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A NUMERICAL MODEL ANALYSIS OF MISSISSIPPI RIVER PASSES NAVIGATION CHANNEL IMPROVEMENTS

Report 1

55-FOOT CHANNEL TESTS

by

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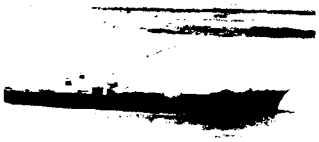

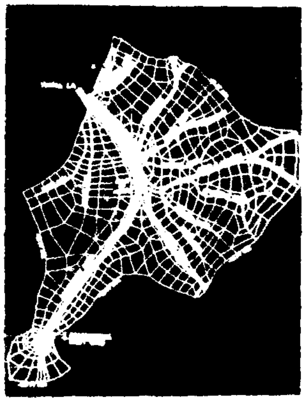

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The proposed deepening of the Southwest Pass of the Mississippi River to 55 feet is analyzed for its impacts on flow distributions and sedimentation changes. Results from two-dimensional numerical hydrodynamic and sediment transport models for a variety of plans and flow conditions are presented. The US Army Corps of Engineers TABS-2 modeling system is used. The constructed models cover the entire Mississippi River Delta downstream of Venice, Louisiana.

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Preface

The study described herein was conducted during 1985-1987 for the US Army Engineer District, New Orleans, by personnel of the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. H. B. Simmons and F. A. Herrmann, Jr., former and present Chiefs, respectively, of HL, and R. A. Sager and W. H. McAnally, former and present Chiefs, Estuaries Division (ED). The study was performed and this report written by Messrs. D. R. Richards and M. J. Trawle, ED. It is the first in a series of reports listed below.

COL Dwayne G. Lee, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

Reports in this series:

Report 1: 55-Foot Channel Tests
Report 2: 45-Foot Channel Tests and Flow Diversion Schemes
Report 3: Bank Breaching Without Supplement 2
Report 4: Two-Dimensional Hydrodynamic and Sediment Transport Verification
Report 5: Three-Dimensional Numerical Model Results

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
feet	0.3048	metres
miles (US statute)	1.609347	kilometres

A NUMERICAL MODEL ANALYSIS OF MISSISSIPPI RIVER PASSES NAVIGATION CHANNEL IMPROVEMENTS

55-FOOT CHANNEL TESTS

Study Objective

1. The objective of this study is to determine the effects of various project geometry changes on the hydrodynamics and sedimentation characteristics of Southwest Pass. The plans include the bank protection works described as Supplement 2 for the existing 40-ft-deep project as well as several channel widths for a 55-ft deepened channel. Detailed descriptions of the project improvements are contained in New Orleans District (LMN) General Design Memorandum (GDM), Mississippi River, Baton Rouge to the Gulf of Mexico, LA, Southwest Pass and Bar Channel, dated April 1984.

Study Design

2. Two-dimensional (2D) numerical models were constructed to study, with the assistance of the existing physical model, the impacts of various channel geometries and improvements on the existing hydrodynamic and sediment transport characteristics of the Mississippi River Passes area. Existing conditions were defined as those that existed in June 1985.

3. Since improvements to any one of the Passes have the potential to alter flow distributions in the delta, a large 2D numerical model was constructed to predict the effects of improvements on these flow distributions. Additionally, most of the delta system can be adequately described in two dimensions. The resolution and size of the delta was set by computational and economic considerations. The 2D model consists of 1,339 elements and 4,038 nodes, making it one of the largest finite-element estuarine models constructed (Figure 1). Since an evaluation can be adequately accomplished using steady-state simulations, this grid size provides economical simulations.

4. The lower portion of Southwest Pass in the jetty and entrance reaches is an area where three-dimensional (3D) simulations are desirable. A 3D numerical model was constructed as an inset of the larger 2D model to provide more accurate simulations in the entrance area. Since 3D models require

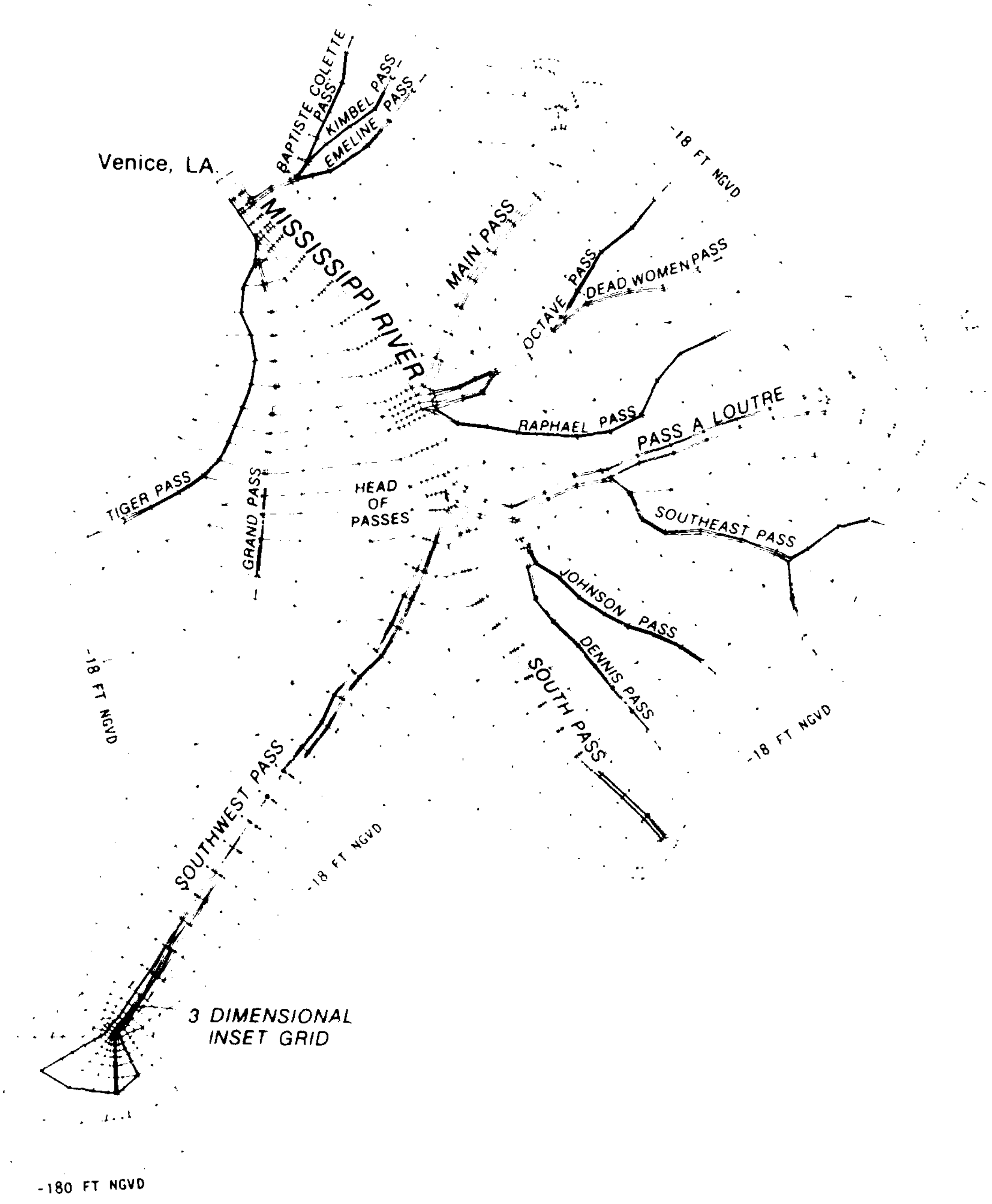

Figure 1. Mississippi River Passes numerical model grid

extensive boundary and initial condition data, the existing physical model was renovated. By design, the main purpose of the physical model was to provide these data. The physical model does not cover the entire delta so it is limited in its ability to predict the proper flow distributions. The 2D numerical model results provide the basis for making the various base to plan comparisons reported herein. Results from 3D numerical studies will be discussed in a separate report.

Modeled Geometries

5. The following geometries were used in the numerical simulations:

   a. BASE - Existing conditions as defined by US Geological Survey (USGS) 7.5 min quads were used for horizontal control and where available the most recent LMN dredging sheets were used for water depths. For the main Mississippi River navigation channel, this included the 40-ft project as described in the sheets dated June 1985. Elsewhere, a combination of older dredge sheets and soundings from a February 1986 trip by the US Army Engineer Waterways Experiment Station (WES) were used.

   b. SUPPLEMENT 2 - The BASE geometry was modified by including the Supplement 2 bank protection works for the main stem of the Mississippi River and Southwest Pass.

   c. PLAN 1 - SUPPLEMENT 2 was modified to include the deep-draft features described in the GDM, and the main navigation channel was deepened to 55 ft over its existing width.

   d. PLAN 2 - PLAN 1 was modified to include a 675-ft channel width in the jetty and entrance channel reaches.

   e. PLAN 3 - PLAN 2 was modified to include a 750-ft channel in the jetty and entrance channel reaches.

   f. PLAN 4 - PLAN 3 was modified to include a narrowing of the existing 800-ft channel width to 750 ft between Head of Passes and Mile 17.5 below Head of Passes.

Hydrodynamic Model Boundary Conditions

6. The steady-state boundary conditions tested included 640,000-, 900,000-, and 1,300,000-cfs nominal discharges at the upstream inflow boundary at Venice, Louisiana. A constant exit head of 0 ft* was used for all

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

simulations described herein, which is adequate for the comparisons of the various plan geometries. Tidal runs are not included due largely to the substantial computer costs required to model a phenomenon that is not highly significant for these high discharges. Each of the discharges modeled represent extremely high flows that dominate the effect of the comparatively weak Gulf of Mexico tidal influences.

Hydrodynamic Model Verification

7. Verification of the hydrodynamic model was accomplished by adjusting eddy viscosity and roughness coefficients to produce observed variations in water surface slope from Venice downstream. Unfortunately, downstream of Venice the quality of stage information decreases substantially due to subsidence of the gages and other maintenance related factors. In addition, there is wind and tide contamination in the record. Enough data exist, however, to provide the stage variations that should be expected for the three different flows. A number of other numerical model studies in the lower Mississippi River were consulted to determine the range of acceptable values for coefficients.

8. After the model was shown to give meaningful water-surface slopes, adjustments were made to yield the proper distributions of flow between the numerous distributaries and overbank areas. The available field data for making these measurements are sparse, but the initial adjustments to get proper water-surface slopes resulted in reasonable flow distributions at Head of Passes based on LMN and WES data. Minor adjustments resulted in good flow distributions throughout the delta.

9. Once water-surface and flow distributions were verified, velocities were inspected for reasonableness against the existing physical model. Depth-averaged velocities compared favorably and no additional adjustments were required. Overall verification of the 2D hydrodynamic model was considered good and the results will be provided in a separate report.

Preliminary Hydrodynamic Results

10. One of the prime reasons for modeling the entire delta, including numerous minor tributaries and the vast marsh areas, was to be able to

determine flow distributions between the different passes and the degree of channel versus overbank flow. Previous model studies had to depend on flow distributions that were either assumed or based on limited field data that were contaminated by astronomical tide or meteorological effects. Perhaps the most valuable capability of this large model is its ability to calculate effects of major projects on flow distributions particularly at Head of Passes.

11. With this in mind, discharge calculation lines were located at the upstream opening of each of the six major distributaries. In addition, they were located downstream in Southwest and South Passes to determine the amount of leakage experienced over the length of the pass. The discharges are expressed in terms of percentages of the incoming flow at Venice and are listed in Tables 1-3.

12. Also presented in Tables 1-3 are typical midstream stages and velocities along the longitudinal axis of the river for each of the six geometries and three flow conditions. The stages agree favorably with the available field data. The velocities are depth-averaged as defined by the use of a 2D vertically averaged model. Velocities from the physical model, when depth averaged, agree favorably with the numerical results.

13. A comparison of the hydrodynamic results from each of the modeled geometries provides a clear and consistent impression of the results expected from each of the plans. Supplement 2 with its bank nourishment and raised elevations has the effect of redistributing as much as 2 percent of the flow at Venice from Southwest Pass into Pass a Loutre with little noticeable change in the portion of the flow into South Pass. Indeed, whenever flows are redistributed in the Head of Passes area, they appear to be between Southwest Pass and Pass a Loutre. This phenomenon was true for all flow conditions.

14. Overall, the bank protection features of Supplement 2 reduce the amount of overbank flow significantly. For the existing (BASE) condition, Southwest Pass flow lost to the openings in the overbanks averaged 55 percent of the total flow entering Southwest Pass for the three flow conditions. With Supplement 2 installed, the overbank loss averaged only about 40 percent. This is due largely to the sealing of the many cuts in the overbanks as well as the overall raising of the banks. In addition, Supplement 2 had the effect of increasing current velocities throughout the length of Southwest Pass on the order of 15 to 40 percent above the BASE condition.

15. Plan 1, which consists of a deepening of the Supplement 2 condition to 55 ft in Southwest Pass and the installation of deep-draft features in South Pass, tends to restore flow into Southwest Pass from Pass a Loutre with little change to South Pass flows. This occurs with only small increases in velocities in Southwest Pass. Plans 2 through 4 provide very little difference in overall flow distributions, stages, or velocities from Plan 1. This is not surprising given that the changes involve small differences in channel widths over a small portion of the system.

16. The variations in the hydrodynamic data resulting from the various geometries occurred in a consistent fashion for each of the three flow conditions. For each flow the Supplement 2 condition with its higher velocities provided the best environment for minimizing shoaling in Southwest Pass. This effect was slightly more apparent with decreasing discharge. Another general observation was that the percentage of overbank flow decreased with decreasing discharge.

Sediment Transport Model Verification

17. Because of the almost continuous dredging activity that typically occurs along Southwest Pass during periods of high river stages, it is difficult to determine representative shoaling rates for high-stage conditions. The approach used in this study to establish high-stage shoaling rates was to evaluate relatively short periods of time in 1982, 1983, and 1984. During these selected time periods, the river stage was high and dredging activity was minimal.

18. Model verification was based on comparison of observed prototype shoaling rates along Southwest Pass during five relatively short periods of time (2 weeks to 1 month) in which the Carrollton stage ranged between 10 to 16 ft and dredging activity along Southwest Pass was nil. Using hydrographic surveys, prototype shoaling rates were calculated during December 1982, January 1983 (Mile 10-20 BHP only), December 1983 (Mile 6-20 BHP only), April 1984 (Mile 0-6 BHP only), and November 1984. The model was adjusted until shoaling along Southwest Pass for the range of flows tested fell within the band provided by the observed shoaling rates. Overall, the 2D sediment transport model behavior agreed well with the observed shoaling patterns. Results

from the verification effort are not included in this report but will be discussed in detail in a separate report.

Preliminary Sedimentation Results

19. Analyses of the sedimentation results provide confirmation of the inferences made from the hydrodynamic data. The numerical sediment transport simulations were made using steady-state currents with a median grain size of 0.15 mm. The sediment transport simulations were conducted for each of the conditions modeled hydrodynamically. Suspended sediment concentrations at the Head of Passes were approximately 150 ppm for the 640,000-cfs tests, 300 ppm for the 900,000-cfs tests, and 500 ppm for the 1,300,000-cfs tests.

20. Sediment transport predictions for each of the modeled conditions are given in Tables 4-6 expressed in cubic yards per month. Reductions or increases in shoaling are expressed in percentages of that observed in the existing (base) condition for that particular flow condition. Verification of the model was accomplished using shoaling data that were partially contaminated by dredging and other nonsteady-state phenomena so the most important figures to be gleaned from the data are the percentages that each condition changes from the base. Astronomical tide and meteorological effects are not modeled in this reporting; however, the percentages predicted in these steady-state simulations should be similar to those that would be predicted by dynamic simulations.

21. In general, the data indicate that Supplement 2 decreases shoaling in Southwest Pass from 5 to 20 percent over the range of flow conditions modeled in the study. For discharges of 640,000, 900,000 and 1,300,000 cfs at Venice, there were decreases in Supplement 2 shoaling of 20, 17, and 5 percent, respectively, over the base condition. For Plan 1, there were increases in shoaling for the 640,000-, 900,000-, and 1,300,000-cfs conditions of 34, 24 and 15 percent, respectively, over the base condition and 68, 49, and 21 percent, respectively, over the undeepened Supplement 2 condition. Variations between the deepened plans with varying channel widths showed undetectable differences in shoaling rates as expressed as feet per month. Differences in the shoaling volumes are probably slightly different but could best be described by the proportionate increase in channel bottom area which of course is quite small.

22. The shoaling predictions presented thus far are averaged over the length of Southwest Pass. There were, however, longitudinal variations in shoaling caused by the various plan geometries. Typically, Supplement 2 tends to increase the shoaling downstream near the entrance. This is caused by the tightening of the overbanks throughout Southwest Pass and the associated increased velocities. The sediment load moves downstream until velocities drop off near the entrance where the effects of Supplement 2 diminish. Comparisons between Supplement 2 and the various deepened plans show no significant changes in longitudinal distribution. Each of the plans includes Supplement 2 works so this is not surprising.

Summary

23. Based on the 2D hydrodynamic model results for the flows tested, the following observations were made:

- a. Supplement 2 works will cause a slight redistribution of flow at Head of Passes, with Southwest Pass flow being reduced by 1 to 2 percent from existing Southwest Pass flow. However, at the same time, velocities along Southwest Pass will increase by as much as 30-40 percent from existing conditions.
- b. Plan 1 will cause a slight redistribution of flow at Head of Passes, with Southwest Pass flow being increased by as much as 2 percent from existing Southwest Pass flow. At the same time, velocities along Southwest Pass will increase by as much as 40 percent from existing conditions.

24. Based on the 2D sediment transport model for the flows tested, the following observations were made:

- a. Supplement 2 works will cause a reduction in shoaling along Southwest Pass of 5 to 20 percent. However, the material transported through Southwest Pass with Supplement 2 will increase the entrance channel shoaling problem.
- b. Plan 1 will cause an increase in shoaling along Southwest Pass of 15 to 34 percent compared to existing conditions.

Table 1

Flow Distribution, Stages, and Velocities for 640,000 cfs at Venice, LA

% of Venice Flow	Base	Supplement 2	Plan 1	Plan 2	Plan 3	Plan 4
B. Collette	3	5	5	5	5	5
Grand/Tiger	4	8	8	8	8	8
Cubits Gap	6	8	7	7	7	7
SWP (& DS)*	32 (15)	30 (20)	32 (24)	32 (24)	32 (24)	32 (24)
SP (& DS)*	17 (2)	16 (2)	16 (2)	16 (2)	16 (2)	16 (2)
PAL	24	29	28	28	28	28
Channel	86	96	96	96	96	96
Overbank**	14	4	4	4	4	4
Stage, ft NGVD†						
Venice	2.7	3.2	3.1	3.1	3.1	3.1
Cubits Gap	2.2	2.6	2.5	2.5	2.5	2.5
Head of Passes	2.0	2.4	2.4	2.4	2.4	2.4
Upper Southwest Pass	0.6	0.8	0.8	0.8	0.8	0.8
Jetties	0.0	0.0	0.0	0.0	0.0	0.0
Velocities, fps†						
Venice	4.5	4.5	4.5	4.5	4.5	4.5
Cubits Gap	3.0	3.0	2.8	2.8	2.8	2.8
Head of Passes	3.0	2.9	2.6	2.6	2.6	2.6
Upper Southwest Pass	1.5	2.0	1.9	1.9	1.9	2.0
Jetties	1.0	1.4	1.5	1.5	1.4	1.4

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* Downstream at entrance.

** Overbank above Head of Passes.

† Typical midstream.

Table 2

Flow Distribution, Stages, and Velocities for 900,000 cfs at Venice, LA

% of Venice Flow	Base	Supplement 2	Plan 1	Plan 2	Plan 3	Plan 4
B. Collette	3	5	5	5	5	5
Grand/Tiger	4	7	7	7	7	7
Cubits Gap	6	8	7	7	7	7
SWP (& DS)*	30 (14)	29 (17)	32 (21)	32 (21)	32 (21)	32 (21)
SP (& DS)*	17 (2)	16 (2)	16 (2)	16 (2)	16 (2)	16 (2)
PAL	22	26	26	26	26	26
Channel	82	91	93	93	93	93
Overbank**	18	9	7	7	7	7
Stage, ft NGVD†						
Venice	3.7	4.2	4.1	4.1	4.1	4.1
Cubits Gap	3.0	3.5	3.3	3.3	3.3	3.3
Head of Passes	2.7	3.2	3.1	3.1	3.1	3.1
Upper Southwest Pass	0.8	1.0	1.0	1.0	1.0	1.0
Jetties	0.0	0.0	0.0	0.0	0.0	0.0
Velocities, fps†						
Venice	6.4	6.3	6.3	6.3	6.3	6.3
Cubits Gap	4.0	3.9	3.7	3.7	3.7	3.7
Head of Passes	4.0	3.9	3.5	3.5	3.5	3.5
Upper Southwest Pass	2.1	2.5	2.5	2.5	2.5	2.7
Jetties	1.4	1.8	2.0	1.9	1.8	1.8

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* Downstream at entrance.
** Overbank above Head of Passes.
† Typical midstream.

Table 3

Flow Distribution, Stages, and Velocities for 1,300,000 cfs at Venice, LA

% of Venice Flow	Base	Supplement 2	Plan 1	Plan 2	Plan 3	Plan 4
B. Collette	3	5	5	5	5	5
Grand/Tiger	4	6	6	6	6	6
Cubits Gap	6	7	6	6	6	6
SWP (& DS)*	29 (13)	28(15)	31 (19)	31 (19)	31 (19)	31 (19)
SP (& DS)*	17 (2)	16 (2)	16 (2)	16 (2)	16 (2)	16 (2)
PAL	21	24	23	23	23	23
Channel	80	86	87	87	87	86
Overbank**	20	14	14	14	14	14
Stage, ft NGVD†						
Venice	5.0	5.5	5.3	5.3	5.3	5.3
Cubits Gap	4.1	4.6	4.3	4.3	4.3	4.3
Head of Passes	3.6	4.1	4.0	4.0	4.0	4.0
Upper Southwest Pass	1.1	1.3	1.3	1.3	1.3	1.3
Jetties	0.0	0.0	0.0	0.0	0.0	0.0
Velocities, fps†						
Venice	8.7	8.7	8.7	8.7	8.7	8.7
Cubits Gap	5.2	5.2	4.9	4.9	4.9	4.9
Head of Passes	5.3	5.2	4.7	4.7	4.7	4.7
Upper Southwest Pass	2.9	3.2	3.3	3.3	3.3	3.5
Jetties	1.9	2.2	2.5	2.4	2.3	2.3

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* Downstream at entrance.

** Overbank above Head of Passes.

† Typical midstream.

Table 4

Reduction in Shoaling Along Southwest Pass (Mile 0-20 BHP) Resulting from Supplement 2 Works

Discharge (1,000 cfs)	Base Shoaling (10^6 cu yd/month)	Supplement 2 Shoaling (10^6 cu yd/month)	Reduction (percent)
640	0.92	0.73	-20
900	1.36	1.13	-17
1300	2.55	2.43	- 5

Table 5

Increase in Shoaling Along Southwest Pass (Mile 0-20 BHP) Resulting from Supplement 2 and 55-Foot Channel (Plan 1)

Discharge (1,000 cfs)	Base Shoaling (10^6 cu yd/month)	Plan 1 Shoaling (10^6 cu yd/month)	Increase (percent)
640	0.92	1.23	+34
900	1.36	1.69	+24
1300	2.55	2.94	+15

Table 6

Increase in Shoaling Along Southwest Pass (Mile 0-20 BHP) 40-Foot Channel with Supplement 2 Works Compared to 55-Foot Channel with Supplement 2 Works (Plan 1)

Discharge (1,000 cfs)	40-Foot Channel Shoaling (10^6 cu yd/month)	Plan 1 Shoaling (10^6 cu yd/month)	Increase (percent)
640	0.73	1.23	+68
900	1.13	1.69	+49
1300	2.43	2.94	+21