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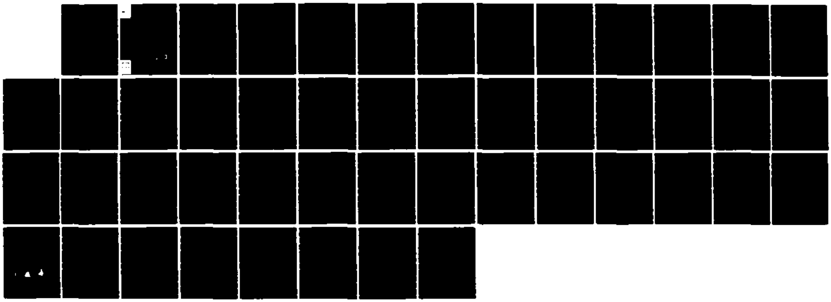

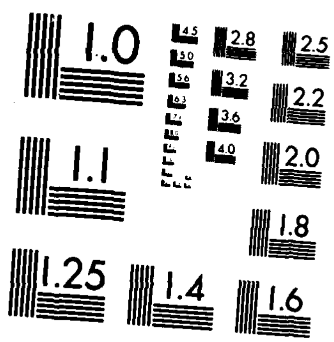
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US Army Corps of Engineers

MISCELLANEOUS PAPER HL-86-7

ESTUARY MODEL TEST EVALUATION

by

Noble J. Brogdon, Jr.

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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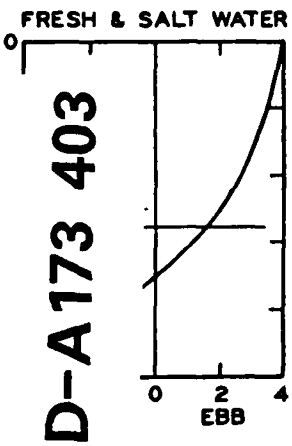

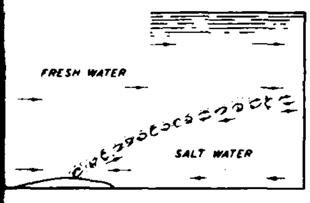

September 1986
Final Report

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19 ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Salinity data from physical model studies of nine estuaries and pertinent information on each estuary were analyzed in an effort to develop rapid and effective techniques to evaluate the changes in salinity that would occur due to modification (deepening) of navigation channels.

Several analysis approaches to the model data were attempted in an effort to achieve the objective of this research unit. At the time of publication, no successful technique had been developed that meets the objective. However, it is recommended that efforts to develop a technique to evaluate the change in salinity due to channel deepening continue.

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19. ABSTRACT (Continued).

The magnitude of salinity change due to channel modification is dependent to a large degree on each of the phenomena listed in the following tabulation. The results and conclusions presented for each estuary studied in this report could be applied, with engineering judgment, to similar systems to reach a quick and general estimate of salinity change due to channel modification.

Estuary	Salinity Intrusion miles	Maximum Width 10^3 ft	Mean Inflow cfs	Mean Tide Range ft	Tidal Prism ft^3	Channel Depth Change ft
Grays Harbor	23	66	10,000	9.0	1.7×10^{10}	10
Tillamook Bay	13	13	28,000	5.7	1.64×10^{9}	22
Matagorda Bay	40	155	800	0.7	8.7×10^{9}	29
Mobile Bay	52	123	61,000	1.3	3.4×10^{10}	10
Savannah River	20	3	8,500	6.9	3.1×10^{9}	6
Charleston Harbor	26	15	15,600	5.2	5.8×10^{9}	5
Georgetown Harbor	19	21	10,000	4.6	3.0×10^{9}	8
James River	65	30	7,350	2.6	8.7×10^{9}	10
Chesapeake Bay	215	156	72,400	2.8	13.9×10^{10}	8

PREFACE

The research described in this report was conducted at the US Army Engineer Waterways Experiment Station (WES) under Work Unit 31720 of the Navigation Hydraulics Civil Works area of the Corps of Engineers Civil Works Research and Development Program sponsored by the Office, Chief of Engineers, US Army.

Personnel of the Hydraulics Laboratory of WES performed this study during the period 1981 to 1986 under the direction of Messrs. H. B. Simmons, former Chief of the Hydraulics Laboratory (retired); F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; J. E. Glover, Chief of the Waterways Division; W. H. McAnally, Jr., Chief of the Estuaries Division; R. A. Boland, former Chief of the Estuary Simulation Branch (retired); and J. V. Letter, Chief of the Estuary Simulation Branch. Mr. N. J. Brogdon, Jr., was Project Engineer and prepared this report.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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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
feet	0.3048	metres
miles (US statute)	1.609347	kilometres

ESTUARY MODEL TEST EVALUATION

PART I: INTRODUCTION

Background

1. The effect of deep-draft channels on salinity distribution is an important design consideration; however, existing techniques for determining the effect of deep-draft channels on salinity distribution are expensive and require considerable time. Salinity is important in determining transport, flushing, and mixing rates and as a tracer to label different water masses. It is also a very important ecological factor to the biologists, since salinity limits the distribution of various species. Considerable information is available from various estuarine systems throughout the world; however, applying these data to specific projects involving navigation channels is difficult.

Purpose

2. The initial objective of the study was to develop rapid and effective techniques to evaluate the changes in salinity that occur due to modification (deepening) of navigation channels.

Scope

3. Coastal US Army Corps of Engineers District Offices were surveyed to obtain pre- and post-dredge modification prototype salinity data. Because this survey yielded very little useful information, a decision was made to concentrate the study on physical model results.

4. Research in this area yielded numerous model studies that included salinity studies; however only nine model studies were isolated that produced salinity data resulting from deepening/widening of the navigation channel. Pertinent information on these nine estuaries, including geometry, channel dimensions, physical phenomena, and effects of changes in channel dimensions on salinities, and summaries of the individual studies are presented in this report in the form of figures and tabulations.

PART II: ESTUARY DATA

Grays Harbor, Washington

Location: Southwest corner of Washington

Freshwater source: Chehalis River

Tide: Diurnal inequality typical of Pacific Coast

	Tide Range, ft*		
Type	Entrance	Maximum Salinity Intrusion	Tidal Prism
Neap	7.2	8.5	--
Mean	9.0	10.1	1.7×10^{10} (Johnson 1972)
Spring	12.3	13.3	--

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

Freshwater inflow (US 96th Congress 1979)

Average annual high	79,000 cfs
Average annual mean	10,388 cfs
Average annual low	994 cfs

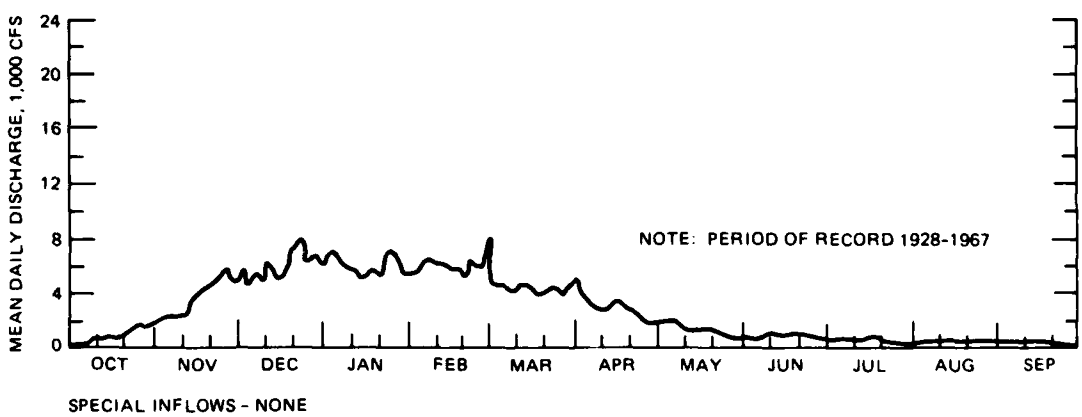

Figure 1. Summary hydrograph, Chehalis River, Grand Mound, Washington

Special inflows: None

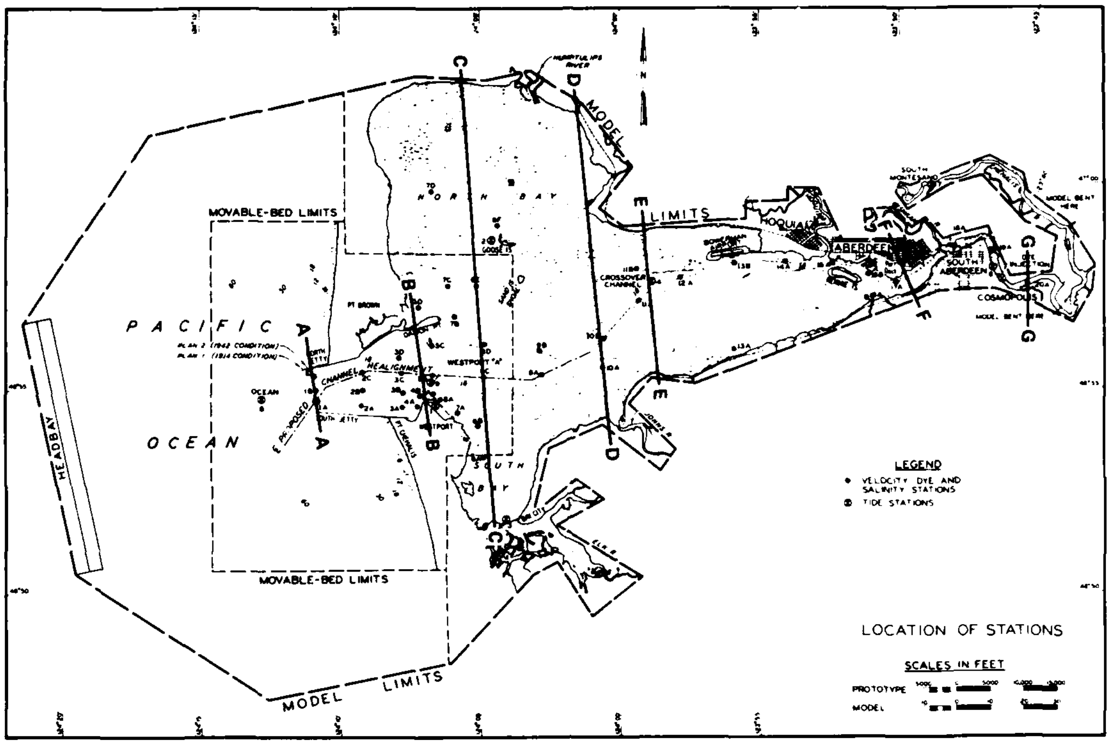

Figure 2. Grays Harbor location map

<u>Geometry:</u> Pear-shaped estuary

Section	Location	Width, ft	Average Depth*	Maximum Depth*
A-A	End of jetties	7,150	45	67
B-B	Mouth	11,100	35	76
C-C	Mile 5	66,300	12	35
D-D	Mile 8	43,200	10	43
E-E	Mile 10	23,500	6	30
F-F	Mile 18	2,900	14	30
G-G	Mile 23 (maximum salinity intrusion)	910	18	31

* In feet referred to the National Geodetic Vertical Datum (NGVD).

Navigation channel dimensions (Brogdon 1976)

Location	Existing Width ft	Existing Depth ft NGVD	Plan Width ft	Plan Depth ft NGVD
Outer bar (mile 1.0)	Natural	42	1,000	50
End of jetties (mile 0)	Natural	65	600	50
Toe of jetties	Natural	70	600	50
Crossover channel (mile 10)	350	35	500	45
Hoquiam Reach (mile 20)	350	35	400	45
Aberdeen Reach (mile 19)	200	35	400	45
End of project (mile 22.5)	200	35	300	45
Extent of maximum salinity intrusion (mile 23)	Natural (900 ft)	31	Natural (900 ft)	31

Physical model (Brogdon 1976)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:500

Salinity changes (Brogdon 1976)

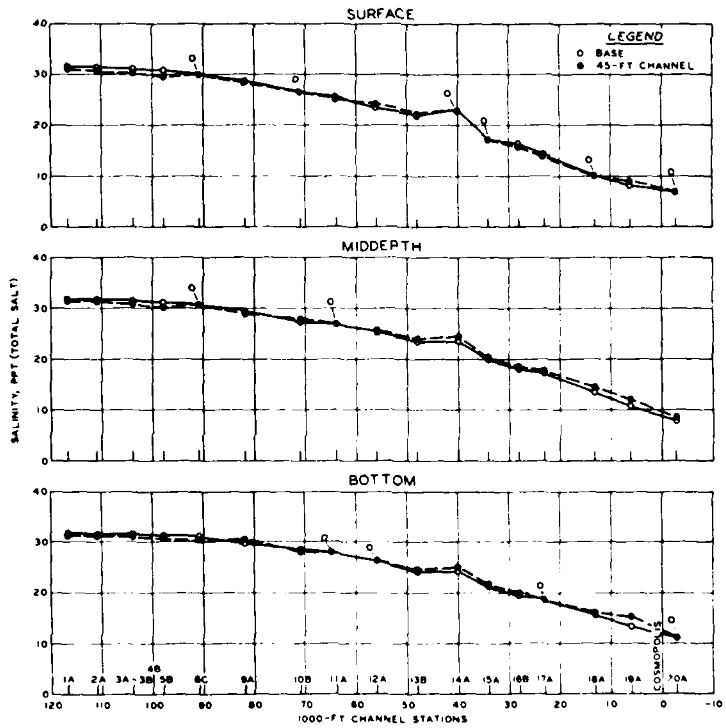

Figure 3. Salinity profile along main navigation channel (1,120 cfs)

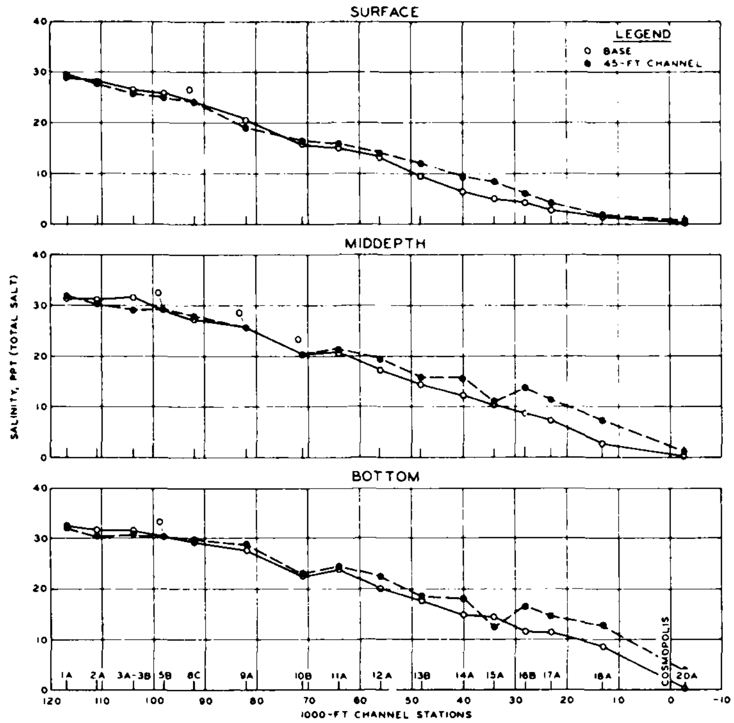

Figure 4. Salinity profile along main navigation channel (6,300 cfs)

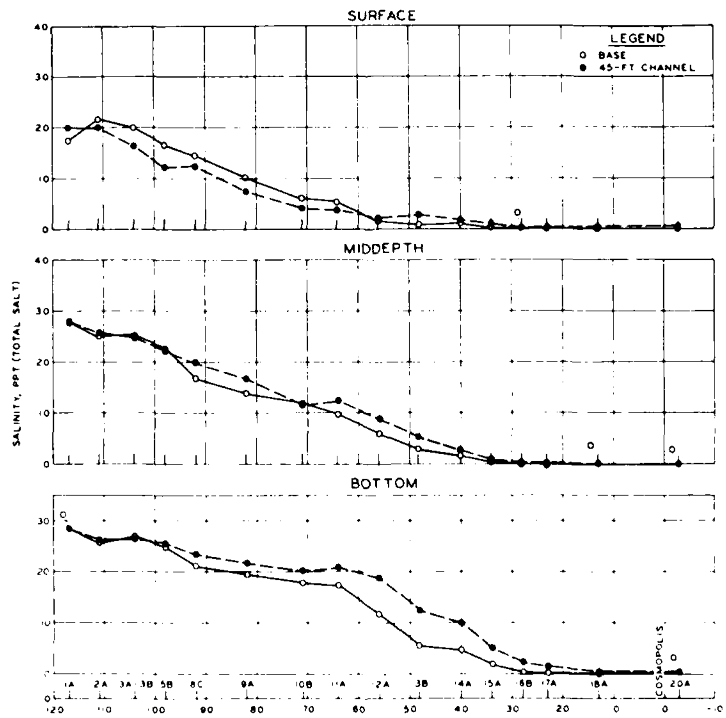

Figure 5. Salinity profile along main navigation channel (32,000 cfs)

Conclusions

5. A redistribution of salinity occurred with increases in the upper portion of the estuary and decreases in the lower portions, including north and south bays. Stratification was increased, particularly in the upper portion of the estuary. This effect was extended progressively further downstream with increased freshwater discharge. Salinity intrusion up the estuary was increased only slightly with tests conducted with the low inflow, but on the order of 2 to 3 miles with tests for the high freshwater discharge.

Tillamook Bay

Location: Northwest coast of Oregon

Freshwater source: Miami, Kilchis, Wilson, Trash, and Tillamook

Tide: Diurnal inequality typical of Pacific Ocean

Type	Tide Range, ft: Entrance	Tide Range, ft: Maximum Salinity Intrusion	Tidal Prism
Mean	5.7	5.2	1.64×10^9*
Spring	7.5	6.6	2.15×10^9*

* Johnson 1972.

Freshwater inflow (Committee on Tidal Hydraulics 1970)

Summer average	455 cfs
Annual water flood	28,300 cfs
2-year winter flood	52,500 cfs
25-year winter flood	83,200 cfs
50-year winter flood	90,000 cfs

Hydrograph: None available

Special inflows: None

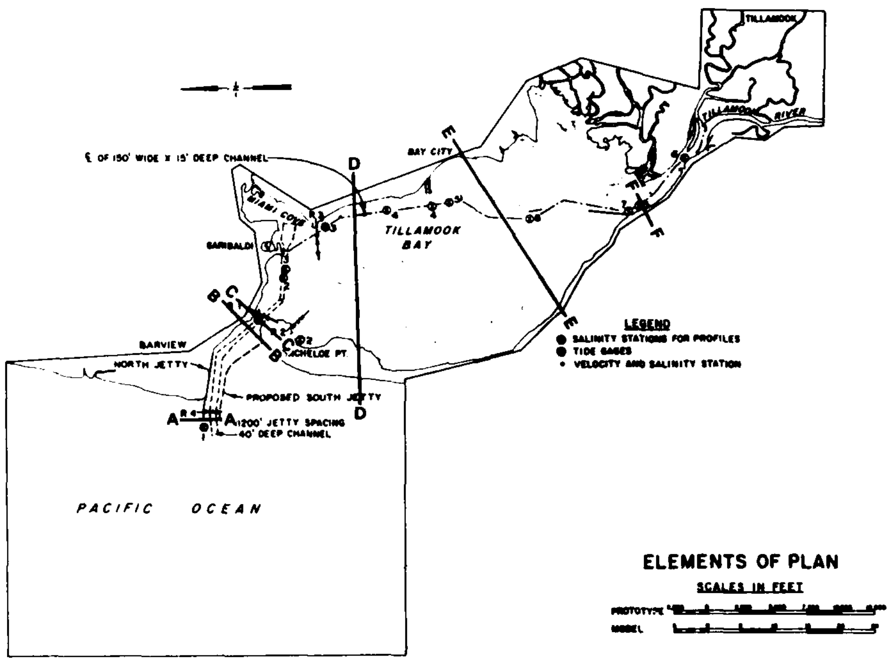

Figure 6. Tillamook Bay location map

Geometry: Irregularly shaped

Section	Location	Width, ft	Average Depth*	Maximum Depth*
A-A	End of jetties	1,200	15	19
B-B	Toe of jetties	2,000	8	27
C-C	Mouth (mile 1.8)	1,485	16	44
D-D	Mile 4	10,500	5	16
E-E	Mile 6	13,200	2	5
F-F	Mile 9 (maximum salinity intrusion)	700	3	6

* In feet referred to mean lower low water (mllw).

Navigation channel dimensions (Fisackerly 1974)

Location	Existing		Plan	
	Width, ft	Depth, ft mllw	Width, ft	Depth, ft mllw
Outer Bar	200	18	500	40
Entrance to Barview (mile 1)	200	18	500	40
Barview to Garibaldi (mile 3)	200	18	300	30
Garibaldi to Tillamook	Natural	3-8	150	15

Physical Model (Fisackerly 1974)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:500

Salinity changes (Fisackerly 1974)

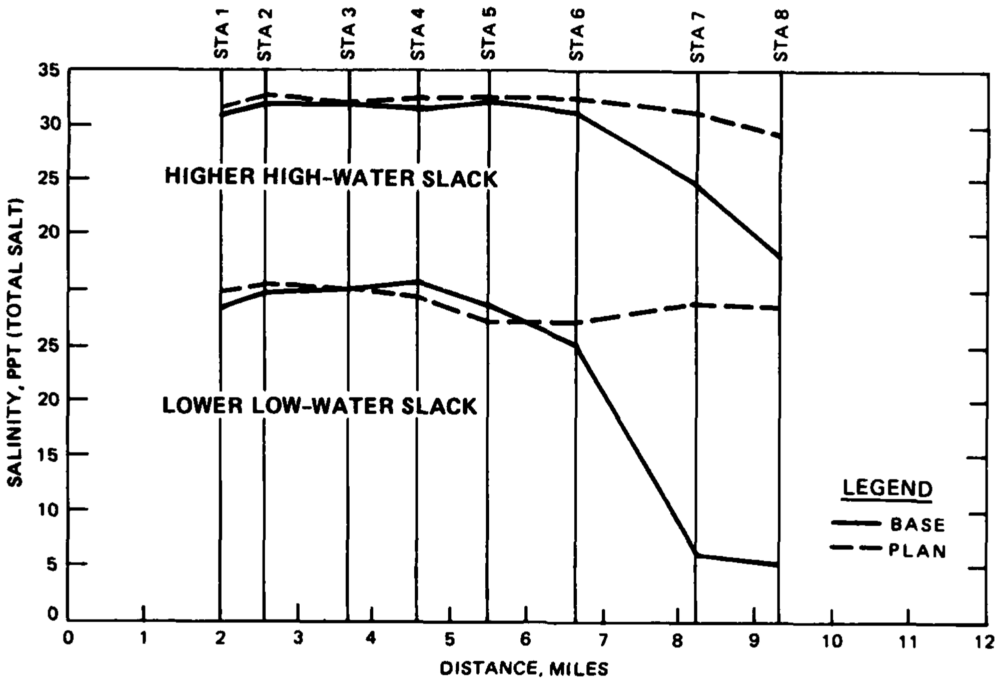

Figure 7. Surface salinity profile (500 cfs)

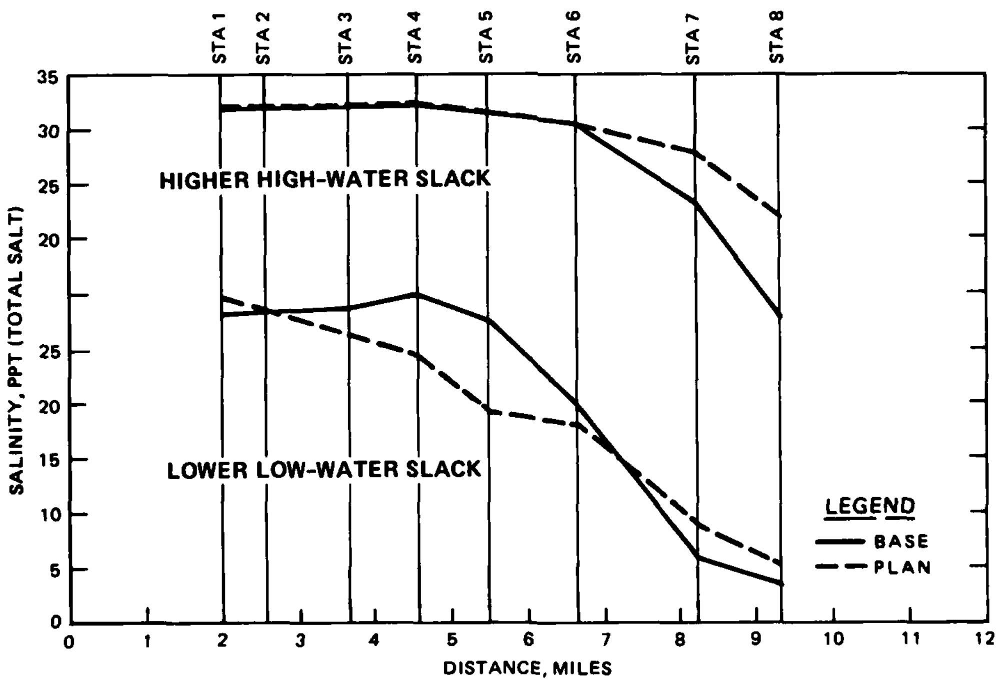

Figure 8. Bottom salinity profile (500 cfs)

Conclusions

6. Minor changes occurred in the lower bay, with exception during minimum salinity, where at sta 4 and 5, surface depth salinities were decreased about 5 and 7 ppt, respectively. This decrease resulted in an increase in stratification in this portion of the estuary. Salinity profiles show large increases in salinity concentrations at sta 8 (most upstream of stations monitored during test) at both surface and bottom depths and during both higher high- and lower low-water slack periods. This increase indicates that the deepened channel plans would significantly increase the upstream extent of salinity intrusion. The largest increase observed (about 24 ppt) occurred at the bottom depth during lower low-water slack.

Matagorda Bay

Location: Southwest Gulf of Mexico, southwest coast of Texas

Freshwater source: Lavaca and Navidad rivers

Tide: Diurnal

Type	Tide Range, ft: Entrance	Tide Range, ft: Maximum Salinity Intrusion	Tidal Prism
Mean*	0.7	0.5	8.71×10^9*
Spring*	1.5	0.7	--

* Committee on Tidal Hydraulics 1971.

Freshwater inflow (Rhodes and Simmons 1966)

Average annual mean	828 cfs*
Average annual high	3,315 cfs

* An additional 1,220 cfs enters the system through local coastal drainage and rainfall on the bay itself (Committee on Tidal Hydraulics 1971).

Hydrograph: None available

Special inflows: None

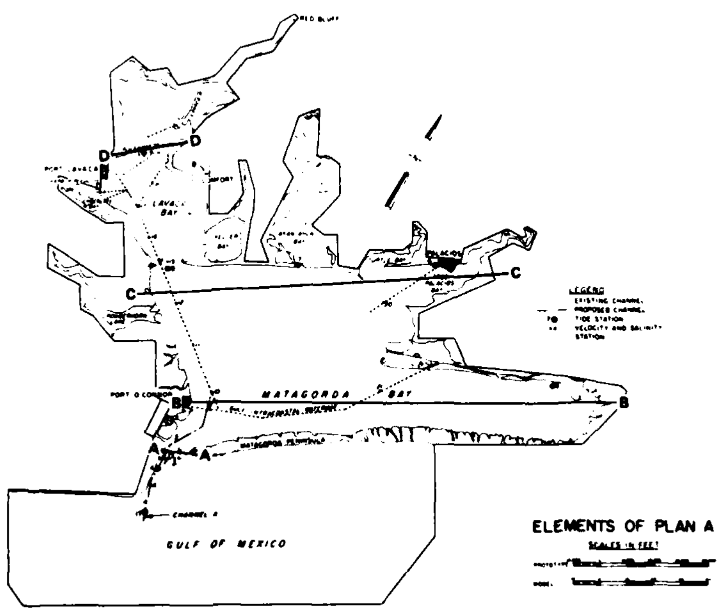

Figure 9. Matagorda Bay location map

Geometry: Irregularly shaped

Section	Location	Width, ft	Average Depth*	Maximum Depth*
A-A	Entrance	6,000	11	35
B-B	Mile 4	155,000	8	13
C-C	Mile 12	121,500	7	13
D-D	Mile 25	11,400	3	5

* In feet referred to mean low water (mlw).

Navigation channel dimensions (Rhodes and Simmons 1966)

Location	Existing		Plan	
	Width, ft	Depth, ft mlw	Width, ft	Depth, ft mlw
Outer bar	Natural	10-11	300	38
Entrance	100	9	300	38
Entrance to Port Lavaca	100	9	200	36

Physical model (Rhodes and Simmons 1966)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:1000

Salinity changes (Rhodes and Simmons 1966) (see Figure 10, following page)

Conclusions

7. Salinities within the new channel below the plane of the existing bottom were appreciably higher than those that occurred at comparable locations. However, there were no appreciable changes in salinity outside the limits of the new channel, or within the limits of the new channel above the plane of the existing bottom.

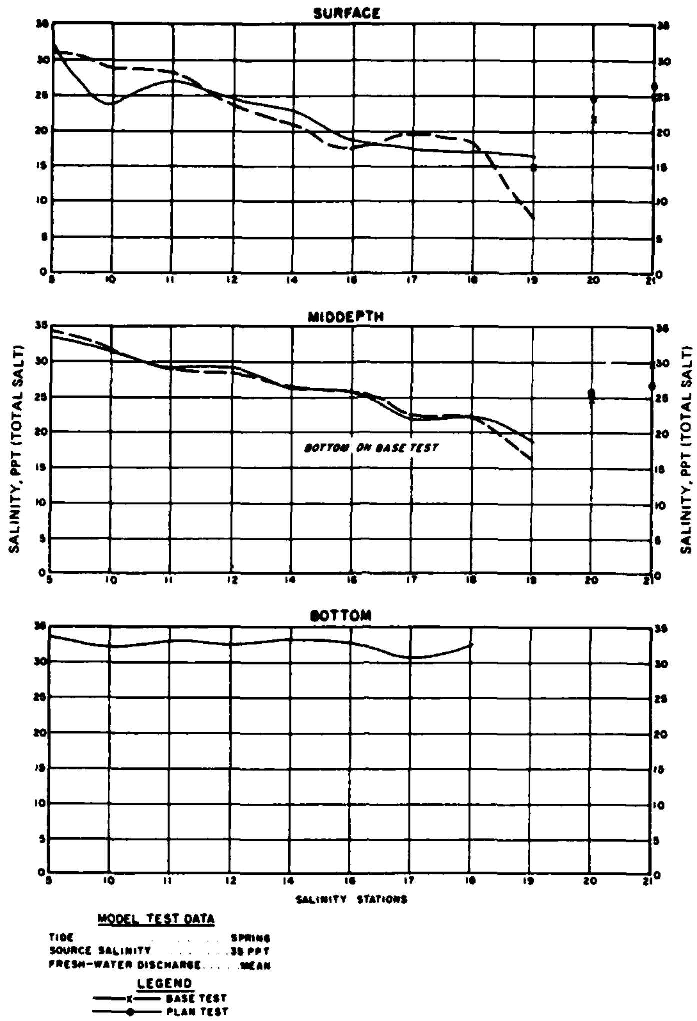

Figure 10. Salinity profiles, Plan A, Test 1 (800 cfs)

Note: Plan A was not the plan recommended as a result of the model study. The recommended plan involved dredging a second entrance about 28,000 ft east of the existing opening and protecting it with jetties. For the purpose of this paper, Plan A was the only plan tested for which direct comparisons of existing and deepened channel salinity data could be made. All other plan studies reflected not only the effects of a deepened channel but also effects of such additions as the second opening and jetties.

Mobile Bay

Location: Central Gulf of Mexico, southwest Alabama

Freshwater source: Tombigbee and Alabama rivers

Tide: Influenced by diurnal tide (single tide per day)

Type	Tide Range, ft: Entrance*	Tide Range, ft: Maximum Salinity Intrusion	Tidal Prism
Neap	1.0	1.5	--
Mean	1.3	1.5	--
Spring	2.5	2.6	3.4×10^{10}**

* Berger and Boland 1979.
** Jarrett 1976.

Freshwater inflow (Committee on Tidal Hydraulics 1971)

Average annual high	574,000 cfs
Average annual mean	61,000 cfs
Average annual low	7,400 cfs

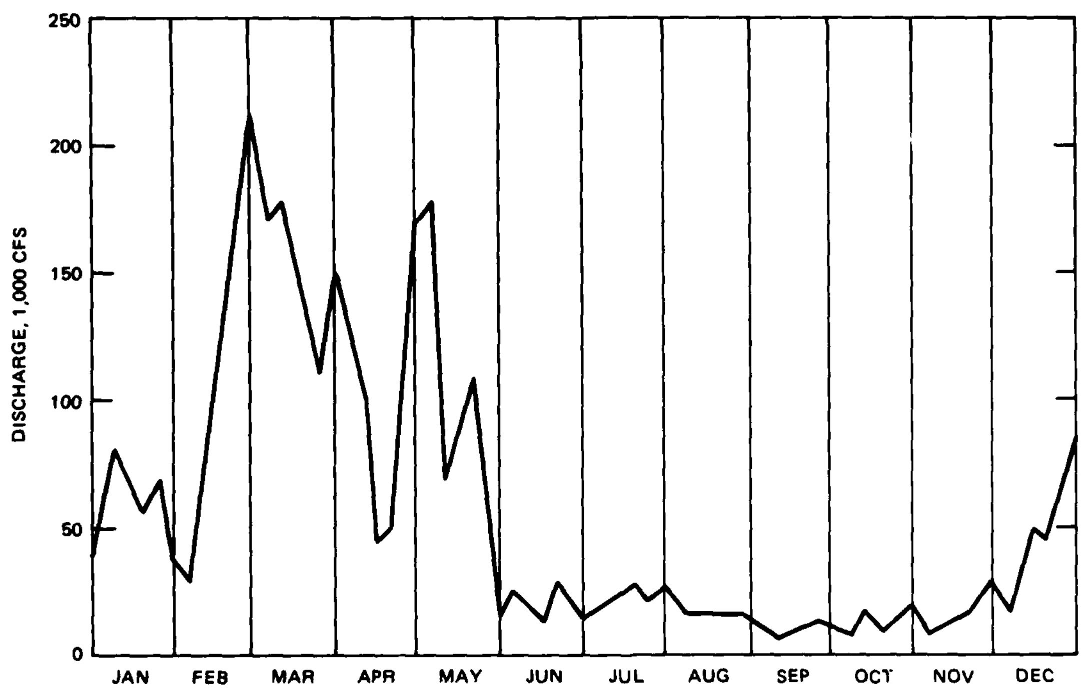

Figure 11. Typical freshwater hydrograph, Tombigbee and Alabama rivers

Special inflows: None

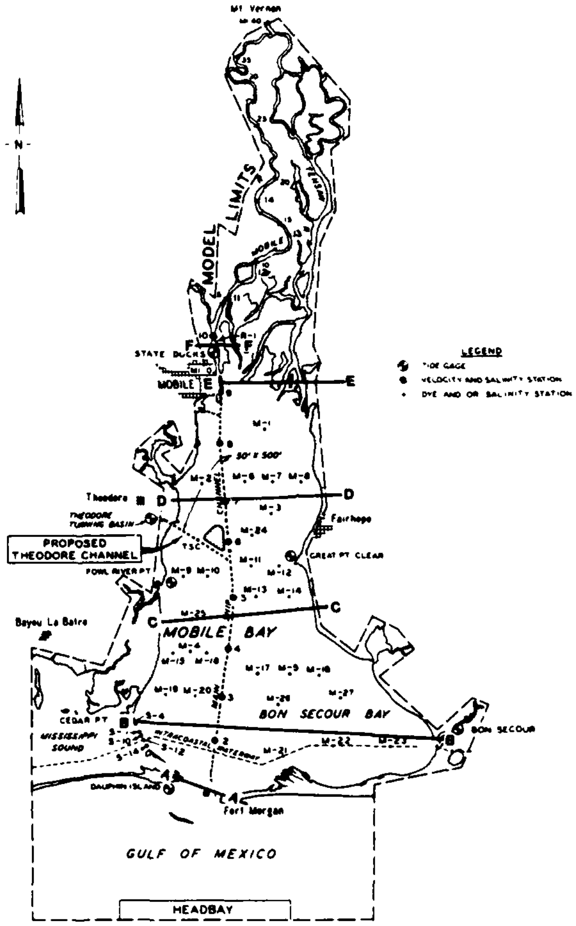

Figure 12. Mobile Bay location map

Geometry: Roughly pear shaped, 30 miles long, maximum width of about 23 miles at lower end

Section	Location	Width ft	Average Depth ft mlw	Maximum Depth ft mlw
A-A	Entrance (mile 0)	16,000	13	46
B-B	Mile 5	123,000	8	40*
C-C	Mile 14	60,400	8	40*
D-D	Mile 22	56,800	7	40*
E-E	Mile 30	37,500	5	40*
F-F	Mile 34	1,300	20	25*

* Navigation channel.

Navigation channel dimensions (Berger and Boland 1979)

Location	Existing Width, ft	Existing Depth, ft mlw	Plan Width, ft	Plan Depth, ft mlw
Outer bar channel	600	42	800	52
Entrance (mile 0) to mile 26	400	40	500	50
Mile 26 to mouth of Mobile River (mile 30)	400	40	700	50
Mile 30 to mile 32	500-775	40	500-775	40
Mile 32 to mile 34	500	25	500	25

Physical model (Berger and Boland 1979)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:1,000

Salinity changes (Berger and Boland 1979)

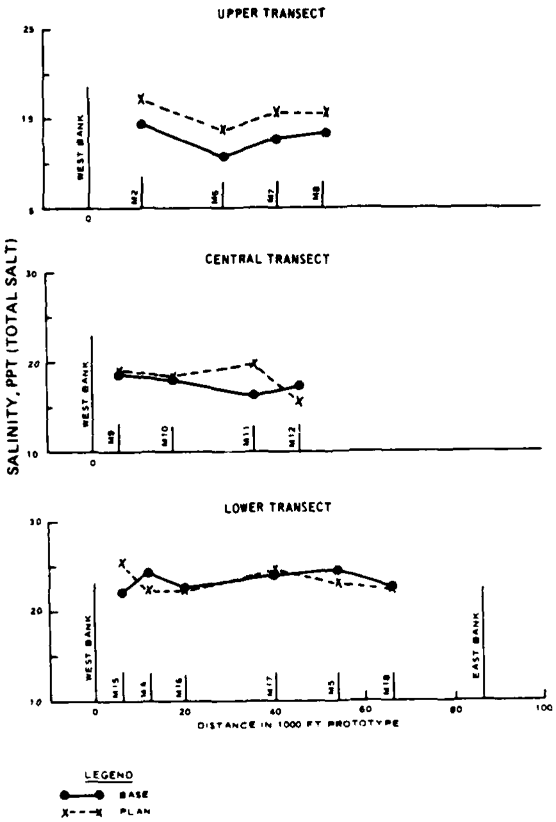

Figure 13. Effects of plan on average surface salinities (15,500 cfs)

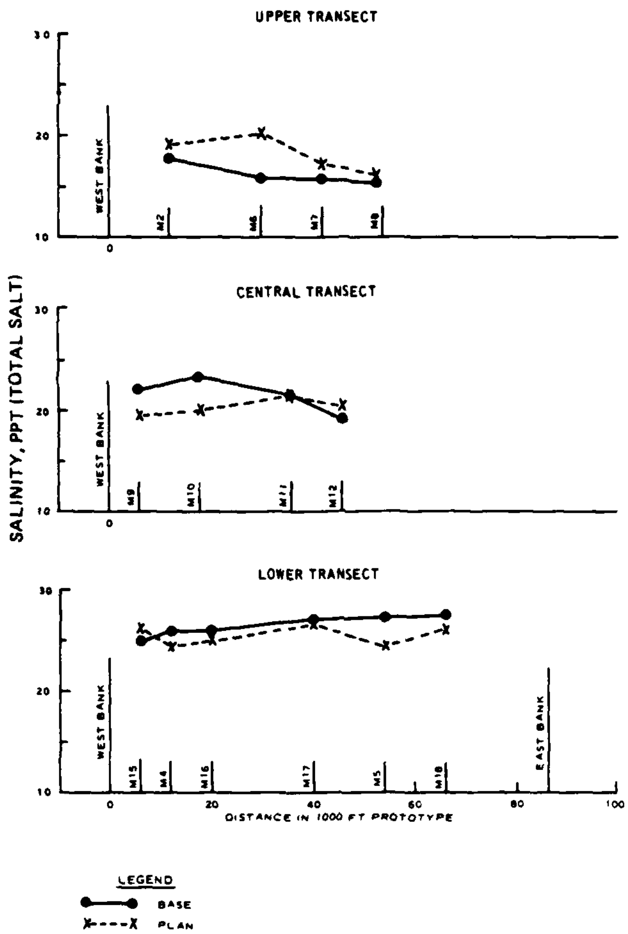

Figure 14. Effects of plan on average bottom salinities (15,500 cfs)

Conclusions

8. Average surface and bottom salinities were increased along the upper transect (mile 23 from the entrance). Generally along the central transect (mile 18), surface salinities were increased east of the channel, and bottom salinities were decreased west of the channel. Average salinities, surface and bottom, along the lower transect (mile 11) were decreased. The exception to this trend was noted at sta M15, where both depths showed an increase in salinity. The improved channel affected an average salinity increase at the surface depth in the upper bay and a decrease of salinity in the lower bay. Average salinity values at the bottom were increased in the upper bay and decreased generally at other locations in the bay.

Savannah River

Location: South Atlantic Coast, partially in South Carolina and in Georgia

Freshwater source: Savannah River

Tide: Semidiurnal

Type*	Tide Range, ft Entrance	Tide Range, ft Maximum Salinity Intrusion	Tidal Prism
Mean	6.9	6.2	--
Spring	8.1	7.2	3.1×10^{9}**

* National Oceanic and Atmospheric Administration, 1981.
** Jarrett 1976.

Freshwater inflow (Committee on Tidal Hydraulics 1971)

Average high	16,000 cfs
Average mean	7,000-10,000 cfs
Average low	5,800 cfs

Note: Inflow is controlled by two reservoirs, Clark Hill and Hartwell.

Hydrograph: None available

Special inflows: None

Geometry: Long, narrow irregular shape (see Figure 15, following page).

Section	Location	Width ft	Average Depth ft mlw	Maximum Depth ft mlw*
A-A	End of jetties (sta 200)	2,500	21	36
B-B	Toe of jetties (sta 196)	2,200	20	36
C-C	Sta 183	1,850	18	34
D-D	Sta 163	1,800	17	34
E-E	Sta 143	1,500	16	34
F-F	Sta 109	600	20	34
G-G	Sta 82	900	19	34

* Channel.

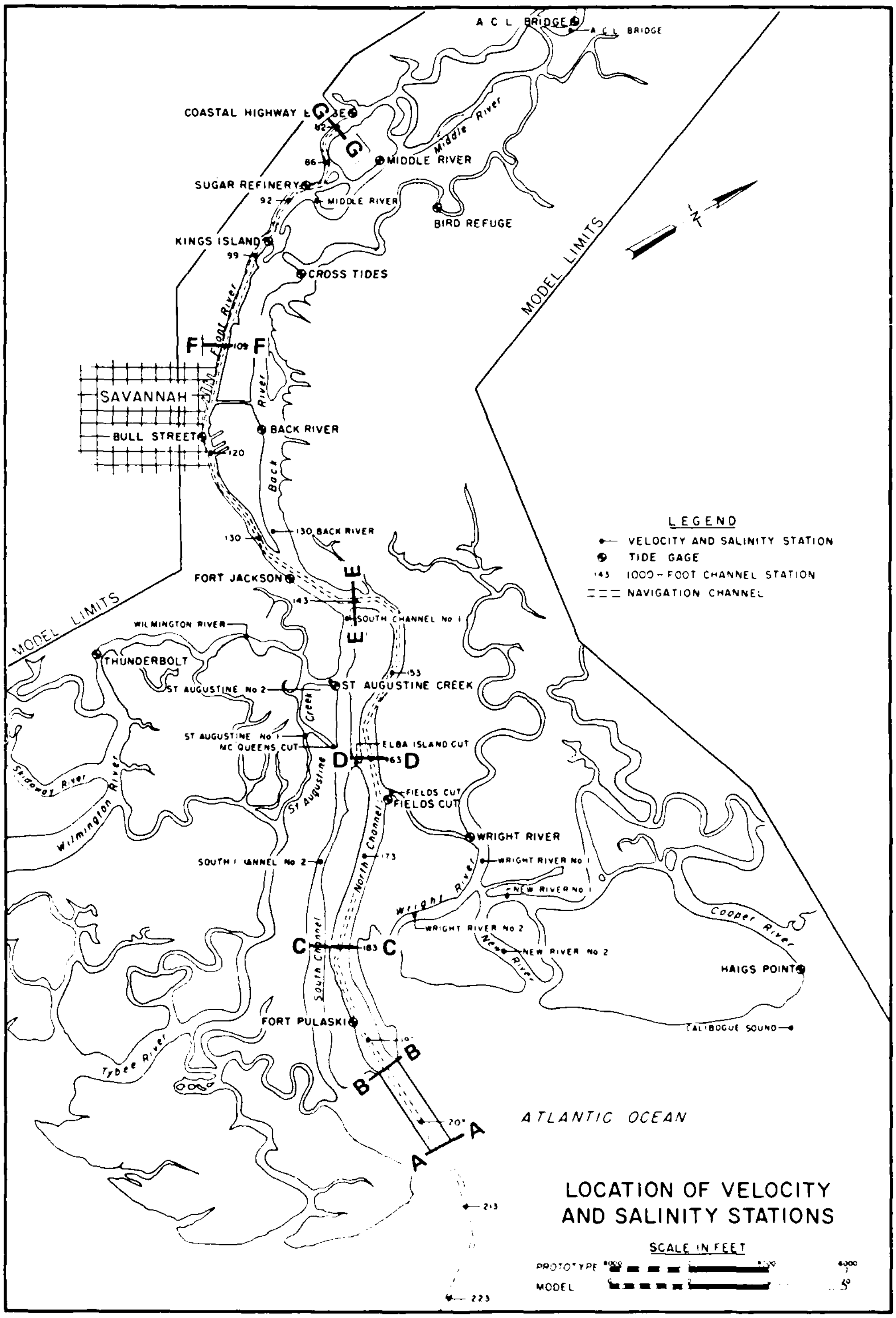

Figure 15. Savannah River location map

Navigation channel dimensions (Rhodes and Simmons 1965)

Location	Existing Width, ft	Existing Depth, ft mlw	Plan Width, ft	Plan Depth, ft mlw
Outer bar	500	36	600	40
End of jetties (sta 200) to sta 194	500	36	500	40
Sta 194 to 94	400	34	400	40
Sta 94 to 82	200	30	200	40

Physical model (Rhodes and Simmons 1965)

Type	Fixed-bed distorted scale
Vertical scale	1:80
Horizontal scale	1:800

Salinity changes (Rhodes and Simmons 1965) (see Figure 16, following page).

Conclusions

9. Salinities were generally increased throughout the harbor, with the greatest increase occurring at the bottom and middepth in Front River. Small decreases in salinities were observed near the ocean end of the channel, primarily at the surface depth.

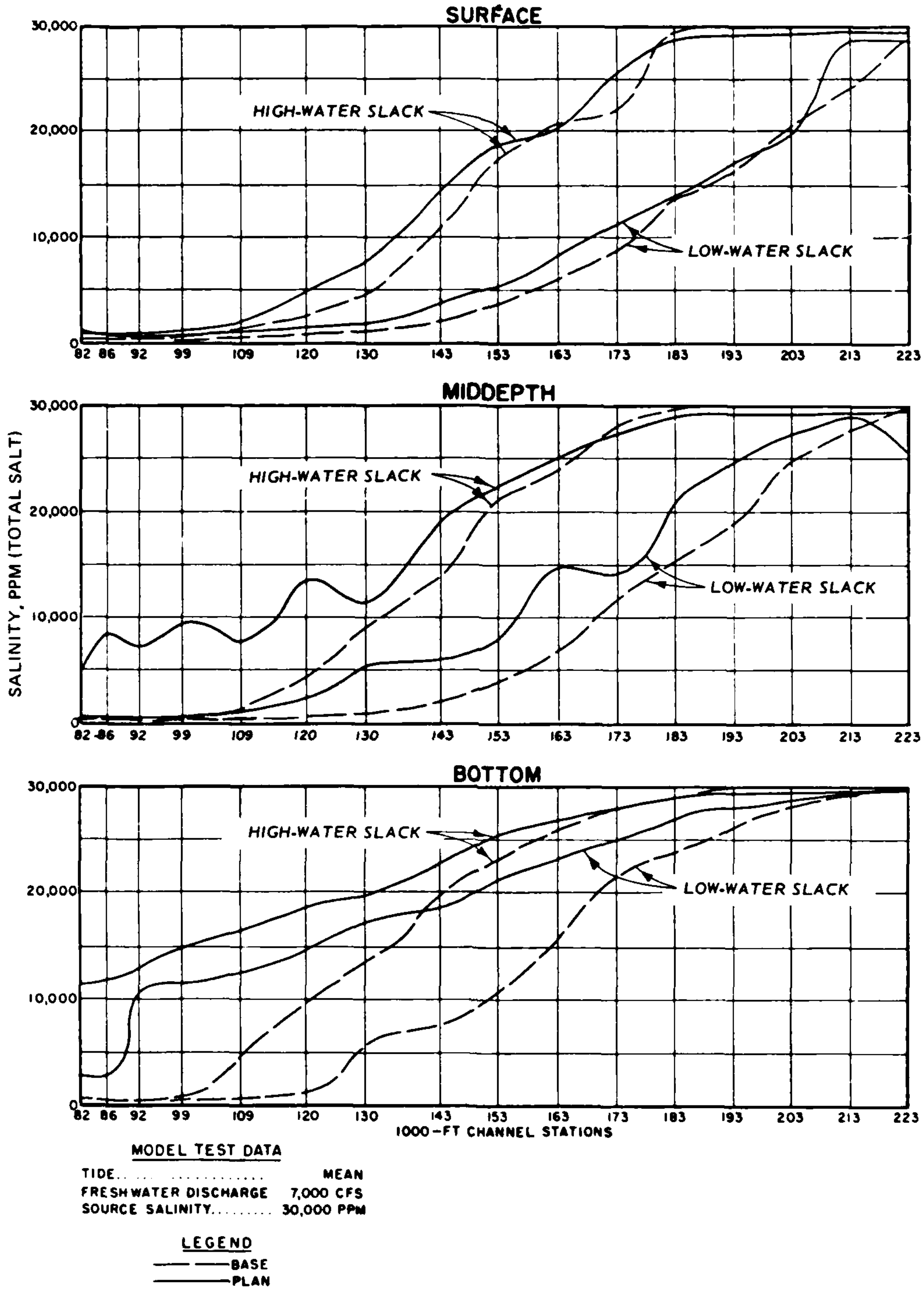

Figure 16. Salinity profiles, Savannah River

Charleston Harbor

Location: Coast of South Carolina

Freshwater source: Cooper River (controlled by Pinopolis Dam), Ashley River, and Wando River

Tide: Semidiurnal tide of diurnal equality

Type	Tide Range, ft Entrance	Tide Range, ft Maximum Salinity Intrusion	Tidal Prism
Mean	5.2	4.2	--
Spring	6.1	5.1	5.75×10^9*

* Jarrett 1976.

Freshwater inflow (Committee on Tidal Hydraulics 1971)

Maximum	28,000 cfs
Average	15,600 cfs
Minimum	2,000 cfs

Hydrograph: None available

Special inflow: Inflow controlled by power plant operation at Pinopolis Dam, Bushy Park combined withdrawals of 1,150 cfs.

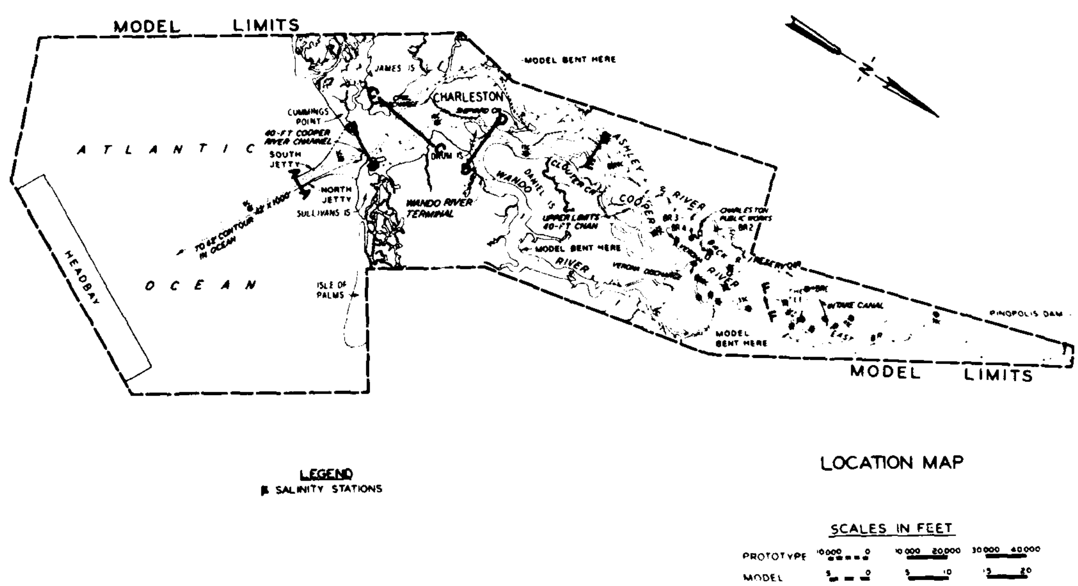

Figure 17. Charleston Harbor location map

Geometry: Irregular shape

Section	Location	Width, ft	Average Depth ft mlw	Maximum Depth, ft mlw
A-A	End of jetties (mile 3)	2,900	20	35
B-B	Mouth (mile 6)	7,200	22	74
C-C	Mile 9	14,700	14	35
D-D	Mile 13	11,300	15	40
E-E	Mile 19	2,600	15	35
F-F	Mile 37	500	16	35

Navigation channel dimensions (Benson 1976)

	Existing		Plan	
Location	Width, ft	Depth, ft mlw	Width, ft	Depth, ft mlw
Outer bar	1,000	35	1,000	42
End of jetties	1,000	35	1,000	42
Mile 6	600	35	600	40
Mile 9	600	35	600	40
Mile 13	900	35	900	40
Mile 19	400	35	400	40
Mile 37	Natural	35*	Natural	35

* Maximum.

Physical model (Benson 1976)

Type	Fixed-bed distorted scale
Vertical	1:100
Horizontal	1:2,000

Salinity changes (Benson 1976)

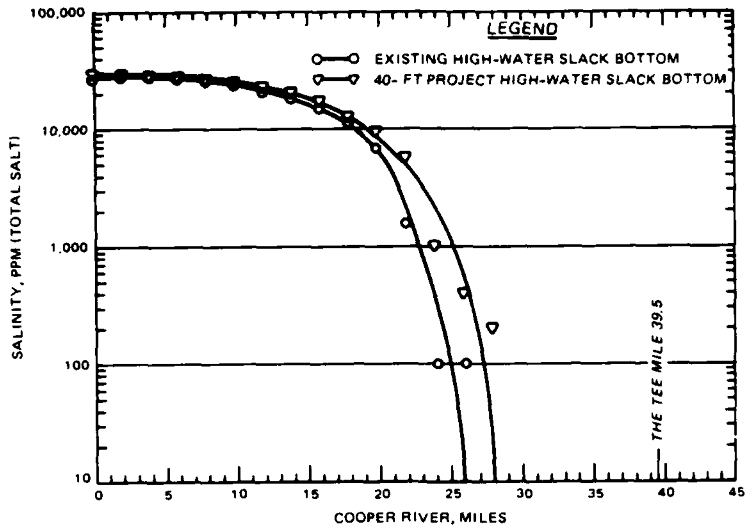

Figure 18. Salinity profile, weekly average discharge 15,600 cfs

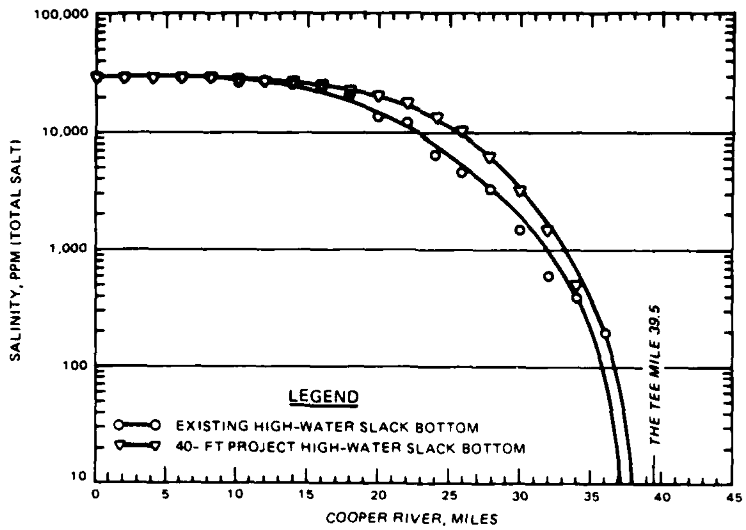

Figure 19. Salinity profile, weekly average discharge 3,500 cfs

Conclusions

10. Tests with the 15,600-cfs weekly average flow and improved channel resulted in increased salinity intrusion of about 1 mile. Salinities in Wando River, Ashley River, and Cloute Creek were increased about 2-3 ppt. Tests conducted with the 3,500-cfs inflow likewise increased salinity intrusion about 1 mile. Bottom salinities between miles 10 and 32 on the Cooper River

were increased from 1 to 7 ppt with the improved channel installed, while salinities in the Ashley River, Wando River, and Cloute Creek were increased generally less than 1-2 ppt.

Georgetown Harbor

Location: Coast of South Carolina

Freshwater source: Pee Dee, Waccamaw, Black, and Sampit rivers

Tides: Semidiurnal

	Tide Range, ft		
Type	Entrance*	Maximum Salinity Intrusion	Tidal Prism
Mean	4.6	3.3	--
Spring	5.4	3.9	3.02×10^9**

* Trawle 1978.
** Jarrett 1976.

Freshwater inflow (Committee on Tidal Hydraulics 1971)

Average annual high	300,000 cfs
Average annual mean	10,000 cfs
Average annual low	2,000 cfs

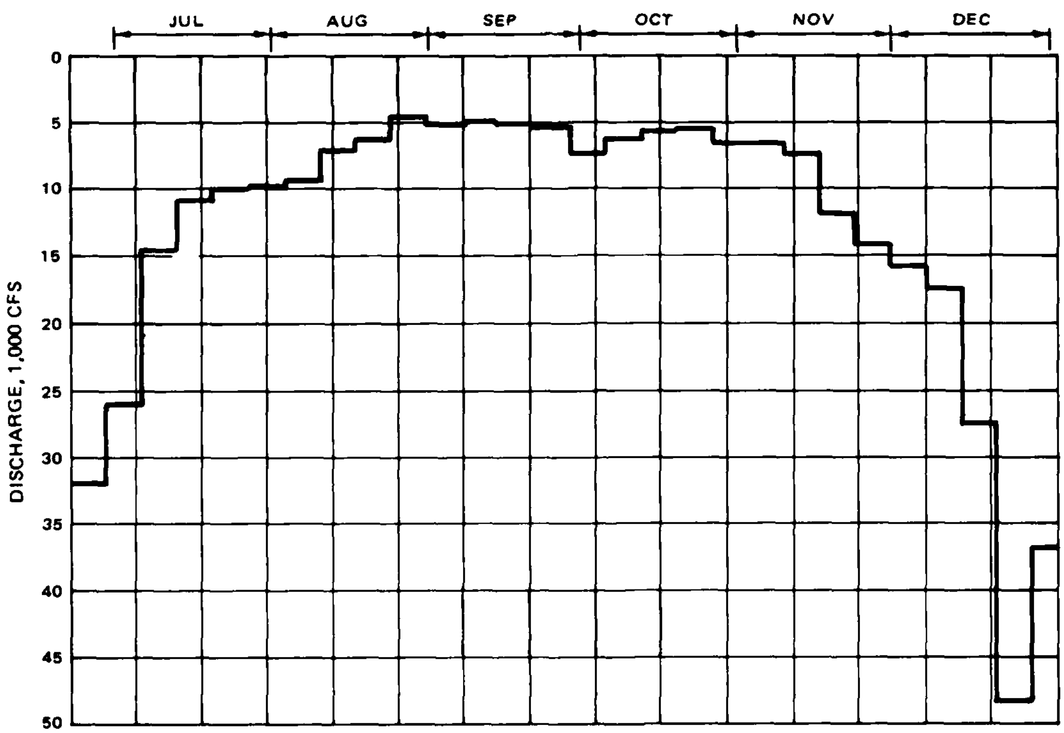

Figure 20. Typical hydrograph, inverted

Special inflows: None

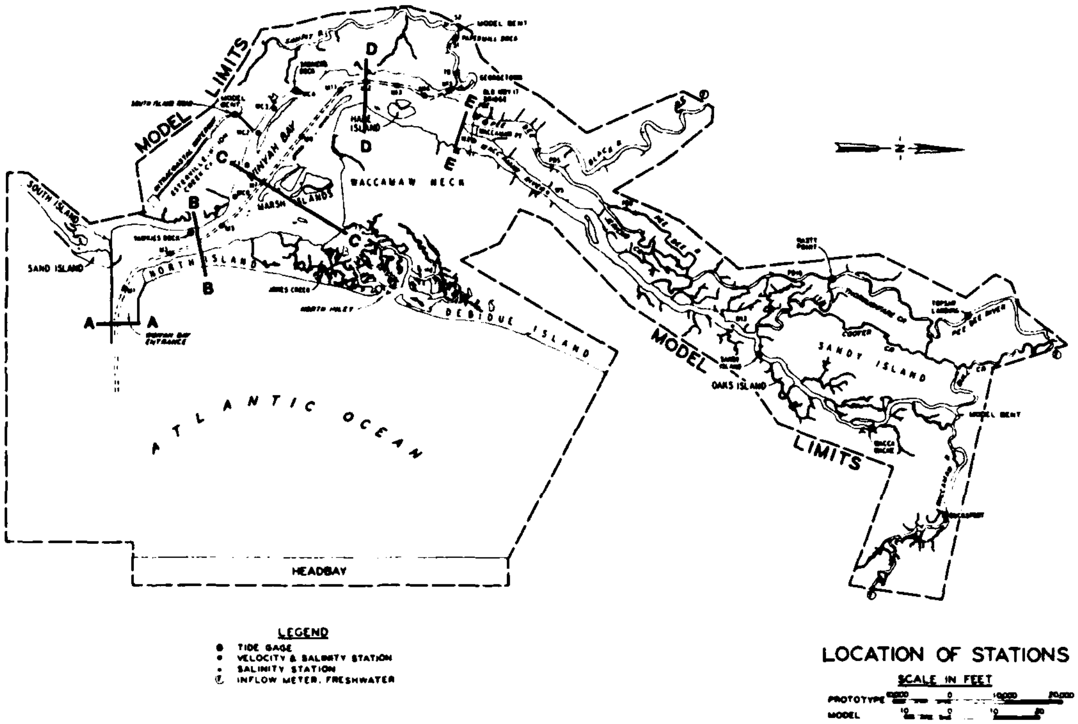

Figure 21. Georgetown Harbor location map

Geometry: Irregularly shaped, varying in width from about 4,000 ft at the entrance to about 24,000 ft at widest point.

Section	Location	Width, ft	Average Depth ft mlw	Maximum Depth, ft mlw
A-A	End of jetty	4,800	20	27
B-B	Mile 4	4,400	14	27
C-C	Mile 7	21,300	3	27
D-D	Mile 12	6,000	8	27
E-E	Mile 16	11,000	5	29

Navigation channel dimensions (Trawle and Boland 1979)

Location	Existing		Plan	
	Width, ft	Depth, ft mlw	Width, ft	Depth, ft mlw
Outer bar	600	27	600	35
End of jetties to mile 2	600	27	600	35
Mile 2 to Georgetown Harbor (mile 16)	400	27	400	35

Physical model (Trawle and Boland 1979)

Type	Fixed-bed distorted scale
Vertical scale	1:80
Horizontal scale	1:800

Salinity changes (Trawle and Boland 1979)

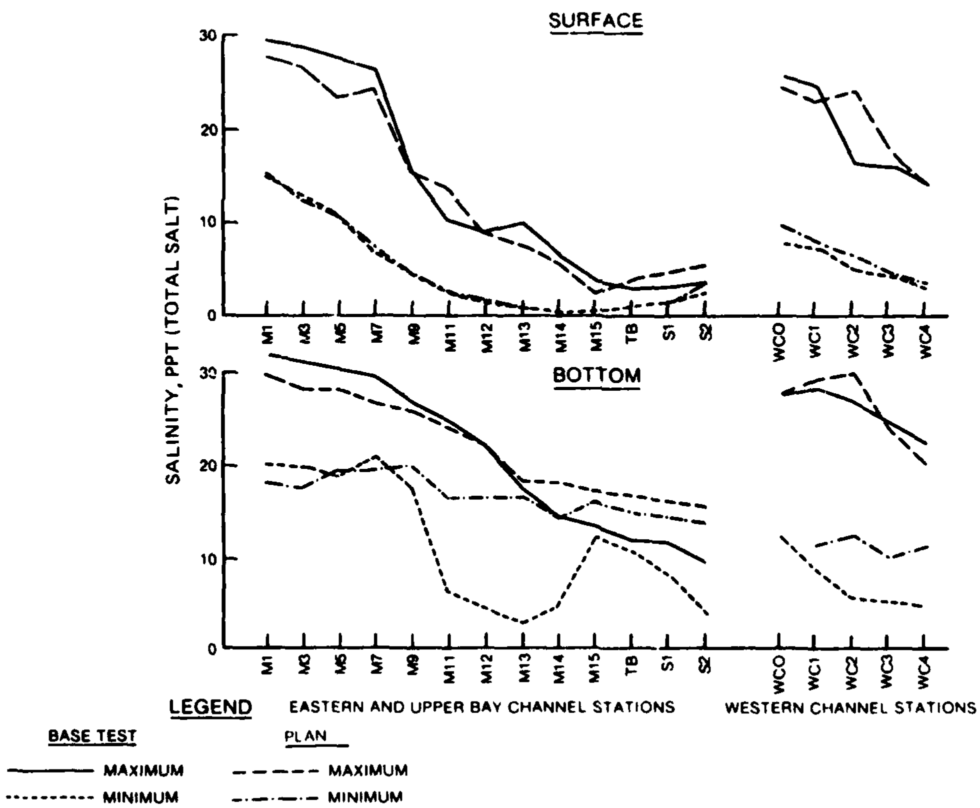

Figure 22. Maximum-minimum salinity profiles (12,000 cfs)

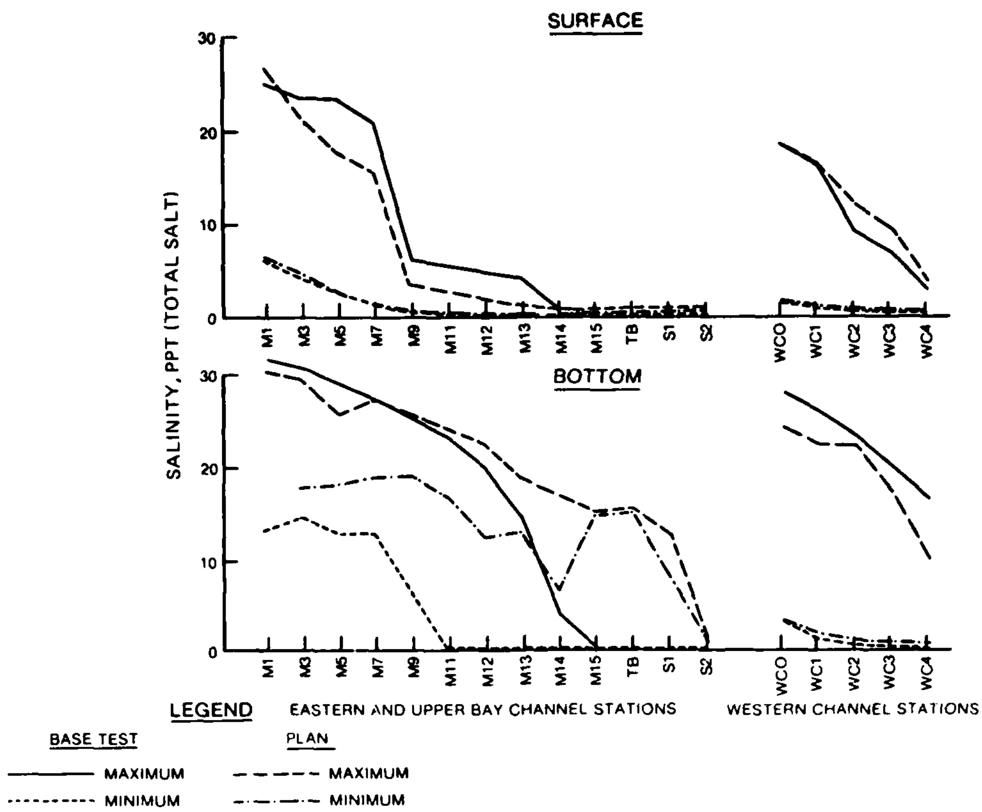

Figure 23. Maximum-minimum salinity profiles
(35,000 cfs)

Conclusions

11. Each of the two flows tested with the improved channel resulted in significant increases in salinities in upper Wingah Bay and Georgetown Harbor and a slight decrease in average salinities in lower Wingah Bay.

James River

Location: Coast of Virginia

Freshwater source: James River

Tide: Semidiurnal

Type	Tide Range, ft Entrance	Tide Range, ft Maximum Salinity Intrusion	Tidal Prism
Neap*	1.6	2.9	--
Mean**	2.6	3.1	8.66×10^9†
Spring**	3.1	3.6	--

* N. J. Brogdon, Jr. "James River Model Verification" (unpublished report), US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

** Committee on Tidal Hydraulics 1971.

† Cronin 1971.

Freshwater inflow (Committee on Tidal Hydraulics 1971)

Average annual high	175,000 cfs
Average annual mean	7,351 cfs
Average annual low	350 cfs

Hydrograph (Scheffner et al. 1981)

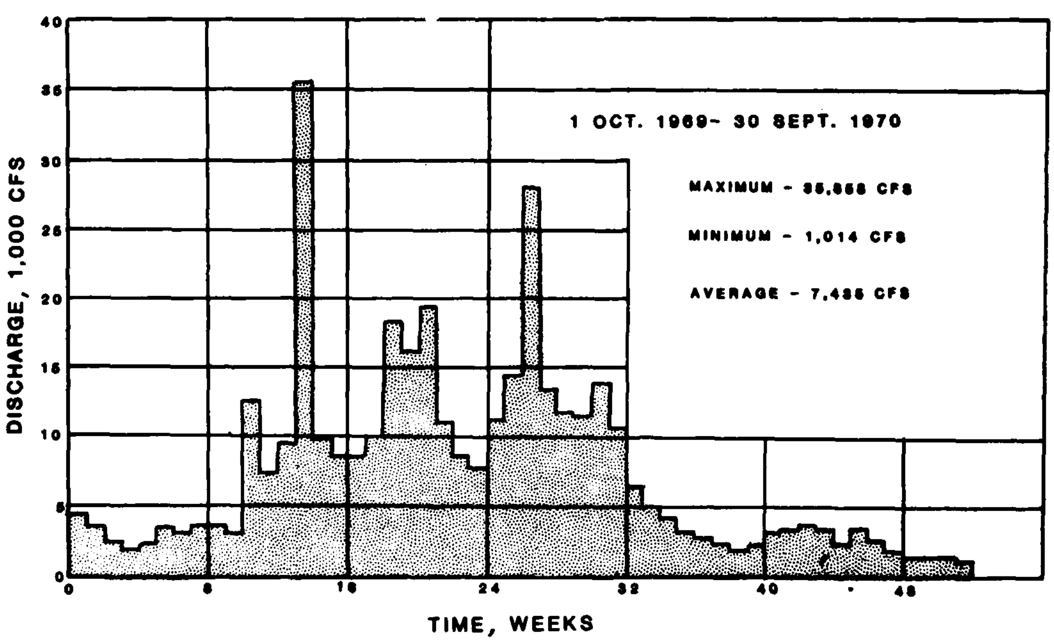

Figure 24. Freshwater inflow hydrograph, typical year

Special inflows: None

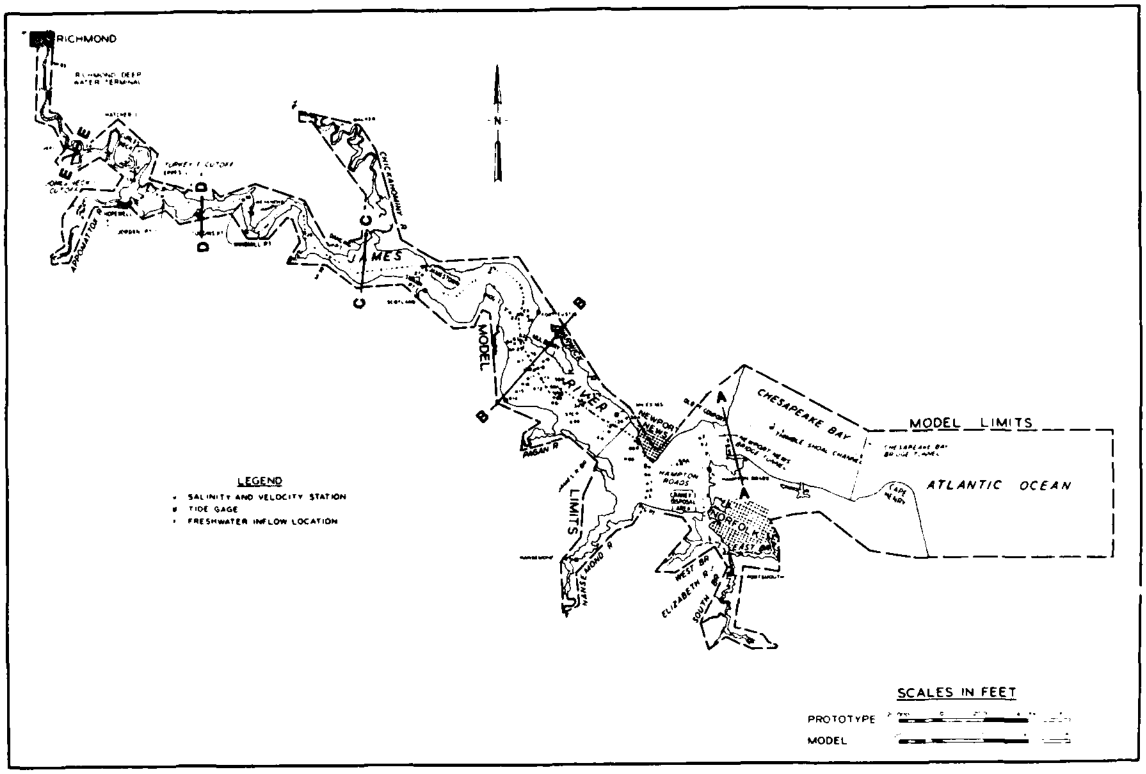

Figure 25. James River location map

Geometry: Irregular, funnel-shaped, relatively shallow

Section	Location	Width ft	Average Depth ft mlw	Maximum Depth ft mlw
A-A	Entrance (mile 0)	12,100	17	78
B-B	Mile 20	30,400	9	27
C-C	Mile 40	17,000	6	21
D-D	Mile 60	6,000	8	26
E-E	Mile 80	1,500	19	25

Navigation channel dimensions
(Committee on Tidal Hydraulics 1971)

Location	Existing Width, ft	Existing Depth, ft mlw	Plan Width, ft	Plan Depth, ft mlw
Entrance (mile 0) to Hopewell (mile 70)	300	25	300	35
Hopewell (mile 70) to Deepwater Terminal (mile 86)	200	25	300	35
Deepwater Terminal (mile 86) to Richmond Harbor (mile 91)	200	15	200	18

Physical Model (Brogdon and Bobb 1966)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:1,000

Salinity changes (Brogdon and Bobb 1966)

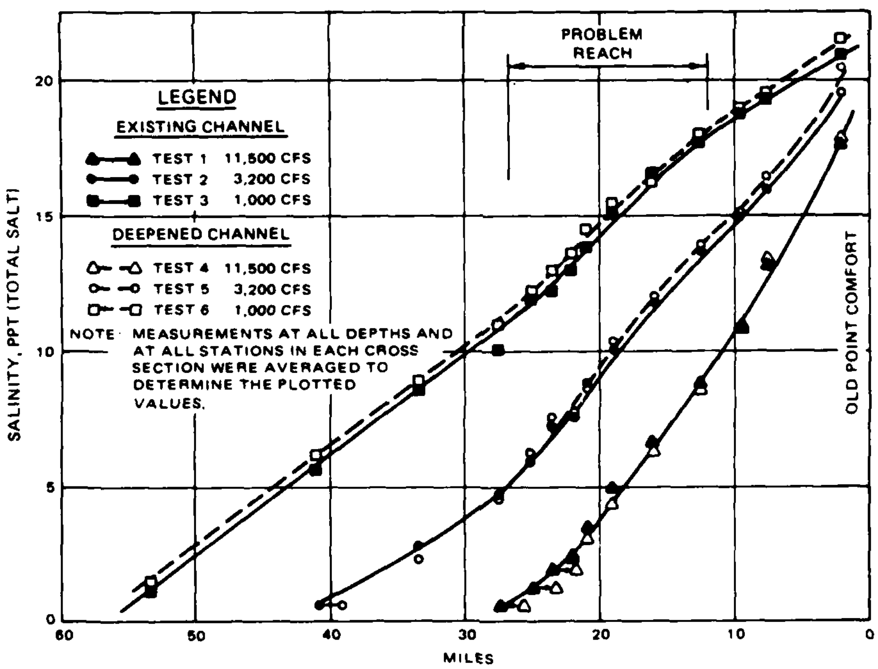

Figure 26. Effects of proposed 35-ft channel on average salinities in James River

Conclusions

12. Tests conducted for a freshwater discharge of 11,500 cfs showed average salinities essentially unchanged. Average salinities obtained with a freshwater discharge of 3,200 cfs were increased by about 0.1 to 0.5 ppt from about mile 2 to mile 25 and were unchanged upstream from this point. For a river discharge of 1,000 cfs, average salinities were generally increased by about 0.4 to 0.6 ppt throughout the length of salinity intrusion. Salinity intrusion would be extended upstream by about 1-2 miles.

Chesapeake Bay

Location: Central east coast of the United States

Freshwater source: Five major rivers--Susquehanna, Potomac, James, York, and Rappahannock.

Tide: Semidiurnal

	Tide Range, ft		
Type	Entrance	Maximum Salinity Intrusion	Tidal Prism
Mean	2.8	1.8	13.96×10^{10}*
Spring	3.4	2.0	--

* Cronin 1971.

Freshwater inflows (Scheffner et al. 1981)

Average annual high	120,000 cfs
Average annual mean	72,414 cfs
Average annual low	30,000 cfs

Hydrograph (Granat and Gulbrandsen 1982)

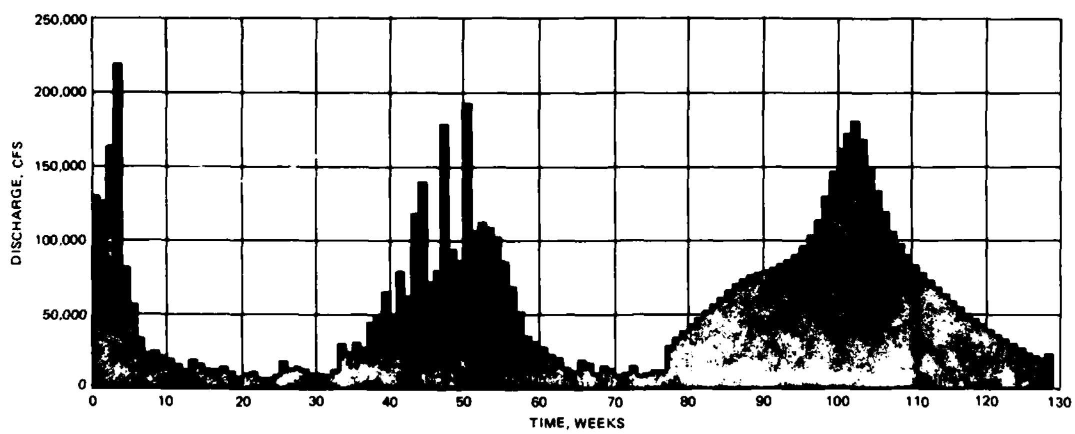

Figure 27. Typical hydrograph

Special inflows: C and D Canal

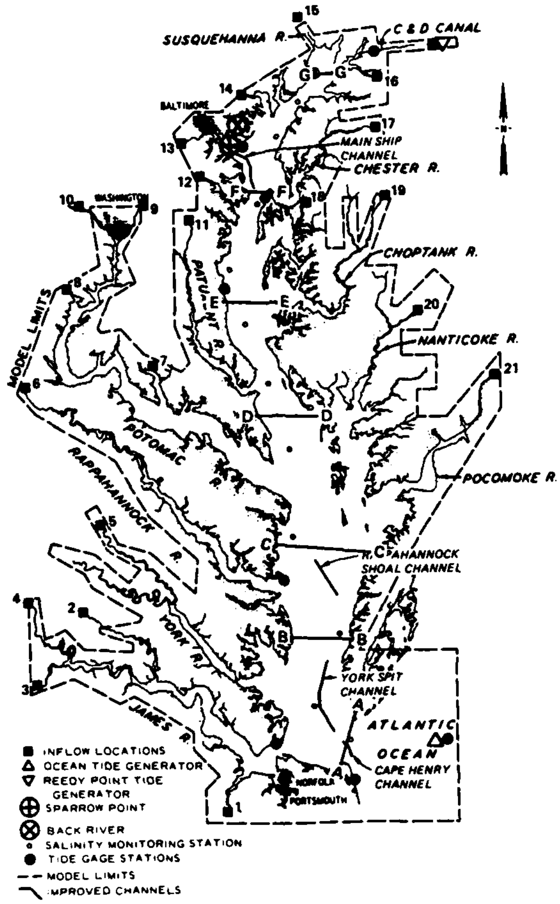

Figure 28. Chesapeake Bay location map

Geometry: Irregular in shape, varying in width from 3 to 33 miles with a length of about 190 miles.

Section	Location	Width ft	Average Depth ft mlw	Maximum Depth ft mlw
	Entire system	--	28	--
A-A	Entrance (mile 0)	58,000	34	77
B-B	Mile 25	76,500	33	69
C-C	Mile 46 (widest)	156,000	33	72
D-D	Mile 75	85,000	33	107
E-E	Mile 105	55,000	33	85
F-F	Mile 125	31,500	29	43
G-G	Mile 150	15,000	9	20

Navigation channel dimensions
(Granat and Gulbrandsen 1982)

Location	Existing		Plan	
	Width, ft	Depth, ft mlw	Width, ft	Depth, ft mlw
Cape Henry (mile 0)	1,000	42	1,000	50
York Spit (mile 12)	1,000	42	1,000	50
Rappahannock Shoal (mile 37)	800	42	1,000	50
Main Ship (mile 133)	800	42	800	50

Note: Channel depth and width in other reaches than above are naturally deeper and wider than plan navigation channel (50 by 1,000 ft).

Physical Model (Granat and Gulbrandsen 1982)

Type	Fixed-bed distorted scale
Vertical scale	1:100
Horizontal scale	1:1,000

Salinity changes (Granat and Gulbrandsen 1982): Tests were conducted with the model reproducing a 28 lunar-day (56 cycles) variable tide and a 2-1/2-year freshwater discharge hydrograph stepped weekly. The typical plot in Figure 29 shows changes to salinities at mile 142, sta CB-7-3 (most upstream station monitored during test).

Conclusions

13. Lower main bay stations below Kent Island illustrate a slight trend of increased salinity in deepwater areas. Stations in the bay entrance and York Spit channel area were the only lower main bay stations to indicate appreciable differences, generally with increased salinity. Salinity intrusion up the James and York rivers was appreciably decreased as a result of the improvement plan. Major salinity differences between base and plan tests occurred in upper bay, upstream from Kent Island. The plan resulted in increasing stratification in this area as surface salinities were decreased while middepth and bottom values were increased. The greatest effects (increased salinity) were observed in the deepened Patapsco River channel where changes were on the order of 5 ppt. The maximum effect was an increase of about 10 ppt. The effects of the improvement plan were found to decrease with distance from the deepened channels and at shellover stations.

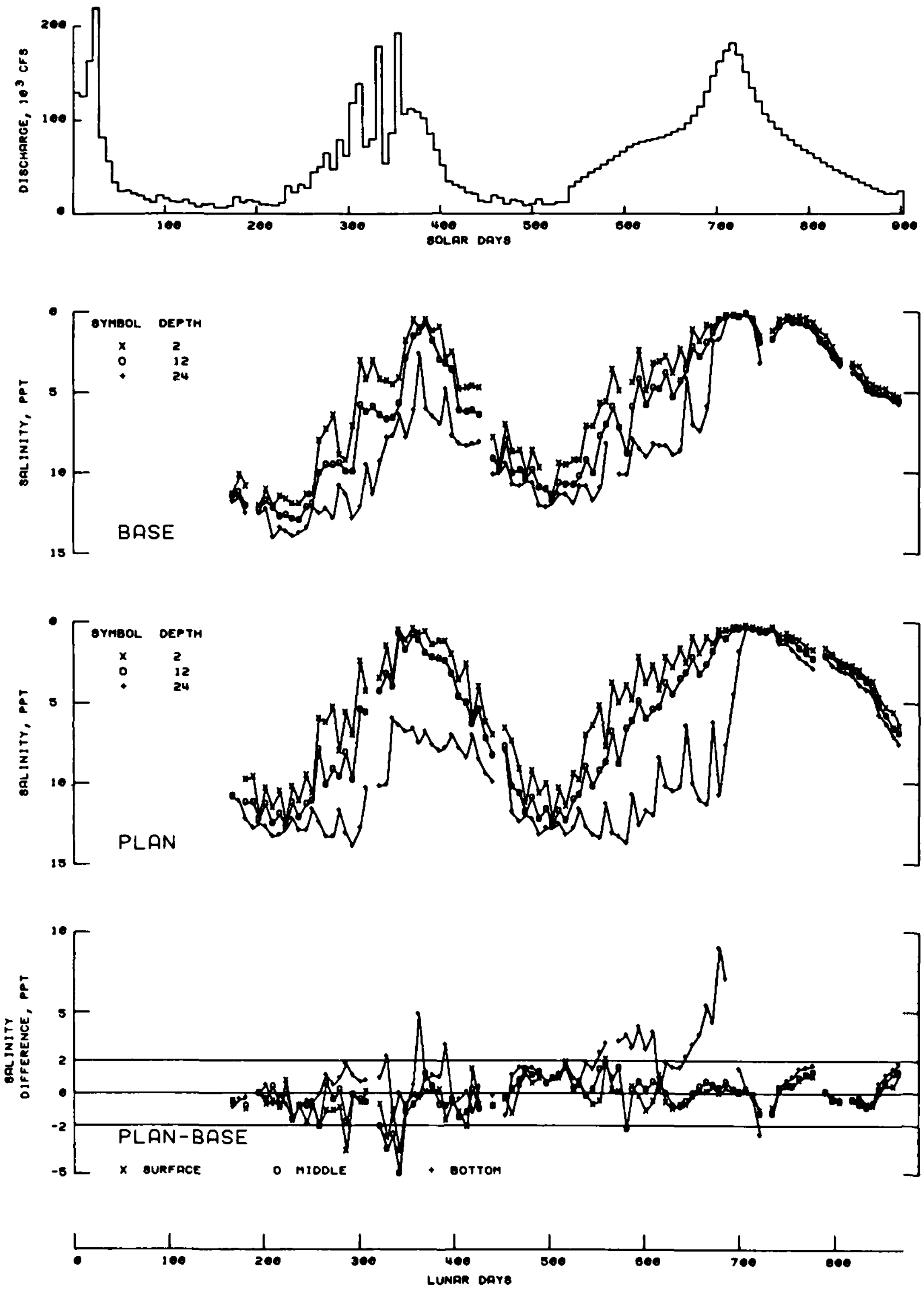

Figure 29. Sta CB-7-3 salinity-time history

PART III: CONCLUSIONS

14. The information in this report provides a first estimate of the magnitude of impact on salinity conditions that can be anticipated for a channel deepening. Extension and extrapolation of findings from one estuary to another are generally very difficult due to the many variables involved.

15. Further research will combine the results herein into a statistical model based on estuarine classification variables and channel deepening parameters.

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