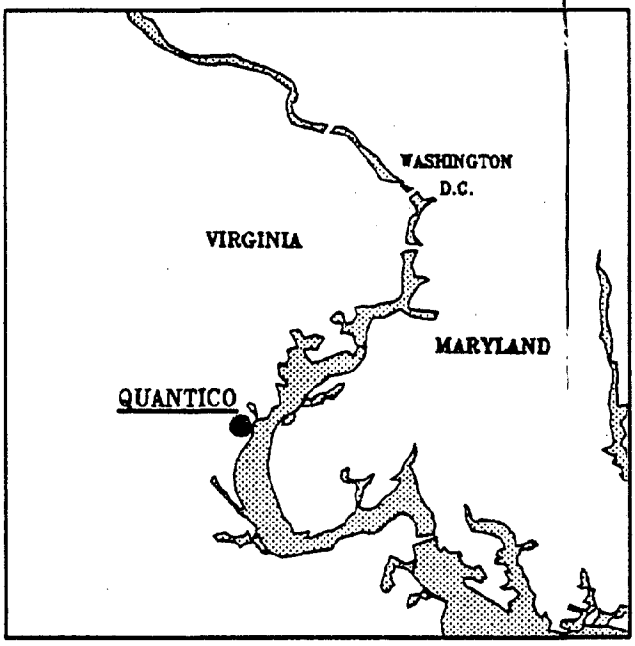
Dewberry & Davis

Final Report

Potomac Riverfront Park Environmental Study



Town of Quantico
Prince William County, Virginia

In Cooperation with:

Northern Virginia Planning District Commission

mber 1989

POTOMAC RIVERFRONT PARK ENVIRONMENTAL STUDY

Final Report

December 28, 1989

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TOWN OF QUANTICO
POTOMAC RIVERFRONT PARK ENVIRONMENTAL STUDY

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

EXECUTIVE SUMMARY

The Town of Quantico is approximately 45 acres in size with an estimated population of approximately 700 people. Prior to 1986, the Town was completely surrounded by the Quantico Marine Corps Base which encompasses approximately 60,000 acres of land area with 15,000 to 20,000 military personnel and civilians. In 1986, the federal government deeded a 4.21-acre parcel along the Potomac River to the Town for public park use subject to specific conditions. This sudden substantial increase in land area (10%) provides the Town an opportunity for direct waterfront access and economic growth. Essential to these goals are the stabilization of the existing shoreline and the selection of an overall project that is consistent with all environmental requirements. The information summarized in this report is intended to provide a sound basis for further pursuing the accomplishment of these goals and objectives. The significant findings during the performance of the environmental and engineering evaluations are briefly summarized in the following paragraphs.

The natural environmental setting of the subject site has been altered by manmade activities since at least the early 1900s. Initially, the Quantico Company, an early commercial enterprise, benefitted by using the area as a seaport with its excellent access to the Potomac River. By 1925, the United States Marine Corps had established their presence totally surrounding the Town and constructing the present-day dock and marina. Ocean-worthy military vessels would frequently visit using the available facilities. Additionally, the channel of Little Creek which naturally flowed directly into the Potomac River along the northern limits of the subject site was diverted to the north adjacent the Richmond, Fredericksburg, and Potomac (RF&P) Railroad and into Quantico Creek. This diversion probably benefitted the RF&P, the Town, and the U.S. Marine Corps Base at the time by reducing the flood damage potential. Seawalls to stabilize the shoreline were also constructed during at least two (2) different periods. The most recent structure can be seen today while the earlier structure has been filled.

Within the shoreline and open water area adjacent the site, the following characteristics prevail:

- Mean Low Water (MLW) is elevation -0.23 foot.
- Mean High Water (MHW) is elevation 1.14 feet.
- Tide Range is 1.37 feet.
- Basin depth gradually increases from 0 foot at the shoreline to 6 feet approximately 600 feet away.
- Average currents are less than 1.0 knot with varying directions dependent on the tide condition.
- Critical design wind direction for shore stabilization is from the north-northeast.
- Shoreline area is classified as a nonvegetated tidal wetland with evidence of local erosion.
- The Potomac River in the area is classified as an estuary within the tidal freshwater salinity zone.
- Water Quality within the basin is good to excellent based on Dissolved Oxygen (DO) and Total Suspended Solids (TSS) levels.
- Heavy metal concentrations in the bottom sediments of the basin area are within the expected range. No toxic substances appear to be present.
- Submerged Aquatic Vegetation (SAV) was present this past summer throughout the basin area. The predominant species were watermilfoil, wild celery, and hydrilla.

The proposed project primarily consists of a public park, with possible restroom facilities and a free-standing restaurant, and a marina with 130 to 140 boat slips. Shoreline stabilization is proposed which involves repairing some portions of the existing seawall with stone reinforcement while completely replacing other portions with a full section riprap revetment structure. A breakwater structure to provide shoreline protection while ensuring a safe harbor within the new marina is also proposed. The proposed project was presented to federal, state, and local agency representatives on August 21 and 22, 1989, at the site to solicit comments and to determine jurisdictional responsibilities. In attendance were representatives of the following agencies:

U.S. Army Corps of Engineers, Norfolk District
Virginia Marine Resources Commission (VMRC)
Virginia Institute of Marina Sciences (VIMS)
Maryland Department of Natural Resources (DNR)
Prince William County
Shoreline Erosion Advisory Service (SEAS) of Virginia

The single most significant comment among all federal and state agencies was that impacts to submerged aquatic vegetation (SAV) are highly undesirable and must be avoided to the extent practical. As of the date this report was finalized, both Maryland DNR and VIMS provided written comments further stressing this concern and indicating that favorable recommendations for permit approval would require design compromises resulting in lesser environmental impacts. Maryland DNR also clarified that at this time the same policies and procedures will be invoked for a wetlands license application regardless of whether or not the project originates from the Virginia or Maryland shoreline. The same regulatory position is expected from the Maryland Department of Environmental Resources, who must issue a Section 401 water quality certificate since the Potomac River below mean low water is within the State of Maryland.

In view of the comments provided, alternatives to the proposed project were investigated to determine the general feasibility of satisfying the proposed project goals and objectives while minimizing impacts to SAVs. Based on the

alternatives evaluated, it appears that impacts to SAVs can be reduced from approximately 5.0 acres to 2.5 acres while still providing a soundly designed public marina for as many as 60 to 70 boat slips. Further reductions or changes in the size or the configuration of the marina are on the verge of being impractical or cost-prohibitive.

The condition of the existing shoreline and seawall warrants some level of repair and additional stabilization regardless of whether or not a marina is constructed. The level of protection and associated cost to construct would increase as improvements to the park area are added. If no shoreline improvements are provided, the shoreline would likely continue to erode and the existing seawall will eventually collapse. Minimum improvements in the form of seawall repairs and riprap protection along the northern portion of the site would reduce the potential for loss of shoreline under frequent storm conditions. More significant repairs should be considered by weighing the costs of initial construction against the potential for property damages (land and/or marina) and emergency maintenance.

In addition to the environmental issues involved with obtaining all of the necessary federal and state approvals to construct the proposed project or any feasible alternatives, a number of other issues must be overcome. These obstacles and the order in which it is recommended that the Town initiate their solution are summarized below:

- Possible parking lot locations for the proposed project need to be investigated in greater detail. Comments from the public and the appropriate representatives of the U.S. Marine Corps Base should be solicited. Impacts to existing residences and Base operations need to be minimized while providing ample parking spaces and functional layout.

- The proposed breakwater structure encroaches into waters where the adjacent shoreline is within the Marine Corps Base. Traditionally,

such an encroachment would likely be unacceptable without permission from the landowner. It is suggested that the Town coordinate with the appropriate representative(s) of Marine Corps Base to obtain the necessary permission prior to preparing any permit applications.

- In order to satisfy the conditions imposed by the federal government when the land was donated, an environmental assessment (EA) appears to be necessary. A scoping meeting with the U.S. Department of Interior is recommended to present the proposed project and to determine the desired format and content of the lead federal agency. The alternatives to be further studied and presented should also be determined. Additional coordination with representatives of the U.S. Army Corps of Engineers, Maryland DOE, and Maryland DNR during the preparation of the EA is recommended.

- Probable disposal sites for 5,000 to 30,000 cubic yards of dredged material need to be identified through coordination with Marine Corps Base personnel and subsequent discussions with the appropriate agencies. The availability of a disposal site will likely dictate the construction schedule.

- Funding alternatives that consider construction costs and estimated revenues from the selected project need to be investigated.

- Compliance with the Chesapeake Bay Preservation Area Designation and Management Regulations will be required within the next year. Resource Protection Areas (RPAs) and Resource Management Areas (RMAs) will need to be designated by the Town through coordination with representatives of Prince William County and the Chesapeake Bay Local Assistance Department. It is recommended that the appropriate representative(s) of the Town contact Prince William County in the near future to establish the lines of communication and to discuss the specific criteria for designating RPAs and RMAs.

Subject to determining the extent of SAVs that can be impacted given the Town's rather unique circumstances, it appears that a marina with a breakwater structure will provide substantial shoreline protection. Additional stabilization measures include replacing and repairing the existing seawall using riprap. The use of wetland vegetation along the shoreline should also be considered during the preparation of an environmental assessment and future discussions with the agencies. Creating a vegetated wetland compatible with the SAVs could be offered as mitigation for the unavoidable impacts.

ACKNOWLEDGEMENTS

The environmental and engineering evaluations performed for this project involved substantial participation on the part of Ms. Beth Topol of the Northern Virginia Planning District Commission. The contributions of Mr. Mitchel P. Raftelis, the Chairman of the Town Council; and Mayor Howard Golognese, the Mayor of the Town; and Mr. Rusty Arcuni, the Harbor Master of the Quantico Marine Corps Base, also assisted in the gathering of information relative to the project. Additionally, representatives from the various federal, state, and local agencies that were contacted over the past year provided invaluable comments and information that will need to be further considered in subsequent phases.

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF APPENDICES

LIST OF EXHIBITS

I. INTRODUCTION

A. PROJECT DESCRIPTION

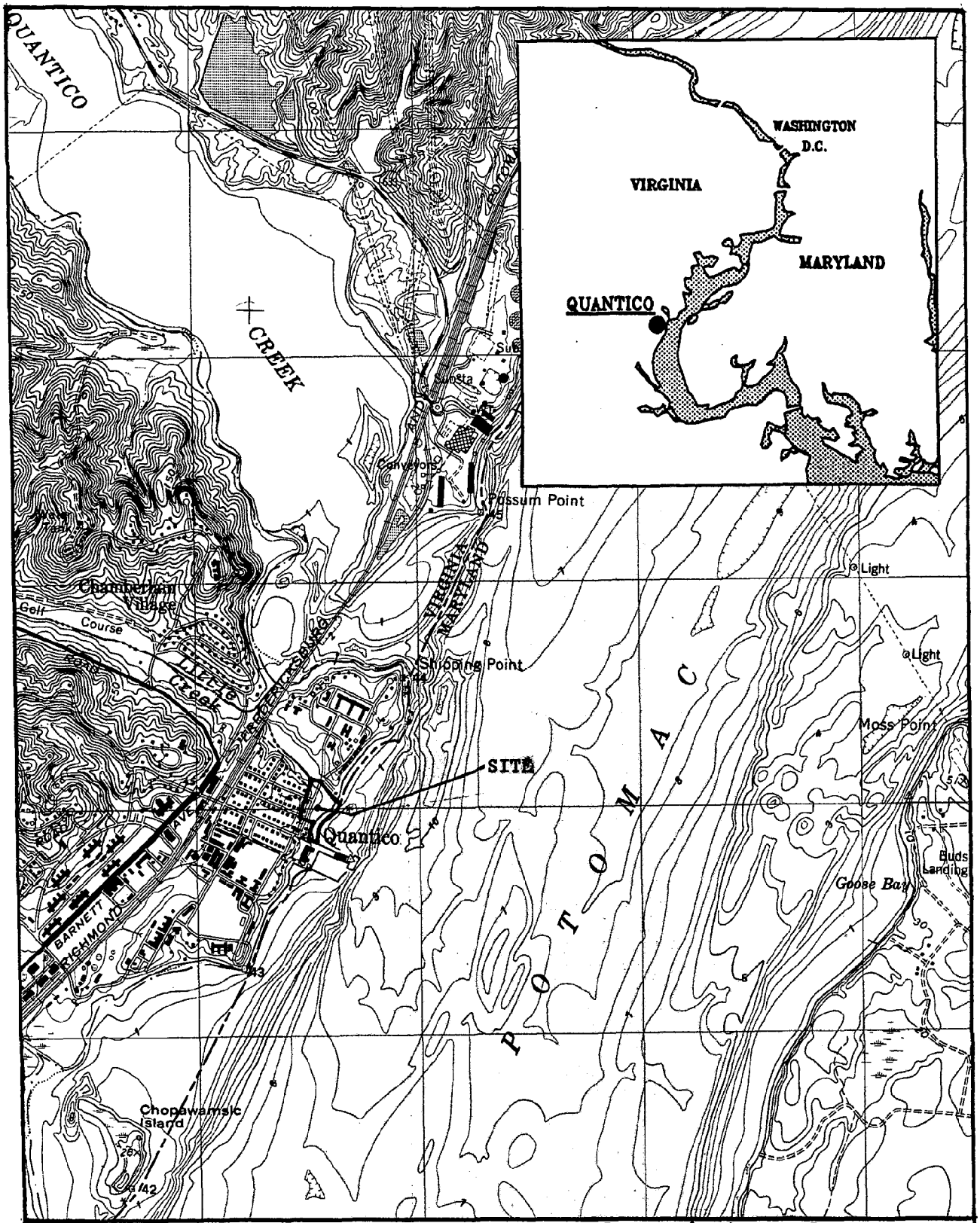
The Town of Quantico is located in Prince William County, Virginia, approximately 30 miles south of Washington, D.C. A Vicinity Map is shown on Figure 1. Except for approximately 500 feet of riverfront property along the Potomac River, the Town is surrounded by the U.S. Marine Corps Base.

The work performed under this contract for the Potomac Riverfront Park Project is based on a "Coastal Resources Management Grant Contract" awarded to the Town of Quantico through the Virginia Council on the Environment. The description of the work scope is specified in the "Request for Proposal 1989" publicly announced by the Town of Quantico. Copies of the grant contract and the public announcement are provided in Appendices 1 and 2.

The riverfront property that is the subject of this project covers a total land area of 4.21 acres, and was deeded to the Town of Quantico in 1986 by the Federal Government. Copies of some of the relevant documents containing various details of this transaction are also included in Appendix 1. The following conditions of property use are significant for the purposes of the present project:

- the property shall be used and maintained exclusively for public purposes;

- the property shall not be sold, leased, assigned, etc., except to another government agency. However, concession agreements to third parties may be allowed with written approval of the Secretary of the U.S. Department of Interior;



Approximate Scale: 1"=2000'

FIGURE 1 - Vicinity Map And Topographical Map

- the property will be subject to various public laws and provisions, including the National Environmental Act of 1969, as amended, the National Historic Preservation Act of 1969, as amended, the Architectural Barrier Act of 1968, Public Laws 90-480, 91-205 and 93-112 (for the physically handicapped), and Executive Orders 11988 and 11990 concerning floodplain management and protection of wetlands.

In conjunction with the above, the Town of Quantico proposes to develop the land as a public park. The principal elements of the proposed park project are a marina consisting of a breakwater and piers, and restoration of the shoreline for recreational use including the repair and replacement of the deteriorated portion of the existing seawall.

The combined park and marina project, referred to hereafter as the proposed project, will provide the Town of Quantico a means for limited economic expansion while greatly improving access to the Potomac River for the general public, both boating and nonboating, and the Marine Corps Base personnel and their families. Thus, the proposed project is also consistent with the State's Comprehensive Outdoor Recreation Plan which identified a significant need for boater access to the Potomac below the Occoquan River.

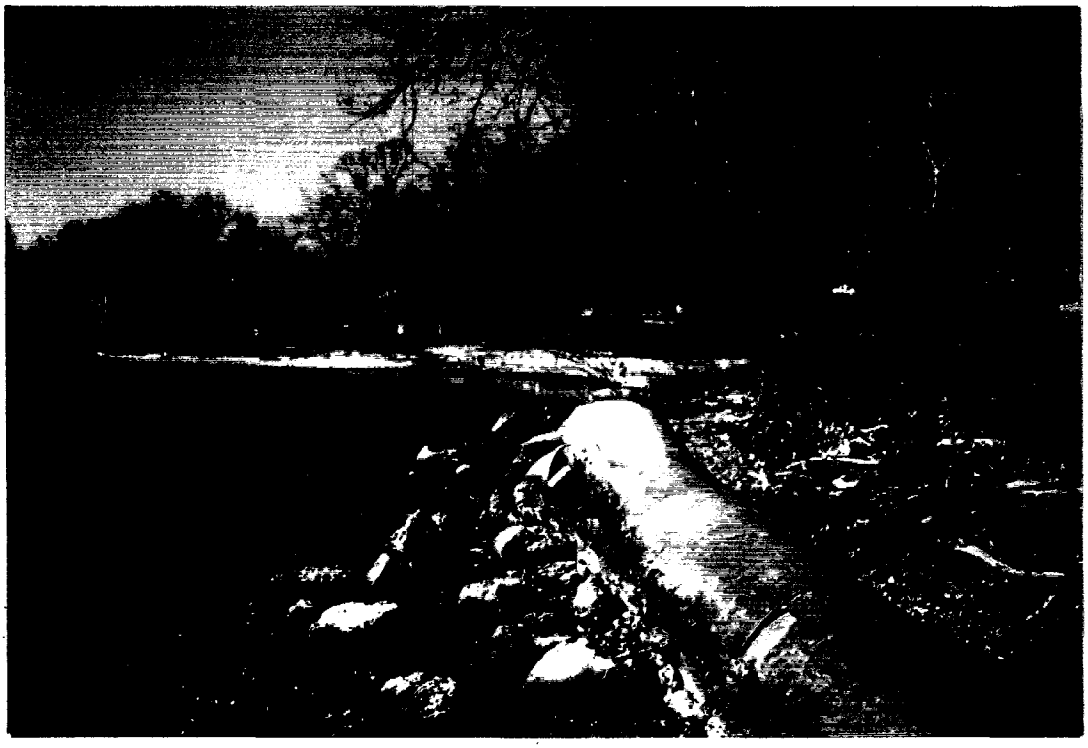
Prior to the engineering design of the proposed project, it was determined that it would be appropriate to conduct an environmental study to identify environmentally sound strategies for stabilization and management of the shoreline so as to prevent adverse environmental impacts in the future.

As mentioned in the application for the grant by the Town of Quantico to the Virginia Council on the Environment, the primary objectives of the first phase of the work represented by this environmental study are:

View Of The Proposed Marina Basin (Looking North)

View Of The Shoreline And Riverfront Park Area (Looking South)

Deteriorated Seawall With Washed-off Backfill



Deteriorated Seawall With Washed-off Backfill

- to eliminate the present adverse conditions, including prevention of the collection of the unsightly debris along the southern end of the shoreline,
- to make recommendations for the restoration of the deteriorated portion of the existing seawall, and to otherwise recommend improvements to the shoreline conditions for public access and recreation purposes,
- to ensure that the proposed improvements will not create adverse environmental impacts,
- to create an environmentally sound, economically feasible and aesthetically pleasant waterfront facility.

It is also mentioned in the Town's application for the grant, that the subsequent phases of the project, not included in the present scope, will incorporate the findings of the present study for performing detailed designs, estimating construction costs, obtaining all applicable federal, state and local approvals and permits, and preparing construction plans, and specifications.

B. STUDY OBJECTIVES AND WORK SCOPE

The objectives of this study were specified in the public announcement by the Town of Quantico as follows:

- to identify environmental sensitivities and make recommendations to protect portions of the Potomac Shoreline,
- to convert this riverfront area into a recreational park and marina in an environmentally sound manner.

The elements of the study's work scope were also identified by the Town with the assistance of the Northern Virginia Planning District Commission (NVPDC) and are listed below:

1. Identification of permits for shoreline stabilization and marina development.
2. A bathymetric survey.
3. Evaluation of shoreline erosion and sedimentation.
4. Sediment analysis.
5. Identification of all dredging needs.
6. Tidal and flood elevation identification.
7. Wind and wave climate assessment.

Additional tasks prescribed by the Town and NVPDC further identifying the deliverables include the following:

1. Listing of environmental constraints and shoreline stabilization needs.
2. Identifying effective angles and design requirements for structures needed to protect shoreline areas.
3. Listing required permits for shoreline stabilization and marina development activities.
4. Identifying all required dredging and possible locations for dredge spoils.
5. Providing a bathymetric map of the study area.

Dewberry & Davis (D&D) performed the work referred to above and in accordance with the study proposal accepted by the Town of Quantico. Notice to Proceed was issued on May 3, 1989.

C. HISTORICAL NOTES

The Town of Quantico is the outgrowth of a small fishing village that was also a railroad siding for the Richmond, Fredericksburg and Potomac Railroad serving Dumfries and towns to the west. Among the important milestones in the development of the Town of Quantico were the formation of the Quantico Company and the arrival of the U.S. Marines.

The following summary of the Town's early history is excerpted from "Quantico: Crossroads of the Marine Corps," pp. 18-19.

> "The Quantico Company was formed after the turn of the century and took up the task of building a town where the Potomac Land and Improvement Company had failed. Although still officially listed as "Potomac," the village soon came to be called "Quantico" because of its location on Quantico Creek and because of the promotional efforts of the Quantico Company."
>
> "A big enterprise of the Quantico Company was to promote the town as a tourist and "excursion" center. Picnic areas were set up, the Potomac river bank was turned into pleasant beaches complete with dressing rooms and refreshment stands, and a flotilla of boats and launches were available for visitors."
>
> "The steamer St. Johns regularly stopped at Quantico, bringing picnickers and tourists from Washington, D.C., to the north and Richmond to the south. In one week alone during the summer of 1916, an estimated 2,600 visitors came to Quantico by launch, steamer, and train, with greater numbers predicted for the following tourist season."
>
> "The Quantico Company advertised Quantico as "The New Industrial City" and offered lots 25 by 110 feet, and villa sites from 5 to 10 acres and laid out one street complete with sewers. At the same time, the company pushed for industry to come into the area."
>
> "Early in 1916 work began on the Quantico Shipyards located near Shipping Point on land now occupied by the Naval Hospital. By mid-1916 railroad sidings had been extended to the site and foundations for three steel-framed buildings had been laid. Reports indicate that that enough ships had been contracted for by that time to keep the plants busy for more than a year. The company planned to build ocean freighters and tankers, with passenger ship construction predicted for the future. The yard was advertised as one of the largest shipyards in the Western Hemisphere."
>
> "In addition, growing United States concern with the war in Europe prompted shipbuilding officials to report that they would soon be bidding for construction of U.S. Navy ships as well."

> "As a fishing village, excursion center, and now a shipbuilding center, Quantico was still not very large or significant, but it was here to stay. Within a year, the U.S. Marines would arrive and permanently put "Quantico" on the map and make its name known around the world."

According to the historical maps, the pier referred to as the Marine Corps Base dock was constructed around 1903-1904. It is clear from a Marine Barracks Plan reproduced in Figure 2 that the dock was in existence at its present-day size and configuration as early as 1919. The size and historical significance of the dock is again illustrated by the 1925 photograph of the ship USS Henderson reproduced in Figure 3. The photograph also shows that the marina on the south side of the pier was fully in place by 1925.

Until the 4.21-acre shoreline segment north of the Marine Base dock was deeded in 1986 by the U.S. Government to the Town of Quantico, the Town had been completely surrounded by Federal property occupied by the Quantico Marine Base. The Town's land access towards the west is by Fuller Road through the Base. The only water access to the Potomac River is along the shoreline segment defining the subject site of the proposed project. The proposed shoreline improvement, riverfront park and marina development project is aimed to bring substantial improvement to these limited access conditions.

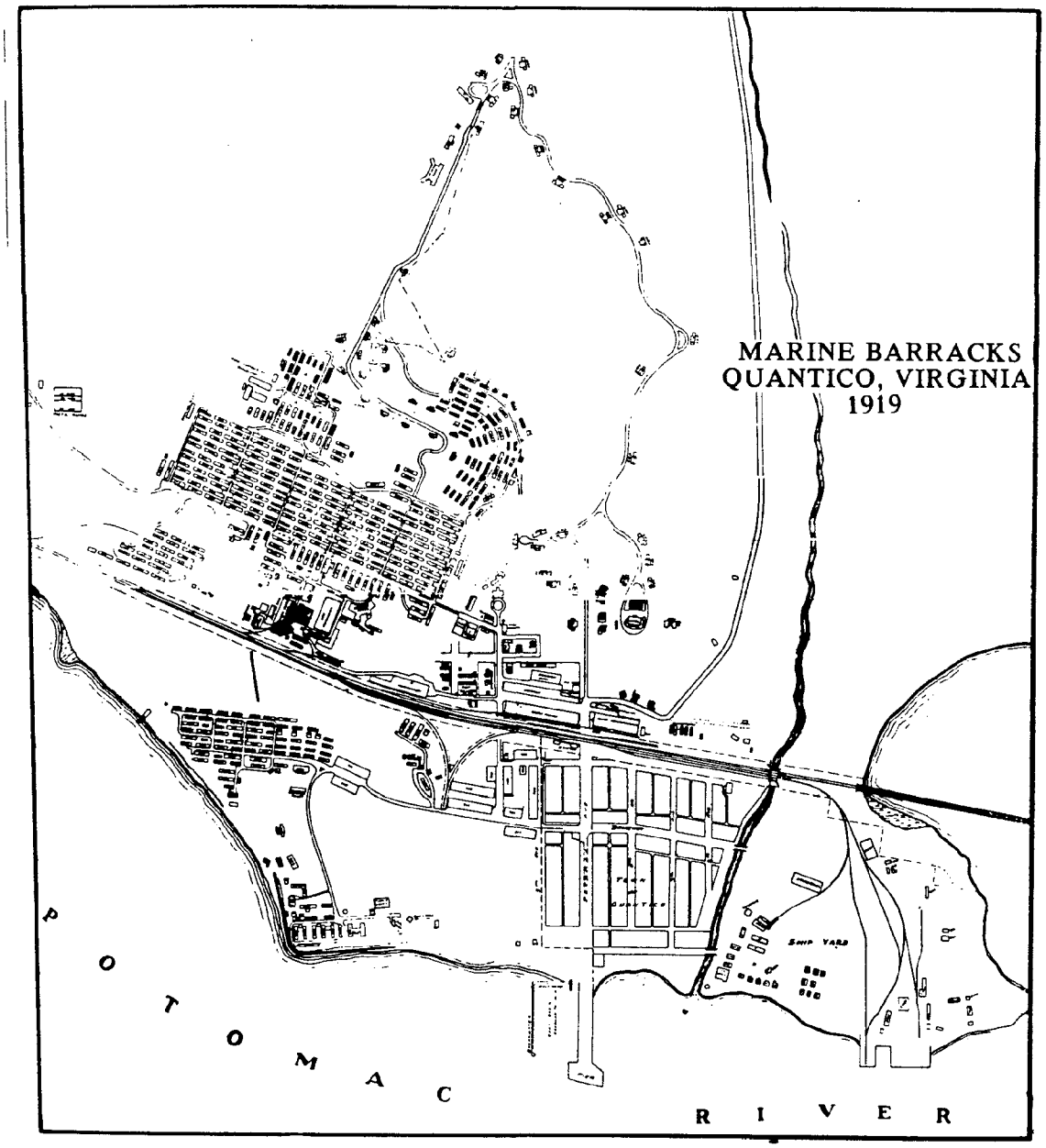
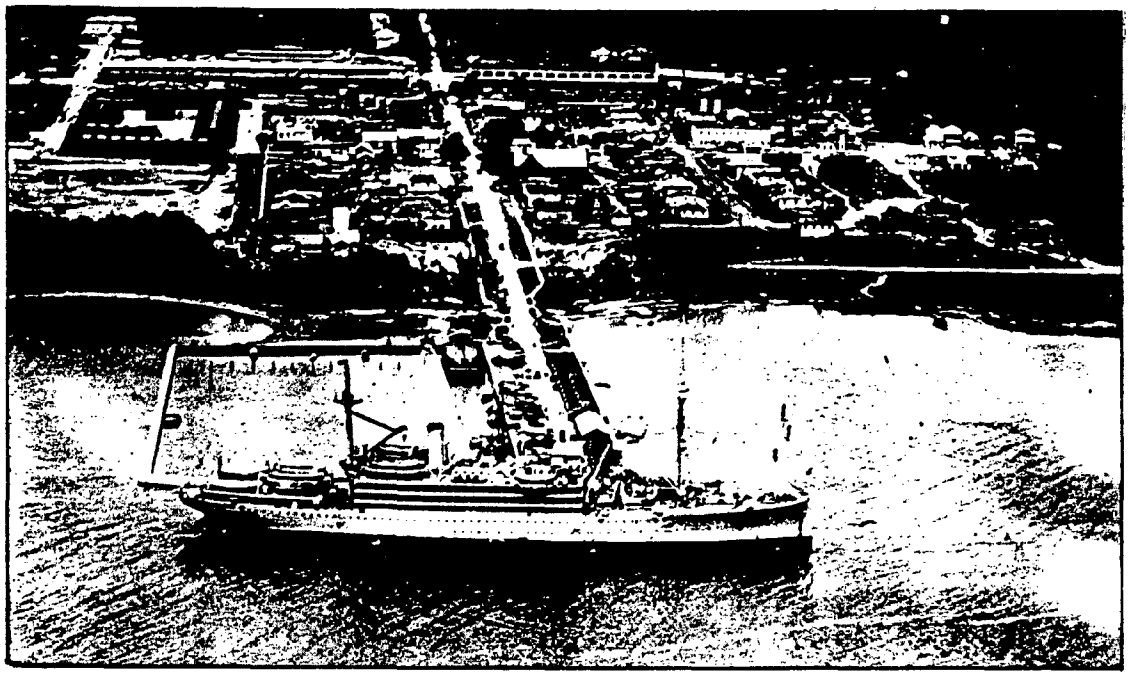


FIGURE 2 - Marine Barracks Plan Of 1919

(Reproduced from, "Quantico: Crossroads Of The Marine Corps", History And Museums Division, Headquarters, U.S. Marine Corps, Washington, D.C.)



The town of Quantico as seen from an aircraft over the Potomac River on 25 May 1925. The USS Henderson *is docked at the pier. The ship is named after Archibald Henderson, 5th Commandant of the Marine Corps. Visible in the upper left of the photograph is the Post Headquarters. (USMC Photo 515892).*

FIGURE 3 - Photograph Of Project Area, May 25, 1925

(Reproduced from, "Quantico: Crossroads Of The Marine Corps", History And Museums Division, Headquarters, U.S. Marine Corps, Washington. D.C.)

II. ENVIRONMENTAL EVALUATIONS

A. GENERAL

This phase of the study consisted of gathering and evaluating primarily three types of data and information. These were:

- Published information including maps, plans, books, newspaper articles, official documents, and similar other documents.

- Narrated and written comments based on personal interviews, telephone conversations, and meetings with knowledgeable individuals and representatives of local, state, and federal governments. These included Mr. Rusty Arcuni, the Harbor Master of the Quantico Marine Base Dock/Marina, and Mr. Mitchel P. Raftelis, the Chairman of the Town Council and long-time resident of the Town of Quantico.

- Field investigations performed by D&D. These included land and bathymetric surveys; tidal and nontidal wetlands delineation and preliminary assessment; preliminary inventory of submerged aquatic vegetation (SAV); sediment sampling and testing; and environmental field measurements that included currents, salinity, total suspended solids, pH and dissolved oxygen, performed at five representative locations during a 14-hour full tidal cycle.

A complete list of the sources of published data and information gathered is provided in Appendix 3. Summaries of interviews and relevant telephone conversations are provided in Appendix 4. Coordination with agency representatives is further described in Section IV.

Field investigations were conducted to compliment the available data and information in order to perform the necessary environmental evaluations. Depth of water adjacent to a shoreline and the rate and manner in which it fluctuates during a given time period directly affect the erosion and deposition trends of any shoreline. Attack of water on a shoreline may be in the form of waves generated by winds and boats, currents, and the rapid rise and fall of water-surface elevations from tidal forces and storm events. Waves initiate the movement of sediment particles otherwise at rest. Such sediment is then carried in a suspended state in the water or along the bottom by currents until favorable conditions for deposition are encountered. Deeper waters promote higher waves and stronger currents which have greater potential for erosion and sediment transport. Accordingly, deeper waters adjacent to a shoreline imply greater chances of shoreline erosion and instability.

The following subsections describe the manner in which available information and site specific field investigations were used to establish site characteristics. These characteristics were then used to assess shoreline stability (Subsection II.K.) and to also identify adverse environmental impacts from the proposed project (Section IV).

The following sections and subsections further describe the scope and findings of the various office and field investigations for collecting and evaluating site specific information.

B. SITE AND AREA GEOLOGY

The site is located in the Coastal Plain Physiographic Province. The Coastal Plan consists mainly of marine sediments which were deposited during successive periods of fluctuating sea level and moving shoreline. The formations dip slightly seaward. Many beds

exist only as fragmental erosional remnants sandwiched between more continuous strata above and below.

The soils in this province are typical of those laid down in a shallow sloping sea bottom: sands, silts, and clays with irregular deposits of shells. Some of the existing formations contain predominately plastic clays interbedded with strata of sands, while others contain predominately sands interbedded with plastic clays.

Figure 4 depicts the area and site geology. This illustration was obtained from the Geologic Map of the Quantico Quadrangle, Prince William and Stafford Counties, Virginia, published by the U.S. Geological Survey (USGS).

Based upon the published USGS mapping, the proposed basin area contains alluvium from Little Creek and Terrace deposits of the Potomac River. The alluvium, consisting of mud, sand, and gravel, would most likely be found overlying the Terrace deposits, in those areas where the alluvium exists. The Terrace deposits are expected to include, from bottom to top, (1) medium to coarse light gray to white sand, thickly bedded (up to 15 feet thick), (2) fine to medium clay sand, thin bedded, interbedded with thin silt and clay beds, (3) light gray or greenish gray sandy clay and silt in units 5 to 10 feet thick, containing scattered pebbles (up to 3" in mean diameter) and cobbles (greater than 3" in mean diameter), and (4) fine to coarse massive orange brown sand, as much as 6 feet thick.

The Potomac Group formation of Cretaceous geologic age underlies the Terrace deposits. The depth to the Potomac formation is not known at this time, although it is not expected to be within the depth of concern for this project. The Potomac Group formation

FIGURE 4 - Site And Area Geology
Quantico Riverfront Park
Quantico, Virginia

(See Next Page For Explanation Of Symbols)

EXPLANATION OF SYMBOLS ON FIGURE 4

SEDIMENTARY ROCKS

QUATERNARY

Holocene

Alluvium

Mud, sand, and gravel forming flood plains of minor streams and swamp and marsh land bordering tidal tributaries of Potomac River

Pleistocene and Holocene (?)

Qt_4
Qt_3
Qt_2
Qt_1

Terrace deposits bordering tidal creeks and minor streams

Mostly sand and pebble to cobble gravel. Qt_3 *is correlative, with* Qp_2.

Qp_2
Qp_1

Terrace deposits of Potomac River

Qp_2, *sequence generally includes, from bottom to top, at least three of the following sediment types: (1) medium to coarse, light-gray to white sand, commonly oxidized bright yellow or orange, thick bedded and coarsely cross-stratified, in units as much as 15 ft thick; (2) fine to medium, gray sand, thin bedded, interbedded with thin silt and clay beds which locally contain abundant wood fragments; unit weathers yellowish brown to pale red, thin beds of limonite common; (3) massive light-gray or greenish-gray sandy clay and silt in units 5 to 10 ft thick; contains scattered pebbles, cobbles, and limonite-filled root tubes; weathers pale red and forms vertical faces in natural exposures; and (4) fine to coarse, massive orange-brown sand as much as 6 ft thick which locally forms uppermost part of terrace. Pebble to cobble gravel, including unstable rock types, exposed along base of wave-cut cliffs about 1 mile north of Possum Point. Base of unit irregular and extends below sea level. Top of unit forms a fairly flat plain at an altitude of 35-40 ft; in southeast corner of map area unit overlain, locally, by dune sand 15-20 ft thick. Corresponds to Talbot terrace of Shattuck (1906) and Chowan terrace of Wentworth (1930)*

Qp_1, *Sand, generally highly oxidized; lenticular units of light-gray sandy clay which weather pale red; and lesser amounts of gravel. Basal 5 or 6 ft consists of sand, cobbles, and boulders as much as 3 ft maximum dimension; rock types include gneiss, schist, amphibolite, red sandstone, and quartzite. Top of terrace is at an altitude of 85-90 ft; base of deposits ranges from 35-50 ft in altitude. Corresponds to Wicomico terrace of Shattuck (1906) and Wentworth (1930)*

consists of light gray to gray quartz sand and highly plastic clay.

C. TOPOGRAPHIC FEATURES

The overland portion of the project area consists of the river-front park that slopes from River Road towards the shoreline. Existing grade elevations along the eastern edge of River Road vary from elevation 6.8 in the northern end to elevation 18.5 in the south. The ground slope from west to east is gentle in the northern segments, and becomes steeper in the south.

The existing seawall provides a barrier along the shoreline with varying heights and effectiveness. Portions of the wall are in relatively good condition providing protection up to elevation 4 feet along the middle segment of the shoreline. Other segments of the wall are not in as good a shape, however. The beach that occupies approximately 200 feet of the shoreline in the south reduces the local height of the wall to less than 1 foot, with evidence of subsidence behind and scour in front of the wall in the extreme south section. Along the northern end of the shoreline, the majority of the wall is totally deteriorated with major subsidence, sink holes and otherwise wash-off of the backfill soil from behind the wall causing exposure of the roots of three large trees of 10" to 12" in diameter.

The underwater topography of the basin is represented by a relatively uniform slope from the shoreline towards the channel of the Potomac River. This gentle slope continues until the bottom elevation reaches elevations -6.0 to -8.0 feet along a section that is nearly normal to the alignment of the Marine Corps Base dock. The water depth then increases abruptly and drastically over a short distance, with bottom elevations dropping to elevations -25.0 to -40.0 within about 50 to 100 feet, down to the

channel section of the Potomac River. This channel extends along the River just outboard of the Marine Base dock, and it is evident from the available historic maps and charts that it has maintained its basic configuration and range of depths. Thus, the basin consists of a gently sloping shelf landward of the threshold section referred to above that runs along a projection drawn from the end of the Marine Base dock towards the north, roughly parallel to the shoreline.

General topographic features are shown in Figure 1. The existing topographic features of the project area are best depicted on the detailed topographic map at a scale of 1"=50' prepared for this study (refer to Exhibit 1).

D. LAND AND BATHYMETRIC SURVEYS

Field surveys were conducted by a D&D field survey crew using the appropriate field equipment and drafted originally to a scale of 1"=50'. This original stable-base field topographic map was subsequently digitized using the AutoCad software for reproducing at multiple scales and presenting the findings (refer to Exhibits 1 and 2).

Vertical and horizontal control data for the field surveys were obtained from published monument and bench mark data. Bench mark data were also confirmed by an official inquiry through the U.S. Coast and Geodetic Survey (USC&GS) regarding reference datum values and any revisions that must be applied to the published data due to changes in the mean sea levels or recent observations. Unless stated otherwise, all elevations referred to in this report are referenced to National Geodetic Vertical Datum of 1929 (NGVD). All relevant details on the bench marks and datum are provided on both the original and digitized versions of the topographic maps.

Copies of the USC&GS' response to our inquiry including tidal data sheet are shown in Appendix 5.

E. ENVIRONMENTAL FIELD MEASUREMENTS

Environmental field measurements for currents and water quality parameters were conducted during a 14-hour period, between 6:00 a.m. and 8:00 p.m., on June 22, 1989. This date and time slot were selected based on the tidal and current evaluations performed for the project site using the 1989 Tide Tables and Tidal Current Tables published by the National Ocean Survey (NOS). It was considered desirable to conduct the field measurements on a day that would provide: (a) Large differences between tidal elevations and currents; and (b) daylight coverage of a full tidal cycle.

Included in the environmental field measurements were the following:

- Currents (direction and velocity)
- Salinity
- Total Suspended Solids (TSS)
- pH
- Dissolved Oxygen (DO)

Measurements were periodically taken at five (5) stations throughout the project area for the entire 14-hour period. The approximate locations of these field measurements are shown in Figure 5. The actual measured values obtained during this field program have been tabulated and are presented in Appendix 6. The results are summarized and discussed in the appropriate sections that follow.

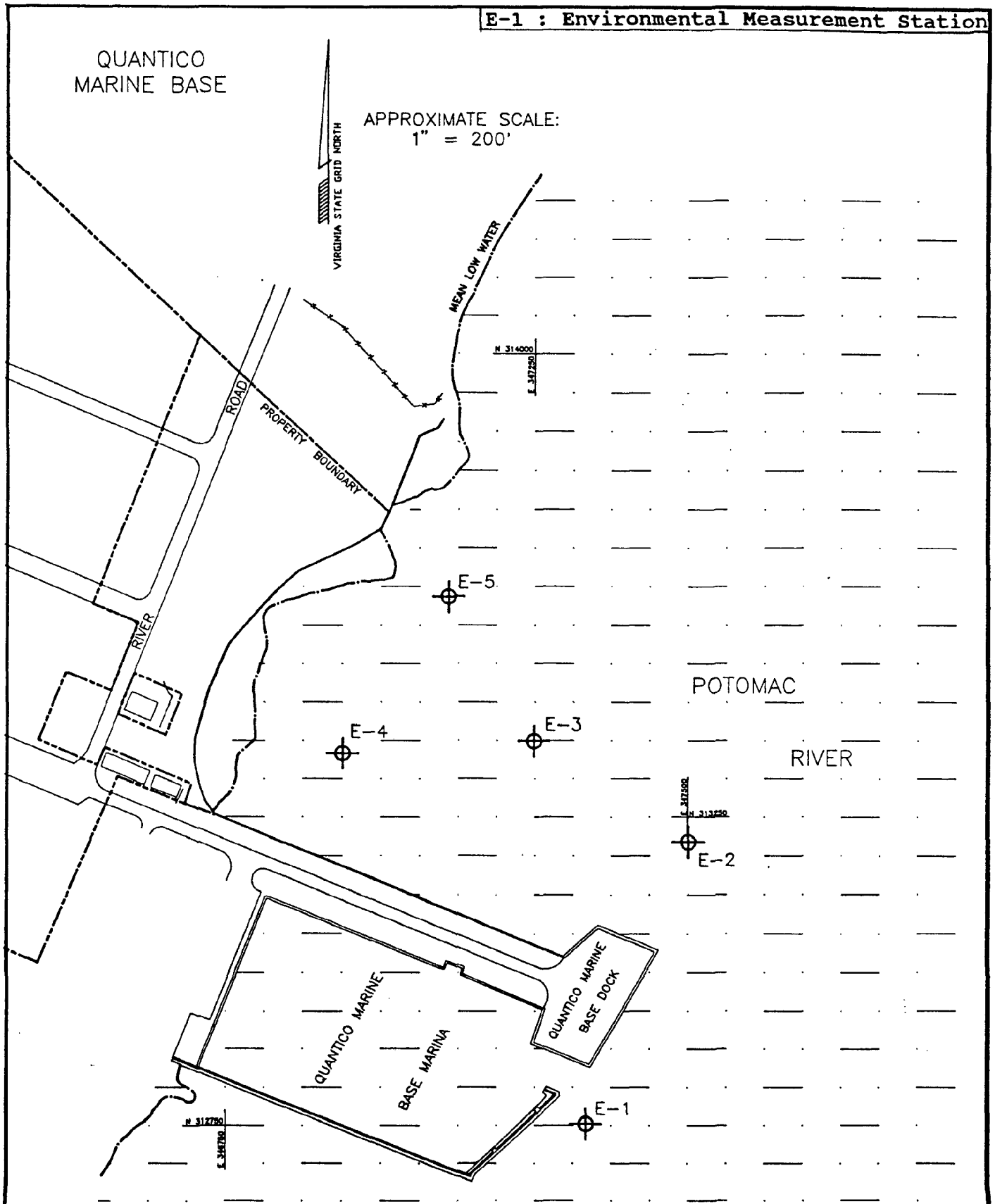


FIGURE 5 – Approximate Locations of Environmental Field Measurements – by Dewberry & Davis, June 22,1989

F. TIDAL ELEVATIONS

Tidal data was obtained from tide tables and information obtained from the USC&GS. Data for Quantico was generated using the data on the times and heights of high and low waters given for Washington, D.C. After appropriate conversion to daylight savings times, the following table shows the time differences and height factors which were applied to the Washington, D.C., data.

Table 1 - Time Differences and Height Factors for Quantico Creek (Station No. 2309)

	Time Difference (Hr)	(Min)	Height Factor
High Water	-1	04	0.51
Low Water	-1	59	0.47

A transposition resulted in the following data at Quantico for June 22, 1989:

Table 2 - Time and Height Predictions of Tides

Washington, D.C.			Quantico		
Time		Height	Time		Height
Hr	Min	(ft)	Hr	Min	(ft)
5	24	0.6	3	25	0.3
10	32	3.5	9	28	1.8
18	13	0.4	16	14	0.2
23	11	3.1	22	7	1.6

The actual selection of the date (June 22, 1989) for performing field measurements was based on an evaluation of tidal data predictions at Quantico for a number of consecutive days. These data predictions are tabulated in Appendix 7 for the period of June 1, 1989 through June 30, 1989 for the tidal elevations, and June 16, 1989 through June 30, 1989 for the tidal currents.

Figure 6 illustrates the variation of tidal elevations estimated for Quantico as described previously. It is clear from the tidal elevation differences indicated on this schematic representation that the 14-hour period between 6:00 a.m. and 8:00 p.m. on June 22, 1989, was chosen appropriately to carry out a representative series of environmental field measurements as planned.

Based on the information provided in the 1989 Tide Tables published by the NOS, the elevations for mean low water (MLW) and mean high water at the project site have been determined to be 0.0 foot and 1.4 feet, respectively.

G. CURRENTS

Published information was obtained from the NOS, which provides guidance on normal tidal currents. The NOS predictions for the Potomac River's maximum currents are 0.7 knot flood (upstream) and 0.9 knot ebb (downstream) at the location defined by the map coordinates 38-31.3 N and 77-16.6 W. This location is approximately 2700 feet due east of the Marine Corps Base dock, and the difference between these maximum ebb and flood currents is consistent with the average River discharge at this section, which approximates to slightly less than a 0.1 knot section-averaged current velocity.

PREDICTED TIMES/HEIGHTS OF TIDES
at Quantico (Station No. 2309)

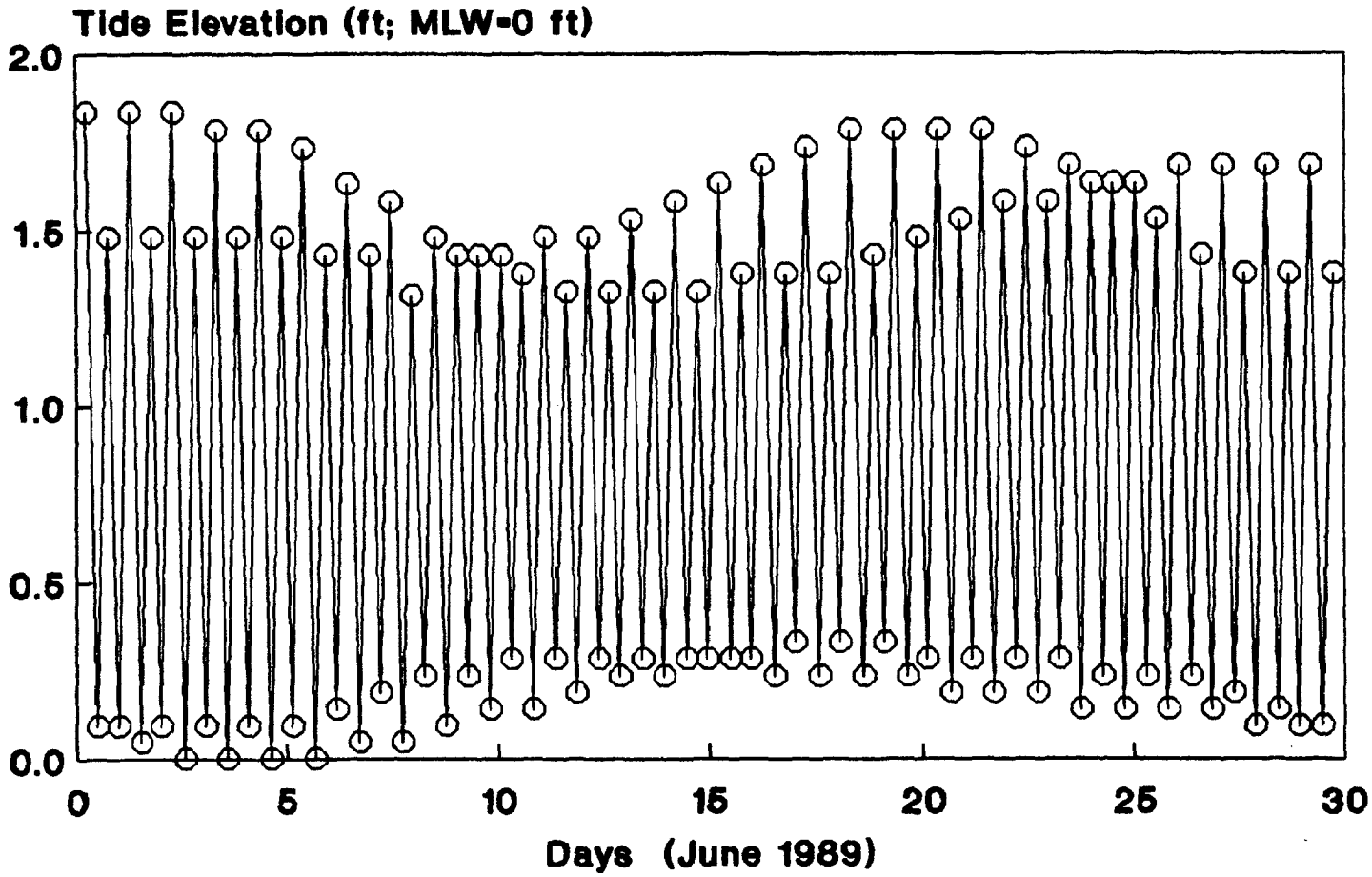


FIGURE 6

The data on tidal current measurements reported by the U.S. Army Corps of Engineers' Waterways Experiment Station indicates a maximum value of 0.8 knots for Quantico.

Similar to the tidal elevation evaluations, tidal current data for Quantico were also estimated based on the 1989 Tidal Current Tables predictions tabulated for "Baltimore Harbor Approach - Off Sandy Point" gage station. To these data, the following time differences and speed ratios were applied:

Table 3 - Time Differences and Speed Ratios for Quantico (Station No. 5796)

Tidal Current Condition	Time Difference Hr	Min	Speed Ratio
Minimum before flood	-0	54	1.0
Flood	-1	04	0.9
Minimum before ebb	-1	32	1.0
Ebb	-1	09	1.1

A transposition resulted in the following data at Quantico for June 22, 1989:

Table 4 - Time and Velocity Predictions for Currents

	Sandy Point			Quantico		
	Time		Vel.	Time		Vel.
Tide	Hr	Min	Knots	Hr	Min	Knots
Ebb	1	45	0.5	0	36	0.6
Min	4	13	0.0	3	19	0.0
Flood	8	00	1.0	6	56	0.9
Min	11	25	0.0	9	53	0.0
Ebb	14	49	1.0	13	40	1.1
Min	18	33	0.0	17	39	0.0
Flood	21	07	0.5	20	03	0.5

As a part of the field measurements conducted on June 22, 1989, current measurements were taken by D&D at the five specified locations previously described. The measurements were taken at

various depths and time intervals for a full tidal cycle. For this purpose, a propeller-type current meter was used. Inspection of the actual current measurement data indicate that all measured current speeds, including those in deep waters just outboard from the Marine Corps Base dock, remained less than 1.0 knot (1.7 ft/sec) and thus appear to agree well with the NOS data and the D&D predictions.

Consequently, based on the preceding data and reported data on other locations along the Potomac River, it appears appropriate to assume that the currents will generally not exceed 1.0 knot (1.7 ft/sec or 1.1 mph) in the vicinity of the project area, including in the deeper channel sections. Comments that were offered during an interview with Mr. Rusty Arcuni, the Harbor Master, indicate that currents as high as 3 knots have been observed. Such comments do not necessarily imply discrepancy, but may be attributed to maintaining sail boat speeds against maximum tidal currents and winds in the opposite direction.

H. WINDS

A summary of the published information by the National Weather Service (NWS) for wind speeds recorded every 3 hours at Quantico during the 1960-1978 period is presented in a tabular format in Appendix 8. These data were recorded with an anemometer 4.0 meters (13.12 feet) above ground mast and need to be increased by 12.8% to conform to the 10-meter (32.81 ft) standard elevation in accordance with the procedures outlined in the Shore Protection Manual.

The data indicates that:

- the strongest winds were 10 m/sec (= 22.4 mph = 32.8 ft/sec)

- the most significant fetch direction for wave generation is towards NNE
- Extreme NNE winds at a given speed are about 1/20 as likely as that speed from all directions

The smooth probability distribution of extreme wind speeds permits extrapolation to this estimate: NNE winds at 35 mph have a likely duration of about 1 hour once in every 20 years.

Also consulted for the effective wind velocity for the site was the "fastest-mile wind speed" chart shown in Figure 7. It appears that fastest-mile wind speeds as high as 70 mph can be expected in the general area for a 25-year return period. For actual design purposes, however, this value should be adjusted considering such effects as the wind duration, shoaling (decrease in water depth) of the waves approaching the project site and nonuniformity of the water depth along the fetch. Such additional detailed analysis is considered beyond the present scope.

I. WAVES

No records of wave measurements were available for the vicinity of Quantico. Consequently, significant wave conditions needed for preliminary design of shoreline stabilization measures and marina structures were estimated based on a wave forecasting procedure described in the U.S. Army Corps of Engineers' publication "Shore Protection Manual." This procedure employs empirical equations to estimate the height and frequency of the wind-generated "shallow water" waves based on three parameters. These parameters are the unobstructed fetch length, the average water depth along the fetch, and the effective wind velocity.

According to these equations, the significant wave height increases as the fetch length, average depth and effective wind speed increase. In many cases, the longest fetch may not be

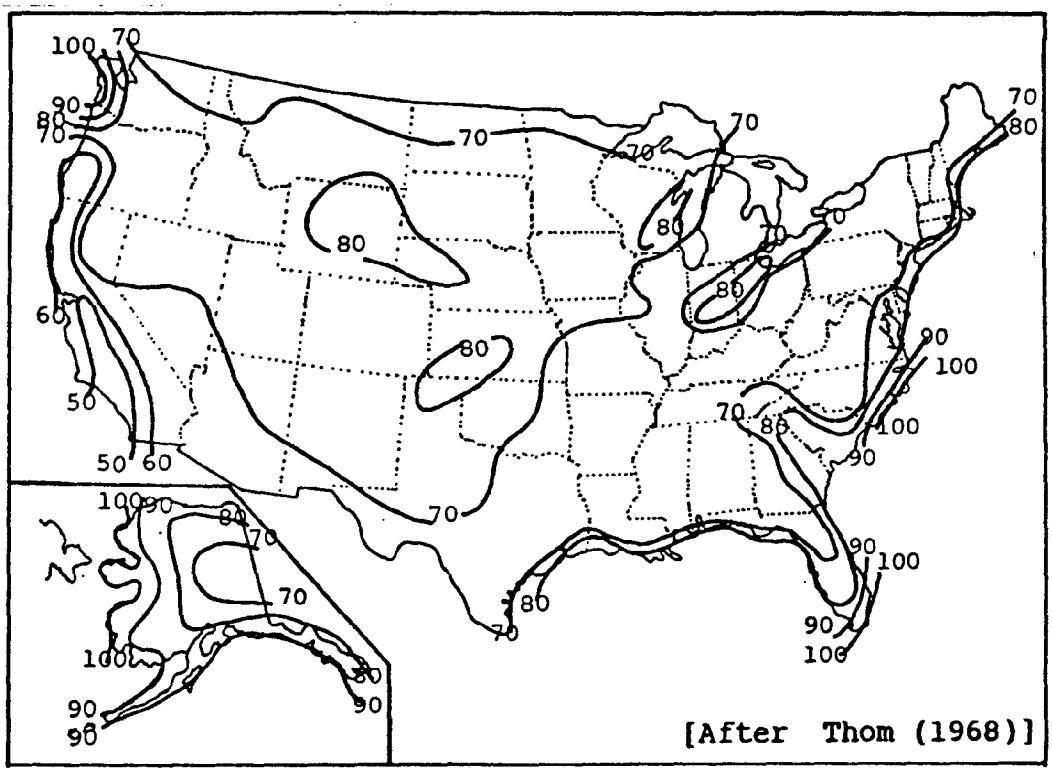


FIGURE 7 - Fastest-Mile Wind Speeds: 25-Year Return Period

(Reproduced From, "Low Cost Shore Protection... A Guide For Engineers And Contractors", 1981)

coupled with the largest average depth or the fastest and most frequent wind speed. Hence, several possible fetch-depth-wind speed combinations were evaluated to determine the most severe design wave conditions for the site.

The fetch and the water depth were determined using depth charts. The prevailing fetch directions were determined to be in the south-east and north-north-east directions with average depths varying between 15 and 30 feet.

The sensitivity of the wave height to the fetch length, wind speed and average water depth is illustrated in Figures 8 and 9, based on the extended analysis of shallow-water wave forecasts presented in Appendix 9. These calculations indicate the effects of the applicable fetch lengths and the average depths are rather small, remaining in the order of 0.5 foot for the maximum ranges of variation for both parameters. On the other hand, for the range of 25 mph to 50 mph applied to the wind speed, the variation of the wave height would be 1 to 1.5 feet.

As pointed out previously, the major exposure of the project area is to waves generated by the NNE winds. Inspection of the depth charts provides an effective fetch length of approximately 55,000 feet and an average depth of 20 feet for wave generation in NNE direction. Extreme NNE winds appear most likely to occur in April. Since local air temperature at this time of year nearly equals Potomac River water temperature, the possible temperature differences need not be considered. Use of the wave forecasting procedures specified in Shore Protection Manual and specifically Eq. (3-28b) and Fig. (3-30) results in the following estimates:

Wind Speed [mph] (Quantico Anemo.)	Wave Height [ft]	Wave Period [sec]	Minimum Wave Duration [hrs]
35	3.5	4.1	1.25
40	4.0	4.0	1.10

WIND-GENERATED WAVE HEIGHT PREDICTION
for Varying Fetches & Average Depths

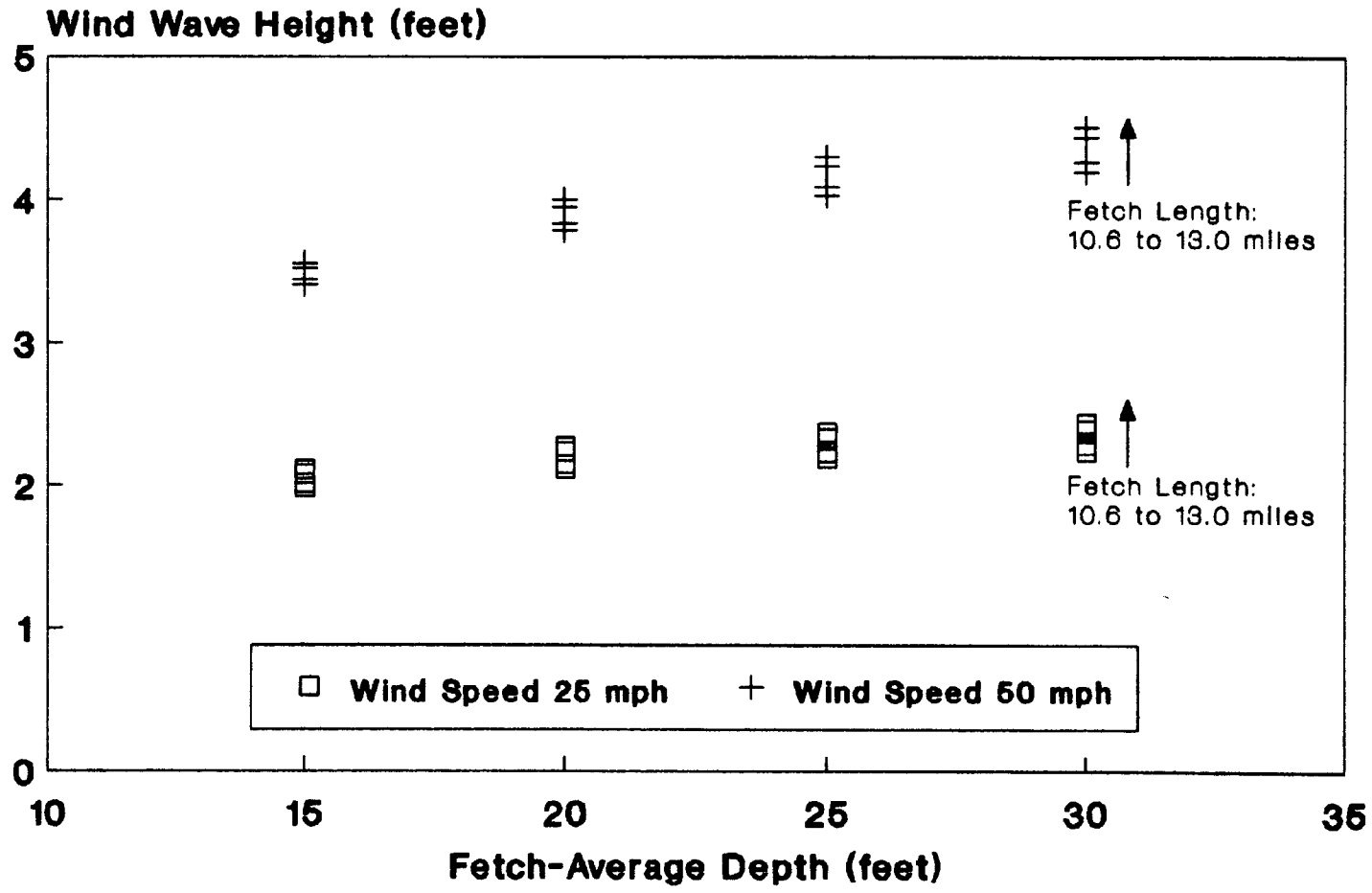


FIGURE 8

WIND-GENERATED WAVE HEIGHT PREDICTION
for Fetch=12.4 miles & Average Depths

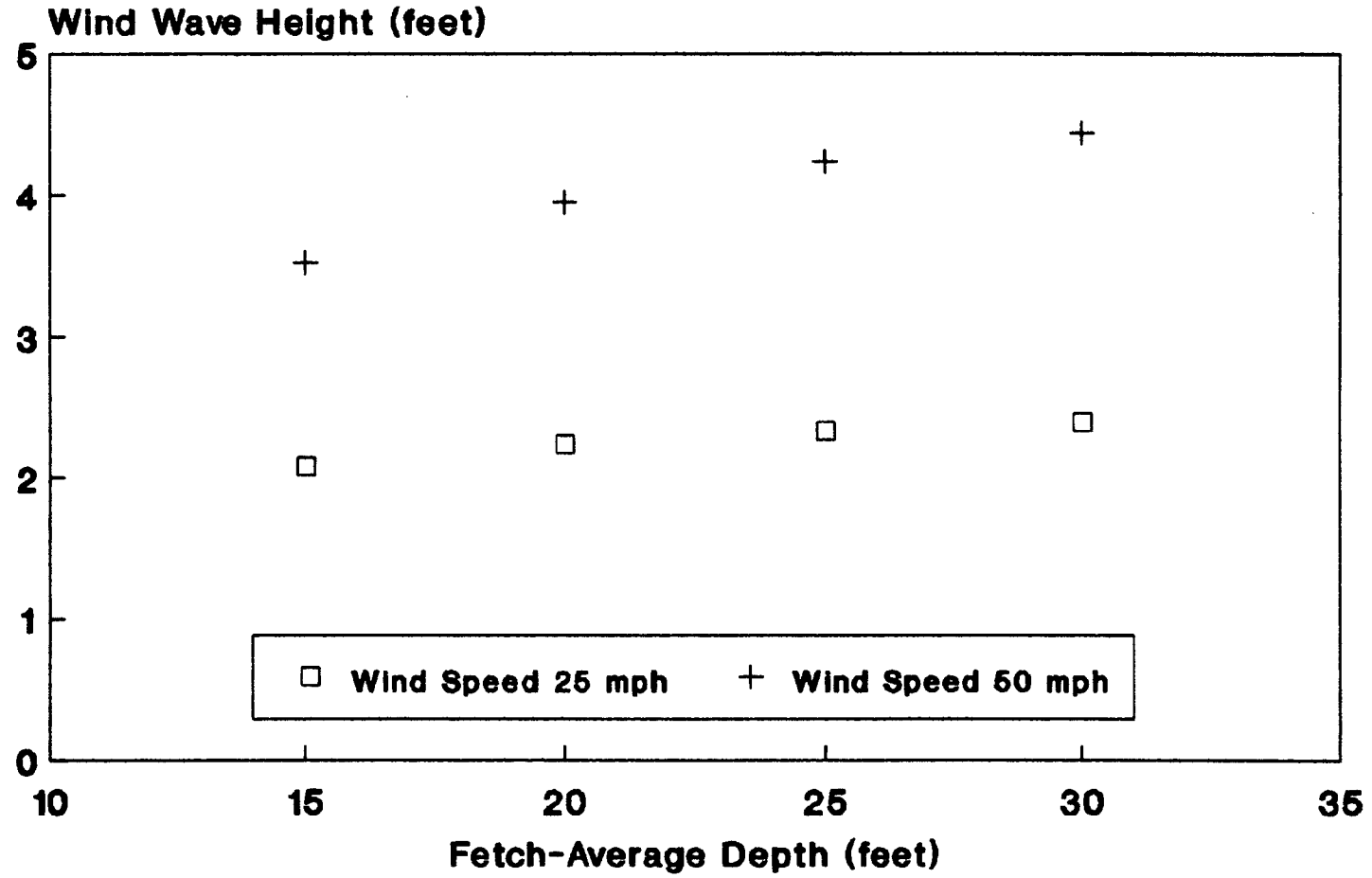


FIGURE 9

Based on the above considerations, an appropriate significant design wave condition appears to be a wave height of 4.5 feet, and a wave period of 4.0 sec. It must be remarked, however, that these values may warrant further adjustments for various actual design purposes involving structures such as breakwaters, groins, piers, bulkheads, revetments and other shoreline protection structures. Additional factors that will need to be considered during design phases are the flood elevations and acceptable levels of risk for overtopping of structures.

J. RIVER WATER SURFACE ELEVATIONS

Data available on flood water surface elevations recorded at NOS Station 8634689 at River Mile 68 near Quantico cover the period from October 1970 to October 1972. This site is located between NOS Station 8635150 at Colonial Beach and 8594900 at Washington, D.C., which are longer-term gage stations. There are ten other NOS Stations with short- and medium-term gage records along the tidal portion of the Potomac River downstream of Washington, D.C. Data for the various flood frequencies and extreme events recorded at these gage stations are summarized in Appendix 10.

Analysis of all these data indicate that the flooding climate in the uppermost reach of the tidal Potomac, north of River Mile 85, is markedly different from the entire lower reach. Only the record at Station 8634214, Alexandria, River Mile 91, correlates with the Washington, D.C., record. On the other hand, all records on the Lower Potomac, between River Miles 7 and 82, show strong correlations. In particular, the short-term record at Quantico matches very well with the medium-term record at Colonial Beach (River Mile 34).

The gage records for the Lower Potomac cover 1960 to 1988 with slight intermittence, which corresponds to approximately the

second half of the 1931-1988 Washington record, during which period 4 of the 9 highest local floods occurred. These events clearly lie on the extreme limb of the Washington flood curve, and represent flooding due to both wind stress and riverine runoff effects. The same flood events are nowhere near as extreme on the Lower Potomac, and the record highs on the Lower Potomac area conversely not truly extreme events at Washington. Notably, in almost half these years, the record event for the three Lower Potomac gages does not match the record event at Washington.

For Quantico, the gage record at Colonial Beach appears to provide firm estimates of flood elevations for recurrence intervals of up to about 10 years. However, most Lower Potomac gages show signs of recorded extremes being unrepresentatively low, where the highest water level is not much above other measured levels. Thus, rare flood elevations, such as 20-year, 50-year levels, are not at all well defined for the Lower Potomac from direct evidence.

The most definitive information appears to be the results from a numerical study of record elevations in Chesapeake Bay by the Virginia Institute of Marine Science (VIMS). Although river-mouth flood elevations developed by VIMS are evidently too low according to the gage data, a curve shift provides apparently appropriate extension from moderately rare elevations to the 500-year event. This smooth curve for extreme water elevations suggests 5 feet to be an appropriate design elevation at Quantico for a return period of approximately 60 years. The 100-year flood elevation is estimated to be between 8 and 10 feet.

It should be noted that the procedure for estimating flood elevations presented above is not intended to replace or supersede published flood elevations and floodplain information by the Federal Emergency Management Agency (FEMA) as part of the National

Flood Insurance Program. Changes to regulatory 100- and 500-year flood elevations and floodplain would require more detailed analysis throughout the entire reach of the Potomac River. The design flood elevation of 5 feet is for a somewhat reasonable level of protection for non-essential (i.e., not related to flood control or flood protection) structures associated with water-dependent uses.

K. SHORELINE EROSION AND BASIN FLOW CHARACTERISTICS

The coastal zone falling within the Town of Quantico corporate limits has several unique shoreline erosion and coastal flow characteristics. Most of these characteristics are attributable to the Quantico Marine Corps Base dock, which has been in place since 1904, if not earlier. Among the other significant factors are the tidal and current flow regimes of the Potomac River, winds and waves, the bottom geomorphology and movable sediments, and the geometric alignment of the shoreline relative to the adjoining Potomac River channel.

The Marine Corps Base dock extends approximately 600 feet into the River. The water depth immediately outboard from the dock varies between 25 and 35 feet. This deep channel extends approximately parallel to the shoreline along a projection drawn from the end of the dock. Landward of this channel segment, the bottom north of the Marine Corps Base dock fairly abruptly rises to an elevation of -6 to -8, and subsequently forms a gently shoaling "plateau" or "shelf" towards the shoreline. Apparently, there are no "dunes" or "sink holes" throughout the basin according to the recent bathymetric survey performed by D&D, and the historic "hydro-graphic charts" and USGS quads.

Contained in Appendix 11 (A through H) are reproductions from several historical maps dating back to 1903 that were available.

Several distances were "scaled" between various points of interest on these maps in an effort to evaluate past migration tendencies of the shoreline in the project area. The most reliable reference is clearly the Marine Corps Base's dock. The dock was constructed around 1904, with no significant changes to its configuration according to the available records. Another possible reference feature is the RF&P Railroad passing through the Town somewhat parallel to the shoreline. It should be noted that the railroad tracks are not depicted on the historic maps as clearly as the Marine Corps Base dock.

Three shoreline positions were considered to best represent the shoreline alignment within the basin area as depicted by points A1, B1, C1, A2, B2, and C2 on the historic map segments reproduced in Appendix 11 (A through D). Point A1 is the intersection of the shoreline and the northern wall of the Marine Corps Base's dock at the western end. The distance from A1 to the eastern end of the dock (A2) measured along the northern edge of the dock was used for reference purposes.

For the second and third shoreline locations (Points B1 and C1), a reference axis was defined by a straight line from the eastern end of the dock (A2) and perpendicular to the northern edge of the dock. The second shoreline position (C1) was selected as the "Hospital" point in the northern edge of the basin, and the third location (B1) lies nearly half-way between the previous two locations. The associated reference distances were then obtained by the lengths of straight lines drawn parallel to the Marine Corps Base's dock between these points and the reference axis.

The variation of the distances between these reference positions was inspected within the reasonable limits of accuracy depicted by the historical maps, USGS Quads and D&D's recent bathymetric survey. It appears that the basin area north of Marine Corps Base

dock has not experienced substantial shoreline migration over the last 80 years. However, there is evidence that local erosion has occurred. The evidence includes significant deterioration of an approximately 100-ft portion of the seawall in its northern end, several sink holes created and large tree roots exposed behind the seawall due to backfill material that washed off, and the riprap stone and concrete blocks placed around the point. The photographs provided in Subsection I.A. clearly illustrate these existing shoreline conditions.

Also featured along the shoreline is the narrow beach in the southern portion. The information exhibited by the available documents, maps and charts does not allow for a reasonably accurate historic assessment of this beach segment. The history of the Quantico Marine Corps Base as told and illustrated in the book "Quantico: Crossroads of the Marine Corps," documents with photographs the shoreline protection function that the dock has served. It also refers to the efforts of "Quantico Company" to develop the area for tourists, including fishing, picnic and other recreation activities. (Refer to historical notes in Subsection I.C.)

The Quantico Marine Corps Base Dock clearly provides a very effective physical barrier for the shoreline and the adjacent coastal area protecting the basin against storms, tides, currents, winds and waves directed from the south and southeast. Consequently, any adverse conditions that may be generated along the Potomac River in the upstream direction do not have noticeable effect on the project basin's environment. This assessment is confirmed by recorded data, field observations provided by the Harbor Master regarding various historical storms, and D&D's inspection of the "very calm" water surface conditions in the basin providing "safe harbor" to the anchored boats during periods with strong southerly winds.

On the other hand, the basin is totally exposed to the winds originating from north and northeast. The longest and deepest effective fetch along the River for wind-generated waves approaching Quantico is towards the North-North-East (NNE). Superposing the River's natural downstream flow and the outgoing tide to these waves will create the most severe conditions for the shoreline and the basin area. This results in a flow pattern that can be described as a counter-clock-wise swirl, entering the basin from the north-north-east at a small angle to the shoreline and leaving the basin along the northern edge of the Marine Corps Base Dock in an easterly direction. This flow pattern in the basin for the ebb cycle has been confirmed with the general orientation of the boats anchored in the area, and by the trends of the D&D current measurements performed at four locations.

It appears likely that the existing shoreline between the Marine Corps Base dock in the south and the Hospital Point in the north may not entirely be the result of a natural process. Based on information gathered during interviews, field observations, and inspection of the existing nontidal wetlands west of River Road, and the review of various historic maps and photographs, several additional features were discovered, as described subsequently.

- A second wall exists behind the current visible seawall, running nearly midway between the current shoreline and River Road. This wall was apparently built several decades ago for the purpose of protecting the residential buildings and River Road from the Potomac River's floods. It is now entirely buried under the existing grade of the riverfront park.

- As illustrated in Appendix 11H, reproduced partially from the 1966 Quad, Little Creek is a small stream flowing east, which turns north along the west side of the RF&P tracks and

joins the Quantico Creek northwest of the Naval Hospital area. Evidently, this is the result of a man-made diversion west of the tracks. In fact, this stream once emptied directly into the Potomac River through its mouth within the basin south of the Hospital Point. The 1940 map, reproduced partially in Appendix 11A, exhibits the stream's alignment prior to its diversion, with its mouth clearly indicated to be in the basin area.

- Based on the information presented in Subsection II.B (Site and Area Geology) and by reviewing the topographic conditions illustrated on the Vicinity Map, portions of the current riverfront park area were apparently filled and reclaimed. These areas include the mouth of Little Creek before it was diverted to the north and the park area behind the existing seawall.

- The nontidal wetland area between the RF&P tracks and River Road is still in place and covers substantially the same area as it probably did before the diversion of the stream. However, no wetlands exist between River Road and the current shoreline in the area that was apparently filled and reclaimed. In addition, the influence of the tide that appears to have been present within the Little Creek channel prior to the diversion is no longer present.

In view of the preceding discussions, the strip of land immediately behind the currently visible seawall appears to be entirely comprised of fill material. This may be a major contributing factor to the erosion tendencies along the current shoreline, particularly where portions of the seawall are deteriorated. The backfill material in these areas has subsided and washed off, creating sink holes and exposing the roots of large trees. A high erosion tendency is also apparent in the area with the riprap and

concrete rubble around the point just north of the deteriorated segment of the wall. It is suggested by the overland and underwater contours that this area was once the mouth of the Little Creek, where the fill material used is more susceptible to erosion than the natural shoreline material.

The existing shoreline clearly needs stabilization which can be achieved through various levels of protective measures. This conclusion is based primarily on the overall evaluation of the conditions and alignments of the existing shoreline, the visible seawall with its washed-off backfill and otherwise deteriorated segments, the presence of fill material behind the existing seawall extending towards the north, and the full exposure of wind and wave attack from the north-northeast. This conclusion is further supported by the evaluations performed to determine expected wave heights, storm surge elevations, and current directions and velocities.

The type of protective measure for the stabilization of the shoreline should be commensurate with the level of riverfront facilities that will eventually be constructed. The basic levels of protection that need to be considered are described below.

- If the current riverfront park is to remain without further development, the objective should be to avoid frequent shoreline maintenance and minimize shoreline erosion under frequent storm conditions. This would involve the repair of the existing seawall, placing riprap for toe protection along the northern portion of the shoreline for approximately 200 feet, and minor grading including the removal of trees with exposed roots in the fill area behind the existing wall. Less frequent maintenance of a similar nature would be required as damage is caused by less frequent floods and high waves. Further structural and

cost-related details commensurate with this type of protection are provided in Subsection 15.D of Appendix 15.

- If the riverfront park is to be developed consisting of added features which will increase property values on the land portion but with no major facilities in the marina basin, the seawall warrants more substantial improvements. The top elevation of the seawall should be raised by 2 to 4 feet along its entire length to a top-of-wall elevation of +5.0 or +6.0 ft. Depending on the actual layout of the land facilities, this level of improvement would provide protection against shoreline erosion and flooding due to less frequent attack of waves, floods, currents and tides generated along the predominant fetch. Again, additional details for this level of improvements are provided in Subsection 15.D of Appendix 15.

- If the riverfront park is to be developed as a commercial marina facility with increased property values on land, more substantial and reliable protection is justified and likely required. It seems inevitable that a breakwater will be the essential element of the required improvements in this case. Various scenarios for this level of improvement is also discussed in Appendix 15 along with the major structural and cost-related details.

L. WATER QUALITY

The Potomac River at Quantico, Virginia, is part of an estuarine system, influenced by the daily ebb and flow of the tides, as well as the mixing that occurs between fresh water from upstream and the more saline waters of the Chesapeake Bay. The salinity gradient is variable, depending both on precipitation differences associated with the time of year and water depth. At Quantico,

the River can be classified as tidal fresh (salinity less than 0.5 parts per thousand [ppt]) or oligohaline (salinity between 0.5 and 5.0 ppt). During the wettest months of the year the tidal fresh zone can extend nearly to Maryland Point, or approximately 10 miles downstream. According to average monthly salinity profiles, salinities reach their highest levels in October, when surface salinity reaches 1.0 ppt and bottom salinity is 2.0 ppt. Extremely wet or dry conditions can alter these monthly averages significantly. Salinity levels recorded during the 1-day field program were less than 0.5 ppt, which would be expected for the month of June and especially so considering the above normal precipitation for the area in the spring of 1989.

During the field analyses undertaken on June 22, 1989, dissolved oxygen (DO) concentrations were recorded at the five sampling locations throughout the day. In general, concentrations increased during the day, as would be expected with the increase in photosynthesis and oxygen production throughout the daylight hours. The lowest concentration, 5.9 milligram per liter (mg/L) was recorded at stations 2 and 3 at 10:00 a.m. The highest concentrations, ranging from 11.2 to 20.0 mg/L, were recorded at stations 4 and 5 late in the afternoon. This represents supersaturation, and is indicative of the higher densities of submerged aquatic vegetation in those areas. In general, DO concentrations are rated good to excellent based on values recognized by the Maryland Department of Natural Resources (DNR) in the "Environmental Atlas of the Potomac Estuary" (1981). Water quality guidelines provided by the Maryland Department of the Environment further indicate that DO levels above 5.0 mg/l are desirable. It should also be noted that these DO concentrations exceed Virginia Water Control Board (VWCB) standards for both minimum and daily average values.

Water samples were also obtained at all five locations and at three different times during the day for later analysis in the laboratory to determine pH and total suspended solids (TSS). Samples were obtained at mid-depth in the shallower areas (stations 3, 4, and 5) and 7 to 8 feet from the surface at stations 1 and 2. The three times at which samples were collected represented ebb, flood, and slack tides.

The pH values ranged from a low of 6.7 to a high of 7.3. While there was no significant difference between stations, average pH values for the five stations at each sampling interval did show an increase throughout the day. The lowest average value of pH was found in the morning, while the highest average value was measured late in the afternoon. This reflects the increase in photosynthesis through the day with an increasing uptake of carbon dioxide and resultant lowering of carbonic acid. All pH values are classified as good to excellent based on information from the Maryland DNR and would be well within the limits specified by the VWCB.

Total suspended solids for June 22, 1989 were very low, ranging from a low value of 2 mg/L to a high of 28 mg/L. Only in two of the 15 samples was the level 20 mg/L or greater, the cutoff between good and excellent classifications, based on Maryland DNR recommendations. In general, lower TSS levels result in less turbidity, thus indicating better water quality.

M. PRELIMINARY WETLAND ASSESSMENT

D&D conducted a preliminary tidal and nontidal wetland assessment focusing on the shoreline area (tidal) and the old Little Creek ravine (nontidal) located near the northern corporate limits. The purpose of this assessment was to identify the approximate

location and extent of wetlands for planning purposes and to assess potential impacts.

Prior to conducting a field investigation, relevant wetland information was examined. The National Wetland Inventory (NWI) Map as prepared by the U.S. Fish and Wildlife Service classifies the ravine along old Little Creek as a lower perennial, open water riverine system (R2OWH). The NWI maps depict the Potomac River as oligihaline, subtidal, open water estuarine system (E1OWL6). Oligihaline describes the range in salinity concentrations while subtidal means that water levels are present at low tide. The NWI map and information is reproduced on Figure 10.

A field investigation was performed on July 20, 1989, based on the three-parameter approach as outlined in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands. Soils were examined with a soil probe, and qualitatively identified with regard to hydric properties by comparison with Munsell color charts. Additionally, dominant plant species were inventoried and hydrologic conditions noted.

The nontidal area along old Little Creek can be described as a ravine with 40- to 50-foot-high banks. The banks appear to be partially composed of fill material. Two smaller ravines with associated swales drain from the south. Both have well-defined banks and appear to handle runoff during storm events. The first swale, located along wetland sample points 1 and 2, contains a small flow and a partially exposed concrete storm sewer pipe. The second swale at wetland sample point 4 begins at a concrete storm sewer pipe opening; however, there was no flow present.

The majority of the tidal shoreline area within the project can be described as nonvegetated wetlands as defined by the Commonwealth of Virginia. The area between mean low water and mean high water

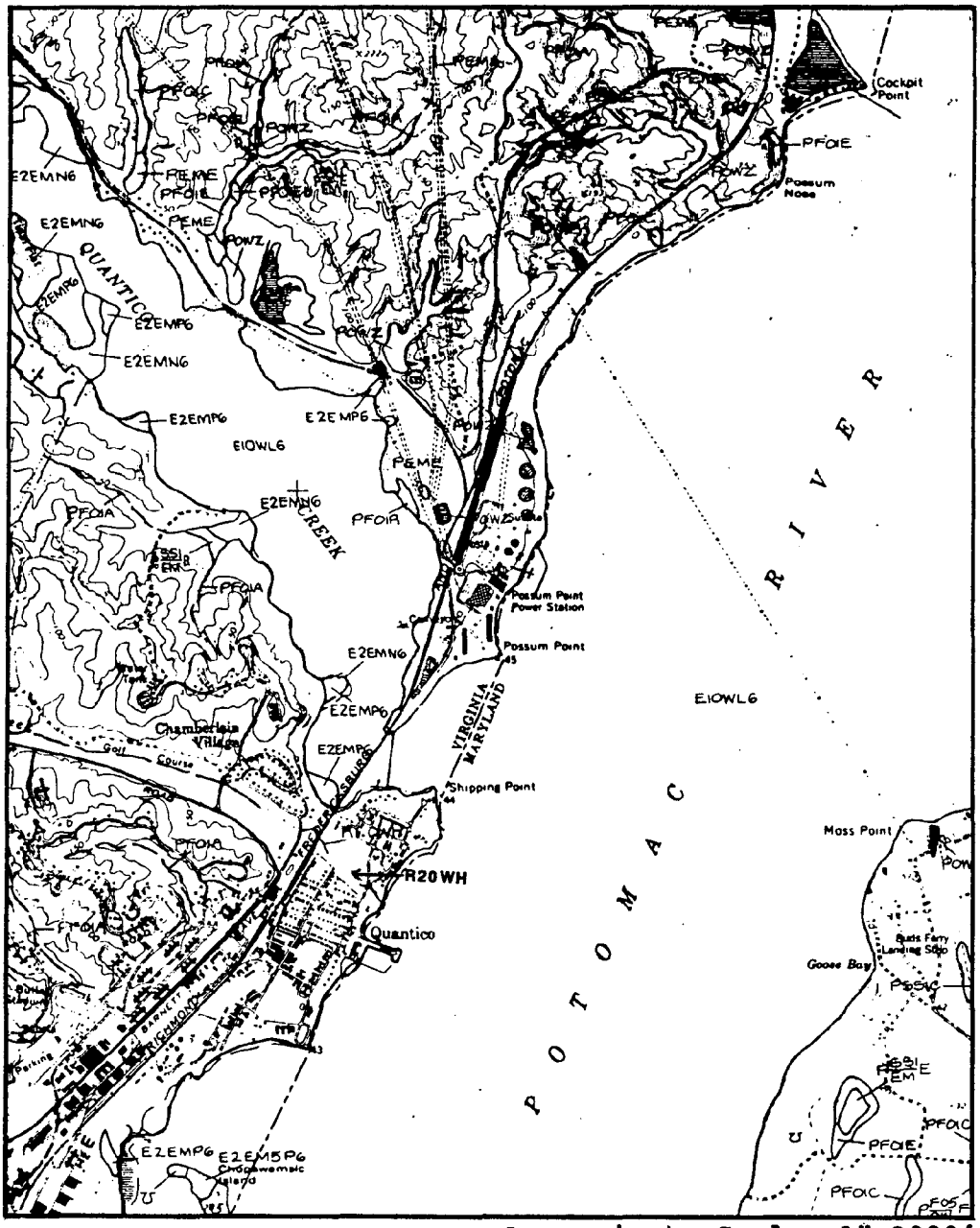


FIGURE 10 - National Wetlands Inventory Information

(Reproduced from "National Wetland Inventory Map" - Quantico, Virginia.)

primarily consists of a sand and/or cobble beach with no apparent wetland vegetation species present.

Approximate tidal and nontidal wetland boundaries as determined during the field investigation and the locations of wetland sample points are shown on Figure 11. Copies of data forms are furnished in Appendix 12.

N. SUBMERGED AQUATIC VEGETATION

During the field work for the water quality analyses undertaken in June 1989, some colonization of hydrilla (Hydrilla verticillata) and wild celery (Vallisneria americana) was observed in the protected area north of the Marine Corps Base dock. A site visit on August 21, 1989, revealed that extensive growth of submerged aquatic vegetation (SAV) had occurred over the course of the summer. The Harbormaster at the Marine Corps Base dock indicated that this was the first summer that SAV had been established to any extent and that hydrilla was causing small craft operation problems within the Marine Corps Base's marina basin, where depths are at least 6 feet at low water.

Representatives of D&D and the NVPDC conducted a survey on September 1, 1989 to visually estimate the types, extent, and dispersion of the SAV throughout the project area. The site was thoroughly traversed by boat to identify the species present and their relative abundance. With regard to the total area, Eurasion watermilfoil, (Myriophyllum spicatum); wild celery; and hydrilla were the most common species observed. Patches of coontail (Ceratophyllum demersum) and water stargrass (Heteranthera dubia) were more scattered. Only a few patches of curly pondweed (Potamogeton crispus) were identified and the greater duckweed (Spirodela polyrhiza) was confined to the most protected areas

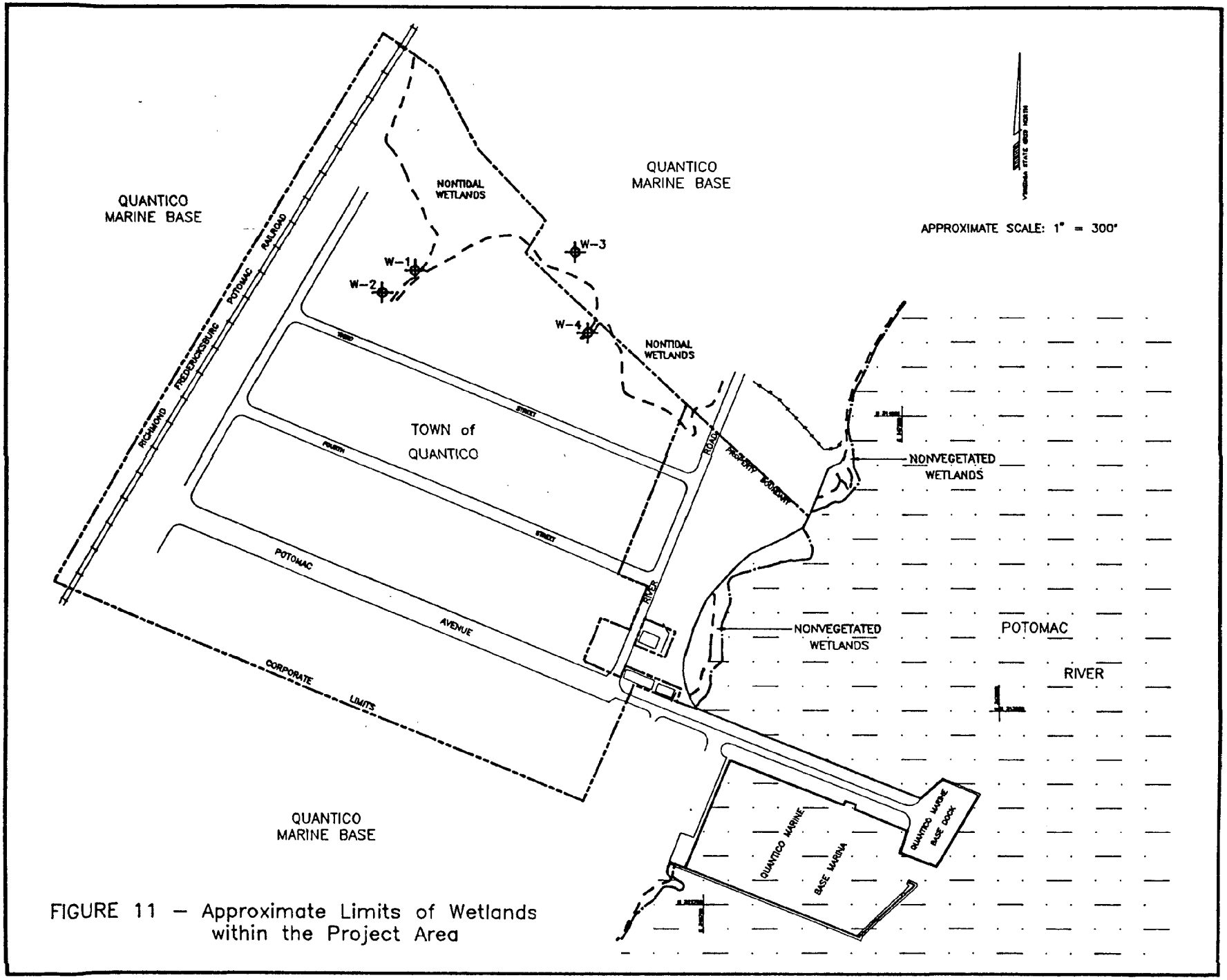


FIGURE 11 – Approximate Limits of Wetlands within the Project Area

along the Marine Corps Base dock. Table 5 lists the species encountered and summarizes their ecologic importance.

Table 5 - Submerged Aquatic Vegetation

Common Name	Scientific Name	Ecologic Importance
Eurasian Watermilfoil	Myriophyllum spicatum	Provides cover and spawning habitat for fish and invertebrates. Foliage consumed by some waterfowl. May crowd out other useful species. Introduced.
Wild Celery	Vallisneria americana	A preferred food of many waterfowl, notably mallards, canvasbacks, and goldeneyes, also consumed by mammals. Provides spawning substrate and habitat for fish and invertebrates.
Hydrilla	Hydrilla verticillata	Forms large mats, impeding recreational uses and potentially crowding out other species in an afflicted area. Introduced to Potomac River (Dyke Marsh) in 1980 by accident.
Coontail	Ceratophyllum demersum	Provides good habitat for fish, and small invertebrates consumed by fish and waterfowl. Foliage is consumed by waterfowl and other wildlife.
Water Stargrass	Heteranthera dubia	Cover for many fish species and habitat for invertebrates consumed by fish and wildfowl, including black ducks, canvasbacks, and scaup.
Curly Pondweed	Potamogeton crispus	Provides spawning substrate for fish and cover for fish and invertebrates. Introduced.
Greater Duckweed	Spirodela polyrhiza	Consumed by some waterfowl.

The above descriptions were taken from the following sources:

Reid, George K., Ph.D.; Pond Life, A Guide to Common Plants and Animals of North American Ponds and Lakes; Golden Press, New York; 1987.

Schloesser, Donald W.; A Field Guide to Valuable Underwater Aquatic Plants of the Great Lakes; Contribution 644, Great Lakes Fishery Laboratory, Ann Arbor, Michigan; 1986.

Interstate Commission on the Potomac River Basin; Potomac Basin Reporter; Volume 39, No. 9, November 1983; Volume 40, No. 3, March 1984.

Figure 12 divides the study area into approximate regions as determined appropriate during the SAV survey. Generally, regions were delineated based on the differences in species encountered and the approximate extent of vegetative cover.

Region 1: The corner where the existing stone seawall and the Marine Corps Base dock meet is 90-100% covered with floating plant material and debris which has blown in, and with rooted aquatic plants, hydrilla and Eurasian watermilfoil in particular.

Region 2: The approximate boundary extends to 75 to 100 feet from shore. The region is 60-80% covered, very predominantly with wild celery.

Region 3: An area of 80-90% vegetative coverage extends the length of the pier and curves around along the edge of the shallow water area. The average depth increases towards the end of the pier. Flora is mixed; it includes large stands of wild celery, coontail, watermilfoil, and some hydrilla, water stargrass and duckweed. The hydrilla becomes more prevalent in the deeper water towards the end of the Marine Corps Base dock.

Region 4: An intermediate zone containing populations of the same floral components as were identified in Region 3 but in lesser numbers, and the few noted specimens of curly pondweed. Total vegetative coverage in the region is approximately 75%. Watermil

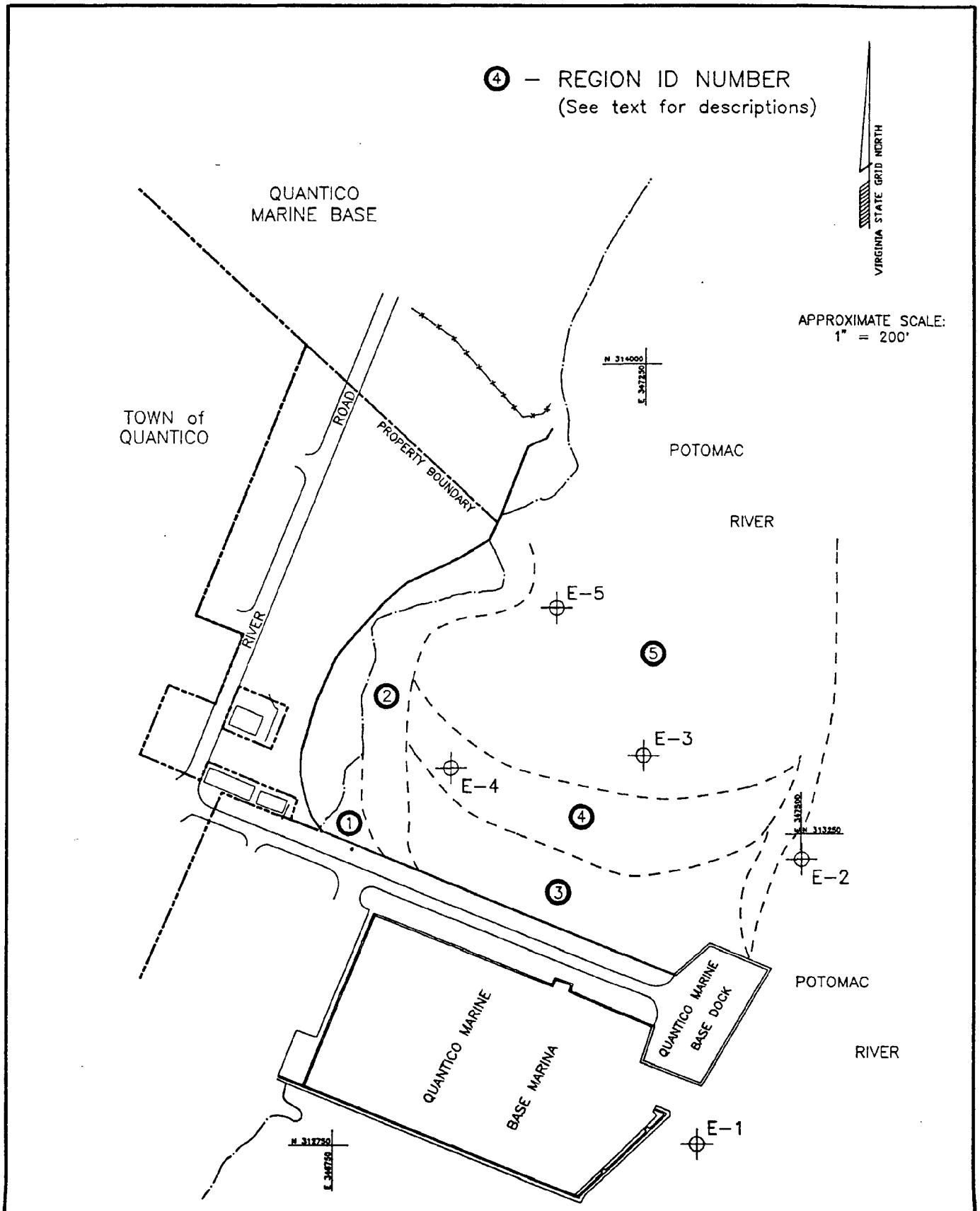


FIGURE 12 – Approximate Regions of Observed Submerged Aquatic Vegetation

foil (dominant), hydrilla, and coontail appear in large mixed stands, all together comprising two-thirds of the total vegetation. Water stargrass contributes approximately 10% of the vegetative cover, and homogeneous clumps of wild celery comprise account for approximately 20% of the cover.

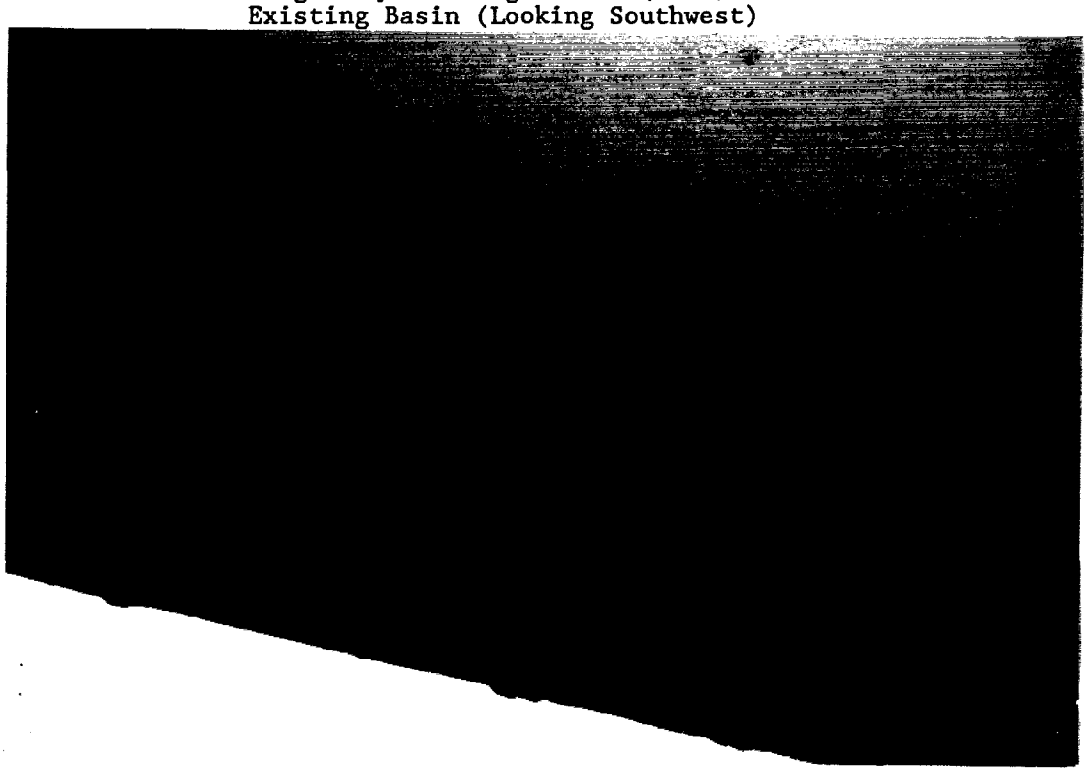
Region 5: The major portion of the site is predominantly open. Total vegetative coverage in the central region is approximately 10-20%; most of this is composed of well-dispersed patches of wild celery. A few stands of water stargrass and watermilfoil also appear. Hydrilla is more evident along the far edge of this area as water depths increase beyond 4 to 5 feet.

In summary, a fairly diverse community of SAV has been established in the protected area formed by the Marine Corps Base dock. The value of this area as fish and wildlife habitat was evident during our site visit. Numerous schools of forage fish were noted, as well as several larger individuals (believed to be the large-mouth bass) likely attracted by the abundance of prey. Great Blue Herons and Green Herons were also noted, while Canada Geese and Mute Swans have been reported by the Harbor Master to frequent the area. As mentioned earlier, this degree of colonization appears to be a very recent phenomenon. Based on the manner in which SAV has reappeared in the Potomac River in recent years it is expected that the more competitive species (especially hydrilla and watermilfoil) will constitute a larger percentage of the vegetative cover in the future. The implication of the type and extent of SAV present is that dredging activities may displace and/or adversely impact existing habitat for fish and wildlife. Impacts to SAVs may also reduce water quality in the project area.

Debris Accumulated In Southwest Corner Of The Existing Basin

Submerged Aquatic Vegetation (SAVs) In The Existing Basin And
View Of The Existing Marine Corps Base Dock (Looking Southeast)

Submerged Aquatic Vegetation (SAVs) In The
Existing Basin (Looking Southwest)



Submerged Aquatic Vegetation (SAVs) In The Existng Basin
In The Vicinity Of The Marine Corps Base Dock

O. SEDIMENTS

On June 21, 1989, D&D gathered sediment samples at the same five locations that environmental measurements were taken (see Figure 5 for locations). The purpose of the sampling was to provide preliminary information regarding sediment composition within possible dredging areas and to perform limited laboratory analysis on a composite sample from the entire project area. The method of obtaining the samples varied dependent on the depth of water. At sampling points 1 and 2, water depths were recorded at approximately thirty (30) feet. At these points, a Penske sediment/ bottom sampler was used for collecting a small surface sample. At point 3, a 6-foot-long, 1-inch-diameter steel pipe was driven into the sediments to a depth of approximately 2 feet using a sledge hammer. The depth of water prevented further penetration. At sampling points 4 and 5, a shovel auger was used since the water depth was less than 3 feet. The penetration depth approached 18 inches. All samples were placed in plastic bags and sent to the environmental laboratory for preparing a composite sample using equal parts from each sample location.

The results of the laboratory analysis are shown in Table 6.

Table 6 - Heavy Metal Concentrations in Composite Sediment Sample

Parameter Tested	Results (mg/kg)
Arsenic	< 0.5
Barium	<50.
Cadmium	< 2.
Chromium	< 8.
Lead	10.
Mercury	< 0.5
Selenium	< 0.1
Silver	< 4.0

All results except lead fell below the detection levels for the test methods used. These levels are within the expected range and

do not indicate a problem with regard to disposal of dredged material regarding toxic substances. The laboratory data sheet is included in Appendix 13.

A visual inspection of each sample was also performed. The sampling depth and the visual classification for each sample are shown in Table 7.

Table 7 - Sediment Data

Sample No.	Sampling Depth	Description
S-1	Surface	Brown clayey sand with shells & gravel
S-2	Surface	Shells
S-3	0-18 inches	Brown clayey sand with shells
S-4	0-18 inches	Tan-gray fine to medium sand with silt
S-5A	0-6 inches	Sandy gravel
S-5B	6-12 inches	Sandy gravel

Sieve analyses to determine soil classification were conducted on samples S-3, S-5A, and S-5B since they correspond to the possible dredging area. The gradation results are shown in Appendix 14. Based on the material properties observed, dredging difficulties are not anticipated within the basin. It should be noted that available geologic maps indicate a potential for cobbly material which could complicate dredging activities, dependent on the type of dredging proposed. Further evaluations on the proposed dredging activities are presented in Appendix 15.

III. PROPOSED PROJECT AND ALTERNATIVES

A. GENERAL

The proposed project as discussed in the remaining sections of this report is generally based on a conceptual plan developed for the Town in 1986 identifying a "Town Marina" with floating piers and a breakwater designed to provide safe harbor for a reasonable number of boats. An additional advantage of the "Town Marina" concept is that it serves the dual function of protecting and stabilizing the majority of the Town's newly acquired shoreline. Using the available conceptual plan as a guide, additional engineering analyses were performed by D&D to further investigate the degree to which the dual objectives are satisfied and to be able to better assess the associated environmental impacts.

Based on the evaluations described in Section II and generally considering cost-effective design and construction practices, each component of the proposed project has been further developed. The structures presented in this section represent suggested engineering schemes that enable the assessment of environmental impacts and the comparison of alternatives.

Alternatives involving refinements and, in some cases, substantial modifications have also been developed for further consideration. The primary intent of identifying alternatives is to assess on a preliminary basis the environmental impacts of scaled-down versions of the project. This cursory alternatives analysis is warranted in view of the unavoidable impacts to submerged aquatic vegetation resulting from the proposed project.

For additional information including assumptions that were made in the development of the proposed project and the alternatives as presented in the following sections, refer to Appendix 15 -

Additional Engineering Considerations and Analysis. The following subsections summarize the overall features of the proposed project and alternatives.

B. OVERALL FEATURES OF THE PROPOSED PROJECT

The features of the proposed project as further developed by D&D consist of the following:

- Breakwater Structure
- Floating Piers and Slips
- Shoreline Improvements
- Upland Park Area

The water portion of the proposed project is conceptualized in plan view as essentially a "mirror image" of the breakwater associated with the existing Marine Corps Base dock and marina. The proposed breakwater will protect the basin from northerly and northeasterly storms, while the existing Marine Corps Base dock will provide the protection from the southerly storms as it has effectively done so to date.

As depicted by the typical cross section shown in Figure 13, the outer side of the breakwater will be protected from erosion at the toe (channelward portion of the structure) by means of quarry-stone riprap. The vertical wall on the marina side will accommodate a number of slips by means of a floating dock and finger piers (catwalks) which may or may not be attached directly to the breakwater itself. Additional details on the proposed breakwater are presented in Appendix 15, Section 15.C.

Also part of the proposed project are two main floating piers, with maximum anticipated lengths of nearly 410 and 530 feet. Various slip configurations along these floating piers and along

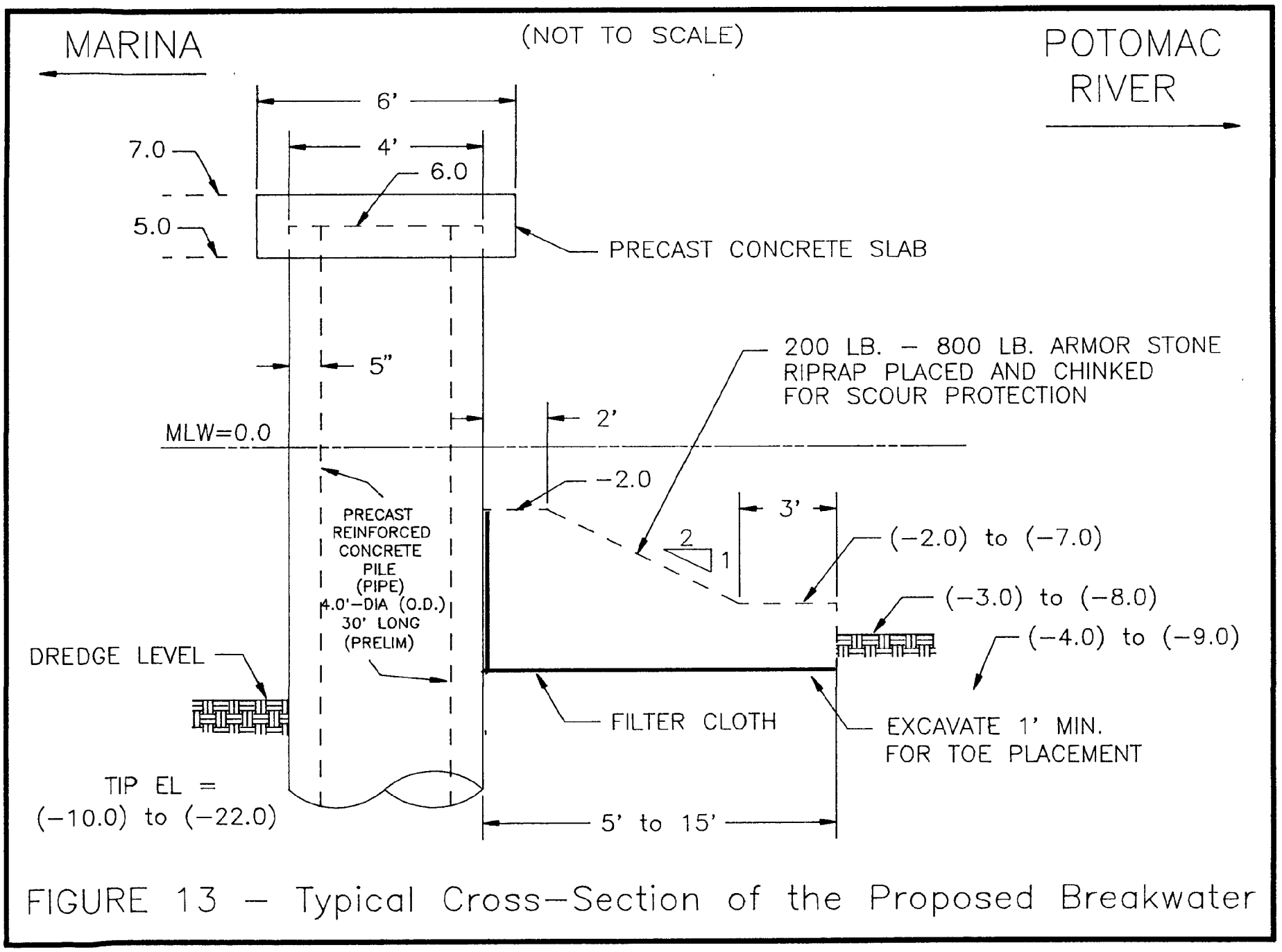


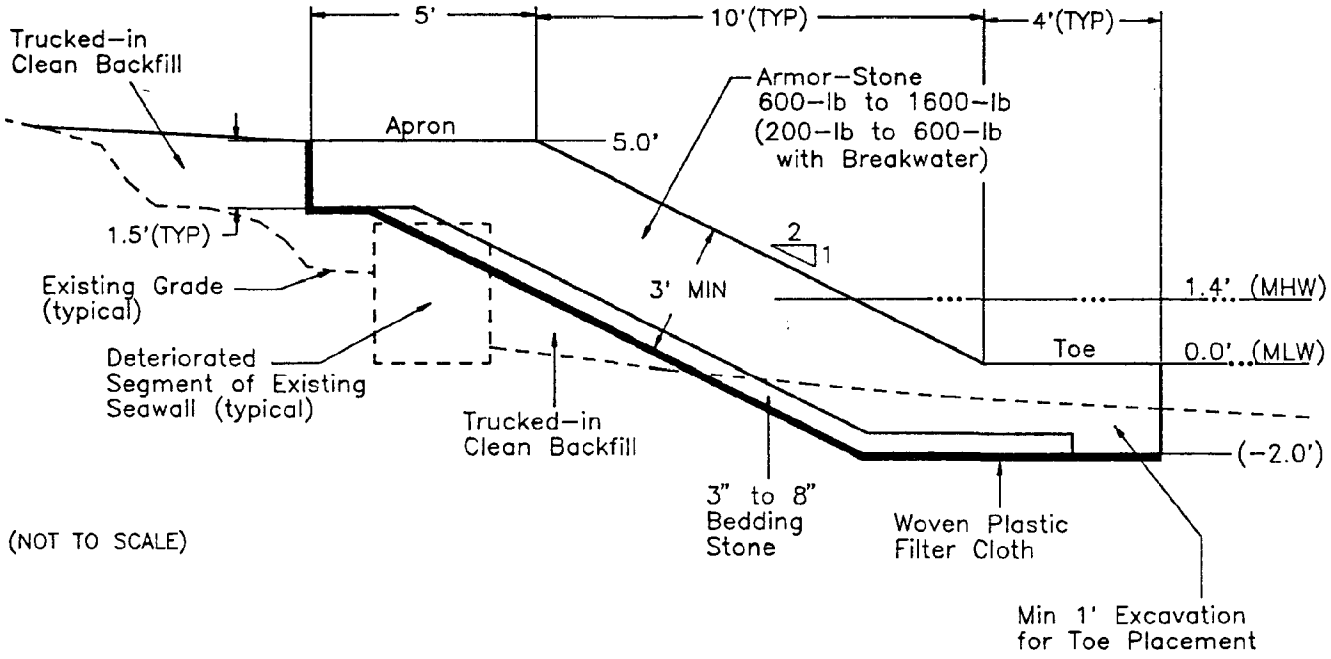
FIGURE 13 – Typical Cross-Section of the Proposed Breakwater

the inner side of the breakwater may be designed to accommodate differing numbers of boats by varying the types and sizes. The proposed marina configuration is shown on Exhibit 3 and provides approximately 130 to 140 slips for boats ranging from 25 to 60 feet in length. Additional details on the marina facilities are also presented in Appendix 15, Section 15.C.

Inherent in the proposed project are repairs to the existing seawall, where practical, and a replacement structure using a full-section quarry-stone revetment where necessary. The repairs will likely include a wedge-shaped stone reinforcement at the toe of the existing seawall. The proposed improvements along the shoreline assume that the breakwater and the piers associated with the marina will be constructed. Hence, the primary function of the seawall under the proposed project concept will be shifted from directly protecting the shoreline from storms to forming a water frontage that is safe for public use, stable, and aesthetically conforming with the proposed upland park area and the proposed marina. Typical sections of both shoreline stabilization structures are shown on Figure 14. Additional details of the proposed seawall improvements are presented in Appendix 15, Section 15.D.

The upland park portion of the proposed project will involve incorporation of a parking area adequate for the proposed marina purposes, concession facilities and other amenities. The entire park area is currently in good condition. Preliminary determinations indicate that the space on the west side of River Road is capable of providing the majority, if not all, of the parking spaces required for the proposed project (park and marina) and should not involve environmental or otherwise major problems. Parking in this area will likely require local site plan approvals and public participation regarding traffic patterns and the use of public streets for parallel parking. More detailed evaluations

(a) FULL-SECTION STONE REVETMENT



(b) WEDGE-SHAPED STONE REINFORCEMENT

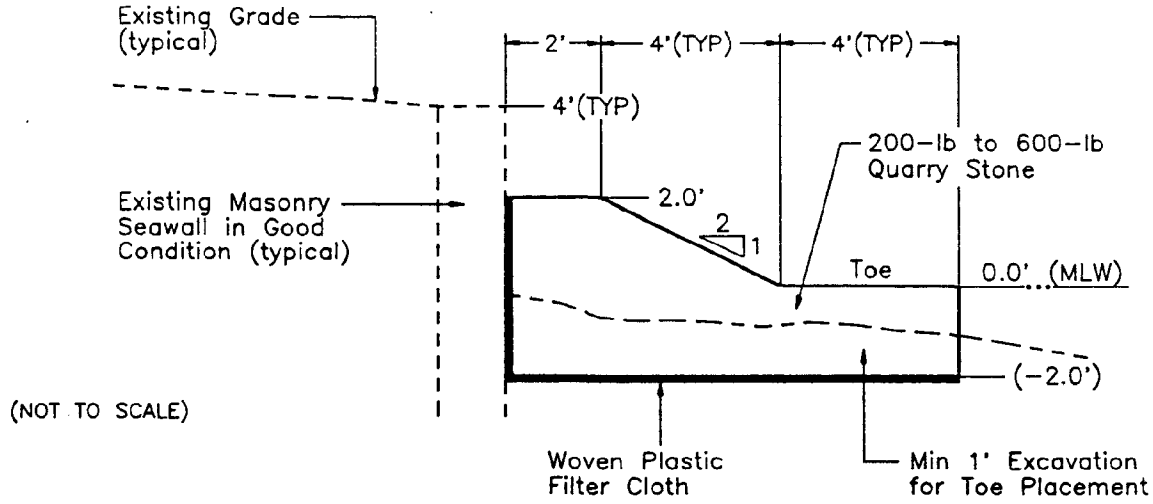


FIGURE 14 – Typical Sections of Stone Revetment and Stone Reinforcement

regarding parking-related improvements are presented in Appendix 15, Section 15.A.

C. ALTERNATIVES

Four (4) alternatives have been considered to the proposed project presented in the preceding subsection.

Alternative 1 - Approximately 60- to 70-slip marina with breakwater and floating piers. Dredging has been avoided in shallow water areas (less than 2 feet below mean low water).

Alternative 2 - Approximately 15- to 20-slip marina without breakwater. Uses a tee section at the end of a single dock and involves minimum dredging.

Alternative 3 - No marina or breakwater with a repaired seawall providing minimum shoreline protection.

Alternative 4 - No marina or breakwater with a new seawall providing substantial shoreline protection.

Each alternative is further discussed in Appendix 15, Section 15.G.

IV. ENVIRONMENTAL IMPACTS OF PROPOSED PROJECT AND ALTERNATIVES

The environmental impacts and inherent mitigation measures associated with the proposed project and the various alternatives are discussed in the following subsections. Each element that may be involved in the realization of a selected project is presented separately. These elements are:

- Seawall improvements for shoreline protection and stabilization
- Breakwater structure
- Pier structures
- Marina basin

A. SEAWALL IMPROVEMENTS

Regardless of whether a breakwater is constructed, the proposed shoreline stabilization activities within the project limits are not expected to create any long-term adverse impact on the environment including adjacent shoreline areas. The environmental conditions created by stone riprap as proposed along the shoreline will, in essence, create a shallow water habitat that otherwise would not exist. The absence of vegetated wetlands along the shoreline and the relatively inactive position of the shoreline within the project limits relative to the adjacent shoreline in the north and south further justify the type and extent of improvements proposed.

Being itself very effectively sheltered by the Marine Corps Base dock, proposed shoreline stabilization measures within the project area are not expected to cause any adverse impact to the shoreline in the north due to southerly winds and currents. With regard to northerly winds and currents, the adjacent shoreline in the north is not likely to be adversely impacted by way of reflected waves or otherwise. Considering the general shoreline alignment in the

project area including the existing and proposed structures, long-shore flow patterns should not impose adverse impacts owing to the proposed riprap seawall improvements. It is also evident that the presence of the Marine Corps Base dock completely eliminates any risk of adverse impact from the proposed stabilization activities along the shoreline south of the Marine Corps Base dock.

Except for short-term impacts during construction which will be confined to the existing shallow water habitat immediately adjacent the shoreline, the proposed shoreline stabilization activities are expected to be a positive environmental influence in the area. Stone riprap is environmentally superior to the other structural measures that are used today to stabilize a shoreline because of the desirable aquatic environment it will create with its sloping face and numerous openings.

Vertical seawalls or bulkheads, on the other hand, whether constructed with masonry, concrete, timber or steel, will promote standing waves and local scour, thus causing greater impacts to the shallow water environment. In order to diminish adverse conditions from existing vertical wall structures, a stone riprap toe protection is commonly proposed where practical. It should also be pointed out that protective coatings such as C.C.A. (chromated copper arsenate) and Coal-Tar-Creosote used to help preserve timber and steel bulkhead material in marine environments are undesirable by most agencies because of impacts to shallow water habitat and overall water quality.

Use of stone riprap along the shoreline is not expected to alter the external conditions promoting debris accumulation in the southwest corner of the basin. The Marine Corps Base dock is the primary reason for the manner in which debris collects. A conceivable effect of the stone protection along the shoreline may be to slow down any long-shore motion of such debris towards the

south which may result in spreading the debris accumulation somewhat more evenly along the shoreline. Periodic maintenance will continue to be required. In any event, debris accumulation should not be considered as an impact to the natural environment.

Major variations should not be expected in any of the environmental aspects discussed herein with respect to the size and extent of the stone riprap proposed for this project, due primarily to the fact that the resultant changes in the alignment of the shoreline will be virtually negligible. The proposed use of stone riprap for the proposed project and the alternatives is the environmentally superior method for shoreline stabilization in the project area.

B. BREAKWATER STRUCTURE

The breakwater structure recommended for the proposed project and Alternative 1 has the potential to impact three regions. These regions are: (1) within the proposed marina basin; (2) outside of the basin; and, (3) on the Potomac River itself. These impacts will be generated by the proposed configuration of the breakwater, the construction material and the construction methods. The short-term impacts resulting from the construction activities are considered to be temporary and minor while the long-term expected impacts are discussed below. Since Alternatives 2, 3, and 4 do not warrant the use of a breakwater structure, no impacts are discussed under this subsection.

Impacts Within the Proposed Basin

The obvious purpose of the proposed breakwater is that it will protect the marina basin and its entire shoreline from the tides, waves, and currents originating from the north-northeast. Since the Marine Corps Base dock already blocks the southerly storms,

the addition of the proposed breakwater north of the existing dock will create a safe harbor basin for the marina under the proposed project and Alternative 1.

In addition to displacing a minimal amount of shallow water area and the associated SAV, some impact caused by the proposed breakwater on the submerged aquatic vegetation within the basin area may be expected due to the retardation of the ebb cycle and river flows currently entering the basin to create the counter-clockwise circulation. Hence, any interaction that may exist between this type of circulation and the existing SAV will be altered. The effect of these new circulation patterns by themselves is not expected to significantly impact the existing SAV. On the other hand, it is also conceivable that the presence of the breakwater by itself may create more favorable conditions for the SAV within the basin by virtue of the calmer waters provided even during the ebb flows down the River.

It is anticipated that the impact of the proposed breakwater on the conditions of debris accumulation will be quite favorable. The breakwater will virtually eliminate the periodic import of debris migrating along the shore by the northerly currents. Additionally, any debris brought along by the southerly currents will likely continue to be deflected by the Marine Corps Base dock past the inlet section of the breakwater towards the north based on the proposed alignment of the offshore segment of the breakwater.

An adverse effect may also be expected because of the augmentation of the normal import pattern of water and sediments into the basin along the shoreline from the north. However, such adverse impacts should be minimized due to the width of the inlet section recommended for the basin. A reasonable circulation within the basin will be maintained with the proposed breakwater structure.

Thus, the proposed breakwater by itself is not expected to result in any significant adverse impacts within the basin and the associated shoreline. On the contrary, owing primarily to the protection it provides from the northerly storms, the proposed breakwater will improve shoreline stability within the basin, by way of creating considerably calmer waters while allowing for effective basin flushing by tidal action.

Impacts Outside the Proposed Basin

The proposed breakwater structure using quarry-stone riprap protection at the toe on the outboard side of the wall along the entire length of the breakwater minimizes adverse impacts to the shallow water areas. The alignment of the shore-attached segment of the proposed breakwater was chosen to be approximately perpendicular to the north-northeast direction and the adjacent shoreline, while the remaining offshore segment follows along the end of the basin "shelf" before the deep channel is reached. It is anticipated that the riprap protection and this configuration of the proposed breakwater will provide the following functions:

- adequately dissipate the energy from waves;
- reflect waves and currents nearly parallel to the shoreline north of the breakwater, thereby minimizing shoreline erosion due to these reflections;
- direct waves and currents along the outboard segment of the breakwater following the deep channel past the end section of the Marine Corps Base dock and down the river, thereby not creating additional circumstances for local erosion; and
- avoid creating adverse conditions, environmental or otherwise, to the shoreline south of the existing Marine Corps Base dock and marina.

There is the likelihood that some of the debris presently observed to periodically accumulate in the southwest corner of the Town's basin will be cut off and directed by the breakwater towards the shore offsite just north of the breakwater or accumulated along the riprap outer wall of the breakwater itself. However, because of the surface roughness, retardation of currents along the wall and overall wave energy dissipation provided by the same stone riprap along the outer wall, any debris brought in contact with the breakwater would likely tend to accumulate locally rather than be moved along the breakwater.

Impacts on the Potomac River

Normally calm waters in the basin area defined by the proposed breakwater structure and other adjacent shallow regions provide sufficient evidence that only a very small quantity of the Potomac River ordinarily flows through the shallow near-shore areas. These conditions will not likely be affected by the presence of the proposed breakwater. The entire breakwater will be placed on the shallow "shelf" section of the River, sufficiently away from the deep "channel" section which conveys the major bulk of the River's flow. Thus, the breakwater with the proposed alignment is not likely to cause any adverse effects on low flow, flood flow, or navigation within the Potomac River.

C. PIER STRUCTURES

The floating piers associated with the marina for the proposed project and Alternative 1 will be supported by a minimum number of piles to limit the lateral motion of the deck sections created by mooring forces and hydrodynamic forces from waves and currents in the basin. These piles will be relatively small in size with the depth of penetration not excessive, and hence will not involve any major disturbance during construction.

With minor wakes due to boating and otherwise calm conditions existing throughout the proposed marina basin, the piles of these piers will not effect or increase local sedimentation activities. Using environmentally inert plastics or otherwise appropriate coating material for protection of the timber piles in the marine environment, and employing appropriate driving techniques, the subsequent interaction of these piles with the surrounding environment will be insignificant. Piers in general, and floating piers in particular, are generally not considered to have significant potential for environmental degradation.

The floating pier system would likely inhibit the growth of SAV within the marina basin because of shading. Areas that would only be partially shaded would likely support SAV, but not necessarily the type of SAV that presently exists. However, it should be noted that under the displacement of existing SAV from dredging activities would render the significance of impacts from the floating pier system inconsequential.. Such impacts are discussed in the following subsection.

D. MARINA BASIN

Impacts to the existing environment within the proposed marina basin are divided into three categories:

- Dredging Activities
- Submerged Aquatic Vegetation Displacement
- Water Quality Degradation

Dredging Activities

The two phases defining dredging activities are the actual dredging and the disposal operations. Both of these phases will affect the environmental, technical, and economic feasibility of

the project. Practically speaking, there are two methods of dredging available for the type of project proposed. These are: (a) mechanical dredging, and (b) hydraulic dredging.

In mechanical dredging, the excavation process is performed by equipment such as bulldozers, draglines, and clamshells. The excavated material is then loaded onto barges or trucks and hauled away to a designated disposal site. Hydraulic dredging, on the other hand, is performed by a cutter operating on the bottom and a dredge pump which hydraulically transports the dredged material through a pipe to the shoreline and beyond. Hydraulic dredging tends to be the more feasible method when an environmentally acceptable site for dredge disposal is available near the dredge site. The possible presence of cobbles in layers in the basin may complicate hydraulic dredging. Nevertheless, dredging can be performed using either method in a manner that would be acceptable to environmental agencies.

The options for upland disposal of the dredged material are either onsite within the park area or offsite preferably within the Marine Corps Base. The proposed project will involve approximately 30,000 cubic yards of dredged material. Unless the entire upland park area can be substantially regraded and used to dry dredged material, onsite disposal is not practical. The low-lying area along the northern project limits has been identified as nontidal wetlands and disposal in this area would be highly objectionable by all agency representatives. Offsite disposal appears to be more practical. Preliminary discussions among representatives of the Marine Corps Base indicate a possibility that an acceptable disposal site may be available. Additional discussions will be required in order to coordinate construction schedules and available sites. At this time, it seems premature to make any definite plans or to expect unconditional commitments. The primary requirement of any upland disposal site is that it is

not located in a wetland or bottomland area and that the dredged material be prevented from reentry to any stream.

The feasibility of disposal within the Potomac River was not pursued to any significant extent with the agencies since it is generally not preferred. Nevertheless, this option could be further considered in the event an upland disposal site cannot be identified or is not available when needed. This type of disposal could be used to create replacement shallow water habitat. Whether or not SAV could be provided would require site specific studies. Additional discussions with the appropriate agencies during the next phase of the project should be considered. It may be possible to identify a spoil area within the Potomac River that may be suitable for a number of similar projects in the area as well as for maintenance dredging requirements in the future.

Alternative 1, which will require approximately 5,000 cubic yards of dredging, would still be difficult to achieve onsite without substantial regrading of the park area. Offsite disposal again appears to be more practical, if a site is available. Dredge disposal for Alternative 2 which involves minimal dredging can likely be integrated into the site work for the park.

Submerged Aquatic Vegetation

The submerged aquatic vegetation (SAV) present in the proposed marina basin that will be displaced during dredging activities is the significant environmental issue facing the proposed project.

SAVs in the dredged parts of the basin will be permanently removed in order to provide safe boating within the marina basin. The navigated portions of the marina basin will probably also require periodic maintenance dredging in the future. Any such impacts can be minimized or entirely prevented with strict application of the

appropriate disturbance control measures during both the initial and the subsequent maintenance dredging operations. The proposed project will directly impact approximately 5.0 acres of SAVs.

Alternative 1 is an attempt to reduce impacts to SAVs, especially those in shallow water areas, while providing a reasonable area with sufficient depths for safe navigation. The dredging operations are concentrated within the relatively deeper portions of the basin (depth greater than 2 feet) and the marina area is confined to the northernmost portion of the basin. Approximately 2.5 acres of SAVs are displaced by this alternative.

Alternative 2, which proposes spanning the SAVs with a pier system and constructing a tee section for approximately 15 to 20 slips, minimizes impacts to SAVs to the maximum extent practical. Minor localized impacts because of shading and pier construction are considered unavoidable. However, safe harbor is not afforded since construction of the breakwater is considered to be cost-prohibitive given the reduced number of slips.

Mitigation sites to recreate SAVs do not appear practical or feasible. The Town of Quantico does not have water frontage on any other portion of the Potomac River. It appears that Alternative 1 avoids impacts to SAVs to the extent practical considering costs and the need to provide improved waterfront access to the Town. Additional information supporting the alternatives analysis are provided in Appendix 15.

Water Quality Degradation

The natural cleansing process of a basin by tidal action is widely referred to as "tidal flushing" and is an environmental requirement that must be satisfied by proposed marinas. The relevant evaluations for the marina basin were made according to the

procedures described in the publication entitled "Coastal Marinas Assessment Handbook," published by the U.S. EPA.

Based on the calculations presented in Appendix 15, Section 15.F, the proposed marina will satisfy the general tidal flushing requirements. To further support this conclusion, the following general remarks are also offered.

The local cross section of the Potomac River is nearly 7,300 feet, with a channel approximately 35 feet deep adjacent to the basin along the western shore. The average depth for a large portion of the remainder of this cross section is nearly 20 feet. The water depth in the existing basin, on the other hand, gradually increases from zero to nearly 8 feet at about 600 feet from the shoreline.

Therefore, the basin forms a relatively shallow shelf gently tapered towards the River. The overall good to excellent water quality observed within the basin indicates the presence of an effective tidal flushing action for the existing conditions.

Based on any scenario of dredging proposed, the proposed marina basin will continue to allow for free tidal movement into and out of the basin. A positive slope in the offshore direction and the generously wide inlet section will ensure that water quality within the marina basin remains within the good range. The proposed project and Alternatives 1 and 2 have these characteristics.

V. SUMMARY OF REGULATIONS AND PERMIT REQUIREMENTS

A. GENERAL

Regulations to protect the natural environment including water quality exist at all levels of government. In view of the heightened awareness and concerns associated with the Chesapeake Bay, the States of Virginia and Maryland have also more recently promulgated regulations consistent with the Chesapeake Bay Preservation Agreement signed by the Governors of Virginia, Maryland, Pennsylvania, and the Mayor of Washington, D.C., in December 1987. The key environmental regulations including the administering agencies are presented in this section. The specific areas of jurisdiction and the permit application procedures envisioned for the proposed project are also summarized.

B. FEDERAL LAWS AND REGULATIONS

The Clean Water Act (CWA) of 1972 including amendments mandates that it is unlawful to add any pollutant to the waters of the United States, including navigable waters and wetlands, without a permit. Section 404 of the CWA requires permits for the discharge of dredged or fill materials. Section 401 requires that any applicant for a federal permit obtain a certification from the state that any discharge will comply with the state's water quality and effluent standards.

Section 10 of the Rivers and Harbors Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable water of the United States.

Section 307 of the Coastal Zone Management Act of 1972 as amended requires that any non-federal applicant for a federal permit within a state's coastal zone furnish a certification that the

proposed activity will comply with the state's coastal zone management program. Generally, no federal permit will be issued until the state has concurred with the applicant's certification.

The lead federal agency involved in the issuance of permits for the proposed project is the U.S. Army Corps of Engineers (USACOE). The permit requirements under Regulatory Programs of the Corps of Engineers (33 CFR Parts 320 through 330), are outlined in detail for Section 404 of the CWA and Section 10 of Rivers and Harbors Act of 1899. D&D has been advised that the authority for administering the regulatory program relative to the proposed project has been delegated to the district engineer in the Norfolk District. Representatives from both the Baltimore District and the Norfolk District have confirmed that an agreement between the Districts exists that specifies that the Norfolk District issues permits for projects associated with Virginia lands. The USACOE's decision to issue a permit will be based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest.

In evaluating the proposed project's impacts the USACOE will likely consult with the Regional Director of the U.S. Fish and Wildlife Service (USF&WS), the Regional Director of the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration, the Regional Administration of the Environmental Protection Agency (EPA), and the heads of the appropriate state agencies. Under the CWA, EPA can veto a Section 404 permit issued by the USACOE. This veto authority has been seldom used but tends to influence the USACOE's administration of the 404 process and an applicant's willingness to incorporate agency comments to further avoid and/or mitigate impacts to wetlands and water quality.

C. STATE LAWS AND REGULATIONS

The proposed project is rather unique in terms of state agency jurisdiction in that the Virginia-Maryland state line is coincident with the Virginia shoreline. The Potomac River itself is within the State of Maryland from the West Virginia boundary to its mouth at the Chesapeake Bay. Therefore, portions of the proposed project below mean low water are within Charles County, Maryland, where areas landward of mean low water are within Prince William County, Virginia. Hence, a combination of Maryland and Virginia state laws are applicable. For the purpose of further discussing the likely areas that each state will claim jurisdiction, the key laws and regulations in each state are identified below without regard to jurisdiction. Jurisdictional areas as determined through discussion with federal, state, and local officials are summarized at the end of this section.

In Virginia, regulations exist that require permits for construction activities that affect the following: subaqueous lands; vegetated and nonvegetated tidal wetlands as defined by the Virginia Code of Regulations; water quality in accordance with Section 401 of the CWA; and the water quality of the Chesapeake Bay in particular, in accordance with the recently adopted Chesapeake Bay Preservation Area Designation and Management Regulations. Additionally, Virginia has regulations regarding siting criteria and adequate provisions for sewerage facilities at marinas.

The Virginia Marine Resources Commission (VMRC) is responsible for issuing subaqueous bed permits which will include a comprehensive siting review process for a proposed marina. VMRC also provides technical assistance to the local wetlands board regarding impacts to tidal wetlands as defined by Virginia law. The Virginia Institute of Marine Sciences (VIMS) advises Virginia's regulatory

bodies on marine environmental matters. The Virginia Water Control Board (VWCB) administers the Section 401 water quality certification program and the Virginia Council on the Environment is responsible for administering the Coastal Zone Management Program. The Bureau of Wastewater Engineering is designated by the State Board of Health in Virginia to issue a certificate attesting to the adequacy of the sewerage facilities to serve marinas and to notify VMRC of issuance or denial of individual applications.

The State of Maryland has similar regulations that require permits for construction activities that affect any wetlands (tidal and/or nontidal), Maryland waters and subaqueous lands, water quality in accordance with Section 401 of the CWA, and water quality of the Chesapeake Bay in accordance with the Critical Areas Legislation and Criteria. Maryland also has siting criteria and sewerage regulations related to marinas.

The Maryland Department of Natural Resources (DNR) is responsible for issuing a wetlands license which would involve a review of all activities and impacts associated with shoreline stabilization and marina construction. The Maryland Department of the Environment (DOE) administers the Section 401 water quality certification program in accordance with the CWA. DNR and DOE both advise local governments regarding natural resources and water quality impacts from proposed projects in Maryland waters.

D. LOCAL LAWS AND REGULATIONS

Prince William County has a wetland ordinance that requires a permit for any project impacting vegetated and/or nonvegetated wetlands. Floodplain ordinances in accordance with the National Flood Insurance Program have also been adopted by the Town of Quantico. Over the next year, the Town is required to designate

Chesapeake Bay Preservation Areas and to adopt the necessary ordinances and criteria in accordance with the Chesapeake Bay Preservation Area Designation and Management Regulations. The key elements that will affect the Town of Quantico involve the following:

- Designating Resource Protection Areas (RPAs)
- Designating Resource Management Areas (RMAs)
- Identifying and Designating Intensely Developed Areas (IDAs) where exemptions to the general criteria are permissible.

Additionally, a full management program within the next 24 months including revisions to comprehensive plans, policies relative to appropriate densities for docks and piers, waterfront access (public and private) and affect on water quality, and potential water quality improvements through the eventual redevelopment of IDAs are to be established.

Critical Areas in Maryland are the counterpart of the Chesapeake Bay Preservation Areas in Virginia. Charles County is responsible for administering the critical areas regulations, and has designated critical areas and adopted the necessary ordinances in accordance with Maryland regulations.

E. SUMMARY

Discussions with representatives of federal, state, and local agencies were conducted by key staff from D&D throughout the preparation of this report. Copies of telephone and written correspondence are included in Appendix 4. Site inspections were held to further solicit comments relative to the proposed project on August 21 and 22, 1989. Table 8 lists the agencies and individuals that have been contacted.

Table 8 - List of Review Agencies

Name and Address of Agency	Contact Person(s) Name, Phone No.	Attended Site Inspection	Regulatory Authority Reference(s)
U.S. Army Corps of Engineers Norfolk District 803 Front Street Norfolk, VA 23510	Ms. Julie Steete Mr. Bruce Williams (804) 441-7652	No No	33CFR Parts 320 through 330
U.S. Army Corps of Engineers Norfolk District Northern Virgina Field Office Plaza South, Suite 102 138 Graham Park Road Dumphries, VA 22026	Mr. James Brogdon (804) 441-7652	Yes	33CFR Parts 320 through 330
U.S. Army Corps of Engineers Baltimore District P.O. Box 1715, NABOP-R Baltimore, MD 21203-1715	Mr. Larry Eastman Ms. Cheryl Smith (301) 962-3478	No	33CFR Parts 320 through 330
U.S. Fish & Wildlife Service Whitemarsh, VA	Mr. Gary Frazer (804) 693-6694	No	Advisory Capacity to US Army Corps of Engineers
U.S. National Marine Fisheries Service Oxford, MD	Mr. Robert Rubleman (301) 226-5771	No	Advisory Capacity to US Army Corps of Engineers
Virginia Marine Resources Commission Habitat Management Division 2600 Washington Ave., P.O. Box 756 Newport News, VA 23607	Mr. Charles Roadley (804) 247-2200	Yes	Section 62.1-3 of the Code of Virginia VR 450-01-0047
Virginia State Water Control Board P.O. Box 11143 Richmond, VA 23230-1143	Mr. Les Balderson (804) 367-6319 (804) 367-0062	No	33CFR Parts 320 through 330
Virginia Institute of Marine Sciences Gloucester Point, VA 23062	Ms. Julie Bradshaw (804) 642-7395	Yes	Advisory Capacity to VMRC and VWCB
Virginia Council on the Environment	Mr. Charles Ellis (804) 786-4500	No	Coastal Zone Management Program Concurrence under 33CFR Parts 320 through 330

Table 8 - List of Review Agencies (Cont'd)

Name and Address of Agency	Contact Person(s) Name, Phone No.	Attended Site Inspection	Regulatory Authority Reference
Virginia Department of Health	Mr. Al Golding (804) 786-1761	No	Section 32.1-246 of the Code of Virginia, Title 32.1, Chapter 6, Article 10
VA Dept. of Conservation & Recreation Division of Soil & Water Conservation Shoreline Erosion Advisory Service P.O. Box 1024 Gloucester Point, VA 23062	Mr. Lee Hill (804) 642-7121	Yes	Advisory Capacity to Virginia Agencies
VA Dept. of Conservation & Recreation Division of Soil & Water Conservation P.O. Box 1425 Tappahannock, VA 22560	Mr. Ned Burger (804) 443-6752	Yes	Advisory Capacity to Various Virginia Agencies
Maryland Dept. of Natural Resources Tidal Wetlands Division Tawes State Office Building D-4 Annapolis, MD 21401	Mr. Doldon Moore, Jr. (301) 974-3871	Yes	Annotated Code of Maryland Natural Resources Articles 8-203, and 801 through 814.
Maryland Dept. of the Environment Standards and Certifications Division 2500 Broening Highway Baltimore, MD 21224	Mr. Sean Smith (301) 631-3609	No	33CFR Parts 320 through 330
Maryland Critical Areas Commission 275 West Street, Suite 320 Annapolis, MD 21401	Mr. Ren Surry (301) 974-2426	No	Annotated Code of Maryland Natural Resources Article Section 8-1814.
Prince William County Planning Office 1 County Complex Court Prince William, VA 22192-9201	Mr. Maurice Foushee (703) 335-6830	Yes	Prince William County Code and Ordinances

Based on the information gathered and assuming existing regulations and administrative procedures remain unchanged, permits from the USACOE, the Commonwealth of Virginia (Bureau of Wastewater Engineering), the State of Maryland (DNR and DOE), and Prince William County will be required prior to construction of the proposed project. Numerous other federal and state government agencies will also be involved in an advisory capacity. Table 9 summarizes the specific comments and outlines the likely permit processing procedures.

Officials from Maryland have advised, in writing, that DNR will conduct the same type of review and enact the same policies and procedures for marinas and shoreline stabilization projects regardless of the location along the Potomac River. It is anticipated that DOE will have the same position regarding the issuance of a Section 401 water quality certificate. Virginia officials have advised verbally that VMRC's jurisdiction will likely be confined to assisting the local wetlands board in Prince William County. Additionally, the VWCB has verbally indicated they may offer comments or be requested to concur with any decision by Maryland DOE. However, Maryland is responsible for issuing all 401 certificates on the Potomac River in this area.

Maryland and Charles County officials have advised that the critical areas legislation has been interpreted to not apply to projects along the Virginia shoreline. However, the Chesapeake Bay Area Designation and Management Regulations to be adopted by Prince William County in cooperation with the Town of Quantico will eventually apply to the proposed project.

Following selection of the proposed project including appropriate refinements based on agency comments and directives from the Town, the necessary permit applications will need to be prepared. A Joint Permit Application as furnished by the VMRC will satisfy the

Table 9 - List of Permit Processes and Agency Remarks

Name of Agency	General Permit Process Procedures	Summary of Remarks
U.S. Army Corps of Engineers Norfolk District	Review the project under the Joint Permit Application, issue public notice if necessary, coordinate other federal agency review and comments, issue Section 404 permit	According to Ms. Steele, only military projects are under Baltimore District's jurisdiction; all other projects are the Norfolk District's responsibility
U.S. Army Corps of Engineers Norfolk District Northern Virgina Field Office	Review the project under the Joint Permit Application, issue public notice if necessary, coordinate other federal agency review and comments, issue Section 404 permit	SAV beds are primary concern regarding proposed dredging for the marina. Stone shoreline stabilization, floating piers and concrete breakwater with riprap toe area generally acceptable to USACOE
U.S. Army Corps of Engineers Baltimore District	Will not be involved	According to Mr. Eastman, Norfolk District is responsible for projects "originating" above MLW in Virginia, including dredging activities with disposal in Virginia
U.S. Fish & Wildlife Service Whitemarsh, VA	Review and provide comments to USACOE	SAV beds are the main concern; would help to determine history, coverage and species composition. Hydrilla is not a nuissance for US F&WS. Less concern regarding marina, is probably flushed well. There would be restrictions on time of dredging. No problem with anadromous and commercial shell fish.
U.S. National Marine Fisheries Service, Oxford, MD	Review and provide comments to USACOE	
Virginia Marine Resources Commission	Will receive and process the Joint Permit Application for all Virginia approvals and permits. Will serve in a coordinating and advisory capacity.	Similar concern as Md/DNR and USACOE. Shoreline area is generally classified as nonvegetated wetlands.
Virginia Institute of Marine Science	Not a regulatory agency	VIMS will advise on wetlands and other environmental aspects of the project. VIMS concurs with the Md/DNR's concerns regarding SAV beds and VMRC's assessment that shoreline is primarily nonvegetated.
VA Dept. of Conservation & Recreation Division of Soil & Water Conservation Shoreline Erosion Advisory Service	Not a regulatory agency	Recommends "riprap" structure to replace existing deteriorated concrete wall and offered technical details; suggested that the undercut trees should be removed.

Table 9 - List of Permit Processes and Agency Remarks (Cont'd)

Name of Agency	General Permit Process Procedures	Summary of Remarks
Maryland Dept. of Natural Resources Tidal Wetlands Division	Issue "Wetlands License" for all activities outboard of MLW line; review dredging/disposal, filling, marina pumpout, tidal flushing, tidal wetlands and SAV impacts and Coastal Zone Management Consistency. Average processing time 6 months.	SAVs in the basin a major concern; mitigation discouraged; dredging in shallow areas highly objectionable; breakwater riprap and shoreline stone improvements would present no problem SAV bed delineation would be helpful; economics is only one of the criteria.
Maryland Dept. of the Environment Standards and Certifications Div.	Issue "Water Quality Certification" for activities outboard of MLW line review dredging/disposal, filling, marina pumpout, tidal flushing, other water quality impacts.	A new law introduced regarding pumpout facilities, to be administered by DNR's Boating Regulation group.
Maryland Critical Areas Commission	Not applicable to proposed project.	According to Ren Surry, neither Maryland Chesapeake Bay Critical Areas Commission nor Charles County will be involved in this project. Maryland's interests would be covered by Md/DoE and DNR.
Prince William County	Local Wetland Board will issue permit in conjunction with the Joint Permit Application	Requires public hearing.

general requirements of the USACOE, the Commonwealth of Virginia, and the Prince William County Wetlands Board. A separate application for a certificate of approval of sanitary or sewerage facilities must be made on a form supplied by the local health department in Virginia. A wetlands license from Maryland DNR and a 401 water quality certificate from Maryland DOE also require separate applications.

APPENDIX 1

Coastal Resources Management Grant and Relevant Documents

JAN 0 1989

COASTAL RESOURCES MANAGEMENT GRANT CONTRACT

This agreement is made this _____ day of _____, 1988, by and between the Council on the Environment (hereinafter referred to as the "Council")
and the Town of Quantico
(hereinafter referred to as the "Grantee").

The parties to this agreement, in consideration of the mutual covenants and stipulations set out herein, agree as follows:

1. **Project:** The Grantee shall carry out the project as set forth in Attachment A. All aspects of this project shall be consistent with the Chesapeake Bay Agreement of 1987, and with the Commonwealth's Coastal Resources Management Program. The project, in accordance with the Chesapeake Bay Preservation Act, shall incorporate general water quality protection measures into any comprehensive plans, zoning ordinances and subdivision ordinances resulting therefrom.

2. **Time of Performance:** The project shall commence on January 1, 1989 and shall terminate on Sept. 30, 1989, the period of performance being 9 months.

3. **Payments:** The Council shall pay the Grantee quarterly on a reimbursement basis, not to exceed $ 14,000 for the project. The said sum, together with the matching funds provided as set forth in Attachment A, shall include the cost of all personnel, all overhead, and all other expenses of the project.

Payment shall be made upon submission of invoices and progress reports and their acceptance by the Council. Such

invoices shall be submitted within ten (10) days following the end of each calendar quarter and shall be detailed in accordance with Attachment A to show what tasks have been completed and to compare the time of completion with the proposed time of completion. Progress reports shall be submitted on forms provided by the Council within ten (10) days following the end of each calendar quarter.

4. Terms and Conditions: Grantee shall comply with the Standard Terms and Conditions of the U. S. Department of Commerce set forth in Attachment B.

5. Liability: The Grantee shall take out and maintain, during the life of this agreement, such bodily injury liability and property damage liability insurance as will protect it from claims of damages for personal injury, including death, as well as from claims for property damage, which may arise from its activities under this agreement. If the Grantee has a self-insurance program, it may self-insure the risks associated with this Agreement in lieu of the commercial insurance required herein.

6. During the performance of this contract, the Grantee agrees as follows:

a. The Grantee will not discriminate against any employee or applicant for employment because of race, religion, color, sex or national origin, except where religion, sex or national origin is a bona fide occupational qualification reasonably necessary to the normal operation of the Grantee. The Grantee agrees to post in conspicuous places, available to employees and applicants for

employment, notices setting forth the provisions of this nondiscrimination clause.

b. The Grantee, in all solicitations or advertisements for employees placed by or on its behalf, will state that such Grantee is an equal opportunity employer.

c. Notices, advertisements and solicitations placed in accordance with federal law, rule or regulation shall be deemed sufficient for the purpose of meeting the requirements of this section.

The Grantee will include the provisions of the foregoing paragraphs a, b and c in every subcontract or purchase order of over $10,000, so that the provisions will be binding upon each subcontractor or vendor.

7. Use of Grant Funds: Grant funds shall only be used for the purposes and activities covered in Attachment A.

8. Fiscal Control: The Grantee shall establish fiscal control and fund accounting procedures which assure proper disbursement of, and accounting for, grant funds and any required non-federal expenditures.

9. Prior Written Approval of Changes: The Grantee must obtain prior written approval from the Council for changes to the project, including, but not limited to, changes of substance in program activities, designs, or plans set forth in the approved application and changes in the approved project budget.

10. Termination for Cause: The Council reserves the right to terminate the grant in whole, or in part, at any time before the date of completion, upon written notice to the Grantee that

it has failed to comply with the conditions of the grant. In connection with such termination, payments made to the Grantee or recoveries by the Council shall be in accord with the legal rights and liabilities of the parties.

11. Termination for Convenience: The Council may terminate the grant if its funding is terminated. The Council or the Grantee may terminate the grant in whole, or in part, if both parties agree that the continuation of the grant program will not produce beneficial results commensurate with further expenditure of funds. The Council and the Grantee shall agree upon the termination conditions, including the effective date and, in the case of partial terminations, the portion to be terminated. The Grantee shall not incur new obligations for the terminated portion after the effective date, and shall cancel as many outstanding obligations as possible. The Council shall allow full credit to the Grantee for the federal share of the noncancellable obligations properly incurred by the Grantee prior to termination.

12. Maintenance of Records and Audit: The Grantee shall maintain all required records and provide the Council an audit performed in accordance with OMB Circular A-128, Audits of State and Local Governments. That audit will be reviewed by the Council for compliance with federal laws and regulations. Grantee will ensure that appropriate corrective action is taken within six months after receipt of the audit report in instances of noncompliance with federal laws and regulations.

13. There are no third party beneficiaries to this contract.

COUNCIL ON THE ENVIRONMENT

Date:_____ By_____
Administrator

_____
Grantee

Date:_____ By_____

Title:_____

6:3/307Fconl

Attachment 2

Cover Sheet
1988 Grant Application Form
Virginia Coastal Resources Management Program

1. **Legal Applicant (Name, Organization and Address)**

   Town of Quantico
   507 C Street
   Quantico, VA 22134

2. **Project Title**

   Environmental Investigation of Shoreline Stabilization

3. **Area of Project Impact**

   Town of Quantico

4. **Project Starting Date and Ending Dates**

   November 1, 1988 to September 30, 1989

5. **Project Duration (in months)**

   11 Months

6. **Proposed Funding**

a.	Federal (CZM)	0
b.	State	$14,000
c.	Local	$ 6,000
d.	Other	0
e.	Total	$20,000

22,000

7. **Brief Description of Applicant's Project**

   A thorough investigation of all environmental factors as they relate to the implementation of measures necessary to stabilize shoreline areas will be performed.

8. **Products**

   The results of the environmental investigation will be a report summarizing the various components described within this proposal, and the identification of strategies necessary to stabilize shoreline areas.

9. **Individual Authorized to Make Application**

   a. **Typed Name and Title**

   Howard Bolognese

   Mayor of Quantico

   b. **Signature and Date Signed**

   Howard Bolognese

   November 15, 1988

Project contact is Mitchel P. Raftelis, Town Councilman

Environmental Investigation of Shoreline and Proposed Marina

COASTAL RESOURCES MANAGEMENT NEED

Description

In 1985 the Town of Quantico received 4.21 acres of prime Potomac riverfront property from the Federal Government. The remainder of the Town is bounded by the Quantico Marine Base. The riverfront property was given to the Town with the understanding that it was to be obtained as a public area for recreational use. The site, which provides the Town's only direct access to the river, currently has no appropriate public access to the river and is bounded by a deteriorating sea wall. Because the river turns at this location, debris from the upper river is often washed in along the shore, where it is trapped, effectively preventing use of this section of the river for recreational activities.

The Town of Quantico proposes developing the land area as a public park and constructing a marina which extends some distance into the river. A conceptual plan for the integrated development of a marina and a public park, with a riverwalk providing pedestrian access to the riverfront from the Town's main street, has been prepared. The key elements of this plan are the construction of a breakwater and piers and the restoration of the deteriorating seawall. However, before the marina and other amenities are designed and constructed, existing shoreline erosion must be properly managed and these areas stabilized. Also, appropriate environmental research must be completed to ensure that the proposed piers, breakwater, and seawall are compatible with the existing adjacent uses and to ensure that the improvements to the riverfront preserve the shoreline, maintain optimal water circulation, and enhance public access to the river.

Impact

The waterfront area encompassed in this proposal represents the only access the Town of Quantico has to the river and also the only area readily available for tax base expansion. Proper planning for the seawall, the breakwater, and the piers will allow the Town to go forward with a limited economic expansion, through the development of the marina and auxiliary marine services, while maintaining the ecological integrity of this portion of the Potomac River. Careful environmental research should provide the information necessary to develop and implement shoreline stabilization measures, and design a breakwater and piers which will prevent the continual accumulation of debris in the cove of the river. When completed the total riverfront project will result in greatly improved river access for both the boating and non-boating public, a reduction in the amount of debris at the shoreline, protection and/or enhancement of water quality, a stabilized shoreline, a more diversified tax base for the Town of Quantico, and improved recreational opportunities for both the residents of the Town of Quantico and the military personnel and their families stationed at the Quantico Marine Base.

Immediacy

Quantico is a town of approximately 600 people and is surrounded, on all sides except the riverfront, by the Quantico Marine Base. Its economic base is derived solely from real estate tax collections. The Town wishes to fulfill the terms of the gift of land it has received from the Federal Government by planning a public use facility along the riverfront. However, because of its

size and its small tax base, the Town has no planning staff and does not have the resources available to conduct the environmental research necessary to plan an environmentally sound waterfront project. Additionally, failure to develop the waterfront may well result in a decrease of the environmental quality of the area as the seawall area continues to deteriorate, shoreline erosion becomes more prevalent, and debris continues to accumulate along the shoreline.

Benefits

The State Comprehensive Outdoor Recreation Plan has identified a significant need for boater access to the Potomac below the Occoquan River. This project will result in the creation of a 111-slip marina as well as a boat launch ramp, significantly increasing boater access to the Potomac. The park's path system will run along the seawall and will be designed to include river outlook areas, providing waterfront access for those who wish to enjoy the river, but who do not own boats.

A well designed marina, along with the development of support services such as a marine store and a restaurant, will offer the Town an opportunity to expand its economic tax base by drawing visitors and boaters to the aesthetically pleasing waterfront area, while providing increased recreational opportunities to the Town's residents. A well conducted environmental investigation will ensure that the marina will function properly over the years and continue to attract visitors to the Town.

Relationship of Proposal

The proposed activities are intended to enable the Town of Quantico to plan an ecologically sound waterfront park and marina and to restore a deteriorating seawall within the Town. The Town of Quantico has been given the waterfront property, which provides its only access to the Potomac River, by the Federal Government on the condition the land be developed for public recreational use. It is the Town's wish to plan and develop a top quality marina and riverfront recreational area. However, the Town lacks the capacity to undertake an in-depth study of the environmental issues involved with the design of the marina and the seawall. Adequate funding of the environmental research is a necessary prerequisite to any further development of the site.

PROPOSAL TO ADDRESS COASTAL RESOURCES MANAGEMENT OPPORTUNITY

Objective

The objective of this proposal is to secure funds to perform an in-depth study of the environmental issues involved with the protection of shoreline areas, and the design of a marina and seawall for the Town of Quantico. If the grant is awarded, the Town's Marina Committee will meet to develop a request for proposals to be sent to coastal and marine engineering firms and other appropriate agencies. After a group is selected, it will begin producing results as described below. When the job is completed, the Town will be prepared to embark on the next stage of development of the marina which is to obtain from an engineering firm final approved construction plans, specifications, cost estimates and all applicable permits.

Previous Studies

A preliminary planning study for the integrated park and marina on the riverfront parcel of land was prepared for the Town of Quantico in the summer of 1986. Two professors, Dr. James Hall and Dr. Ernest Morant, from Hampton University performed the study using funds that were provided from the Department of Housing and Urban Development. The products of the study include a two-page narrative, a cost estimate and a conceptual layout of the park and marina. A copy of these results is attached to this proposal. The results of this study will be used as a point of departure for the in-depth environmental investigation associated with this proposal.

Description

The purpose of the project is to thoroughly investigate the waterfront area in terms of environmental factors so that the Town of Quantico can ensure that shoreline areas are preserved and adequate information is developed so that proposed development programs can proceed without impacting shoreline areas. Also this program will help determine the effects on water quality due to poor circulation; and effects of wind and waves on shoreline areas.

Specifically, the Town will engage an environmental consultant to provide the services described below. The Town Treasurer and the Town Clerk for the Town of Quantico will manage the project and be the contacts with the environmental consultant. Below are described the tasks to be performed by the consultant.

- A list of permits that the Town will be required to apply for will be provided.
- A bathymetric survey of the proposed marina area from the existing Marine Corps dock to the upstream property line will be performed such that a contour map of the area is produced.
- Shoreline changes will be investigated by reviewing old photographs and maps of the area to predict the amount of erosion and sedimentation and to allow a design of the breakwaters, piers and seawalls that take this into account.
- Sediments will be sampled and analyzed to determine any environmental sensitivities and to specify methods of dredging.
- An investigation of the amount of dredging to be done during construction of the marina will be performed. Factors to be considered in the investigation include the type of boats that are expected to use the marina and their associated drafts; the rate of sedimentation; and the life of the project. Possible locations of where the dredged material can be placed will be determined.
- Various tidal and flooding elevations will be investigated to establish needed shoreline protection measures, and the final elevations of piers and seawall.

- o A study of the wind and wave climates will be performed to determine the required strength of the breakwater and seawall, and needed shoreline stabilization measures.

Consistency

A thorough study of the environmental and physical factors involved in shoreline stabilization needs will be utilized by the Town of Quantico so that riverfront development programs do not adversely impact shoreline area. Also, this effort is consistent with the design of a water front park area, and is consistent with the Town's wishes of developing the riverfront area in a manner such that the Town citizens and tourists can safely enjoy the recreational benefits that their Town has to offer. The terms of the proposal are also consistent with the stipulations that the Federal Government required when the land was given as a gift. This proposal is clearly consistent with the goals of the Coastal Resources Management Program that state its purpose is "to assist local governments . . . to address issues such as protection and enhancement of water quality and living aquatic resources, the protection and management of shoreline areas, and the accommodation of growth and development in an environmentally sound manner."

Costs

	Total	Funding Request	Local Gov't Match	
Personnel Costs - Salaries and fringe benefits				
Town of Quantico Treasurer (9%)	$ 2,400	$	($ 2,400)	in-k
Contracted Services	$17,400	$14,000	($ 3,400)	cash
Subtotal	$19,800	$14,000	($ 5,800)	
Direct Costs - Postage, Supplies and Reproduction	$ 200	$	($ 200)	
	$20,000	$14,000	($ 6,000)	

Duration

The project will commence on November 1, 1988 and be completed by September 30, 1989 allowing eleven months to perform the desired tasks.

Product

The Town of Quantico expects to receive a report illustrating environmental constraints and shoreline stabilization needs. This report will include the most effective angle of the outer jetty to protect the shoreline area and design requirements of the seawall to prevent shoreline erosion. This report will be further utilized by the Town of Quantico to revise the layout of the marina and modify previous design requirements of the breakwater, piers and seawall which take into account the findings of this environmental investigation of the riverfront area.

LAW OFFICES
TURNER, BRICE & HORTON
EXECUTIVE ENTERPRISES BUILDING
236 SOUTH FRALEY BOULEVARD
DUMFRIES, VIRGINIA 22026

JAMES S. G. TURNER
JANICE J. BRICE
ROSS G. HORTON

(703) 221-1131
METRO 385-8460

May 3, 1985

Mr. James Coleman, Regional Director
National Parks Service, Mid Atlantic Region
United States Department of the Interior
143 South Third Street
Philadelphia, Pennsylvania 19106

Re: (Portion) Parcel No. 8
Marine Corps Development Command
Quantico, Prince William County, Virginia
GSA Control No. 4-N-VA-493-M

Dear Mr. Coleman:

On behalf of the Town of Quantico, Virginia, I am pleased to transmit an original and four copies of an application by the Town to acquire the above-referenced property located within the Town for development for park and recreation purposes. The area in question includes six parcels containing a total of 4.21 fee acres.

Please be advised that the Town of Quantico is willing to take immediate possession of the subject property upon approval. Much of the property can be put to immediate use since it is already used for park and recreation purposes.

The proposed development of park and recreational facilities on the site can be accomplished in harmony with the housing area located in the Town adjacent to the site and in harmony with the surrounding military base. This park will be an asset not only to the Town but also to the surrounding community including personnel stationed at the Marine Corps facility at Quantico. If there are any questions concerning this application, please do not hesitate to contact me. On behalf of the Town, I would like to thank you for your assistance in this important matter.

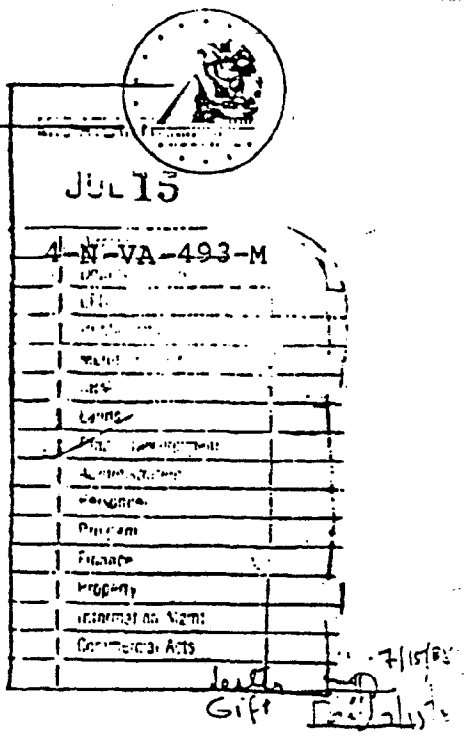
Very truly yours,

Ross G. Horton

RGH/pde
encls.

cc: Town Council, Town of Quantico

General Services Administration, Region 4
75 Spring Street SW.
Atlanta, GA 30303



July 10, 1985

Mr. James W. Coleman, Jr.
Regional Director
U. S. Department of the Interior
National Park Service
Mid-Atlantic Region
143 South Third Street
Philadelphia, PA 19106

Dear Mr. Coleman:

Reference is made to your letter of May 10, 1985, to Mr. Donald F. Layfield requesting that the property identified below be assigned to the Secretary of the Interior for conveyance at 100 percent public discount to the Town of Quantico, Virginia, for public park or recreational purposes.

Property Identification	Reporting Agency	Description
4-N-VA-493-M	Marine Corps Development and Education Command Quantico, VA 22134	(P) Parcel No. 8, Marine Corps Development Command, Quantico, Prince William County, Virginia (4.21 A.)

Pursuant to the authority vested in the Administrator of the General Services Administration by the provisions of the Federal Property and Administrative Services Act of 1949, 63 Statute 377, as amended, and a delegation of that authority by him, I hereby assign the above-mentioned property to the Secretary of Interior for disposal for public park and recreational purposes as outlined above, in accordance with the provisions of Section 203(k)(2) of said Act, subject to the terms, conditions, reservations, and restrictions, if any, contained in the Report of Excess Real Property.

We transfer this property subject to your compliance with the provisions of the National Environmental Policy Act of 1969, as amended; the National Historic Preservation Act of 1966, as amended; Executive Orders 11988 and 11990, subject: Floodplain Management and Protection of Wetlands; and other appropriate guidelines, regulations, laws, and executive orders pertaining to the future use of this property.

No objection is interposed to the proposed conveyance of the property at 100 percent public benefit allowance, subject to the usual terms and conditions in transfers of property for on-site use.

The responsibility for custody and accountability of the property and the protection and maintenance thereof, pending disposition, will be governed by the provisions of Federal Property Management Regulation 101-47.402.

Enclosed is a copy of Standard Form 118 covering the property. If you need additional information, please let us know.

Sincerely,

B. C. MALTBY
Acting Director
Disposal Division

Enclosure

DESCRIPTION OF EXCESS PROPERTY ADJOINING TOWN OF QUANTICO

This is the division of a parcel of land located at the Marine Corps Development and Education Command, Quantico, Virginia in the County of Prince William. The division is as a result by the Command to excess six parcels of land containing 4.21 acres of an original 4.38 acre parcel acquired in 1942 for an improved access to the US Naval Hospital. Said parcel of land is shown on the Real Estate Summary Map 1309517, in the Plat Description as Item No 6, containing 4.38 acres and was the civil deed of taking No 473 dtd 10-13-42 and on the Composite Property Map, PW Dwg No 1739 and is listed as Parcel No 8. The said parcel will be divided into 7 parcels of land and will be identified as Parcels "A" through "G".

Parcel "A"

Said parcel begins at a point which is located N 67° 25' 00" W 53.33' from US Mon No 134, and is located on the west edge of the right-of-way leading to the Naval Regional Medical Clinic and the north edge of Potomac Avenue. Thence continuing along the right-of-way of Potomac Avenue N 67° 25' 00" W 88.03' to an iron pipe set in concrete; thence N 22° 35' 00' E 120.00' to a point; thence S 67° 25' 00" E 88.03' to a point in the edge of the right-of-way leading to Naval Regional Medical Clinic; thence along the edge of the said right-of-way S 22° 35' 00" W 120.00' to the point of beginning containing an area of .243 acre.

Parcel "B"

Said parcel is located on the west edge of the Naval Regional Medical Clinic right-of-way and is N 22° 35' 00" E 116.00' along the said right-of-way from Parcel "A". Thence N 67° 25' 00" W 88.03' to a point; thence N 22° 35' 00" E 50.00' to a point; thence S 67° 25' 00" E 88.03' to a point in the above mentioned right-of-way; thence S 22° 35' 00" W 50.00 ' to the point of beginning containing .101 acre. Said parcel is a continuation of Fourth Avenue in the Town of Quantico.

Parcel "C"

Parcel "C" begins at a point which is located on the west edge of the Naval Regional Medical Clinic right-of-way and is a common corner with Parcel "B". Running N 67° 25' 00" W 88.03' to a point; thence N 22° 35' 00" E 230.00' to a point which is a common corner with Third Avenue; thence S 67° 25' 00" E 88.03' to a point in the said right-of-way; thence S 22° 35' 00" W 230.00' along the right-of-way to the point of beginning containing .465 acre.

Parcel "D"

Said parcel begins at a point that is a common corner to Parcel "C", and the Naval Regional Medical Clinic right-of-way. Running N 67° 25' 00" W 88.03' to a point; thence N 22° 35' 00" E 40.00' to a point; thence S 67° 25' 00" E 88.03' to a point in the said right-of-way; thence S 22° 35' 00" W 40.00' along the right of way to the point of beginning containing .081 acre and is the continuation of Third Avenue in the Town of Quantico.

Parcel "E"

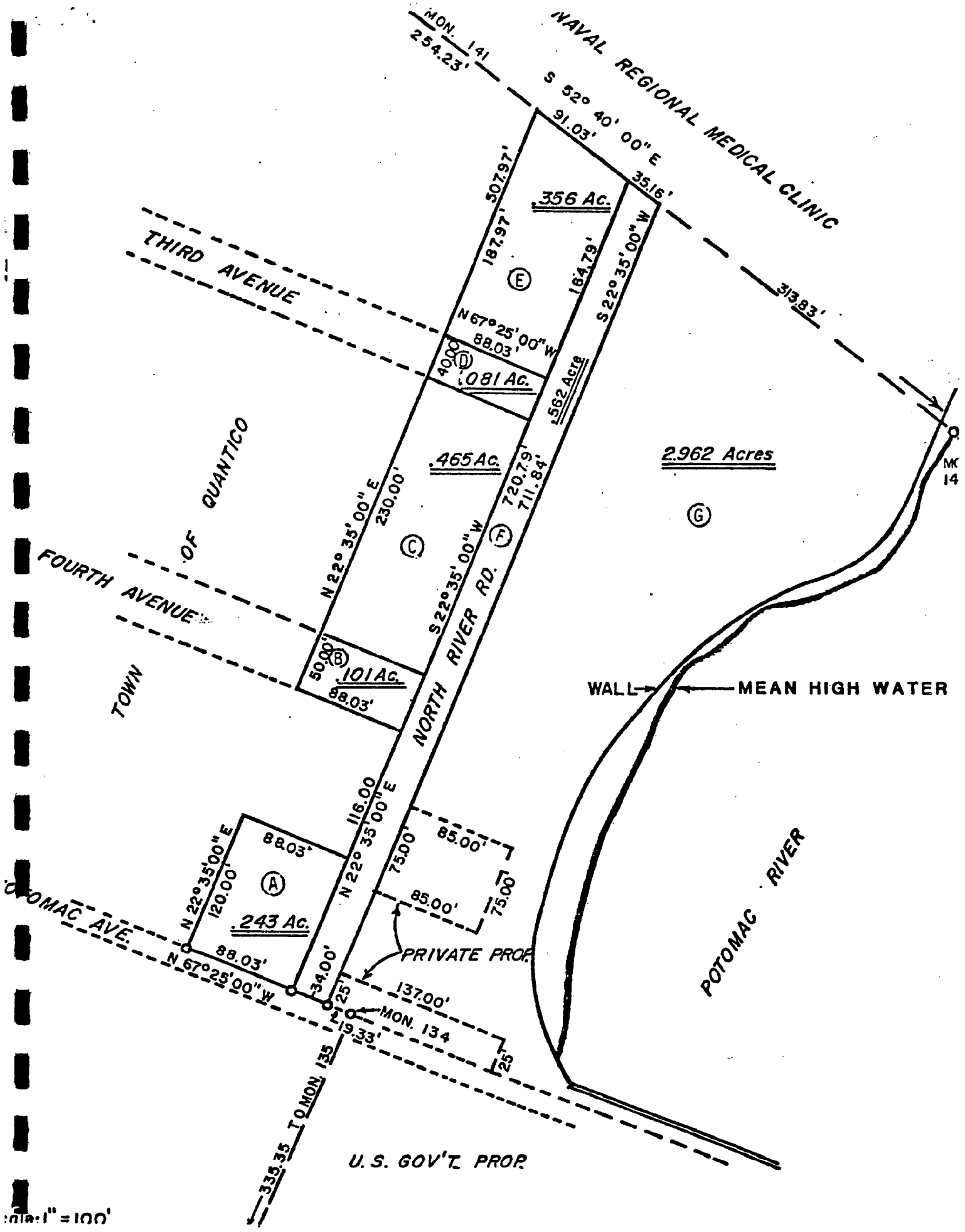
Said parcel begins at a common corner with Parcel "D" and the Naval Regional Medical Clinic right-of-way. Running, N 67° 25' 00" W 88.03' to a point; thence N 22° 35' 00" E 187.97' to a point in the line from Prop Mon 141 to Prop Mon 142; thence along the same S 52° 40' 00" E 91.03; to a point on the Naval Regional Medical Clinic right-of-way; thence along said right-of-way S 22° 35' 00" W 164.79; to the point of beginning containing .356 acre.

Parcel "F"

Said parcel includes North River Road and is the Naval Regional Medical Clinic right-of-way. Parcel begins at a point N 67° 25' 00" W 19.33' from US Prop Mon No 134. Running N 67° 25' 00" W 34.00 to a point located on the north edge of Potomac Avenue and a common corner to Parcel "A"; thence N 22° 35' 00" E 720.79' to a point in the line from US Prop Mon 141 to US Prop Mon 142; thence running with the same S 52° 40' 00" E 35.16' to a point; thence S 22° 35' 00 W 711.84' to the point of beginning containing .562 acre of which .168 acre is a part of the original 4.38 acre deed of taking and .394 acre which is North River Road, formerly known as Shipyard Road and is excluded from excessing.

Parcel "G"

Beginning at a point which is the intersection of the north edge of Potomac Avenue, east edge of the Naval Regional Medical Clinic right-of-way, and the old Riverview Hotel Property. Said point is N 67° 25' 00" W 19.33' from US Gov't Prop Mon No 134. Running N 22° 35' 00" E 711.84' to a point in the line from Prop Mon No 141 to Mon No 142; thence S 52° 40' 00" E 313.83' to US Prop Mon No 142; thence with the mean high water mark of the Potomac river to the intersection of the Northeasterly right-of-way line of Potomac Avenue; thence running N 67° 25' 00" W along the right-of-way line of Potomac Avenue to the point of beginning. Parcel "G" excludes two parcels of land that are privately owned. The acreage figure for Parcel "G" was determined by subtracting Parcels "A" through "F" from the original deed of taking, civil No 473 dtd 10-13-42, containing 4.38 acres. Unable to mathematically close the boundary traverse due to original deed description calling for along the mean high water mark of the Potomac River to the intersection of the Northeasterly right-of-way line of Potomac Avenue; thence along the right-of-way line of Potomac Avenue to the point of beginning.


MON. 141
254.23'
NAVAL REGIONAL MEDICAL CLINIC
S 52° 40' 00" E
91.03'
35.16'
313.83'
507.97'
187.97'
.356 Ac.
E
164.79'
S 22° 35' 00" W
THIRD AVENUE
N 67° 25' 00" W
88.03'
40.00'
D
.081 Ac.
.562 Acre
2.962 Acres
G
MK 14
TOWN OF QUANTICO
.465 Ac.
C
N 22° 35' 00" E
230.00'
720.79'
711.84'
S 22° 35' 00" W
F
NORTH RIVER RD.
FOURTH AVENUE
50.00'
B
.101 Ac.
88.03'
WALL
MEAN HIGH WATER
116.00
N 22° 35' 00" E
88.03'
A
N 22° 35' 00" E
120.00'
.243 Ac.
75.00'
85.00'
85.00'
75.00'
POTOMAC AVE.
88.03'
N 67° 25' 00" W
34.00'
25'
PRIVATE PROP.
137.00'
MON. 134
19.33'
25'
POTOMAC RIVER
335.35' TO MON. 135
U.S. GOV'T. PROP.
1" = 100'

APPENDIX 2

Town of Quantico's Request for Proposals 1989

TOWN OF QUANTICO
P.O. BOX 152
QUANTICO, VIRGINIA 22134

January 30, 1989

Ms. Cara Bobchek
Director of Marketing
Dewberry & Davis
8401 Arlington Boulevard
Fairfax, VA 22031

Dear Ms. Bobcheck:

The Town of Quantico is accepting proposals for work to be conducted under a Coastal Resources Management Grant. The objective of this project is to identify the environmental sensitivities of a portion of the Potomac river front that is to be developed into a public park and marina.

As part of the work program the selected consultant should provide the Town with a report identifying:

- Expected impacts of park and marina development.
- Strategies to protect the shoreline area and other identified environmentally sensitive areas.
- Necessary sea walls, jetties, groins, bulkheads, etc., and design criteria.
- Required permits.
- Required dredging.

Also a bathymetric survey of the study area should be performed and a bathymetric map of the area should be provided to the Town.

The project completion date is September 1, 1989. A copy of the Request for Proposals as it appeared in the Monday, January 30, 1989, edition of the Washington Post, is enclosed.

If you have any questions, please direct them to Beth Topol, Environmental Planner for the Northern Virginia Planning District Commission, 703-642-0700.

Sincerely,

Mitchell Raftelis
Councilman, Town of Quantico

MR/BT/ls
Enclosure

Rec'd 2/1/89

Shoreline Management

The Town of Quantico is accepting proposals for work to be performed under a Coastal Resources Management Grant. The project is designed to identify environmental sensitivities and make recommendations to protect portions of the Potomac Shoreline. The goal is to convert this riverfront area into a recreational park and marina in an environmentally sound manner.

The scope of work will include but not be limited to:

1. Identification of permits for shoreline stabilization and marina development.
2. A bathymetric survey.
3. Evaluation of shoreline erosion and sedimentation.
4. Sediment analysis.
5. Identification of all dredging needs.
6. Tidal and flood water elevation identification.
7. Wind and wave climate assessment.

Expected products include a report:

1. Listing environmental constraints and shoreline stabilization needs.
2. Identifying effective angles and design requirements for structures needed to protect shoreline areas.
3. Listing required permits for shoreline stabilization and marina development activities.
4. Identifying all required dredging and possible locations for dredge spoils.

Also, a bathymetric map of the study area must be provided.

Six copies of the proposal should be submitted to the Town of Quantico, P.O. Box 152, Quantico, VA 22134 by February 21, 1989, 4:00 p.m. For more info. call 703-642-0700. The Town may accept or reject any or all proposals. EOE.

APPENDIX 3

List of Sources of Information and Selected Bibliography

APPENDIX 3

LIST OF SOURCES OF INFORMATION AND SELECTED BIBLIOGRAPHY

The following is a list of historic maps, plans, photographs, communications, and other documents and sources of information that were obtained through the Town of Quantico, Quantico Marine Corps Base, Northern Virginia Planning District Commission and other sources. Also furnished is a list of selected bibliography.

- Coastal Resources Management Grant Contract.
- Quantico Municipal Park Quitclaim Deed, and relevant communication between the U.S. National Parks Service, General Services Administration and Town's Attorney.
- Quantico Municipal Park Deed Signing Ceremony, and relevant addresses and documents.
- Quantico Municipal Park Proposal, 1"=100' scale Concept Plan, by James Hall III, Hampton University, through Community Assistance Grant, U.S. Department of Housing and Urban Development, Summer 1986.
- Zoning Ordinance, Town of Quantico.
- Town Code, Town of Quantico.
- Town of Quantico Plat.
- Comprehensive Plan, Text and Maps, Town of Quantico, 1980.
- FEMA Report, February 1978, and FIRM Map.
- U.S. Coast and Geodetic Survey, Potomac River, Douglas Point to Cockpit Point, Maryland and Virginia, Soundings, 1:10,000 Scale, 1904.
- U.S. Coast and Geodetic Survey, Potomac River, Aquia Creek to Mattawoman Creek, Maryland and Virginia, Land Topography and Shoreline, 1:20,000 Scale, 1903-1904.
- Joseph Barry, Surveyor, Plat Showing Property of the Quantico Company, Shoreline, 1"=400' scale, 1916.
- Subsurface Survey Bureau, Preliminary Map Boundary Showing Parcels 1,2 &3, and U.S. Marine Corps Reservation, Quantico, Shoreline, 1"=1000' scale, 1920.
- Quantico Marine Corps Base, Map of Marine Barracks, with Soundings, 1"=200' scale, June 30, 1928.
- U.S. Coast and Geodetic Survey, Topographic Map No. T-5763, Maryland-Virginia Potomac River, Neabsco Creek - Quantico, 1:10,000 Scale, 1940.
- National Ocean Survey, Hydrographic Survey No. 9322, Virginia-Maryland, Potomac River, Vicinity of Quantico, Soundings, 1:10,000 scale, 1972.
- U.S. Geologic Survey, Quantico, VA.-MD., SE/4 Quantico 15' Quadrangle, 1:24,000 scale, 1966, Photorevised 1983, Bathymetry added 1982.

SELECTED BIBLIOGRAPHY

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DeChiara, Joseph, and Koppelman, Lee E.:
"Waterfront Development: Docks and Floats, Marinas," in Time-Saver Standards for Site Planning, McGraw-Hill, New York, 1984.

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Mixing in Inland and Coastal Waters, Academic Press, New York, 1979.

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The Pile Buck Annual, Jupiter, FL, 1988.

U.S. Army Corps of Engineers:
Low Cost Shore Protection ... A Guide for Engineers and Contractors, Office of the Chief of Engineers, Washington, D.C., 1981.

U.S. Army Corps of Engineers:
Low-Cost Shore Protection, Final Report on the Shoreline Erosion Control Demonstration Program (Section 54), Office of the Chief of Engineers, Washington, D.C., 1981.

U.S. Army Corps of Engineers:
Shore Protection Manual, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

U.S. Army Corps of Engineers:
Engineering and Design: Design of Coastal Revetments, Seawalls, and Bulkheads, EM 1110-2-1614, 30 April 1985.

U.S. Army Corps of Engineers:
Engineering and Design: Hydraulic Design of Small Boat Harbors, EM 1110-2-1615, 25 September 1984.

U.S. Department of Commerce:
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Tidal Currents 1989, NOAA, National Ocean Survey, Washington, D.C., 1989.

U.S. Environmental Protection Agency:
Coastal Marinas Assessment Handbook, Region IV, Atlanta, GA, April 1985.

Whiteneck, Lawrence L., and Hockney, Lester A.:
Structural Materials for Harbor and Coastal Construction, McGraw-Hill, New York, 1989.

APPENDIX 4

Personal Interview Summaries, Records of Correspondence

QUANTICO RIVERFRONT STUDY

PROJECT STAFF SITE VISIT JUNE 16, 1989

ATTENDEES: Oner Yucel, Bob Hallermeier, Mark Headly and Rusty Arcuni (Harbor Master)

- The meeting was held for two purposes:
  1. To discuss various aspects of the project with Rusty,
  2. For Bob H. Mark H. to inspect the site.

- We presented a quick overview of the project based on D&D's preliminary topo, and expressed our intention to conduct soon some field measurements with a boat. We showed the a table of tide range calculations OY had prepared and confirmed its accuracy with Rusty. Upon our request, Rusty voluntereed the following comments:

  * Currents can be strong. During the tide coming up the river, the marina basin is protected by the Marine Base dock, and hence is usually quiescent. During the ebb cycle as the tide leaves down the river, however, the marina basin is subjected to a very visible and consistent "whirl" created by currents coming in from north and after following a counterclockwise course leave the basin in a direction roughly perpendicular to the river. [It was a day with moderate southerly winds and the tide was receding according to the tide table predictions. We observed that the boats anchored immediately north of the dock were quite protected, while those anchored further away from the dock and in somewhat less protected positions had taken different orientations, indicating the local current directions.]

  * The Marine Base dock has been flooded to the level of my knees [which we estimated to be 8.5', or 3 ft above the top of dock, 5.5' MSL] on an otherwise calm day without wind-driven waves a few years ago [probably during the 1985 storm. Bob H. indicated that there may be a need for revewing the 100-year flood levels.] However, no damage was sustained to the boats that were attached to the floating docks within the marina basin. Nevetheless, Rusty commented that a higher breakwater should probably be designed for the proposed marina.

  * Rusty does not remember any maintenance dredging ever done in and around the marina. The 30' to 35'-deep hole outboard of the dock has always been there, and the marina basin itself has never paused any "draft" problems for the boats (up to 40' to 50' length).

  * Rusty indicated that the Base marina is always clean and they certainly prevent oil spills from occuring, but the Town's beach needs clean-up four times a year.

* Rusty indicated that the depths shown on D&D's topo are inaccurate are basically good, except that they should nearly 5' deeper along the perimeter of the basin, and that along a line projected parallel to the outer edge of the Marine dock, the depths should be 20' to 25'. [MH and OY checked the spot shots in the area shown on the preliminary topo, and decided that the discrepancy may not be a serious one. However, MH will explore the possibility of using fish-finder to confirm the water depths in the area during their field work. Upon his request, we will furnish Rusty with copies of the current and 1928 topo as well as other plans.]

* Rusty also pointed out that there is an underwater storm drain pipe approximately following the property line in the north, that is exposed during extremely low tide conditions. [Mark H will try to locate it.]

* Rusty strongly criticized the previous sketch plan in regards to the "solid wall" in the south as well as distant and inadequate parking facilities. He suggested that there is no need for the wall in the south, that the parking facility should be next to the shoreline to accomodate temporary and permanent storage of boats.

* Rusty agreed with our plans of creating a mirror image of the Marine Base marina in the Town marina basin, including the "sufficiently long" breakwater in the north and strongly recommended "floating docks" south of the breakwater.

* Rusty commented that the proposed marina should best be designed primarily for "large, luxury" boats for "rich" indivuals to retire in Quantico, and suggested that the Town marina should have at least 40 slips for 40' to 50' boats. Accordingly, he suggested that the marina basin should be dredged to 6' to 8' depth.

* Rusty indicated that except for the visible beach area south of the shoreline, the bottom of the marina basin is all mud. He also suggested that the "dredge problem" will be a formidable one, and asked several times as to how D&D is planning to dispose of the dredge material. The only logical place he can suggest for the disposal site is the "wetlands" area northwest of River Road, but recognizes the problem with these tidal wetlands.

* Rusty referred to the six large-size "ice-eaters" he has in the Marine Base marina, strongly recommended that we consider ice as a major problem.

* Rusty expressed his willingness to help us as needed.

Dewberry & Davis

Record of Communication

Date 6-28-89

Talked With Mr. Chuck Roadley

Of VMRC

Phone No. 804 247-2200

Recorder

Incoming ☐ Outgoing ☑

Reference Quantico

Routing OY

Quantico

Action

Information MH

Topic: Marina Permits / Jurisdiction

- Marina siting criteria will be sent to me.
- Anything landward of MLW will involve VA Wetlands and PW County, MD will handle water side. (SBP)
- Subaqueous Bed Permit would not be issued by VMRC if it is Maryland waters
- Mr. Roadley suggested we get a copy of "Policy Clarifying Licence Requirements for Projects in MD Waters along VA Shore Tidal Portion of Potomac River" from MD.
- VMRC uses quad map in ~~western~~ entire and eastern area of state to determine if SBP is required. If intermittent, not generally needed. If perennial, SBP should be obtained.
- I discussed nontidal wetlands, 401, 404, and regulations in general. Mr. Roadley was very helpful.

Dewberry & Davis

Record of Communication

Date 6-28-89

Talked With Ed Easlick

Of VWCB

804 367-1868

Phone No.

Recorder K. Thompson

Incoming ☐ Outgoing ☑

Reference Quantico Marina

Routing OY

Quantico File

Action

Information /cc Mark Headley

Topic: 401 Program in VA

Mr. Easlick advised me that VWCB recently advised the USACOE, Norfolk District, that they intend to require 401 certification on all projects that qualify for Nationwide Permit #26. I asked if VWCB intends to get such word out to industry/public. He didn't seem to have an answer for this other than joint permit procedure should take care of it. I explained my concerns. I requested that he send me whatever information is available to the public that will help me in understanding VWCB 401 Program. He stated little other than internal admin. directives exist. He will send what he can.

Regarding 401 jurisdiction for Marina such as Quantico, he suggested I call following:

VMRC — Whoever

VWCB — Les Balderson 367-6319

VA Council on Env. — Charlie Ellis (804) 786-4500

Dewberry & Davis

Record of Communication

Date 7-13-89 / 7-19-89

Talked With Cheryl Smith

Of Baltimore COE

Phone No. (301) 962-3478

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico, VA

Routing

Action

Information

Topic:

Neither Cheryl Smith nor Greg Steyr were in on 7-13

- Called back 7-19 and talked to Larry Eastman, who is also in her section.

- It was his understanding that projects originating above MHW in VA, not involving fill of Md waters, were handled by Norfolk. He thought that was also the case for dredging (as long as you were disposing of it in VA)

- Their office would be involved from a coordination standpoint because of Md state agency involvement.

- He hadn't heard of official policy document

- He'll check w/ Cheryl Smith and call me back if anything he said was incorrect.

Dewberry & Davis

Record of Communication

Date 7-13-89

Talked With Mac McGlaun

Of Northern Neck Field Office - COE

Phone No. (804) 462-5382

Recorder Headley

Incoming ☐ Outgoing ☒

Reference Quantico

Routing

Action

Information

Topic:

- Norfolk District would review application

It was his impression that Baltimore District would be involved, but only to coordinate with the MD agencies that are involved because of state jurisdiction over Potomac River proper.

- He hadn't heard of any official policy document regarding jurisdiction.

Dewberry & Davis

Record of Communication

Date 7-19-89

Talked With Larry Eastman

Of Baltimore COE

Phone No.

Recorder Headly

Incoming ☒ Outgoing ☐

Reference Quantico, VA

Routing

Action

Information

Topic:

Larry checked w/ Cheryl Smith ... "they think it's Norfolk" -- even if dredging is proposed.

The way they like to handle it, even in cases of theoretical overlapping of jurisdictions, is that one district just takes care of everything. We would like to think that's Norfolk.

He suggested calling them -- if they don't agree, then everyone will have to sit down and work something out.

Dewberry & Davis

Record of Communication

Date 8-3-89

Talked With Ren Serey

Of Critical Areas Commission

Phone No. (301) 974-2426

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico

Routing

Action

Information

Topic:

He's not sure of Commission's jurisdiction over projects in Potomac that originate from Virginia shore.

- He'll check with someone (probably attorney) and get back to me.

- Regarding site visit, depending on jurisdiction (and interest) he's agreeable to coming over -- he'll let us know when he knows more about their jurisdiction.

- Called 8-8 to ask about their jurisdiction and find out if he can attend meeting on 21st -- will have to check again on 8-9-89.

* 8-10-89 -- Neither Critical Areas Commission nor the Charles County folks will be involved with this project -- State of Maryland's interests will be covered by Md Dept of Env. and their Tidal Wetlands Group.

Dewberry & Davis

Record of Communication

Date 8-4-89

Talked With Dolden Moore

Of DNR - Tidal

Phone No. (301) 974-3871

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico

Routing

Action

Information

Topic:

Dolden not in -- left message

-Calling to confirm site visit

-Missed each other a bunch of times --

Corey Yucel was in their office and Dolden is set for the meeting ~~on~~ on the 21st.

Dewberry & Davis

Record of Communication

Date 8-4-89

Talked With Bob Zepp

Of U.S. Fish & Wildlife Service

Phone No. (301) 269-5448

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico

Routing

Action

Information

Topic: Zepp in meeting in field

Need: 1) General Comments on marina / shore protection along that portion of Potomac.

2) Would he be interested in site visit?

3) Hydrilla or other SAV a problem?

4) Who's contact for projects like this at NMFS? (Oxford?)

Also left message on 8-9-89

8-8- (804) 693-6694

→ Talk to Gary Frazer in Whitemarsh, VA field office. Gary pretty much is responsible for VA projects.

Dewberry & Davis

Record of Communication

Date 8-4-89

Talked With Sean Smith

Of Md Dept of Env.

Phone No. (301) 631-3603

Recorder Healy

Incoming ☐ Outgoing ☒

Reference QUANTICO

Routing

Action

Information

Topic:

Sean in field -- we'll hook up on Monday.

- Site Visit set for 8-21- or 8-22

Can Sean attend? Maybe on 21st if he rearranges something else. Probably 22nd as a back-up.

- Also, please send most recent version of Marina Assessment Guidelines.

↳ Will do.

Their new address --
2500 Broening Hwy
Baltimore, Md
21224

7-1-89 ⇒ New law regarding ~~pump~~ pump out facilities introduced
- Administered by boating group of DNR -- If he can find anything on this he'll send it

8-11-89 - Sean cannot make it on the 21st. He'll check and see if the 22nd is OK. He'd still like the info. packet though.

Dewberry & Davis

Record of Communication

Date 8-4-89

Talked With Bruce Williams

Of Norfolk COE

Phone No. (804) 441-7652

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico

Routing

Action

Information

Topic:

- Bruce not in when I finally got through. Person who took message will talk to Bruce and/or Julie Steele and have whoever wants to answer my jurisdictional question give me a call.

- Julie called back -- As long as it has nothing to do with Marine Base, it's Norfolk's jurisdiction (Baltimore handles military installations along the Potomac though)

Dewberry & Davis

Record of Communication

Date 8/4/89

Talked With LEE HILL

Of SEAS

Phone No. (804) 642-7121

Recorder OY

Incoming [ ] Outgoing [X]

Reference QUANTICO

Routing OY FILE ~~[illegible]~~

Action

Information

Topic: SITE MTG

- I briefly described the project, work done so far, and the objectives of the site mtg.
- Hill asked who we're dealing with at the Corps of Engrs. (I replied: Brogdon
- HILL IS willing to cooperate, advise and attend the site mtg.

He can't make it on Aug 21.

He can make it on Aug 22, 10:30 am (he suggested!)

~~[illegible]~~

... we'll have to call him to confirm!

Omer,

Mark & I have tent. set meeting on Aug 21 because VMRC & VIMS have a conflict on Aug 22. However, if MD wants the 22nd, we will shift. We'll need to sort out early next week.

Dewberry & Davis

Record of Communication

Date 8-8-89

Talked With Al Golding

Of VA Health Dept.

Phone No. 804 786-1761

Recorder Kurt Thompson

Incoming ☐ Outgoing ☑

Reference Quantico Marina

Routing CY

Quantico File

Action

Information

Topic: I explained our project for Town to him. I requested that he provide relevant information. He's sending regulations. He'll also send certificate applications & necessary for getting VMRC boat/marina ~~facility~~ facility approvals.

Dewberry & Davis

Record of Communication

Date 8-8-89

Talked With Gary Frazer

Of U.S. FWS - Whitemarsh, VA

Phone No. (804) 693-6694

Recorder Headly

Incoming ☐ Outgoing ☒

Reference Quantico, VA

Routing

Action

Information

Topic:

He's responsible for FWS review of projects in Virginia. He'd be interested in site visit, but can't make it on the 21st. He did say that if VIMS was going to be there, his interests would be fairly well represented.

Their concerns would be with Submerged Aquatic Vegetation (SAV) and impacts to it. It's helpful for him to know areal coverage of it and species composition. (Hydrilla isn't a "nuisance" species to the FWS). It would also be helpful to know SAV history -- is it a recent colonization, or has there always been some SAV at site.

Benthic organisms would also be impacted to some degree. In a year or two there'd be some recolonization, but there'd probably be fewer organisms and a different make-up of species.

Dewberry & Davis

Record of Communication

Date 8-8-89

Talked With Frazer

Of

Phone No.

Recorder

Incoming ☐ Outgoing ☐

Reference Quantico (cont.)

Routing

Action

Information

Topic:

In general, since it's on the open Potomac and probably well-flushed, he didn't think there'd be as many environmental concerns as with something in a cove or up a tidal creek.

Anadromous fish shouldn't be a big concern either, for same reason as above. Conceivably there would be time of year restrictions on dredging activities. Commercial shellfish not a problem either

- Contact at NMFS in Oxford, Md is Bob Rubleman (301) 226-5771

MEMORANDUM

August 11, 1989

TO : Various Agency Representatives
FROM : Kurt R. Thompson, P.E., Dewberry & Davis KT
SUBJECT : Quantico Potomac Riverfront Environmental Study

Per telephone conversations with representatives of Dewberry & Davis, this is to provide directions and additional relevant information concerning the site meeting scheduled on the above referenced project.

We are planning to meet at the site near the beach area in the southern portion of the park between River Road and shoreline, at noon on August 21, 1989. Please consult attached directions, a vicinity map and a project schematic.

Also attached for your information are a brief description of the project and a list of the various agency representatives who may attend the site meeting.

If you are unable to attend this meeting, or have any questions, please contact me or Oner Yucel at (703) 849-0554.

Thank you very much for your cooperation.

Agency Representatives to Attend the Site Meeting:

Ms. Beth Topol
NVPDC, 7630 Little River Turnpike, Suite 400
Annandale, VA 22003 (703) 642-0700

Mr. Mitchel P. Raftelis
503 C Street, Quantico, VA 22134 (703) 640-7979

Mr. James E. Brogdon
U.S. Army Corps of Engineers, Northern Virginia Field Office
Plaza South, Suite 102, 138 Graham Park Road
Dumphries, VA 22026 (703) 221-6967

Mr. Les Balderson
Virginia State Water Control Board, P.O. Box 11143
Richmond, VA 22230-1143 (804) 367-0062

Mr. Chuck Roadley
Virginia Marine Resources Commission, P.O. Box 756
Newport News, VA 23607 (804) 247-2200

Mrs. Julie Bradshaw
Virginia Institute of Marine Sciences
Gloucester Point, VA 23062 (804) 642-7395

Mr. Lee Hill
Shoreline Erosion Advisory Service, P.O. Box 1024
Gloucester Point, VA 23062 (804) 642-7121

Mr. Doldon Moore, Jr.
Department of Natural Resources, Water Resources Administration
Tidal Wetlands Division, Tawes State Office Building, D-4
Annapolis, MD 21401 (301) 974-3871

Mr. Sean Smith
Department of the Environment
Standards and Certifications Division, 2500 Broening Highway
Baltimore, MD 21224 (301) 631-3609

Mr. Maurice Foushee
Prince William County, Planning Office
1 County Complex Court
Prince William, VA 22192-9201 (703) 335-6830

Directions:

* From Washington, DC and north/east: Take I-95 South
  From Richmond, VA and south: Take I-95 North

* Take Exit 50 to 619 East (also Fuller Road) for Quantico.

* Follow Fuller Road to end, passing through the Quantico Marine Base Gate. You may tell the guard at the gate that you will be going to the marina, and he should let you through. Follow to the Town of Quantico.

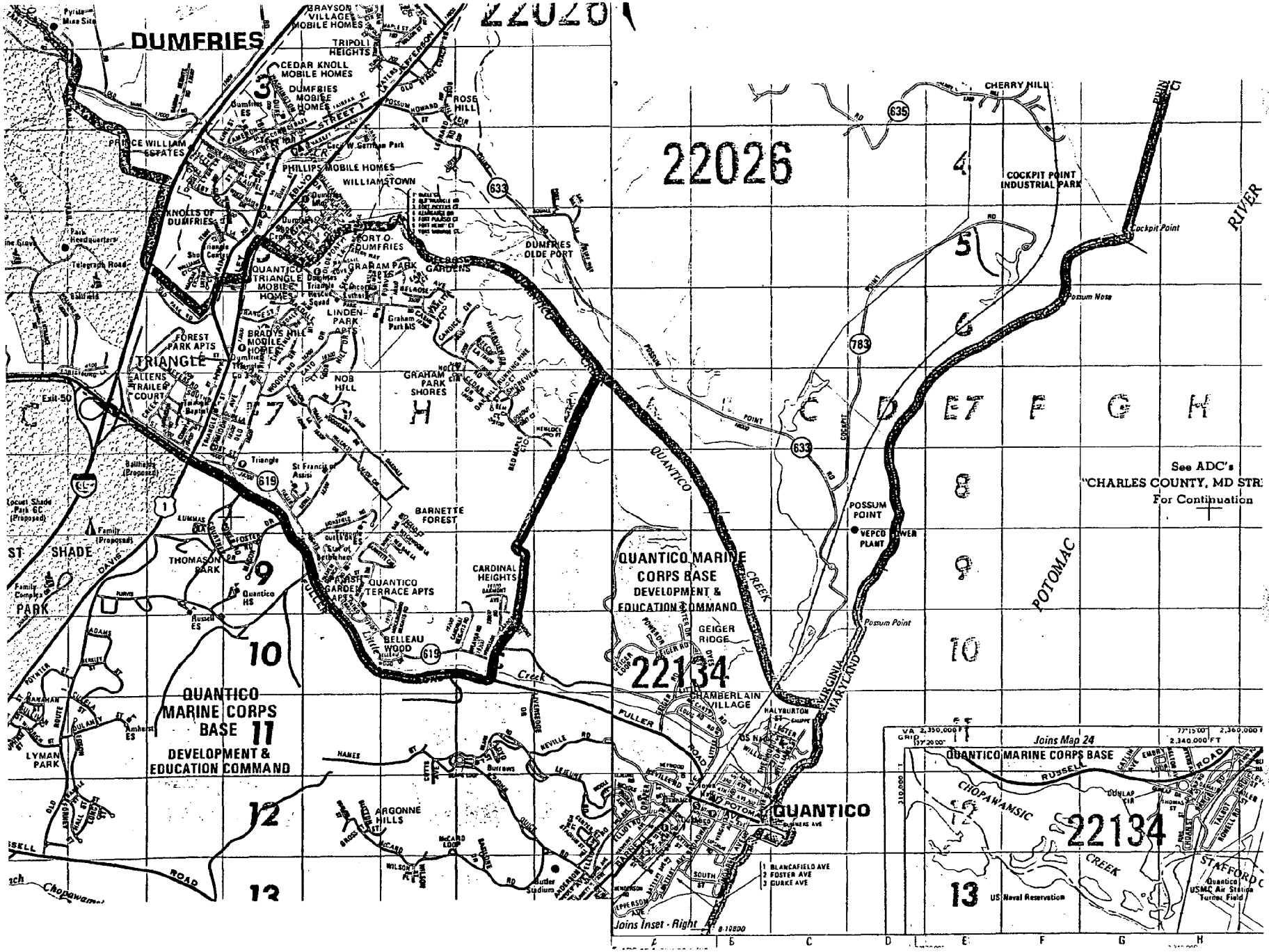
* Turn left, crossing the railroad tracks, on to Potomac Avenue and into the Town. Follow to end of Potomac Avenue, which continues to become the Marine Base's dock. Turn left on to River Road. The project area is on the right, between River Road and the shoreline, also north of the Quantico Marine Base's dock.

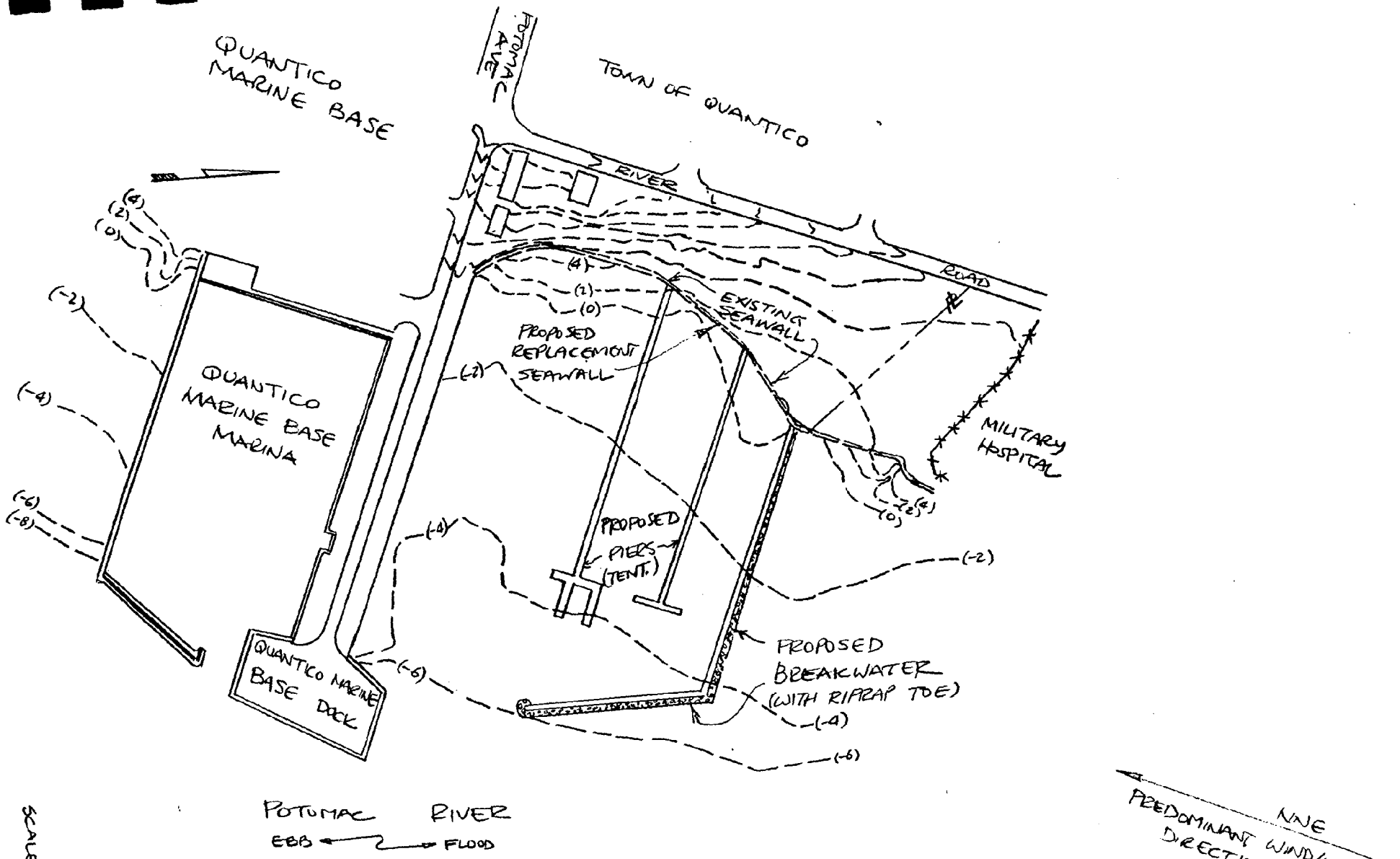
PROJECT DESCRIPTION

Dewberry & Davis (D&D) was selected to perform the environmental and engineering services for this project on behalf of the Town of Quantico, Virginia, and the Northern Virginia Planning District Commission (NVPDC).

Shoreline stabilization is an essential element of the proposed public park and marina facilities in the area donated to the Town of Quantico by the Federal Government. As shown on the attached vicinity map, the riverfront in this project area is the only access to the Potomac River for the Town.

The condition of the shoreline is featured by a deteriorated masonry seawall with accompanying shoreline erosion and a narrow beach along a short segment of the shoreline in the south. Field surveys and environmental measurements, historic trends of the shoreline migration, analysis of published information and other evaluations revealed that a breakwater can provide an adequate stabilization and protection means for the shoreline and the proposed public park and marina facilities. Thus, one primary purpose of the project is to study the environmental aspects of the project, including the potential environmental impact of the proposed structures and dredging activities. Also included in the project work scope is to identify and assess all aspects of permit processing at the local, state and federal levels.


DUMFRIES
TRIANGLE
QUANTICO MARINE CORPS BASE
DEVELOPMENT & EDUCATION COMMAND
QUANTICO
22026
22134
POTOMAC
RIVER
QUANTICO CREEK
Joins Map 24
Joins Inset - Right
See ADC's "CHARLES COUNTY, MD STR
For Continuation


QUANTICO MARINE BASE
POTOMAC AVE
TOWN OF QUANTICO
RIVER
ROAD
EXISTING SEAWALL
PROPOSED REPLACEMENT SEAWALL
QUANTICO MARINE BASE MARINA
QUANTICO MARINE BASE DOCK
PROPOSED PIERS (TENT.)
PROPOSED BREAKWATER (WITH RIPRAP TOE)
MILITARY HOSPITAL
(4)
(2)
(0)
(-2)
(-4)
(-6)
(-8)
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EBB
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NNE
PREDOMINANT WIND/WAVE DIRECTION
SCALE: 1"=200' (±)

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503 C Street, Quantico, VA 22134 (703) 640-7979

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Mr. Doldon Moore, Jr.
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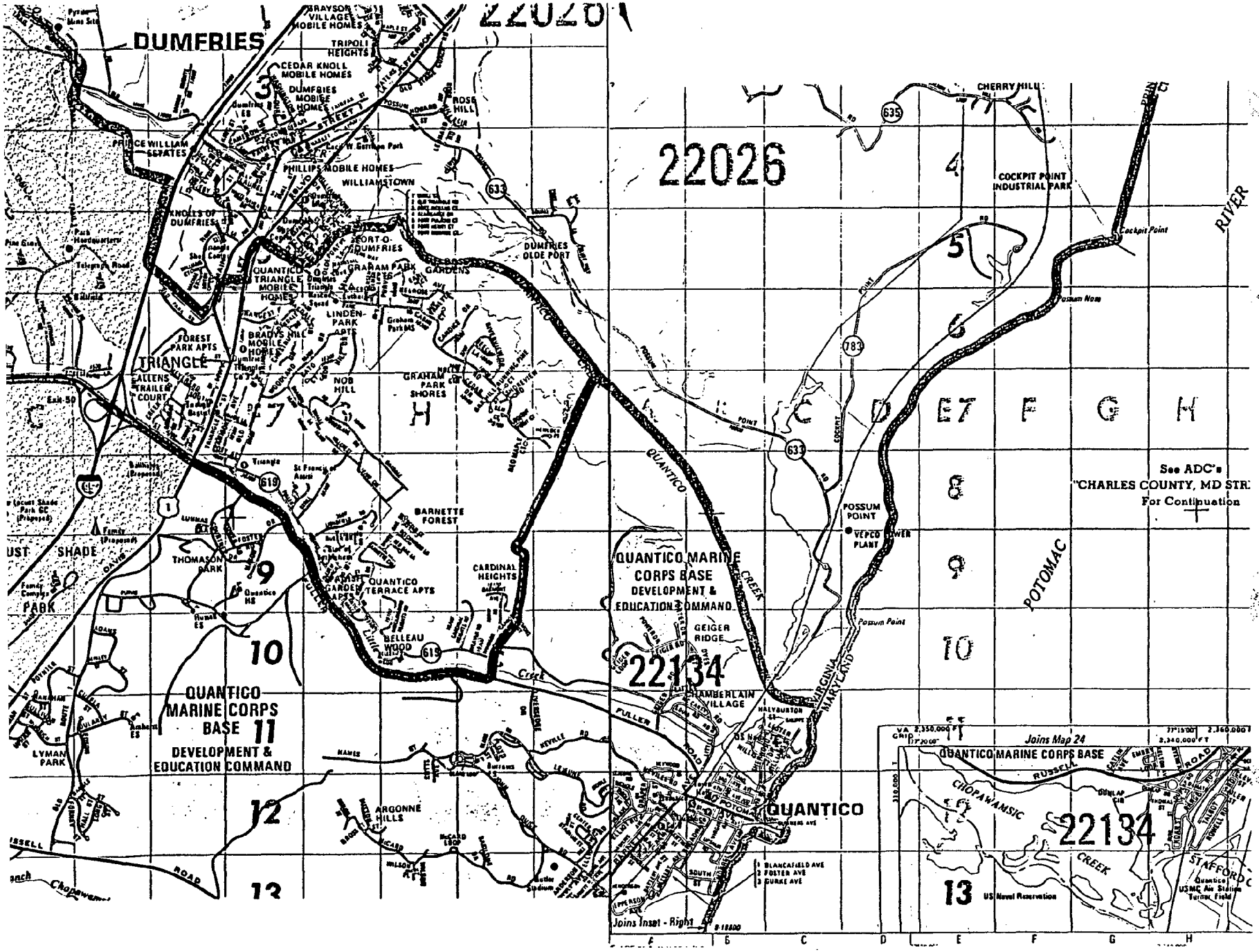
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QUANTICO MARINE CORPS BASE
DEVELOPMENT & EDUCATION COMMAND
QUANTICO
22026
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POTOMAC
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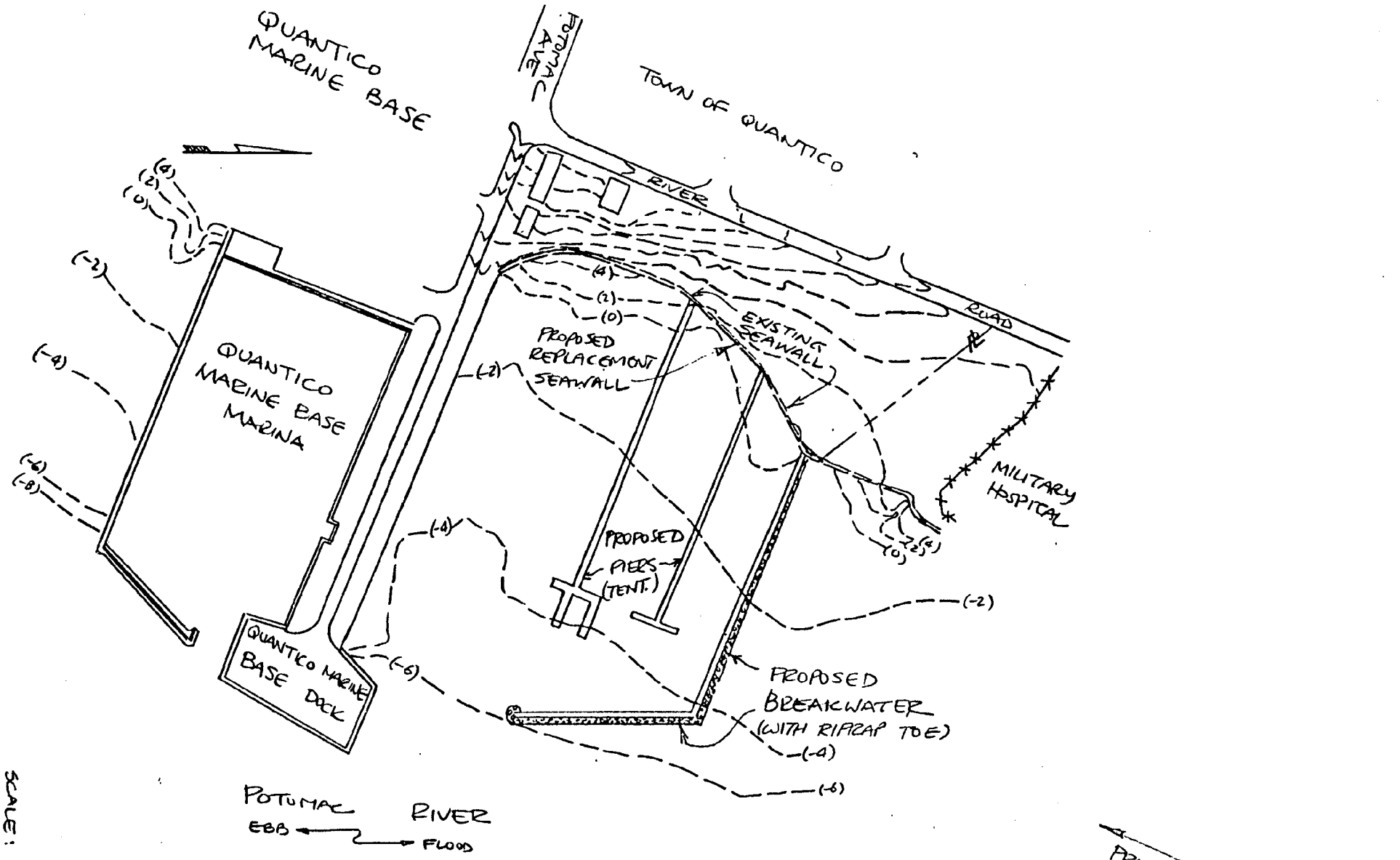
QUANTICO CREEK
COCKPIT POINT INDUSTRIAL PARK
POSSUM POINT
VEPCO POWER PLANT
See ADC's "CHARLES COUNTY, MD STR.
For Continuation
Joins Map 24
Joins Inset - Right
CHOPAWAMSIC CREEK
STAFFORD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TOWN OF QUANTICO
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EXISTING SEAWALL
PROPOSED REPLACEMENT SEAWALL
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PROPOSED PIERS (TENT.)
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POTOMAC RIVER
EBB
FLOOD
NNE
PREDOMINANT WIND/WAVE DIRECTION
SCALE: 1"=200' (±)

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mr. Sean Smith
Department of the Environment
Standards and Certifications Division
2500 Broening Highway
Baltimore, Maryland 21224

Dear Mr. Smith:

Furnished are the following items related to the Interagency site meetings held on August 21, and 22, 1989:

- Agenda
- Summary Minutes
- List of Invited Persons and/or Attendees

Please review the above information. Written comments concurring with or clarifying the minutes are requested from each agency by September 15, 1989. Additional comments are also encouraged.

On behalf of the Town of Quantico and the Northern Virginia Planning District Commission, your attendance at the site meeting and any other assistance provided is greatly appreciated.

If you have any questions, please do not hesitate to call either myself or Oner Yucel at 849-0552.

Sincerely,

DEWBERRY & DAVIS

Kurt R. Thompson, P.E.
Associate

KRT:bae

Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mr. Les Balderson
Virginia State Water Control Board
P.O. Box 11143
Richmond, Virginia 22230-1143

Dear Mr. Balderson:

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KRT:bae

Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mr. Ned H. Burger
Environmental Engineer
Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
P.O. Box 1425
Tappahannock, Virginia 23060

Dear Mr. Burger:

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cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

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8401 Arlington Boulevard
Fairfax, VA 22031-4666
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August 23, 1989

Mr. Maurice Foushee
Prince William County
Planning Office
1 County Complex Court
Prince William, Virginia 22192-9201

Dear Mr. Foushee:

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Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mr. Doldon Moore, Jr.
Department of Natural Resources
Water Resources Administration
Tidal Wetlands Division
Tawes State Office Building
D-4
Annapolis, Maryland 21401

Dear Mr. Moore:

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Kurt R. Thompson, P.E.
Associate

KRT:bae

Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mr. Lee Hill
Chief Engineer
Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
Shoreline Erosion Advisory Service
P.O. Box 1024
Gloucester Point, Virginia 23062

Dear Mr. Hill:

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Associate

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Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

August 23, 1989

Mrs. Julie Bradshaw
Virginia Institute of Marine Sciences
Gloucester Point, Virginia 23062

Dear Mrs. Bradshaw:

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Dewberry & Davis

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8401 Arlington Boulevard
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August 23, 1989

Mr. Chuck Roadley
Environmental Engineer
Virginia Marine Resources Commission
2600 Washington Avenue
P.O. Box 756
Newport News, Virginia 23607

Dear Mr. Roadley:

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Enclosures

cc: Ms. Beth Topol, NVPDC

Dewberry & Davis

Architects Engineers Planners Surveyors

8401 Arlington Boulevard
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703 849-0100

August 23, 1989

Mr. James E. Brogdon
Environmental Scientist
Regulatory Branch
U.S. Army Corps of Engineers
Northern Virginia Field Office
Plaza South, Suite 102
138 Graham Park Road
Dumphries, Virginia 22026

Dear Mr. Brogdon:

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DEWBERRY & DAVIS

Kurt R. Thompson, P.E.
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Enclosures

cc: Ms. Beth Topol, NVPDC

QUANTICO RIVERFRONT ENVIRONMENTAL STUDY

AGENDA FOR INTERAGENCY SITE MEETING ON AUGUST 21 and 22, 1989

I. INTRODUCTIONS

D&D, NVPDC, Town of Quantico, Agencies

II. BRIEF DESCRIPTION OF PROJECT

Project History
Shoreline Stabilization
Marina (Conceptual Plan)
Park (Conceptual Plan)

III. FIELD/PUBLISHED DATA/INFORMATION GATHERING

Historical Records and Other Data/Information
Land and Bathymetric Surveys
Tides
Winds
Waves
Currents
Flood Elevations
Wetlands
Sediments
Water Quality (Salinity, TSS, DO, pH)
Preliminary Contacts with Permitting Agencies

IV. PROPOSED PROJECT AND ALTERNATIVES

Proposed Riverfront Park and Marina
- Breakwater
- Marina
- Riverfront Park

Environmental Aspects of Proposed Project
- Breakwater
- Dredging
- Tidal Flushing

Alternative Shoreline Stabilization Scenarios

VI. DISCUSSION

Jurisdictional Responsibilities
Solicitation of Verbal/Written Comments on Permits/Project

QUANTICO RIVERFRONT ENVIRONMENTAL STUDY

SUMMARY MINUTES FOR INTERAGENCY SITE MEETING ON AUGUST 21, 1989

The first meeting was held on August 21, 1989. In attendance were:

James Brogdon, US Army Corps of Engineers, Northern Virginia Field Office;
Charles Roadley, VMRC;
Julie Bradshaw, VIMS;
Doldon Moore, MD/DNR/Wetlands Division;
Mitchell Raftelis and Howard Bolognese, Town of Quantico;
Beth Topol, NVPDC;
Kurt Thompson, Oner Yucel and Mark Headly, D&D.

After introductions, Kurt Thompson presented a brief history and work scope of the proposed shoreline stabilization, waterfront park and marina project.

Oner Yucel and Mark Headly followed with brief descriptions of the field and published data and information gathering activities undertaken to date by D&D. These activities include the field and bathymetric surveys, evaluation of historical maps and other documents on tides, waves, winds, currents, sediments and 100-yr flood elevation, as well as preliminary field work on on-site and off-site wetlands identification, currents and water quality (salinity, TSS, DO, pH) measurements, and "grab" sampling of bottom sediments and the associated analyses and evaluations.

Oner Yucel also presented highlights of the proposed park and marina concept, including the associated breakwater and piers, as well as the preliminary dredging and tidal flushing aspects of the marina portion of the project.

Kurt Thompson emphasized that the main purpose of this meeting was to introduce the project to the agencies as a concept, to identify jurisdictional responsibilities and possibly obtain comments from the agency representatives on the various aspects of the proposed project. In this regard, Kurt Thompson asked for observations and comments on the project from each agency representative. Subsequent comments in written form after receiving the minutes of the meeting were also encouraged.

The following is a summary of the observations and comments that were offered during the site meeting.

Doldon Moore (Md/DNR/Wetlands Division):

* pointed out that part of the proposed project that is outboard (waterside) of the Mean Low Water line along the shoreline is in Maryland waters, and hence falls under Maryland's jurisdiction.

* subject to DNR's review and issuance of a "wetlands license" would be the proposed marina with its breakwater and piers, the associated dredging activities including the method of dredging and dredge material disposal, pumpout facilities, impacts to the "shallow water habitat" also referred to as "submerged aquatic vegetation (SAV)" and "tidal flushing" aspects; and portion of the shoreline protection structure outboard of the Mean Low Water line.

* the same aspects of the project would also be subject to review for a "water quality certification" from Maryland's Department of the Environment.

* based on observation from the shoreline, it appears that the proposed marina basin is covered to a large extent with hydrilla, wild celery and other SAVs. From the shallow water habitat viewpoint, dredging associated with the proposed marina in this basin is generally objectionable to Md/DNR. It is likely that the US EPA and US Fish & Wildlife Service, National Marine Fisheries, other agencies and special interest organizations would respond unfavorably to the public notice that would be advertised by the Md/DNR.

* potential for mitigation for this shallow water habitat site appears very low, and any proposal in this regard would likely be discouraged, mainly because there is scarce evidence of success in Maryland in the case of SAVs.

* "delineation of the beds" to better describe the type and density of the various SAVs may be useful, if it is desired to further explore any locations that may be agreeable to Md/DNR for dredging.

* with minimum or no dredging, the proposed breakwater with riprap toe protection and the floating piers would likely be found less objectionable.

* if dredging is done using clamshell, it would not require "water quality certification" by Maryland's Department of the Environment. The land-side disposal in Virginia would be local issue, unless its outfall affects Maryland waters.

* "economics" is only one of the criteria, and is often outweighed by the environmental criteria.

* no major problems are anticipated with the shoreline protection part of the proposed project.

James Brogdon (US Corps of Engineers, VA):

* US Corps of Engineers' Baltimore District will not be involved in this project.

* US Corps of Engineers Norfolk District would have the jurisdiction regarding the issuance of a Section 404 permit for any fills and a Section 10 permit for the structures.

* mainly because of the SAVs present in the proposed marina basin, the proposed project will likely be controversial, with close scrutiny by the US EPA, US F&WS, and National Marine Fisheries.

Charles Roadley (VMRC):

* other than being the "clearing house" for permit processing, VMRC would have very limited jurisdiction for this project.

* based on observations, it appears that the shoreline is a nonvegetated wetland by Virginia definitions.

* VMRC would provide "over-sight" to assist the local wetlands board in regards to the nonvegetated wetlands (the zone between MLW and MHW).

Julie Bradshaw (VIMS):

* VIMS would only provide comments, if any, on this project, mainly to aid the local wetlands board.

* VIMS concurred that the shoreline appears to be composed of mostly non-vegetated wetlands.

QUANTICO RIVERFRONT ENVIRONMENTAL STUDY

SUMMARY MINUTES FOR INTERAGENCY SITE MEETING ON AUGUST 22, 1989

A Second meeting was held on August 22, 1989. Attending were:

Lee Hill, Chief Engineer of the Shoreline Programs Bureau (SEAS), and
Ned Burger, Environmental Engineer, both representing VA Dept of Conservation & Recreation, Div of Soil & Water Conservation

Maurice Foushee, Prince William Co., Planning Office,

Oner Yucel, D&D.

Oner Yucel provided essentially the same background information as in the previous day's meeting.

The comments provided by Lee Hill on the impact to the existing SAVs with the proposed project was essentially in agreement with the previous agency representatives. Lee Hill concentrated mostly on the shoreline protection aspects of the proposed project, and recommended that a wedge-shaped riprap toe protection be considered along the existing seawall, in addition to renovating its deteriorated portions.

Agency Representatives Invited and Attended the Site Meetings:

Ms. Beth Topol
NVPDC, 7630 Little River Turnpike, Suite 400
Annandale, VA 22003 (703) 642-0700

Mr. Mitchel P. Raftelis
503 C Street, Quantico, VA 22134 (703) 640-7979

Mr. James E. Brogdon
Environmental Scientist, Regulatory Branch
U.S. Army Corps of Engineers, Northern Virginia Field Office
Plaza South, Suite 102, 138 Graham Park Road
Dumphries, VA 22026 (703) 221-6967

Mr. Chuck Roadley
Environmental Engineer
Virginia Marine Resources Commission
2600 Washington Avenue, P.O. Box 756
Newport News, VA 23607 (804) 247-2200

Mrs. Julie Bradshaw
Virginia Institute of Marine Sciences
Gloucester Point, VA 23062 (804) 642-7395

Mr. Lee Hill
Chief Engineer
Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
Shoreline Erosion Advisory Service, P.O. Box 1024
Gloucester Point, VA 23062 (804) 642-7121

Mr. Doldon Moore, Jr.
Department of Natural Resources, Water Resources Administration
Tidal Wetlands Division, Tawes State Office Building, D-4
Annapolis, MD 21401 (301) 974-3871

Mr. Maurice Foushee
Prince William County, Planning Office
1 County Complex Court
Prince William, VA 22192-9201 (703) 335-6830

Other Individuals Who Also Attended the Site Meetings:

Mr. Howard Bolognese
Mayor, Town of Quantico
314 Potomac Avenue
Quantico, VA 22134 (703) 640-6613

Mr. Ned H. Burger
Environmental Engineer
Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
P.O. Box 1425
Tappahannock, VA 23060 (804) 443-6752

Agency Representatives Also Invited But Were Unable to Attend:

Mr. Les Balderson
Virginia State Water Control Board, P.O. Box 11143
Richmond, VA 22230-1143 (804) 367-0062

Mr. Sean Smith
Department of the Environment
Standards and Certifications Division, 2500 Broening Highway
Baltimore, MD 21224 (301) 631-3609

THE COLLEGE OF WILLIAM AND MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

August 28, 1989

Mr. Kurt R. Thompson
Dewberry & Davis
8401 Arlington Boulevard
Fairfax, VA 22031-4666

Dear Mr. Thompson:

Thank you for the opportunity to comment on the proposed activity at the Quantico shoreline. I have reviewed the minutes of our August 21, 1989 meeting. Please substitute the following comments for those which are attributed to me in your August 23, 1989 letter. I believe that the substitutions more accurately represent the comments which I made at the meeting.

1. VIMS is not a regulatory agency, but advises Virginia's regulatory bodies on marine environmental matters.

2. VIMS will provide specific comments on the marine environmental impacts of the proposal once specific plans are submitted. In general, the comments would reflect the Wetlands Guidelines promulgated by VMRC, addressing the justification for shoreline stabilization and minimization of potential environmental impacts.

3. VIMS concurs with Maryland Department of Natural Resources comments on the importance of the existing SAV beds to the marine environment and would recommend that they be preserved.

4. VIMS concurs with VMRC observations that the shoreline consists primarily of nonvegetated wetlands.

In addition, I would like to emphasize the high ecological value of the existing SAV beds and their incompatibility with the type of marina facility proposed. If I can be of further assistance on this project, please do not hesitate to contact me.

Sincerely,

Julie G. Bradshaw

Julie G. Bradshaw
Marine Scientist

Gloucester Point, Virginia 23062 (804) 642-7000

Board on Conservation
and Development of Public Beaches

COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION
DIVISION OF SOIL AND WATER CONSERVATION
Shoreline Programs
P. O. Box 1024
Gloucester Point, Virginia 23062
(804) 642-7121

September 5, 1989

Mr. Kurt R. Thompson, P.E.
Dewberry and Davis
8401 Arlington Boulevard
Fairfax, Virginia 22031-4666

RE: SPS #90063

Dear Mr. Thompson:

On August 22, Ned Burger and I met with Oner Yucel at the site of the proposed shoreline stabilization, waterfront park and marina project for the Town of Quantico on the Potomac River. Maurice Foushee was also at the meeting. The purpose of the site visit was to discuss the shoreline erosion control measures required for the project.

The Shoreline Situation Report: Prince William County, Virginia provides no historical erosion data for the area. The report does state that the majority of the area is stable. The area of the proposed project is protected by a concrete bulkhead. We make the following recommendations based on our site visit and subsequent analysis of the problem:

1. The existing concrete bulkhead is beginning to fail. To protect the bank from erosion, we recommend a properly designed and constructed riprap (large rock) structure. The structure should be installed against the existing bulkhead. In the areas where the structure has failed, the riprap should be placed against the bank to minimize encroachment beyond the mean high water position. The riprap should be constructed on a 2:1 (horizontal/vertical) slope or flatter. A minimum of two layers of armor rock should be used. Each armor rock should weigh a minimum of 300 pounds. The toe of the riprap should be buried a minimum of 3 feet below the mean low water elevation. An alternative to the buried toe is a riprap apron. The apron consists of 2 layers of armor rock extending a minimum of 6 feet onto the bottom. A layer of filter cloth should be used under and behind the riprap. The riprap should be extended inland or properly connected to neighboring structures to prevent erosional flanking.

2. The undercut trees on the upriver end of the project should be cut and the stumps removed. Tree removal should allow the riprap structure to be placed against the eroding bank.

3. During the site visit, we discussed plans for the proposed marina and breakwater. The presence of submerged aquatic vegetation may limit the site's suitability for marina development. If the Town of Quantico decides to construct the marina, care should be taken to minimize marina impacts on the submerged aquatic vegetation.

The above recommendations are made in my capacity as an advisory agent in shoreline erosion control matters. The suggestions should not be considered as binding you to any particular course of action as they are intended to indicate what we think would be the best solution in terms of cost and effectiveness. Our examination of the site or this report does not constitute permission by the Commonwealth, or its agencies, to proceed with implementation of control measures. Permits from State and Federal agencies are generally required for shoreline modification.

You should also be aware that success in shoreline erosion control cannot be guaranteed as there are many variables involved. In this regard, we suggest care in selecting a contractor. Our comments concerning construction are intended as guidelines developed from our experience in viewing structures which have been successful or have failed.

If you decide to construct a control measure, an assessment of the impacts of the project on the environment will be given by the regulatory agencies. Our advice is given with the idea of reducing environmental impacts associated with our recommendations. Although this has been considered in our recommendations, the permit reviewing agencies may desire additional information or measures.

Services available through this office include: review of the permit application; review of design and construction plans; and inspection of structures under construction when plans have been reviewed by this office. We recommend that a copy of this report be attached to the permit application.

Please call me if you have questions or if I may be of further assistance.

Sincerely,

Carlton Lee Hill

Carlton Lee Hill
Chief Engineer

smt

cc: Diana C. Dutton, Executive Director; Prince William SWCD
Deborah Cross, DSWC

William Donald Schaefer
Governor

Maryland Department of Natural Resources

Water Resources Administration
Tawes State Office Building
Annapolis, Maryland 21401

Torrey C. Brown, M.D.
Secretary

Catherine P. Stevenson
Director

September 25, 1989

Kurt R. Thompson, P.E.
Dewberry and Davis
8402 Arlington Boulevard
Fairfax, VA 22031-4666

Re: 90-PL-0215
Town of Quantico

Dear Mr. Thompson:

Thank you for your letter of August 23, 1989 regarding the site review for the above referenced project. In short, I concur with the content of the meeting minutes which were forwarded to this office.

I have reviewed the marina proposal with Mr. Charles Wheeler, Program Director, in light of the Department's policy as related to the protection of existing and historical submerged aquatic vegetation beds (SAV). The Department of Natural Resources will review and enact the same policies and procedures for marina and shoreline development projects along the Virginia shoreline of the Potomac River as is done with all projects in Maryland waters.

Therefore, based on site conditions and the existence of a dense and diversified SAV bed at the project site, it is very unlikely that the Department would provide a favorable recommendation to the Maryland Board of Public Works for a nearshore marina which involves dredging.

Options which the Department would view as favorable and would result in a lesser degree of environmental damage are:

* Fix pier structures that would be elevated over the SAV bed so that shading impacts are reduced. Along with the mooring of boats outboard of the SAV bed.

* An elevated fishing pier with "T" head that is located outboard of the SAV bed.

Telephone: (301) 974-3871
DNR TTY for the Deaf: 301-974-3683

I thank you for the opportunity to meet, review and comment on this project at this early stage. If you have any questions or need further assistance, please feel free to contact me.

Sincerely,

Doldon W. Moore, Jr.
Tidal Wetlands Division

DWM:ew

APPENDIX 5

U.S. Coast and Geodetic Survey Inquiry and Tidal Data Sheet

NOAA FORM 61-18
17-781

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REMIT PAYMENT TO:
U.S. Dept. of Commerce/NOAA
RAS/DC 1, Attn: Collection Officer
11420 Rockville Pike
Rockville, MD 20852
(301) 443-8160

ORDER NUMBER: C233- 592/89
TASK NUMBER: RK3A02
DATE: July 10, 1989
RE: YOUR REQUEST OF (Date): June 29, 1989
REFERENCE CODE: 1603-14- 12
COST OF DATA: 25.00
AMOUNT RECEIVED: None
AMOUNT OF ORDER:
REFUND DUE:
AMOUNT DUE: 25.00

STATEMENT

TO: Mr. Oner Yucel, Ph.D.
Dewberry and Davis
8401 Arlington Boulevard
Fairfax, Virginia 22031-4666

Make checks or money orders payable to NOS, NOAA in this amount.
Tear off here and return top portion with remittance.

ACKNOWLEDGEMENT OF REQUEST

Your request is answered as checked below. Any remittance should be made by check or money order.
Return top portion of form when remitting amount due. Refunds will be made as soon as possible.

XX ☒ The data requested ☒ enclosed ☐ being sent under separate cover ☐ except as indicated below ☐ not available in this agency.

☒ The cost of the data you requested is shown above. Please remit full amount.

☐ Your remittance was insufficient. Please remit amount due.

☐ Delivery will be delayed pending receipt of amount due.

☐ The data listed below is not available.

☐ The data listed below will be available about _____
- ☐ Will be forwarded when available.
- ☐ Reorder at a later date.

☐ The data you requested is available from _____

☐ Your letter has been referred to that agency.

☐ The data you inquired about and the prices thereof are:
- ☐ Listed in remarks.
- ☐ In attachment.

☐ Your description is inadequate. Order will be held pending receipt of:
- ☐ More complete description.
- ☐ Selection of items from attachment.

☐ Your check or money order is being returned.
- ☐ See Remarks.

REMARKS

Benchmark information for tide station 863-4689 Quantico, Potomac River, with inferred value of NGVD-MLW for the 1960-78 Epoch.

ID# 103

SIGNATURE: James R. Hubbard
TITLE: Chief, Tidal Datum Quality Assurance Section

8634689

5/3/76

VIRGINIA - 27

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

TIDAL BENCH MARKS

Quantico, Potomac River
Lat. 38°31.2'; Long. 77°17.2'

BENCH MARK 1 (1928) is a standard disk, stamped "1," set in the top of a concrete bulkhead on the south side of the marine wharf, 9 feet west of the northeast corner of a small boat basin, 4 feet from the inshore face of the main outer dock, and 1 foot north of the edge of the bulkhead. Elevation: 6.00 feet above mean low water.

BENCH MARK 2 (1928) is a standard disk, stamped "2," set on the top of the north retaining wall of a pier, 68 feet west of the northwest corner of a building on the pier, and 56 feet northwest of a fire hydrant. Elevation: 6.07 feet above mean low water.

BENCH MARK 3 (1928) is a standard disk, stamped "3," set in the top of a breakwater on the south side of Marine Wharf, about 45 feet southwest from the outer end of the pier, and about midway between two large bitts. Elevation: 5.98 feet above mean low water.

BENCH MARK 4 (1932) is a standard triangulation station disk, stamped "MARINE 1932 2," set in the top of the east end of the north retaining wall of Marine Wharf, 13 feet west of the inside corner of the dock and pier, and 6 feet east of the northeast corner of the building. Elevation: 6.00 feet above mean low water.

BENCH MARK 5 (1959) is a standard disk, stamped "NO 5 1959," set flush in a concrete slab at the intersection of Potomac and Summers Avenues, 26 feet west of the centerline of Summers Avenue, and 3 feet west of the street corner sign for the two avenues. Elevation: 24.97 feet above mean low water.

BENCH MARK 6 (1959) is a standard disk, stamped "NO 6 1959," set flush in the top of the retaining wall at a railway station, 17.5 feet west of the northwest corner of the station building, and 12 feet east of the center of double tracks. Elevation: 33.89 feet above mean low water.

Quantico, Potomac River

BENCH MARK A 233 (1941) is a standard disk, stamped "A 233 1941," set in the top of a concrete foundation at MCAS, a field in front of a barracks at Semaphore 777, on the west side of the tracks. Elevation: 22.47 feet above mean low water.

Mean low water at Quantico, Potomac River is based on 15 months of records, November 1970 through October 1972, reduced to mean values. Elevations of other tide planes referred to this datum are as follows:

1941-59 TIDAL EPOCH

	Feet
Mean high water	1.40
Mean tide level ← NGVD	0.70 ← 0.41 (1941-59)
Mean low water	0.00 ← 0.23 (1960-78)

The estimated highest water level to the nearest half foot is ten feet above mean low water. The estimated lowest water level to the nearest half foot is four and one-half feet <u>below</u> mean low water.

NGVD = National Geodetic Vertical Datum of 1929 (formerly Sea Level Datum of 1929)

Elevations of Bench Marks at this location have not been updated to the 1960-78 Tidal Epoch. Mean Sea Level rose 0.18 foot at Washington, DC between the 1941-59 and the 1960-78 Tidal Epochs. To arrive at an inferred value for NGVD-MLW for the 1960-78 Tidal Epoch, apply the 0.18 foot rise in MSL to the 1941-59 value of NGVD-MLW (0.41 ft) to make the 1960-78 inferred NGVD-MLW value to be 0.23 foot.

VERTICAL CONTROL ELEVATIONS FOR THE FOLLOWING BENCH MARKS FOR ADJUSTMENT 1972:

	Above NGVD
"1" = 5.584 Feet	"
"2" = 5.656 Feet	"
"3" = 5.561 Feet	"
"MARINE 1932 2" = 5.584 Feet	"
NO 5 1959 = 24.557 Feet	"
NO 6 1959 = 33.478 Feet	"
A 233 1941 = 22.054 Feet.	"

APPENDIX 6

Tabulation of Field Measurements for Currents and Water Quality on June 22, 1989

Mark Hebert
A:11 Bukevile
Mark Haus
6-22-89

AIR TEMP (AM): 22.5
WIND VELOCITY: 2.17 FPS

Quantico, VA
Velocity / water measurements.

SAMPLE POINT	TIME (AM)	VELOCITY DIRECTION FROM	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (ppm)	WATER TEMP (°C)	SALINITY (ppt)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	Wind corrected pH / pH	COMMENTS
2 a	6:45	210°	0.82 0.70	1 7	—	—	—	—	—	—	23	/	
1 a	6:54	235°	1.39 1.00	1 7	—	—	—	—	—	—	31	/	
3 a	7:06	150°	0.09 0.06	1 2.5	—	—	—	—	—	—	5	/	Not sure of velocity direction
4 a	7:13	150°	0.05	1.5	—	—	—	—	—	—	3	/	
5 a	7:17	150°	0.07	1.0	—	—	—	—	—	—	2	/	
2 b	7:46	210°	1.31 0.44	1.0 7.0	6.5	25	0.4	195	K-2 12759	7.0	27	11 6.7	
1 b	7:59	210°	0.93 0.86	1.0 7.0	6.2	25	0.5	196	C-1 12760	8.0	29	13 6.9	
3 b	8:10	320°	0.09	2.5	6.1	25	<0.5	220	N-1 12761	2.5	5	6 6.8	
4 b	8:18	15°	0.05	2.0	6.1	25.8	<0.5	205	HH-2 12762	2.0	4	12 7.0	
5 b	8:32	30°	0.03	1.5	6.2	25.7	<0.5	210	W-2 12763	1.5	3.5	28 6.9	
1 c	8:58	210°	0.60 0.17	1.0 7.0	—	—	—	—	—	—	30	/	Salinity & Conductivity meters not working properly.
2 c	9:05	210°	0.66 0.16	1.0 7.0	—	—	—	—	—	—	27	/	

6-22-85

Air Temp (AM): 22.5
Wind velocity: 2.17 FPS

Quantico, VA
Velocity / Water measurements

SAMPLE POINT	TIME	VELOCITY DIRECTION FROM	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (ppm)	WATER TEMP. (°C)	SALINITY (ppt)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	Total suspended solids (mg/l) / pH	COMMENTS
3/c	9:11	0°	0.03	2.5	—	—	—	—	—	—	5		
4/c	9:16	15°	0.04	2.0	—	—	—	—	—	—	4.2		
5/c	9:24	170°	0.02	1.5	—	—	—	—	—	—	3.5		
1/d	10:00	210°	0.05 0.03	1.0 7.0	6.0	25.7	<0.5	212	—	—	26		
2/d	10:11	40°	0.28 0.31	1.0 7.0	5.9	25.7	<0.5	212	—	—	29		
3/d	10:17	20°	0.17	3.0	5.9	25.9	<0.5	218	—	—	6		
4/d	10:23	40°	0.03	2.0	6.0	26.0	<0.5	215	—	—	4		
5/d	10:29	10°	0.15	1.5	6.0	26.0	<0.5	225	—	—	3		
1/e	11:00	50°	1.42 0.13	1.0 7.0	—	—	—	—	—	—	31		
2/e	11:15	5°	0.78 1.0	1.0 7.0	—	—	—	—	—	—	34		
3/e	11:18	30°	0.08	3.0	—	—	—	—	—	—	6		
4/e	11:35	35°	0.025	2.0	—	—	—	—	—	—	4		

6-22-89

Air Temp (AM): 22.5
Wind velocity: 2.17 FPS

Quantico, VA
Velocity/Water measurements

SAMPLE POINT	TIME	VELOCITY DIRECTION FROM:	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (PPM)	WATER TEMP. (°C)	SALINITY (PPT)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	Total Water Column Readings / pH	COMMENTS
5 / e	11:48 AM		0.19	1.5	—	—	—	—	—	—	3		
1 / f	PM 12:08	355°	1.56 1.72	1.0 7.0	6.8	26.0	<0.5	238	C-2 12764	7.0	34	20 / 7.0	Further out because of docked barge.
2 / f	12:19	40°	1.47 0.98	1.0 7.0	7.0	25.0	—	—	S-2 12765	7.0	29	16 / 6.8	
3 / f	12:30	20°	0.06	2.5	7.0	25.0	—	—	P-1 12766	7.0	5	11 / 7.0	
4 / f	12:44		0.04	2.0	7.1	25.5	—	—	M-3 12767	2.0	4	20 / 6.8	
5 / f	12:49	40°	0.14	1.5	7.6	25.5	—	—	EE-1 12768	1.5	3	9 / 7.1	
1 / g	1:05	20°	1.38 1.04	1.0 7.0	—	—	—	—	—	—	31		
2 / g	1:14	30°	1.64 1.52	1.0 7.2	—	—	—	—	—	—	33		
3 / g	1:17	45°	0.08	2.5	—	—	—	—	—	—	5		
4 / g	1:24	20°	0.02	1.5	—	—	—	—	—	—	3.5		
5 / g	1:30	15°	0.17	0.90	—	—	—	—	—	—	2.25		
1 / h	2:04	35°	0.52 0.58	1.0 7.0	—	—	—	—	—	—	28		

6-22-89

Air Temp (AM): 22.5
Wind velocity: 2.17 FPS

Quantico, Va.
Velocity/Water measurements

SAMPLE POINT	TIME	VELOCITY DIRECTION FROM:	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (PPM)	WATER TEMP (°C)	SALINITY (PPT)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	Total suspended solids mg/l / pH	COMMENTS
2/h	2:14	20°	1.06 0.82	1.0 7.0	—	—	—	—	—	—	15		
3/h	2:20	0°	0.02	2.0	—	—	—	—	—	—	5		
4/h	2:24	60°	0.01	1.5	—	—	—	—	—	—	3		
5/h	2:28	355°	0.04	1.5	—	—	—	—	—	—	3		
1/i	3:09	30°	0.66 0.10	1.0 7.0	7.9	26.0	—	—	—	—	29		
2/i	3:15	30°	0.94 0.28	1.0 7.0	8.0	26.0	—	—	—	—	30		
3/i	3:38	210°	0.03	2	9.6	27.0	—	—	—	—	4.5		
4/i	3:47	0°	0.02	0.9	11.2	26.5	—	—	—	—	2.75		
5/i	3:51	0°	0.01	0.5	11.2	26.5	—	—	—	—	2		
1/j	4:02	0°	0.05 0.24	1.0 7.0	—	—	—	—	J-3 12769	—	28	14 / 7.0	
2/j	4:10	195°	0.29 0.48	1.0 7.0	—	—	—	—	W-1 12770	7	22	3 / 6.8	
3/j	4:18	170°	0.04	2.0	—	—	—	—	H-1 12771	2.0	4.5	8 / 6.9	

6-22-89

Air Temp. (AM): 22.5
Wind velocity: 2.17 FPS

Quantico, VA
Velocity/Water measurements

SAMPLE POINT	TIME	VELOCITY DIRECTION FROM:	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (PPM)	WATER TEMP. (°C)	SALINITY (PPT)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	TIDAL STAGE (HIGH/LOW) / pH	COMMENTS
4 / j	4:27	170°	0.02	1.5	—	—	—	—	R-1 12772	1.5	2.75	7 / 7.3	
5 / j	4:32	210°	0.04	0.5	—	—	—	—	B-1 12773	0.5	1.5	2 / 6.9	
1 / k	5:03	200°	0.09 0.27	1.0 7.0	8.3	28.5	0.80	347	—	—	30		
2 / k	5:11	160°	0.07 0.01	1.0 7.0	8.3	26.5	—	370	—	—	26		
3 / k	5:19	200°	0.09	2.0	8.9	27.0	—	—	—	—	4.5		
4 / k	5:25	150°	0.04	0.9	12.5	27.0	—	—	—	—	2.75		
5 / k	5:28	160°	0.06	0.9	20.0	27.0	—	—	—	—	1.75		
1 / l	6:00	225°	0.72 1.00	1.0 7.0	—	27.5	<0.5	290	—	—	31		
2 / l	6:05	190°	1.08 0.92	1.0 7.0	—	—	—	—	—	—	23		
3 / l	6:10	160°	0.12	2.0	—	—	—	—	—	—	4.75		
4 / l	6:13	140°	0.12	1.5	—	27.5	<0.5	290	—	—	3.0		
5 / l	6:16	135°	0.08	1.0	—	—	—	—	—	—	2.0		

QUANTICO, VA

VELOCITY / WATER MEASUREMENT

SAMPLE POINT	TIME	VELOCITY DIRECTION FROM:	VELOCITY (FPS)	DEPTH OF VELOCITY (FEET)	DISSOLVED OXYGEN (PPM)	WATER TEMP. (°C)	SALINITY (PPT)	CONDUCTIVITY (μmhos)	SAMPLE BOTTLE #	DEPTH OF BOTTLED SAMPLE	DEPTH OF BOTTOM	COMMENTS
1 / m	6:58	210°	1.27 1.36	1.0 7.0	—	28	<0.5	240	+	—	32	
2 / m	7:05	190	0.83 0.77	1.0 7.0	—	—	—	—	—	—	25	
3 / m	7:10	150°	0.13	2.5	—	—	—	—	—	—	5.25	
4 / m	7:14	95°	0.03	1.5	—	27.5	<0.5	228	—	—	3.5	
5 / m	7:22	—	0.10	1.0	—	—	—	—	—	—	2.5	

APPENDIX 7

Predicted Tidal and Current Data at Quantico for June 1989

TIMES AND HEIGHTS OF HIGH AND LOW WATERS TRANSPOSED FROM WASHINGTON, DC

QUANTICO CREEK - STATION NO. 2309, 1989 TIDE TABLES, P.219
(DAYLIGHT SAVINGS TIMES)

	TIME DIFF hr	min	HEIGHT FACTOR
HIGH WATER (-)	1	4	0.51
LOW WATER (-)	1	59	0.47

DATE, DAY	WASHINGTON, DC PREDICTIONS TIME hr	min	HEIGHT ft	QUANTICO PREDICTIONS TIME hr	min	HEIGHT ft
6/1-TH	6	4	3.6	5	0	1.8
	13	34	0.2	11	35	0.1
	18	41	2.9	17	37	1.5
6/2-FR	1	24	0.2	23	25	0.1
	6	56	3.6	5	52	1.8
	14	31	0.1	12	32	0.0
	19	38	2.9	18	34	1.5
6/3-SA	2	19	0.2	0	20	0.1
	7	49	3.6	6	45	1.8
	15	26	0.0	13	27	0.0
	20	30	2.9	19	26	1.5
6/4-SU	3	13	0.2	1	14	0.1
	8	39	3.5	7	35	1.8
	16	16	0.0	14	17	0.0
	21	22	2.9	20	18	1.5
6/5-MO	4	7	0.2	2	8	0.1
	9	28	3.5	8	24	1.8
	17	7	0.0	15	8	0.0
	22	15	2.9	21	11	1.5
6/6-TU	4	59	0.2	3	0	0.1
	10	18	3.4	9	14	1.7
	17	54	0.0	15	55	0.0
	23	8	2.8	22	4	1.4
6/7-WE	5	48	0.3	3	49	0.1
	11	7	3.2	10	3	1.6
	18	40	0.1	16	41	0.0
	23	59	2.8	22	55	1.4
6/8-TH	6	39	0.4	4	40	0.2
	11	58	3.1	10	54	1.6
	19	24	0.1	17	25	0.0
	0	52	2.8	22	53	1.3
6/9-FR	7	31	0.5	5	32	0.2
	12	54	2.9	11	50	1.5
	20	6	0.2	18	7	0.1
6/10-SA	1	48	2.8	0	44	1.4
	8	22	0.5	6	23	0.2
	13	53	2.8	12	49	1.4
	20	49	0.3	18	50	0.1

TIMES AND HEIGHTS OF HIGH AND LOW WATERS TRANSPOSED FROM WASHINGTON, DC (Cont'd)

DATE, DAY	WASHINGTON, DC PREDICTIONS			QUANTICO PREDICTIONS		
	TIME		HEIGHT	TIME		HEIGHT
	hr	min	ft	hr	min	ft
6/11-SU	2	40	2.8	1	36	1.4
	9	18	0.6	7	19	0.3
	14	49	2.7	13	45	1.4
	21	31	0.3	19	32	0.1
6/12-MO	3	34	2.9	2	30	1.5
	10	13	0.6	8	14	0.3
	15	49	2.6	14	45	1.3
	22	15	0.4	20	16	0.2
6/13-TU	4	23	2.9	3	19	1.5
	11	11	0.6	9	12	0.3
	16	47	2.6	15	43	1.3
	22	59	0.5	21	0	0.2
6/14-WE	5	10	3.0	4	6	1.5
	12	6	0.6	10	7	0.3
	17	39	2.6	16	35	1.3
	23	47	0.5	21	48	0.2
6/15-TH	5	52	3.1	4	48	1.6
	13	1	0.6	11	2	0.3
	18	29	2.6	17	25	1.3
6/16-FR	0	33	0.6	22	34	0.3
	6	33	3.2	5	29	1.6
	13	51	0.6	11	52	0.3
	19	14	2.7	18	10	1.4
6/17-SA	1	22	0.6	23	23	0.3
	7	10	3.3	6	6	1.7
	14	39	0.5	12	40	0.2
	19	56	2.7	18	52	1.4
6/18-SU	2	11	0.7	0	12	0.3
	7	46	3.4	6	42	1.7
	15	25	0.5	13	26	0.2
	20	35	2.7	19	31	1.4
6/19-MO	3	0	0.7	1	1	0.3
	8	25	3.5	7	21	1.8
	16	10	0.5	14	11	0.2
	21	11	2.8	20	7	1.4
6/20-TU	3	47	0.7	1	48	0.3
	9	4	3.5	8	0	1.8
	16	51	0.5	14	52	0.2
	21	51	2.9	20	47	1.5
6/21-WE	4	34	0.6	2	35	0.3
	9	47	3.5	8	43	1.8
	17	33	0.4	15	34	0.2
	22	29	3.0	21	25	1.5

TIMES AND HEIGHTS OF HIGH AND LOW WATERS TRANSPOSED FROM WASHINGTON, DC (Cont'd)

DATE, DAY	WASHINGTON, DC PREDICTIONS			QUANTICO PREDICTIONS		
	TIME		HEIGHT	TIME		HEIGHT
	hr	min	ft	hr	min	ft
6/22-TH	5	24	0.6	3	25	0.3
	10	32	3.5	9	28	1.8
	18	13	0.4	16	14	0.2
	23	11	3.1	22	7	1.6
6/23-FR	6	13	0.6	4	14	0.3
	11	20	3.4	10	16	1.7
	18	54	0.4	16	55	0.2
	23	59	3.1	22	55	1.6
6/24-SA	7	7	0.6	5	8	0.3
	12	12	3.3	11	8	1.7
	19	38	0.3	17	39	0.1
6/25-SU	0	50	3.2	23	46	1.6
	8	3	0.5	6	4	0.2
	13	8	3.2	12	4	1.6
	20	24	0.3	18	25	0.1
6/26-MO	1	44	3.2	0	40	1.6
	9	4	0.5	7	5	0.2
	14	9	3.0	13	5	1.5
	21	13	0.3	19	14	0.1
6/27-TU	2	43	3.3	1	39	1.7
	10	8	0.5	8	9	0.2
	15	14	2.8	14	10	1.4
	22	6	0.3	20	7	0.1
6/28-WE	3	44	3.3	2	40	1.7
	11	14	0.4	9	15	0.2
	16	20	2.7	15	16	1.4
	23	5	0.2	21	6	0.1
6/29-TH	4	45	3.3	3	41	1.7
	12	21	0.3	10	22	0.1
	17	26	2.7	16	22	1.4
6/30-FR	0	6	0.2	22	7	0.1
	5	45	3.3	4	41	1.7
	13	22	0.2	11	23	0.1
	18	27	2.7	17	23	1.4

TIMES AND VELOCITIES OF SLACK WATER AND MAXIMUM CURRENTS
TRANSPOSED FROM BALTIMORE HARBOR APPROACH (OFF SANDY POINT)

QUANTICO - STATION NO. 5796, TIDAL CURRENT TABLES 1989, P.174
(DAYLIGHT SAVINGS TIMES)

	TIME DIFF hr	min	SPEED RATIO
MIN BEFORE FLOOD (-)	0	54	1
FLOOD (-)	1	4	0.9
MIN BEFORE EBB (-)	1	32	1
EBB (-)	1	9	1.1

DATE, DAY	SANDY POINT PREDICTIONS TIME hr	min	VELOCITY knots		QUANTICO PREDICTIONS TIME hr	min	VELOCI knots
6/16-FR	3	46	1.1	F	2	42	1.0
	7	26	0.0		5	54	0.0
	10	44	0.9	E	9	35	1.0
	14	44	0.0		13	50	0.0
	16	46	0.3	F	15	42	0.3
	18	55	0.0		17	23	0.0
	21	54	0.5	E	20	45	0.6
6/17-SA	0	28	0.0		23	34	0.0
	4	28	1.1	F	3	24	1.0
	8	6	0.0		6	34	0.0
	11	31	1.0	E	10	22	1.1
	15	33	0.0		14	39	0.0
	17	33	0.3	F	16	29	0.3
	19	45	0.0		18	13	0.0
	22	40	0.5	E	21	31	0.6
6/18-SU	1	7	0.0		0	13	0.0
	5	8	1.2	F	4	4	1.1
	8	47	0.0		7	15	0.0
	12	12	1.1	E	11	3	1.2
	16	17	0.0		15	23	0.0
	18	19	0.3	F	17	15	0.3
	20	35	0.0		19	3	0.0
	23	24	0.5	E	22	15	0.6
6/19-MO	1	48	0.0		0	54	0.0
	5	51	1.2	F	4	47	1.1
	9	27	0.0		7	55	0.0
	12	53	1.1	E	11	44	1.2
	16	56	0.0		16	2	0.0
	19	1	0.4	F	17	57	0.4
	21	24	0.0		19	52	0.0
6/20-TU	0	9	0.5	E	23	0	0.6
	2	32	0.0		1	38	0.0
	6	32	1.1	F	5	28	1.0
	10	6	0.0		8	34	0.0
	13	32	1.1	E	12	23	1.2
	17	31	0.0		16	37	0.0
	19	43	0.4	F	18	39	0.4
	22	13	0.0		20	41	0.0

TIMES AND VELOCITIES OF SLACK WATER AND MAXIMUM CURRENTS
TRANSPOSED FROM BALTIMORE HARBOR APPROACH (OFF SANDY POINT)

QUANTICO - STATION NO. 5796, TIDAL CURRENT TABLES 1989, P.174
(DAYLIGHT SAVINGS TIMES)

	TIME DIFF hr	min	SPEED RATIO
MIN BEFORE FLOOD (-)	0	54	1
FLOOD (-)	1	4	0.9
MIN BEFORE EBB (-)	1	32	1
EBB (-)	1	9	1.1

DATE, DAY	SANDY POINT PREDICTIONS TIME hr	min	VELOCITY knots		QUANTICO PREDICTIONS TIME hr	min	VELOCI knots
6/21-WE	0	56	0.5	E	23	47	0.6
	3	20	0.0		2	26	0.0
	6	15	1.1	F	5	11	1.0
	10	46	0.0		9	14	0.0
	14	11	1.1	E	13	2	1.2
	18	3	0.0		17	9	0.0
	20	25	0.5	F	19	21	0.5
	23	5	0.0		21	33	0.0
6/22-TH	1	45	0.5	E	0	36	0.6
	4	13	0.0		3	19	0.0
	8	0	1.0	F	6	56	0.9
	11	25	0.0		9	53	0.0
	14	49	1.0	E	13	40	1.1
	18	33	0.0		17	39	0.0
	21	7	0.5	F	20	3	0.5
6/23-FR	0	0	0.0		22	28	0.0
	2	41	0.5	E	1	32	0.6
	5	13	0.0		4	19	0.0
	8	46	0.9	F	7	42	0.8
	12	5	0.0		10	33	0.0
	15	28	1.0	E	14	19	1.1
	19	2	0.0		18	8	0.0
	21	53	0.6	F	20	49	0.5
6/24-SA	0	57	0.0		23	25	0.0
	3	40	0.5	E	2	31	0.6
	6	21	0.0		5	27	0.0
	9	41	0.7	F	8	37	0.6
	12	45	0.0		11	13	0.0
	16	8	0.9	E	14	59	1.0
	19	32	0.0		18	38	0.0
	22	38	0.8	F	21	34	0.7
6/25-SU	1	57	0.0		0	25	0.0
	4	42	0.6	E	3	33	0.7
	7	36	0.0		6	42	0.0
	10	36	0.6	F	9	32	0.5
	13	27	0.0		11	55	0.0
	16	51	0.8	E	15	42	0.9
	20	6	0.0		19	12	0.0
	23	26	0.9	F	22	22	0.8

TIMES AND VELOCITIES OF SLACK WATER AND MAXIMUM CURRENTS
TRANSPOSED FROM BALTIMORE HARBOR APPROACH (OFF SANDY POINT)

QUANTICO - STATION NO. 5796, TIDAL CURRENT TABLES 1989, P.174
(DAYLIGHT SAVINGS TIMES)

	TIME DIFF hr	min	SPEED RATIO
MIN BEFORE FLOOD (-)	0	54	1
FLOOD (-)	1	4	0.9
MIN BEFORE EBB (-)	1	32	1
EBB (-)	1	9	1.1

DATE, DAY	SANDY POINT PREDICTIONS TIME hr	min	VELOCITY knots		QUANTICO PREDICTIONS TIME hr	min	VELOCI knots
6/26-MO	2	57	0.0		1	25	0.0
	5	50	0.6	E	4	41	0.7
	8	59	0.0		8	5	0.0
	11	39	0.5	F	10	35	0.5
	14	11	0.0		12	39	0.0
	17	38	0.8	E	16	29	0.9
	20	43	0.0		19	49	0.0
6/27-TU	0	17	1.0	F	23	13	0.9
	3	57	0.0		2	25	0.0
	6	55	0.7	E	5	46	0.8
	10	25	0.0		9	31	0.0
	12	43	0.4	F	11	39	0.4
	14	59	0.0		13	27	0.0
	18	27	0.7	E	17	18	0.8
	21	24	0.0		20	30	0.0
6/28-WE	1	11	1.1	F	0	7	1.0
	4	55	0.0		3	23	0.0
	8	2	0.8	E	6	53	0.9
	11	47	0.0		10	53	0.0
	13	49	0.3	F	12	45	0.3
	15	54	0.0		14	22	0.0
	19	18	0.7	E	18	9	0.8
	22	10	0.0		21	16	0.0
6/29-TH	2	3	1.2	F	0	59	1.1
	5	50	0.0		4	18	0.0
	9	5	0.9	E	7	56	1.0
	12	59	0.0		12	5	0.0
	14	54	0.3	F	13	50	0.3
	16	55	0.0		15	23	0.0
	20	17	0.7	E	19	8	0.8
	23	0	0.0		22	6	0.0
6/30-FR	2	58	1.3	F	1	54	1.2
	6	43	0.0		5	11	0.0
	10	1	1.0	E	8	52	1.1
	13	59	0.0		13	5	0.0
	15	57	0.3	F	14	53	0.3
	18	0	0.0		16	28	0.0
	21	13	0.6	E	20	4	0.7
	23	52	0.0		22	58	0.0

APPENDIX 8

Tabulation of Published Wind Speed Records at Quantico (1960-1978)

PERCENT, FREQUENCY OF OCCURRENCE, WIND DIRECTIONS VS WIND SPEED

LOCATION: QUANTICO, VA [VA 1377360.133; FROM 600822 THROUGH 781231; NO OF VALID OBSERVATIONS: 45202

SPEED [m/sec]	SPEED [ft/sec]	SPEED [mph]	SPEED [knots]	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
CALM	CALM	CALM	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.6	15.6
1	3.3	2.2	1.9	0.4	0.3	0.3	0.3	0.5	0.3	0.5	0.7	1.7	0.6	0.3	0.4	1.1	2.2	2.6	0.9	0.0	13.1
2	6.6	4.5	3.9	1.1	0.6	0.7	0.7	0.9	0.7	1.2	0.7	3.7	1.3	0.6	0.5	1.2	2.8	4.3	1.8	0.0	22.8
3	9.8	6.7	5.8	1.3	0.7	0.9	0.7	0.7	0.5	1.1	1.9	3.4	1.3	0.5	0.4	0.7	1.7	2.7	1.8	0.0	20.3
4	13.1	8.9	7.8	1.1	0.6	0.7	0.5	0.3	0.3	0.6	1.6	1.9	0.8	0.4	0.3	0.5	0.9	1.5	1.5	0.0	13.5
5	16.4	11.2	9.7	0.8	0.4	0.4	0.2	0.1	0.1	0.2	1.0	1.0	0.5	0.3	0.2	0.3	0.6	1.2	1.3	0.0	8.6
6	19.7	13.4	11.7	0.4	0.2	0.1	0.1	0.0	0.0	0.1	0.4	0.4	0.1	0.1	0.0	0.1	0.4	0.6	0.7	0.0	3.7
7	23.0	15.7	13.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.4	0.3	0.0	1.4
8	26.2	17.9	15.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.6
9	29.5	20.1	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2
10	32.8	22.4	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	36.1	24.6	21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	39.3	26.8	23.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	42.6	29.1	25.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	45.9	31.3	27.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	49.2	33.6	29.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	52.5	35.8	31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	55.7	38.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	59.0	40.3	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	62.3	42.5	36.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	65.6	44.7	38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	82.0	55.9	48.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	98.4	67.1	58.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	114.8	78.3	68.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			:	5.3	2.9	3.1	2.5	2.5	1.9	3.7	6.4	12.2	4.6	2.2	1.8	4	8.9	13.6	8.6	15.6	
AVERAGE SPEED:				3.55	3.41	3.16	2.96	2.44	2.58	2.76	2.79	2.87	2.8	3.05	2.67	2.6	2.78	2.96	3.63	0.00	

APPENDIX 9

Shallow Water Wave Forecasts

APPENDIX 9

SHALLOW WATER WAVE FORECASTING

As it is often the case, there is a lack of site-specific data on waves for the immediate vicinity of Quantico. Furthermore, there is no theoretical or empirical development that can be readily applied to a particular project site for determining the appropriate design characteristics of wind-generated waves. The interim method recommended by the U.S. Corps of Engineers uses the representative average values of the wind speed and water depth evaluated over a specified fetch to calculate the design values of the wave height, period and duration, defined by the following dimensionless equations [Shore Protection Manual, Eqs. (3-28b), (3-39), (3-40) and (3-41)]:

$$\frac{gH}{U_A^2} = 0.283 \tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right] \tanh\left\{\frac{0.00565\left(\frac{gF}{U_A^2}\right)^{1/2}}{\tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]}\right\}$$

$$\frac{gT}{U_A} = 7.54 \tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right] \tanh\left\{\frac{0.0379\left(\frac{gF}{U_A^2}\right)^{1/3}}{\tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]}\right\}$$

$$\frac{gt}{U_A} = 5.37 \times 10^2 \left(\frac{gT}{U_A}\right)^{7/3}$$

where:
- H = design wave height [ft]
- T = design wave period [sec]
- t = minimum effective wind duration [minutes]
- F = fetch length [ft]
- d = average water depth [ft]
- U_A = adjusted wind speed [ft/sec]

and, $U_A = 0.589 * U^{1.234}$, [U and U_A in miles/hour]
with U = standard wind speed at 10-meter elevation

After evaluating the design wave characteristics based on an appropriate number of alternative F, d and U values for the site, the above equations can be used to estimate H, T and t. Also available are time-saver charts based on these equations each developed for a constant water depth. The chart for the average depth of d = 20.0 ft is reproduced in Figure 9.1.

Many complexities are ordinarily involved in the process of generation of waves by surface winds of varying effectiveness over a number of fetches with varying depths and shoaling characteristics. In order to evaluate the sensitivity of the design wave characteristics to the variations in the three design parameters, a series of calculations were performed. The results are presented in Table 9.1, and summarized typically in Figures 9.2 and 9.3 to illustrate the sensitivity of the design wave height to the design parameters. Apparently, the effects of the applicable fetch lengths and average water depths along these fetches are relatively small, and remain in the order of 0.5 ft for the maximum ranges of both parameters. For the range of 25 mph to 50 mph applied to the effective wind speed, on the other hand, the variation of the design wave height would range from 1.0 ft to 1.5 ft for varying fetch lengths and average water depths.

These sensitivity evaluations, supported by the various historic data and indications, suggest that a generally valid design wave should probably have a significant wave height of H = 4.0 ft, a significant period of T = 4.0 sec, and should correspond to an effective wave-generating wind lasting no more than 1-1/4 hours. These values would be used as a guideline, only, and may need further adjustments depending on the structure to be designed or the environmental process to be taken into consideration. These additional considerations will include the effects of extreme tide and flood elevations, uprush of waves along the face of a sloping structure, and acceptable levels of risk for overtopping of the various types of structures involved in the project.

TABLE 9.1

SHALLOW-WATER WAVE FORECASTING [SHORE PROTECTION MANUAL, EQS. (3-39, 3-40), P. 3-55]

Eq. (3-39): H1 = (gH/U^2) = 0.283 * tanh A1 * tanh [B1 / tanh A1]

Eq. (3-40): T1 = (gT/U) = 7.540 * tanh A2 * tanh [B2 / tanh A2]

with: H1=(gH/U^2), T1= gT/U, d1=gd/U^2, F1=gF/U^2
A1=(0.530)(d1)^(3/4), B1=(0.00565)(F1)^(1/2)
A2=(0.833)(d1)^(3/8), B2=(0.03790)(F1)^(1/3)

where: H = Design Value of "Shallow-Water" Wave Height [feet]
T = Design Value of "Shallow-Water" Wave Period [sec]
F = Length of Unobstructed Fetch [miles]
U = Effective Wind Speed [miles/hour]
d = Average Water Depth Along the Fetch [feet]

This program calculates:

A. the simple average depth of water along a given fetch F, and

B. the design wave height H, and design wave period T, using the above equations, the computed average depth d, and a given fastest-speed wind velocity U

QUANTICO - FIRST APPROXIMATIONS FOR DESIGN WAVE CHARACTERISTICS

Average Depth d (ft)	Fetch F (mi)	Wind Speed U(mph)	d1	F1	A1	B1	H1	H	A2	B2	T1	T
20.0	12.4	35.0	0.24	8.0E+02	0.18	0.16	0.04	3.0	0.49	0.35	2.23	3.5
20.0	12.4	40.0	0.19	6.1E+02	0.15	0.14	0.03	3.3	0.44	0.32	2.04	3.7
20.0	12.4	45.0	0.15	4.8E+02	0.13	0.12	0.03	3.6	0.41	0.30	1.88	3.9
25.0	12.4	35.0	0.31	8.0E+02	0.22	0.16	0.04	3.1	0.53	0.35	2.27	3.6
25.0	12.4	40.0	0.23	6.1E+02	0.18	0.14	0.03	3.5	0.48	0.32	2.08	3.8
25.0	12.4	45.0	0.18	4.8E+02	0.15	0.12	0.03	3.9	0.44	0.30	1.93	3.9

QUANTICO - ADDITIONAL CALCULATIONS FOR DESIGN WAVE CHARACTERISTICS

Average Depth d (ft)	Fetch F (mi)	Wind Speed U(mph)	d1	F1	A1	B1	H1	H	A2	B2	T1	T
15.0	12.4	25.0	0.36	1.6E+03	0.25	0.22	0.05	2.1	0.57	0.44	2.69	3.1
20.0	12.4	25.0	0.48	1.6E+03	0.31	0.22	0.05	2.2	0.63	0.44	2.77	3.2
25.0	12.4	25.0	0.60	1.6E+03	0.36	0.22	0.06	2.3	0.69	0.44	2.82	3.2
30.0	12.4	25.0	0.72	1.6E+03	0.41	0.22	0.06	2.4	0.74	0.44	2.86	3.3
15.0	13.0	25.0	0.36	1.6E+03	0.25	0.23	0.05	2.1	0.57	0.45	2.72	3.1
20.0	13.0	25.0	0.48	1.6E+03	0.31	0.23	0.05	2.3	0.63	0.45	2.80	3.2
25.0	13.0	25.0	0.60	1.6E+03	0.36	0.23	0.06	2.4	0.69	0.45	2.86	3.3
30.0	13.0	25.0	0.72	1.6E+03	0.41	0.23	0.06	2.4	0.74	0.45	2.90	3.3
15.0	10.6	25.0	0.36	1.3E+03	0.25	0.21	0.05	2.0	0.57	0.42	2.60	3.0
20.0	10.6	25.0	0.48	1.3E+03	0.31	0.21	0.05	2.1	0.63	0.42	2.67	3.0
25.0	10.6	25.0	0.60	1.3E+03	0.36	0.21	0.05	2.2	0.69	0.42	2.72	3.1
30.0	10.6	25.0	0.72	1.3E+03	0.41	0.21	0.05	2.2	0.74	0.42	2.75	3.1
15.0	11.1	25.0	0.36	1.4E+03	0.25	0.21	0.05	2.0	0.57	0.42	2.63	3.0
20.0	11.1	25.0	0.48	1.4E+03	0.31	0.21	0.05	2.1	0.63	0.42	2.70	3.1
25.0	11.1	25.0	0.60	1.4E+03	0.36	0.21	0.05	2.2	0.69	0.42	2.75	3.1
30.0	11.1	25.0	0.72	1.4E+03	0.41	0.21	0.05	2.3	0.74	0.42	2.79	3.2
15.0	12.4	50.0	0.09	3.9E+02	0.09	0.11	0.02	3.5	0.34	0.28	1.70	3.9
20.0	12.4	50.0	0.12	3.9E+02	0.11	0.11	0.02	4.0	0.38	0.28	1.76	4.0
25.0	12.4	50.0	0.15	3.9E+02	0.13	0.11	0.03	4.2	0.41	0.28	1.79	4.1
30.0	12.4	50.0	0.18	3.9E+02	0.15	0.11	0.03	4.4	0.44	0.28	1.82	4.2
15.0	13.0	50.0	0.09	4.1E+02	0.09	0.11	0.02	3.6	0.34	0.28	1.72	3.9
20.0	13.0	50.0	0.12	4.1E+02	0.11	0.11	0.02	4.0	0.38	0.28	1.77	4.0
25.0	13.0	50.0	0.15	4.1E+02	0.13	0.11	0.03	4.3	0.41	0.28	1.82	4.1
30.0	13.0	50.0	0.18	4.1E+02	0.15	0.11	0.03	4.5	0.44	0.28	1.85	4.2
15.0	10.6	50.0	0.09	3.4E+02	0.09	0.10	0.02	3.4	0.34	0.26	1.64	3.7
20.0	10.6	50.0	0.12	3.4E+02	0.11	0.10	0.02	3.8	0.38	0.26	1.69	3.9
25.0	10.6	50.0	0.15	3.4E+02	0.13	0.10	0.02	4.0	0.41	0.26	1.73	3.9
30.0	10.6	50.0	0.18	3.4E+02	0.15	0.10	0.03	4.2	0.44	0.26	1.75	4.0
15.0	11.1	50.0	0.09	3.5E+02	0.09	0.11	0.02	3.4	0.34	0.27	1.66	3.8
20.0	11.1	50.0	0.12	3.5E+02	0.11	0.11	0.02	3.8	0.38	0.27	1.71	3.9
25.0	11.1	50.0	0.15	3.5E+02	0.13	0.11	0.02	4.1	0.41	0.27	1.75	4.0
30.0	11.1	50.0	0.18	3.5E+02	0.15	0.11	0.03	4.3	0.44	0.27	1.77	4.0

QUANTICO - ADDITIONAL CALCULATIONS FOR DESIGN WAVE CHARACTERISTICS

Average Depth d (ft)	Fetch F (mi)	Wind Speed U(mph)	d1	F1	A1	B1	H1	H	A2	B2	T1	T
15.0	12.4	25.0	0.36	1.6E+03	0.25	0.22	0.05	2.1	0.57	0.44	2.69	3.1
20.0	12.4	25.0	0.48	1.6E+03	0.31	0.22	0.05	2.2	0.63	0.44	2.77	3.2
25.0	12.4	25.0	0.60	1.6E+03	0.36	0.22	0.06	2.3	0.69	0.44	2.82	3.2
30.0	12.4	25.0	0.72	1.6E+03	0.41	0.22	0.06	2.4	0.74	0.44	2.86	3.3
15.0	13.0	25.0	0.36	1.6E+03	0.25	0.23	0.05	2.1	0.57	0.45	2.72	3.1
20.0	13.0	25.0	0.48	1.6E+03	0.31	0.23	0.05	2.3	0.63	0.45	2.80	3.2
25.0	13.0	25.0	0.60	1.6E+03	0.36	0.23	0.06	2.4	0.69	0.45	2.86	3.3
30.0	13.0	25.0	0.72	1.6E+03	0.41	0.23	0.06	2.4	0.74	0.45	2.90	3.3
15.0	10.6	25.0	0.36	1.3E+03	0.25	0.21	0.05	2.0	0.57	0.42	2.60	3.0
20.0	10.6	25.0	0.48	1.3E+03	0.31	0.21	0.05	2.1	0.63	0.42	2.67	3.0
25.0	10.6	25.0	0.60	1.3E+03	0.36	0.21	0.05	2.2	0.69	0.42	2.72	3.1
30.0	10.6	25.0	0.72	1.3E+03	0.41	0.21	0.05	2.2	0.74	0.42	2.75	3.1
15.0	11.1	25.0	0.36	1.4E+03	0.25	0.21	0.05	2.0	0.57	0.42	2.63	3.0
20.0	11.1	25.0	0.48	1.4E+03	0.31	0.21	0.05	2.1	0.63	0.42	2.70	3.1
25.0	11.1	25.0	0.60	1.4E+03	0.36	0.21	0.05	2.2	0.69	0.42	2.75	3.1
30.0	11.1	25.0	0.72	1.4E+03	0.41	0.21	0.05	2.3	0.74	0.42	2.79	3.2
15.0	12.4	35.0	0.18	8.0E+02	0.15	0.16	0.03	2.7	0.44	0.35	2.16	3.4
20.0	12.4	35.0	0.24	8.0E+02	0.18	0.16	0.04	3.0	0.49	0.35	2.23	3.5
25.0	12.4	35.0	0.31	8.0E+02	0.22	0.16	0.04	3.1	0.53	0.35	2.27	3.6
30.0	12.4	35.0	0.37	8.0E+02	0.25	0.16	0.04	3.3	0.57	0.35	2.31	3.7
15.0	13.0	35.0	0.18	8.4E+02	0.15	0.16	0.03	2.7	0.44	0.36	2.18	3.5
20.0	13.0	35.0	0.24	8.4E+02	0.18	0.16	0.04	3.0	0.49	0.36	2.25	3.6
25.0	13.0	35.0	0.31	8.4E+02	0.22	0.16	0.04	3.2	0.53	0.36	2.30	3.7
30.0	13.0	35.0	0.37	8.4E+02	0.25	0.16	0.04	3.3	0.57	0.36	2.33	3.7
15.0	10.6	35.0	0.18	6.8E+02	0.15	0.15	0.03	2.6	0.44	0.33	2.08	3.3
20.0	10.6	35.0	0.24	6.8E+02	0.18	0.15	0.03	2.8	0.49	0.33	2.15	3.4
25.0	10.6	35.0	0.31	6.8E+02	0.22	0.15	0.04	3.0	0.53	0.33	2.19	3.5
30.0	10.6	35.0	0.37	6.8E+02	0.25	0.15	0.04	3.1	0.57	0.33	2.22	3.5
15.0	11.1	35.0	0.18	7.2E+02	0.15	0.15	0.03	2.6	0.44	0.34	2.11	3.4
20.0	11.1	35.0	0.24	7.2E+02	0.18	0.15	0.04	2.9	0.49	0.34	2.17	3.5
25.0	11.1	35.0	0.31	7.2E+02	0.22	0.15	0.04	3.0	0.53	0.34	2.21	3.5
30.0	11.1	35.0	0.37	7.2E+02	0.25	0.15	0.04	3.1	0.57	0.34	2.24	3.6

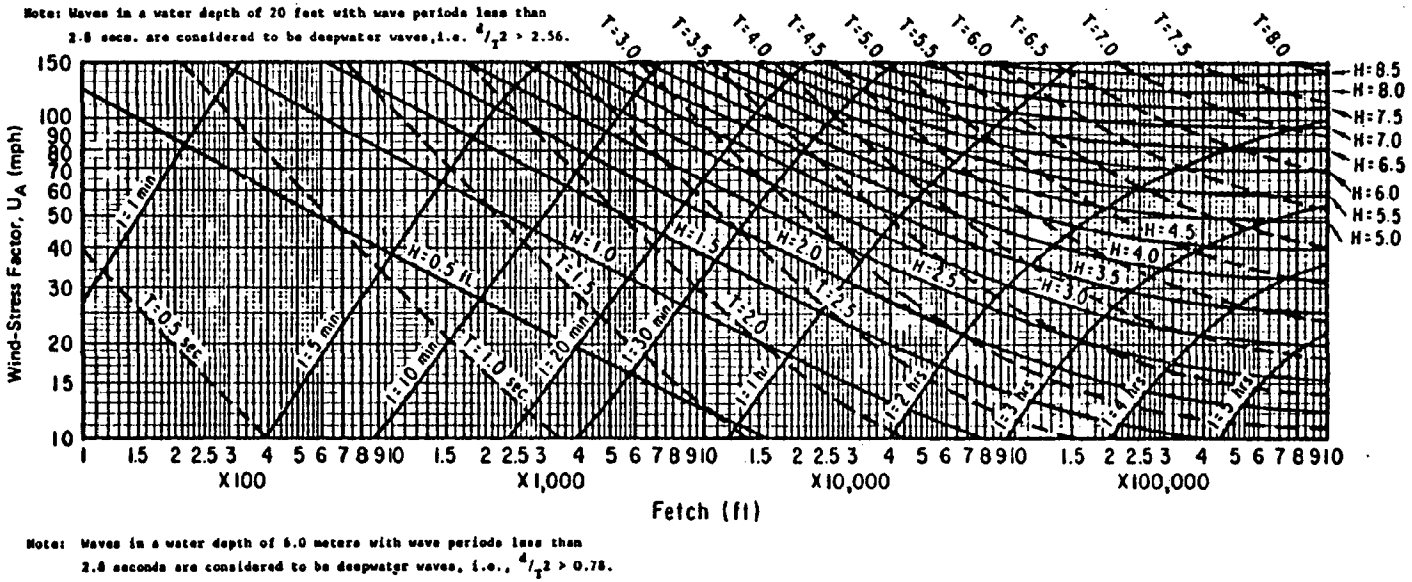


FIGURE 9.1 - Forecasting Curves For Wind-driven Shallow Water Waves For A Constant Depth Of 20 Feet

(Source: Shore Protection Manual, Figure 3-27)

WIND-GENERATED WAVE HEIGHT PREDICTION
for Fetch=12.4 miles & Average Depths

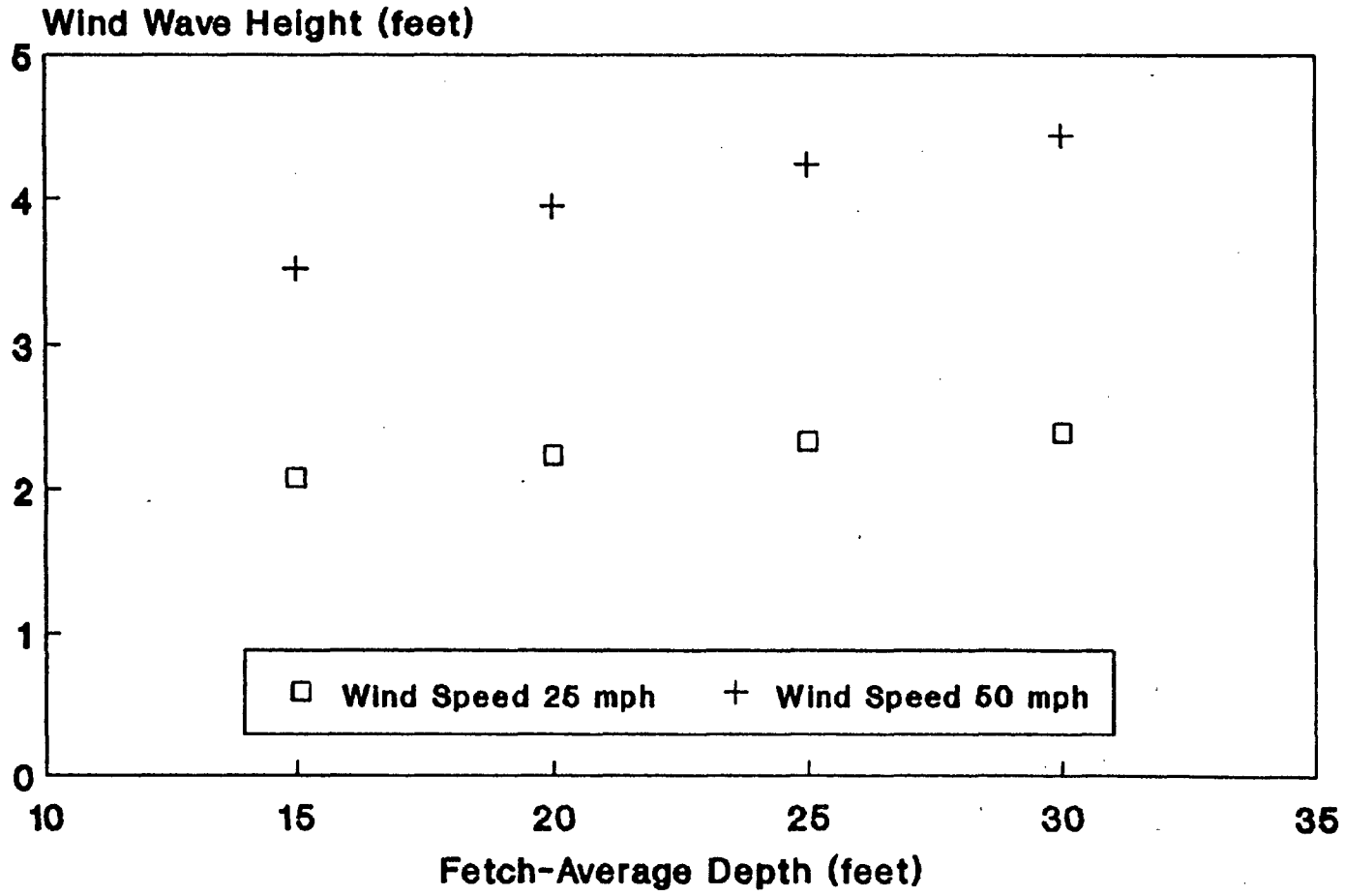


FIGURE 9.2

WIND-GENERATED WAVE HEIGHT PREDICTION
for Varying Fetches & Average Depths

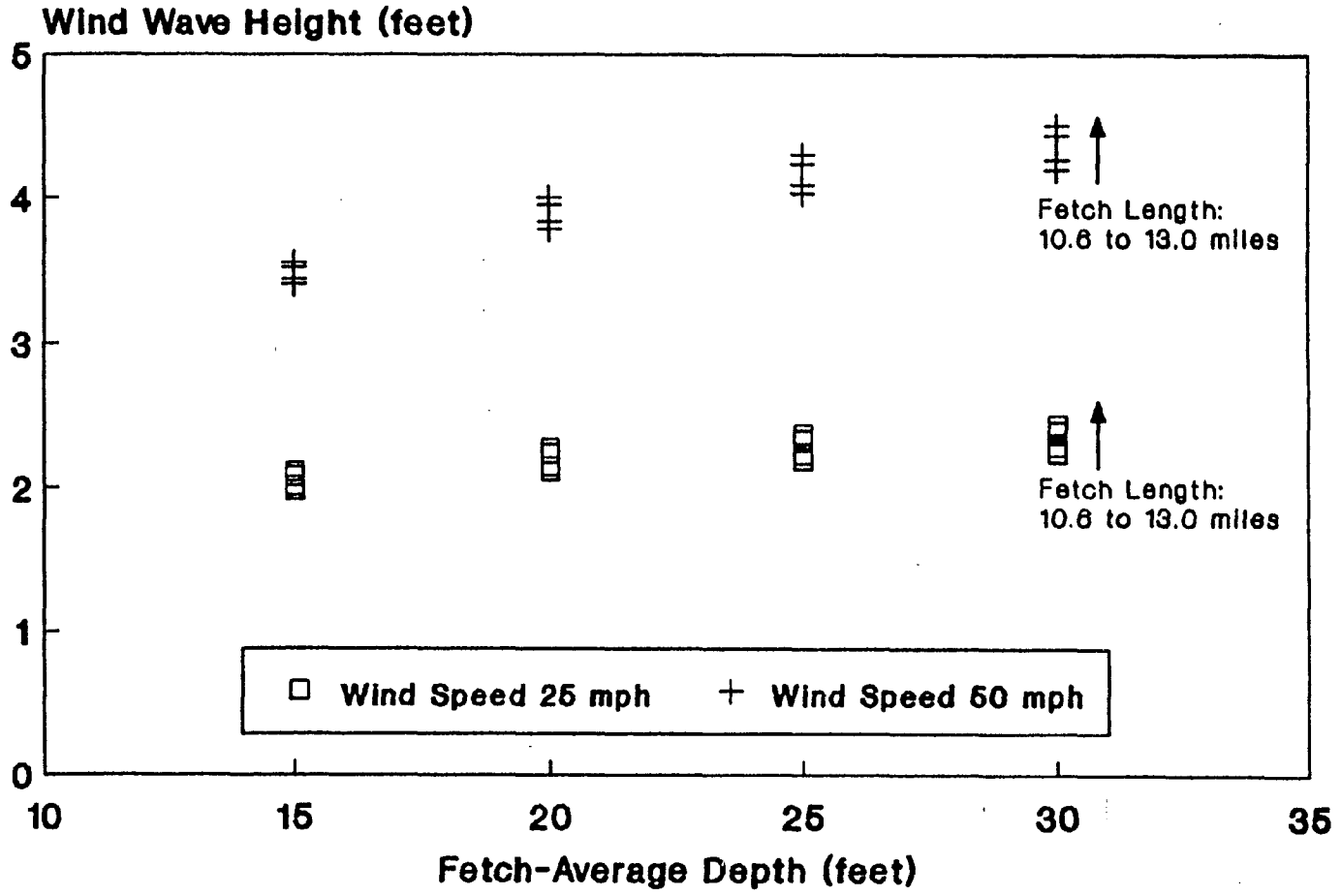
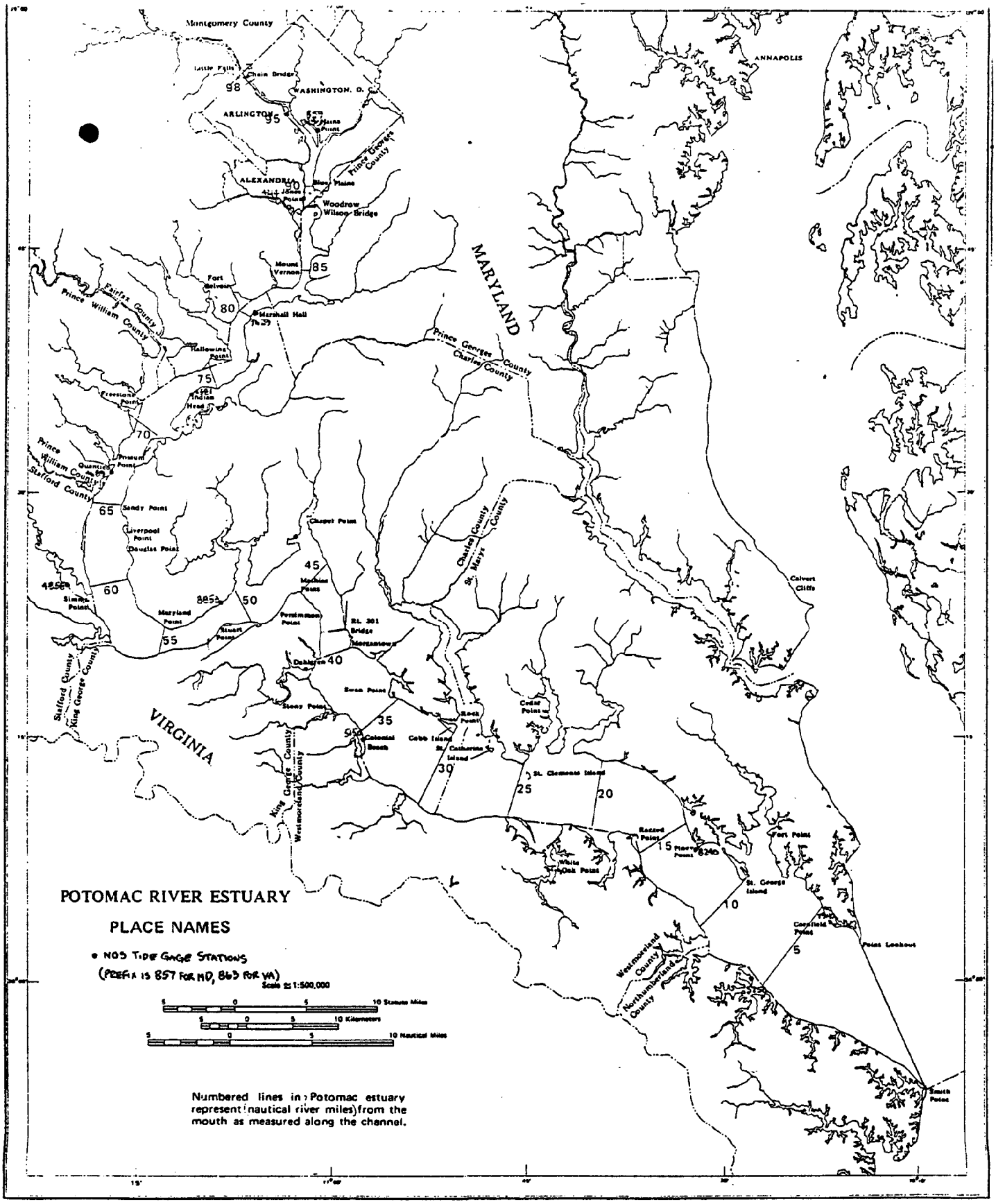


FIGURE 2.3

APPENDIX 10

Summary of Relevant Tidal Gage Records


POTOMAC RIVER ESTUARY
PLACE NAMES
• NOS TIDE GAGE STATIONS
(PEEFA IS 857 FOR MD, 863 FOR VA)
Scale ≅ 1:500,000
10 Statute Miles
10 Kilometers
10 Nautical Miles
Numbered lines in Potomac estuary represent nautical river miles from the mouth as measured along the channel.
MARYLAND
VIRGINIA
Montgomery County
Prince George's County
Prince William County
Fairfax County
Stafford County
King George County
Charles County
St. Mary's County
Westmoreland County
Northumberland County
WASHINGTON, D. C.
ARLINGTON
ALEXANDRIA
ANNAPOLIS
Chain Bridge
Little Falls
Hains Point
Jones Point
Woodrow Wilson Bridge
Mount Vernon
Fort Belvoir
Marshall Hall
Hallowing Point
Freestone Point
Indian Head
Possum Point
Quantico
Sandy Point
Liverpool Point
Douglas Point
Chapel Point
Maryland Point
Stuart Point
Persimmon Point
Rt. 301 Bridge
Mattawoman
Dahlgren
Swan Point
Sloop Point
Colonial Beach
Cobb Island
St. Catherine Island
Cedar Point
Beach Point
St. Clements Island
Hazard Point
Piney Point
White Oak Point
St. George Island
Fort Point
Coan Field Point
Point Lookout
Calvert Cliffs
Smith Point

DATUM REFERENCE

Station number - 863 4689

Station Name - Quantico, Virginia

Dates Datum(s) applies to:

From: January 1971 To: October 1972

Subtract 1.41 feet to refer values to MLW. Epoch - 1960 - 1978

Subtract 2.78 feet to refer values to MHW.

Subtract 1.60 feet to refer values to NGVD.

HIGHEST TIDE OBSERVED

MONTH	1971		1972		1970					
	DATE	FEET	DATE	FEET	DATE	FEET	DATE	FEET	DATE	FEET
Jan.	*14	3.36	22	3.99						
Feb.	*27	3.99	no data							
Mar.	29	4.44	available							
Apr.	22	3.79								
May	30	3.89	27	4.44						
June	16	4.57	22	4.97						
July	13	3.67	7	4.32						
Aug.	27	4.05	16	4.11						
Sept.	12	4.16	4	4.62						
Oct.	*2	4.91	6	4.88						
Nov.	*18	4.25			14	4.60				
Dec.	9	3.82			*13	3.87				
Year										

REMARKS: * partial months

LOWEST TIDE OBSERVED

MONTH	1971		1972		1970					
	DATE	FEET	DATE	FEET	DATE	FEET	DATE	FEET	DATE	FEET
Jan.	*16	-0.09	20	0.96						
Feb.	*15	0.23								
Mar.	4	-0.46								
Apr.	10	0.34								
May	3	0.56	5	0.90						
June	10	0.95	10	-0.01						
July	20	0.93	4	0.83						
Aug.	12	0.83	10	0.82						
Sept.	5	1.30	20	1.03						
Oct.	*11	1.29	15	0.71						
Nov.	*22	-1.24			24	0.22				
Dec.	18	-1.90			*26	-0.17				
Year										

NATIONAL OCEAN SURVEY POTOMAC RIVER DATA ON WATER ELEVATIONS

NOS RIVER MILE	NOS STATION	TIME SPAN	Water Elevations, [ft, NGVD] MHW	1-Mo.	2-Mo.	1-Yr.	2-Yr.	10-Yr.	Record, Date
7	8577940 Cornfield Harbor, MD	11/70-02/72	1.13	2.20	2.50	--	--	--	2.94 10/01/71
8	8635750 Lewisetta, VA	1974 on	1.10	1.90	2.15	2.90	3.00	3.25	3.34 03/19/83
16	8578240 Piney Point, MD	1960-1976	1.08	1.85	2.10	2.75	2.95	3.65	4.04 03/08/62
36	8635150 Colonial Beach, VA	1972 on	1.45	2.40	2.65	3.25	3.50	4.00	3.97 09/06/79
53	8578769 Port Tabacco, MD	11/70-10/72	1.10	2.30	2.50	--	--	--	3.37 06/72
61	8574858 Aquia Creek, VA	11/70-09/72	1.13	2.30	2.45	--	--	--	3.25 12/70
68	8574689 Quantico, VA	11/70-10/72	1.18	2.30	2.60	--	--	--	3.37 06/22/71
74	8579381 Indian Head, MD	10/70-10/72	1.29	2.55	2.75	--	--	--	3.51 06/72
82	8579629 Marshall Hall, MD	10/70-10/72	1.69	2.75	3.20	--	--	--	3.83 06/72
91	8634214 Alexandria, VA	05/74-07/75	2.01	3.15	3.20	--	--	--	6.62 12/74
95	8594900 Washington, DC	1931 on	2.09	2.09	3.00	3.90	4.30	6.60	10.44 10/17/47

ANNUAL HIGH WATER LEVELS AT NOS POTOMAC RIVER GAGES (LONG RECORDS) [ft, NGVD]

Year	Sta # 8594900 Washington, DC		Sta # 8635150 Colonial Beach		Sta # 8635750 Lewisetta, VA		Sta # 8578240 Piney Point, MD		Sta # 8634687 Quantico, VA	
1960	4.04	02/18					2.84	07/30		
1961	4.44	10/29					3.04	10/24		
1962	5.34	03/08					4.04	03/08		
1963	3.64	09/06								
1964	4.04	03/05								
1965	4.34	02/25					2.24	06/16		
1966	4.24	09/14								
1967	3.94	05/26					3.44	05/26		
1968	4.19	05/28								
1969	3.94	11/02					2.84	11/02		
1970	4.44	04/02					3.94	11/03		
1971	4.34	10/25							3.31	10/02
1972	7.04	06/24					3.24	06/21	3.37	06/22
1973	4.32	04/27	3.22	10/29			2.64	04/18		
1974	6.89	12/01			3.26	12/--				
1975	5.61	09/27	3.23	09/01	2.98	11/09				
1976	4.26	01/02			2.46	04/01				
1977	4.34	12/20	3.50	09/26	3.09	12/21				
1978	5.64	01/26	3.48	04/27						
1979	6.56	02/26	4.07	09/06	2.99	09/06				
1980	4.14	01/18	3.14	01/17	2.92	10/25				
1981	3.82	11/16	3.27	11/16	2.74	11/16				
1982	4.44	06/13	3.36	10/10	3.03	10/25				
1983	4.84	03/19	3.93	03/19	3.34	03/19				
1984	5.12	02/16	3.94	03/29	3/10	03/28				
1985	7.53	11/04	3.92	11/01	2.93	11/05				
1986	4.94	12/02	3.88	12/02	3.00	12/02				
1987	4.65	10/17	3.82	04/17	2.87	09/20				
1988	4.22	04/14	3.49	04/13	3.17	04/13				
MLW :	-0.68	10/78	-0.21	10/78	-0.17	10/78	-0.34	10/78	-0.19	10/78
MHW :	2.09		1.45		1.10		1.18		1.18	

EXTREME WASHINGTON, DC, FLOODS IN OTHER POTOMAC RIVER GAGE RECORDS [ft, NGVD]

June 1972 (Agnes) :

8.04 at Washington, DC, on 06/24/72	5th highest in record
3.83 at Marshall Hall	3.28 at Aquia Creek
3.51 at Indian Head	3.37 at Riverside
3.37 at Quantico on 06/22/72	3.24 at Piney Point on 06/21/72

December 1974 :

6.89 at Washington, DC, on 12/01/74	8th highest in record
6.62 at Alexandria	2.81 at Colonial Beach on 12/16/74
	2.54 at Piney Point on 12/16/74
	3.26 at Lewisetta

February 1979 :

6.56 at Washington, DC, on 02/26/79	9th highest in record
2.88 at Lewisetta	

November 1985 (Juan) :

7.53 at Washington, DC, on 11/04/85	6th highest in record
[also 7.25 at Washington, DC, on 11/07/85]	
3.92 at Colonial Beach on 11/01/85	2.93 at Lewisetta on 11/05/85

March 1962 :

4.04 at Piney Point on 03/08/62	Highest over 13 years
5.34 at Washington, DC	4-Yr flood elevation

September 1979 :

4.07 at Colonial Beach 03/08/62	Highest over 15 years
5.56 at Washington, DC	5-Yr flood elevation
2.99 at Lewisetta	2-Yr flood elevation

March 1983 :

3.34 at Lewisetta	Highest over 14 years
4.84 at Washington, DC	3-Yr flood elevation
3.93 at Colonial Beach	7-Yr flood elevation

FLOOD WATER LEVELS OF REGIONAL SIGNIFICANCE [ft, NGVD]:

11.3	Projected 100-Year Flood Water Elevation at Washington, DC
10.44	Highest Recorded Water Elevation at Washington, DC, 1931-1988
7.9	Projected 100-Year Flood Water Elevation, Quantico, VA, FEMA Study
7.0	Tentative Wall Elevation for Marina Perimeter Structure (Breakwater)
3.97	Highest Recorded Flood Water Elevation, Colonial Beach, VA, 1972-1988
3.4	Projected Annual High Flood Water Elevation, Quantico, VA [Highest Recorded Flood Water Elevation, 1972-1972]
1.14	Mean High Water Level, Quantico, VA, 1960-1978 Tidal Epoch
0	National Geodetic Vertical Datum [NGVD]
-0.23	Mean Low Water Level, Quantico, VA, 1960-1978 Tidal Epoch

APPENDIX 11
(A through H)

Historical Maps Depicting Topographic, Hydrographic and Boundary Features from 1903 to 1975

U. S. COAST AND GEODETIC SURVEY

TOPOGRAPHIC MAP

No. T-5763

MARYLAND – VIRGINIA

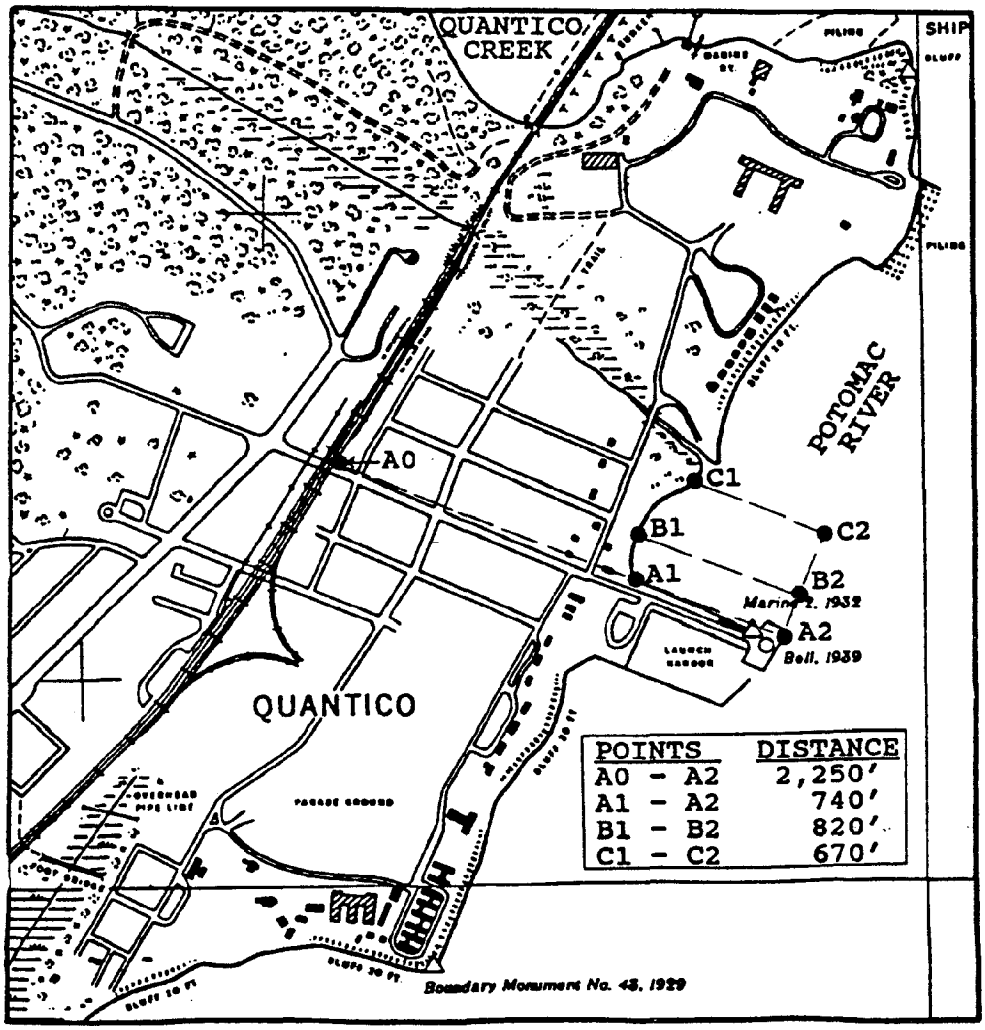
POTOMAC RIVER

NEABSCO CREEK – QUANTICO

SCALE 1:10,000

(1 inch = 833.33 ft.)

This Map, Without Contours, Was Compiled From Air Photographs Taken June 29, October 25, 1938, And April 23, 1939, And Supplemented By Other Surveys To May 15, 1940



APPENDIX 11A - U.S. Coast And Geodetic Survey Topographic Map (1938-1940)

NATIONAL OCEAN SURVEY

A. L. POWELL, Director

HYDROGRAPHIC SURVEY No. 9322

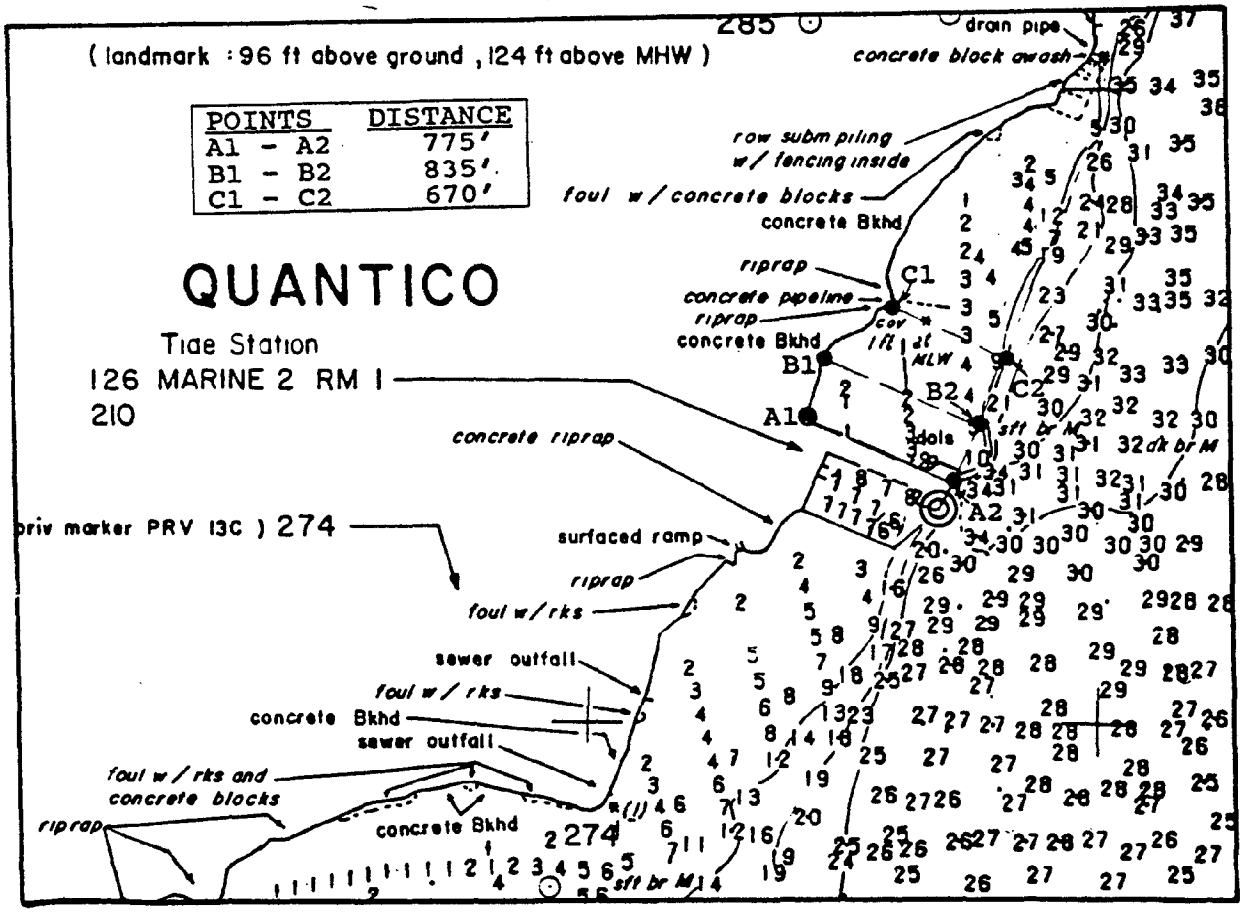
VIRGINIA - MARYLAND

POTOMAC RIVER

VICINITY OF QUANTICO

Date of Survey . . . May - October, 1972
Scale . . . . . 1 : 10,000
Chief of Party. G.R. Schaefer, N.C. Austin
Surveyed by. . . . . Ship's Officers

SOUNDINGS IN FEET
at Mean Low Water



APPENDIX 11B - National Ocean Survey Hydrographic Map (1972)

DEPARTMENT OF COMMERCE AND LABOR
COAST AND GEODETIC SURVEY
O. H. Tittmann, Superintendent.

POTOMAC RIVER

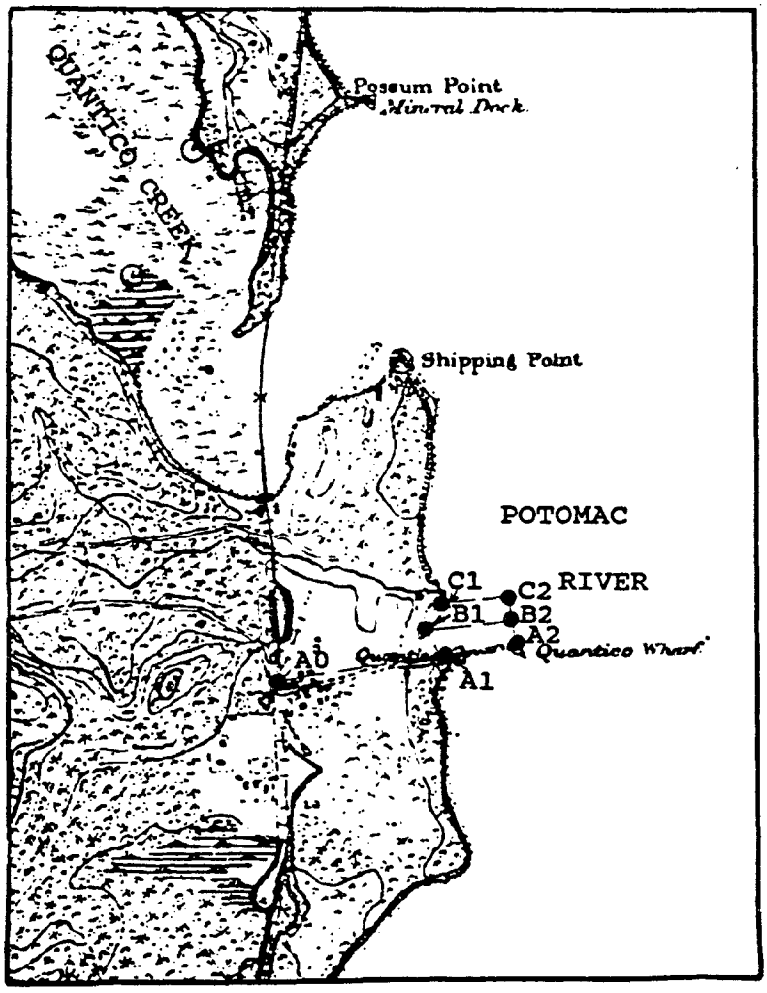
AQUIA CREEK TO MATTAWOMAN CREEK

MD. AND VA.

Plane Table Survey by S. Forney Asst. Chief of Party

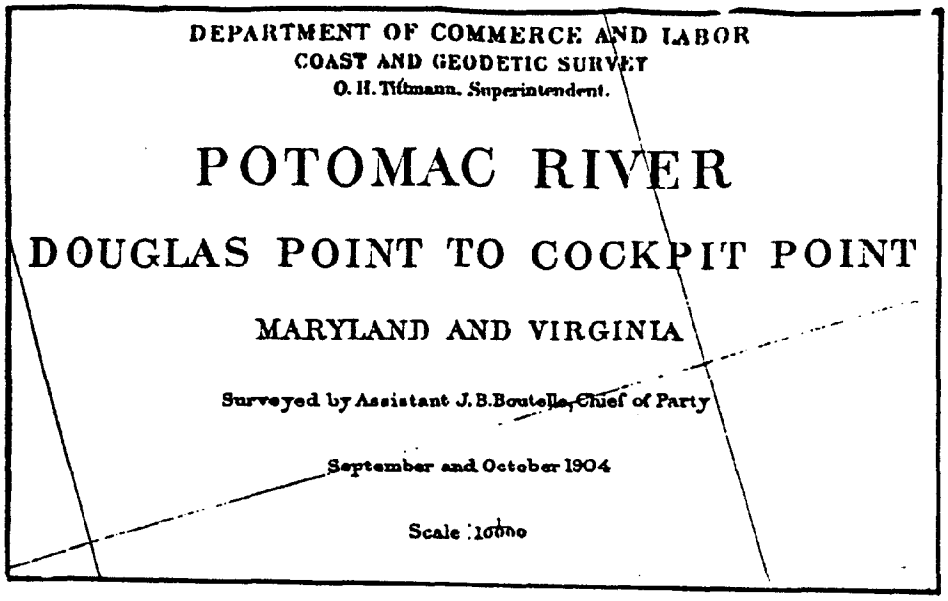
1903-1904

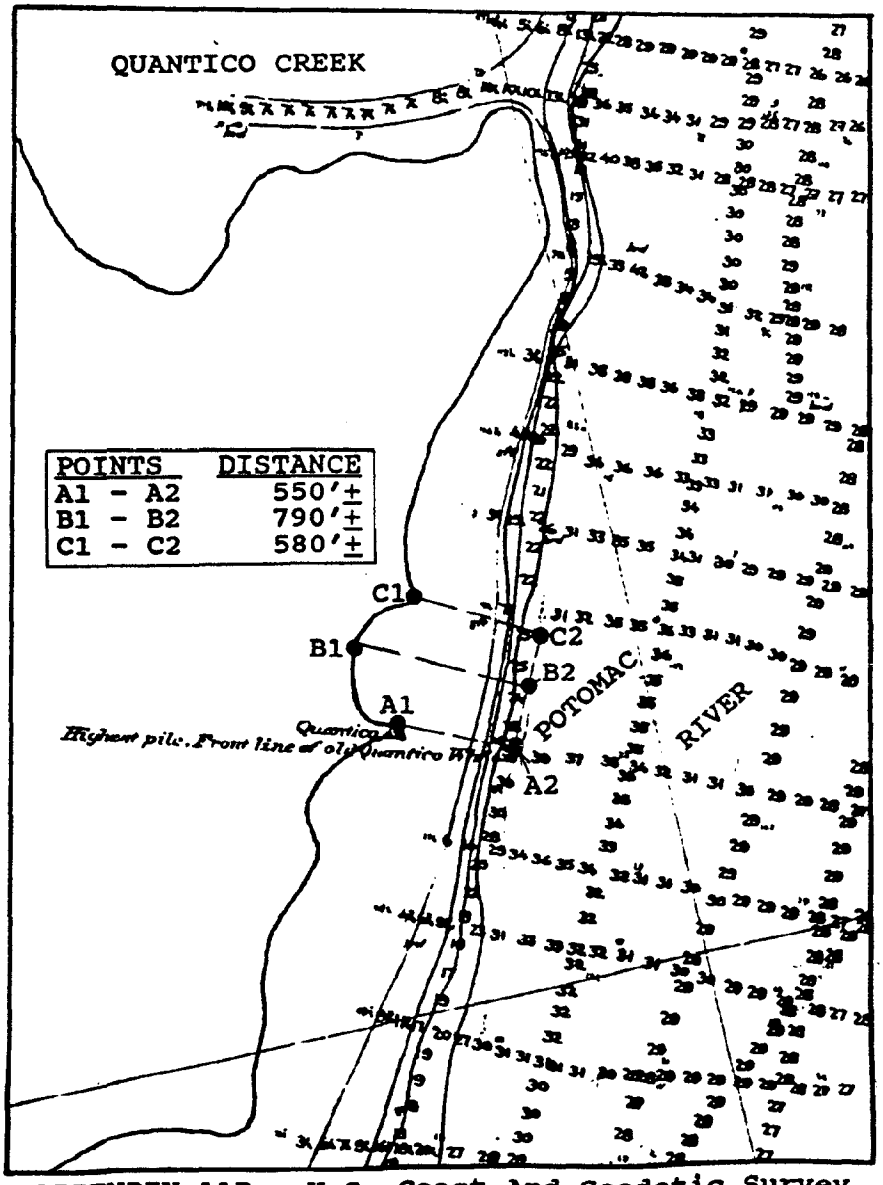
Scale 20000



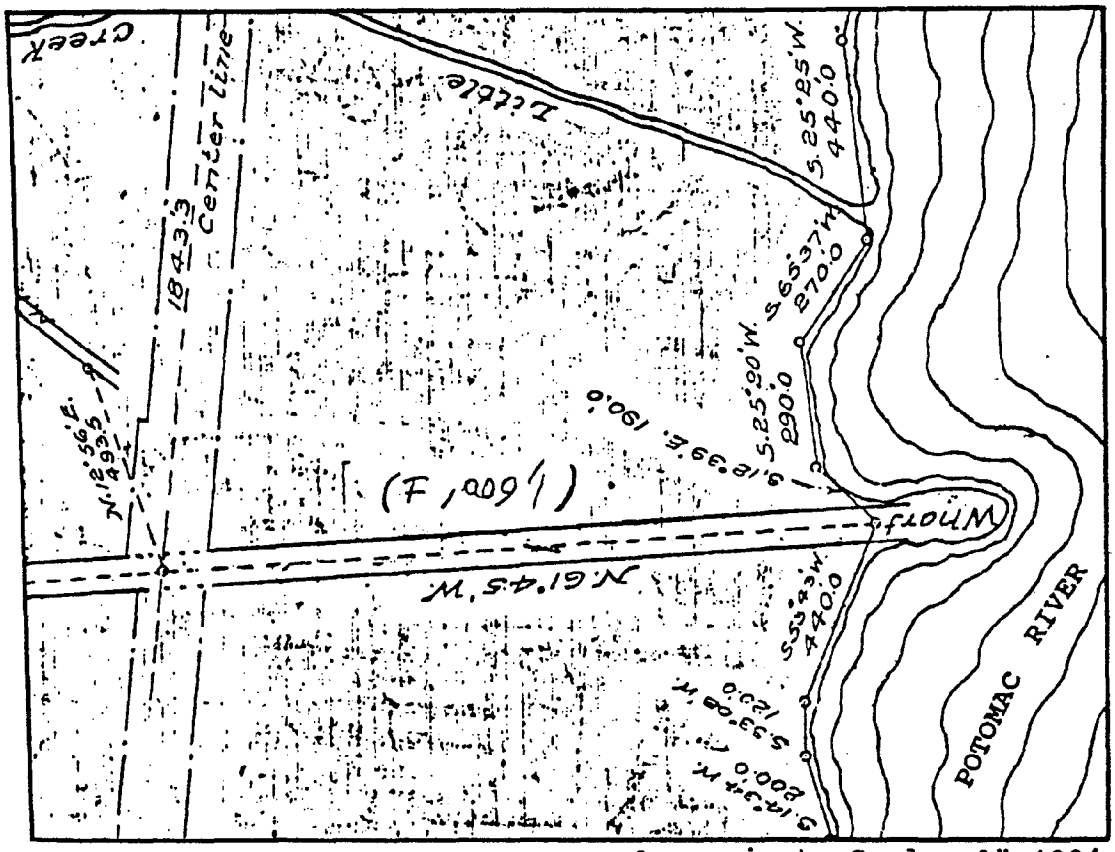
POINTS	DISTANCE
A0 - A2	2,250′
A1 - A2	670′±
B1 - B2	840′±
C1 - C2	670′±

APPENDIX 11C - U.S. Coast And Geodetic Survey
Topographic Map (1903-1904)



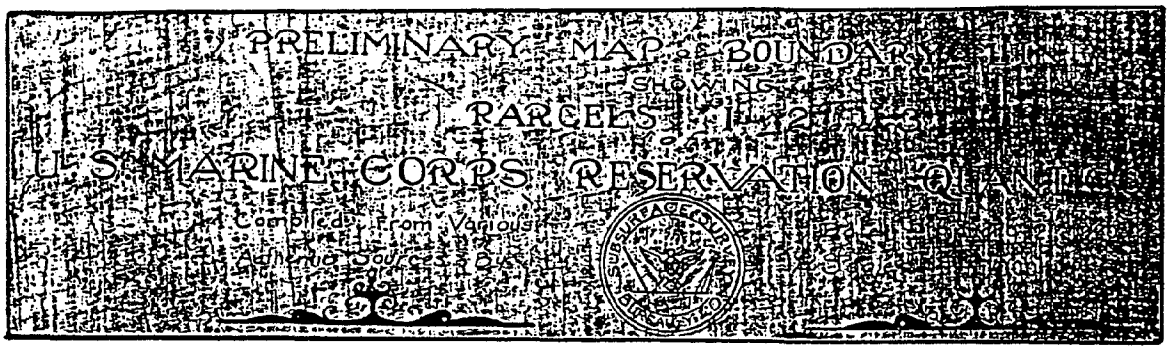


APPENDIX 11D - U.S. Coast And Geodetic Survey Hydrographic Map (1904)

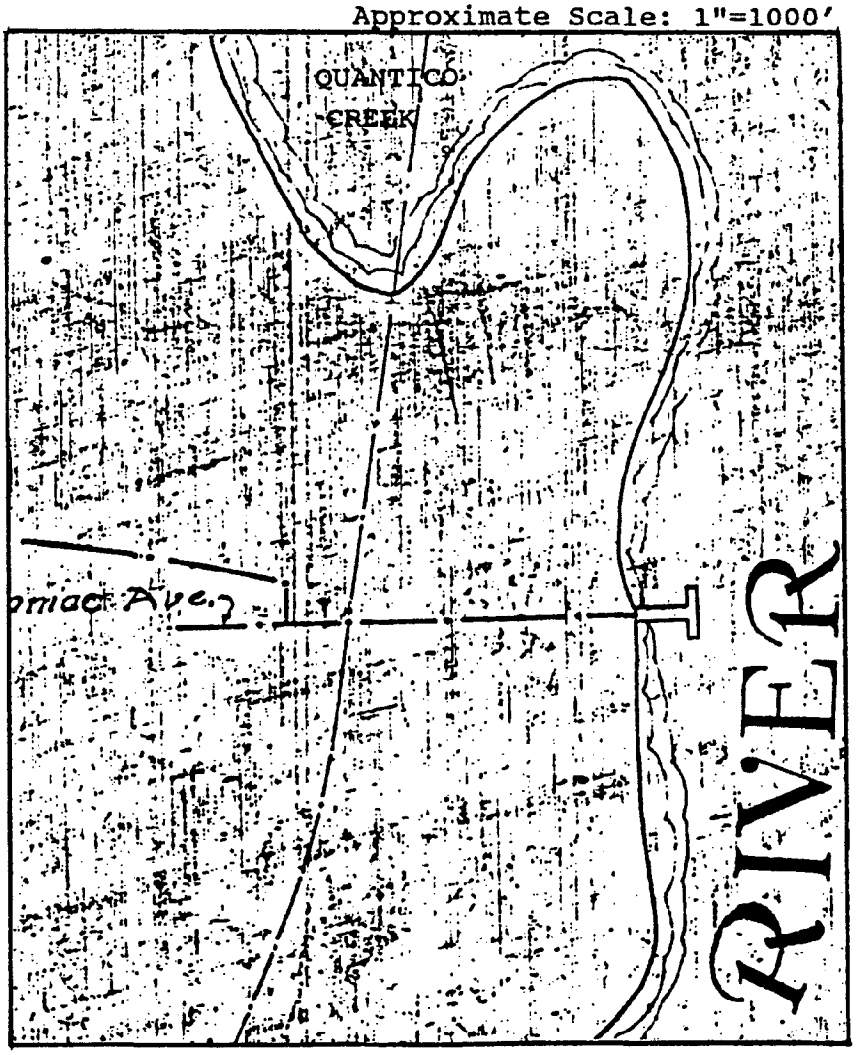


Approximate Scale: 1"=400'

APPENDIX 11E - Plat Showing Property Of The Quantico Company, February 19, 1916, Joseph Berry, Surveyor, Fairfax County, Virginia



Approximate Scale: 1"=1000'



APPENDIX 11F - Preliminary Boundary Map Of The Quantico Marine Corps Base, January 21, 1920

QUANTICO, VA. – MD.
SE/4 QUANTICO 15' QUADRANGLE
38077-E3-TB-024

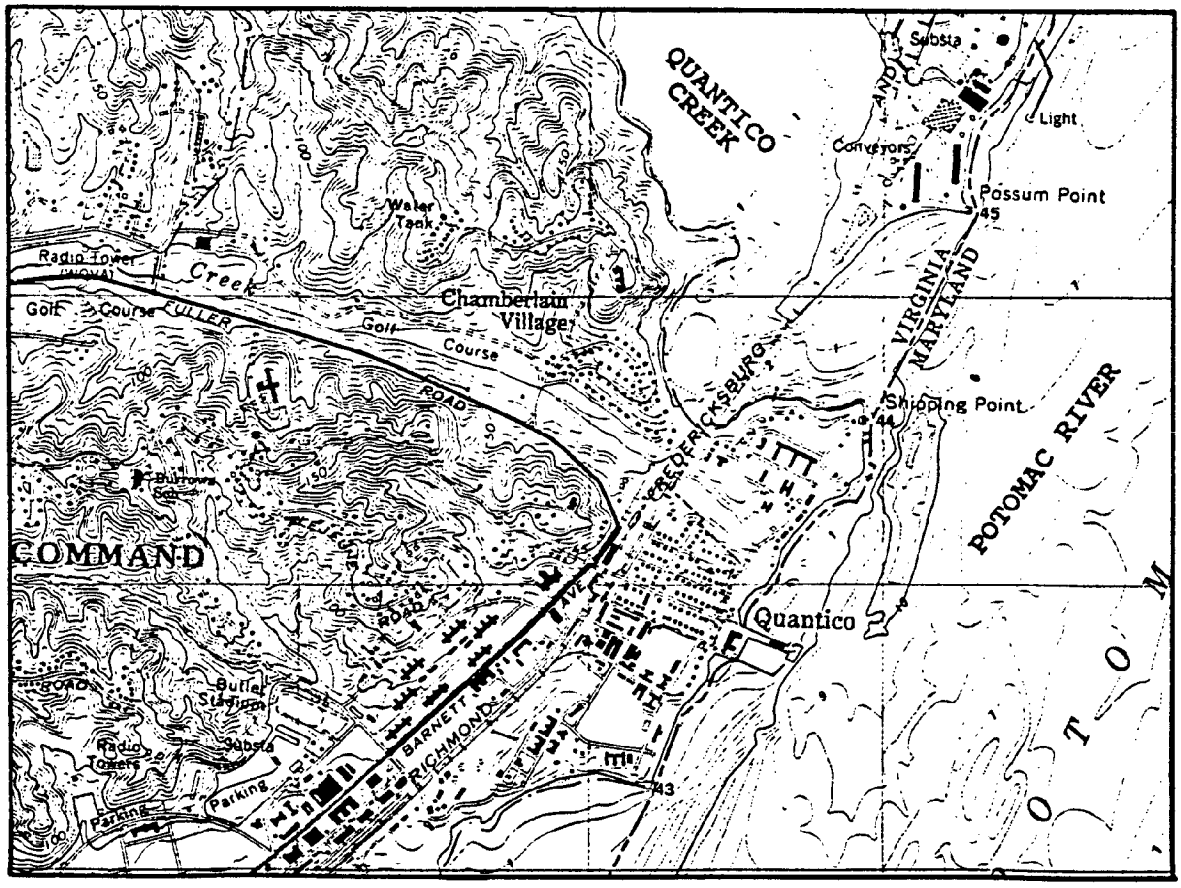
1966
PHOTOREVISED 1983
BATHYMETRY ADDED 1982
DMA 5561 III SE-SERIES V834

SCALE 1:24000

1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BATHYMETRIC CONTOUR INTERVAL 1 METER
WITH SUPPLEMENTARY 0.5 METER CONTOURS
DATUM IS MEAN LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
THE MEAN RANGE OF TIDE IS APPROXIMATELY 0.4 METER

Mapped By The Defense Mapping Agency
Edited And Published By The Geological Survey
And The National Ocean Service In Cooperation
With Commonwealth Of Virginia Agencies
Control By NOS/NOAA, And USCE



APPENDIX 11G - U.S. Geological Survey Topographical And Bathymetric Map (1966, 1982, And 1983)

MARINE CORPS BASE, QUANTICO

SERIES V834S EDITION 1-DMATC

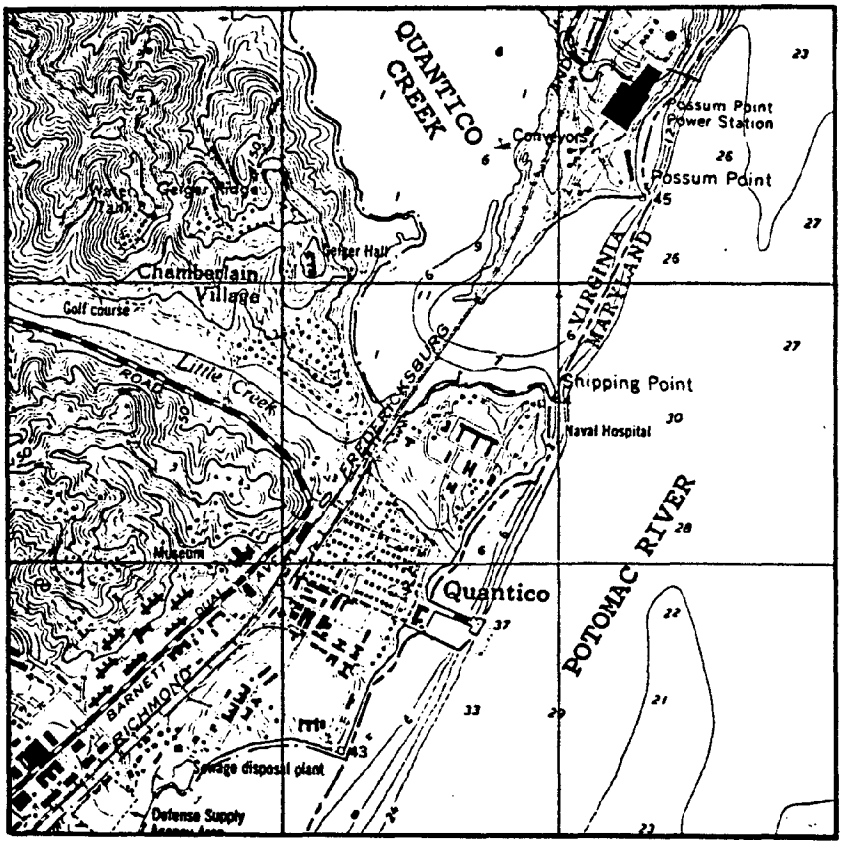
Prepared and published by the Defense Mapping Agency
Topographic Center, Washington, D. C.

LEGEND

MAP INFORMATION AS OF 1975

ON THIS MAP, A LANE IS GENERALLY CONSIDERED AS BEING A MINIMUM OF 8 FEET (2.5 METERS) IN WIDTH.

Scale 1:25,000



APPENDIX 11H - Defense Mapping Agency Map (1975)

APPENDIX 12

Nontidal Wetland Data Form

DATA FORM
ROUTINE ONSITE DETERMINATION METHOD[1]

Field Investigator(s): Mark Haus Date: 7/20/89
Project/Site: Potomac Riverfront Park State: VA County: Prince William Co.
Applicant/Owner: Town of Quantico Plant Community #/Name: Area 1 (W-1)
Note: If a more detailed site description is necessary, use the back of data form or a field notebook.

Do normal environmental conditions exist at the plant community?
Yes X No _____ (If no, explain on back)
Has the vegetation, soils, and/or hydrology been significantly disturbed?
Yes _____ No X (If yes, explain on back)

VEGETATION

Dominant Plant Species	Indicator Status	Stratum	Dominant Plant Species	Indicator Status	Stratum
1. Red Oak	FACU-	T	11. Grape Sp.	FAC-FACU	V
2. White Oak	FACU-	T	12.		
3. Poison Ivy	FAC	V	13.		
4. Virginia Creeper	FACU	V	14.		
5. Jewelweed	FACW	H	15.		
6. Lizard's Tail	OBL	H	16.		
7. Bracken Fern	FACU	H	17.		
8. Silky Dogwood	FACW	S	18.		
9. Black Cherry	FACU	S	19.		
10. Southern Arrowood	FAC	S	20.		

Percent of dominant species that are OBL, FACW, and/or FAC 50%
Is the hydrophytic vegetation criterion met? Yes X No _____
Rationale: 50% of the dominants are facultative and/or wetter

SOILS

Series/phase: Dumfries and Mattapex* Subgroup:[2] _____
Is the soil on the hydric soils list? Yes _____ No X Undetermined _____
Is the soil a Histosol? Yes _____ No X Histic epipedon present? Yes _____ No X
Is the soil: Mottled? Yes X No _____ Gleyed? Yes _____ No X
Matrix Color: 5Y3/1 10YR4/2 Mottle Colors: 10YR4/6
Other hydric soil indicators: _____
Is the hydric soil criterion met? Yes X No _____
Rationale: Chroma of 2 with mottles and less than 2 without mottles

HYDROLOGY

Is the ground surface inundated? Yes _____ No X Surface water depth: _____
Is the soil saturated? Yes X No _____
Depth to free-standing water in pit/soil probe hole: 10 to 12"
List other field evidence of surface inundation or soil saturation.

Is the wetland hydrology criterion met? Yes X No _____
Rationale: Saturated Soils

JURISDICTIONAL DETERMINATION AND RATIONALE

Is the plant community a wetland? Yes X No _____
Rationale for jurisdictional decision: _____
All three parameters present

[1] This data form can be used for the Hydric Soil Assessment Procedure and the Plant Community Assessment Procedure.
[2] Classification according to "Soil Taxonomy."

*Based on phone conversation with Prince William County SCS

DATA FORM
ROUTINE ONSITE DETERMINATION METHOD[1]

Field Investigator(s): Mark Haus Date: 7/20/89
Project/Site: Potomac Riverfront Park State: VA County: Prince William Co.
Applicant/Owner: Town of Quantico Plant Community #/Name: Area 2 (W-2)
Note: If a more detailed site description is necessary, use the back of data form or a field notebook.

Do normal environmental conditions exist at the plant community?
Yes X No _____ (If no, explain on back)
Has the vegetation, soils, and/or hydrology been significantly disturbed?
Yes _____ No X (If yes, explain on back)

VEGETATION

Dominant Plant Species	Indicator Status	Stratum	Dominant Plant Species	Indicator Status	Stratum
1. Jewelweed	FACW	H	11. Common Greenbriar	FAC	V
2. Tulip Tree	FACU	T	12. False Nettle	FACW+	H
3. Red Oak	FACU-	T	13.		
4. Virginia Creeper	FACU	V	14.		
5. Sumac	UPL	S	15.		
6. Black Cherry	FACU	S	16.		
7. Red Maple	FAC	S	17.		
8. Japanese Honeysuckle	FAC-	V	18.		
9. Poison Ivy	FAC	V	19.		
10. Sassafras	FACU	T	20.		

Percent of dominant species that are OBL, FACW, and/or FAC 50%
Is the hydrophytic vegetation criterion met? Yes X No _____
Rationale: 50% of dominants are facultative or wetter

SOILS

Series/phase: Dumfries and Mattapex* Subgroup:[2] _____
Is the soil on the hydric soils list? Yes _____ No X Undetermined _____
Is the soil a Histosol? Yes _____ No X Histic epipedon present? Yes _____ No X
Is the soil: Mottled? Yes _____ No X Gleyed? Yes _____ No _____
Matrix Color: 2.5Y5/4 Mottle Colors: _____
Other hydric soil indicators: _____
Is the hydric soil criterion met? Yes _____ No X
Rationale: Matrix Chroma

HYDROLOGY

Is the ground surface inundated? Yes _____ No X Surface water depth: _____
Is the soil saturated? Yes _____ No X
Depth to free-standing water in pit/soil probe hole: Well-drained
List other field evidence of surface inundation or soil saturation.

Is the wetland hydrology criterion met? Yes _____ No X
Rationale: Well-drained, upland area

JURISDICTIONAL DETERMINATION AND RATIONALE

Is the plant community a wetland? Yes _____ No X
Rationale for jurisdictional decision: Hydric soils and wetland hydrology not present

[1] This data form can be used for the Hydric Soil Assessment Procedure and the Plant Community Assessment Procedure.
[2] Classification according to "Soil Taxonomy."
*Based on conversation with Prince William County SCS

DATA FORM
ROUTINE ONSITE DETERMINATION METHOD[1]

Field Investigator(s): Mark Haus Date: 7/20/89
Project/Site: Potomac Riverfront Park State: VA County: Prince William Co.
Applicant/Owner: Town of Quantico Plant Community #/Name: Area 3 (W-3)
Note: If a more detailed site description is necessary, use the back of data form or a field notebook.

Do normal environmental conditions exist at the plant community?
Yes X No _____ (If no, explain on back)
Has the vegetation, soils, and/or hydrology been significantly disturbed?
Yes _____ No X (If yes, explain on back)

VEGETATION

Dominant Plant Species	Indicator Status	Stratum	Dominant Plant Species	Indicator Status	Stratum
1. Black Willow	FACW	T S	11. Silky Dogwood	FACW	S
2. Button Bush	OBL	S	12. Sweetflag	OBL	H
3. Pickeral Weed	OBL	H	13.		
4. Grape Sp.	FAC-FACW	V	14.		
5. Jewelweed	FACW	H	15.		
6. False Nettle	FACW+	H	16.		
7. Goldenrod Sp.	OBL-FACU	H	17.		
8. Sycamore	FACW-	S	18.		
9. Silver Maple	FACW	T	19.		
10. Cattail	OBL	H	20.		

Percent of dominant species that are OBL, FACW, and/or FAC 100%
Is the hydrophytic vegetation criterion met? Yes X No _____
Rationale: > 50% of dominants are facultative or wetter

SOILS

Series/phase: Dumfries and Mattapex* Subgroup:[2] _____
Is the soil on the hydric soils list? Yes _____ No X Undetermined _____
Is the soil a Histosol? Yes _____ No X Histic epipedon present? Yes _____ No X
Is the soil: Mottled? Yes X No _____ Gleyed? Yes _____ No X
Matrix Color: 7.5YR3/0 Mottle Colors: _____
Other hydric soil indicators: _____
Is the hydric soil criterion met? Yes X No _____
Rationale: Matrix chroma of zero

HYDROLOGY

Is the ground surface inundated? Yes X No _____ Surface water depth: 4"
Is the soil saturated? Yes X No _____
Depth to free-standing water in pit/soil probe hole: _____
List other field evidence of surface inundation or soil saturation.

Is the wetland hydrology criterion met? Yes X No _____
Rationale: Saturated conditions subject to periodic flooding

JURISDICTIONAL DETERMINATION AND RATIONALE

Is the plant community a wetland? Yes X No _____
Rationale for jurisdictional decision: All three parameters present

[1] This data form can be used for the Hydric Soil Assessment Procedure and the Plant Community Assessment Procedure.
[2] Classification according to "Soil Taxonomy."

*Based on phone conversation with Prince William County SCS

DATA FORM
ROUTINE ONSITE DETERMINATION METHOD[1]

Field Investigator(s): Mark Haus Date: 7/20/89
Project/Site: Potomac Riverfront Park State: VA County: Prince William Co.
Applicant/Owner: Town of Quantico Plant Community #/Name: Area 4 (W-4)
Note: If a more detailed site description is necessary, use the back of data form or a field notebook.

Do normal environmental conditions exist at the plant community?
Yes X No _____ (If no, explain on back)
Has the vegetation, soils, and/or hydrology been significantly disturbed?
Yes X No _____ (If yes, explain on back)

VEGETATION

Dominant Plant Species	Indicator Status	Stratum	Dominant Plant Species	Indicator Status	Stratum
1. Red Oak	FACU-	T	11. Rose Sp.	OBL-FACU	S
2. Jewelweed	FACW	H	12. Slippery Elm	FAC	T
3. Red Maple	FAC	S	13.		
4. Silver Maple	FACW	S	14.		
5. Silky Dogwood	FACW	S	15.		
6. Catalpa	FAC	T	16.		
7. Honeysuckle	FAC-	V	17.		
8. Black Cherry	FACU	S	18.		
9. Black Locust	FACU-	T	19.		
10. Sycamore	FACW-	T	20.		

Percent of dominant species that are OBL, FACW, and/or FAC 73%
Is the hydrophytic vegetation criterion met? Yes X No _____
Rationale: > 50% of dominants are facultative and wetter

SOILS

Series/phase: Fill Subgroup:[2] _____
Is the soil on the hydric soils list? Yes _____ No X Undetermined _____
Is the soil a Histosol? Yes _____ No X Histic epipedon present? Yes _____ No X
Is the soil: Mottled? Yes _____ No _____ Gleyed? Yes _____ No _____
Matrix Color: Fill material - varied Mottle Colors: _____
Other hydric soil indicators: _____
Is the hydric soil criterion met? Yes _____ No X
Rationale: Area composed of fill material

HYDROLOGY

Is the ground surface inundated? Yes _____ No X Surface water depth: _____
Is the soil saturated? Yes _____ No X
Depth to free-standing water in pit/soil probe hole: _____
List other field evidence of surface inundation or soil saturation.
Well defined channel
Is the wetland hydrology criterion met? Yes X No _____
Rationale: Well-drained swale that periodically floods

JURISDICTIONAL DETERMINATION AND RATIONALE

Is the plant community a wetland? Yes X No _____
Rationale for jurisdictional decision: Facultative or wetter vegetation exist and hydrology is present (even though fill did not exhibit usual hydric characteristics)

[1] This data form can be used for the Hydric Soil Assessment Procedure and the Plant Community Assessment Procedure.
[2] Classification according to "Soil Taxonomy."

APPENDIX 13

Laboratory Analysis Data Sheet on Composite Sediment Sample

DATA SUMMARY SHEET

Report No: 8679 Date: 08/21/89

Client: Town of Quantico
c/o Dewberry & Davis
Attn: Mark Headly
W.O. No. 05661-PZ874-ENG

Coll: 06/21/89
Recv: 06/22/89

Sample Description: Soil (Composite) - 12774

Sample Source: Stations 1,2,3,4,5 - Quantico Bay

Parameter	Results
Arsenic, mg/kg	<0.5
Barium, mg/kg	<50.
Cadmium, mg/kg	<2.
Chromium, mg/kg	<8.
Lead, mg/kg	10.
Mercury, mg/kg	<0.5
Selenium, mg/kg	<0.1
Silver, mg/kg	<4.0

NOTES:

1. Results expressed in ppm (mg/kg) dry weight.
2. Samples were dried and composited by weight.
3. Sample digestion was performed using EPA Method 3010.
4. Analysis was performed using atomic absorption (Flame spectroscopy).

William P. Batton
Director Signature

8/24/89
Date

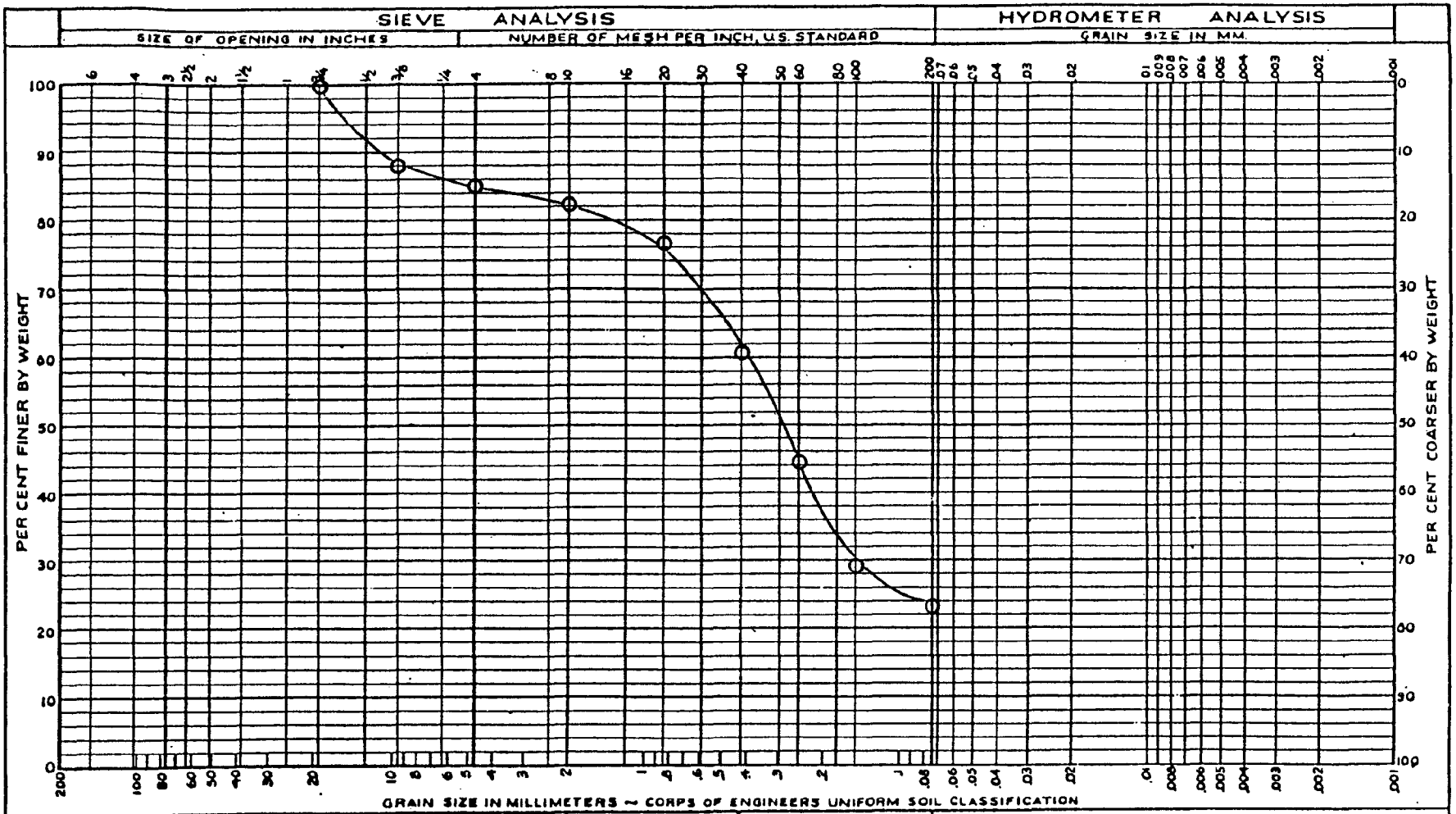
APPENDIX 14

Gradation Analysis Results on Sediment Samples from Samples No. 3, 5A, and 5B

Quantico 9-11-89

Sample:	S-3	S-5A	S-5B
Sieve		% Passing	
2 in		100.0	100.0
1 in		81.5	87.2
3/4 in	100.0	69.0	77.9
3/8 in	88.0*	50.1	58.1
No 4	85.1	37.4	46.9
No 10	82.3	30.2	39.2
No 20	76.4	21.6	31.7
No 40	60.8	8.1	16.6
No 60	44.3	3.0	7.9
No 100	29.3	1.9	3.9
No 200	23.4	0.9	2.6
Liquid Limit	28		
Plastic Limit	18	NP	NP
Plasticity Index	10		
Classification	SC	GP	GP

* All Shells



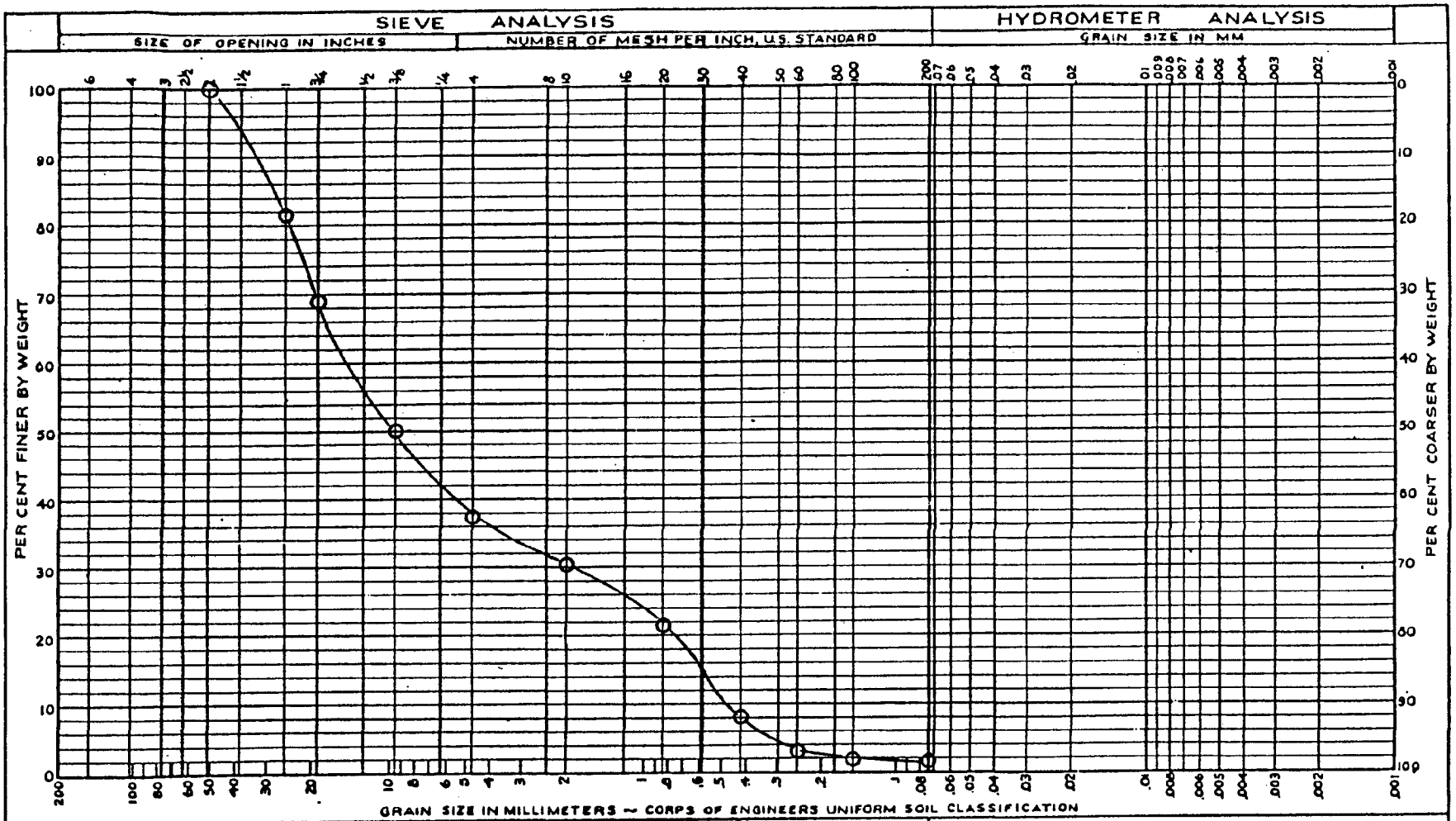
SAMPLE NO.	DEPTH - FT.	CLASSIFICATION	NAT W.C.	L L	P I	
S-3		SC		28	10	

GRADATION CURVES

Plotted:
Checked:

PROJECT Quantico
Sample data
S-3
Submitted by
Expl. or gp. sample No.
W/O No.
(Date of report)
Chief, Soil Mechanics Branch

[redacted]



SAMPLE NO.	DEPTH - FT.	CLASSIFICATION	NAT W.C.	L.L.	P.I.	
S-5A						

GRADATION CURVES

Plotted:

Checked:

PROJECT Quantico

Sample data

No. 5A

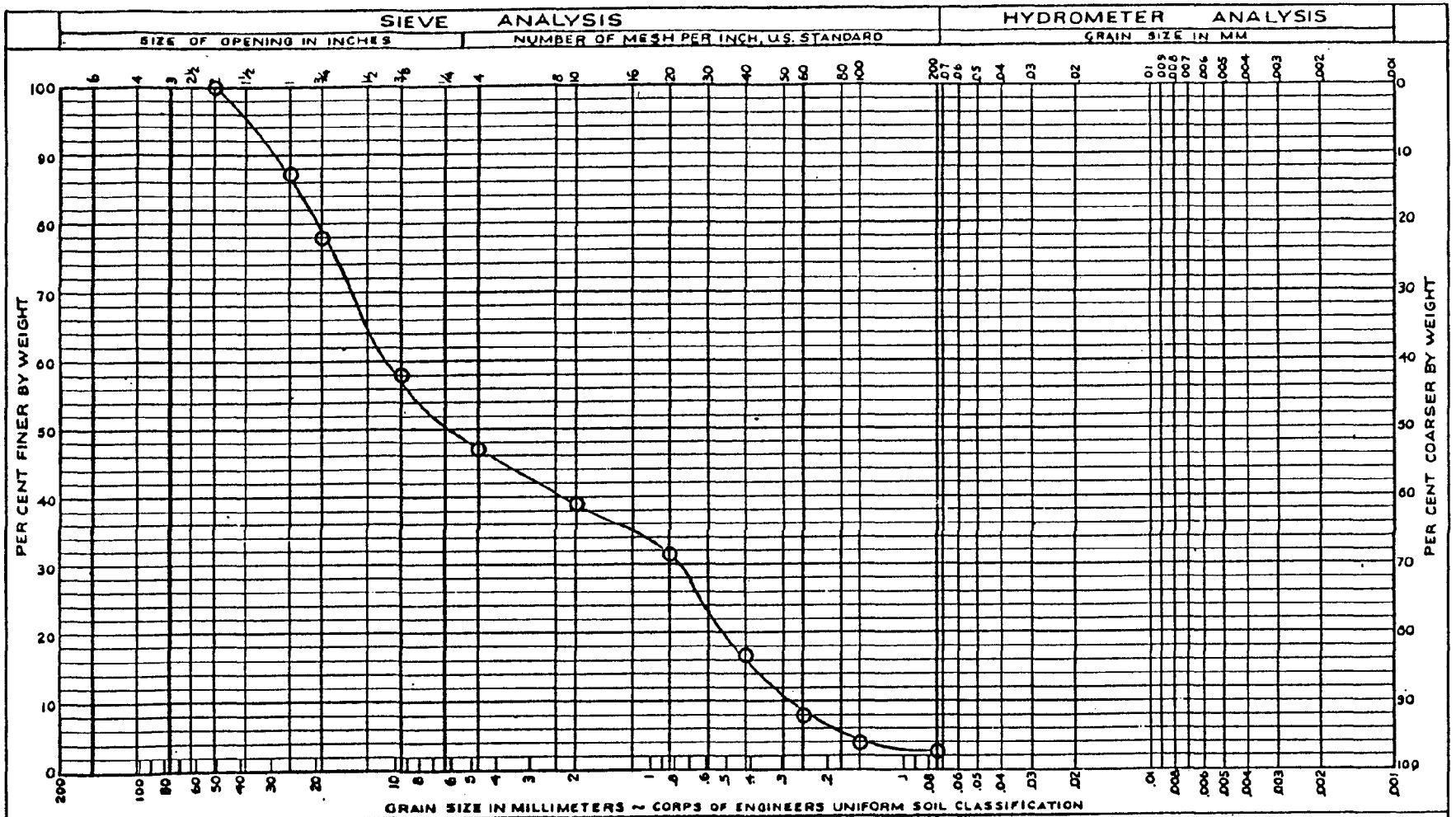
Submitted by

Expl. or gp. sample No.

W/O No.

(Date of report)

Chief, Soil Mechanics Branch



SAMPLE NO	DEPTH - FT.	CLASSIFICATION	NAT W.C.	L L	P I	
S-5B						

GRADATION CURVES

Plotted:

Checked:

PROJECT Quantico

Sample data

No 5B

Submitted by

Expl. or gp. sample No.

W/O No.

(Date of report)

Chief, Soil Mechanics Branch

APPENDIX 15
(A through F)

Additional Engineering Considerations and Analysis

APPENDIX 15

ADDITIONAL ENGINEERING CONSIDERATIONS AND ANALYSES

15.A. PUBLIC RIVERFRONT PARK FACILITIES

Conceptual Site Features

The upland portion of riverfront park area is easily accessable from west by way of the River Road (Exhibit 2). A short spur from River Road preferably along the Town's property line with the Naval Hospital in the north would provide the additional access required for both vehicular and better pedestrian access to the shoreline and the docking facilities.

The surface of the spur road could be paved or simply stabilized, but will have an open section in either case. This spur will take approximately 5,000 sq-ft of the park area including a 40-ft wide turn-around provided at the road's end where a boat ramp can be constructed at the shoreline.

For off-street parking purposes, a strip of land exists on three parcels of Town property along the western side of the River Road with a total length of at least 520 ft that appears to have no potential of grading problem for a minimum 20-ft wide parking area. This implies a minimum of (520 ft)/(9 ft) => 57 spaces for standard parking oriented perpendicular to the road. A 10-ft wide strip along the eastern side of River Road, on the other hand, would provide a minimum of (500 ft)/(18 ft) => 27 spaces. Thus, a total of 57+27 => 84 parking spaces are available for the marina, with additional area available for trailers.

Because there are no specific regulations in effect by either the Town of Quantico or by Prince William County regarding parking requirements for marina facilities, it was decided to apply the widely acceptable criteria of one off-street parking space with minimum dimensions of 9 ft x 18 ft for every two slips proposed for the marina. Thus, the minimum 84 parking spaces available would allow for a minimum of 2x84 => 168 slips for the marina.

Preliminary Site Limitations

It appears from the preceding preliminary evaluations that no site limitations or problems should be encountered in allocating adequate parking in the upland portion of the park and providing access spur to the shoreline under normal cicumstances.

Furthermore, due to the absence of any wetlands vegetation in the park area, these upland park area activities will not likely produce any major adverse environmental impacts. Finally, no special problems should be encountered in regards to additional minor upland amenities, such as a concession stand, a restaurant, a ships' store and similar public facilities. Clearly, however, the overall extent and likelihood of these "amenity" facilities is closely related to the degree of realization achievable for the proposed marina facilities on the "water" side of the project.

Preliminary Cost Estimates:

Considering only the improvements related to parking spaces and the spur access road, the following gross estimates can be made:

84 parking spaces, 84x9'x18'	= 13,608 sq-ft
Spur access road, 250'x20'	= 5,000 sq-ft
Shoreline turn-around, 40'x40'	= 1,600 sq-ft
Gross total surface area	= 20,200 sq-ft

Using 20,000 sq-ft or less than 1/2 acres of paved area including the spur access road and all parking, the upland park portion of the proposed project activities will probably require nearly (20,000 SF x $1.25/SF of surface =>) $25,000. A more detailed account of this and other conceivable "upland facilities" aspects of the project would be part of the future planning, engineering and costing studies.

15.B. MARINA FACILITIES

Boat Distribution Characteristics

An evaluation of the current boating trends in the region is an important step in planning of marina facilities. Such an evaluation was performed using a computerized data base for the Potomac Estuary, and other data gathered for various marinas in Virginia and Maryland. A graphic presentation of these boat distribution data are given in Figures 15.1 and 15.2.

Also considered carefully were the particular site conditions of the proposed Quantico marina basin, in regards to boating and navigation characteristics. It is important to note that the project site is quite unique with its immediate access to the minumum 25-ft deep waters of the main channel of the Potomac River. This implies that the boats will spend virtually negligible navigation time between the marina and the main channel of the Potomac River.

A discussion was held with Mr. Rusty Arcuni, the Harbor Master of the Marine Corps Base marina and dock, on the overall features of the facility in regards to boating. It was learned that there has been a significant demand for slips to accomodate larger boats mainly because of the extreme proximity of the wide open and deep waters of the Potomac River. Similar conditions and criteria will certainly be valid for the proposed marina.

Preliminary Features of the Marina Structures and Facilities

The main features of the proposed marina will be two floating piers with slips on both sides and on ends, additional slips off a floating dock along the marina side of the breakwater, the seawall with t least partial improvements and a boat ramp. Of the several possible configurations and number of slips, the ultimate selection will depend on both economic and environmental factors, including the typical dimensions of these structures (refer to Table 15.1), but perhaps more importantly, the extent of dredging that can be realized.

Two dredging scenarios considered for the proposed marina basin are illustrated in Figures 15.3 and 15.4. Dredging Scenario No. 1 is to accomodate 143 slips and calls for lowering the bottom elevation to an elevation of approximately -8 MLW between the Tees of the floating piers and the breakwater, while the remainder of the basin would be lowered to the approximate elevation of -6 MLW. Dredging Scenario No. 2, on the other hand, involves a largely "scaled-down" dredging to accomodate 68 slips only at the deeper portions of the basin. The possible dock configurations for these two cases are summarized in Table 15.2.

The marina layouts considered above are based on a breakwater constructed with the proposed alignment to protect the basin from northerly storms. Without the breakwater, the marina would be reduced from that of a sheltered harbor to an open pier. A marina with a very small number slips will probably not justify the cost of the breakwater.

Section 15.G presents the principal elements and the associated preliminary cost estimates for the proposed project and four additional alternatives. Regarding the extents of dredging and docking configurations considered, these alternatives provide a fairly wide spectrum of the potential applications. Nevertheless, a more detailed study will eventually be needed to determine the extent of dredging, boat size distribution, dock and slip layouts desired and to finalize breakwater alignment and cross section, subsequent to the resolution of the environmental questions.

Table 15.1 - Typical Dimensions for Piers, Slips and Catwalks

* From Ramsey & Sleeper: Architectural Standards, 7th Ed., p. 180 *

Length Group of Boat [ft]	Maximum Beam of Boat [ft]	Maximum Beam of Boat [in]	Minimum Distance to Anchor Pile [ft]	Minimum Distance to Anchor Pile [in]	Minimum Clear Width for Each Slip [ft]	Minimum Clear Width for Each Slip [in]	Gross Width of Each Slip [ft]	Gross Width of Each Slip [in]	Width of Catwalk [ft]	Width of Catwalk [in]	CL to CL Width of Each Pair of Slips [ft]	CL to CL Width of Each Pair of Slips [in]	Minimum Clear Fairway Width [ft]	Minimum Clear Fairway Width [in]	Total Catwalk Length [ft]
Up to 14	6	7	17	0	8	10	10	9	4	0	25	6	21	0	12
14 to 16	7	4	19	0	9	8	11	7	4	0	27	2	24	0	12
16 to 18	8	0	21	0	10	5	12	4	4	0	28	8	27	0	14
18 to 20	8	7	23	0	11	1	13	0	4	0	30	0	30	0	16
20 to 22	9	3	25	0	11	9	13	8	4	0	31	4	33	0	18
22 to 25	10	3	28	0	13	1	14	0	4	0	32	0	37	6	18
25 to 30	11	3	33	0	14	3	15	2	4	0	34	4	45	0	20
30 to 35	12	3	38	0	15	8	17	7	4	0	39	2	52	6	22
35 to 40	13	3	43	0	16	11	18	10	4	0	41	8	60	0	24
40 to 45	14	1	48	0	17	11	19	10	4	0	43	8	67	6	26
45 to 50	14	11	53	0	19	0	20	11	4	0	45	10	75	0	28
50 to 60	16	6	63	0	21	0	22	11	4	0	49	10	90	0	34
60 to 70	18	1	73	0	23	0	24	8	4	0	53	4	105	0	34
70 to 80	19	9	83	0	24	11	26	7	4	0	57	2	120	0	34

Table 15.2 - Town of Quantico Marina: Alternative Dock Configurations

PROPOSED PROJECT :

Length Group of Boat	NUMBER OF SLIPS IN EACH DOCK							TOTAL ALL DOCKS
	DOCK A	DOCK B	DOCK C	DOCK D	DOCK E	DOCK F	DOCK G	
< 20'			10			14		24
21' to 25'		25	15			24		64
26' to 35'				20	22			42
36' to 40'	8							8
41' to 50'	4							4
> 50'							1	1
GRAND TOTAL	12	25	25	20	22	38	1	143

ALTERNATIVE 1 :

Length Group of Boat	NUMBER OF SLIPS IN EACH DOCK							TOTAL ALL DOCKS
	DOCK A	DOCK B	DOCK C	DOCK D	DOCK E	DOCK F	DOCK G	
<= 20'								0
21' to 25'		10	12			14		36
26' to 35'				10	9			19
35' to 40'	8							8
41' to 50'	4							4
> 50'							1	1
GRAND TOTAL	12	10	12	10	9	14	1	68

BOAT REGISTRATION, VIRGINIA & MARYLAND
Boat Size Distribution

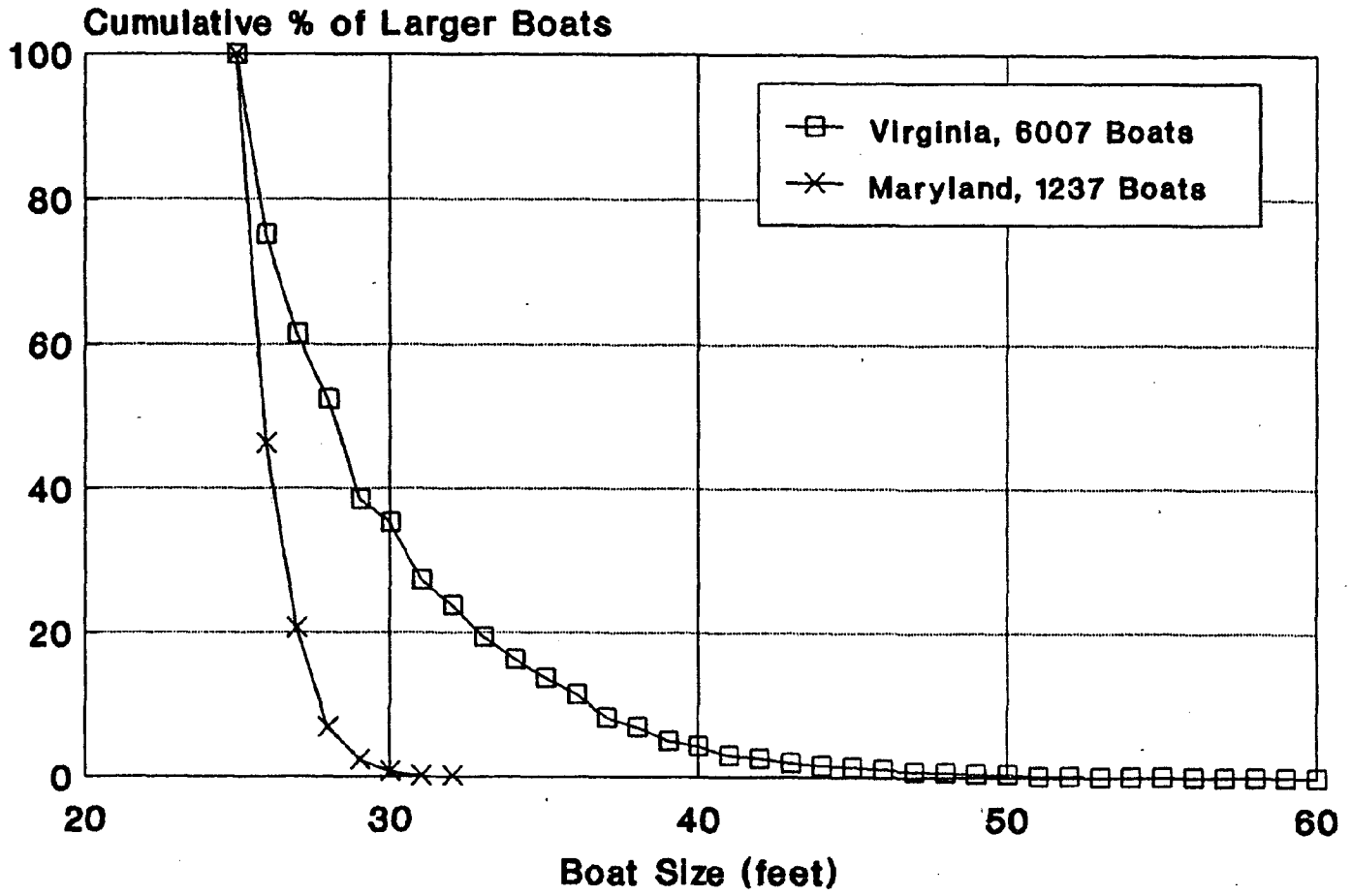
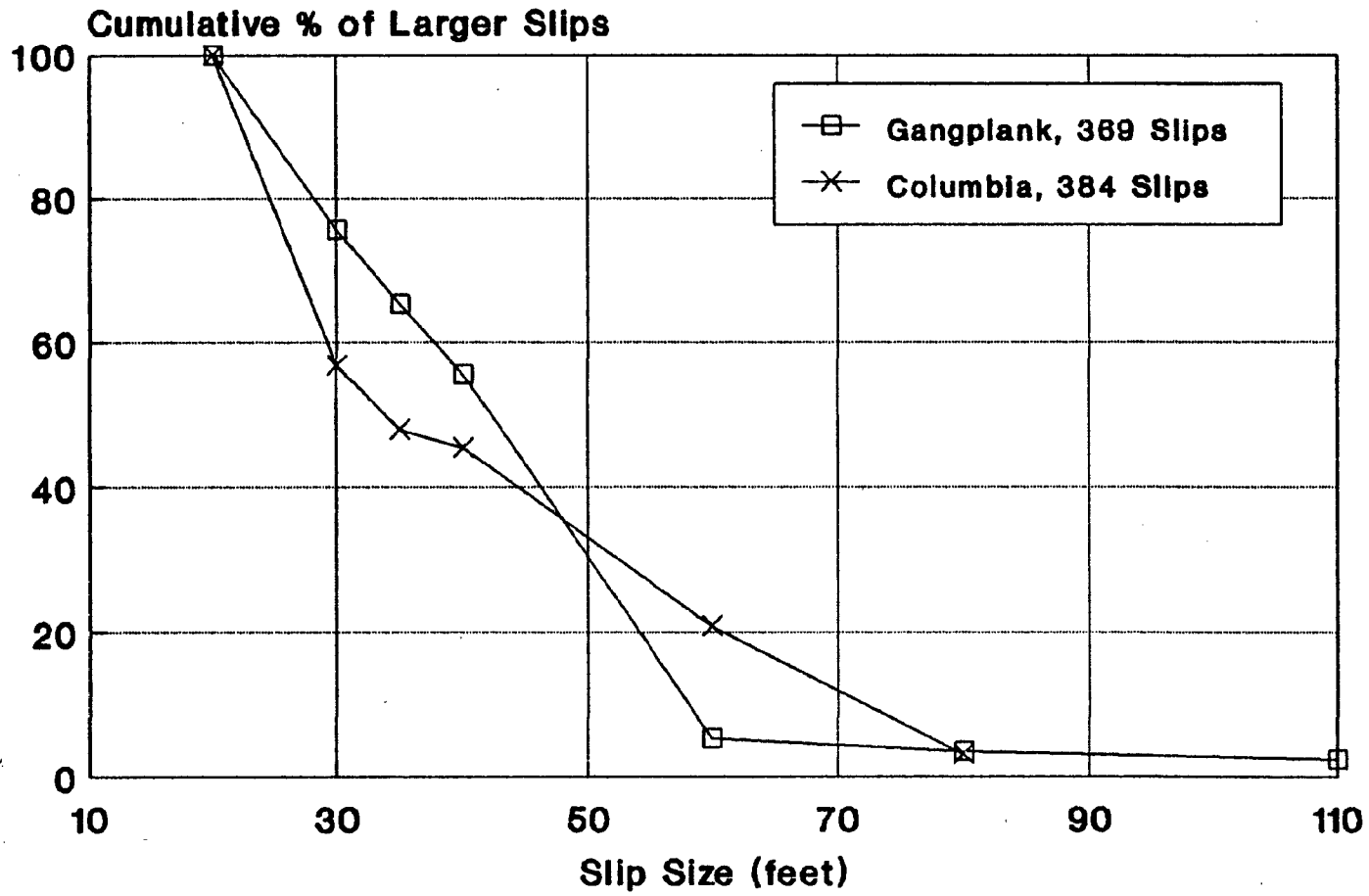


FIGURE 15.1 - Registered Boat Size Distributions in Virginia & Maryland

TWO MARINAS IN WASHINGTON, D.C.
Slip Size Distribution



FIGUR E 15.2 - Slip Size Distributions for two Marinas in Washington, D.C.

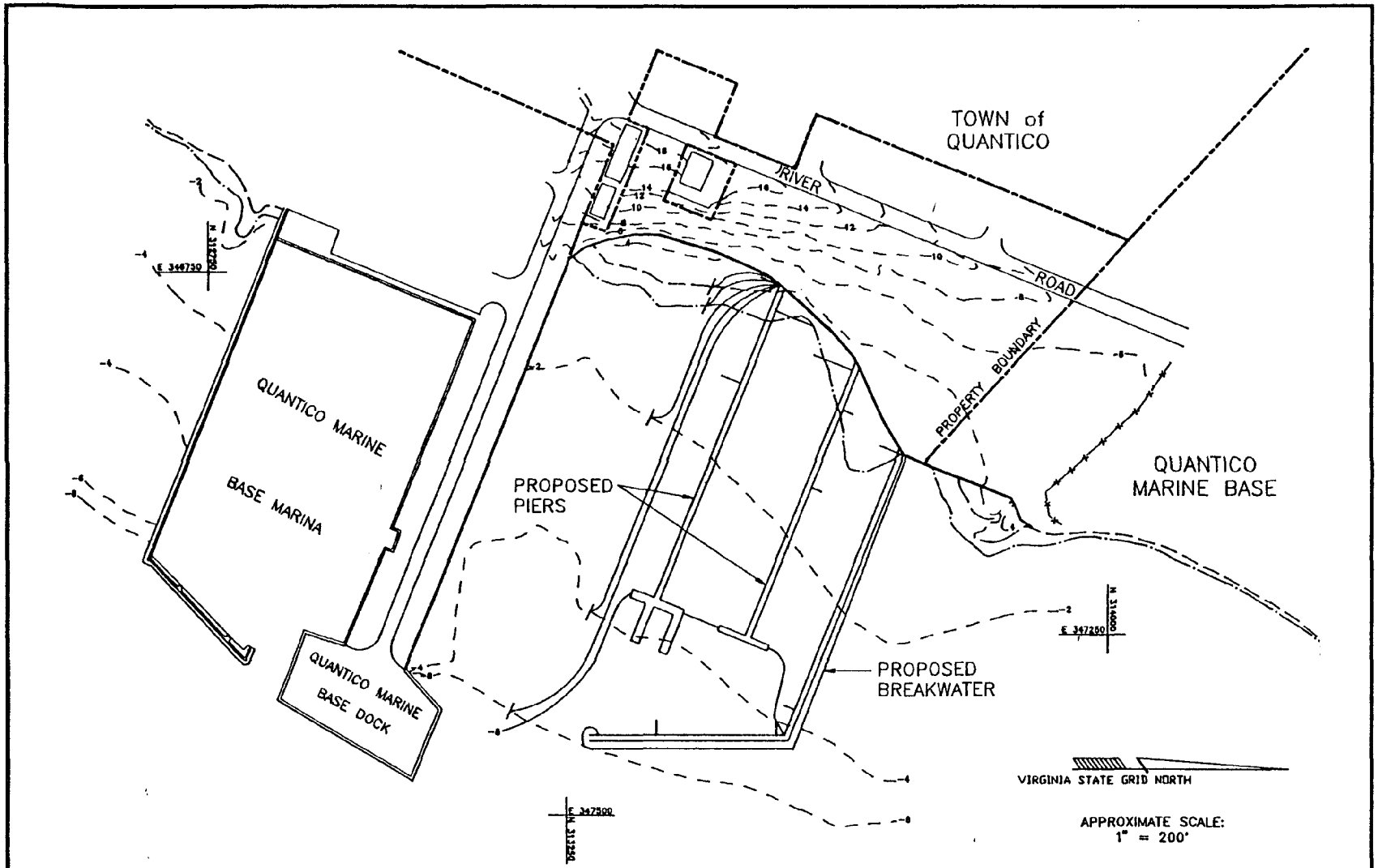


FIGURE 15.3 – Dredging Scenario No. 1

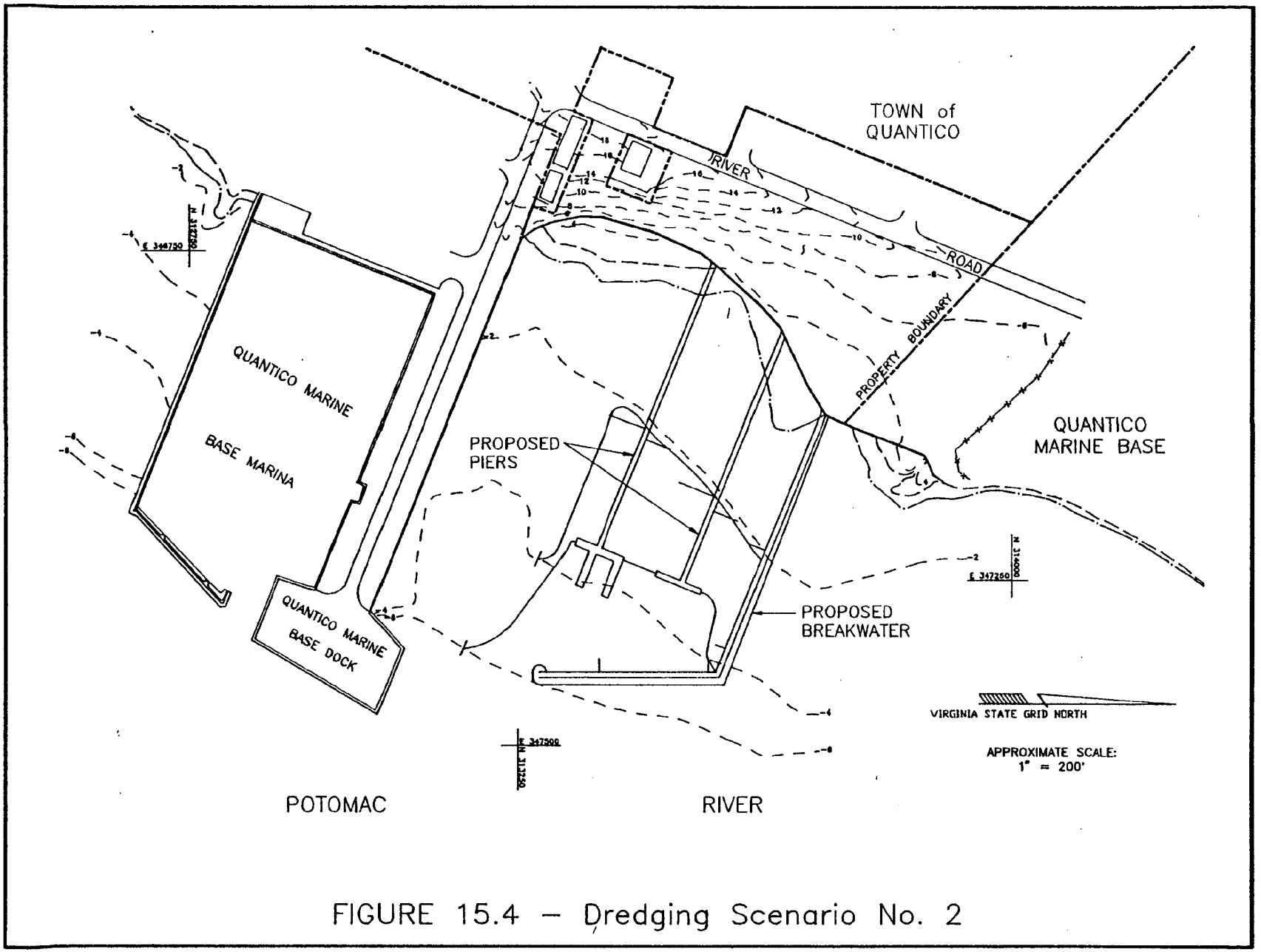


FIGURE 15.4 – Dredging Scenario No. 2

Materials and Construction Methods

After a review of the available literature, several discussions and correspondence with several manufacturers and contractors, site-specific conditions and regional trends, it was determined that the floating docks will consist of modular deck and frame systems with standard fenders and anchorage or support piles. It is a common feature of these systems that polyethylene floats with polystyrene beads provide long-lasting protection against salt-water corrosion, ice and boat impact damage, and harmful marine biota. Floating docks also provide a specified freeboard and adequate spacing for passage of currents, debris and ice. Furthermore, ice control equipment (ice-eaters) will virtually be a mendatory option for this project.

The construction and installation methods and the equipment used vary among the manufacturers. Adequately prepared specifications and inspection procedures would ensure environmentally feasible, economically viable and structurally safe floating docks.

Preliminary Cost Estimates

For the proposed project, the floating piers involve 1,620 feet of the 8-foot wide standard docks, and an additional 180 feet of 12-foot wide fuel docks. Currently, the average unit cost of the typical floating docks is $23.00 per square feet (SF) of the deck area for the material and installation, with additional $6.50/SF for utilities and approximatelty $8.00/SF for guide piles. Hence, applying a total installed unit cost of $37.50/SF, the estimated cost of the floating docks for the proposed scenario becomes:

[(1,620')(8')+(180')(12')] [$37.50/SF] = (15,120 SF) ($37.50/SF) = $567,000.

Cost estimates for the floating pier components of the various alternatives considered are presented in Section 15.G.

15.C. BREAKWATER

Preliminary Configuration

As depicted by Exhibits 3 or 4, the configuration of the proposed breakwater is basically a symmetrical image of the Marine Corps Base marina on the south side of the Marine Corps Base dock with the dock itself being the axis of symmetry. This configuration is recommended for all alternative designs. However, its exact point of attachment to the shoreline may be subject to revision due to easement and setback requirements to be determined later.

The breakwater is formed of two principal segments. The portion attached to the shoreline is approximately 450 ft long, and parallel to the northern edge of the Marine Corps Base dock. As such, this segment is also approximately perpendicular to both the shoreline and the north-north-east direction expected to produce the "design storm" waves. The second segment is nearly 280-ft long and defines the northern end of the inlet to the proposed marina basin, whereas the inlet's southern end is defined by the Marine Corps Base dock.

Based on tidal and riverine flood evaluations and design wave predictions, the top elevation for the breakwater was set as 7.0 ft above MLW for the entire breakwater for the purposes of this concept study. This top elevation is about 1.5 ft higher than the that of the Marine Corps Base dock, and expected to provide a safe harbor for the marina basin with a fairly low risk of being overtopped during most storms.

Materials and Construction Method

Structurally, the breakwater will be constructed of precast reinforced concrete pipe/piles with timber fillers, quarry-stone riprap toe protection on the outboard side of the wall, and a reinforced concrete slab cap on top. A typical section of the breakwater is shown schematically in Figure 13.

Based on preliminary geotechnical and hydrodynamic evaluations, the precast reinforced concrete piles was tentatively set to be 4 ft in diameter with 5-inch wall thickness and 25-ft length in deeper parts of the basin. These dimensions would be typical for the offshore segment of the breakwater with the proposed dredging conditions. For less dredging and near the shoreline with shallower depths, these dimensions would decrease. In particular, the pile length required could be reduced to about 15 ft. However, determination of the actual pile lengths required must await detailed geotechnical investigations and finalization of the basin geometry.

The piles will be driven using several inches of space and timber fillers will be applied after all the piles are in place. These timber fillers could be sized to fit locally and will render the wall basically impermeable. In addition to providing a smoother surface on the marina side, use of spaced pilings will also help reduce the risk of pile damage during driving and will result in significant savings in both material and labor costs.

The top of the piles will be covered with a minimum 18-inch thick reinforced concrete slab running along the entire breakwater. The primary functions of this slab will be to provide lateral support for the piles and uniform appearance to the wall despite the likely unevenness of the pile tops after they are driven.

The marina side of the breakwater wall will be a vertical wall extending down to the existing or otherwise dredged bottom. This is not expected to promote local scour at the base of the wall in view of the low-speed boating and otherwise calm waters within the marina basin.

In order to reduce the risk of scour on the outer side of the wall exposed to the waves and currents of the Potomac River, on the other hand, quarry-stone type riprap will be placed along its base for toe protection. For a design wave height of 4.5 ft, the average weight of the armor stone required will be about 640 lbs, increased to nearly 875 lbs for a 5-ft high design wave. The Shore Protection Manual suggests that a ±25%-spread should be applied around these average sizes to determine the minimum and maximum sizes of stone for the top layer of a stone revetment. It should be noted, however, that these stones will provide toe protection to the breakwater, and as such, all be submerged at least 2 ft below water surface, unlike a stone revetment which would be directly exposed to the oncoming waves. It should also be remarked that these stone sizes are applicable for the offshore segments of the breakwater with relatively deep water and the waves breaking in the immediate vicinity of the breakwater thus dorectly and fully impacting the structure. As the water depth decreases towards the shoreline along the outer wall of the breakwater, smaller size stones may be used because of the reduced wave height due to shoaling effects and breaking of waves farther away from the breakwater.

The preceding considerations lead to the following design recommendations for the riprap protection:

- use 200-lb to 800-lb armor stones to form the top layer;
- use gradually smaller armor stones near the shoreline, but no less than 200-lb to 600-lb stones on the top layer;
- use the heavier stones to form a minimum 3-ft wide toe;
- excavate minimum 1-ft below existing grade to place the toe;
- use smaller (50-lb to 100-lb) stones for the lower layers;
- use a woven plastic filter cloth along the entire base of the riprap and up the face of the breakwater;
- provide 2-ft wide top and 2:1-sloped face for the riprap as determined by the local water depth;
- provide the 3-ft wide toe as a minimum, even where the water depth is shallow and does not allow for a sloped-face.

An adequately designed riprap will efficiently dissipate the energy of oncoming waves, and thereby minimize reflection and virtually eliminate the risk of local scour in front of the breakwater. It will also provide a favorable environment for the shallow water habitat with its essentially porous strcuture.

Preliminary Cost Estimates

PRECAST CONCRETE PILES:

The 4-ft diameter, circular, precast reinforced concrete piles will be spaced at approximately 5-ft intervals. For all piles, the top elevation will be approximately constant, about 1.0' below the top of the reinforced concrete cap running along the entire breakwater, pile top elevation of +6.0 MLW. The bottom or the tip elevation will depend on the actual location of the pile, and governed by the detailed design requirements accounting for the local geotechnical and design wave characteristics. For the "offshore segment" of the breakwater running nearly parallel to the shoreline, where the water depth adjacent to the breakwater will be maximum with the existing or otherwise dredged bottom elevation being approximately -7.0 MLW, with nearly 28-ft long piles, depending on the stiffness of the local soil strata. For the shallowest regions of the breakwater, the minimum value of 16 ft is used. Thus:

Total of 146 piles: 66 @ 8-ft, 20 @ 24-ft, 20 @ 20-ft, and 40 @ 16-ft; total of 3,368-ft length for all piles, unit cost of $95/LF (linear foot, vertical, in place, including the treated timber fillers=, and hardware): 3,368-ft x $95/LF = $319,960

PRECAST CONCRETE CAP:

The cap section of the breakwater will be reinforced concrete, probably cast in place after the piles are driven, with a total (conservative) volume of 6-ft wide x 2-ft deep x 730-ft long / (27 cu-ft/C.Y.) = 325 C.Y., and estimated cost of:

@ $175/C.Y. (in place)= $56,875

HAND RAILS:

A pair of aluminum hand rails will run along each side of the top of the breakwater, with a total length of 2x730 ft=1,460 ft and estimated cost of:

@ $41/LF (in place) $59,860

QUARRY-STONE RIPRAP TOE PROTECTION:

Four different typical cross sections were considered for the quarry-stone riprap for toe protection to be placed along the outer wall of the breakwater based on the local water depth. All of these cross sections have the same apron-top elevation of -2.0 MLW; whereas the toe-top elevation varies between -6.0 and -2.0 MLW, as tabulated below:

DESCRIPTION/LOCATION OF TOE-RIPRAP SEGMENT	APPROX LENGTH [FT]	APPROX. AVE.TOE ELEV[FT]	APPROX. VOLUME [C.Y.]
N-S Segment, Offshore	280	-6.0	518.5
W-E Segment, outermost 50'	50	-6.0	92.6
W-E Segment, next 200'	200	-3.0	192.6
W-E Segment, next to shore	200	-2.0	44.1
Entire Riprap Toe Protection	730		847.8

With unit weight of 1.5 Tons/C.Y., total weight =>> 1,300 tons

Use unit cost of $50/Ton for quarry-stone riprap toe in place:

Total Cost of Quarry-Stone Riprap Toe Placed = $65,000

Based on the above, the total estimated cost of the entire breakwater may be evaluated as follows:

Subtotal, Construction Cost	$501,695
Mobilization, @ 2.5% of Construction Cost	$ 12,543
Subtotal, Construction + Mobilization Costs	$514,237
Contingency, @ 20% of Construction+Mobilization Costs	$102,847
TOTAL BREAKWATER COST	$617,085
AVERAGE COST OF BREAKWATER ($617,085/730 ft) =	$845/LF

ALTERNATE DESIGN: QUARRY-STONE BREAKWATER

An alternate design to the breakwater with precast concrete piles referred to above is a quarry-stone breakwater with the following preliminary features for its maximum cross section:

Top width	= 4.0 ft	Top Elev	= +7.0 ft
Side Slopes	= 2:1	Toe top Elev	= -6.0 ft
Toe Width	= 4.0 ft	Toe bottom Elev	= -8.0 ft

The minimum cross section, on the other hand, will have:

Top width	= 4.0 ft	Top Elev	= +7.0 ft
Side Slopes	= 2:1	Toe top Elev	= -0.0 ft
Toe Width	= 4.0 ft	Toe bottom Elev	= -2.0 ft

Quarry-stone in the 600-lb to 1,200-lb range would be recommended to provide stability for the top layer of the breakwater against design wave heights of up to 5.0 ft where the breakwater is at its maximum size. For the layers below the top layer, and along the segments of the breakwater with shallower water depths, the stone size may be as low as 200-lb to 800-lb range. With 330 ft of the full section, and the remaining 400-ft transition to the minimum cross section, the following preliminary quantity and cost estimates are obtained:

11,600 C.Y = 17,400 tons of 200-lb to 1,200-lb quarry-stone:

@ $50/ton in place (including filter cloth)	= $ 870,000
Contingency @ 15% (Lower-risk construction)	= $ 130,500
TOTAL QUARRY-STONE BREAKWATER COST	= $1,000,500
AVERAGE COST OF BREAKWATER ($1,000,500/730 ft)	= $1,370/LF

A comparison based strictly on the preceding preliminary cost estimates for the proposed and alternative breakwater scenarios clearly favors the proposed scenario.

15.D. SEAWALL IMPROVEMENTS

Preliminary Configuration

The proposed scenario with breakwater involves replacement of the deteriorated portion with a full-section stone revetment and improvement of the remainder portion of the existing seawall with wedge-shaped stone reinforcement and otherwise minor repairs.

The deteriorated portion of the existing seawall is approximately 100-ft long, and it exhibits broken concrete rubble, considerable wash-off of backfill material and exposed roots of three trees within 10 to 15 feet of the wall alignment. This segment would be replaced by a full-section quarry-stone revetment with a top elevation of +5.0 MLW at its 5-ft wide apron, 2:1-sloped face and 4-ft wide toe and the toe top placed at approximately at MLW, with the typical geometrical features as shown in Figure 15(a).

The segment of the wall to be reinforced covers nearly 200 ft of the shoreline within the proposed marina basin area. As shown in Figure 15(b), the riprap toe protection would be wedge-shaped, with a top elevation of +2.0 MLW at its 2.0-ft minimum wide apron, a 2:1-sloped face where required, and the toe-top again placed at approximately MLW. This reinforcement may be extended as necessary beyond the marina basin portion of the shoreline, excluding perhaps the beach segment of the shoreline.

It is recommended that the shoreline segment north of the Town property be also stabilized with or without the breakwater. This may be achived using the full-section stone revetment where there is no structure protecting the shoreline or the wedge-shaped reinforcement with the same features as those being recommended for the Town's shoreline. Consequently, the off-site shoreline improvements would basically be a continuation of the Town's stabilized shoreline.

Materials and Construction Method

Quarry-stone will be used for both the full-section revetment and stone reinforcement. With the breakwater in place, the stones along the Town's shoreline will be in the 200-lb to 600-lb range. Because the offsite segment of the shoreline in the north adjacent to the Town's shoreline will be exposed to northerly storms irrespective of the breakwater, 600-lb to 1,600-lb armor stones should be used to protect this segment of the shoreline. In either case, larger stones will be placed to form the toe section, with smaller stones to be placed up the 2:1-sloped face forming at least a 2-stone thick section. In order to form a relatively smooth surface and provide added stability, 50-lb to 200-lb stones will be used for "chinking" the armor stone, particularly in the case of the full-section stone revetment. The existing bottom will be excavated a minimum of 1-ft for toe placement, and elsewhere along the base of the structure as necessary. This will reduce the risk of instability due to local scour and settlement in the future.

Woven plastic filter cloth will be laid along the entire base of the stone structures with the fabric material not extending beyond the base to prevent the risk of local scour induced by the possible flopping motion of material. Over the filter cloth, a protective layer 3-inch to 8-inch bedding-stone will be placed before the quarry-stone layers are placed.

Any existing storm drain pipes will be extended through the stone revetment or stone reinforcement structure to discharge at the 1:2-sloped face with an invert elevation at or above MLW in order to ensure adequate outfall.

Finally, it is important that these structures be constructed by the method of "placement" and not by "dumping" the stones in order to achieve long-lasting stability.

Preliminary Cost Estimates

Based on the preceding considerations and the geometric features shown in Figures 14(a) and 14(b) in Section III.B, the following preliminary cost estimates were obtained:

DESCRIPTION/LOCATION OF STONE STRUCTURE	APPROX LENGTH [FT]	APPROX VOLUME [CY]	APPROX WEIGHT [TONS]
Full-Section Stone Revetment	100	196	275
Transition Section	50	75	105
Stone Reinforcement	150	155	217
Entire Improvement	300	426	597

Using 600 tons of quarry-stone and unit cost of $50/ton in place including mobilization, excavation for toe placement, material and labor for bedding stone and filter fabric:

Construction cost, seawall improvement	= $30,000
Additional wall repair and regrading, etc.	= $ 7,500
Subtotal, construction cost	= $37,500
Contingency, @20% of subtotal construction cost	= $ 7,500
APPROXIMATE STONE SEAWALL IMPROVEMENT COST	= $45,000
AVERAGE COST OF IMPROVEMENT PER L.F. OF SEAWALL	= $150/LF

Because the average cost of stone delivered to site, its handling by the conventional equipment and other labor associated with armor-stone structure construction are practically independent of the armor-stone size range considered for this project, the above cost estimates are valid for stone shoreline improvement scenarios both with and without the breakwater in place.

15.E. DREDGING

Preliminary Characteristics of Dredge Material

An important objective of the environmental field measurements was to gather water and sediment samples in representative locations throughout the project area and assess the likelihood of the presence of hazardous or otherwise environmentally sensitive constituents in the basin material proposed to be dredged. These investigations were further supplemented by a review of the general water quality of Potomac River in the region, a preliminary geologic evaluation presented in the Geotechnical Consultant's Report, and an overall evaluation of the chances for hazardous waste disposal in the vicinity that would possibly impact the project area, and the bottom sediments in the proposed marina basin, in particular.

No heavy metals were encountered in these samples, leading to the conclusion that the likelihood of finding toxic constituents in the marina basin was practically negligible.

It was also determined that the material is mostly granular with particles finer than 0.1 mm being no more than 20 % towards the southwest corner of the basin, and less than 5% elsewhere in the basin, with no cohesion or otherwise plastic behavior. There is a chance of encountering cobble size material, according to the general geologic information available for the vicinity, which has the potential of complicating dredging activities to a certain extent, at least locally.

It can be concluded, nevertheless, that the dredge material is not likely to present any major environmentally unfavaroble characteristics during the actual dredging, transportation or disposal phases of the dredging operations, irrespective of whether the proposed dredging is carried out hydraulically or mechanically.

Approximate Quantities

Two dredging scenarios are considered in conjunction with the proposed marina layouts shown schematically in Figures 15.3 and 15.4. Dredging Scenario No. 1 is aimed at accomodating a full-scale marina under the given environmental circumstances of the basin, while Dredging Scenario No. 2 seeks to minimize the amount of dredging for a viable marina. In both cases, the marina is confined to the northern half of the basin, leaving the southern half adjacent to the Marine Corps Base dock quite undisturbed. Dredging Scenario No. 1 calls for dredging the bottom of the basin to an average elevation of -8.0 MLW outboard from the proposed fueld dock or the end of the floating piers, and to an average elevation of -6.0 MLW virtually up to the shoreline in the remainder of the proposed marina area. Under this scenario, assuming a 3:1 slope along the perimeter of dredging, the total dredge volume will be approximately 30,000 cubic yards and the total surface area to be disturbed will be nearly 5.0 acres. The area disturbed will be about 56% of he total basin area, defined essentially by the Marine Corps Base dock, the shoreline and the proposed breakwater.

For Dredging Scenario No. 2, the approximate dredge volume and surface area of disturbance are reduced to 4,500 cubic yards and 2.5 acres, respectively, corresponding to a drastically reduced surface area disturbance of only 28% of the entire basin area.

It should also be noted that "no dredging" is not a practical option when associated with a marina of virtually any size, however small it may be. Even though the marina area may be drastically reduced and confined to the naturally deepest portions of the basin, there will nevertheless be some periodic distuirbance of the bottom. In order to assure safe navigation conditions for the boats, it will be necessary to periodically clear any local deposits of the sediments along with any submerged aquatic vegetation that may emerge on the bottom.

Proposed Dredging Method and Alternative Scenarios

Depths involved and the size range and type of sediments found in the bottom of the basin area do not suggest either mechanical or hydraulic method of dredging to be preferred over the other. In the case of this project, the final determining factor will be the actual dredge volume that will be handled, the location of the dredge disposal site and the overall environmental features of each scenario.

If only a small amount of material is dredged from the deepest parts of the basin, it would probably be performed mechanically by a clamshell, for example, and either barged or trucked to the disposal site.

If a relatively large quantity is to be dredged and the material in the deeper portions of the basin bottom is adequate, hydraulic dredging may be more feasible. In this case, the dredged material would presumably be pumped on to a barge anchored in the deep channel next to the dredging area and hauled away to a certified disposal site more economically. An overland slurry pipeline would become another viable alternative if an upland disposal site is found within a sufficent distance to the marina basin.

A final decision as to the choice of dredging method must await the selection of the dredging scenario, dredge disposal site and relevant economic and environmental evaluations.

Preliminary Cost Estimates

Without having selected a dredging scenario or dredging and disposal methods, it is possible to estimate only a plausible range of dredging costs for the proposed project. For this purpose, the unit cost of dredging will be assumed to be in the range of $10/ton to $15/ton, corresponding to the optimistic and worst scenarios. Using these values and the quantity estimates for the two scenarios that involve actual dredging, the following are obtained.

Dredging Scenario	Dredge Volume	% of Basin Disturbed	Cost Range ($) Low	High
No. 1	30,000 CY	56%	300,000	450,000
No. 2	4,500 CY	28%	45,000	67,500

These estimates show that a 50% reduction in the surface area of the basin disturbed will accomodate slightly less than half the number of slips but provide a nearly eight-fold reduction in the volume and the estimated handling cost of the dredge material.

15.F. TIDAL FLUSHING

The term "tidal flushing" refers to the renewal of a marina basin's waters by tidal action, but also includes contributions of riverine, wind-driven and density currents to the process. The primary purpose of a tidal flushing study is to estimate the average time it would take for the tidal exchange and other hydrodynamic action to dilute the concentration of a pollutant introduced to the marina basin to a specified acceptable level. The basin and inlet geometry, basin volume and tidal ranges are the basic parameters controlling the process.

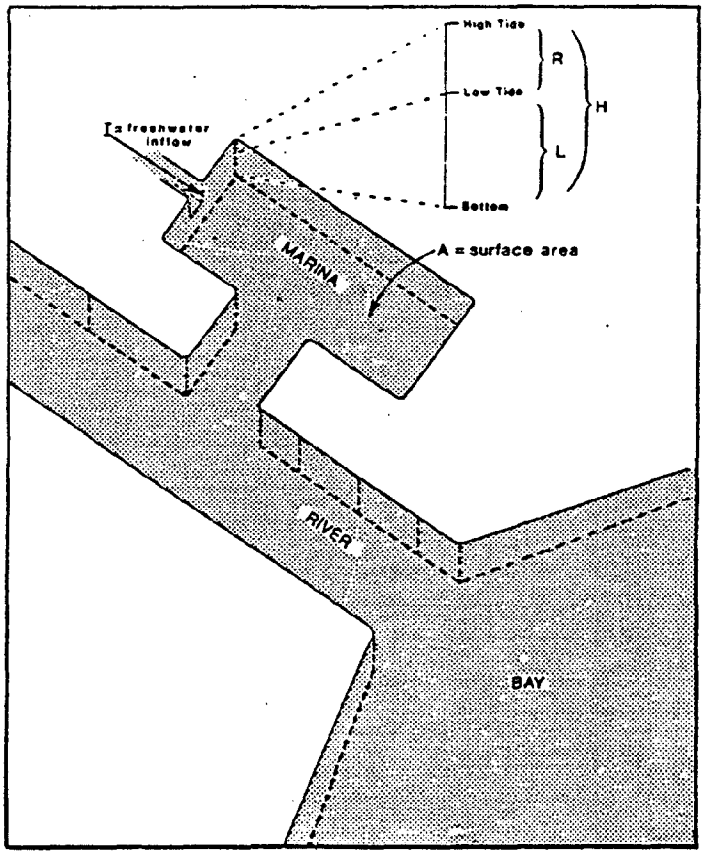
The process of temporal (varying with time) and spatial (varying with space) dilution of a point-source or nonpoint-source pollutant in a tidal basin can easily be extremely complex depending on these parameters. An analytical solution to this complex turbulent diffusion and dispersion problem does not exist. Numerical solutions can be obtained for specific site geometry and hydrodynamic conditions using finite-difference and finite-element methods that are available. However, engineers widely prefer using the "tidal prism" models in marina water quality evaluations, because these models are relatively simple to use and also known to provide generally conservative results.

Such a simplified "tidal prism" model recommended by the U. S. Environmental Protection Agency is illustrated schematically in Figure 15.5, along with the recommended equation to calculate the "time of flushing" for these semi-open marinas. Of the various simplifying assumptions inherent to this model are that complete mixing occurs at all times for both pollutants and tidal motion in the basin, and that the residence time of a pollutant in the basin is equal to the time it takes to replace the basin volume at the average tidal exchange rate. A "sensitivity" analysis was performed with this model to evaluate the overall water quality characteristics of the proposed marina basin.

The simplified EPA equation defined in Figure 15.5 employs the tidal-prism concept in estimating an approximate "flushing time" required to reduce or dilute a pollutant to a desired fraction of its original concentration, designated by D in the formula. In the sensitivity calculations for this project, 2%, 5% and 10% dilution levels were used for D.

Taken as constants for the project were the surface area and the volumes of the marina at low and high tide levels, and the time between consecutive high tides. Another parameter that was varied in these calculations was the return flow factor, b, or the fraction of the previously flushed pollutant to return to the marina. It is conceivable, however, that this parameter is probably very close to zero. Indeed, considering the size and depth of the river section and the river channel velocities in comparison with those of the marina, it is quite unlikely for a pollutant flushed out of the marina basin into the river by the tide to return to the basin within the next tidal cycle nearly 12.5 hours later, even in miniscule fractions. Nevertheless, a series of calculations were performed with return flow factor values of 2%, 5% and 10%.

Table 15.3 summarizes the results obtained with the sensitivity calculations, whereas Figure 15.6 illustrates the variation of the expected flushing periods for varying marina basin depths and dilution levels. As expected, the flushing period decreases as the "dredge" depth of the marina basin is decresed and as the desirable dilution level is increased. More specifically, these relatively conservative calculations indicate that it will take approximately three days to dilute a pollutant's concentration to



$$T_f = \frac{T_c \text{Log} D}{\text{Log}\left(\frac{AL + bAR - IT_c}{AH}\right)}$$

where:
- T_f = Time of flushing (hours)
- T_f = Tidal cycle, high tide to high tide (hours)
- A^c = Surface area of marina (m^2)
- D = Desired dilution factor
- R = Range of tide (m)
- b = Return flow factor (dimensionless)
- I = Non-tidal freshwater inflow (m^3/hour)
- L = Average depth at low tide (m)
- H = Average depth at high tide (m).

FIGURE 15.5 - Schematic Of Representative Semi-enclosed Marina Basin And Relevant Simplified Tidal Flushing Model

(Source: U.S. Environmental Protection Agency, Coastal Marinas Assessment Handbook)

Table 15.3 - Tidal Flushing Calculations with EPA Model

Source: US Environmental Protection Agency, Coastal Marinas Assessment Handbook, 1985.

Simplified equation to estimate time of flushing for a confined marina:

$$Tf = Tc * Log (D) / Log \{[VL+b(VH-VL)-VF]/VH\}$$

where:		Typical Project Data
Tf = Time of flushing [hrs]	=	196.3 hrs = 8.2 days
Tc = Time between consecutive high tides [hrs]	=	12.5 hrs
D = Desired dilution level	=	10 %
VL = Volume of water in the Marina at Low Tide	=	19,200 cu-ft
VH = Volume of water in the Marina at High Tide	=	22,800 cu-ft
VF = Fresh water inflow to the marina during one tidal cycle	=	0 cu-ft
b = Fraction of previous flushing returning to the marina	=	2 %

Also used in tabular data presentation:

A = Marina surface area [sq-ft]	=	2,400 sq-ft
DL = Depth of water in the marina at Low Tide	=	8.0 ft
DH = Depth of water in the marina at High Tide	=	9.5 ft
DT = Tidal range (=DH-DL) [ft]	=	1.5 ft

QUANTICO MARINA - Sensitivity Calculations

Tc [hrs]	D	b	A [sq-ft]	TR [ft]	DL [ft]	DH [ft]	VL [cu-ft]	VH [cu-ft]	Tf [hrs]	Tf [days]
12.50	0.02	0.10	2,500	1.5	8.0	9.5	20,000	23,750	319.0	13.29
12.50	0.02	0.10	2,500	1.5	7.0	8.5	17,500	21,250	282.7	11.78
12.50	0.02	0.10	2,500	1.5	6.0	7.5	15,000	18,750	246.4	10.27
12.50	0.02	0.10	2,500	1.5	5.0	6.5	12,500	16,250	210.0	8.75
12.50	0.02	0.10	2,500	1.5	4.0	5.5	10,000	13,750	173.6	7.23
12.50	0.02	0.10	2,500	1.5	3.0	4.5	7,500	11,250	137.1	5.71
12.50	0.05	0.10	2,500	1.5	8.0	9.5	20,000	23,750	244.3	10.18
12.50	0.05	0.10	2,500	1.5	7.0	8.5	17,500	21,250	216.5	9.02
12.50	0.05	0.10	2,500	1.5	6.0	7.5	15,000	18,750	188.7	7.86
12.50	0.05	0.10	2,500	1.5	5.0	6.5	12,500	16,250	160.8	6.70
12.50	0.05	0.10	2,500	1.5	4.0	5.5	10,000	13,750	133.0	5.54
12.50	0.05	0.10	2,500	1.5	3.0	4.5	7,500	11,250	105.0	4.37
12.50	0.10	0.10	2,500	1.5	8.0	9.5	20,000	23,750	187.8	7.82
12.50	0.10	0.10	2,500	1.5	7.0	8.5	17,500	21,250	166.4	6.93
12.50	0.10	0.10	2,500	1.5	6.0	7.5	15,000	18,750	145.0	6.04
12.50	0.10	0.10	2,500	1.5	5.0	6.5	12,500	16,250	123.6	5.15
12.50	0.10	0.10	2,500	1.5	4.0	5.5	10,000	13,750	102.2	4.26
12.50	0.10	0.10	2,500	1.5	3.0	4.5	7,500	11,250	80.7	3.36

QUANTICO MARINA - Sensitivity Calculations (Cont'd)

Tc [hrs]	D	b	A [sq-ft]	TR [ft]	DL [ft]	DH [ft]	VL [cu-ft]	VH [cu-ft]	Tf [hrs]	Tf [days]
12.50	0.02	0.05	2,500	1.5	8.0	9.5	20,000	23,750	300.9	12.54
12.50	0.02	0.05	2,500	1.5	7.0	8.5	17,500	21,250	266.5	11.10
12.50	0.02	0.05	2,500	1.5	6.0	7.5	15,000	18,750	232.1	9.67
12.50	0.02	0.05	2,500	1.5	5.0	6.5	12,500	16,250	197.6	8.23
12.50	0.02	0.05	2,500	1.5	4.0	5.5	10,000	13,750	163.1	6.79
12.50	0.02	0.05	2,500	1.5	3.0	4.5	7,500	11,250	128.4	5.35
12.50	0.05	0.05	2,500	1.5	8.0	9.5	20,000	23,750	230.4	9.60
12.50	0.05	0.05	2,500	1.5	7.0	8.5	17,500	21,250	204.1	8.50
12.50	0.05	0.05	2,500	1.5	6.0	7.5	15,000	18,750	177.7	7.40
12.50	0.05	0.05	2,500	1.5	5.0	6.5	12,500	16,250	151.3	6.30
12.50	0.05	0.05	2,500	1.5	4.0	5.5	10,000	13,750	124.9	5.20
12.50	0.05	0.05	2,500	1.5	3.0	4.5	7,500	11,250	98.3	4.10
12.50	0.10	0.05	2,500	1.5	8.0	9.5	20,000	23,750	177.1	7.38
12.50	0.10	0.05	2,500	1.5	7.0	8.5	17,500	21,250	156.9	6.54
12.50	0.10	0.05	2,500	1.5	6.0	7.5	15,000	18,750	136.6	5.69
12.50	0.10	0.05	2,500	1.5	5.0	6.5	12,500	16,250	116.3	4.85
12.50	0.10	0.05	2,500	1.5	4.0	5.5	10,000	13,750	96.0	4.00
12.50	0.10	0.05	2,500	1.5	3.0	4.5	7,500	11,250	75.6	3.15
12.50	0.02	0.02	2,500	1.5	8.0	9.5	20,000	23,750	290.9	12.12
12.50	0.02	0.02	2,500	1.5	7.0	8.5	17,500	21,250	257.5	10.73
12.50	0.02	0.02	2,500	1.5	6.0	7.5	15,000	18,750	224.2	9.34
12.50	0.02	0.02	2,500	1.5	5.0	6.5	12,500	16,250	190.7	7.95
12.50	0.02	0.02	2,500	1.5	4.0	5.5	10,000	13,750	157.2	6.55
12.50	0.02	0.02	2,500	1.5	3.0	4.5	7,500	11,250	123.6	5.15
12.50	0.05	0.02	2,500	1.5	8.0	9.5	20,000	23,750	222.8	9.28
12.50	0.05	0.02	2,500	1.5	7.0	8.5	17,500	21,250	197.2	8.22
12.50	0.05	0.02	2,500	1.5	6.0	7.5	15,000	18,750	171.7	7.15
12.50	0.05	0.02	2,500	1.5	5.0	6.5	12,500	16,250	146.1	6.09
12.50	0.05	0.02	2,500	1.5	4.0	5.5	10,000	13,750	120.4	5.02
12.50	0.05	0.02	2,500	1.5	3.0	4.5	7,500	11,250	94.7	3.94
12.50	0.10	0.02	2,500	1.5	8.0	9.5	20,000	23,750	171.2	7.13
12.50	0.10	0.02	2,500	1.5	7.0	8.5	17,500	21,250	151.6	6.32
12.50	0.10	0.02	2,500	1.5	6.0	7.5	15,000	18,750	131.9	5.50
12.50	0.10	0.02	2,500	1.5	5.0	6.5	12,500	16,250	112.3	4.68
12.50	0.10	0.02	2,500	1.5	4.0	5.5	10,000	13,750	92.6	3.86
12.50	0.10	0.02	2,500	1.5	3.0	4.5	7,500	11,250	72.8	3.03

TOWN OF QUANTICO MARINA
Tidal Flushing Estimates

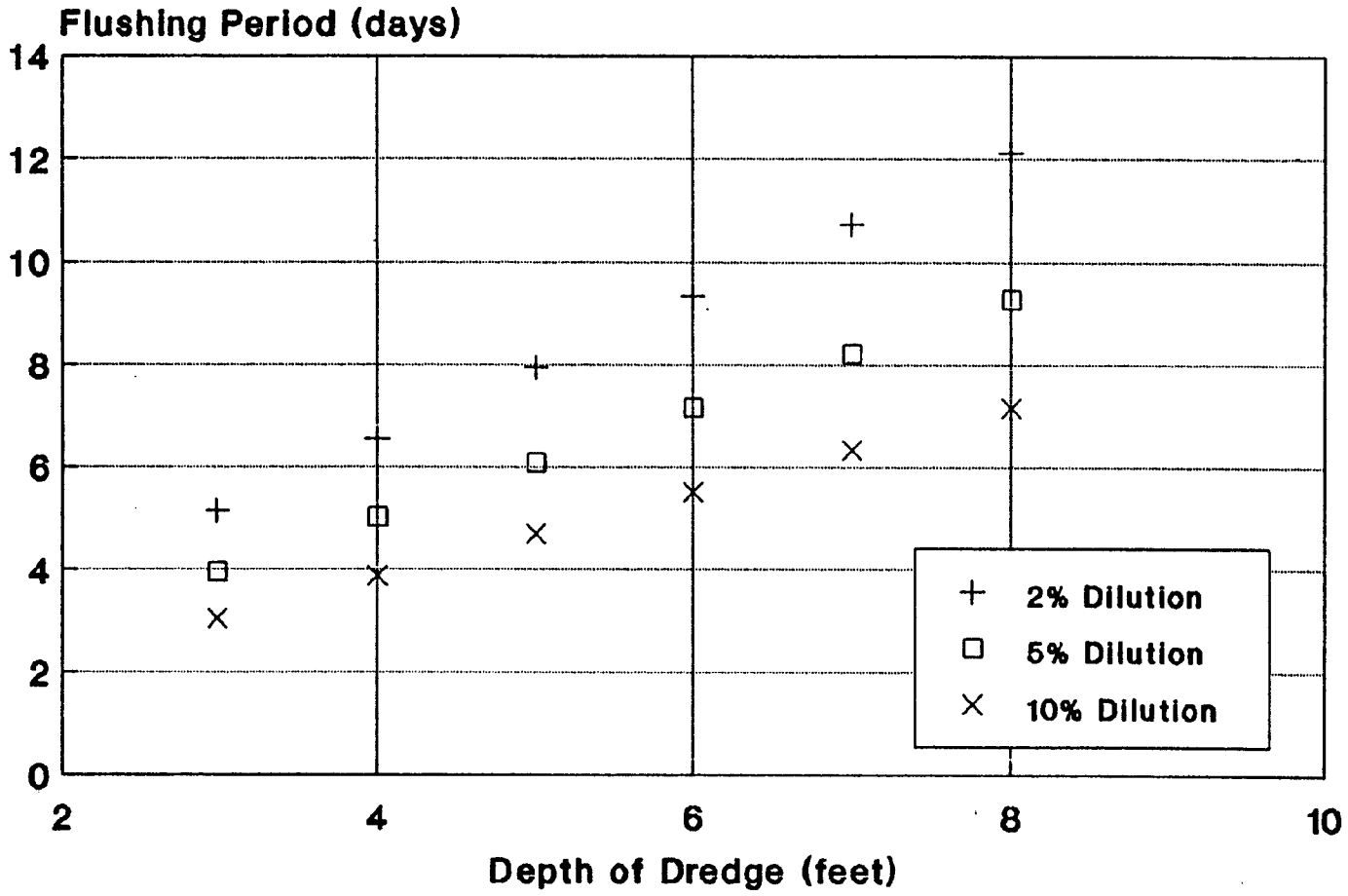


FIGURE 15.6 - Tidal Flushing Estimates

nearly 10% of its original value, and no more than five days to dilute the same to the 2% level. Based on the general guidelines provided by the EPA manual, these results indicate satisfactory "flushing" characteristics for a marina.

There are several other factors that should be considered to ensure a satisfactory water quality and flushing characteristics for a marina. It is extremely important that the bottom slope within the marina is consistently positive and preferably increases towards the inlet section. Additionally, there should be virtually no "dead-zone" corners within the marina basin, whereby effective circulation is prevented by inappropriate geometric features of the docks, groins and breakwaters.

The preceding principles and guidelines were taken into due consideration in the geometric design of the proposed marina both in plan and elevation views.

15.G. COST OF THE PROPOSED PROJECT AND ALTERNATIVES

Based on the various environmental and economic characteristics presented in this study, the principal components of the proposed project and its four alternatives were identified. Based on the individual project component costs and descriptions provided in Table 15.4, a summary of project descriptions and overall cost estimates for the proposed project and each of its alternatives are given in Table 15.5.

It should be emphasized that these design alternatives and the associated costs are subject to refinement and revisions due to environmental, economic and policy-related developments and constraints likely to affect the future project conditions.

Table 15.4 - Summary of Preliminary Cost Estimates for Major Project Components

Project Component and Primary Features	Component Cost
Shoreline: Stabilization, Quarry-Stone Revetment and Riprap Toe	$ 45,000
Shoreline: Stabilization and Seawall Repair for Minimum Protection	$ 20,000
Breakwater: Precast Reinforced Concrete Pipe/Pile and Riprap Toe	$ 625,000
Breakwater: 600-lb to 1,600-lb Armor Stone, Full Section	$ 1,000,000
Two Floating Piers: Dock along Concrete Breakwater, 143 Slips	$ 567,000
Two Floating Piers: No Dock along Stone Breakwater, 110 Slips	$ 361,500
Two Floating Piers: Dock along Concrete Breakwater, 68 Slips	$ 483,840
Two Floating Piers: No Dock along Stone Breakwater, 40 Slips	$ 308,480
Single Floating Pier: with Tee only, Total of 600 ft, 20 Slips	$ 153,600
Dredging: DS #1, Dredge 56% of basin to EL= -6' and -8'	$ 450,000
Dredging: DS #2, Dredge 28% of basin to EL= -4' and -6'	$ 67,500
Dredging: Minimum dredging (grubbing) only at deep waters	$ 15,000
Upland Riverfront Park: Beach, Parking and Spur Access for 143 Slips	$ 30,000
Upland Riverfront Park: Beach, Parking and Spur Access for 110 Slips	$ 30,000
Upland Riverfront Park: Beach, Parking and Spur Access for 68 Slips	$ 15,000
Upland Riverfront Park: Beach, Parking and Spur Access for 40 Slips	$ 10,000
Upland Riverfront Park: Beach, Parking and Spur Access for 20 Slips	$ 5,000
Upland Riverfront Park: Spur Access, Minimum Improvements	$ 5,000

Table 15.5 - Summary of Preliminary Cost Estimates for Proposed Project and Several Alternatives

Features of Proposed Project and Selected Alternatives	Project Cost	Slips
PROPOSED PROJECT:		
Precast Reinforced Concrete Pipe/Pile Breakwater with Timber Fillers; Stone Riprap Shoreline Stabilization with Seawall and Beach Improvement; 143-Slip Marina with Two Floating Piers; 6' and 8' Dredging (30,000 CY); Parking and Spur Access Improvements in the Upland Riverfront Park Area	$ 1,717,000	143
With Armor-Stone Breakwater (instead of Concrete), 110-slips	$ 1,886,500	110
ALTERNATIVE 1:		
Similar to Proposed Scenario, but with much less Dredging; includes Precast Reinforced Concrete Pipe/Pile Breakwater with Timber Fillers; Stone Riprap Shoreline Stabilization with Seawall and Beach Improvement; 68-Slip Marina with Two Floating Piers; Much Less Dredging (4,500 CY); Parking and Spur Access Improvements in the Upland Riverfront Park Area	$ 1,236,340	68
With Armor-Stone Breakwater (instead of Concrete), 40-slips	$ 1,430,980	40
ALTERNATIVE 2:		
No Breakwater; Min. Dredging; Single Floating Pier with Tee; 20 Slips; Stone Riprap Shoreline Stabilization with Seawall and Beach Improvement; Minor Parking and Spur Access Improvements in the Upland Park Area	$ 218,600	20
ALTERNATIVE 3:		
No Breakwater: No Piers; No Marina Facilities; No Dredging in the Basin; Seawall Repair for Minimum Shoreline Protection and Beach Improvement; Minor Improvements in the Upland Area	$ 25,000	0
ALTERNATIVE 4:		
No Breakwater; No Piers; No Dredging in Basin; Stone Riprap Shoreline Stabilization with New Seawall for Substantial Shoreline Protection; Minor Beach, Parking and Spur Access Improvements in the Upland Area	$ 50,000	0

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