

AD-A070 627

ARMY ENGINEER DISTRICT PHILADELPHIA PA  
LONG RANGE SPOIL DISPOSAL STUDY. PART VI. SUBSTUDY 5. IN-RIVER --ETC(U)  
JUN 69

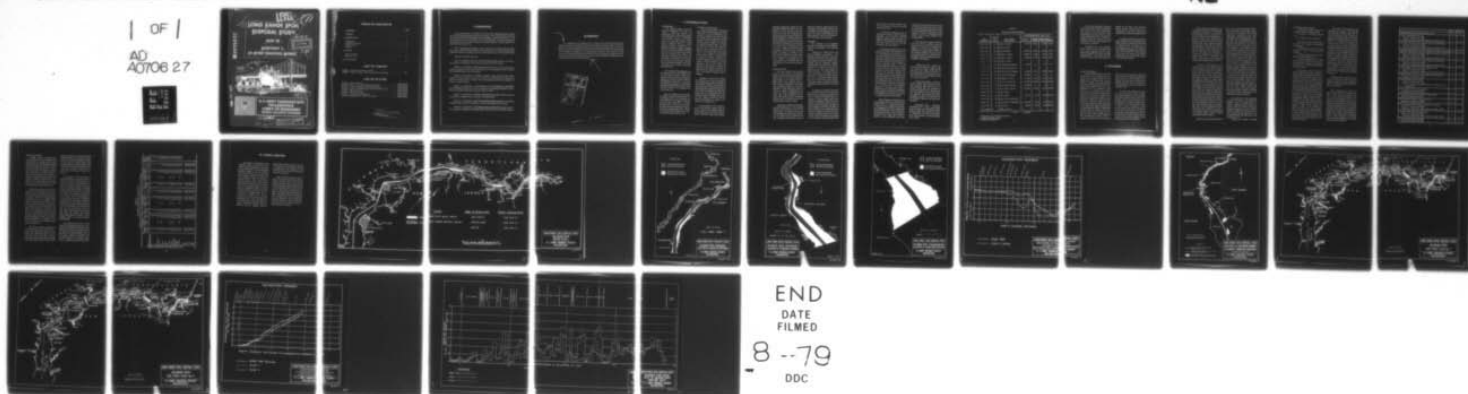
F/G 8/8

UNCLASSIFIED

NL

| OF |

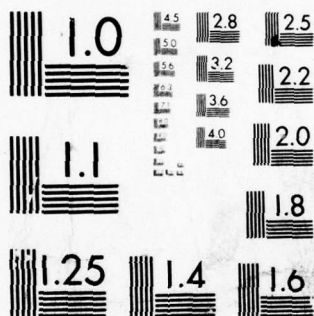
AD  
A0706 27



END  
DATE  
FILMED

8--79

DDC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AD A 070627

UUU FILE COPY

LEVEL

A060 626

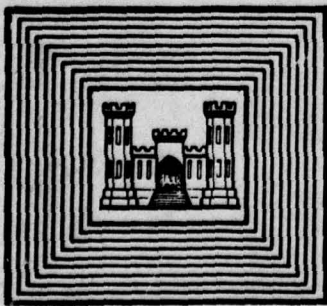
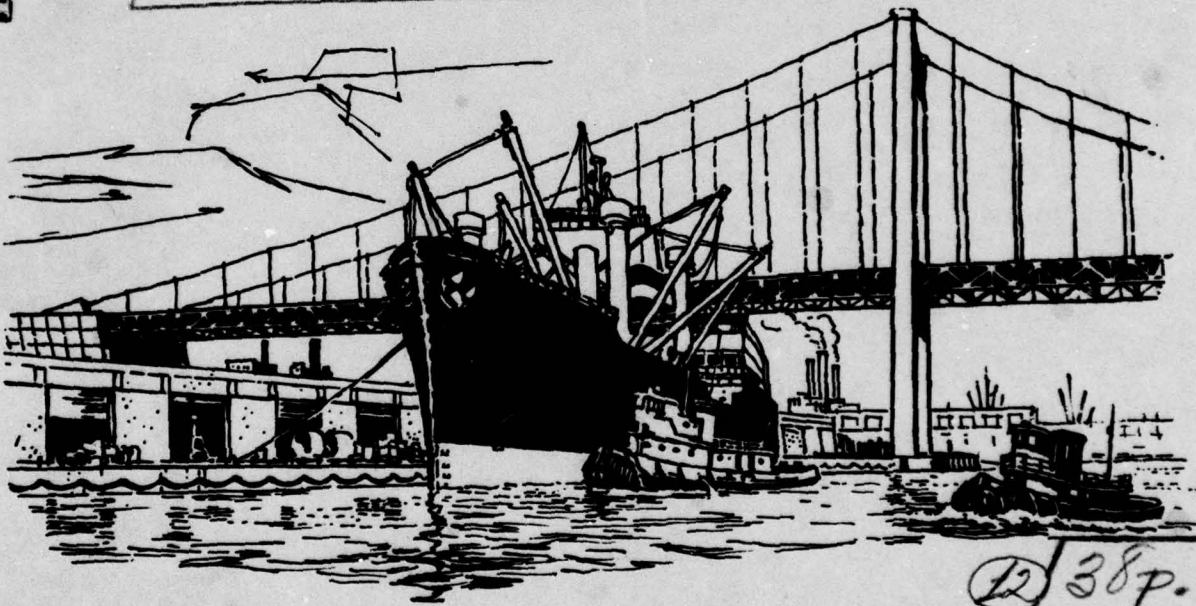
# LONG RANGE SPOIL DISPOSAL STUDY.

PART VI.

SUBSTUDY 5.

IN-RIVER TRAINING WORKS.

D D C  
RECEIVED  
JUN 29 1979  
RECEIVED



U.S. ARMY ENGINEER DIST.  
PHILADELPHIA  
CORPS OF ENGINEERS  
NORTH ATLANTIC DIVISION

11 JUN 69

This document has been approved  
for public release and sale; its  
distribution is unlimited.

410 358

mt

## TABLE OF CONTENTS

	Page
FOREWORD .....	i
SUMMARY .....	ii
I. INTRODUCTION .....	1
Background .....	1
Purpose of this Study .....	1
Scope of Study .....	2
Problem .....	2
II. STUDIES .....	5
Plans Considered .....	5
Results of Tests .....	9
III. CONCLUSIONS .....	11

## LIST OF TABLES

TABLE 1 - Channel and Anchorage Shoaling .....	4
TABLE 2 - Effects of Plans 7 and 11 on Accumulative Shoaling .....	10

## LIST OF PLATES

PLATE 1 - Major Shoal Areas .....	Back of book
PLATE 2a, 2b, 2c - Location of Shoreline Revisions .....	Back of book
PLATE 3 - Velocity Data; Bottom Flow Predominance .....	Back of book
PLATE 4 - Channel and Shoreline Revisions 50' Channel Tests .....	Back of book
PLATE 5 - Dike Study, Plan 7 .....	Back of book
PLATE 6 - Dike Study, Plan 11 .....	Back of book
PLATE 7 - Accumulated Shoaling Data .....	Back of book
PLATE 8 - Shoaling Rates - Model Test Results .....	Back of book

This document has been approved  
 for public release and sale; its  
 distribution is unlimited.

## FOREWORD

This study and report was completed as one of the six Sub-Studies which comprise the overall Long Range Disposal Study in the Delaware. The overall study was conceived and initiated by the then Philadelphia District Engineer, Colonel W.W. Watkin, Jr., who had been directed to such an effort by the Chief of Engineers. The Project Manager for this Sub-Study was Mr. Joseph F. Phillips with guidance from Mr. Lloyd A. Duscha, P.E. and Mr. Lewis Caccese, P.E.

The "Long Range Spoil Disposal Study" consists of seven parts which are listed below. Part I, which is "General Data on the Delaware River," contains detailed background data which is pertinent to this report. This report is Part VI of the overall study.

The study is divided as follows:

PART I - GENERAL DATA ON THE DELAWARE RIVER furnishes the information and data on the Delaware River which is pertinent to the entire study.

PART II - SUB-STUDY 1, SHORT RANGE SOLUTION evaluates the remaining disposal area capacity in terms of its remaining life, and to recommend any further desirable and acceptable disposal area developments.

PART III - SUB-STUDY 2, NATURE, SOURCE, AND CAUSE OF THE SHOAL develops, in depth, the basic data as to the nature of the Delaware River shoals, their sources, and their causes. It is hoped that this knowledge may reveal new concepts for the better control of shoals.

PART IV - SUB-STUDY 3, DEVELOPMENT OF NEW DREDGING EQUIPMENT AND TECHNIQUE identifies the best in dredging plant and dredging technique for Delaware River dredging maintenance tasks now and in the future.

PART V - SUB-STUDY 4, PUMPING THROUGH LONG LINES examines the merits of transporting dredging materials many miles through pipelines.

PART VI - SUB-STUDY 5, IN-RIVER TRAINING WORKS determines the potential of training works for control of shoaling. It involves considerable model testing.

PART VII - SUB-STUDY 6, DELAWARE RIVER ANCHORAGES considers the effect of man-made anchorage on shoaling problems and the merits of alternate solutions.

## SUMMARY

It is apparent that the changes in river sections that would result from extreme canalizing of the estuary would not induce the necessary downstream shift of the shoaling due to the effect of salinity density currents. Extensive training works to reduce the flow area also were ineffective in moving the several shoaling areas downstream enough to be of benefit in reducing the cost of maintenance. Since the shoals cannot be moved out of the present high shoaling areas with the aid of training works regardless of cost, it will be necessary to develop improved and more efficient methods of dredging and disposing of material from the existing system.

Accession For	
INTER GRA&I	
DOY TAB	
Unannounced	
Classification	
<i>As on file</i>	
By	
Distribution/	
Availability Code	
Dist	Avail and/or special
<i>A</i>	

# I. INTRODUCTION

## BACKGROUND

The Delaware River, and particularly the Philadelphia Port Area, constitutes a major port complex. Over 100,000,000 tons of waterborne commerce move through the Port of Philadelphia each year. This commerce relies in large part on the man made 40-foot channel which is constantly subjected to regular shoaling. Therefore, maintenance of the 40-foot depth requires constant dredging. With the result that 7,000,000 to 8,000,000 cubic yards of shoal material are dredged from the Delaware River channel and anchorages and placed ashore each and every year. A characteristic of this dredging is that, for the most part, shoaling, and the subsequent dredging, takes place in repetitive locations and at reasonably predictable rates.

The most significant shoaling areas are: Marcus Hook, Pa., Philadelphia, Pa. and New Castle, Delaware. These areas represent the majority of the dredging requirements necessary to maintain the Port of Philadelphia. From this, it is apparent that any better approaches to the dredging and spoil disposal problems in these areas will have relevance to the dredging work in the entire river.

Since the shoaling occurs primarily at specific locations, disposal areas for the dredged spoil in these vicinities are of key importance. The supply of disposal areas in these critical areas is severely limited because of past use of the most desirable areas and the physical development of the remaining areas. Plate 1 shows the most significant shoaling areas of the river and the related disposal areas.

## PURPOSE OF THIS STUDY

One of the objectives of the Long Range Spoil Disposal Study for the Delaware River is the determination as to whether any modification of the shoreline by training works or additional training structures could be effective in appreciably reducing the shoaling of the navigation channels and anchorages, or in shifting areas to locations from which the material could be disposed of more economically. All feasible improvement plans were to be considered and evaluated initially without regard to economic costs or relation to existing or potential developments along the river. In the extreme instance, partial canalization and major reduction in width of river, could be envisioned. It was desired to consider any plan which would eliminate or reduce to a major extent the shoaling which now occurs in the navigation channels and anchorages.

Although a utopian goal of flushing all sediment to the ocean was sought, it was recognized that any plan which would encourage the shoaling to concentrate in areas downstream of Philadelphia, Marcus Hook, and other intensely developed areas from which the dredging and proper disposal could be accomplished more economically would be of benefit. This would, of course, require coordination with the plans for development of onshore or inclosed river disposal areas.

The determination of the effectiveness of any proposed training works can best be tested in the hydraulic model of the Delaware Estuary at the Corps of Engineers Waterways Experiment Station,

Vicksburg, Mississippi, (Referred to subsequently as WES). This model was completed in 1947 and has been used intermittently ever since for testing many different proposals involving training dikes, channel alignments, sediment traps, dispersion of pollution, river entrance jetties, and flow regulation plus others. The model has also been utilized by private interests for a variety of tests. The model, built to a scale of 1:1000 vertically and 1:100 horizontally, includes the entire Estuary, Capes to Trenton (a distance of 132 miles) and the tidal portions of most tributaries. The results of a number of previous hydraulic and shoaling tests of various plans were considered when developing plans to be tested in the present study.

#### SCOPE OF STUDY

The study included review of the results of tests made in the Delaware Estuary Model for an enlarged navigation channel, and of the tests of considered improvements in the Schuylkill River - Marcus Hook reach. Analysis was also made of tests accomplished at the Waterways Experiment Station for the Corps Committee on Tidal Hydraulics which involved an extreme streamlining of the Estuary for study of flushing characteristics. This study investigated the hydraulic and shoaling effects of proposed training works in specific reaches from Pettys Island to Artificial Island.

Updating and summarizing the dredging and shoaling data of the navigation channels was included as part of this study. Effects on shoaling trends of the private dredging for maintenance of slips, etc., and sand and gravel operations were also considered. The locations to be con-

sidered for potential training works were coordinated with possible sites for the development of in-river disposal areas for future use, and the effectiveness of enlarging specific areas of the estuary to act as silt traps was investigated.

#### PROBLEM

The shoaling of the navigation channels and anchorages of the Delaware Estuary is attributed to the following sources:

1. *Erosion of Upland Areas and Beds and Banks of Tributaries* - The sediment produced thereby is carried to the Estuary by fluvial flow, particularly during high flow periods. Based on data secured from the suspended sediment sampling station at Trenton, New Jersey, operated for 20 years by the U.S. Geological Survey, and other stations of shorter duration, it is estimated that the total contribution to the estuary from upland sources is about 2.2 million tons per year. This is equivalent to about 4.8 million cubic yards of material as dredged. This total includes an assumed bed load contribution equal to 10% of the suspended load.

2. *Changes in the Bed of the Estuary* - Outside the limits of the navigation channels and anchorages changes occur due to natural and man-made causes. A change in velocity regimen could result in scour or shoaling, modification of the effective shoreline by structures could influence the velocity pattern, and sand and gravel dredging could induce changes as well as indicate scour. Analysis of available data indicates that the bed of the estuary (as defined above) from Trenton to New Castle has deepened at an annual rate of 2.6 million cubic yards, while from

New Castle to Artificial Island, there has been shoaling of about one million cubic yards a year.

3. Additional possible sources of shoaling are erosion of banks, dredging operations, sewer effluents, industrial effluents, natural organic processes, and inflow from the Atlantic Ocean. Quantities from these sources have not yet been evaluated to any useful degree.

The apparent shoaling rates for the navigation channels and anchorages have been developed based on repetitive surveys and dredging records obtained since 1955. Prior to this date older and different methods of dredging and disposal were in use and the data are not comparable to present conditions. Table 1 lists the estimated annual shoaling rates. It should be noted that the total annual average shoaling is approximately 9 million cubic yards for the navigation channels and anchorages. The rate of shoaling per unit length of channel in the Marcus Hook area is more than twice that in any other reach. The enlargement of the river area due to the Marcus Hook Anchorage is considered to be a major cause of this condition. Since this is also the reach of high industrial use with additional developments being planned, the disposal of maintenance dredging from this reach of the river is rapidly becoming a major problem.

The development of disposal areas by enclosing areas of the river with retaining dikes is a physical possibility, of course, but any substantial and economic development of this type would likely bring forth objections from conservationists and others. Such a plan is being envisioned for the upper end of Tinicum Island, but many objections from some

industries and boating interests will have to be overcome before this plan can come to fruition. Enclosing large areas of the river also affects the tidal prism, causing changes in currents in the upstream areas which in turn can cause changes in the shoaling pattern.

Over the years a number of training works have been constructed along the Estuary for the purpose of improving the alignment of currents and reducing the shoaling rates along specific reaches of the navigation channels. The major works are described briefly in the following subparagraphs, moving geographically downstream from Philadelphia:

1. Mifflin Bar Dike - Along west shore, opposite Billingsport Range, original construction began in 1885 and the dike was raised in 1894 and 1916. The required maintenance of the navigation channel in this reach was materially decreased as a result of this work.

2. Chester Island Dike - Across secondary channel along New Jersey shore and connecting with upstream end of Chester Island. Dike was completed in 1915 and the effective flow section of the river was reduced and the main channel was deepened. Scour holes have since developed at either end of the dike, but the beneficial effects of the dike have continued.

3. Pennsville Dike - Extending downstream from the New Jersey shore along the upper end of Deepwater Point Range, the dike was constructed in 1944. In combination with Pea Patch Island Dike, local benefits of reduced shoaling were realized.

TABLE 1  
Channel and Anchorage Shoaling

Reach Channel Stas.	Miles from Mouth*	Channel Ranges and Anchorages.	Annual Shoaling Rates, Cubic Yards			
			Total Av. for Reach	Rate per 1000 ft. of Chan.		
				Average	Median	Maximum
-153 to -150	131	Trenton - Cochran	57,000	19,000	17,000	33,000
-150 to -148	130	Cochran - Biles	-	-	-	-
-148 to -132	128	Biles - Whitehill	204,000	12,800	13,000	33,000
-132 to - 96	123	Whitehill - Landreth	428,000	11,900	11,000	31,000
- 96 to - 63	116	Landreth - Beverley	501,000	15,200	13,000	42,000
- 63 to 0	108	Beverley - Harbor	-	-	-	-
0 to + 4	103	Port Richmond Anchorage	95,000	NA	NA	NA
+ 4 to + 55	98	Philadelphia Harbor Rges.	-	-	-	-
+ 55 to + 77	88	W. Horseshoe - Billingsport	706,000	32,100	25,000	81,000
+ 61 to + 72	92	Mantua Creek Anchorage	430,000	NA	NA	NA
+ 77 to +113	83	Billingsport - Chester	413,000	11,500	10,500	36,000
+113 to +131	79	Chester - Marcus Hook	2,142,000	119,000	121,000	192,000
+118 to +131	81	Marcus Hook Anchorage	400,000	NA	NA	NA
+131 to +164	74	Marcus Hook - Bellevue	1,405,000	42,600	44,500	103,000
+164 to +167	71	Cherry Island	-	-	-	-
+167 to +175	70	Cherry Island	570,000	47,500	61,000	121,000
+175 to +188	68	Cherry Island - Deepwater P.	-	-	-	-
+188 to +221	63	Deepwater P. - Bulkhead Bar	1,022,000	31,000	31,000	100,000
+221 to +235	58	New Castle	792,000	56,600	57,000	178,000
+235 to Mouth		Baker, Liston, etc.	-	-	-	-
Total			9,165,000			

\*Miles shown are at mid-points of reaches.  
-Signifies negligible shoaling  
NA signifies not applicable

4. Pea Patch Island Dike - Extending upstream from Pea Patch Island along the west side of New Castle to Deepwater Point Ranges. It was constructed in 1932 and produced some local effects in shifting the shoaling. However, no reduction in shoaling along this reach of river was realized until the above described Pennsville Dike was completed.

5. Bulkhead Bar and Kilcohook Dikes - These are located along the New Jersey shore opposite the Pea Patch Island Dike. Bulkhead Bar Dike extending perpendicularly to the shore was constructed in 1892, and the Kilcohook Dike

parallel to the shore was constructed during 1924-26. Together they form a constriction in the river and form the boundaries of the Kilcohook Disposal Area.

6. Reedy Island Dike and Artificial Island - The dike extends downstream from Reedy Island, and Artificial Island forms a constriction and is connected to the New Jersey shore. The construction of this combined improvement was completed about 1917 and resulted in some scouring of the main river section and reduced maintenance effort along the Baker Range of the navigation channel.

## II. STUDIES

### PLANS CONSIDERED

It can be theorized that if the shoaling material is to be transported by the currents to the Atlantic Ocean or to the deeper areas of Delaware Bay, the river should be reshaped to provide gradually increasing sections from the head of navigation toward Delaware Bay. Local enlargements such as anchorages, which tend to act as sediment traps, should therefore be excluded from consideration. Such a plan was tried in connection with flushing tests conducted at WES by other interests, in which the Delaware Estuary Model was utilized for such tests. The estuary was streamlined from Philadelphia to near Miah Maull Light with the widths increasing from about 2000' at Philadelphia to about 8000' in Delaware Bay. The shoreline revisions are shown on the 3 sheets of Plate 2. While no shoaling tests were accomplished, analysis of the resulting flow conditions reveal that there

would be a net upstream flow along and near the bottom to a point just upstream of New Castle. Thus, there would be no possibility with this plan of inducing the shoaling material (which moves generally near the bottom) to advance seaward beyond New Castle.

As part of this flushing investigation, tests were also run with a considerably lesser modification of the shoreline, also shown on Plate 2. The results of the hydraulic tests with this plan also show a net upstream flow along the bottom for as far upstream as Pea Patch Island, which is about 5 miles downstream of New Castle. It appears that as the irregularities of the river cross-sections are reduced, the tendency for stratification of flow to develop is increased. The resulting density currents due to salinity produce the net upstream movement near the bottom.

These flushing tests brought out the relationship of upstream and downstream currents near the bottom at various locations along the estuary. A comparison of the data resulted in establishing what is known as a "null" point. This marks the location downstream of which the bottom currents have a net upstream movement and upstream of which the net movement near the bottom is toward the ocean. The shifting of this null point is indicative of how far downstream one could hope to transfer the shoaling material under the various plans tried or envisioned. Examples of the upstream and downstream velocity relationships are shown on Plate 3.

A previous investigation of the section of the river from Schuylkill River to Marcus Hook involving dikes, sediment traps, and disposal areas was reported on in Misc. Paper No. 2-887 of the Waterways Experiment Station. This report dated March 1967 is titled "Results of Hydraulic and Shoaling Studies in Marcus Hook Schuylkill Reach of Delaware River." This investigation was concerned with what improvements would be feasible to reduce the dredging costs in that heavy shoaling reach of the river. While the purposes of these tests did not include the development of plans for shifting the shoal downstream of this reach, there was no evidence that the enclosing of some water areas to provide for disposal of dredge spoil would have any major beneficial effect on shifting of the shoaling areas to any appreciable degree in the downstream direction. The plans tested included silt traps as well as diked areas and it was noted that the shoaling pattern could be shifted locally with only little benefit.

Model tests were also conducted as

part of the "Channel Dimension Study," but a formal report on the results of these tests is not yet available. The channel improvement considered in this study would result in a 50' deep channel, generally 1000' wide from Philadelphia to the Sea. The plan envisioned that numerous disposal areas would have to be established to retain the large amount of new work dredging. It was assumed that few areas would be available, and that diked areas in the estuary would be required. The channel alignment and ultimate shoreline revisions as tested are shown on Plate 4. The results of the model tests indicated an overall shoaling index of 1.5 for the areas to be maintained, which means that the shoaling rate with the modified channel alignment and revised shoreline would be 50 percent higher than with existing conditions. This increase is due to a greater tendency for retention of material in the proposed deeper and wider navigation channel. The reductions in river cross-sections caused by the diked areas along some reaches did reduce the shoaling in specific ranges, but the effect was localized. Again, there was no evidence that these extensive diked areas would be effective in shifting the shoaling pattern downstream to any significant and beneficial degree.

In connection with the Long Range Disposal Area Studies, it was decided to consider a plan of training works that would be extensive and that could be expected to shift the location of intensive shoaling downstream to near Artificial Island if possible. The location and extent of these training works were to be considered without the imposition of any constraints due to:

1. Effect on or relation to existing

developments along the shore

2. Existing or future channel and anchorage locations and dimensions

3. Location of proposed disposal areas

4. Probable cost of construction

The layout of these proposed training works was designed to accomplish the following:

1. Allow moderate increase in tidal currents in areas of present intensive shoaling;

2. Align the tidal currents to prevent deposition in undesirable areas;

3. Provide openings at the downstream end of the major dikes to prevent any appreciable changes in the general tide levels and to prevent any reduction in the tidal prism.

In consultation with the staff at the Waterways Experiment Station a number of training works, which appeared to have a potential beneficial effect, were located on maps of the Estuary. Eighteen items, including dikes, artificial fills, disposal areas, and silt traps, were considered, and grouped in various combinations into 16 plans for proposed testing in the model to determine their hydraulic effects. Prior to actual testing in the model, further discussions were held and it was decided that the first complete testing would be accomplished with the elements of Plan 7 installed in the model, which consisted of 15 elements between Pettys Island and Artificial Island. These elements are located on Plate 5. The elements of Plans 8, 9 and 10 were minor modifications and some deletions of those in Plan 7. Only partial model tests were conducted with these plans installed, and visual effects were noted during the tests of Plans 8, 9 and 10.

The results of the Hydraulic and shoaling tests of Plan 7 were reviewed and discussed with WES staff. The effects on currents were also viewed in the model by engineers from the District. Modifications and deletions of some elements were considered desirable. Additional tests were then accomplished with the elements of Plan 11 installed in the model. See Plate 6 for layout. Details of Plans tested and results obtained are discussed in later paragraphs. The major difference in Plan 11 when compared to Plan 7 is that the upstream ends of the training dikes were lowered to about mean low water to allow more upstream flow during flood current. The range of tide above Wilmington was reduced from present values as a result of the Plan 7 training dikes, and the contours along the dikes of Plan 11 would provide for greater flood flows.

Shoaling tests were performed in the model for only Plan 7 and 11, and the elements of these plans are described in detail as follows and shown on Plates 5 and 6, respectively.

Other modifications of these elements were installed in the model after Plan 7 tests and partial hydraulic tests were run. The analysis of these data resulted in the development of Plan 11 to represent the most likely plan of accomplishing the desired results. As previously indicated no estimates of costs or probable economic justification were evaluated for these plans as it was desired to determine whether any system of training dikes regardless of cost could cause the shoaling areas to shift downstream to desirable locations without detriment to the normal tide and velocity conditions.

	Plan 7	Plan 11
Enlargement of Pettys Island for Disposal Area	X	X
Dike at Philadelphia Navy Yard 7850 feet in length above MHW 5000 feet in length above MHW, 2850 feet in length at MLW	X	X
Dike from New Jersey shore, opposite mouth of Schuylkill River 17150 feet in length above MHW 13000 feet in length above MHW, 4150 feet in length at MLW	X	X
Tinicum Island Disposal Area with stream-lined channel thru Island	X	X
Dike encompassing Chester-Monds Island and extending downstream 16000 feet in length above MHW 12000 feet in length above MHW, 1200 feet in length at MLW	X	X
Dike from New Jersey shore, opposite Marcus Hook Anchorage 21650 feet in length above MHW 20500 feet in length above MHW, 2650 feet in length at MLW	X	X
Dike extending south from mouth of Oldmans Creek 31500 feet in length above MHW 30150 feet in length above MHW, 4350 feet in length at MLW	X	X
Dike along Delaware shore, under Delaware Memorial Bridge 18500 feet in length above MHW	X	
Dike including Pennsville Dike 15500 feet in length above MHW 8400 feet in length above MHW, 4100 feet in length upper end existing dike	X	X
Dike including Pea Patch Island Dike 11500 feet in length above MHW	X	
Dike extending from south end of Pea Patch Island 4500 feet in length above MHW	X	
Dike south from Finns Pt. along Salem Cove 19000 feet in length above MHW	X	
Dike connecting Reedy Island with Reedy Pt. South Jetty 15600 feet in length above MHW 11000 feet in length above MHW, 2750 feet in length at MLW	X	X
Dike extending south from Elsinboro Pt. 10000 feet in length above MHW 7250 feet in length above MHW, 2750 feet in length at MLW	X	X
Dike including Reedy Island Dike 17000 feet in length above MHW	X	X

## RESULTS OF TESTS

Analysis of the data secured from these recent model tests indicated that with the Plan 7 training works in place the range of tide was increased one-half foot for the reach from Ship John to New Castle, and a decrease of 0.5 to 1 foot for the reach upstream of Edgemoor. Similar data for the Plan 11 system of dikes indicate that the range of tide would be generally in agreement with the base test values or existing conditions. This is no doubt due to the lowering of the upper section of the dikes which allowed more flow, particularly during flood current.

The location and extent of the training dikes, of course, influence the currents in localized areas. The maximum velocities at the center of the channel generally show an increase with Plan 7 installed when compared with base test conditions. With Plan 11, these channel velocities are generally less than with Plan 7. However, at the upper end of Liston Range and along Marcus Hook Range the velocities with Plan 11 are somewhat greater than the base test. The maximum velocity during the tidal cycle was about 4 feet per second and occurred along the upper end of Liston Range with Plan 11, as compared to  $3\frac{1}{2}$  feet per second at several locations under base test conditions.

The effects of salinity conditions in the Estuary were noted with the Plan 7 system of training dikes installed in the model. The results show that in the general area of the Pa-Del State Line the equivalent salinity concentration at high water slack would be about 5 miles further

upstream with Plan 7 than under existing conditions. This is a situation to be anticipated as a result of the decrease in range of tide. Since the normal range of tide was substantially recovered with the Plan 11 dikes it can be expected that the salinity pattern with Plan 11 would also be much closer to that under existing conditions.

The testing to show the effect on shoaling quantities and patterns was detailed to the extent that material was retrieved from units of channel 5000 feet in length. The results are shown on Table 2 and the accumulated values of shoaling quantities are plotted on Plate 7. It should be noted that the quantity retrieved from the channel and anchorages during the test of Plans 7 and 11 was approximately 10% less than for the base test. Therefore, a comparison of distribution of shoaling should take this into account. There is evidence of an upstream shift of the shoaling in Tinicum Range and a downstream shift from the Marcus Hook area for the dike plans. The results of the Plan 11 tests show that material that shoaled Marcus Hook Range in the base test was probably shifted to the Bellevue-Cherry Island Ranges.

The shoaling with the Plan 7 dikes indicated more intensive shoaling in scattered areas probably due to the more severe changes in the flow characteristics along the estuary. The block diagram, Plate 8, illustrates the channel shoaling by the unit reaches. There is no evidence of appreciable shifting of the intensive shoaling in a significant downstream direction.

TABLE 2  
DELAWARE RIVER MODEL DIKE STUDY  
EFFECTS OF PLANS 7 AND 11 ON ACCUMULATIVE TOTAL SHOALING

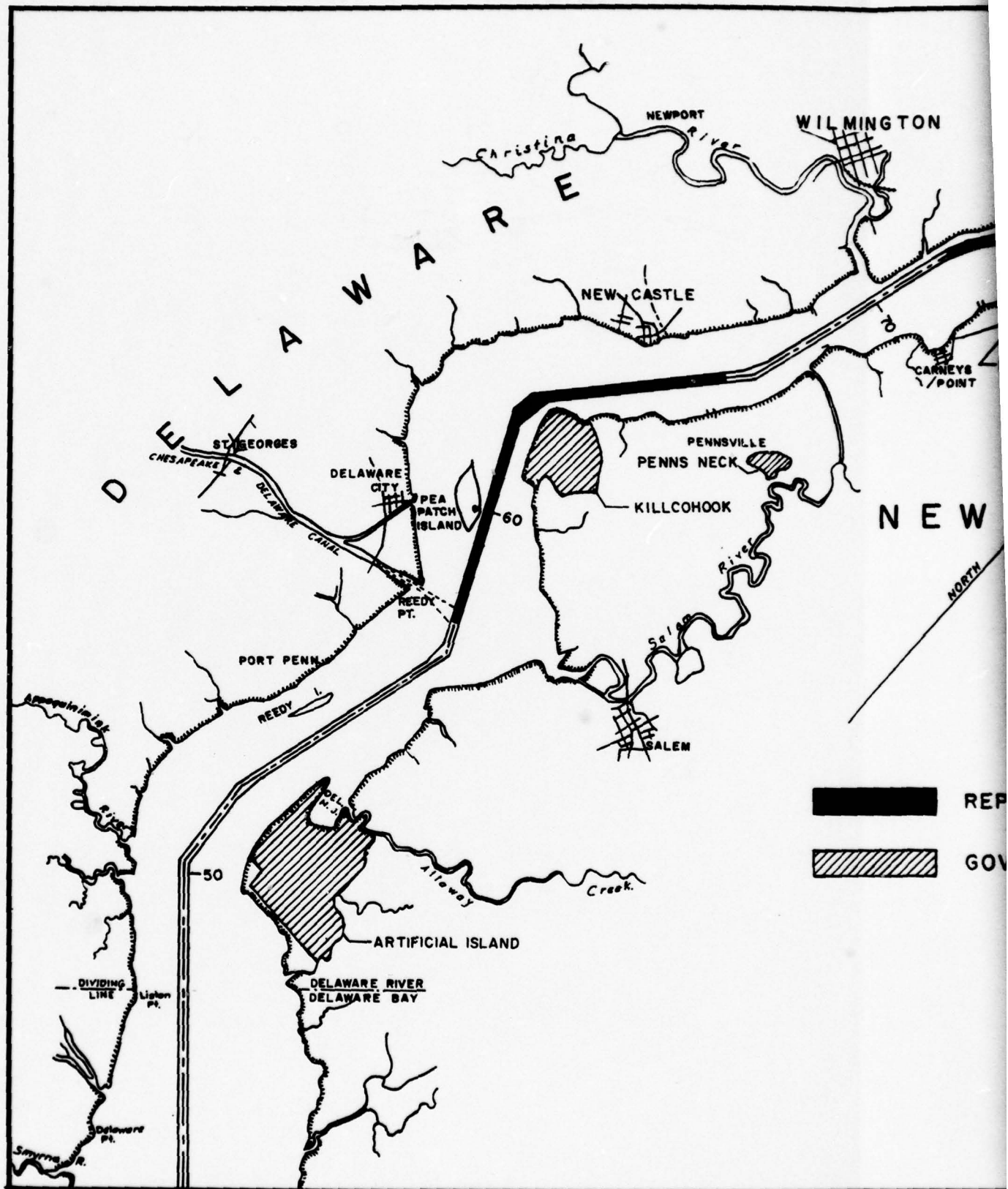
AREA	BASE TEST				PLAN 7 DIKES				PLAN 11 DIKES				Diff. in Totals Plan 11 - Plan 7	
	Channel		Anchorage		Channel		Anchorage		Channel		Anchorage			
	Volume cu cm	Total cu cm	Volume cu cm	Accum. Total cu cm	Volume cu cm	Total cu cm	Volume cu cm	Accum. Total cu cm	Volume cu cm	Total cu cm	Volume cu cm	Accum. Total cu cm		Difference cu cm
NAVIGATION RANGE														
Delair	100	100	70	70	70	70	110	110	110	110	110	110	110	+ 40
Draw	35	135	50	120	50	120	40	150	40	150	40	150	40	+ 30
Fisher	30	165	40	160	40	160	30	180	30	180	30	180	30	+ 20
Harbor	90	255	85	245	85	245	75	255	75	255	75	255	75	+ 10
Phila. Waterfront	1585	2,130	2190	2,690	255	2,690	1615	2,065	1615	2,065	195	2,065	195	- 625
Horseshoe	790	2,920	1175	3,865	115	3,865	800	2,865	800	2,865	1490	2,865	1490	- 1000
Mifflin	2360	9,150	1140	5,120	115	5,120	3800	8,155	3800	8,155	1490	8,155	1490	+ 3035
Billingsport	460	9,610	1730	6,850	115	6,850	475	8,630	475	8,630	1490	8,630	1490	+ 1780
Tinicum	2810	12,420	4570	11,420	115	11,420	1755	10,385	1755	10,385	1490	10,385	1490	- 1035
Eddystone	145	12,565	500	11,920	115	11,920	285	10,670	285	10,670	1490	10,670	1490	- 1250
Chester	845	13,410	1385	13,305	115	13,305	665	11,335	665	11,335	1490	11,335	1490	- 1970
Marcus Hook	5595	24,610	6300	21,920	2315	21,920	3835	16,125	3835	16,125	955	16,125	955	- 5795
Bellevue	2820	27,430	3620	25,540	385	25,540	5060	21,185	5060	21,185	360	21,185	360	- 4355
Cherry Island	3935	33,455	4645	30,570	385	30,570	4595	26,140	4595	26,140	360	26,140	360	- 4430
Deepwater Point	4825	38,280	3120	33,690	385	33,690	6145	32,285	6145	32,285	360	32,285	360	- 1405
Bulkhead Bar	455	38,735	1465	35,155	385	35,155	425	32,710	425	32,710	360	32,710	360	- 2645
New Castle	5355	44,090	910	36,065	385	36,065	5705	38,415	5705	38,415	360	38,415	360	+ 2350
Reedy Island	2585	48,235	3230	39,595	300	39,595	3915	42,630	3915	42,630	300	42,630	300	+ 3035
Baker	1215	49,450	4040	43,635	300	43,635	1250	43,880	1250	43,880	300	43,880	300	+ 245
Liston:														
62-65	1010	50,460	1795	45,430		45,430	350	44,230		44,230		44,230		- 6230
66-68	4000	54,460	2785	48,215		48,215	4670	48,900		48,900		48,900		- 5560
69-71	2455	56,915	2920	51,135		51,135	2930	51,830		51,830		51,830		- 5085
72-74	3185	60,100	2430	53,565		53,565	2650	54,480		54,480		54,480		- 5620
75-77	3185	63,285	3335	56,900		56,900	3870	58,350		58,350		58,350		- 4935
78-80	3960	67,245	4155	61,055		61,055	3820	62,170		62,170		62,170		- 5075
81-83	1775	69,020	1520	62,575		62,575	985	63,155		63,155		63,155		- 5865

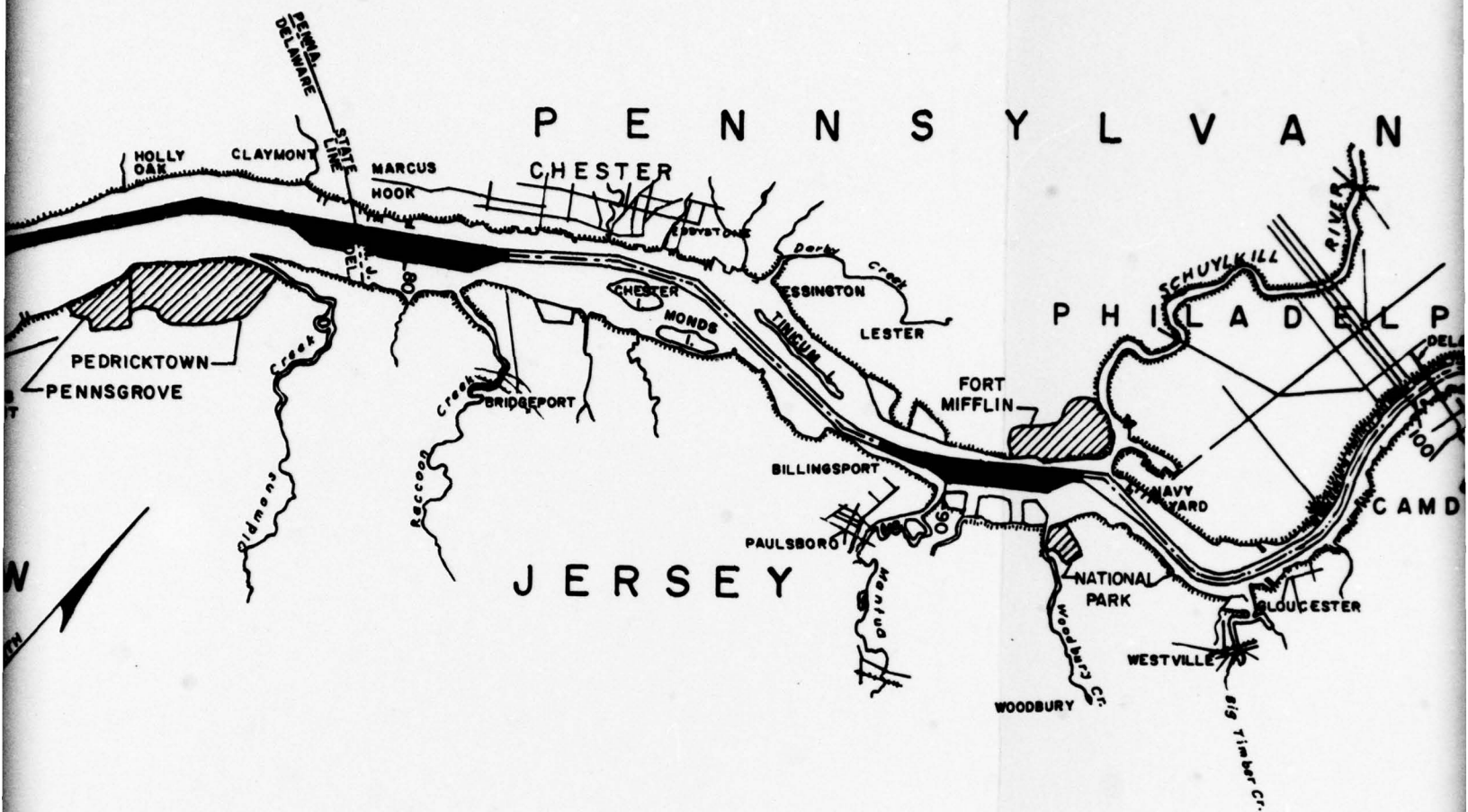
### III. CONCLUSIONS

The system of training dikes for the Delaware Estuary as tested in the hydraulic model at the Waterways Experiment Station consisted of a series of long dikes generally parallel to the river channels and tied to the shore at the upper end. Plan 11 differs from Plan 7 in that the up-river tie-backs to shore were lowered to mean low water to allow a more uniform and greater flow to pass a given section. The extreme length of dikes in the system would cost an enormous amount of money and a very significant benefit must result if such construction were to be seriously considered for accomplishment. The results show a shifting of the intensive shoaling areas, but not always in a downstream direction. It can be concluded that, even though some downstream shifting is evident, desirable objectives were not achieved since the shoaling would be

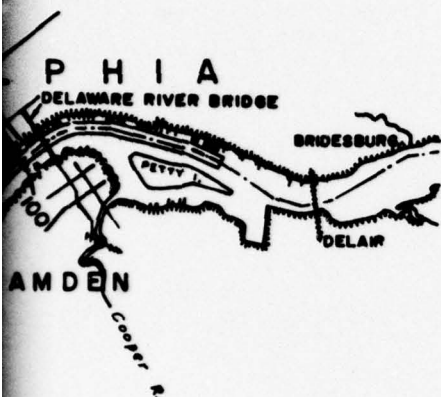
spread along several reaches of the river from Tinicum to Liston Ranges. The goal of getting much of the shoaling to occur much closer to the Artificial Island areas could not be realized.

Since even this extensive system of dikes did not show the desired results, an ultimate shoreline pattern was not developed that could serve as a goal toward which any changes should be directed. Two of the training dikes that were located adjacent to and partially encroaching on the Mantua and Marcus Hook Anchorages did effect a considerable reduction in shoaling of the anchorage area due to decrease in flow area. Therefore, if these anchorages could be eliminated or reduced in size the dikes adjacent to these areas could be incorporated into such a plan.





I A



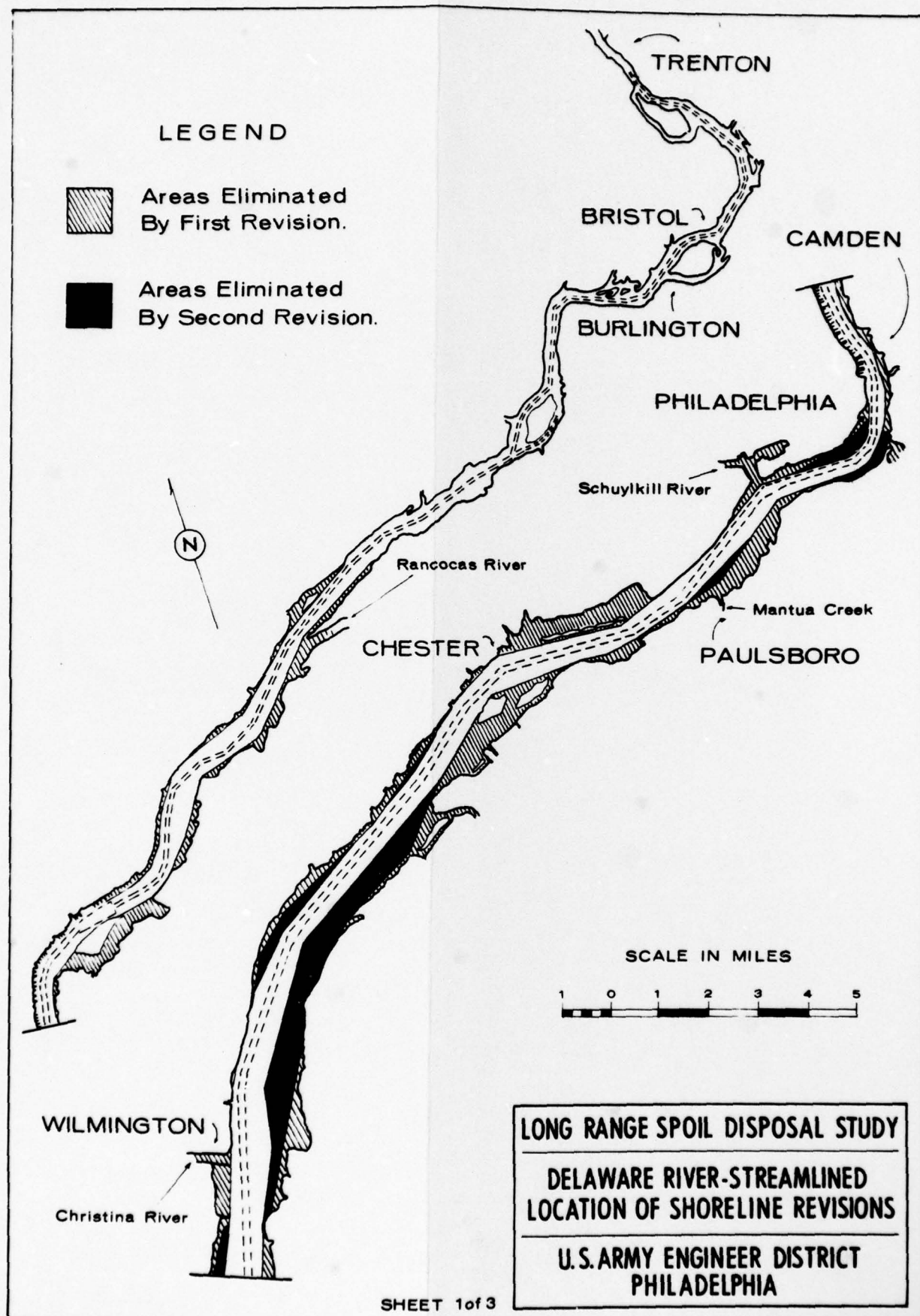
**LONG RANGE SPOIL DISPOSAL STUDY**

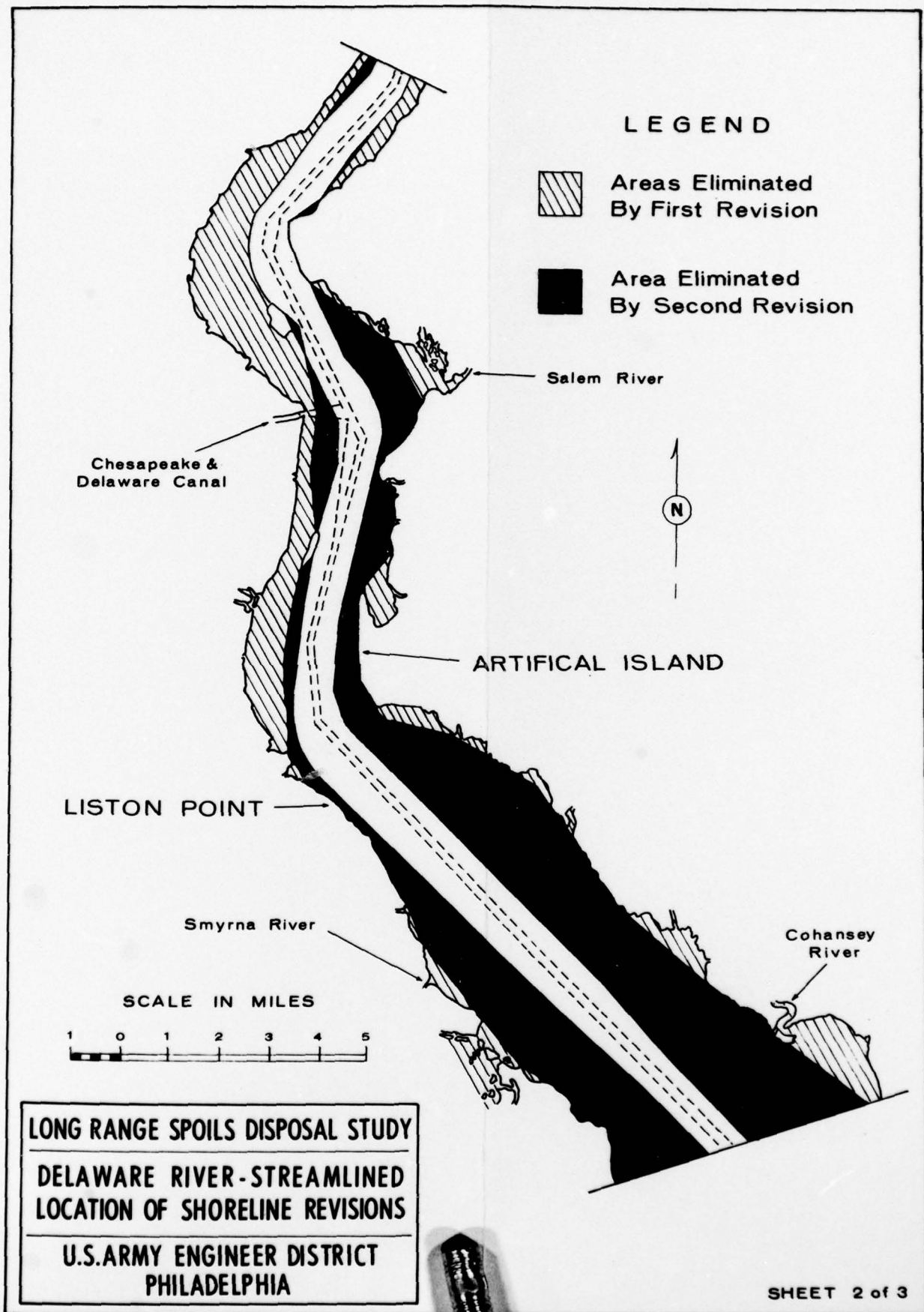
**DELAWARE RIVER  
MAJOR SHOALS**

**U. S. ARMY ENGINEER DISTRICT  
PHILADELPHIA**

PLATE 1

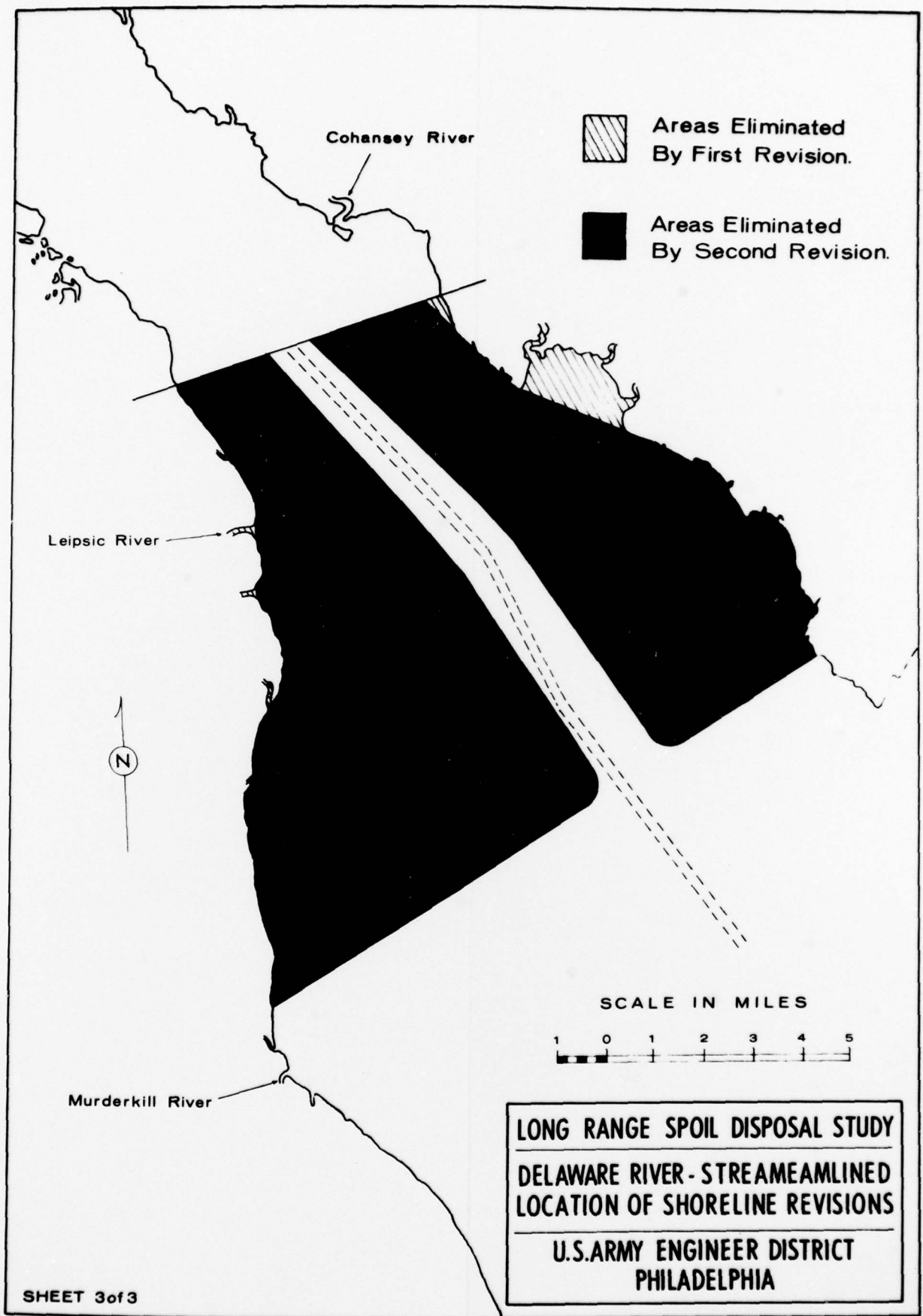
3





SHEET 2 of 3

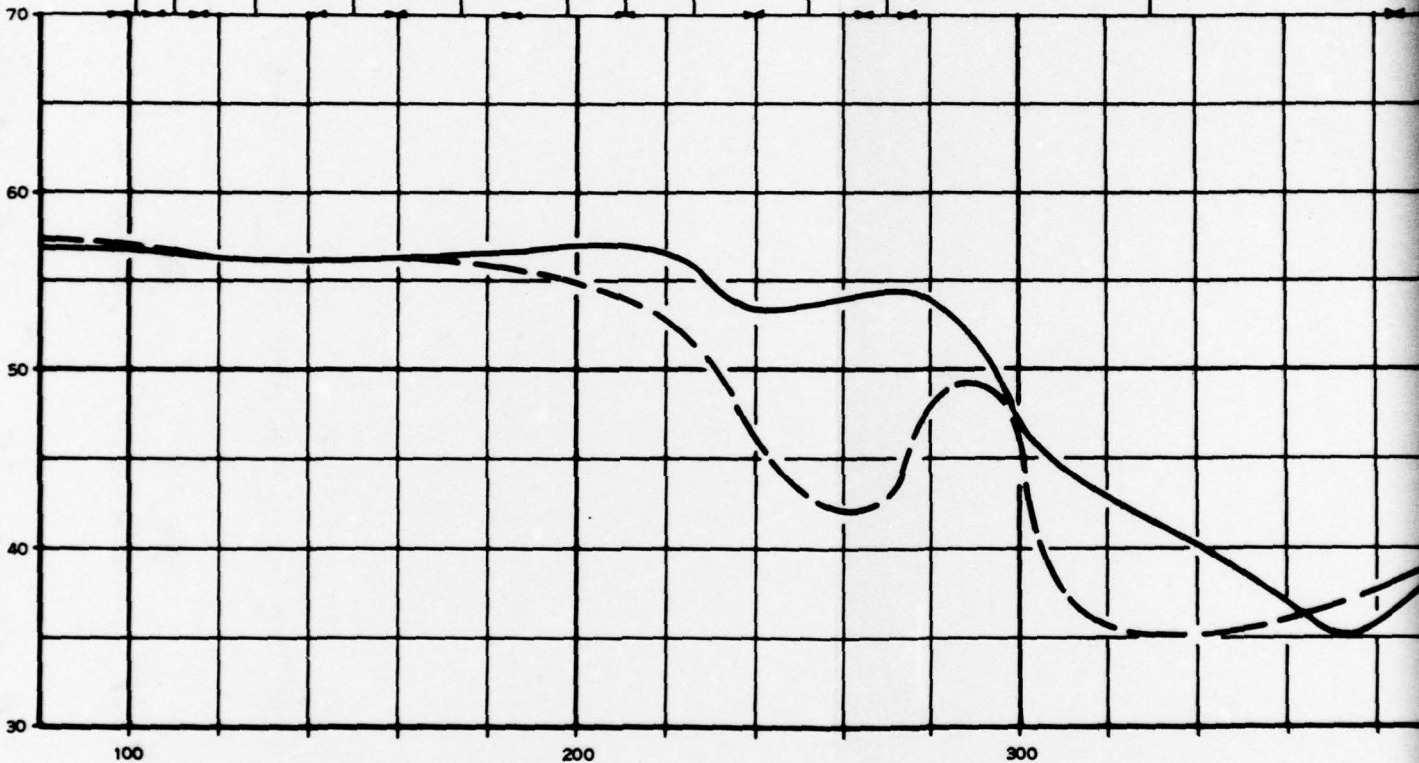
PLATE 2-B



# NAVIGATION RANGES

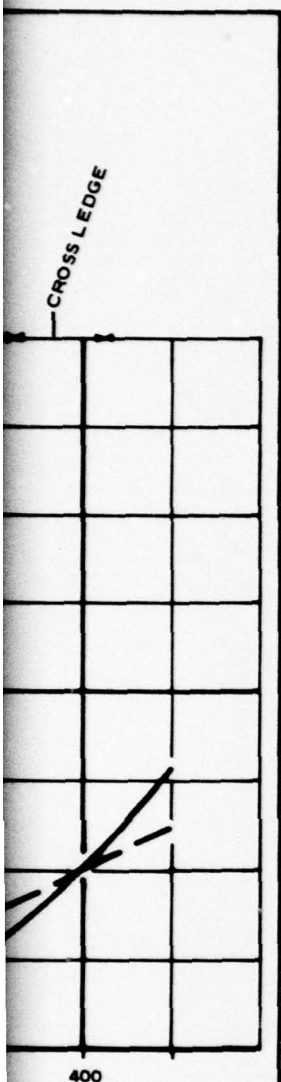
PERCENT TOTAL FLOW DOWNSTREAM

EBB PREDOMINANCE  
FLOOD PREDOMINANCE



— BASE TEST  
- - - PLAN 11 DIKES

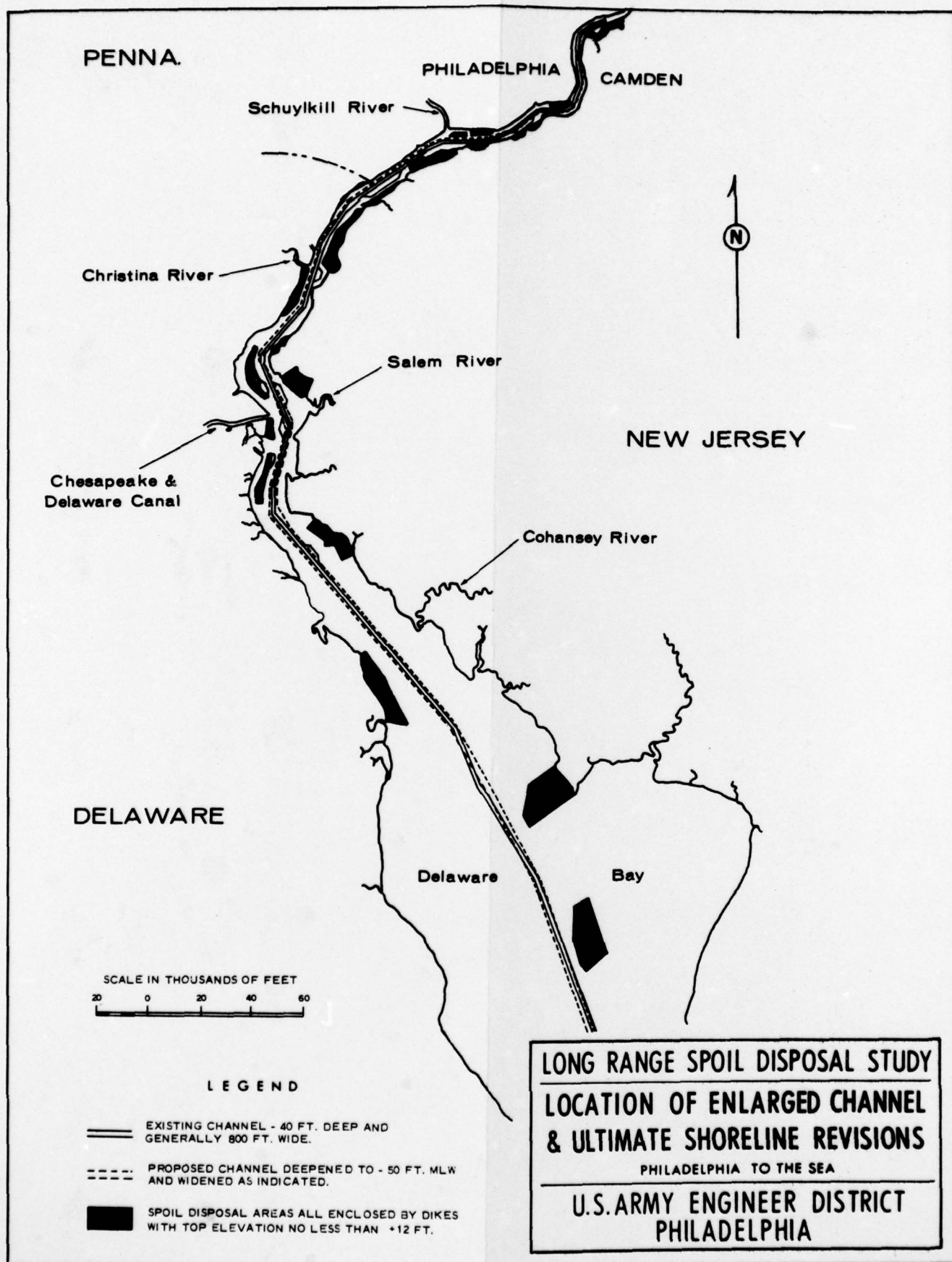
LONG RANGE SPOIL DISPOSAL  
DELAWARE RIVER  
VELOCITY DATA  
BOTTOM FLOW PREDICTIONS  
U. S. ARMY ENGINEER  
PHILADELPHIA

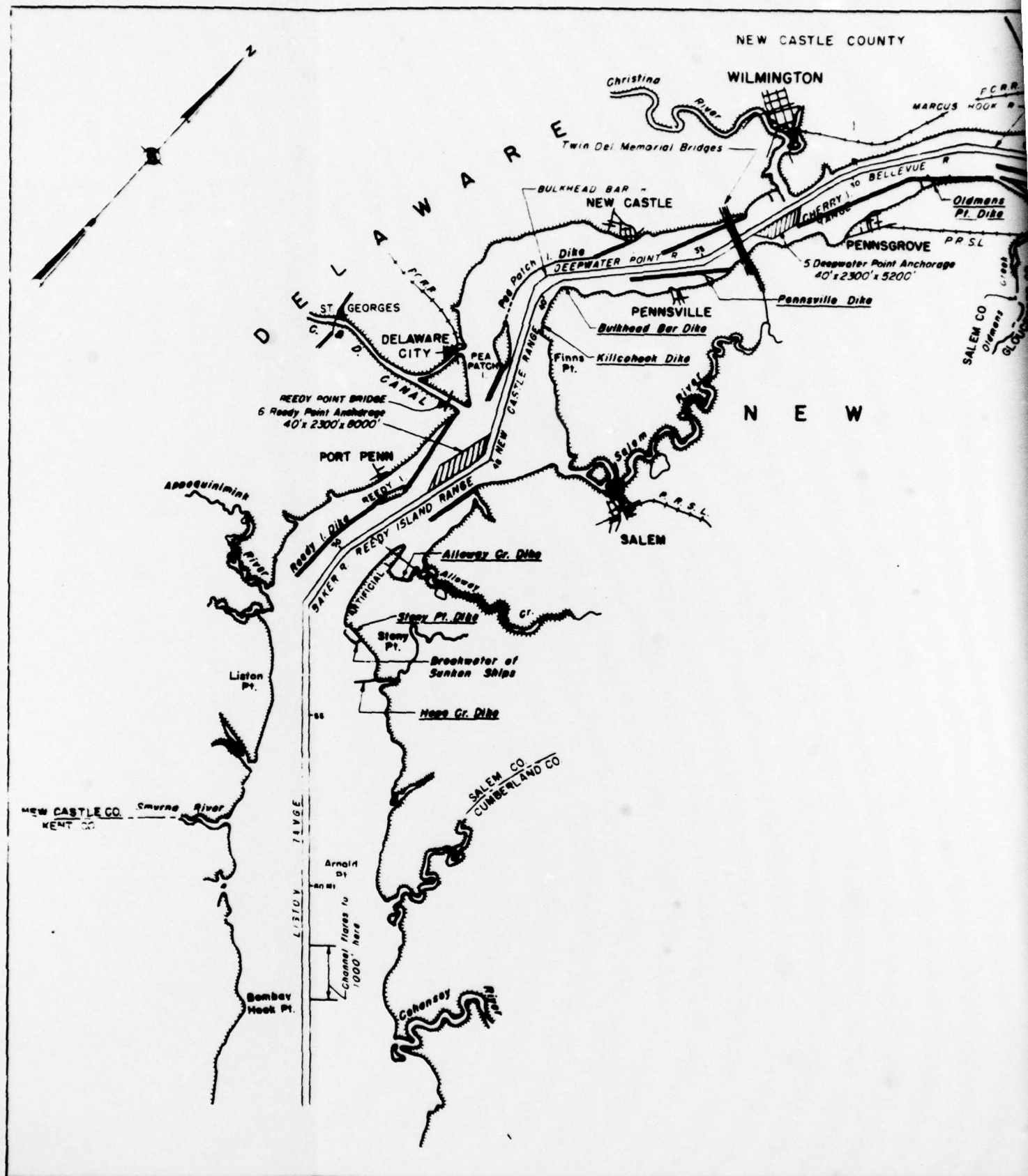


PROPOSAL STUDY  
R MODEL  
ATA  
DOMINANCE  
R DISTRICT  
IA

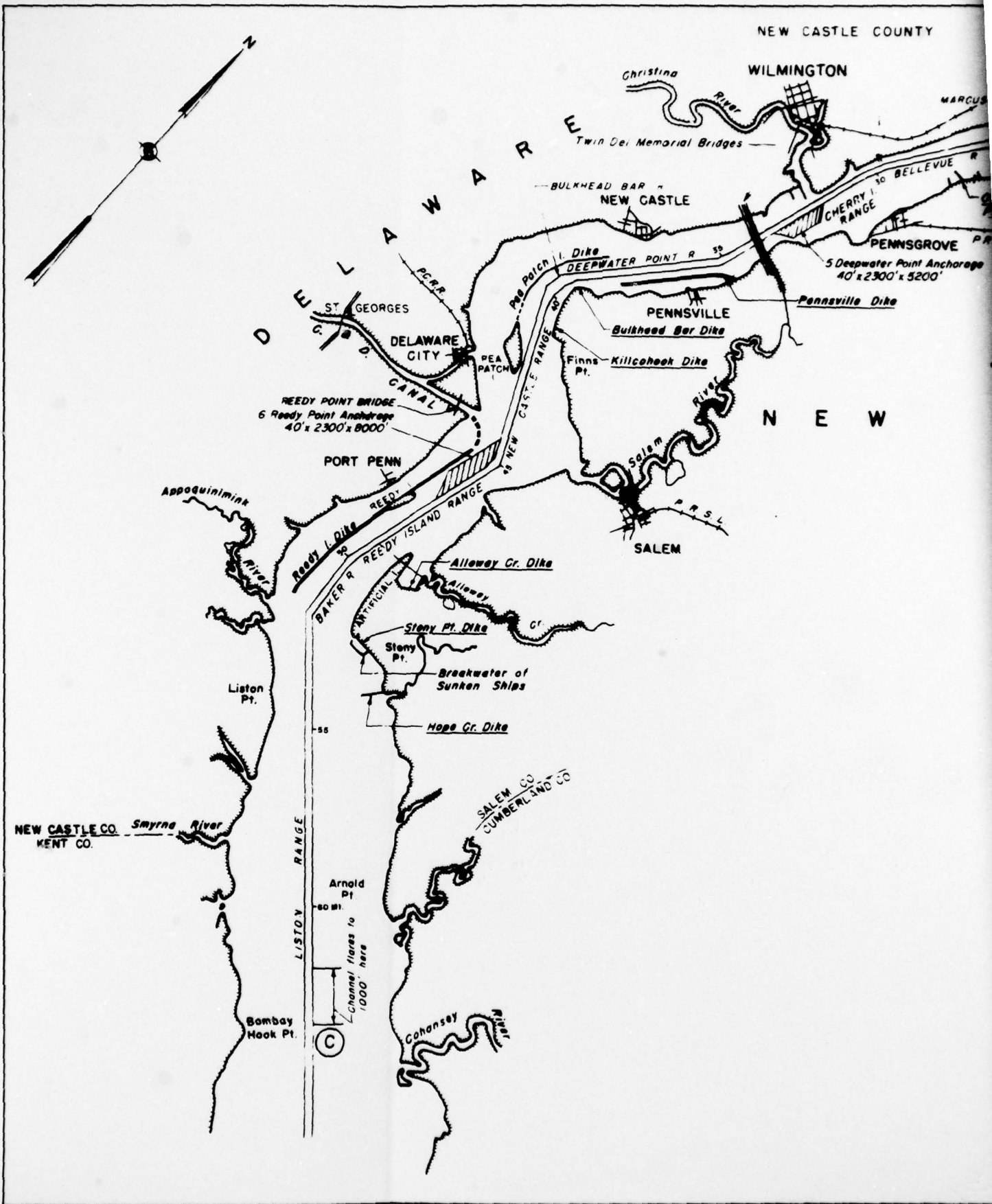
PLATE 3

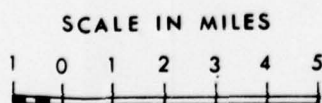
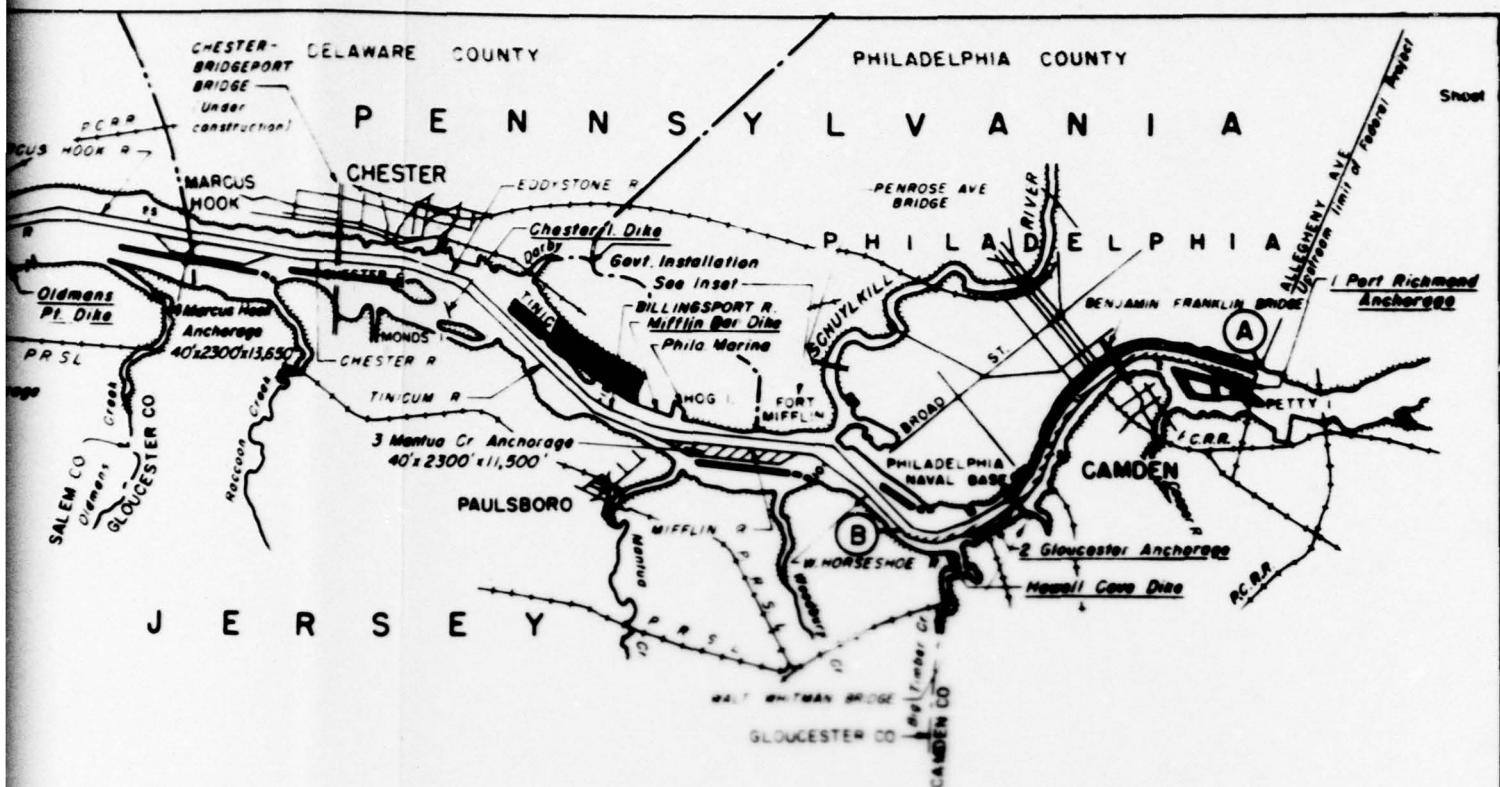
2











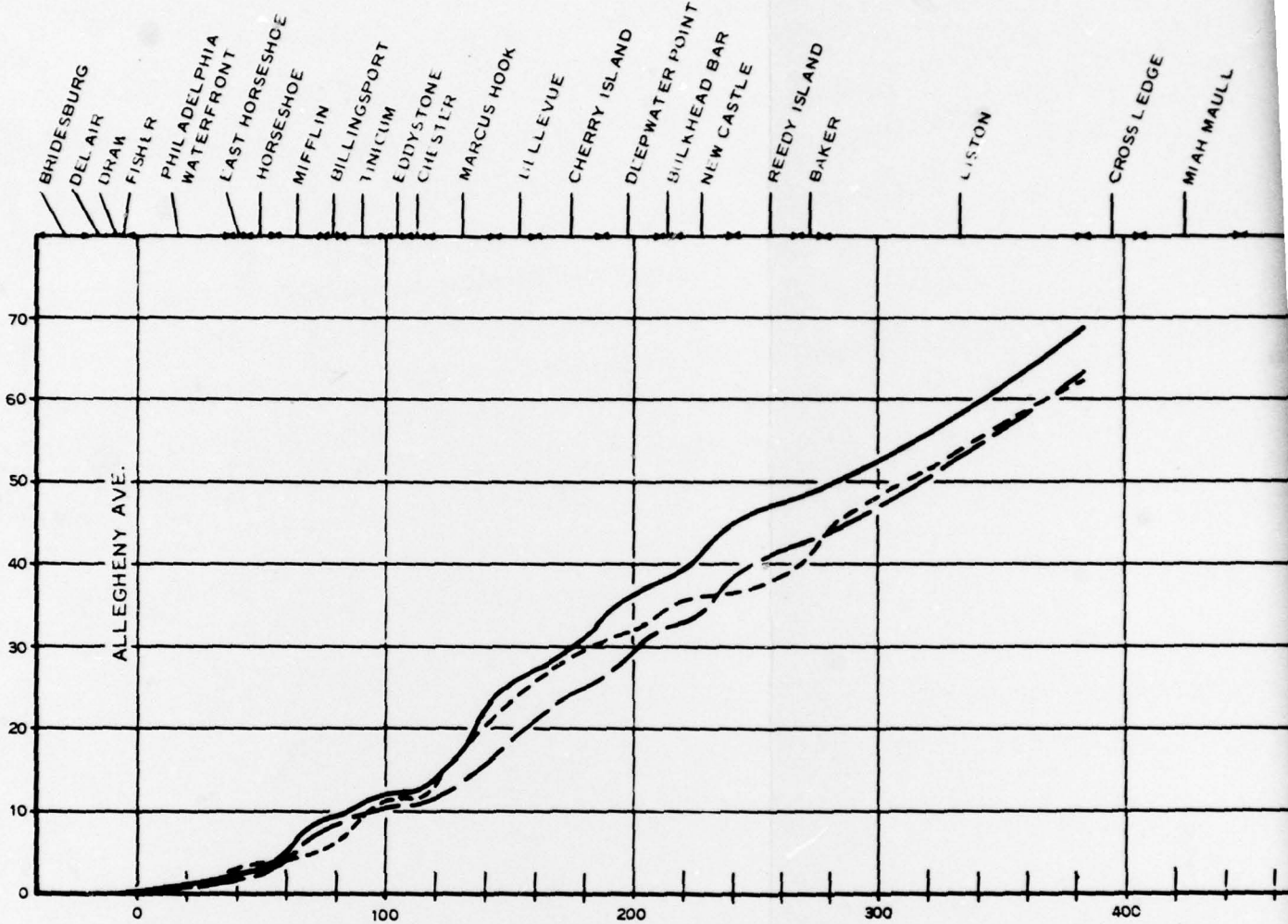
# LONG RANGE SPOIL DISPOSAL STUDY

## DELAWARE RIVER DIKE STUDY-PLAN No.11

U.S.ARMY ENGINEER DISTRICT  
PHILADELPHIA

# NAVIGATION RANGES

ACCUMULATED TOTAL SHOALING  
IN 1000 CU. CM.



1000 FT. CHANNEL STATIONS - From Allegheny Ave., Philadelphia

- BASE TEST (Existing)
- - - - - PLAN 7
- · - · - PLAN 11

## LONG RANGE SPOIL DIS

DELAWARE RIVER  
ACCUMULATED SHO  
NAVIGATION CHANNEL &  
EXISTING VS. PLAN  
DELAIR TO LISTON RA

U. S. ARMY ENGINEER  
PHILADELPH

BRANDY WINE


500

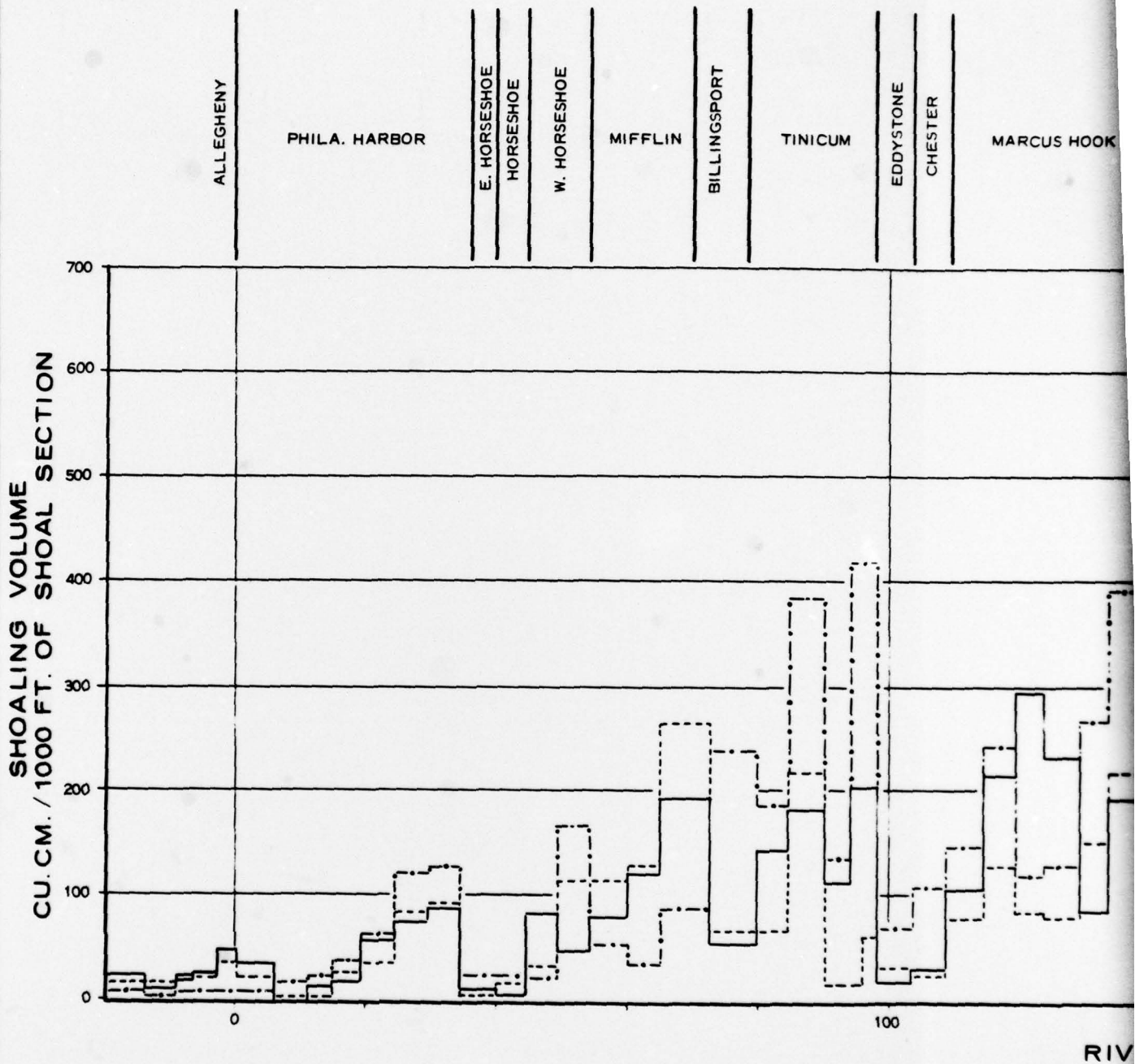
## DISPOSAL STUDY

R MODEL  
MOALING  
& ANCHORAGES  
ANS 7 & 8  
RANGES INCL.

ER DISTRICT  
HIA

PLATE 7

2



### LEGEND

Base Test —————

Plan 7 .....-.....

Plan 11 - - - - -

BELLEVUE

CHERRY ISLAND

DEEPWATER  
POINT

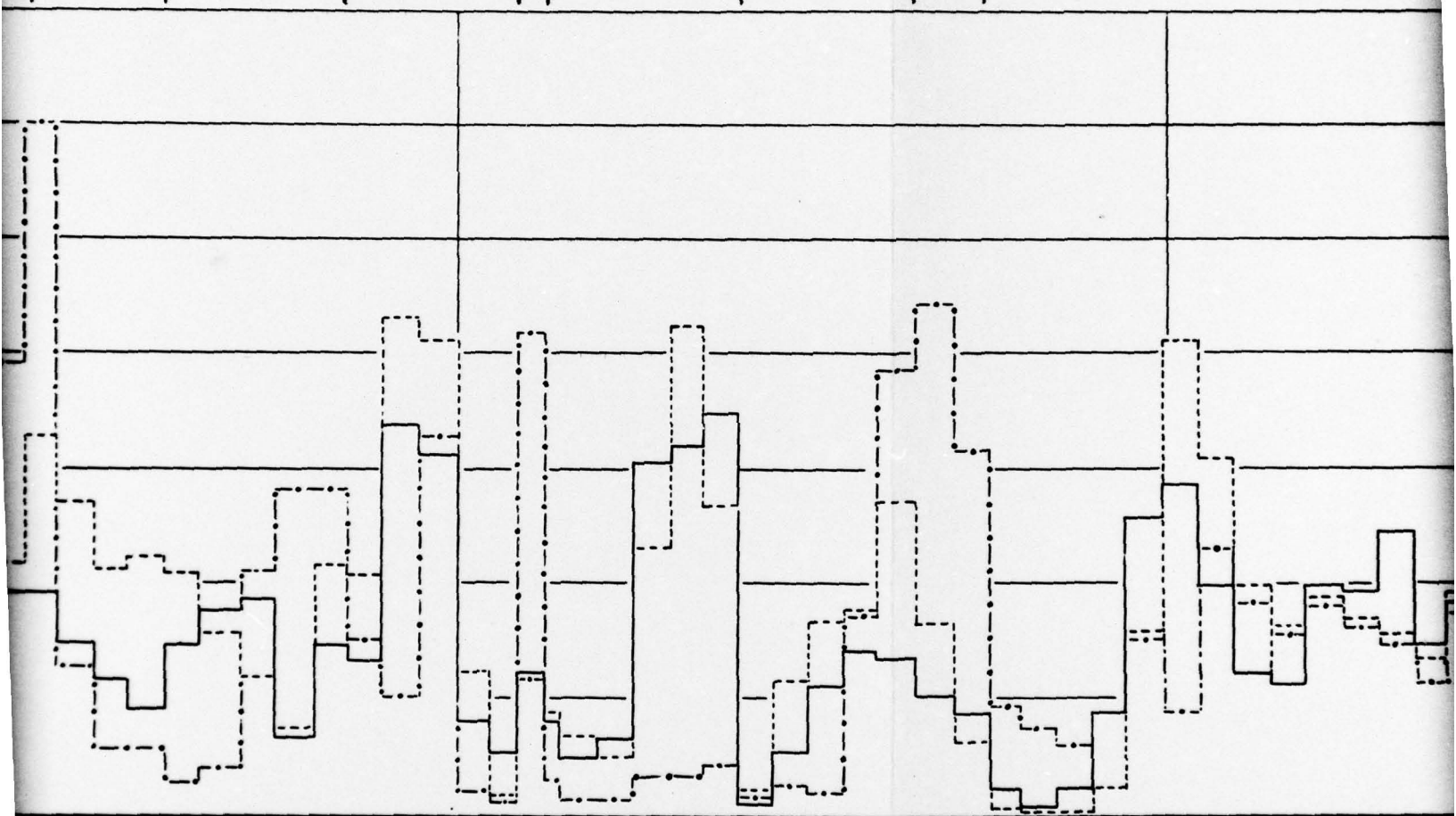
BULKHEAD BAR

NEW CASTLE

REEDY ISLAND

BAKER

LISTON



200

300

ER STATIONING IN THOUSANDS OF FEET

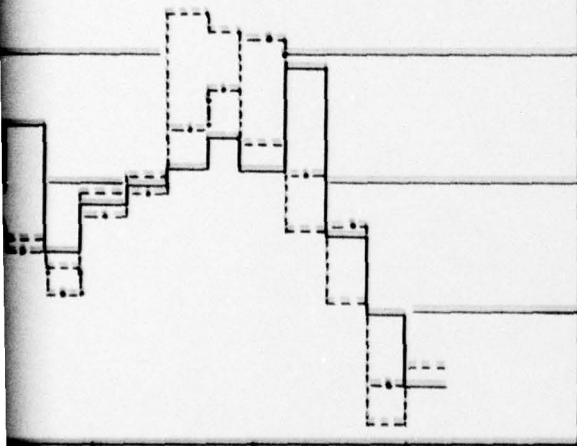
LON

U

2

ON

CROSS  
LEDGE



400

**LONG RANGE SPOIL DISPOSAL STUDY**

**DELAWARE RIVER MODEL  
TESTS OF TRAINING DIKES  
SHOALING RATES**

**U. S. ARMY ENGINEER DISTRICT  
PHILADELPHIA**

PLATE 8

3