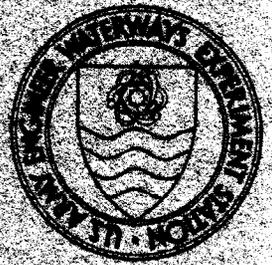


# DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT D-77-13

## DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA POTOMAC RIVER, VIRGINIA

by

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October 1977

Final Report

Approved For Public Release; Distribution Unlimited



Prepared for Office, Chief of Engineers, U. S. Army  
Washington, D. C. 20314

Under DMRP Work Unit 4A17A

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SUBJECT: Transmittal of Technical Report D-77-13

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1. The technical report transmitted herewith represents a detailed design for developing and restoring a wetland at Dyke Marsh (Fairfax County, Virginia) using dredged material from the Potomac River estuary. This work unit (4A17A) was conducted as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A is a part of the Habitat Development Project (HDP) of the DMRP and is concerned with the development, testing, and evaluation of the environmental, economic, and engineering feasibility of using dredged material as a substrate for marsh development.

2. Dyke Marsh, located along the Potomac River, is a vestige of a formerly large wetland area. Approximately half of the original marsh was destroyed by sand and gravel mining prior to Federal ownership. The site is now a unit of the George Washington Memorial Parkway and is administered by the National Park Service for the preservation of wetland habitat.

3. A feasibility study (Work Unit 4A17) identified the economic and technical constraints associated with dike construction and dredged material placement for marsh restoration at Dyke Marsh. Site specificity, preliminary containment design, availability of construction materials, identification of construction alternatives, and procedures for material placement were evaluated, and restoration using dredged material was found to be technically feasible. The feasibility study is described in Technical Report D-76-6.

4. The subject study, conducted by the DMRP with the support and cooperation of the U. S. Army Engineer District, Baltimore, and the National Park Service, presents the results of a detailed engineering design for restoration of an 11-hectare wetland area. The detailed design describes sampling and testing programs to determine the suitability of channel sediments for use as a marsh substrate, presents a methodology for correlation of in situ channel sediment volume and containment area volume, and evaluates containment area sizing for the retention of suspended solids. Containment area operation and

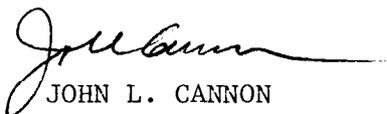
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procedures for placement of dredged material are also discussed. A comprehensive program of construction and post-construction monitoring is recommended to permit evaluation of engineering considerations of marsh development using dredged material.

5. Work Unit 4A17A, Work Unit 4A17, and several other related work units deal with operational aspects of marsh development such as retaining and protective structures (4A07A), guidelines for material placement for marsh creation (4A08), and prediction of final stable marsh elevation (4A16). Other DMRP sites involving marsh establishment on fine-textured sediments are located near Windmill Point, Virginia (4A11); Apalachicola, Florida (4A19); and San Francisco, California (4A18).



JOHN L. CANNON  
Colonel, Corps of Engineers  
Commander and Director

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report D-77-13	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RIVER, VIRGINIA		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michael R. Palermo and Timothy W. Zeigler		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Effects Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DMRP Work Unit 4A17A
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE October 1977
		13. NUMBER OF PAGES 217
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES  Appendixes A, B, C, and D are reproduced on microfiche enclosed in an envelope inside the back cover of this report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Dredged material            Potomac River Dyke Marsh, Va.            Containment areas Marshes		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Results of detailed engineering studies regarding use of dredged material to expand an existing marshland area are presented. Sampling and testing programs are described that allowed determination of the suitability of channel sediment for use as marsh substrate. Foundation studies indicated conditions at the demonstration site are adequate for construction of a containment facility.		

(Continued)

20. ABSTRACT (Continued).

A methodology for correlation of in situ channel sediment volume and containment area volume is presented. The methodology incorporates basic principles of containment area volumetric sizing and accounts for consolidation of the newly placed marsh substrate. Laboratory tests using a full height column were performed to simulate the sedimentation phase of the dredging process. Conventional consolidation tests were then performed on samples taken from the column for evaluation of the consolidation phase.

Evaluations were made regarding containment sizing for retention of suspended solids, containment area operation, and procedures for placement of dredged material. Results of retaining dike stability analyses, dike settlement analyses, and erosion protection requirements are presented. Availability of construction materials for the containment facility and recommended construction procedures are described.

A comprehensive program of construction and post construction monitoring was recommended to allow evaluation of the engineering considerations of marsh development using dredged material.

## EXECUTIVE SUMMARY

The objective of this report is to present the results of detailed engineering studies regarding use of dredged material to expand a portion of Dyke Marsh, a freshwater intertidal marsh located about one mile south of Alexandria, Virginia, along the west bank of the Potomac River.

Dredged material for this project would be obtained primarily from maintenance dredging operations on the Potomac River just below the Woodrow Wilson Memorial Bridge, south of Alexandria. Results of the detailed studies indicate that the sediment is suitable for use as marsh substrate and that site conditions are adequate for construction of a containment facility.

Undisturbed samples of the channel sediment were taken and laboratory tests were performed to determine suitability for use as marsh substrate. A sizing methodology was developed to correlate in situ channel sediment volumes with containment area volumes to assure that final substrate elevations would be established within the intertidal zone. The methodology involved use of laboratory sedimentation tests and conventional consolidation tests, incorporating the basic principles of containment area volumetric sizing and accounting for consolidation of the newly placed marsh substrate.

Evaluations were made regarding containment sizing for retention of suspended solids, freeboard requirements, weir placement and size, and procedures for placement of dredged material. Stability analyses were performed for the retaining dikes and potential dike settlement and erosion protection requirements were evaluated. Studies were performed to determine availability of suitable construction materials and optimum construction procedures for the retaining dikes. A combination of end-dump construction using sand and gravel and dragline placement of on-site materials was recommended.

The proposed demonstration area will significantly add to the area of productive marshland at Dyke Marsh and will allow evaluation of engineering considerations of marsh development using dredged material at a full-scale field site.

## PREFACE

This report presents the results of detailed engineering studies regarding use of dredged material to expand a marshland near Alexandria, Virginia. The study was conducted as Work Unit 4A17A of the Dredged Material Research Program (DMRP) for the Office, Chief of Engineers, at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. This work unit is a part of the Habitat Development Project, Dr. Hanley K. Smith, Manager.

The study was conducted by the Environmental Engineering Division (EED) of the Environmental Effects Laboratory (EEL) at the WES, under the general supervision of Dr. John Harrison, Chief, EEL, and Mr. A. J. Green, Chief, EED; and under the direct supervision of Mr. R. L. Montgomery, Chief, Design and Concept Development Branch, EED.

This report was written by Mr. Michael R. Palermo, EED, and Mr. Timothy W. Zeigler, Engineering Geology and Rock Mechanics Division, Soils and Pavements Laboratory, WES. Appreciation is expressed to Dr. Richard S. Hammerschlag, Ecological Services Laboratory, National Park Service, and Mr. Ronald Silver, U. S. Army Engineer District, Baltimore, for their assistance.

The Directors of WES during the study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)  
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
cubic yards	0.7645549	cubic metres
feet per second	0.3048	metres per second
cubic feet per second	0.02831685	cubic metres per second
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (force) per square foot	47.88026	pascals
tons (force) per square foot	95.76052	kilopascals
acres	4046.856	square metres
degrees (angular)	0.01745329	radians

DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA

POTOMAC RIVER, VIRGINIA

PART I: INTRODUCTION

Background

1. The area known as Dyke Marsh is a typical intertidal marshland located on the west bank of the Potomac River approximately 1 mile\* south of Alexandria, Virginia, as shown in Figure 1. Expansion of the present marshland area at Dyke Marsh using dredged material from the Potomac River navigation channel is being considered in a joint effort between the National Park Service (NPS) and the U. S. Army Engineer District, Baltimore (BD).

2. An initial feasibility study for the proposed marsh expansion was completed by the U. S. Army Engineer Waterways Experiment Station (WES) in November 1976.<sup>1</sup> The study was based upon preliminary field and laboratory investigations and determined that marshland expansion was generally feasible from an engineering standpoint. A separate environmental assessment for the project was also initiated.<sup>2</sup> Additional engineering studies were recommended so that a detailed design for the project could be completed. This report presents the detailed engineering design for Dyke Marsh.

Description of the Project

3. Expansion of marshland at Dyke Marsh will involve placement of an initial demonstration area with the configuration shown in Figure 2. The dredged material used for the proposed marshland expansion will be taken from a shoal area in the Potomac River navigation channel

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\* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 6.

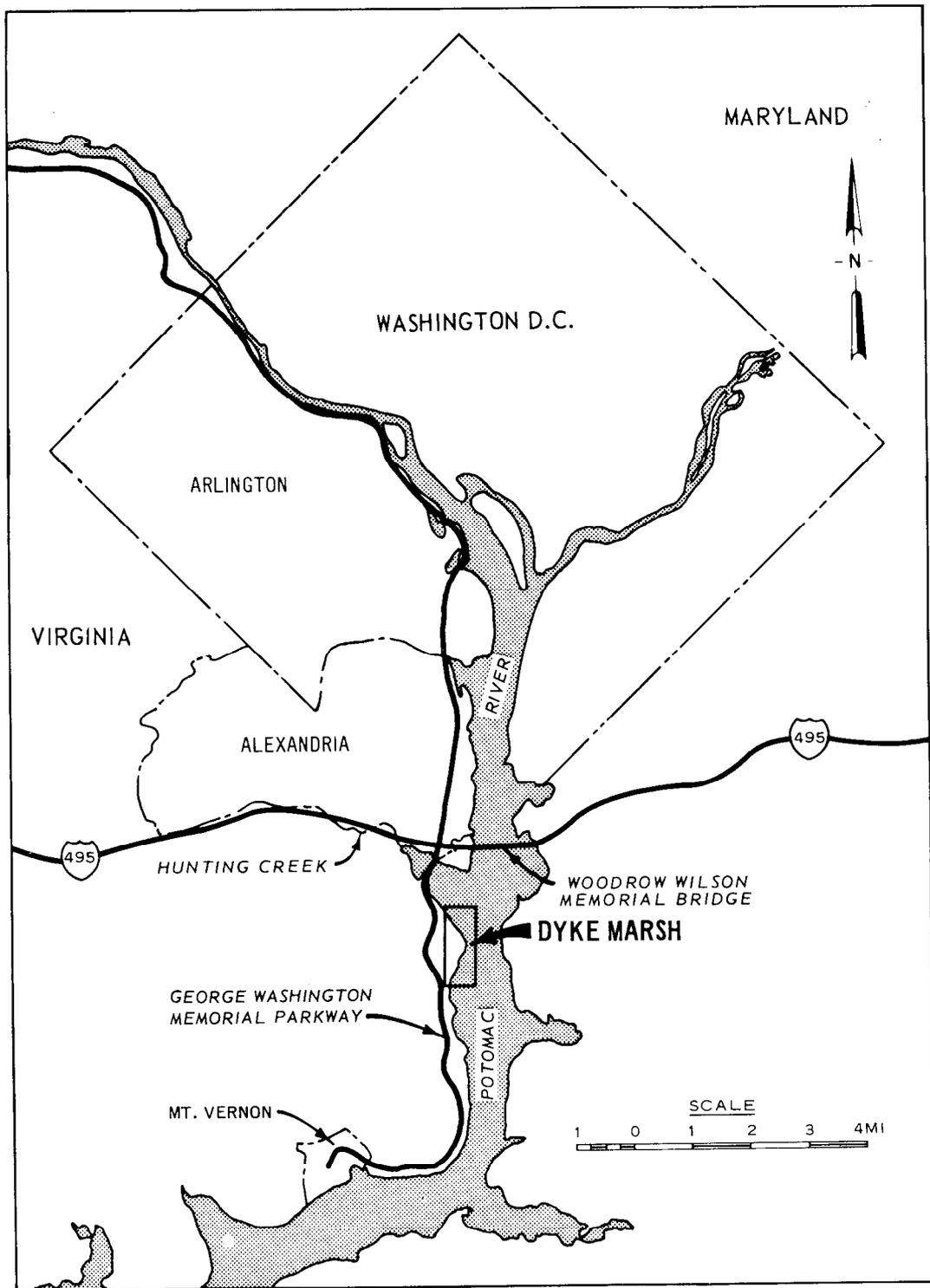


Figure 1. Location map of Dyke Marsh

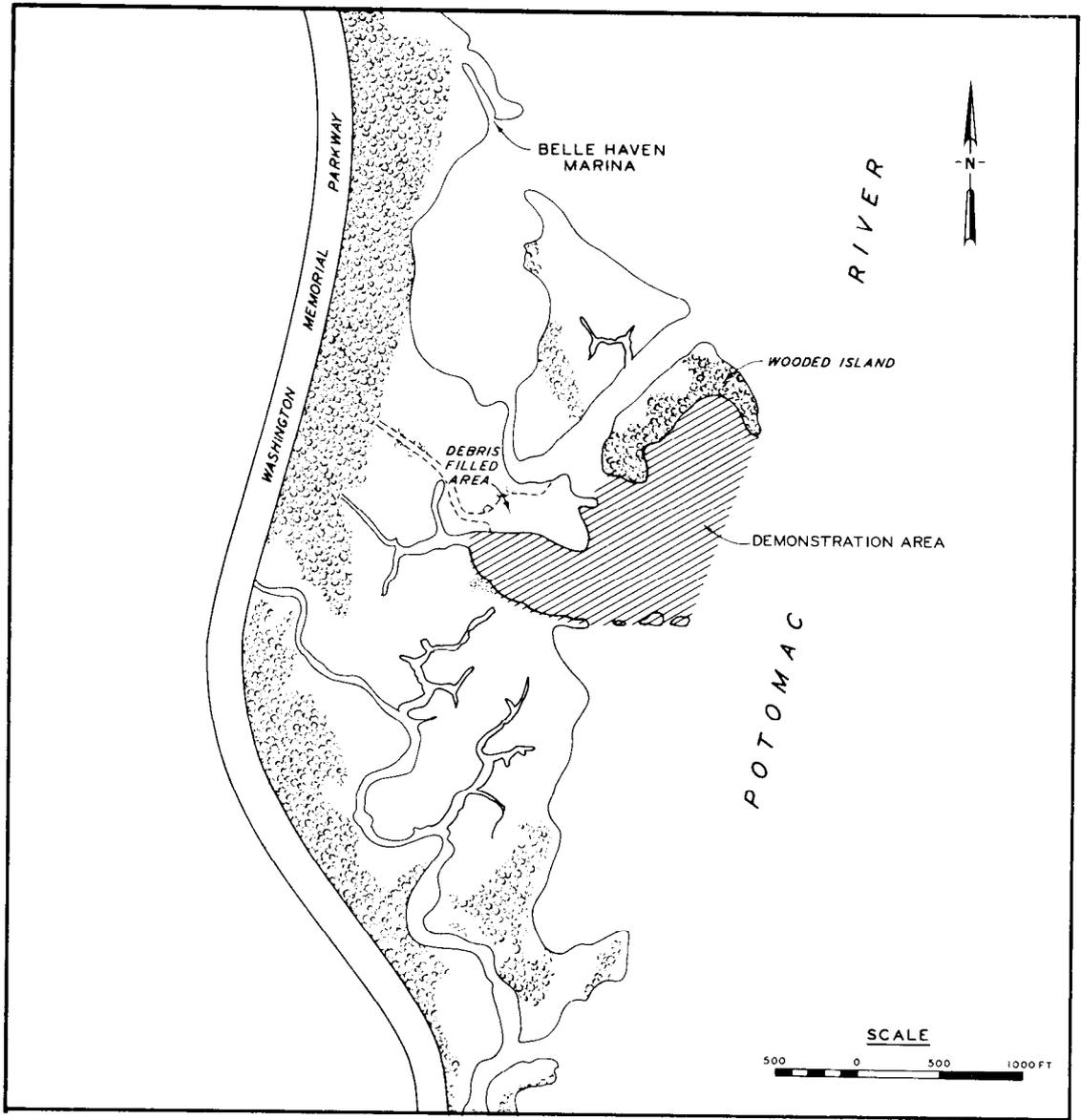


Figure 2. Location of demonstration area

immediately south of the Woodrow Wilson Memorial Bridge. Construction of a retaining dike system with outlet weirs will allow placement of dredged material to elevations within the tidal range. The demonstration area will be bounded by the existing wooded island on the north limit, shallows on the south limit, a cove formed by existing marshland, and the main retaining dike. The retaining dike system is necessary to confine the dredged material and control excessive erosion of the newly placed substrate during consolidation and initial marsh establishment. Ample protection of the existing marshland from siltation will be provided by a temporary back dike. Following initial sedimentation and consolidation of the dredged material, the retaining dikes will be lowered to elevations that will allow tidal ebb and flow and natural establishment of vegetation. More detailed site history and background information was presented in the feasibility study.<sup>1</sup>

#### Purpose

4. The purpose of this report was to document results of all engineering studies relating to the proposed expansion of marshland at Dyke Marsh using material dredged from the Potomac River navigation channel. This study will serve as detailed design documentation for the marsh expansion project from which plans and specifications for project construction can be prepared.

#### Scope

5. The scope of this report was restricted to engineering and economic considerations. Factors relating to natural establishment of vegetation have been identified in other Dredged Material Research Program (DMRP) research. Environmental considerations of the project are addressed by the separate environmental assessments.<sup>2</sup>

6. The detailed design was based upon information gathered in initial field and laboratory investigations used to establish feasibility of the project and additional investigations performed specifically for this study. Design considerations covered in this report include

the sizing of the containment area, design of the retaining dike system, availability of construction materials, procedures for placement of the dredged material, and economic constraints associated with the project. The appendixes to the report are as follows:

<u>Appendix*</u>	<u>Title</u>
A	Laboratory Test Results for Shoal and Column Sedimentation Samples
B	Field Investigations and Laboratory Tests for Riverine Sources of Sand
C	Field Investigations and Laboratory Tests-Debris Fill Area and Wooded Island
D	Laboratory Tests of Foundation Soils
E	Notation

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\* Appendixes A, B, C, and D are reproduced on microfiche enclosed in an envelope inside the back cover of this report.

## PART II: CONTAINMENT AREA SIZING

7. Containment areas are generally sized to provide adequate detention time for particle settling to meet water-quality standards for suspended solids and to provide adequate storage capacity for the volume of material to be dredged. Suspended solids concentrations in containment area effluents are limited to 13 g/l above ambient conditions by BD specifications. Within the project area, no other water-quality standards concerning suspended solids or turbidity generated by dredged material disposal operations currently exist. Storage capacity per se was not of prime concern.

8. However, marsh creation or expansion projects using dredged material require accurate sizing studies to correlate volumetric relationships of in situ sediment volumes and containment area volumes. Final elevation of the dredged material within the substrate must fall within the intertidal zone to ensure proper establishment of marsh vegetation. The average intertidal range at the Dyke Marsh demonstration area is 3.0 ft; therefore sizing studies were required to predict the volume of dredged material necessary to provide final substrate elevations within the intertidal range.

9. The sizing studies conducted for the Dyke Marsh demonstration area to meet water-quality and volumetric requirements were based on data obtained during both the feasibility and detailed design phases of the project.

### Shoal Investigations

10. The Potomac River navigation project provides for a channel 24 ft deep and 200 ft wide from the mouth of the river to Giesboro Point at Washington. One area of shoaling lies immediately below the Woodrow Wilson Memorial Bridge, south of Alexandria (Figure 3).

11. A hydrographic survey of the shoal had been made by the BD in 1972. Grab samples of the shoal sediment were taken during the feasibility study to determine general physical and chemical properties.

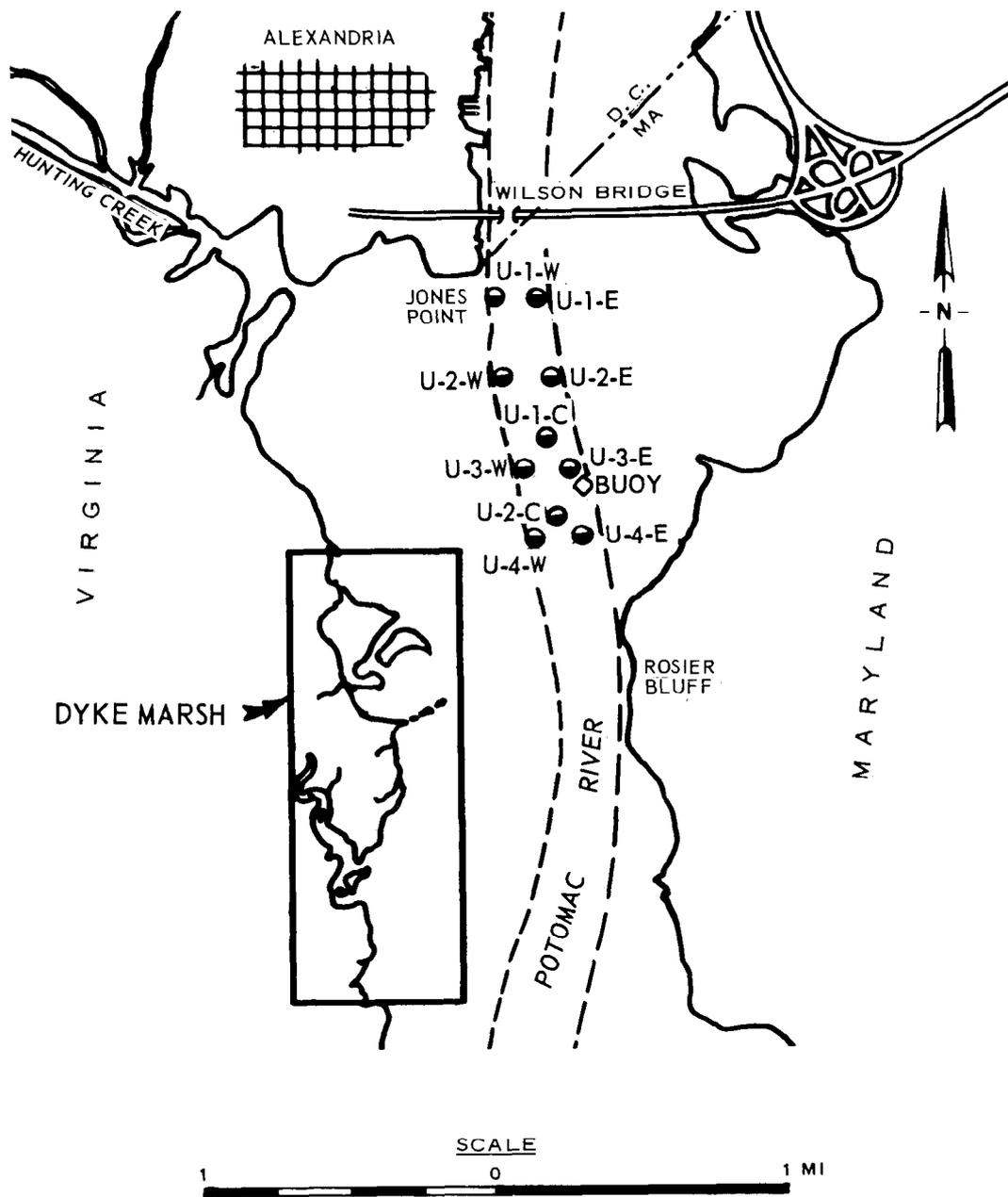


Figure 3. Shoal location and boring plan

These surface samples indicated significant amounts of coarse-grained sediment that might be used in dike construction operations. The shoal was tentatively selected for use in the Dyke Marsh expansion project because of the convenient location and apparently desirable properties of the material.

12. The properties of the sediment to be dredged are critical in determining precise correlation between in situ channel volumes and volumes ultimately used in the containment. Therefore, more detailed investigations of the shoal were undertaken for precise determinations of the sediment properties and volumes.

13. An updated hydrographic survey was conducted by the BD in May 1976 as part of the detailed design. The survey indicated a significant reduction in the required dredging volume as compared to the 1972 survey, evidently due to gradual erosion of the shoal by scour. The total in situ volume of available dredged material above the navigation depth limits was determined to be approximately 142,000 yd<sup>3</sup>.

14. Ten borings were made within the shoal to estimate volumes of coarse- and fine-grained sediments present and to obtain undisturbed sediment samples for use in sizing studies. Locations of the borings are shown in Figure 3. The borings were made by the WES Soils and Pavements Laboratory (S&PL) using a barge-mounted rotary drill rig. Undisturbed samples were taken with a 3-in. Shelby tube sampler. A large bulk sample was also taken at boring location U-2-C for use in sedimentation tests. Laboratory tests performed on the samples included classification under the Unified Soil Classification System (USCS)<sup>3</sup> and determinations of water content, Atterberg limits, grain-size distribution, specific gravity, and density-void ratio. All tests were conducted according to accepted CE procedures.<sup>4</sup> Results of the laboratory tests are presented in Appendix A.

15. Graphic logs of the shoal borings are presented in Figure 4. The large amounts of coarse-grained sediment indicated by the earlier bottom grab samples were not present in the upper sediment layers in the shoal borings. At the time of the later exploration, the shoal consisted essentially of clayey silts (MH) and clays (CH) to an

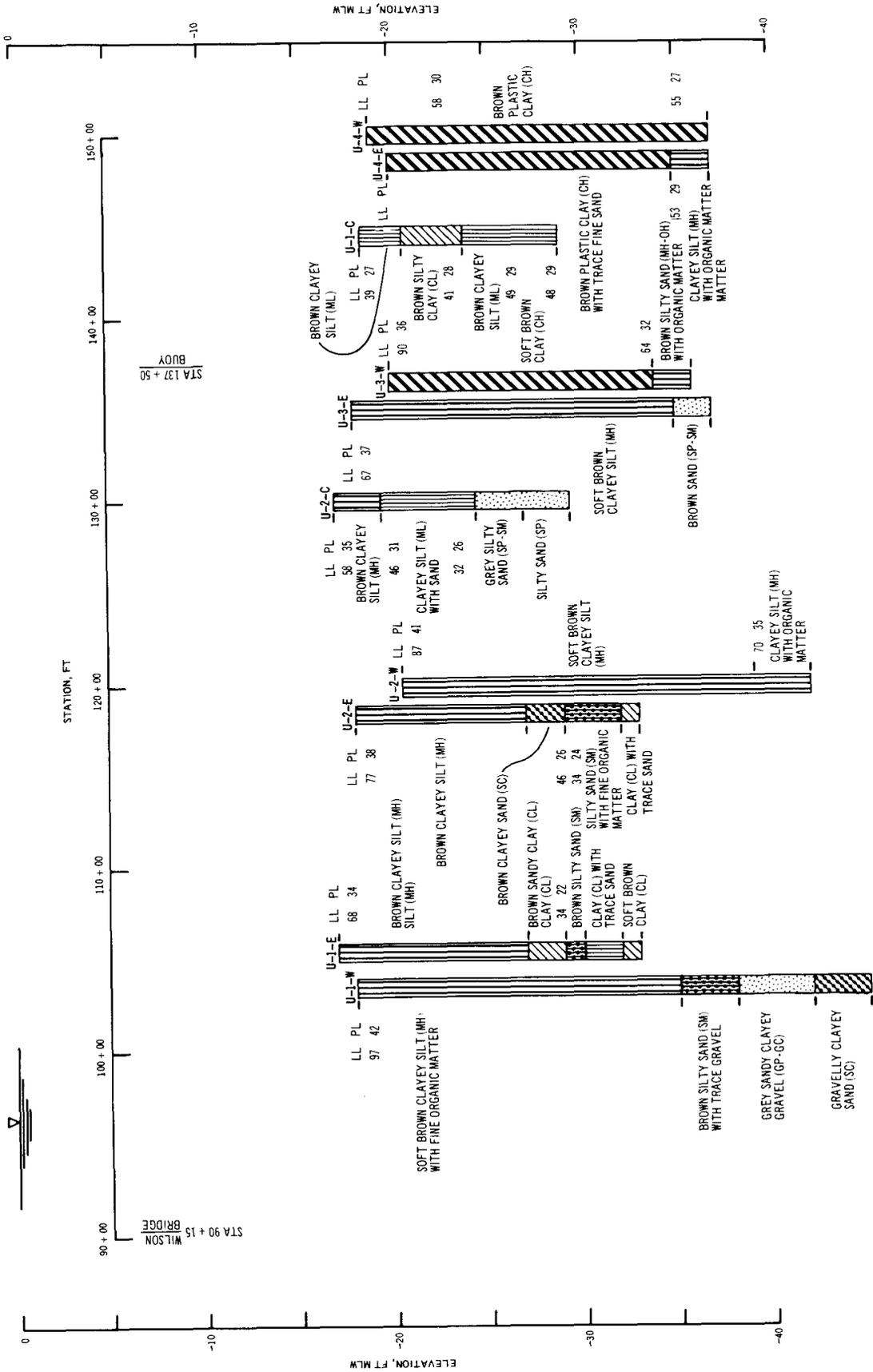


Figure 4. Graphic logs of shoal borings

approximate elevation of -35 ft mean low water (mlw).

### Determination of Containment Area Volume

#### Methodology

16. Correlation of in situ sediment volumes and dredged material volumes in the containment area is usually expressed in terms of a bulk-ing factor. Determination of this factor is necessary in marsh develop-ment operations using dredged material to ensure final elevations within the acceptable range for marsh substrate.

17. A methodology for correlation between in situ volumes and con-tainment volumes for marsh creation projects has been proposed in DMRP research conducted by the Massachusetts Institute of Technology (MIT).<sup>5</sup> The MIT method utilizes sedimentation tests performed in a 7.9-in.-diam, 35.4-in.-high column to predict void ratio distribution of the upper sedimented layers. Constant-head permeability tests and specialized slurry consolidation tests are then used to determine the probable void ratio distribution for higher effective stresses resulting from thicker lifts of sedimented material.

18. The sedimentation test proposed by MIT assumes that an equi-librium condition is reached when the interface settlement slows to 0.04 in./day. This condition will not develop in tests on fine-grained dredged material after reasonable periods due to continued consolidation of the dredged material under its own overburden weight. Material tested by the MIT consisted of low plasticity silts (ML), which would tend to stabilize quickly. The Dyke Marsh material was classified as a high plasticity silt (MH), which would exhibit continued consolidation following initial sedimentation similar to a plastic clay. A sizing method was therefore developed that was based upon the concepts devel-oped by the MIT work and would consider both sedimentation and consoli-dation of the material. The modified sizing method is described in the following paragraphs.

19. The volume occupied by a dredged material within a containment area depends upon the sedimentation characteristics of the material

exhibited during the containment filling process and the ultimate consolidation of the sedimented dredged material slurry under its own weight. Identification of these parameters involves the following determinations:

- a. The in situ channel sediment properties including the void ratio distribution.
- b. The void ratio distribution of the sedimented dredged material at the completion of the containment filling operation.
- c. The consolidation characteristics of the sedimented dredged material and containment area foundation material.
- d. The bulking factor and the volume of dredged material required to attain a suitable substrate elevation, considering both the sedimentation and consolidation process.

#### Channel sediment properties

20. Laboratory tests performed on undisturbed samples from borings U-1-C and U-2-C and the bulk samples were used to establish in situ properties of the channel sediment. Test results are summarized in Appendix A.

21. In situ void ratios  $e^*$  were computed from natural water content and specific gravity values using the following relationship:

$$Se = \frac{wG_s}{100} \quad (1)$$

where

S = degree of saturation (assumed 100 percent)

e = void ratio

w = natural water content, percent

$G_s$  = specific gravity

22. In situ void ratios e were also computed from values of wet and dry unit weight using the relationship:

$$e = \frac{V_v}{V_s} = \frac{\gamma_{sat} - \gamma_d}{\gamma_d} G_s \quad (2)$$

---

\* A list of notations is given in Appendix E.

where

$e$  = void ratio

$V_v$  = volume of voids

$V_s$  = volume of solids

$\gamma_{sat}$  = saturated unit weight, pcf

$\gamma_d$  = dry unit weight, pcf

$G_s$  = specific gravity

23. Values computed from these two equations were in close agreement. Plots of the void ratio versus elevation for borings U-1-C and U-2-C are shown in Figure 5. These plots essentially show a constant void ratio with depth for the in situ sediment. All samples from boring U-1-C and the upper four samples from boring U-2-C were clayey silt (MH) and silt (ML), with an average void ratio of 1.70. The lower two samples from boring U-2-C were silty sand (SM-SP), with an average void ratio of 0.75.

#### Sedimentation tests

24. In order to predict the void ratio distribution of the sedimented dredged material following the containment filling operation, it is necessary to simulate the sedimentation process in laboratory tests. The most direct approach is a simple column sedimentation test. MIT sedimentation tests employed columns only 35.4 in. in height, and other laboratory tests and methods were used to predict void ratio distribution of deeper layers. These requirements were circumvented in the Dyke Marsh tests by use of a sedimentation column equal in height to the expected average thickness of sedimented material in the containment area.

25. The sedimentation column was constructed using plexiglass sections 2 ft in length and 7.9 in. in diameter. Provisions were made for assembly of the sections with watertight O-ring seals to a usable column height of 10 ft. The sectioned column allowed sampling of the test sediment from top to bottom as the sections were removed. The column configuration is shown in Figure 6. Seven lifts of channel sediment slurry were applied in succession to reach a sediment height of approximately 7.5 ft. This sediment height approximates the average

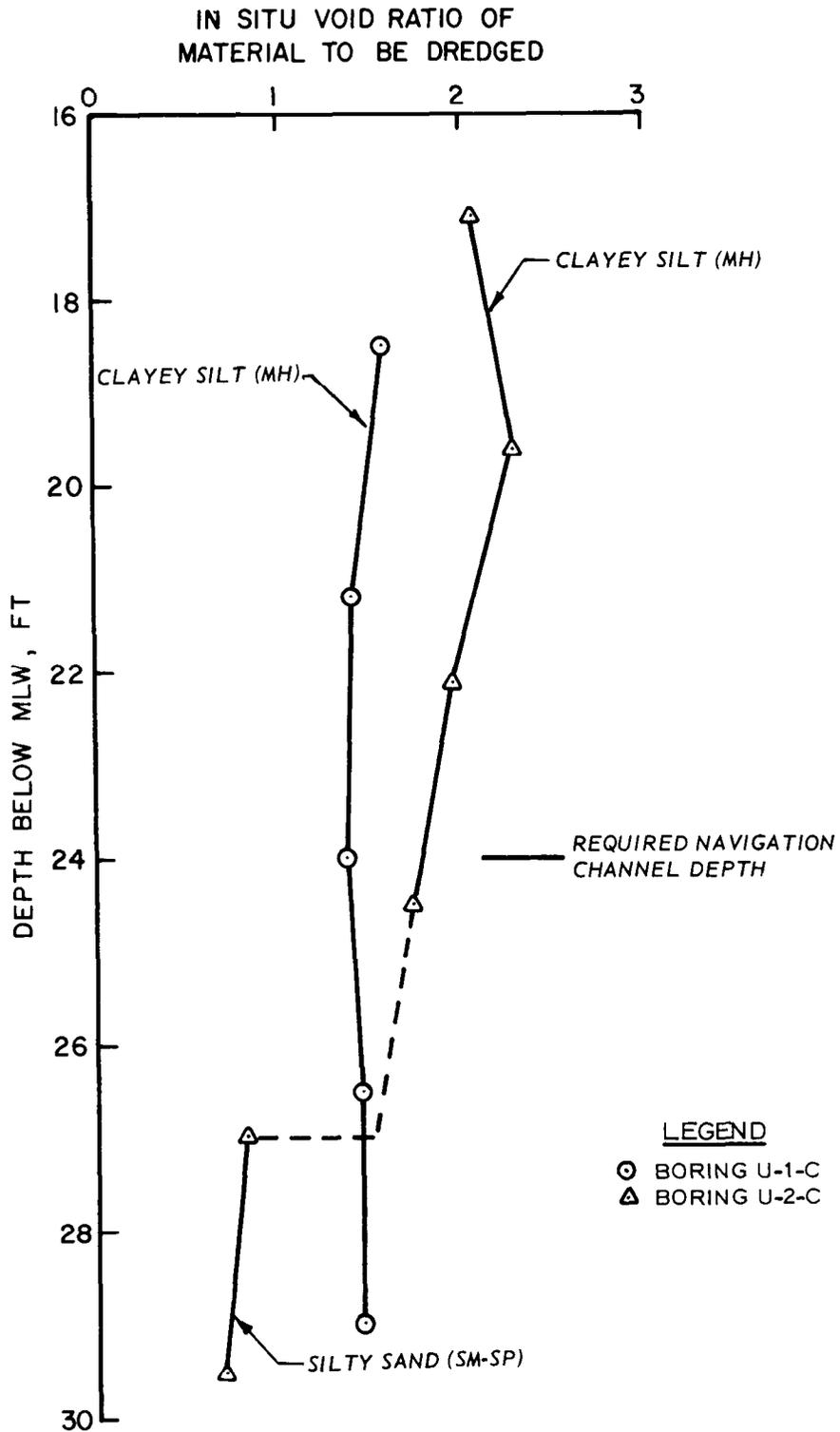


Figure 5. In situ void ratio versus depth distribution for material to be dredged

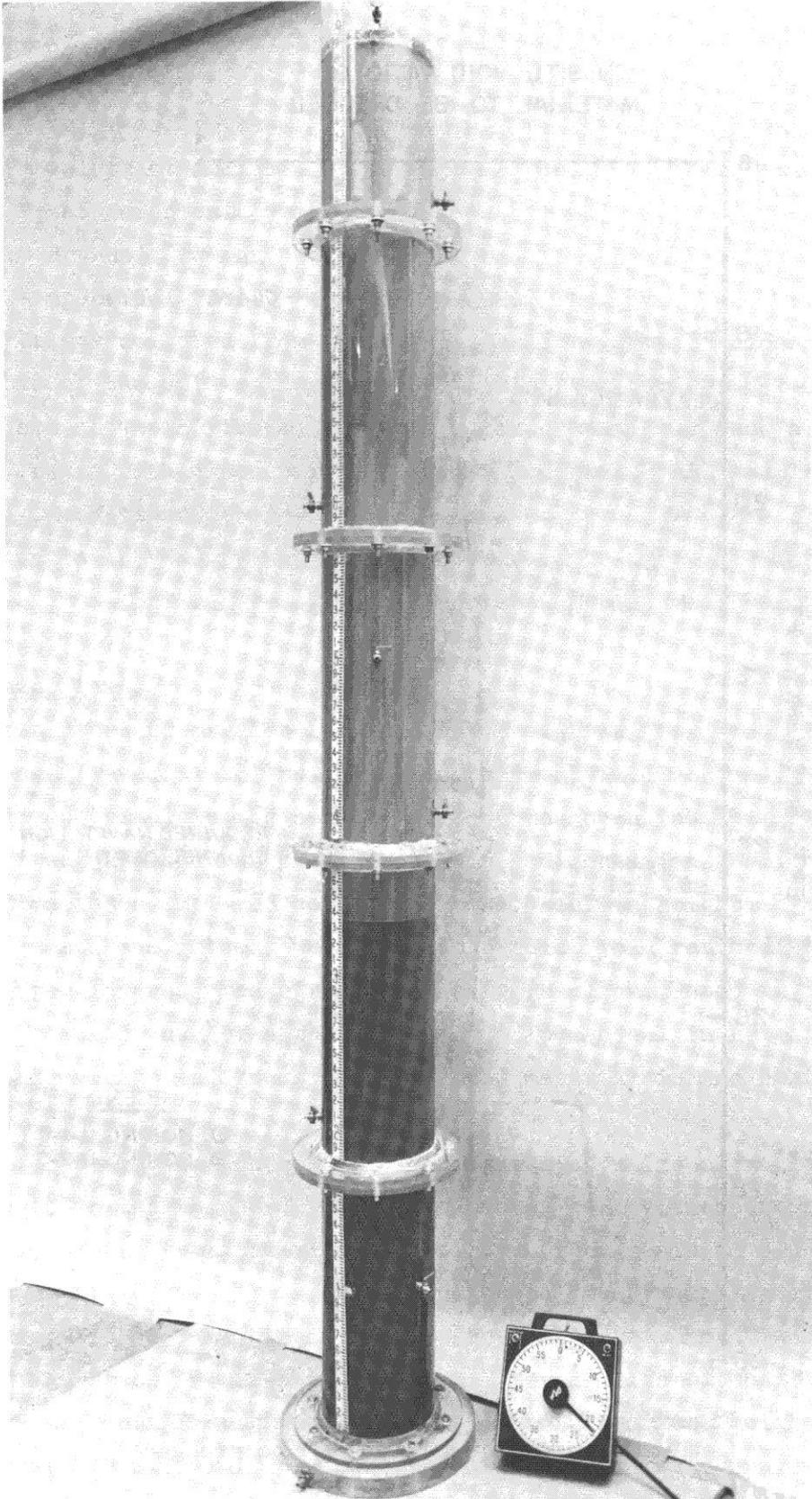


Figure 6. Photograph of column sedimentation test

depth of dredged material in the containment area if the area is filled to an el +2.5 ft mlw as recommended in the feasibility study.

26. A slurry was made of a mixture of tap water and channel sediment material taken from boring location U-2-C shown in Figure 3. The clayey silt (MH) material was considered representative of the sediment material present throughout the shoal area to be dredged. Properties of this material are presented in Appendix A. The slurry contained an average of 13 percent solids by weight, representative of anticipated concentrations during the disposal operation. Each slurry lift was poured into the column to an initial height of 9 to 9.5 ft. An interface between the supernatant liquid and settling solids formed rapidly, and its change in height with time was recorded. Plots of interface height vs. time for each slurry lift are shown in Figure 7. Each lift was allowed to settle until the change in interface height with time became essentially linear as shown in Figure 7, after which the supernatant liquid was drained and a new slurry lift added. A photograph of the test column and test in progress is shown in Figure 6.

27. After completion of the sedimentation tests, the column was dismantled, and sediment samples were obtained at 6-in. depth intervals. The water content, specific gravity of solids, and grain-size distribution were determined at each sample depth. Individual test data are presented in Appendix A.

28. Void ratios were computed using Equation 1. The distribution of computed void ratios for the sedimentation column is shown in Figure 8. The variation in void ratio indicated in Figure 8 was probably caused by the incremental filling of the column, with each lift of slurry tending to form a layer grading from finer to coarser with depth.

29. Hydrometer analyses conducted on the column samples indicated coarser grain size for those samples yielding lower void ratios. The actual containment filling operation will concentrate this coarser material near the dredge pipe outlet, and the layering effect will not be evident. The average void ratio within the sedimentation column was 3.26, which is considered to approximate the average void ratio of the dredged material shortly after filling the containment area.

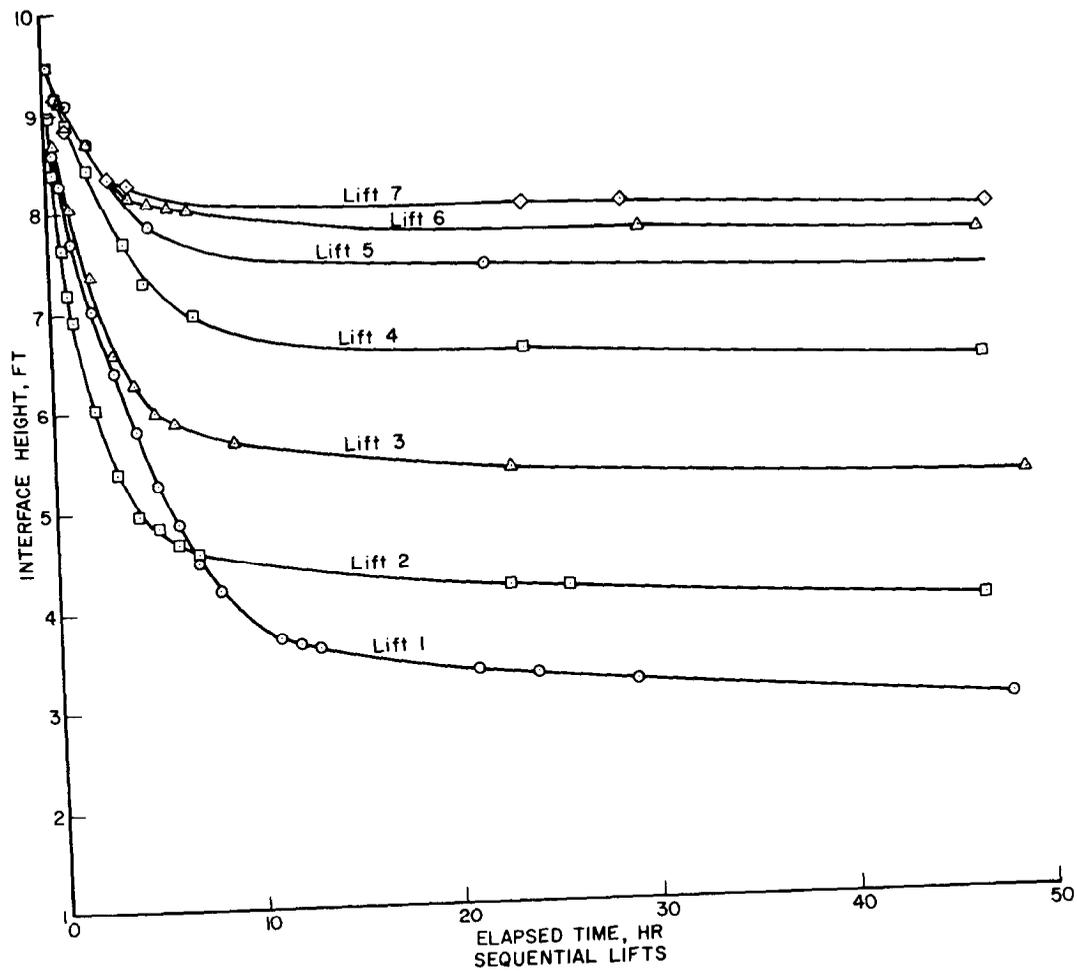


Figure 7. Column sedimentation testing--interface heights versus time

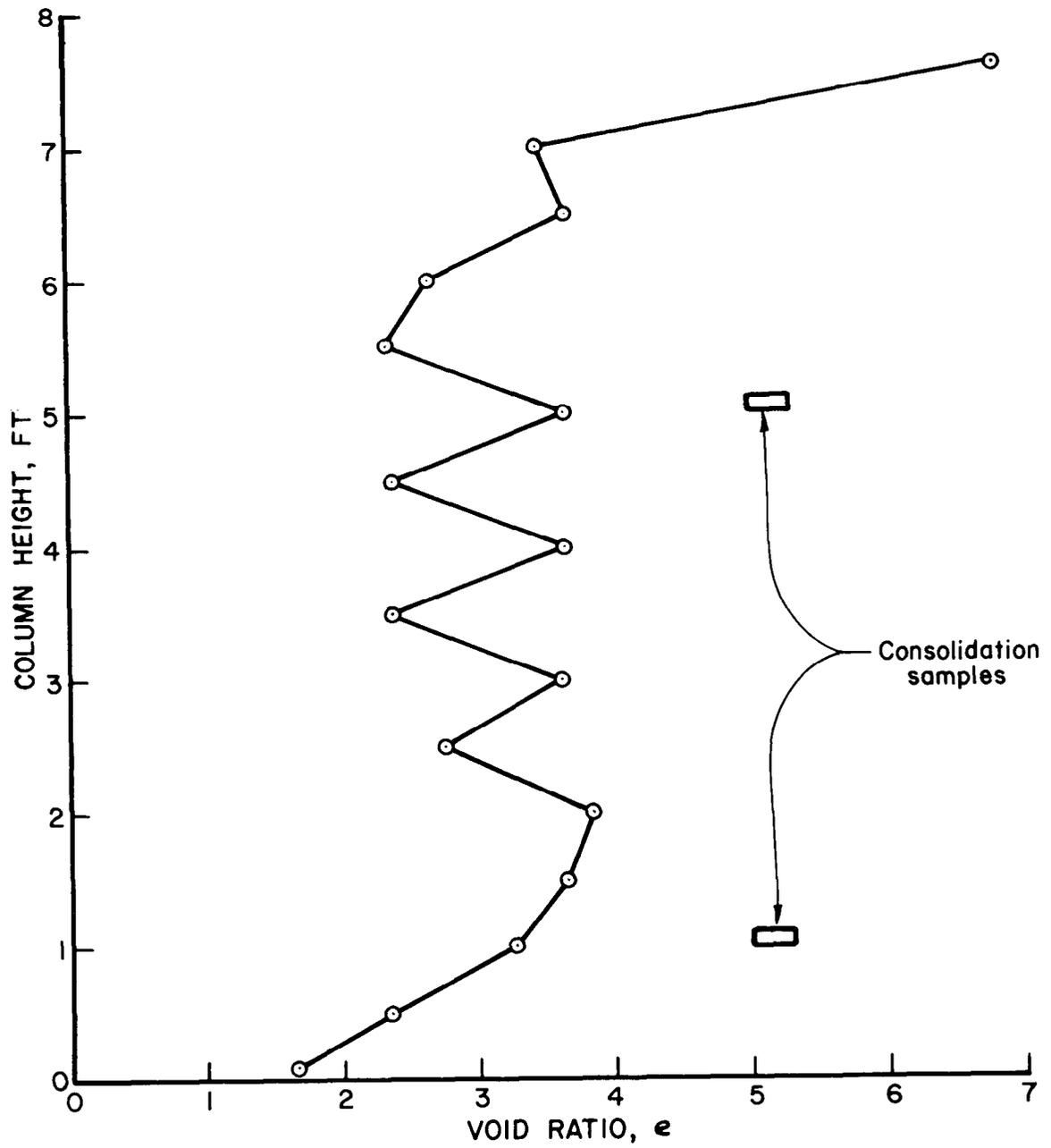


Figure 8. Column void ratios and location of consolidation samples

30. The effective stress plot within the sedimentation column was determined from submerged unit weights computed using the following relationship:

$$\gamma_{\text{sub}} = \frac{\gamma_w (e + G_s)}{1 + e} - \gamma_w \quad (3)$$

where

$\gamma_{\text{sub}}$  = submerged unit weight, pcf

$\gamma_w$  = unit weight of water (62.4 pcf)

$e$  = void ratio of dredged material as measured in the sedimentation column

$G_s$  = average specific gravity of sediment ( $G_s = 2.68$ )

An effective stress plot was constructed by accumulation of the effective unit weights over the known volume of the sedimentation column and is shown in Figure 9. The plot was later used in an estimate of ultimate consolidation of the dredged material under its own overburden stress.

#### Consolidation tests

31. Conventional consolidation tests were performed on two samples taken from the sedimentation column so that the final void ratios under overburden stress could be determined. The consolidation specimens were taken at column heights of 5.0 to 5.1 ft and 1.0 to 1.1 ft located as shown in Figure 8. Standard 2.5-in.-ID consolidation rings were placed on the dredged material layer and material was removed from the exterior of the ring, allowing the specimen to be seated under the weight of the ring. Both specimens were then placed in standard floating-ring consolidometers and were consolidated under successive loads of 0.004, 0.148, 0.04, 0.08, 0.16, and 0.32 tsf. Each load level was maintained for 48 hr to ensure that complete primary consolidation had occurred. Individual consolidation curves are presented in Appendix A. An average coefficient of consolidation of  $0.005 \text{ cm}^2/\text{sec}$  was computed using the square root of time fitting method.

32. The void ratio-log effective stress ( $e\text{-log } \bar{p}$ ) relationships for both specimens are shown plotted in Figure 10. Both tests yielded practically linear  $e\text{-log } \bar{p}$  curves. Initial void ratios of the samples as removed from the column are also shown. Overburden loads for the

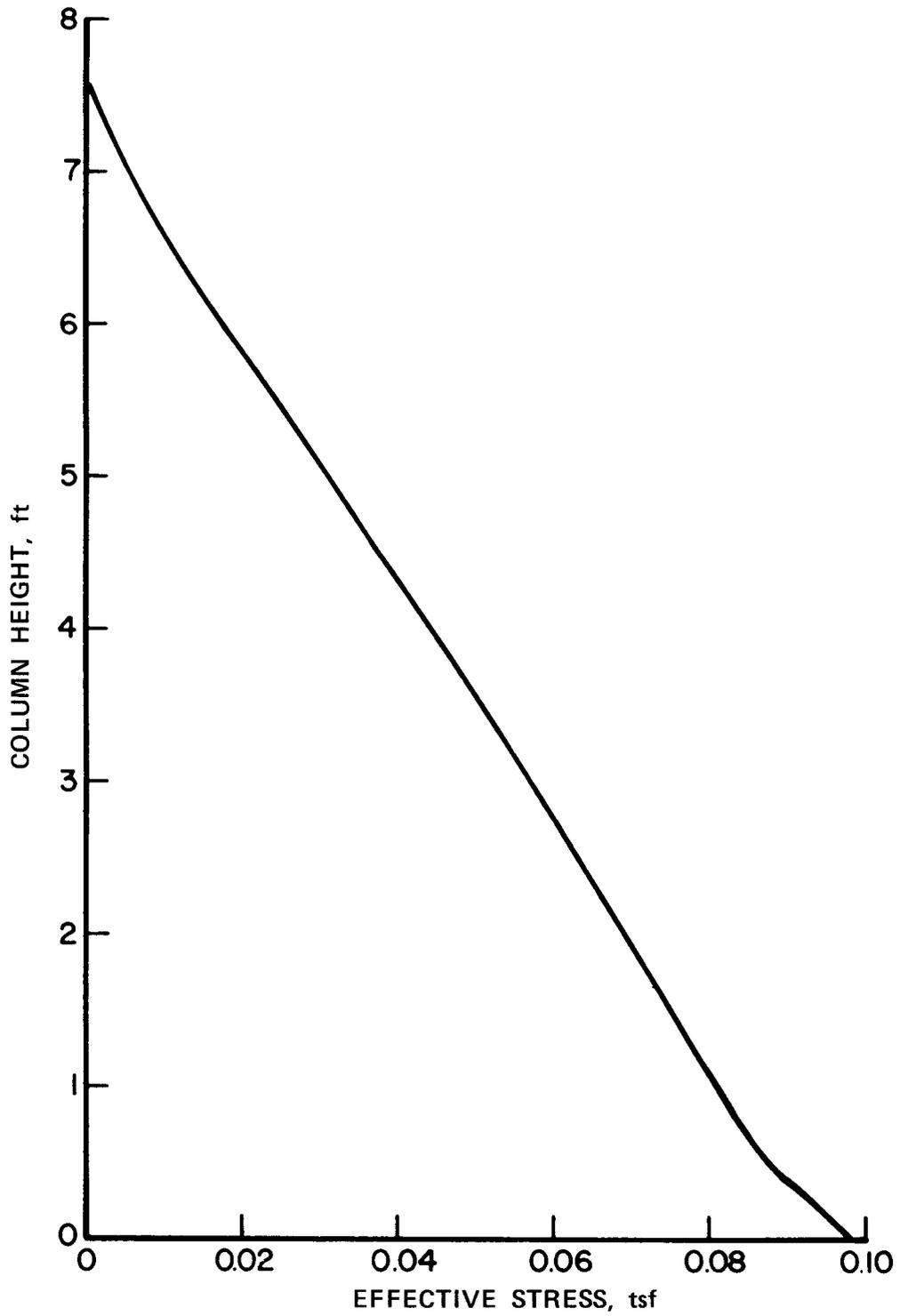


Figure 9. Effective stress plot for sedimentation column

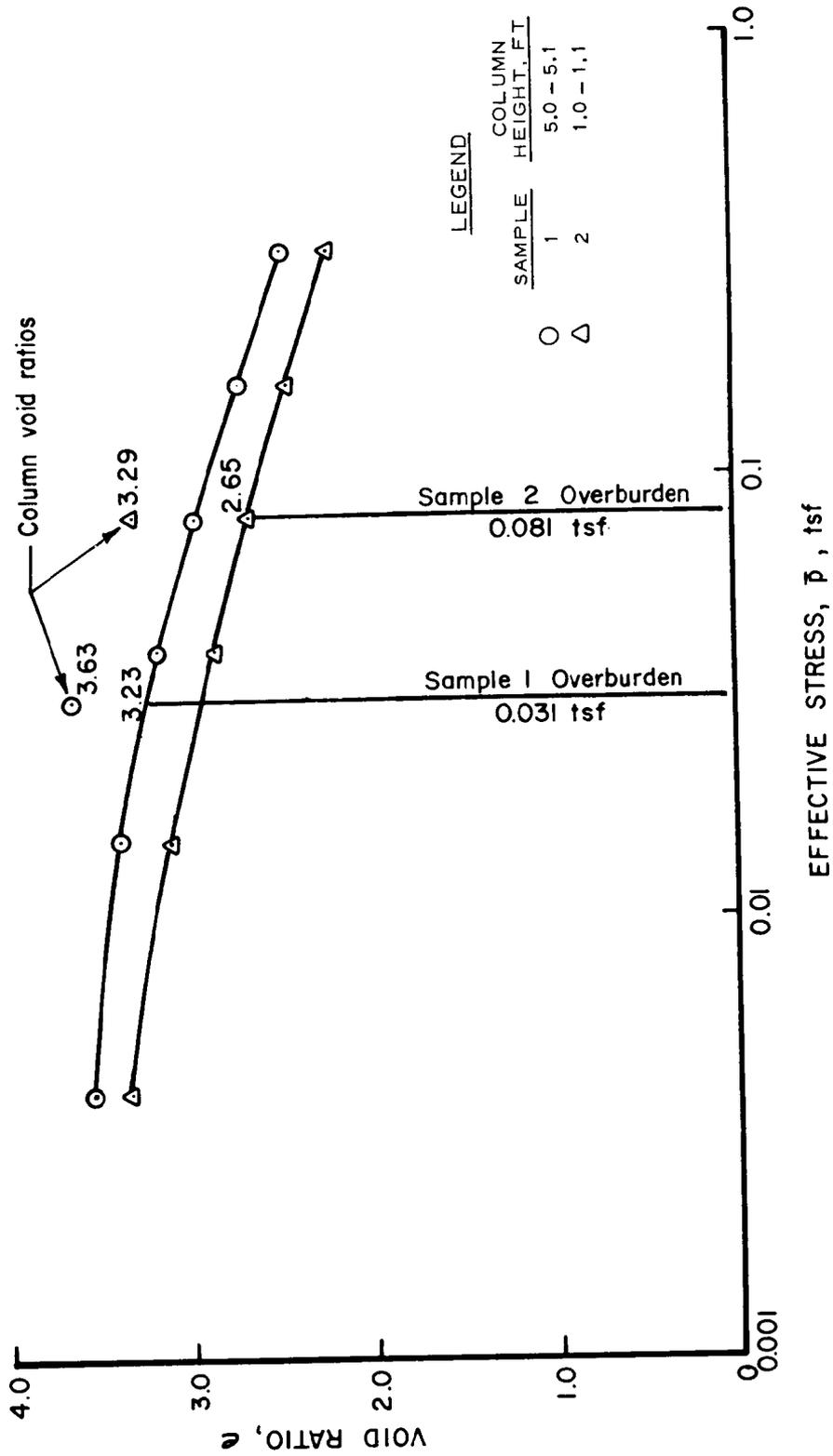


Figure 10. Void ratio versus effective stress

two consolidation samples were 0.031 tsf and 0.081 tsf for the upper and lower samples, respectively, as shown in Figure 8. Column void ratios for the samples were 3.63 and 3.29 while final void ratios as determined by the consolidation tests were 3.23 and 2.65, respectively, as shown in Figure 10. Ultimate settlement of the substrate was determined as the difference in these void ratios as described in paragraph 40.

Dredging volume requirements

33. The volume capacity of the Dyke Marsh demonstration area was determined based on the dike alignment, bottom contours (Figure 11), and initial filling to el +2.50 ft mlw as recommended in the feasibility study. The capacity of the demonstration area will be approximately 354,000 yd<sup>3</sup> of sedimented dredged material.

34. The containment volume or volume of sedimented dredged material can be related to the in situ volume of channel sediment to be dredged by the bulking factor, defined as:

$$BF = \frac{V_a}{V_b} \quad (4)$$

where

BF = bulking factor

V<sub>a</sub> = total volume of sedimented dredged material

V<sub>b</sub> = total volume of in situ channel material

35. The sedimented and in situ volumes can further be expressed as:

$$V_a = V_s(1 + e_a) \quad (5)$$

and

$$V_b = V_s(1 + e_b) \quad (6)$$

where

V<sub>s</sub> = volume of solids

e<sub>a</sub> = average void ratio of the sedimented dredged material

e<sub>b</sub> = average void ratio of the in situ channel material

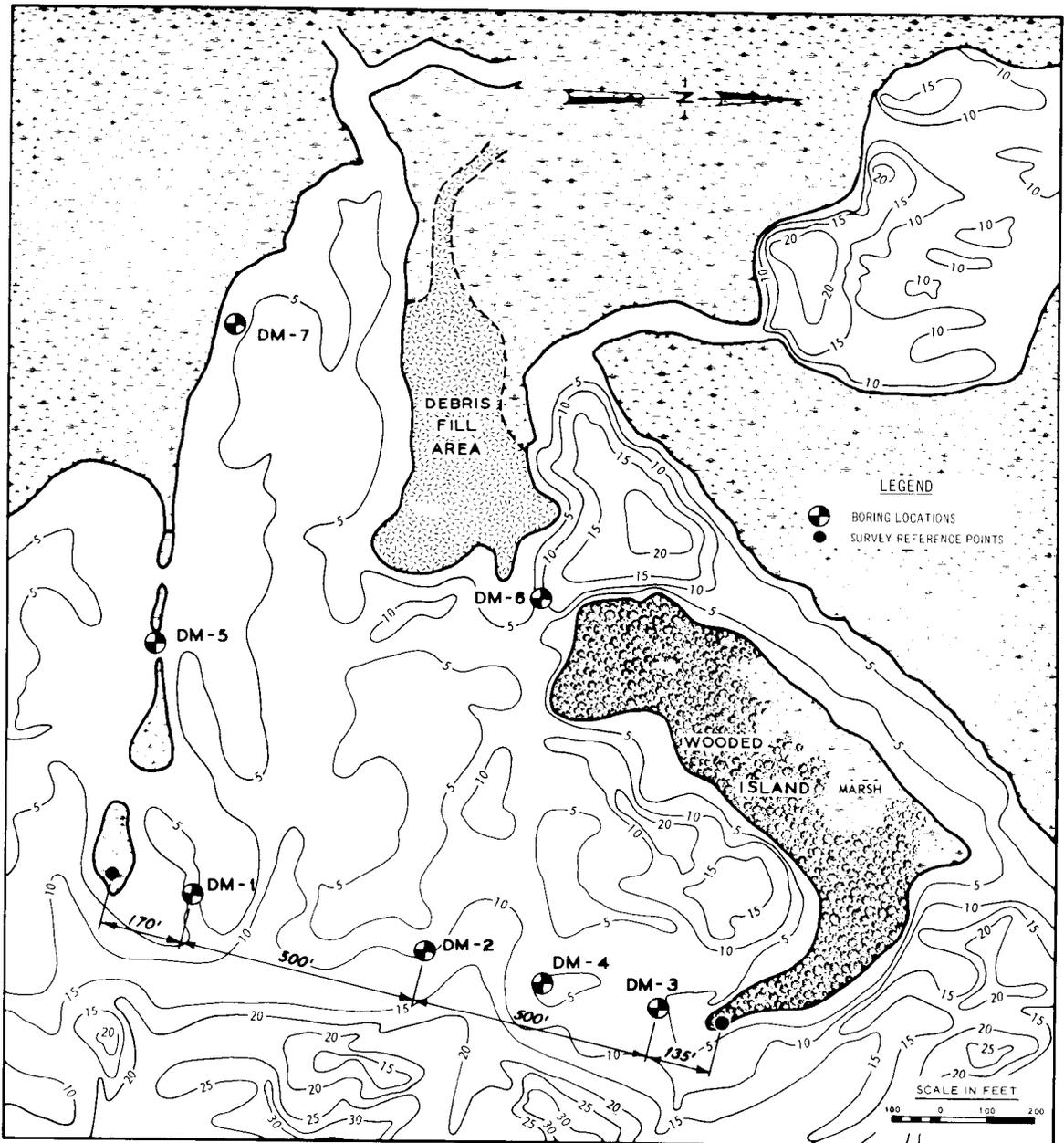


Figure 11. Containment area boring plan and bottom contours

36. The volume occupied by solids remains unchanged; therefore, the bulking factor may be expressed as:

$$BF = \frac{1 + e_a}{1 + e_b} \quad (7)$$

37. An average in situ channel void ratio of 1.70 was determined based on results from undisturbed samples of silt from the shoal area. The average sedimented void ratio for the demonstration area was estimated at 3.26 based on measured values from the column sedimentation testing. The bulking factor was computed as 1.58 using Equation 7.

38. The containment area capacity of 354,000 yd<sup>3</sup> and bulking factor of 1.58 yields a required dredging volume of 224,000 yd<sup>3</sup>. An additional 10 percent should be dredged to account for efficiency of the cutterhead and sluice, bringing the total required dredging volume to 246,000 yd<sup>3</sup>. The latest channel survey indicated that the dredging volume required to meet the navigation channel depth of 24.0 ft below mlw is an estimated 142,000 yd<sup>3</sup>. This estimate includes the normal two-ft overdredge to el -26.0 ft mlw. An additional volume of 106,000 yd<sup>3</sup> above project requirements must be dredged to fill the Dyke Marsh demonstration area. The additional yardage must be obtained through additional overdredging or from other dredged material disposal operations.

#### Ultimate substrate settlement

39. Following the placement of dredged material within the containment area to an initial el +2.50 ft mlw, the material will consolidate under its own overburden pressure. The foundation material will also undergo consolidation caused by the weight of dredged material. Laboratory consolidation tests performed on sedimented material from the column tests and on undisturbed samples of the foundation material were used to predict the magnitude of ultimate settlement.

40. Dredged fill consolidation. The conditions simulated in the column sedimentation test were assumed to represent field conditions shortly after filling the containment area. The material sedimented in the column was not fully consolidated under the overburden load; therefore, the settlement of dredged material after filling is governed by

the difference between (a) the sample void ratio as measured in the sedimentation column and (b) the sample void ratio after consolidation under an effective stress corresponding to the sample depth in the column. Consolidation tests performed on two samples of the column sediment yielded void ratio-effective stress relationships shown in Figure 10. The effective stress and void ratio measured within the sedimentation column at the sample depths were as follows:

Sample No.	Column Height, ft	Effective Stress $\bar{p}$ , tsf	Void Ratio	
			Column $e_1$	Final $e_2$
1	5.0-5.1	0.031	3.63	3.23
2	1.0-1.1	0.081	3.29	2.65

41. Final void ratios as measured in the column sample consolidation tests are also shown above. Sample 1 is assumed to represent the dredged fill from a depth of 0 to 4 ft and Sample 2 is assumed to represent the dredged fill from a depth of 4 to 8 ft. Ultimate settlement was computed using the relationship:

$$S = \frac{e_1 - e_2}{1 + e_1} H \quad (8)$$

where

S = ultimate settlement, ft

$e_1$  = initial void ratio (measured in the sediment column)

$e_2$  = final void ratio (after consolidation)

H = thickness of layer

42. Ultimate settlements computed using Equation 8 were 0.33 ft for the 0- to 4-ft layer and 0.58 ft for the 4- to 8-ft layer. Consolidation-time data indicated that consolidation would be essentially complete within four months.

43. Foundation consolidation. Consolidation of the foundation due to placement of dredged material was estimated from a laboratory consolidation test performed on an undisturbed sample taken from Boring DM-4 located as shown in Figure 11. The sample was considered representative of the upper layers of similar foundation material present

over the entire proposed location of the containment area. Results of this consolidation test are presented in Appendix D.

44. The placement of an average thickness of 8 ft of dredged material would represent an increase in effective stress of approximately 0.10 tsf (see Figure 9). Ultimate settlement of the foundation due to this load was computed as 0.41 ft using Equation 8.

45. Total ultimate settlement. The total ultimate settlement of the dredged material substrate was determined by adding settlements due to consolidation of the sedimented dredged material due to its own overburden load and consolidation of the foundation material. The total predicted ultimate settlement was 1.32 ft, assuming that material would be initially placed to el +2.50 ft m.l.w. Final substrate elevation would therefore be approximately +1.20 ft, slightly below the mid-tidal range. Examination of consolidation-time data for both dredged material and foundation material indicated that stabilization of the marsh substrate would be controlled by the dredged material consolidation rate. Stabilization would be essentially complete within four months of initial placement.

#### Sizing for suspended solids removal

46. Research is currently being conducted by the DMRP concerning containment area sizing for removal of suspended solids. At present, a conservative design for suspended solids removal can be performed based on Stokes Law for discrete particle settling. It is assumed that efficiency of the containment area is a function of the settling velocity of the particles, surface area of the containment, and the flow rate through the containment. Settling efficiencies based on discrete particle theory are reduced by currents caused by eddies, wind, and thermal convection. Accounting for these reductions in efficiency and assuming specific gravity of solids of 2.68 and a water temperature of 20°C, the expression for removal of a proportion of suspended particles P is:

$$P = 1 - \left( 1 + \frac{9000D^2}{Q/A} \right)^{-1} \quad (9)$$

where

P = proportion of particles removed

D = equivalent particle diameter, cm

Q = flow rate, cfs

A = containment surface area, ft<sup>2</sup>

Efficiency of the Dyke Marsh containment area was computed to be 87 percent using this expression with a surface area of 29 acres, average flow rate for a 12-in. dredge, and particle size from the sediment samples. This efficiency would meet existing criteria for effluent water quality.

## PART III: RETAINING DIKE DESIGN

47. The design of the main retaining dikes and temporary back dike was undertaken in a manner identical to that of any earthen embankment. Results of field investigations and laboratory testing were used in conventional engineering analysis for designing dike sections based on dike stability and evaluating potential dike settlement. Containment area layout and plan of the dike locations are shown in Figure 12. General requirements for design of earthen embankments are outlined in appropriate Corps of Engineers (CE) design manuals,<sup>7,8</sup> and factors relating specifically to dredged material retaining dike design are identified by DMRP research.<sup>9</sup>

### Soils and Foundation Investigation

#### Field investigation

48. Three borings (DM-1, DM-2, and DM-3) were made along the main dike center line for the feasibility study. These borings were made in 7 to 10 ft of water using floating plant and were advanced to a depth of 50 ft below river bottom. Four additional borings (DM-4 through DM-7) were made for the detailed design to further define foundation conditions along the main dike center line and other reaches of the retaining dike system. These borings were also made from floating plant and were carried to a depth of approximately 60 ft below river bottom except boring DM-7 that was carried approximately 15 ft below river bottom. Locations of all borings are shown on the site boring plan presented in Figure 11. Graphic boring logs are shown in Figures 13 and 14.

49. Three-in. undisturbed tube samples were taken in fine-grained cohesive material and split spoon samples were taken in cohesionless soils. Standard penetration resistances were recorded for the cohesionless soils with a 1-3/8-in.-ID, 2-in.-OD split spoon sampler using a 140-lb hammer with a 30-in. drop. Blow counts are shown with the graphic boring logs in Figures 13 and 14.

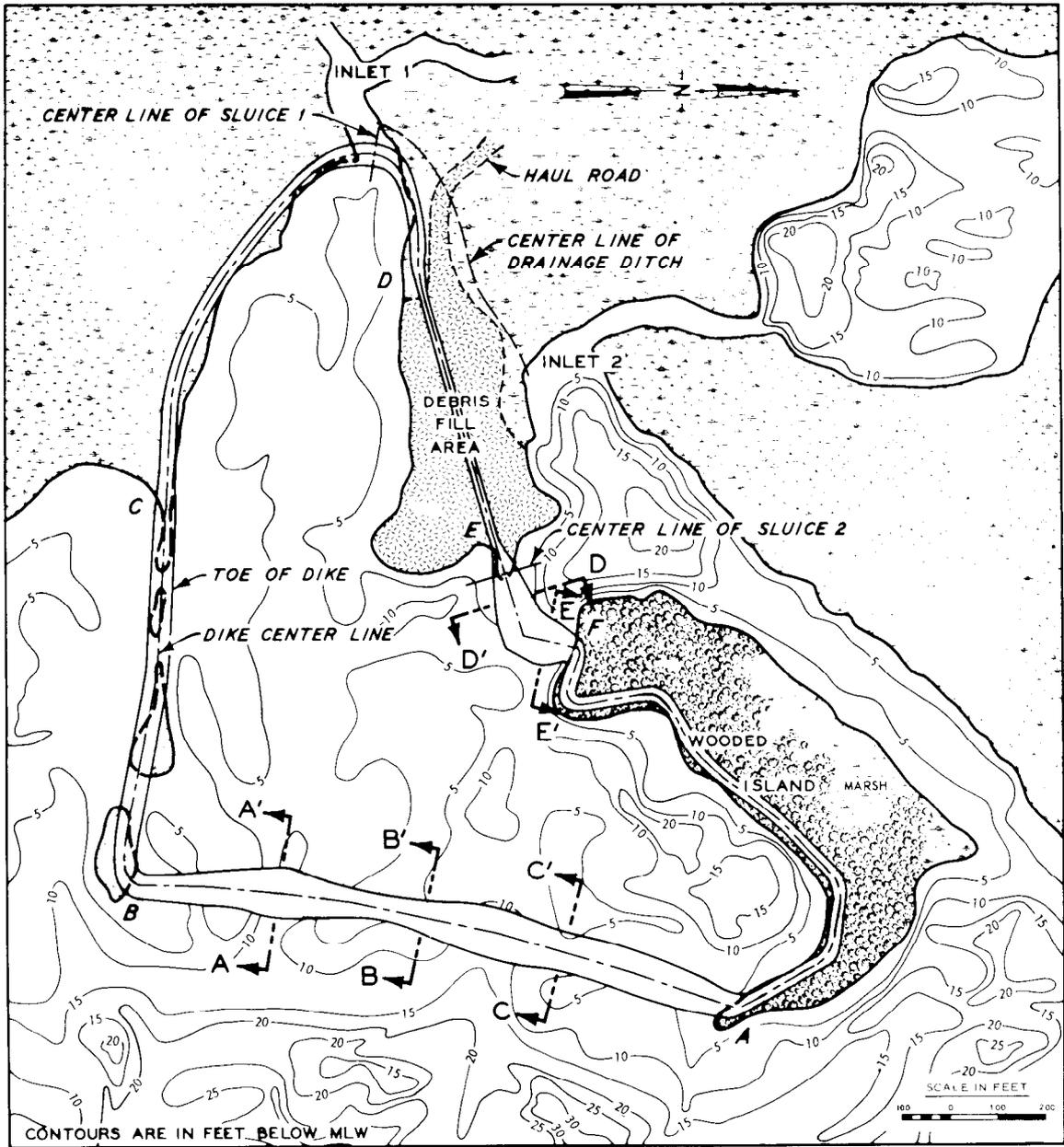
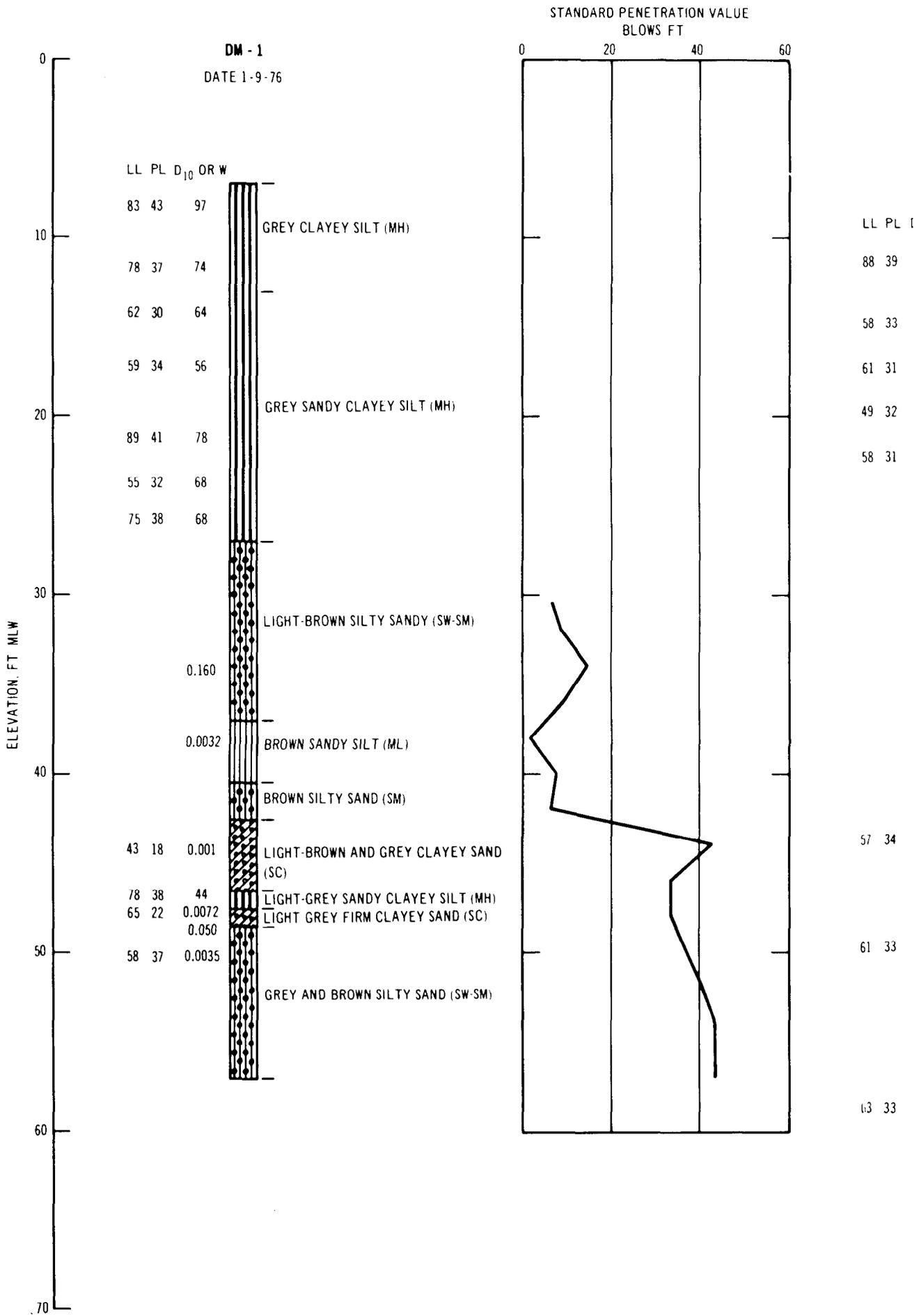
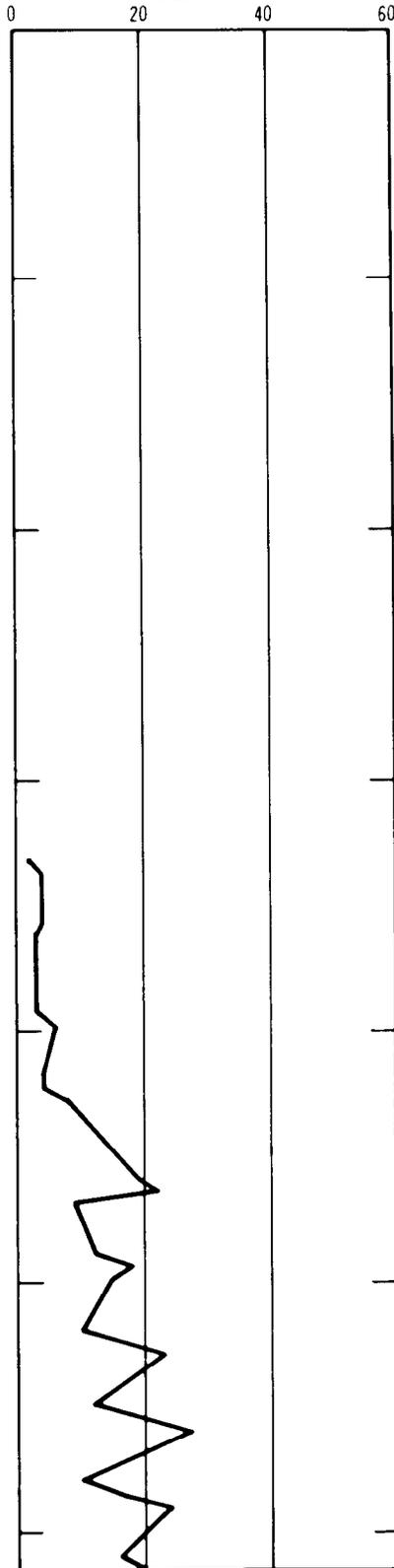


Figure 12. Containment area layout and plan of dikes



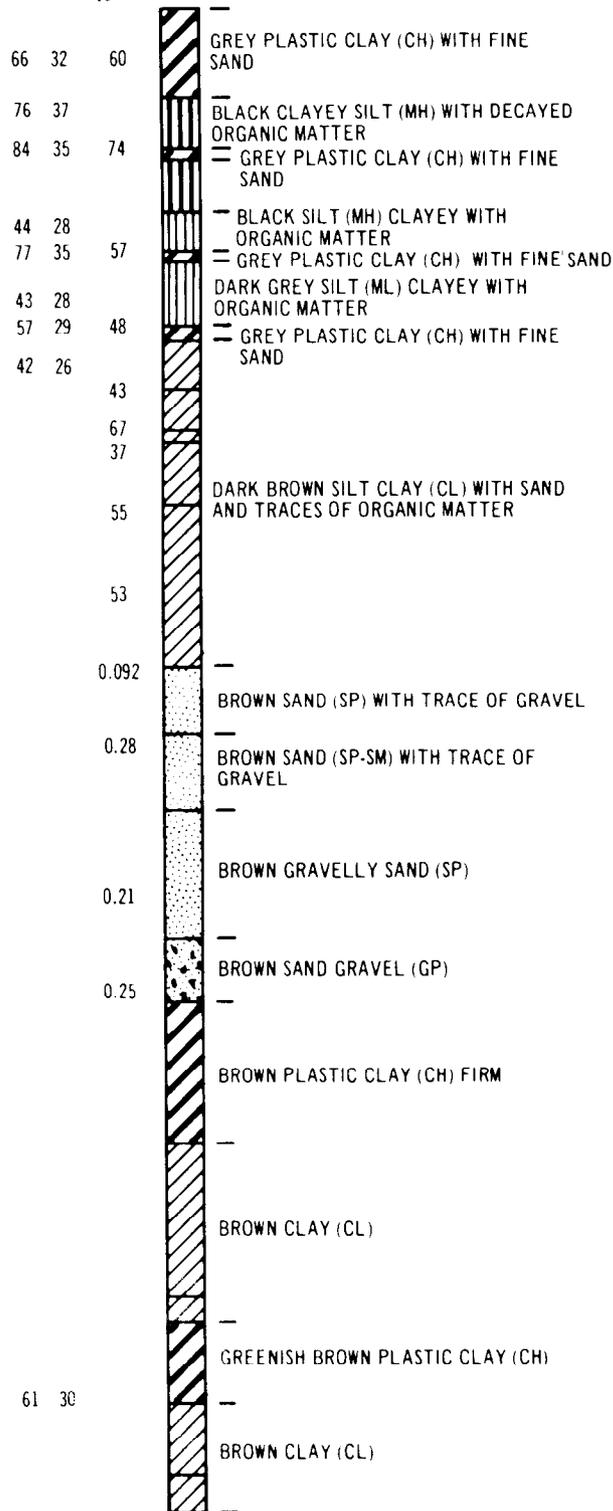


STANDARD PENETRATION VALUE  
BLOWS/FT



DM - 4

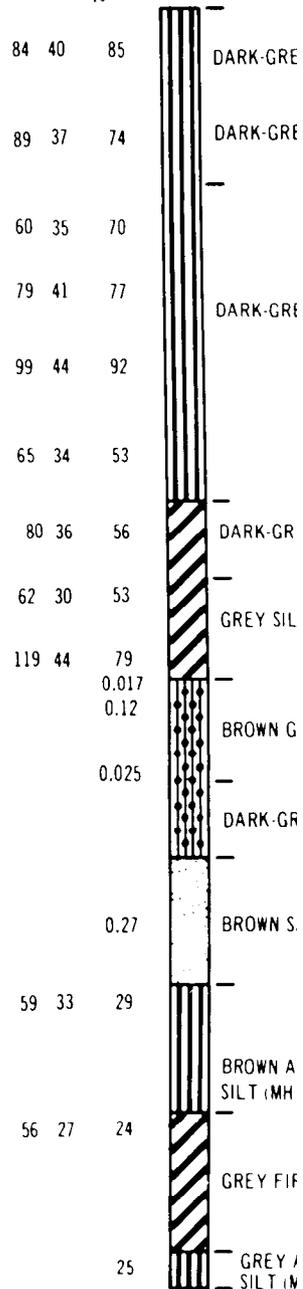
LL PL D<sub>10</sub> OR W



DM - 3

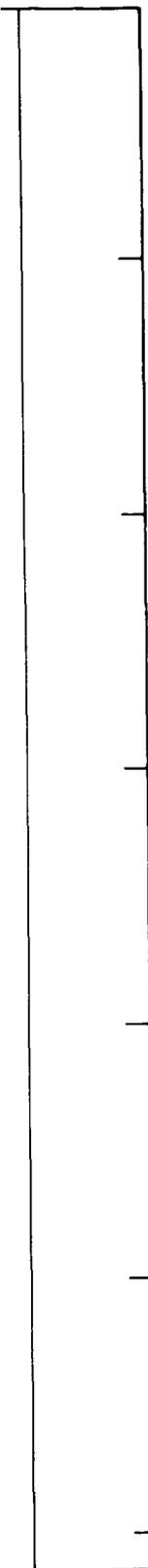
DATE 1-30-76

LL PL D<sub>10</sub> OR W



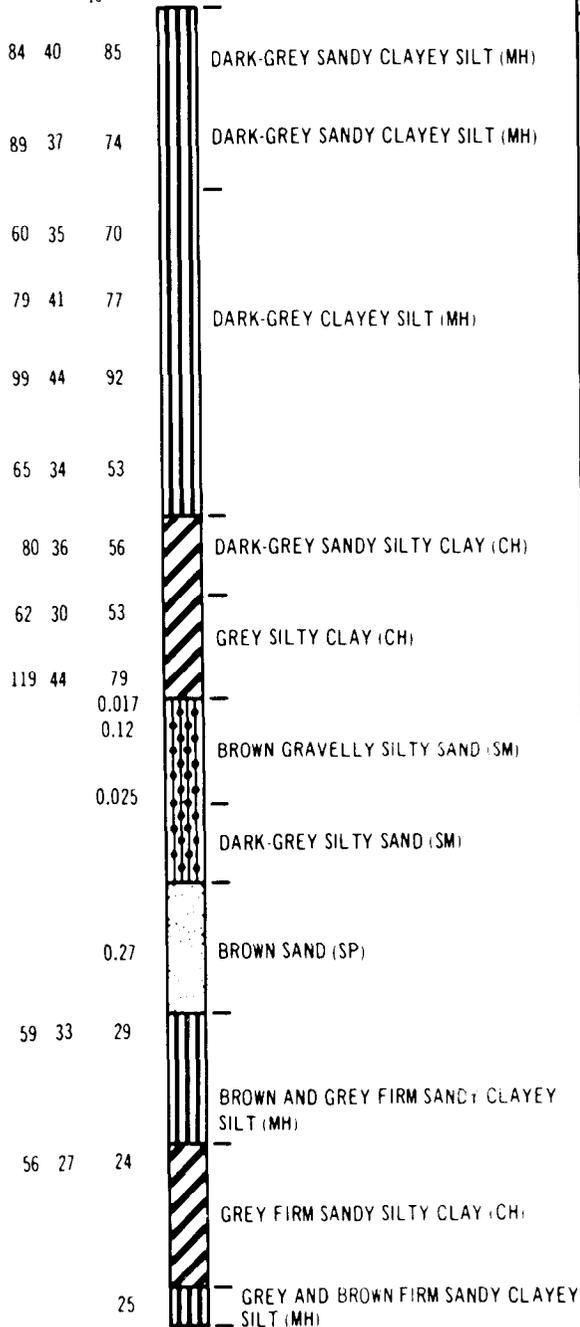
ION VALUE

40 60



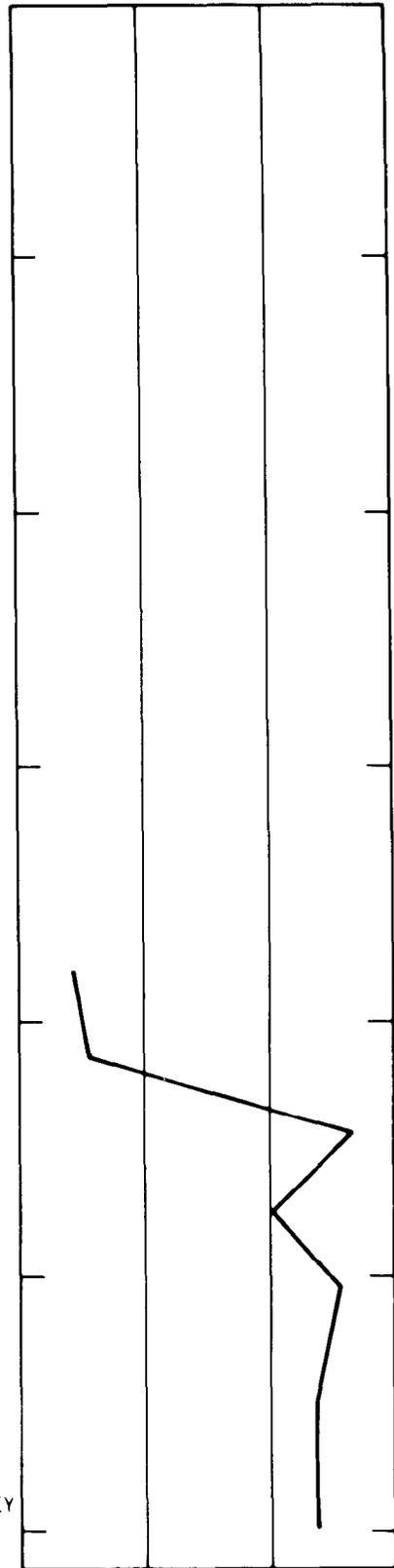
DM - 3  
DATE 1-30-76

LL PL D<sub>10</sub> OR W



STANDARD PENETRATION VALUE  
BLOWS/FT

0 20 40 60



ELEVATION, FT. MLW



### Laboratory testing

50. Laboratory testing for the feasibility study was performed by the BD Soils Laboratory and the WES S&PL and consisted of classification of all samples under the USCS; water content determinations for all fine-grained samples; and Atterberg limits, grain-size analyses, unconfined compression tests, and consolidated undrained R triaxial tests on selected samples. A similar laboratory testing program was conducted for samples taken from the detailed design borings. Additional shear strength tests including unconfined compression and consolidated undrained R triaxial were performed on selected samples. A consolidation test was also performed on a sample from the compressible upper strata. All laboratory testing for the detailed design was performed by the WES S&PL.

51. Results from both the feasibility study and detailed design testing programs are shown with the graphic boring logs in Figures 13 and 14. Shear strength test results for selected samples are summarized in Table 1. Individual test data are presented in Appendix D.

### Soil conditions

52. Soil conditions beneath the main retaining dike reach A-B are represented by the generalized soil profile presented in Figure 15. These conditions were extrapolated from borings DM-1 through DM-4. Conditions were essentially unchanged from those determined by the feasibility study borings except that an additional thickness of clay was indicated by boring DM-4 along reach A-B. An upper layer of clayey silt (MH) and clay (CL and CH) extended from average el -10.0 ft mlw to -30.0 ft mlw and was underlain by a stratum of loose silty sand (SM) extending to el -43.0 ft mlw and firmer layers of sand and silty sand below el -43.0 ft mlw. Conditions represented by the generalized soil profile were used in the stability analyses for the main dike reach A-B. Soft clay layers were also indicated near the surface by boring DM-5. However, the foundation conditions indicated by boring DM-5 did not dictate a separate stability analysis for reach B-C.

53. Foundation conditions for dike reach E-F were indicated by boring DM-6 shown in Figure 14. This dike reach joined the debris fill

Table 1

Summary of Test Results on Selected Foundation Soils

<u>Boring</u>	<u>Sample</u>	<u>Elevation</u> <u>ft mlw</u>	<u>Classifi-</u> <u>cation</u> <u>(USCS)</u>	<u>Atterberg</u>		<u>Shear Strength</u>		
				<u>Limits</u>		<u>Type</u>	$\phi$	<u>Cohesion</u>
				<u>LL</u>	<u>PL</u>	<u>Test</u>	<u>Degrees</u>	<u>psf</u>
DM-2	B-3	-18.5	MH	61	31	R	14	800
DM-3	B-3	-18.5	MH	60	35	R	18	0
DM-3	B-7	-28.5	CH	80	36	UC	0	179
DM-3	B-8	-33.5	CH	62	30	UC	0	252
DM-3	B-9	-35.5	CH	119	44	UC	0	349
DM-4	4-A	-21.0	ML	43	28	UC	0	164
DM-4	5-A	-23.0	CL	42	26	UC	0	118

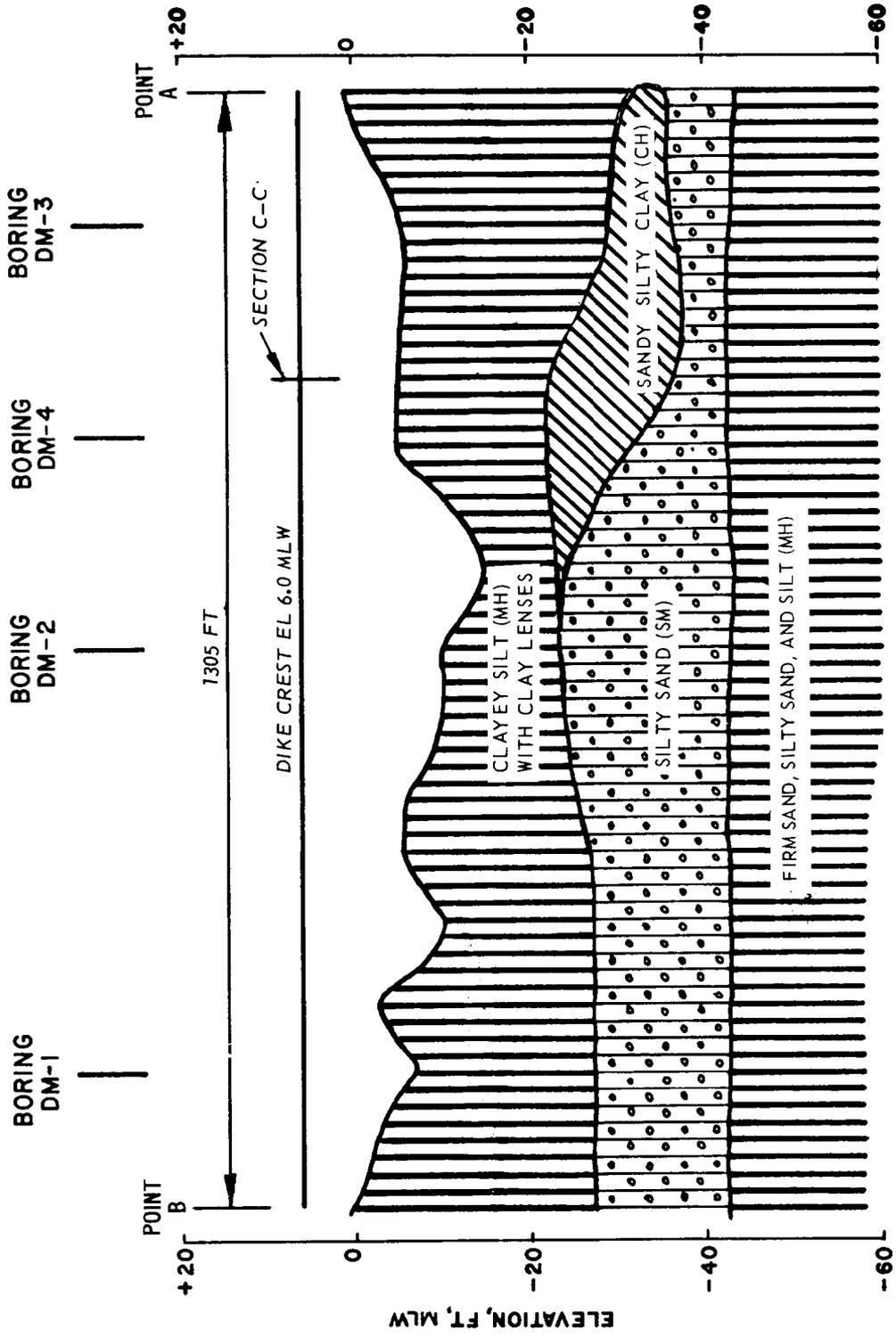


Figure 15. Generalized soil profile, dike reach A-B

area and the existing wooded island. Surface deposits of sand were evident in this vicinity and were indicated by this boring to extend to el -25.0 ft mlw. Layers of clay and silt extended from el -25.0 to -37.0 ft mlw and were underlain by silty sand.

54. Boring DM-7 shown in Figure 14 was taken adjacent to dike reach C-D and indicated that the existing marsh material consisted of clay (CH and CL) extending to el -15.0 ft mlw, underlain by silty sand.

### Retaining Dike Stability

#### Design conditions

55. Dike sections described later in Part IV were analyzed for the possible failure conditions that might occur under field conditions. Only the main dike section A-B was analyzed for the feasibility study. This section was reanalyzed for the detailed design in light of additional foundation data and the dike reaches C-D and E-F were also analyzed. Three conditions were considered in the design of the retaining dike: the after-construction case, the long-term or steady seepage condition, and the case of sudden drawdown.

- a. The most critical condition encountered for a retaining dike placed on soft foundation soils occurs immediately after placement of the dike and is termed the after-construction case. This case considers the condition when foundation soils have not yet undergone consolidation and shear strength has not yet increased due to placement of the embankment load.
- b. Once dredged material is placed in the containment area, a condition of steady state seepage from the higher marsh substrate to the mean low tidal elevation may develop. This case is the long-term or steady seepage condition.
- c. The tidal fluctuation of approximately 3 ft at Dyke Marsh could subject the retaining dike to a condition in which the water level is lowered at a faster rate than the dike and foundation material can drain, which could result in excess pressures and seepage forces. This is termed the sudden-drawdown case.

#### Shear strength

56. Shear strengths for the stability analyses were chosen based

on laboratory tests on foundation soils as summarized in Table 1 and on previous CE experience with similar soils. The unconsolidated undrained Q-strength for foundation clays and consolidated undrained R-strength for foundation silt were chosen from plots presented in Appendix D. The following tabulation summarizes design shear strengths selected for the unconsolidated undrained (Q), consolidated undrained (R), and consolidated drained (S) conditions. These strengths were selected based on tests conducted for both the feasibility study and detailed design. In the analyses, dike fill material was assumed to have shear strengths identical to that shown for sand and dredged material was assumed to have no shear strength.

Material	Unconsolidated Undrained Q		Consolidated Undrained R		Consolidated Drained S	
	$\phi$	Cohesion	$\phi$	Cohesion	$\phi$	Cohesion
	Degrees	psf	Degrees	psf	Degrees	psf
Clay: upper	0	140	10	300	22	0
lower	0	250	10	300	22	0
Silt	--	--	14	300	28	0
Sand	--	--	--	--	30	0
Dike fill	--	--	--	--	30	0

Stability analyses

57. All slope stability analyses were made using procedures outlined in appropriate CE design manuals.<sup>7,8</sup> Both the circular arc method and wedge method of slope stability were employed, and computer programs developed at WES were used to aid the analysis.<sup>10,11</sup> Stability analyses were conducted for various dike configurations, varying the dike side slopes and crown widths until acceptable factors of safety were achieved. Minimum factors of safety for the various failure conditions analyzed were found by variation of the locations of potential failure surfaces. A minimum factor of safety against shear of 1.3 is considered adequate for retaining dikes and was used as an acceptable stability criterion except where noted.

58. The main dike reach including segments A-B and B-C was

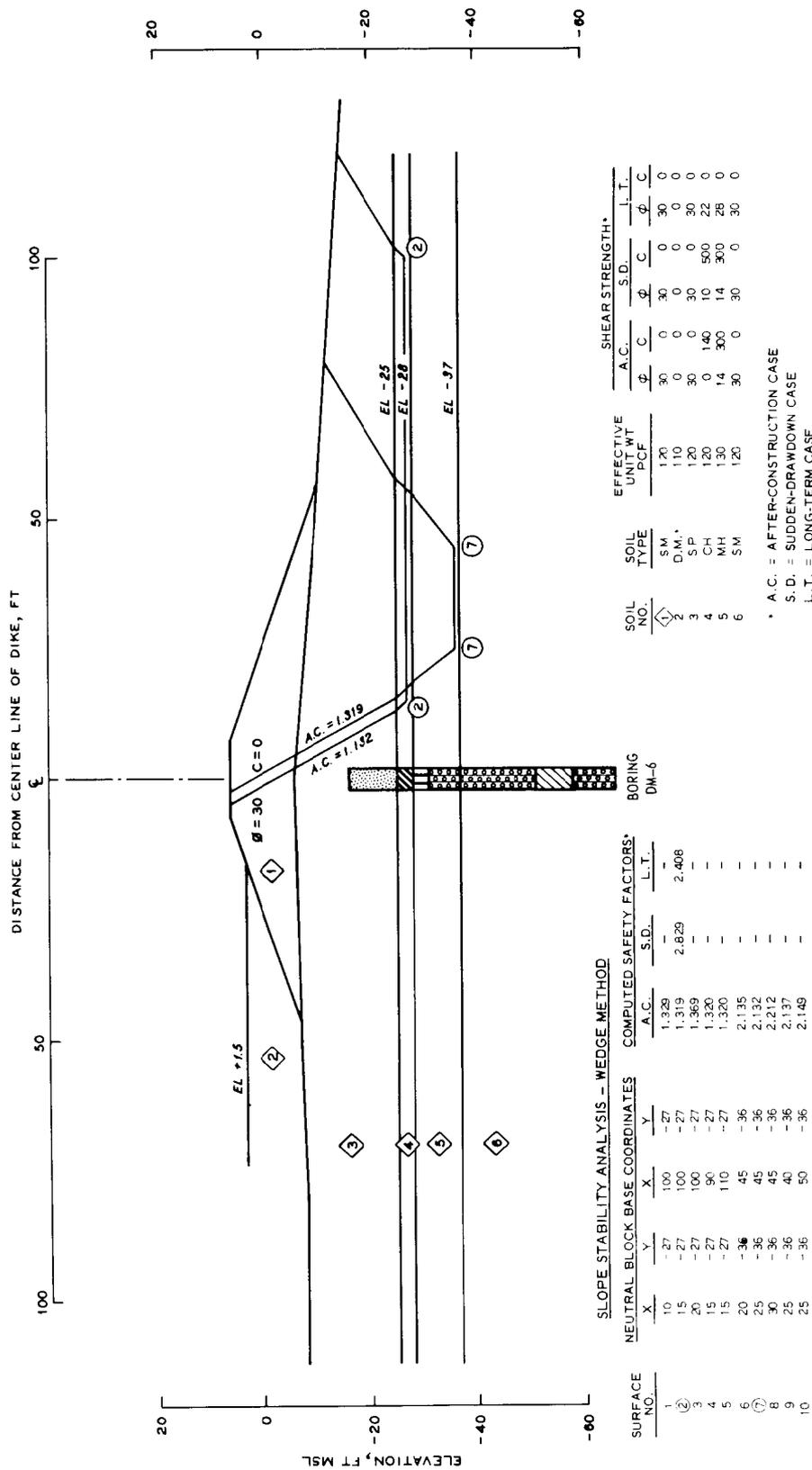
analyzed for after-construction, sudden-drawdown, and steady seepage conditions. Results of the analyses are presented in Figure 16. Stratifications used were based upon the generalized soil profile presented in Figure 15. Configurations of the upper and lower clay strata were based on composite data from borings DM-3 and DM-4. The location selected for analysis is shown as section C-C in Figure 12 and is also indicated on the generalized soil profile in Figure 15. This section was considered the most critical for dike segments A-B and B-C. A minimum factor of safety of 1.66 was computed for the after-construction case for dike side slopes of one vertical on three horizontal (1V on 3H) and a 10-ft crown width.

59. Dike reach E-F joining the wooded island and debris fill area was analyzed using section D-D, located as shown in Figure 12. Stratification used in the analysis was based on boring DM-6 and only the after-construction case was considered critical for these foundation conditions. Results of the analysis for 1V-on-3H side slopes and 10-ft crown width are presented in Figure 17.

60. The back dike reach C-D was analyzed using a typical section presented in Figure 18. Boring DM-7 was taken adjacent to this reach and indicated clay (CH and CL) extending to an el -15 ft mlw. The marsh material extending landward from this boring location also consisted of clay (CH). Shear strength for all clay was assumed equal to that for the upper clay defined in the shear strength plot presented in Appendix D. Based on these soil conditions, only the after-construction case was considered critical. Construction of the back dike will be accomplished by borrowing material from the containment interior as described in Part IV and indicated in Figure 18. The dike should be placed to disturb the minimum area of existing marsh. Although the proposed dike height is quite low, the stability analyses indicated that a minimum setback distance of 60 ft from the present mlw line was necessary to achieve a safety factor above 1.15 for the after-construction case. Results of the analysis for 1V-on-3H side slopes and 5-ft crown width are presented in Figure 18.

61. Shear strengths and stratification used in the back dike





**SLOPE STABILITY ANALYSIS - WEDGE METHOD**

SURFACE NO.	NEUTRAL BLOCK BASE COORDINATES		COMPUTED SAFETY FACTORS*	
	X	Y	A.C.	L.T.
1	10	-27	1.328	-
2	15	-27	1.319	2.408
3	20	-27	1.369	-
4	15	-27	1.320	-
5	15	-27	1.320	-
6	20	-36	2.135	-
7	25	-36	2.132	-
8	30	-36	2.212	-
9	25	-36	2.137	-
10	25	-36	2.149	-

SOIL NO.	SOIL TYPE	EFFECTIVE UNIT WT PCF	SHEAR STRENGTH*			
			A.C.	S.D.	L.T.	C
1	SM	120	30	0	30	0
2	D.M.	110	0	0	0	0
3	SP	120	30	0	30	0
4	CH	120	0	140	10	500
5	MH	130	14	300	14	300
6	SM	120	30	0	30	0

\* A.C. = AFTER-CONSTRUCTION CASE  
 S.D. = SUDDEN-DRAWDOWN CASE  
 L.T. = LONG-TERM CASE  
 $\phi$  = FRICTION ANGLE IN DEGREES  
 C = COHESION IN PSF  
 \*\* D.M. = DREGGED MATERIAL

Figure 17. Slope stability analysis, reach E-F

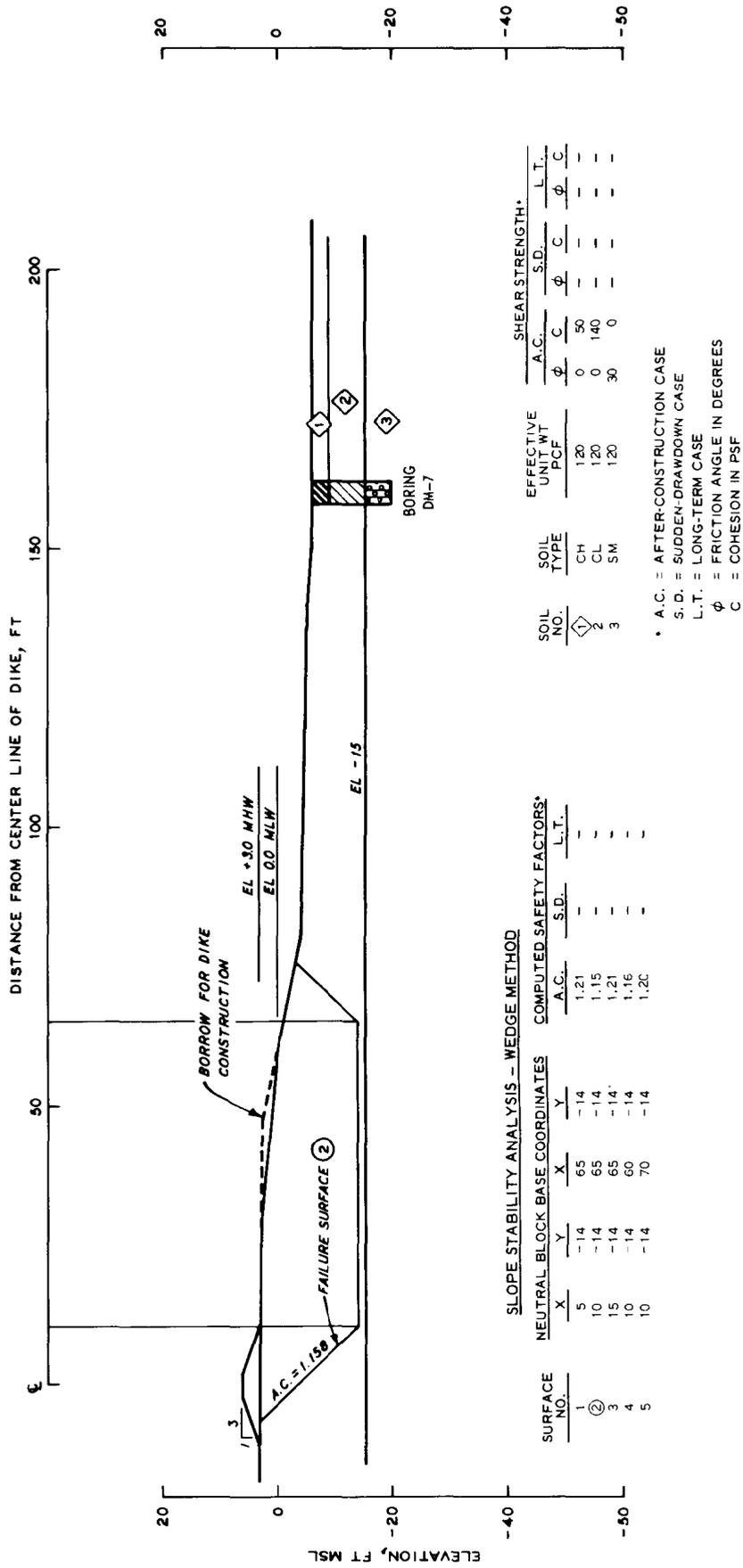


Figure 18. Slope stability analysis, reach C-D

analysis were quite conservative. The section analyzed was also the most critical found along the back dike reach. From a practical standpoint, a setback less than 60 ft could be used. No dredged material will be against this dike during the project life other than isolated reaches that may lie below el +2.5 ft mlw, and water will be pooled to approximately el +4.0 ft mlw (as described in Part IV) only during the filling operation. The most critical conditions encountered during the construction phase may result in localized sloughing of the dike, but this condition can be remedied before the filling operation commences. Shear strengths will also increase with time following dike placement. For this reason, a setback for the back dike center line of 40 ft from present mlw line should prove satisfactory. The dike crown should be widened to 10 ft in the vicinity of the sluice to ensure added stability.

#### Dike Settlement

62. Settlement of the retaining dike due to consolidation of the former river bottom materials was estimated from laboratory consolidation test data. Dike section C-C shown in Figure 12 was considered the most critical. A dike section with 1V-on-3H side slopes and a 10-ft crown width would impose an effective stress of approximately 0.53 tsf on the dike foundation. Conventional settlement analyses were performed and indicated an ultimate settlement of 1.58 ft. The time-settlement relationships also were determined from consolidation test data. Approximately 15 percent of ultimate consolidation or less than 0.25 ft would occur during the first 12 months following dike placement. The marsh vegetation should be sufficiently established by that time to allow removal of the upper portions of the dike system, making any further settlement inconsequential.

#### Slope Protection Requirements

##### Exterior slopes

63. Dike slopes exposed to river current and wave action will

require protection against erosion. Maximum current velocities for Jones Point, Alexandria, immediately north of Dyke Marsh, are 1.64 fps.<sup>12</sup> This is well below the suggested mean scour velocity of 2.0 fps for fine sand.<sup>13</sup> No slope protection due to river current is required; therefore, slope protection design was based on predicted wave heights only.

64. Wave heights in the Potomac River near Dyke Marsh were predicted to range from less than 0.5 ft during normal conditions to 2.5 ft during severe storm conditions. These predictions were based on examination of available wind data and application of graphs and procedures contained in the Shore Protection Manual.<sup>14</sup> Since a major breach in the dike would be detrimental only during the brief period of marsh establishment, a design against severe storm conditions is unwarranted.

65. A wave height of 1.5 ft was selected for riprap design. Riprap layer thickness and stone sizes were computed based on information given in EM 1110-2-2300.<sup>7</sup> A 12-in.-thick layer of riprap extending from the dike crest to a maximum depth of 3 ft below mlw will be required along the exterior slopes of dike reaches A-B and B-C shown in Figure 12. The riprap should be well graded and have a maximum rock size of 65 lb, median rock size of 16 lb, and a minimum rock size of 2 lb. Filter cloth will be required beneath the riprap layer.

#### Interior slopes

66. Interior dike slopes would be subject to minor wave action caused by wind-generated waves and currents set up by the dredge slurry discharge. Interior slopes to el -3.0 ft mlw should be covered with a single layer of polyethylene sheeting to prevent erosion.

## PART IV: CONTAINMENT AREA CONSTRUCTION

### General Requirements

67. The Dyke Marsh containment area plan and dike alignment are shown in Figure 12. The retaining dike will extend over a distance of 5300 ft and form the perimeter of the containment area. Alternative methods for dike construction were investigated in the feasibility study, and a combination of several acceptable methods was recommended for further investigation. Under the detailed design, specific construction methods were identified for each dike segment and are presented in the following paragraphs.

68. The retaining dike will be constructed to el +6.0 ft mhw along its entire length, providing an average exterior freeboard of 3 ft at mean high water (mhw). The dike was not designed to prevent overtopping during severe storms. The proposed freeboard would prevent excessive overtopping and erosion during periods of 1.5- to 2-ft-high waves or high tides of 5 ft. Examination of available wind and tide data indicated that these conditions would occur over brief periods each year. Dredged material will be placed to el +2.5 ft mhw within the containment area as described in Part II. This will require an interior pool to approximate el +4.0 ft mhw for effective settling, leaving an interior freeboard of 2 ft.

69. Side slopes for the dike of 1V on 3H are acceptable from a stability standpoint. Detailed foundation studies and stability analyses were presented in Part III.

### Dike Construction

#### Dike reaches A-B and B-C

70. The feasibility study recommended that hydraulically placed coarse-grained fill be used for construction of dike reaches A-B and B-C shown in Figure 12. Channel sediment samples taken during the feasibility study had indicated that significant quantities of coarse-grained

material were present in the channel to be dredged. However, boring and sampling operations in the channel as described in Part II indicated that the material to be dredged consisted primarily of clayey silt (MH) with only a trace of sand. In a few of the channel borings, sand and gravel layers containing approximately 30 percent silt and clay were encountered at depths of 5 to 10 ft below the required navigation channel depth of 24 ft below m<sub>l</sub>w. The material to be dredged from the channel is therefore considered to be unsuitable for hydraulic dike construction.

71. Field investigations were also conducted to locate other riverine sources of sand outside the channel to be dredged. Random sampling of channel sediments was conducted from approximately 2-1/2 miles north to 4-1/2 miles south of Dyke Marsh. Isolated areas of sand were located, but later exploratory borings revealed that quantities were not satisfactory for use in hydraulic dike construction. Results of these field investigations are presented in Appendix B. The lack of well-defined significant quantities of riverine sand near Dyke Marsh has eliminated the possibility of hydraulic dike construction.

72. The feasibility study also identified end-dumping as an acceptable method of construction for reaches A-B and B-C. End-dumping material from trucks is considered technically feasible but unacceptable based on the environmental assessment.\* Truck access to dike reaches A-B and B-C would require construction of a haul road either along the wooded island or through the existing marsh along dike reaches A-F and C-D as shown in Figure 12. Road construction and prolonged traffic along the wooded island or through the marsh would cause unacceptable environmental disturbance. Also, access to Dyke Marsh requires excessive truck traffic on the George Washington Memorial Parkway. Acquisition of necessary permits for travel along the parkway may be difficult to obtain and damaged pavement sections would have to be repaired following dike construction.

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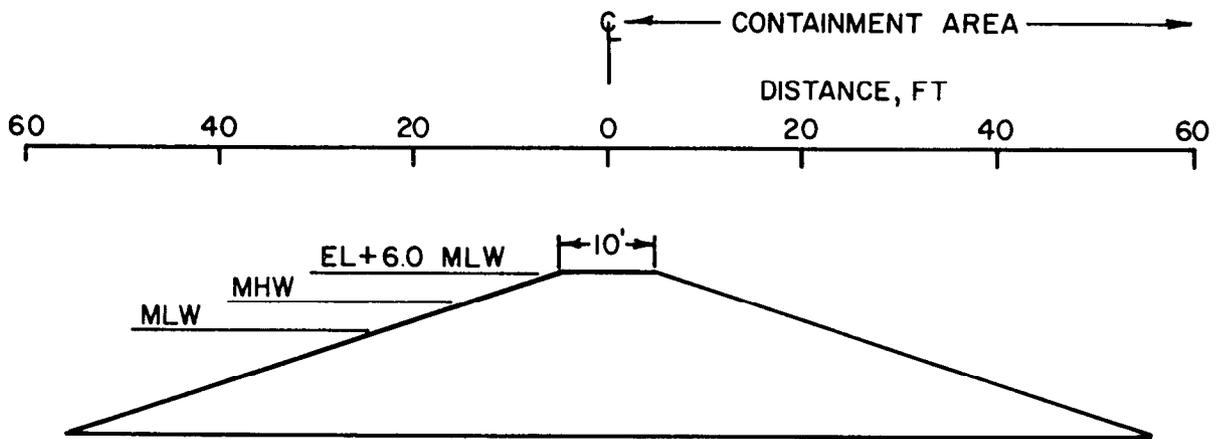
\* Conclusions derived from discussions in August 1976 between WES and NPS personnel responsible for the environmental assessment of the Dyke Marsh project.

73. Construction of segments A-B and B-C could be accomplished by end-dumping from barges. Although not considered in the feasibility study, placement of material from barges is considered technically feasible and would minimize environmental disturbance to the existing marsh and wooded island. Convenient access to the site can be made along the Potomac River. It is recommended that material be hauled in shallow draft barges and placed by barge-mounted crane. The shallow river bottom along dike reach B-C will likely limit construction to periods of high tide; however, continuous construction along the major portion of dike reach A-B will be feasible. Typical dike cross sections for dike reaches A-B and B-C are shown in Figure 19. Slope protection consisting of filter cloth and riprap will also be required on the outer slopes as described in Part III. Riprap can be obtained from a local commercial quarry, barged to the site, and placed by barge-mounted crane.

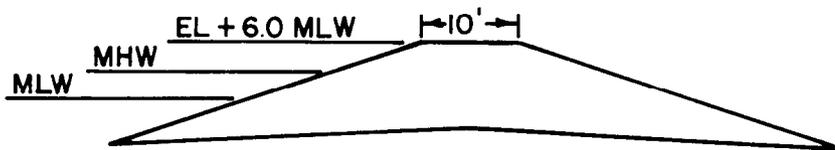
74. Dike construction material should consist of coarse-grained fill such as sand or sand and gravel mixtures. Fill should contain less than 20 percent silt- and clay-sized materials to prevent excessive turbidity during placement. The only definite sources of suitable fill are commercial sand pits. Since commercially available sand is costly, an attempt was made to locate an alternative low-cost fill. A potential source of suitable fill is material planned for excavation and removal in tunnel construction for the Washington Metropolitan rail rapid transit system (METRO). Construction on the system began in 1969 and is scheduled for completion in 1983. Baltimore District contacted personnel in charge of planning METRO construction and determined that portions of the material to be excavated are suitable for dike construction; however, material is presently being stockpiled for possible use as embankment fill for aboveground transit system construction. This material may become available in the future. The availability of fill from the METRO project should be reexamined prior to final selection of fill for dike reaches A-B and B-C.

#### Dike reach E-F

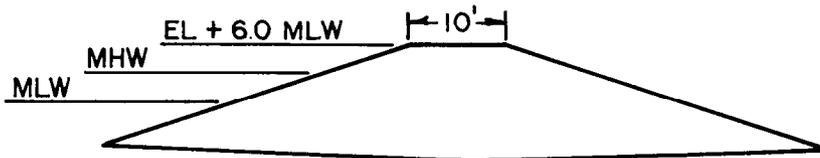
75. Dike reach E-F extends through the water from the tip of the



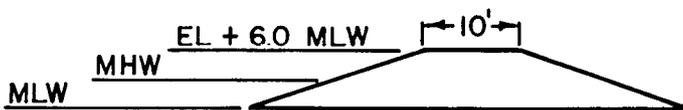
a. Section A-A' (reach A-B)



b. Section B-B' (reach A-B)



c. Section C-C' (reach A-B)



d. Typical section for reach B-C

Figure 19. Dike cross sections for reaches A-B and B-C (cross-section locations are shown in Figure 12)

debris fill area to the wooded island as shown in Figure 12. This dike segment is conveniently located for truck end-dump construction using material from the debris fill area as recommended in the feasibility study. Typical dike cross sections for reach E-F as constructed by end-dumping are shown in Figure 20. Sluice 2 will be located along reach E-F as shown in Figure 12. End-dumping from trucks should be acceptable for this segment. During dike construction, environmental disturbance to the marsh and wooded island would be minimal with truck traffic confined to the debris fill area. Truck traffic on the George Washington Parkway should present no problems since trucks will be empty, and trips to and from the marsh will be infrequent.

76. Thirty-two general sample borings were taken within the debris

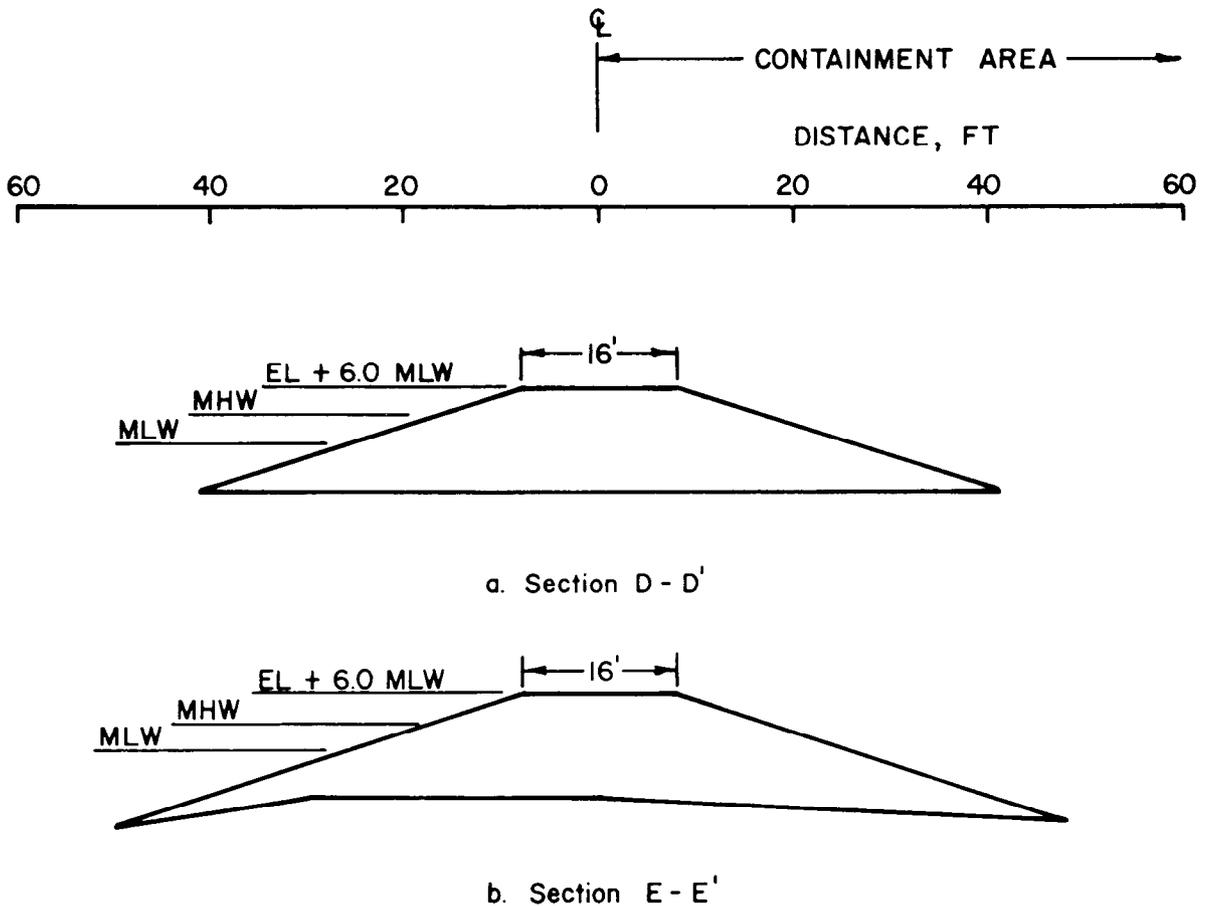


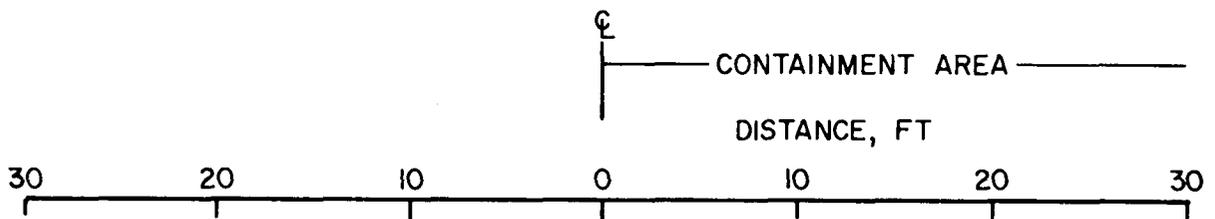
Figure 20. Dike cross sections for reach E-F (cross-section locations are shown in Figure 12)

fill area for the detailed design. Laboratory classifications and gradation analyses were performed on the samples. Boring logs and results of the laboratory tests are presented in Appendix C. The material consisted largely of clayey and silty sand and gravel with brick, asphalt, and concrete fragments. The concrete fragments were contained throughout the fill and were large enough to stop 9-in. auger borings prematurely at depths of 1 to 3 ft in all but a few of the borings. These concrete fragments may limit economical excavation of the debris fill to depths less than 3 ft.

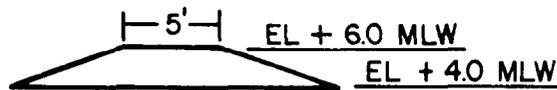
77. The quantity of debris fill available for dike construction is also limited by other considerations. Because the marsh is visited regularly by local residents and organized wildlife societies, it is desirable to maintain a large area for convenient observation of the marsh and access to the river. It is recommended that excavation of the debris fill material be limited to the upper 2 to 3 ft and be restricted to the portion inside the containment area. Dredged material will later cover the excavated portion of the debris fill area to enhance marsh development.

#### Dike reach C-D

78. Dike reach C-D is located along the border of the existing marsh as shown in Figure 12. The average elevation along the dike alignment is an estimated +3.0 ft m.l.w. A typical dike cross section is shown in Figure 21. The crest width of 5 ft should be widened to 10 ft across inlet 1 in the vicinity of sluice 1 as discussed in Part III. As recommended in the feasibility study, dike reach C-D should be constructed by dragline-placed fill. A mat-supported conventional dragline or pontoon-supported dragline could be used for fill placement. Dike fill should be borrowed from inside the containment area directly adjacent to the dike alignment. Stability considerations as described in Part III dictate that the dike center line along segment C-D be set back a distance of 40 ft from the m.l.w. line. This should allow sufficient room for borrow of material for dike construction during periods of low tide. The material should be incrementally placed in thin lifts of 1 to 2 ft and allowed to dry between lifts to increase dike stability.



a. Typical dike section on marsh (reach C-D) and wooded island (reach F-A)



b. Typical dike section on debris fill area (reach D-E)

Figure 21. Dike cross sections for reaches C-D, F-A, and D-E

Dike reach D-E

79. Dike reach D-E extends across the central portion of the debris fill area as shown in Figure 12. The average elevation of the debris fill surface along the dike alignment is an estimated +4.0 ft mlw. A typical dike cross section is shown in Figure 21. Dike fill should be placed by dragline. Debris fill area material borrowed from inside the containment area and directly adjacent to the dike alignment should be used for construction. The debris fill consists largely of clayey and silty sand and gravel. However, large concrete fragments may limit economical excavation to depths less than 3 ft.

Dike reach F-A

80. Dike reach F-A extends along the border of the wooded island as shown in Figure 12. This dike is necessary to prevent encroachment of the dredged material and subsequent environmental damage on the wooded island. The average elevation along the dike alignment is an estimated +2.0 ft mlw. A typical dike cross section is shown in

Figure 21. Dike fill should be placed by dragline and compacted by bulldozer. Fill should be borrowed from inside the containment area directly adjacent to the dike alignment. Surface sampling indicated that the material along the border of the wooded island consisted primarily of sand and gravel with some clay. (Gradation curves are given in Appendix C.)

### Sluice Structures

81. Sluice structures are required for draining the containment area during and after the dredging operations. It is recommended that sluice structures be placed at the two locations shown in Figure 12. Sluice 1 will be located at the apex of the existing cove on dike reach C-D, and Sluice 2 will be located near the tip of the debris fill area on dike reach E-F. These sluice locations will add flexibility to the filling operation and later will aid marsh establishment by allowing more effective circulation of tidal flow throughout the containment area. A drainage ditch will be required to connect inlets 1 and 2 as shown in Figure 12 to provide a flow path for effluent from sluice 1 and to maintain as nearly as possible the present drainage conditions within the existing marsh. The drainage ditch can be excavated by dragline to dimensions of 4 ft wide by 2 ft deep with excavated material placed inside the containment area. Discharge through sluice 2 would flow directly into inlet 2 as shown in Figure 12.

82. Drop inlet type sluices with adjustable height stoplog gates are recommended. The stoplogs can be added or removed as necessary to regulate effluent flow from the containment area. However, it is recommended that the stoplogs be set at +4.0 ft mlw to allow for ponding which will in turn promote more effective solids removal. A required weir crest length of 32 ft was computed based on a maximum allowable head of 0.2 ft over the weir crest and a continuous flow rate for a 12-in. dredge of  $9.4 \text{ ft}^3/\text{sec.}^6$

83. During dredging, the major portion of flow from the containment area should be regulated by sluice 1. Sluice 1 is located farthest from the intended dredge pipe discharge points described in Part V.

This location will provide maximum sedimentation time for the dredged slurry. It is recommended that sluice 1 be constructed with a 20-ft weir length and sluice 2 with a 12-ft weir length as shown in Figures 22 and 23, respectively.

#### Cost Estimates

84. Containment area construction costs in 1976 dollars were estimated based on unit prices determined by the BD to be applicable in the Washington, D.C., area. Construction costs for individual dike reaches including sluice structures and slope protection are summarized in Table 2. Locations of dike reaches and sluices are shown in Figure 12. The total containment area construction cost, including purchase of dike fill material, is estimated to be \$730,490. Construction of the in-water dike reaches A-B and B-C, not including slope protection, comprises \$562,250 or 77 percent of the total estimate. This cost could be significantly reduced if dike fill could be obtained from METRO projects rather than commercial sand pits. The base price of commercial sand, not including transportation to the barges, is an estimated \$7.25/yd<sup>3</sup>. If METRO fill were used, the base price of the fill would be eliminated, resulting in an estimated savings of \$235,625. The total containment area construction cost estimate would then be \$494,865.

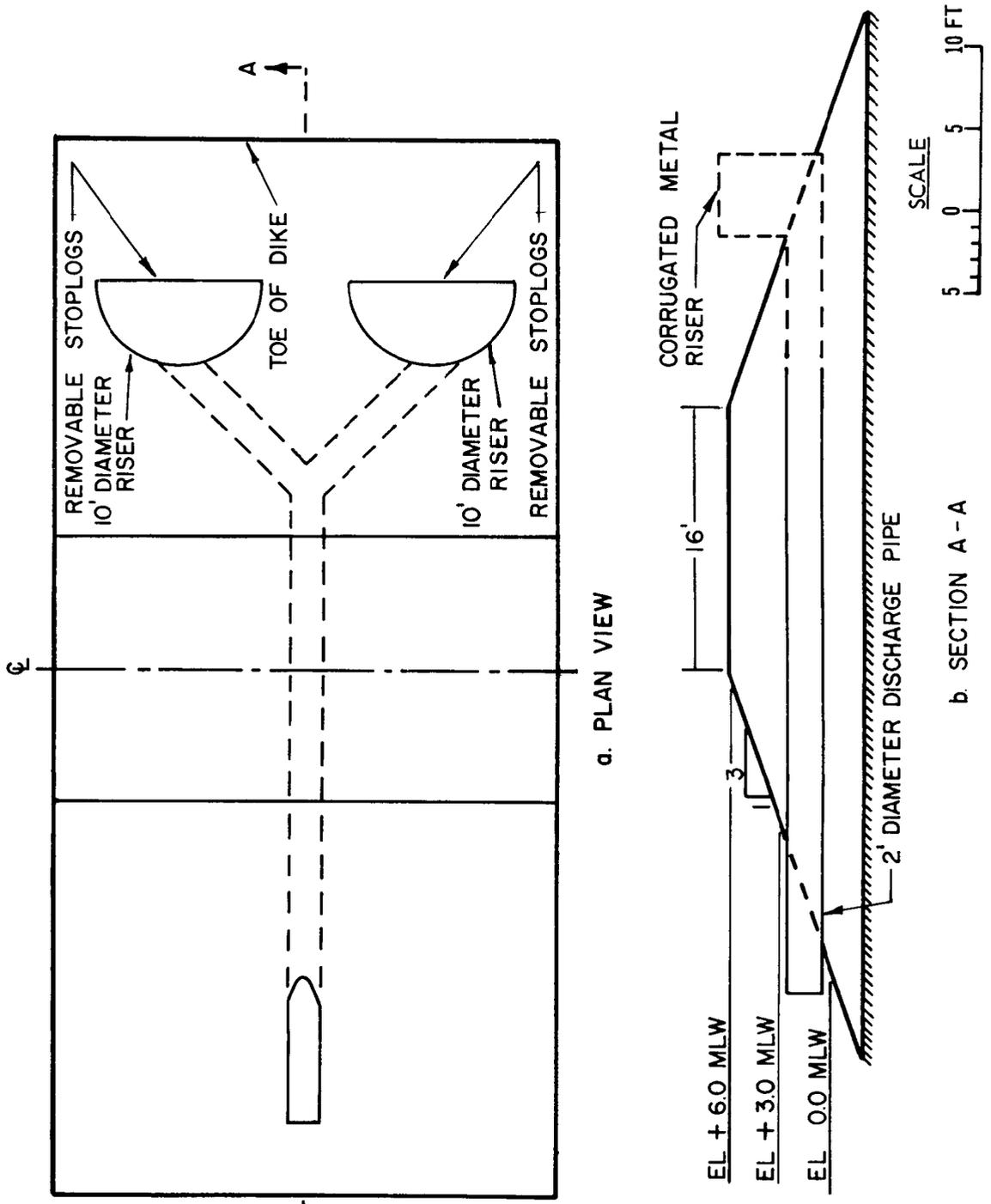


Figure 22. Plan and section for sluice 1

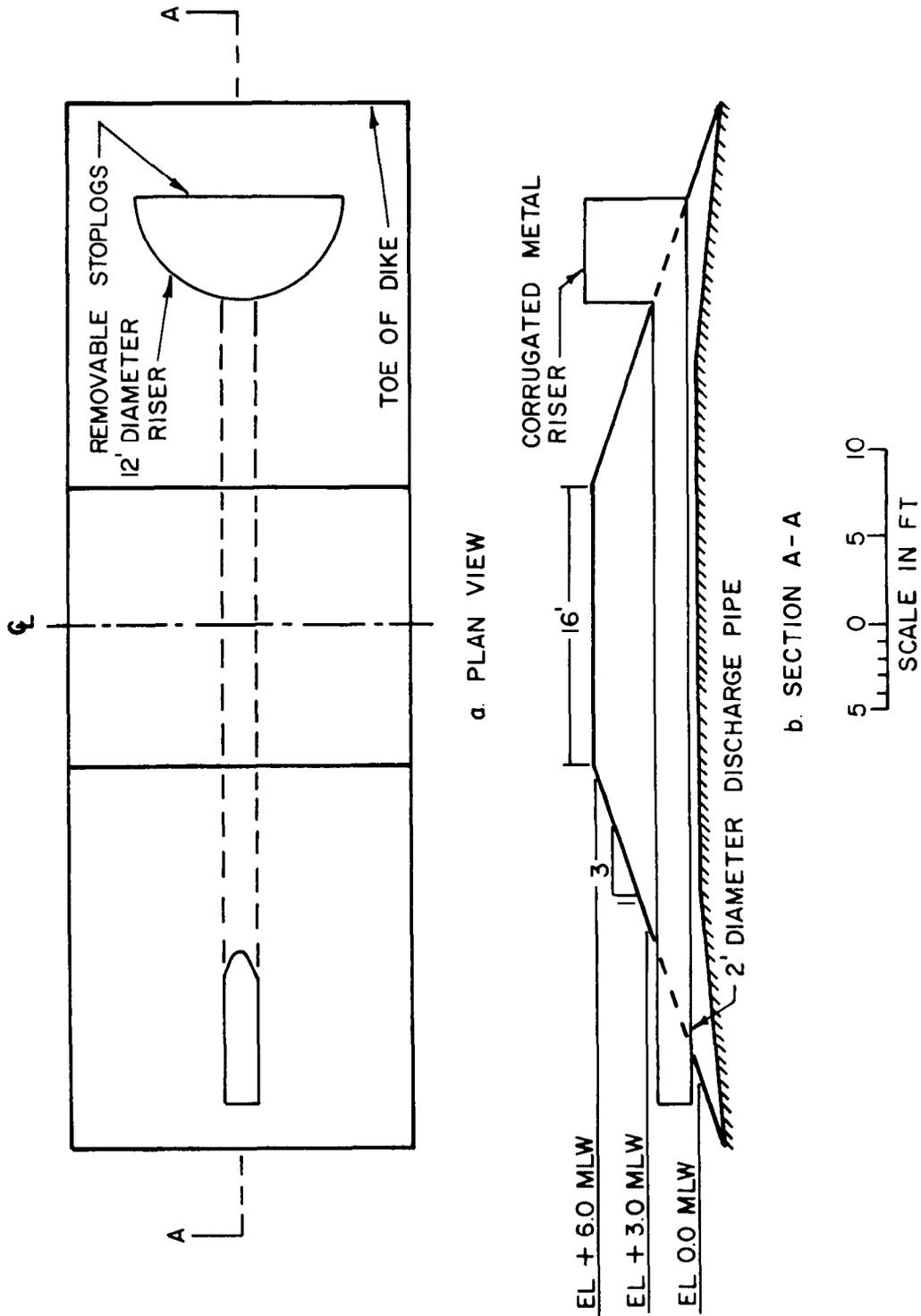


Figure 23. Plan and section for sluice 2

Table 2

Containment Area Construction Costs

Item	Construction Material			Construction			Total \$
	Source	Volume yd <sup>3</sup>	Method	Cost/yd <sup>3</sup>	Method	Cost/yd <sup>3</sup>	
Reach A-B:							
Fill (sand)	Commercial	27,500	Barge Placement	17.30	Barge Placement	17.30	475,750
Riprap (stone)	Commercial	1,300	Barge Placement	61.40	Barge Placement	61.40	79,820
Filter cloth	--	--	--	--	--	--	5,500
Reach B-C:							
Fill (sand)	Commercial	5,000	Barge Placement	17.30	Barge Placement	17.30	86,500
Riprap (stone)	Commercial	550	Barge Placement	61.40	Barge Placement	61.40	33,770
Filter cloth	--	--	--	--	--	--	2,500
Reach C-D:							
Fill	Adjacent to dike	3,000	Dragline-Bulldozer	3.00	Dragline-Bulldozer	3.00	9,000
Reach D-E:							
Fill	Adjacent to dike	550	Dragline-Bulldozer	3.00	Dragline-Bulldozer	3.00	1,650
Reach E-F:							
Fill	Debris fill area	4,000	Truck End-dumped	4.00	Truck End-dumped	4.00	16,000
Reach F-A:							
Fill	Adjacent to dike	3,000	Dragline-Bulldozer	3.00	Dragline-Bulldozer	3.00	9,000
Sluice 1	--	--	--	--	--	--	3,000
Sluice 2	--	--	--	--	--	--	3,000
Polyethylene sheeting	--	--	--	--	--	--	5,000

PART V: DREDGED MATERIAL PLACEMENT  
AND MARSH ESTABLISHMENT

Dredging Operation

85. An estimated 246,000 yd<sup>3</sup> of material will be dredged to fill the containment area to an average el +2.5 ft mlw as discussed in Part II. The dredged material surface will consolidate an estimated 1.3 ft to establish a final average marsh surface el +1.2 ft mlw. This elevation will place the majority of the final marsh substrate within the intertidal zone.

86. The containment area will be filled by alternation of discharge between points A and B shown in Figure 24. Discharge at the two locations will improve circulation of dredged material throughout the area. The dredge pipe will be supported on pontoons with the ends of the pipe at points A and B elevated 3 to 5 ft above the water surface. The NPS has requested that localized surface mounding be created as much as possible by the dredging operation. In the feasibility study,<sup>1</sup> it was recommended that mounds be formed near the discharge points by selectively dredging pockets of coarse-grained material within the channel. Recent explorations in the channel as described in Part II and Appendix A have failed to locate significant quantities of coarse-grained material. However, some mounding should occur in the shallow water areas near points A and B through the particle separation and buildup of coarser material that commonly occurs near dredge pipe outlets.

87. Effluent suspended solids can be monitored by periodic sampling at the sluices. At times, sluice 2 should be closed to increase flow of material into the cove area bordered by dike reaches C-D and D-E shown in Figure 24. This procedure will increase sedimentation efficiency because of the longer flow path between sluice 1 and the dredge pipe outlets. Sluice stoplogs can be added or removed as necessary to increase or decrease effluent flow from the containment area.

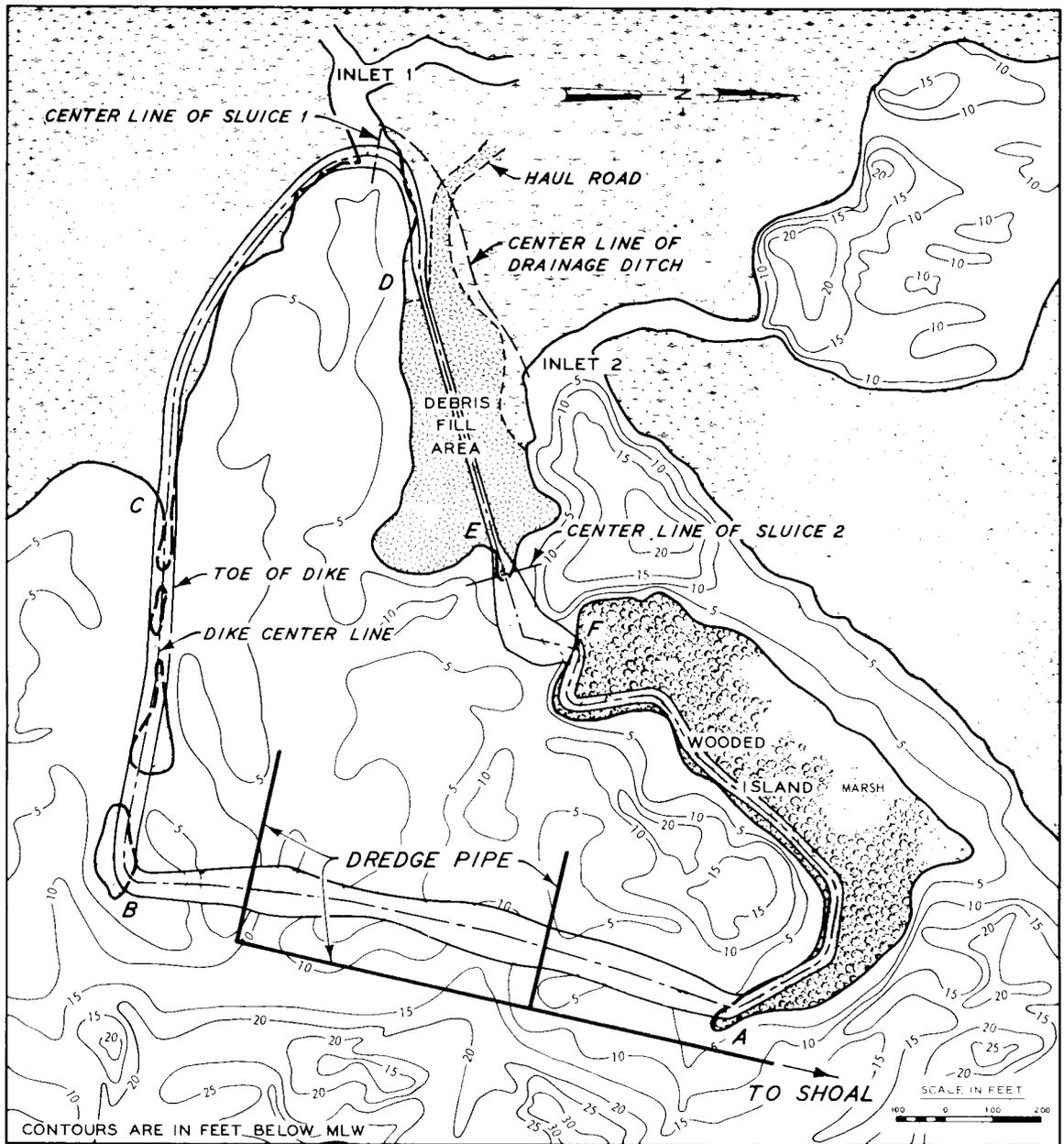


Figure 24. Dredged material placement scheme

However, the water level within the containment area should be limited to a maximum elevation of +4.0 ft mlw.

#### Production Rate

88. Continuous dredging using a 12-in. pipeline dredge is recommended. An estimated 60 days will be required to fill the containment area. This estimate is based on an average production rate of 5,000 yd<sup>3</sup> per day, a 246,000 yd<sup>3</sup> volume of dredged material, and a 10-day allowance for shutdowns due to moving discharge pipes or mechanical breakdowns.

#### Marsh Establishment

89. After dredging is complete, surface water should be drained through the sluices and a 2- to 3-month period allowed for initial consolidation and surface drying. The dikes should then be breached in two low-energy locations to allow tidal circulation throughout the containment area. DMRP experience indicates that tidal circulation after a short period of consolidation and drying will establish marsh vegetation with negligible erosion of the dredged material surface. Initially the dikes should be breached near locations C and F shown in Figure 24. Tidal circulation and vegetative growth should be observed within the area. Periodically, additional dike sections should be breached. It is estimated that within 1 year after filling the containment area, the entire dike length could be leveled to an average el +1.5 ft mlw.

## PART VI: CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

90. Based on the data as described in the Dyke Marsh feasibility study and this report, the following conclusions were drawn:

- a. The proposed demonstration area size of 28 acres would significantly add to the area of productive marshland at Dyke Marsh and would allow evaluation of engineering considerations of marsh development using dredged material at a full-scale field site.
- b. Detailed sampling of the shoal area to be dredged indicated that the in situ material is suitable for use as marsh substrate. The time required for substrate settlement and stabilization is estimated to be 4 months based on consolidation characteristics of the material.
- c. Gradual erosion of the shoal area to be dredged has resulted in a shortage of required material needed to fill the demonstration area to elevation suitable for marsh substrate. The additional material must be acquired from other dredging projects in the vicinity or through additional overdredging in the navigation channel shoal.
- d. A methodology was developed to correlate in situ channel volumes with containment area volumes. The method incorporated the basic principles of containment area sizing as developed by previous DMRP research and also accounted for potential consolidation of the newly placed marsh substrate.
- e. Sedimentation testing for containment area sizing employed a full-height column equal to the average thickness of the substrate, which allowed direct determination of the void ratio distribution for use in containment area sizing.
- f. Consolidation test specimens were successfully taken from the sedimentation column, and conventional consolidation tests were performed. Data from the consolidation tests allowed prediction of substrate settlements following the dredging operation.
- g. Considering sedimentation and consolidation behavior of the dredged material and consolidation of the demonstration area foundation, the substrate should initially be placed to el +2.5 ft mlw. The predicted final elevation of the substrate is approximately +1.2 ft mlw.
- h. A retaining dike system will be required to contain the dredged material substrate and to prevent excessive

substrate erosion, siltation of the existing marsh, and excessive turbidity during placement. Based on freeboard requirements and stability analyses, the dike crown elevations should be constructed to el +6.0 ft mlw with side slopes of 1V on 3H.

- i. Sufficient quantities of coarse-grained material for use in hydraulic dike construction are not present in the shoal area to be dredged. Field investigations did not identify any other suitable sources of riverine sands; therefore, hydraulic construction is not feasible for this project.
- j. End-dumped placement of sand and gravel from barges is the optimum method of construction of dike segments A-B and B-C shown in Figure 12. The material used for this construction could be purchased commercially, but should be taken from the METRO project or other free sources if possible.
- k. End-dumped placement of on-site material from trucks is the optimum method of construction of dike segment E-F shown in Figure 12. Material for the construction will be borrowed from the debris fill area. Only the upper 3 ft of the portion inside the containment area should be removed, which would allow dredged material to form additional substrate for marsh expansion.
- l. Conventional dragline placement is the optimum method of construction of necessary diking along the debris fill area, segment D-E. The material should be borrowed from inside the containment area directly adjacent to the dike.
- m. Dragline placement using a marsh crane or equal is the optimum method of construction of the dike bordering along the existing marsh, segment C-D. The dike center line along this segment should be set 40 ft from the mlw line to allow for borrow adjacent to the dike and to ensure stability.
- n. Dragline placement using marsh crane is the optimum method of construction of necessary diking along the wooded island, segment F-A. Fill should be borrowed from within the containment directly adjacent to the dike alignment.
- o. Drop inlet sluices should be placed at locations 1 and 2 shown on Figure 12, with weir lengths of 20 ft and 12 ft, respectively.
- p. Foundation conditions at the demonstration site as defined by feasibility study and detailed design data are adequate to support the retaining dike system.

- q. Stability analyses performed indicate that dike sections with side slopes of 1V on 3H and a crown el +6.0 feet mlw are well within acceptable stability criteria.
- r. Minor displacement of soft bottom material will occur along segments of dike construction, but long-term settlements of the dike should be negligible.
- s. Based on data gathered in the feasibility and detailed design studies, marshland may be expanded in stages by successive diking and filling, eventually restoring the marsh to its original configuration.

#### Recommendations

91. Based on the data presented in the feasibility study and this report, the following recommendations are made:
- a. Plans and specifications should be prepared for the demonstration area based on data presented in the feasibility study and detailed design.
  - b. The retaining dike system should be constructed according to the layout indicated in Figure 12. Dike crown el +6.0 ft mlw should be used to provide adequate free board. Sluice structures and drainage provisions should be provided as described in Part IV.
  - c. The main dike reaches A-B and B-C as shown in Figure 12 should be constructed using coarse-grained sand or sand and gravel mixtures end-dumped from barges. Filter cloth and riprap are recommended for protection against erosion. Side slopes of 1V on 3H and 10-ft crown widths should be used.
  - d. A more detailed examination of available fill material from the METRO transit system project should be conducted and, if found acceptable, considered for use in construction of dike reaches A-B and B-C.
  - e. Dike reach E-F should be constructed by end-dumping from trucks using material from the debris fill area shown in Figure 12. Side slopes of 1V on 3H with a 10-ft crown width should be used. Excavation of the area should be limited to depths of 3 ft to allow maximum marshland expansion.
  - f. Flotation-type draglines or draglines on mats should be used to construct dike reach C-D. The dike should be set back a minimum of 40 ft from the mlw line. Construction should be accomplished by borrowing material from within

the containment area, spreading it in thin layers, and allowing each layer to dry between placement operations. Side slopes of 1V on 3H with a 5-ft crown width should be used except adjacent to the sluice structure, where a 10-ft crown width should be used.

- g. Dike reach F-A should be constructed by use of a dragline. Fill should be borrowed from inside the containment adjacent to the dike alignment. Side slopes of 1V on 3H with a 5-ft crown width should be used.
- h. A program of strict construction monitoring should be implemented to ensure integrity of the retaining dike system. Post-construction monitoring should also be initiated to validate analyses conducted for volumetric sizing and substrate consolidation. The site should be instrumented with settlement plates and piezometers to be monitored in a program of periodic surveys.
- i. A 12-in. dredge should be used to fill the demonstration area. An estimated 246,000 yd<sup>3</sup> of in situ channel material would be required. The material should be dredged primarily from the shoal area located south of the Woodrow Wilson Bridge with supplemental yardages obtained by additional over-dredging or from other dredging projects. A field determination of contained volumes should be made to verify containment area volumetric sizing studies.
- j. The dredged material should be placed to el +2.5 ft m<sub>l</sub>w to provide a final marsh substrate elevation within the mid-tidal range. During the filling operation, an interior pool el +4.0 ft should be maintained to promote the most effective sedimentation.
- k. Effluent suspended solids should be monitored during the filling operation to validate analyses for containment area sizing for effluent water quality.

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Palermo, Michael R

Detailed design for Dyke Marsh demonstration area, Potomac River, Virginia / by Michael R. Palermo and Timothy W. Ziegler. Vicksburg, Miss. : U. S. Waterways Experiment Station, 1977.

70 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-13)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit 4A17A.

Appendixes A-D on microfiche in pocket.

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TA7.W34 no.D-77-13