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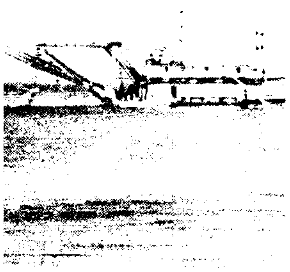

HYDRAULICS
LABORATORY

TECHNICAL REPORT HL-90-20

DREDGING ALTERNATIVES STUDY CUBITS GAP, LOWER MISSISSIPPI RIVER

Report 1

TABS-1 NUMERICAL MODEL INVESTIGATION

by

Ronald R. Copeland

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

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13. ABSTRACT *(Maximum 200 words)*

A numerical model study of the Mississippi River between Reserve, LA, at river mile 140.8, and East Jetty, LA, at river mile -19.6, was conducted to evaluate dredging alternatives in the Cubits Gap and Head of Passes reaches. The TABS-1 one-dimensional model was used. The model was adjusted to reported dredging quantities in Southwest Pass over a period of several years. The model was circumstantiated by reproducing dredging at Cubits Gap in 1989. An 11-year hydrograph was used to determine annual dredging requirements for existing conditions. Alternatives that included advance maintenance, a sediment trap, and flow reduction in Cubits Gap were compared to existing conditions The advance maintenance and Cubits Gap flow reduction alternatives were determined to be the most effective in terms of the percent of time that project depth could be maintained. The flow reduction alternative provided for a significant decrease in total dredging requirements.

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PREFACE

The numerical model investigation of dredging alternatives for Cubits Gap on the Lower Mississippi River, reported herein, was conducted at the US Army Engineer Waterways Experiment Station (WES) at the request of the US Army Engineer District, New Orleans (LMN). This is Report 1 of two reports. Report 2 describes a two-dimensional numerical model study.

This investigation was conducted during the period November 1989 to January 1990 by personnel of the Hydraulics Laboratory at WES under the direction of Messrs. Frank A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; Marden B. Boyd, Chief of the Waterways Division; and Michael J. Trawle, Chief of the Math Modeling Branch (MMB), WD. The project engineer and author of this report was Mr. Ronald R. Copeland, MMB. Technical assistance was provided by Mrs. Peggy Hoffman, MMB. This report was edited by Mrs. Marsha Gay, Information Technology Laboratory, WES.

During the course of this study, close working contact was maintained with Messrs. Cecil Soileau and Bill Garrett, LMN, who provided data, technical assistance, and review.

Commander and Director of WES during the preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
degrees Fahrenheit	5/9*	degrees Celsius or kelvins
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

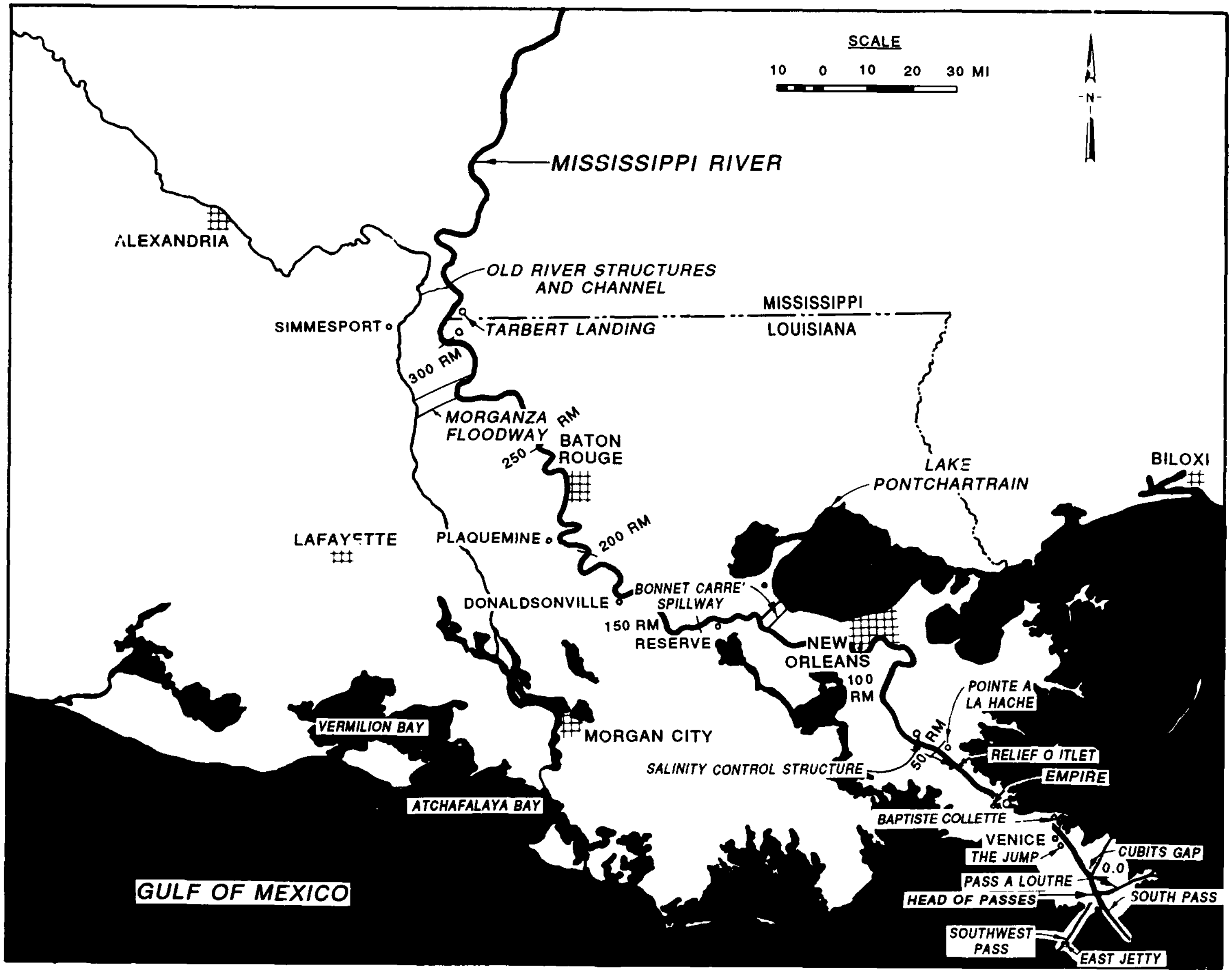

Figure 1. Location map

DREDGING ALTERNATIVES STUDY

CUBITS GAP, LOWER MISSISSIPPI RIVER

TABS-1 NUMERICAL MODEL INVESTIGATION

PART I: INTRODUCTION

The Prototype

1. About 160 miles* of the Lower Mississippi River between Reserve, LA, at river mile 140.8,** and East Jetty, LA, at river mile -19.6, were investigated (Figure 1). This reach of the Mississippi River is contained by levees and high bluffs between Reserve and Baptiste Collette, at river mile 11.4. Baptiste Collette is the first of several natural distributaries that make up the Mississippi River delta. Two more distributaries are located at The Jump, river mile 10.5, and Cubits Gap, river mile 3.0. Three major distributaries, Pass a Loutre, South Pass, and Southwest Pass, disseminate from Head of Passes at mile 0.0. This study follows Southwest Pass, which is the primary navigation channel, to East Jetty at the river's outlet.

2. This study focuses on shoaling problems in the vicinity of Cubits Gap at mile 3.0. Upstream from Cubits Gap the river is relatively deep, about 70 ft at mile 5.0. The channel depth decreases as it approaches the distributary, so that downstream from Cubits Gap dredging is frequently required to maintain a 45-ft-deep navigation channel. Shoaling in the vicinity of Cubits Gap has become more frequent in recent years. This may be associated with an increased outflow through Cubits Gap. Extensive dredging is also required annually at Head of Passes. In this study the Cubits Gap reach is defined between miles 4.0 and 0.86, and the Head of Passes reach is defined between miles 0.86 and -1.9.

Purpose and Scope of the Model Study

3. The initial purpose of this investigation was to evaluate two

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* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

** River miles in this report are above Head of Passes based on the 1962 survey.

proposals to improve dredging operations in the vicinity of Cubits Gap. The two alternatives were compared to the existing conditions: a 45-ft-deep, 750-ft-wide navigation channel, with 3 ft of overdredging. The first proposal calls for advance maintenance, which increases the overdredging depth from 3 to 5 ft so that after dredging the channel depth is 50 ft deep instead of 48 ft deep. The second proposal is a 1,000-ft-wide sediment trap, dredged to elevation -50.0,* adjacent to the navigation channel between miles 0.0 and 4.0. During the course of the investigation, two additional proposals were investigated. One was a modified sediment trap and the other was a reduction in the outflow through Cubits Gap by some structural means. In evaluating the last alternative, flow redistribution quantities were uncertain at the time of this investigation, so an arbitrary 50 percent reduction in the discharge through Cubits Gap was assigned. The effect of the alternatives on dredging operations in both the Cubits Gap and Head of Passes reaches was evaluated by comparing total annual sediment accumulations, sediment accumulation rates, number of days before encroachment into the project depth, and the number of days that project depth was lost with designated dredging capacities.

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* All elevations (el) and stages cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

PART II: THE MODEL

Description

4. The TABS-1 one-dimensional sedimentation program was used to develop the numerical model for this study. Development of this computer program was initiated by Mr. William A. Thomas at the US Army Engineer District, Little Rock, in 1967. Further development at the US Army Engineer Hydrologic Engineering Center (USAEHEC) by Mr. Thomas produced the widely used HEC-6 generalized computer program for calculating scour and deposition in rivers and reservoirs (USAEHEC 1977). Additional modification and enhancement to the basic program by Mr. Thomas at the US Army Engineer Waterways Experiment Station (WES) led to the TABS-1 program currently in use (Thomas 1980, 1982). The program produces a one-dimensional model that simulates the response of the riverbed profile to sediment inflow, bed material gradation, and hydraulic parameters. The model simulates a series of steady-state discharge events and their effects on the sediment transport capacity at cross sections and the resulting degradation or aggradation. The program calculates hydraulic parameters using a standard-step backwater method assuming subcritical flow.

5. The numerical model used in this study was originally developed to study the effect of several Mississippi River flow diversion schemes on dredging in Southwest Pass. That model extended from Reserve at mile 140.8 to East Jetty at river mile -19.6. Model geometry was based on the 1975 hydrographic survey. Roughness coefficients were adjusted to make calculated water-surface elevations match average stages at several gages. The model included clay, four silt sizes, and three sand sizes, including very fine, fine, and medium sand. Sand inflow was calculated at Reserve from another numerical model that extended to Tarbert Landing, MS, at river mile 306.3. Sediment inflow to that model was based on average sediment inflow measurements taken between 1976 and 1982 at Tarbert Landing. Clay and silt inflow was determined from 1972-1982 measurements at Tarbert Landing, New Orleans, LA (mile 102.7), and Belle Chasse, LA (mile 76.0). The bed material gradation was determined from a long-term trend study that reproduced measured aggradation in the study reach between 1963 and 1975. Sediment deposition and entrainment coefficients for silt and clay were adjusted until calculated dredging quantities in Southwest Pass corresponded to reported values for an 8-year period. The model was

considered to be sufficiently adjusted to evaluate shoaling in the vicinity of Cubits Gap. However, additional geometric refinements were made to the model in the Cubits Gap reach.

Channel Geometry

6. Geometry for most of the numerical model was based on the 1975 hydrographic survey, updated to reflect Supplement II improvements (US Army Engineer District (USAED), New Orleans, 1984). In the vicinity of Cubits Gap the geometry was updated using 1989 survey data for cross sections between miles 0.0 and 4.7 and using the 1983 hydrographic survey for cross sections between miles 4.7 and 10.7. Cross sections are located in Figure 2. Initial bed elevations at the start of model runs were set at -48.0 in the navigation channel from East Jetty to Cubits Gap. This reflects a project channel after 3 ft of overdredging. Initial bed elevations of -50.0 were used in this reach for the advance maintenance alternative.

Hydrographs

7. Discharge hydrographs are simulated in the numerical model by a series of steady-state events. The duration of each event is chosen such that changes in bed elevation, due to deposition or scour, do not significantly change the hydraulic parameters during that event. At relatively high discharges, durations need to be short; time intervals as low as 2 days were used in this study. At low discharges, the time intervals may be extended; time intervals up to 31 days were used in this study.

8. A hydrograph simulated by a series of steady-state events of varying durations is called a histograph. The histographs used in this study were based on mean daily flow measurements at Tarbert Landing. Annual histographs were developed for the years 1974-1983 and 1989. In addition, a shifted annual histograph was used to represent an average year. These histographs were used to obtain annual maintenance figures for a range of hydrologic conditions. The 1979 hydrograph, which represents a high runoff year, and 1989 hydrograph, which is the most recent runoff year, received more attention in this investigation, and more results using these hydrographs are presented herein. Historical histographs for water years 1974-1983, 1979, and 1989 and

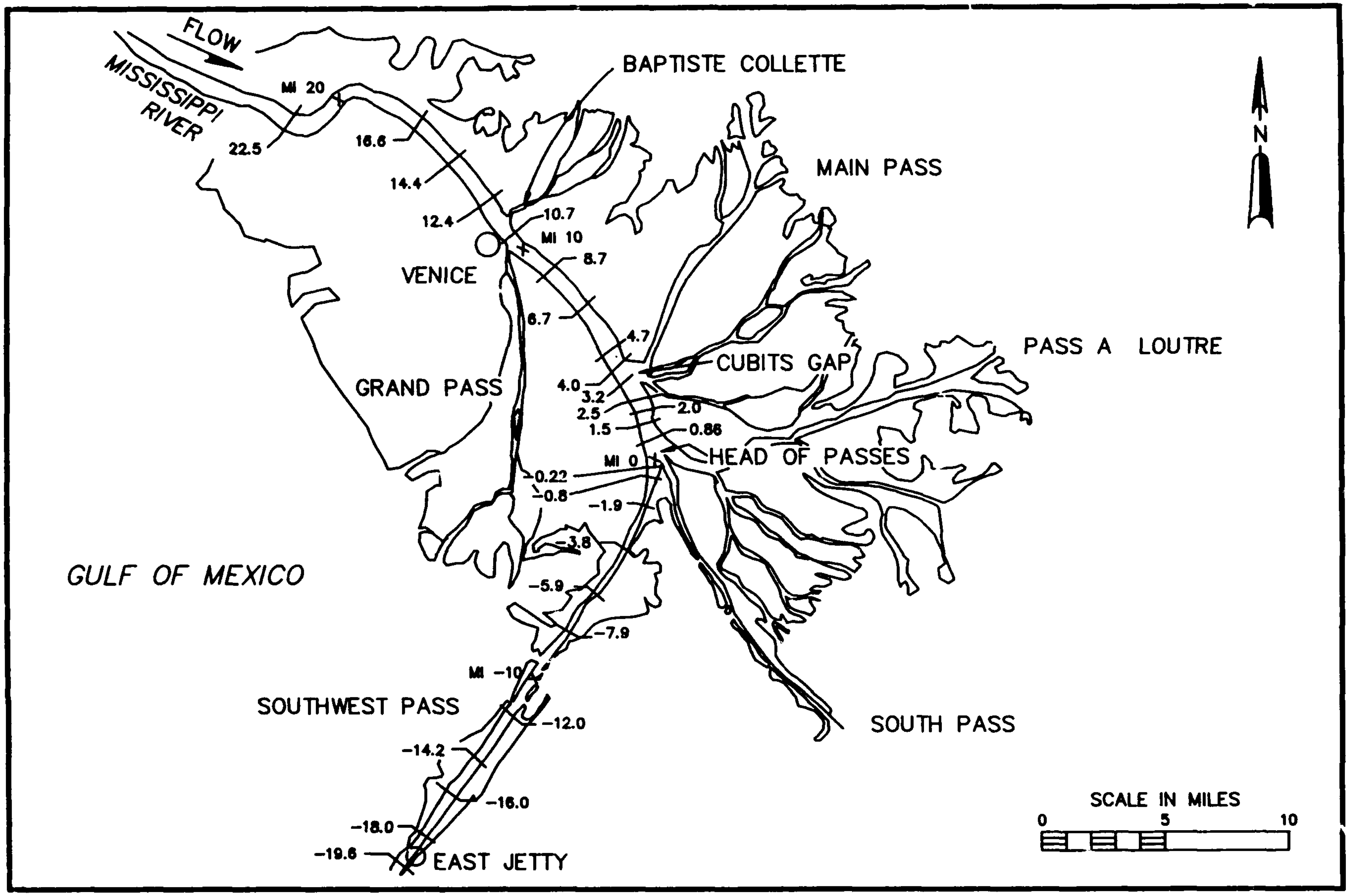

Figure 2. Cross-section locations

the shifted annual histograph are shown in Plates 1-4, respectively.

Distributary Flow Distribution

9. Distributary flow percentages in the model were based on calculations from a TABS-2 two-dimensional model study conducted at WES (Richards and Trawle 1988). Flow percentages through Cubits Gap were revised to account for increases determined from measurements taken by New Orleans District in 1983 and 1989, and by WES in 1989. Based on these measurements, flow diversion in the numerical model at Cubits Gap and over the natural levees in the vicinity of Cubits Gap was varied between 30,000 cfs, or 15 percent of the total riverflow at Venice, LA, at 200,000 cfs, and 351,000 cfs, or 27 percent at 1,300,000 cfs.

10. Discharges downstream from Bonnet Carré Spillway were reduced to account for measured flows diverted in 1975, 1979, and 1983. This structure is operated to maintain a maximum flow of 1,250,000 cfs at New Orleans.

Water Temperature

11. Water temperature data were obtained from US Geological Survey (USGS) Water Quality Records (USGS 1975, 1976-1983). Monthly values at seven gages were averaged to obtain a representative temperature for the entire study reach. Water temperatures ranged from 42° F in winter to 84° F in summer.

Downstream Water-Surface Elevations

12. Water-surface elevations at the downstream model boundary were based on average monthly stages at East Jetty. These are shown in the following tabulation (USAED, New Orleans, 1984):

Month	Stage	Month	Stage
January	0.6	July	2.0
February	0.7	August	1.9
March	1.5	September	1.9
April	2.0	October	1.3
May	2.1	November	1.0
June	1.9	December	1.0

Channel Roughness

13. Manning's roughness coefficients in the numerical model were adopted from the previous model study. In that study, average stage-discharge curves were determined for eight gages in the study reach. Manning's roughness coefficients were then adjusted so that calculated water-surface elevations matched average recorded stages for a range of discharges. Adopted values of Manning's roughness coefficients varied between 0.016 and 0.026. Using the roughness coefficients from the previous numerical model study and the average monthly downstream water-surface elevations at East Jetty, calculated stages at Venice are compared to recorded stages for the 1989 hydrograph in Figure 3. Calculated stages are slightly higher, probably due to differences in average monthly and actual stages at East Jetty. However, general trends with discharge are similar, and differences in stages are insignificant when compared to water depths of about 50 ft.

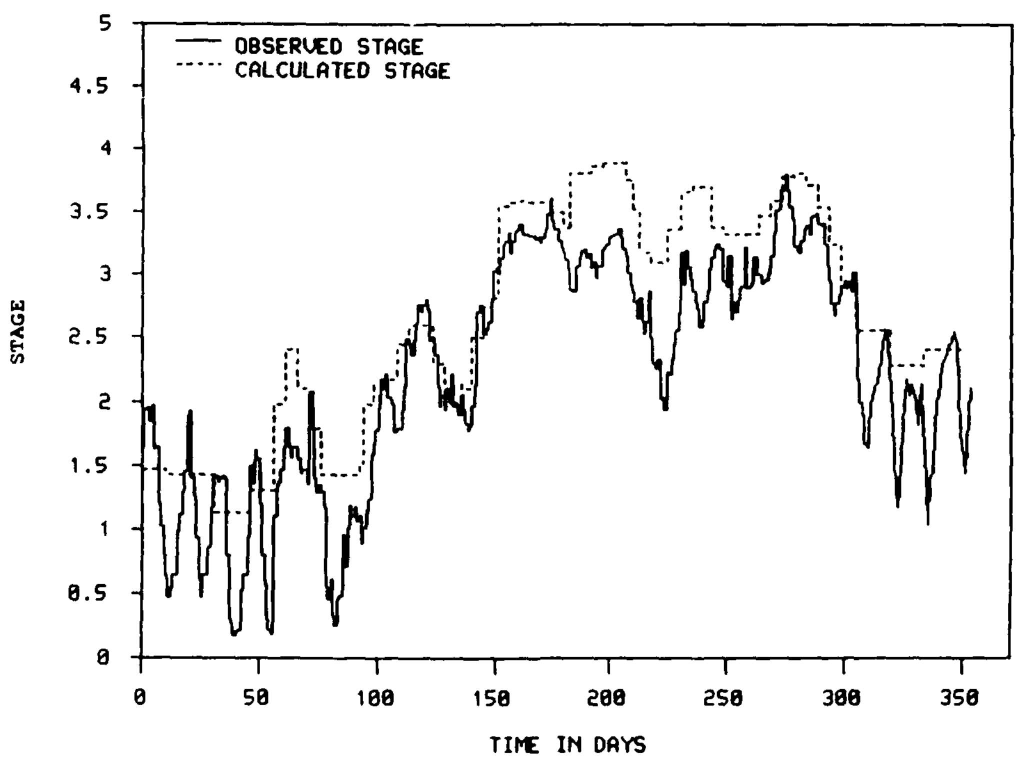

Figure 3. Calculated and recorded stages at Venice, 1989 hydrograph

Sediment Inflow and Outflow

14. The upstream boundary of the model was at mile 140.8, where sediment inflow concentrations were calculated from the previous model based on 1976-1982 measurements at Tarbert Landing. In the numerical model, the distributary sand concentration was 50 percent of the river sand concentration; distributary silt and clay concentrations were 100 percent of the river silt and clay concentrations.

Bed Material Gradations

15. Initial bed material gradations in the numerical model were based on calculated gradations from the previous numerical model study. These represent 1975 conditions, which compare favorably with 1989 samples collected in the Cubits Gap reach by WES as shown in Plate 5.

Transport Function

16. The Laursen-Madden transport function (USAEHEC 1977) was used in this study because calculated and measured transport for each sand size class compared favorably. Measured and calculated transport rates at New Orleans (Carrollton) and Belle Chasse are compared in Figures 4 and 5, respectively.

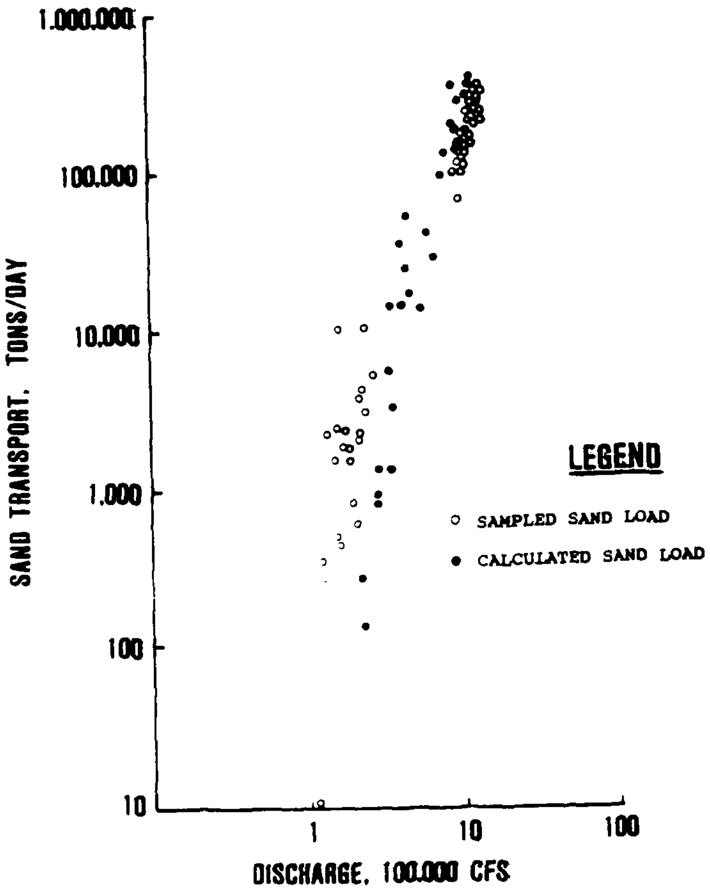

Figure 4. Measured and sampled sand discharge at Carrollton, LA (river mile 102.7)

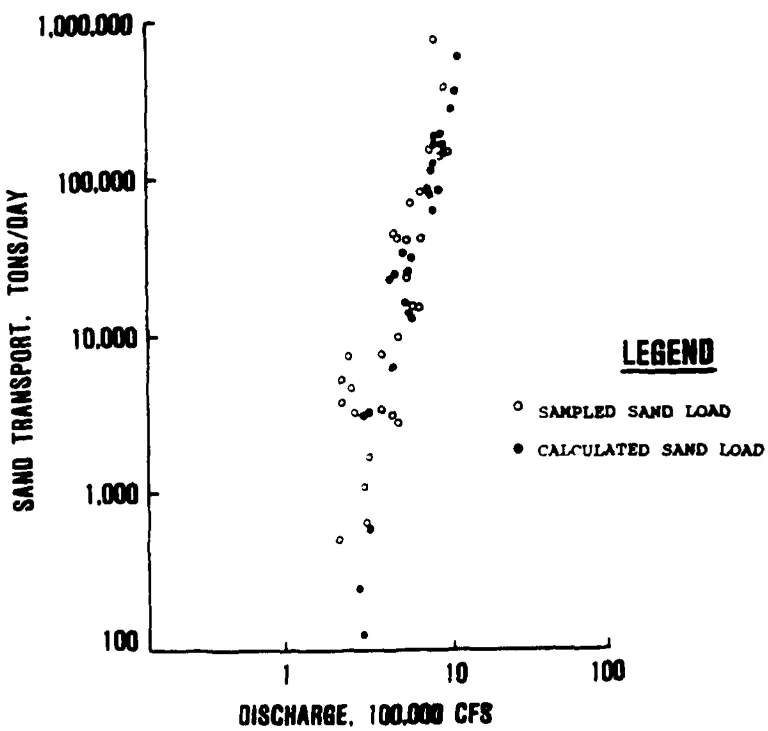

Figure 5. Measured and sampled sand discharge at Belle Chasse (river mile 76.0)

PART III: MODEL CIRCUMSTANTIATION

17. The numerical model was used to calculate sediment accumulation and dredging for the October 1988-May 1989 hydrograph in the vicinity of Cubits Gap and Head of Passes. In these tests, dredging back to el -48.0 was calculated for March and May, corresponding to active dredging periods in the prototype. Calculated quantities were not directly comparable to reported quantities because the initial bed geometry and the exact limits of dredging were unknown. The purpose of the comparison was to determine if calculated results are reasonable. Model and prototype calculations are compared in Table 1. The combined calculated dredging in the Cubits Gap and Head of Passes reaches was within 2 percent of reported dredging; however, calculated dredging in the vicinity of Cubits Gap is greater than reported, and in Head of Passes is less than reported.

PART IV: STUDY RESULTS

Test Procedure

18. Geometries for the proposed alternatives were incorporated into the adjusted numerical model and run with various hydrographs. Calculated annual sediment accumulations in the Cubits Gap and Head of Passes reaches were then compared to evaluate alternatives. In the numerical model, deposition was limited to the navigation channel for existing and advance maintenance conditions. With the sediment trap, deposition was allowed to occur in both the navigation channel and the sediment trap. In these tests, dredging occurred at the end of the water year in September and only in the navigation channel. Dredging of sediment deposited in the sediment trap was not required to maintain the navigation channel, but will eventually have to be done to maintain the effectiveness of the sediment trap. Calculated sediment deposition in the sediment trap was considered to be deferred dredging. Annual sediment accumulation comparisons between existing conditions and the advance maintenance and sediment trap alternatives using the 1989, 1979, and shifted annual hydrographs are shown in Tables 2-4, respectively. Differences between 1989 dredging quantities for the existing conditions in Tables 1 and 2 are due to the extension of the hydrograph from May to September. Both alternatives resulted in more combined sediment accumulation in the Cubits Gap and Head of Passes reaches than with existing conditions. Advance maintenance resulted in between 7 and 12 percent more sediment accumulation; the sediment trap, between 12 and 14 percent. Percent increases in sediment accumulation were higher in the Cubits Gap reach, especially with the sediment trap, with increases of between 82 and 119 percent.

1989 Hydrograph

19. Progressive profiles of the navigation channel bed elevation with existing conditions calculated by the numerical model during the simulation of the 1989 hydrograph are shown in Figure 6. Profiles for the advance maintenance and sediment trap alternatives are shown in Plates 6 and 7, respectively. These profiles show that cross sections at miles 2.0 and 2.5 are the most critical with respect to sediment deposition in the Cubits Gap reach.

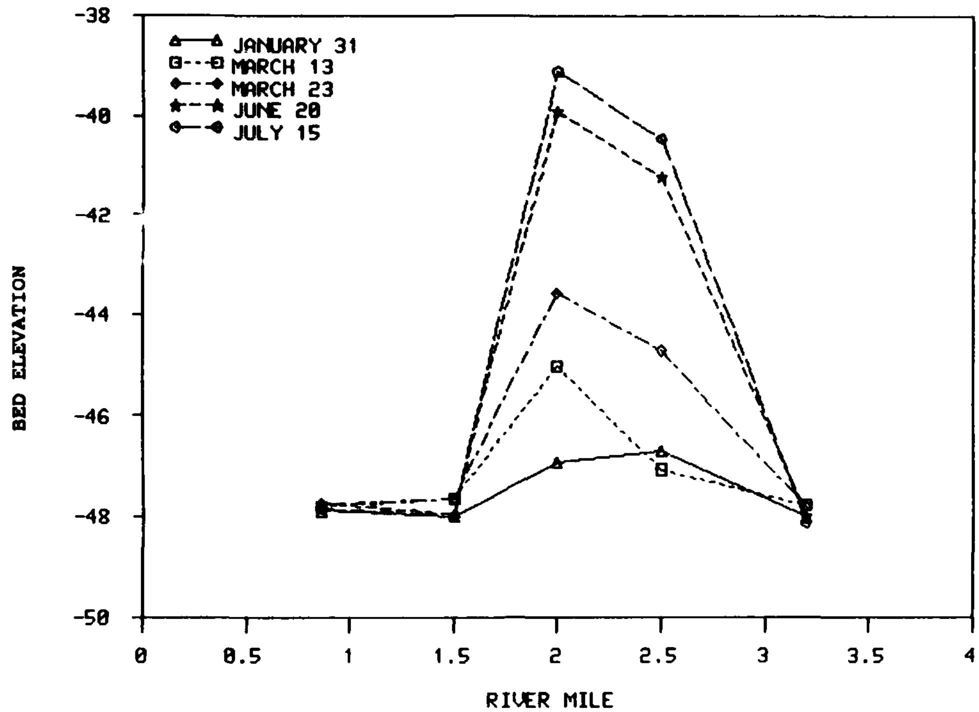

Figure 6. Calculated progressive bed profiles during 1989 hydrograph with existing conditions

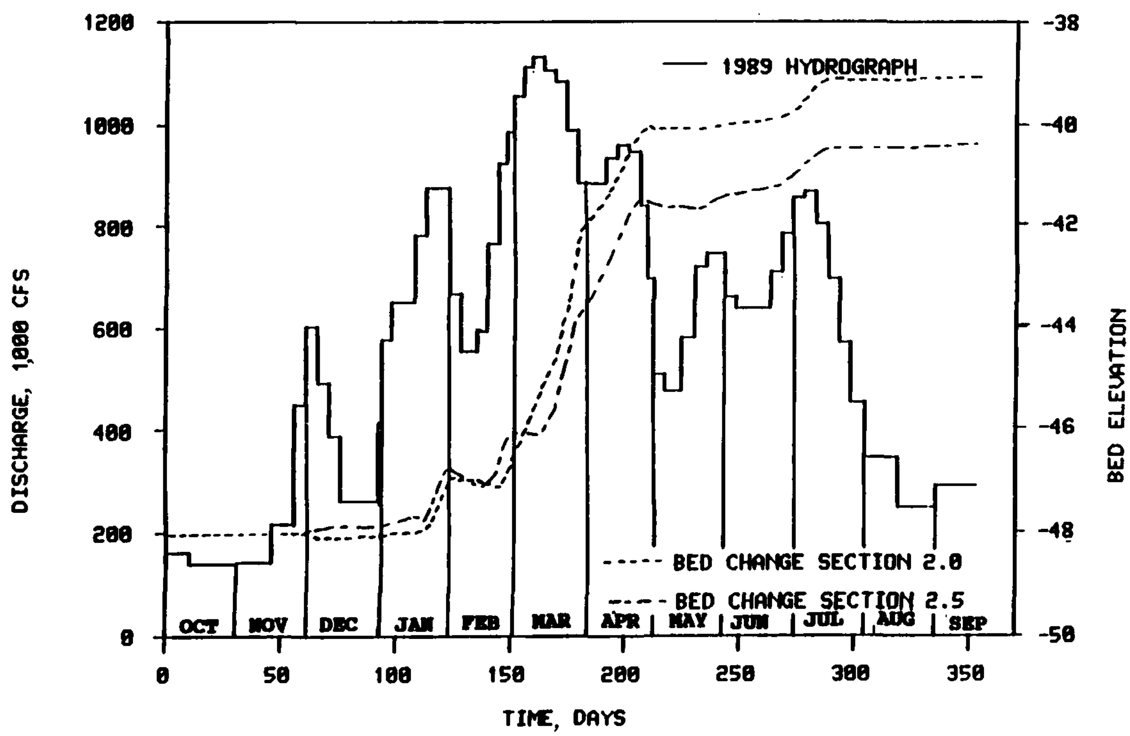

Figure 7. Calculated bed changes at miles 2.0 and 2.5 during 1989 hydrograph with existing conditions

Figure 7 shows calculated bed changes with existing conditions at miles 2.0 and 2.5 during the 1989 hydrograph. Most of the sediment deposition occurred in March and April at the highest discharges.

20. Maximum calculated bed elevation changes for existing conditions and for the advance maintenance and sediment trap alternatives during the 1989 hydrograph are shown in Figures 8 and 9 for the Cubits Gap and Head of Passes reaches, respectively. The length of time before project depth, at el -45.0, is lost can be determined from these figures. These calculated results should be considered relative; they are applicable to the 1989 hydrograph and subject to assumptions implicit in the model formulation. With the given conditions, advance maintenance provides 10 extra days of project depth; and the sediment trap, 2 extra days. In Head of Passes, advance maintenance provides 18 extra days of project depth; and the sediment trap, 11 extra days.

21. Sediment accumulation rates in the Cubits Gap reach during the 1989 hydrograph are shown in Plates 8-10. In the Cubits Gap reach with the existing and advance maintenance conditions, sediment accumulated fastest on the recession limb of the hydrograph, about a week after the peak flow. With the sediment trap, the highest accumulation rate was on the rising limb of the hydrograph, just before the peak flow. In Head of Passes, maximum accumulation rates occurred on the recession limb of the hydrograph, about a week after the peak flow, for all three conditions (Plates 11-13).

1979 Hydrograph

22. Maximum calculated bed elevation changes for existing conditions and for the advance maintenance and sediment trap alternatives during the 1979 hydrograph are shown in Figures 10 and 11 for the Cubits Gap and Head of Passes reaches, respectively. The length of time before project depth is lost can be determined from these figures. With this hydrograph, advance maintenance provided 7 extra days of project depth in the Cubits Gap reach, but the sediment trap lost project depth 5 days sooner than with existing conditions. In Head of Passes, the sediment trap provided an additional 13 days before project depth was lost; and advance maintenance, an additional 18 days.

23. Sediment accumulation rates in the Cubits Gap and Head of Passes reaches during the 1979 hydrograph are shown in Plates 14-19. Maximum sediment accumulation rates occurred on the rising limb of the hydrograph, about a

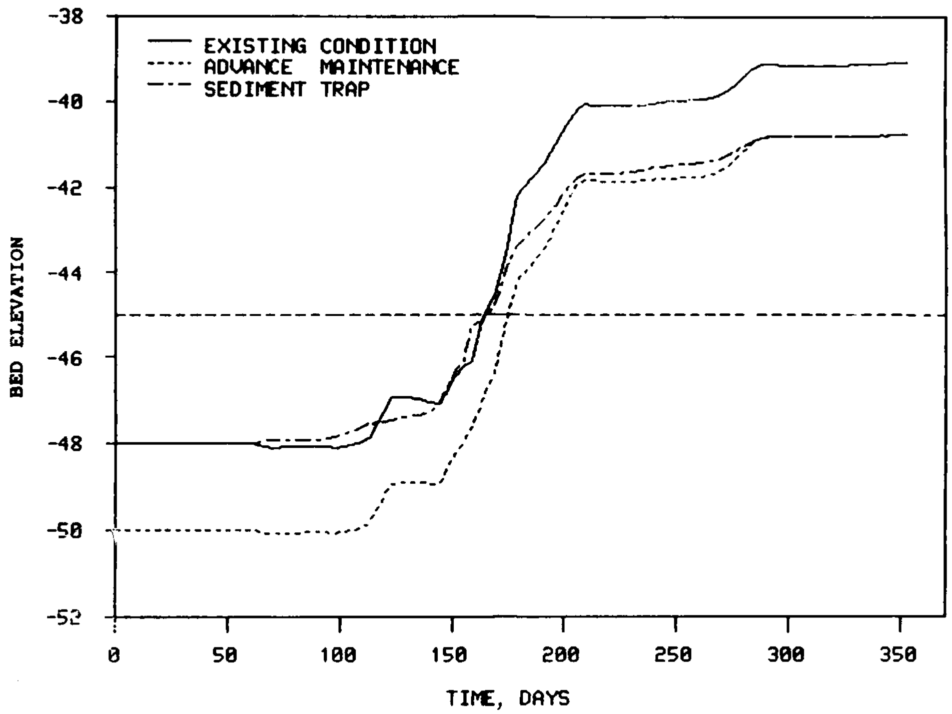

Figure 8. Maximum calculated bed elevation changes in Cubits Gap reach during 1989 hydrograph

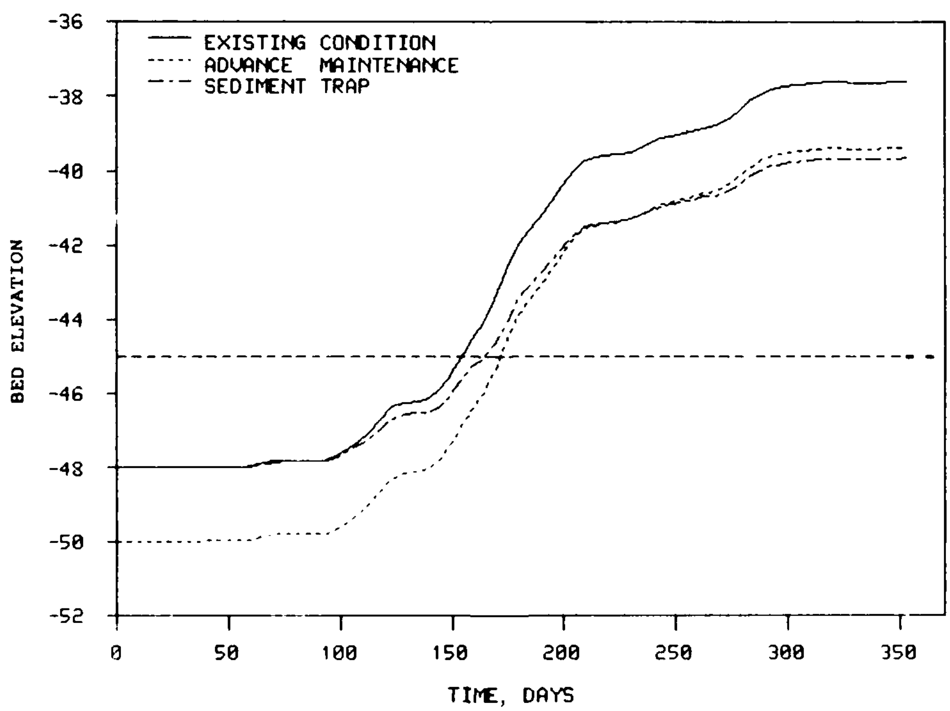

Figure 9. Maximum calculated bed elevation changes in Head of Passes reach during 1989 hydrograph

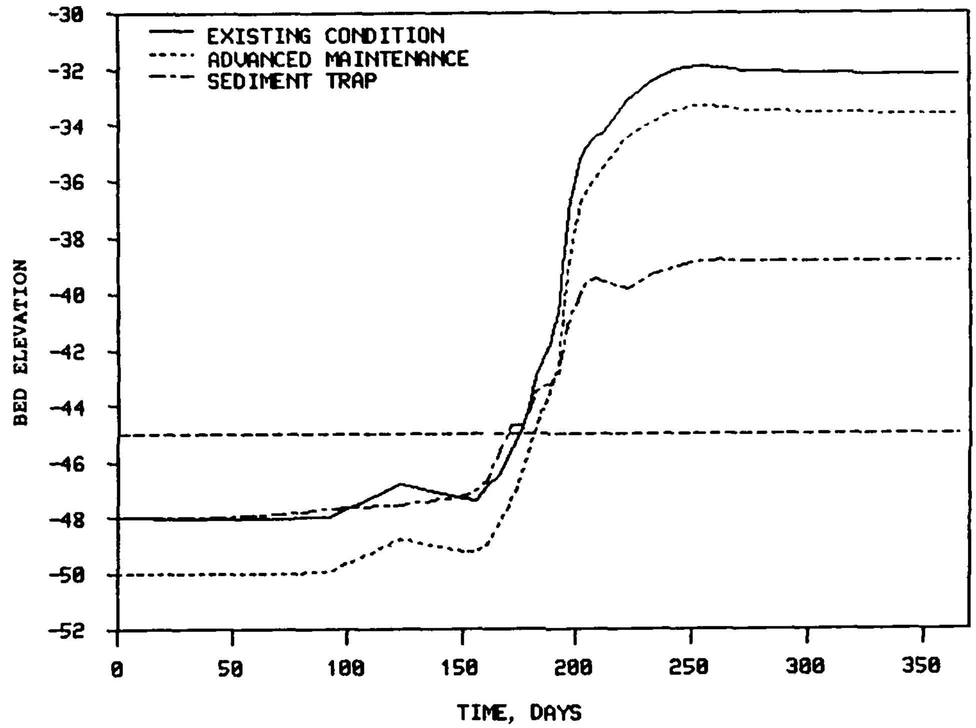

Figure 10. Maximum calculated bed elevation changes in Cubits Gap reach during 1979 hydrograph

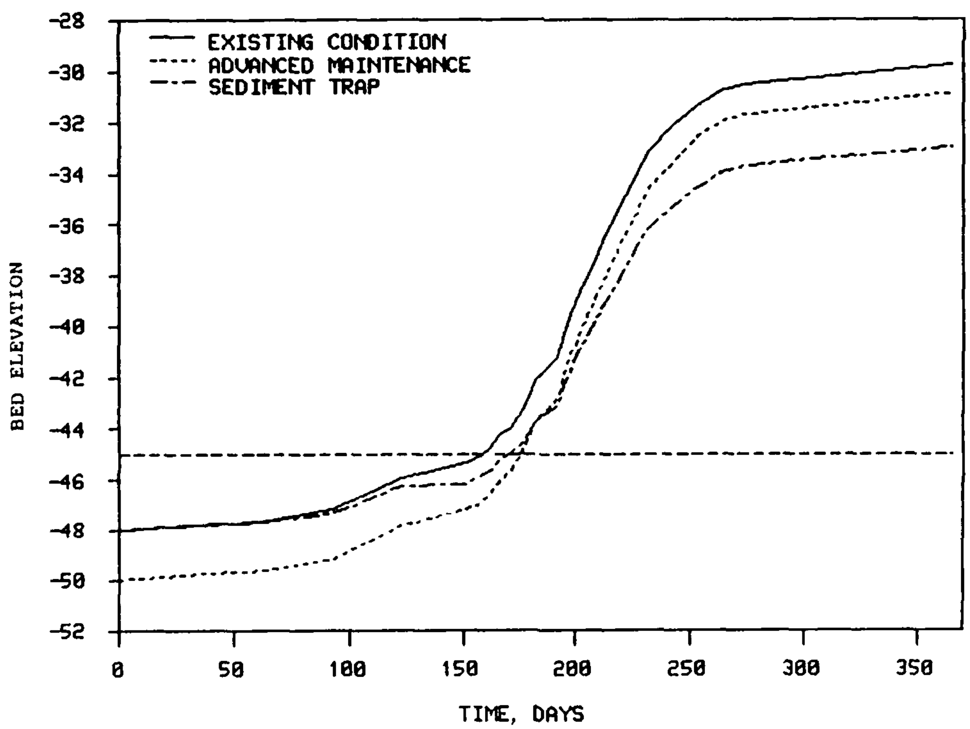

Figure 11. Maximum calculated bed elevation changes in Head of Passes reach during 1979 hydrograph

week before the peak flow, for all conditions tested in both Cubits Gap and Head of Passes.

Shifted Annual Hydrograph

24. Maximum calculated bed elevation changes in the Cubits Gap reach for existing conditions and for the advance maintenance and sediment trap alternatives during the shifted annual hydrograph are shown in Figure 12. This hydrograph was run for 2 years without dredging to determine the length of time before project depth was lost. With this hydrograph and the assumptions implicit in the model, el -45.0 was not exceeded in the Cubits Gap reach until the second year with the advance maintenance plan. Project depth was exceeded on the recession limb of the hydrograph for both the existing conditions and the sediment trap plan. The advance maintenance plan provided 324 extra days of project depth. With the sediment trap plan, dredging would be required 25 days sooner than with existing conditions. In Head of Passes, project depth was lost during the first year for all conditions tested. The advance maintenance plan provided an additional 39 days before losing project depth; the sediment trap provided an additional 9 days (Figure 13).

25. Sediment accumulation rates in the Cubits Gap and Head of Passes reaches were calculated using the shifted annual hydrograph. The highest accumulation rate was at the peak of the hydrograph for all conditions tested. The number of days that project depth would be lost was calculated assuming a dredging capacity of 25,000 and 50,000 cu yd per day in both the Cubits Gap and Head of Passes reaches. Dredging commenced on the day that project depth was encroached upon at the lesser of the accumulation rate or the dredging capacity. Once the accumulation rate exceeded the dredging capacity, project depth was considered lost. Dredging was continued at the designated dredging capacity rate until the sediment that deposited above el -45.0 was removed. Maximum accumulation rates and the number of days that project depth would be lost with dredging capacities of 25,000 and 50,000 cu yd per day are listed in Table 5. With this hydrograph, project depth was lost on the recession limb when accumulation rates were decreasing. Project depth was lost only with existing conditions in Head of Passes where the accumulation rate exceeded the dredging capacity.

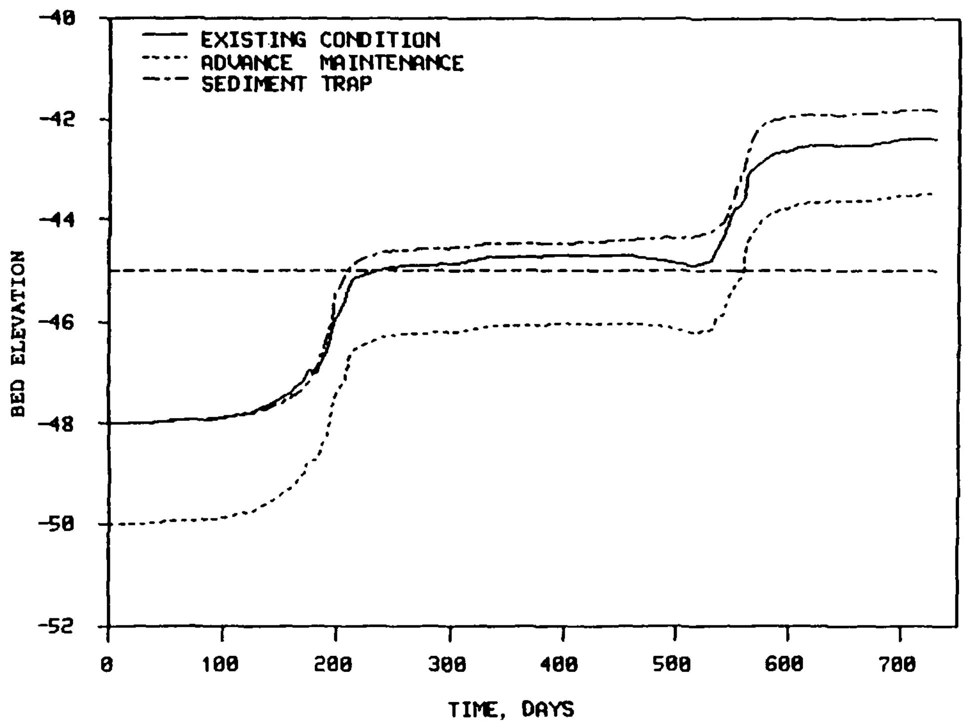

Figure 12. Maximum calculated bed elevation changes in the Cubits Gap reach, shifted hydrograph, run for 2 years

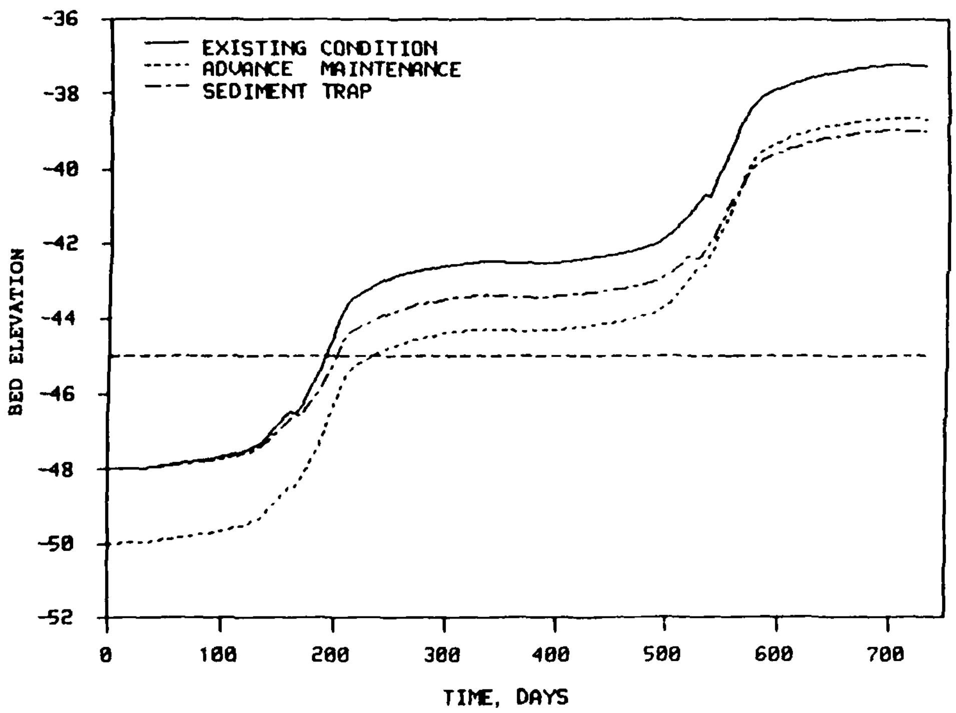

Figure 13. Maximum calculated bed elevation changes in the Head of Passes reach, shifted hydrograph, run for 2 years

Sensitivity to Movable-Bed Width

26. In this test, sediment deposition in the Cubits Gap reach was allowed to occur across a 1,750-ft-wide movable bed for existing conditions and advance maintenance, in addition to the sediment trap. For this test, deposition was weighted by depth in the numerical model. Because the movable-bed width was the same for all test cases, this provided a more realistic evaluation of the sediment trap when compared to existing conditions and advance maintenance.

27. The comparison between reported and calculated dredging in 1989 is shown in Table 6. These figures are not directly comparable because the initial bed geometry and the exact limits of dredging are unknown, but it provides a basis for evaluating model performance. The total of calculated dredging and deposition was the same as calculated dredging with the original movable-bed width assignment. Calculated dredging in Cubits Gap was very close to reported dredging, but calculated dredging in Head of Passes was less than reported. The calculated combined dredging total in Head of Passes and Cubits Gap is within 2 percent of reported dredging.

28. Comparisons of annual dredging between existing conditions, advance maintenance, and the sediment trap using the 1989 hydrograph are shown in Table 7. Deferred dredging in the Cubits Gap reach is sediment deposited outside the navigation channel and occurs in all test conditions. The advance maintenance plan resulted in an increase in total dredging of about 460,000 cu yd, or 8 percent. The sediment trap plan resulted in an increase in total dredging of about 720,000 cu yd, or 12 percent. These quantities are within 4 percent of those calculated with the original movable-bed widths.

29. Maximum calculated bed elevation changes in the Cubits Gap reach for existing conditions and for the two alternatives, during the 1989 hydrograph, are shown in Figure 14. With the advance maintenance proposal, the navigation channel did not reach el -45.0 during the first year. The 1989 hydrograph was repeated to determine the length of time required to reach el -45.0. Compared to existing conditions, the sediment trap caused more accumulation and provided 30 fewer days before maintenance was required The advance maintenance provided an open channel all year and part of the next year for a total of 341 extra days. This sensitivity study gives a better evaluation of the sediment trap in terms of its temporal performance in

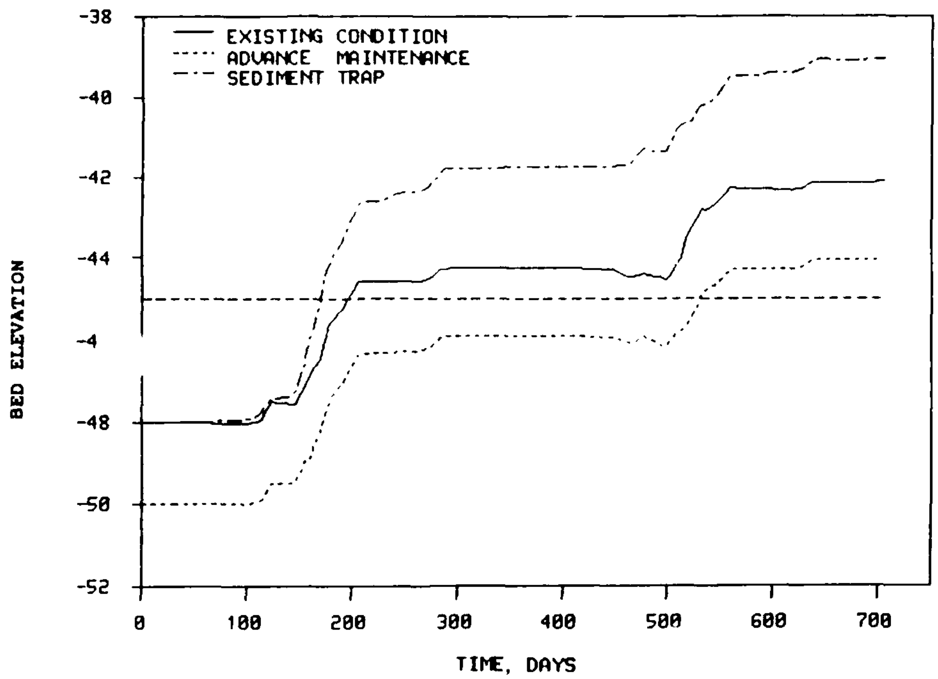

Figure 14. Maximum calculated bed elevation changes in Cubits Gap reach during 1989 hydrograph with 1,750-ft-wide movable-bed width

keeping the navigation channel open. When movable-bed widths were equal for the existing conditions and the two alternatives, the sediment trap was considerably less effective.

Sediment Trap in the Navigation Channel

30. A modified sediment trap alternative was tested. This proposal called for an increase in the width of the navigation channel between Head of Passes and mile 4.0 to 1,000 ft and an increase in overdredging to 5 ft. In the numerical model, initial bed elevations in Southwest Pass and in the vicinity of Cubits Gap were set at -50.0. This proposal was tested using the 1989 hydrograph. Results are listed in the following tabulation and should be compared to results from existing conditions and the other two alternatives in Table 2.

Reach		Amount million cubic yards	Percent Increase
Head of Passes		4.22	-1
Cubits Gap		2.37	36
	Total	6.59	10

Using the 1989 hydrograph, this plan resulted in an increase in total annual dredging in Head of Passes and Cubits Gap of 580,000 cu yd, or 10 percent, and provided 17 extra days of project depth in the Cubits Gap reach and 21 extra days in the Head of Passes reach. Calculated bed elevation changes in the Cubits Gap reach for this plan are compared to existing conditions in Figure 15.

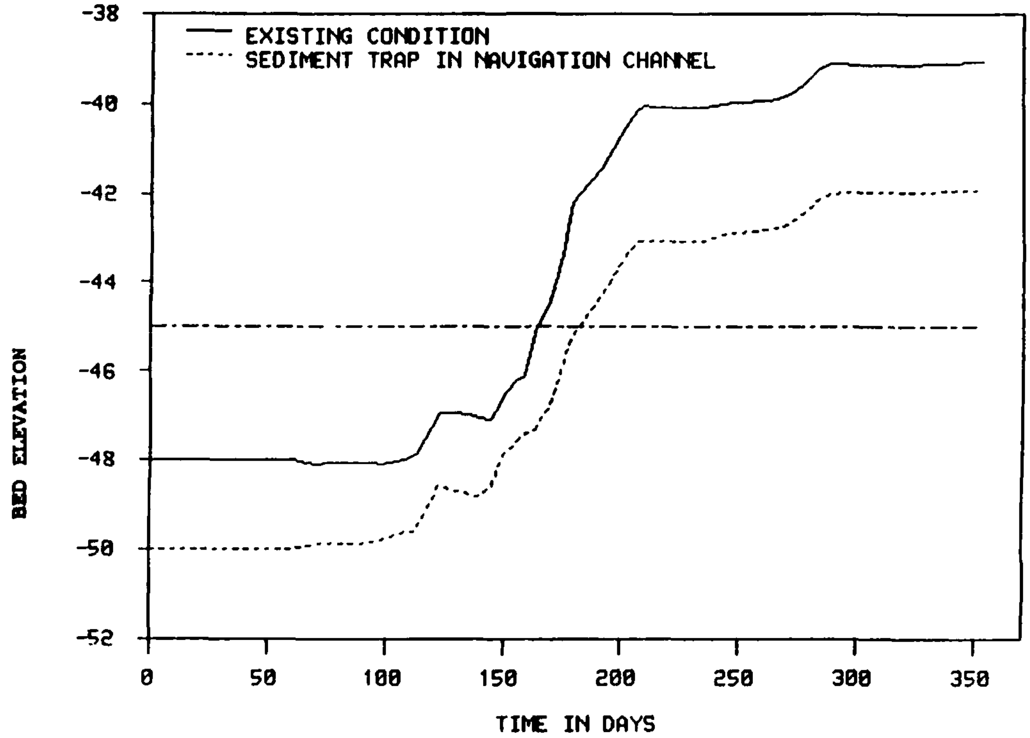

Figure 15. Maximum calculated bed elevation changes in Cubits Gap reach during 1989 hydrograph with sediment trap in navigation channel

Effect of Reducing Outflow at Cubits Gap

31. The sensitivity of shoaling downstream from Cubits Gap to the quantity of flow diverted through Cubits Gap was evaluated with the numerical model. Under existing conditions, sand concentrations through Cubits Gap are lower than in the Mississippi River because the bed through the gap is about 20 ft higher than in the river. Downstream from Cubits Gap there is less water in the river to carry the higher sand concentrations, and a potential for shoaling is created. The numerical model was used to determine the effect of a 50 percent reduction in flow through Cubits Gap. Specific structural

proposals with known diversion percentages may be evaluated when these plans become available.

32. The effect of reducing flow through Cubits Gap was tested using the 1989 hydrograph. Calculated annual dredging quantities and the percent increase from existing conditions are listed in the following tabulation and should be compared to results from existing conditions in Table 2.

Reach		Amount million cubic yards	Percent Increase
Head of Passes		4.05	-5
Cubits Gap		0.48	-72
	Total	4.53	-25

With the 1989 hydrograph, reducing flow through Cubits Gap by 50 percent resulted in a decrease in total annual dredging in Head of Passes and Cubits Gap of 1,480,000 cu yd, or 25 percent.

33. Calculated bed elevation changes in the navigation channel in the vicinity of Cubits Gap with the 50 percent flow reduction are compared to existing conditions in Figure 16. The 1989 hydrograph was run for 2 years without dredging to determine when project depth would be lost. With this hydrograph and the assumptions implicit in the model, project depth was not lost in the vicinity of Cubits Gap until the second year, providing 405 extra days of project depth. Accumulation rates decreased as the navigation channel filled, so that accumulation rates were less in the second year, as shown in Plate 20. In the second year, on the date that project depth was lost, the accumulation rate was 5,000 cu yd per day. The maximum calculated accumulation rate was 21,000 cu yd per day.

34. Calculated bed elevation changes in the navigation channel in Head of Passes with the 50 percent flow reduction are compared to existing conditions in Figure 17. With this hydrograph and the assumptions implicit in the model, project depth was lost during the first year in Head of Passes 4 days sooner than with existing conditions. Accumulation rates in Head of Passes are shown in Plate 21. On the date that project depth was lost, the accumulation rate was 37,000 cu yd per day. The maximum calculated accumulation rate was 49,000 cu yd per day.

35. The number of days that the project depth of 45 ft would be lost during the 1989 hydrograph was calculated assuming a dredging capacity of 25,000 and 50,000 cu yd per day in both the Cubits Gap and in Head of Passes

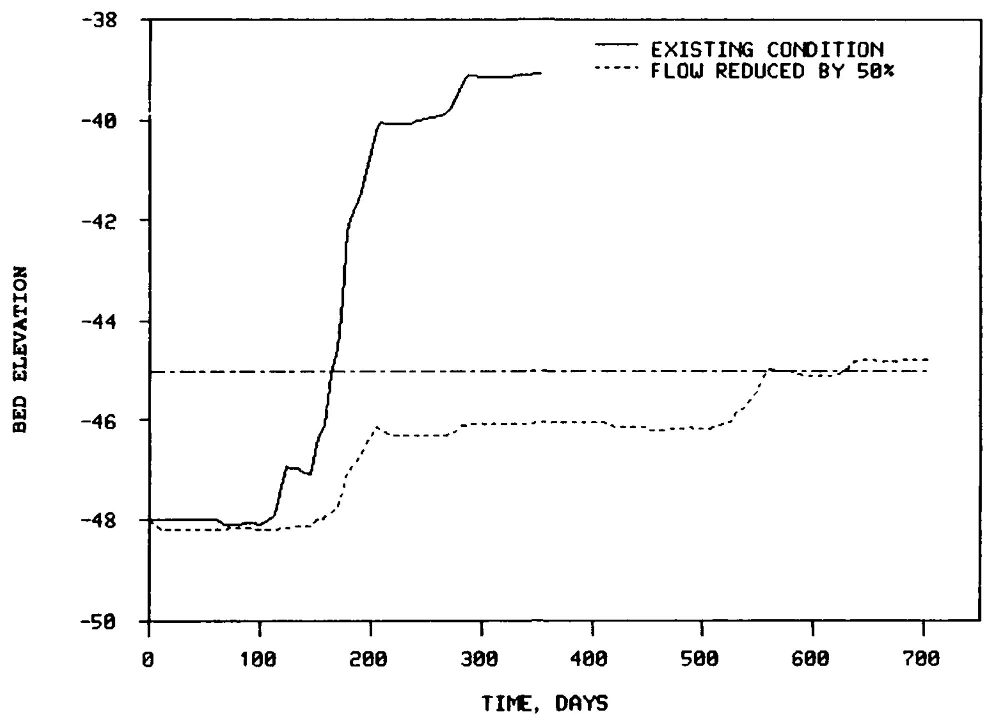

Figure 16. Maximum calculated bed elevation changes in Cubits Gap reach during 1989 hydrograph with outflow through Cubits Gap reduced by 50 percent

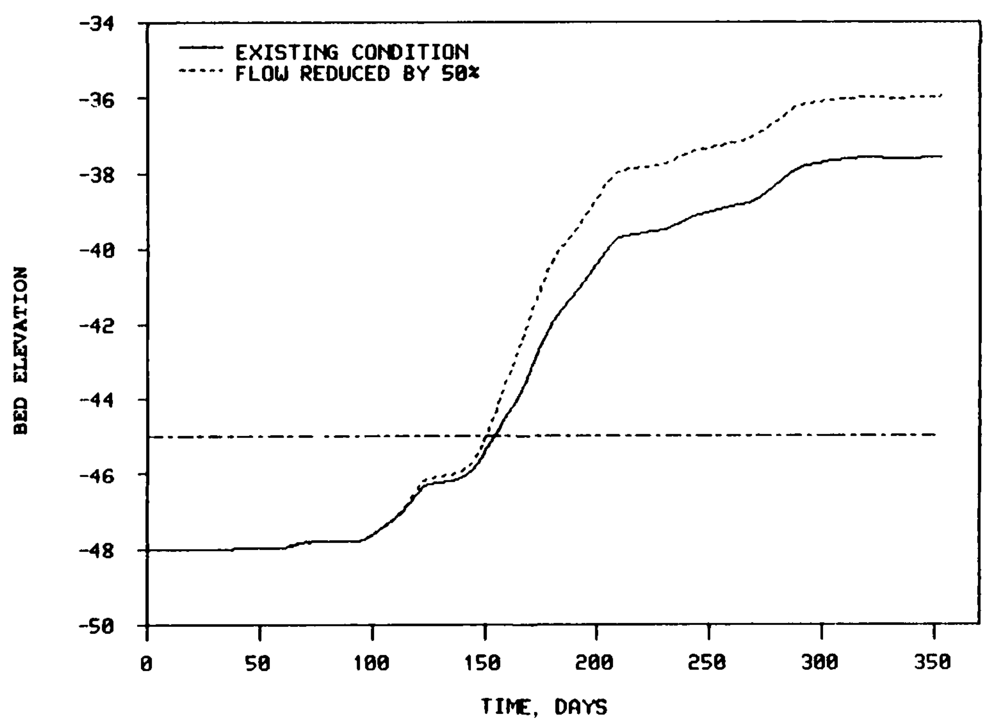

Figure 17. Maximum calculated bed elevation changes in Head of Passes during 1989 hydrograph with outflow through Cubits Gap reduced by 50 percent

reaches. With the 1989 hydrograph, project depth was not lost in Cubits Gap or in Head of Passes with a dredging rate of 50,000 cu yd per day. However, in Head of Passes, with a dredging capacity of 25,000 cu yd per day, project depth was lost on the rising limb of the hydrograph when accumulation rates were increasing, and was lost for 81 days.

1974-1983 Annual Hydrographs

36. The dredging alternatives and the effect of reducing Cubits Gap outflow were evaluated using the 1974-1983 and 1989 annual hydrographs. Annual sediment accumulation, additional days before project depth encroachment, maximum sediment accumulation rates, and the number of days that the project depth was lost were calculated and are listed for each hydrograph in Tables 8-18. A summary of sediment accumulation is shown in Table 19 and is used to calculate an average accumulation for the 11 years in Table 20. A summary of the number of days project depth was lost is shown in Table 21 and is used to predict the percent of time that project depth would be maintained over the 11 years.

37. The greatest benefits from the advance maintenance alternative were realized during years with slightly above average runoff (1974, 1975, 1989). Benefits were negligible during low runoff years where there was no encroachment into project depth, but sediment accumulation was greater. The extra sediment storage capacity provided by the advance maintenance alternative was insufficient to compensate for sediment deposition during very high runoff years (1979 and 1983). One benefit from advance maintenance was realized as the extra storage capacity provided additional days before project depth was lost. A good example of this is the 1982 hydrograph where the peak discharge and maximum accumulation occurred early in the water year when there was sufficient storage provided by the advance maintenance to contain the deposited sediment. An additional 66 days were provided in the Cubits Gap reach and an additional 37 days in the Head of Passes reach. Additional benefits may be attained during years where the storage capacity is sufficient to contain the sediment deposited during periods of maximum sediment accumulation. Dredging may then be able to keep up with sediment accumulation on the recession limb of the hydrograph. A good example of this is the 1974 hydrograph where project depth was not lost until the falling limb of the hydrograph with advance

maintenance, but was lost just before the peak flow with existing conditions. As a result, project depth was maintained for 23 more days with advance maintenance and a 25,000-cu-yd-per-day dredging capacity. Of these 23 days, 12 are attributed to extra storage on the rising limb, and 11 to storage of the peak accumulation. With the 11 annual hydrographs, project depth was maintained 94 percent of the time in the Cubits Gap reach and 84 percent of the time in the Head of Passes reach with the advance maintenance alternative and a dredging capacity of 25,000 cu yd per day. This is an improvement over existing conditions, which provide for project depth 93 percent of the time in the Cubits Gap reach and 81 percent of the time in the Head of Passes reach. With a dredging capacity of 50,000 cu yd per day, project depth was maintained 98 percent of the time in the Cubits Gap reach and 95 percent of the time in the Head of Passes reach for both existing and advance maintenance conditions.

38. The extra storage capacity provided with the advance maintenance alternative has the disadvantage of reducing sediment transport potential and thus increasing sediment accumulation rates. The advance maintenance alternative results in a combined 6 percent increase in sediment accumulation.

39. The sediment trap alternative involves significant increases in the channel cross-sectional area, which decreases sediment transport potential. As a result, sediment accumulation in Cubits Gap was 88 percent higher. During the 11 annual hydrographs, combined sediment accumulation in Cubits Gap and Head of Passes was 10 percent higher with the sediment trap. With the sediment trap alternative, maintaining project depth in Cubits Gap would be more difficult. With a dredging capacity of 25,000 cu yd per day, project depth was maintained 86 percent of the time with the sediment trap alternative compared to 93 percent of the time with the existing conditions. In Head of Passes, project depth was maintained 88 percent of the time with the sediment trap compared to 81 percent of the time with existing conditions. With a dredging capacity of 50,000 cu yd per day, project depth was maintained 95 percent of the time with the sediment trap alternative compared to 98 percent of the time with the existing conditions. In Head of Passes, project depth was maintained 97 percent of the time with the sediment trap compared to 95 percent of the time with existing conditions.

40. Reducing the outflow through Cubits Gap provided reduced shoaling in the Cubits Gap reach for all hydrographs tested. This included both high- and low-runoff years. Average annual shoaling was reduced 81 percent in the

Cubits Gap reach and 8 percent in the Head of Passes reach, with a combined reduction of 26 percent. In the Cubits Gap reach, with a dredging capacity of 25,000 cu yd per day, project depth was maintained 100 percent of the time when flow through Cubits Gap was reduced by 50 percent. The shoal downstream from Cubits Gap is due primarily to reduced transport potential created by the distributary. Reducing the impact of the distributary by reducing its outflow also reduces the shoaling problem downstream. Project depth was maintained 80 percent of the time in Head of Passes with a dredging capacity of 25,000 cu yd per day and 96 percent of the time with 50,000 cu yd per day. In some relatively low runoff years (1980 and 1982), conditions appeared to be worse at Head of Passes with this alternative because there were more days without project depth than for existing conditions. This condition was created because the shoal at Cubits Gap was scoured at high flows, which caused increased sediment accumulation temporarily in Head of Passes. This condition was eventually overcome, and for years with slightly above average runoff, the increased sediment transport potential provides benefits in Head of Passes as well as in the Cubits Gap reach.

Effect of Upstream Agitation Dredging

41. The effect of introducing additional sediment into suspension due to agitation dredging downstream from Venice was evaluated with the numerical model. In the model, this material was not taken from the active riverbed and suspended, but was simply added to the sediment load in suspension. Dredging operations were simulated for 182 days, between 1 October 1988 and 31 March 1989. Dredging rates of 24,000, 12,000, and 6,000 cu yd per day were tested. The effect of the increased sediment load on bed elevation changes in the Cubits Gap reach is shown in Figure 18. Bed elevation changes in Head of Passes were negligible. The agitation dredging caused an increased shoaling rate in Cubits Gap, so that project depth was lost 43 days sooner with agitation dredging of 24,000 cu yd per day, 42 days sooner with agitation dredging of 12,000 cu yd per day, and 41 days sooner with agitation dredging of 6,000 cu yd per day. The effect of agitation dredging on sediment accumulation in the Cubits Gap and Head of Passes reaches is listed in the following tabulation.

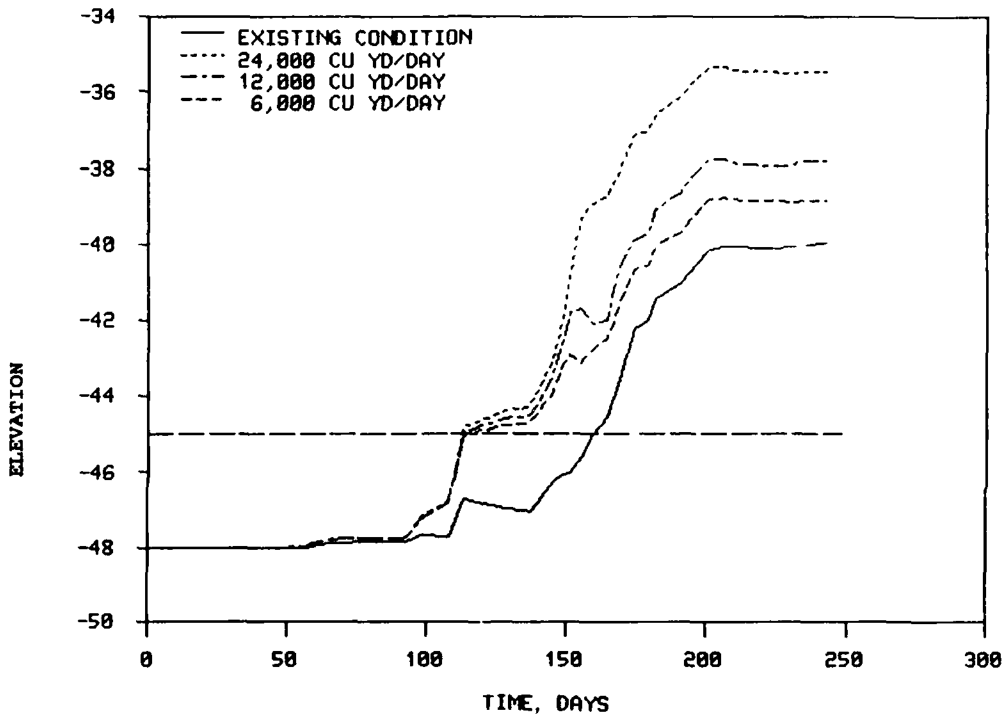

Figure 18. Maximum calculated bed elevation changes in Cubits Gap reach with introduction of additional suspended sediment downstream from Venice

Reach	Accumulation, million cubic yards: Existing Conditions	Agitation Dredging Rate cu yd/day: 24,000	12,000	6,000
Cubits Gap	1.07	2.39	1.81	1.48
Head of Passes	2.38	2.57	2.55	2.53
Total	3.45	4.96	4.36	4.01

42. Numerical model results indicated that a significant portion of the sediment introduced into the system downstream from Venice deposited before it reached Cubits Gap. When the simulation was extended through the end of 1989 and the shifted annual hydrograph added to the simulation, 48, 38, and 16 percent of the additional sediment remained upstream of Cubits Gap at agitation dredging rates of 24,000, 12,000, and 6,000 cu yd per day, respectively. A sediment budget that accounts for the distribution of the sediment added by agitation dredging is listed in Table 22. Sediment deposited by agitation dredging may take several years to pass through the river system, during which time it will continue to affect shoaling at Cubits Gap.

Forecasting with the Numerical Model

43. The numerical model was used to forecast sediment accumulation rates and dredging requirements in the Cubits Gap and Head of Passes reaches. Required input was initial channel geometry, sediment inflow, and a forecast hydrograph. For testing purposes, the same sediment inflow used in the existing model, which was based on 1976-1982 measured data, was used with the numerical model to forecast sediment accumulation rates for a 5-week forecast hydrograph between 10 January 1990 and 12 February 1990. The forecast model simulation started in October 1988 and extended to 12 February 1990. Dredging of the navigation channel was simulated in June 1989 when actual dredging operations ceased. Initial bed elevations in the navigation channel were set such that calculated bed elevations on 2 January 1990 matched surveyed bed elevations in the navigation channel. The numerical model predicted an accumulation of 140,000 cu yd in Head of Passes, and degradation of 2,000 cu yd in the Cubits Gap reach. Maximum bed elevation changes were 0.34 ft in Head of Passes and 0.03 ft in the Cubits Gap reach. No encroachment into project depth was forecast.

PART V: CONCLUSIONS

44. Sediment accumulation in the Cubits Gap and Head of Passes reaches during an annual hydrograph can be estimated using the TABS-1 one-dimensional numerical model. Dredging quantities can be estimated if initial bed geometry, sediment inflow, and hydrology are defined. Calculated sediment accumulation during the 1989 hydrograph was within 2 percent of reported dredging quantities.

45. Alternative dredging operations can be evaluated using the numerical model by comparing the performance of the alternatives to the performance of the existing channel. Dredging requirements in the Cubits Gap and Head of Passes reaches are dependent on the annual hydrograph. Eleven annual hydrographs (1974-1983 and 1989) were used to calculate sediment accumulation quantities and the number of days that project depth could be maintained with designated dredging capacities. For the 11 years tested, with existing conditions, and a dredging capacity of 25,000 cu yd per day, project depth can be maintained 93 percent of the time in the Cubits Gap reach and 81 percent of the time in the Head of Passes reach. With a dredging capacity of 50,000 cu yd per day, project depth can be maintained 98 percent of the time in the Cubits Gap reach and 95 percent of the time in the Head of Passes reach.

46. The advance maintenance alternative provides its greatest benefit during years with slightly above average runoff. Numerical model results for the 11 annual hydrographs, advance maintenance, and a dredging capacity of 25,000 cu yd per day predicted project depth could be maintained 94 percent of the time in the Cubits Gap reach and 84 percent of the time in the Head of Passes reach. With a dredging capacity of 50,000 cu yd per day, project depth was maintained 98 percent of the time in the Cubits Gap reach and 95 percent of the time in the Head of Passes reach. Combined sediment accumulation was 6 percent higher with this alternative.

47. The sediment trap alternative significantly reduces sediment transport potential in the Cubits Gap reach, resulting in greater sediment accumulation. With the 11 annual hydrographs, sediment accumulation was 88 percent higher in the Cubits Gap reach and 10 percent higher in the combined Cubits Gap and Head of Passes reaches. With the sediment trap and a dredging capacity of 25,000 cu yd per day, project depth was maintained 86 percent of the

time in the Cubits Gap reach and 88 percent of the time in the Head of Passes reach. With a dredging capacity of 50,000 cu yd per day, project depth was maintained 95 percent of the time in the Cubits Gap reach and 97 percent of the time in the Head of Passes reach. This performance is not an improvement over existing conditions, even though the sediment trap alternative was evaluated with a wider movable-bed width in the numerical model.

48. Given that Cubits Gap captures between 15 and 27 percent of the total riverflow at Venice, using the average from 11 annual hydrographs, the numerical model study indicated that with a 50 percent reduction of the outflow through Cubits Gap, shoaling in the Cubits Gap reach would be reduced by 81 percent, and in the Head of Passes reach by 8 percent. Sediment accumulation in the combined Cubits Gap and Head of Passes reaches would be reduced by 26 percent. Project depth would be maintained 100 percent of the time in the Cubits Gap reach and 80 percent of the time in the Head of Passes reach with a dredging capacity of 25,000 cu yd per day. With a dredging capacity of 50,000 cu yd per day, project depth could be maintained 96 percent of the time in Head of Passes.

49. Agitation dredging, which introduces additional suspended sediment into the flow, will increase sediment accumulation rates downstream, and will influence downstream shoaling rates for several years.

50. The numerical model may be used to forecast sedimentation in the Cubits Gap and Head of Passes reaches. Reliable forecasting depends on a reliable forecast hydrograph, reliable sediment inflow, and the availability of initial bed elevations for the navigation channel. The model can be useful to dredging management by assisting the Operations Division to anticipate problem periods earlier, thus allowing for more orderly scheduling of dredging operations on a routine rather than emergency basis.

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Table 1

Comparison of Calculated and Reported Dredging in the Vicinity of Head of Passes and Cubits Gap, 1989

Reach		Amount Dredged million cubic yards
	Reported Dredging	
Cubits Gap		0.8
Head of Passes		4.3
	Total	5.1
	Calculated Dredging	
Cubits Gap		1.5
Head of Passes		3.5
	Total	5.0

Note: Calculated dredging based on October 1988 through May 1989 hydrograph. Reported dredging occurred between February and May 1989.

Table 2

Calculated Dredging and Deferred Dredging

1989 Hydrograph

Reach		Amount Dredged million cubic yards			Percent Increase	
		Annual	Deferred	Total	Annual	Total
			Existing Channel			
Head of Passes		4.27	--	4.27	--	--
Cubits Gap		1.74	--	1.74	--	--
	Total	6.01	--	6.01	--	--
			Advance Maintenance			
Head of Passes		4.40	--	4.40	3	3
Cubits Gap		2.06	--	2.06	18	18
	Total	6.46		6.46	7	7
			Sediment Trap			
Head of Passes		3.38	--	3.38	-21	-21
Cubits Gap		1.50	1.88	3.38	-14	94
	Total	4.88	1.88	6.76	-19	12

Note: Deferred dredging is sediment deposited outside the navigation channel.

Table 3

Calculated Dredging and Deferred Dredging

1979 Hydrograph

Reach		Amount Dredged million cubic yards Annual	Deferred	Total	Percent Increase Annual	Total
			Existing Channel			
Head of Passes		6.54	—	6.54	--	--
Cubits Gap		2.76	—	2.76	--	--
	Total	9.30	—	9.30	--	--
			Advance Maintenance			
Head of Passes		7.06	—	7.06	8	8
Cubits Gap		3.35	—	3.35	21	21
	Total	10.41	—	10.41	12	12
			Sediment Trap			
Head of Passes		5.54	—	5.54	-15	-15
Cubits Gap		2.07	2.95	5.02	-25	82
	Total	7.61	2.95	10.56	-18	14

Note: Deferred dredging is sediment deposited outside the navigation channel.

Table 4

Calculated Deposition and Dredging

Shifted Annual Hydrograph

Reach		Amount Dredged million cubic yards Annual	Deferred	Total	Percent Increase Annual	Total
			Existing Channel			
Head of Passes		2.59	—	2.59	--	--
Cubits Gap		0.67	—	0.67	--	--
	Total	3.26	—	3.26	--	--
			Advance Maintenance			
Head of Passes		2.74	—	2.74	6	6
Cubits Gap		0.80	—	0.80	19	19
	Total	3.54	—	3.54	9	9
			Sediment Trap			
Head of Passes		2.17	—	2.17	-16	-16
Cubits Gap		0.61	0.86	1.47	-9	119
	Total	2.78	0.86	3.64	-15	12

Note: Deferred dredging is sediment deposited outside the navigation channel.

Table 5

Shifted Annual Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.67	—	21,000	0 (0)
Head of Passes	2.59	—	34,000	22 (0)
Total	3.26			
		Advance Maintenance		
Cubits Gap	0.80	324	22,000	0 (0)
Head of Passes	2.74	39	37,000	0 (0)
Total	3.54			
		Sediment Trap		
Cubits Gap	1.47	-25	33,000	0 (0)
Head of Passes	2.17	9	26,000	0 (0)
Total	3.64			

Table 6

Comparison of Calculated and Reported Dredging in the Vicinity of Head of Passes and Cubits Gap 1989

Reach		Amount Dredged million cubic yards
	Reported Dredging*	
Cubits Gap		0.8
Head of Passes		4.3
	Total	5.1
	Calculated Dredging**	
Cubits Gap		0.7
Head of Passes		3.5
	Total	4.2
	Calculated Dredging and Deposition	
Cubits Gap		1.5
Head of Passes		3.5
	Total	5.0

Note: This table is for movable-bed widths of 1,750 ft in Cubits Gap reach and depth-weighted deposition.

* Reported dredging between February and May 1989.

** Calculated dredging based on October 1988 to May 1989 hydrograph.

Table 7

Calculated Dredging and Deferred Dredging

1989 Hydrograph

Reach		Amount Dredged million cubic yards Annual	Deferred	Total	Percent Increase Annual	Total
		Existing Channel				
Head of Passes		4.28	—	4.28	--	--
Cubits Gap		0.82	0.92	1.74	--	--
	Total	5.10	0.92	6.02	--	--
		Advance Maintenance				
Head of Passes		4.45	—	4.45	4	4
Cubits Gap		1.01	1.02	2.03	23	17
	Total	5.46	1.02	6.48	7	8
		Sediment Trap				
Head of Passes		3.37	—	3.37	-21	-21
Cubits Gap		1.51	1.86	3.37	84	94
	Total	4.88	1.86	6.74	-4	12

Note: Deferred dredging is sediment deposited outside the navigation channel.

Table 8

1974 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	2.03	—	88,000	41 (15)
Head of Passes	4.97	—	80,000	118 (19)
Total	7.00			
		Advance Maintenance		
Cubits Gap	2.21	12	87,000	18 (5)
Head of Passes	5.12	17	81,000	94 (26)
Total	7.33			
		Sediment Trap		
Cubits Gap	3.62	1	81,000	82 (28)
Head of Passes	3.89	10	60,000	63 (11)
Total	7.51			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.44	>234	14,000	0 (0)
Head of Passes	4.81	-5	55,000	115 (15)
Total	5.25			

Table 9

1975 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	1.65	—	38,000	12 (0)
Head of Passes	4.24	—	44,000	102 (0)
Total	5.89			
		Advance Maintenance		
Cubits Gap	1.81	10	39,000	6 (0)
Head of Passes	4.35	20	44,000	79 (0)
Total	6.16			
		Sediment Trap		
Cubits Gap	3.31	1	58,000	76 (13)
Head of Passes	3.46	12	35,000	61 (0)
Total	6.77			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.56	48	27,000	0 (0)
Head of Passes	4.16	-5	42,000	93 (0)
Total	4.72			

Table 10

1976 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.18	—	2,000	0 (0)
Head of Passes	1.55	—	11,000	0 (0)
Total	1.73			
		Advance Maintenance		
Cubits Gap	0.20	*	2,000	0 (0)
Head of Passes	1.64	*	13,000	0 (0)
Total	1.84			
		Sediment Trap		
Cubits Gap	0.41	*	3,000	0 (0)
Head of Passes	1.41	*	10,000	0 (0)
Total	1.82			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.00	*	500	0 (0)
Head of Passes	1.38	*	11,000	0 (0)
Total	1.38			

* No encroachment on project depth.

Table 11

1977 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before *Project Depth* Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.34	—	9,000	0 (0)
Head of Passes	1.64	—	15,000	0 (0)
Total	1.98			
		Advance Maintenance		
Cubits Gap	0.44	*	10,000	0 (0)
Head of Passes	1.73	*	16,000	0 (0)
Total	2.17			
		Sediment Trap		
Cubits Gap	0.71	*	12,000	0 (0)
Head of Passes	1.40	11	12,000	0 (0)
Total	2.11			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.06	*	400	0 (0)
Head of Passes	1.53	7	17,000	0 (0)
Total	1.59			

* No encroachment on project depth.

Table 12

1978 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.63	—	17,000	0 (0)
Head of Passes	2.50	—	29,000	17 (0)
Total	3.13			
		Advance Maintenance		
Cubits Gap	0.72	*	17,000	0 (0)
Head of Passes	2.63	36	31,000	0 (0)
Total	3.35			
		Sediment Trap		
Cubits Gap	1.15	**	36,000	0 (0)
Head of Passes	2.10	9	20,000	0 (0)
Total	3.25			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.11	*	5,000	0 (0)
Head of Passes	2.27	2	29,000	17 (0)
Total	2.38			

* No encroachment on project depth.

** Encroachment on project depth on day 241 of hydrograph.

Table 13

1979 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	2.52	—	105,000	76 (11)
Head of Passes	7.00	—	122,000	225 (86)
Total	9.52			
		Advance Maintenance		
Cubits Gap	2.95	7	105,000	92 (21)
Head of Passes	7.20	18	128,000	204 (83)
Total	10.15			
		Sediment Trap		
Cubits Gap	4.52	-5	156,000	138 (63)
Head of Passes	5.93	13	96,000	169 (60)
Total	10.45			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.34	>190	11,000	0 (0)
Head of Passes	6.64	-8	95,000	223 (63)
Total	6.98			

Table 14

1980 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.88	—	34,000	2 (0)
Head of Passes	2.40	—	32,000	19 (0)
Total	3.28			
		Advance Maintenance		
Cubits Gap	1.04	*	37,000	0 (0)
Head of Passes	2.51	25	35,000	0 (0)
Total	3.55			
		Sediment Trap		
Cubits Gap	1.46	18	33,000	0 (0)
Head of Passes	1.98	8	25,000	0 (0)
Total	3.44			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.14	*	15,000	0 (0)
Head of Passes	2.46	-4	39,000	31 (0)
Total	2.60			

* No encroachment on project depth.

Table 15

1981 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	0.31	—	2,000	0 (0)
Head of Passes	1.56	—	13,000	0 (0)
Total	1.87			
		Advance Maintenance		
Cubits Gap	0.37	*	3,000	0 (0)
Head of Passes	1.60	*	13,000	0 (0)
Total	1.97			
		Sediment Trap		
Cubits Gap	0.63	*	6,000	0 (0)
Head of Passes	1.39	*	12,000	0 (0)
Total	2.02			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.02	*	1,000	0 (0)
Head of Passes	1.52	*	13,000	0 (0)
Total	1.54			

* No encroachment on project depth.

Table 16

1982 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	1.37	—	41,000	5 (0)
Head of Passes	3.64	—	38,000	0 (0)
Total	5.01			
		Advance Maintenance		
Cubits Gap	1.67	66	46,000	0 (0)
Head of Passes	3.76	37	39,000	0 (0)
Total	5.43			
		Sediment Trap		
Cubits Gap	2.34	74	50,000	0 (0)
Head of Passes	2.89	27	26,000	0 (0)
Total	5.23			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.23	*	5,000	0 (0)
Head of Passes	3.84	-40	68,000	9 (5)
Total	4.07			

* No encroachment on project depth.

Table 17

1983 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	4.12	—	94,000	116 (48)
Head of Passes	7.20	—	108,000	214 (85)
Total	11.32			
		Advance Maintenance		
Cubits Gap	4.50	9	94,000	108 (47)
Head of Passes	7.39	13	124,000	189 (79)
Total	11.89			
		Sediment Trap		
Cubits Gap	6.30	16	134,000	190 (75)
Head of Passes	5.77	13	85,000	152 (65)
Total	12.07			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.88	152	17,000	0 (0)
Head of Passes	7.01	-8	85,000	226 (75)
Total	7.89			

Table 18

1989 Hydrograph Summary

Reach	Annual Accumulation million cubic yards	Extra Days Before Project Depth Lost Without Dredging	Maximum Sediment Accumulation Rate cu yd/day	Days Project Depth Lost with Dredging Capacity of 25,000 (50,000) cu yd/day
		Existing Conditions		
Cubits Gap	1.74	—	40,000	21 (0)
Head of Passes	4.27	—	55,000	81 (11)
Total	6.01			
		Advance Maintenance		
Cubits Gap	2.06	10	40,000	13 (0)
Head of Passes	4.40	18	58,000	55 (11)
Total	6.46			
		Sediment Trap		
Cubits Gap	3.38	2	75,000	61 (15)
Head of Passes	3.38	11	44,000	52 (0)
Total	6.76			
		50% Flow Reduction Cubits Gap		
Cubits Gap	0.45	*	21,000	0 (0)
Head of Passes	3.67	-4	49,000	81 (0)
Total	4.12			

* No encroachment on project depth.

Table 19

Annual Sediment Accumulation

Year	Reach	Accumulation, million cubic yards			
		Existing Conditions	Advance Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
1974	Cubits Gap	2.03	2.21	3.62	0.44
	Head of Passes	4.97	5.12	3.89	4.81
	Total	7.00	7.33	7.51	5.25
1975	Cubits Gap	1.65	1.81	3.31	0.56
	Head oi Passes	4.24	4.35	3.46	4.16
	Total	5.89	6.16	6.77	4.72
1976	Cubits Gap	0.18	0.20	0.41	0.00
	Head of Passes	1.55	1.64	1.41	1.38
	Total	1.73	1.84	1.82	1.38
1977	Cubits Gap	0.34	0.44	0.71	0.06
	Head of Passes	1.64	1.73	1.40	1.53
	Total	1.98	2.17	2.11	1.59
1978	Cubits Gap	0.63	0.72	1.15	0.11
	Head of Passes	2.50	2.63	2.10	2.27
	Total	3.13	3.35	3.25	2.38
1979	Cubits Gap	2.52	2.95	4.52	0.34
	Head of Passes	7.00	7.20	5.93	6.64
	Total	9.52	10.15	10.45	6.98
1980	Cubits Gap	0.88	1.04	1.46	0.14
	Head of Passes	2.40	2.51	1.98	2.46
	Total	3.28	3.55	3.44	2.60
1981	Cubits Gap	0.31	0.37	0.63	0.02
	Head of Passes	1.56	1.60	1.39	1.52
	Total	1.87	1.97	2.02	1.54
1982	Cubits Gap	1.37	1.67	2.34	0.23
	Head of Passes	3.64	3.76	2.89	3.84
	Total	5.01	5.43	5.23	4.07
1983	Cubits Gap	4.12	4.50	6.30	0.88
	Head of Passes	7.20	7.39	5.77	7.01
	Total	11.32	11.89	12.07	7.89
1989	Cubits Gap	1.74	2.06	3.38	0.45
	Head of Passes	4.27	4.40	3.38	3.67
	Total	6.01	6.46	6.76	4.12

Table 20

Annual Sediment Accumulation

Averaged from 11 Hydrographs

Reach	Existing Conditions	Advance Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
		Accumulation, million cubic yards		
Cubits Gap	1.30	1.48	2.44	0.25
Head of Passes	3.74	3.87	3.08	3.46
Total	5.04	5.35	5.52	3.71
		Percent Annual Increase in Accumulation		
Cubits Gap	—	14	88	−81
Head of Passes	—	4	−18	−8
Total		6	10	−26

Table 21

Days Without Project Depth with Dredging Capacity

of 25,000 (50,000) cu yd per day

Year	Reach	Existing Conditions	Advance Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
1974	Cubits Gap	41 (15)	18 (5)	82 (28)	0 (0)
	Head of Passes	118 (19)	94 (26)	63 (11)	115 (15)
1975	Cubits Gap	12 (0)	6 (0)	76 (13)	0 (0)
	Head of Passes	102 (0)	79 (0)	61 (0)	93 (0)
1976	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1977	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1978	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	17 (0)	0 (0)	0 (0)	17 (0)
1979	Cubits Gap	76 (11)	92 (21)	138 (63)	0 (0)
	Head of Passes	225 (86)	204 (83)	169 (60)	223 (63)
1980	Cubits Gap	2 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	19 (0)	0 (0)	0 (0)	31 (0)
1981	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1982	Cubits Gap	5 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	9 (5)
1983	Cubits Gap	116 (48)	108 (47)	190 (75)	0 (0)
	Head of Passes	214 (85)	189 (79)	152 (65)	226 (75)
1989	Cubits Gap	21 (0)	13 (0)	61 (15)	0 (0)
	Head of Passes	81 (11)	55 (11)	52 (0)	81 (0)
11-Year Total	Cubits Gap	273 (74)	237 (73)	547 (194)	0 (0)
	Head of Passes	776 (201)	621 (199)	497 (136)	795 (158)

Note: Percent of Time Project Maintained

Reach	Existing Conditions	Advance Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
Cubits Gap	93 (98)	94 (98)	86 (95)	100 (100)
Head of Passes	81 (95)	84 (95)	88 (97)	80 (96)

Table 22

Distribution of Sediment Added by Agitation Dredging

	Deposited in River million cubic yards			Diverted Through Outlets million cubic yards		
Hydrograph	Upstream Cubits Gap	Cubits Gap Reach	Head of Passes	Cubits Gap	Pass a Loutre and South	East Jetty
			24,000 cu yd/day			
31 Mar 89	2.39	1.33	0.19	0.25	0.21	-0.01
31 May 89	2.22	1.31	0.27	0.27	0.30	-0.01
30 Sep 89	2.20	1.28	0.30	0.27	0.32	-0.01
End of shifted	2.11	1.35	0.30	0.28	0.32	-0.01
			12,000 cu yd/day			
31 Mar 89	0.91	0.74	0.18	0.16	0.20	0.00
31 May 89	0.86	0.65	0.24	0.16	0.28	0.00
30 Sep 89	0.87	0.60	0.26	0.16	0.30	0.00
End of shifted	0.83	0.60	0.27	0.17	0.32	0.00
			6,000 cu yd/day			
31 Mar 89	0.23	0.42	0.16	0.10	0.19	0.00
31 May 89	0.20	0.33	0.21	0.11	0.25	0.00
30 Sep 89	0.22	0.28	0.23	0.10	0.27	0.00
End of shifted	0.18	0.31	0.20	0.11	0.29	0.01

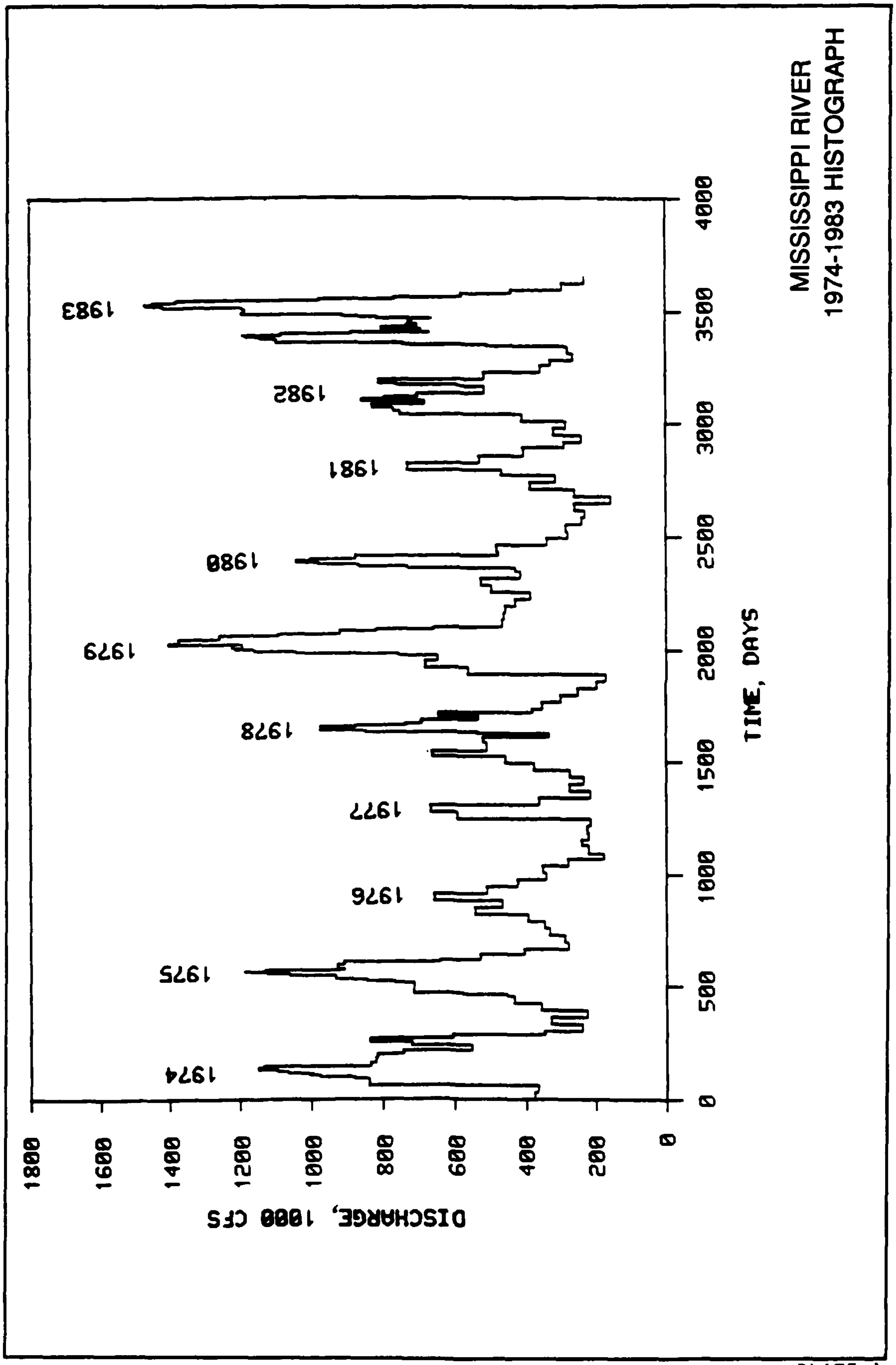

MISSISSIPPI RIVER
1974-1983 HISTOGRAPH
DISCHARGE, 1000 CFS
TIME, DAYS
0
200
400
600
800
1000
1200
1400
1600
1800
0
500
1000
1500
2000
2500
3000
3500
4000
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983

PLATE 1

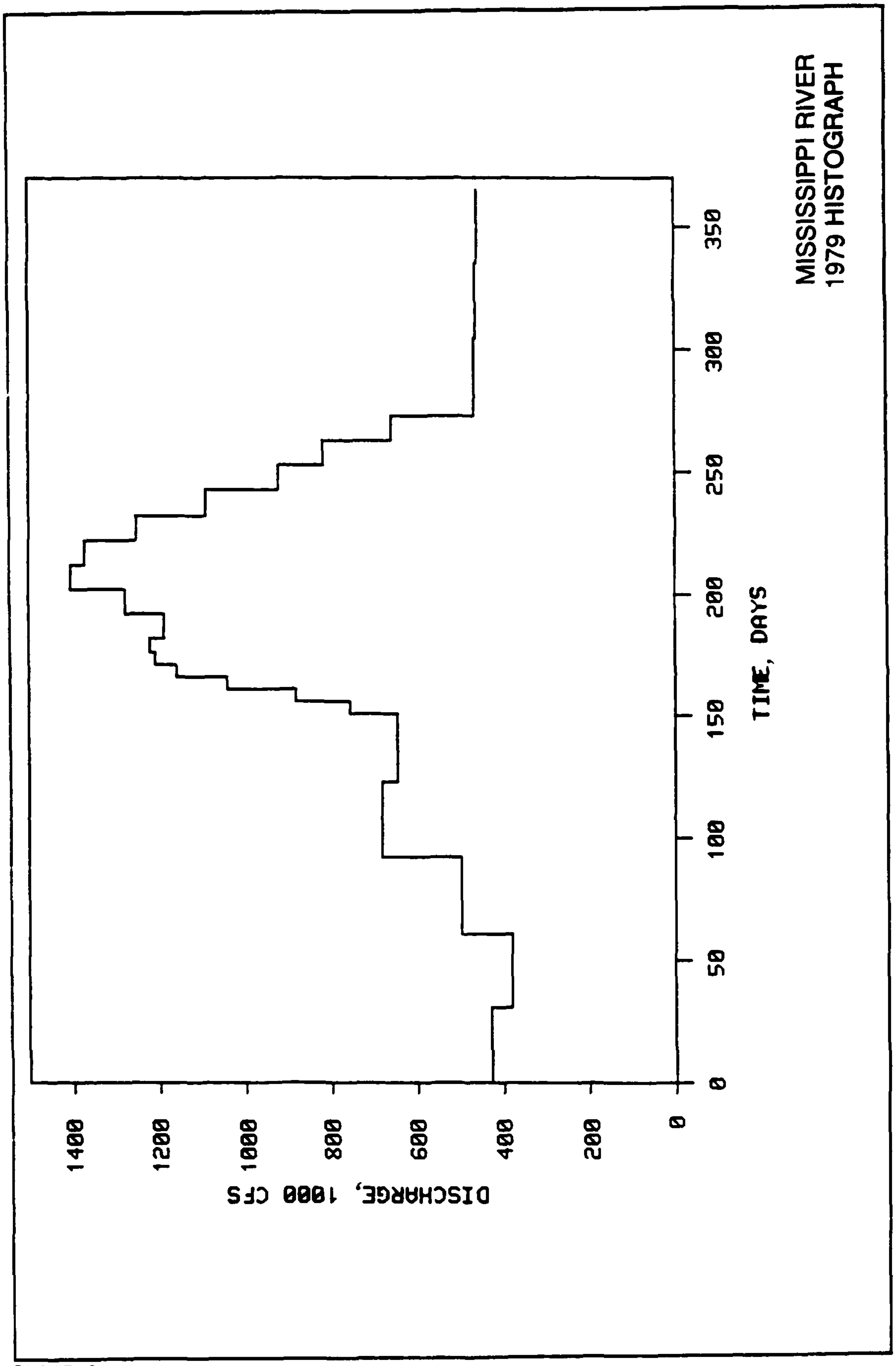

MISSISSIPPI RIVER
1979 HISTOGRAPH
TIME, DAYS
0
50
100
150
200
250
300
350
DISCHARGE, 1000 CFS
0
200
400
600
800
1000
1200
1400

PLATE 2

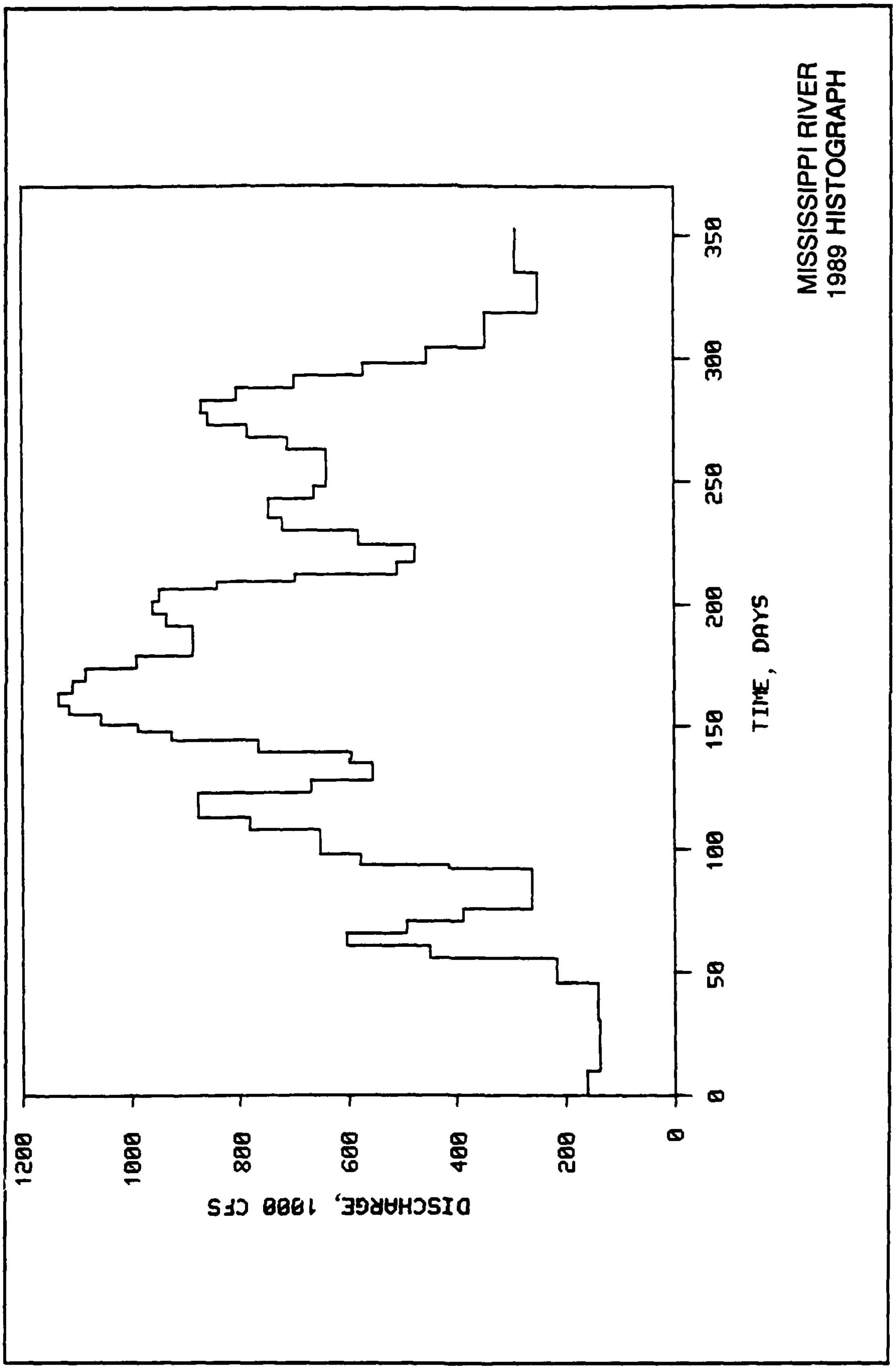
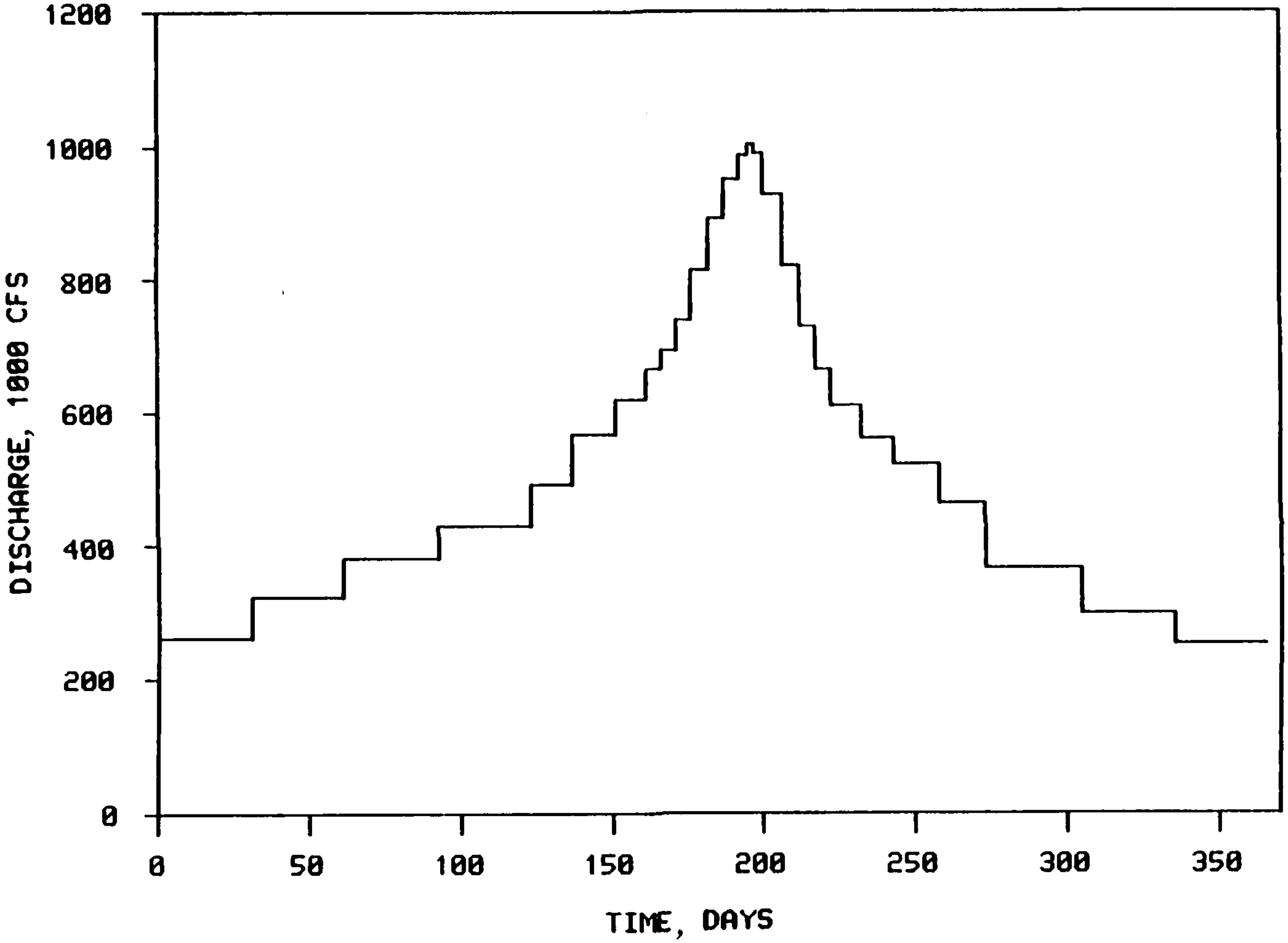
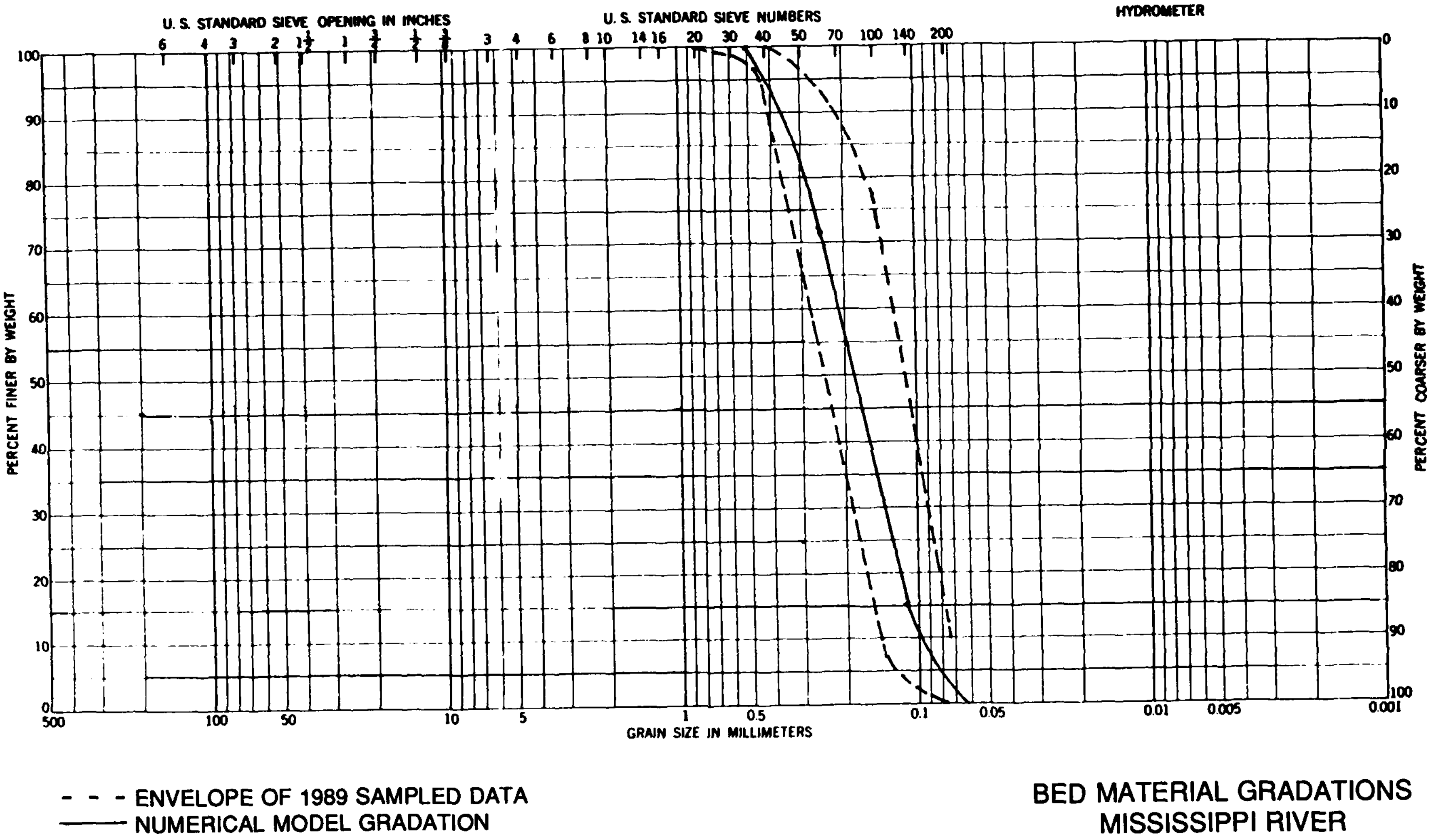

MISSISSIPPI RIVER
1989 HISTOGRAPH
DISCHARGE, 1000 CFS
TIME, DAYS
0
200
400
600
800
1000
1200
0
50
100
150
200
250
300
350

PLATE 3



MISSISSIPPI RIVER
SHIFTED ANNUAL HISTOGRAPH

PLATE 4



BED MATERIAL GRADATIONS
MISSISSIPPI RIVER
MILE 3.0 TO 11.0

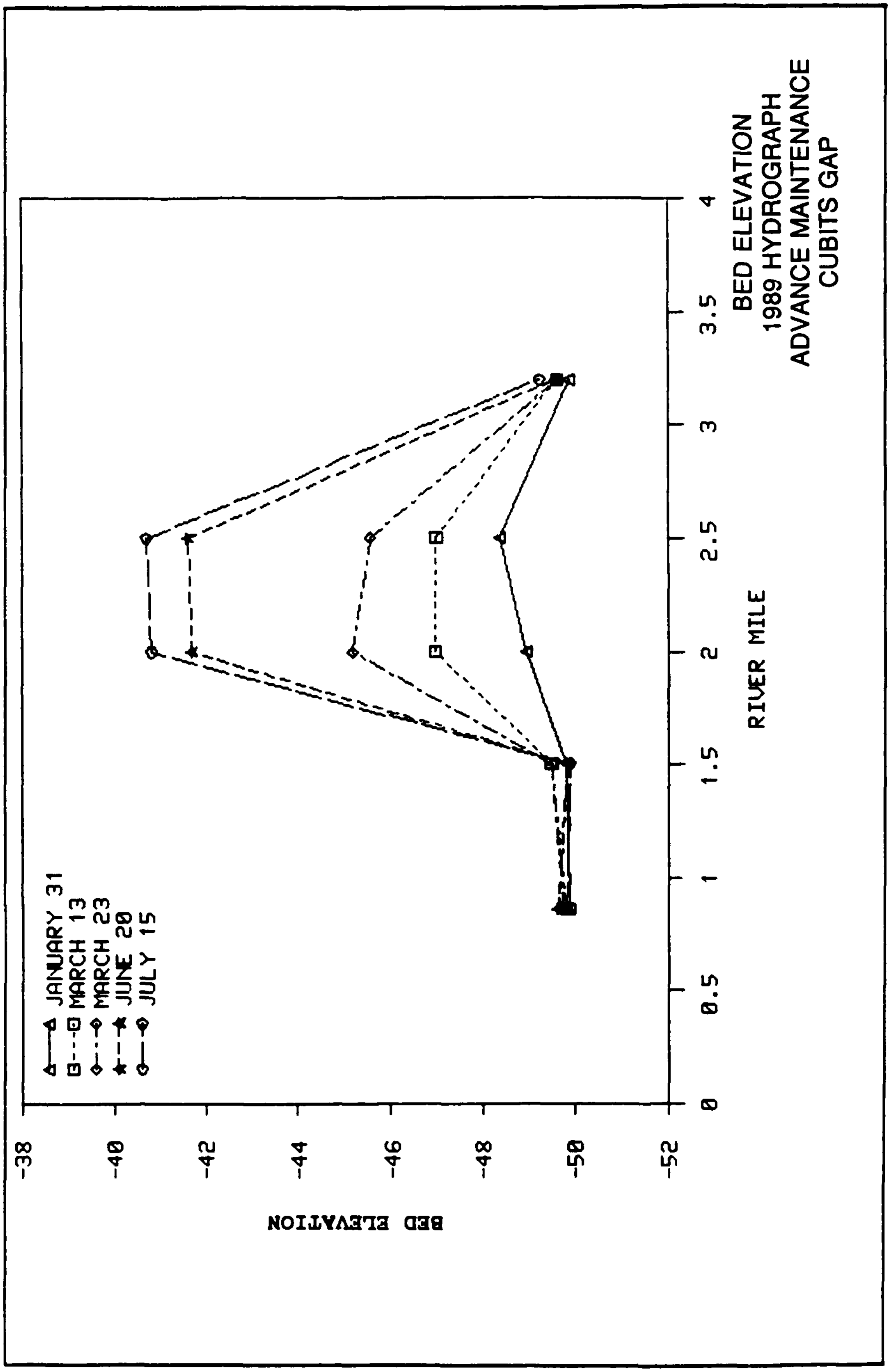
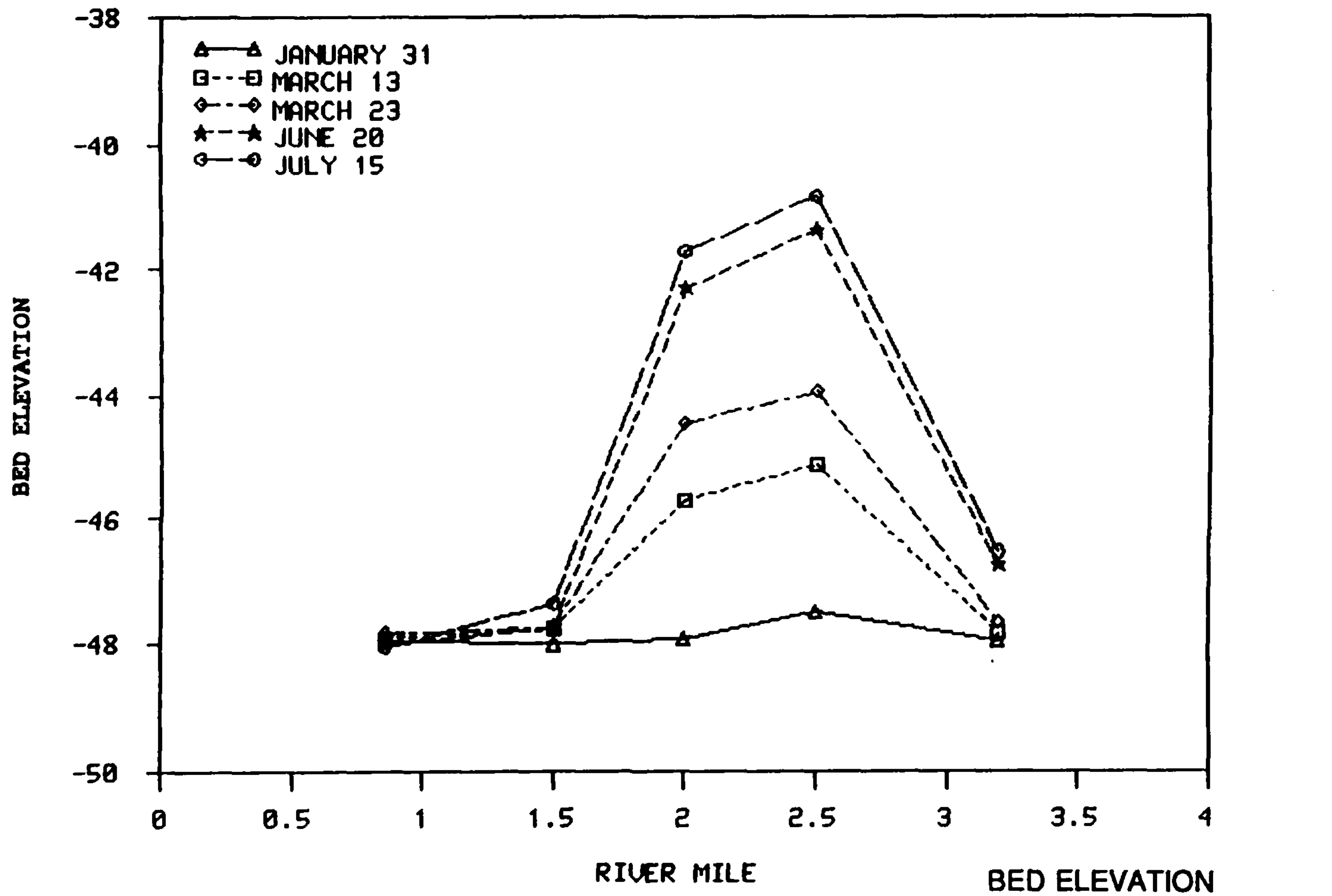
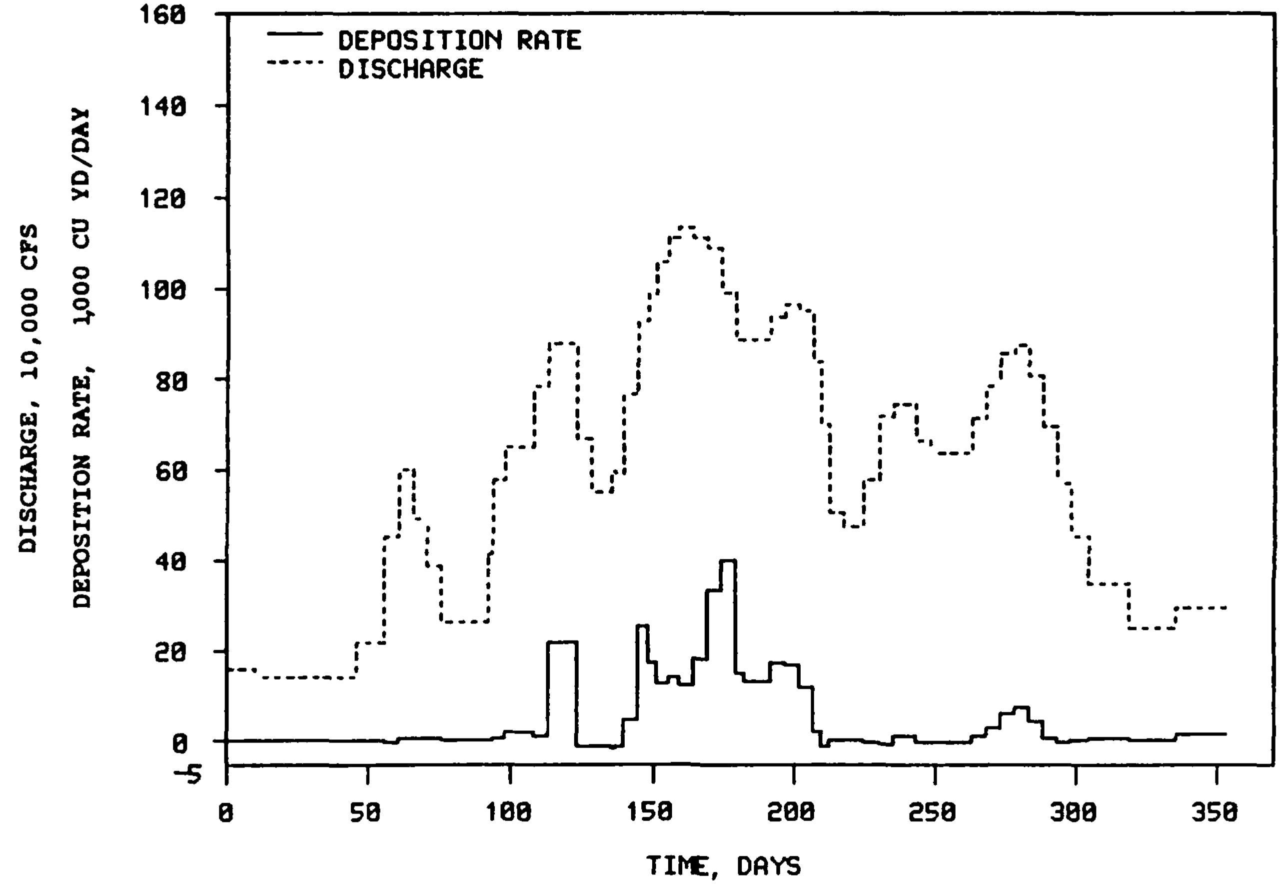

BED ELEVATION
1989 HYDROGRAPH
ADVANCE MAINTENANCE
CUBITS GAP
JANUARY 31
MARCH 13
MARCH 23
JUNE 20
JULY 15
RIVER MILE
BED ELEVATION
0
0.5
1
1.5
2
2.5
3
3.5
4
-38
-40
-42
-44
-46
-48
-50
-52

PLATE 6

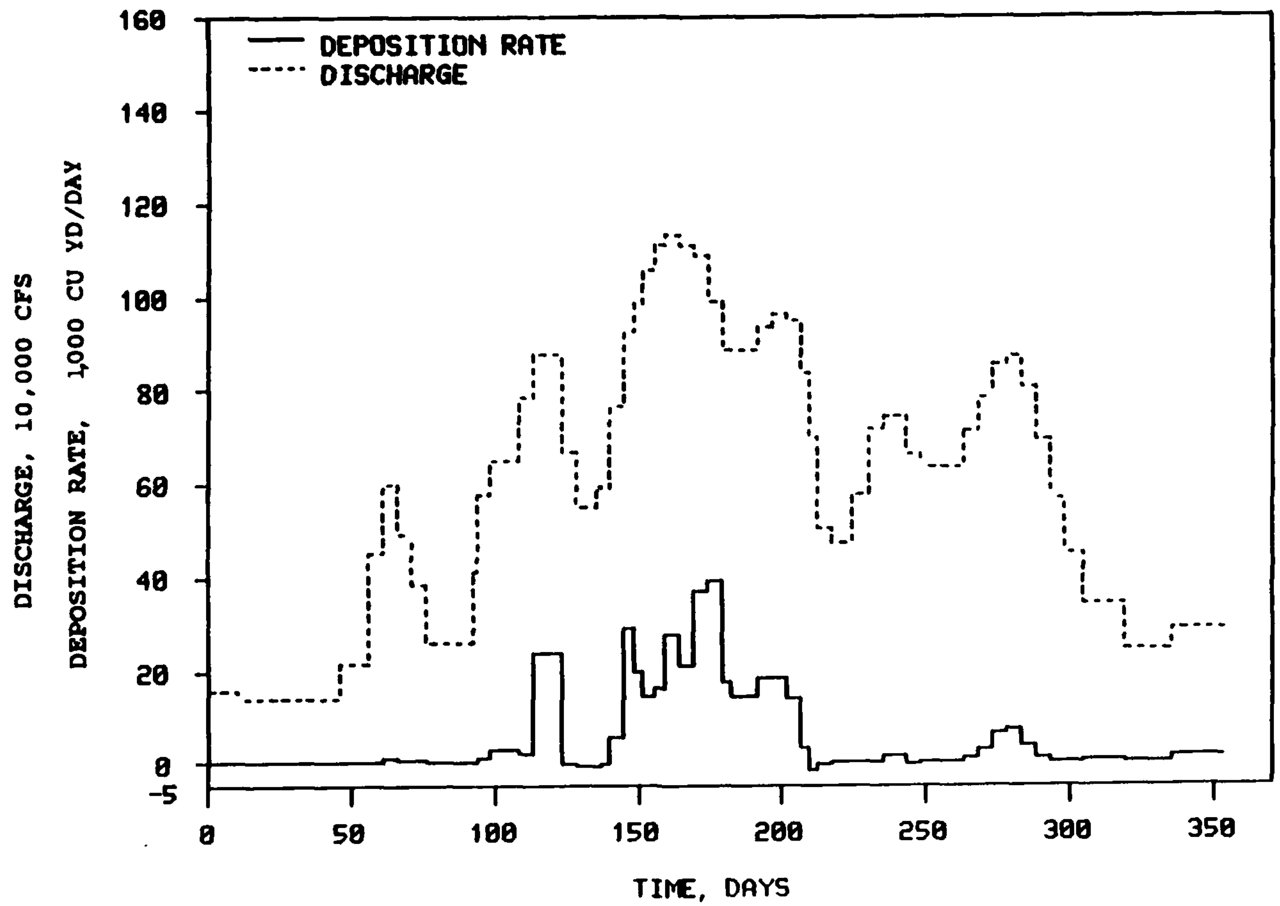


BED ELEVATION
1989 HYDROGRAPH
SEDIMENT TRAP IN NAVIGATION CHANNEL
CUBITS GAP

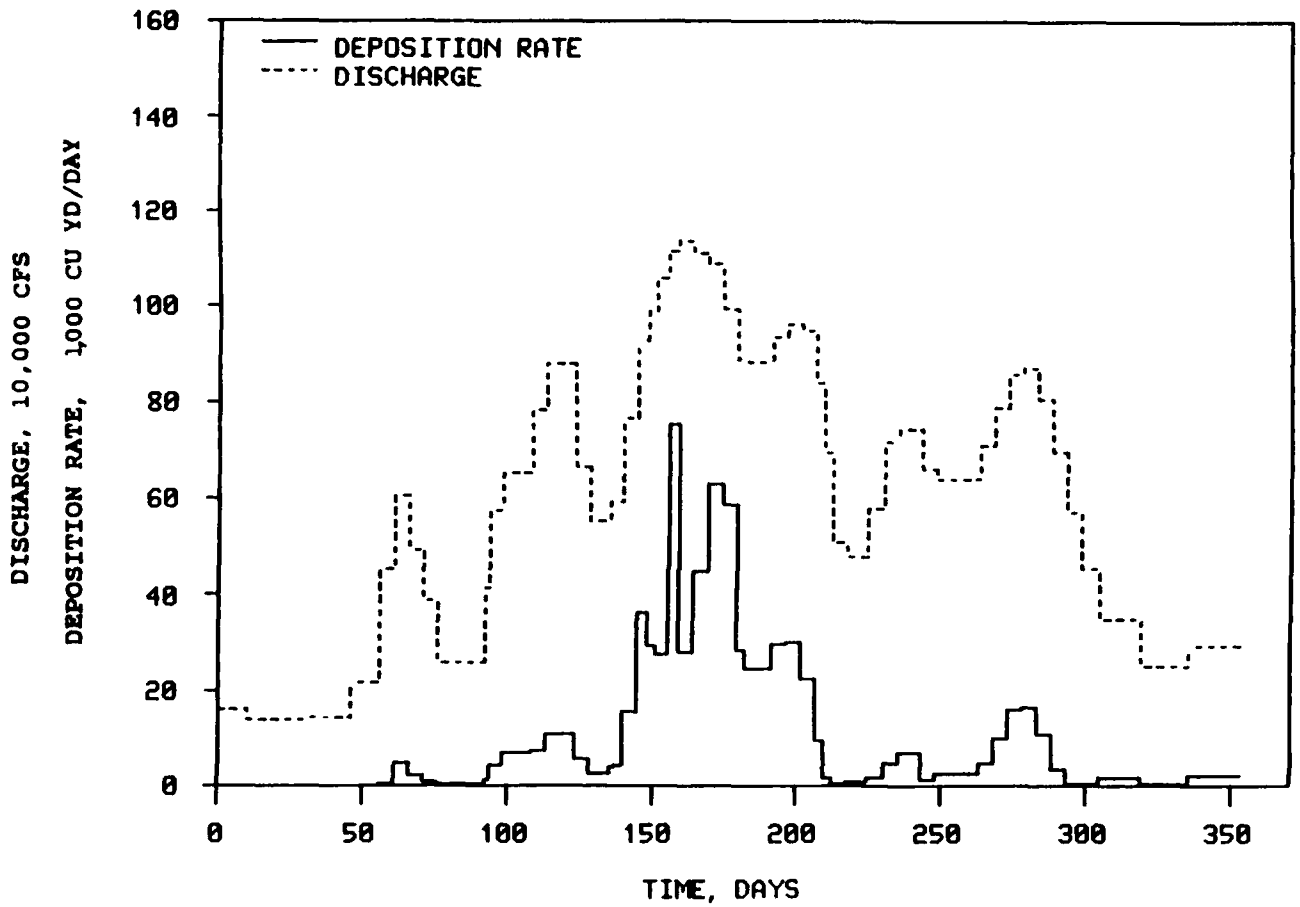


SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
EXISTING CONDITION
CUBITS GAP

PLATE 8

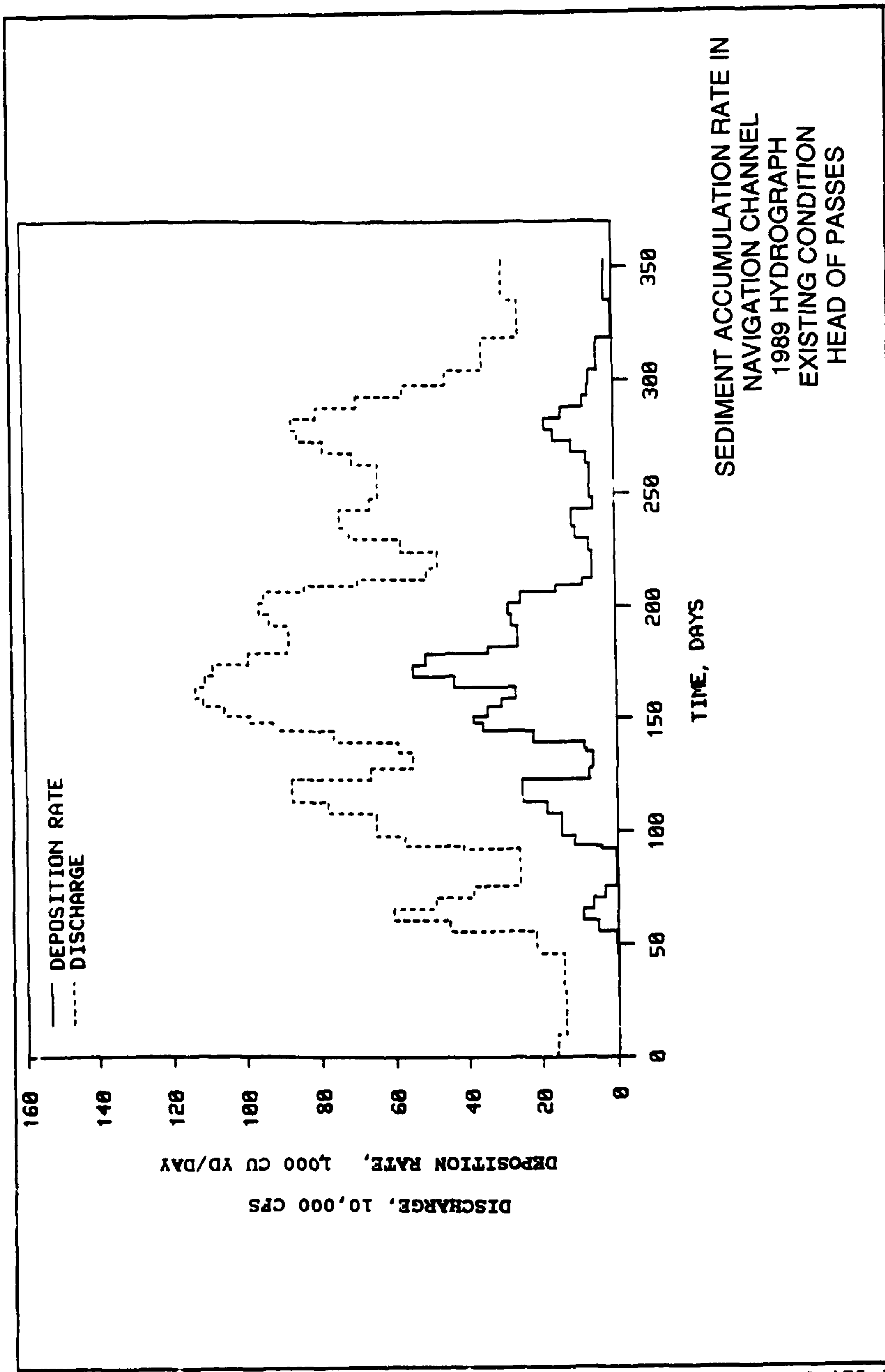


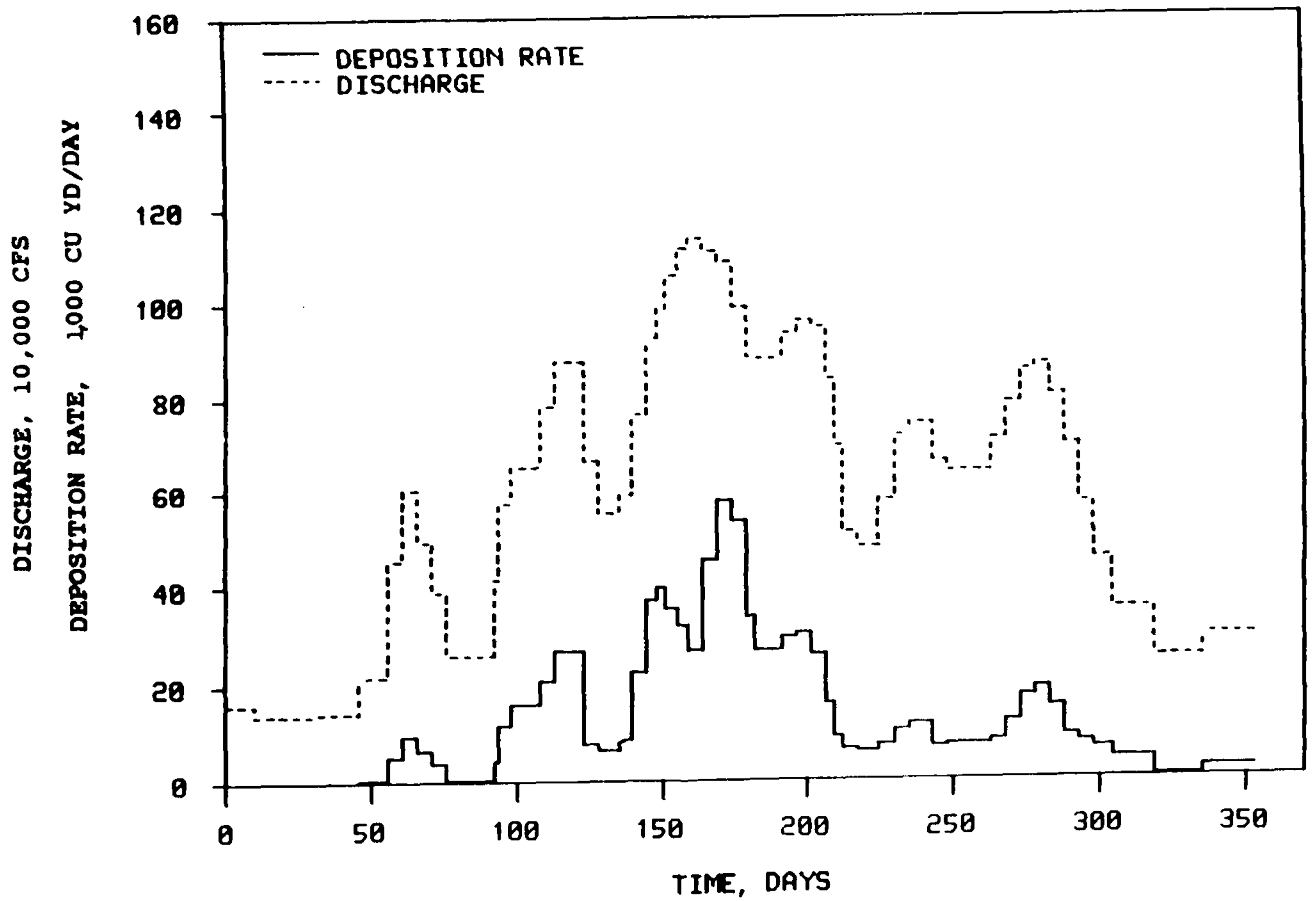
SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
ADVANCE MAINTENANCE
CUBITS GAP



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
SEDIMENT TRAP
CUBITS GAP

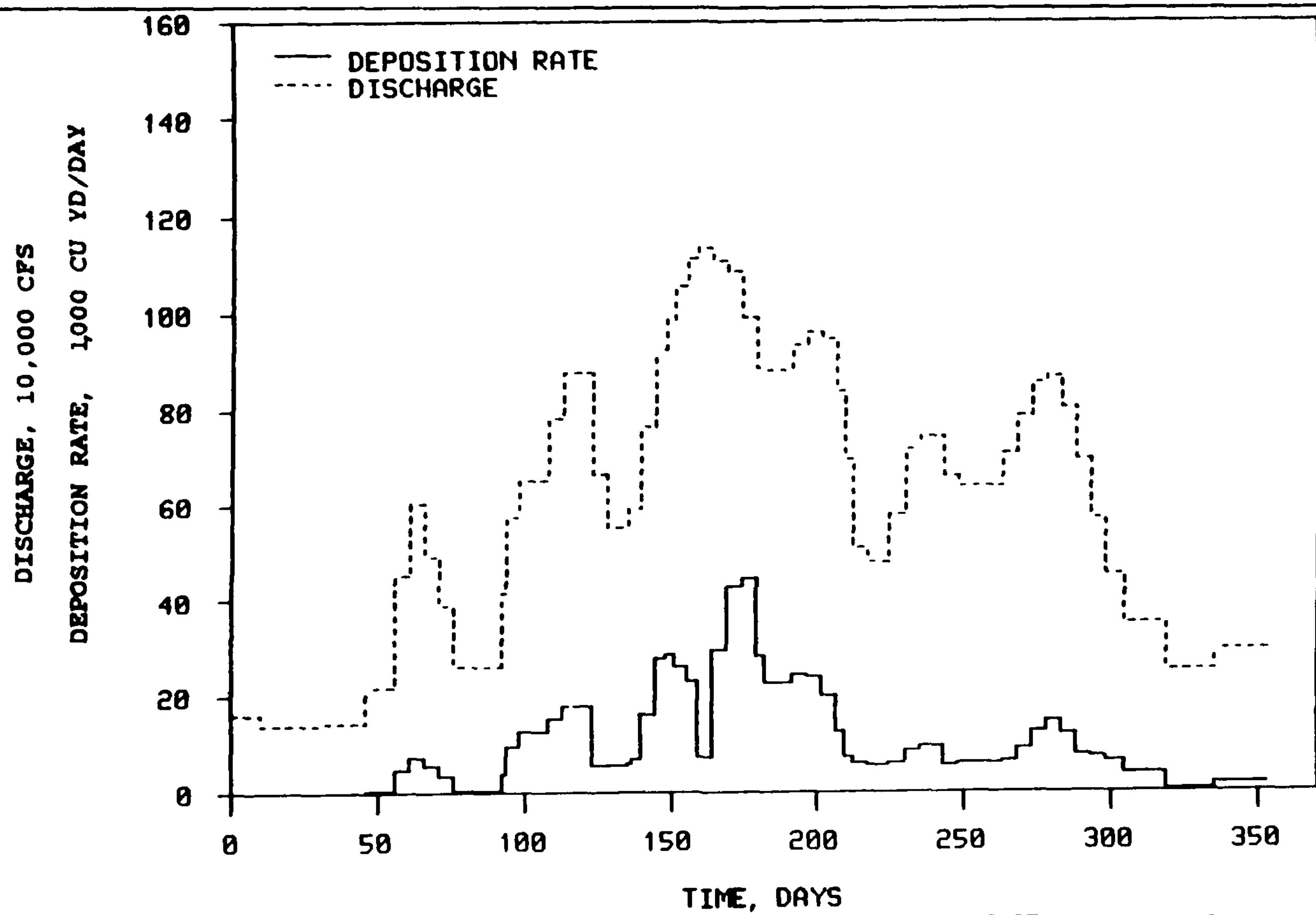
PLATE 10


SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
EXISTING CONDITION
HEAD OF PASSES
DEPOSITION RATE
DISCHARGE
DISCHARGE, 10,000 CFS
DEPOSITION RATE, 1,000 CU YD/DAY
TIME, DAYS
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250
300
350



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
ADVANCE MAINTENANCE
HEAD OF PASSES

PLATE 12



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
SEDIMENT TRAP
HEAD OF PASSES

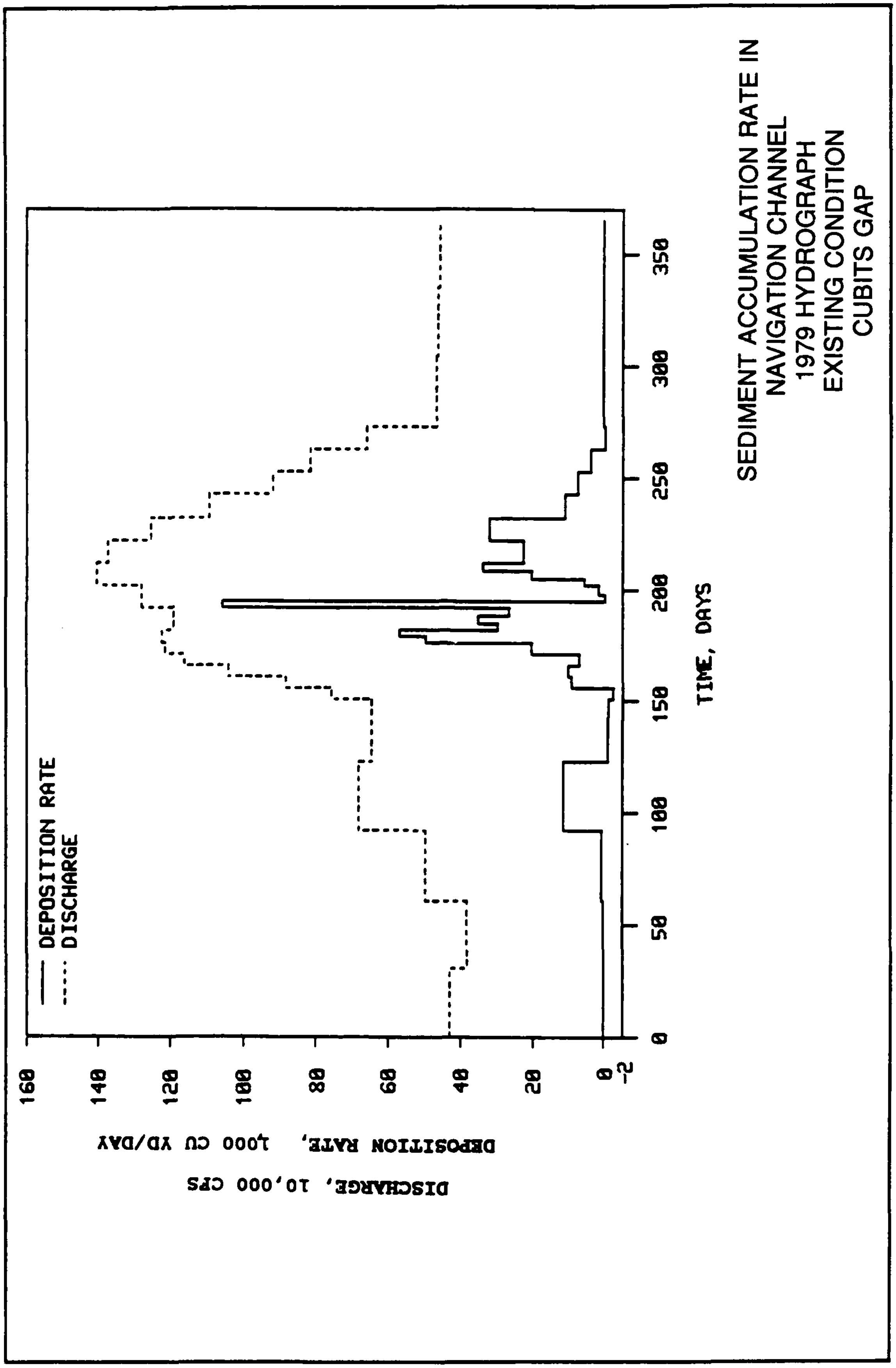

SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
EXISTING CONDITION
CUBITS GAP
DEPOSITION RATE
DISCHARGE
TIME, DAYS
DEPOSITION RATE, 1,000 CU YD/DAY
DISCHARGE, 10,000 CFS
0
50
100
150
200
250
300
350
-2
20
40
60
80
100
120
140
160

PLATE 14

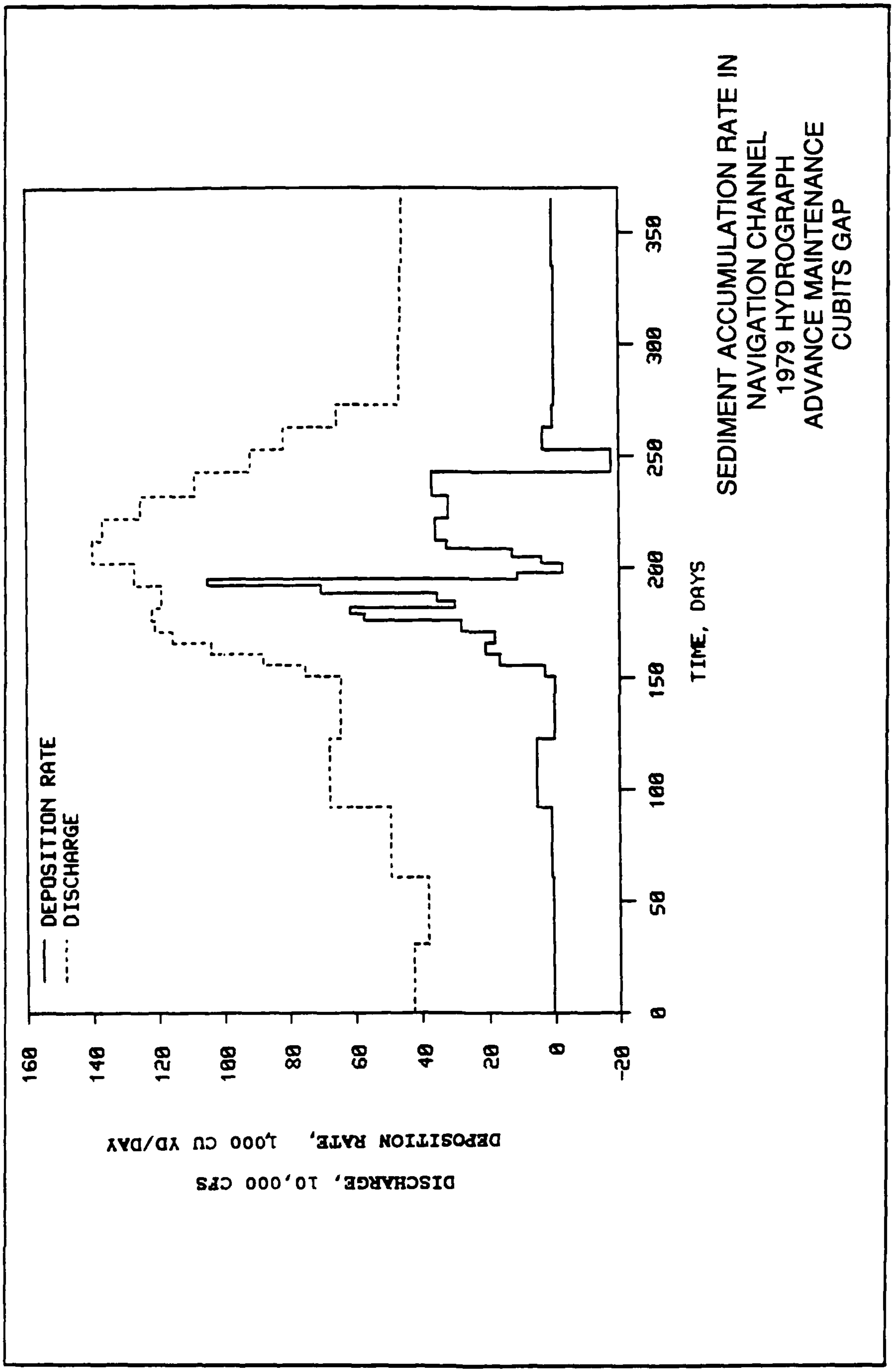
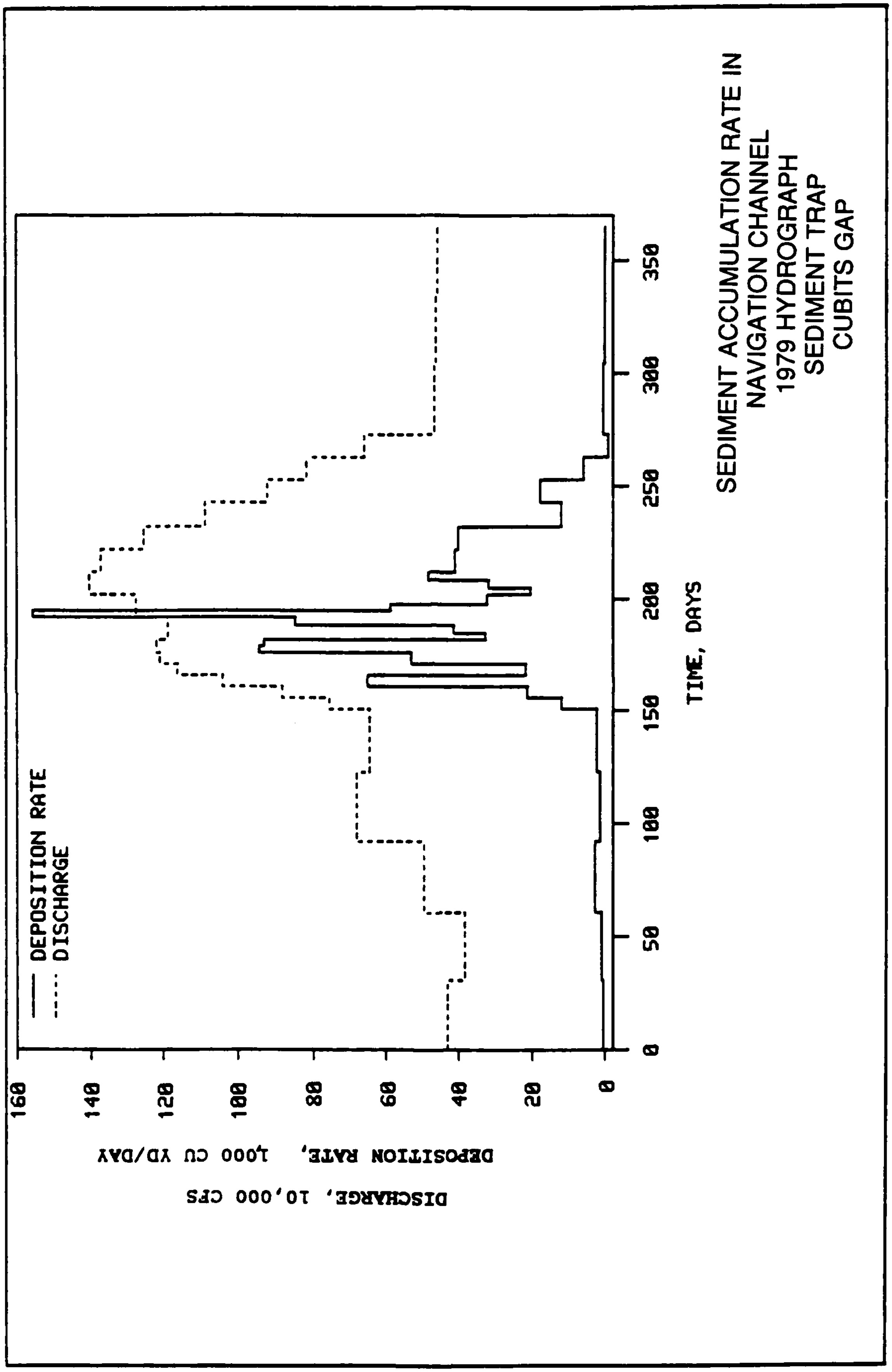
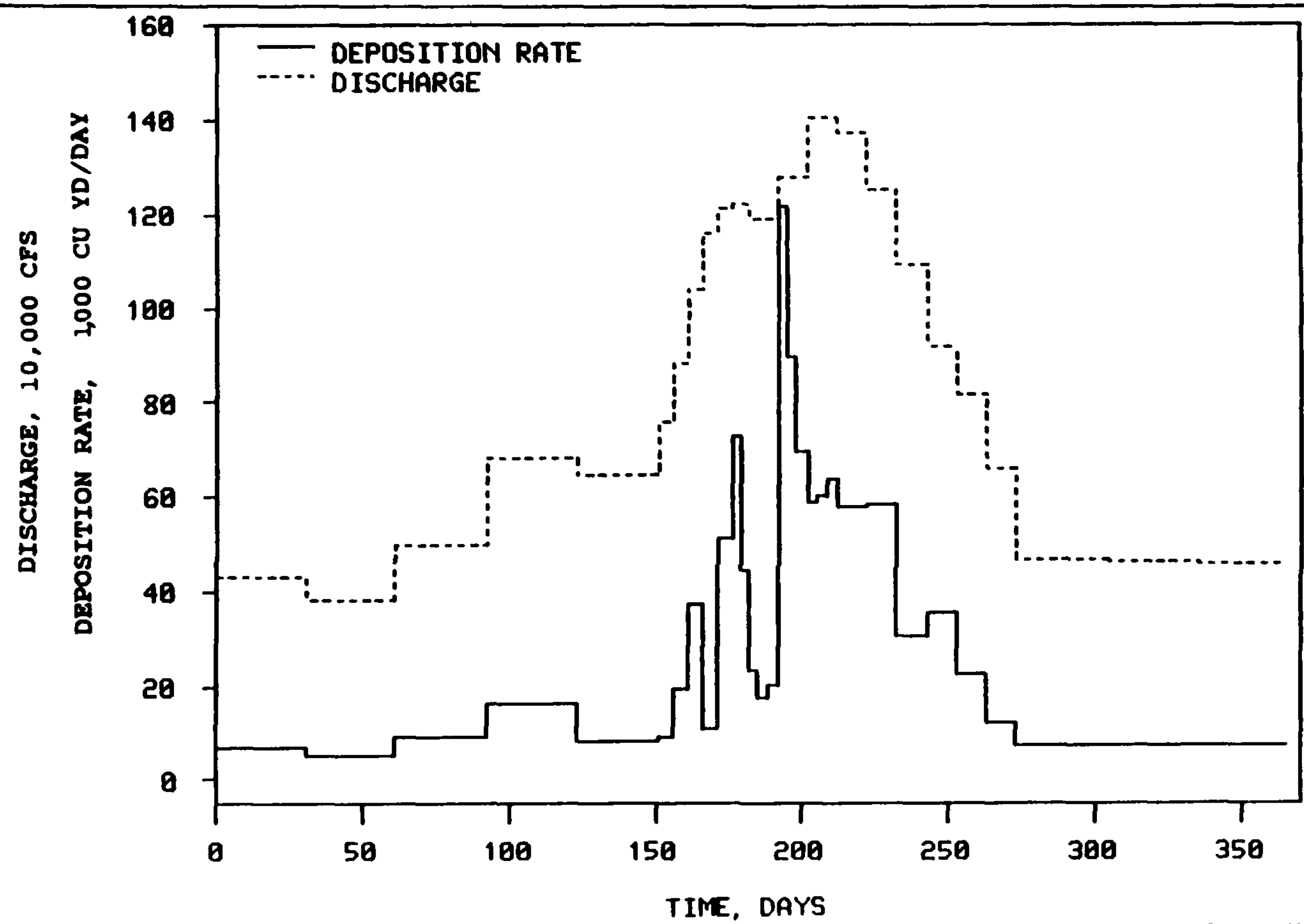

SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
ADVANCE MAINTENANCE
CUBITS GAP
DEPOSITION RATE
DISCHARGE
TIME, DAYS
DEPOSITION RATE, 1,000 CU YD/DAY
DISCHARGE, 10,000 CFS
0
50
100
150
200
250
300
350
160
140
120
100
80
60
40
20
0
-20

PLATE 15

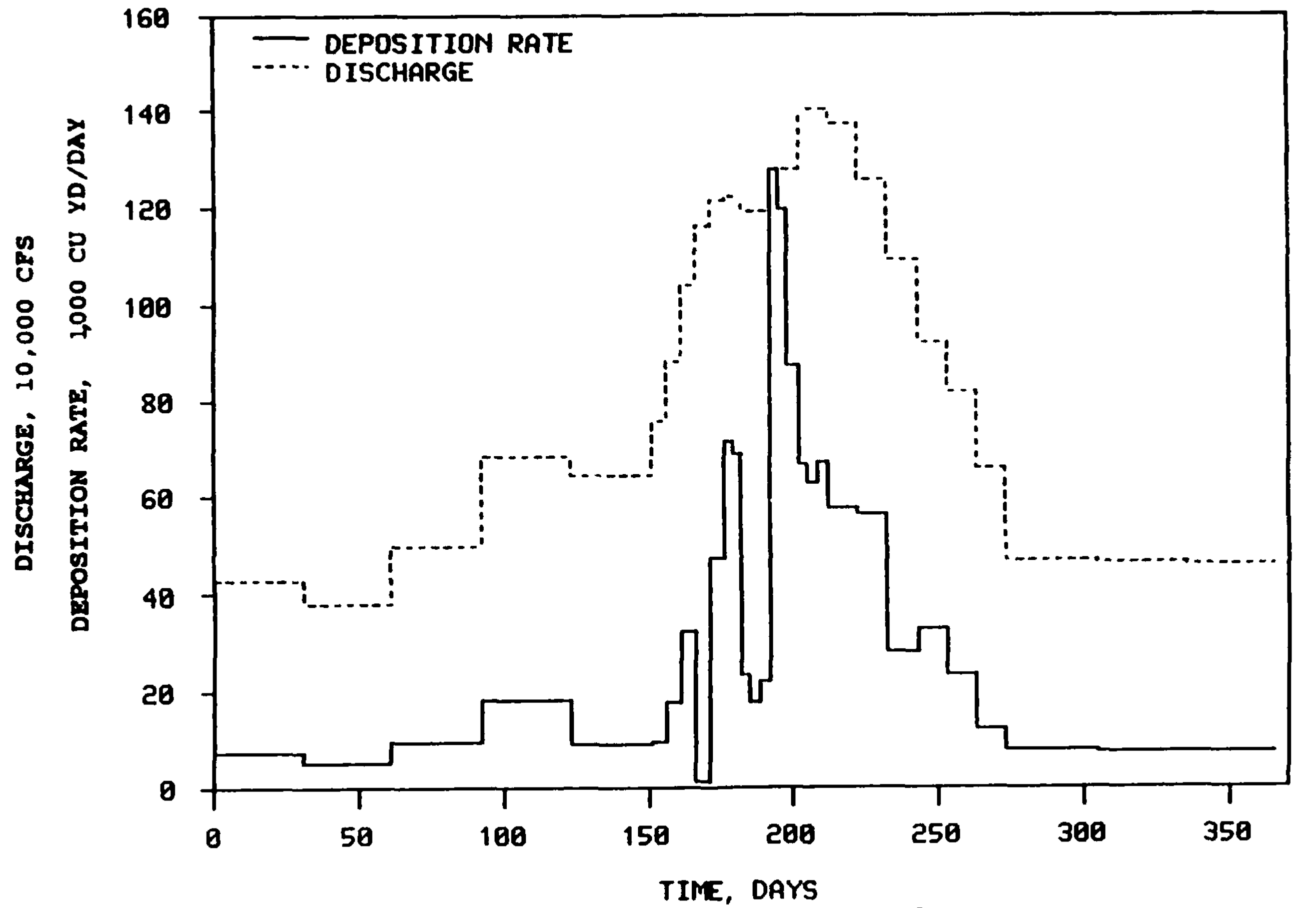


SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
SEDIMENT TRAP
CUBITS GAP
DEPOSITION RATE
DISCHARGE
TIME, DAYS
DEPOSITION RATE, 1,000 CU YD/DAY
DISCHARGE, 10,000 CFS
0
50
100
150
200
250
300
350
0
20
40
60
80
100
120
140
160

PLATE 16

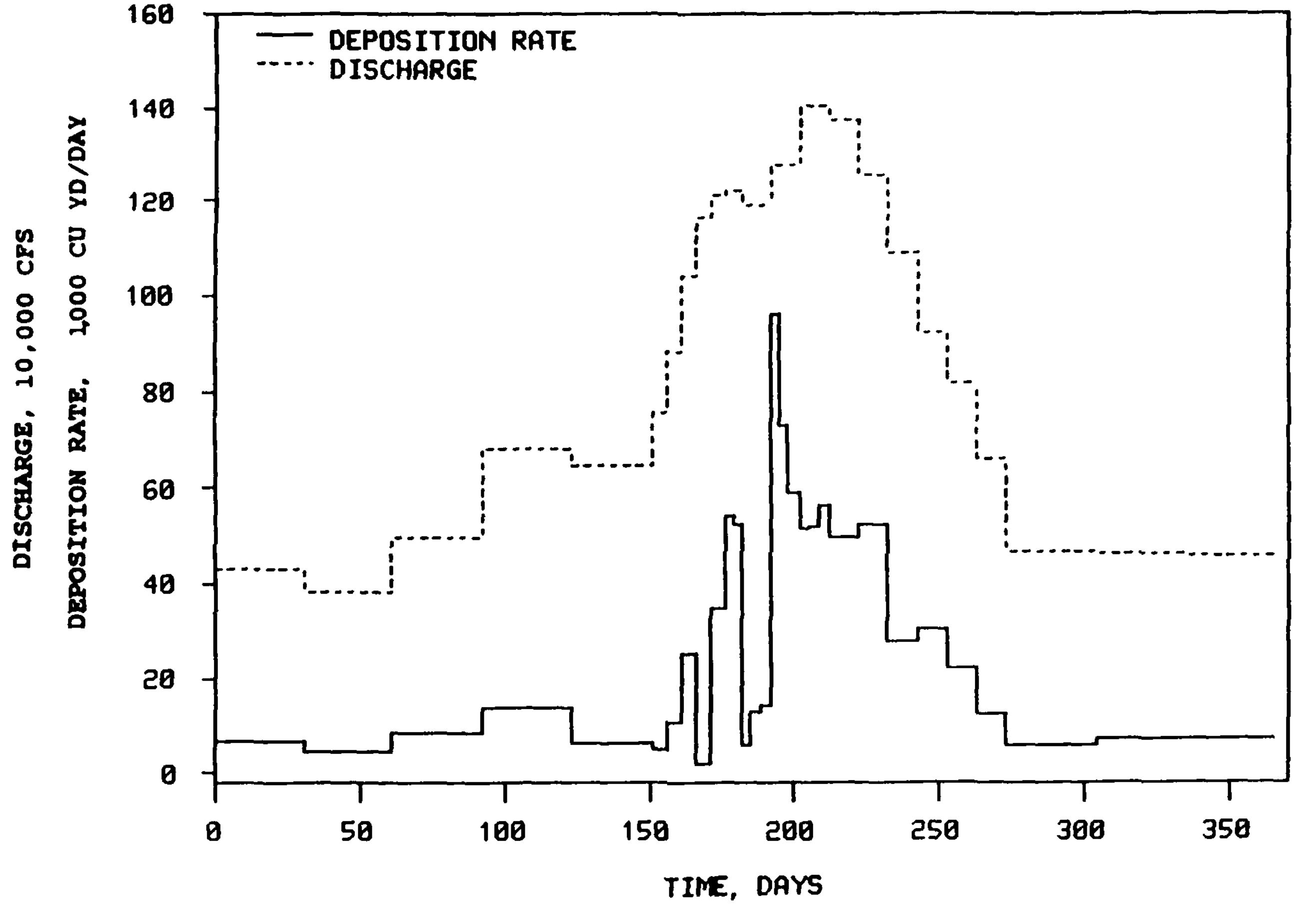


SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
EXISTING CONDITION
HEAD OF PASSES

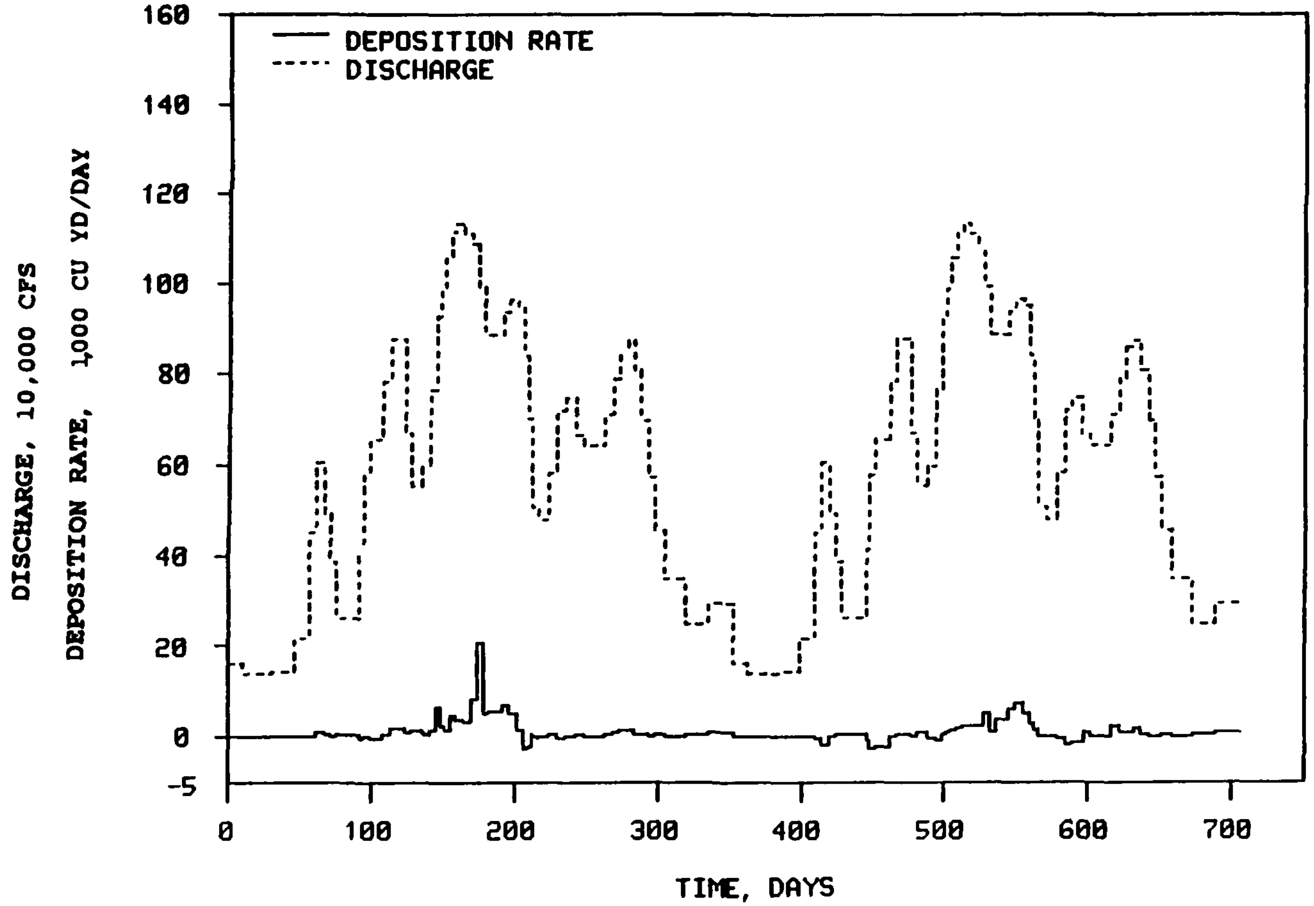


SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
ADVANCE MAINTENANCE
HEAD OF PASSES

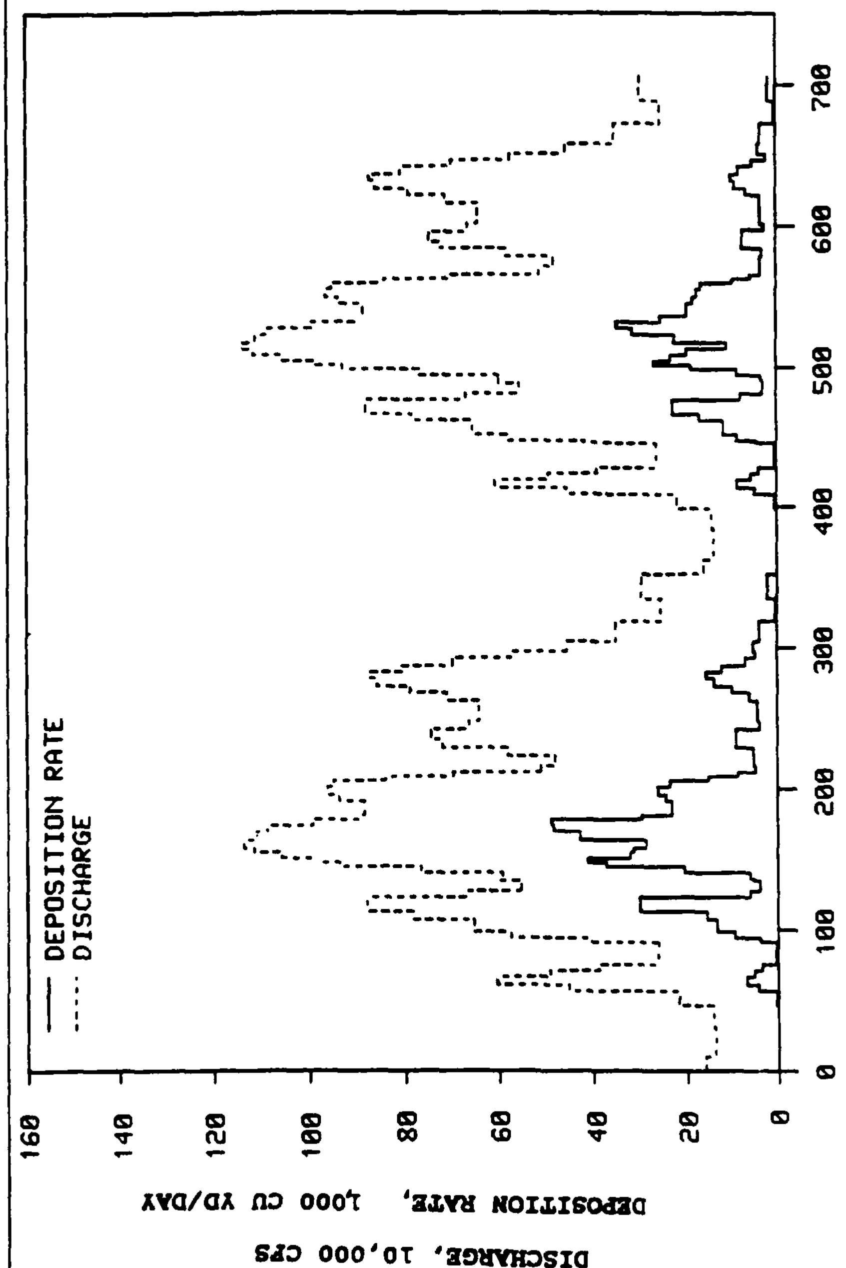
PLATE 18



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1979 HYDROGRAPH
SEDIMENT TRAP
HEAD OF PASSES



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
FLOW REDUCED BY 50 PERCENT
CUBITS GAP



SEDIMENT ACCUMULATION RATE IN
NAVIGATION CHANNEL
1989 HYDROGRAPH
FLOW REDUCED BY 50 PERCENT
HEAD OF PASSES