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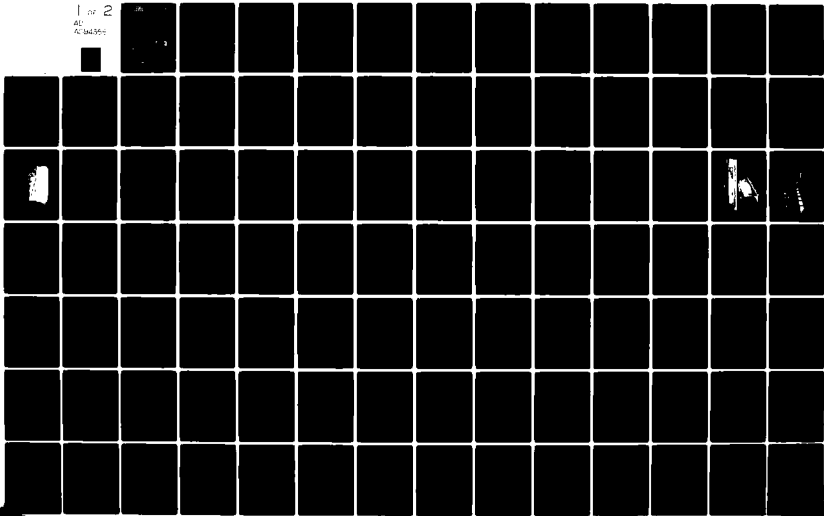

LEVEL II

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INVESTIGATION INTO DEEP-DRAFT VESSEL BERTHING PROBLEMS AT SELECTED U.S. NAVAL FACILITIES

By

Dr. John F. Hoffman, P.E.

FOR

OFFICE OF NAVAL RESEARCH
AND
NAVAL FACILITIES ENGINEERING COMMAND

EG&G

INVESTIGATION INTO DEEP-DRAFT VESSEL BERTHING PROBLEMS AT SELECTED U.S. NAVAL FACILITIES

by

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Office of Naval Research
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To Convert . . .	Into . . .	Multiply By . . .
inches	centimeters	2.540
feet	meters	0.3048
yards	meters	0.9144
miles	kilometers	1.609
acres	hectares	0.4047
sq miles	hectares	259.0
gallons	liters	3.785
cu feet	liters	28.32
cu yards	cubic meters	0.7646
pounds/sq ft	dynes/sq cm	478.8
knots	meters/second	0.5144
horse power	watts	746.0

EXECUTIVE SUMMARY

Described in this report are the results of a detailed investigation of shoaling in the pier slips and associated waterways of six deep-draft harbors used by the U.S. Navy. These are the Naval Air Station at Alameda, CA, the Naval Station and Naval Shipyard at Charleston, SC, the Naval Station at Mayport, FL, the Naval Station at Norfolk, VA, the Naval Air Station at Pensacola, FL, and the Naval Air Station, North Island, San Diego, CA. In addition to shoaling, the bioclogging of the screens of aircraft carriers' "sea chests" at Norfolk, VA was investigated.

Prior to the investigation of specific harbors, home-porting information was updated. Also updated were data concerning the drafts of Aircraft Carriers (CV, CVT, CVN) Fast Combat Support Ships (AOE), Oilers (AO), and Replenishment Oilers (AOR). Initially, submarines were included in this study but information at pertinent installations, such as Charleston, SC, was considered as classified and little if any information was available. Additionally, time did not permit inspection of submarine installations such as that at Point Loma, CA.

As the result of updating Table 7-4 in "Design Manual 26 - Harbor and Coastal Facilities" the Maximum Operating Load of aircraft carriers was found to exceed the Limit in all carriers except the U.S.S. EISENHOWER. This is shown in Tables 2-2 and 2-3.

Tidal extremes for the subject harbors was also updated to the latest information available from the National Ocean Survey. These are shown in Table 2-4. It is to be noted that Extreme Low Water at the installations investigated ranged from 2.2 feet below the reference datum at Pensacola, FL, (Mean Low Water for the East and Gulf coasts and Mean Lower Low Water for the West coast) to 3.3 feet below the reference datum at Charleston, SC. Water levels at elevations below the reference datum are called "negative" tides.

Dredging is usually based on Mean Low Water or Mean Lower Low Water. Consequently, during the period of negative tides the water depth in the berth is less than desirable and groundings may take place.

Methods of dredging commonly used to dredge pier slips are described together with less-frequently used methods that have been used in slip maintenance.

The problem of offshore as well as onshore dredge spoil disposal is addressed. Included are discussions on the use of the elutriate test, the bioassay, and the in-situ bioassay in determining the toxicity of the dredge spoil. These tests are required by both the Environmental Protection Agency and the Corps of Engineers in many instances.

Retardation of the deposition of sediments or the flushing of pier slips of resuspended sediments are ways of reducing the costly dredging burden. A section in the report addresses the methods of sediment control.

Individual naval facilities investigation included the on-site interrogation of various public works personnel, port services personnel, and other personnel as the situation required. The Corps of Engineers in whose district a specific naval facility was located was also contacted.

Information in this report based on these interviews and other research is contained in sections entitled: Ship Movement, Current Velocity, Elevations of Bottom Tips of Pilings (should future deepening necessitate lowering the elevation of the bottom of a slip), Shoaling and Shoaling rate, Submarine Sediments, Dredging, Dredge Spoil Disposal, Problems, and Recommendations.

At Alameda Naval Air Station, the waterway problem is the large quantity of dredging necessary to maintain satisfactory depths in the approach channel, turning basin, and the pier slips. Major recommendations include:

1. reduce turning basin area from eight million square feet to six million square feet.

2. close seaplane basin to keep silt from washing into the turning basin.

3. seal off opening in southern breakwater to eliminate the ingress of silt into the turning basin.

At the Charleston, SC Naval Station and Shipyard, shoaling of the pier slips and channel is due largely to the diversion of the Santee River flow into the Cooper River for purposes of developing hydroelectric power. This took place in 1942. The magnitude of the problems created is such that a rediversion is scheduled to take place in 1983. It is estimated that the volume of spoil dredged annually by the U.S. Navy will decrease from 3 million cubic yards to 1.2 million cubic yards. A problem that has not yet surfaced is that of spoil disposal. Presently, the spoil from the U.S. Navy-owned and operated dredge "Orion" is pumped through a submerged pipeline to Clouter Island disposal area which is shared with the Corps of Engineers. Studies have indicated that the storage capacity for future spoil at this site is limited. Although the volume of spoil will be reduced after the rediversion of the Santee River in 1983, maintenance dredging will still be required. In all liklihood this will be at a reduced rate.

At Mayport Naval Station aircraft carrier piers C-1 and C-2 have a siltation problem. This has been sufficiently serious to prevent the start-up of aircraft carriers. The bottom of the berth has been as little as one and one-half feet below the "sea chest". Recommendations to correct these problems include the use of side jets located at the pier to flush the sediments into the turning basin during the ebbing tide. Also recommended is an interceptor system located at the entrance to the turning basin to trap sediment and to pump the sediment beneath the St. John's River to replenish the beach on the north side of the northern jetty.

Problems at the Naval Station at Hampton Roads, VA include excessive shoaling of pier slips and the clogging of sea chests of aircraft carriers berthed in Pier 12 by hydroids and bryozoans. Although this latter problem has been recognized since 1962, no satisfactory solution has been found. A number of recommendations are made in the report together with recommendations for collecting additional data.

Pensacola Naval Air Station has only one aircraft carrier based at that Station - the U.S.S. LEXINGTON. Dredging is sporadic and at the time of writing (1979-80) some maintenance dredging was anticipated. A problem with the toxicity of the sediments has occurred for the sediments were found to contain arsenic. This precluded the seaward disposal of the contaminated sediments. The problem of land disposal of the toxic sediments has not fully been resolved (1979).

Documentation of three shoaling problems at the North Island Naval Air Station, San Diego, CA. is in hand. These concerned the ingestion of silt into the "sea chest" of the aircraft carriers berthed at Piers J, L, M, N, O, and P. Another problem concerned the grounding of the aircraft carrier U.S.S. CONSTELLATION on 18 January 1977 while it was berthed at Piers M and N. Groundings of aircraft carriers in the turning basin have been reported verbally but no documentation is available to support these situations. Among the recommendations made is the use of side-washing water jets at Piers J, L, M, N, O, and P to flush the sediment accumulation at these piers during the ebbing tide.

In addition to recommendations for specific naval installations, eight general recommendations are made. These include: use of air bubble agitation to remove sediments from pier slips, changing the datum for dredging to Extreme Low Water from Mean Lower Low Water, and investigating the feasibility of various dredging approaches to reduce dredging costs and down time for pier slips.

SECTION I

INTRODUCTION

In Naval ports, aircraft carriers are sustaining heavy fouling at pier side as well as during entering and leaving the berthing area. The fouling is usually caused by the suction of bottom sediment due to the proximity of mud line in the berth to sea chests of the aircraft carrier. The intake of 100,000 gpm cooling water through four ports located at the keel and the discharge at the same rate directly downward through the same number of ports in a once-through cooling system with less than seven feet beneath the carrier resuspends in the water column material lying on the bottom. This results in frequent malfunction of the turbine generator and distilling plant as well as excessive wear of ship's machinery and pump components. In the case of Norfolk Naval Base, silt is not the only problem for the sea chests of aircraft carriers have also been clogged seriously by invertebrates identified as hydroids and bryozoans.

The object of the present study is to collect data from reports and interviews relevant to describing existing conditions. Although, aircraft carriers have been the subject of the main thrust of this study, portions of it pertain to Fast Combat Support Ships (AOE), Oilers (AO), and Replenishment-Oilers. Also, while it is recognized that modern nuclear submarines, especially newer models, are also deep-draft vessels, the extent of secrecy surrounding those ships precluded any extensive study in this area.

Initially the naval bases and air stations selected by NAVFAC for this study were Naval Station, Norfolk, VA (especially Pier 12), Naval Air Station, Pensacola, FL, Naval Air Station, Alameda, CA, and North Island Naval Air Station, Coronado, CA. Subsequently, the Naval Station and Shipyard at Charleston, SC, and the Naval Station at Mayport, FL, were added.

Contacts in the various Naval Facilities Engineering Command Divisions were furnished by Dr. Michael Kim of Naval Facilities Engineering Command, Alexandria, VA. Meetings with pertinent personnel at the naval bases and at the naval air stations were set up through these contacts. The personnel included as a minimum public works engineers, Staff Civil Engineer, Port Services Officer, and the Chief Engineers of any aircraft carriers in port. In order to facilitate the exchange of information a questionnaire was utilized. This questionnaire is shown in Appendix A.

Meetings or telephone conferences were also held with personnel of the U.S. Geological Survey, PERA-CV, Naval Sea Systems Command, David Taylor Naval Ship Research and Development Center, National Ocean Survey (NOAA), the Corps of Engineers of the Norfolk, Jacksonville, and Los Angeles Districts and the Waterways Experiment Station. Two meetings were attended at NAVFAC, Alexandria, VA, which concerned hydraulic and mathematical modeling of the velocity field below an aircraft carrier berthed in Pier 12. Further, PERA-CV at Puget Sound Naval Shipyard, Bremerton, WA, was contacted concerning the projected weight and stability of aircraft carriers.

A literature search was conducted using the Defense Documentation Center as well as individual technical indexes, technical journals, technical magazines and technical books. The Waterways Experiment Station Library was also contacted for pertinent reports. Background was also assembled from construction plans, miscellaneous memos, messages, and correspondence.

An oceanographic research student, under supervision, is searching the literature for characteristics of and natural enemies of Sertularia argentae, the problem hydroid in Pier 12, Norfolk, VA. Another student has conducted some studies on the movement of sediment and hydroids in the Hampton Roads area using the Chesapeake Bay Model.

Discussed first in the following text is the general information pertinent to the problem. This includes homeporting of ships, ship characteristics, tidal information for ports concerned, dredging, sediment control in slips, and ship berthing procedures. After that the following individual ports are discussed: Alameda, CA, Mayport, FL, Norfolk, VA, Pensacola, FL, San Diego, CA, and Charleston, SC.

SECTION II

GENERAL BACKGROUND

2.1 HOMEPORT FOR DEEP-DRAFT VESSELS.

Deep-draft vessels for the purpose of this report are those vessels that have a draft in excess of 35 feet.

Shown in Table 2-1 is the homeport for deep-draft vessels in Alameda Naval Air Station, CA, Mayport Naval Air Station, FL, Norfolk Naval Station, VA, Pensacola, FL, and North Island Naval Air Station, Coronado, CA, as of 28 February 1980.

Table 2-1 considers Aircraft Carriers (CV, CVN, CVT), Fast Combat Support Ships (AOE), Oilers (AO), and Replenishment Oilers (AOR). Authoritative information on deep-draft submarines was not readily available.

2.2 DRAFT AND DISPLACEMENT - DEEP DRAFT VESSELS.

Shown in Table 2-2 is a tabulation of characteristics for U.S. Naval Vessels with drafts in excess of 35 feet. Included in this table are aircraft carriers (CV, CVN), Fast Combat Support Ships (AOE), Replenishment-Oilers (AOR), and Oilers (AO's). Table 2-2 is an abbreviated updated version of Table 74 from NAVFACENGCOM Design Manual 26 entitled "Harbor and Coastal Facilities". Data used for updating Table 2-2 was obtained from Naval Sea Systems Command (Tucker, 1979).

Shown in Table 2-3 are drafts and displacements of the aircraft carriers in both the Atlantic and Pacific Fleets for 1979 and projected to late 1980s and early 1990s (PERA-CV, 1979). Maximum Operating Load Drafts (forward and aft) are those reported by the ship over a recent three month deployment period. Maximum Operating Load Displacement is based on the maximum mean draft reported by a ship during this deployment period. Full load condition is the condition when the ship

TABLE 2-1: HOMEPORT FOR DEEP-DRAFT VESSELS IN ALAMEDA, CA, CHARLESTON, SC, MAYPORT, FL, NORFOLK, VA, PENSACOLA, FL, AND CORONADO, CA*

Class	Name	Homeport	Effective Date
	Aircraft Carriers		
CV 41	MIDWAY	Yokosuka, Japan	6-30-73
CV 43	CORAL SEA	Alameda, CA	2-10-79
CV 59	FORRESTAL	Mayport, FL	10-01-77
CV 60	SARATOGA	Mayport, FL	12-01-73
CV 61	RANGER	Coronado, CA	3-17-78
CV 62	INDEPENDENCE	Norfolk, VA	1-10-59
CV 63	KITTY HAWK	Coronado, CA	3-17-77
CV 64	CONSTELLATION	Coronado, CA	3-15-76
CV 66	AMERICA	Norfolk, VA	1-23-65
CV 67	JOHN F. KENNEDY	Norfolk, VA	9-07-68
CVN 65	ENTERPRISE	Alameda (?) Bremerton	1-15-79
CVN 68	NIMITZ	Norfolk, VA	4-11-75
CVN 69	DWIGHT D. EISENHOWER	Norfolk, VA	9-12-77
CVN 70	CARL VINSON	Undesignated	
CVT	LEXINGTON	Pensacola, FL	
	Fast Combat Support Ships (AOE)		
AOE 3	SEATTLE	Norfolk, VA	4-05-69
AOE 4	DETROIT	Norfolk, VA	1-01-74
	Oilers (AO)		
AO 98	CALOOSAHATCHEE	Norfolk, VA	2-04-75
AO 147	TRUCKEE	Norfolk, VA	11-23-55

* Based on OPNAV Instruction 3111.14U CH-3, 15 Aug 1979 updated 18 Feb 1980.

TABLE 2-1: HOMEPORT FOR DEEP-DRAFT VESSELS IN ALAMEDA, CA, CHARLESTON, SC, MAYPORT, FL, NORFOLK, VA, PENSACOLA, FL, AND CORONADO, CA* (Cont'd)

Class	Name	Homeport	Effective Date
	Replenishment Oiler (AOR)		
AOR 1	WICHITA	Alameda, CA	1-24-75
AOR 2	MILWAUKEE	Norfolk, VA	1-01-74
AOR 3	KANSAS CITY	Alameda, CA	2-16-74
AOR 4	SAVANNAH	Norfolk, VA	12-05-70
AOR 5	WABASH	Alameda, CA	9-06-73
AOR 6	KALAMAZOO	Norfolk, VA	6-29-79
AOR 7	ROANOKE	Alameda, CA	6-01-77

* Based on OPNAV Instruction 3111.14U CH-3, 15 Aug 1979 updated 28 Feb 1980.

TABLE 2-2: MEAN DRAFT AT FULL LOAD FOR VESSELS WHERE THE MEAN DRAFT EXCEEDS 35 FEET. (BASED ON INFORMATION FROM NAVFACENGCOM DESIGN MANUAL 26, TABLE 7-4, REVISED BY NAVAL SEA SYSTEMS COMMAND, (TUCKER, 1979)

Class of Ship	Length Overall (ft)	Beam at Water Line (ft)	Immersion (tons per in.)*	Full Load Displacement (tons)*	Mean Draft Full Load (ft)	Calculated Mean Draft Full Load (ft)**
AO-51,98,99	644	75	92	35600	35.8	
AO-143-148	656	86	104	36640	33.1	
AO-177-179	592	88	84	27378	32.5	
AOE-1 to 4	800	107	145	53500	39.1	
AOR-1 to 7	659	96	115	39675	35	
CV-41,43	968	121	186	64800	36	35.1,35.6
CV-59	1046	130	236	78700	36	34.8
CV-60						36.6
CV-61						36.8
CV-62						36.7
CV-63	1063	130	236	80200	37	37.0
CV-64	1072	130	236	81800	37	37.3
CV-66	1048	130	236	81600	37	37.0
CV-67	1048	130	236	81700	37	35.9
CVN-65	1123	133	248	87700	37	36.7
CVN-68-70	1092	134	253	91300	37	36.7

* One ton is equal to 2240 lbs.

** Average of Calculated Mean Draft Full Load from "Ships System Status Program - Weight and Stability" PERA-CV Nov 1979 forward and aft.

TABLE 2-3: MAXIMUM OPERATING AND PROJECTED DRAFTS FOR UNITED STATES AIRCRAFT CARRIERS OF THE ATLANTIC AND PACIFIC FLEETS[1]

Name of Carrier	Class of Ship	Maximum Operating Load Draft as of Nov 1979 - feet Fwd	Aft	Projected Draft (year)[2,3] - feet	Maximum Operating Load Displacement As of Nov 1979 Tons[4]	Projected Displacement[2] (year) - tons[4]
			Atlantic Fleet			
EISENHOWER	CVN-69	39.67[5]	39.67[5]	-	100250[5]	(FL) 93465 (2007)
NIMITZ	CVN-68	38.33	39.75*	See footnote (3)	96209	(FL) 92702 (2005)
JOHN F. KENNEDY	CV-67	37.00*	37.25*	do	84338*	(FL) 82153 (1998)
AMERICA	CV-66	36.50	39.00*	37.35	80162	(FL) 82872 (1995)
INDEPENDENCE	CV-62	38.50*	38.16*	See footnote (3)	84250*	(FL) 81338 (1989)
SARATOGA	CV-60	39.00*	39.00*	do	86729*	(FL) 80569 (1986)
FORRESTAL	CV-59	37.50*	38.00*	do	81525*	(FL) 77642 (1985)
			Pacific Fleet			
ENTERPRISE	CVN-65	38.25	39.66*	See footnote (3)	93249*	(OP) 91749 (1991)
CONSTELLATION	CV-64	37.75*	40.00*	do	83786*	(FL) 82591 (1991)
KITTY HAWK	CV-63	37.50*	38.70*	37.31	80870*	(FL) 82104 (1991)
RANGER	CV-61	40.00*	37.83*	See footnote (3)	85830*	(FL) 81776 (1987)
CORAL SEA	CV-43	37.00*	38.75*	do	67935*	(FL) 65904 (1987)
MIDWAY	CV-41	37.16*	38.41*	See footnote (3)	68118*	(FL) 64664 (1985)
			Other			
CARL VINSON	CVN-70	Same class as CV-68 (Key, 1979)				

* Limit is exceeded. Limit load (or draft) refers to the stability condition when a certain amount of damage is sustained.

1 Based on "Ships Status Program-Weight and Stability" PERA-CV Naval Sea Systems Command November 1979.

2 Year enclosed in parenthesis is year to which projections of displacements have been made and contained in the above publication. (OP) indicates projection based on average operating displacement. (FL) indicates projection on basis of full load displacement

3 Draft at projected displacement based on Immersion data obtained from Naval Sea Command (Tucker, 1979). Where present (1979) maximum operating displacement exceeds projected displacement no entry has been made.

4 Long tons - one long ton = 2240 lbs.

5 Limit

is ready for service in every respect, including items of variable load (accomodations and effects, ammunition, aircraft, provisions, stores, etc.).

The average Operating Load Displacement is based on the average of the operating drafts reported by the ship over a recent three month deployment period.

Projection of the displacement for each individual ship by PERA-CV was based on a 70-ton per year growth factor used for the remaining years of a ship's life. This growth factor is the average yearly weight growth of eleven aircraft carriers based on historical data held by PERA-CV.

It should be noted that the latest date of any projection was 2007. The Carrier Service Life Extension Program (SLEP) considers the life of the present aircraft carriers to extend to the year 2000 and beyond. The Program Management Plan (Feb 1980) indicates that the life of the CV Class of Aircraft Carriers will be extended 15 years to terminate in the years 2002 to 2005. Added load during this period will result in deeper drafts.

As can be seen in Table 2-3 the Maximum Operating Load Displacement for all carriers except the U.S.S. KITTY HAWK and the U.S.S. AMERICA exceeds the projected displacement. Furthermore, the Maximum Operating Load Displacement for all the carriers listed except the U.S.S. EISENHOWER, U.S.S. NIMITZ, and the U.S.S. AMERICA exceed the Limit. Limit refers to the stability condition when a certain amount of damage is sustained.

The Maximum Operating Load Draft (either forward or aft or both) exceeded the Limit in all the carriers listed except the U.S.S. EISENHOWER.

Under keel clearance for pier slips according to NAVFACENGCOM Design Manual 26 "Harbor and Coastal Facilities" indicates an underkeel clearance of two feet for the maximum load draft of the largest vessel to be accommodated is necessary. In European channels it is not uncommon to have ten percent of draft used as a criterion (Hoffman, 1978). Deep-draft ships with a draft on the order of 40 feet on this basis would have a four foot underkeel clearance. In certain channels of Holland where a firm bottom is overlain with a fluid submarine sediment the keels of ships penetrate the layer providing this layer does not have a density greater than 1.2. By using a back-scattering gamma ray device, the top of a fluid submarine mud layer is detected apart from a firm bottom and can be mapped. Determinations are made weekly for selected waterways by the Rijkswaterstaat and made available to mariners. Such an approach is not applicable to aircraft carriers and other naval vessels that have the cooling water intakes on the underside of the ship.

Marlow and Fang (1979) have not assigned a numerical value to underkeep clearance but have taken a statistical approach to determine the operational water depth of a port. "The nautical chart depth is adjusted by a calculated amount, depending on a selected probability of occurrence, to reflect the uncertainties and inaccuracies of water depth measurements, tidal prediction, and siltation rate . . . It is considered (that) this procedure provides a rational approach in water depth determination for ship traffic and port dredging operations."

On the basis of the data contained in Table 2-3, the Maximum Operating Load Draft of 40 feet for the U.S.S. RANGER (Pacific Fleet) should be selected as the draft of the CV and CVN Class aircraft carriers considered in designing berths, turning basins, and approach channels. By taking 40 feet as the carrier draft criterion for berths there will be a complete interchangeability of aircraft carrier berthing facilities on both the east and west coasts of the United States.

It should be noted comparing Tables 2-2 and 2-3 that at least once the observed Maximum Operating Load draft as of November 1979 has exceeded the design Mean Draft Full Load criteria by as much as 3 feet.

2.3 TIDAL EXTREMES.

Shown in Table 2-4 are tidal extremes for the harbors of Alameda, CA, Charleston, SC, Mayport, Fl, Norfolk, VA, Pensacola, FL, and San Diego, CA. These data, based on records and summaries obtained from the National Oceanographic and Atmospheric Administration (NOAA), 1979, are current through December 1978.

The headings are based on the nomenclature of NOAA as listed in "Tide and Current Glossary, 1975."

TABLE 2-4: TIDAL DATA FOR SELECTED U.S. NAVAL FACILITIES WHERE DEEP-DRAFT VESSELS ARE BERTHED

Location	Extreme high water (ft)[1]	Mean higher high water (ft)[1]	Mean high water (ft)[1]	Mean lower low water (ft)[1]	Mean low water (ft)[1]	Extreme low water (ft)[1]	Datum[1]	Last Date of Available Data
Atlantic Fleet								
Charleston, SC	10.7		5.5(0.4)[2]		-0.3(-0.3)	-3.3(-0.6)	*	Dec 1978
Mayport, FL	7.4(-0.2)		4.5		0.0	-3.2(-0.2)	MLW	Dec 1977
Hampton Roads, VA (Sewells Point)	8.5		2.5		0	-3.1	MLW	Dec 1977
Portsmouth, VA (Norfolk Naval Shipyard)	9.2(-0.3)		2.8		0.0	-3.1(0.4)	MLW	Dec 1976
Naval Air Training Command								
Pensacola, FL	8.9		1.3		0.0	-2.2	MLW	Dec 1977
Pacific Fleet								
Alameda, CA	9.0(0.2)	6.4	5.8	0.0	1.1	-2.2(0.3)	MLLW	Dec 1977
San Diego, CA	8.3(0.2)	5.7 (-0.1)	5.0(-0.1)	0.0	0.9	-2.8(-0.2)	MLLW	Dec 1977

[1] Datum is the level from which the heights of tides are measured:

MLW = mean low water
MLLW = mean lower low water
MLWS = mean low water springs
MHHW = mean higher high water
MHW = mean high water
MHWS = mean high water springs
EHW = extreme high water
* = Charleston low water datum based on observations from 1941-1959.

[2] ( ) difference compared to data listed in Design Manual 26.
Negative sign indicates tabulated value is lower than the value listed in Design Manual 26.

Note: 1. Corrections to NAVFACENGCOM Design Manual 26 "Harbor and Coastal Facilities" based on data from NOAA, April 1979.
2. Mean low water (MLW) and mean lower low water (MLLW) based on observations from 1941-1959.

Extreme high (low) low water is the highest (lowest) elevation reached by the sea as recorded by a tide gage during a given period. The National Ocean Survey (NOS) routinely documents monthly and yearly extreme high (low) waters for its control stations.

Mean High (Low) Water is the arithmetic mean of the high (low) water heights observed during the period 1941-1959. For a semi-diurnal or mixed tide, the two high (low) waters of each tidal day are included in the mean.

Mean Higher High (lower low) Water is the arithmetic mean of the higher high (Lower Low) water levels of a mixed tide from 1941-1959 and includes only the higher high (lower low) water of each pair of high (low) waters of a tidal day.

Water levels that occur in a tidal day which are lower than the reference datum are referred to as negative tides.

Extreme High Water can be a constraint on ship movement insofar as antennas, etc. may not clear manmade structures such as bridges and therefore preclude the strategic movement of ships.

Extreme Low Water can be a constraint on deep-draft ship movement insofar as when it occurs, ships groundings in berths, turning basins and channels may take place. Furthermore, the load of silt drawn into the "sea chests" of aircraft carriers may increase.

The occurrence of both extremes in water level is very infrequent. Economically, to maintain a berth or harbor at a depth to cope with Extreme Low Water and its problems described above appears to be an unwarranted expense. However, the Mean Low Water Datum and the Mean Lower Water Datum implies that water levels lower than those means have occurred as well as shallower water levels higher than those means have occurred. Selection of the appropriate water depth to be maintained in a berth and/or turning basin should be based on a statistical analysis of the frequency of occurrence of water levels below MLW and MLLW.

2.4 DREDGING.

In order to accommodate ships with a draft deeper than the natural water depth in harbors and estuaries, channels are dredged in selected locations within a harbor. The bathymetry of the harbor or estuary before dredging represents the natural effect of sedimentation. Sediments, once deposited, are shifted by tides, river flows, storms, waves, and ship passage. Dredged channels act as catch basins trapping these shifting sediments. Once in the deeper channels sediments are not easily dislodged by water movement, if at all. As a result of the accumulation of these sediments, the underkeel clearance of ships navigating in these channels decreases. Removal of the sediment by maintenance dredging is a necessity to enable the continuation of the flow of ship traffic.

Pier slips, turning basins, and channels are usually dredged one to two feet deeper than the desired depth for purposes of economy. Accurate control of dredging is not possible. Rather than trying the dredged exactly to a desired depth by careful manipulation of the dredging equipment and pay for the additional time involved, it is cheaper to pay for the extra foot or two of dredging. There may be some gain by this procedure insofar as the additional dredged depth may allow for additional siltation before dredging is necessary but a number of factors preclude this from being a generality.

Maintaining the depth of the naval facilities and approach channels may require singly or in combination the efforts of the Corps of Engineers, private contractors and in two harbors navy-owned equipment.

Described briefly below are the three major dredging methods used to remove sediments from channels, pier slips and turning basins in the United States. These are the hopper dredge, the hydraulic cutterhead pipeline dredge, and the clam shell bucket and scow. A fourth dredging method, the bucket dredge, is briefly described but is not in use in the United States.

2.4.1 HOPPER DREDGE.

A hopper dredge, which is shown in Figure 2-1, basically consists of a hugh holding tank(s) or hopper surrounded by a ship. The tank is filled in the following fashion. A dredging head, located outboard of the ship and at the lower end of a pipe connected to a centrifugal pump ploughs along the bottom

Figure 2-1. A Hopper Dredge

loosening the sediment. The hopper dredge moves forward at a speed of about three knots. The head weighs on the order of 10 tons. Simultaneously, the centrifugal pump pumps the loosened sediment into the hopper. When the hopper is filled the dredge steams to a disposal area, the bottom doors open and the dredge spoil contained in the hopper is released.

Hopper dredges can contain more than 11,000 cubic yards in their hoppers and can excavate material from as deep as 70 feet below the water level. The McFarland, built for the Corps of Engineering in 1967 has an overall length of 300 feet, a beam of 72 feet, a draft of 22 feet, and a hopper capacity of 3,100 cubic yards.

Alternate methods of unloading the spoil are by pumping through a pipeline using centrifugal pump or by discharging through a pipeline a short distance from the dredge. The latter method is called sidecasting. One of the newest designs in hopper dredges has the hull split open and the entire contents can be released in less than a minute.

According to World Dredging Magazine (Feb 1980) the U.S. Corps of Engineers has 14 dredges ranging in capacity from 500 cubic yards to 8,115 cubic yards. The ownership of hopper dredges in the United States is not necessarily confined to the government, at least two of the larger dredging companies have their own.

2.4.2 HYDRAULIC CUTTERHEAD PIPELINE DREDGE. The description of the operation of this type of dredge has been succinctly presented by Gren (1979).

"The Cutterhead Suction Dredge, also called the pipeline dredge, is the most widely used type of dredge in the United States and is the basic tool of the private dredging industry. This type of dredge utilizes a rotating cutter on the end of the dredge ladder which physically excavates the material from its in situ condition and mixes the material with dilution water and from there it is pumped hydraulically and discharged through a stern connection to pontoon and shore pipe. The dredge is generally controlled on stern mounted spuds and is swung from one side of the channel to the other by means of swing gear. The Cutterhead Suction Dredge provides a dredging tool which under proper conditions can handle large volumes of material in an economical fashion. Equipped with the properly designed cutterhead this dredge can excavate material ranging from light silts to heavy rock properly blasted or can dig softer sedimentary rock in relatively thin lenses. It can effectively pump the dredged material through floating and shore discharge lines to disposal sites. With the aid of booster pumps in the line, the material can be pumped to disposal sites located at great distances from the waterway being dredged."

"The pipeline dredge, with its trailing discharge line, does present a navigation hazard in areas of high vessel density. As a general practice, the pipeline dredge should not be employed in dredging work in the main navigation channels wherein a danger exists to the dredge and passing vessels. In instances where a navigation channel has to be crossed, submerging the pipeline reduces this hazard. Limitations on sunction pipe length and spuds for holding the dredge in position practically limit the conventional pipeline dredge to excavation depths of 60 feet. Specially designed ladders have extended this depth to 200 feet. Dredges operated in rough waters frequently utilize anchor cables in lieu of spuds."

"Cutterhead dredges come in sizes, as measured by the diameter of pump discharge, varying from 6 inches to 42 inches. Contractor-owned equipment in the United States today varies from 6-inch dredges with about 300 H.P. on the dredging pump to 42-inch dredges with more than 10,000 H.P. Cutter horsepower varies from 75 H.P. or less on quite small dredges to more than 2,500 H.P. on larger dredges. They can operate over a wide range of depths; even on occasion being utilized to excavate material above water level. The production rate of each size dredge may vary considerably depending on the characteristics of the material to be dredged. For example, the normal production for a typical 27-inch dredge could range from 150 cubic yards per hour in blasted rock to perhaps 2,000 cubic yards per hour in mud and soft clays."

2.4.3 <u>CLAMSHELL BUCKET AND SCOW</u>. The commonest and perhaps the oldest method of dredging is that using a clam shell bucket raised and lowered by a crane mounted on a barge filling an adjacent scow or barge. Ideally, the clam shell bucket closes tightly, however, this is usually not the case. As a consequence, sediment-ladened water is distributed throughout the water column as the bucket is raised. Environmentally, this is undesirable.

Scows vary as to dumping capability. Some are self-propelled, others must be towed to the dump site. Releasing the spoil at the dump site may be made by opening bottom doors, tilting the barge sideways, pumping off the spoil by means of centrifugal pumps, or using a clam shell bucket which is least desirable. A recent innovation is the split hull barge that enables dumping in less than a minute.

Though inefficient, one big advantage to using a bucket and scow is its mobility. Dredging at the base of bulkheads and fender piles can take place with no damage to equipment or piers and bulkheads. It does not have an extensive pipeline as in the Cutterhead Pipeline dredge and it can dredge in places that are inaccessible to the hopper dredge.

2.4.4 BUCKET DREDGE. This type of dredge is not used in the United States but because of its frequent use in Europe (Hoffman, 1978) and other parts of the world a brief description is presented here. A bucket dredge, also called a ladder-bucket dredge utilizes an endless chain of buckets moving between two ladders or guides that extend into the water at an angle to the deck. In some instances the buckets have teeth welded to the cutting edge. The buckets scoop up the bottom material and dump it into a chute that overhangs a barge. The material slides along the chute into the barge. Two kinds of barges are used, one self-propelled, the other towed. Similar to the lateral movement of the head of a cutterhead pipe line dredge, the bucket dredge dredges a swath being swung laterally by means of cables fastened to anchors located off the starboard and port sides. Bucket dredges can dredge in depths of water up to about 38 m. Rates of dredging can be up to about 800 m^3/hr.

Described below are four methods that have been used in maintaining pier slips but owing to the relatively low rate of production their use for dredging large areas is not feasible. These methods are: agitation dredging, Pneuma method, educators, and the Mudcate dredging system. The descriptions given on the following pages are limited. Additional information is contained in NAVFACENGCOM sponsored report USNA-EPRD-37 (Hoffman, 1977).

2.4.5 AGITATION DREDGING. Agitation dredging is the removal of sediment from pier slips and wharves located adjacent to shipping channels by suspending the sediment by agitation at the time of an ebbing tide. The suspended sediment is carried to the main channels by the outflowing water and thence down channel. Agitation is accomplished by dragging an I-beam or similar device behind a tug or by means of deflecting downward wash from boat propellers.

Owing to the fact that dredging the main channels falls within the purview of the Corps of Engineers, the Corps requires reimbursement for all sediment dredged by agitation dredging. For example, in the case of Savannah River piers, Savannah, GA, reimbursement is at a rate of $176 per hour of dragging time. In this river, the Corps of Engineers' 1973 records indicated that approximately 450 hours of agitation dredging was performed in the Savannah Harbor.

2.4.6 PNEUMA DREDGE SYSTEM. The pneuma dredge system is a dredging system that is unique. It has the capability of being able to remove sediments with a minimum of resuspension in the water column.

The pneuma system consists of four principle components.

- A pump body which consists of three cylinders bolted together. Each cylinder has only one moving part - an inlet check valve.

- A distributor to receive compressed air delivered through a single line from one or more compressors and distribute it cyclically to the three cylinders of the pump body; and to receive the used air from the cylinders and exhause it to atmosphere.

- Air compressors which may be diesel or electrically driven.

- Compressed air delivery lines are usually a combination of steel pipe and hose and a slurry delivery line which is a combination of steel and/or plastic pipe, and rubber hose.

The operation is as follows: the cylinders are submerged, so that the inlet ports are in contact with the material to be dredged. Atmospheric pressure exists inside the empty submerged tanks. The difference between the internal atmospheric pressure and the external hydrostatic pressure at the submerged depth causes the inlet valve to open and a mixture of water and sediment to enter the cylinder. When the cylinder is filled, external and internal pressures are equal and the inlet valve closes because of its own weight. Compressed air from the distributor enters the cylinder from the top and forces the slurry into the discharge pipe which extends almost to the bottom of the cylinder. The distributor causes a cyclic operation of the tanks such that a constant flow is maintained in the discharge manifold.

To date this method has been used to a limited extent in the United States. However, wider use of this method has been made in Japan.

2.4.7 EDUCTOR SYSTEMS IN DREDGING. The use of eductors for dredging pier slips is useful in noncohesive sediments. The basic eductor works on the principle of the Venturi tube. When a jet of water is constricted in a tapered tube a vacuum is created. Fluid from the surrounding environment moves towards the chamber. If the eductor rests on a sandy submarine bottom, both sand and water are sucked into the vacuum chamber and passed along with the flow. If on a flexible hose, the eductor in this case sinks into the sand to form a crater. Fluidized sands then move laterally to the low point in the crater.

Use of an eductor system to pass littoral drift beneath two jetties to prevent beach starvation at Virginia Beach was investigated by the Corps of Engineers Waterways Experiment Station (WES). Before system installation, shoal areas at Rudee Inlet resulted from the deposition of sand, prevented the ingress and egress of boats, as well as starved the beach at Virginia Beach. (Hoffman, 1977).

The basic system consists of an eductor that sucks up sand and pumps it to a pump. The pump pumps it through 1,800 feet of pipe beneath Rudee Inlet to the north side of the jetty where longshore currents transport it northward. A crater formed around the eductor results in the movement of sand laterally to the eductor. The slope of the crater wall is about one vertical on two horizontal.

Thus a crater ten feet deep has a diameter of 40 feet. To facilitate movement, the sand in the vicinity of the eductor is fluidized by two jets located on either side of the eductor. The rate of flow through each jet pipe is 75 gallons per minute (gpm). Once the desired depth is reached, the eductors are manually moved by scuba divers to an adjacent location.

2.4.8 MUD CAT DREDGING SYSTEM. The Mud Cat is a compact, portable machine designed to hydraulically remove sediment deposited in waterways, marinas and impoundments.

In this dredging system, a hydraulically-operated boom lowers a horizontally mounted auger-cutter assembly into the material to be excavated. The auger-cutter assembly dislodges and delivers the material to the pump suction intake. The slurry is pumped to a pipeline for transmission to a remote location.

The dredge is comprised of an integrally welded platform supporting a diesel engine, a centrifugal pump, the horizontal auger-cutter assembly, and the control center. The principal controls are hydraulically operated. It is easily transported from site to site and can be launched and retrieved quickly. Generally, a crane is used for this purpose. The overall dimensions are eight feet wide, nine feet and three inches high, and 30 to 39 feet long depending on the model.

Prior to placing the machine in operation, an anchored cable network is rigged and a pipeline assembled. A portion of the cable is threaded through a winch mechanism which propels the machine in forward and reverse directions along a guide cable.

Materials are excavated as the dredge moves forward and backward. Several passes are normally required in the same cut to excavate underwater materials to a predetermined depth.

Limitation in equipment has made it possible to dredge to a depth of 20 feet only.

In order to use a dredge to greater depth the following changes must be made:

1. The power requirements would have to be increased.

2. Support winches would be required to raise and lower a longer boom due to added weight.

3. A submersible pump, either hydraulically or electrically powered, would have to be designed and mounted on the end of the boom directly behind the auger.

2.5 DREDGE SPOIL DISPOSAL.

The disposal of spoil from dredging is becoming an increasing problem. The environmental effects of dredge spoil disposal are being examined critically for possible impacts on the environment thus reducing the places available for disposal.

Various places where spoil has been dumped with varying degrees of acceptance are:

1. diked-disposal areas
2. open-water dumping
3. land fill
4. nonproductive wetland fill

Dike disposal areas have been constructed since the mid 1950s when Craney Island in Norfolk Harbor was built. These are engineered structures with rip-rapped dikes on the water sides. A method of offloading the spoil is provided together with an outlet for the return of water to the adjacent water bodies. Barges can be off-loaded by pumping. Cutterhead pipeline dredges can discharge directly to the area by means of pipeline. Hopper dredges can offload by pumping. The size of these areas constructed initially depends upon the anticipated volume of spoil to be contained in the area for a selected period of years.

Where the spoil has settled sufficiently to have an adequate bearing capacity, a second peripheral dike may be constructed on top of the disposal area to contain a second "layer" of spoil. Bearing capacities of the spoil and that of the underlying in situ material must be taken into account or else structural failure will result. After the area is filled the land created is often of value economically.

Open water dumping appears to be an easy solution to the spoil disposal problem. However, the expense of steaming time to a designated dredge spoil site and the expenditure of fuel, in some cases, has led to the use of diked disposal sites (i.e., Craney Island). Certain U.S. Navy problems have occurred in open water sites that limit the use of this practice. Dredging for deepening the Thames River leading to Groton, CT to permit the passage of SSN 688 Class submarines led to problems with environmental groups that ultimately ended up in court (Hoffman, 1977). One of the major contentions of the plaintiffs was that the dredge spoil was flowing laterally outside the designated area to blanket bottom-dwelling organisms. They also contended that the long-term effects of pollutants, especially heavy metals, would be distributed throughout the food web and would ultimately effect man.

Another problem with open water spoil disposal occurred at the Naval Station at San Diego where the dredge sediments could not pass the bioassay test as described in COE-EPA publication "Ecological Evaluation of Proposed Discharge of Dredged Material Into Open Waters" July 1977. This test is described below.

One of the first tests instituted by the Corps of Engineers to test for the suitability of the dredge spoil was the elutriate test. Stripped of technical details, the test essentially consists of analyzing the water column at the dump site for concentrations of selected toxicants. A sample of the spoil from the dredge site is mixed with the water and agitated. The mixture is then filtered to remove suspended material and analyzed for the same toxicants as the water from the water column. If the increase in concentration is less than 50 percent, the spoil is considered to be acceptable for open water disposal at the site in question.

Inasmuch as this approach was limited to the toxicants for which analysis was made, a broader view utilized the bioassay method. In this test an organism prevalent at the dump site is contained in laboratory tanks with the spoil that was a candidate for disposal. If the mortality of the organism exceeded acceptable limits after the designated period of time, the spoil was considered to be unacceptable for disposal at the dump site.

Perhaps a more realistic approach has been proposed in a paper entitled "Application of the Biotal Ocean Monitor System to In Situ Bioassays of Dredged Material" (W. Pequegnat, 1979). In this method selected indigenous organisms are contained in open water area where disposal of the spoil is to take place. The containment could vary from large cages suspended in the water column to wholly-enclosed containments from the water surface to the bottom. For testing purposes a spoil would be dumped within the containment and the effects on the organisms observed. At present, only a few tests patterned after this test have been run. However, such an approach offsets the criticism made concerning laboratory bioassay that the organisms are stressed too highly in the laboratory environment and the results do not represent the actual situation.

The third possible spoil disposal site is landfill. In many areas such an alternative is not feasible because of land values. Where sand and gravel or minerals have been strip-mined, however, depositing spoil in the depressions may have merit. Important to the feasibility of such an approach is the cost of transportation of the dredge spoil from the point of dredging to the point of disposal. Each area would probably require a different solution. In Holland, dredge spoil from Rotterdam Harbor is to be pumped from a receiving barge through a pipeline and distributed on polders. (Hoffman, 1978).

Wetlands are commonly thought to be inviolate. This may not necessarily be true, however, for not all wetlands are biologically productive. Environmental evaluation of the impact of the disposal of spoil on a wetland may show that it can be more beneficial to the ecosystem if certain other conditions are provided. Most states have laws regarding such procedures and any action must conform to these regulations as well as to the directives of the federal Environmental Protection Agency and the Fish and Wildlife Service.

Environmental problems involved in the disposal of dredge spoil are too numerous to be detailed here. However, a few brief comments are made below.

Disposal of contaminated dredge spoil on land can affect the environment in three ways. Leaching of the toxicants by infiltration of precipitation can transport these toxicants to ground water aquifers. Ground water transports these toxicants to nearby streams, bays, or ocean and thus transfers toxicants from the disposal site in solution to a water body. The slow movement of ground water results in the long time retention of these toxicants and contamination of water pumped from wells located between the spoil disposal area and the surface water body to which discharge takes place may take place for a long period of time.

Runoff of precipitation from contaminated spoil piles can result in a more rapid contamination of water bodies. Furthermore, runoff can seep into the land surface en route and enter the ground water system. Even if the spoil is not contaminated, erosion of fine particles move into a water body increasing its turbidity. This turbidity reduces the photosynthetic activity and hence decreases the biological productivity of the aqueous environment.

The third effect occurs in the atmospheric environment. Tests have shown that wind blowing over spoil piles containing polychlorinated biphenyls (PCBs) can distribute these carcenogens over a widespread area. As the result of this mechanism, PCBs have been reported in Anarctica. Additionally, dumping of dredge spoil can release noxious gases, such as hydrogen sulfide, causing a temporary impact on the environment depending on the point of disposal. Hydrogen sulfide usually occurs in aqueous organic sediments due to the lack of oxygen. Anaerobic bacteria, thriving in such an environment, break down chemical salts, such as sulfates, for the oxygen necessary for metabolism. Such a condition was noted during a visit to the dredge disposal site at Kings Bay Submarine Support Facility, GA, in January 1980.

2.6 SEDIMENT CONTROL IN PIER SLIPS.

Dredging removes the sediment after it has settled in a berth, turning basin, or channel. However, other means are used to retard the deposition of sediments in berths. How much prevention takes place is a question of dollar investment.

Control of sediment deposition in channels has been tried by means of training walls, spur dikes, etc., but such methods are not always effective. The problem might be transfered to a point further down-channel.

Curtain barriers are one means of preventing siltation from entering a berth. Presently, under test in Mare Island Naval Shipyard is a curtain barrier. This is shown in Figure 2-2. A tug tows the curtain barrier from the berth when a ship is scheduled to enter the berth.

Curtain barriers are also being considered for use in the Port of Rotterdam, Holland (Hoffman, 1978). The Office of Chief Engineer of the Port of Rotterdam has studied 26 different methods of the construction of silt curtains across harbor entrances. The plan selected for use in one of Rotterdam's harbors involves a curtain that will be about 925 feet in length and will cost about $3,250,000 (1978) to construct. It is expected to reduce the dredging in the harbor by 30% an annual savings of $1,000,000.

Jets to flush a berth at the appropriate stage of tide is a third means of decreasing siltation.

Presently installed at Pier 235 Mare Island Ship Yard, San Francisco, CA, is such a system (Van Dorn, et al, 1978). Shown in Figure 2-3 is a ten-branch, 150-hp, 1,000 square meter array of 60 hydraulic jets designed, fabricated, and emplaced on the predredged mud bottom of a capital ship berth at Mare Island Naval Shipyard. Actuated twice daily for 35 minutes in synchronization with the ebb flow in Mare Island Strait, the array controlled sediment deposition within the perimeter of influence. A control area in an adjacent berth having a similar size and exposure experienced a 45 cm (18 in.) deposit in an abnormally dry year 1977. An equivalent area in the same berth, but behind the array, received about half the latter deposit as the result of partial shielding by the array.

A third method of keeping sediment from berth is to trap the sediments by means of siltation or sedimentation basins. The Corps of Engineers tested the use

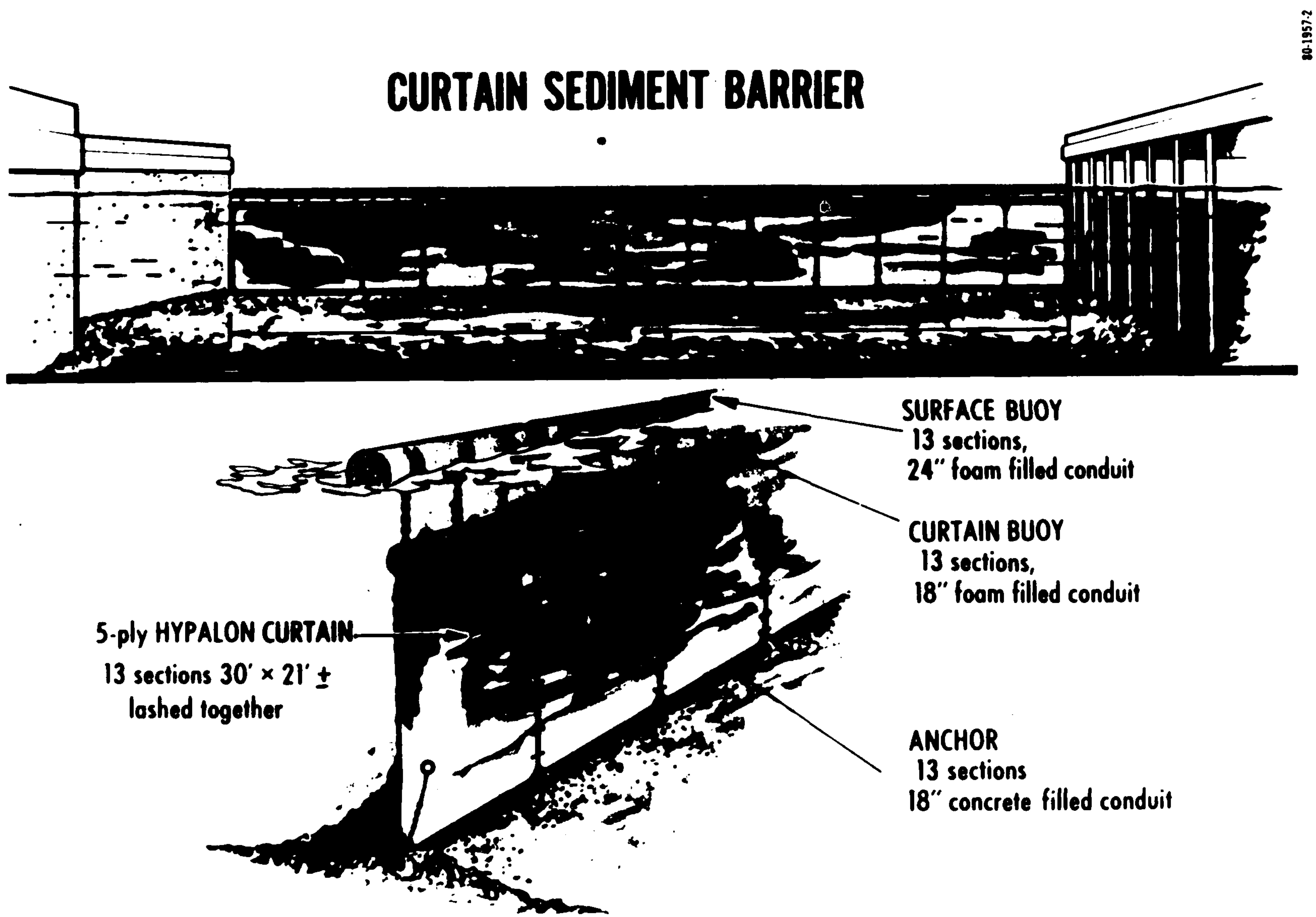


Figure 2-2. Curtain Sediment Barrier

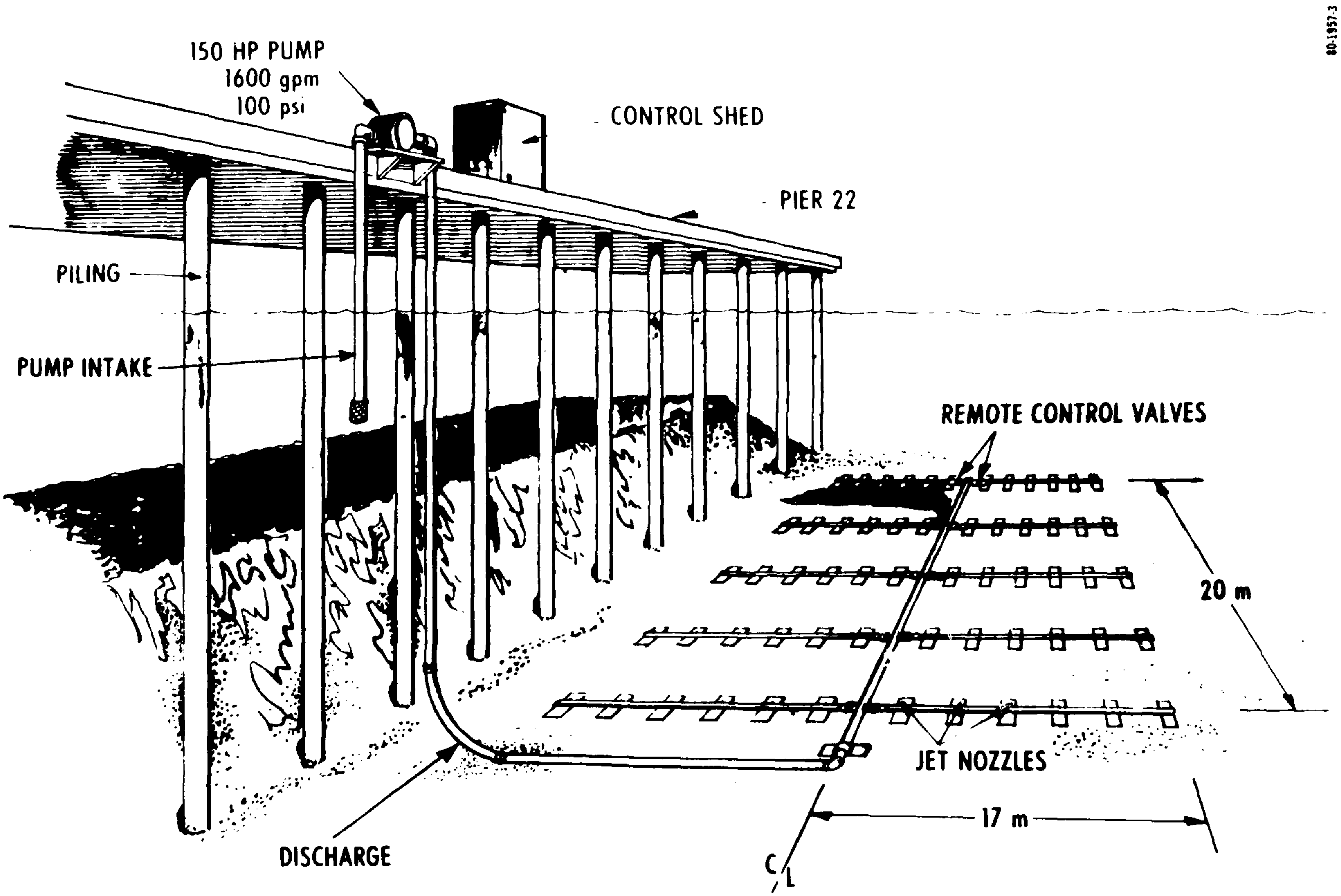


Figure 2-3. Prototype 60-jet Array Installed at Mare Island Shipyard

of these in a model of N.Y. Harbor in the Waterways Experiment Station, Vicksburg, Mississippi as a means of the prevention of the deposition of sediments in berths. However, as the result of inconclusive data from the studies no action in this direction has been taken.

In certain parts of Europe it is felt that dredging efficiency can be increased by increasing the density of the fine-grain sediment (Hoffman, 1978). Two methods are used to accomplish this:

1. Leave the sediments on the bottom for a longer time period to allow consolidation.

2. Allow the sediments to accumulate to a greater depth to allow consolidation before dredging. This requires overdredging to accommodate the increase in accretion and still maintain a satisfactory under-keel clearance.

Sedimentation basins in the bottom of waterways are used in Europort, Holland and in the River Clyde at Glasgow, Scotland. In the latter waterway three basins each 300 feet by 3,300 feet and 8 feet below channel depths are used to trap the sediments that, according to the Conservancy Engineer would settle in pier slips (Hoffman, 1978).

Other methods were tested by the Corps of Engineers (Simmons, 1967), in a model of the Hudson River, extending from the Battery to George Washington Bridge (scaled 1:300 horizontally and 1:100 vertically). Tests were made to determine the relative effectiveness of various schemes for reducing shoaling in some of the larger pier slips. "Among the schemes investigated were spur dikes located upstream and/or downstream from the ship entrances, submerged sills across the slip entrances, pneumatic barriers (bubble screens) or water jet barriers across the slip entrances, and pneumatic barriers (bubble screens) placed longitudinally in the slips. The results of these tests showed conclusively that pneumatic barriers placed longitudinally in the slips were by far the most effective of the schemes tested for reducing shoaling of the slips, and it appeared that the effectiveness of this scheme is related to the fact that barriers placed in this manner generate turbulence over the slip as a whole and thus inhibit the deposition of suspended sediments. However, as stated previously, the laws for scaling the model air demand to prototype dimensions are presently unknown, so it was not possible to design and prepare construction and operation estimates for a prototype pneumatic barrier installation equivalent to that tested in the model. Based on the effectiveness of this scheme in reducing shoaling, it is believed that the additional research required to develop the unknown model laws and scaling factors is well justified."

SECTION 3

ALAMEDA NAVAL AIR STATION

3.1 INTRODUCTION.

Shown on Figure 3-1 is the general location of Alameda Naval Air Station in relation to San Francisco Bay. The ship channel is roughly 4,000 feet long by 1,000 feet wide, extending from deep water in San Francisco Bay to the eastern end of the breakwater. Shown in Figure 3-2 are details of the Naval Station itself. Inside the breakwater the channel widens along the southerly limits to provide a turning basin approximately 4,000 feet long and 2,500 feet wide. At the easterly end of the turning basin two piers, Piers 2 and 3, each 1,200 feet long, provide berths for deep-draft aircraft carriers. The north slip is 500 feet wide; the middle berth is 600 feet to 500 feet wide as it approaches the eastern end of the waterway. Pier 1 is a smaller pier about 700 feet long, open only to the south for berthing. Project depth of the ship channel, turning basin and berthing area is 42 feet below MLLW. Along the northerly edge of the turning basin and in line with the entrance to the berthing area there is a 650-foot gap in the seawall which permitted access to the seaplane base. Across from the turning basin and opposite the lagoon entrance is a 750-foot gap in the breakwater that permits direct access for small vessels into the lagoon area.

The Alameda Naval Air Station was established as an airfield, seaplane base, and carrier base in 1941. Located on the North side of the turning basin is the inactive seaplane basin. The seaplane basin is no longer used for any purpose but the docking of small rescue boats. It is not dredged to operating depth. The seaplane basin is approximately 3,000 by 1,600 feet and the average depth is about 15 feet.

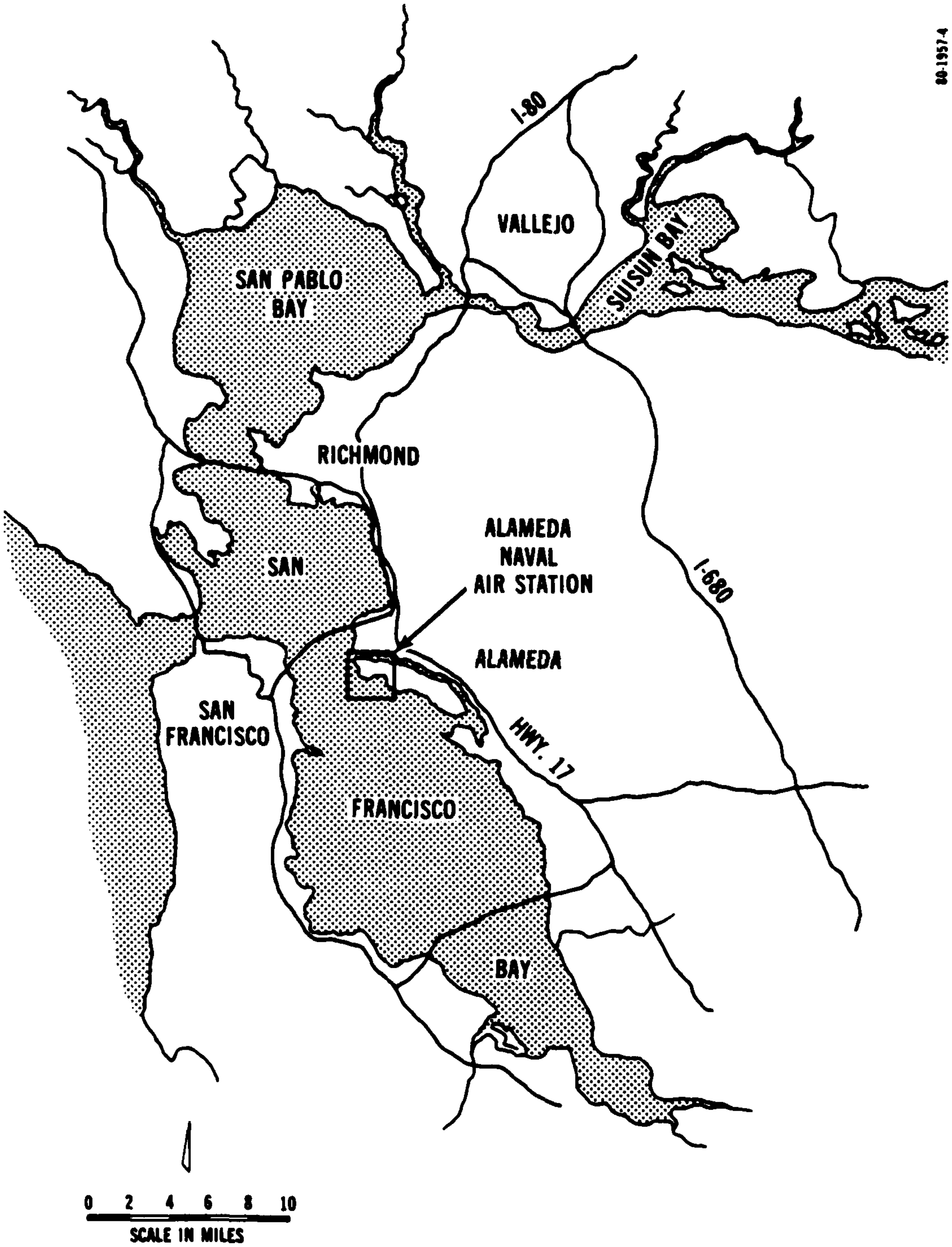


Figure 3-1. General Location of Alameda Naval Air Station

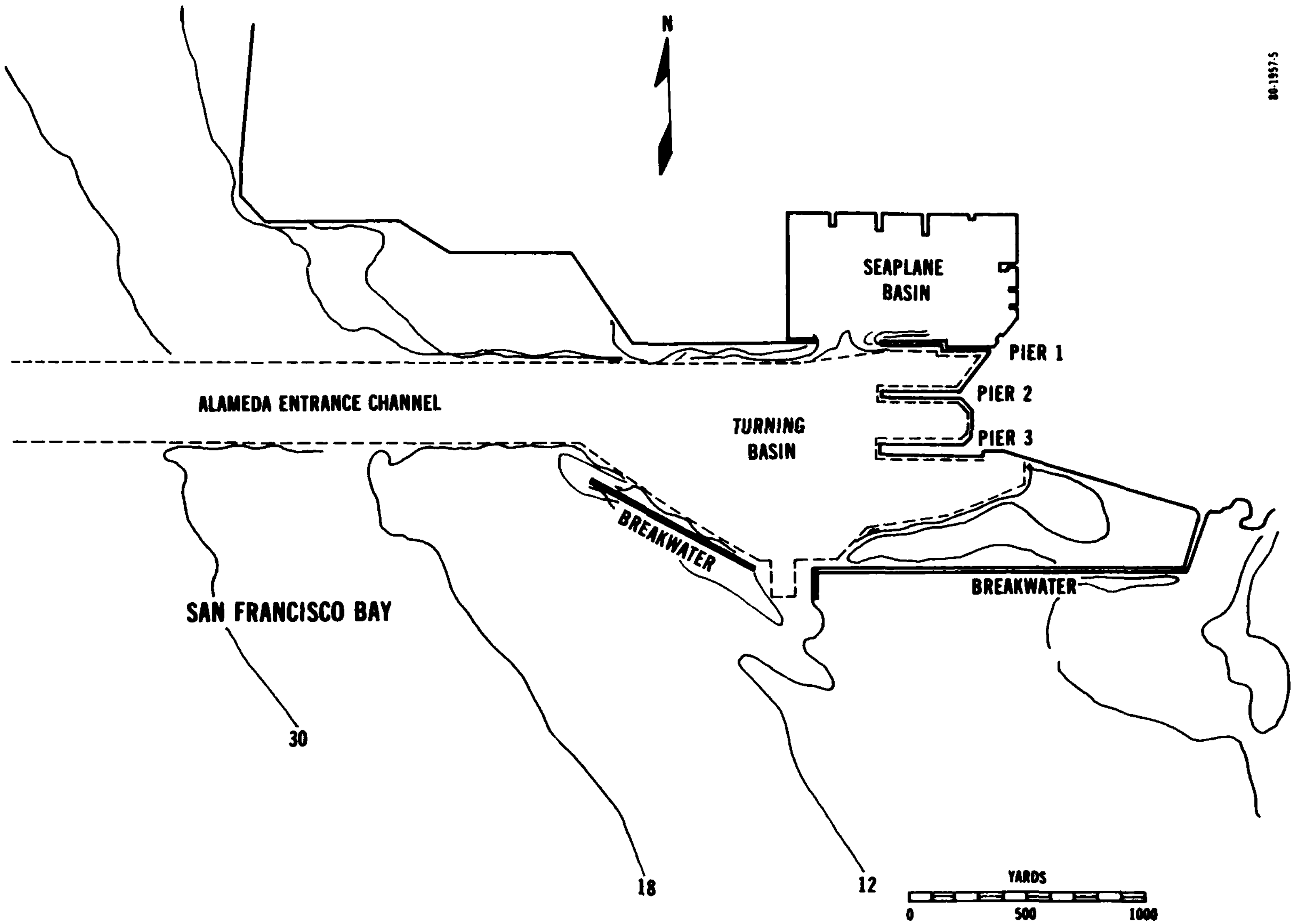


Figure 3-2. Details of the Berthing and Turning Basin Facilities of the Alameda Naval Air Station

This facility is the home port of two aircraft carriers, the U.S.S. ENTERPRISE and the U.S.S. CORAL SEA. The nuclear-powered ENTERPRISE (CVN-65) is the largest carrier operating out of Alameda, with an overall length of 1,123 feet, a maximum width of 237 feet, a beam of 133 feet and a maximum draft of 40 feet (see Table 2-2). The second carrier, the CORAL SEA has an overall length of 968 feet, a maximum width 222 feet, beam 121 feet and maximum draft 39 feet (see Table 2-2).

In addition to carriers, Alameda is used for the berthing of other deep-draft Naval vessels including four replenishment oilers (AOR) having a draft of 35 feet.

3.2 SHIP MOVEMENT.

According to Fleet Guide - San Francisco, 7th edition, 1976 contract services are rendered to naval ships by the San Francisco Bar Pilots as ordered by the Port Services Office (PSO) San Francisco.

San Francisco pilot boats "San Francisco" or "Drake" maintain station 24 hours a day in the vicinity of the San Francisco light buoy, two miles west of the main ship channel. Under normal circumstances bar pilotage terminates at the degaussing range off the San Francisco waterfront where Navy docking pilots will board the vessel from tugs.

Although there are no tidal constraints to ship movement, aircraft carriers are brought in at low tide.

All ships having masthead heights over 190 feet above the water, including radar antenna, must use caution in passing under the San Francisco-Oakland Bay Bridge. Under extreme conditions the heights of the longest spans above water may vary as much as 10 feet depending upon temperature and load. Abnormally high temperatures and congested traffic upon the bridge can cause the catenaries of the long spans to drop several feet below the published heights.

3.3 CURRENT VELOCITIES.

Ships entering San Francisco Bay on a strong flood tide, and passing the south pier of the Golden Gate Bridge close aboard, often experience a strong shear force to the starboard caused by a peculiar deflection of the current by the bridge pier.

This shear cannot be readily overcome by the rudder and, in some cases, has resulted in complete loss of control of the course steered.

Large current eddies having the same effect are found in the vicinity of the foundation piers of the San Francisco-Oakland Bridge and the Richmond-San Rafael Bridge.

Vessels departing San Francisco Bay on a strong ebb current must use extreme caution to avoid excessive speed which can cause the vessel to take heavy seas on the foredeck.

Surface currents in the entrance channel to Alameda Naval Air Station on an incoming tide flow across the channel from north to south, while near the bottom the currents flow parallel to the channel's length from west to east. On an outgoing tide, both surface and bottom currents flow across the channel from south to north.

In the turning basin currents are less pronounced than in the entrance channel, but tend to follow the length of the basin, both at the surface and along the bottom, west to east on flood tide and east to west on ebb tide.

Through the opening in the southern breakwater there is a flow of water out of the turning basin to the south on flood tide and conversely a flow into the turning basin to the north on ebb tide.

There is shallow water to the north of the entrance channel, between the channel and the shoreline of the Naval Air Station landing field; and a large shallow water area to the south of the channel and the turning basin. Water depths range from about 7-feet to 18-feet (Crawford, 1974). Pilots indicate a speed of about 10 knots is generally maintained in the channel to assure steerageway against tidal currents and winds. Maximum currents in the channel and turning basin are estimated at about 2.0 knots. Pilots taking ships into Alameda, however, feel currents are sometimes considerally stronger than this estimate.

Seldom do two ships attempt to use the entrance channel at the same time, according to the Harbormaster staff at Treasure Island. Crabbing of carriers because of the effect of winds on high superstructures can cause these ships to use a large portion of the channel's width. Currents are also said to cause some navigational problems, particularly within the turning basin.

The larger carriers stir up mud from the bottom with their propeller wash in the turning basin, which pilots indicate is visible from ships' bridges. These carriers may arrive or depart at maximum draft of 37 feet.

Carriers do not have any electronic protuberances on hull which add to draft. Salt water intakes are, however, located at the bottom of the hull and silt can be drawn in if the underkeel clearance in the berthing, basin, or channel areas is inadequate (Crawford, 1974).

Figure 3-3 shows surface and bottom current directions during flood and ebb tides near the channel entrance, in the turning basin, and just outside of the 750-foot gap in the breakwater at Alameda Naval Air Station. There is a remarkable difference between the direction of the flood currents in the upper and lower water column. The flow in the upper column crosses the channel in a southeast direction, while at the same time flow in the lower strata makes a sharp turn into and moves eastward up the channel. Thus, the tidal prism within the basin fills largely through the lower water column. Surface and bottom ebb currents in and near the channel entrance move in approximately the same direction as the flood currents. The tidal prism empties largely through the upper water column, the surface ebb currents ranging up to a maximum of 2.5 feet per second, while the bottom currents range from 0 to 0.2 feet per second during the entire phase of the tidal cycle. The velocity of circulation in the turning basin and the berthing area is very weak since the surface and bottom currents are near slack most of the tidal cycle. Peak velocities on the bottom are about 0.3 feet per second and at the surface range up to 0.5 or 0.6 feet per second for only a few hours during the tidal cycle. Surface and bottom flood and ebb velocities have maximum values of about 2 feet per second at the 750-foot gap in the breakwater. These are considerably less during most of the tidal cycle. The flow through the gap contributes to what little circulation exists in the turning basin and berthing area, but apparently its influence is not very strong because of the low velocities in the basin.

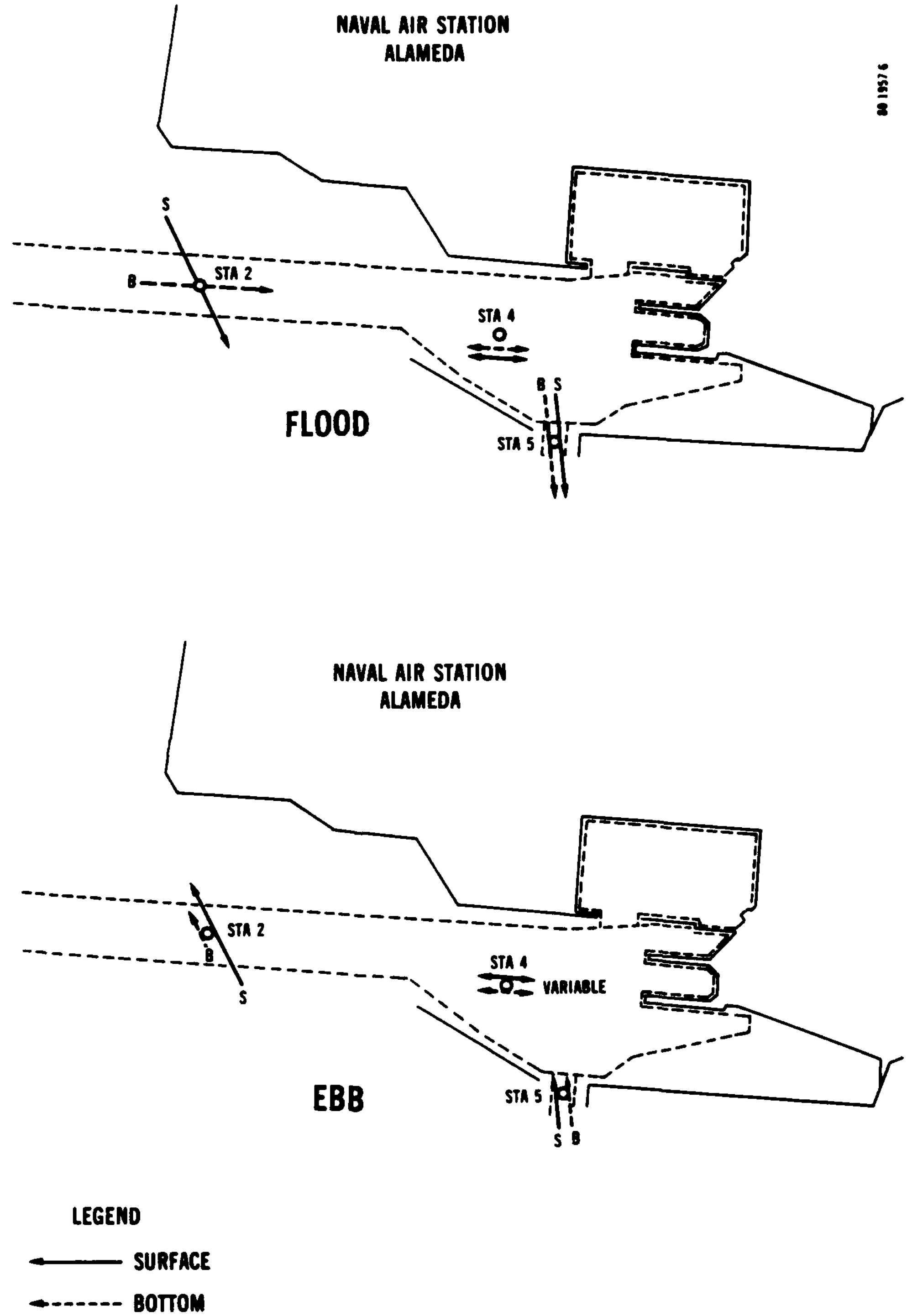


Figure 3-3. Current Directions in the Approach Channel and Turning Basin of Alameda Naval Air Station

3.4 SHOALING RATE.

Water depth under Piers 1, 2, and 3 is considerably less than 42 feet. The depth to which supporting piling are driven into the Bay bottom is unknown.

Navy siltation study records of the Alameda channel, basin, and berthing areas have been reviewed. These data indicate that the rate of siltation from 1957 to 1959 was two to three times as great as from 1959 to 1961. Each study period was preceded by dredging. The rate was approximately 5-6 feet per year from 1957 to 1959, and two feet or less per year from 1959-1961. Measurements were made in the channel, turning basin and adjacent to the south side of Pier No. 3.

In studying siltation patterns, at Alameda Naval Air Station, evaluation was made of a U.S. Army Corps of Engineers sketch presented with their Environmental Impact Report of Proposed Dredging at Alameda Naval Air Station, dated August, 1973. This depicts areas to be dredged in 1973 to bring channel, basin, and berthing areas to operational depth of 42 feet plus one foot overdredge. This sketch illustrates locations of most significant siltation. See Figure 3-4.

It would appear that muds are migrating on outgoing tides from the shallow seaplane basin into the main turning basin through the 650-foot opening. There is a depth differential of about 25 feet between the seaplane basin and turning basin. A tongue of sediment extends outward some 1,000 feet into the turning basin from the entrance to the seaplane basin, and is quite evident in the dredging sketch.

The sketch also indicates that siltation is probably caused within the turning basin by ebb tides pulling sediment in from the shallow bay area to the south, through the 750-foot wide opening in the southern breakwater. Water depths to the south of the opening are less than 15-feet, presenting an extensive shallow water area that is often high in suspended sediments from wind and wave agitation of the mud bottom.

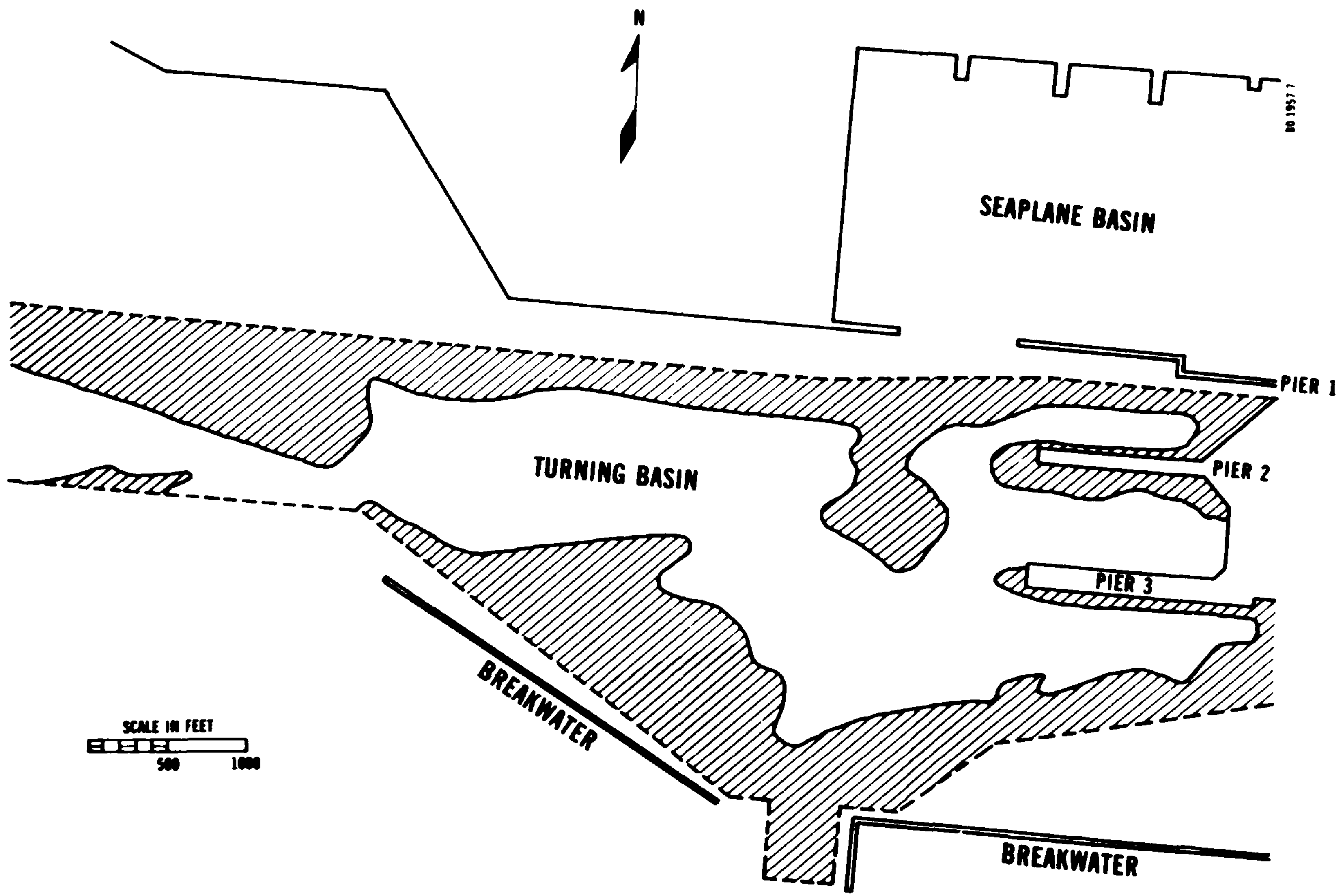


Figure 3-4. Siltation Patterns in the Waterway at Alameda Naval Air Station

On the north side of the entrance channel and turning basin is a band of siltation running the length of the facility from the east end of the seaplane basin westward to about that point at which the entrance channel intersects the eighteen-foot Bay depth contour. This siltation is probably due to the movement of sediments from the shallow waters immediately to the north of the basin and channel into the deeper water. The incoming tide may accelerate this action as do the effects of propeller wash from ships using the channel. Prevailing northwesterly winds would also enhance the movement of Bay muds into the entrance channel from the north, particularly in that area of open shallow water adjacent to the channel bounded on the north and east by the landing field at Alameda Naval Air Station.

Siltation is evident parallel to the length of Piers 1, 2, and 3. This is, undoubtedly, due in part to the slumping of sediments from beneath the piers into the adjacent deeper dredged waters of the berthing areas. The condition may be aggravated by the effects of propeller wash from tugs docking vessels at the piers and other activities associated with vessel berthing (Crawford, 1974).

The significance of the tidal circulation in Alameda Naval Air Station can be seen in the shoaling at the Station. In Table 3-1 is listed the shoaling quantities by channel sections. The individual sections are shown in Figure 3-5. Maximum shoaling rates occur in the channel and turning basin and are due largely to the tranquil flow conditions throughout the tidal cycle. Since the tidal prism of the basin fills primarily through the lower water column which normally contains the heaviest sediment concentrations and empties mainly through the upper water column, sediment that enters during the filling of the basin is trapped and subsequently deposited.

3.5 SUBMARINE SEDIMENTS.

The bottom sediments, typical Bay fine-grained silts and clays, are readily agitated, suspended and transported by wind, wave, and tidal action, as well as from the rotation of ships' propellers. The median grain diameters for two grab samples obtained by the Corps of Engineers in 1971 were 3.8 and 4.6 microns. There are no known rock outcrops or surficial consolidated sediments in the channel, turning basin, berthing area of adjacent shallow-water areas.

TABLE 3-1. ESTIMATED ANNUAL SHOALING RATES IN THE CHANNEL AND TURNING BASIN AT ALAMEDA NAVAL AIR STATION

Channel Sections	Shoal Material (Cubic Yards)	Percent of Total
1	5,000	0.5
2	10,000	1.0
3	26,000	2.6
4	147,000	14.7
5	252,000	25.2
6	168,000	16.8
7	184,000	18.4
8	208,000	20.8
Totals	1,000,000	100%

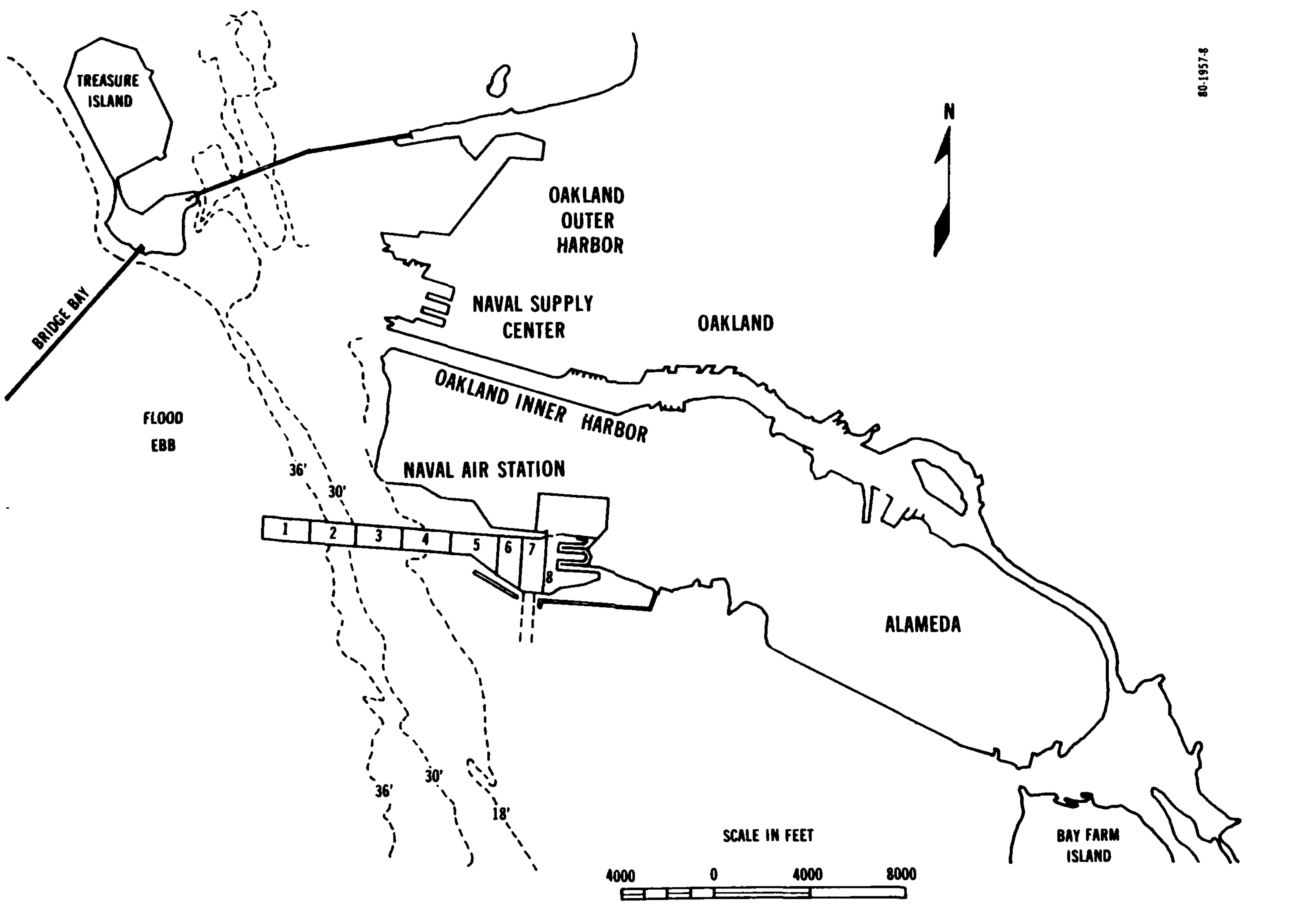


Figure 3-5. Sections of Alameda Waterway for which Shoaling Rates are Tabulated in Table 3-1

Based on four test borings made for the extension of Pier 2 underlying the piers, berths, turning basin, and the associated channel there is about 15 to 20 feet of gray to black silty clay to clayey silt overlying an apparently continuous layer of yellow-brown sand about 20 feet thick. This sand is underlain by about 35 feet of gray clayey sand. At the lower part of this layer there are discontinuous layers of fine to medium dense sand ranging from about four feet to 17 feet in thickness, containing clay lenses.

3.6 DREDGING.

Maintenance dredging at Alameda Naval Air Station has been performed in fiscal years 1950, 1951, 1953, 1954, 1958, 1959, 1961, 1963, 1965, 1967, 1968, 1969, 1970, 1971, and 1972. Dredging in the main ship channel and turning basin is by hydraulic and hopper dredges, and in the small boat dock and pier areas by bucket and scow.

Annual dredging volumes range from less than 1,000,000 to over 1,600,000 cubic yards. Shown in Table 3-2 is the maintenance dredging history of the station from 1959 to present. This table does not include the clamshell dredging immediately around the piers. Based on annual maintenance dredging during fiscal years 1959-1964 by hopper dredge, the average annual volume is 1,000,000 cubic yards. A disposal site in the vicinity of the entrance to Alameda Naval Air Station, approximately 58 feet below MLLW, was utilized prior to 1971. In 1972 critically shoaled areas were excavated using a hydraulic dredge to pump the material to a land disposal site at the station.

In the past, the spoil was dumped in the Bay's main channel off the Alameda Naval Air Station. Currently, because of State and Federal environmental controls, dredge spoil is dumped at the Alcatraz area where the water depth and tidal action are believed to be adequate for rapid dispersion of the sediments.

3.7 PROBLEMS.

There are no sea chest clogging problems, either from biomass or fine sediments, with the aircraft carrier. The turning basin seems to be of adequate dimensions. The only problem is one of the large quantities of dredging necessary to keep the approach channel, turning basin, and the pier slips at a satisfactory depth.

TABLE 3-2. MAINTENANCE DREDGING HISTORY
ALAMEDA NAVAL AIR STATION 1959-1977*

Fiscal Year	Dredging Period	Quantity Cubic Yards	Method	Disposal Site
1959	10 Nov 58-11 Jan 58	1,600,000	Hopper	San Francisco Bay opposite entrance NASA-58 ft. MLLW.
1961	10 Feb-15 Mar 61 and 13-23 May 61	947,000	Hopper	Do.
1963	21 Oct-23 Nov 63 and 17-20 Dec 63	909,500	Hopper	Do.
1965	1-15 Mar 65	618,900	Hopper	Do.
	2 May-5 Jun 65	1,412,000	Hopper	Do.
1967	4-25, 27-28 Feb to 14 May 67	854,700	Hopper	Do.
1968	19-28 Dec 67	201,500	Hopper	Do.
	28 Feb-24 Mar 68	115,200	Hopper	Do.
1968	28 Feb-24 Mar 68	80,000	Clamshell	Do.
1969	23 Feb-24 Mar 69	1,144,000		Do.
		50,000	Clamshell	
1970	11 Jan-5 Feb 70	922,500	Hopper	Do.
	2 Jun-24 Sep 70	659,000	Hydraulic	Land Disposal.
1971	8-12 Mar 71	217,000	Hopper	San Francisco Bay opposite entrance NASA.-58 ft. MLLW.
1972		155,000	Hydraulic	Land Disposal.
1973		1,500,000	Hopper	--
1974-76		2,389,400	Hopper	--
1976-77		450,000±	--	--

*Based on data from Crawford (1974) and station records.

3.8 RECOMMENDATIONS.

Crawford (1974) suggested reducing the turning basin area from 8 million square feet to about 6 million square feet, still allowing the largest carrier to turn unassisted comfortably. With tug-assisted maneuvering the turning basin area might be reduced even further.

Within the berthing area, the only possible reduction in dredging might occur on the south side of Pier 3 where the width of the berthing area exceeds Design Manual Standards.

These suggested reductions on dredging in the turning basin and berthing areas would result in less efficient ship maneuverability and cause an increase in time for berthing and departing Navy vessels. Considerable savings would exist in periodic dredging operations.

Crawford (1974) suggested several methods to control the rate of siltation and the extent of dredging at the Alameda Naval Air Station. These are as follows:

a. Close the seaplane basin to keep silt from washing out of the seaplane basin into the turning basin area on the ebbing tides.

b. Seal off the opening in the southern breakwater to eliminate the movement of silt from the shallow water area south of the breakwater into the turning basin.

c. Extend the existing breakwaters 2,500 feet to the eighteen-foot Bay contour. This extension, paralleling that part of the entrance channel that transects the shallow water to the south, will prevent Bay muds from slumping in the channel and will retard the entry of silt-ladened water from entering the channel.

d. Deepen the area south of Pier 3 to form settling basin.

e. Channel from opening in southern breakwater to deep water.

SECTION IV

MAYPORT NAVAL STATION

4.1 INTRODUCTION.

Mayport Basin (Ribault Bay), is about 1/2 mile long and about 700 yards wide. As can be seen in Figure 4-1 it is located on the south side of the St. Johns River, Florida, about 1-1/2 miles west of the river entrance into the ocean. The river at the point of entry is kept open by means of jetties.

By sea, Mayport Basin is about 560 miles from Hampton Roads, Virginia, 175 miles from Charleston, South Carolina, and 440 miles from Key West, Florida.

4.2 SHIP MOVEMENT.

Two deep-draft vessels are homeported in Mayport. These are the aircraft carriers U.S.S. FORRESTAL and the U.S.S. SARATOGA. Characteristics of these vessels are listed in Tables 2-2 and 2-3. These are berthed at berths C-1 and C-2 (see Figure 4-1).

Prior to arrival at St. Johns Lighted Whistle Buoy "2STJ", all ships planning to berth in Mayport Basin contact MAYPORT TUG CONTROL for permission to enter port. Specific berthing assignments are made through MAYPORT TUG CONTROL. Permission to get underway is also granted through MAYPORT TUG CONTROL who then will provide tug coordination service.

The city of Jacksonville has requested, that where possible, ships avoid passing through the St. Johns River bridges between the hours of 0700-0900, 1100-1400, and 1600-2100, as very heavy vehicular traffic is handled at these times.

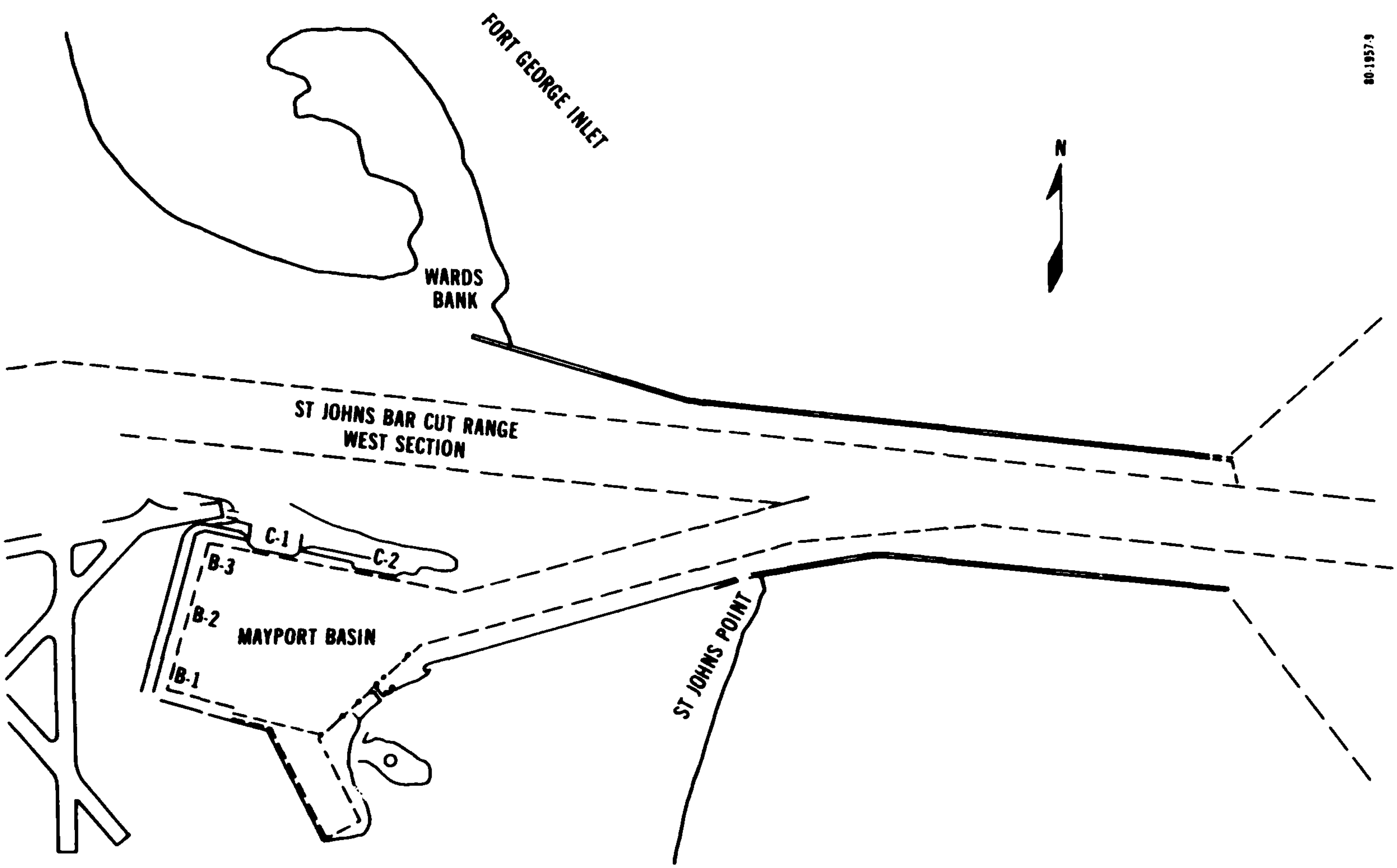


Figure 4-1. Mayport Channel Approach and Turning Basin

4.3 CURRENT VELOCITY.

Due to tidal currents in the river at the port of Jacksonville, precautionary measures must be taken and maneuvering done at or near times of slack water where possible. This is especially important in the close quarters encountered in the local shipyards.

Currents in the entrance to the turning basin are variable, according to the Chief Harbor Pilot. At a depth of eight feet the current velocity differs markedly from that at the surface both in direction and magnitude.

Extreme Low Water is 3.2 feet below MLW.

4.4 ELEVATION OF BOTTOM TIPS OF PILING.

The elevation of the bottom edge of the sheet piling cells in berths B-1, B-2, B-3, C-1, and C-2 is 57 feet below MLW. At present these berths are dredged to 42 feet below MLW. There is some indication that in Fiscal Year 1980 these berths will be deepened to 45 feet below MLW. After this time the tips of the sheet piling will be 12 feet below the bottoms of the berths. Any further deepening of these berths will necessitate a structural analysis of the piling to insure stability of the bulkhead.

4.5 SHOALING RATE.

Shoaling rate at berth C-1 was reported to have a build-up of sediment from October 1978 to May 1979 from 42 feet below MLW to 37 feet below MLW. The shoaling was five feet in seven months or at the average rate of about 0.7 feet per month.

4.6 SUBMARINE SEDIMENTS.

The results of nine test borings made during the middle of March 1979 into the bottom of Mayport turning basin by Acker Drill Co. under the supervision of the Corps of Engineers (Jacksonville District) indicate black soft sandy clayey silt about a foot thick immediately beneath the floor of the basin. This is underlain by fine to medium quartz sand containing some silt and clay to an elevation of about 48 feet below MLW where the test borings were terminated.

4.7 DREDGING.

Shown in Table 4-1 is the dredging that has taken place in the slips and turning basin of Mayport Naval Station from 1959-1978. The methods of dredging include hopper dredge, hydraulic pipeline-cutterhead dredge, and bucket and scow. During the years of 1959, 1961, 1969, and 1974, it was necessary to use both a hopper dredge and a hydraulic dredge in the same year. During the other years, except 1977, either one or the other was employed in dredging. In 1977 dredging utilized a bucket and scow. The hopper dredge and scow transported the spoil to an offshore dumping site. The hydraulic dredge pumped the spoil onto waste land at the Naval Air Station.

The amount of spoil dredged annually ranged from 290,000 cubic yards to 1,960,000 cubic yards. If the exact dates of dredging were known the large discrepancy may be interpreted. However, dredging at Mayport averages out annually to be 586,000 cy in the 20-year period 1959-78. It is estimated that about 85 percent of the spoil comes from the turning basin. The remainder comes from the channel and near the bulkheads.

4.8 PROBLEMS.

Piers C-1 and C-2 experience a rapid build-up of sediment. At the time of the visit to the Naval Station (25 May 79) the Chief Engineer of the SARATOGA reported that scuba divers observed an underkeel clearance of about one and one-half feet. With sediment as close as that to the sea chest and other water intakes, silt problems within the piping, heat exchangers, etc., occur. During the occurence of water level near the Extreme Low Water stage the carrier could have its keel resting on the bottom.

Dredging the turning basin by hopper dredge removes only the accumulated sediments in the turning basin. The area between the circular configuration in which the hopper dredge moves and the rectangular shape of the waterway is not dredged. Consequently, the sediment accumulates in the berthing areas for aircraft carriers (C-1 and C-2) and is not removed unless dredged by a hydraulic pipeline-cutterhead dredge or by a bucket and scow.

TABLE 4-1. ANNUAL VOLUME OF SPOIL DREDGED FROM THE ENTRANCE CHANNEL AND THE TURNING BASIN MAYPORT NAVAL STATION 1959-1978

Dredging Method	Date	Contractor	Volume of Spoil - (cubic yards)	Total Cost	Disposal Area
Hydraulic Pipe-line Cutterhead	1959	N.A.	8,992	$ 11,641	N.A.
	1961	Arundel Dredging Co.	1,363,070	297,824	Upland
	1963-64	Parkhill-Goodloe Co., Inc.	289,050	152,040	Upland
	1964-65	Norfolk Dredging	1,962,067	545,954	Upland
	1967	Standard Dredging	868,479	482,473	Upland
	1969	Parkhill Goodloe Co., Inc.	441,323	513,504	Upland
	1974-75	Parkhill Goodloe Co., Inc.	736,084	943,285	Upland
Bucket and Scow	1977	American Dredging	1,789,701	2,523,903	Ocean Disposal
Hopper Dredge	1959	Corps of Engineers	1,372,000	258,554	Ocean Disposal
	1961	do.	10,280	9,658	do.
	1962	do.	425,132	140,180	do.
	1969	do.	961,916	240,187	do.
	1971-72	do.	935,869	N.A.	do.
	1974	do.	451,637	N.A.	do.
	1978	do.	94,665	N.A.	do.
Grand Total			11,710,265 cubic yards		

N.A. - not available

4.9 RECOMMENDATIONS.

Two recommendations are made to control the problem of siltation at Mayport Naval Air Station. One is to study the feasibility and implementation of a jet array (see beginning of report) to keep berthing slips C-1 and C-2 clear of sediments. This would wash the sediments into the turning basin where a hopper dredge could remove them.

The second recommendation is to study the feasibility and implementation of the educator sand-crater method of dredging for the removal of the sediments entering the channel and/or turning basin and bypass them the short distance across the St. John's River to the beach north of the north jetty for beach replenishment.

SECTION V

NORFOLK NAVAL STATION

5.1 INTRODUCTION.

Hampton Roads, also referred to from a Navy standpoint as Norfolk harbor, is utilized by both military and commercial shipping. Four rivers flow into Norfolk harbor. These are the James River, Elizabeth River, Layfayette River, and the Nansemond River. Shown in Figure 5-1 is the interrelationship of the lower Chesapeake Bay, Hampton Roads, and the U.S. Naval Station.

5.2 SHIP MOVEMENT.

Vessels from the Atlantic Ocean cross the southern part of Chesapeake Bay between Cape Henry and Cape Charles. After crossing Chesapeake Bay, vessels proceed through Entrance Reach at Hampton Roads, part of which is dredged to maintain its depth, to the harbor itself. At Hampton Roads Entrance Reach separates into two channels - Newport News Channel and Norfolk harbor reach. Newport News Channel terminates at Newport News where the James River has a depth of from 46 to 64 feet. Norfolk harbor reach, the channel servicing the U.S. Naval Station at Sewell's Point, terminates at the Elizabeth River. All the aforementioned channels are maintained at a depth of 45 feet below MLW.

Presently in the preliminary stages is a Corps of Engineers' plan for improving Norfolk harbor. The study, Congressionally mandated, "provides modification of the port by deepening the existing 45-foot channels to a depth of 55 feet below MLW up to the coal terminals in Norfolk and Newport News, the existing 40-foot channel on Elizabeth River and Southern Branch to a depth of 45 feet below MLW, and the existing 35-foot channel on Southern Branch between River Mile 15 and 17.5 to a depth of 40 feet below mean low water over the existing channel widths. A new 800-foot turning basin at the terminus of the proposed 40-foot improvement would also be provided. In addition, the selected plan provides for three fixed

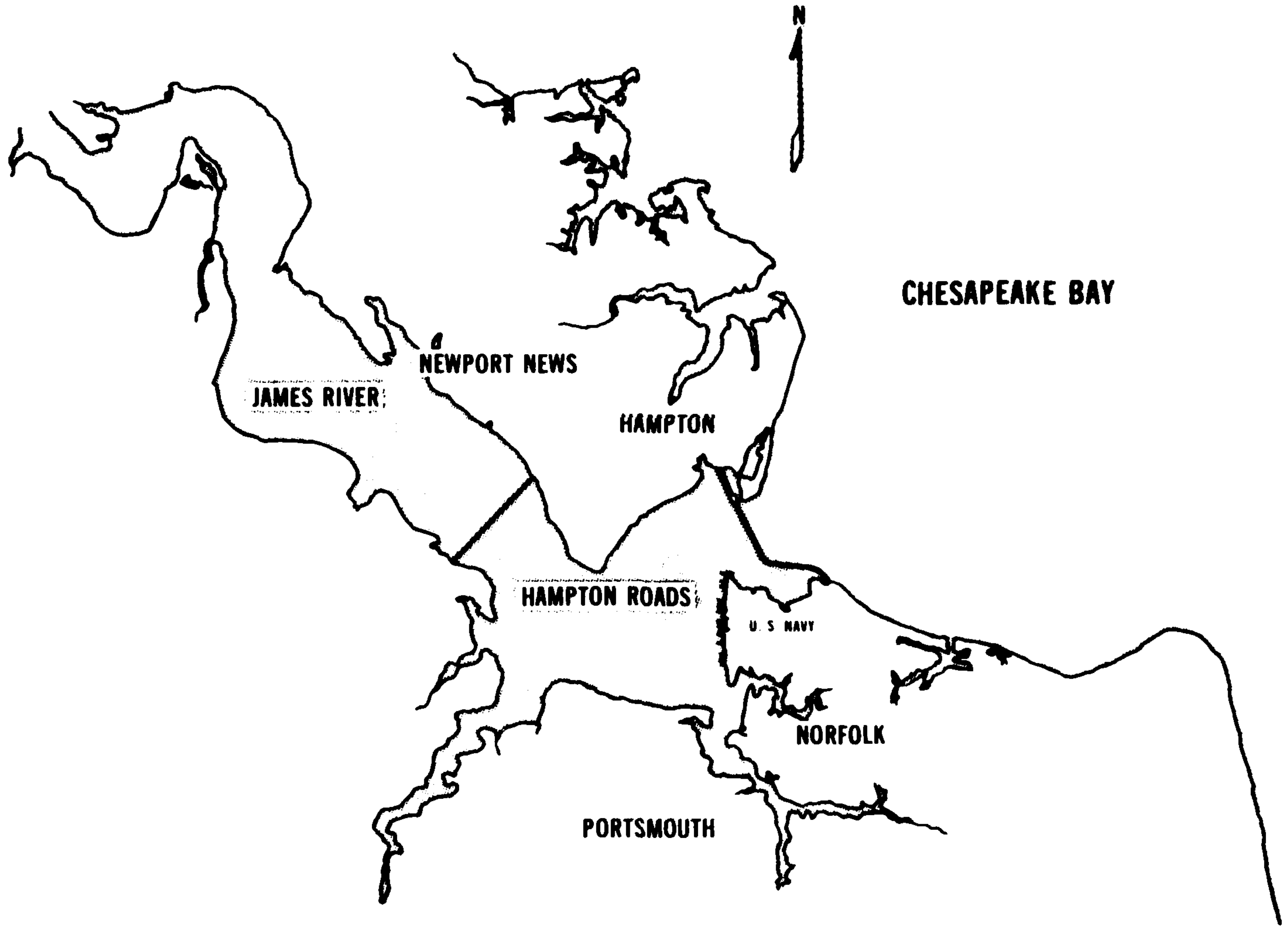


Figure 5-1. Map showing the Interrelationship of the lower Chesapeake Bay, Hampton Roads, and U.S. Navy Piers at Sewell's Point.

mooring anchorage areas, each capable of handling two large vessels simultaneously. In connection with the 55-foot channel improvement, a new channel would be dredged off Cape Henry in the Atlantic Ocean. This channel would be 1,000 feet wide and be dredged to a project depth of 57 feet below MLW. The additional 2 feet is necessary to account for wave action in the open ocean. The passage above underlined is the channel modification that would probably have the greatest beneficial impact on the pier slips of the Naval Station. Prior to becoming an accomplished fact, however, hearing processes, design, and construction are necessary. It is conceivable that 10 years may elapse before the channel deepening is an accomplished fact.

All types of U.S. Navy vessels, including submarines, are brought into the harbor and berthed by U.S. Government harbor pilots (Civilian). A vessel is boarded at Chesapeake Light. The harbor pilot is usually transported by tug but occasionally a helicopter is used. Aircraft carriers require up to eight tugs for berthing with lines being attached to the carrier at a point about 1,000 yards from Pier 12.

Based on the depth of berth deep-draft ships in the AO 51, 98, and 99 Class (draft 36 foot) and in the AOR 1 to 7 Class (draft 35 feet) can be berthed in pier slips 2, 3, 4, 5, 7, 12, and 20 at present (March 1980). Slips on the north and south sides of Pier 12, however, are at present reserved for aircraft carriers (CN, CVN). Pier 7 on occasion has been used for berthing aircraft carriers (CV,CVN).

Deep-draft ships in the AOE 1 to 4 Class (draft 39 feet) can only be berthed in pier slips 7, 12, and 20 and still provide adequate under-keep clearance.

Deep-draft ships in the AO 143 to 148 Class (draft 33 feet) and in the AO 177 to 179 Class (draft 32.5 feet) can be berthed in pier slips 2, 3, 4, 5, 7, 12, and 20. It may also be possible to berth the ships in these classes in pier slips 10, 21, 22N, 23, 24, and 25. However, shoaling and extremely low water levels may place limitations on movement.

Aircraft carriers of all classes can be berthed only in piers 7, 12, and 20. Maximum Operating Load drafts range from 37 feet (U.S.S. JOHN F. KENNEDY and U.S.S. RANGER) to 40 feet (U.S.S. CONSTELLATION) (See Table 2-3). Sea chests for cooling water intake are located on the underside of the aircraft carriers necessitate an under-keel clearance of at least five feet, if not more.

The above berthing schedule hinges upon the assumption that adequate facilities exist at the indicated piers to service the subject vessels, that excessive shoaling has not taken place in the pier, and that extremely low water levels have not occurred. Based on historical measurements Extreme Low Water at Hampton Roads gage is three feet below Mean Low Water. Mean Low Water implies the water levels in piers are at levels below Mean Low Water at least some of the time. Accordingly, the depth of water in a pier slip could be up to three feet lower than the design dredged depth. This combined with excessive shoaling could reduce considerably the depth of water in the berth.

5.3 <u>CURRENT VELOCITY</u>.

According to Port Services Officer (Keith, 1979) currents, affected by both tide and wind, influence berthing to the extent that it is desirable to berth vessels in the period from one hour before slack to one hour after slack. There is a scarcity of current velocity data for Norfolk harbor. Isolated measurements have been made but there is no program of continuous measurements.

An idea as to bottom current velocities can be obtained from a report by Boland and Babb (1969). In this report a proposed dike extension to the east side of Craney Island disposal area was tested in a Waterways Experiment Station (WES) model of the James River. The base plan evaluated conditions as they existed at the time of testing prior to innovation. Listed in Table 5-1 are the maximum surface and botton current velocities resulting from their studies of the base plan.

Velocity measurements made on the James River model at a later date (Boland, 1972) correspond closely to the results found by Boland and Babb.

TABLE 5-1. MAXIMUM SURFACE AND BOTTOM CURRENT VELOCITIES IN HAMPTON ROADS, VA FROM HYDRAULIC MODEL STUDIES (BOLAND AND BABB, 1969)

Location	Maximum Current Velocity - feet per second			
	Surface		Bottom	
	Flood	Ebb	Flood	Ebb
Confluence of Norfolk Harbor and Newport News Channels	2.9	3.2	1.9	2.2
Midway between Pier 12 and Pier 7 in Norfolk Harbor Channel	0.9	2.0	1.3	0.8
Near Pier 25 in Norfolk Harbor Channel	0.9	1.7	1.3	0.7
Extreme western side of Newport News Middle Ground (depth of water 16-20 ft.)	2.2	3.4	2.3	1.9
Newport News Channel South of Newport News Point	2.1	1.8	2.2	1.9

Brehmer et al (1967) mentions values for current velocities of more than one knot near the bottom off Sewell's Point reach and less than 0.5 knots in the access channel off Pier 12 but does not elaborate.

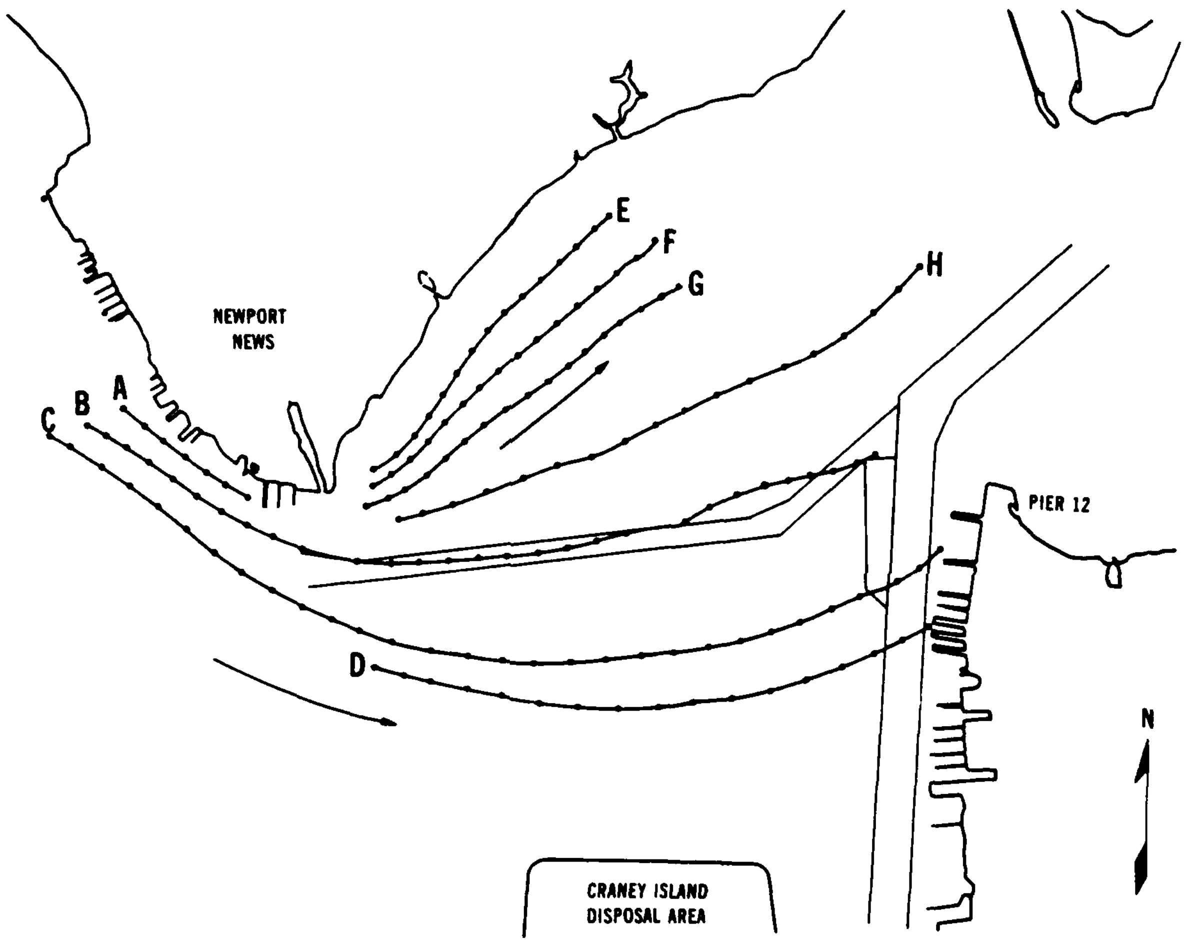
The Fleet Weather Guide for Hampton Roads (1978) only gives currents pertinent to the navigation of ships. In Hampton Roads the comment is made that winds greatly influence the currents and at times attain velocities in excess of those given on the Current Tables. In the Newport News Channel the currents do not always follow the channel. The average velocities in mid-channel at strength of flood or ebb is about one and one-half knots.

A demonstration at the Chesapeake Bay Model on October 20, 1979 indicated that at times a bottom current flow into Norfolk harbor at Hampton Roads took place concurrent with surface outflow from the harbor. Bottom currents were marked by injecting dye, top currents were tagged with floating confetti.

Electronically-tracked drogues tracked surface currents on an ebbing tide (Welch, 1972) from the lower part of the James River where they had been released across the Newport News Middle Ground terminated in the vicinity of Piers 4 and 10. The paths of these drogues and the other drogues are shown in Figure 5-2. It is conceivable that with more drogues than the seven used in this test spaced closer, a drogue could have terminated in one of the berths at Pier 12.

Information of the velocity of water movement within the pier slips of Norfolk Naval Station is scarce. The only data that exists is that for Pier 12.

A short-term study for Scripps Oceanographic Institution (Van Dorn, et al, 1977) cites a study by the Virginia Institute of Marine Sciences (VIMS) (Rulecki and Ayers, 1974). Currents measured on 23 June and 15 September 1973 deep within the berthing area on the north side of Pier 12 indicated that both the bottom and surface currents were "weak and erratic rarely exceeding 10 cm/sec (0.2 knots)."



NOTE:

DOTS ON LINES REPRESENT 10-MINUTE INTERVALS.
TRUCKS A-D AND E-H WERE OBTAINED ON SEPARATE RUNS.

Figure 5-2. Drogue Tracks Showing Streaklines during Ebb Tide in Hampton Roads

5.4 SHOALING RATE.

Some idea as to siltation in Pier 12 is shown in Figure 5-3 (Brehmer et al, 1967). Depicted are areas where the berths have shoaled from one to two feet and from two to three feet in an 18-month period from 1961-1963.

Listed in Table 5-2 are shoaling rates for the individual pier slips at the U.S. Naval Station. These are based on the volume of spoil dredged over a known time period. As can be seen in Table 5-2, the annual shoaling rate varies from about one to two feet.

Sediments that are dredged from within the pier berths are silt to coarse clay probably resulting from the flocculating of suspended sediment and the bedload sediment movement from the rivers flowing into Hampton Roads. Available information as to the change of salinity of the harbor water with depth indicates that a tidal wedge exists in Hampton Roads. Inflowing river water containing suspended sediment mixes with saline water in the harbor which causes a coalescence of the suspended particles and they flocculate out in the salt wedge (Hoffman, 1976).

There is also a possibility that sediment is carried in from the lower part of Chesapeake Bay by the inflowing tidal current.

On the other hand, Byrne (1972) in a study of harbor conditions relating to the effect of a proposed bridge-tunnel crossing of Hampton Roads near Craney Island indicates that "the tidal flow over Hampton Flats is such that flood currents dominate over the ebb currents. Wind from the northeast through the east to southwest have sufficient fetch to generate waves capable of stirring the bottom sediments of the Flats. Given the frequency and intensity of winds in the area coupled with tidal currents, the direction of the net bottom sediment-transport should be to the southwest from the Flats."

5.5 SUBMARINE SEDIMENTS.

A detailed knowledge of the sediments below the navy pier slips at Sewell's Point is not available. Some inference can be drawn, however, from test borings made for Piers 11 and 12.

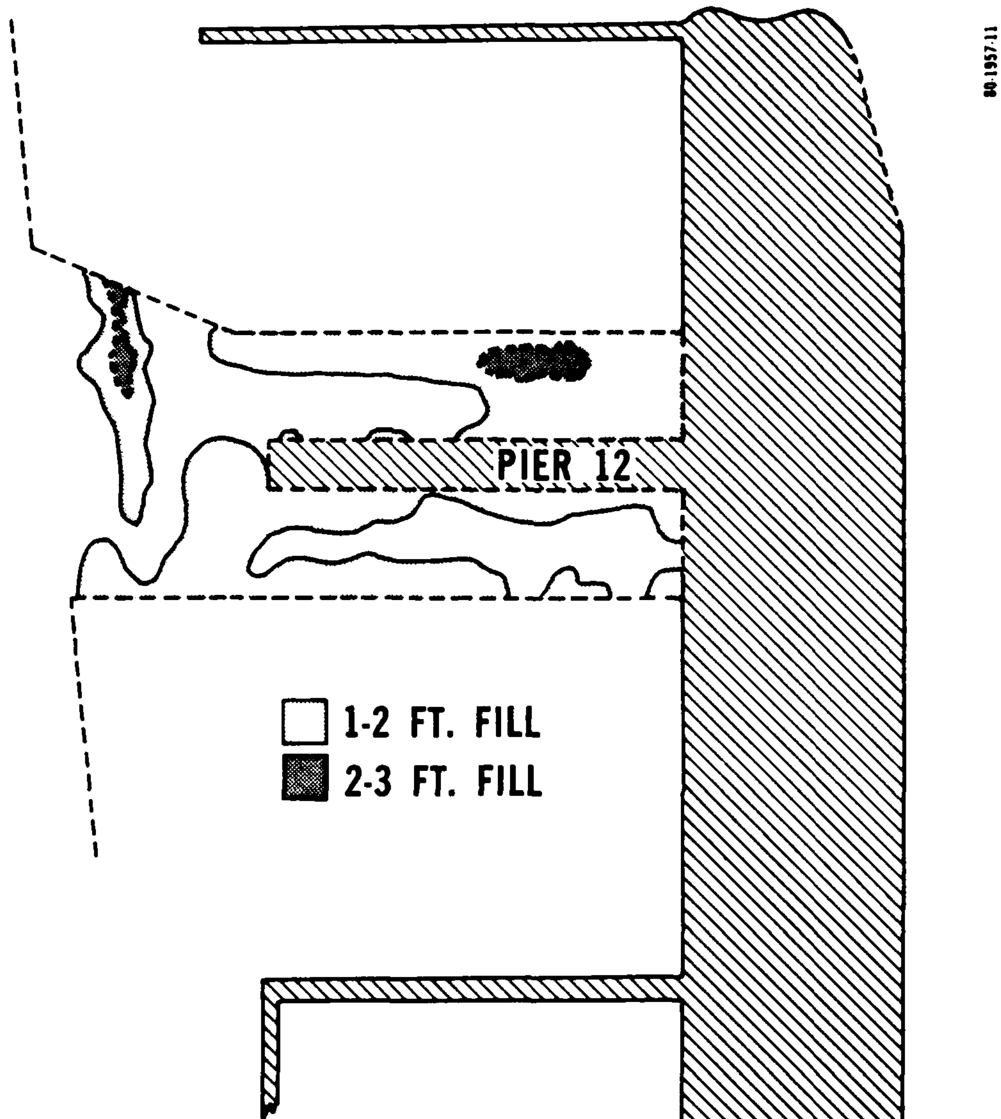


Figure 5-3. Distribution of Siltation Rates in Pier 12 Basins During an 18-month Period, 1961-1963 (after Brehmer, et al, 1967)

TABLE 5-2. MINIMUM DEPTHS OF PIER BERTHS FOR DEEP-DRAFT VESSELS AT NORFOLK NAVAL STATION UPON COMPLETION OF DREDGING TOGETHER WITH THE SHOALING RATES

Pier No.*	Class of Deep-Draft Vessel Berthed	Desired Dredged Depth feet below MLW	Interval between Dredging, years	Average Shoaling Rate, feet/yr
2	AOR	40	2	1.6
3	**	40	2	1.8
4	**	40	2	1.6
5	**	40	2	1.6
7	CV,CVV	45	2.7	2.0
10	**	36	2	N.A.
12	CV,CVN	45	2	2.0
20	AO	45	3	1.9
21	**	35	2.5	1.9
22N	SSN	36	2.5	1.0
23	SSN	36	2.5	N.A.
24	**	36	3.3	N.A.
25	**	36	3.3	1.5

* where information on the north and south sides of a pier is the same only one figure is entered.

** surface vessel has draft less than 35 feet.

N.A. Not Available

The sediments underlying the proposed Pier 11 as determined from ten test borings made by Froehling and Robertson, Inc., Norfolk, VA (1978) are comprised of unconsolidated sands, shell, silts, and clays to a depth of at least 80 feet below sea level (depth of boring). The top layer of sediment is a thin (2 to 5 foot thick) layer of sand at the bulkhead and at the end of the proposed pier. Interposed between this sand laterally is a clay layer up to four feet thick. Underlying the top material are discontinuous layers of sand, silty sand, and shell hash. For the most part, these layers contain traces of clay and silt. The shell is probably a residual from a time less than 20,000 years ago when sea level was rising from a stand of about 400 feet below to the present stand of sea level.

The sediments underlying Pier 12, schematically shown on a set of construction plans (drawing 46795 of Praeger and Kavanaugh - 1956), indicate essentially the same geologic composition as the test borings made for Pier 11. However, four of these borings extended to a depth of 125 feet and two to a depth of 175 feet below MLW. At an elevation of about 93 to 102 feet below MLW there seems to be a 23 to 25 feet thick discontinuous layer of clay.

5.6 DREDGING.

Dredging of the Naval Station pier slips is accomplished by means of a hydraulic cutterhead pipeline dredge. Shown in Table 5-2 is a minimum depth of berth below mean low water, the interval between dredging pier slips and the annual shoaling rate for the piers at Norfolk Naval Station. This information was supplied by the staff of the Naval Station Public Works Officer (Kelley, 1980). Additional information on the annual volume of dredging is contained in Appendix B.

5.7 DREDGE SPOIL DISPOSAL.

Dredge spoil from Norfolk harbor channels and pier slips is pumped to Craney Island. Craney Island, constructed in the middle 1950s, is a diked-disposal area located on the south side of Norfolk harbor. A permanently installed pipeline extending along the bottom of the harbor permits hydraulic cutterhead pipeline dredges to pump directly to the disposal area through a temporary connection without interfering with navigation.

Estimates of the life expectancy of Craney Island as a spoil containment vary from two to eight years. At present (March 1980) hearings are scheduled for the construction of a new containment area about 10 miles from Norfolk harbor. The following is from the Corps of Engineers' Report entitled "Summary of Study Findings Norfolk Harbor and Channels Virginia, Deepending and Disposal."

"The Suffolk Spoil Disposal Site would encompass approximately 6,000 acres of wooded wetland just north of U.S. Route 460 near the Suffolk-Chesapeake city boundary line. About 4,000 acres would be required to accommodate the estimated 3.8 million cubic yards of polluted dredged material generated annually from maintenance of the existing channels and anchorages as well as private and public permit activity inside Hampton Roads Harbor over a period of 50 years. The remaining 2,000 acres would be constructed for the proposed new work and increased annual maintenance associated with the proposed channel and anchorage plan."

"The Suffolk Disposal Site is located about 10 miles inland from Craney Island and is not accessible by navigable water routes. Dredged material would be transported to the site from a rehandling area on the southwest corner of the Craney Island Disposal Area by a 20-inch pipeline. Water would be returned to the Elizabeth River near Craney Island by means of a separate 16-inch pipeline. The pipeline system would utilize five successive booster stations. The levee at the site would be a simple, nonriprapped, earth-raised type with 1 on 3 side slopes. In addition, it would include an impervious slurry cutoff trench in order to seal the site."

5.8 PROBLEMS.

Problems in the U.S. Navy berths of Norfolk harbor may be divided into two categories; shoaling of pier berths and marine invertebrates that are sucked into the cooling water intakes of aircraft carriers.

5.8.1 SHOALING. Not only is shoaling expensive because of the required maintenance dredging but it can result in the inactivation of ships as well as excessive wear on pumps, piping, and heat exchangers.

Groundings have been reported but have not been documented. One such grounding in mud occurred involving the aircraft carrier U.S.S. INDEPENDENCE at Pier 7 (date and stage of tide not available). Similarly, groundings of AO's in Pier 2 have been reported but have not been documented (date and stage of tide not available.)

Groundings at low tide result in a delay of departure time until the water level rises. Groundings at high tide indicates a shoaling problem. It is possible that use of the berth could be lost for a month during the dredging period.

Information on the above shoaling problems depended on memory rather than an accurate documentation as to the time, stage of tide, and ultimate method of departure from the pier. Accordingly, it is difficult to draw firm conclusions from conjectured circumstance rather than firm documentation.

It has been indicated by the Corps of Engineers (Norfolk District) that a large part of the annual volume of dredge spoil from Norfolk Harbor reach, which totals about 830,000 cubic yards, has been shifted towards Hampton Roads since the construction of Craney Island Spoil Disposal Area. Prior to that a larger part of the spoil from Norfolk Harbor reach was dredged closer to the Elizabeth River. The effect on the piers of the Norfolk Naval Station is unknown for sufficient historical data is not available.

5.8.2 <u>HYDROIDS</u>. Dredging is a problem for it is expensive and the berth is not available for use. However, the more serious problem at Norfolk Naval Station is the clogging of the intakes of the aircraft carriers berthed on both sides of Pier 12 and on occasion in Pier 7 by invertebrates.

A detailed investigation of messages noting this problem has not been made inasmuch as the messages in hand show a similar pattern of occurrence. After discussion with the people concerned little would be gained by an exhaustive investigation. The pattern is that marine organisms become lodged against the intake screens of the auxiliary and main condenser intakes causing the cooling water temperature to rise to such a point that the generating plants are rendered inoperative. In some cases it has been necessary for the aircraft carrier to proceed to the anchorage and have the screens cleaned by divers. In other cases divers have to clean the screens with the carrier in the berth.

Carriers so affected include the U.S.S. DWIGHT D. EISENHOWER, U.S.S. NIMITZ, U.S.S. FORRESTAL, U.S.S. JOHN F. KENNEDY, and the U.S.S. ENTERPRISE. Other carriers may have been affected but the information is not in hand. Inasmuch as this problem was studied in the period 1962 to 1966 by the Virginia Institute of Marine Sciences (VIMS) under NAVFACENGCOM-Atlantic Division contract, the problems must have been serious prior to 1962. All such problems encountered to date have occurred in the period from November through March and hence must be considered a winter season problem.

The marine organisms identified as the problem is a hydroid Sertularia argentea and a bryozoan Alcyonidium verrilli. The hydroid is considered to be 90% to 95% of the carrier problem in Pier 12 and the bryozoan 5% to 10% of the problem (Ho, 1979). No estimates for Pier 7 have been made.

Although studied in detail taxonomically (Hancock, et al, 1956, Calder, D., 1966, Calder, 1971), little is known of its location in the environs of Norfolk harbor. Calder (1966) found some locations in the lower Chesapeake Bay, Hampton Roads, and Norfolk harbor. Brehmer et al (1967) based on a dredge sampling indicated that the major growing area for the hydroid was the Newport News Middle Ground. The same reference indicated "that the two forms primarily responsible for operational difficulties of deep-draft vessels were setting and growing on the shoals of Hampton Roads or Chesapeake Bay and were dislodged by wave action and then carried into the berthing areas by currents."

Some details concerning the hydroid Sertularia argentea are discussed below. It consists of colonies up to 10 to 12 inches high with many branches. Its growth is not continuous throughout the year, however, peak growth (four-fifths of total) occurred in the months of May to September. Branches and side-branches break off in the winter when growth virtually ceases and are carried away by the currents. Regeneration, however, results in the detached branches setting and forming new colonies away from the parent colony (Hancock, et al 1956).

Additional information on Sertularia argentea is contained in Appendix C.

At the time of writing (1980) there is no idea as to the extent of the major areas of growth - whether it is in the extensive open water such as lower Chesapeake Bay and Hampton Roads and/or in the lower part of the various rivers flowing into Hampton Roads. Nothing is in hand to indicate to what extent it is influenced by the environment. Little is in hand to indicate the probability of control by natural predators or toxins. These may exist, however, the information has to be researched. Mechanical removal by raking of the colonies in areas away from Piers 7 and 12, if located, may prove not to be a solution for broken branches not recovered can regenerate themselves. Raking is the method by which the hydroid is commonly harvested in Germany and England. A possible solution, if the parent colonies can be located might be to surround the bottom area with a low lying fence to encourage siltation and thereby bury them with natural sediments. Inasmuch as the hydroid Sertularia argentea requires a firm substrate reproduction in that area would probably not occur. Further study of this approach is required to determine its feasibility.

HO et al (1979) and Brehmer et al (1967) indicated that the hydroids move in the lower part of the water column having a density of about 1.15. HO et al (1979) indicated that the results of flume tests indicated that the hydroids at a bottom current of 0.15 knots would start them rolling or sliding along the smooth, level flume floor. At water velocities in the flume of 0.46 knots the hydroids still remained on the bottom. Water velocities in excess of 0.46 knots were considered sufficient to raise them in the water column.

The information listed in Table 5-1 indicates that during some part of the tidal cycle (mean or ebb) a sufficient current velocity exists in the harbor away from the pier slips to move hydroids. The harbor area in which this would apply is bounded on the south by an east-west extension of the northern dike of Craney Island, on the north-south line from Newport News Point. The area extends northeasterly to Entrance Reach at a line extending westward from Fort Wool. Measurements were not made outside this area.

Based on the information available it seems that the hydroids can be moved anywhere in the Hampton Roads area under the influence of river flow and tidal action. Randomness of movement can be further intensified by the wind in areas in those parts of the harbor where the water depth is less than 18 feet. Reference to a nautical chart of Hampton Roads indicates that these shallow areas extend over more than 50 percent of the harbor.

5.9 RECOMMENDATIONS.

Shown in Table 5-3 are methods that have been suggested or utilized for the control of the above-mentioned problems. These were obtained from files, messages, correspondence, and the technical literature.

The hydroid problem, apparently simple, has not been solved. It may necessitate the use of a combination of methods rather than a single method. One such combination would be to dredge a 200 foot-wide sump in Norfolk Harbor reach to 55 feet below MLW. The sump would extend from Pier 7 northward to the breakwater north of Pier 12. A plastic curtain in front of Pier 11 and 12 would retard the entry into the berths of invertebrates as well as sediment.

Additional information is required concerning the hydroid problem. Two pieces of information needed are the hydroid source and hydroid movement.

Seabed drifters of different colors should be distributed at selected points within the harbor as well as at waterway entry points to the harbor. Time of arrival and number of drifters should be recorded for each pier.

All U.S. Navy piers at Sewell's Point should be dragged to determine if the pier slips provide a haven for the hydroids as well as providing information concerning possible problems should there be a rescheduling of the class of ship berthed at a certain pier.

TABLE 5-3. METHODS SUGGESTED OR UTILIZED FOR THE CONTROL OF THE HYDROID AND/OR SEDIMENTATION PROBLEM IN HAMPTON ROADS-NORFOLK HARBOR REACH, VA

Method	Where Applied	Implementation	Remarks
Mechanical Elimination	Within pier slip	rake with bottom dredge	presently (1980) used in winter months only
	do	intake water passes over grinder (cominutator)	not tried. NAVSEA in general is opposed to a modification of ship design
	do	agitation by dragging I-beam of ebbing tide	not tried - tidal current probably too low to be effective
Barriers	Entrance to pier slip	plastic curtains	being tested at Mare Island Shipyard, CA at present (1980)
	do	bubble screen (water or air)	not tried at NORVANAVSTA-tested by Corps of Engineers on N.Y. Harbor Hydraulic Model-results good but not pursued
	do	inflatable rubber-fabric barrier	not tried
Flushing	Within pier slip	horizontal water jets	being tested at Mare Island Shipyard CA at present (1980)
	Within pier slip	air lift: Ventra-Vac	tested at Pier 12 NORNAVSTA present design considered unsatisfactory

TABLE 5-3. METHODS SUGGESTED OR UTILIZED FOR THE CONTROL OF THE HYDROID AND/OR SEDIMENTATION PROBLEM IN HAMPTON ROADS-NORFOLK HARBOR REACH, VA (Cont'd)

Method	Where Applied	Implementation	Remarks
Flushing (cont'd)	do	agitation by the propeller wash of tugs	tested and found unsatisfactory. Hoffman (1977) describes successful trial by propeller wash deflected downward.
Interception	Outside of pier slip	trenches in front of pier slip	not tried, expensive possibility of working, dredging constraints (see below)
	do	deepening Norfolk Harbor reach to 55 feet below MLW	preliminary hearings by Corps of Engineers (Norfolk District) took place on March 21, 1980. Implementation of plan estimated to be eight to ten years away, if plan is approved and funded.
	Within pier slip	sumps	not tried, density of hydroid may preclude settling in sump only. Aircraft carrier problem may be intensified as intake passes over sump.
	Within pier slip	slope of bottom of pier slip toward channel	not tried. Density of hydroids, low velocity of ebbing flow, and adhesion of sediments may inhibit moment into main channel.

TABLE 5-3. METHODS SUGGESTED OR UTILIZED FOR THE CONTROL OF THE HYDROID AND/OR SEDIMENTATION PROBLEM IN HAMPTON ROADS-NORFOLK HARBOR REACH, VA (Cont'd)

Method	Where Applied	Implementation	Remarks
Biological Control	In waterways where colonies grow	bacteria, viruses, toxins, parasites, natural predators	not tried, research necessary, sufficient branches may survive to repopulate area
	do	bury with environmentally acceptable dredge spoil released from hopper dregdes	do
Ship Modification	On board the aircraft carrier	backflush	NAVSEA, in general, is opposed to any modification of carrier design
	do	movable screen across intake with scraper to remove organic material	do
	do	Babcock Strainer	tried but requires attendance
	do	Variable speed pump	tried with varying degrees of effectiveness
	do	explode hydroids with heat around intake	not tried
	do	drop-off screens overlying intake screens	not tried. These would drop off from internal control when ship starts out of berth
	do	ultrasonics	not tried.

A research program should be instituted to see what natural predators exist and what toxins can be used for hydroid control without disturbing the environment.

Information as to the upward velocity of water which causes the hydroids to rise should be determined. Any velocity field determination either by physical or numerical models or by mathematical analysis will require this information.

Lastly, a more formal program of documentation and tabulation of incidences of bioclogging and groundings should be instituted. With respect to the latter the date, time, and tidal stage should be part of the collected data.

SECTION VI

PENSACOLA NAVAL AIR STATION

6.1 INTRODUCTION.

The Naval Air Station at Pensacola is located about four miles southwest of the city of Pensacola, Florida on the Pensacola Bay. The location is shown in Figure 6-1. Santa Rosa Island, a barrier beach, separates Pensacola Bay from the Gulf of Mexico.

Three rivers, the Escambia River, the Blackwater River, and the Yellow River drain into the Pensacola Bay.

The only deep-draft vessel moored at the naval air training station is the training carrier U.S.S. LEXINGTON (AVT). The U.S.S CORAL SEA is being considered as a possible future replacement of the U.S.S. LEXINGTON, the U.S.S. CORAL SEA has a Maximum Operating Draft of 39 feet (See Table 2-3).

The U.S.S. LEXINGTON is moored at Pier 303, the destroyer "ROBERT OWENS" DDA27 is moored at Pier 302, and five seagoing tugs are moored at Piers 302 and 303A.

6.2 SHIP MOVEMENT.

In the period from July 1978 to Sept 1979, the U.S.S. LEXINGTON spent 314 days at Pensacola Naval Air Station (67%). The remainder of the time was spent on CARQUALS, Corpus Christi, TX, Fleet CARQUALS, Rescue CARQUALS, Pensacola, FL.

The length of stay in Pensacola in that period ranged from 2 days to 30 days.

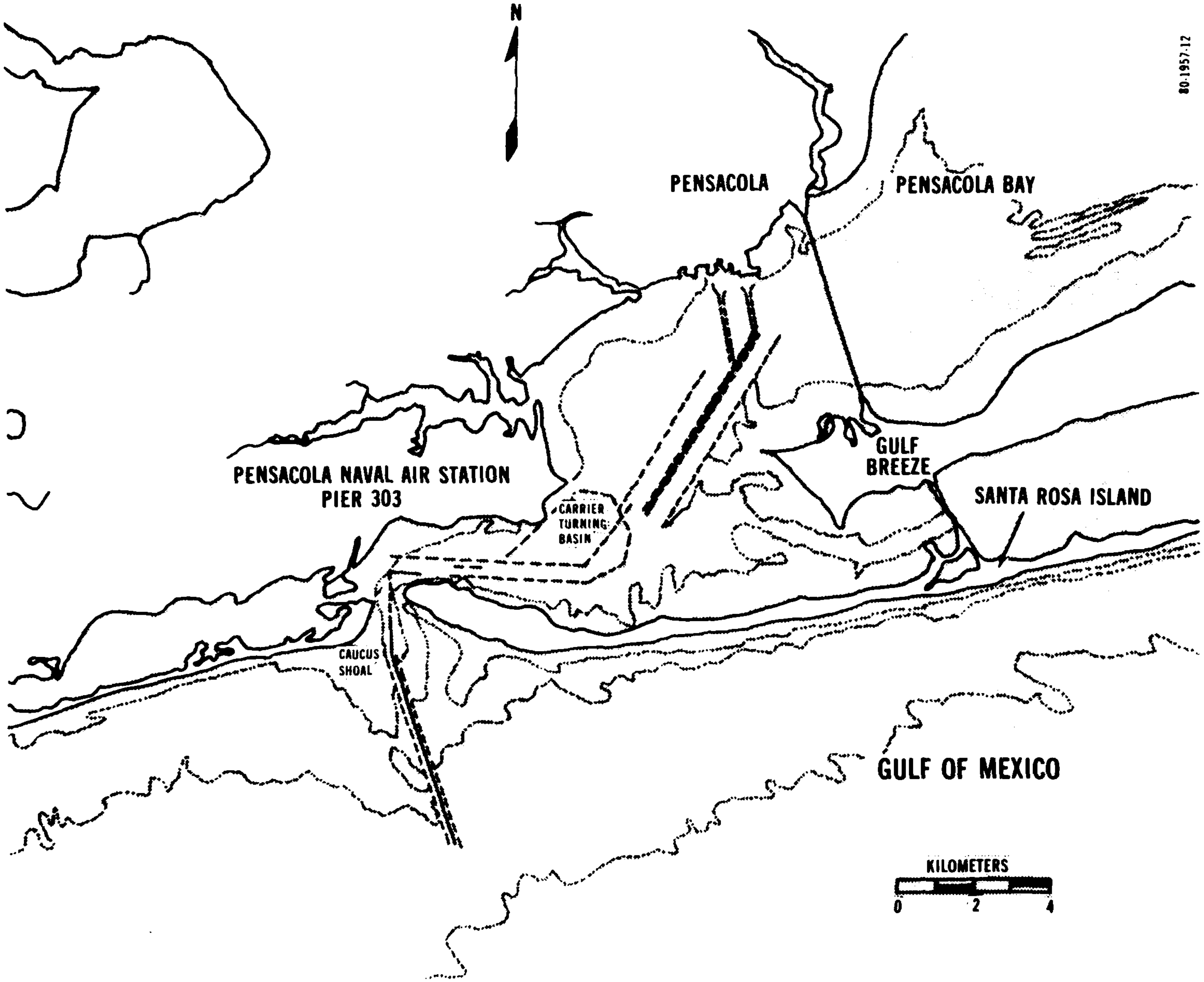


Figure 6-1. Map Showing Location of Pensacola Naval Air Station, FL

Arrivals and departures of commercial vessels at the Port of Pensacola is coordinated with the movement of the U.S.S. LEXINGTON.

There are no tidal constraints to the movement of the U.S.S. LEXINGTON, however, on occasion wind does affect manuevering (Lovelace, 1979). Extreme low water is 2.2 below MLW. Other tidal data are contained in Table 2-4.

The aircraft carrier comes into the pier under its own power. Tugs assist in the latter part of the berthing procedure. In some cases, the carrier is brought in under control of the Captain, at other times it is brought in under control of a harbor pilot.

6.3 CURRENT VELOCITIES.

There are no data available concerning the velocity of currents in Pensacola Bay (Lovelace, 1979).

6.4 SHOALING RATE.

There is no definite shoaling pattern. Heaviest shoaling seems to occur with the incidence of sizeable storms. Review of the dredging history indicates that dredging was not required in the channel or turning basin between 1963 and 1967. After that dredging was required in 1968, 1969, 1970, and 1971. In 1979 investigations were being made in preparations for dredging in late 1979 or 1980.

Additional comments regarding shoaling are made in the subsequent section entitled "Dredging".

6.5 ELEVATION OF THE BOTTOM TIP OF PIER PILING.

Information is not available as to the elevation of the bottom of the pier piling. However, it was indicated (Lovelace 1979) that most of the piles are wooden and extend to a depth of 72 feet below MLW. These have been inspected twice and no problems were evident. It was also indicated that no structural problems would be encountered if the berthing area adjacent to Pier 303 were lowered to 40 feet below MLW.

6.6 SUBMARINE SEDIMENTS.

Eight Vibracore borings were taken during July 1978 under the supervision of the Corps of Engineers (Mobile District). The depth of these borings below the bottom of the water column ranged from 9.5 feet to 15.9 feet. The depths of water in which these borings were made ranged from 35 feet to 50 feet.

The results of these borings indicate that the sediments underlying the bottom of the turning basin and the associated channel consists of about a foot of silty sand underlain by a layer of clay. The borings were not continuous, therefore, it is not possible to determine what the intervening material was. If the clay was continuous over an extensive area, the dredging cost of any deepening of pier berths, turning basin or channel could be substantially higher than if sand were involved.

6.7 DREDGING.

According to NESO (1975), the "primary dredging requirements of Pensacola Air Station are that the depth and width of the 3.4 mile entrance channel and 1,200 acre mooring basin be suitable for the U.S.S. LEXINGTON. To accomplish this Mobile, Alabama, District of the U.S. Army Corps of Engineers (COE) has been contracted to maintain the basin at 35 feet and the channel dimensions at 37 feet x 800 feet; for commercial purposes the channel need only be 35 feet by 500 feet." The excess dredging is paid for by the Navy.

"Hopper dredging with disposal at a designated ocean site is employed almost exclusively for the Navy areas at Pensacola. One exception to this occurred in 1968 when a private pipeline dredge was used to deepen the channel near its major bend at Ft. Pickens and dumped the sandy spoil on Santa Rosa Island." Recent dredging requirements are shown in Table 6-1.

"Since 1963, the Navy has paid for 62% of the total dredging. The percentage since 1968 has been only 43% because: (1) the dredging needs of the commercial interests have increased; and, (2) the large Navy requirements of 1963 and 1967 are somewhat anomalous and may have been new work rather than maintenance dredging (the massive Navy dredging in 1970 was in response to shoaling created by Hurricane Camille in 1969)."

TABLE 6-1. PENSACOLA DREDGING HISTORY 1963 THROUGH MAY 1975
(FROM NESO, 1975)

NAVY FUNDED

YEAR	AREA DREDGED		AMOUNT DREDGED
1963	Channel & Basin		2,359,086 cubic yards
1967	" "		1,132,637 " "
1968	" "		717,085 " "
1969	" "		239,637 " "
1970	Channel		1,561,323 " "
1971	"		171,292 " "
		TOTAL	6,181,060 cubic yards

NON-NAVY FUNDED

1963	Channel		121,200 cubic yards
1967	"		150,000 " "
1969	"		218,456 " "
1969	Inner Bay & Harbor		1,427,906 " "
1970	Channel		696,181 " "
1973	Inner Bay & Harbor		848,166 " "
1975	Channel		343,481 " "
		TOTAL	3,805,390 " "

Navy dredging accounted for 62% of the total dredging between 1963 and May 1975.
(Information supplied by the Mobile District Corps of Engineers)

"It would be unrealistic to convert the dredging history to an average shoaling rate. The sandy sediment shifts in response to meteorological and hydrological changes that are not entirely predictable, and shoaling does not recur in the same amount or location. Since the large channel dredging requirement of 1970, due to Hurricane Camille, shoaling has been even less extensive than earlier. The mooring basin has not been dredged since 1969, yet in 1974 its average depth was 40 feet, 5 feet deeper then the operating depth. Mr. Sam Lovelace, NAS Public Works Center, attributes this lack of shoaling to some undefined sedimentation change resulting from Hurricane Camille; he has also observed that when the U.S.S. LEXINGTON is used frequently, the turbulence it creates tends to clear the same from the channel and basin".

"Because there is no established shoaling rate, NAS relies on periodic soundings made by the COE and on soundings made by the U.S.S. LEXINGTON while entering or leaving the facility. With this data NAS maintains up-to-date depth charts and requests dredging when needed. As a complement to this approach, the COE, on the basis of its soundings informs Mr. Lovelace of the need for dredging and schedules the hopper dredge if Mr. Lovelace concurs and if necessary funds are available".

Pensacola is hampered by maintenance requirements which have been accumulating for many years. For example, the existing approach channel cuts through 7 km of the shoal tidal delta off Pensacola Bay, and through other shoal areas for a distance of about 3 km. This approach and entrance channel must continue to be dredged periodically to maintain a channel bottom depth of 37 feet below MLW.

The existing configuration of the approach channel appears to indicate that maintenance cost will increase in the future due to the normal evolution of the tidal delta formed by Caucus Shoal, Middle Ground, and East Bank (See Figure 6-1).

Should another aircraft carrier be homeported at Pensacola Naval Air Station, say "CORAL SEA" (C-43) a greater depth of channel, turning basin, and berthing area will be required. The present Maximum Operating Draft of the "CORAL SEA" is about 39 feet. If the bottom of the waterways is lowered to, say, 42 feet below MLW about 3.4 million cubic yards must be removed from the turning basin and 2 million cubic yards from the channel - totaling 5.4 million cubic yards. This would be new dredging (capital) and more expensive than maintenance dredging.

Up to the present, spoil has been dumped in the Gulf of Mexico at a site about 3 miles offshore. Future spoil disposal, however, may require a change. The results of a standard elutriate test of the sediments have shown that arsenic exists in the elutriate in unacceptable concentrations and the Corps of Engineers may require stripping of the top layer and disposal upland. Tentatively, the disposal area will be a diked area adjacent to the station starting at a point about 800 feet north of Pier 302.

There are indications that the State of Florida (Department of Environmental Regulations) is concerned with the problem of the upland disposal of arsenic and the Corps of Engineers (Mobile District) may require a bioassay to determine the suitability of open-water disposal of spoil (Lovelace, 1979).

6.8 RECOMMENDATIONS.

No recommendations can be made at the time of writing (May 1980) concerning the spoil disposal problems at the Pensacola Naval Training Station until the postures of the Environmental Protection Agency, the Corps of Engineers, and the State of Florida are known.

From an economic standpoint it may be well to make a feasibility study of a plan proposed by Van Dorn, et al (1977). By cutting a new entrance to Pensacola Bay east of the existing entrance a much shorter approach channel from deep water (3 km vs 7 km) would result. As a consequence there would be a decrease in maintenance dredging. Should a new entrance channel be dredged, the existing channel should be closed to permit the full effect of the tidal prism of the bay to maintain a scouring action in the channel to further reduce dredging maintenance.

SECTION VII

NORTH ISLAND NAVAL AIR STATION

7.1 INTRODUCTION.

Three naval facilities involving waterways located in the environs of San Diego, CA are shown in Figure 7-1. These are:

1. The San Diego Naval Station located in San Diego on San Diego Bay.

2. North Island Naval Air Station located in Coronado, across the Bay southwest from San Diego.

3. The Submarine Base at Point Loma located east of the North Island Naval Air Station across the inlet.

The naval facility investigated and discussed below is North Island Air Station. Four aircraft carriers are homeported at North Island. These are: The U.S.S. RANGER, the U.S.S. KITTY HAWK, the U.S.S. CONSTELLATION, and the U.S.S. CORAL SEA. Three other deep-draft ships are also homeported in San Diego. These are: the U.S.S. SACRAMENTO (AOR), the U.S.S CAMDEN (AO), and the U.S.S. RONOAKE (AOE).

7.2 SHIP MOVEMENT.

Normally a harbor pilot boards an incoming vessel at Ballast Point. Aircraft carriers proceed to a point offshore of mooring "Julliett" where three tugs are secured by lines. Aircraft carriers proceed to the turning basin where turning is either in a clockwise or counterclockwise rotation in preparation for berthing. Three carriers can be berthed at berths "Lima", "Oscar", and "Poppa". A fourth carrier can be berthed at "Julliett". Previously berths "Mike" and "November" were used.

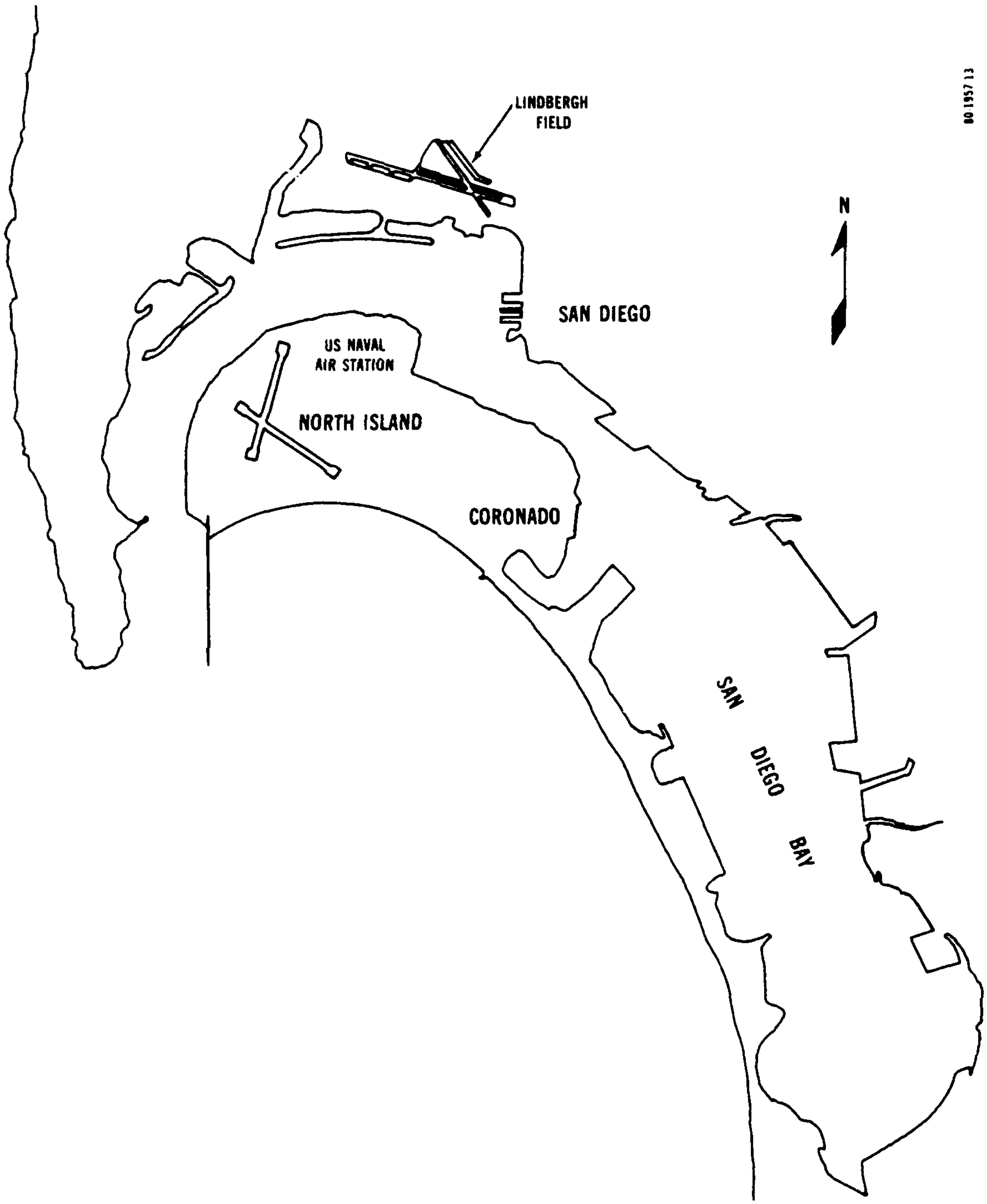


Figure 7-1. Map of San Diego and Environs Showing the Location of the North Island Naval Air Station

The other deep-draft ships (AO, AOE, and AOR) are berthed on a "space available" basis.

7.3 CURRENT VELOCITY.

The Fleet Guide - San Diego, Eight edition 1978 indicates that the current is generally in the direction of the channels. Depending upon the stage of the tide, the velocity near the entrance usually varies from 0.5 to 3 knots. On the ebb, there is a slight set toward Zuniga Shoal southward of the end of the jetty. Care should be taken while passing Ballast Point, as a cross-current deflected from Ballast Point may cause a ship to take a sudden shear.

These are currents at or near the surface. Bottom current studies were made by the Waterways Experiment Station (Fisackerly, 1974) for verification of a model of San Diego Bay. The field measurements were made continuously in the period 21-27 January 1967, using a Price current meter held two feet above the bottom. At two points on either side of the entrance channel about 1,000 feet north of Ballast Point the maximum bottom velocity at ebb tide was 1.6 and 1.8 feet per second. At flood tide the maximum bottom velocity was 2.2 and 1.6 feet per second respectively. At two points about 1,000 feet off Berth "J" and on either side of the channel the maximum bottom velocity at ebb tide was 1.0 and 0.8 feet per second. At flood tide the maximum bottom velocity was 0.8 feet per second for both stations.

7.4 SHOALING RATE.

Based on the case histories cited under the section entitled "Problems" excessive shoaling appears to be taking place along the quay walls especially Pier Berths "J", "M", "N", "O", and "P". Conclusive evidence concerning excessive shoaling in the turning basin is not in hand. Some shoaling is taking place as indicated by the need for dredging.

7.5 SUBMARINE SEDIMENTS.

Although a number of test borings have been made very few have been made in the vicinity of the turning basin and the above-mentioned quay walls. Evaluating the data indicates that the sediment at the floor of these areas is fine sand to silty sand. Clay is indicated at depths in some of the areas and cemented cobbles have been reported at Point Loma.

7.6 DREDGING.

The amount of spoil dredge from the North Island turning basin and channel is essentially unavailable. The Corps of Engineers (Los Angeles District) uses a hopper dredge to dredge these areas. In-person contact with the Corps of Engineers (Holt, 1979) has netted little in the way of information. It is presumed that the dredging pattern followed by the hopper dredge results in the amount of spoil intertwined with other dredgings so that it is difficult to separate the two. The berths are dredged by bucket and scow.

The turning basin and berths are maintained at 42 feet below MLLW.

Liddy (1979) has indicated dredging projects undertaken solely by the U.S. Navy. These are listed below:

Dredged Location	Type of Dredging	Date	Volume of Spoil-cy	Cost
Ammunition Pier-1st phase	New	1976	198,000	$1,059,000
Berths at Quay Wall	Maintenance	Mar 77	171,000	759,133
Ammunition Pier-2nd phase	New	1979	515,000	3,281,000
Pier J/K	Maintenance	1980	31,500	141,750

Spoil is usually dumped at one of two ocean disposal areas two to three miles southwest of Point Loma Lighthouse. Dredge spoil area "LA 4" is located at Lat. N32°35'00", Long. W117°17'30". Dredge spoil area "LA 5" is located at Lat. 32°35'50", Long. W117°20'40". Under present EPA and Corps of Engineers' practice (Los Angeles District) ocean disposal may require bioassay of the spoil (see Dredge Spoil Disposal section in GENERAL BACKGROUND) and the U.S. Navy may encounter the same problem that was encountered at Pier 2 at the Naval Station.

On occasion dredge spoil from San Diego Bay has been used for beach replenishment on the Silver Strand on Imperial Beach. The fact that the spoil can be used for beach replenishment indicates the high percentage of sand in the spoil.

7.7 PROBLEMS.

Documentation of three problems are in hand although others may exist.

The aircraft carrier U.S.S. RANGER on 27 May 1976 incurred pier-side fouling in Pier "J". As a result it was necessary to clean air coolers on two SSTGs and blow out the evaporator pump suction. The SSTG air coolers were found to be clogged with sea shells.

The U.S.S. RANGER on 7 December 1976 encountered fouling as the result of getting underway from Pier "O", "P". Heavy accumulations of black sand occurred on the inlet side of both main condensers. The damage reported was the wiping of the thrust shoes on Number 6 SSTG, the loss of mechanical seals on several first pumps and damage of shaft packing on several cooling water and circulating water pumps.

The aircraft carrier U.S.S. CONSTELLATION on 18 January 1977: diver-inspection revealed that the entire starboard side and part of the port side were in mud. This was while the carrier was berthed at Berths "M" and "N". The ships draft at that time was 34.5 feet forward and 36 feet aft, "...with a depth below mean low tide of 40 feet and the height of water level of 1.6 feet there should have been 7.1 feet clearance forward and 5.6 feet clearance aft. Ship's draft was taken again at high tide, with no change in ship's draft the ship ... was clear of the bottom of about 6 feet.

In the same message concerning the U.S.S. CONSTELLATION"... while maneuvering the ship into berths "M", "N" it was noted that L. P. turbine exhaust trunks on all engines were overheating. It is now suspected that silt-laden sea water was being passed through the main condensers. On 18 January numbers 1, 2, and 3 main condensers were inspected. No silt was found. Number 4 was not inspected due to steaming.

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INVESTIGATION INTO DEEP-DRAFT VESSEL BERTHING PROBLEMS AT SELEC--ETC(U)
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"During recent in port periods while moored at Berths "M" and "N" several problems have been encountered which are not believed to be caused by shallow water." The above quotations were excerpted from a message to COMNAVAIRPAC from the U.S.S. CONSTELLATION.

Comments concerning shoaling in the turning basin have been made but positive evidence is not in hand. The carrier U.S.S. ORISKENY was reported by Forrest (1979) to have grounded in the turning basin. Divers drove stakes in the areas that were suspected and the maneuver was repeated. The stakes were not disturbed.

7.8 RECOMMENDATIONS.

A study be made as to the feasibility of the use of a jet array for each of the berths "J", "L", "M", "N", "O", and "P". By jetting periodically on an ebbing tide it may be possible to keep the berths sufficiently clean to eliminate suction intake problems for aircraft carriers.

The incidence of groundings of deep-draft vessels in the turning basin should be noted togther with the date and the stage of tide. Negative tides have been noted and a study of the conditions may require a reevaluation of the datum used for establishing the depth to which the basin should be dredged.

SECTION VIII

CHARLESTON NAVAL COMPLEX

8.1 INTRODUCTION.

Charleston Harbor, shown in Figure 8-1, is formed by the Cooper, Ashley, and Wando Rivers. The Cooper River, the principal tributary of Charleston Harbor, is a tidal estuary formed by the confluence of its East and West Branches (locally termed "The Tee") at a point about 32 miles upstream from the harbor entrance. The Cooper River and its branches above the dredged channels are meandering streams bordered by marshes and abandoned rice fields; from "The Tee" the West Branch extends northward where it connects with the Tailrace Canal of the Santee-Cooper project of the South Carolina Public Service Authority. Watershed areas of the East and West Branches are generally drained by small poorly-defined channels traversing thickly wooded swamps.

The drainage area of the West Branch between "The Tee" and the hydroplant is about 185 square miles; drainage area of the East Branch above "The Tee" is about 133 square miles. Prior to 1942, the average streamflow at "The Tee" was on the order of 200 cfs. Since 1942, when the hydroplant began operation, almost all of the flow from the 14,700 square miles of the Santee River Basin has been diverted into Cooper River and Charleston Harbor. The lower Santee now carries only 500 cfs continuous flow required to be released at the Santee Dam of the Santee-Cooper development and flood flows in excess of the capacity of the Pinopolis hydroplant.

Existing authorizations for Navy and commercial navigation consist mainly of a channel 35 feet deep from the Atlantic Ocean to the Naval Weapons Annex with varying widths and a channel 35 feet deep and 500 feet wide through Town Creek. The location of the U.S. Naval Base and the U.S. Naval Weapons Station are shown in Figure 8-1.

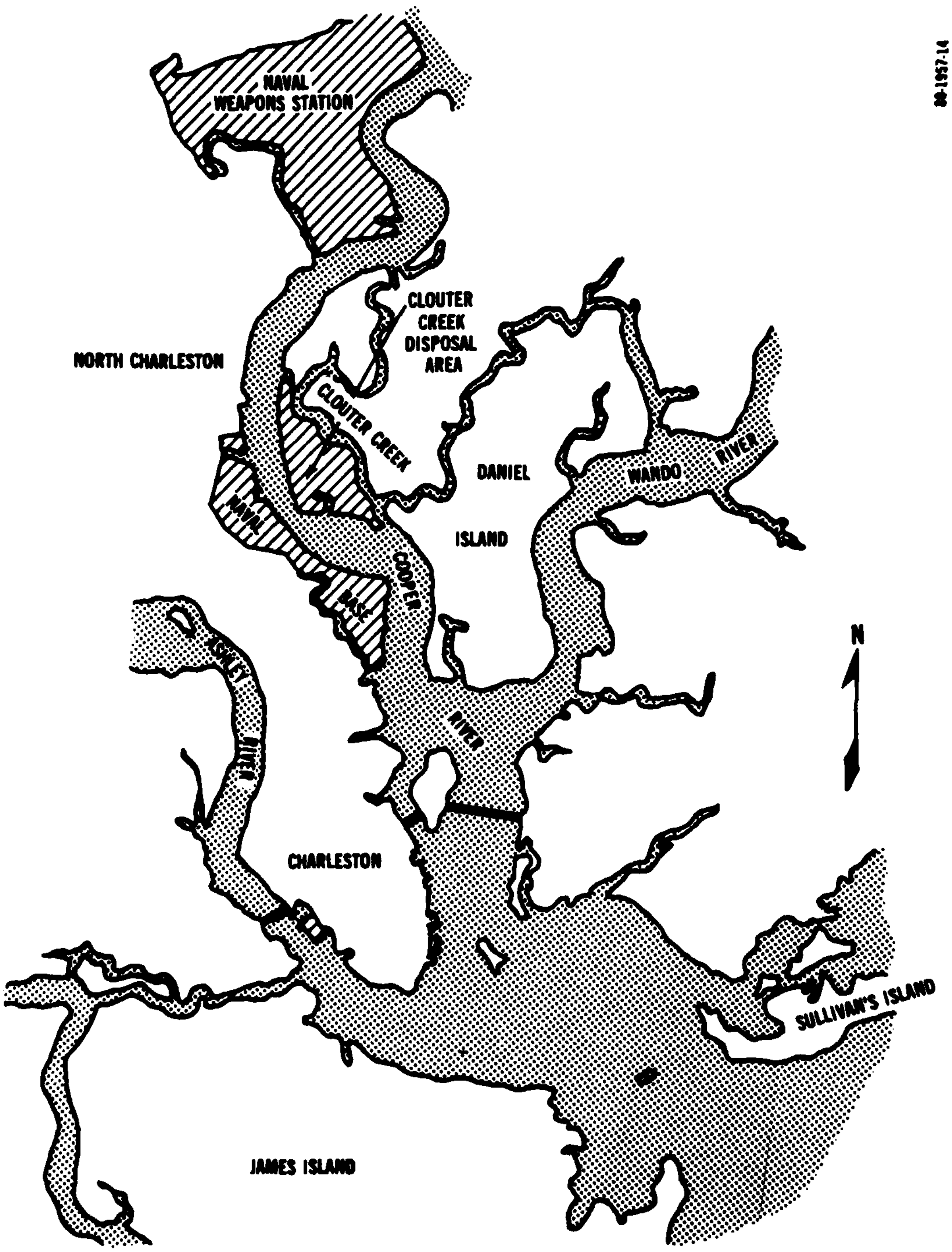

Figure 8-1. Location of the U.S. Naval Station and U.S. Naval Shipyard at Charleston, SC

The Naval Ammunition Depot channel extends from the head of the authorized commercial navigation project (vicinity of Goose Creek) upstream 3.5 miles. A channel for the U.S. Navy Noise Measurement Facility extends from the end of the NAD channel 1.0 miles upstream. Both of these channels have a project depth of 35 feet with variable widths. Numerous Navy slips, docks and piers are on the western side of the Cooper River. Nuclear submarines, based at one of the Navy docks, require a 35-foot channel.

8.2 SHIP MOVEMENT.

Listed in Table 8-1 are the berth dimensions and water depths at the U.S. Naval Station and the U.S. Naval Shipyard, Charleston, SC.

Ship movement according to estimates made by Blandford (1980) is as follows:

1. Spruance class - 100 moves per year
2. Submarines - SSBN - at least one move per day
3. Submarines - SSN - 70 moves per year.

With the exception of the TRIDENT, all types of submarines have been berthed at the Naval Station. The movement of submarines was considered as classified, however, and little further information was made available.

Berthing vessels at the Naval Facility requires considerable skill (Piner, 1980). The presence of a five-knot current at times and a narrow channel width of 600 feet requires berthing by docking pilots (U.S. Navy-civilian). Harbor pilots (civilian) bring the navy vessels from Sea Buoy 2C to the boundary of the Naval Station where docking pilots take the helm.

8.3 CURRENT VELOCITY.

Information contained in Fleet Guide - Charleston - Seventh Edith 1979 indicates that "In the approaches to Charleston Harbor, the most important water movements (surface) are rotary tidal currents. Nontidal currents are of little significance with the possible exception of currents associated with tropical storms or other high winds".

TABLE 8-1. BERTH DIMENSIONS AND WATER DEPTHS AT THE U.S. NAVAL STATION AND THE U.S. NAVAL SHIPYARD, CHARLESTON, SC

Naval Station

Pier	Berth Length[1]-ft North	Berth Length[1]-ft South	Depth[1]-ft North	Depth[1]-ft South
K	916	916	35	35[3]
L	740	740	35	35
N	1157	1126	35	35
P	1375	1375	35	35
Q	1037	987	35	35
R	670	670	30	30
S	561	534	35	35
T	561	534	35	35
U	570	555	20	20
M	1260	1260	35	35

Naval Shipyard

Pier	Usable Length	Depth Alongside
317F(J)	718	35
352(C)	1045	35
314(D)	1119	35
317B(F)*	835	30
317C(F)	871	30
317D(G)	902N 718S	35
317E(H)	718	35N 30S

* Fueling berth

Notes

1 Usable length along each side of the pier.
2 Feet at MLW. Subject to silting.
3 Fuel Pier utilized for Fueling/Docking Units.

Charleston harbor has a "semi-diurnal" tide. The tide has two nearly equal high waters and two nearly equal low waters during each lunar day. The mean range of tide, the difference in height between mean high and mean low water, within Charleston harbor approximates 5.0 feet. The spring range of tide throughout the harbor is approximately 6.0 feet at most locations. Extreme low water is 3.3 feet below Charleston low water datum (See Table 2-4).

When northeasterly winds or storms of long duration occur the mean range may be increased by 2 or 3 feet higher than predicted by Tide Tables, East Coast, North and South America. Tides higher than predicted result with southerly winds and falling pressure; tides lower than predicted result with westerly winds and rising pressure.

Shown in Figure 8-2 are the average surface current velocities for Charleston harbor. At ebb tide the average surface current velocity is 2.0 knots where the Cooper River enters Charleston harbor.

At another location, based on 95 current observations on 15 May 1975 made in the Cooper River during a spring tide range of 6.5 ft, the maximum ebb surface velocity in mid-channel was 1.33 m/sec (4.4 ft/sec or 2.6 knots) (Van Dorn et al, 1977). The location of these measurements is shown in Figure 8-3.

Figure 8-4 shows a 19-hour segment of the record from the fixed current meter that was located 1.5 m above the botton at the end of Pier G, together with the associated tide record. Both ebb and flood currents were very strong, the flood current attaining almost 1.2 m/sec (2.3 knots). Both the duration and maximum velocity of the flood phase are larger than the ebb, so that the integrated water flux at this depth is upstream. "Since the tidal flux must be equal in both directions, and the entire river has a net positive downstream flux equal to the fresh water runoff from all upstream sources, it is manifest that ebb predominance prevails in the upper layers of the Cooper, and flood predominance near the bottom" (Van Dorn et al, 1977).

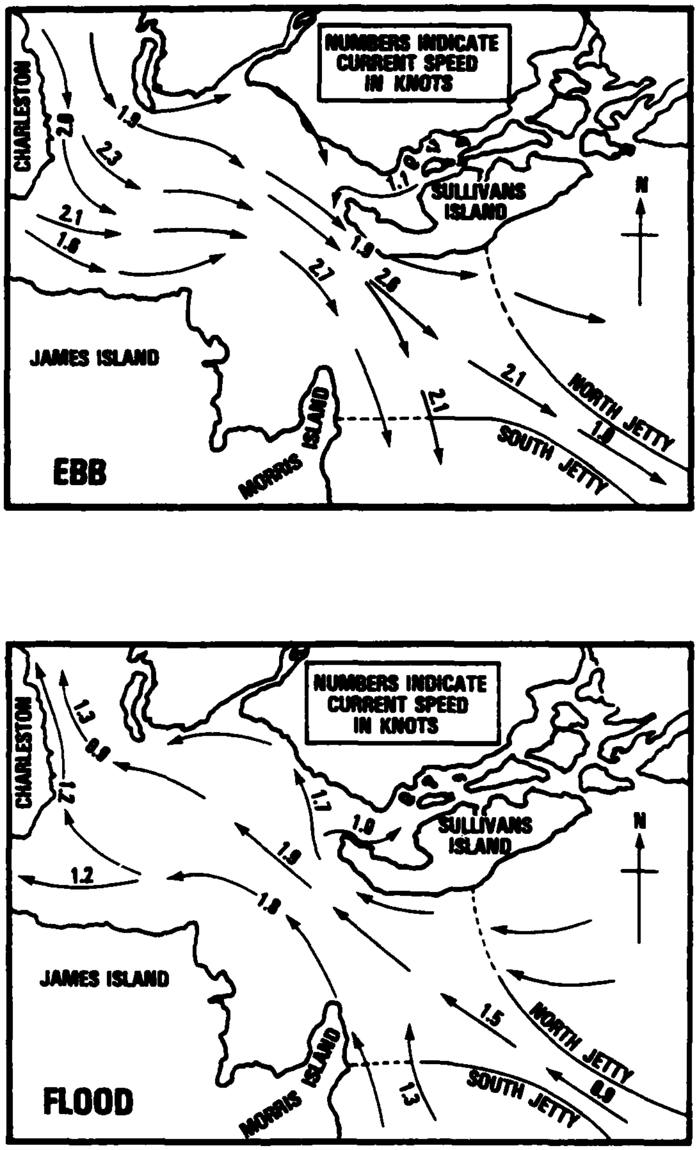

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Figure 8-2. Average Surface Current Velocities Due to Tides, Charleston, SC Harbor (Fleet Guide, 1979)

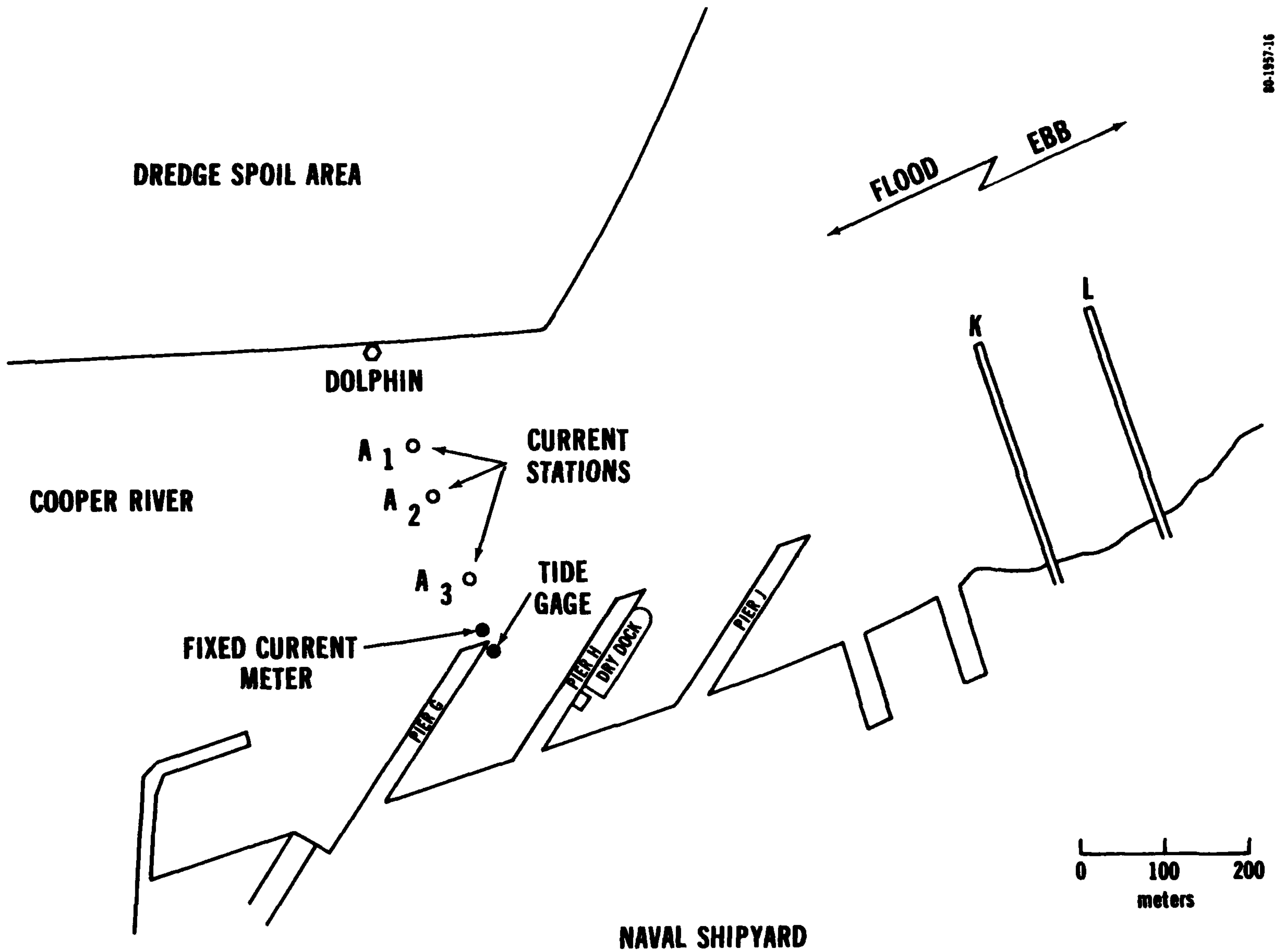
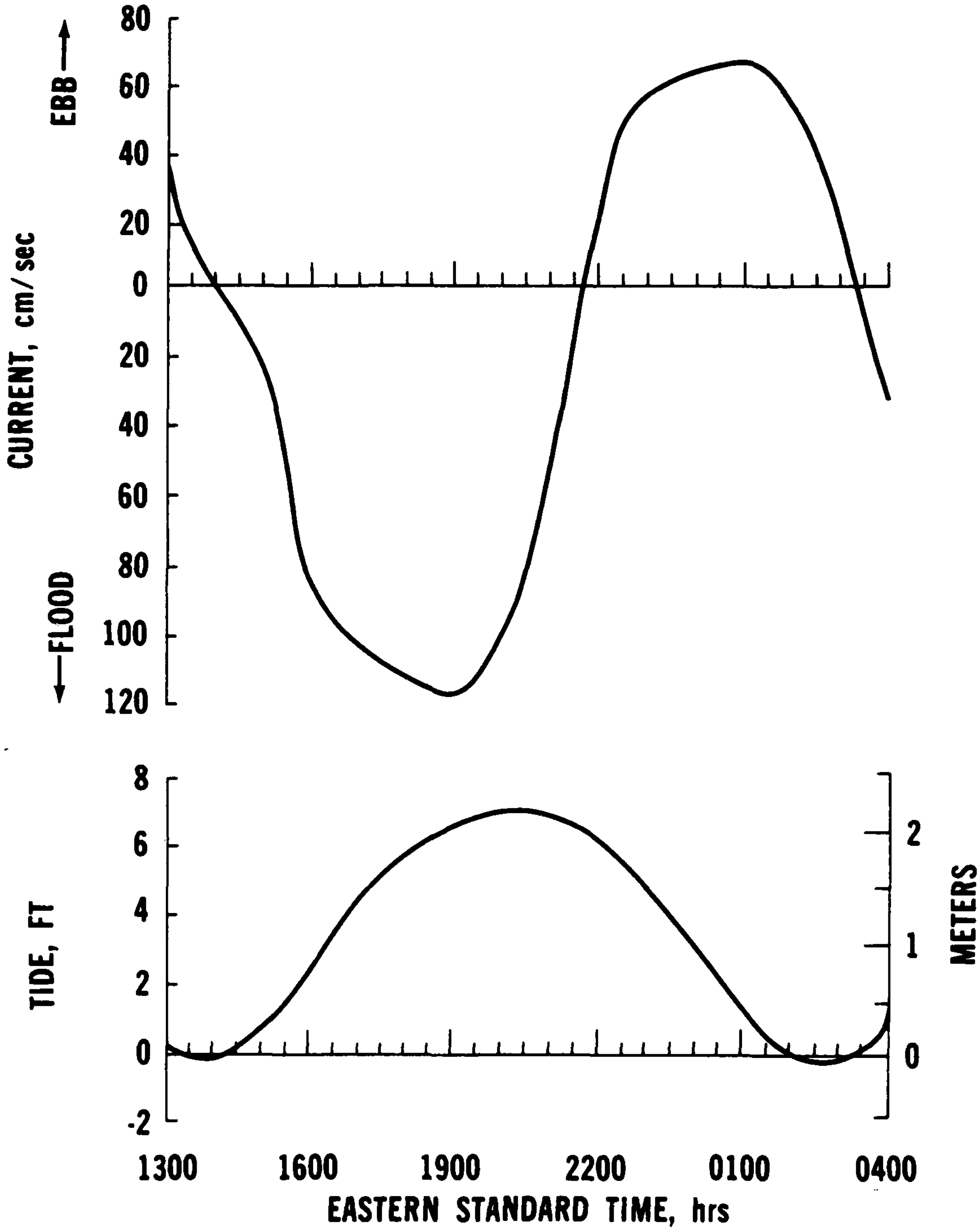


Figure 8-3. Location of Current Measuring Stations at the Naval Shipyard, Charleston, SC



NOTE:
SENSOR WAS 1.5 METERS (5 FEET) FROM BOTTOM.

Figure 8-4. Tidal Current at the End of Pier G on 15 May 1975

8.4 SHOALING RATE.

Beginning in 1942, a phenomenal increase occurred in the rate of shoaling in Charleston Harbor. Deposits of black muck material began to settle in the harbor. Large shoals began to form in the project channels. After removal by dredging they reformed quickly in the same locations so that frequent dredging became necessary to maintain project depths. Slips which were easily maintained before began to shoal rapidly to low tide level unless dredged. At some locations slips which had been dredged to full depth would refill in little over a year unless cleaned out. Specific areas of shoaling are discussed under the section entitled "Dredging".

Two physical changes affecting Cooper River had occurred just before the increased shoaling became evident. The Santee-Cooper hydroelectric project began operation in early 1942 and the navigation project depth in Cooper River was increased from 30 to 35 feet in 1941 and 1943. It was evident that the latter change could be of little effect for most of the project channel was naturally deeper than 35 feet prior to 1940. Further, model studies showed that deepening the navigation channels would have increased the shoaling by only 10% (all other factors remaining equal). Therefore, only the increase in the flow in the Cooper River could account for the marked change. It was thought at first that the condition might be temporary pending a period of adjustment but this proved not to be the case.

The annual volume of maintenance dredging in the Charleston Harbor area increased from less than 500,000 cubic yards prior to 1942 for the entire harbor to a current volume estimated to be more than 10,000,000 cubic yards. Total estimated costs to date in the period from 1942-1965 by the Corps for added maintenance dredging due to operation of Santee-Cooper project is in excess of $17,000,000. The total estimated cost incurred by the Corps of Engineers, the U.S. Navy and all others is in excess of $24,000,000 for the same period.

Studies of an hydraulic model of Charleston Harbor from 1947 to 1954 indicated that less than 0.3 percent of the increase in shoaling is attributable to the deepening of the channel in 1941-1942. The major part of the shoaling increase was found to be directly due to the operation of the Santee-Cooper power development which increased the average mean fresh-water discharge in Cooper River from 72 cfs at Pinopolis to 15,000 cfs. Pinopolis hydroelectric station is about 46 river miles above Charleston Harbor. The model revealed that the effects of the fresh-water flow were (a) to create a predominate flood flow condition at the bottom of the channel thus preventing the stream from discharging its load to the sea; and (b) to greatly increase the amount of colloids and dissolved solids available to shoal the harbor.

An analysis of the quantitative study of the sources of shoaling resulted in the following findings: (a) that the Santee-Cooper project is responsible for about 85 percent of the present shoaling within Charleston Harbor, the other 15 percent being that which would occur without Santee-Cooper; (b) that "new" sediment entering the harbor and navigation project is equal to about 58 percent of the total subject to dredging. About 40 percent of this "new" sediment passes through the penstocks at Pinopolis Dam, 33 percent results from pickup in the Cooper River above the head of navigation, and the remaining 27 percent is considered "background" sediment. "Background sediments" are sediments which are believed to have occurred prior to the diversion of the Santee River and which would occur naturally even under reduced flow criteria. In the sediment budget phase of the study it was determined that the sources listed above and directly identifiable with the Santee-Cooper diversion accounted for only 43 percent of the total volume presently subject to initial deposition within the navigation project. Fifteen percent of the total is chargeable to background. Forty-two percent is termed as "runback." "Runback" is defined as that part of the shoaling which stems from previously dredged materials, but which returns to navigation channels and must be rehandled, plus those resuspended sediments originally deposited outside the navigation channel which are redeposited within the channel (Corps of Engineers, 1966).

Shoaling rates in Charleston Harbor vary from year to year. The most significant factor influencing these rates is the fresh waters diverted into the harbor by the Santee-Cooper Hydroelectric Project. In comparing inflow rates and dredging rates it is readily apparent that dredging necessary to maintain navigability increases as the discharge into the Cooper River at the Pinopolis Hydroelectric Powerplant increases.

In order to alleviate the problem of shoaling 80 percent of the flow in the Cooper River is to be rediverted into the Santee River.

Construction of the necessary facilities is presently underway with a completion date scheduled for late 1983. When rediversion is utltimately in effect, a reduction in releases from the present Pinopolis hydro-electric plant will occur, resulting in reduced freshwater flow in the Cooper River. This will be accompanied by an upstream incursion of saline waters. The distance of incursion under all combinations of tide, streamflow, and external conditions is not precisely known. (South Carolina Water Resources Commission, 1979). The effect of the diversion on dredging is discussed in that section.

8.5 SUBMARINE SEDIMENTS.

Studies of Charleston Harbor bottom sediments made by the Charleston District of the Corps of Engineers (1976) indicates that several major sediment types have been deposited within the Charleston estuary. These include a longshore drift and continental shelf sand component being deposited over the major part of the estuary itself, and Holocene sand bars present within the landward rivers. The longshore drift shelf sand is concentrated both in the vicinity of the harbor mouth where it grades seaward into continental shelf sands as well as along the north half of the estuary to the vicinity of Mt. Pleasant. Bottom samples obtained in the vicinity of the jetties and landward between Ft. Sumter and Ft. Moultrie contain over 90 percent sand size materials. Landward of these locations the sand fraction is intermixed with silt and clay increasing abruptly toward the west and more gradually toward the north.

Sand also occurs in bottom sediments in the Wando and Cooper Rivers. The accumulations here are related to Holocene and recent channel deposits. In the Ashley River, similar deposits occur at depth, but surficially are buried by recent silt and clay.

Between the two sand components the floor of the estuary is covered by dark-gray sludge composed of more then 75 percent silt and clay. Within the area of occurrence of the sludge there is no apparent relationship between physical size characteristics, water depth, and harbor currents. It is assumed that the silt-clay fractions are present in flocculated state such that their aggregated masses behave physically as much coarser particles.

Review of test borings made for various pier extensions indicate that the sediments described above are underlain by thin layers of sand and silt. These layers in turn are underlain by marl (calcareous clay) which seems to be underlating but continuous. This marl appears to be hard and forms a good foundation for seating piles (Butler, 1980).

8.6 DREDGING.

Dredging in the pier slips of the Charleston Naval Station and Naval Shipyard is accomplished by means of the Navy-owned and operated dredge "ORION". The "ORION" is a hydraulic cutterhead dredge with a 20-inch diameter suction line and a 16-inch diameter discharge line. The depth maintained is essentially 35 feet below Mean Low Water. The frequency of dredging and target depths are shown in Figure 8-5.

The spoil resulting from dredging is pumped through either of two pipelines which lie at the bottom of the Cooper River to the Clouter Creek disposal area. This is shown in Figure 8-1. The average volume of spoil dredged annually is 2,700,000 cubic yards. Show in Table 8-2 are the figures for the annual dredging in the period 1942 to 1965. These appear to be a little lower than the above-mentioned average that is recurrent in the reports.

The Naval Shipyard dredge "ORION" is staffed and maintained by the Maintenance Department. Accurate records are maintained on all dredge-related costs and are summarized (for the period 1975-1978) in Table 8-3.

The navigation channel in that portion of the Cooper River abutting the naval facilities is maintained to a depth of 35 feet below Mean Low Water by the Corps of Engineers by means of an hydraulic cutterhead dredge. Detailes concerning the dredging frequency and target depths are shown in Figure 8-6. The dredge spoil, which is pumped to either Clouter Creek disposal area or Yellow Creek disposal area, amounts to about 1,300,000 cubic yards annually.

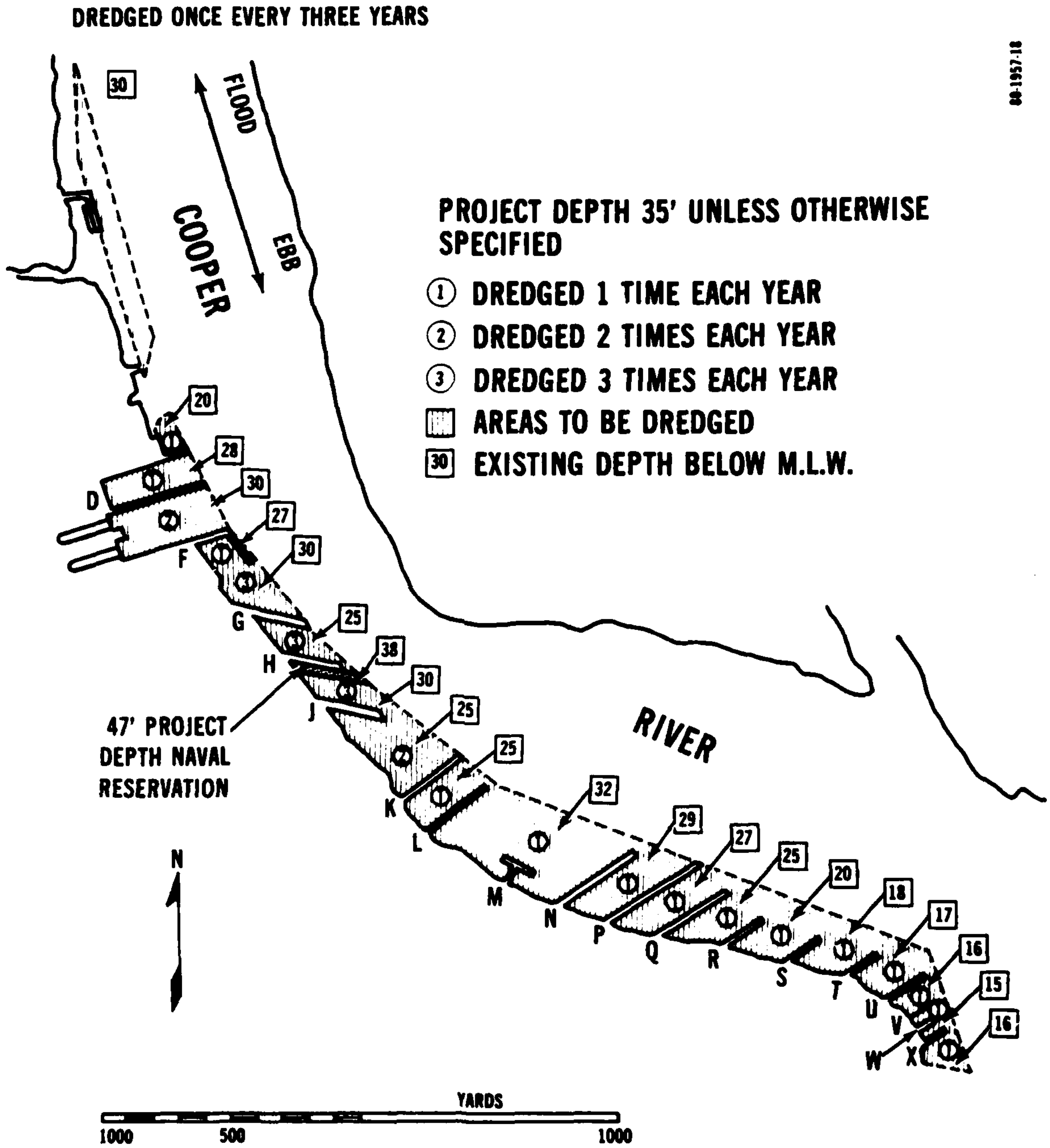


Figure 8-5. Areas Dredged by the U.S. Navy In and Around Navy Piers and Slips

TABLE 8-2. MAINTENANCE DREDGING AT THE U.S. NAVAL STATION AND THE U.S. NAVAL SHIPYARD AT CHARLESTON, SC FOR FISCAL YEARS 1942-1965 (CORPS OF ENGINEERS, 1966)

Fiscal Year	Navy Channel (by COE)	Navy Slips (by Navy)
1942		367,000
1943		441,120
1944		514,640
1945		588,160
1946		661,680
1947		735,200
1948		808,720
1949		882,240
1950		955,760
1951		1,029,280
1952		1,029,280
1953	500,000	1,029,280
1954	1,470,875	1,029,280
1955	-	1,102,800
1956	-	1,176,320
1957	-	1,249,840
1958	-	1,323,360
1959	-	1,396,880
1960	1,538,337	1,470,400
1961	1,241,590	1,543,920
1962	434,407	1,617,440
1963	407,000	1,690,960
1964	1,008,875	1,764,480
1965	1,976,524	1,764,480

TABLE 8-3. SUMMARY OF NAVY DREDGING COSTS, 1975-78

	Cubic Yards Dredged	Total Operating Expenses	Cost Per Cubic Yard $
1975	2,700,000	$ 680,871.25	.25
1976	2,700,000	$ 857,006.95	.32
1977	2,700,000	$ 860,833.63	.32
1978	2,700,000	$1,167,268.07	.43

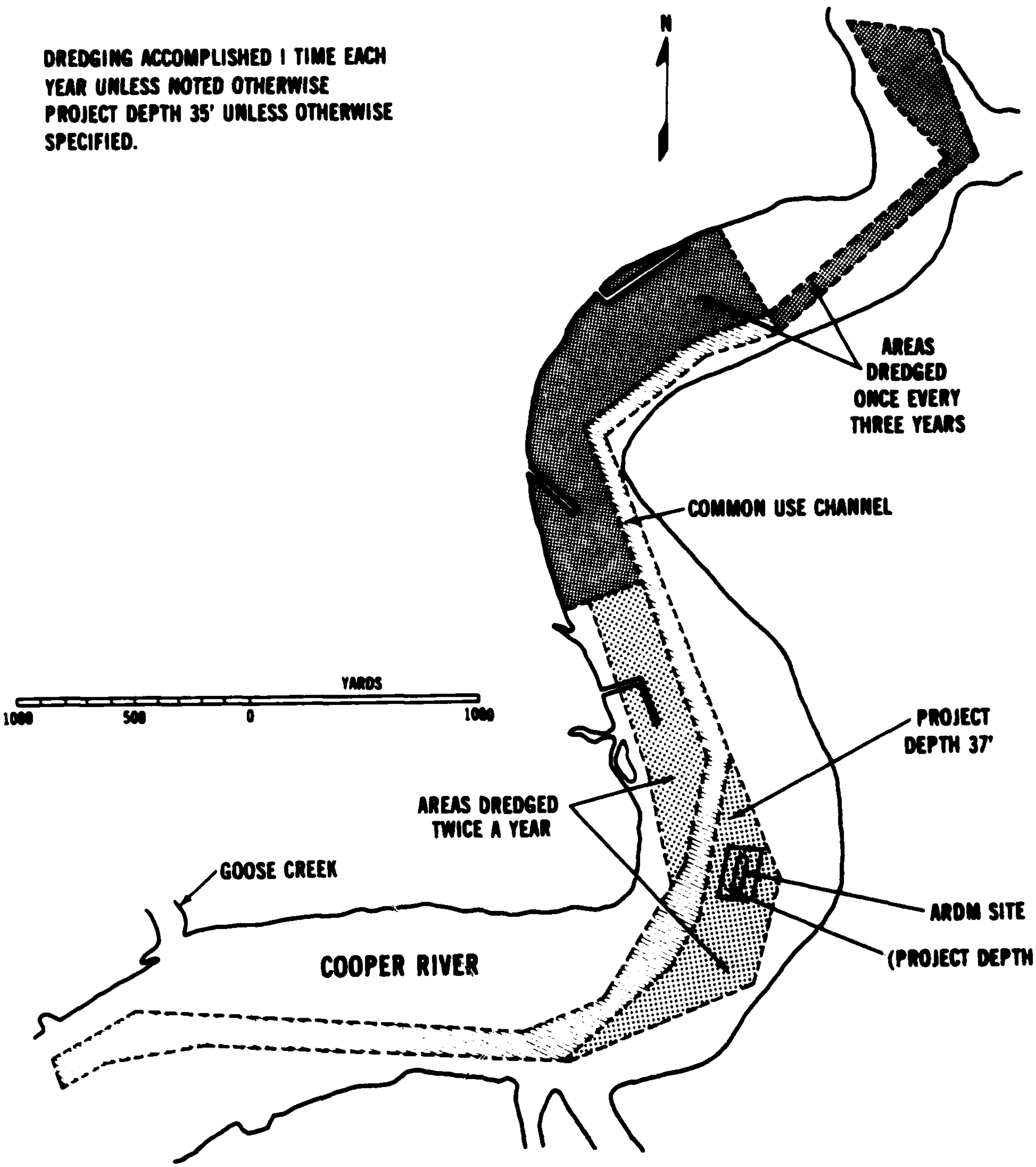


Figure 8-6. Cooper River Channel in the Proximity of the Naval Facilities Maintained by the U.S. Army Corps of Engineers

The estimated decrease in dredging as the result of the rediversion of the waters of the Santee River is shown in Table 8-4. It should be noted that the present U.S. Navy dredging requirements are reduced to a little more than one-third of the present requirements. This may not be an unmixed blessing for as the silt load decreases and the salinity moves further up the Cooper River biofouling and other aquatic biological problems may be initiated or intensified.

8.7 <u>DREDGE SPOIL DISPOSAL</u>.

Prior to the advent of heavy shoaling, spoil from maintenance dredging was placed in deep water areas of the harbor convenient to the site of dredging. This practice continued after the rapid increase in shoaling until it became evident that much of the spoil remained in suspension for a time and drifted back into the channels. A policy of diking land areas for the containment of spoil was established to reduce this process and thereby save costs.

Presently, dredge spoil from the Navy facilities is pumped to the downriver end of the Clouter Creek Island from two discharges positioned 2,000 feet apart. The location of these pipelines is shown in Figure 8-7. The Corps of Engineers, in conjunction with the Navy, has divided the disposal area into two sections by means of a dike.

Where practical, earth moving equipment is used to direct the discharge flow by digging flow diversion canals. The consistency of the pumped mud is such, however, that the earth moving machinery readily "bogs" down and cannot penetrate appreciably into the disposal area. Consequently, a buildup of material in the area of the two discharges has resulted.

Drainage of the water from the spoil is important for spoil consolidation. Tests by the U.S. Army have included trenching of the surface with mechanical digging equipment and a towed disc wheel. A synthetic drainage pipe has also been buried in dredged sediments. Inspection of the disposal site indicates that the disposal area used by the Corps is better drained than the area used by the Navy (Battelle Institute, 1979). For this reason a coordinated drainage effort is needed between both the Army and the Navy since the Army's land area can be adversely affected by uncontrolled drainage from the Navy's site.

TABLE 8-4. COMPARISON OF THE ESTIMATED AVERAGE VOLUME OF SPOIL TO BE DREDGED ANNUALLY FROM THE COOPER RIVER AFTER REDIVERSION WITH THAT PRESENTLY DREDGED ANNUALLY. FOR AVERAGE FRESH WATER IN-FLOWS OF 3000 CFS AND 15600 CFS RESPECTIVELY

Shoal Reach	Expected Annual Dredge Spoil cubic yards 15,600 cfs	3,000 cfs
Noise Measurement Facility	120,000	37,000
Naval Ammunition Depot Channel	840,000	250,000
Goose Creek	36,000	17,000
Charleston Harbor:		
Shoals 1 & 2	414,020	39,370
Shoal 3	78,240	7,440
Shoal 4	221,680	21,080
Shoal 5	74,980	7,130
Shoal 5A	736,760	70,060
Shoal 6	117,360	11,160
Shoal 6A	638,960	60,760
Shoal 6B	71,720	6,820
Shoal 6C	534,640	50,840
Customhouse Reach	143,440	13,640
Tidewater Reach	228,200	21,700
Navy Slips and Docks	3,000,000	1,220,000
Shipyard River	790,000	370,000
Other Slips and Docks	130,000	53,000
Shem Creek	2,000	1,000
Anchorage Basin	720,000	210,000
Entrance Channel	1,250,000	500,000
Total	10,148,000	2,968,000

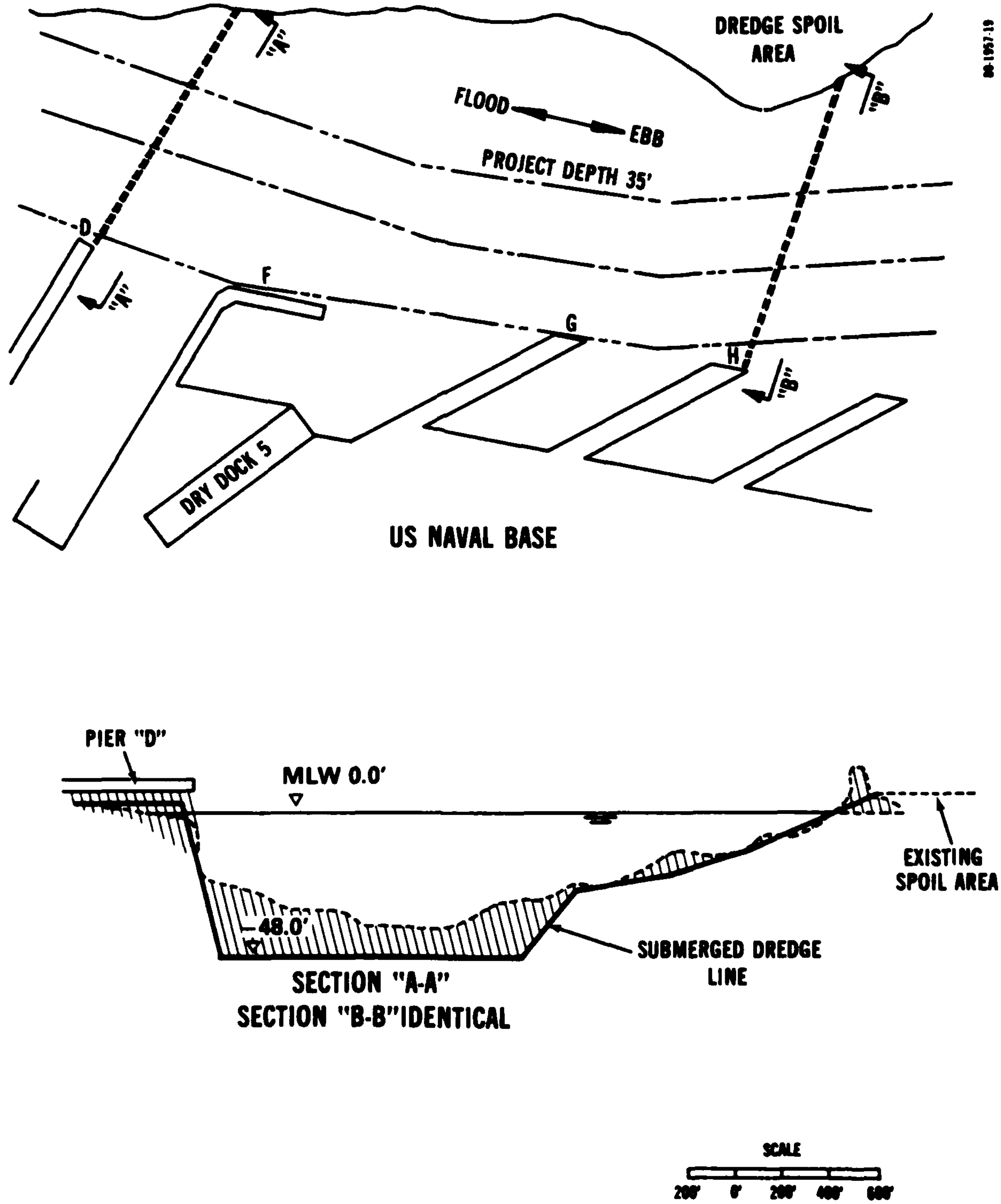


Figure 8-7. Location and Profile of Pipelines for Transferring Dredge Spoil to Clouter Island Disposal Area

Studies have indicated that the usefulness of Clouter Creek Island as a spoil disposal area is relatively short lived (Battelle Institute 1979). A site that may be a possible alternative is the abandoned Antenna Range. The site is quite small (125 acres) when compared to the Clouter Creek site. The costs of preparation for use must be carefully related to its limited size. Major cost considerations will include; construction of a ± 7,000 ft. discharge line from Pier X to the disposal site; constructing new perimeter dikes; installing new spillways; clearing some or all abandoned antenna equipment; and, operating with heavy tree growth, or taking steps to flatten the trees and internal topography.

Based upon the guidance of the Engineering Division, Public Works made an initial survey of the area. Two traverses were established and profiled. The topography of the site varies from heavily wooded with trees of up to a foot in diameter, to open flat areas and boggy swamps. Except in areas of old dikes the elevation lies between 12 and 14 feet. For estimating purposes a 13 foot elevation can be used.

The site extended to its fullest potential could contain 125 acres. Dikes ranging from 6 to 11 feet or more would be required to establish a top of dike profile of 20 foot elevation.

Setting dikes back from view approximately 100 feet to provide a "green belt" would be aesthetically advisable and the use of low lying wetland in the most southern tip should provide one million cubic yards of spoil capacity. To gain this mission cubic yard capacity will require construction of 11,000 ft. of retaining dike and some 7,000 ft of 16" dredge line from Pier X to a suitable discharge location at the disposal site. At least two spillways would also be required.

A preliminary estimate for dike construction at $4.00 per linear foot would be $40,000.00 to $45,000.00. Cost of placing 16" dredging line at $104 per foot for a distance of 7,000 ft. would create an expenditure of $728,000.00. Spillway costs are estimated at about $12,000.00. The costs are based on current costing for Corps of Engineers dike and spillway construction and Navy's present pipelaying costs (Battelle Institute, 1979).

On this basis an overall cost of $785,000.00 would be made to gain a containment capacity of 1,000,000 cubic yards.

8.8 PROBLEMS.

The two main problems related to dredging in the Charleston naval facilities are the dredging costs and the availability of areas for the disposal of dredge spoil. The volume of spoil should be decreasing during the 10-year period after the rediversion of the Santee River, now considered to take place in 1983 (Corps of Engineers, 1966). Accompanying this should be a decrease in dredging costs providing the influence of inflation is not a predominating feature.

The availability of disposal areas, however, may be a cause for concern. This problem from a Navy standpoint should be evaluated thoroughly from both the standpoint of expected annual volume, consolidation of spoil in the disposal area, and the volume available for future use. Although the amount of dredge spoil will decrease with the rediversion of the waters of the Santee River the need for dredging in navy facilities will continue.

8.9 RECOMMENDATIONS.

Inasmuch as the major problems of the Charleston Naval Station and Shipyard are connected with the rediversion of the Santee River it is recommended that:

1. An accurate record of soundings be kept after the rediversion and the effect of the rediversion on the Navy's dredging problem be evaluated.

2. Potential dredge spoil disposal areas be investigated more thoroughly.

3. Investigate the feasibility of consolidating the spoil at Clouter Island and constructing a new dike upon the existing spoil.

4. Investigate the feasibility of using a system of water jets to flush the sediment in pier slips into the main channel. This has been used successfully at the Mare Island Shipyard in the San Fransisco Bay area.

5. Investigate the feasibility of resuspending the sediment within a pier slip using air bubbles at a time when the ebbing tidal currents are at a maximum.

6. The biological effects be investigated of the increase in the salinity and decrease in suspended particulates in the Cooper River from the standpoint of creating problems for the naval facilities.

7. Investigate the feasibility of establishing an array of current meters with read outs in the Port Services Office in order to determine the current variation in various piers and in the channel. Tabulation of the information with time would be of assistance to the harbor pilots as well as to captains who feel that they wish to berth their own vessels.

SECTION IX

GENERAL RECOMMENDATIONS

Recommendations concerning each deep-draft harbor investigated have been made in the section concerning the individual harbor. However, certain recommendations involve all the harbors considered. These are listed below:

1. A feasibility study should be made as to the use of an air bubble screen parallel to the longitudinal axis of the berth to control sedimentation in a berth (see pages 2-32 of this report).

2. Convert the datum used to relate the depth of a berth from Mean Low Water or Mean Lower Low Water to Extreme Low Water. The mean is derived from some values less than the mean and some values greater than the mean. Extreme Low Water is the lowest value observed in a period of years and is a relatively stable datum.

3. A uniform U.S. Navy-wide system should be adopted for the periodicity of sounding water depths in a berth to determine the need for dredging. Data should be recorded on a standard form using a standard procedure.

4. A study should be made to determine the frequency of occurrence of stages of water levels in the harbor below the MLW or MLLW datum.

5. A feasibility study should be made of deepening the berth to a depth greater than design depth to increase the time interval between dredgings.

6. A feasibility study should be made of optimizing the dredging of all berths within the naval facility in a given time period incurring one mobilization and demobilization cost and obtaining a lower unit cost because of the larger volume of dredging.

7. A log should be kept by the Public Works Officer at each naval installation reporting all groundings with information as to time, date, exact stage of tide, and conditions under which the groundings took place. The stage of the water level should be from the instrument record and not from the Tide Tables.

8. An investigation into the advantages and disadvantages of an in-house dredging capability at each naval facility based on the experience of the Naval Station at Charleston, SC and the Mare Island Shipyard.

SECTION X

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Appendix A

Questionnaire
for the Investigation
of Berthing Problems

APPENDIX A

Source of Info:

QUESTIONNAIRE
FOR THE
INVESTIGATION OF
BERTHING PROBLEMS

__________ Naval Base

__________ Date

A. SHIP MOVEMENT

1. Types and classes of ships berthed: together with Pier assignments?

2. Is (are) there any change(s) anticipated in the types and classes of vessels to be berthes? If so, what changes and when?

3. Frequency of arrivals (a) and departures (d) by types and classes (for as long of a time period as possible).

4. What is the complete plan for berthing:

   a. aircraft carriers?
   b. nuclear submarines?
   c. AOE's?

5. Problems involved in berthing together with dates of occurrence:

6. Has biofouling or bioclogging of the cooling water intake taken place? If yes, cite individual cases and dates.

7. What special port conditions enter into the berthing procedure.

8. Other.

B. CONSTRUCTION OF PIERS CONCERNED (include elevation of lower end of piles and elevation of bottom of berth)

C. DREDGING

1. Amount of maintenance dredging (by years) at each slip of a deep draft vessel, including submarines, or for the turning basin. Include also frequency of dredging.

2. Depth of water below mlw or mllw (other datum-specify)_______________ in each pier slip concerned:

Pier Slip	Before Dredging-ft	After Dredging-ft

3. Method of dredging both berths and channels. Specify by berths, if available. Is (are) the method(s) satisfactory?

4. Place and method of spoil disposal.

5. Any future new dredging anticipated?

D. TIDES AND CURRENTS

1. Tidal range and stages (extremes) related to _____________ datum.

2. Interrelationship of various pertinent datums.

3. Velocity of currents, ebb and flood, bottom, mid, and top if known. Measured by whom, date, and point(s) of measurements.

E. SEDIMENTATION

1. Are test borings for pier slips, piers, and navigation channel available? If yes, where? Obtain copies.

2. Type of sediment in pier slips, channel?

F. POLLUTION OF WATER and Sediments in Berthing or Turning Basin Area (Obtain reports and analyses where possible)

Appendix B

Additional Information on the Annual Volume of Dredging at the U.S. Naval Station, Norfolk, VA

APPENDIX B

Additional Information on the Annual Volume of Dredging at the U.S. Naval Station, Norfolk, VA (Litte, 1976)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
2/11/28	end 10/10/29	On Land Adj. Adj. Shoreline	50,000 cyd*, NOB,† Willoughby Bay
11/24/29	12/24/29-5/5/30	Offshore South of Thimble Shoal	670,480 cyd, Pier 7, NOB (to 40 ft. MLW)
4/1/32	5/17/32-8/29/32	As Above	332,000 cyd. Pier 7, NOB
3/16/34	4/9/34-6/21/34	Chesapeake Bay Dump	240,000 cyd, Pier 7, NOB
11/20/34	1/16/35-4/12/35	As Above	325,000 cyd, Piers 2 & 3, NOB
2/2/26	4/2/36-6/29/36	As Above	303,617 cyd, Pier 7, NOB
4/26/37	7/1/37-8/16/37	Offshore Chesapeake Bay	300,000 cyd, Piers 2 & 3, NOB
4/27/38	end 10/31/38	Onshore at Lagoon Outside Willoughby Bay	340,000 cyd, Pier 7 NOB

* cyd = cubic yards
† NOB = Naval Operations Base

APPENDIX B

(Continued)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
6/8/38	4/38	On Land - 75,000 cyd. Rem. Dumped S. End of Lagoon (as above)	210,000 cyd, Pier 2 & 3 250,000 cyd, Pier 7, NOB
5/10/40	6/10/40-9/13/40	Offshore Dump Chesapeake Bay	181,495 cyd, Piers 3 & 7, NOB
10/29/40	11/20/40-5/23/41	Offshore Dump Willoughby Bay	750,000 cyd, Pier 7, NOB
2/24/44	3/4/44-3/28/44	On Land, NOB	200,000 cyd, N. of Pier 2, S. of RR Piers, NOB new 40' MLW Channel
6/25/45	7/9/45-10/23-46	As Above	500,000 cyd, Piers 2, 3, 4, 5 & 7, NOB
7/8/49	9/12/49-10/26/49	Scow Dump As Above	155,680 cyd, Pier 7, NOB, bucket dredge (to -40 ft.)
6/19/50	1950	NK	300,000 cyd, Willoughby Bay, Nav. Air Stn, and Convoy Escort Piers 21, 22, 23

APPENDIX B

(Continued)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
9/5/50	1950	Offshore Hampton Roads Nr. Fort Wool	160,000 cyd, Bet. Piers 5 & 7, NOB
1/16/53	1950	NK	474,800 cyd, Approach and Piers 20,21,22, 2, 3, 5 & 7, and Lagoon (now small-boat basin)
9/6/55	end 7/25/56	Chesapeake Bay No. Cape Charles	656,800 cyd, Bucket and Hopper Dredges, Approaches and Bet. Piers 2, 3, 4, 5 & 7, NOB
7/22/57	start 7/24/57	Scow Dump to Craney Island rehandling basin and/or off-shore Cape Charles in Chesapeake Bay	35,000 cyd, Pier 23, NOB (to -30 ft. MLW).
2/24/44	3/4/44-3/28/44	On Land Disposal NOB	200,000 cyd, N. of Pier 2, S of RR Pier (to -40 ft. MLW)
5/19/58	1958	Scow Dump Craney Island rehandling basin	260,000 cyd, Bucket Dredge, Pier 12, NOB (to -40 fet. MLW)

APPENDIX B

(Continued)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
10/31/58	11/27/58-12/24/58	Scow Dump As Above	105,000 cyd, Bucket Dredge, S. of Pier 12, NOB
1/19/59	start 3/2/59	Scow Dump As Above	48,173 cyd, Pier 23, NOB; 7.393 cyd. Pier 21, NOB; 88,734 cyd, Pier 20, NOB; bucket dredge
5/19/60	8/11/60-11/19/60	Scow Dump Craney Island Rehandling Basin	186,000 cyds, Pier 12, NOB, bucket dredge
2/28/61	Start 8/1/61	Direct hydraulic pump out to Craney	500,000 cyd, Pier 22, NOB (to -33 ft. MLW), hydraulic dredge
2/23/62	1962	Dump Scow and Direct Pipeline to Craney Island	697,000 cyd, Piers 4, 5 & 7: 334,000 cyd, Pier 12, NOB: hydraulic and bucket dredges
1/8/63	3/2/63-6/13/63	As Above	497,630 cyd, Piers 2, 5 & 7: 104,750 cyd, Pier 22, NOB: hydraulic and bucket dredges

APPENDIX B

(Continued)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
7/6/64	start 7/20/64	Dump Scow Craney Island	371,000 cyd, Piers 2, 3 & 4, NOB, bucket dredge
6/3/65	1965	Dump Scow and Direct Pump Out Craney Island	912,000 cyd, D&S Piers 20, 21, 22, 23, NOB
1/25/68	2/27/68-6/40/68	As Above	665,000 cyd, Piers 2, 3, 4, 5, 12 & C, NOB hydraulic and bucket dredges
1968	8/68-9/68	Craney Island Direct Pipeline	113,000 cyds, maintenance dredging, Elizabeth River
1968	9/68-12/68	As Above	670,000 cyds, maintenance dredging
1969	10/69-1970	Craney Island Dump Scow	85,000 cyds, D&S Piers, and Piers 2, 5, 7 & 12
3/11/70	1970	On Land Fill N. of Pier 12, NOB	Reclaim 21 acres of land at Nav Air Stn, N of Pier 12
1970	start 6/70	Craney Island	203,325 cyds, both sides of Pier 12

APPENDIX B

(Continued)

Date Permit Application	Period of Dredging	Spoil Disposal Site	Dredging Details
1972	start 6/72	Craney Island	240,000 cyds, Piers 2, 3 & 22
9/11/73	1973/1974	Direct Pump Out and Dump Scow Craney Island	700,000 cyds, maintenance work Piers 20, 21, 22, 23, 2, 3, 4 & 5, and Service Craft Basin, NOB, bucket and hydraulic dredges
1/31/74	1974	Direct Pump Out to Craney Island	123,000 cyds, S/S Pier 2 (to -35 ft.) NOB, hydraulic dredge
7/15/74	1974	Dump Scow Craney Island	33,000 cyds, Fleet Landing Facility, small-boat channel (to -8 ft.), also extension of breakwater, NOB
8/13/74	1974	Direct Pump Out to Craney Island	76,000 cyds, maintenance work (to -45 ft.), channel and floating dock facility, NOB

Appendix C

Excerpts from "Notes on the Biology of the *Sertularia argentea*"

APPENDIX C

Excerpts from "Notes on the Biology of the Sertularia argentea" by David Hancock, R. E. Drinnan and W. N. Harris, 1956

"In recent years in Great Britain a fishery has developed for certain hydroids collectively termed 'white weed'. The hydroid Sertularia is raked up from the sea-bed, processed, dyed and used, largely in the United States of America, for decorative purposes. Fishing for white weed is not new, it was practiced in Germany between the wars. German scientists examined various aspects of the fishery, and of the biology of the hydroids concerned."

"The main center of the industry is the Thames Estuary, where the hydroids grow in extensive beds, on a bottom of sand and shells, on which the weed can be fished commercially by boats equipped with simple iron rakes."

"Sertularia and other hydroids provide a satisfactory habitat for a number of free and fixed epizoic forms. Most often associated with Sertularia are encrusting bryozoans, which may cover stems, branches and even gonothecae, obviously in some cases with harmful effects. One colony of length 510 mm was found to be covered from 40 to 240 mm. Up to 85 percent of the colonies in a sample of white week taken from the Maplin Sands in August 1953 carried encrusting Bryozoa. A thickly encrusted main stem is often devoid of side branches, and shows the effects of severe competition and suffocation. The settlement of Bryozoa reduces the commercial value of white weed."

"To a lesser extend encrustation by other hydroids also occurs. Where present they often form a dense covering as do some peritrichous ciligates."

"The larvae of several bivalves find a suitable settling place in fronds of white weed, which may be found with many thousands of notilid spat on their branches. Sertularia taken from Fleetwood in August 1954 was in such a condition, and these accumulations of developing bivalves must be of great interest to demersal fish. From the Maplin Sands samples, the largest numbers of bivalve spat were taken in July."

"It is questionable whether any of these animals feed directly on Sertularia. At certain times of the year the lower parts of the older colonies are devoid of branches. This might be due to the feeding of some predator. However, denuding of side branches is almost always confined to the lower part of the stem, and is more likely to be due to the annual decline of the colony towards the end of the year when the lower branches are shed."

"Colonies have also been taken regularly in which only the bases of certain side branches remained, covered by Bryozoa, while other branches were intact. Where a bryozoan was present at the base the rest of the branch was dead. This would also contribute towards the loss of side branches."

"Of twenty flatfish taken from a whiteweed bed at Fleetwood in August 1954, only two dabs contained isolated fragments of Sertularia, which were among vast quantities of mussel spat in the stomach. The heavy settlement of mussel spat on Sertularia has been mentioned previously and the presence of the Sertularia was believed to be incidental."

"Hunt (1925) took fragments of hydroids from the stomach of Leander, and Mistakidis (in press) has recorded occasional fragments of Sertularia from Pandalus."

"Harrison (1944) mentions that several observers have maintained that caprellids feed on hydroids and algae, but that such an occurrence is probably exceptional. He found that caprellids fed on copepods and nauplii from the plankton. During frequent observations made by the writers caprellids were observed feeding in the manner suggested by Harrison and did not take Sertularia."

"*Idulia* has not been observed feeding, but Browne (1907) has described the intensive feeding of *Tergipes* on *Synoryne*."

"It is considered unlikely that the exploitation of white weed can be substantially detrimental to commercial fisheries, while many fisherman believe that the constant harrowing of the sea-bed by the rakes is beneficial to the development of benthos generally, and of assistance to many fish during feeding."

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dredging; dredges; sedimentation; siltation; shoaling; sediment control; sediment transport; dredge spoil disposal; environmental impacts.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Described in this report are the results of a detailed investigation of shoaling in the pier slips and associated waterways of six deep-draft harbors used by the U.S. Navy. These are the Naval Air Station at Alameda, CA; the Naval Station and Naval Shipyard at Charleston, SC; the Naval Station at Mayport, FL; the Naval Station at Norfolk, VA; the Naval Air Station at Pensacola, FL; and the Naval Air Station North Island, San Diego, CA. In addition to shoaling, the bioclogging of the screens of aircraft carriers' "sea chests" →

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20. (Cont'd). at Norfolk, VA was investigated. Tidal extremes for the subject harbors were updated to the latest information available from the National Ocean Survey. Methods of dredging commonly used to dredge pier slips are described together with less-frequently used methods that have been used in slip maintenance. The problem of offshore as well as onshore dredge spoil disposal is addressed. Included are discussions on the use of the elutriate test, the bioassay, and the in-situ bioassay in determining the toxicity of the dredge spoil. A section in the report addresses methods of sediment control. Information in this report based on interviews and other research is contained in sections entitled: Ship Movement, Current Velocity, Elevations of Bottom Tips of Pilings, Shoaling and Shoaling rate, Submarine Sediments Dredging, Dredge Spoil Disposal, Problems, and Recommendations. In addition to recommendations for specific Naval installations, eight general recommendations are made.

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