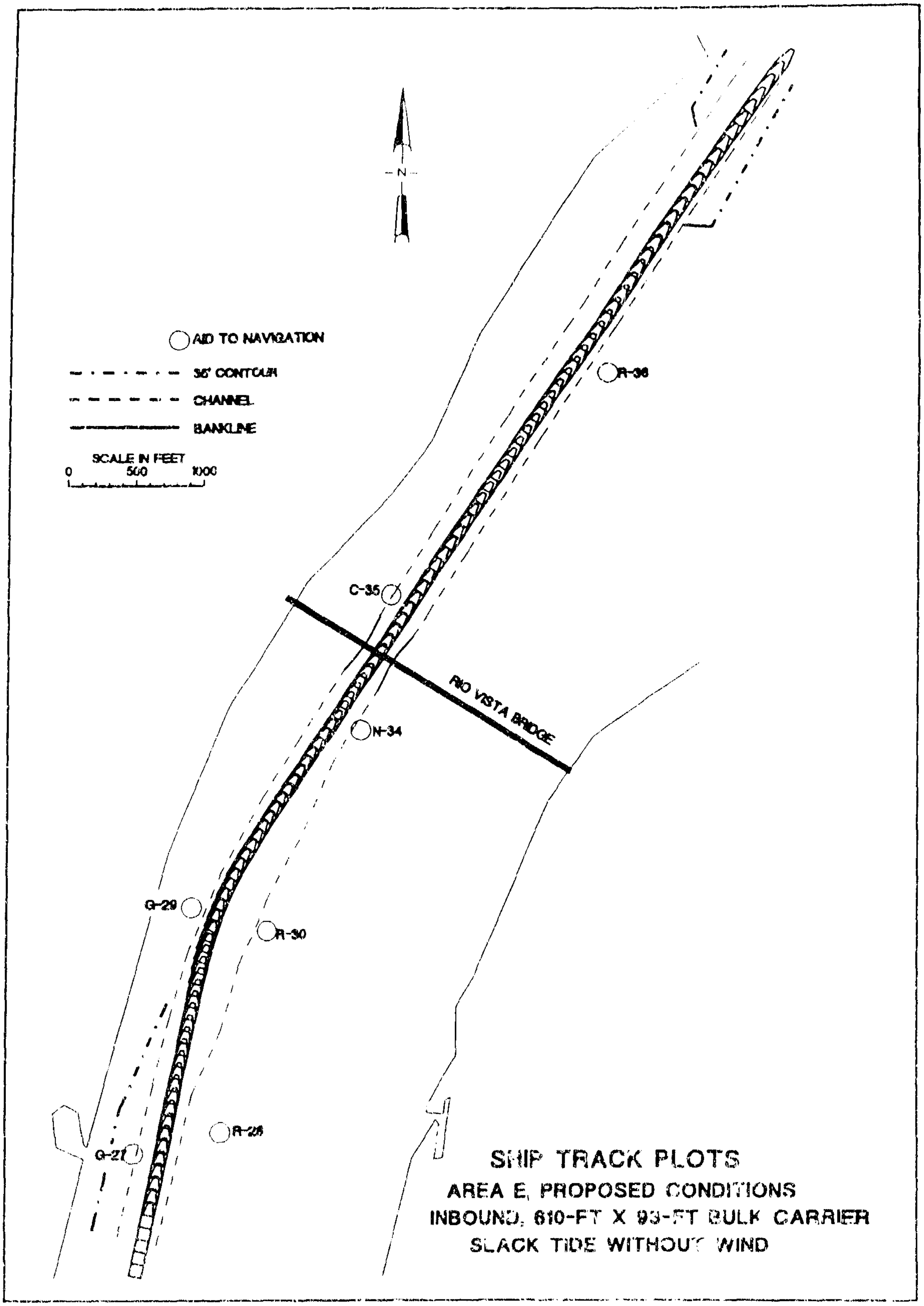
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
INBOUND, 810-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

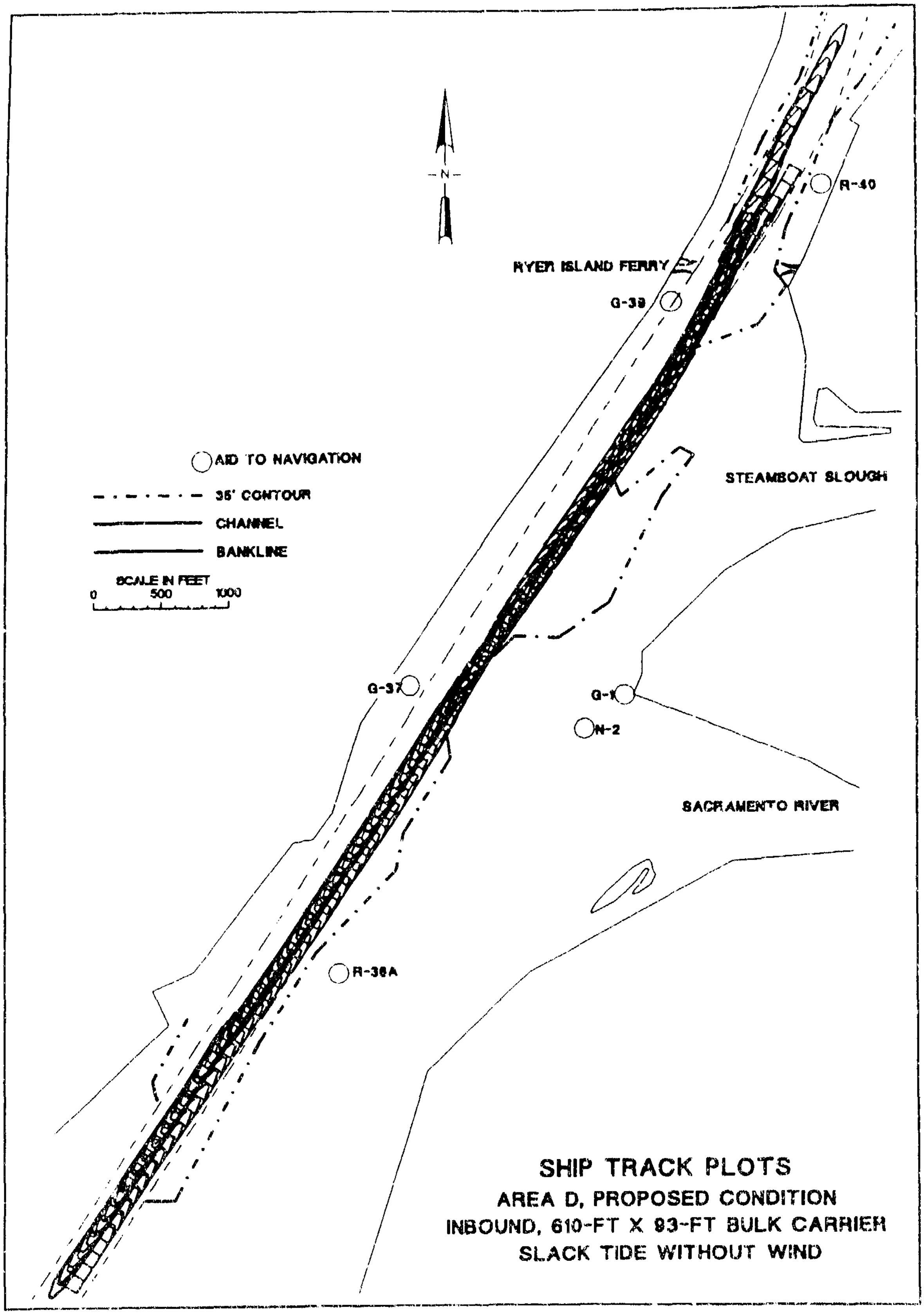


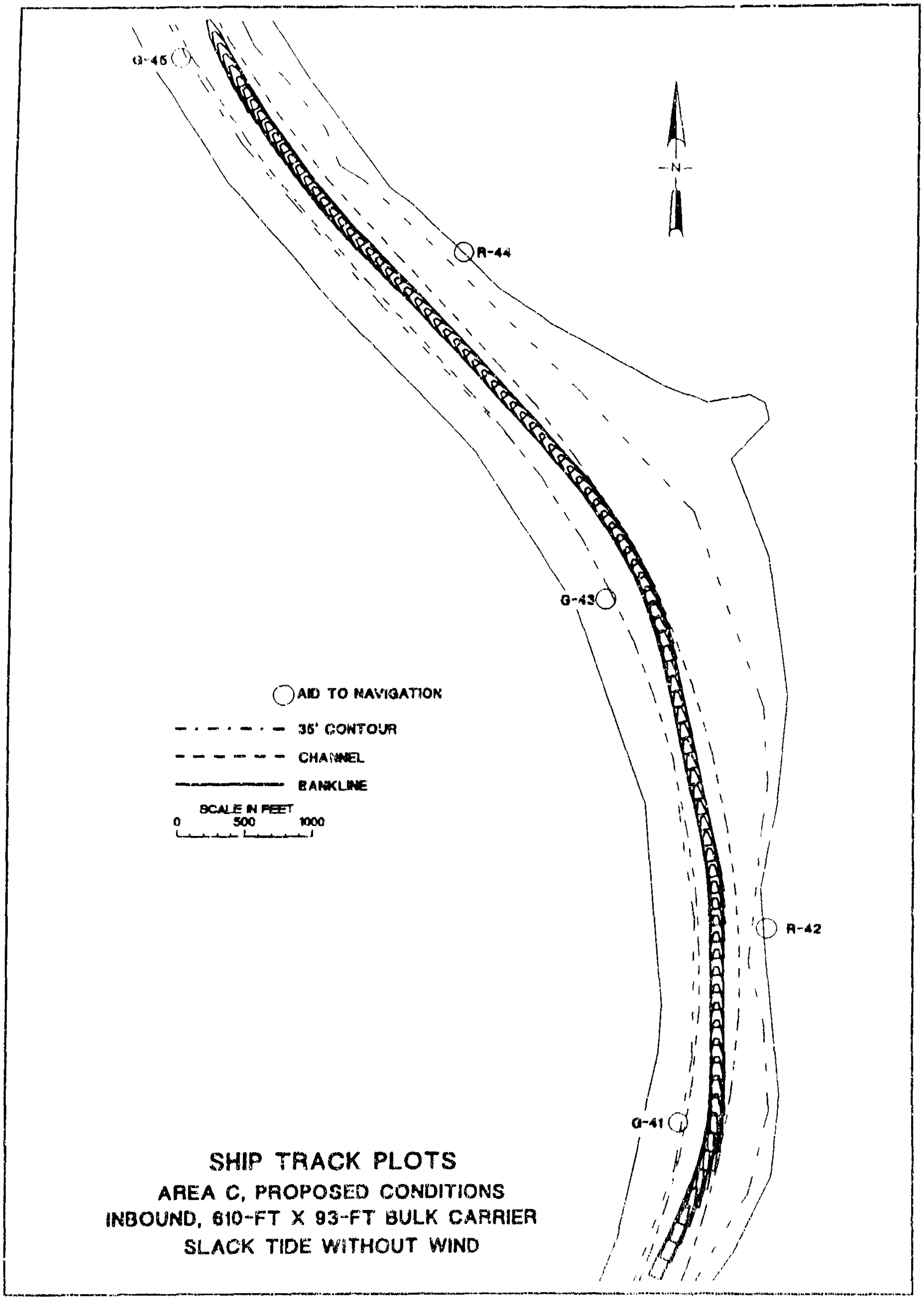
SHIP TRACK PLOTS
AREA 5, PROPOSED CONDITIONS
INBOUND, 510-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



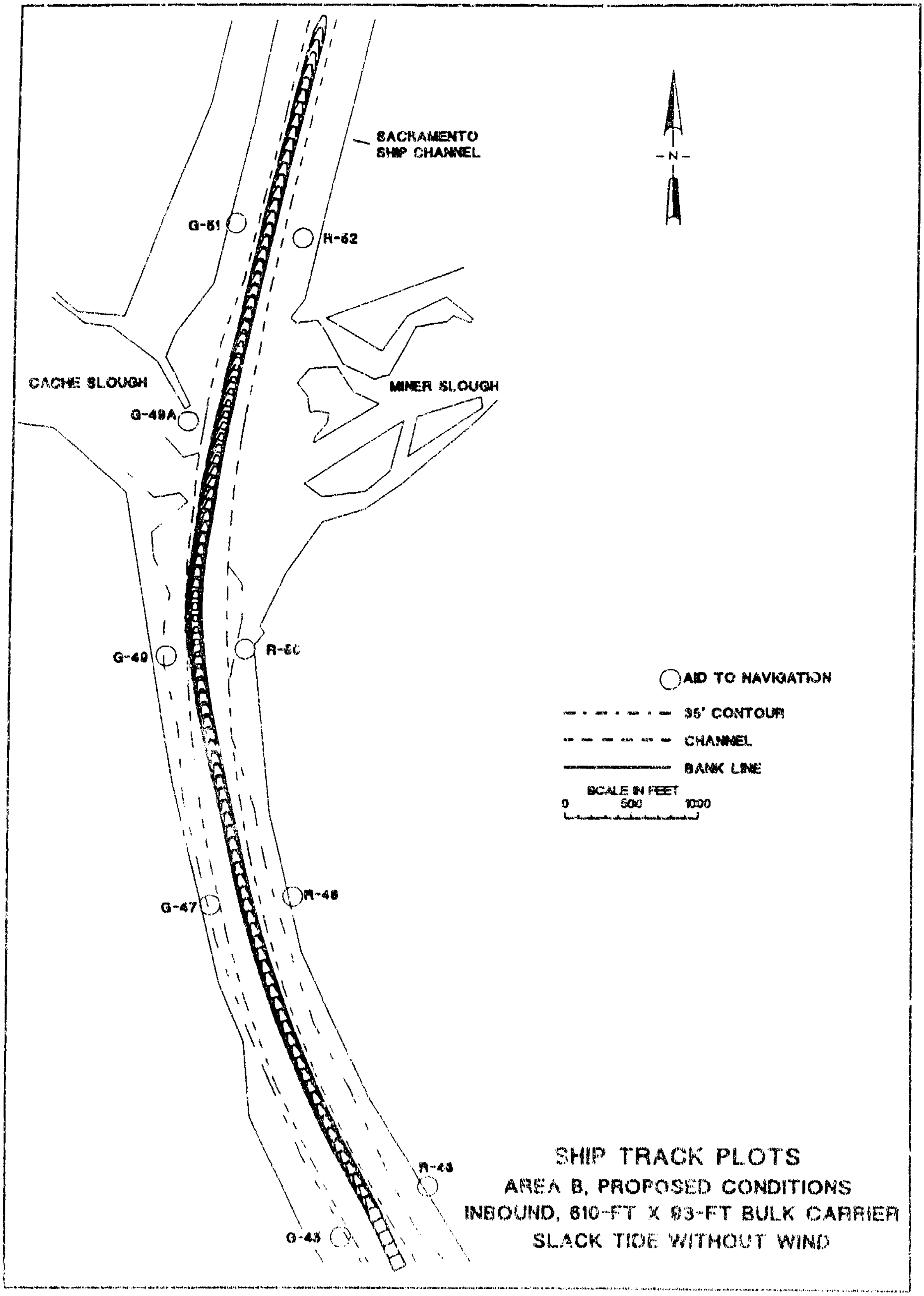
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND


AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
N
R-36
C-35
RIO VISTA BRIDGE
N-34
G-29
R-30
R-26
G-27
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND

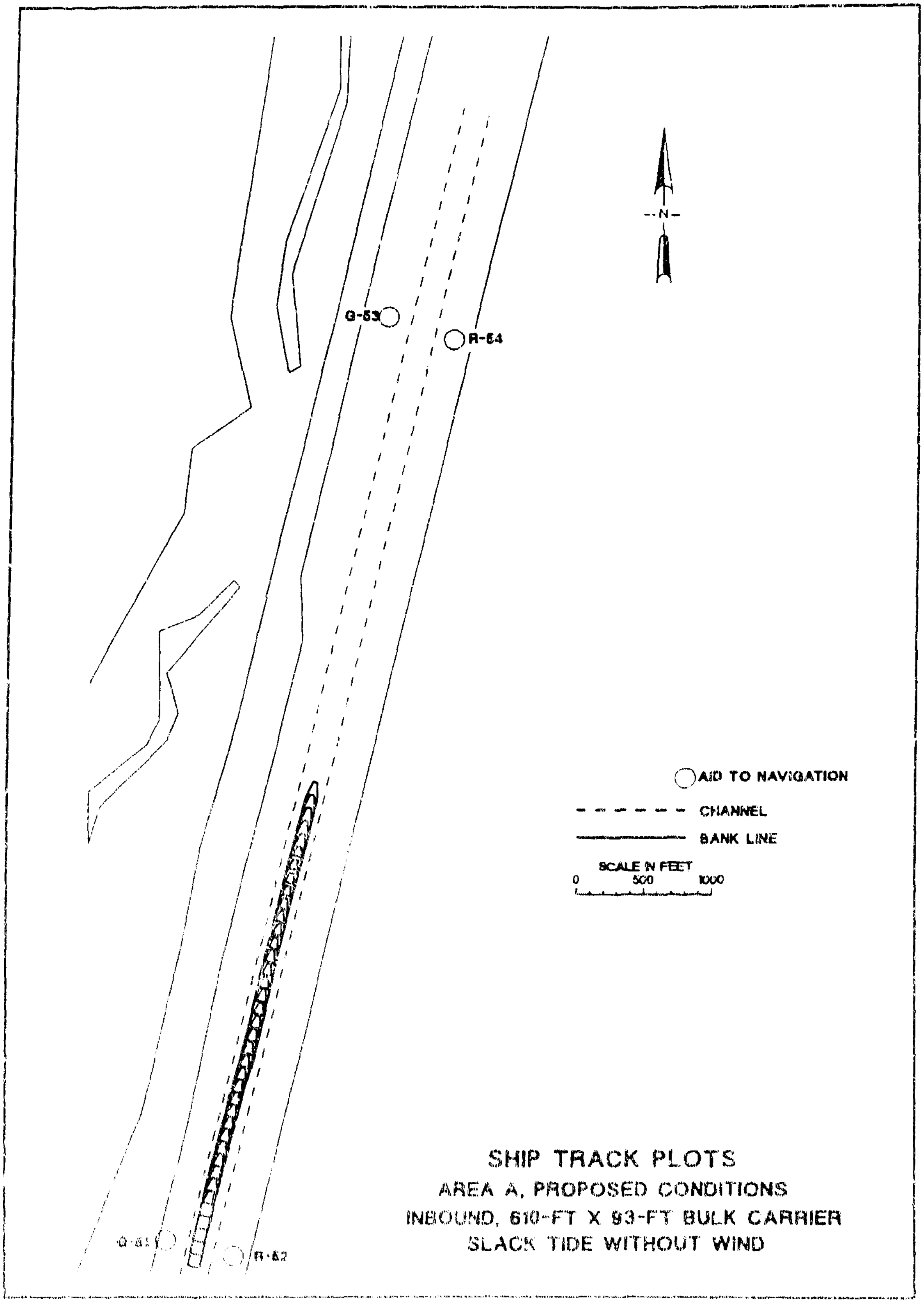

RYER ISLAND FERRY
R-40
G-39
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
STEAMBOAT SLOUGH
G-37
G-1
N-2
SACRAMENTO RIVER
R-38A
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



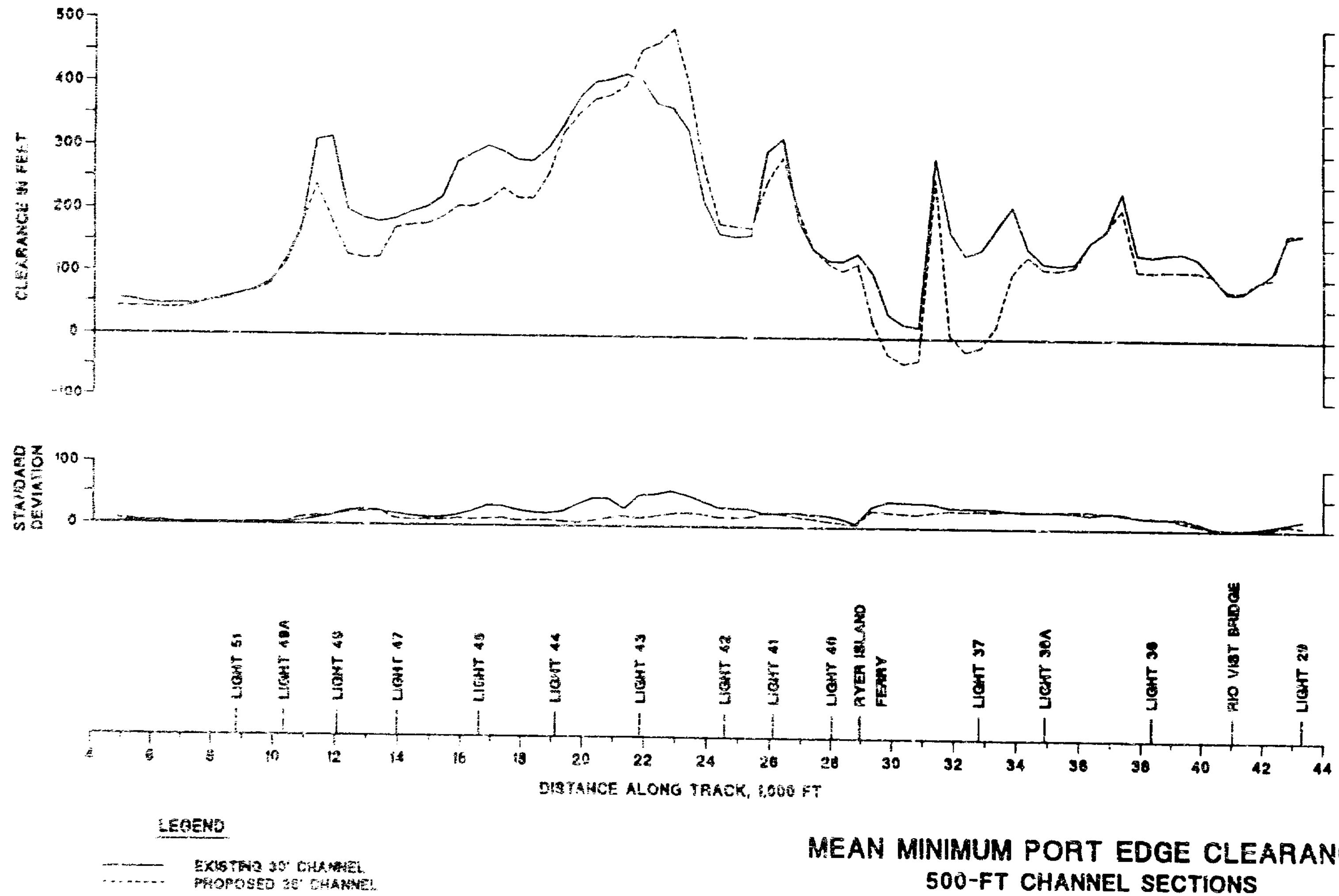
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



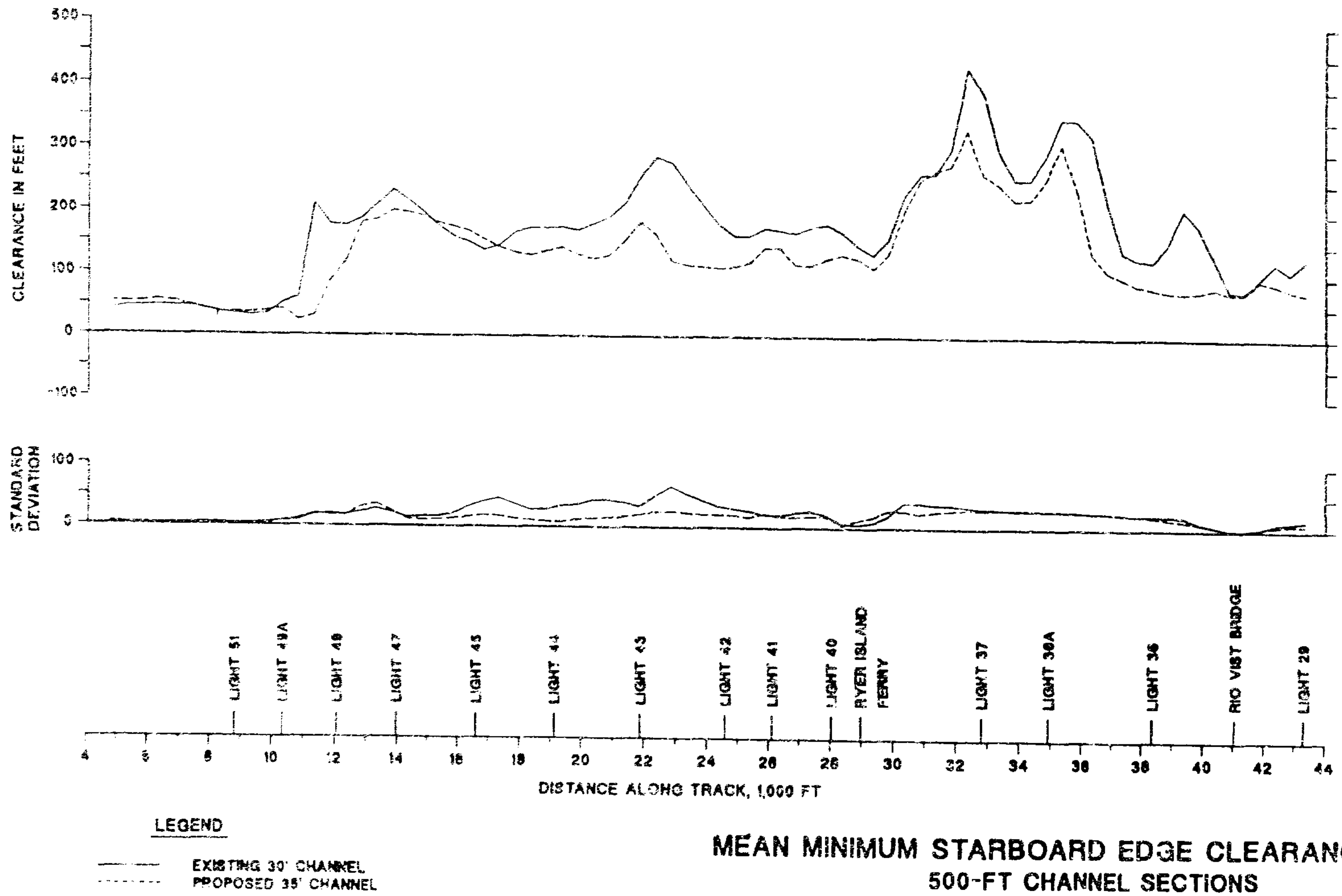
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITIONS
INBOUND, 810-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



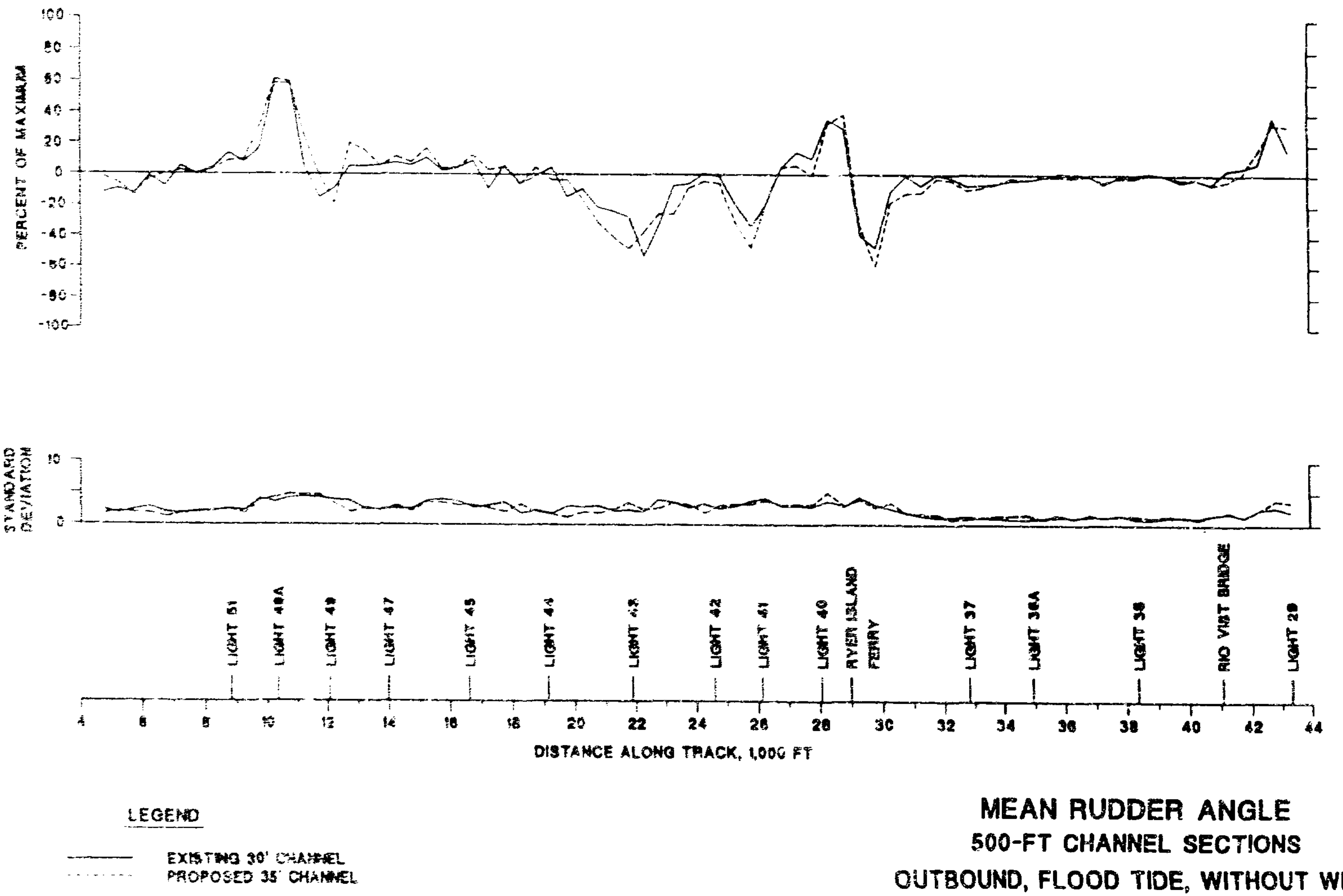
SHIP TRACK PLOTS
AREA A, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
SLACK TIDE WITHOUT WIND



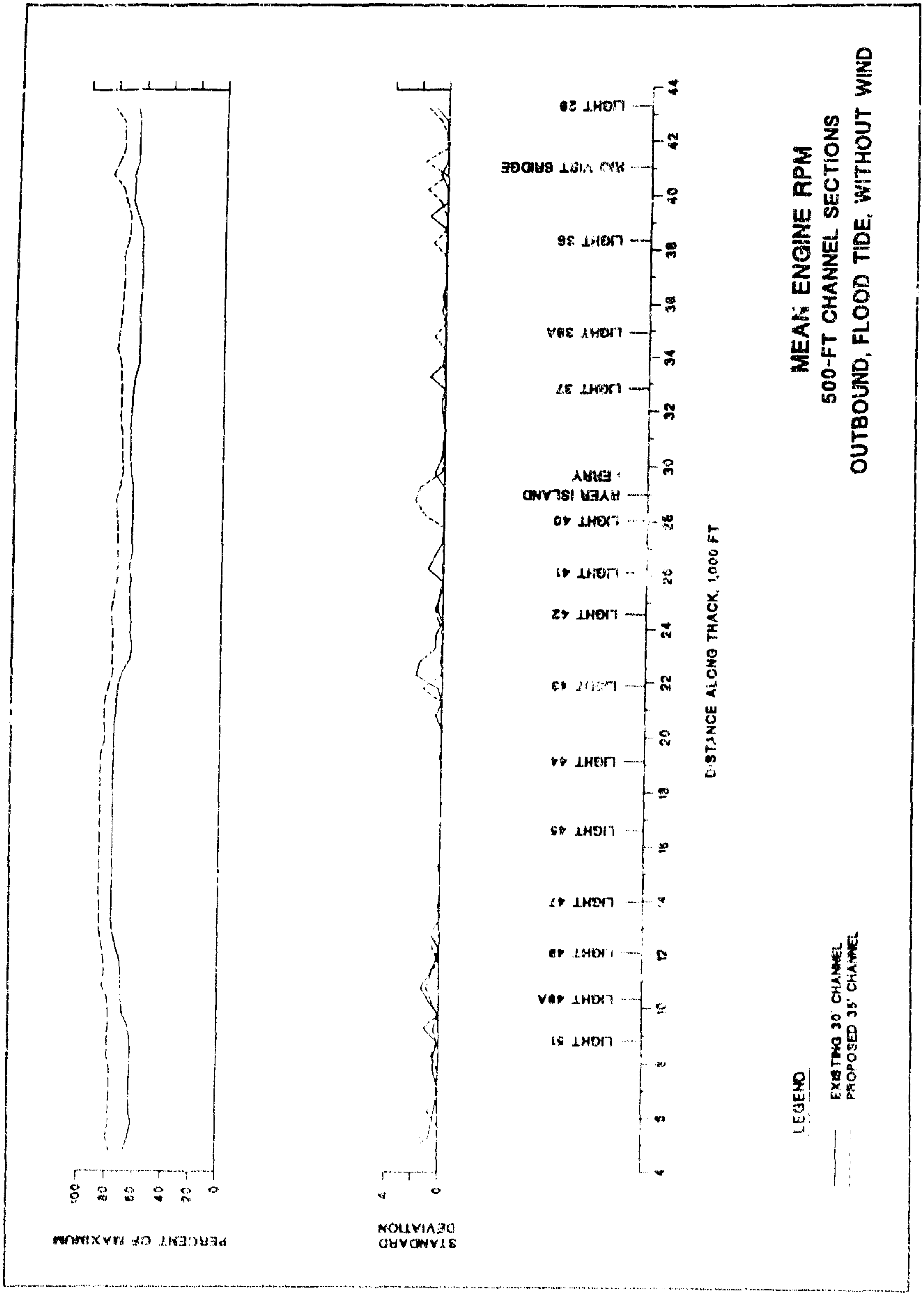
MEAN MINIMUM PORT EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND

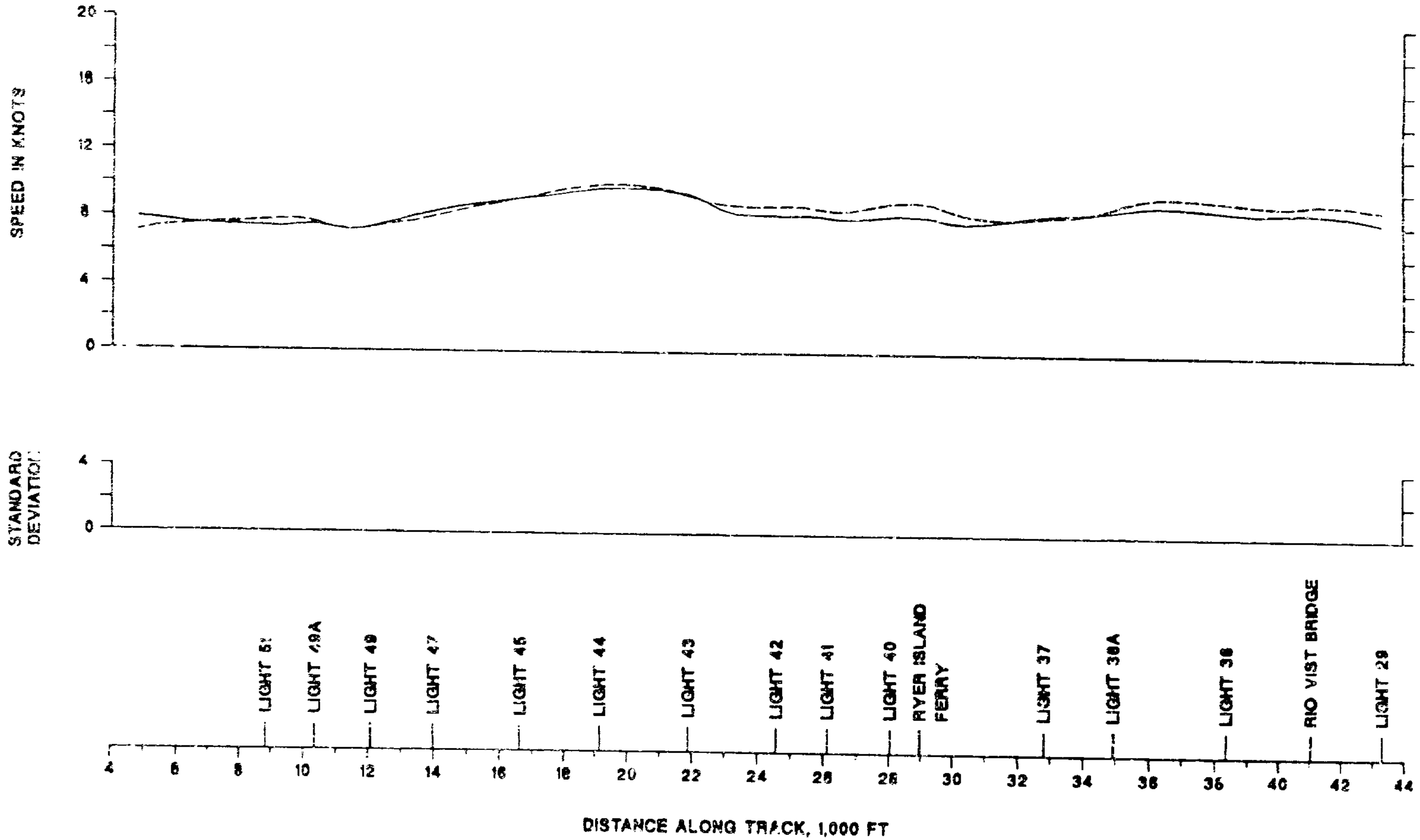


MEAN MINIMUM STARBOARD EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND



MEAN RUDDER ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND

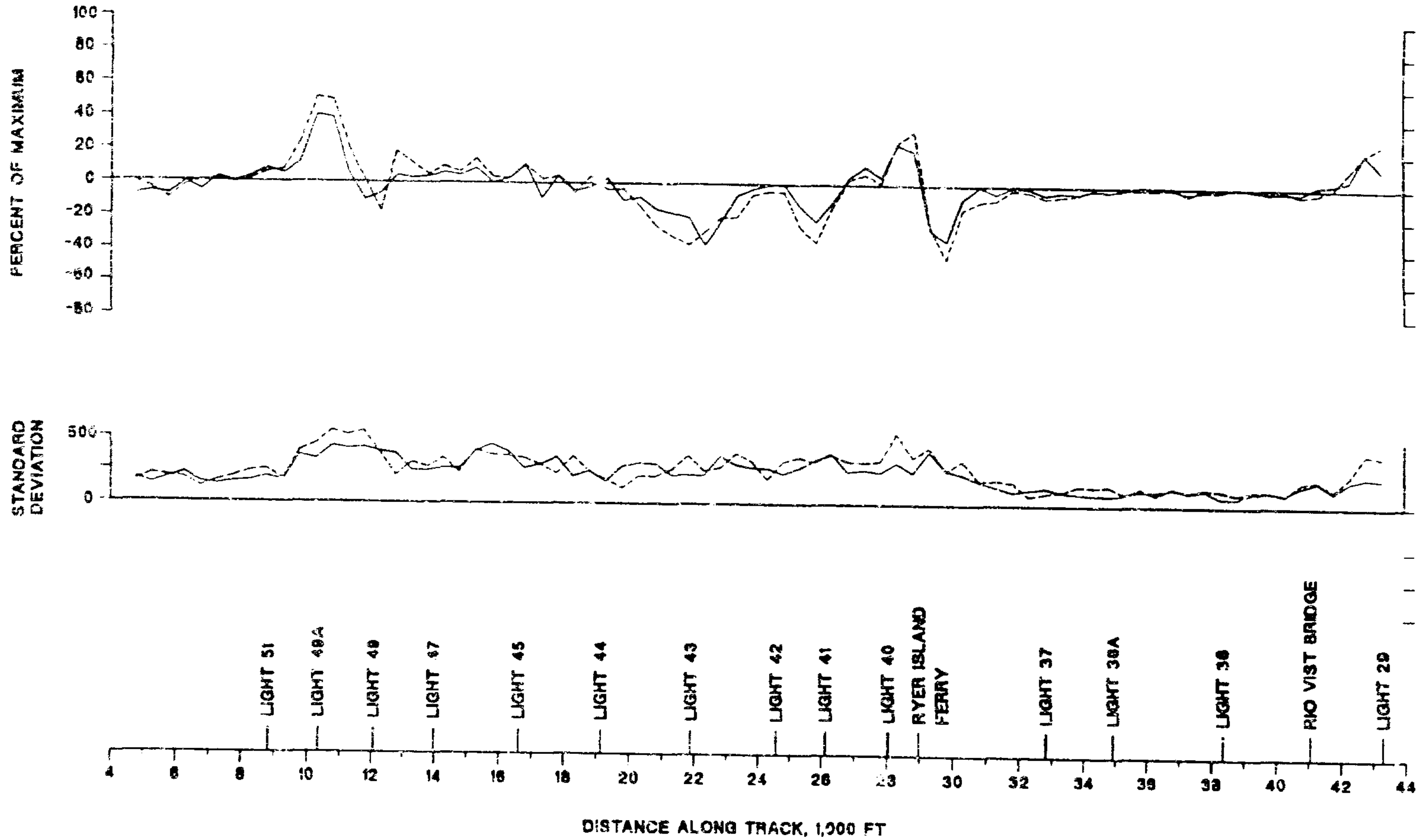

MEAN ENGINE RPM
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND
PERCENT OF MAXIMUM
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 29
RIO VISTA BRIDGE
LIGHT 36
LIGHT 36A
LIGHT 37
FERRY
RYER ISLAND
LIGHT 40
LIGHT 41
LIGHT 42
LIGHT 43
LIGHT 44
LIGHT 45
LIGHT 47
LIGHT 48
LIGHT 49A
LIGHT 51
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL



LEGEND

—— EXISTING 30' CHANNEL
------- PROPOSED 35' CHANNEL

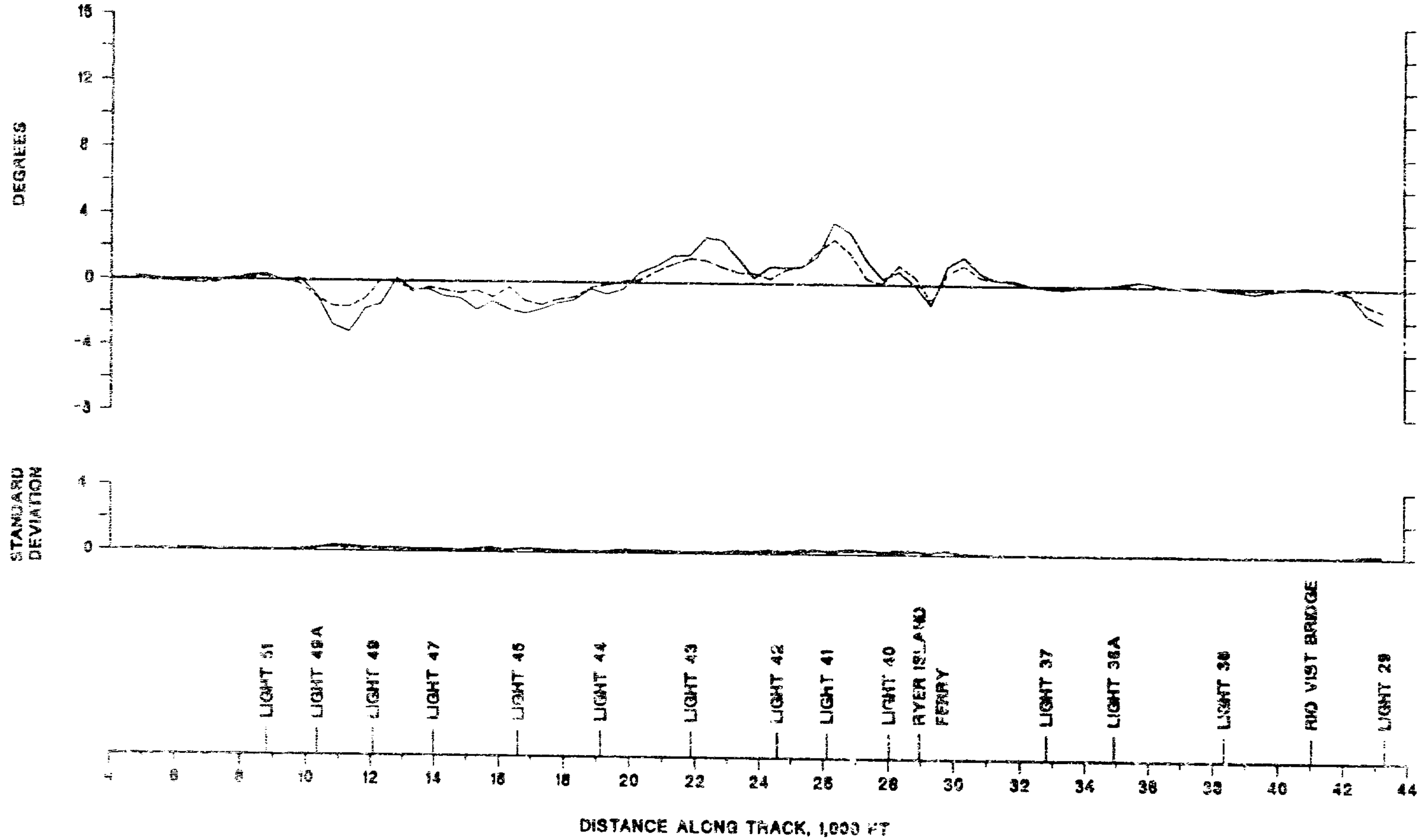
MEAN SHIP SPEED
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND



LEGEND

——— EXISTING 30' CHANNEL
- - - - PROPOSED 35' CHANNEL

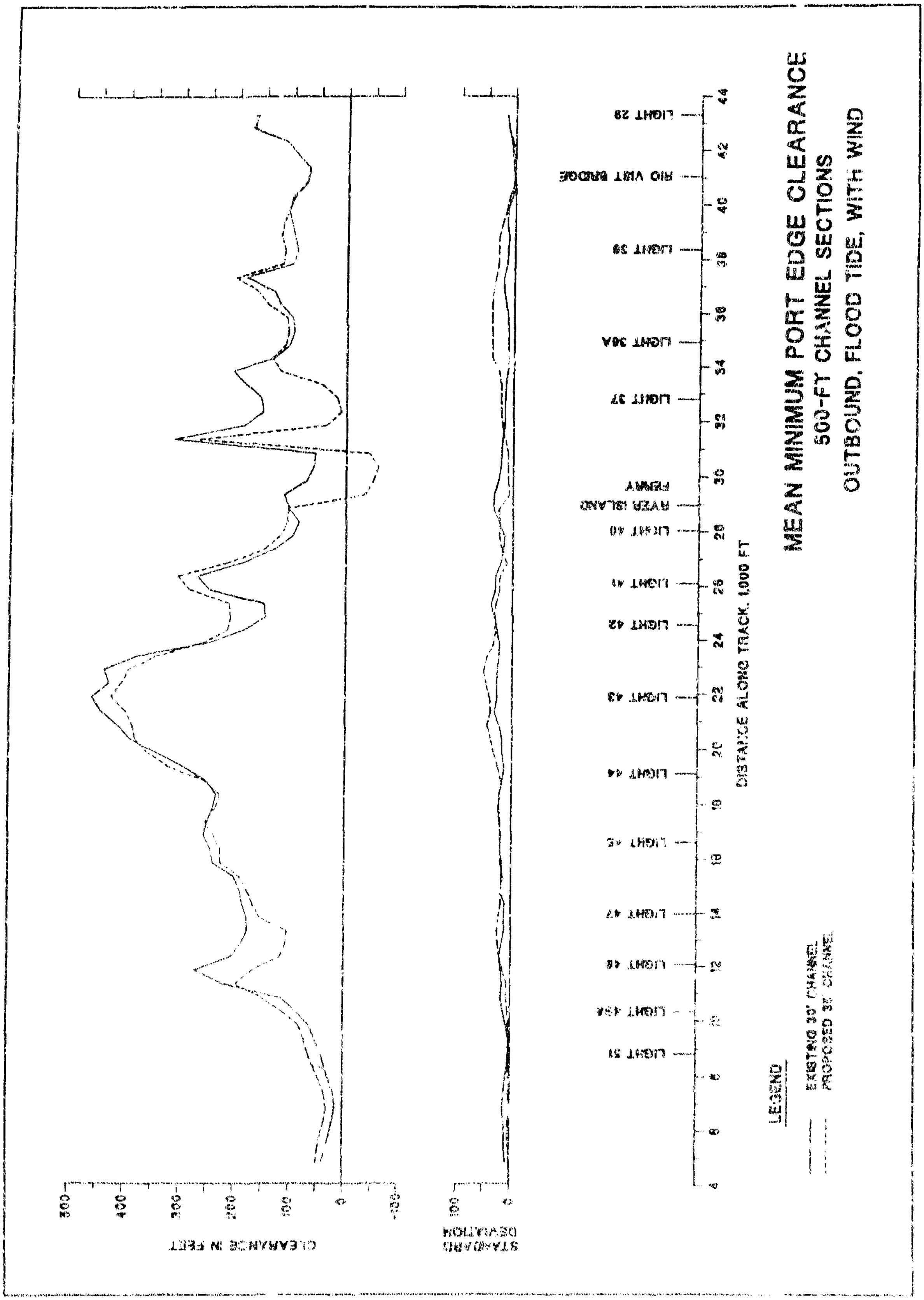
MEAN MANEUVERING FACTOR
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND

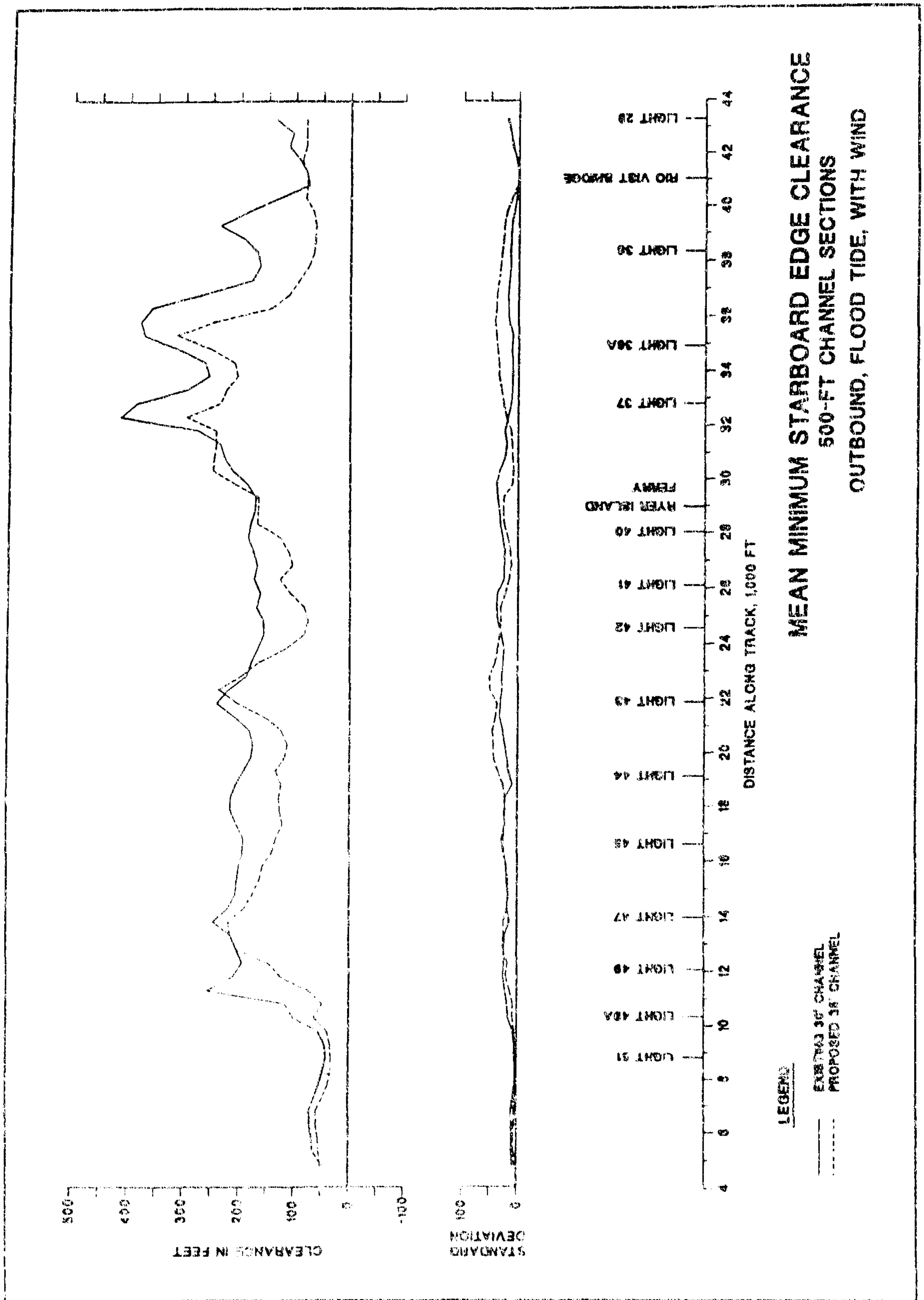


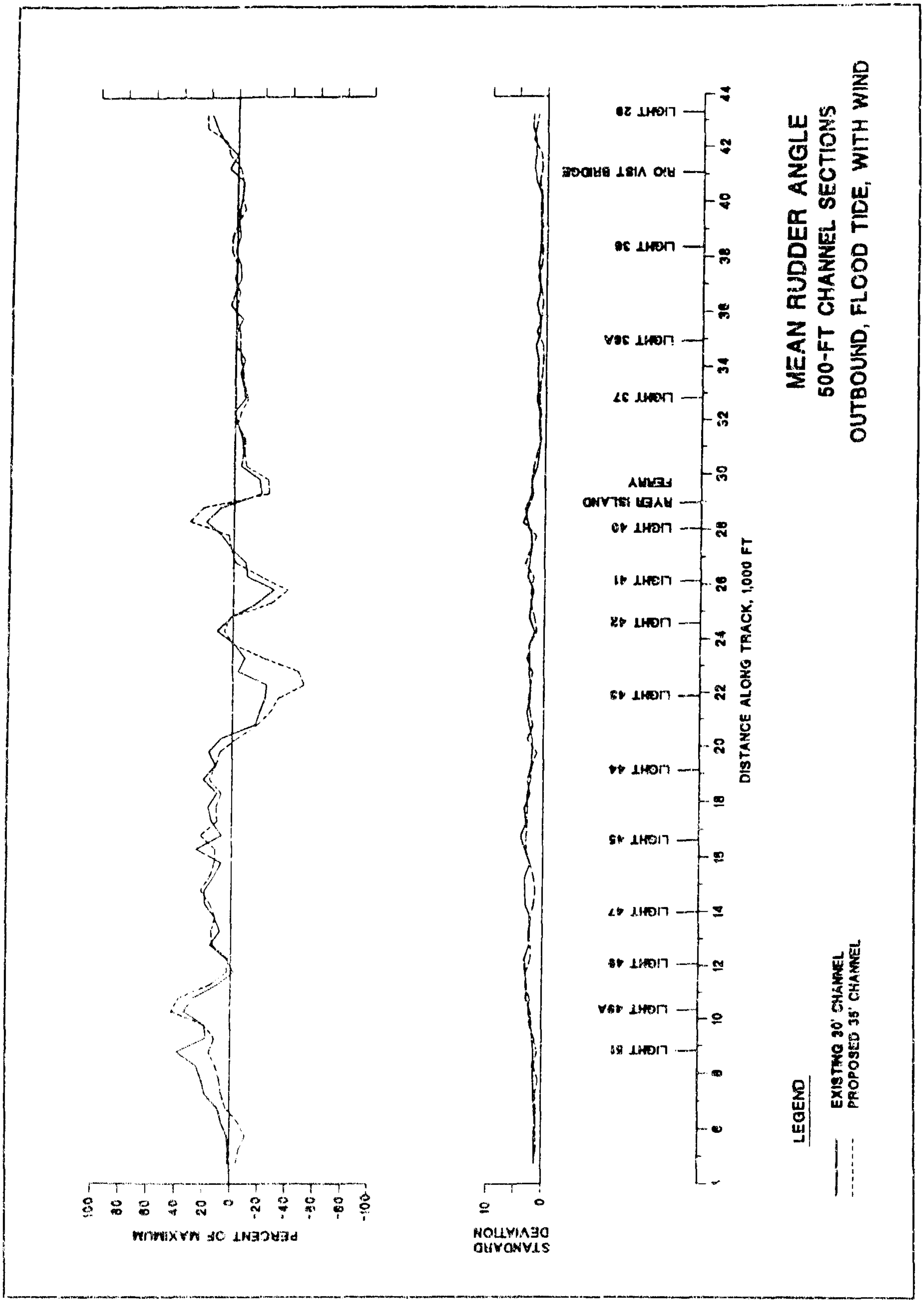
LEGEND

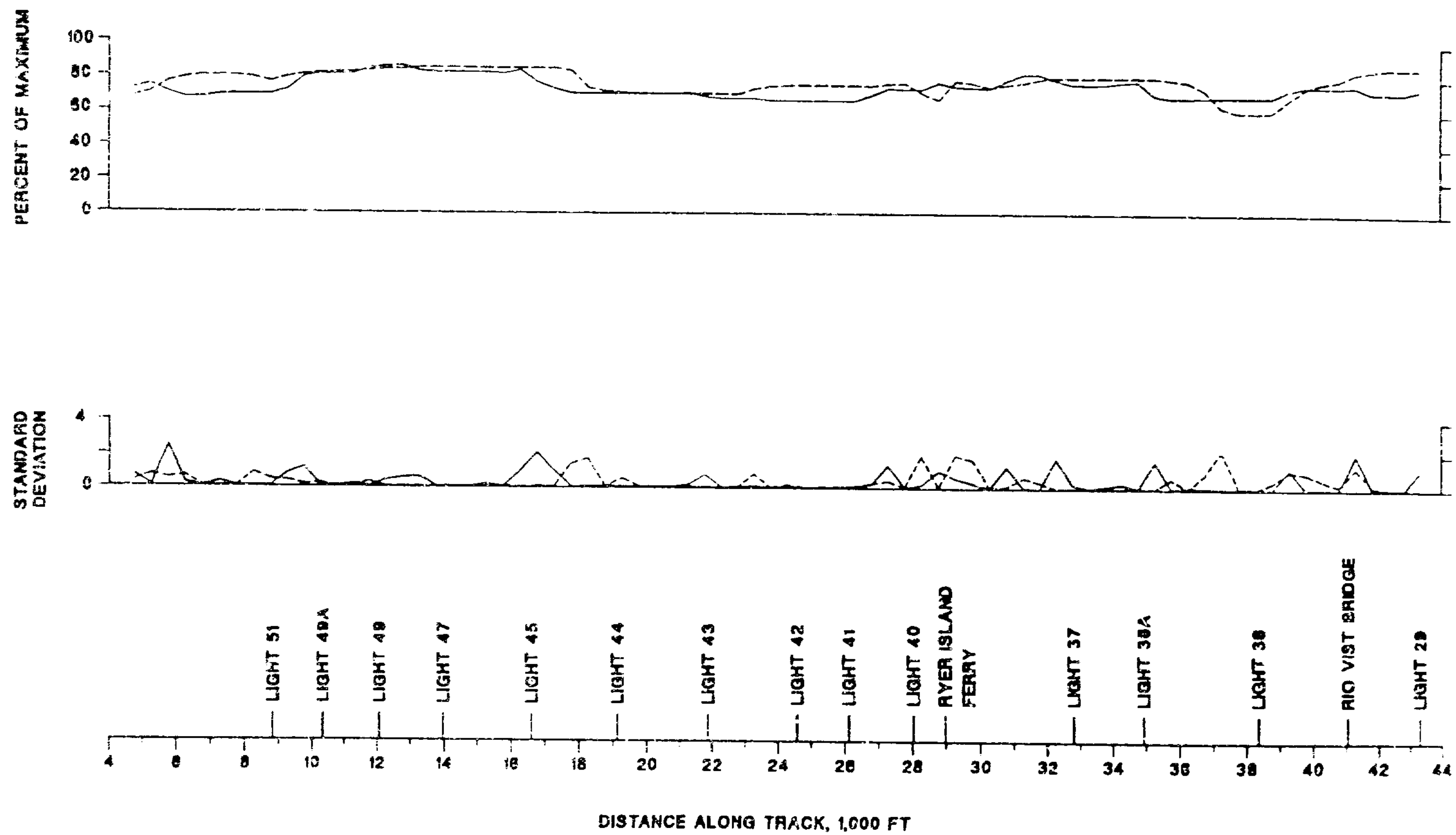
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

MEAN DRIFT ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITHOUT WIND


MEAN MINIMUM PORT EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL


MEAN MINIMUM STARBOARD EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
LIGHT 51
LIGHT 49A
LIGHT 49
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 36
RIO VISTA BRIDGE
LIGHT 29

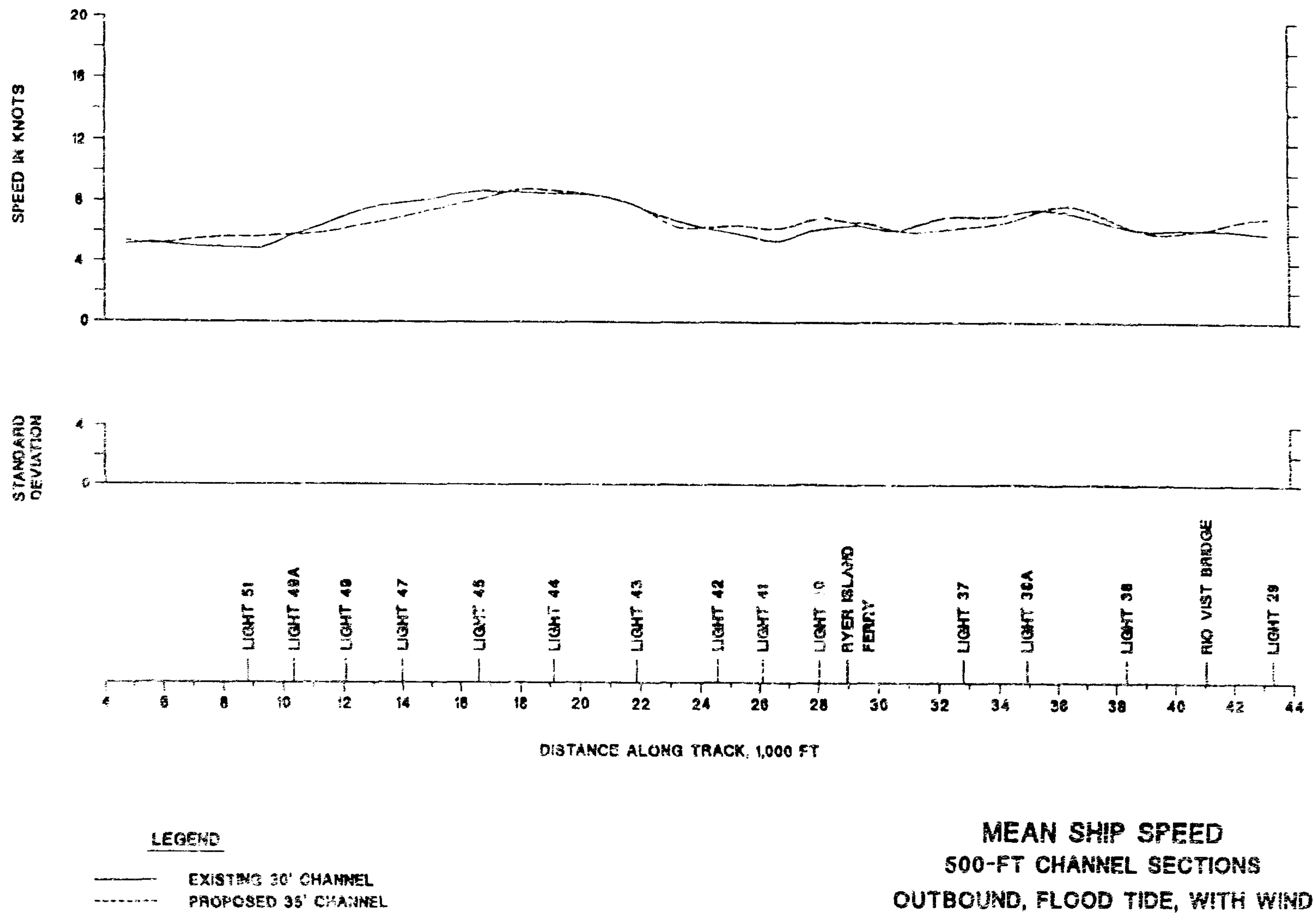

MEAN RUDDER ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND
PERCENT OF MAXIMUM
100 80 60 40 20 0 -20 -40 -60 -80 -100
STANDARD DEVIATION
10 0
DISTANCE ALONG TRACK, 1,000 FT
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
LIGHT 51
LIGHT 49A
LIGHT 48
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND
FERRY
LIGHT 37
LIGHT 36A
LIGHT 38
RIO VIST BRIDGE
LIGHT 28
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL



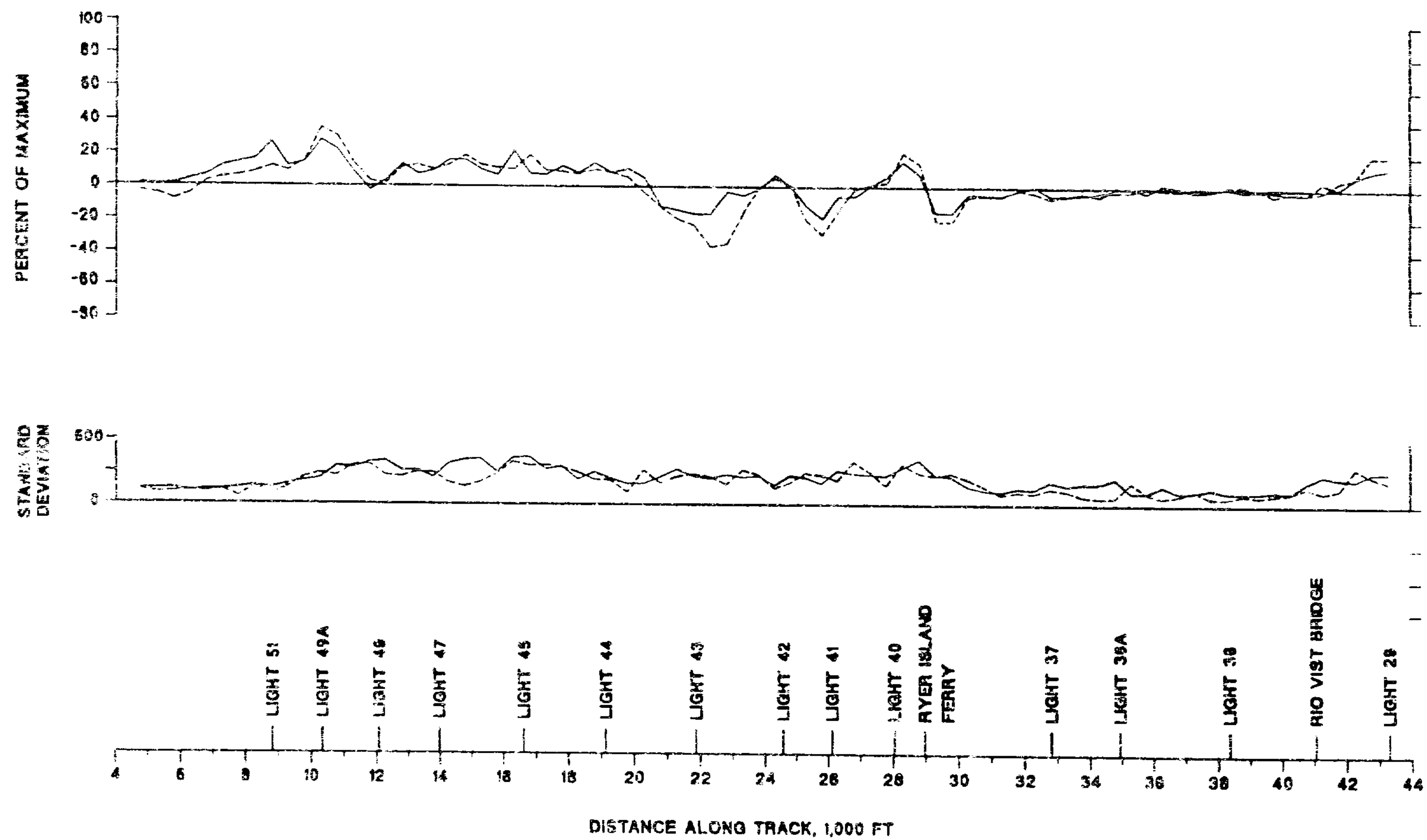
LEGEND

—— EXISTING 30' CHANNEL
- - - PROPOSED 35' CHANNEL

MEAN ENGINE RPM
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND



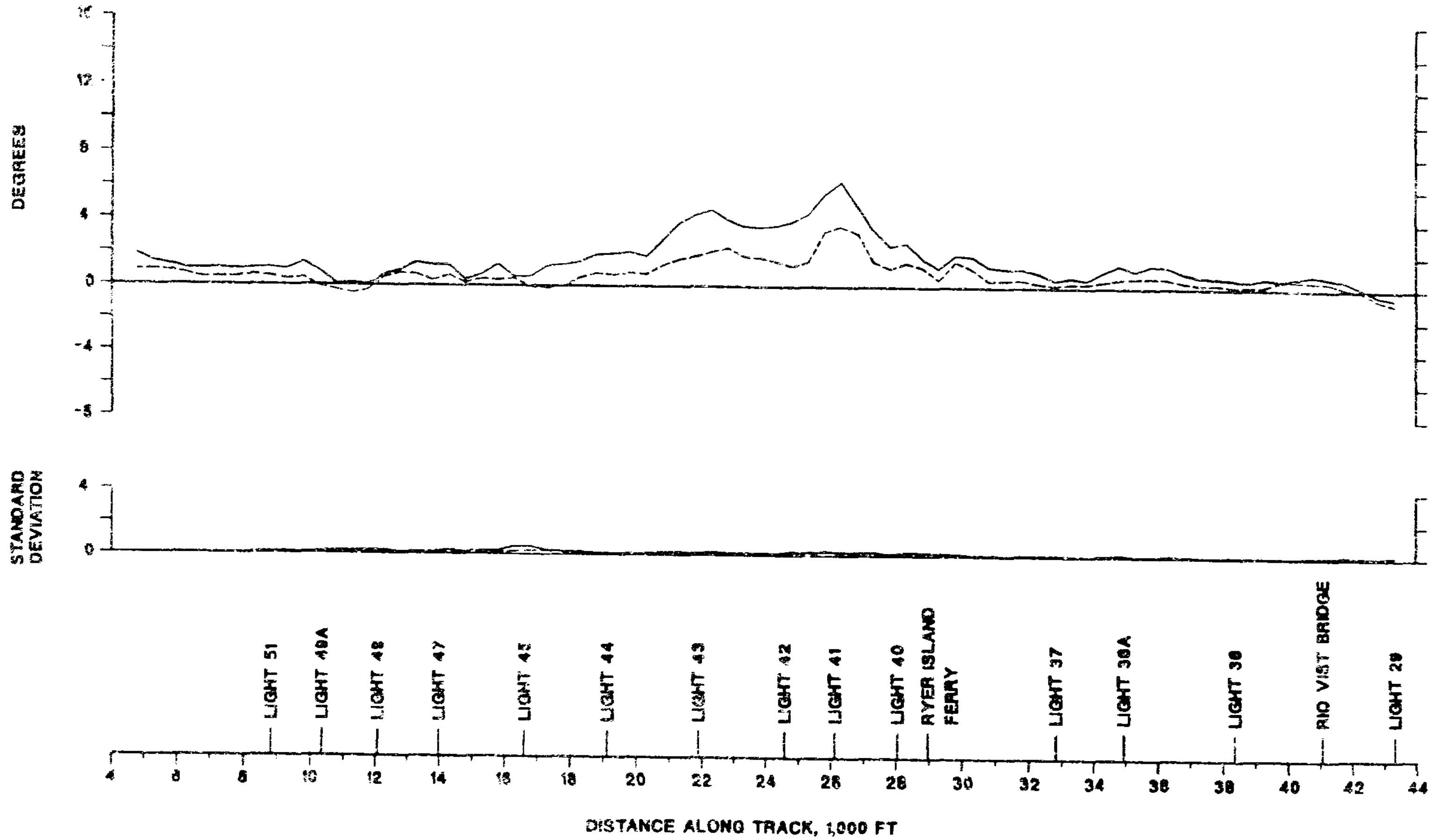
MEAN SHIP SPEED
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND



LEGEND

EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

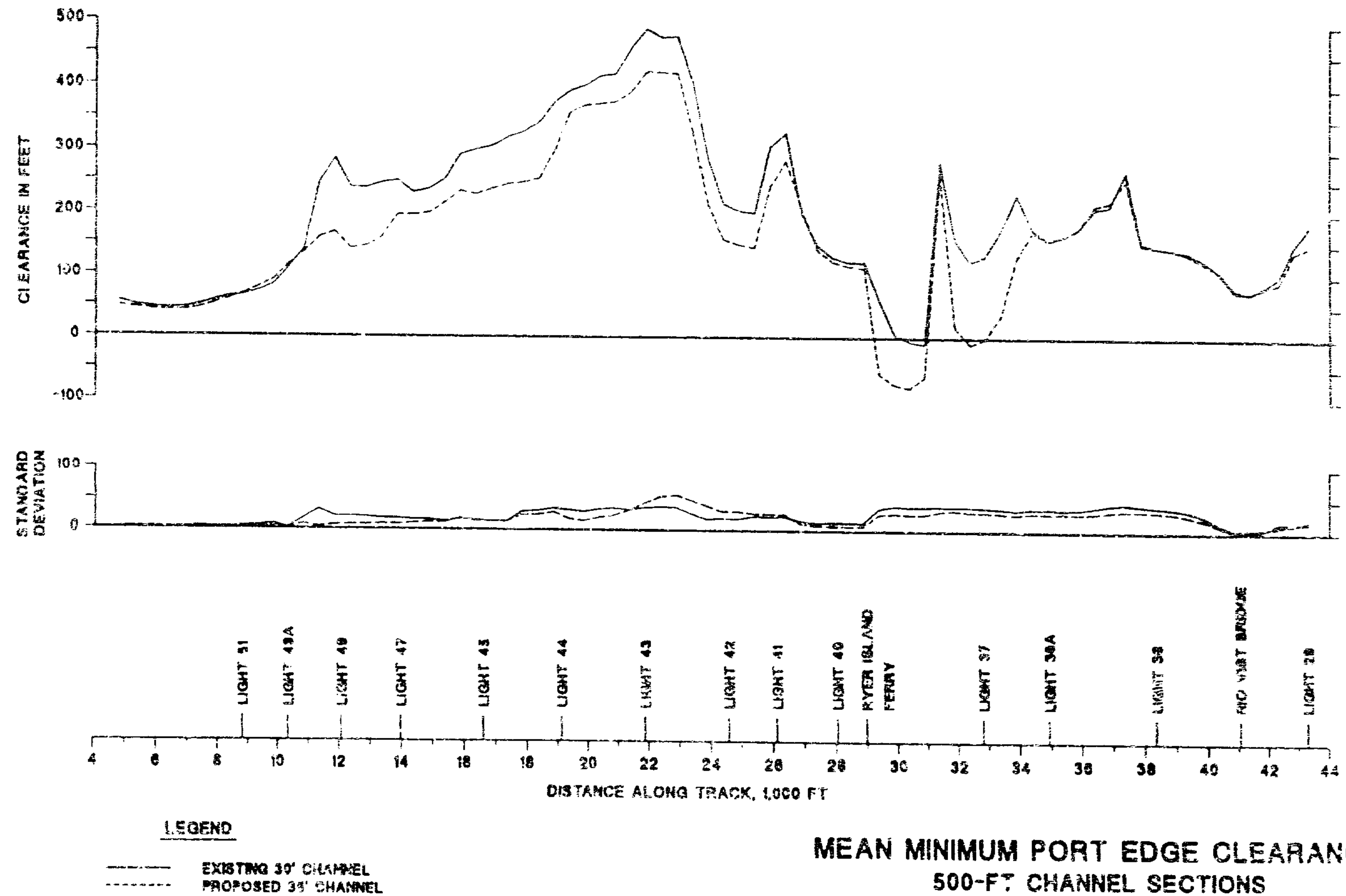
MEAN MANEUVERING FACTOR
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND



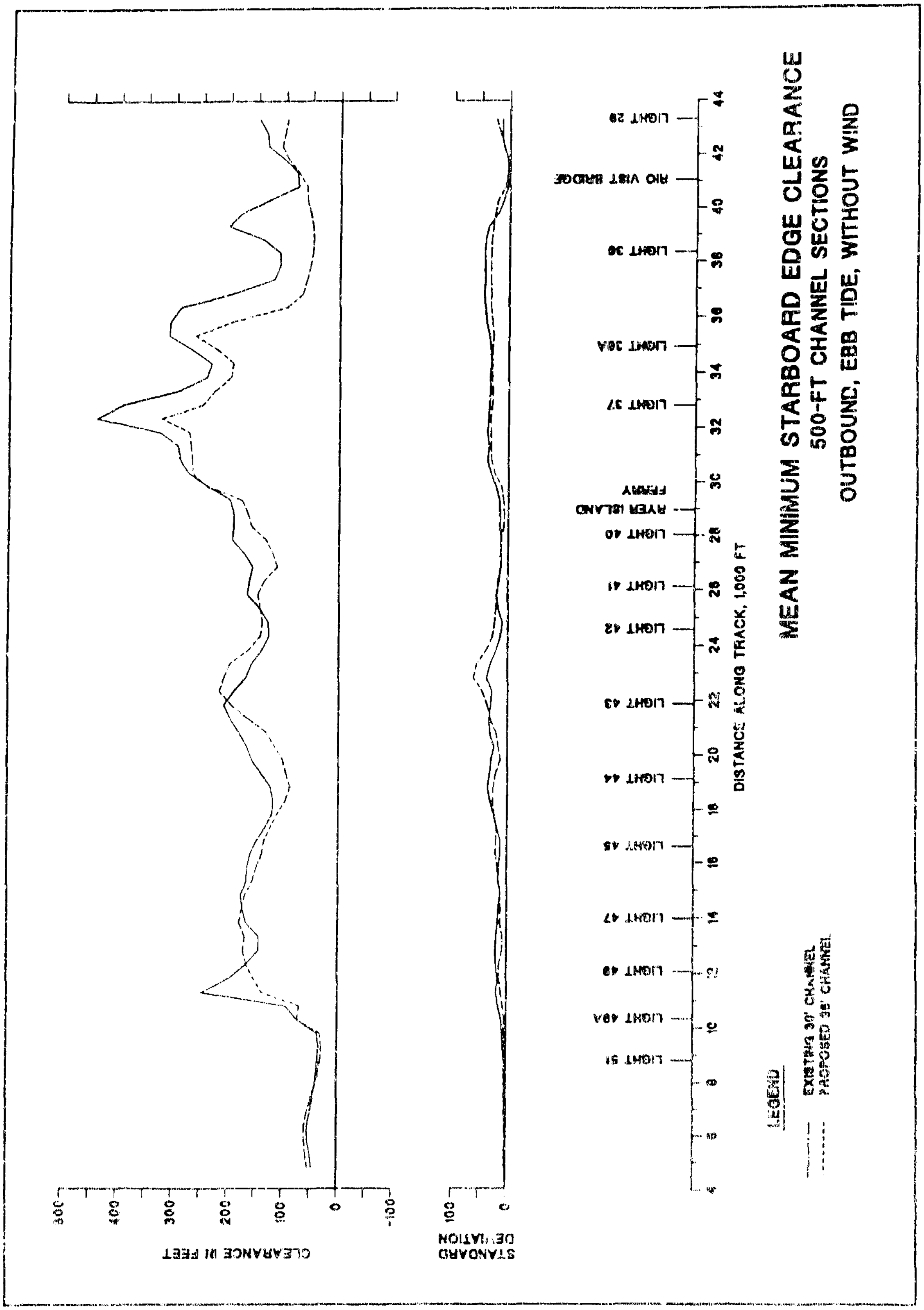
LEGEND

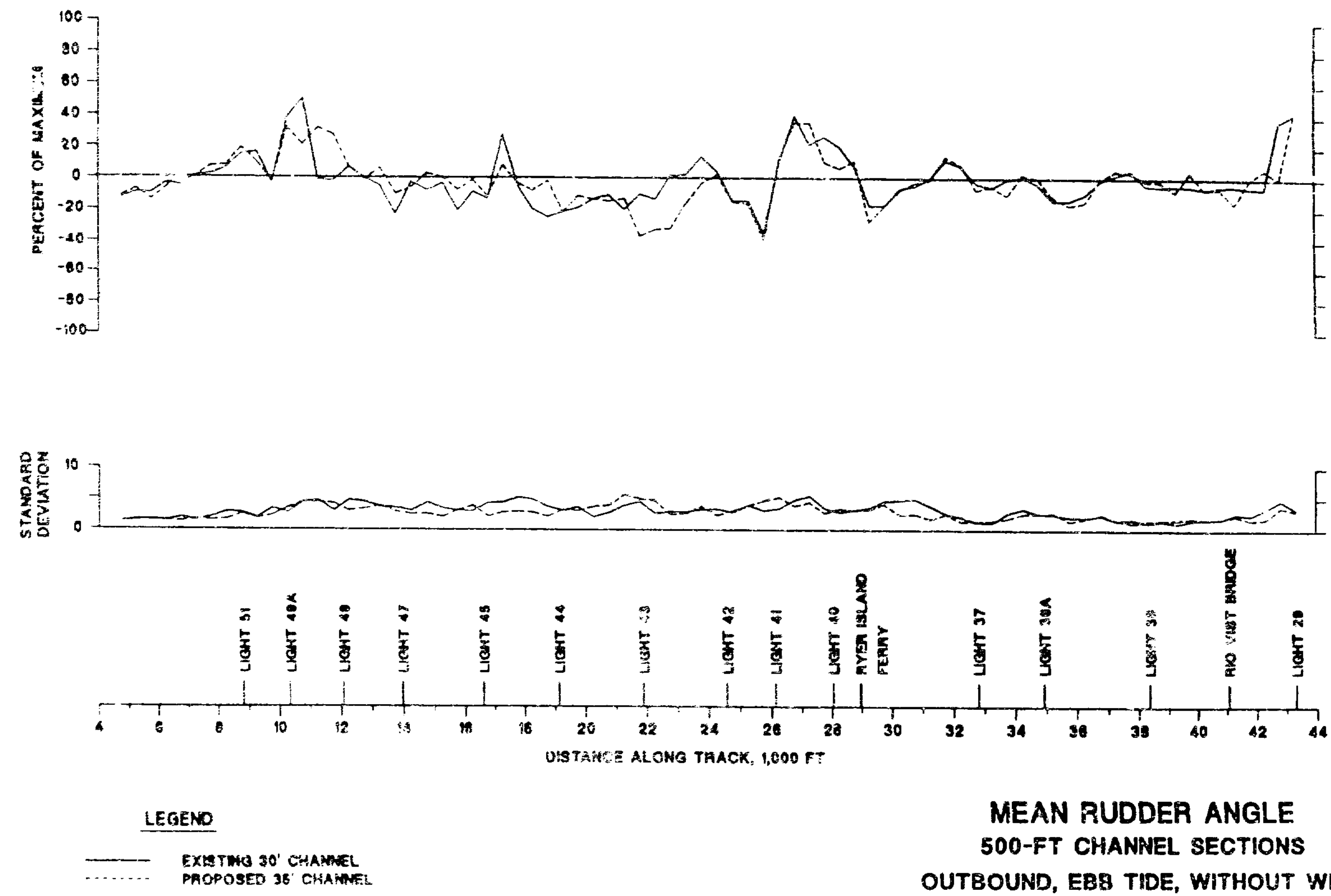
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

MEAN DRIFT ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, FLOOD TIDE, WITH WIND

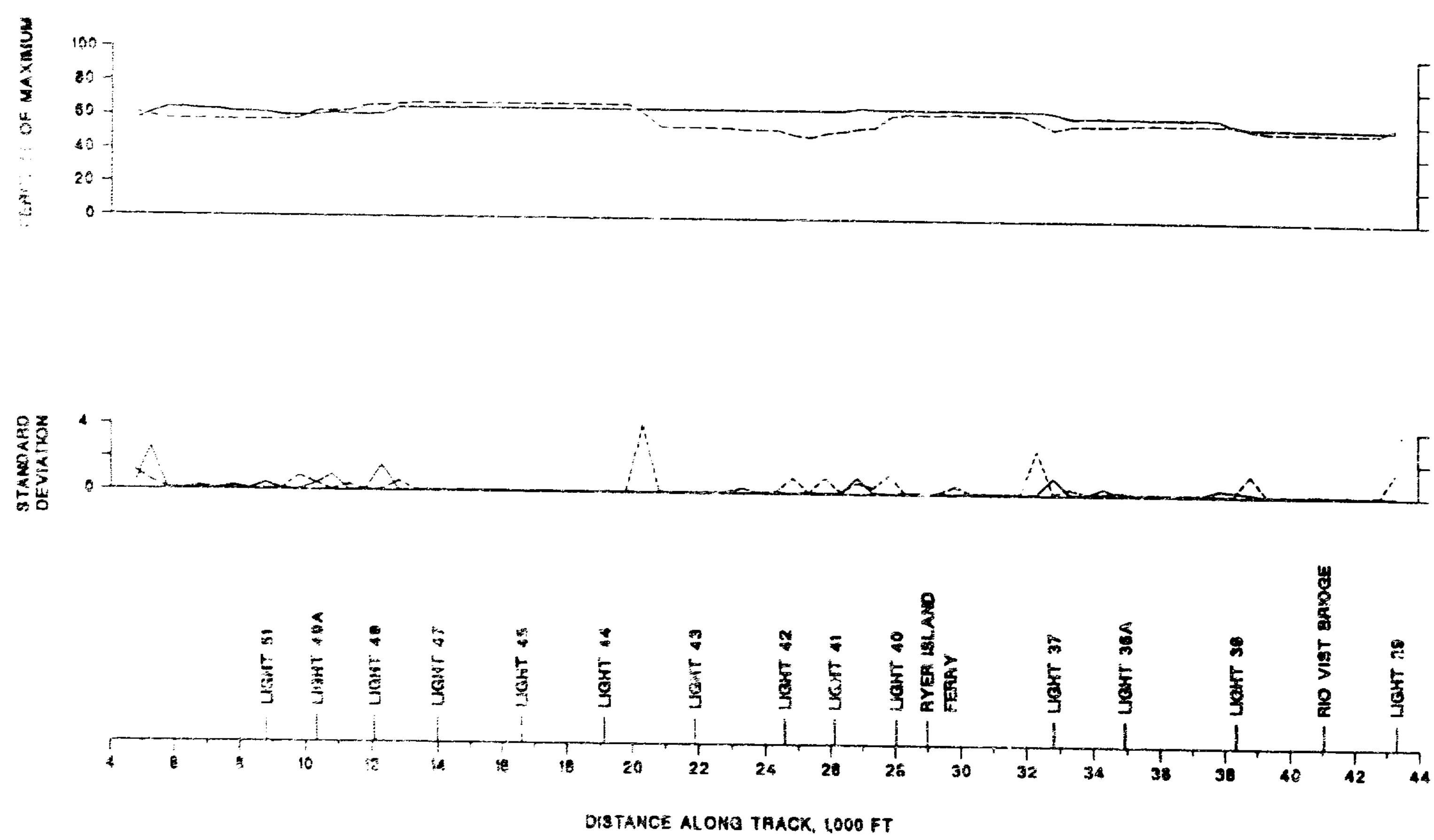


MEAN MINIMUM PORT EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND


MEAN MINIMUM STARBOARD EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 51
LIGHT 49A
LIGHT 49
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 36
RIO VISTA BRIDGE
LIGHT 29
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL



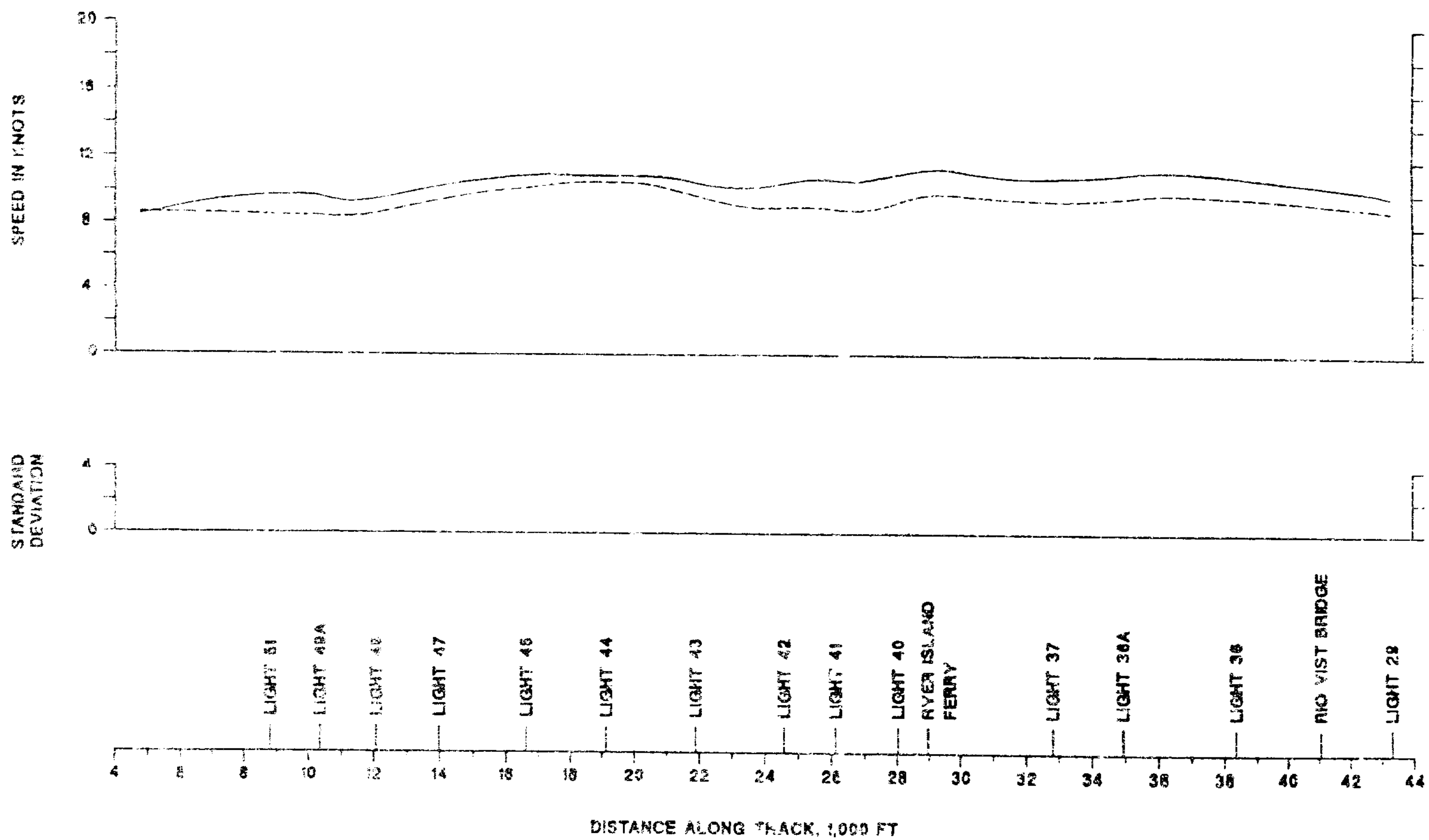
MEAN RUDDER ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND



LEGEND

EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

MEAN ENGINE RPM
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND



LEGEND

EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

MEAN SHIP SPEED
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND

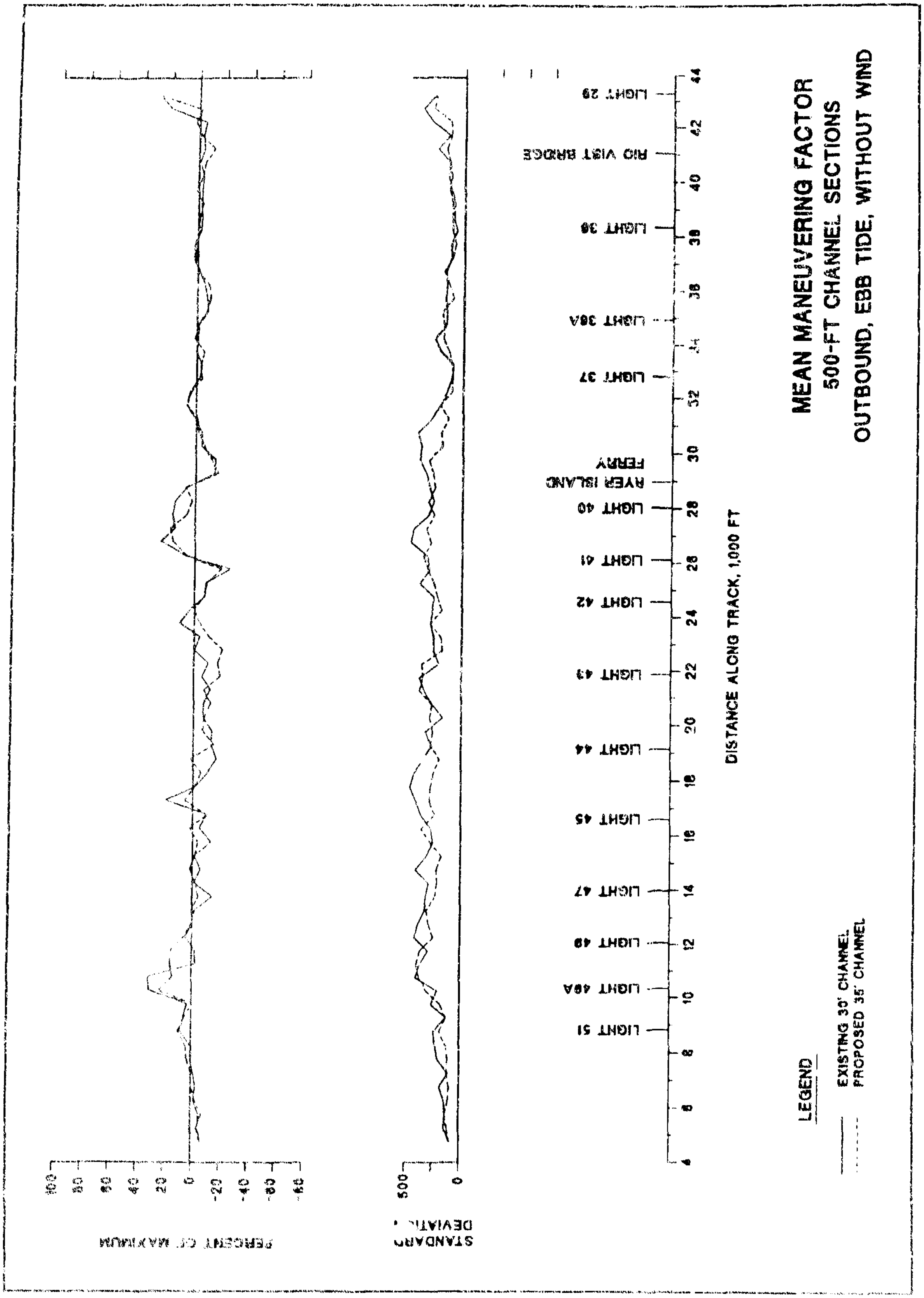
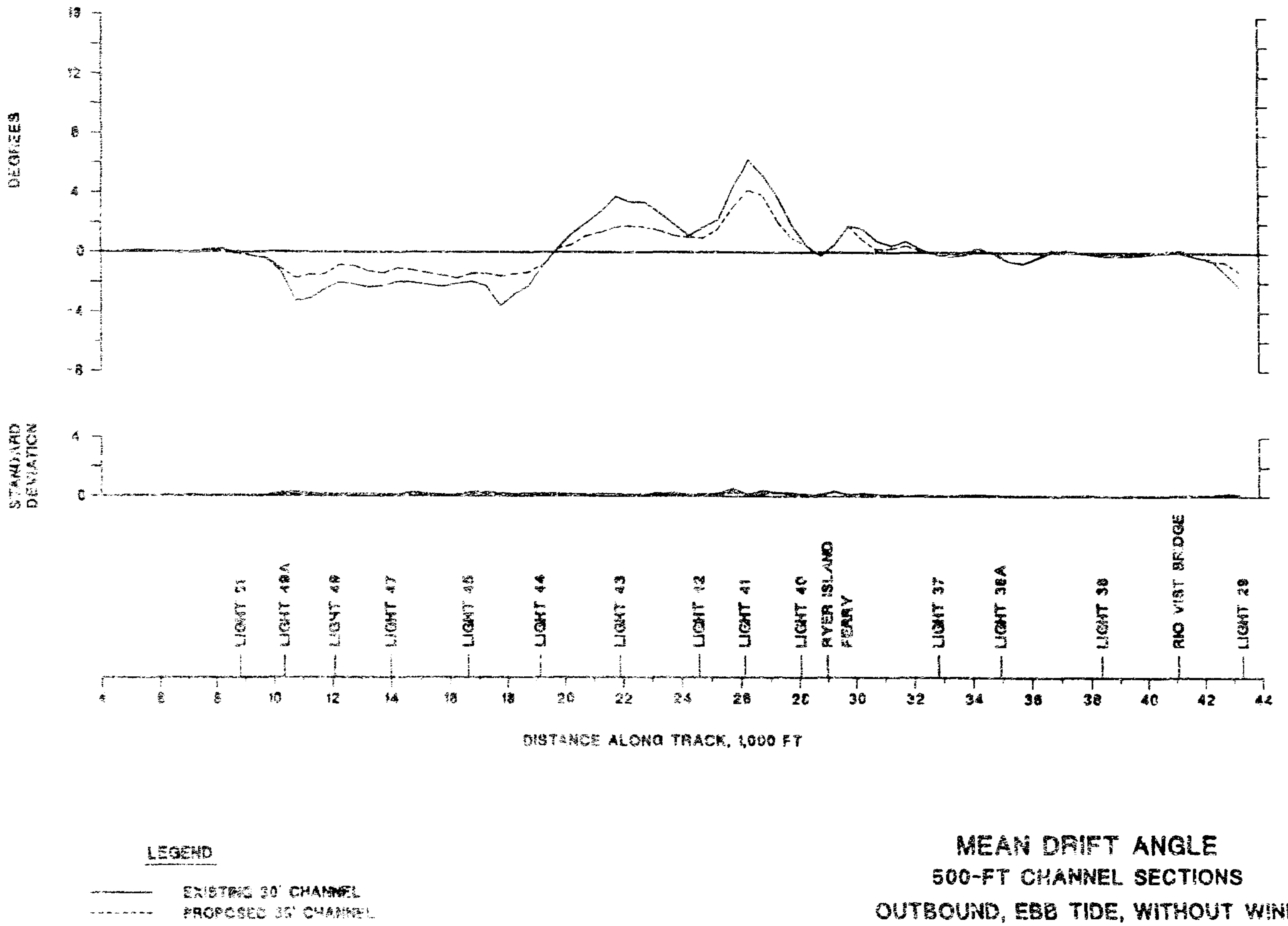
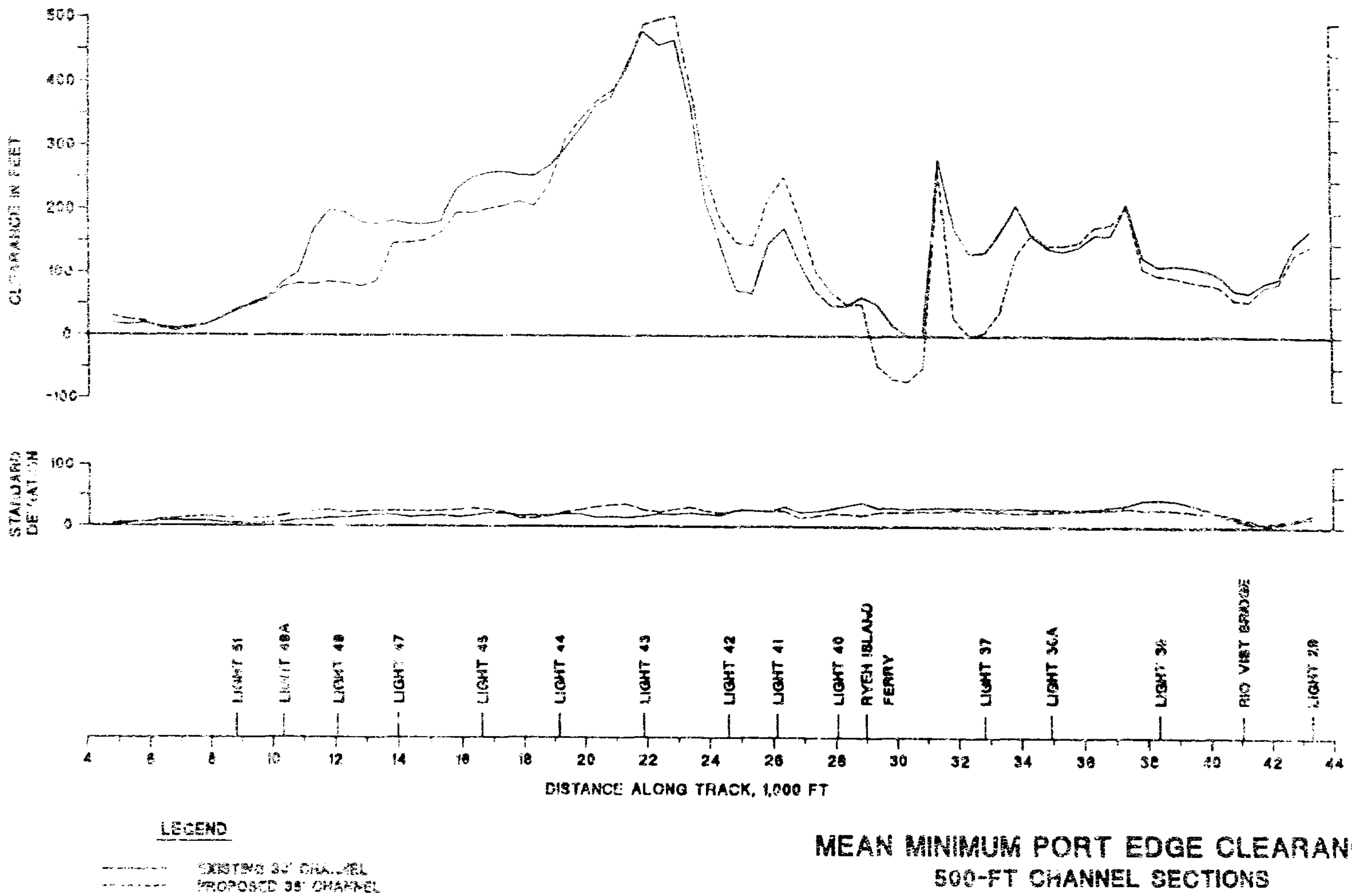

MEAN MANEUVERING FACTOR
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
DISTANCE ALONG TRACK, 1,000 FT
PERCENT OF MAXIMUM
STANDARD DEVIATION

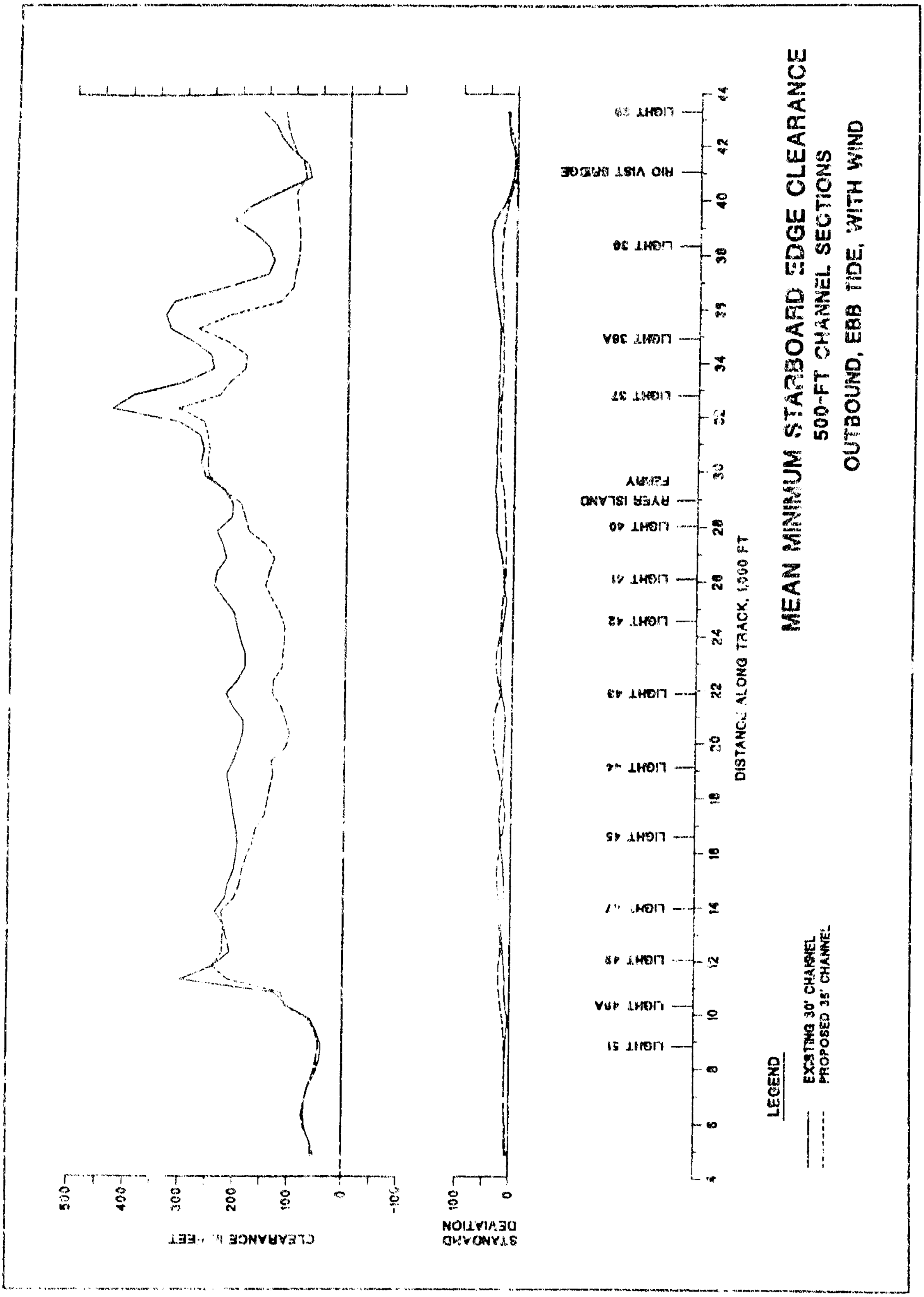
Plate 86



MEAN DRIFT ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITHOUT WIND



MEAN MINIMUM PORT EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND


MEAN MINIMUM STARBOARD EDGE CLEARANCE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
LIGHT 51
LIGHT 49A
LIGHT 48
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND
FERRY
LIGHT 37
LIGHT 36A
LIGHT 36
RIO VIST BRIDGE

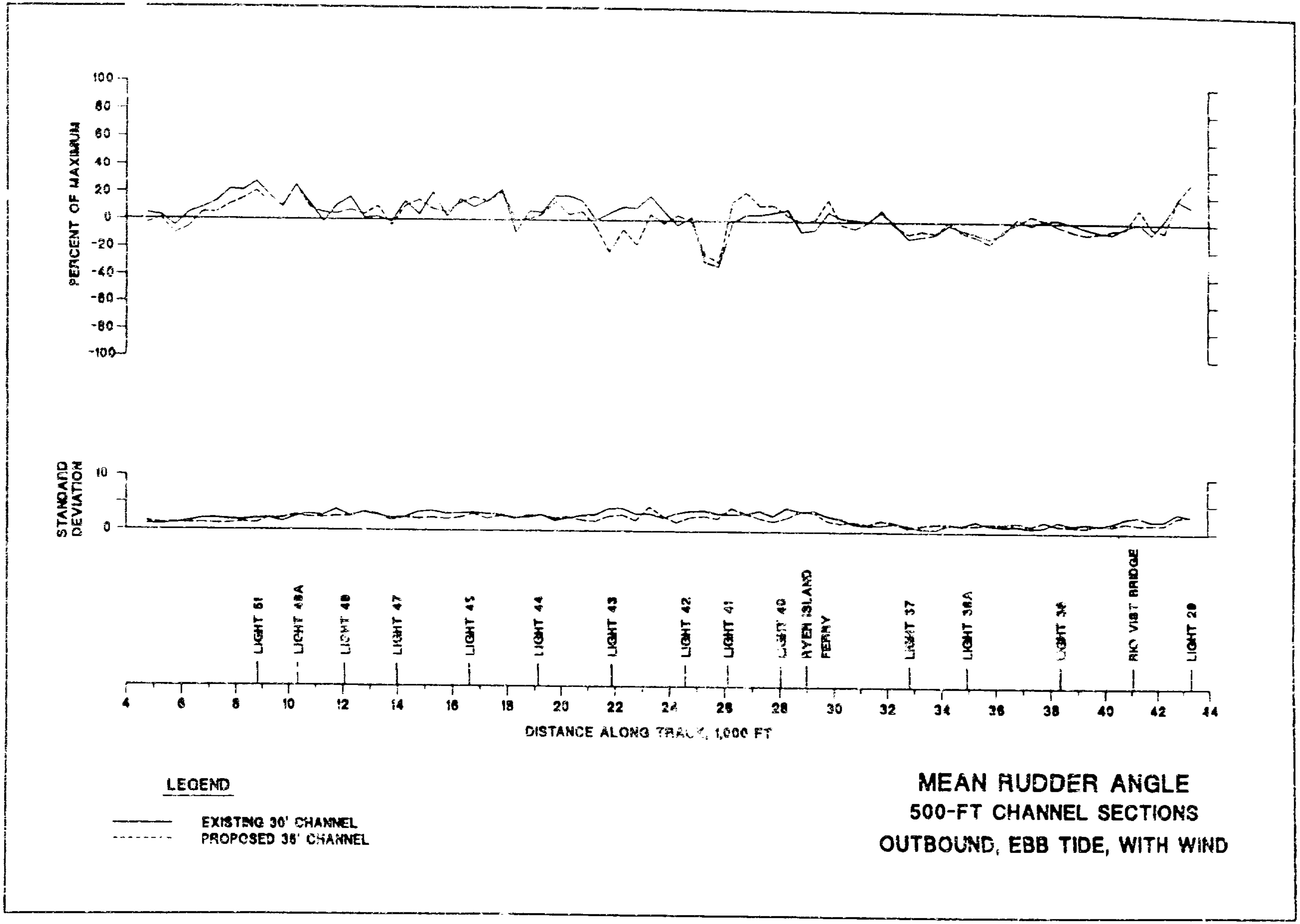
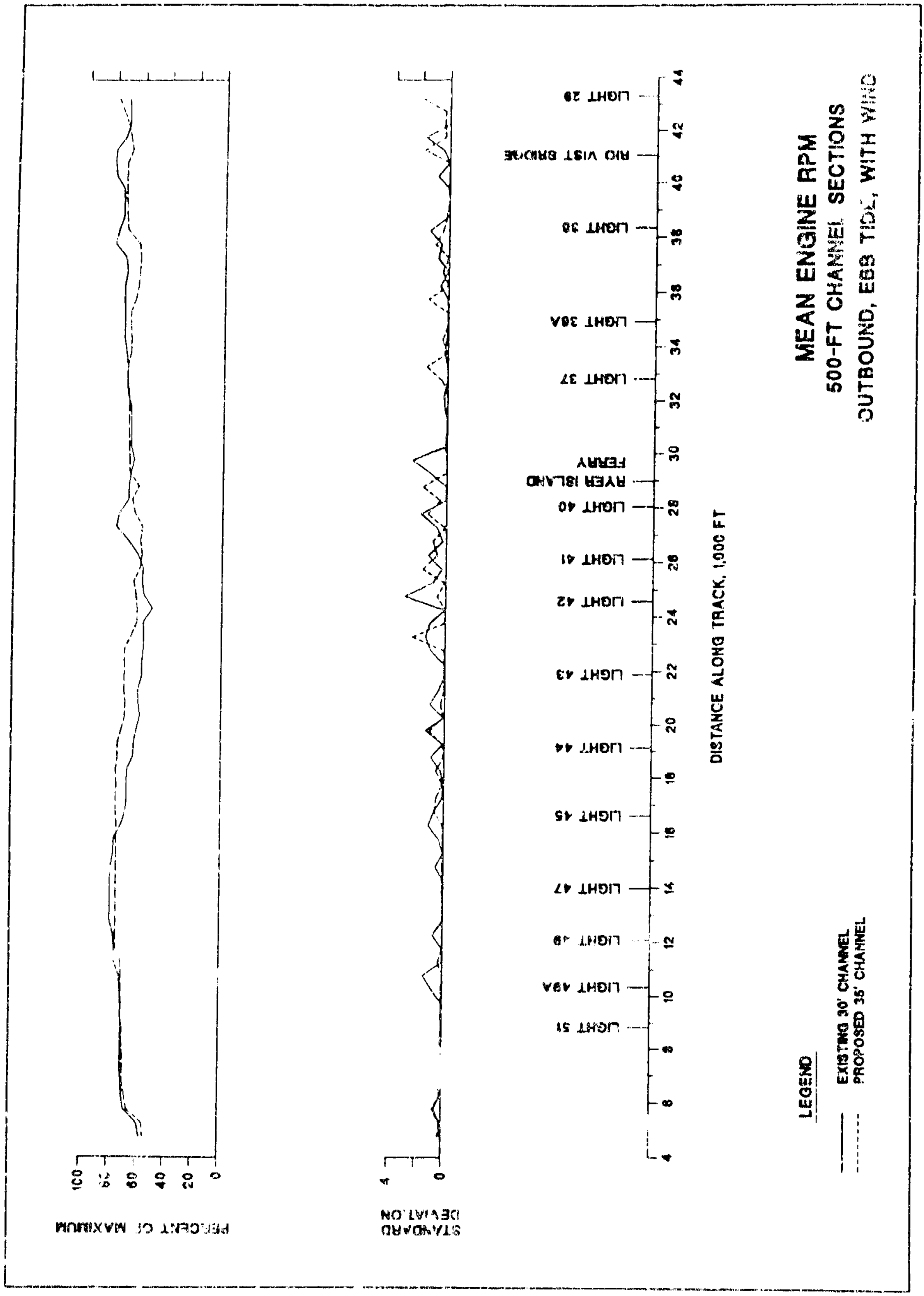
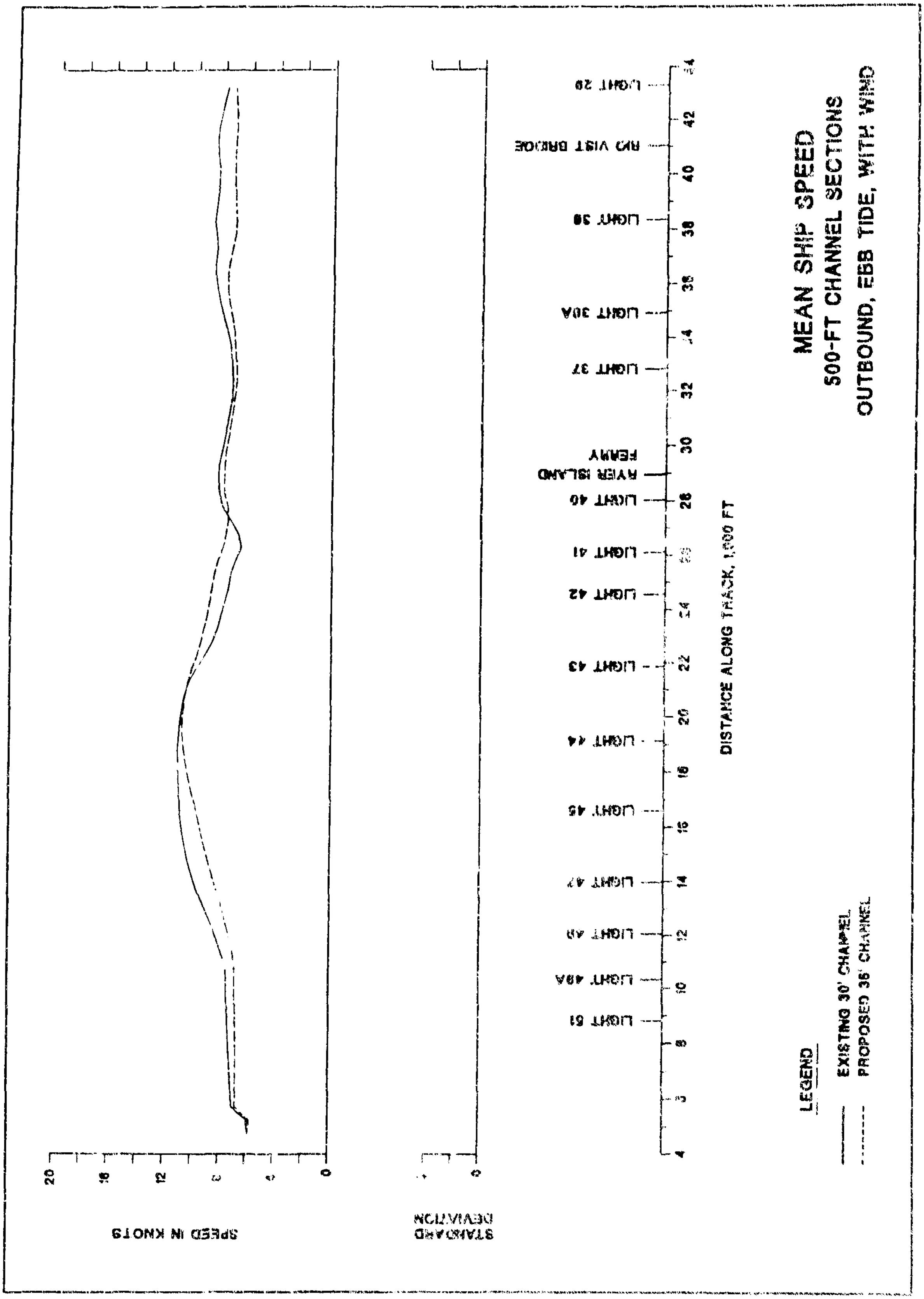
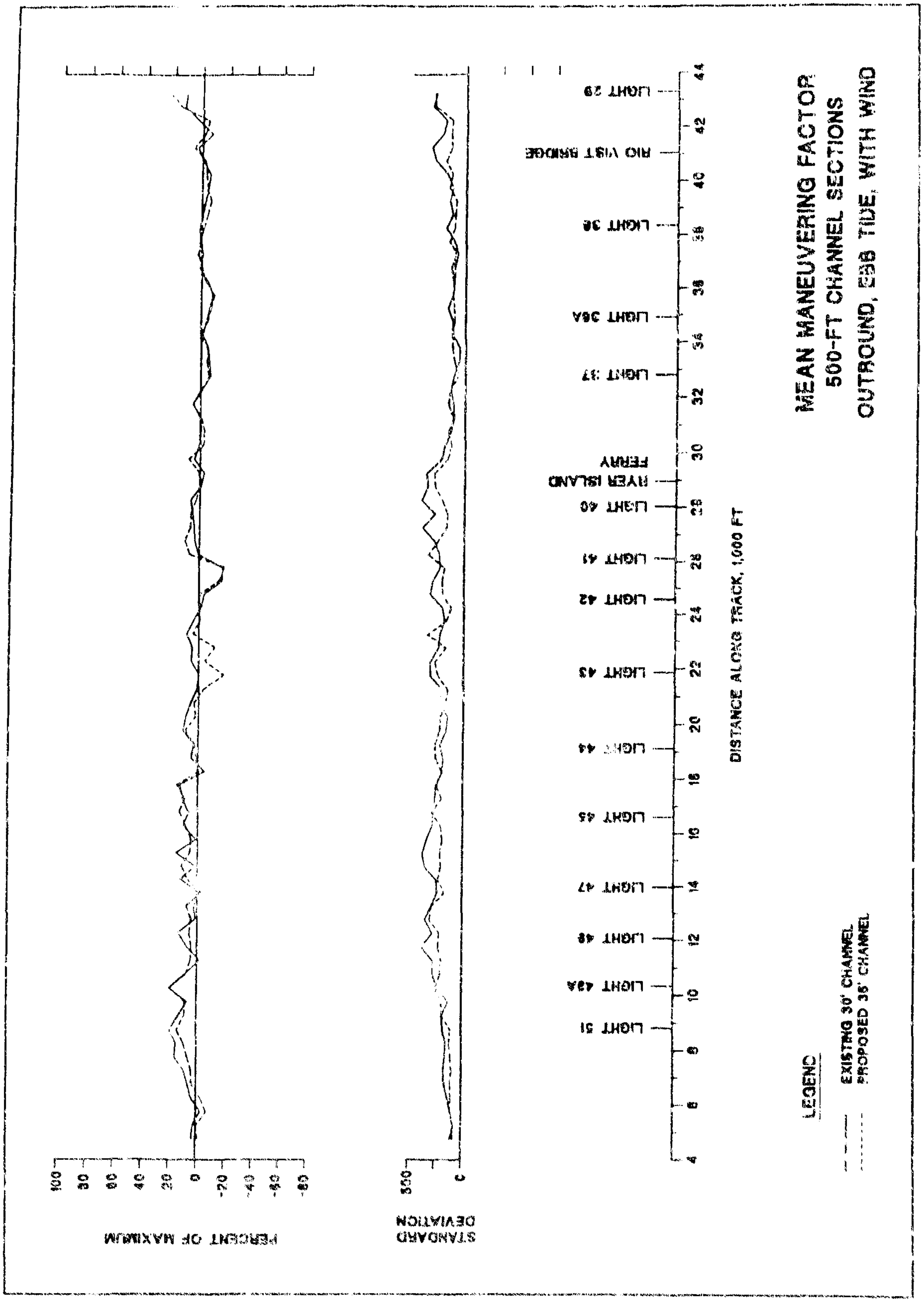
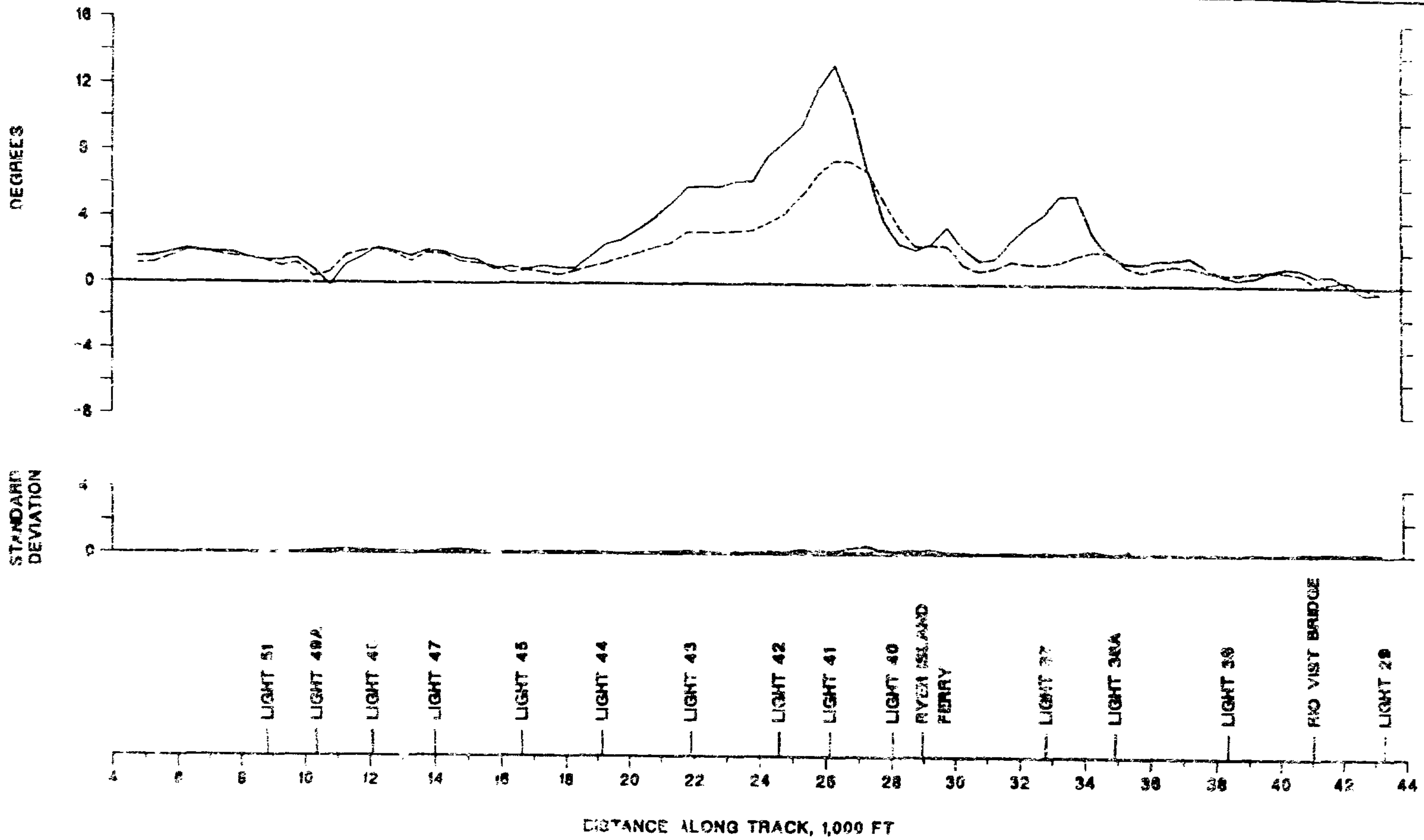

PERCENT OF MAXIMUM
100
80
60
40
20
0
-20
-40
-60
-80
-100
STANDARD DEVIATION
10
0
LIGHT 51
LIGHT 48A
LIGHT 48
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 34
RIO VIST BRIDGE
LIGHT 29
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
DISTANCE ALONG TRACK, 1,000 FT
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
MEAN RUDDER ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND

Plate 100


MEAN ENGINE RPM
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND
PERCENT OF MAXIMUM
100
75
60
40
20
0
STANDARD DEVIATION
4
0
DISTANCE ALONG TRACK, 1,000 FT
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
LIGHT 51
LIGHT 49A
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 38
LIGHT 29
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL


MEAN SHIP SPEED
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
SPEED IN KNOTS
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 29
RIO VISTA BRIDGE
LIGHT 30A
LIGHT 37
RYER ISLAND FERRY
LIGHT 40
LIGHT 41
LIGHT 42
LIGHT 43
LIGHT 44
LIGHT 45
LIGHT 47
LIGHT 48
LIGHT 49A
LIGHT 51

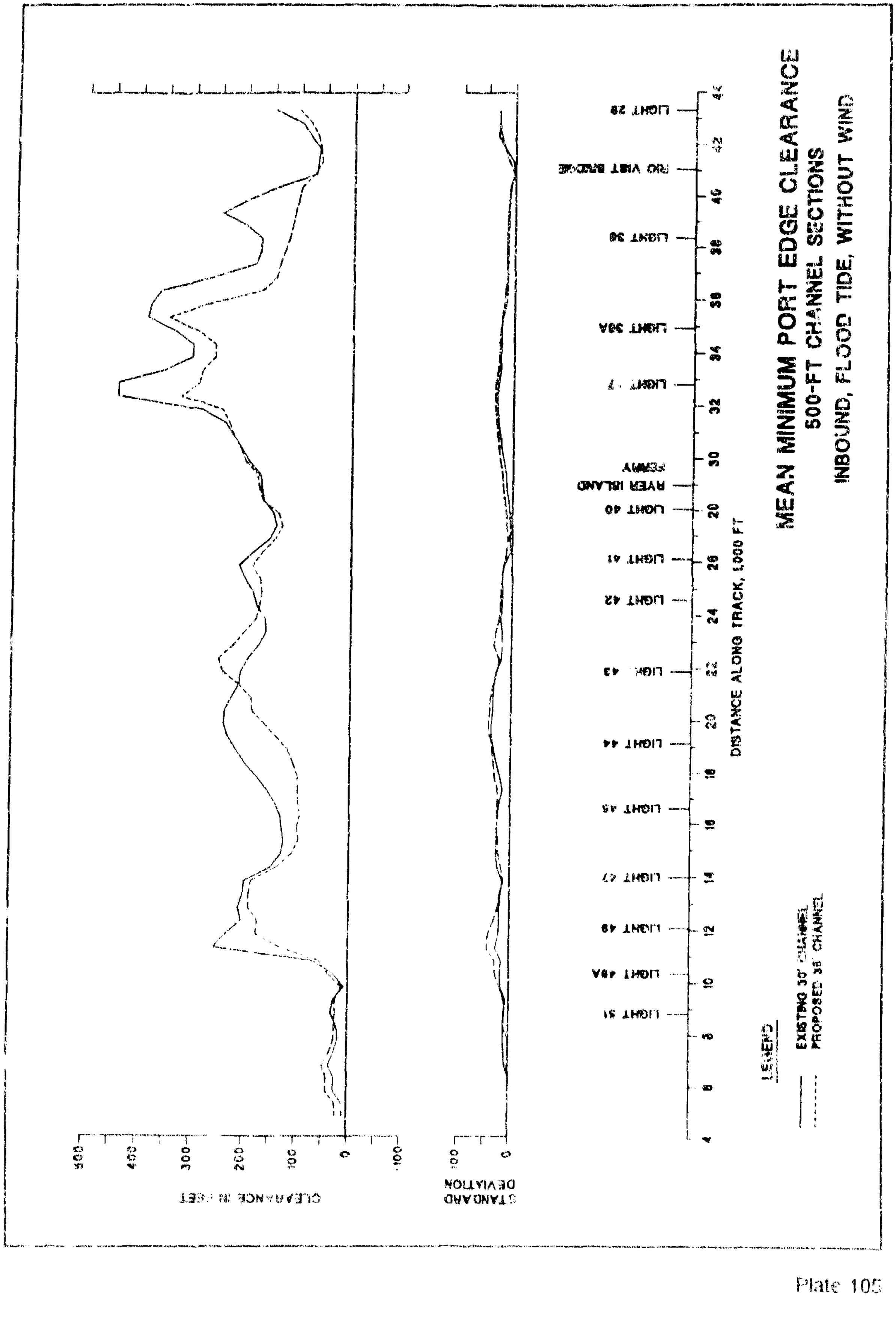

MEAN MANEUVERING FACTOR
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND
PERCENT OF MAXIMUM
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 29
RIO VISTA BRIDGE
LIGHT 36
LIGHT 36A
LIGHT 37
RYER ISLAND
FERRY
LIGHT 40
LIGHT 41
LIGHT 42
LIGHT 43
LIGHT 44
LIGHT 45
LIGHT 47
LIGHT 48
LIGHT 48A
LIGHT 51
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

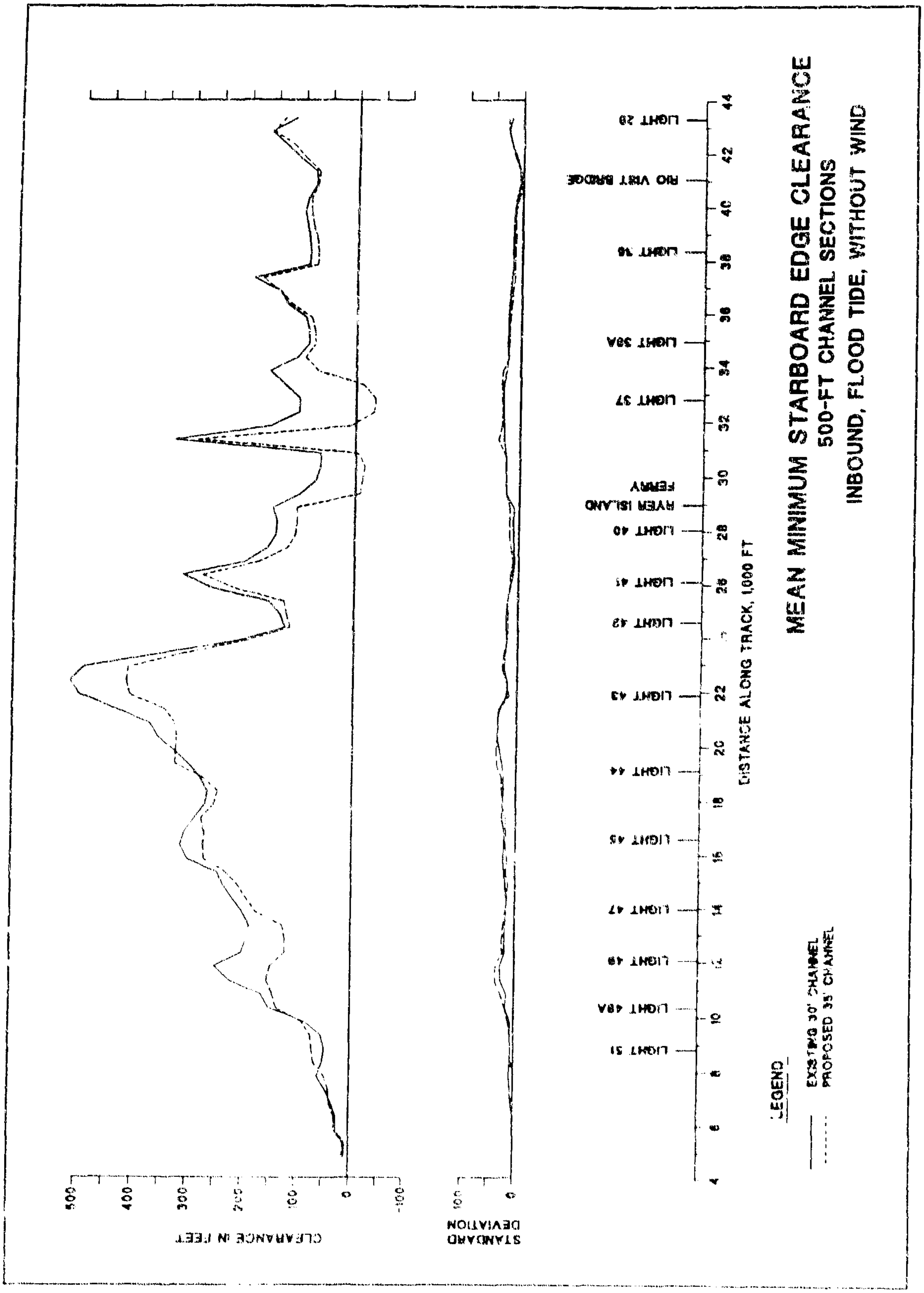


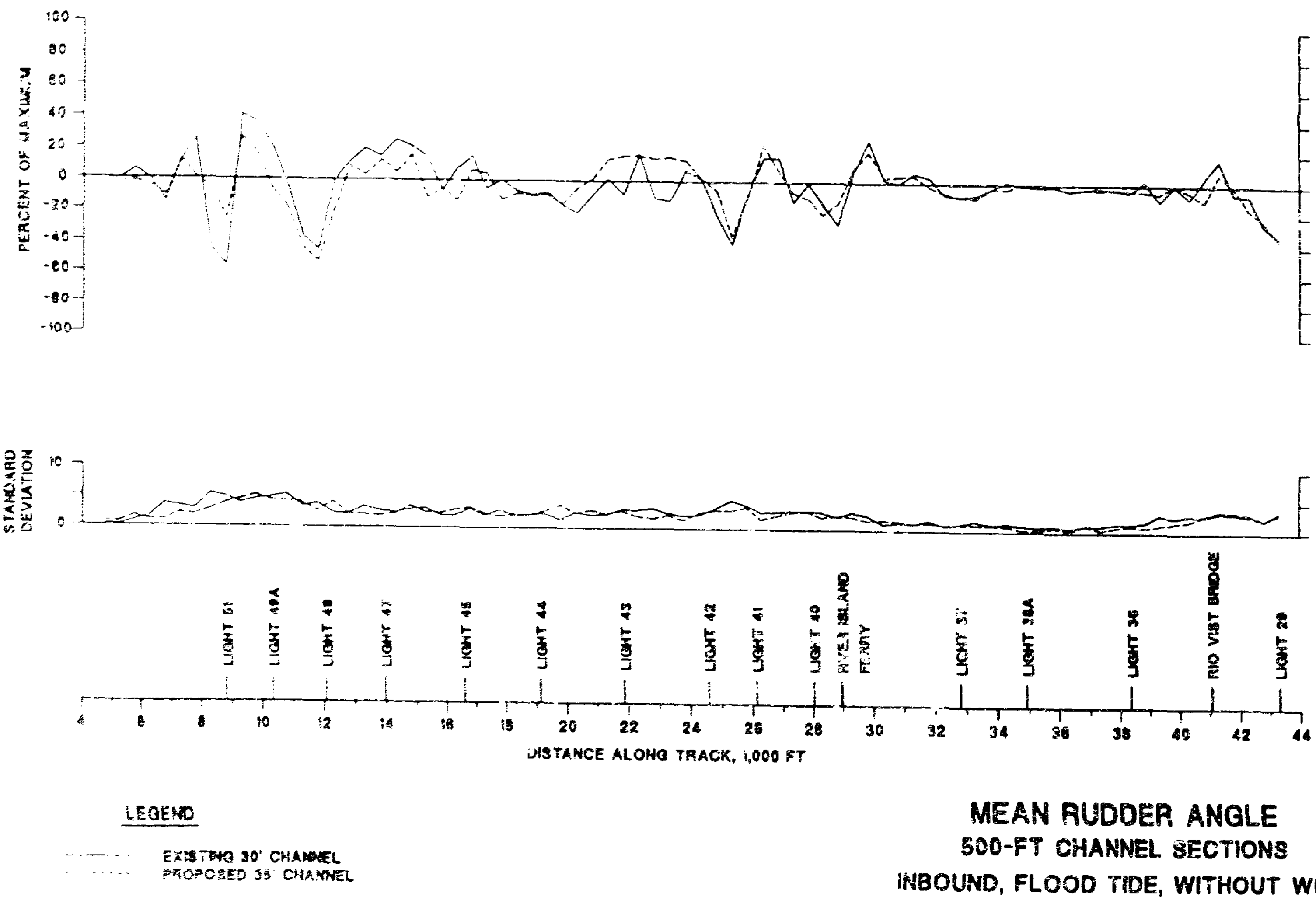
LEGEND

—— EXISTING 30' CHANNEL
- - - PROPOSED 35' CHANNEL

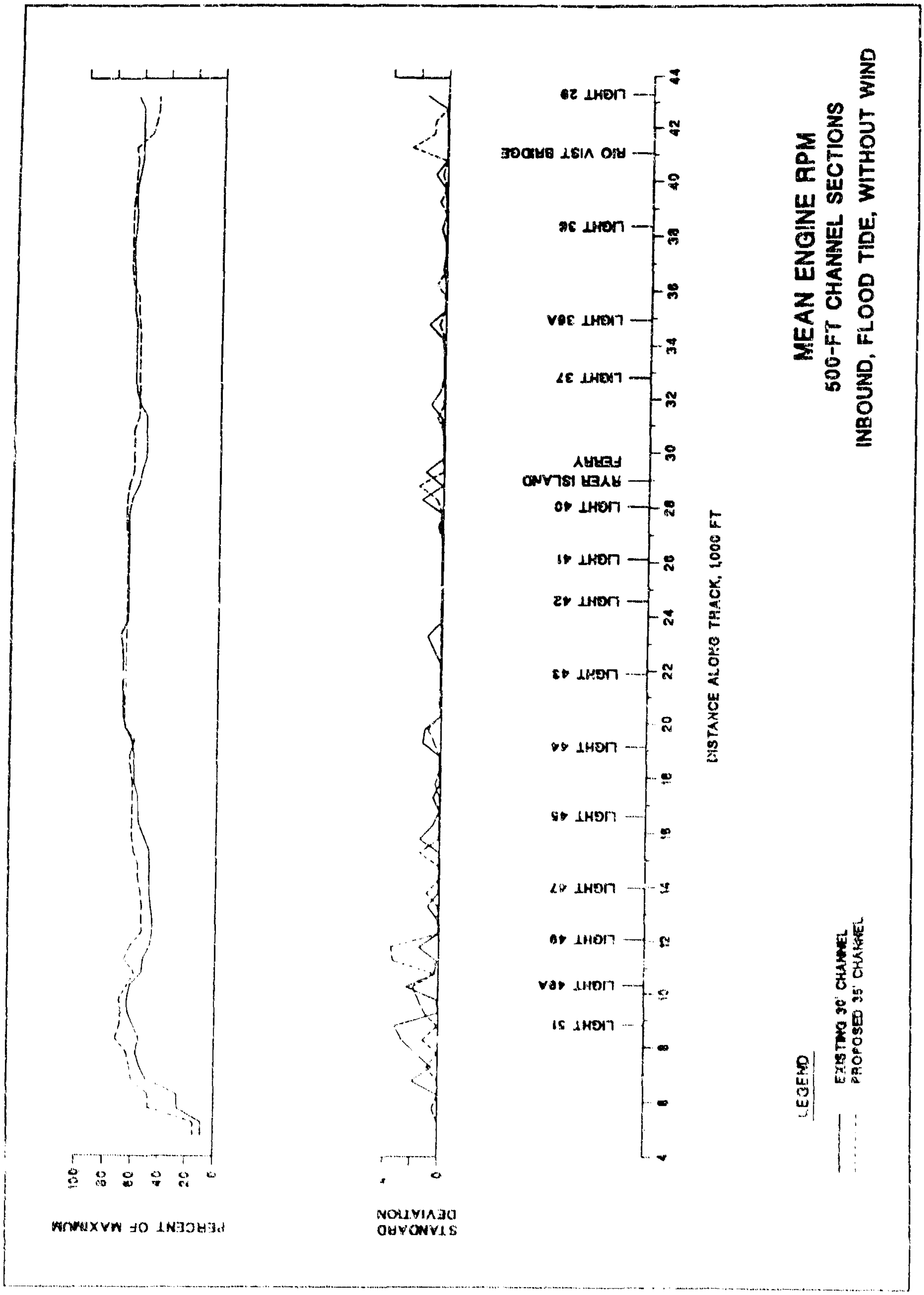
MEAN DRIFT ANGLE
500-FT CHANNEL SECTIONS
OUTBOUND, EBB TIDE, WITH WIND

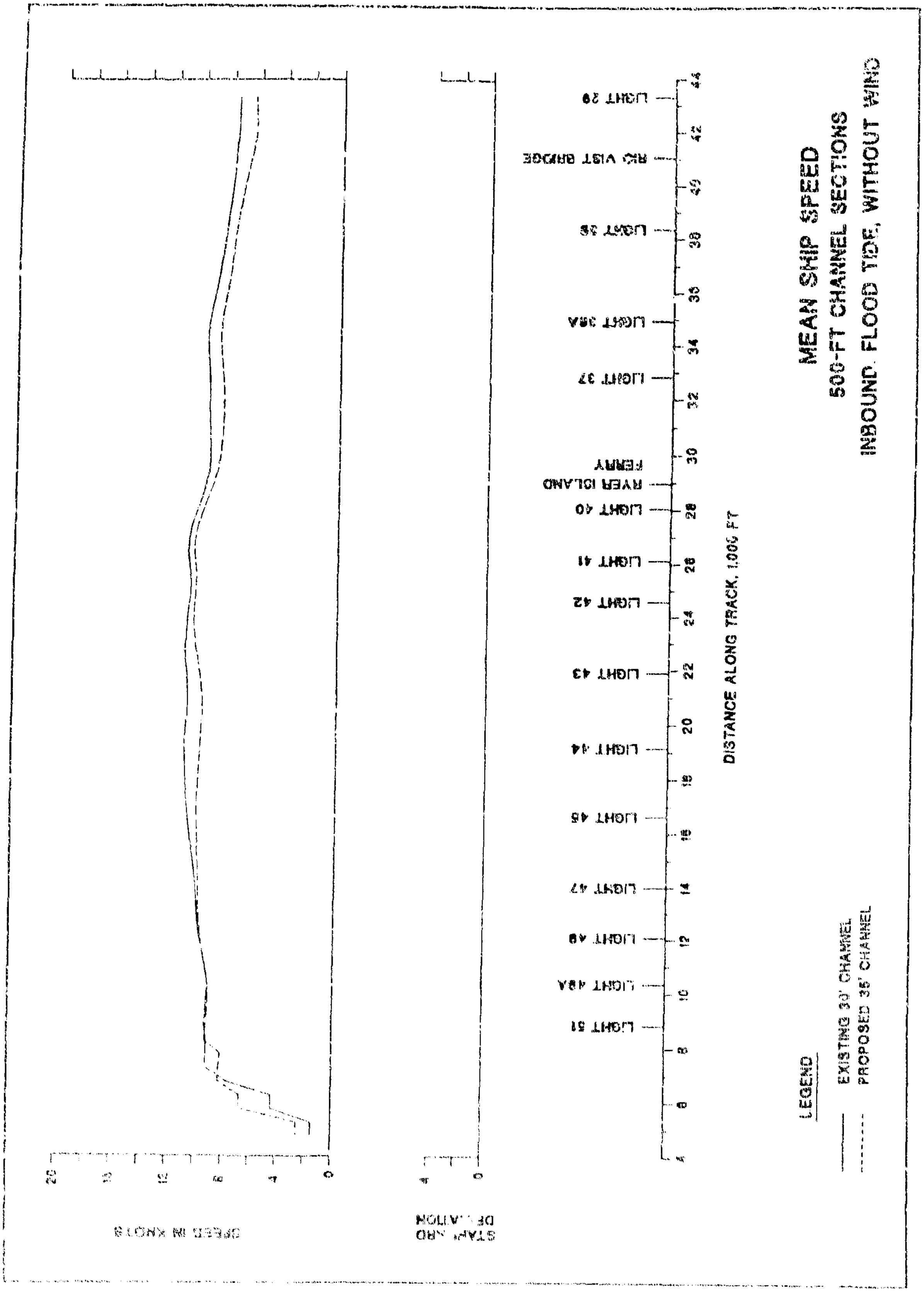

MEAN MINIMUM PORT EDGE CLEARANCE
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 51
LIGHT 49A
LIGHT 48
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 38A
LIGHT 36
RIO VISTA BRIDGE
LIGHT 28
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

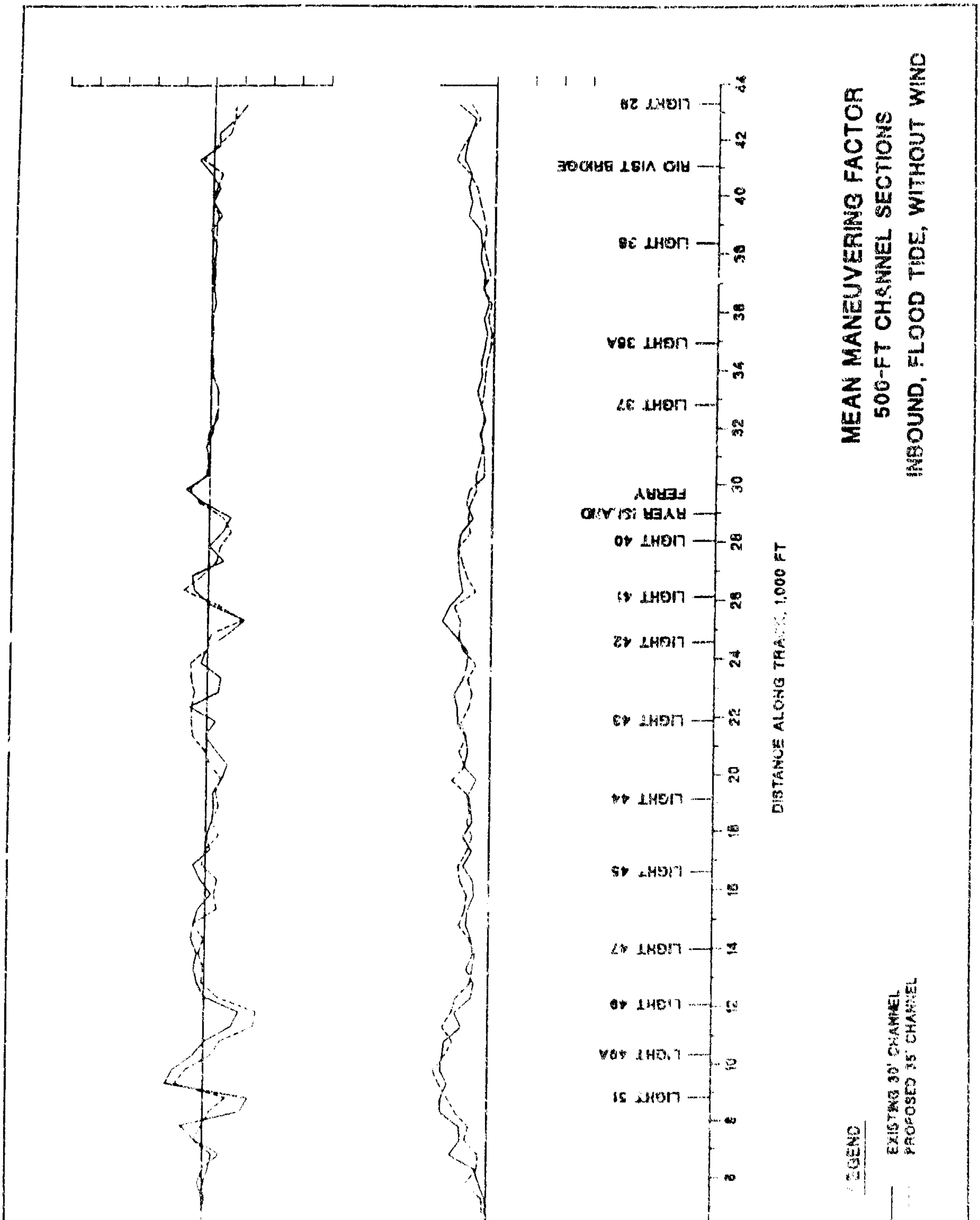

MEAN MINIMUM STARBOARD EDGE CLEARANCE
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
CLEARANCE IN FEET
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 51
LIGHT 49A
LIGHT 49
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 16
RIO VISTA BRIDGE
LIGHT 20
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

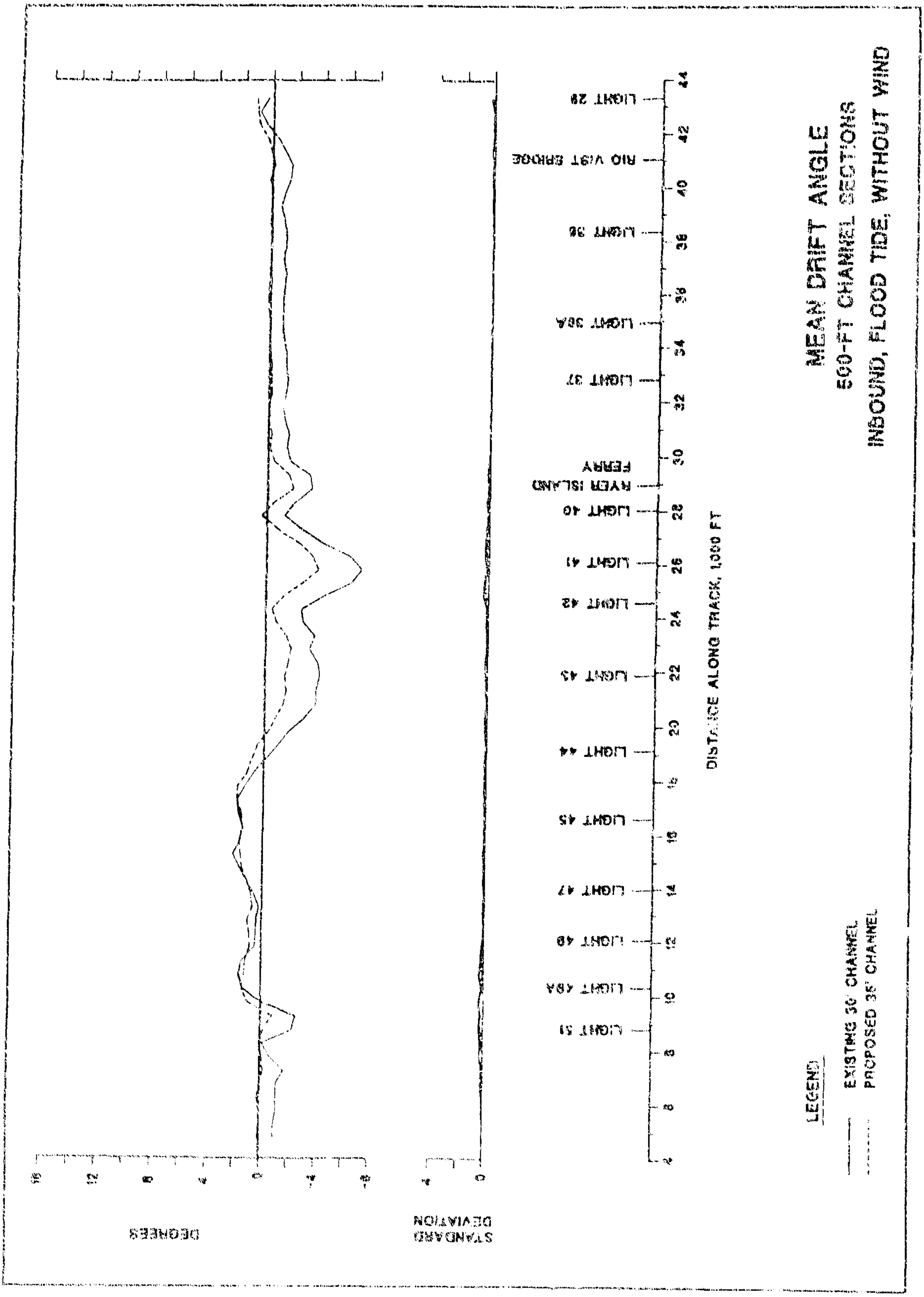


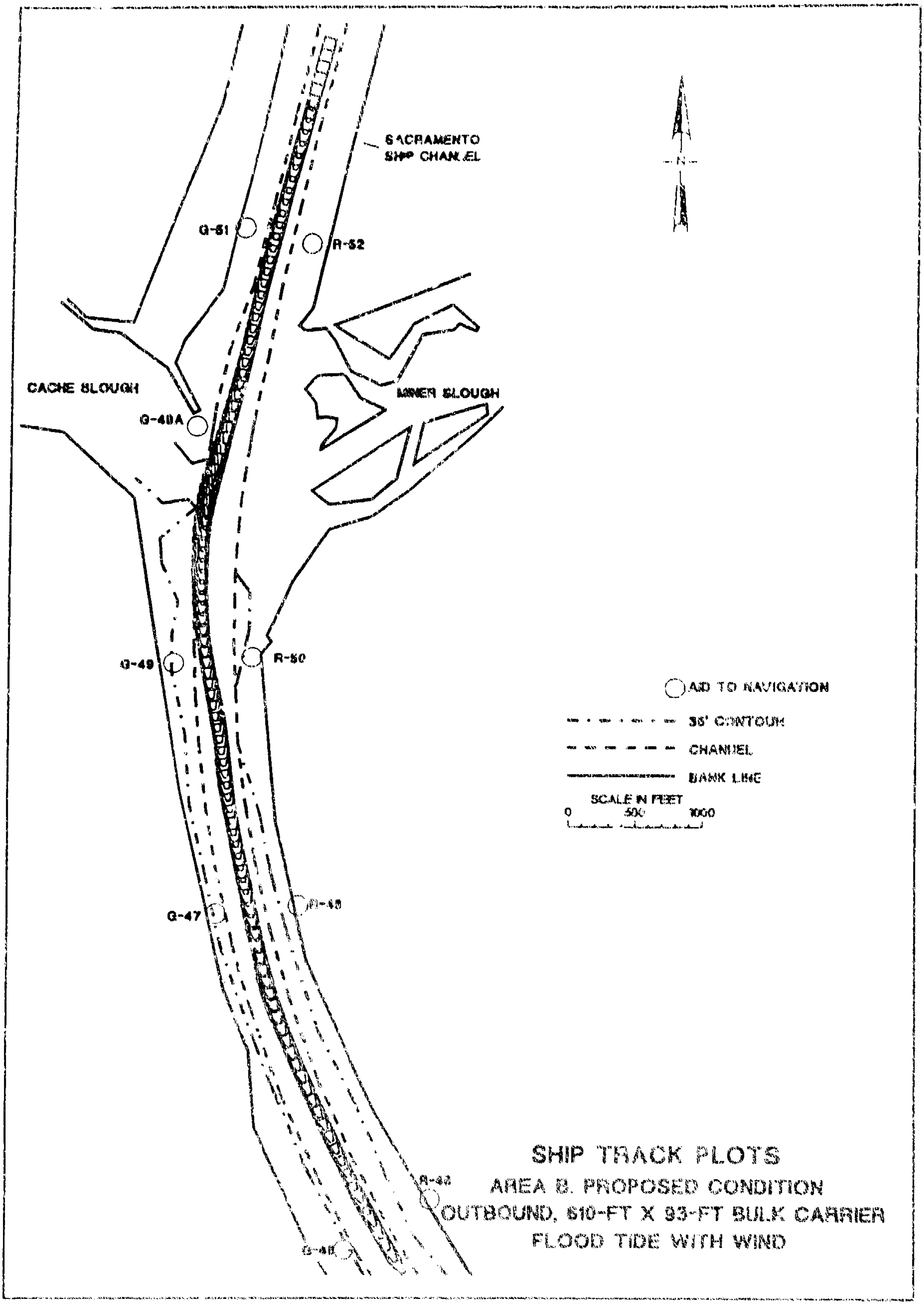
MEAN RUDDER ANGLE
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND


MEAN ENGINE RPM
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
PERCENT OF MAXIMUM
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 51
LIGHT 49A
LIGHT 49
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 36
RIO VIST BRIDGE
LIGHT 29
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL

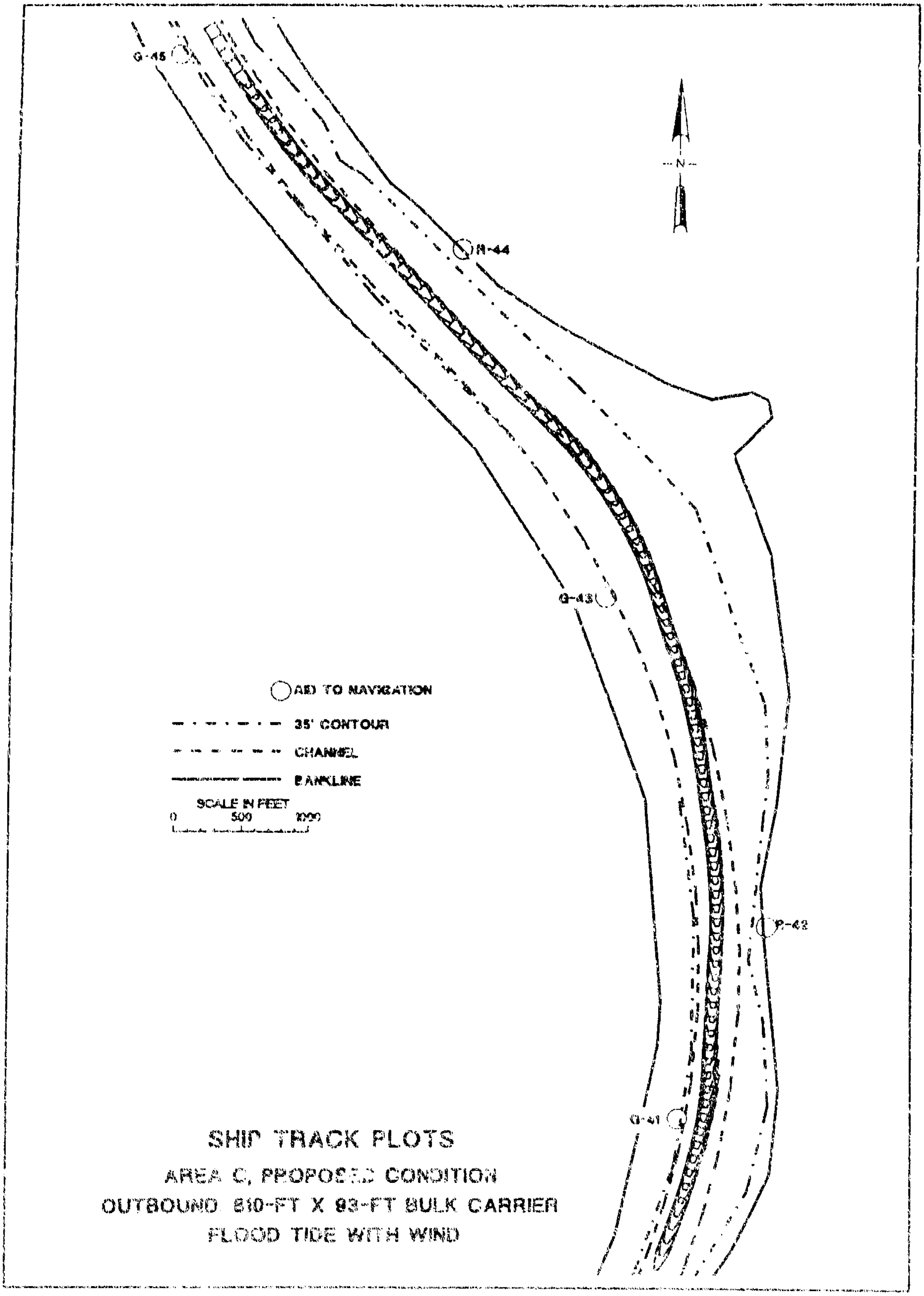

MEAN SHIP SPEED
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
SPEED IN KNOTS
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 39
RIO VISTA BRIDGE
LIGHT 38
LIGHT 38A
LIGHT 37
RYER ISLAND
FERRY
LIGHT 40
LIGHT 41
LIGHT 42
LIGHT 43
LIGHT 44
LIGHT 45
LIGHT 47
LIGHT 48
LIGHT 48A
LIGHT 51
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL


MEAN MANEUVERING FACTOR
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
PERCENT OF MAXIMUM
STANDARD DEVIATION
DISTANCE ALONG TRACK, 1,000 FT
LIGHT 28
RIO VIST BRIDGE
LIGHT 38
LIGHT 36A
LIGHT 37
RYER ISLAND FERRY
LIGHT 40
LIGHT 41
LIGHT 42
LIGHT 43
LIGHT 44
LIGHT 45
LIGHT 47
LIGHT 49
LIGHT 49A
LIGHT 51
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL


MEAN DRIFT ANGLE
500-FT CHANNEL SECTIONS
INBOUND, FLOOD TIDE, WITHOUT WIND
LEGEND
EXISTING 30' CHANNEL
PROPOSED 35' CHANNEL
DISTANCE ALONG TRACK, 1,000 FT
DEGREES
STANDARD DEVIATION
LIGHT 51
LIGHT 49A
LIGHT 49
LIGHT 47
LIGHT 45
LIGHT 44
LIGHT 43
LIGHT 42
LIGHT 41
LIGHT 40
RYER ISLAND FERRY
LIGHT 37
LIGHT 36A
LIGHT 36
RIO VISTA BRIDGE
LIGHT 29



SHIP TRACK PLOTS
AREA B. PROPOSED CONDITION
OUTBOUND, 610-FT X 83-FT BULK CARRIER
FLOOD TIDE WITH WIND

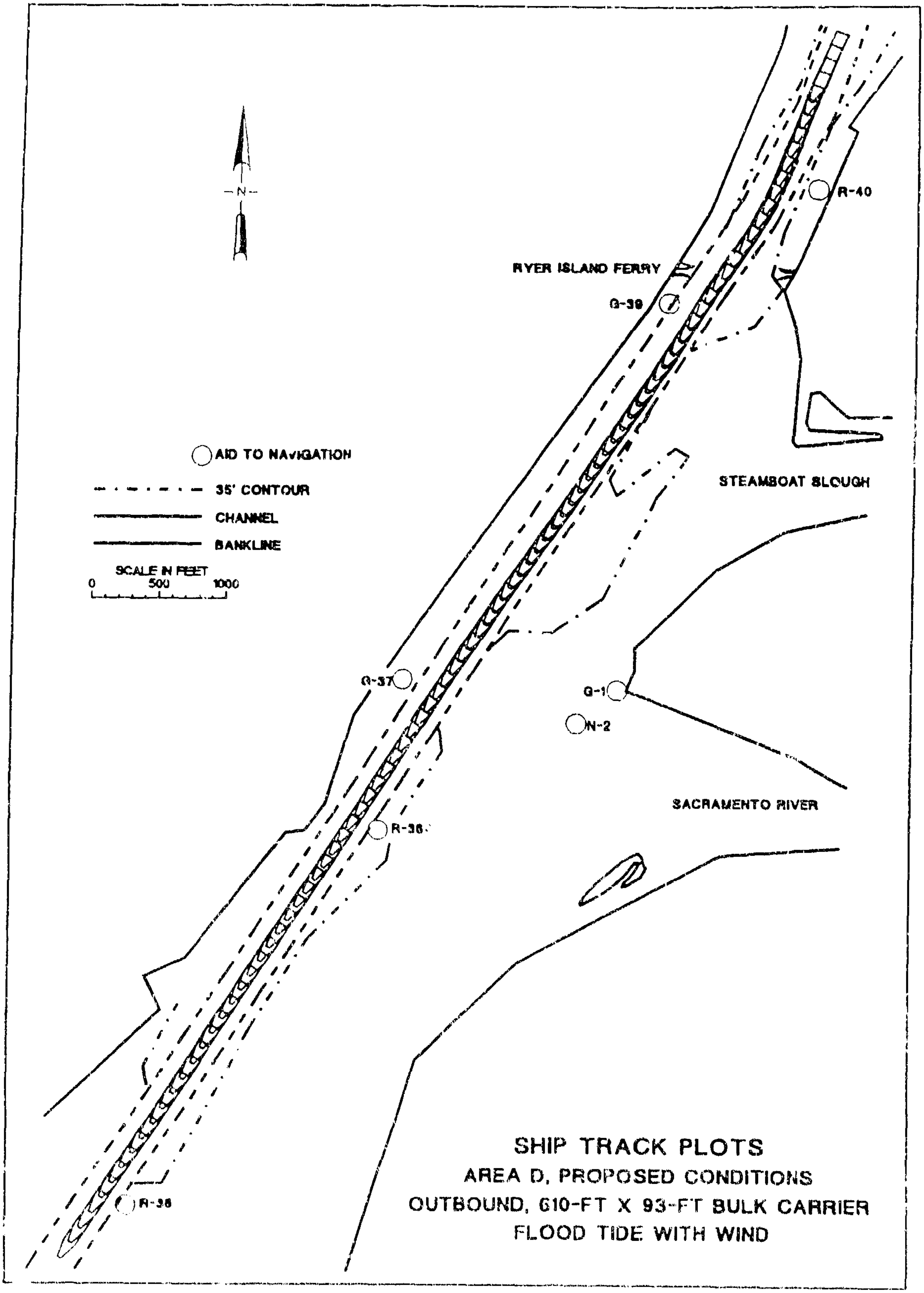


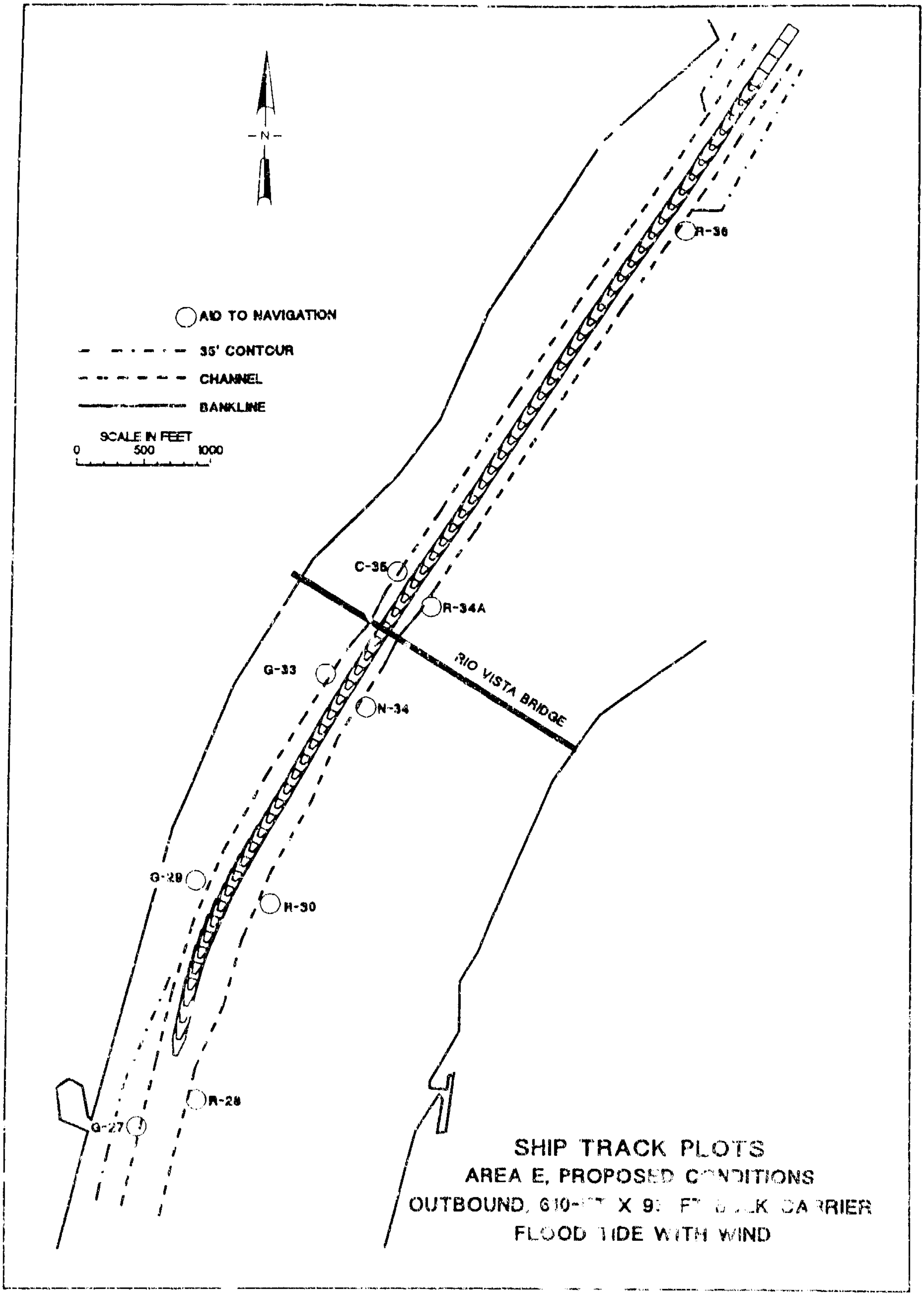
SHIP TRACK PLOTS

AREA C, PROPOSED CONDITION

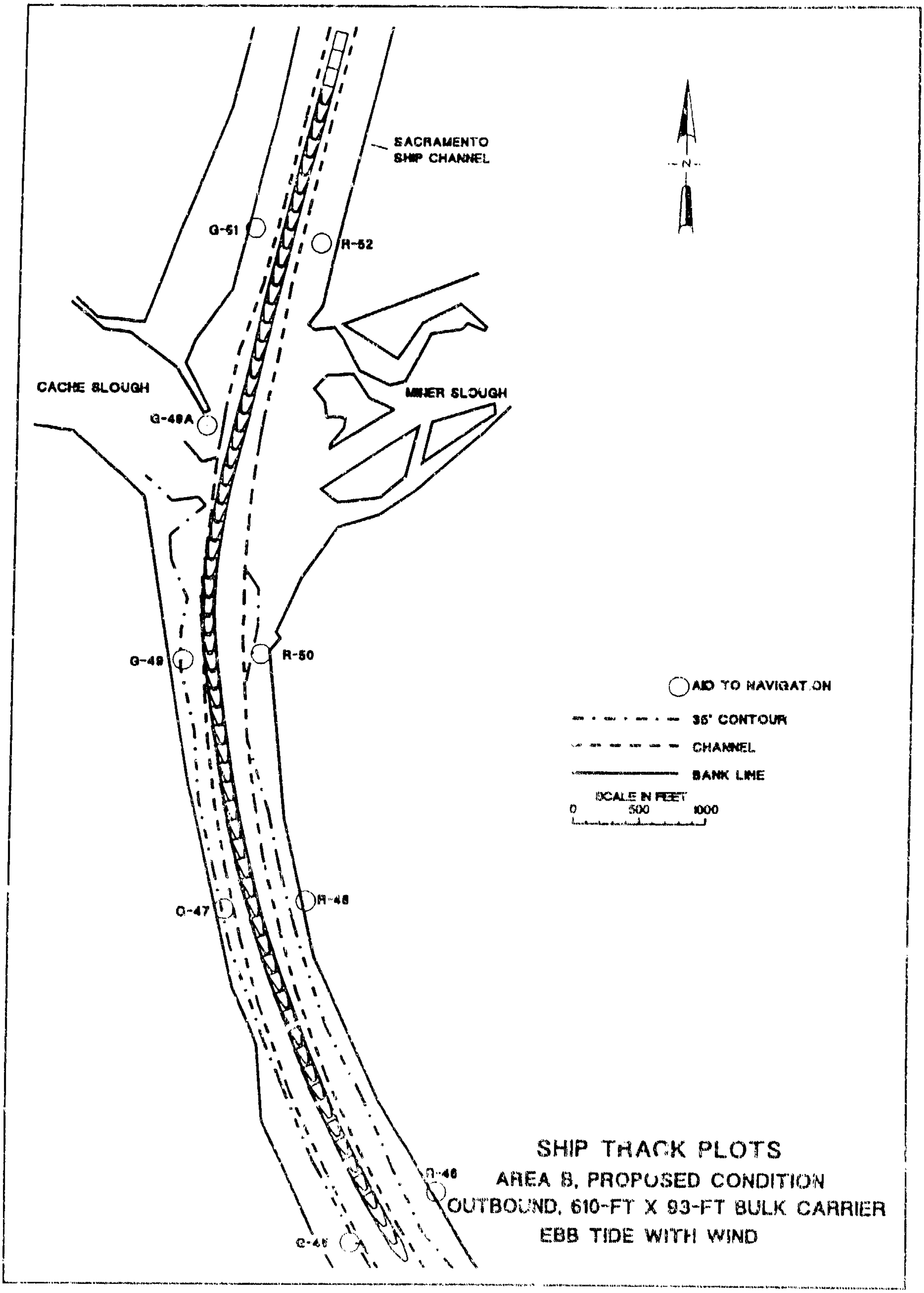
OUTBOUND 810-FT X 93-FT BULK CARRIER

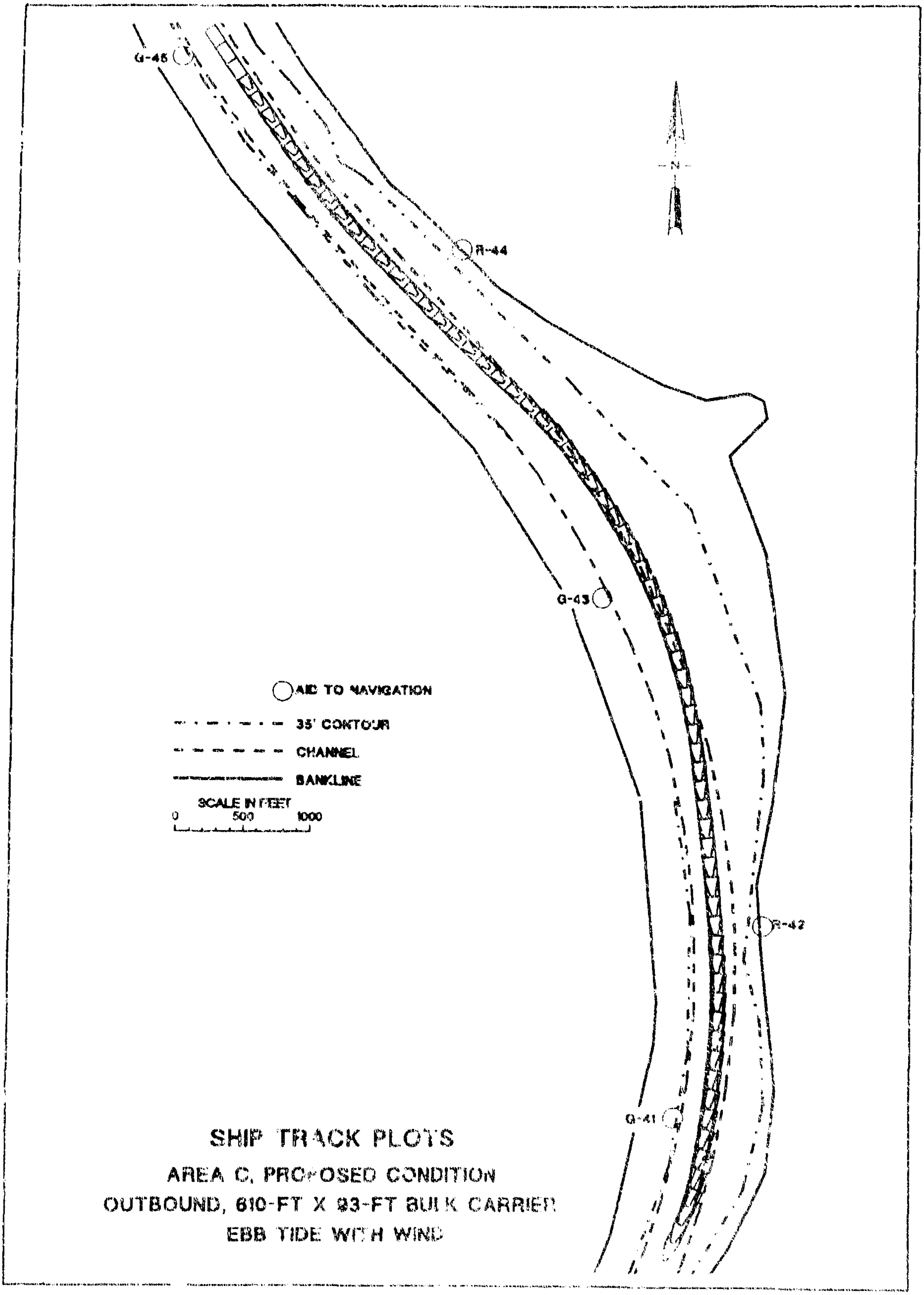
FLOOD TIDE WITH WIND


-N-
RYER ISLAND FERRY
G-39
R-40
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
STEAMBOAT SLOUGH
G-37
G-1
N-2
SACRAMENTO RIVER
R-36
R-38
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 9[illegible]-FT BULK CARRIER
FLOOD TIDE WITH WIND


SACRAMENTO SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
G-49
R-50
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0
500
1000
G-47
R-48
R-46
G-45
SHIP TRACK PLOTS
AREA 8, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

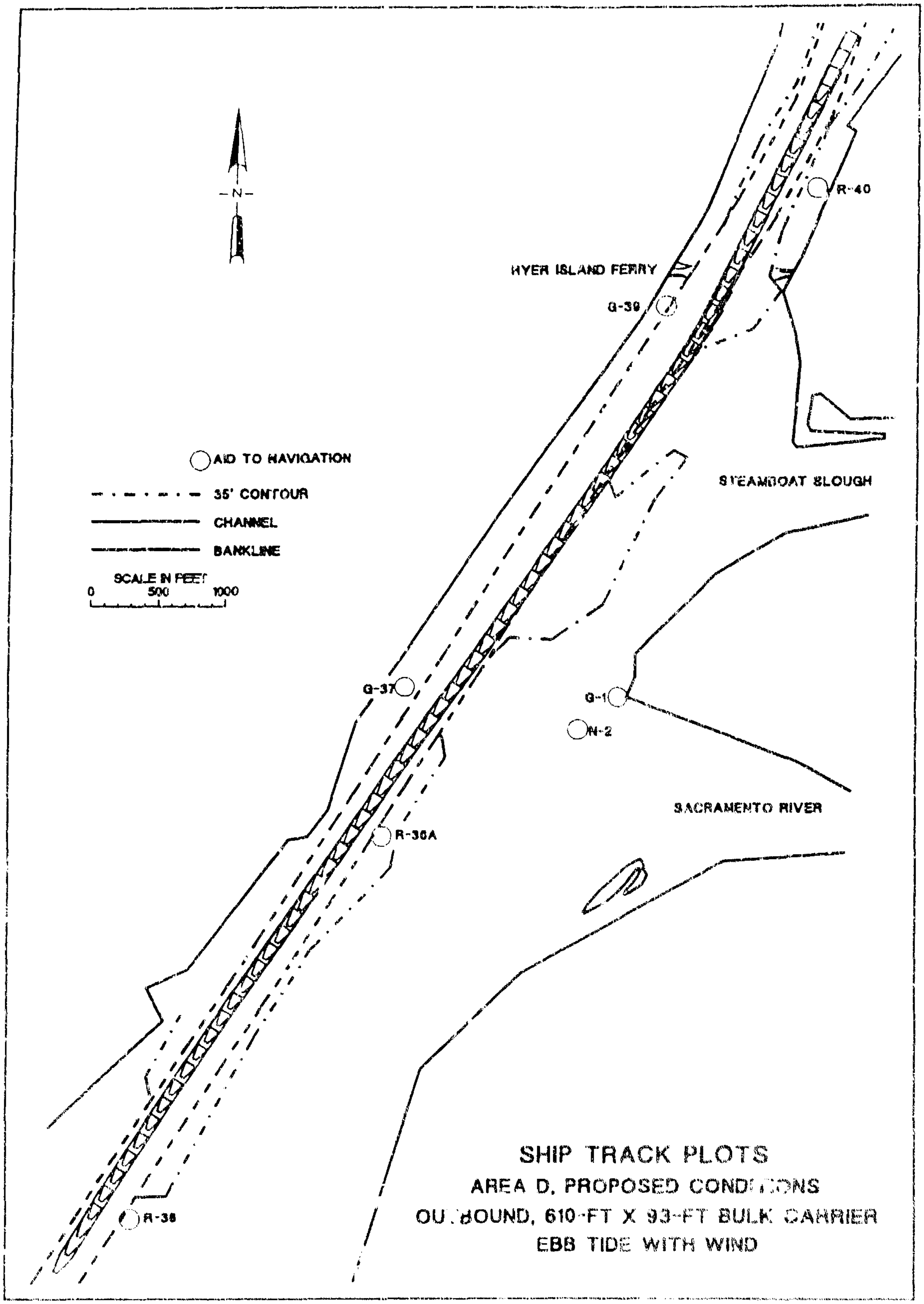


SHIP TRACK PLOTS

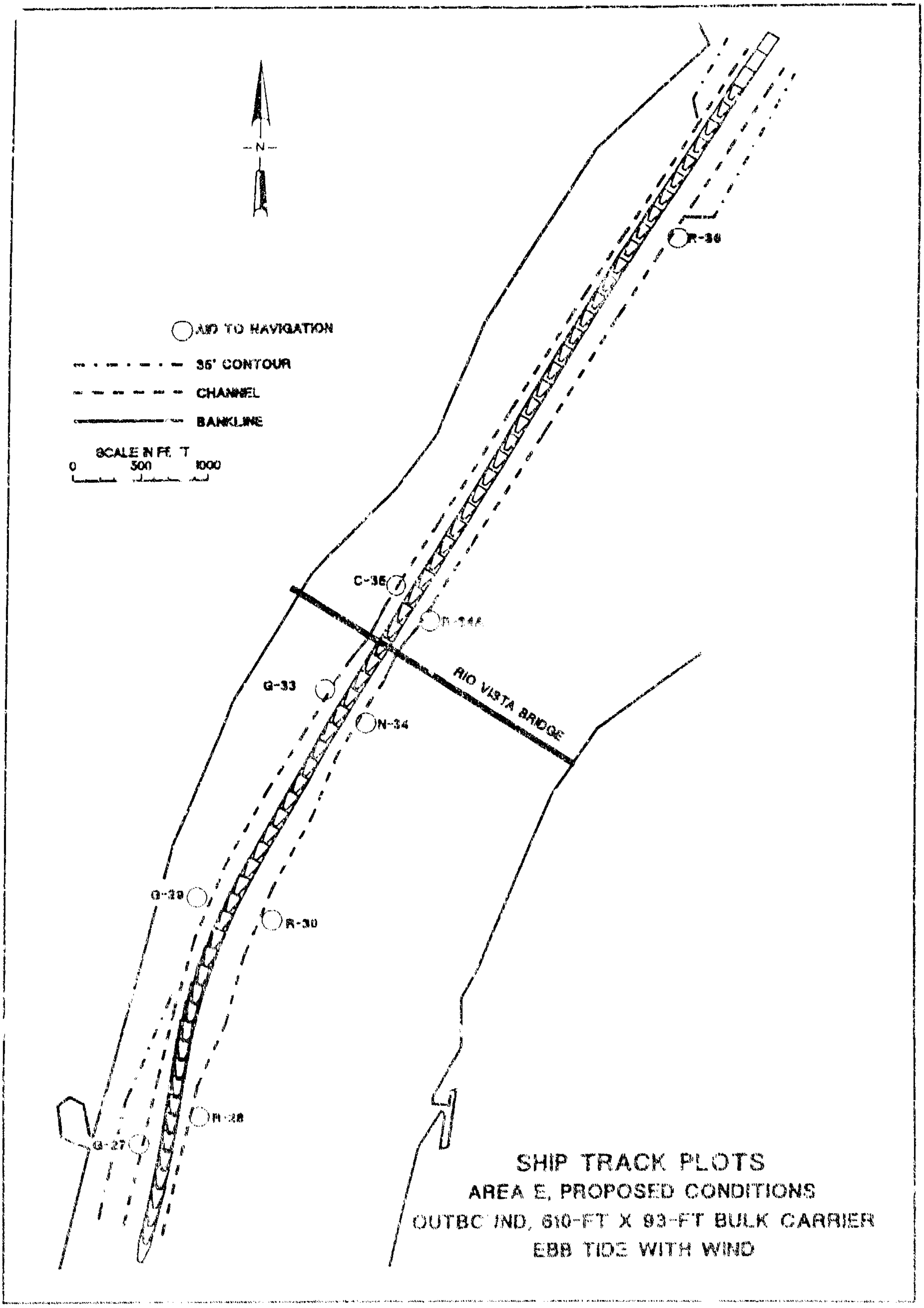
AREA C, PROPOSED CONDITION

OUTBOUND, 610-FT X 93-FT BULK CARRIER

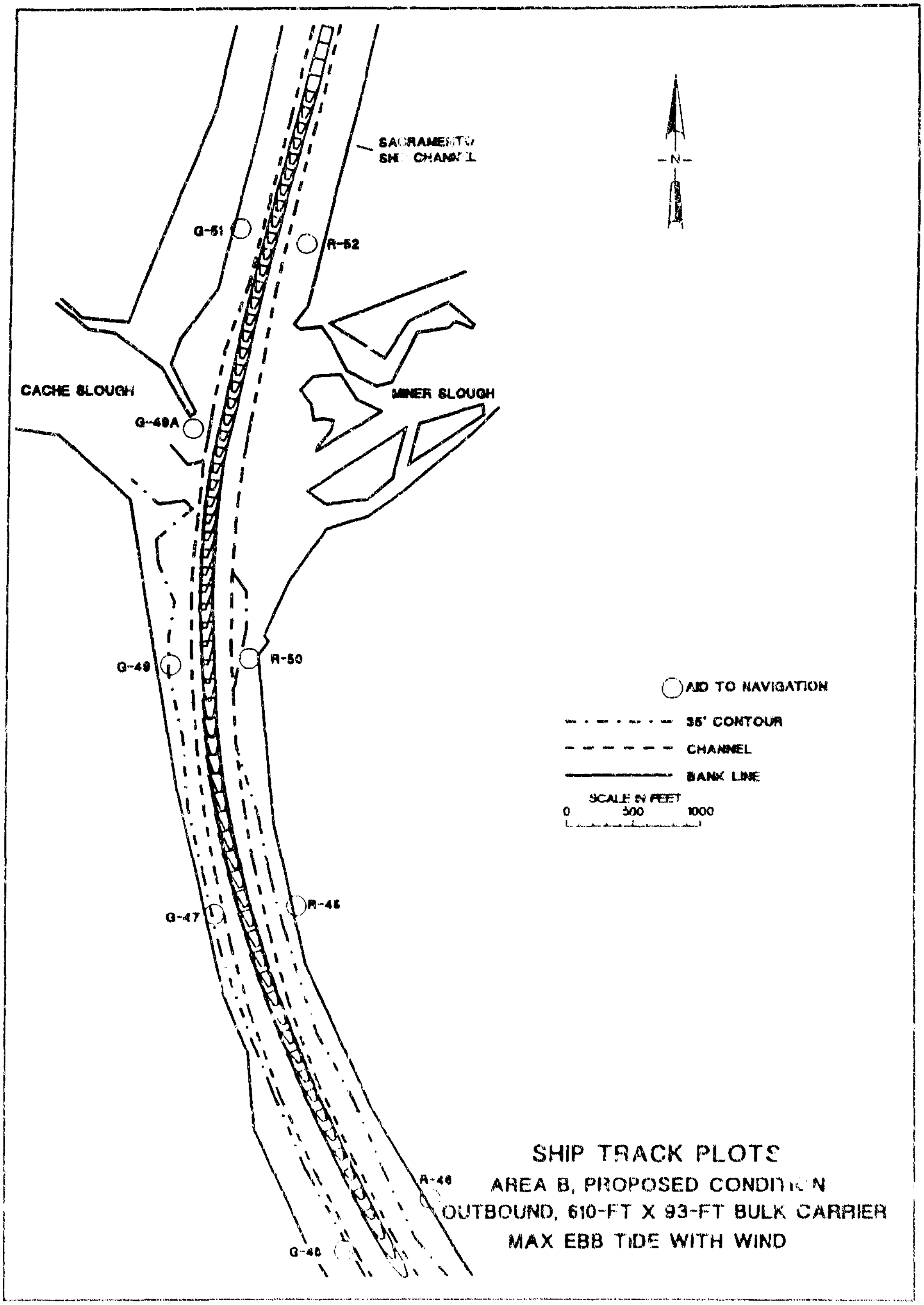
EBB TIDE WITH WIND



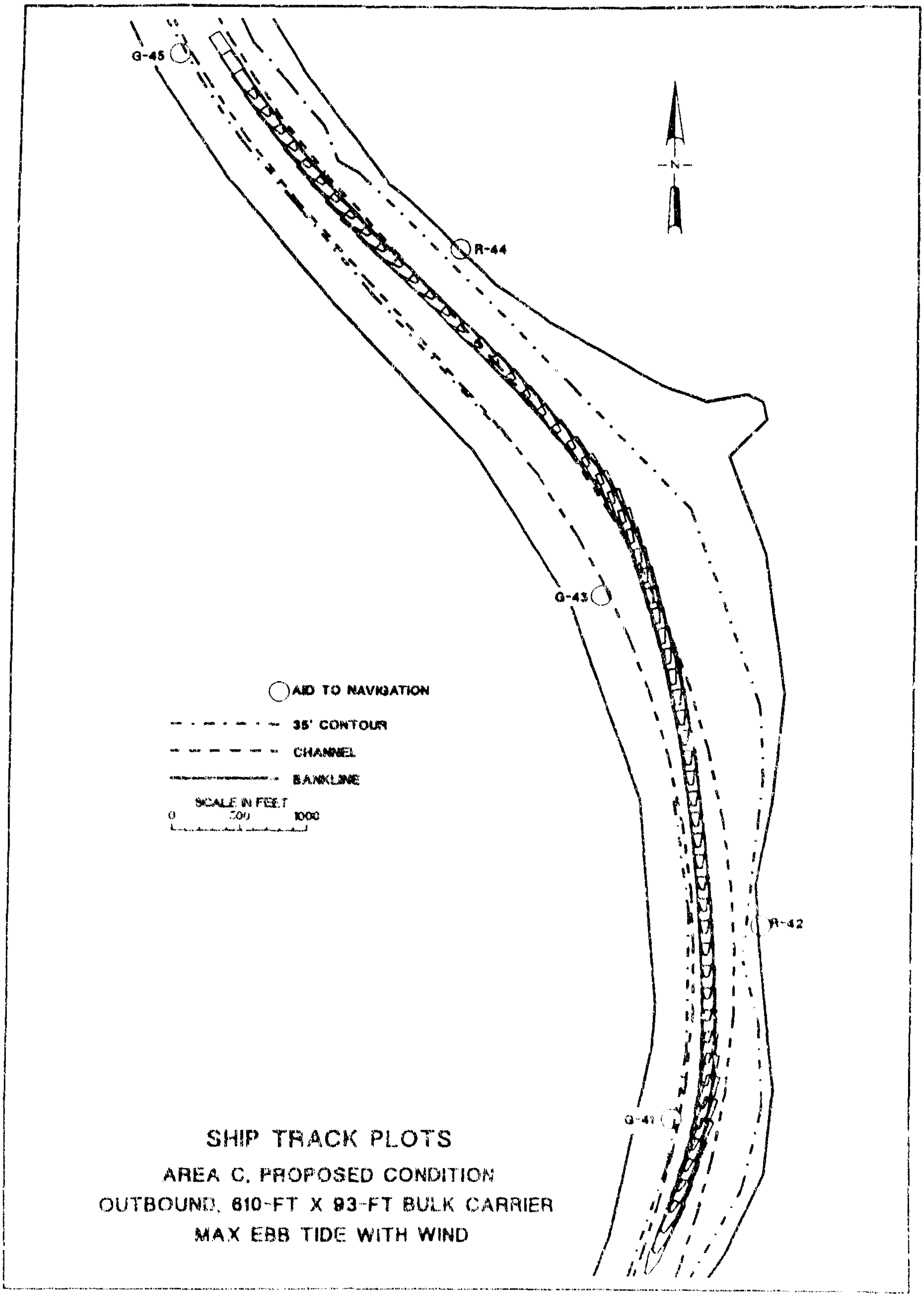
N
HYER ISLAND FERRY
G-39
R-40
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
STEAMBOAT SLOUGH
G-37
G-1
N-2
SACRAMENTO RIVER
R-36A
R-36
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND



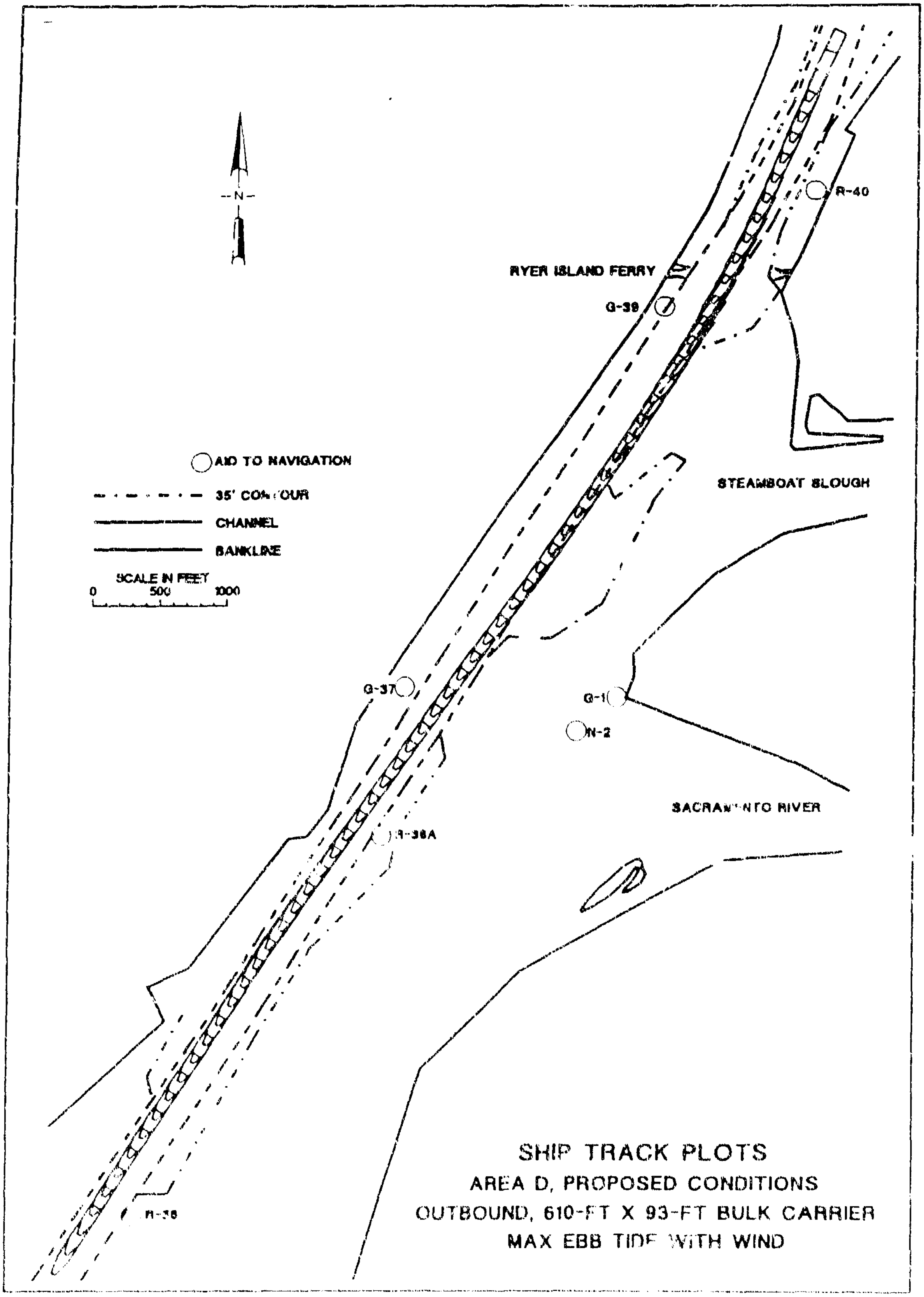
SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
OUTBC'IND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND



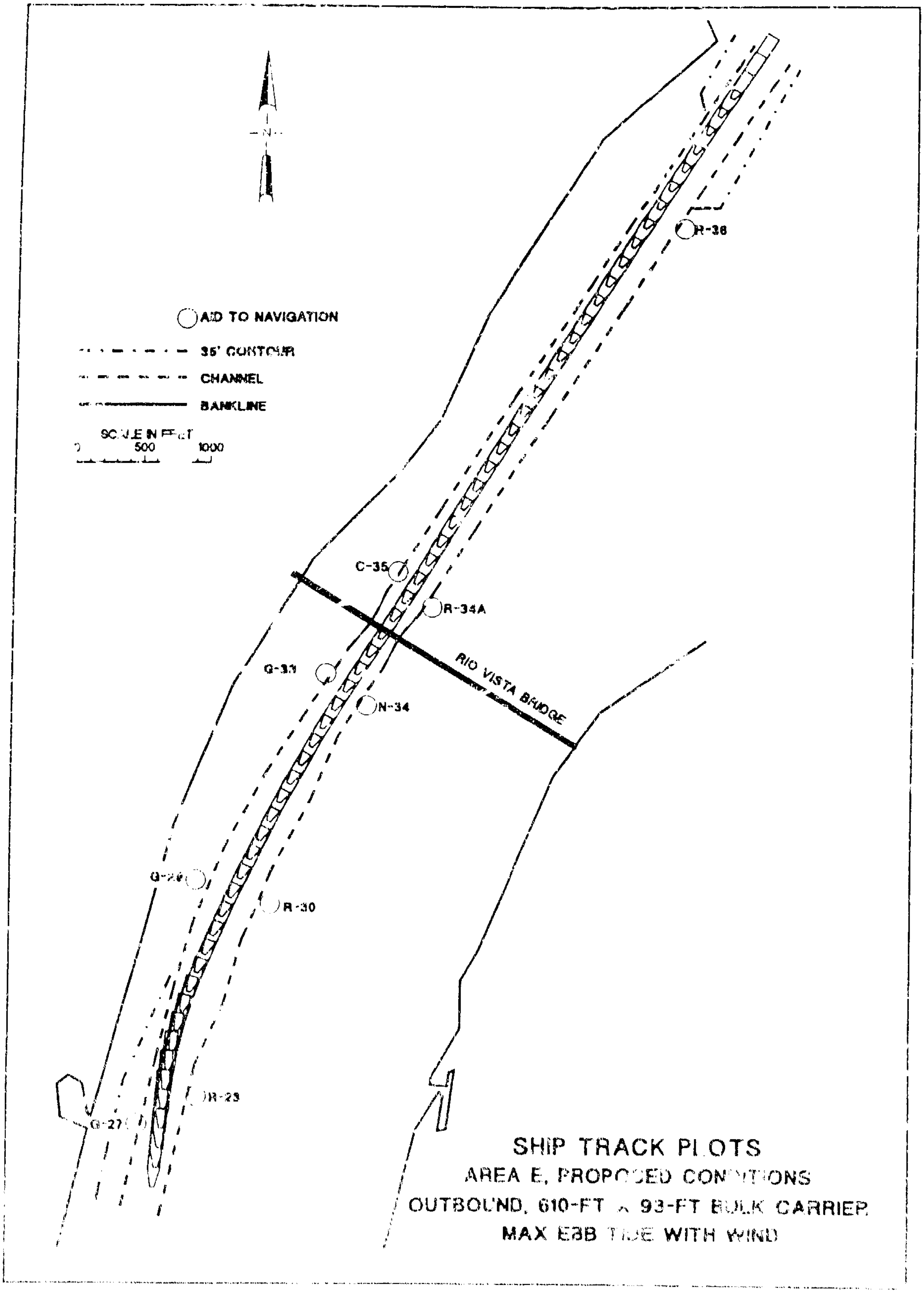
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND

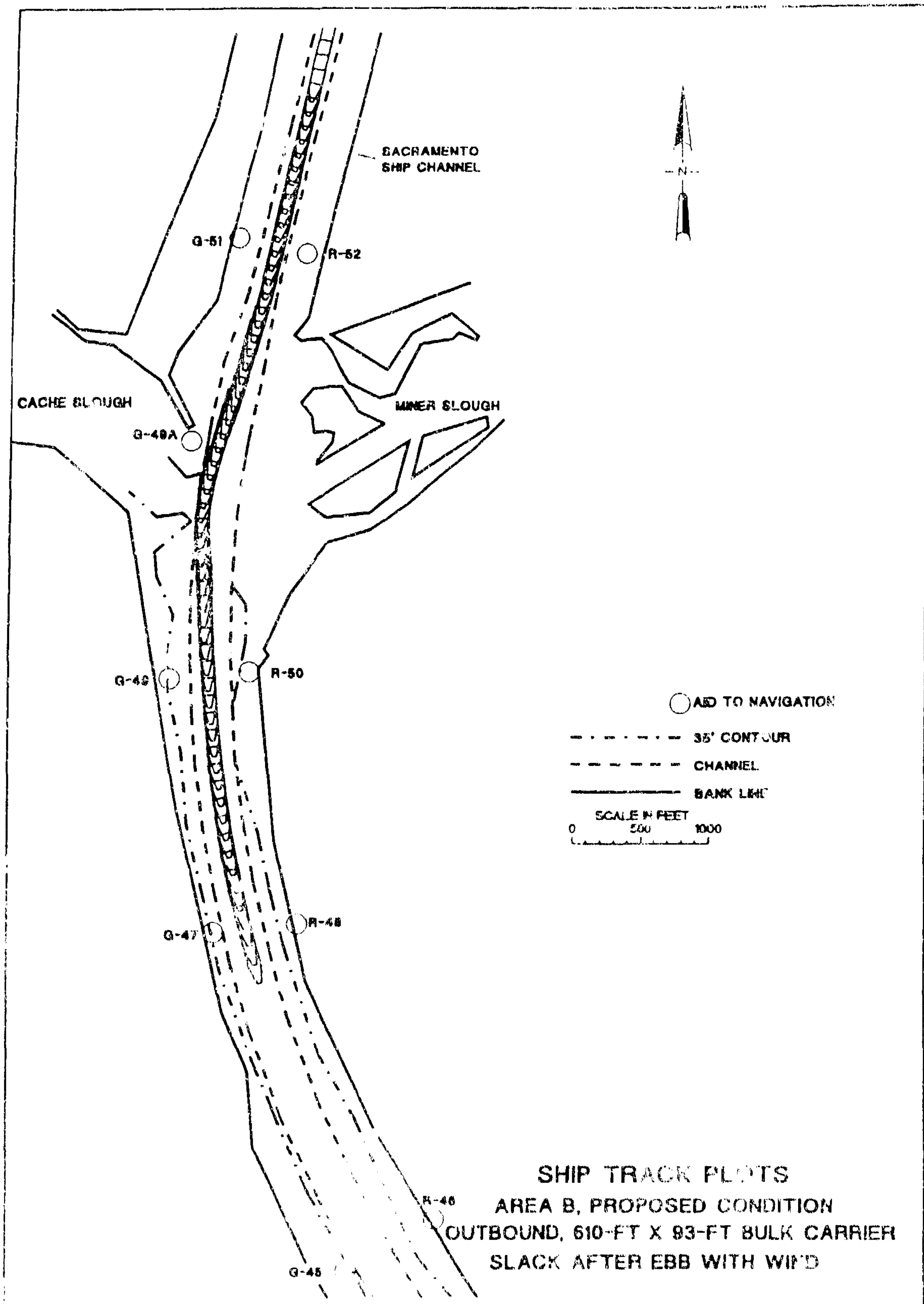


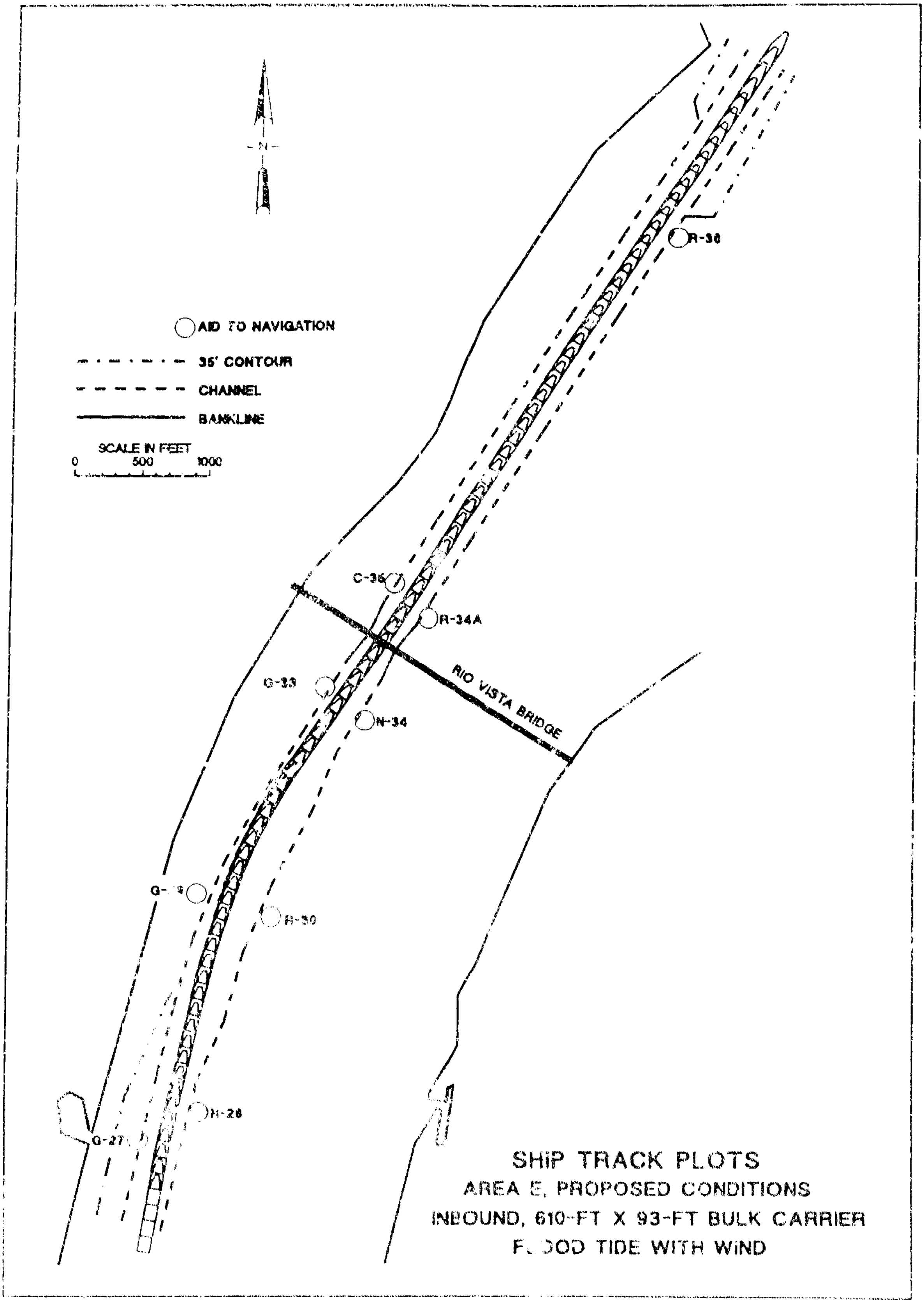
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND



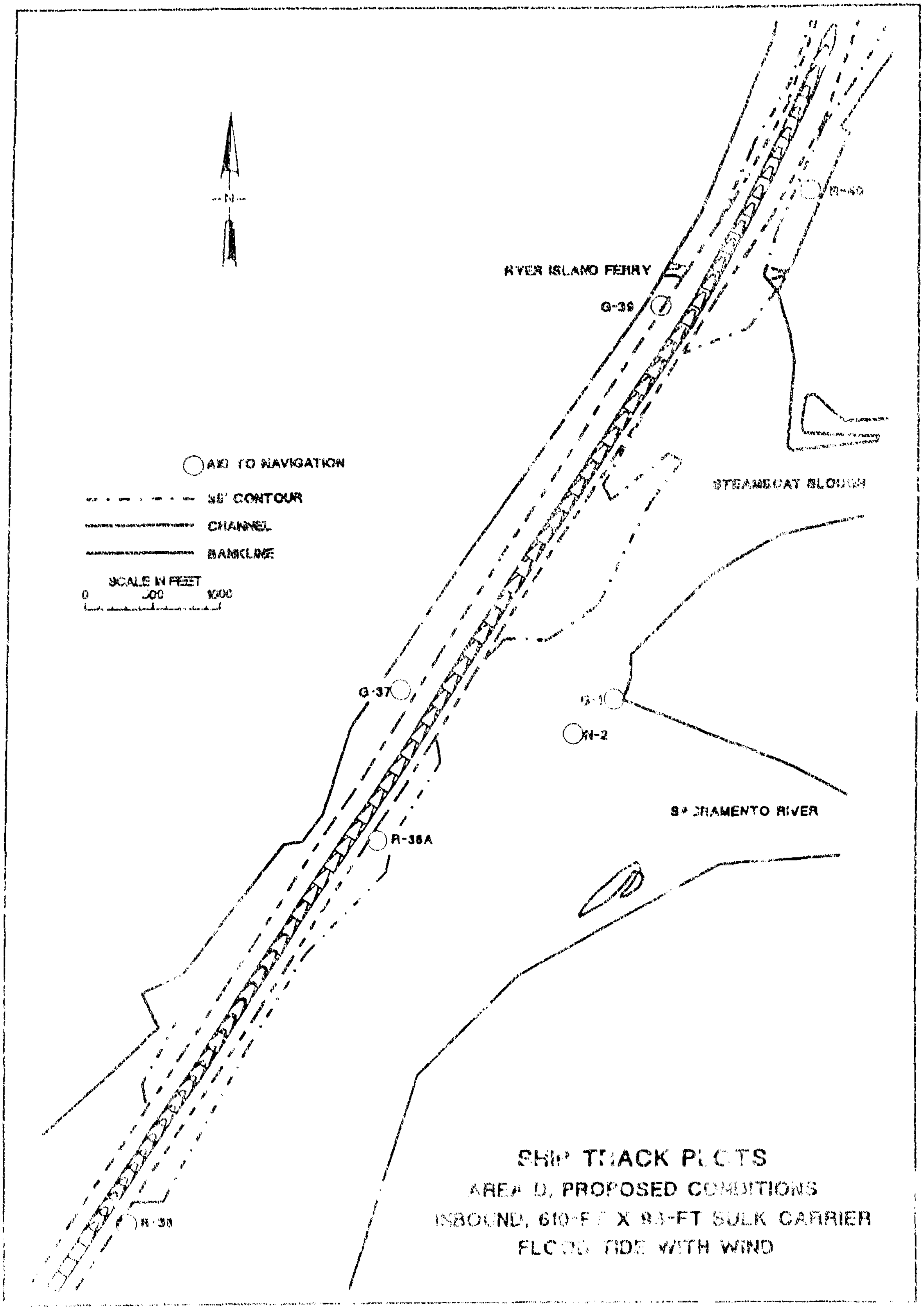
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITIONS
OUTBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND


AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
500
1000
R-36
C-35
R-34A
G-33
N-34
RIO VISTA BRIDGE
R-30
R-23
G-27
SHIP TRACK PLOTS
MAX EBB TIDE WITH WIND


SACRAMENTO
SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
G-49
R-50
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0 500 1000
G-47
R-48
R-46
G-45
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITION
OUTBOUND, 610-FT X 93-FT BULK CARRIER
SLACK AFTER EBB WITH WIND



SHIP TRACK PLOTS
AREA E, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



SHIP TRACK PLOTS
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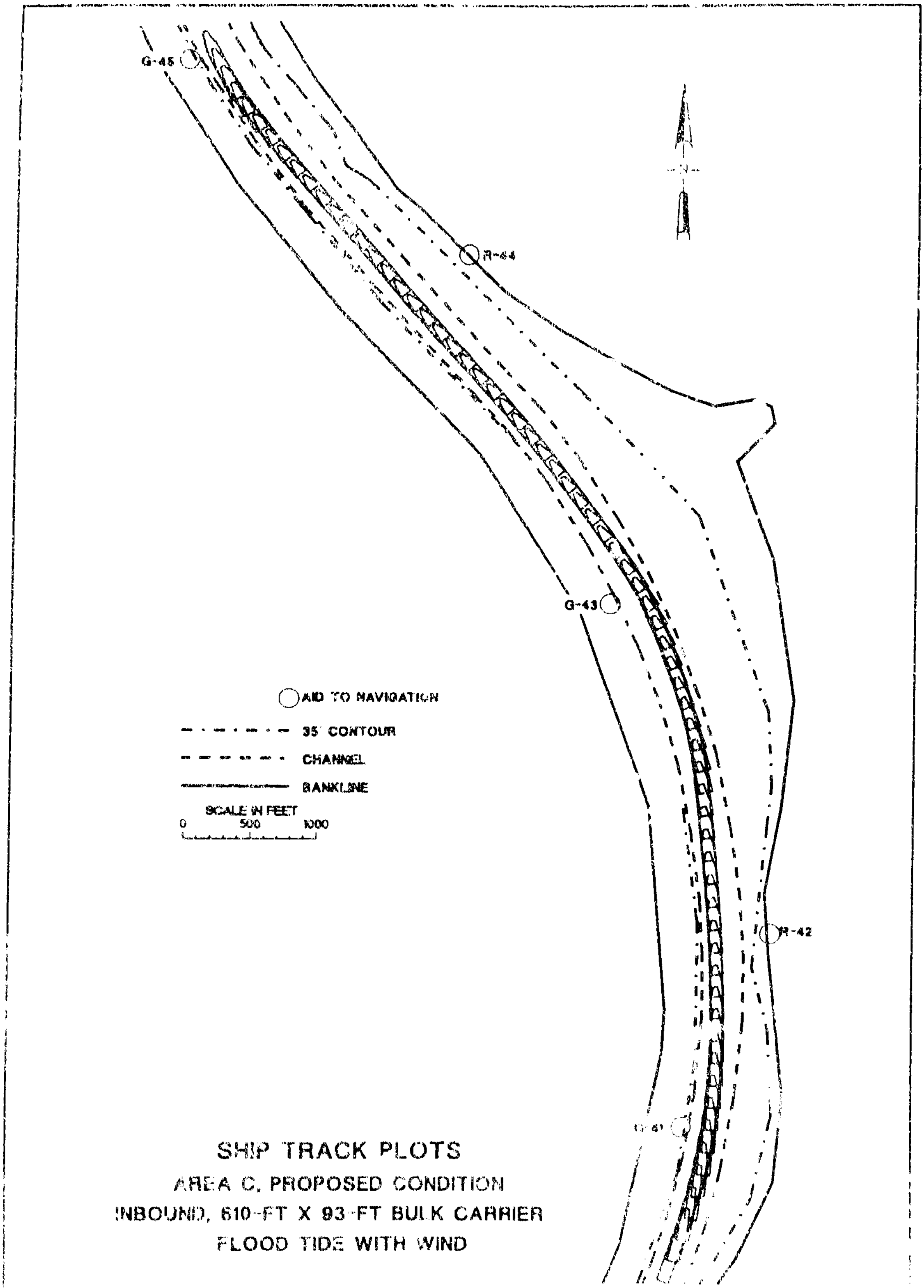
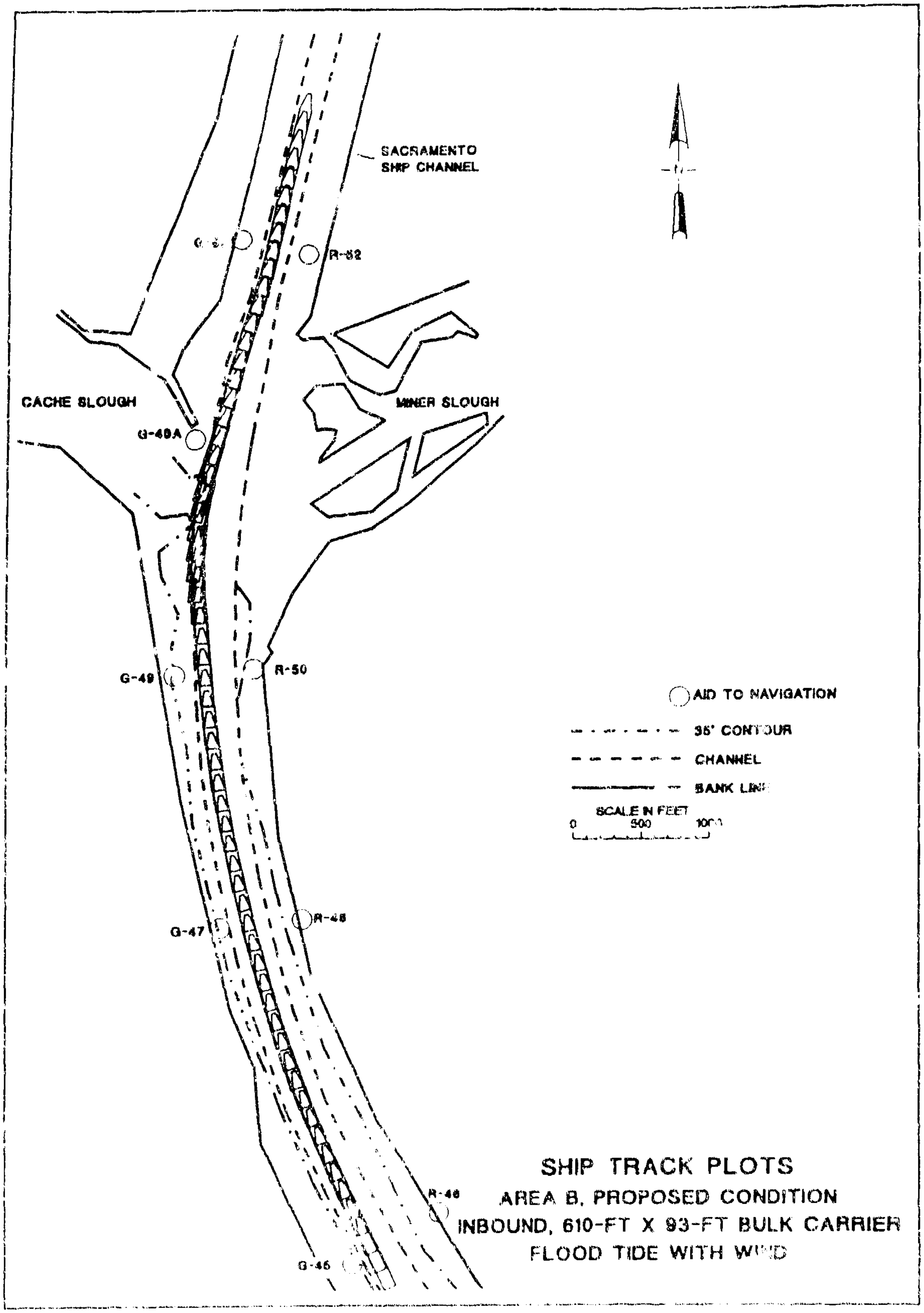
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

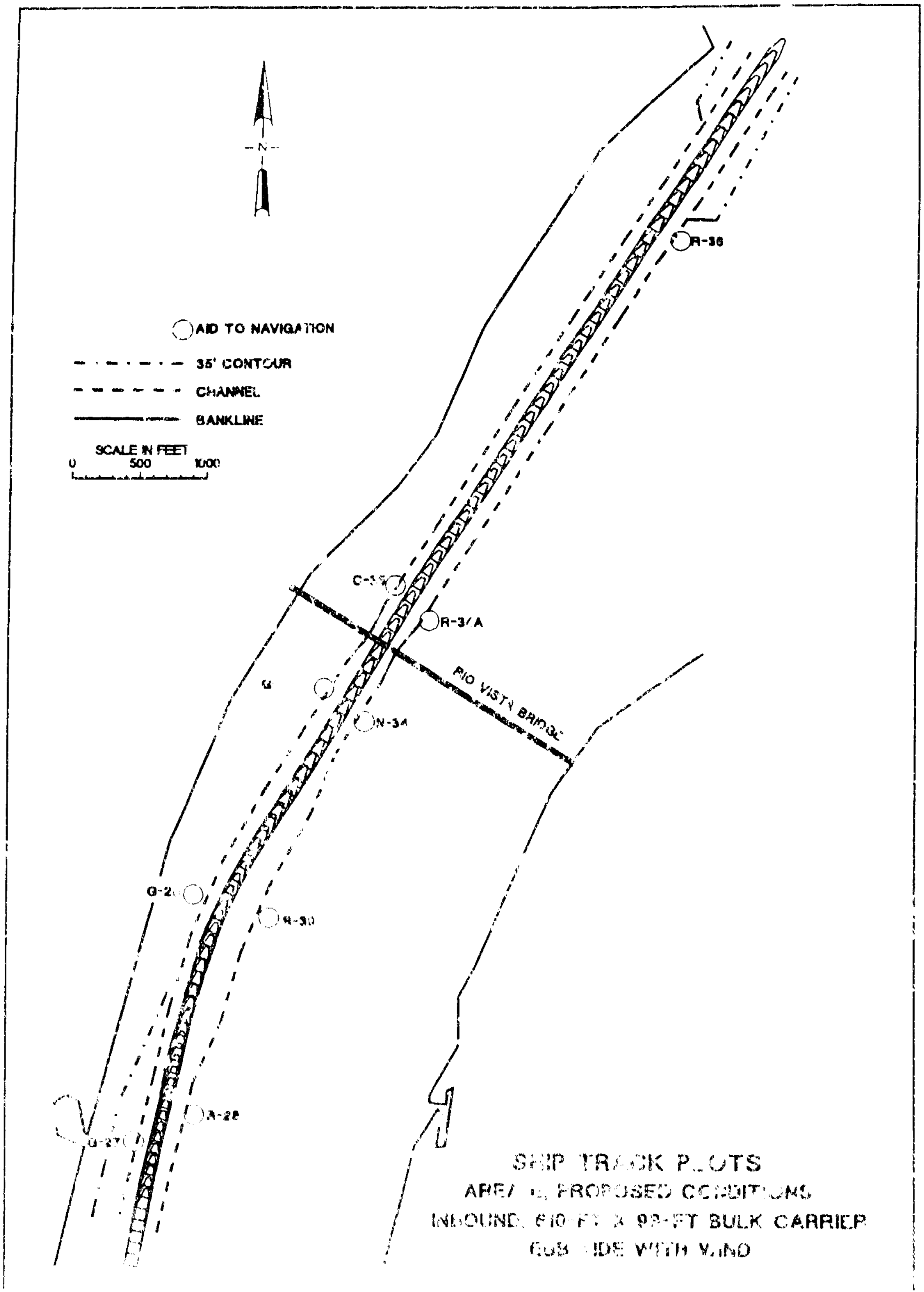


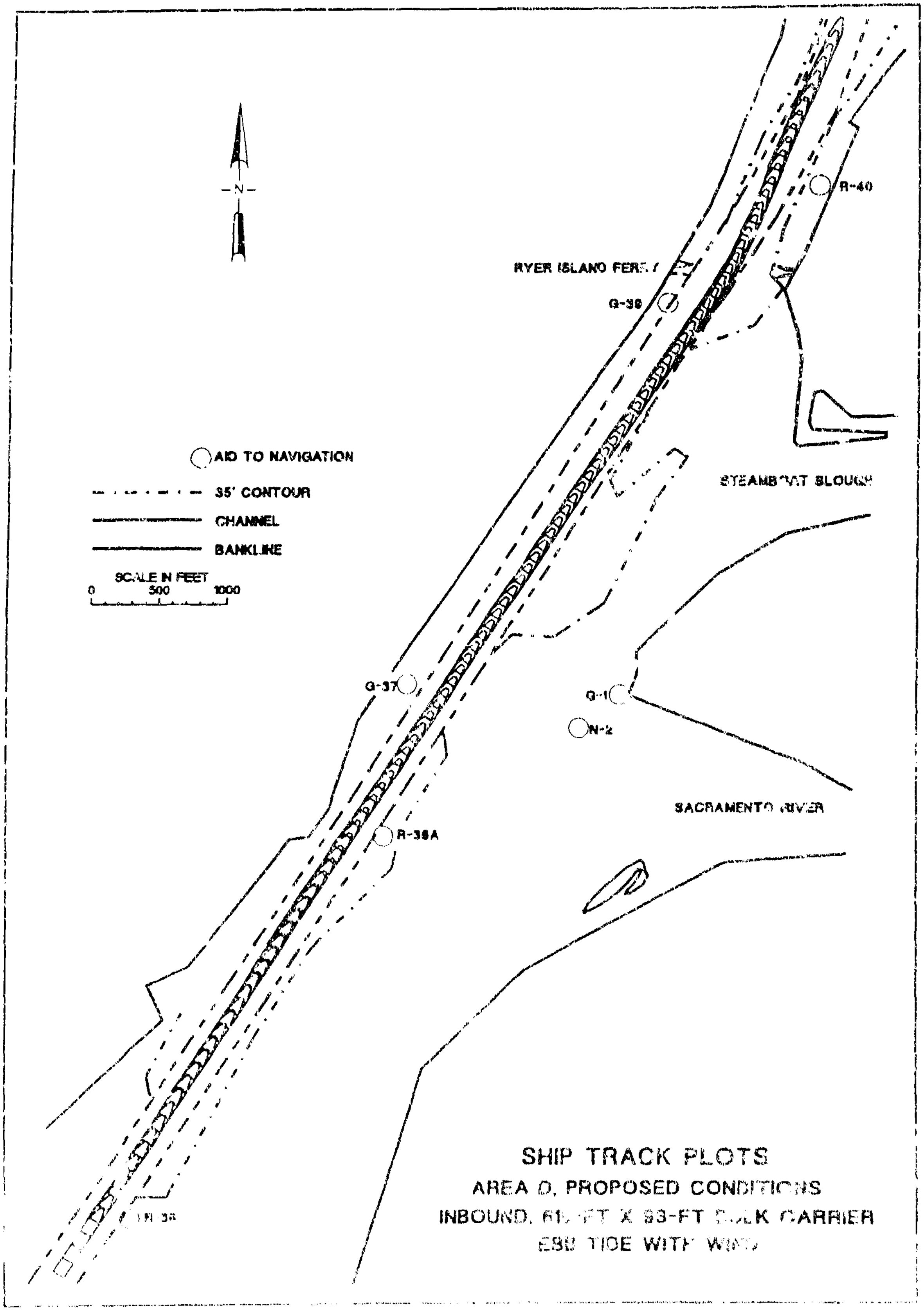
SHIP TRACK PLOTS
AREA C, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND



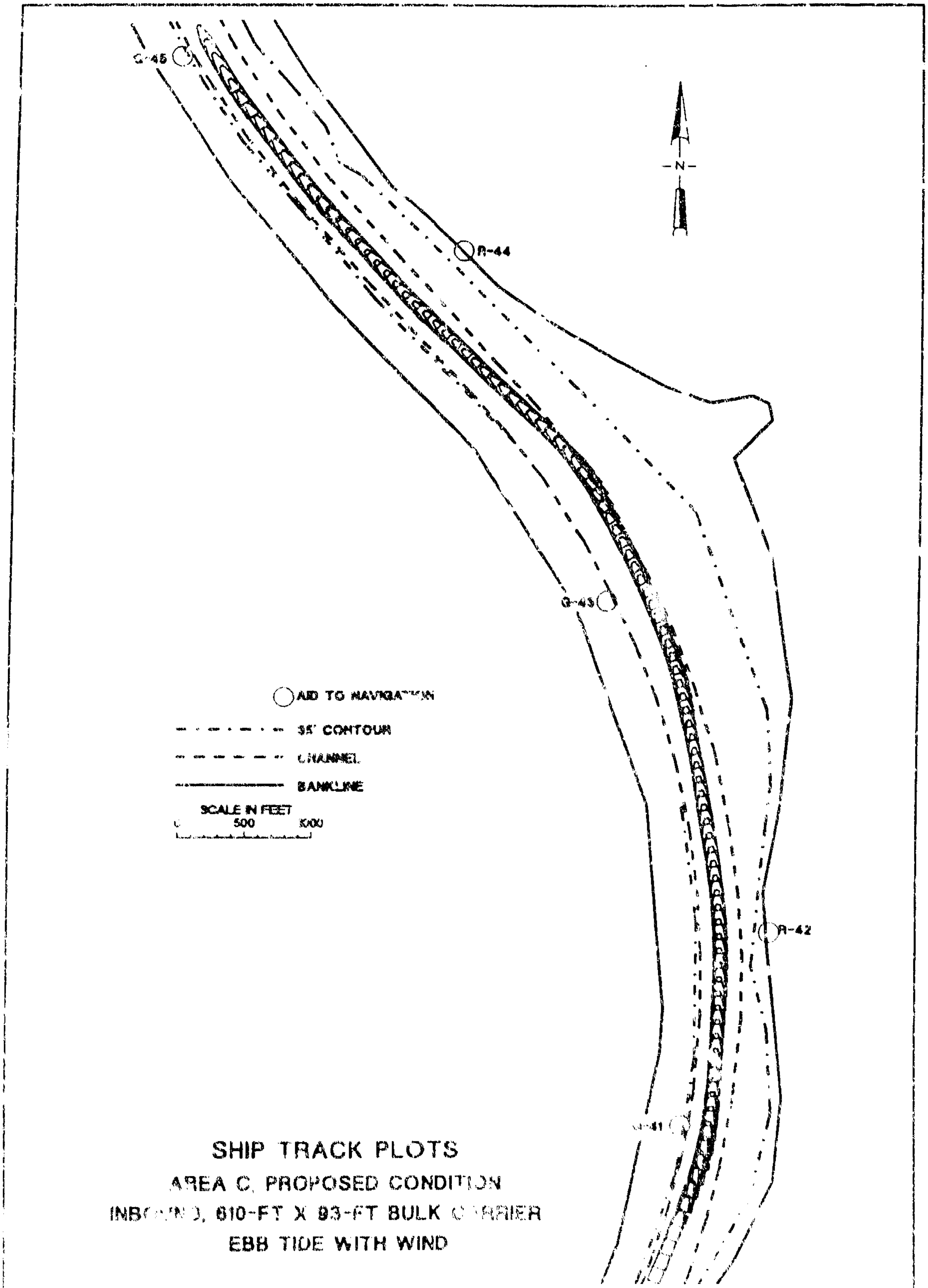
SHIP TRACK PLOTS
AREA B, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
FLOOD TIDE WITH WIND

Plate [illegible]

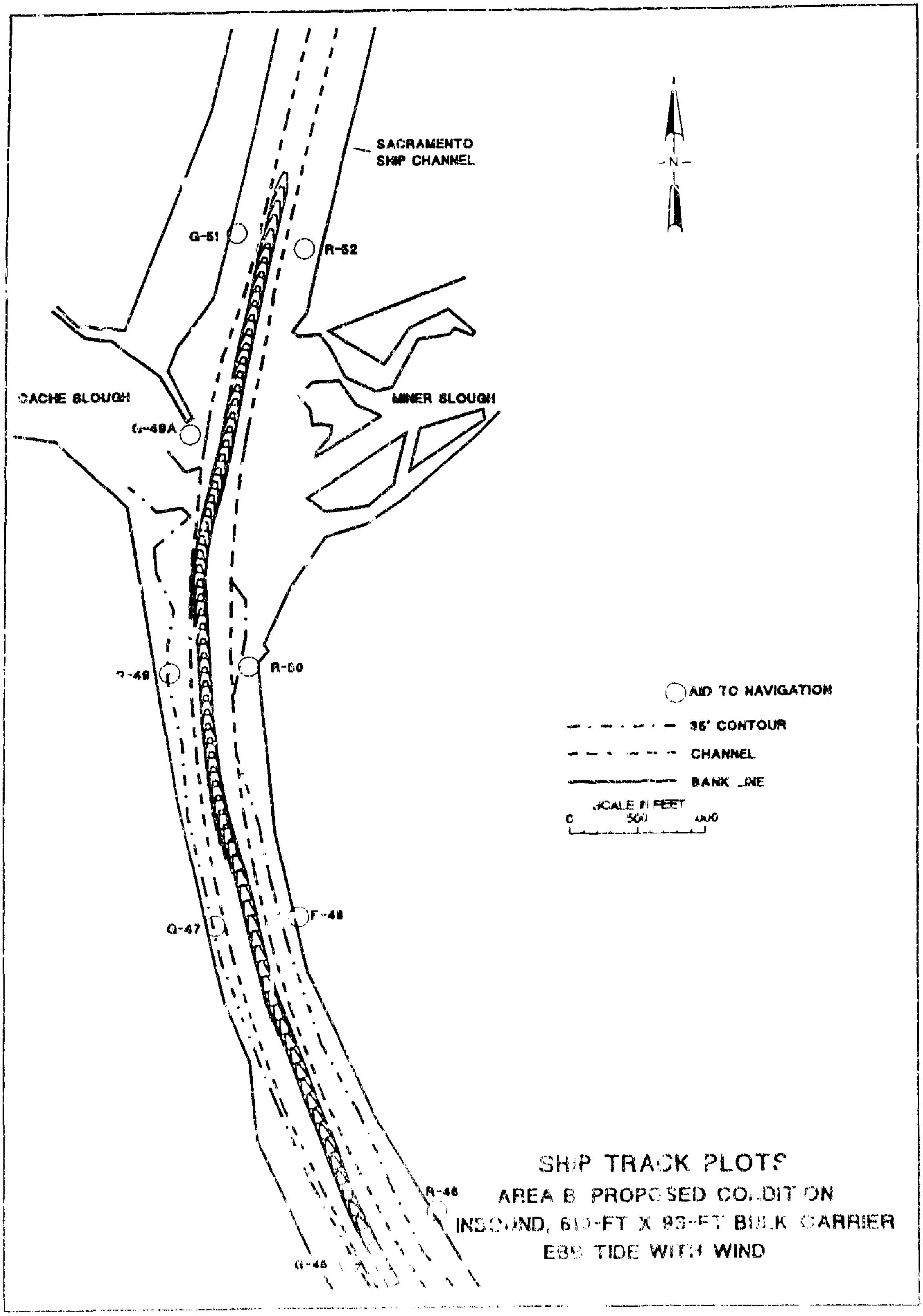

N
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0
500
1000
R-36
R-3/A
RIO VISTA BRIDGE
N-34
G-2
R-30
R-28
SHIP TRACK PLOTS
AREA [illegible], PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
[illegible] SIDE WITH WIND

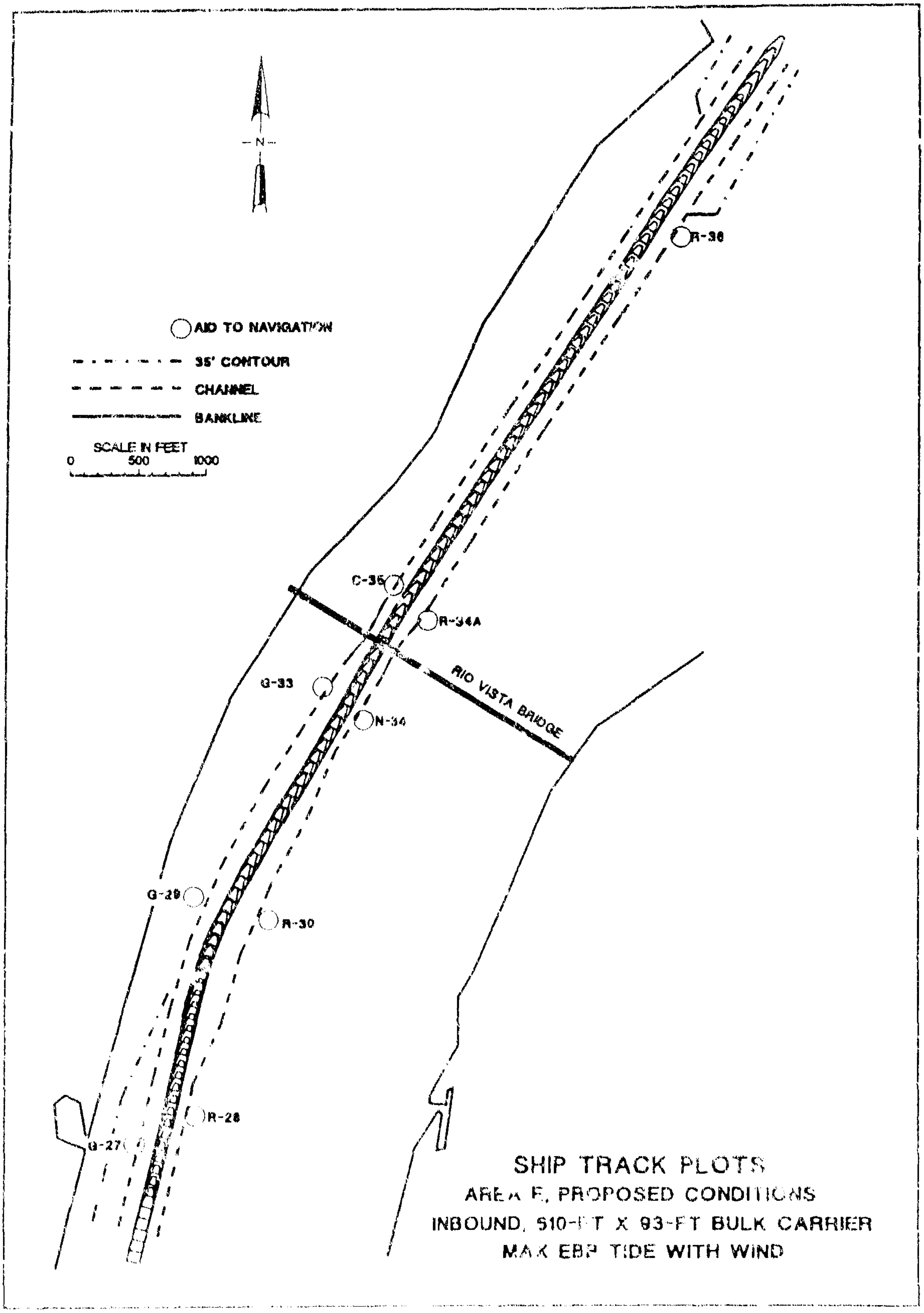


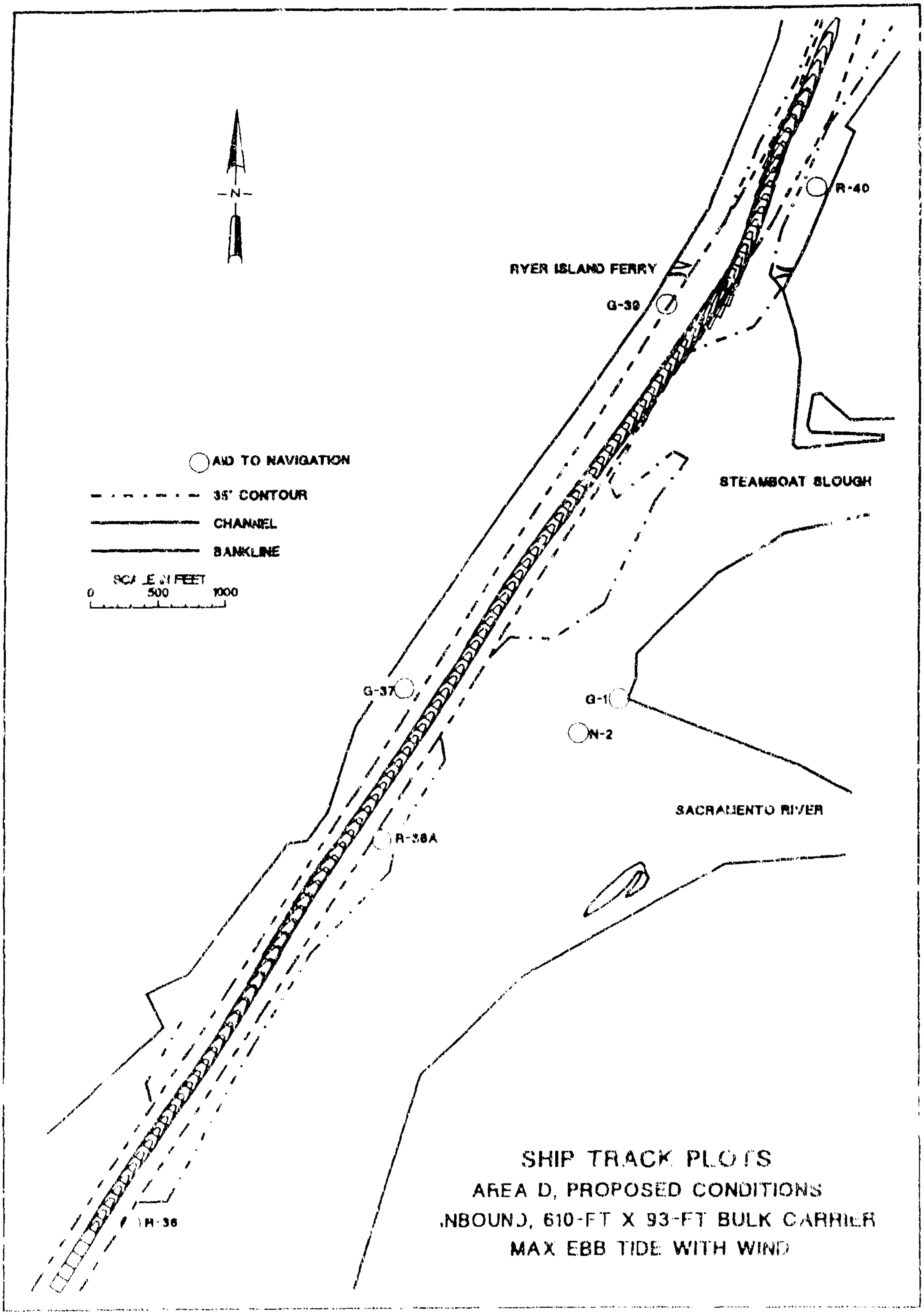
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITIONS
INBOUND, 61?-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

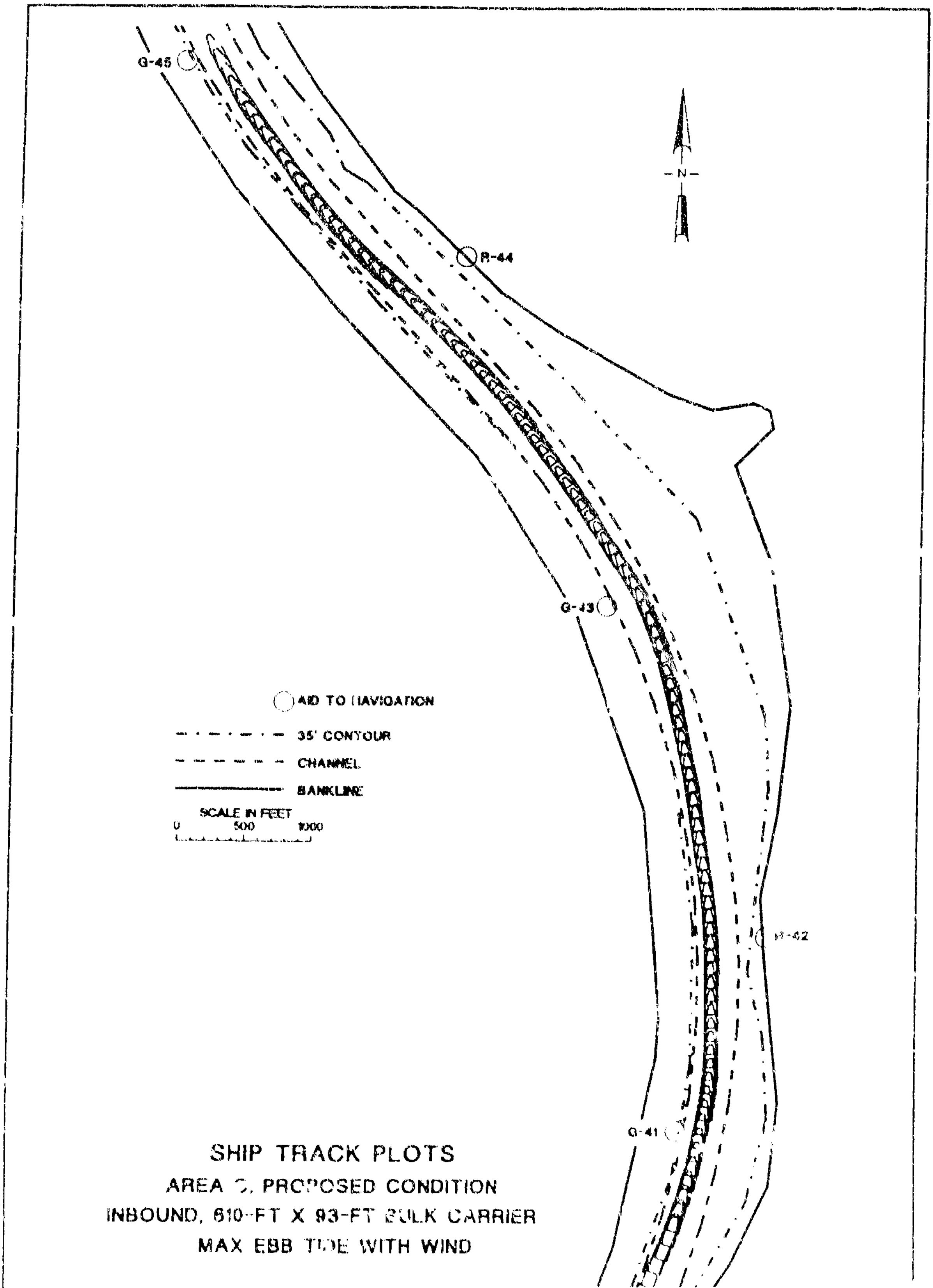


SHIP TRACK PLOTS
AREA C, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
EBB TIDE WITH WIND

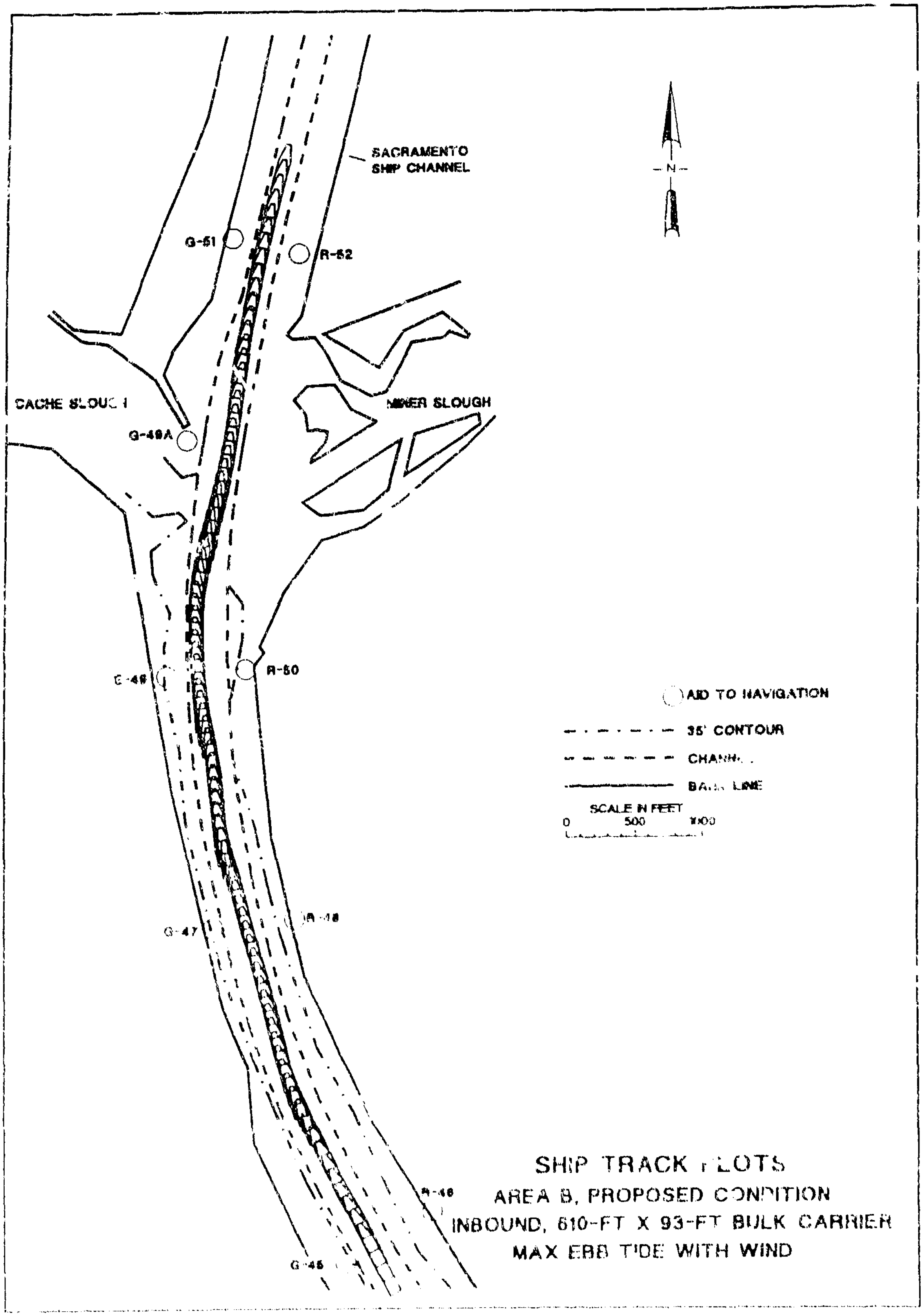

SACRAMENTO
SHIP CHANNEL
N
G-51
R-52
CACHE SLOUGH
MINER SLOUGH
G-49A
R-50
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANK LINE
SCALE IN FEET
0
500
G-47
R-46
G-45
SHIP TRACK PLOTS
AREA B PROPOSED CONDITION
EBB TIDE WITH WIND


N
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
SCALE IN FEET
0 500 1000
R-36
C-35
R-34A
RIO VISTA BRIDGE
G-33
N-34
G-29
R-30
R-28
G-27
SHIP TRACK PLOTS
INBOUND, 510-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND


N
RYER ISLAND FERRY
R-40
G-39
AID TO NAVIGATION
35' CONTOUR
CHANNEL
BANKLINE
STEAMBOAT SLOUGH
0
500
1000
G-37
G-1
N-2
SACRAMENTO RIVER
R-38A
R-36
SHIP TRACK PLOTS
AREA D, PROPOSED CONDITIONS
INBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND

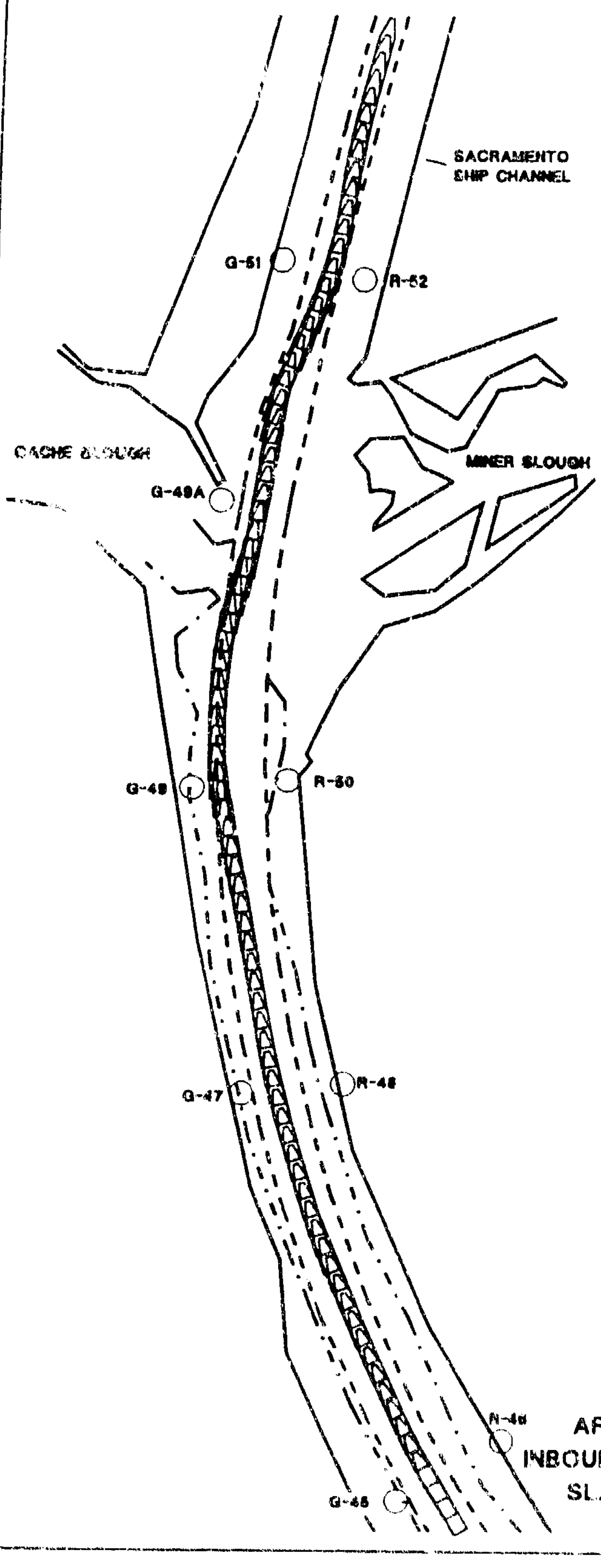


SHIP TRACK PLOTS
AREA C, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND



SHIP TRACK PLOTS
AREA B, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
MAX EBB TIDE WITH WIND

Plate 136



SHIP TRACK PLOTS
AREA B, PROPOSED CONDITION
INBOUND, 610-FT X 93-FT BULK CARRIER
SLACK AFTER EBB WITH WIND

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13. ABSTRACT *(Maximum 200 words)*

This report describes a real-time ship simulation investigation of the proposed design for improving the Sacramento River, river miles 12 to 20, California. The proposed improvements called for deepening the existing 300-ft-wide project from 30 to 35 ft. The purpose of the navigation study was to determine if the existing width was adequate for the deeper drafted vessels. A numerical model study of currents in the area was undertaken to develop the current database for the simulation. Tests were conducted with the San Francisco Bar Pilots to determine the optimum channel width.

14. SUBJECT TERMS
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Port of Sacramento
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