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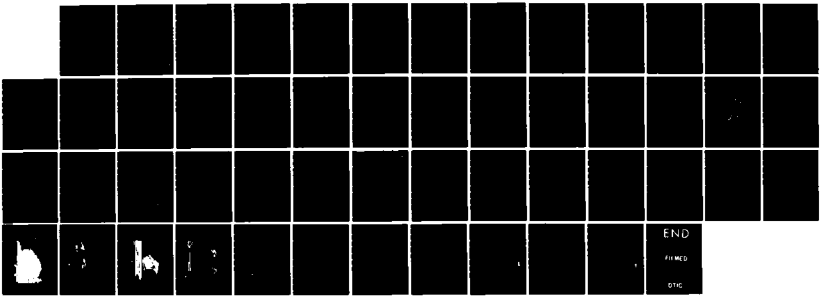

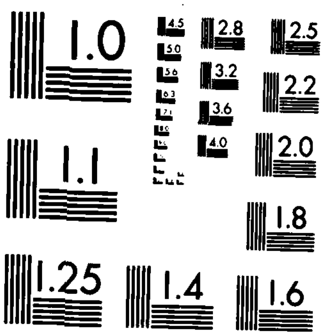

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TITLE: THE ADEQUATE DEPTH ASSURANCE PROGRAM: TESTING AND APPLICATION OF SEDIMENTATION CONTROL TECHNOLOGY IN NAVY HARBORS

AUTHOR: J. A. Bailard

DATE: March 1985

SPONSOR: Naval Facilities Engineering Command

PROGRAM NO: Y1316-01-006-610

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NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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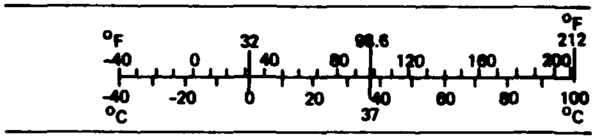
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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A development plan is presented for a 7-year Adequate Depth Assurance Program. The objective of the program is to provide adequate water depths at all Navy harbor facilities. The program approach is to seek an optimal mix of generic and site-specific solutions to the sedimentation problems at each site. The program will be evolutionary in nature and will build upon earlier work in testing and applying alternative sedimentation control technologies.

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CONTENTS

APPENDIXES

INTRODUCTION

The U.S. Navy is faced with increasing problems in maintaining project depths within its harbor berthing areas. Recent trends towards increased ship drafts, increased restrictions on dredge spoil disposal, and increased unit dredging costs have produced a situation whereby conventional dredging approaches are no longer adequate. The problem of inadequate water depth impacts the Navy through decreased fleet readiness, increased damage to ships, and increased operational costs.

Factors influencing the problem of adequate water depths in harbors can be summarized as follows. Estuaries have a relatively shallow natural depth which reflects a delicate balance between depositional and erosional processes. Natural depths were adequate when shallow draft vessels were the norm, however, the trend towards deeper draft vessels (Figure 1) has caused channels and berths to be deepened by dredging.

Increasing the depth of channels and berths increases the rate of sedimentation by reducing the bottom stress induced by tidal flows and allowing a greater penetration of the salt wedge into the estuary. Reduced bottom stresses decrease the rate of resuspension of flocculated clay sediments, while increased flocs. Together, these factors cause increased rates of sedimentation in the artificially deepened areas (see Figure 2). This is especially true in quiet water, cul-de-sac type, berthing areas which are prevalent throughout the Navy.

Mounting population pressures within the coastal zone, coupled with increased public awareness of the environment, have caused the issue of dredge spoil disposal to become particularly sensitive. Suitable land area for upland disposal of drege spoils is becoming extremely limited, especially when the material is contaminated. In many cases, more expensive ocean disposal becomes the only viable alternative. The above trends, when coupled with inflation, have led to a dramatic rise in the unit cost of dredging (Figure 3).

Although the overall Navy dredging problem has been increasing with time, Navy maintenance dredging budgets have not kept pace. The result has been more frequent and prolonged departures from project depths on a Navywide basis. In part, the seriousness of this problem has been masked by a decrease in the number of berths being actively maintained. This has been possible because the size of the fleet has been decreasing in recent years. This trend, however, has begun to be reversed as the number of ships in the fleet is increased from the current 450 ships to 600 ships by the mid 1990's (Cowhill, 1983).

Inadequate water depth is a particularily serious problem for the Navy. In addition to the highly publicized groundings which sometimes occur at a number of harbors, Navy ships are routinely unable to leave a berth during portions of the tidal cycle. In both cases, the ships are unable to move, thus compromising fleet readiness.

Inadequate water depths cause other less visible problems for Navy ships. For example, Navy ships have their cooling water intakes located on the bottoms of their hulls. While operating their boilers at berth, sediment is being constantly pumped through their cooling water systems. Under moderate conditions, this leads to shortened condenser life times; severe conditions can cause a complete plugging of the tubes, requiring the ship to go "cold iron." Additional impacts from inadequate water depths include damage to rudders, propellers, sonar domes, and paint systems. SUPSALV (Uhler, 1984) reports than in most instances, the damage is not so much inflicted by the soft sediments as by the debris which is imbedded in the bottom.

Twelve Navy harbors in the continental United States (CONUS) have significant dredging problems (Malloy, 1980). The annual dredging volumes for the six most serious problem sites are shown in Figure 4. Kings Bay TRIDENT Base leads the list with a projected dredging volume of 5 millon yd^3/yr (Granat, 1984). Charleston Naval Base is next, followed by Alameda Naval Air Station, Mayport Naval Station, Mare Island Naval Shipyard (MINSY), and Norfolk Naval Station. The total annual dredging volume is in excess of 12 million yd^3/yr. With current unit dredging costs averaging \$2.50/yd^3, the annual maintenance dredging budget for the Navy is estimated to be \$30 million. Based on the above mentioned trends, it is expected that this budget requirement will double in the next 13 years (Figure 5).

Recently, the Navy has made progress in developing improved methods for providing adequate water depth in berthing areas. Beginning in 1975, the Naval Facilities Engineering Command and the Office of Naval Research have sponsored research to identify and test alternative sediment management concepts. These concepts are based on interrupting the sedimentation processes as opposed to simply improving conventional dredging methods. The research programs have been primarily field-oriented with an emphasis on full-scale testing of alternative sedimentation control concepts.

Four sedimentation control concepts have been tested to date. These included the scour jet array (both spatial and linear arrays), the passive barrier curtain (both tidal-lift and pneumatic-lift curtains), the vortex foil array, and the crater-sink sand bypassing concept. The four concepts are based on either the resuspension or exclusion of flocculated clay sediments, or the interception of littoral sand transport. A brief description of each concept and its present development status is provided in the Appendix; in general, each concept is ready for advanced and engineering development.

PROBLEM STATEMENT

U.S. Navy national defense requirements mandate free and open access for the fleet to and from Navy shore support installations, including harbor and pier facilities. Although the Corps of Engineers is largely responsible for the dredging of ship channels, dredging of turning basins, berthing areas, and docks is a Navy responsibility. In many Navy facilities, sediment accumulations are causing inordinate demands on scarce resources as exhibited by excessive maintenance dredging requirements; delays in transit; increased ship wear due to sea suction ingestion of sediment and fouling organisms; inoperable berths at times of low tide; difficulties in operating floating drydocks and graving docks; and exposure of underwater weapon system appendages to potential damage.

Table 1 contains a summary of specific operational problems which have been identified at individual Navy harbors. A more detailed account of these problems may be found in the Appendix. The problems listed in Table 1 are far from exhaustive, but serve to indicate the nature, extent, and severity of the Navy's problem with inadequate water depths.

For reasons indicated above, simply increasing project depths and reducing the time interval between maintenance dredging will not solve all of the Navy's sedimentation problems. A more comprehensive approach is required. Site surveys are needed at each Navy problem harbor to assess the underlying causes of the sedimentation problem and to determine the most effective methods of dealing with the problem. Attention should be focused on determining the optimum project depth for a particular harbor or berthing area, based on the type of bottom material present, the type of ships using the berth, the range in the tide, the frequency of dredging, and the mean and variance of the sedimentation rate. New methods of measuring and defining the location of the bottom are needed.

In summary, there is increasing evidence which suggests that the Navy's existing dredging program is resulting in:

- Reduced fleet readiness
- Decreased operation capability
- Increased logistical support requirements
- Damage to Navy assets

OBJECTIVE AND PROJECTED BENEFITS

The overall objective of the Adequate Depth Assurance Program is to provide adequate water depth for ships in Navy Harbors. Specific program objectives include:

- 1) Determine water depth requirements for each Navy harbor;
- 2) Develop locally optimum methods for providing adequate water depth in Navy harbors;
- 3) Develop Navy criteria, specifications, and documentation to deal with present and future sedimentation problems.

Specific benefits associated with meeting the overall program objective include:

- Eliminated instances of ship operations in "thick water," i.e., mud.

- Eliminated instances of delays in ship transit due to siltation in berths.

- Eliminated instances of sea suction fouling by sediment or organisms.

- Enhanced operational readiness.

Specific performance measures that will be required of any sediment management/reduction alternative if it is to be considered a viable candidate are as follows:

- Better levels of service must result for the same level of resource commitment.

- Ancillary asset utilization costs (e.g., diver costs, ship energy consumption, idle time of riggers, crane operations, drydock downtime) should be reduced.

- Minimal additional manpower supportability requirements can be imposed.

- Operation must be compatible with existing activities and pose no burden that jeopardizes other efforts.

Since new and emerging candidate technologies differ widely in characteristics, specific attributes required to meet the above program objectives may differ (capital cost versus operation and maintenance cost, operational availability, mean time between failures, mean time to repair, system life, etc.) but will be determined during trade-off studies and subsequently demonstrated during test and evaluation. This will ensure that the information is in hand to provide the most cost-effective alternative at a given problem site.

PROGRAM APPROACH

Given the broad range of variation between harbors, it is obvious that no single technological alternative to conventional maintenance dredging will be universally optimum for all Navy harbors. Instead, locally optimal solutions will be assembled on a harbor-by-harbor basis from a growing set of sedimentation control alternatives.

A five-step program will be used to implement the above conceptual approach at each of the Navy harbor facilities having significant dredging problems. In the first step, a site evaluation will be performed at each facility to assess the critical sedimentation processes present and to review the facility's current dredging program and resources.

In the second step, the data gathered in Step 1 will be analyzed and a preliminary local Adequate Depth Assurance Plan (ADAP) will be formulated with input from local command personnel. Elements of the plan may range from a simple streamlining of the existing dredging program to the development of an entirely new sediment management concept.

Where local conditions dictate the need for new ideas or the adaptation of concepts proven elsewhere, they will be tested on a subharbor basis (i.e., a single pier or berth within the overall harbor). The objective of the ADAP will be to select an optimal mix of generic sedimentation control systems, site specific control measures, and procedural changes in dredging operations. The plan will address the user's long-term sedimentation problems and will include program, user, and military-construction- (MILCON) funded elements.

In the third step, any of the sediment management systems identified in the local ADAP will be designed, constructed, tested, and evaluated. A Test Plan, developed in conjunction with the preliminary ADAP, will be used as guidance for the tests. Because of the seasonal nature of most sedimentation problems, testing of systems will generally be conducted for at least 1 year.

In the fourth step, the final ADAP for the facility will be prepared following the completion of all testing. This will be the principal deliverable for the program. The plan will assess the results of the above tests as well as tests conducted at other sites and will identify specific procedures and systems that will help the facility to provide adequate water depth to the fleet. In addition to the plan, conceptual designs will be provided for all of the proposed sedimentation control systems, along with guidance for developing system specifications. This user document package will provide the facility with test validated data to allow an architectural and engineering (A&E) firm to prepare a construction data package.

In the fifth step, technical assistance will be provided to the facility to ensure implementation of the ADAP. One element of this assistance may be to help the facility develop a MILCON project application. The above five-step approach is diagrammed in the Adequate Depth Assurance Program Delta chart shown in Figure 6.

The development program described above is evolutionary in nature, with new sediment management concepts being introduced as proven ones are standardized, and new Navy harbor problems examined as solutions to previous ones are developed. At this time, the sites addressed by our resource needs projection include: Mayport Naval Station, Mare Island Naval Shipyard, Kings Bay Submarine Base, Charleston Naval Station, Norfolk Naval Base, Alameda Naval Air Station, and Philadelphia Naval Shipyard. Technologies which will be developed at each site are discussed below.

PROGRAM PLAN

Rationale

The proposed program is an amalgam of site studies and technology development efforts. Major areas identified for technology development include:

1. Water jet array

2. Vortex foil array

3. Curtain barrier
4. Tidal current modification
5. Asymmetrical sand fence
6. Site specific solutions (i.e., venting canal or training wall)
7. Instrumentation/survey needs
8. Optimum project depth methodologies
9. Ship/sedimentation effects

The foregoing list of technology category areas represent in part sedimentation reduction concepts which have been validated in previous 6.1 and 6.2 research programs. In fact, a key feature of this program is a building upon the accomplishments of basic research results sponsored by ONR.

Several new technology areas are also included in the above list. Two new areas include tidal current modification and the asymmetrical sand fence, both of which are directed specifically at the sizable sedimentation problems at Kings Bay. Other areas of new technology (instrumentation needs, optimum project depth methodologies, and ship/sedimentation effects) address problems which are common to all of the designated Navy harbors having significant dredging problems.

Most of the Navy harbor sites which have been identified as having significant dredging problems were visited last year. The purpose of these visits was to discuss elements of the proposed Adequate Depth Assurance Program and to obtain a first-hand look at the dredging problems at each site. Based on these visits, the matrix shown in Table 1 was developed to identify potential technology applications at each site.

Budget limitations preclude developing adequate depth assurance plans for each Navy problem harbor. Sites were selected based on the magnitude of their maintenance dredging problems and to some degree on the strategic importance of each site. One of the objectives used in formulating a site schedule was to maintain a continuity of ongoing activities initiated during prior NAVFAC/ONR funded programs. The sites which were selected for study along with the particular technology/application area to be examined are shown in Table 2.

Figure 7 contains a Work Breakdown Structure (WBS) for the proposed program. For the purpose of this plan, the structure is carried out only to the second level, however, project management will be carried out on the third level. The WBS illustrates the site-driven nature of the program. As discussed earlier, the work assigned to each site shares a number of common activities including: a site evaluation, development of a preliminary ADAP, development of critical system technologies, development of a final ADAP, and development of a user data package. The common activities have already been described. The following is a description of the technology development tasks, the instrumentation development tasks, and the ancillary study tasks.

Technology Development Tasks

Venting Canal. A venting canal was proposed by Jenkins et al. (1981) as a solution to the shoaling problem in the turning basin at Mayport Naval Station. The efficiency of the canal was evaluated by Bailard and Jenkins (in publication), and an optimum size for the canal was recommended. The concept for the canal is to exploit the water level inequality that develops between the basin and the adjacent St. Johns River. Water will be drawn into the basin through the canal during the early stages of flood tide, decreasing the inflow through the entrance channel. Since the shallow canal will selectively pass only the clearer surface waters (relative to the water entering the entrance channel), a reduction in the net sediment influx into the basin will be achieved.

The Naval Station has obtained Navy MILCON project approval for the canal. Design of the canal is currently being done by SOUTHDIV. Anticipating that the canal will be completed by the beginning of FY87, the proposed program calls for providing technical assistance during the 6-month design phase and monitoring the performance of the canal for a period of 1 year following construction.

Scour Jet Test Bed. At present, the scour jet array concept has been validated; however, specific design engineering data are needed relating to flow rates, nozzle sizes, system geometries, cross/co-current effects, and physiochemical augmentation options. Additional needs include: a more thorough assessment of system components, a more advanced control system, and the development of rotating or scanning jet nozzles. To achieve the greatest amount of information in the shortest period of time, a test bed is proposed.

The test bed will be installed along a single quaywall berth at MINSY and operated for a period of 2 years. Although a test bed scour jet array system has been designed by Bailard and Camperman (1983), more recent developments in jet deployment technologies and control system design suggest the need for a partial redesign. It is estimated that the design and construction of the test bed array will take about 15 months.

Vortex Foil Test Bed. Vortex foils are still in their early stages of development. Extensive testing is needed to determine optimum array configurations, foil shapes, deployment techniques, fabrication methods, and material selections. Additional tests are needed to determine the effects of current strength, downstream effects, and salt wedge interaction. A test bed is again the preferred choice.

At present, MINSY is constructing five foils to be tested as an array beneath a submarine. Technical assistance is being provided by Scripps Institution of Oceanography (SIO). The proposed plan calls for SIO to monitor the performance of this array for a period of 1 year prior to designing a test bed to be installed at MINSY. Design and construction of the test bed are estimated to take 15 months, followed by a 2-year test period.

Barrier Curtain Test Bed. The concept of a passive barrier curtain to prevent the intrusion of sediment into a berthing area has been partially validated. Previous tests of several different curtain designs,

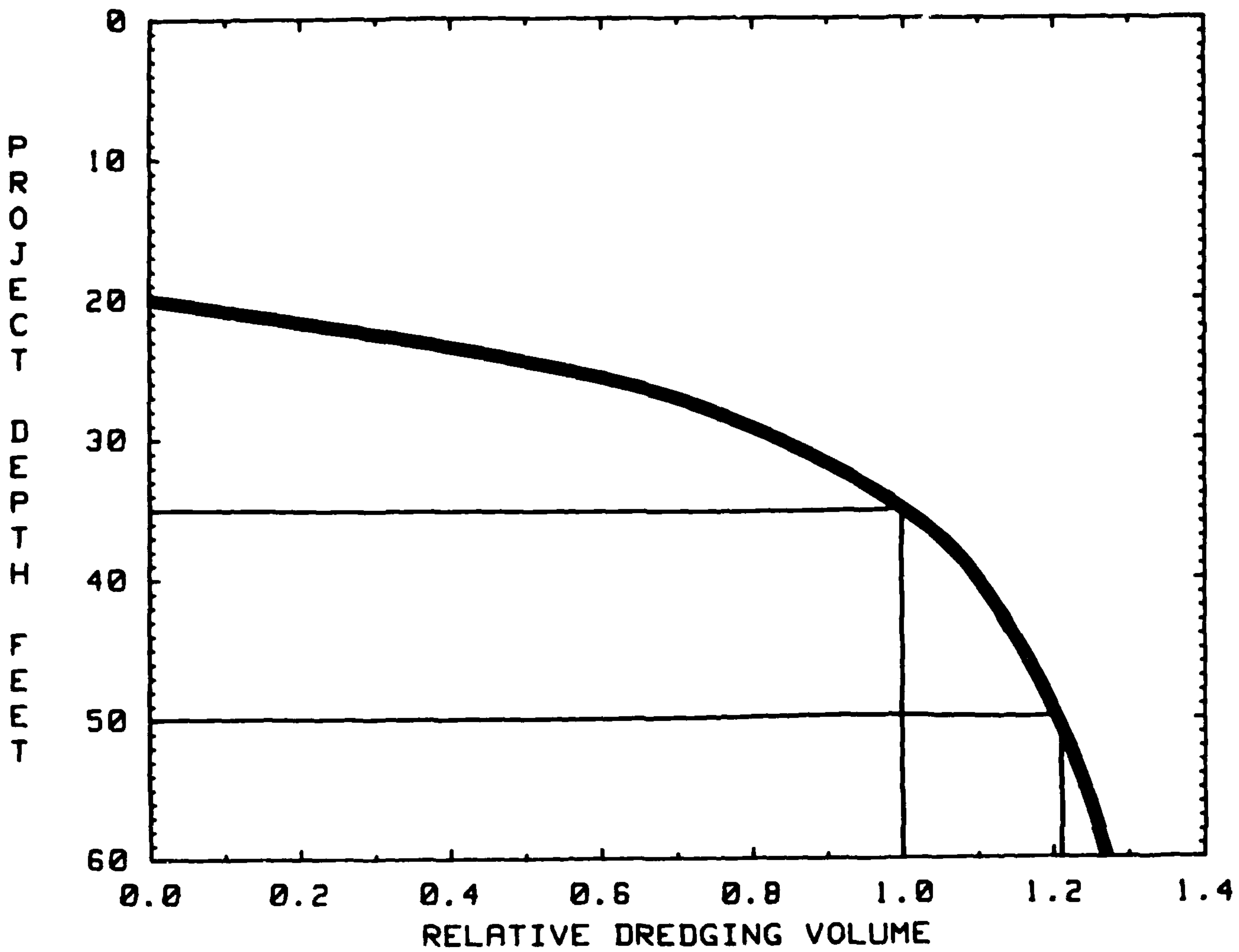

Figure 2. Increasing the project depth in a channel from 35 feet to 50 feet will cause an estimated 20% increase in the rate of sedimentation.

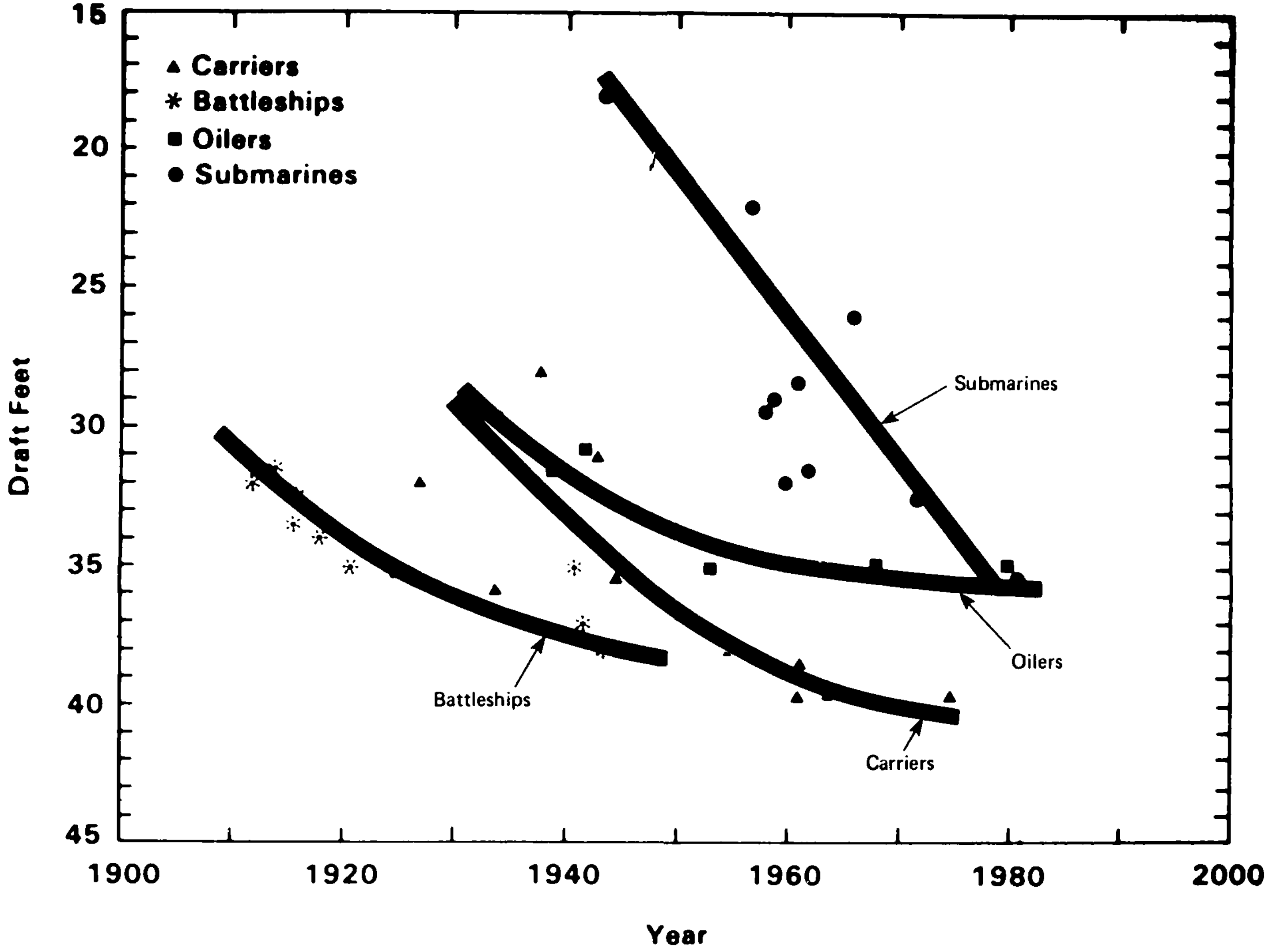

Figure 1. The drafts of most types of Naval ships have continually increased with time (data in part from U.S. Navy DM 26.3).

Table 5. Deliverables for the Adequate Depth Assurance Program (ADAP)

No.	Deliverable	Completion Date
1	Mayport Preliminary ADAP (TN) and Test Plan	FY85
2	Venting Canal Test and Evaluation (TR)	FY88
3	Mayport Final ADAP (TR) and User Data Package	FY88
4	Mare Island Preliminary ADAP (TN) and Test Plan	FY85
5	Mare Island Jet Array Test Bed Test and Evaluation (TR)	FY88
6	Mare Island Vortex Foil Test Bed Test and Evaluation (TR)	FY89
7	Mare Island Curtain Test Bed Test and Evaluation (TR)	FY89
8	Mare Island Final ADAP (TR) and User Data Package	FY90
9	Kings Bay Preliminary ADAP (TN) and Test Plan	FY86
10	Kings Bay Tide Modification Test and Evaluation (TR)	FY89
11	Kings Bay Sand Fence Test Bed Test and Evaluation (TR)	FY90
12	Kings Bay Final ADAP (TR) and User Data Package	FY90
13	Charleston Preliminary ADAP (TN) and Test Plan	FY86
14	Charleston Scanning Jet Array Test and Evaluation (TR)	FY89
15	Charleston ARDM Jet Jet Array Test and Evaluation (TR)	FY90
16	Charleston Final ADAP (TR) and User Data Package	FY91
17	Alameda Preliminary ADAP (TN) and Test Plan	FY86
18	Alameda Gap Closure Test and Evaluation (TR)	FY90
19	Alameda Final ADAP (TR) and User Data Package	FY91
20	Norfolk Preliminary ADAP (TN) and Test Plan	FY87
21	Norfolk Gate Curtain Test and Evaluation (TR)	FY90
22	Norfolk Final ADAP (TR) and User Data Package	FY91
23	Philadelphia Preliminary ADAP (TN) and Test Plan	FY88
24	Philadelphia Caisson Jet Array Test and Evaluation (TR)	FY90
25	Philadelphia Final ADAP (TR) and User Data Package	FY90

Table 4. Major Milestones for the Adequate Depth Assurance Program (ADAP)

Milestone	Mayport	MINSY	Kings Bay	Charleston	Alameda	Norfolk	Philadelphia
Assess sedimentation problem and potential solution	FY85	FY85	FY86	FY86	FY86	FY87	FY87
Formulate approach to problem	FY86	FY85	FY86	FY86	FY86	FY87	FY88
Complete testing of siltation control technology	FY88	FY89	FY90	FY90	FY90	FY90	FY90
Provide facility with recommended solution	FY89	FY91	FY91	FY91	FY91	FY91	FY91

Table 2. Potential Application of Sediment Management Technologies to Candidate Harbor Sites

Site	Curtains	Jets	Foils	Sand Bypass	Site Specific Applications
Alameda	X	X			X
Charleston	X	X	X		X
Kings Bay		X	X	X	X
Mare Island	X	X	X		X
Mayport		X			X
Molate Point		X			X
Norfolk	X				X
Philadelphia	X	X	X		X
Port Canaveral				X	
Port Hueneme				X	

Table 3. Technology Areas Proposed for Each Site

Site	Technology
Mayport	Venting canal
Mare Island	Scour jet array test bed, vortex foil array test bed, curtain barrier test bed
Kings Bay	Tidal currents modification, asymmetrical sand fence
Charleston	Scanning scour jet array, ARDM jet array
Norfolk	Trench, gated barrier curtain
Alameda	Gap closure
Philadelphia	Caisson jet array

Table 1. Summary of Specific Operational Problems

Problem	Harbors											
	Kings Bay	Charleston	Alameda	Mayport	Mare Island	Norfolk	Philadelphia	Earle	Port Hueneme	Port Canaveral	Molate Point	New London
Occasional groundings	X	X	X	X						X		X
Damage to ship appendages		X	X	X								
Inability to move at certain tides		X		X	X		X	X			X	
Sea suction fouling		X			X	X	X					
Silting in at berth		X			X		X					
Dwindling spoils capacity		X		X		X				X		
Permit difficulties	X	X	X	X	X	X	X	X	X	X	X	X
Drydock and ARDM siltation		X				X			X			X
Unavailable berths		X			X		X	X				
Inadequate depths for ship husbandry	X		X	X		X		X			X	X

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CONCLUSIONS AND RECOMMENDATIONS

The Navy for its own benefit and operational readiness must take action to remove the following deficiencies:

- There is increasing evidence that the Navy's present maintenance dredging program does not provide adequate water depth in its harbors.
- Inadequate water depth in Navy berthing areas is responsible for decreased fleet readiness, damage to critical ship appendages, and increased logistics costs.
- Long-term trends in ship design and unit dredging costs coupled with the projected increase in the size of the fleet suggest that maintenance dredging budget requirements will double from 1980 levels by 1993.
- Conventional dredging approaches, even if funded at substantially increased levels, will not provide a complete solution to the problem of inadequate water depths in Navy berthing areas.

As a means of providing adequate water depths in Navy berthing facilities, a 7-year program is recommended which consists of the following elements:

- A user-driven program that seeks to identify and implement locally optimum solutions should be pursued at each facility having serious dredging problems.
- At each site, the program should start with an assessment of the sedimentation environment and the existing dredging program. This should be followed by the development of a preliminary adequate depth assurance plan, test and evaluation of recommended sediment management solutions, finalization of a local adequate depth assurance plan, and follow-up technical assistance as required.
- Recommended solutions should draw upon a streamlining of existing conventional dredging methodologies, application of an expanding base of proven alternative sediment management concepts, and the testing and development of new concepts as required.

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Recently, the Dutch have begun to explore the effects of different densities of fluid mud suspensions on the maneuvering of ships in channels (Hellema, 1981). Based on this work, the bottom has been defined as that point having a specific gravity of 1.2. The U.S. Army Corps of Engineers is also interested in this problem with respect to navigation channels (Butler, 1984). The proposed plan is to conduct a literature review of this research topic and determine possible applications of this work in the present program.

Sediment Effects of Ship Cooling Systems. The Dutch have been primarily concerned with the effects of sediment suspension on ship maneuverability. For Navy vessels with bottom cooling system intakes, there is the added effect of pumping sediment-ladened water through the cooling water system. Conversations with the David Taylor Naval Ship Research and Development Center (DTNSRDC) (Morton, 1983) suggest that water with a high sediment load can cause premature failure of the condenser tubes. This task will explore the effects of different levels of sediment concentrations on condenser tube corrosion/erosion.

Optimum Project Depth Methodology. Specifying a project depth for a berth should involve more than just considering the maximum draft of all vessels which use the berth, the minimum tide level, and a fixed factor of safety. Instead, one should also consider the statistical range in the tide, the estimated rate of shoaling, the frequency of dredging, the cost of dredging, and the effect of different sediment concentration levels on ship cooling water systems. Quite possibly, each berth might have a different optimum project depth. This task will develop a systematic methodology for determining the optimum project depth for a particular berth. The results of this work will have direct application in all Navy harbors having sedimentation problems.

Schedule and Budget

Figure 8 is a Gantt chart containing the proposed schedule and budget for the Adequate Depth Assurance Program. The schedule covers a time span from FY85 to FY91. The costs are broken down on a task-by-task as well as on an annual basis. The total program budget is $8.62M.

MAJOR MILESTONES AND DELIVERABLES

The major milestones for the proposed adequate depth assurance program consist of the completed preliminary and final adequate depth assurance plans (ADAPs) for each of the 7 designated Navy harbors. Major milestones and scheduled delivery dates are listed in Table 4.

Deliverables for the proposed program consisting of preliminary local adequate depth assurance plans (with associated test plans), test reports on alternative sedimentation control technologies, and final adequate depth assurance plans (with associated conceptual design documents). Program deliverables and scheduled delivery dates are listed in Table 5.

be to use a portable pump to power the array. In this way, one pump could be shared among a number of drydocks. The proposed program calls for a 12-month design and construction period followed by 1 year of testing.

Instrumentation Procurement/Development Tasks

Concentration Probe. In previous field studies by SIO, sediment concentrations have been measured by filtering water samples. This is a very accurate technique; however, it is cumbersome and costly. The proposed task will explore recent instrumentation developments in measuring sediment concentration optically or acoustically. If possible, instruments will be purchased and modified as needed. If not, the feasibility of developing a new instrument will be explored under separate (6.2) programs or as an addition to this program.

Shoaling Monitor. The present method of monitoring sedimentation in test areas is to make repeated fathometer surveys using a 40-kHz echo sounder. While this method can be used to detect sediment accumulation as well as aspects of the depositional structure, it cannot be used to detect the time of occurrence of mud storms or other related phenomena. For this reason, a continuously recording shoaling monitor would be beneficial. This sensor could be used to interpolate short-term sedimentation rates between fathometer surveys and to pinpoint major shoaling events.

The monitoring system should be suitable for use beneath moored vessels. Currently, the only way to assess shoaling beneath a moored vessel is to perform a diver survey. This is an expensive method of surveying that depends on the availability of diver support. A preferable alternative would be to develop a sensor that could remotely detect the amount of sediment accumulation in a test area. A possible system might consist of a series of upward-looking micro-fathometers or a series of conductivity probes. Preliminary tests of the latter type of device were conducted by Cromwell and Wade (1980).

Shear Stress Probe. The economics of a scour jet array are very sensitive to the magnitude of the shear stress to be imposed on the bottom. Field experiments have shown that a stress of 0.008 to 0.010 lb/ft^2 (4 to 5 $dynes/cm^2$) is appropriate for conditions at MINSY; however, the physical properties of the flocculated muds are known to vary between different sites. A simple device is needed to assess the shear strength of the "fluid mud" layer, either in situ or dockside using a newly acquired sample of mud.

Ancillary Study Tasks

Bottom Definition Assessment. Presently, there is significant interest in the user and scientific communities to better define the location of bottoms composed of flocculated clay sediments. Often there is no precise interface that separates the bottom from the overlying mud suspension. Instead, the density of the fluid/sediment suspension gradually increases with depth. When different sounding instruments are used to detect the "bottom," each instrument gives a different answer.

or with a curtain skirt. Details will be worked out during the design phase of the development. Design and construction are estimated to take 15 months, followed by a 1-year test period.

Trench. Norfolk Naval Base has a continual problem with hydroid organisms plugging up the intakes of their carriers. These tumbleweed-like organisms are carried into the carrier berths by tidal currents. When the carrier fires off its boilers, the hydroids are sucked onto the sea chest grating, forcing the ship to shut down its engines. Based on modeling studies by Rudausky and Wang (1982), a trench across the mouth of the berthing area was proposed as a means of intercepting the influx of hydroids. A secondary benefit was the proposed reduction in the rate of sedimentation. Norfolk will construct the trench in FY85 and monitor its performance for a year. NCEL will provide assistance in analyzing the data and interpreting the results.

Gated Barrier Curtain. The test bed curtain planned for MINSY will be designed to enclose the area between two finger piers (a span of about 250 feet). At Norfolk Naval Base, the size of the area to be enclosed (Berth 12) is substantially larger and will include nonberthing as well as berthing areas. To apply barrier curtain technology to this site, it will be necessary to develop an alternative type of curtain consisting of a gated section connected to semi-immobile sections. Occasionally, all of the curtain will have to be moved (i.e., for installation and recovery), but most of the time only the gate section will be opened and closed for ship traffic. The gated barrier curtain will take advantage of the technology developed from the curtain test bed at MINSY.

Breakwater Gap Closure. It has been hypothesized (Van Dorn et al, 1976) that one of the primary causes of the high rate of sedimentation experienced in the turning basin at Alameda Naval Air Station is the gap in the breakwater surrounding the basin. The gap, acting in conjunction with the entrance opening, allows a net water circulation to pass through the basin during ebb and flood tidal flow. This causes sedimentation in excess of that which would be caused by the tidal prism alone.

A MILCON project to close the breakwater gap is currently programmed for FY88. Anticipating that construction will be completed by FY89, the proposed program calls for monitoring shoaling the turning basin for a period of 1 year. The program also designates limited funds to provide technical assistance to WESDIV during project design.

Caisson Jet Array. Philadelphia Naval Shipyard (PNSY) (as well as MINSY and Charleston Naval Shipyard) has an extensive number of drydocks that are notched back into the waterfront. The caissons to the drydocks are positioned some distance into the notch, so that an area of quiet water is formed in front. This area is subject to heavy shoaling, so it must be dredged whenever the drydock is opened.

The proposed plan is to develop a scour jet array system to prevent siltation in front of the drydock caissons. Most probably the system will be a linear type of array using fixed jets. One possibility may be to use the existing drydock dewatering pumps. Another possibility may these efforts are successful, the proposed plan calls for monitoring channel shoaling for a period of 1 year following remedial alteration of channel geometry.

Asymmetrical Sand Fence. One of the problems at Kings Bay is the lengthy entrance channel that will required at St. Mary's Inlet. This channel is slated to extend more than 5 miles offshore. Shoaling in the entrance channel will consist of sandy material. The large size of the entrance channel probably prevents a successful application of sand bypassing technology; however, substantial tidal current energy is available. A possible solution to this problem may be an asymmetrical sand fence.

The concept of an asymmetrical sand fence is to act as a one-way valve for sand transported by tidal currents in the entrance channel. During flood flow, the sand fence would block the transport of sand into the entrance, while during ebb flow the fence would allow the free transport of sand out of the entrance. A net seaward transport of sand would result. The proposed sand fence would achieve this action through an asymmetrical hydrodynamic design. One possible configuration would be to have a series of asymmetrical foils positioned vertically upward from the bottom. In one direction (ebb) the foils would appear streamlined to the flow, causing little or no wake. In the other direction (flood), the foils would appear bluff to the flow, causing a large wake and thus impeding sediment transport.

The proposed program will investigate the concept of an asymmetrical sand fence through laboratory and field tests. The laboratory tests will focus on exploring fence geometries and hydrodynamic effects. The 1 year of laboratory tests will be followed by 1 year of field tests of the most promising concept. If successful, a test bed will be built to determine optimum geometries, fabrication techniques, and material selections.

Scanning Scour Jet Array. Fixed jets are suitable for linear arrays; however, spatial arrays are best served by scanning (i.e., rotating) jet configurations. Spatial arrays are needed in large berthing areas that are subject to weak cross-berth currents. Scanning jet nozzle technology will first be explored using the scour jet array test bed planned for MINSY; however, the first full-scale implementation of this technology will be made at Charleston Naval Base. It is anticipated that a complete finger pier berth will be fitted with a scanning jet spatial array constructed of "soft" components. The latter include hoses and floating jet mounts, which can be expected to survive an anchor dragging episode with a minimum of damage. A period of 15 months is anticipated for the design and construction of the array, followed by a 1-year test period.

ARDM Jet Array/Curtain. Siltation beneath floating drydocks (ARDM) is a continual problem for the Navy. The deep holes required by the 50-foot-plus drafts of these drydocks cause a natural collection point for flocculated clay sediments. At Charleston, it is not unusual for the ARDM site to be freshly dredged prior to each repair evolution. The proposed plan will be to fit an ARDM site with either a scour jet array while successful, were hampered by overly complicated designs. For systematic tests to be conducted, a better curtain design must be developed that can be rapidly and consistently opened and closed using a minimum of personnel.

The proposed plan calls for the design, test, and evaluation of a curtain test bed at MINSY. The design effort will be broken into two parts: (1) a concept generation effort, and (2) the final design of the selected concept. These efforts will take about 9 months. Following a 9-month construction phase, the test bed curtain will be tested for a period of 2 years.

The curtain test sequence will cover a wide range of performance and engineering design tests. Performance tests will include evaluating the effects of different curtain heights, counter and cross currents, and differing degrees of vertical stratification of the water column. Specific engineering design data will be dependent on the selected curtain design; however, tests will be conducted on component reliability, material selection, fabrication techniques, and deployment techniques.

Tidal Current Modification. In addition to shoaling in quiet water berthing areas, the sedimentation problem at Kings Bay TRIDENT Base will involve shoaling in over 12 miles of navigation channel. Moreover, while shoaling in the berthing areas will be composed of flocculated clay sediments, the shoaling in the navigation channels will include both clay, silt, and sand-sized sediments. The extensive nature of the expected shoaling problem at Kings Bay suggests that a global approach to the problem will be needed. One such approach has been suggested by Aubrey and Speer (1983) of Woods Hole Oceanographic Institute (WHOI).

Applying diagnostic modeling techniques to field measurements of tidal currents, Aubrey and Speer (1983) have found evidence to suggest that the flood or ebb dominance of the tidal currents in shallow estuarine channels may be altered by small changes in the channel geometry or cross section. The sensitivity of the flood/ebb dominance to changes in channel geometry is caused by the nonlinear nature of the flow processes that dominate shallow tidal flows. The concept is to reduce unwanted shoaling by changing a flood-dominated flow into an ebb-dominated flow, thereby producing a net seaward transport of sediment throughout the channel.

Although the concept of modifying tidal current characteristics through alteration of the channel cross section is presently only a theoretical possibility, it holds the promise for reducing unwanted sedimentation on a global (channel-wide) scale. Moreover, because it is device independent, it will not obstruct ship movements, nor does it require energy to operate. As a result, although the concept must at present be considered high risk, it has the potential for a high benefit/payback.

The proposed program is to fund the required theoretical and field work in the first year, followed by a second year of data analysis. The result of this work will be recommendation for changes in the channel cross-section and geometry. These changes will be modeled by the U.S. Army Waterways Experiment Station using a previously developed hybrid model for Kings Bay. It is anticipated that funds for any recommended channel dredging will be provided by OICC TRIDENT. Anticipating that

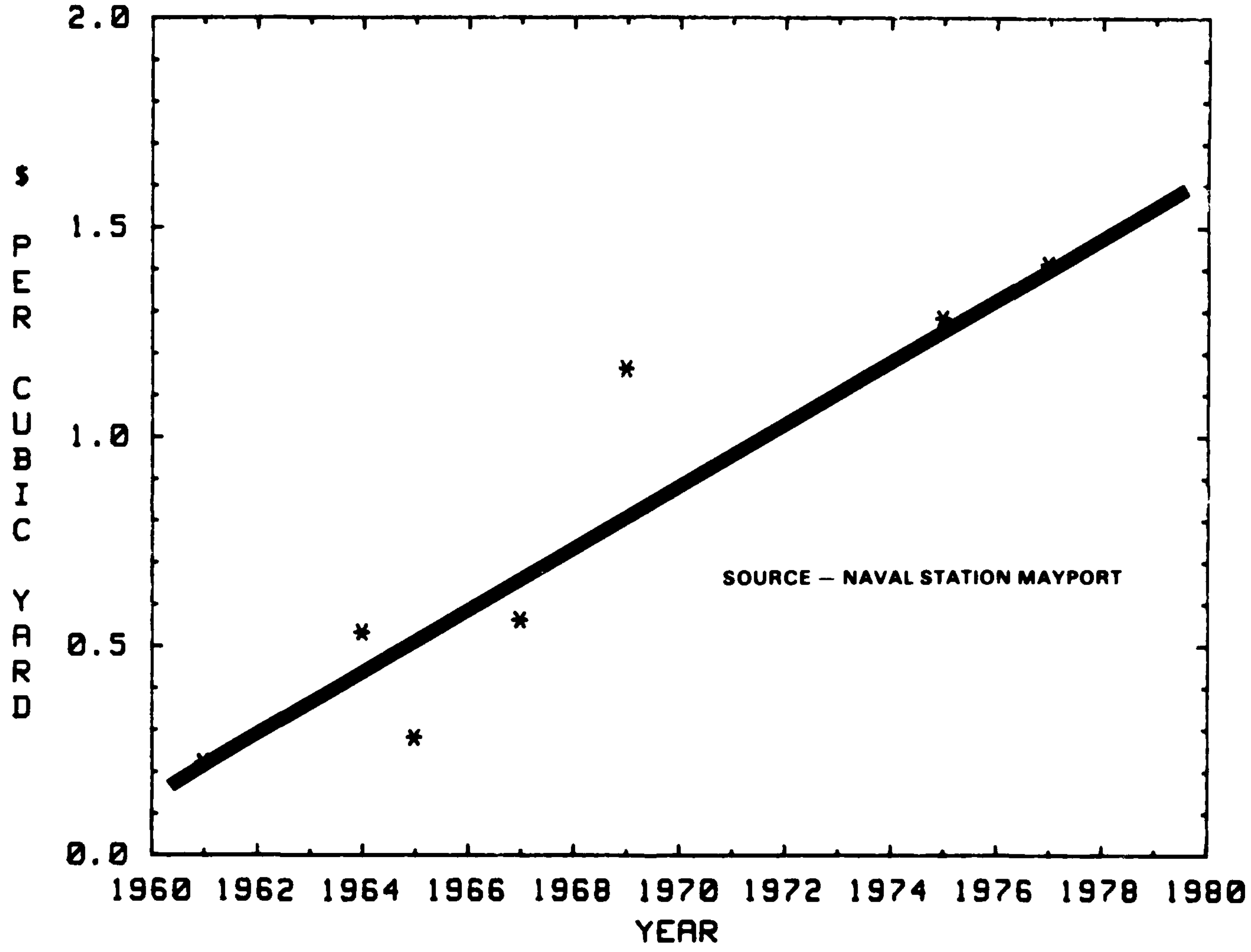

Figure 3. The unit cost of dredging has continually increased with time.

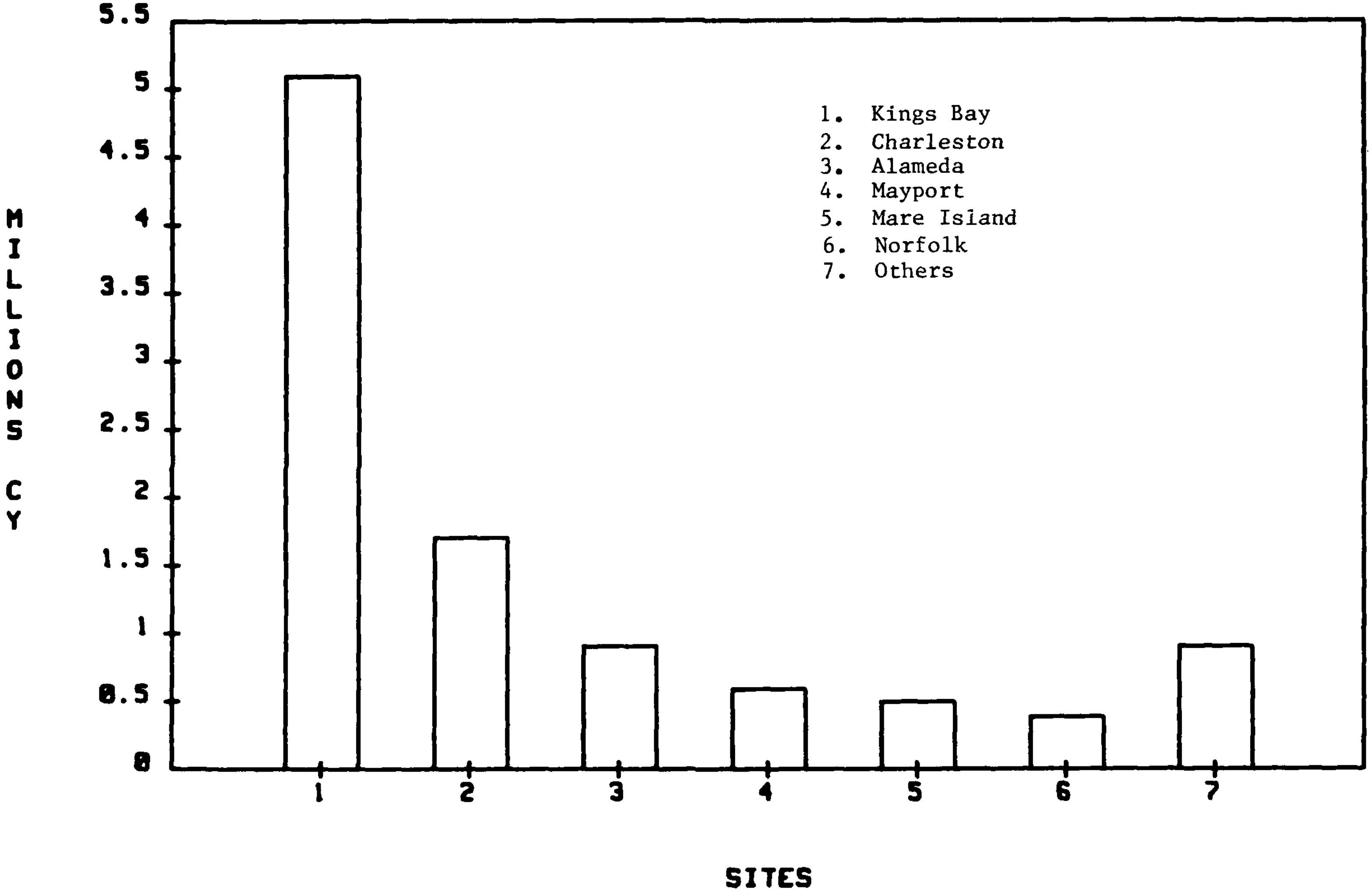

Figure 4. Estimated annual maintenance dredging volumes for the six Nay harbors with the most significant dredging problems.

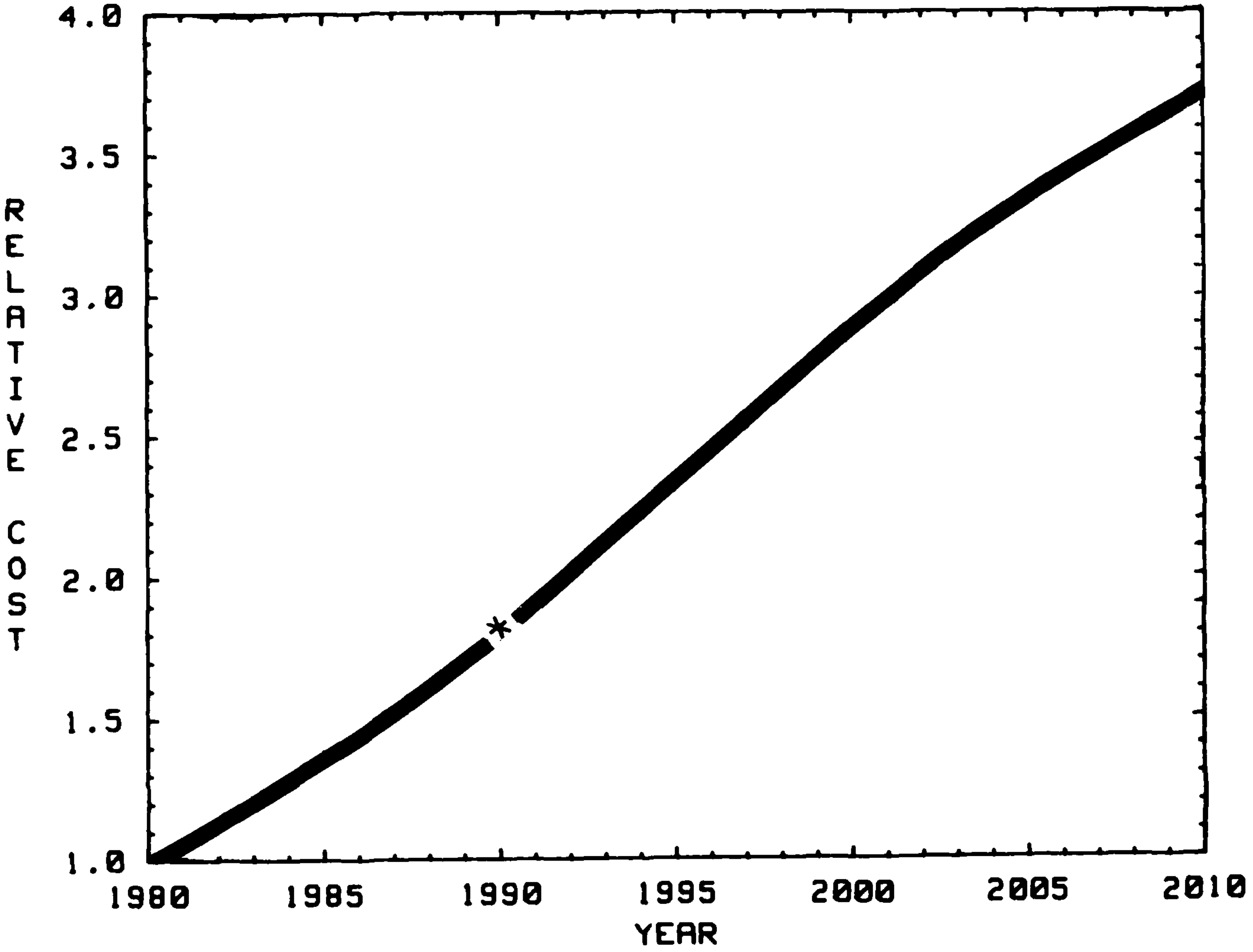

Figure 5. Projected maintenance dredging costs (relative to 1980) are expected to double by 1993.

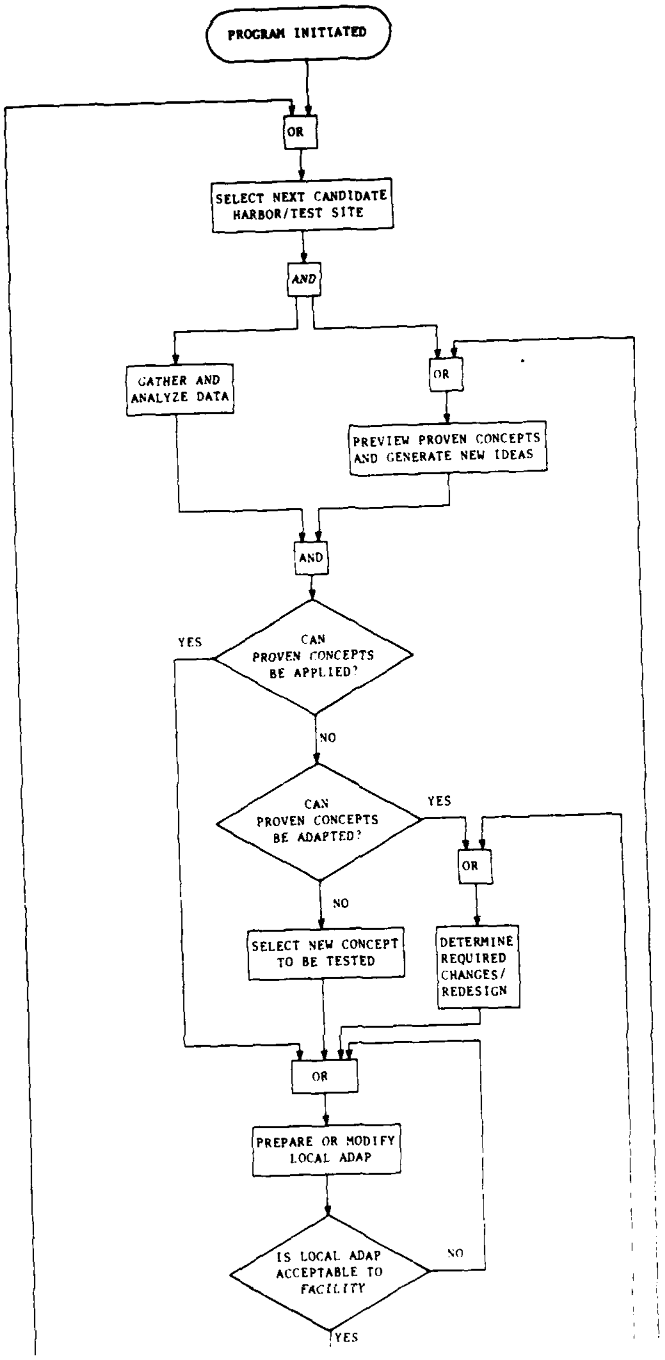

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Figure 6. Delta chart showing the proposed approach for the Adequate Depth Assurance Program.

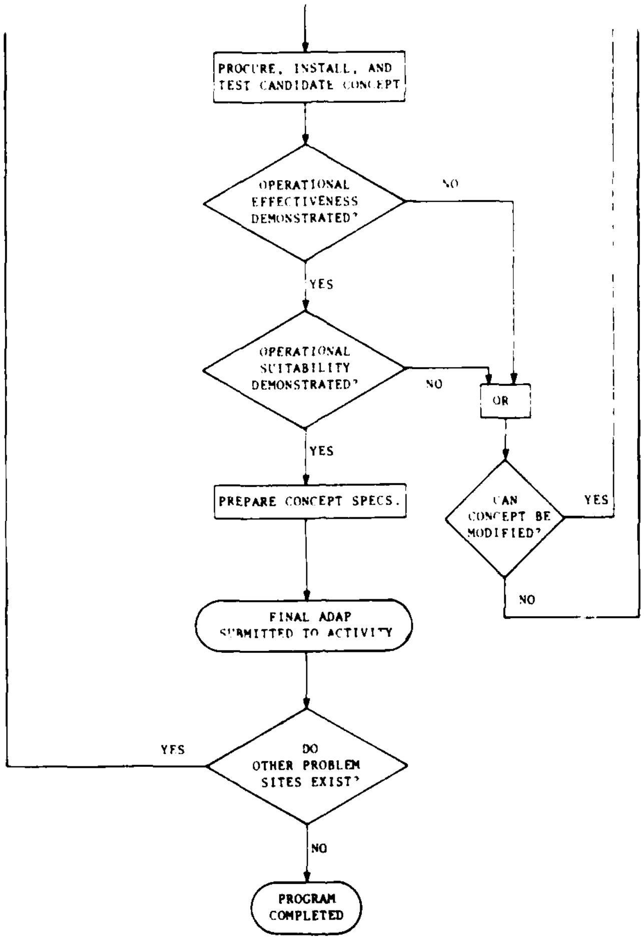


Figure 6. Continued.

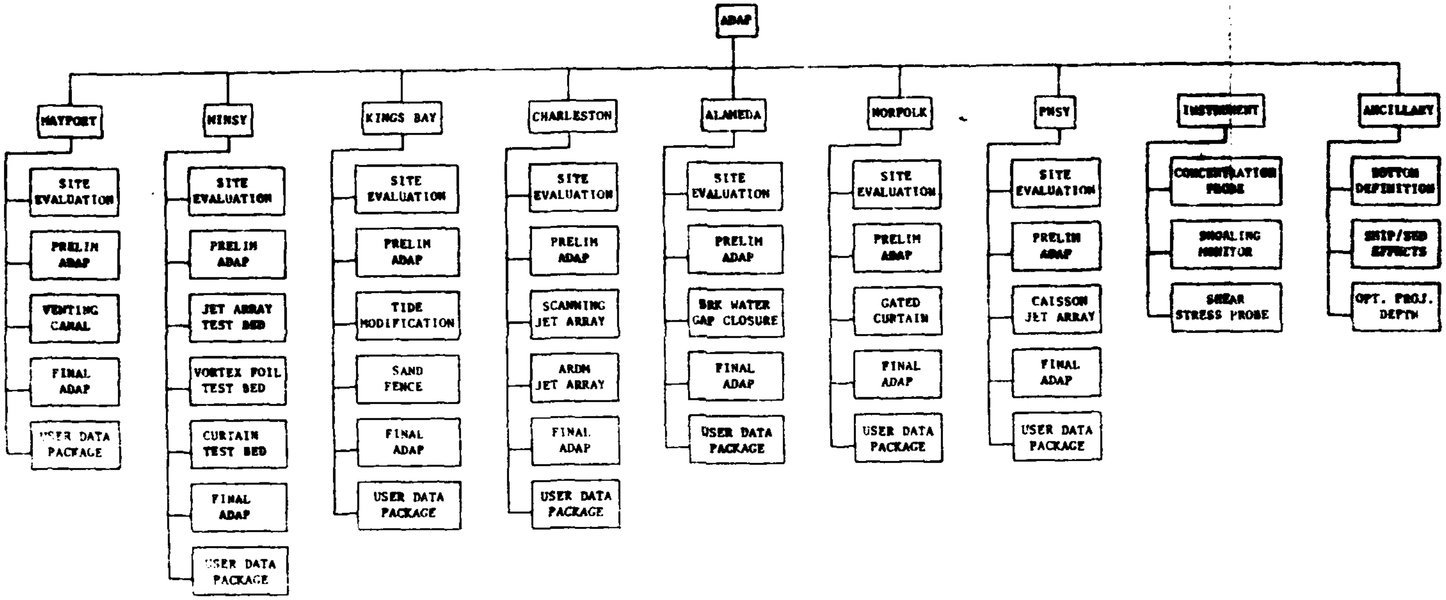
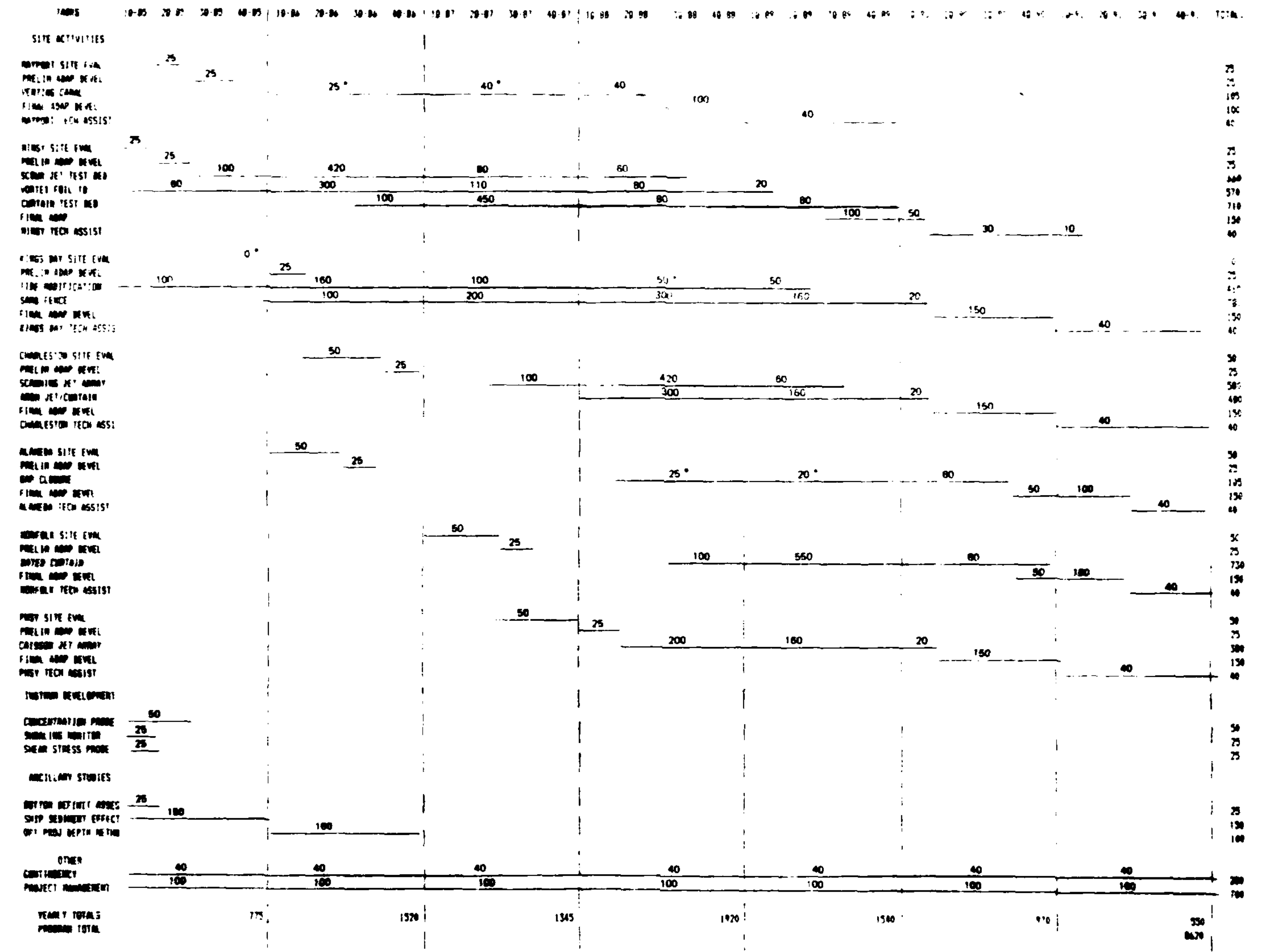


Figure 7. Work breakdown structure for the Adequate Depth Assurance Program.



*Joint funding with activity

Figure 8. Gantt chart showing the proposed schedule and budget for the Adequate Depth Assurance Program.

Appendix A

PRESENT STATUS OF ALTERNATIVE SEDIMENT MANAGEMENT TECHNOLOGY

The following is a brief description of the scour jet array, vortex, foil array, curtain barriers, and crater-sink sand bypassing concepts and their present development status.

SCOUR JET ARRAY

A scour jet array consists of a series of underwater jets that act to prevent siltation in a berthing area by resuspending any flocculated clay sediment that was deposited during the previous slack water. If this sediment is immediately resuspended and directed out of the berthing area into an ebbing tidal flow, then the sediment will be carried from the area. Two types of scour jet array concepts have been tested: the spatial jet array and the linear array.

Figure A-1 shows a schematic representation of a spatial scour jet array that was tested at Mare Island Naval Shipyard (MINSY). The array consisted of 70 jets distributed across a 110- by 66-foot section of a berthing area. The jets were distributed along a central manifold having 10 legs with 7 jets on each leg. The array was powered by a pier-mounted centrifugal pump. Pneumatic pinch valves were used to control the flow to each leg so that each branch pair of jets could be operated sequentially.

An automatic control system was used to operate the jet array. The control system consisted of an electronic logic circuit coupled to an electromechanical timing circuit, the latter activating a series of pneumatic solenoids. The logic circuit used a pressure sensor to determine when to start the timing sequence, so that the jets could be activated at the start of ebb tide.

The system was operated twice daily for 4 months. Each duty cycle consisted of a 7-minute sequencing of each pair of jets. The system was started at the onset of ebb tidal flow with the pump flow directed to the innermost branch pair of jets. After 7 minutes, the flow was directed to the next branch pair of jets and so on until all of the branches had been operated. By sequencing the jet array in this manner, all of the newly deposited clay flocs were swept out of the berth into Mare Island Straits.

During its 4 months of operation, the spatial scour jet array system was 100% effective in preventing siltation in the test area. At the same time, an adjacent control area experienced 1.5 feet of shoaling. Two operational problems were encountered with the system. First, the rubber bladders inside the pneumatic pinch valves began to fail near the end of the test period. Second, shortly after the end of the test period, an anchor was dragged through the test area during the berthing of a ship. The primary effect of this was to dislocate of a portion of the array. However, it was learned that dragging an anchor while entering a berth is the perogative of the pilot and might occur as often as once or twice a year at a particular berth.

An alternative configuration for a scour jet array is to place the jets linearly along one side of a berth. This type of linear scour jet array is particularly well-suited to quaywall berthing configurations adjacent to a navigation channel. Figure A-2 shows a schematic representation of a linear scour jet array tested at MINSY. The array was situated along one portion of a 2,300-foot-long unobstructed quaywall on the western bank of Mare Island Strait.

The linear jet array shown in Figure A-2 consisted of 10 jets equally spaced over a 205-foot-long berth. Because of a rock toe at the base of the quaywall, the jets were positioned about 8 feet above project depth for the berth The jets were directed downward at an angle of 20 degrees to generate a continuous scour pattern beginning at the outer edge of the rock toe. The jet array was powered by a centrifugal water pump mounted on the top of the quaywall. Flow to each jet was controlled by a pneumatic pinch valve so that the entire pump discharge could be sequentially directed through each jet.

The control system used to operate the linear scour jet array was identical to that used in the spatial scour jet array. The only change was to increase the individual jet duty cycle time from 7 to 12 minutes. The operating sequence for the jet array was to activate the jet farthest upcurrent at the onset of ebb tidal flow and to sequentially operate the adjacent jets until all of the jets had been activated.

The array was operated for an 18-month period between May 1979 and September 1980. During this time, numerous interruptions occurred. Most of the interruptions were related to shipyard improvements in the quaywall area, but repeated failures of the pinch valve liners were also found to be a problem. The control system was another source of difficulty, since it required a cumbersome reset procedure after each power failure. Nevertheless, repeated bathymetric surveys of the test area showed that while the array was operational, all sedimentation was prevented out to a distance of 70 feet from the quaywall.

In summary, the scour jet array concept has been validated. The remaining tasks are to optimize the system variables and proceed with advanced and engineering development. A test bed scour jet array has been designed to systematically explore the effects of different jet flow rates, jet diameters, jet orientations, and jet duty cycle times (Bailard and Camperman, 1983). The test bed array incorporates a number of system improvements, including pneumatically actuated butterfly valves, a vertical turbine pump, fiberglass pipe, and a microprocessor-based control system.

An economic analysis of scour jet arrays suggests that fixed jet linear arrays are economically viable in areas of high dredging cost (\$7/yd^2 or greater). High cost areas include those areas with high rates of deposition or areas with difficult access for conventional dredges and thus high unit dredging costs. Linear arrays with partially scanning (rotating) jets would reduce these costs by a factor between 2 and 5. Spatial arrays, especially those with fully scanning (360-degree) jet nozzles, have the potential for reducing system costs by an order of magnitude over arrays with fixed jets. A cost reduction of this magnitude would extend the potential application of scour jet arrays to nearly all of the Navy harbors with sedimentation problems. Obviously the problem of dragging anchors will have to be overcome.

VORTEX FOIL ARRAY

The vortex foil is a passive resuspension device that extracts energy from the passing tidal current (Jenkins, in publication). Arrays of these foils are used to prevent sediment deposition in areas of moderate tidal currents. The concept for the vortex foil was developed by Scripps Institute of Oceanography with funding from the Office of Naval Research (ONR).

Referring to Figure A-3, each vortex foil consists of a submerged underwater wing moored about 3 feet off the bottom by a short tether wire connected to a swivel and screw anchor. The delta-shaped foil is buoyant, with its lifting surface oriented either downward (an upwash foil) or upward (a downwash foil). When tidal currents move past the foil, horseshoe-shaped vortices are shed from its trailing edge, similar to those shed from an airplane wing. The vortices are advected downstream by the tidal current, imposing an enhanced shear stress on the bottom and resuspending any newly deposited sediments. In the downwash mode, the full scouring energy of the vortices is directed at the bottom, while in the upwash mode, the foil directs the sediment up into the water column so that it is carried away by the ebbing currents. In general, a vortex foil array will use a combination of downwash and upwash foils to prevent siltation over a substantial area of the bottom.

The foils tested to date have had a delta or swept-back shape with a 20-foot wing span, a 5-foot root chord, and a 3-foot tip chord. The foils were constructed from foam using injection molds. Each wing displaced about 2,400 pounds of water; however, the wings were reinforced and ballasted with an internal steel rebar structure to achieve a design static buoyancy of 625 pounds. The foils were covered with a thin layer of fiberglass and coated with antifouling paint. Each foil was moored to a single screw anchor by a short steel cable. The screw anchors had a 13-foot-long shaft extension to allow full penetration into the undredged bottom and a float collar/shear plate at the top of the shaft to prevent any lateral movement.

The swept-back shape of the foils serves several purposes. First, the sweep of the leading edge of the foil serves to generate leading edge vortices, which acted in conjunction with the trailing edge vortices. More vortices translate into enhanced scouring action downstream of the foil. The second function of the sweep angle is to keep the foil pointed in the proper direction. The mooring was designed to pivot freely, allowing the foil to reverse direction with the reversing tidal currents. Finally, the delta shape keeps the center of buoyancy aft of the center of hydrodynamic pressure, thus maintaining stable flight.

In 1982, a small array of foils were tested at MINSY. The test area was a 100- by 100-foot area situated adjacent to the 2,300-foot-long quaywall. Normally, the bottom in this area slopes downward towards the channel; however, prior to the start of the test, the area was dredged flat. During the period between November 1982 and November 1983, three foils were tested in the study area. The leading foil was a downwash configuration, while the other two foils were upwash configurations. During this time 10 feet of shoaling was observed in an adjacent control area.

Surveys of the test area showed that the foils provided complete protection from deposition locally, while providing a measure of protection in a path that extended both upcurrent and downcurrent from the array. The width of this path decreased with increasing distance from the array, and the level of protection showed a similar decrease with distance. During the 1-year test, the array prevented an estimated 1,065 yd^3 of deposition in the study area.

In summary, the concept of the vortex foil has been validated. Additional research and development are needed to determine the optimum geometry for the arrays, the optimum size for an individual foil, improved installation methods, and less costly fabrication methods.

CURTAIN BARRIER

A third method that can be used to prevent siltation in berthing areas is to exclude the sediment from entering the area. Studies have shown that under conditions of strong deposition, 90% of the sediment is in the lower few meters of the water column. Consequently, a partial height curtain barrier can be used to exclude most of the sediment from a berthing area without having to construct a full height dam. A partial height barrier will still allow normal tidal exchange into and out of the berth; however, the exchange will involve only relatively sediment-free surface water.

Curtain barriers are bulky devices that have the potential for blocking ship movements into and out of a berth. Consequently, some method of opening and closing the curtain is needed. In addition, the curtain must be semimobile to facilitate deployment and repair. A curtain that is lifted by the tide is one method of providing a degree of mobility.

Figure A-4 is a schematic representation of a tidal-lift curtain barrier that was tested at the finger pier complex at MINSY. The study was especially well-suited for the test since a lateral seal to the basin was provided on one side by a concrete quaywall and on the other side by an undredged mud bank beneath the adjacent pier. A 3- to 6-foot gap over the top of the curtain allowed free tidal exchange while preventing any significant sediment flux into the basin.

The 275-foot-long curtain consisted of 13 interconnected sections, each about 20 feet in length. Each section was 30 feet high and was fabricated from a nylon-reinforced neoprene material. An 18-inch-diam concrete-filled anchor was attached to the base of each curtain section, while a similar-sized foam-filled float was attached to the top. At the surface, a 24-inch-diam foam-filled float was attached to the intermediate float by a series of three lifting chains. Both of the floats and the anchor were fabricated from galvanized steel conduit.

Opening and closing the curtain proceeded as follows. At low tide preceding movement of the curtain, the slack lifting chains were shortened and secured by a chain stopper. With the ensuing flood tide, the additional buoyancy of the surface float was sufficient to lift the anchor free from the mud, allowing the curtain to float freely. At this point, the curtain was swung to one side of the berth using a small utility boat. The curtain was closed by reversing this procedure.

Repeated bathymetric surveys showed that during the 4-month test period, about 2 feet of deposition occurred inside the test berth, while 6 feet of deposition occurred outside the berth. This represents a 70% effectiveness during a period of high deposition, even though the curtain was left open for several protracted periods of time. Fortunately, the latter had a relatively minor impact on the experiment because most of the deposition occurred during February when the curtain was open for only 3 days.

One of the reasons the curtain was left open during the test period was that it was too cumbersome. Clearly, the repeated shortening and lengthening of the chains required to cycle a single ship into and out of a berth served to demonstrate that a successful curtain barrier must be able to be rapidly opened and closed using a minimum of personnel. The tidal-lift curtain failed in this regard and was not suitable for its intended use. The design might have merit, however, as a semifixed portion of a larger curtain with a more easily opened "gate" section. The gate section could consist of a two-story curtain described below.

The shortcomings of the tidal-lift curtain for use in a berth with high levels of ship traffic were in many ways overcome by a different type of curtain that used compressed air to raise and lower the curtain. Figure A-5 shows a schematic representation of a two-story curtain barrier. The rationale behind a two-story curtain is to provide an upper story that can be rapidly raised and lowered to let a shallow draft vessel into and out of the berth. This is accomplished by way of a small hose bladder that can be rapidly filled or purged of air. The lower story can be raised more slowly using a series of air bladders attached to the anchor modules when a deep draft vessel needed to access or egress the berth.

A two-story curtain was tested at MINSY for 12 months using the same berth as was used for the tidal-lift curtain. The two-story curtain consisted of 13 sections coupled together to span the 275-foot-wide entrance to the berth. The lower curtain sections were salvaged from the earlier tidal-lift curtain and then modified; the upper curtain sections were newly constructed from thinner Hypalon material. Both the upper and lower curtain sections featured pneumatic buoyancy control and the entire curtain could be winched to one side of the berth without the use of a boat.

The main modification to the lower curtain sections was to reduce the height of the sections to 16 feet. The lower curtain sections used the same anchor modules and intermediate floats as did the tidal-lift curtain. Other modifications included: fitting each section with tension-relieving cables running from the float to the anchor on each side, adding shear plates to the anchor modules to stabilize the curtain against lateral loading, and fitting three independently regulated air bladders to each anchor module.

Inflating and deflating the air bags was controlled by a series of air regulators connected to a common air distribution manifold. Each air regulator was connected to a single air bladder via a flexible air hose. The air regulators were necessary to ensure an even flow into the air bladders during filling regardless of variations in bladder depth. The separate connections eliminated any cross flow between the air bladders. As a safety precaution, each curtain section was capable of being raised by two of the three air bladders.

The upper curtain sections were fabricated from single-ply Hypalon material. A continuous 6-inch-diameter collapsible hose provided buoyancy for the entire upper section. This hose could be rapidly deflated and inflated, allowing a shallow draft vessel easy access to the berth.

Repeated surveys showed that during the 4.5-month test period between 17 November 1981 and 4 April 1982, about 2 feet of deposition occurred inside the test berth versus about 5 feet of deposition inside an adjacent control berth. During this time, however, the curtain was often left open for extended periods. Unfortunately, these periods were poorly documented. Nevertheless, the curtain was 60% efficient in reducing shoaling inside the test area compared with shoaling in the adjacent unprotected control berth.

In summary, future engineering development of the barrier curtain concept must address the need for a simpler method of opening and closing the curtain. In addition, work is needed to develop more modular designs that utilize low-cost, durable materials.

CRATER-SINK SAND BYPASSING

This system refers to the process of intercepting the littoral sand transport entering an inlet navigation channel and returning it to the downcast beach (Figure A-6). The system uses a craterlike depression excavated in the seafloor to intercept the sand transport. Generally, the crater is excavated using a submerged jet pump, assisted by a conventional dredge pump used as a booster. The capture radius of the crater can be augmented by using one or more fluidizing pipes.

The advantages of a crater-sink sand bypassing system over a conventional dredge are its ability to operate in all types of weather, its noninterference with ship navigation, and its potential lower cost.

Several crater-sink sand bypassing systems have been tested to date. The most successful test was at Rudee Inlet, Va. This site had the advantage of clean sand instead of sand with cobbles and kelp debris that plagued tests of the system on the West Coast. The U.S. Army Corps of Engineers is currently funding the design of a large crater-sink sand bypassing system for use at Oceanside Harbor, Calif.

In summary, the crater-sink sand bypassing system is still in the early stages of development. Problems with fouling by kelp, cobbles, and large shells need to be resolved before the system can be applied to many types of sites. For this reason, the system is probably best suited for sites located along the Southeast and Gulf coasts of the United States at this time.

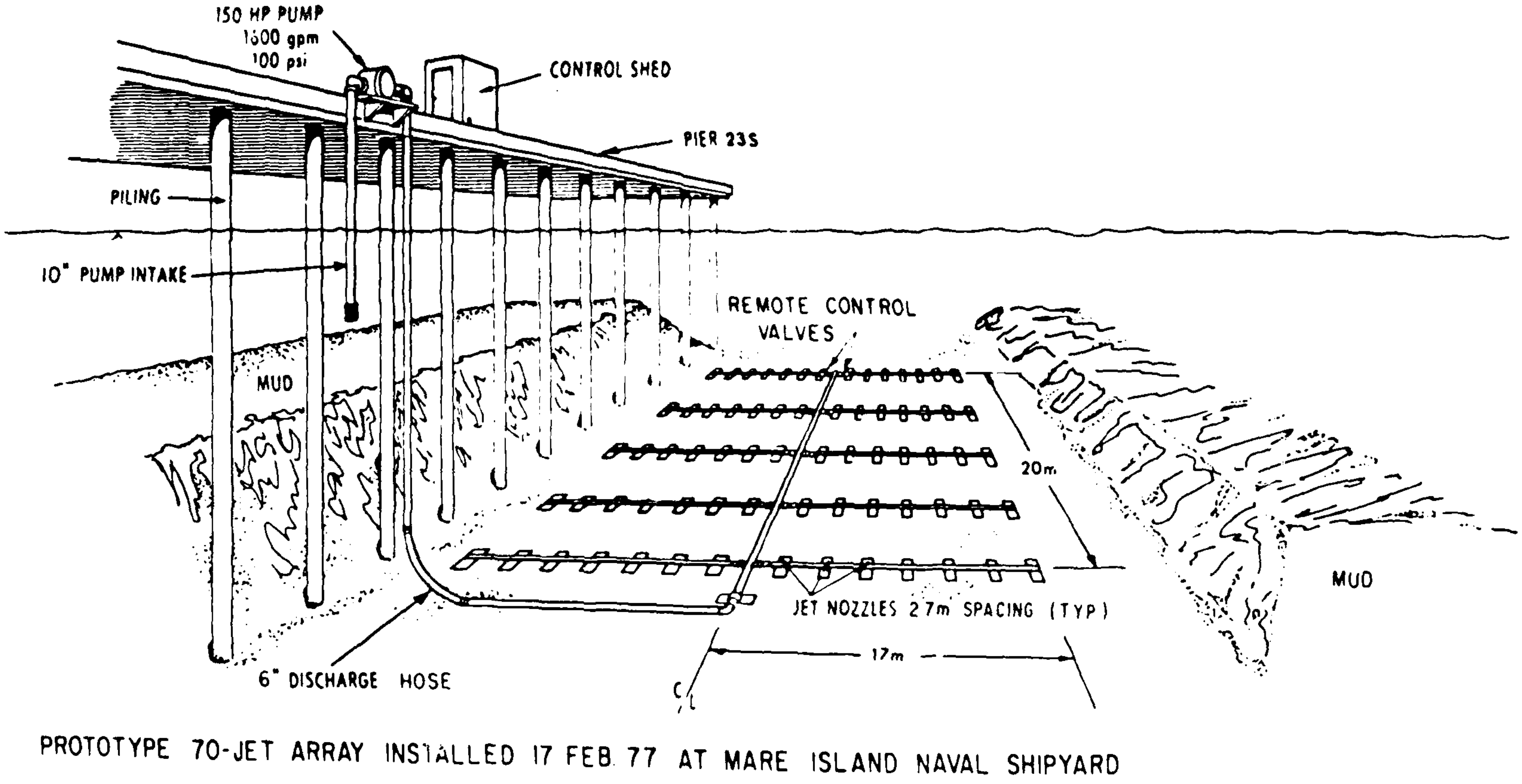
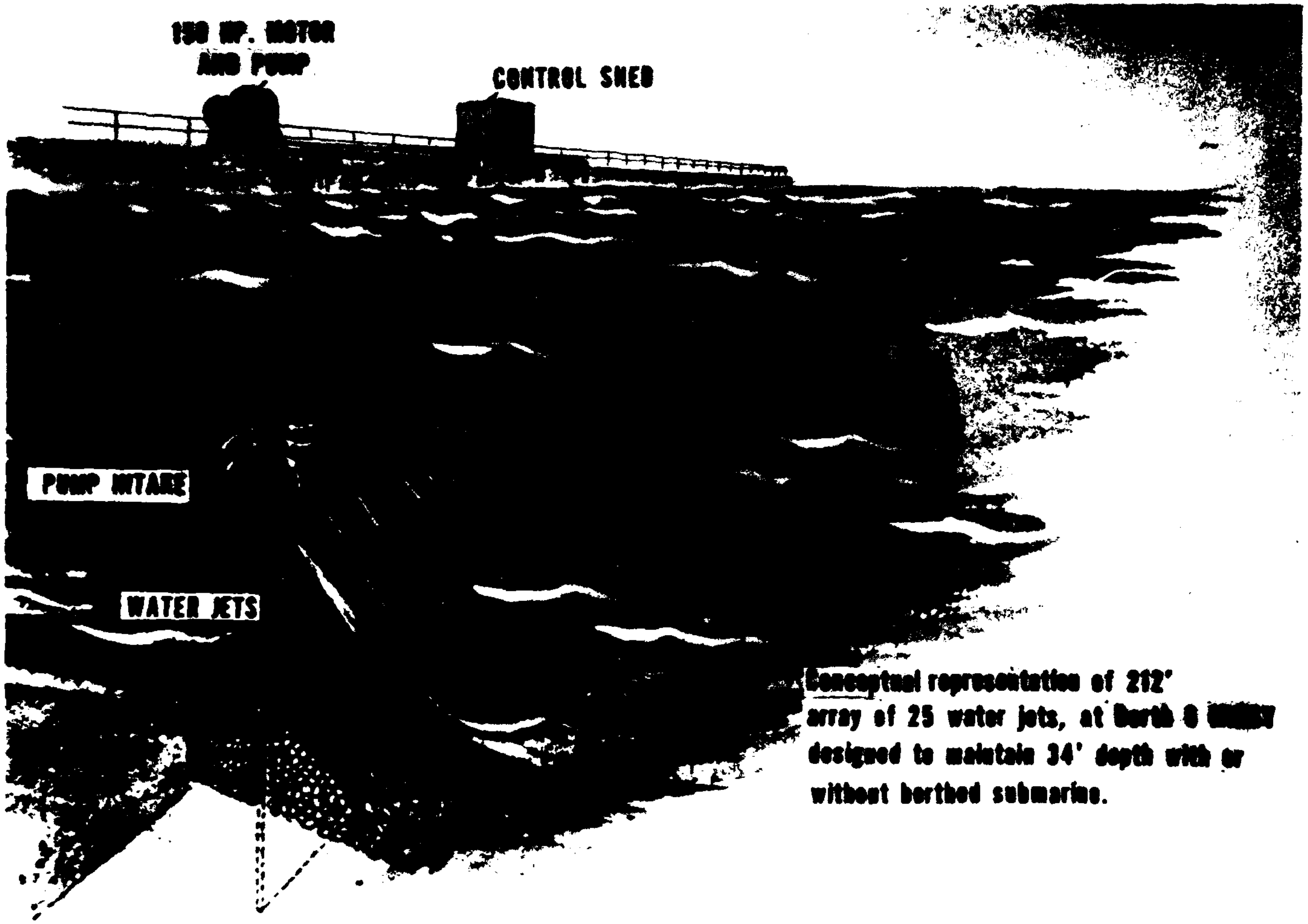


Figure A-1. Schematic view of a spatial scour jet array tested at Mare Island Naval Shipyard.



Conceptual representation of 212' array of 25 water jets, at Berth 8 MINSY designed to maintain 34' depth with or without berthed submarine.

Figure A-2. Schematic view of a linear scour jet array tested at Mare Island Naval Shipyard.

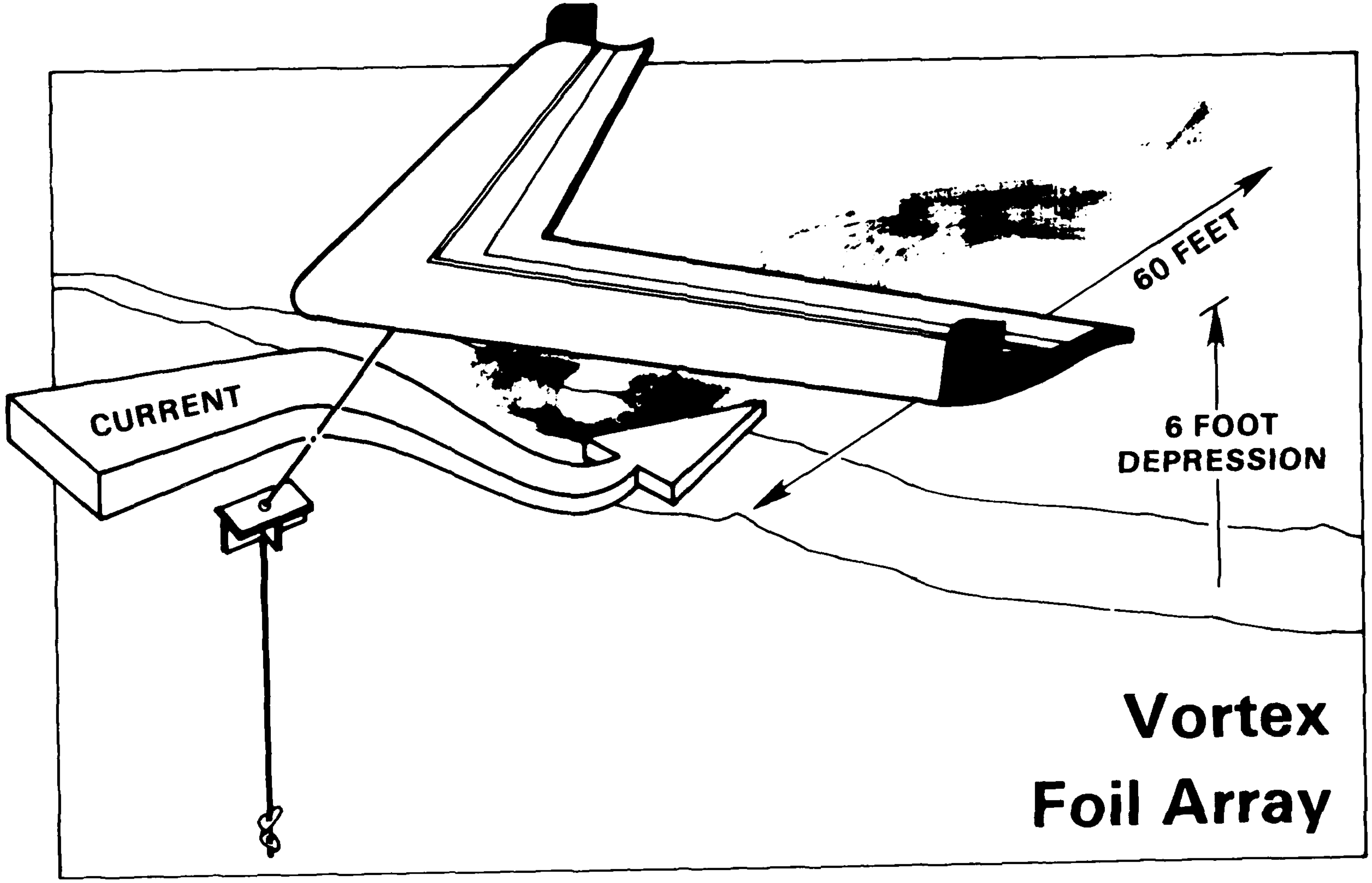


Figure A-3. Schematic representation of the tidal flow past a vortex foil creating a zone of scour behind the foil. The foils are used in arrays to prevent sediment deposition.

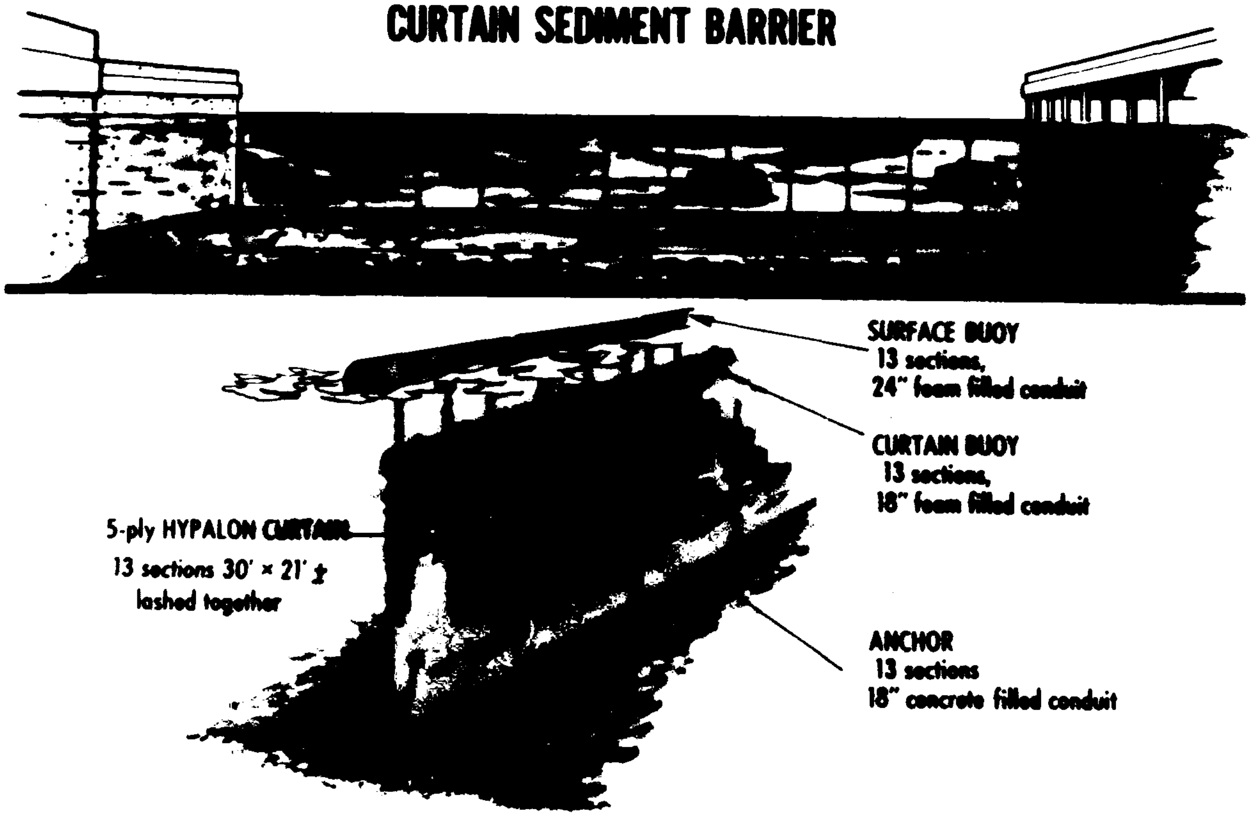


Figure A-4. Schematic view of a tidal-lift curtain barrier. The upper surface floats are used to lift the curtain by shortening the connection chains at low tide.

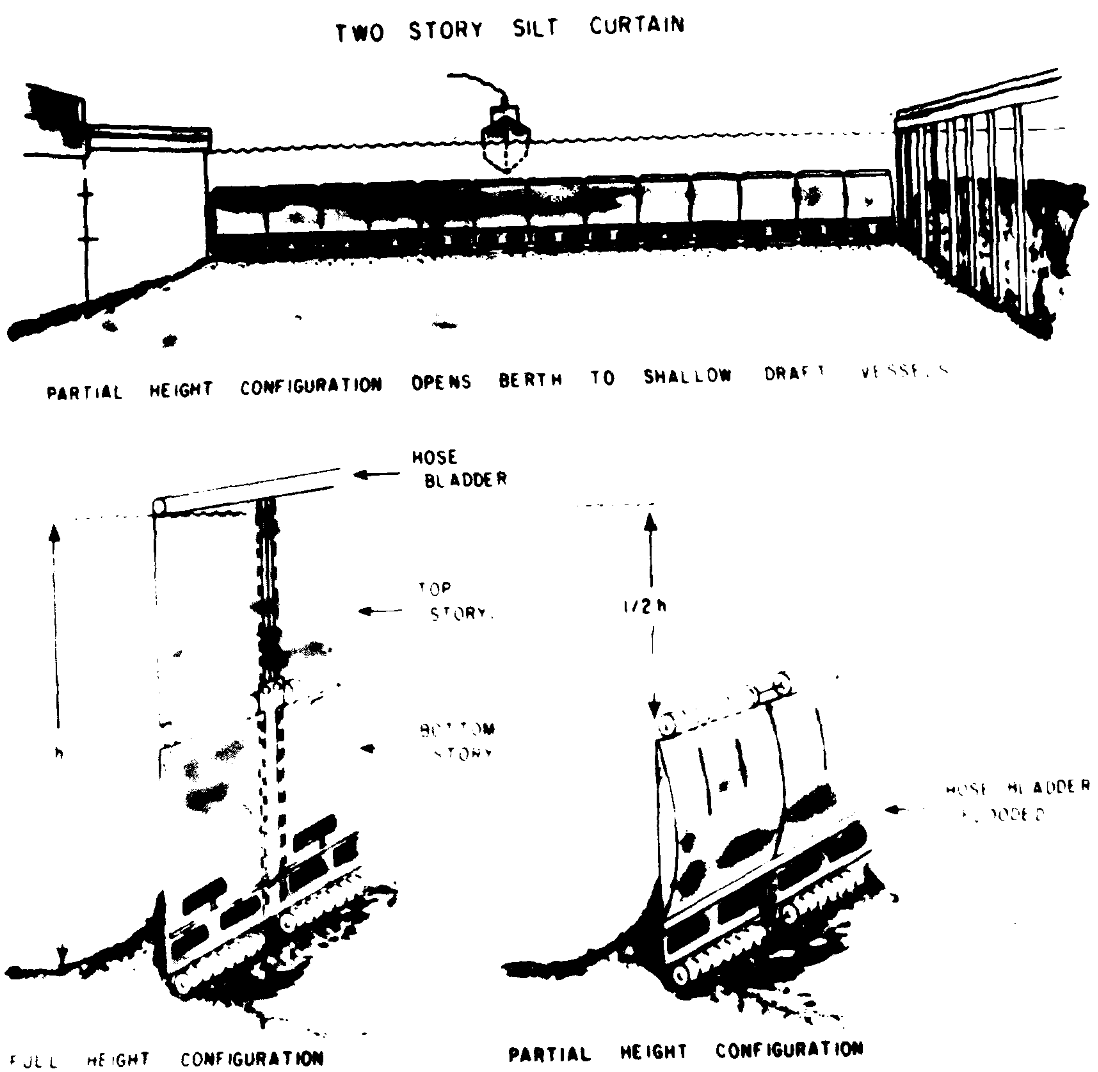
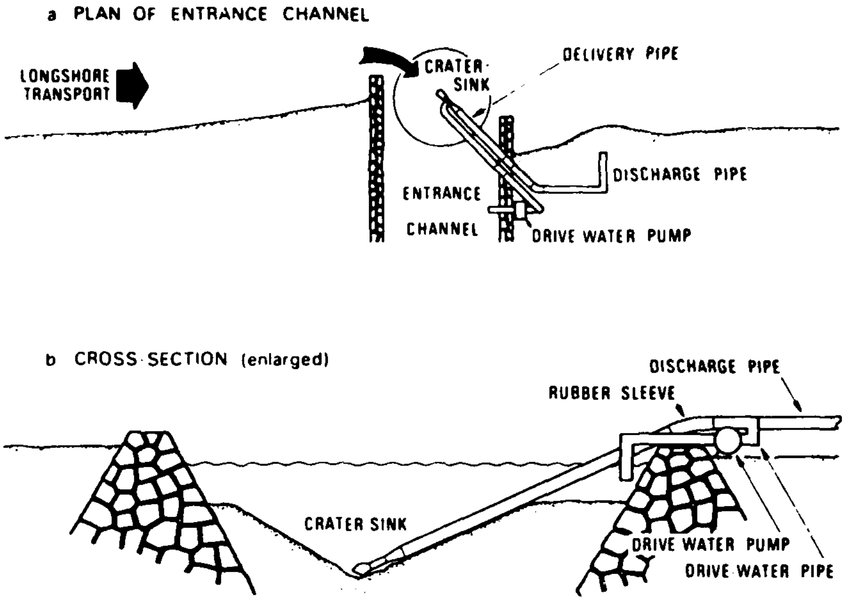


Figure A-5. Schematic view of a pneumatic two-story curtain barrier. The upper section can be lowered independently of the bottom section to allow the transit of shallow vessels. Both sections are raised and swung out of the way to allow the transit of a deep draft vessel.

Crater - Sink Sand Bypassing



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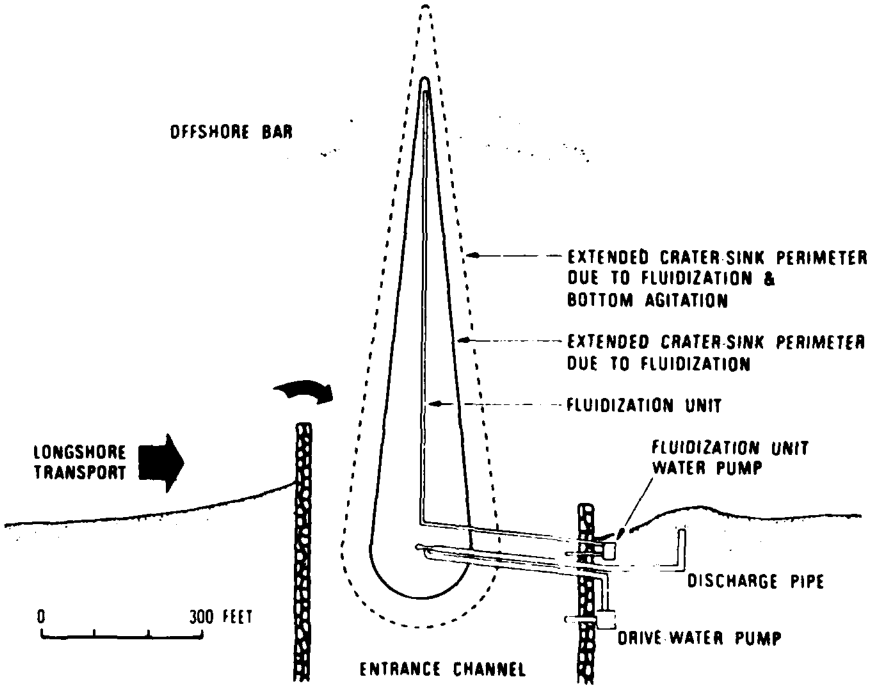

2. Augmentation by Sand Fluidization

Figure A-6. Schematic view of a crater-sink sand bypassing system with (bottom) and without (top) a sand fluidization unit to extend the capture radius of the crater.

Appendix B

SPECIFIC OPERATIONAL PROBLEMS ASSOCIATED WITH INADEQUATE WATER DEPTHS AND UNWANTED SILTATION

- Siltation in approach channels used by carriers and TRIDENT submarines poses the risk of accidental grounding of these vessels (e.g., Alameda, New London, Port Canaveral).

- Although not officially considered groundings, Navy ships are frequently forced to "plow through the mud" to access or egress berths, posing threats to vulnerable underwater appendages (e.g., sonar domes) and increasing wear and risk of damage to propulsion system components (e.g., Charleston).

- Navy ships are being silted in at shipyard berths, resulting in delays, inordinate tug demands, and increased risk of damage during exiting maneuvers (e.g. MINSY).

- Dewatering of dredge material disposal areas often limits dredging operations, creating problems for ship movements (e.g., Charleston).

- Upper capacity limits of many Navy upland dredge material disposal areas are being approached (e.g., Mayport has about 2 years useful life remaining; Port Canaveral and Charleston have less than 10 years remaining).

- The 600-ship Navy of the 1990s will require deeper project depths in many locations and more berthing space, aggravating present Navy dredging problems (e.g., berthing footage shown on paper at PNSY, MINSY, and Charleston is only partially usable today because of undredged sediment accumulations).

- Obtaining permits for dredging and spoil disposal is becoming more difficult, creating delays, restricting ship movements, and contributing to rising costs (e.g., NWS Earle).

- Increased project depths can produce disproportionate increases in Navy dredging requirements because of waterfront structural incompatibilities (e.g., the 3-foot-depth increase at MINSY to accommodate Los Angeles class submarines will result in the Navy having to dredge to 250 feet from the quaywall rather than only 100 feet).

- The hole under floating drydocks acts as a settling basin that rapidly fills with sediment. In some areas this hole must be redredged each time the drydock is used. This produces ancillary costs for demooring and remooring the floating drydocks (ARDM) to allow dredging to take place, as well as lost time (and cost) and capability while it occurs (e.g., Charleston, Kings Bay, New London).

- Ships undergoing repairs and outfitting at docksides must be "hand dredged" by divers at some locations. This dredging is done at great cost, espeically if required prior to completion, since rigging, scaffolding, and utility connections must be removed and replaced (e.g., dredging around a submarine berthed at the MINSY quaywall can cost over $20K in diver time alone).

- Carrier sea suction fouling by marine bottom organisms (e.g., hydroids) can result in exit delays, unusual ship excursions, and reduced operational capability for periods of time which, although difficult to quantify in terms of cost, represent unwarranted fleet risks and reduced operational readiness (e.g., Norfolk Pier 12).

- The movement and reseating of drydock caissons to allow access and egress to graving docks can require "hand dredging" by divers and days of lost time while a proper seal is obtained. Often considerable sediment must be removed from the drydock floor after dewatering (e.g., at MINSY it may require 3 to 5 days and a cost of $6,000 to $11,000 just for diver time).

- SUPSALV reports needing at least 5 feet of keel clearance at low tide for normal hull cleaning activites and at least 10 feet of keel clearance for screw changes or sonar dome replacements. Very few of the Navy harbors with dredging problems have any excess keel clearance.

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