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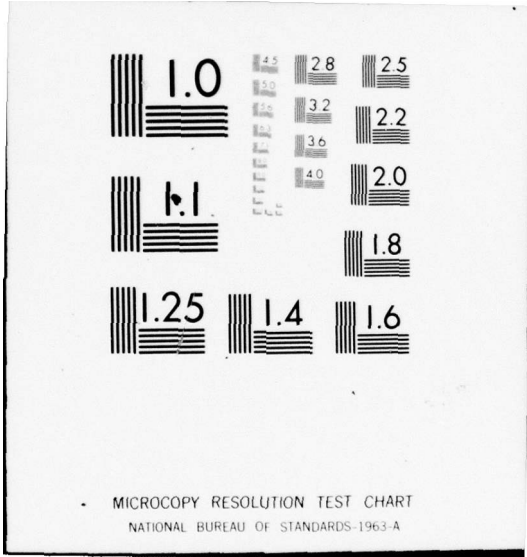
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DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT D-77-13

DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA POTOMAC RIVER, VIRGINIA

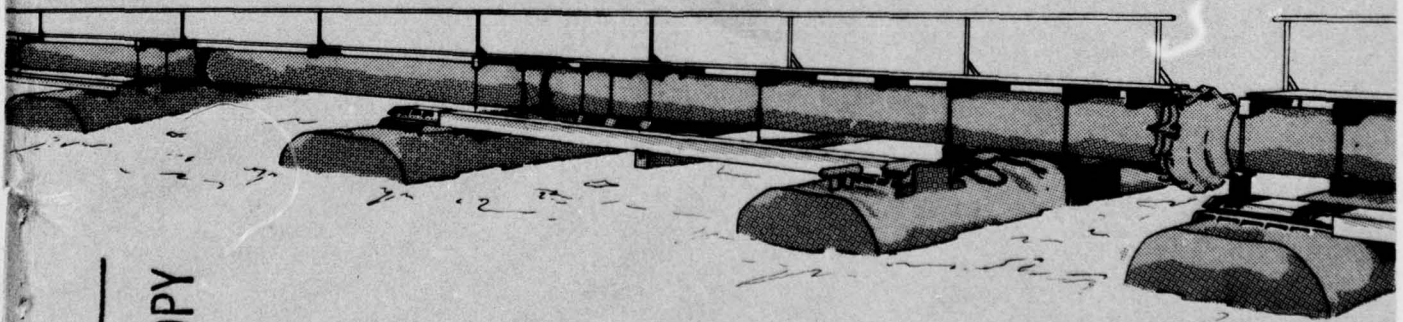
by

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October 1977
Final Report

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Under DMRP Work Unit 4A17A

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SUBJECT: Transmittal of Technical Report D-77-13

TO: All Report Recipients

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

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

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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.

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

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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:

Multiply	By	To Obtain
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 1976.¹ 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.² 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

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

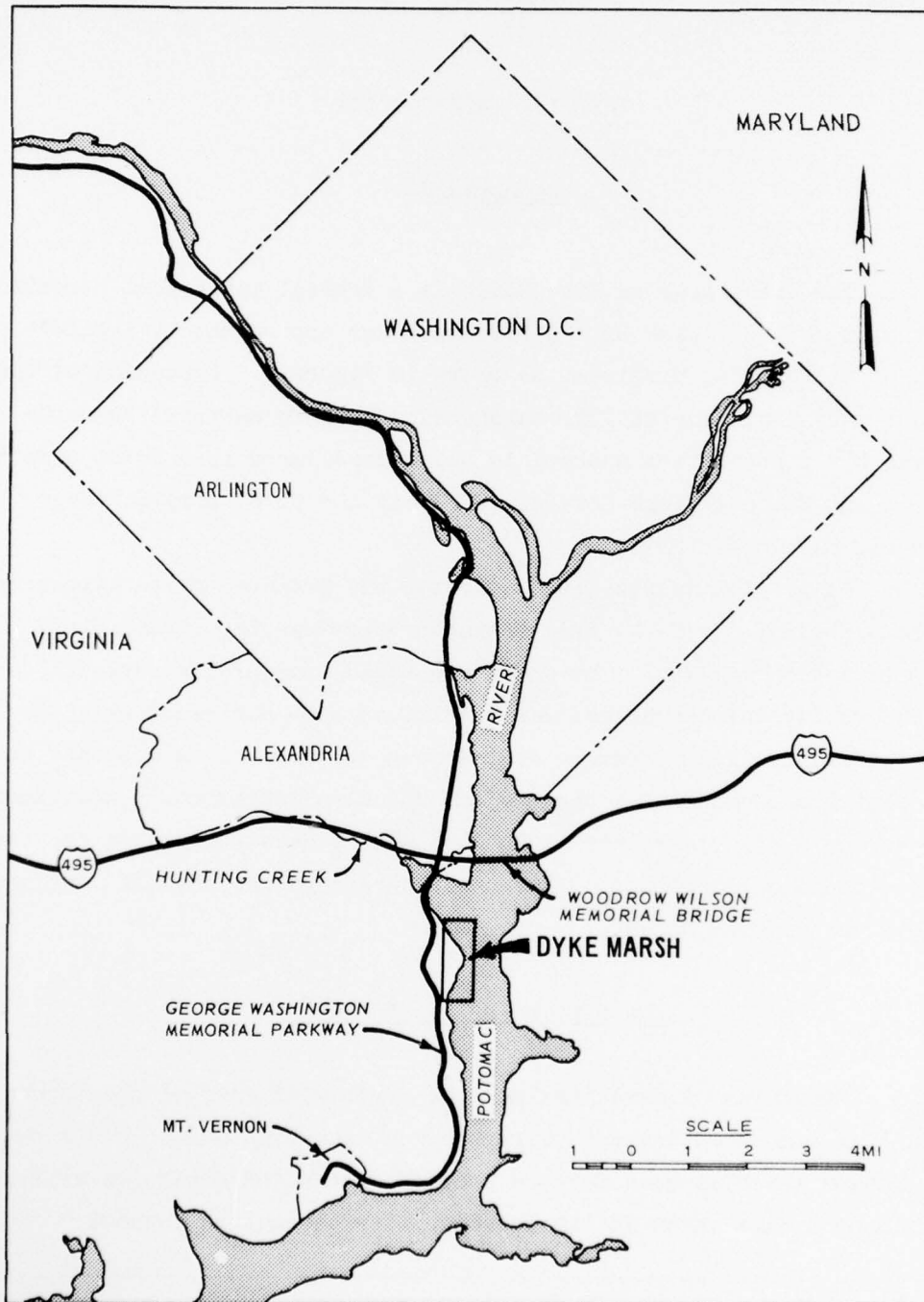


Figure 1. Location map of Dyke Marsh

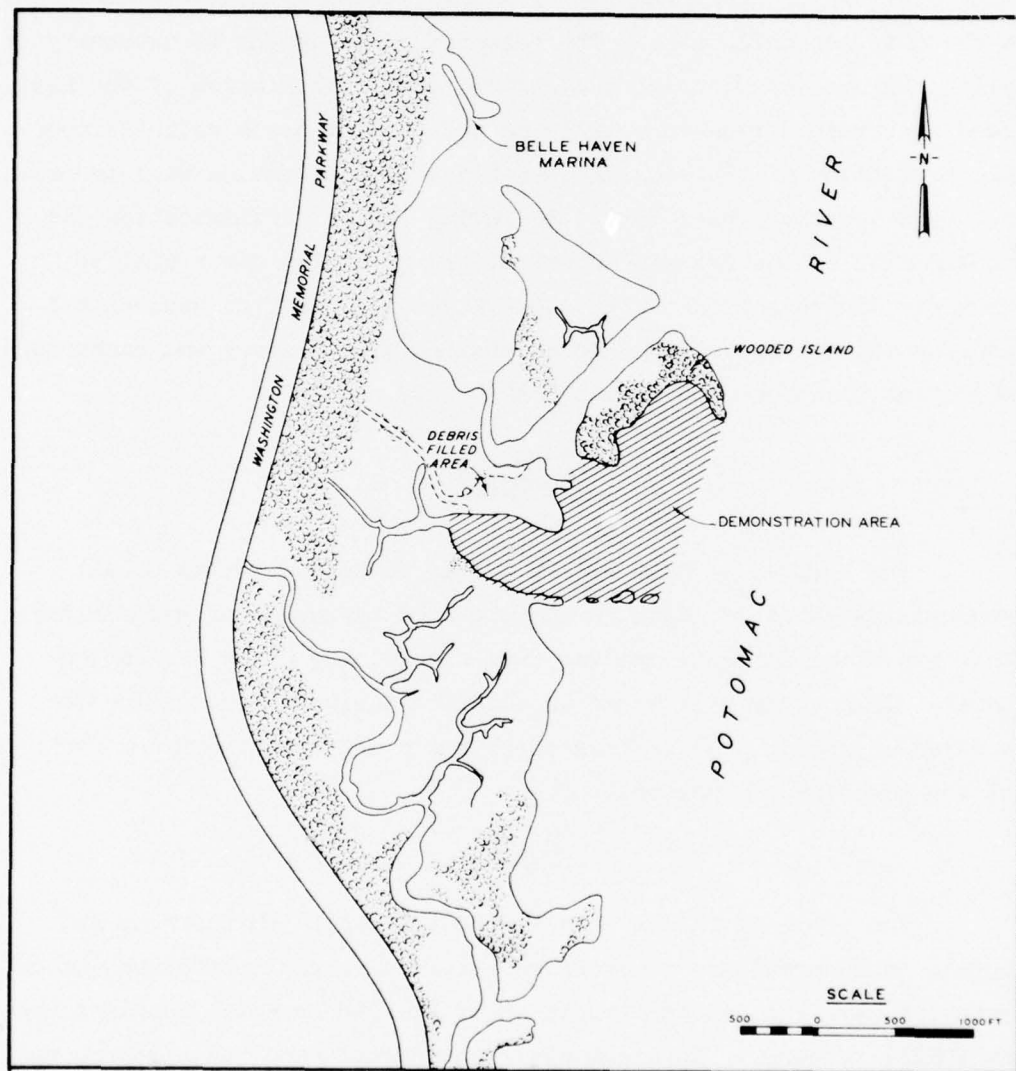


Figure 2. Location of demonstration area

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.¹

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.²

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

* 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.

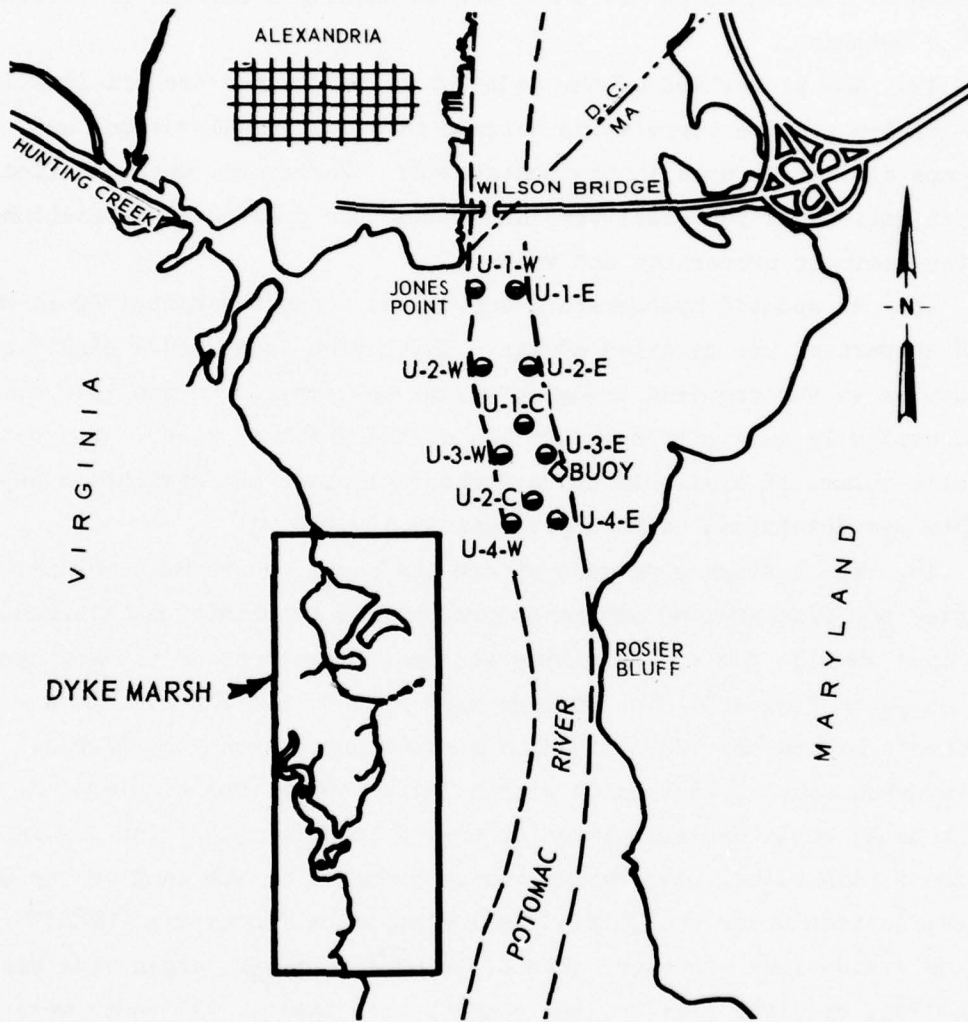


Figure 3. Shoal location and boring plan

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 yd³.

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)³ 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.⁴ 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

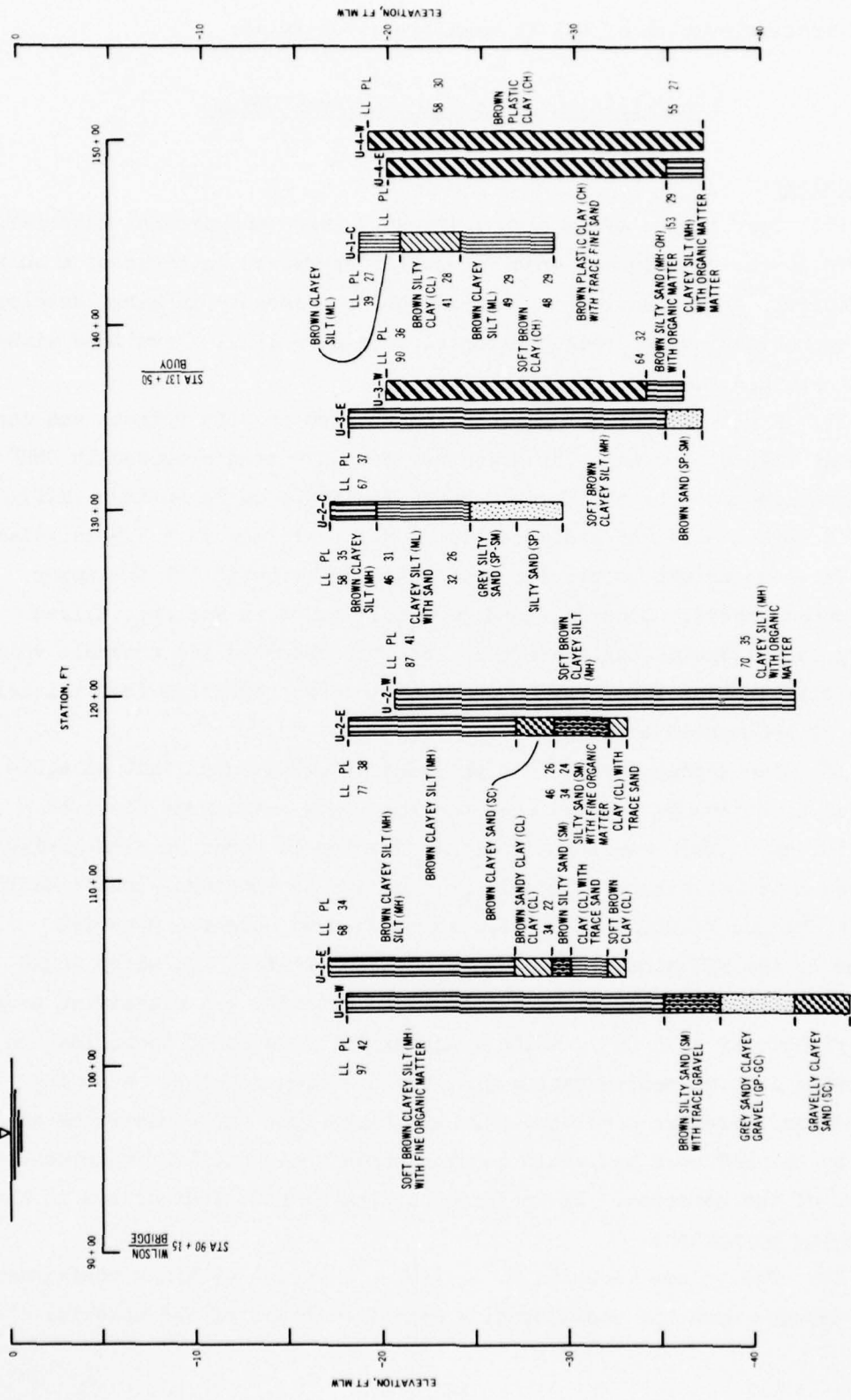


Figure 4. Graphic logs of shoal borings

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-factor. Determination of this factor is necessary in marsh development 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 containment volumes for marsh creation projects has been proposed in DMRP research conducted by the Massachusetts Institute of Technology (MIT).⁵ 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 equilibrium 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 developed by the MIT work and would consider both sedimentation and consolidation 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

γ_{sat} = saturated unit weight, pcf

γ_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

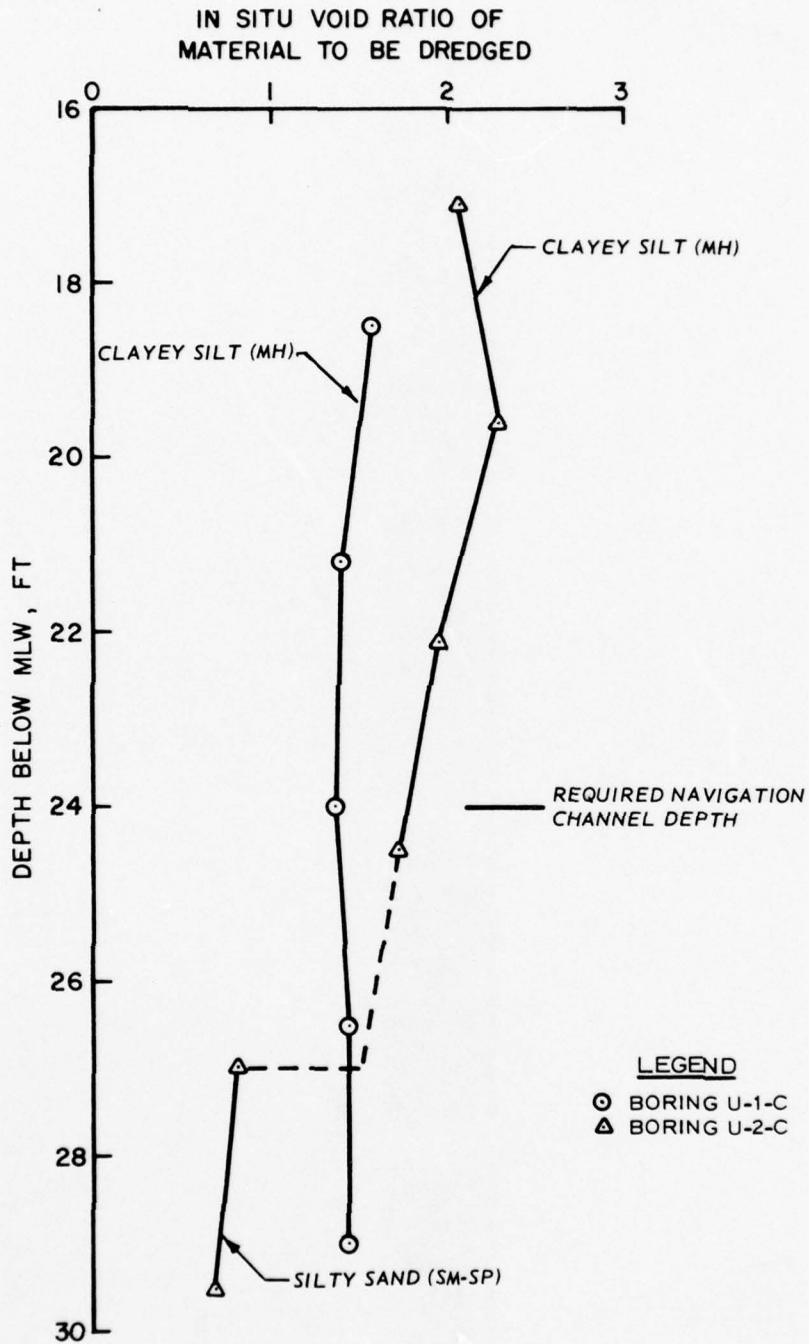


Figure 5. In situ void ratio versus depth distribution for material to be dredged

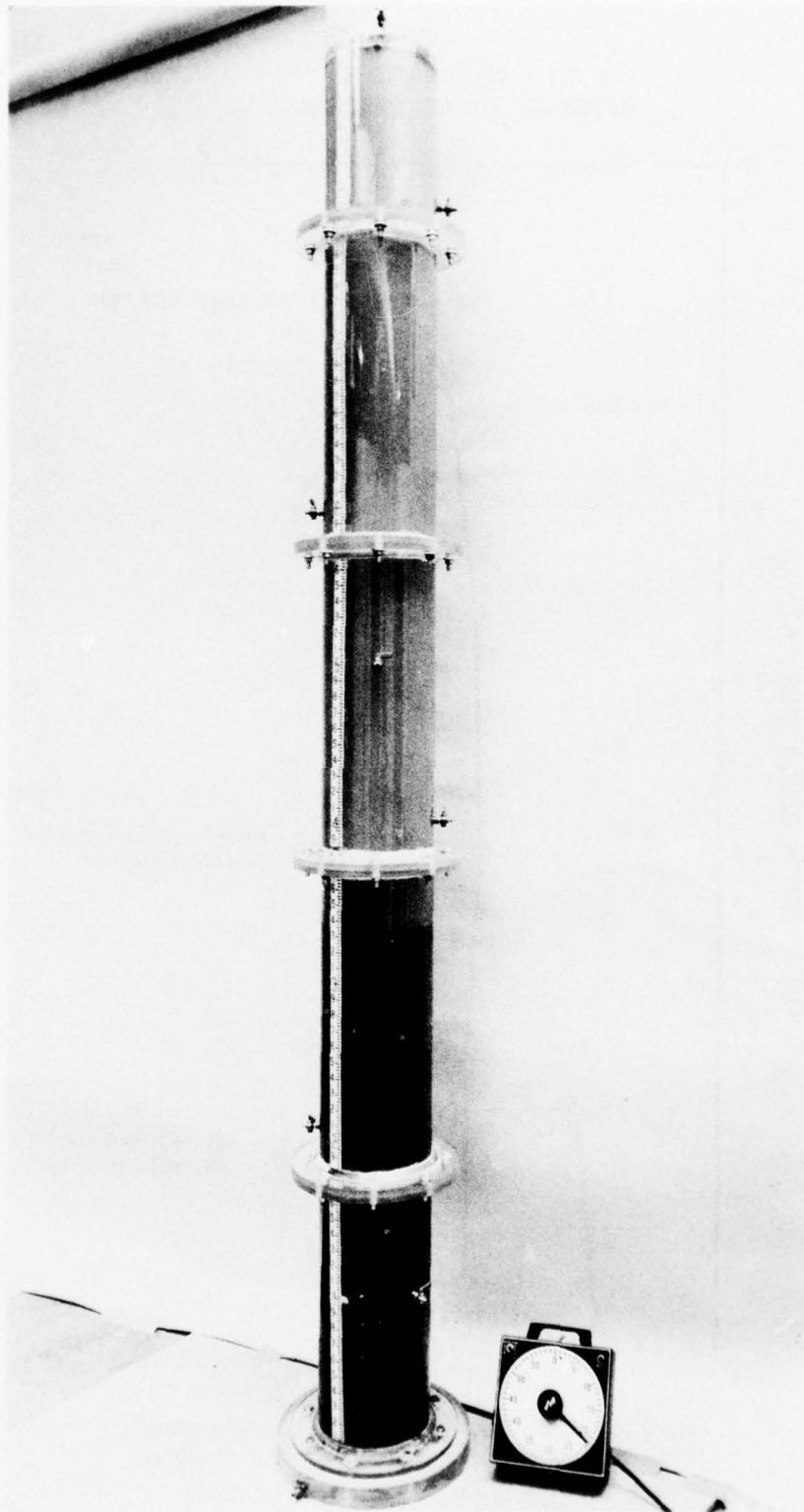


Figure 6. Photograph of column sedimentation test

depth of dredged material in the containment area if the area is filled to an el +2.5 ft mhw 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.

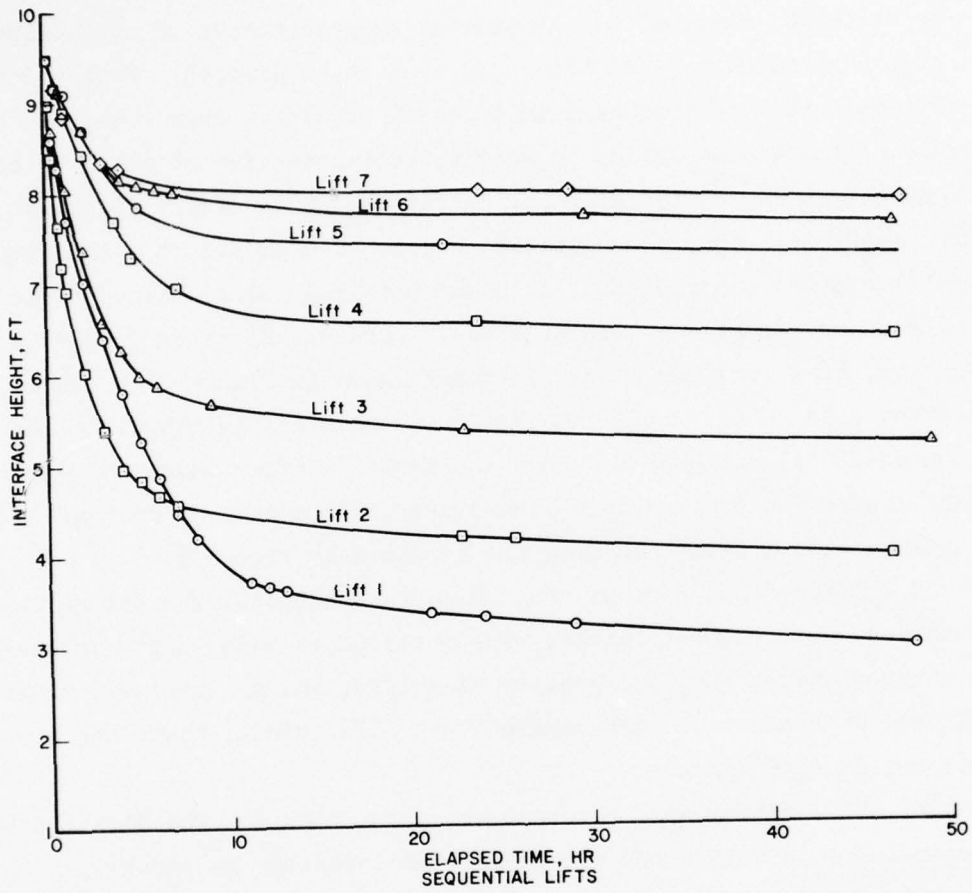


Figure 7. Column sedimentation testing--interface heights versus time

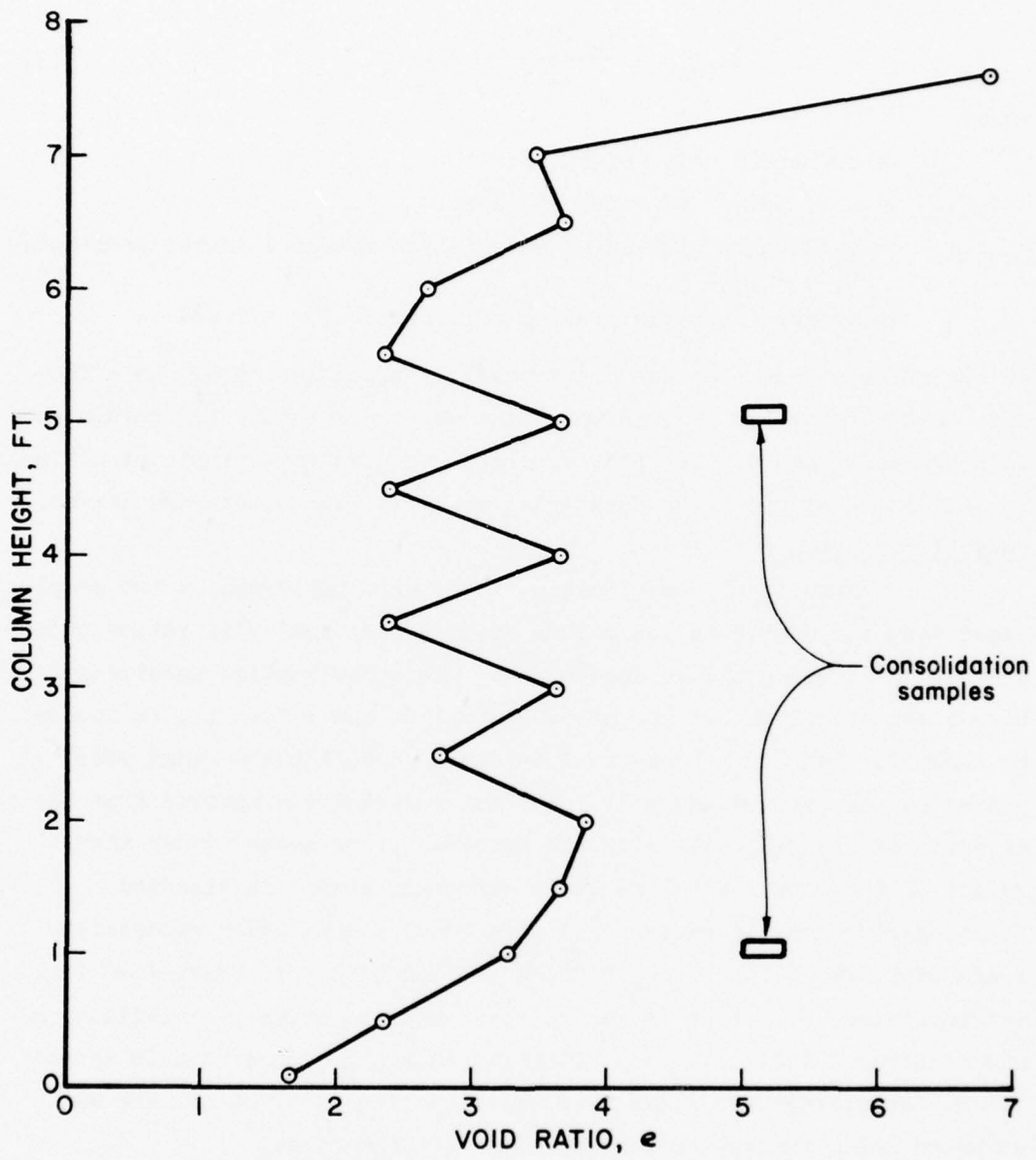


Figure 8. Column void ratios and location of consolidation samples

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

γ_{sub} = submerged unit weight, pcf

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

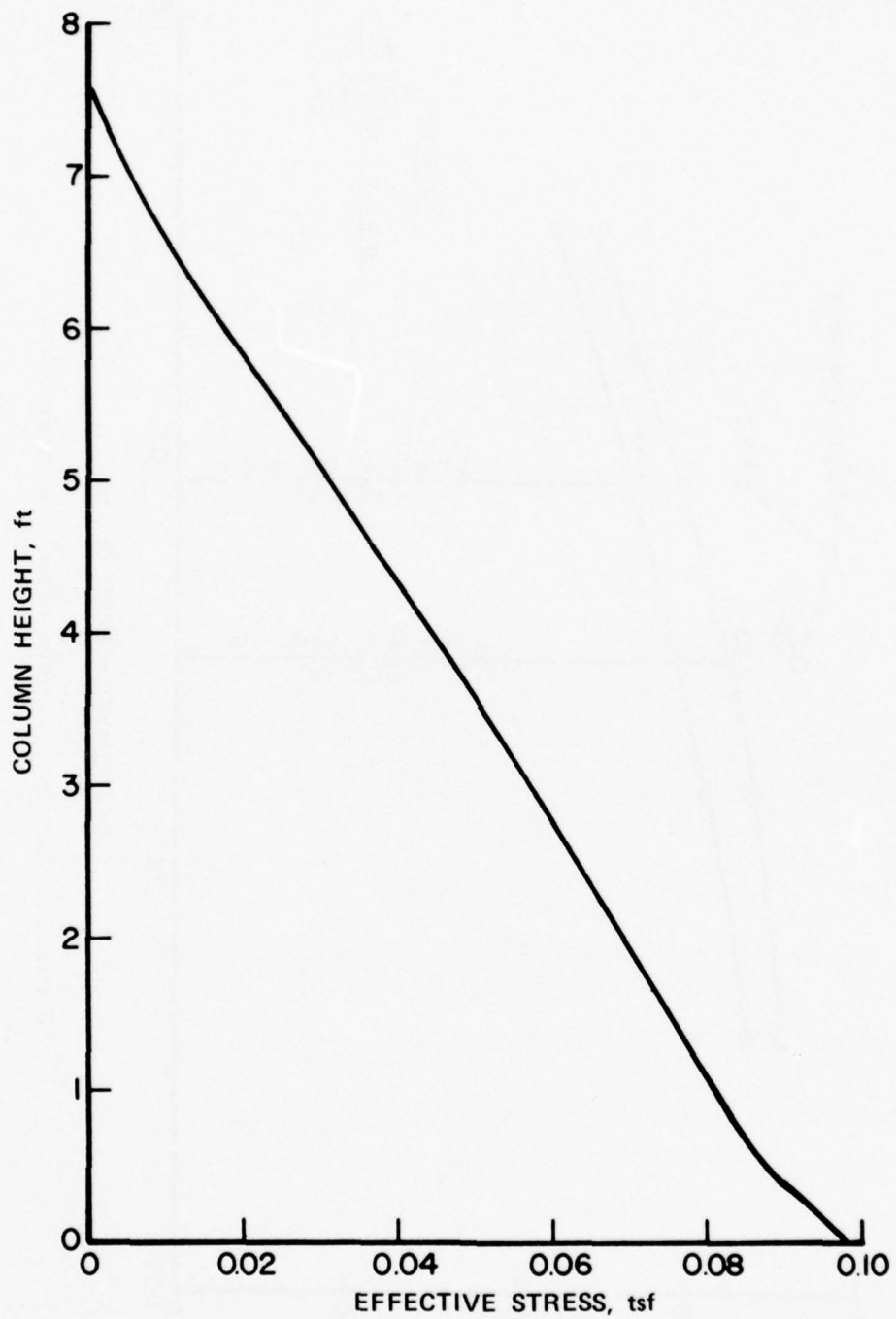


Figure 9. Effective stress plot for sedimentation column

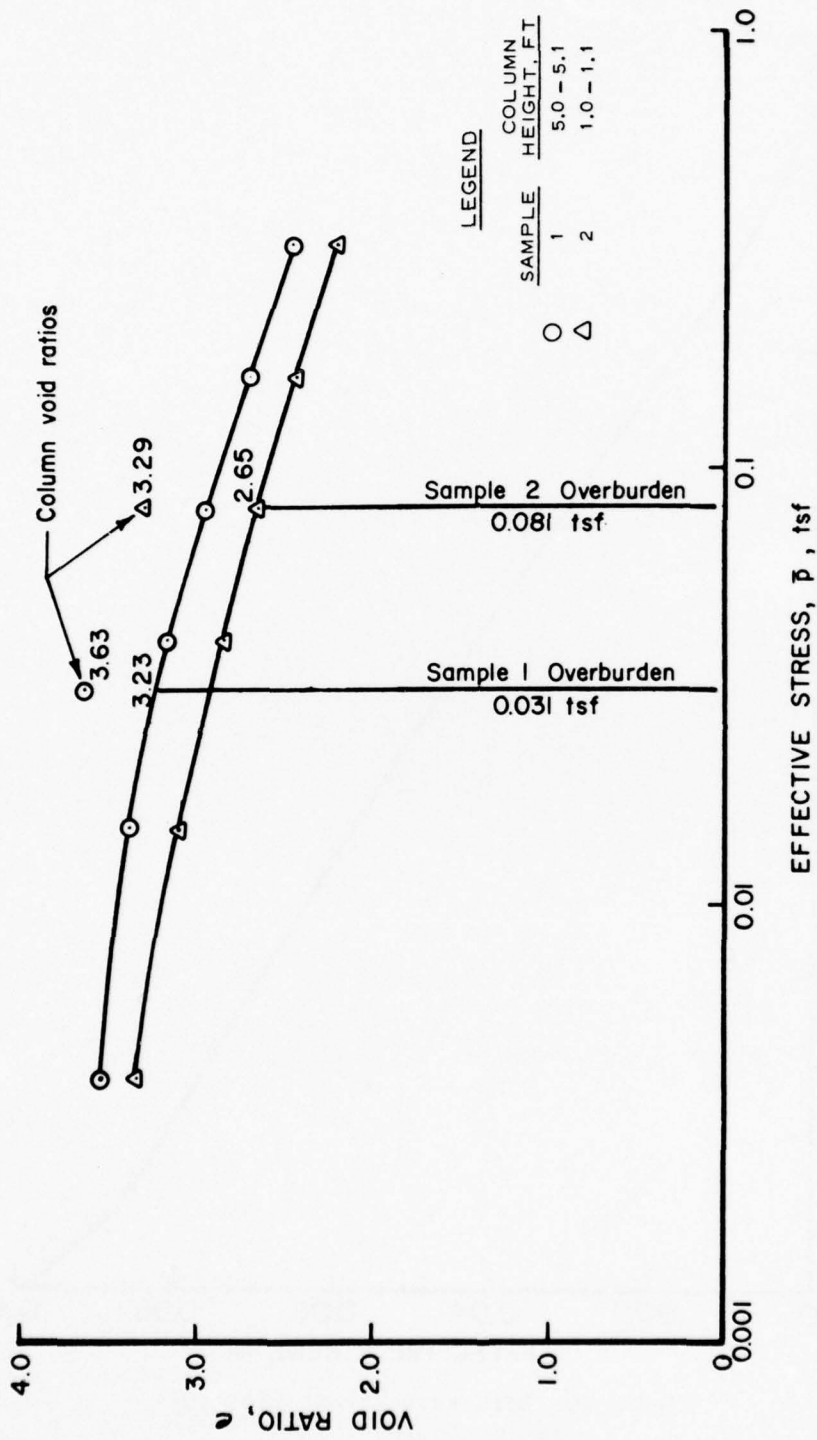


Figure 10. Void ratio versus effective stress

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 yd³ 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_a = total volume of sedimented dredged material

V_b = 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_s = volume of solids

e_a = average void ratio of the sedimented dredged material

e_b = 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 yd³ and bulking factor of 1.58 yields a required dredging volume of 224,000 yd³. 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 yd³. 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 yd³. This estimate includes the normal two-ft overdredge to el -26.0 ft mlw. An additional volume of 106,000 yd³ 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 mlw. 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, ft²

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,^{7,8} and factors relating specifically to dredged material retaining dike design are identified by DMRP research.⁹

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.

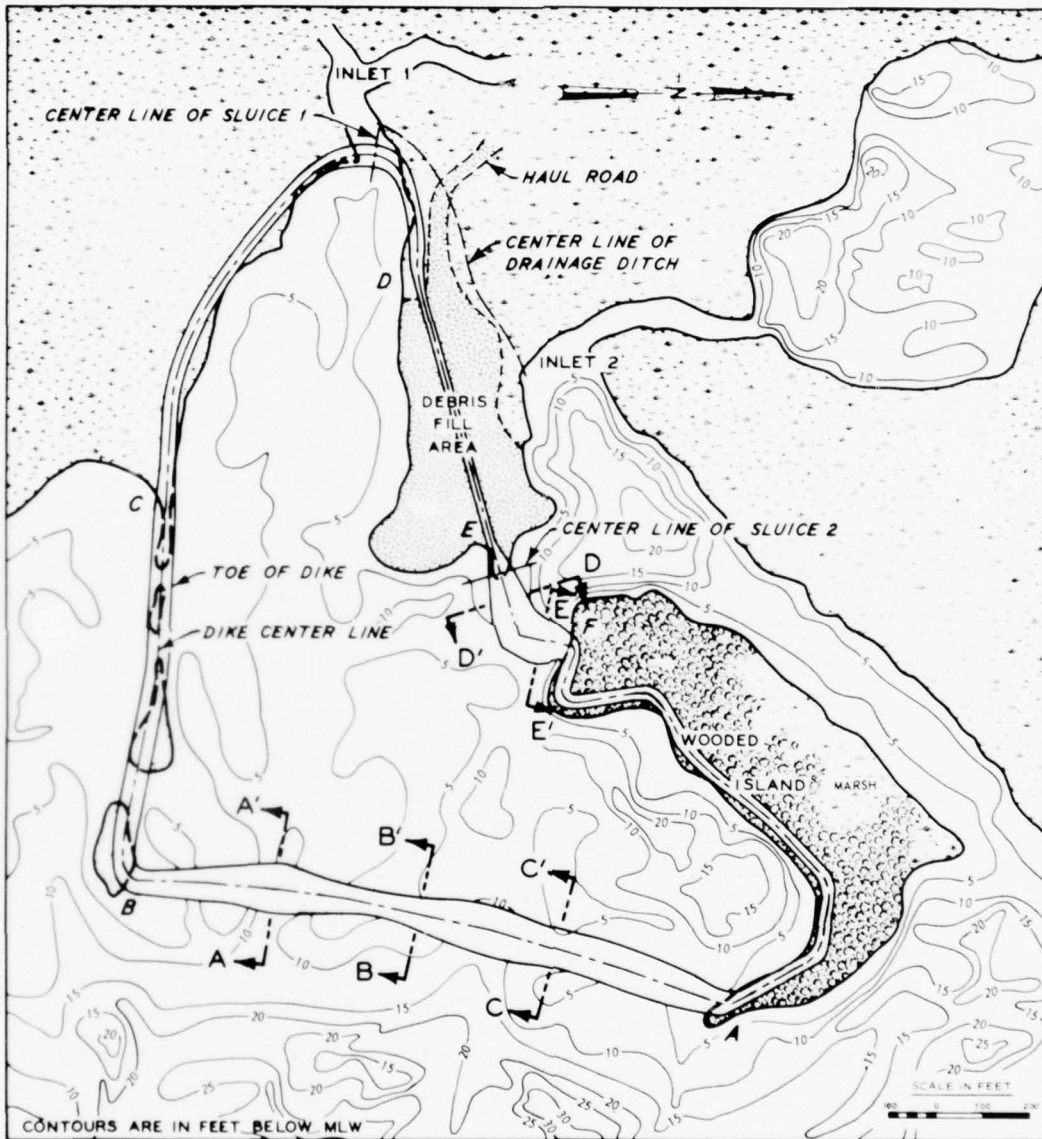
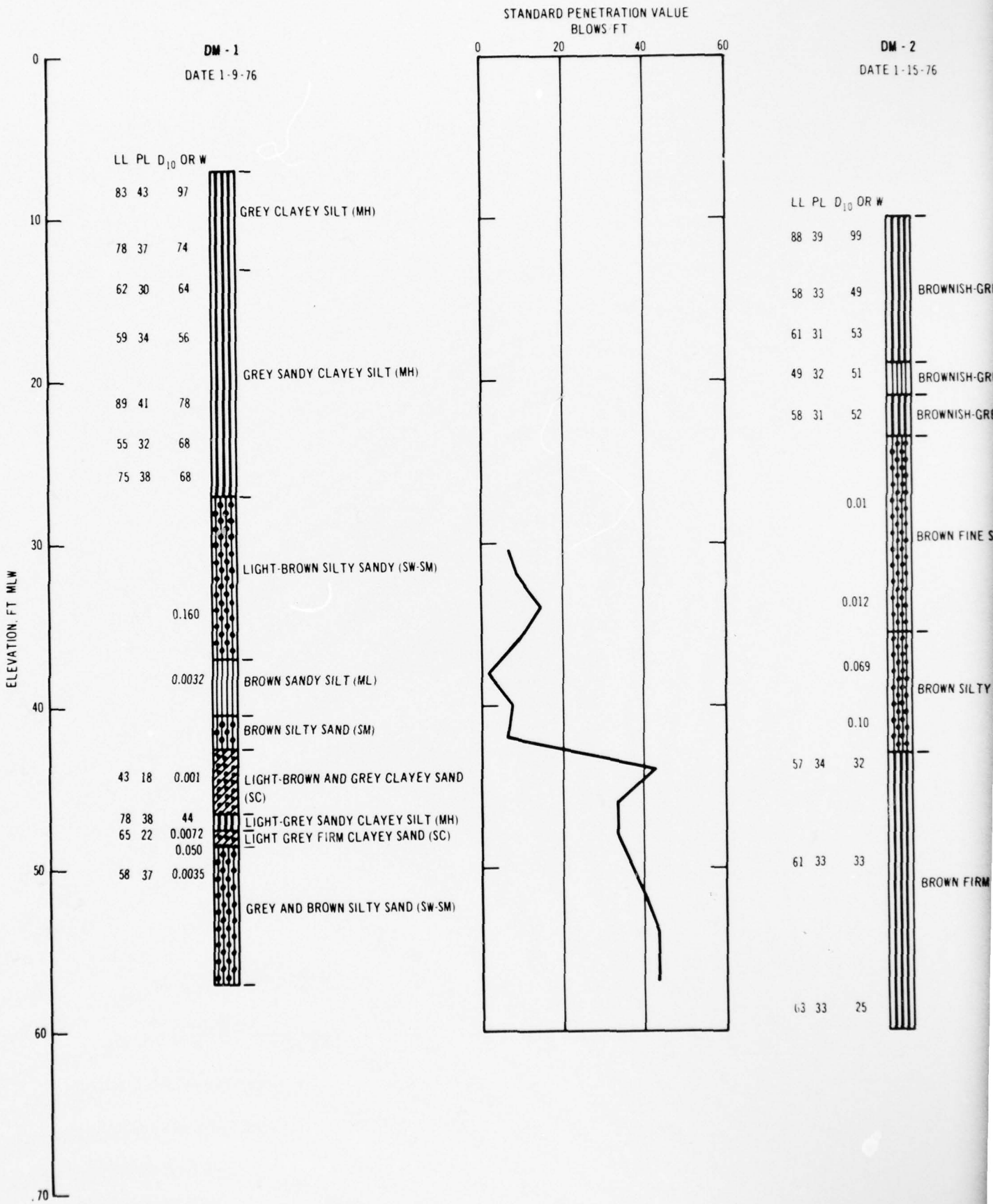


Figure 12. Containment area layout and plan of dikes



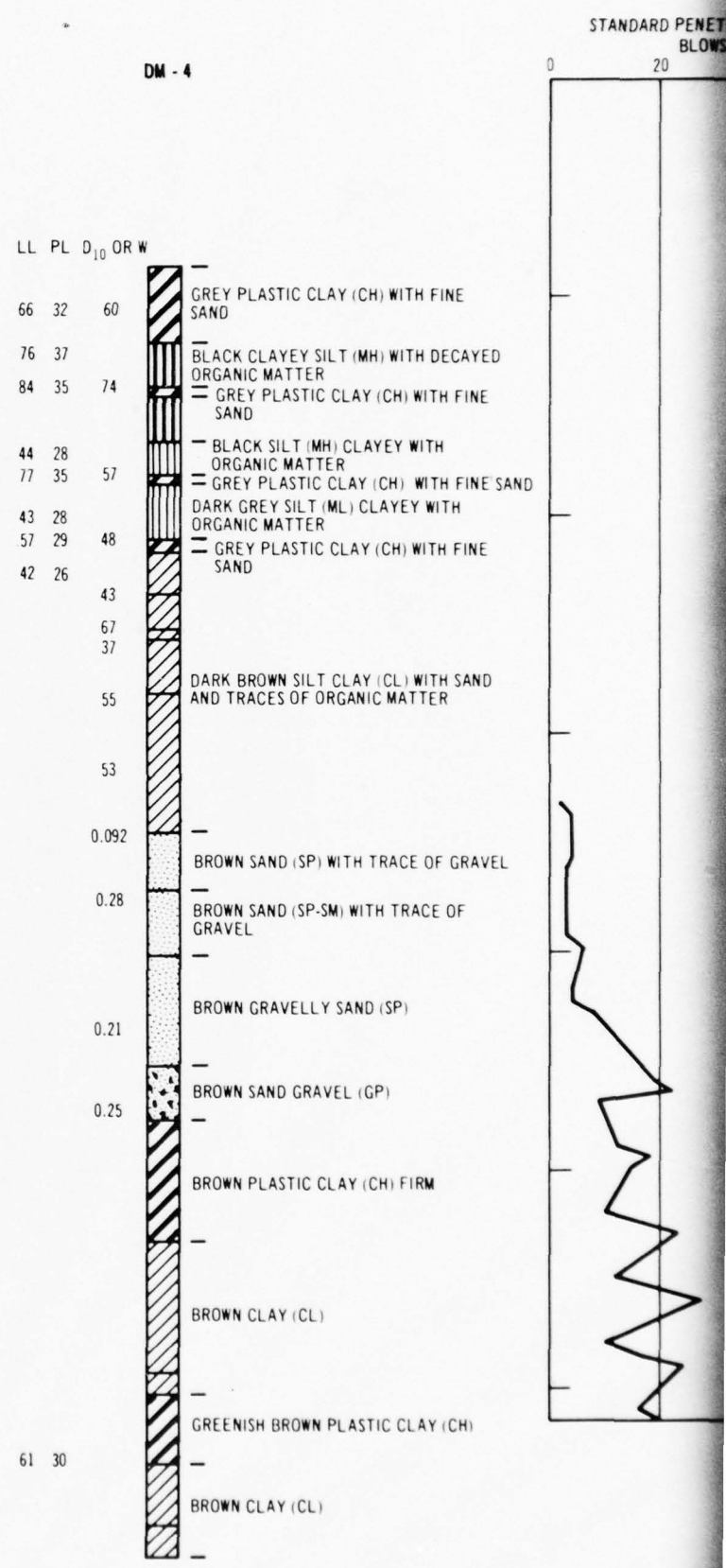
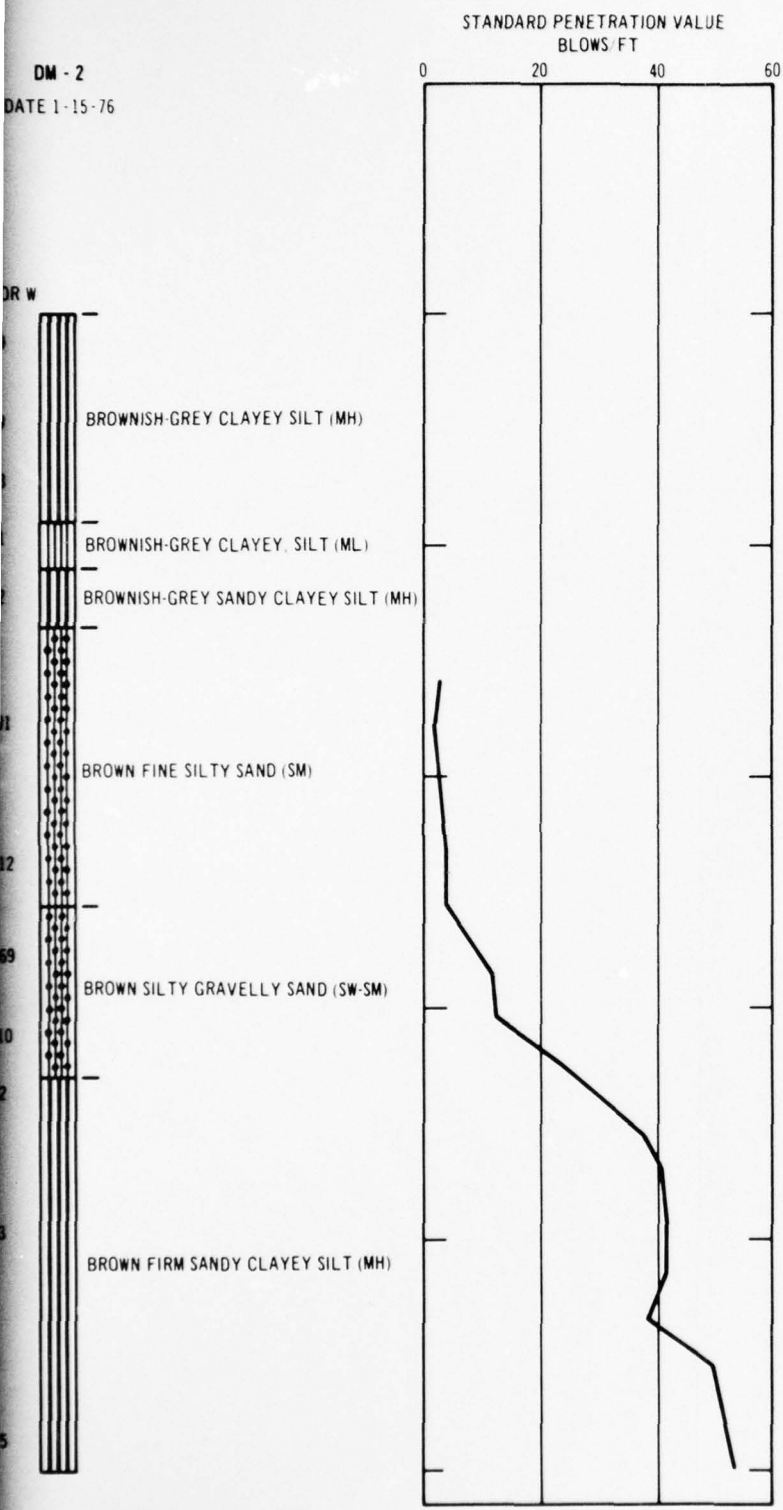
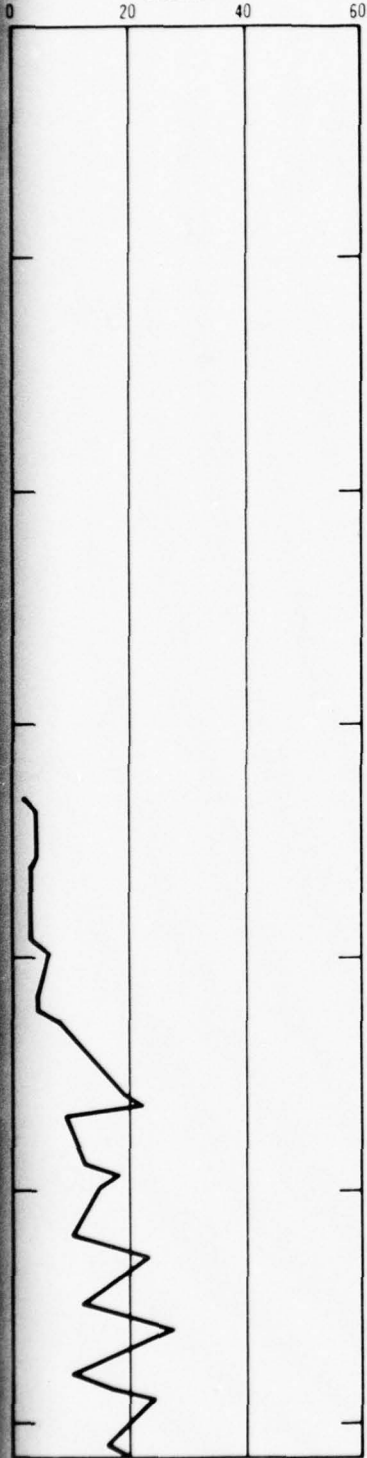


Figure 13. Boring logs IM-1 through DM-4

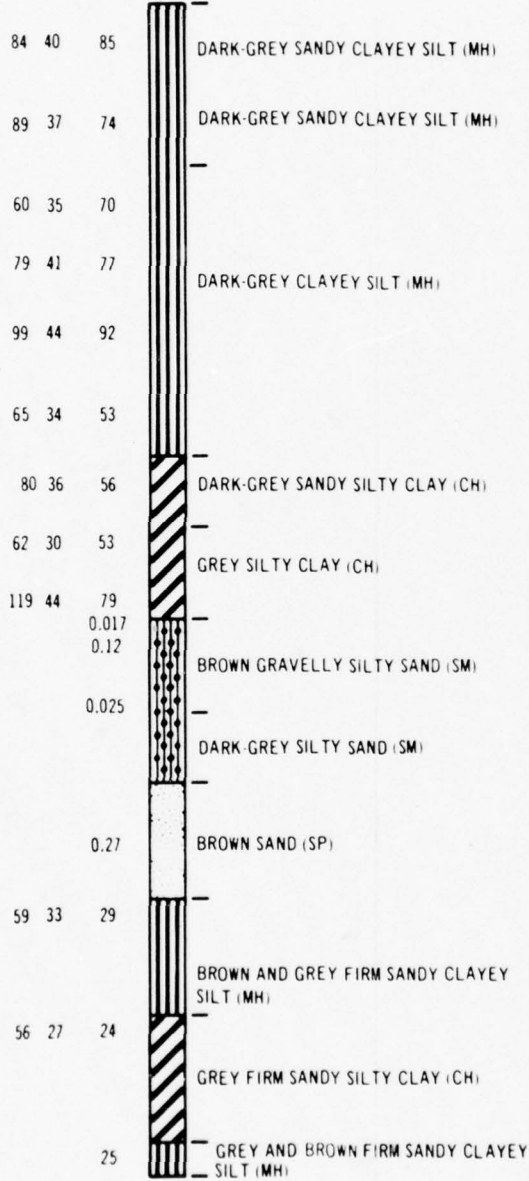
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STANDARD PENETRATION VALUE
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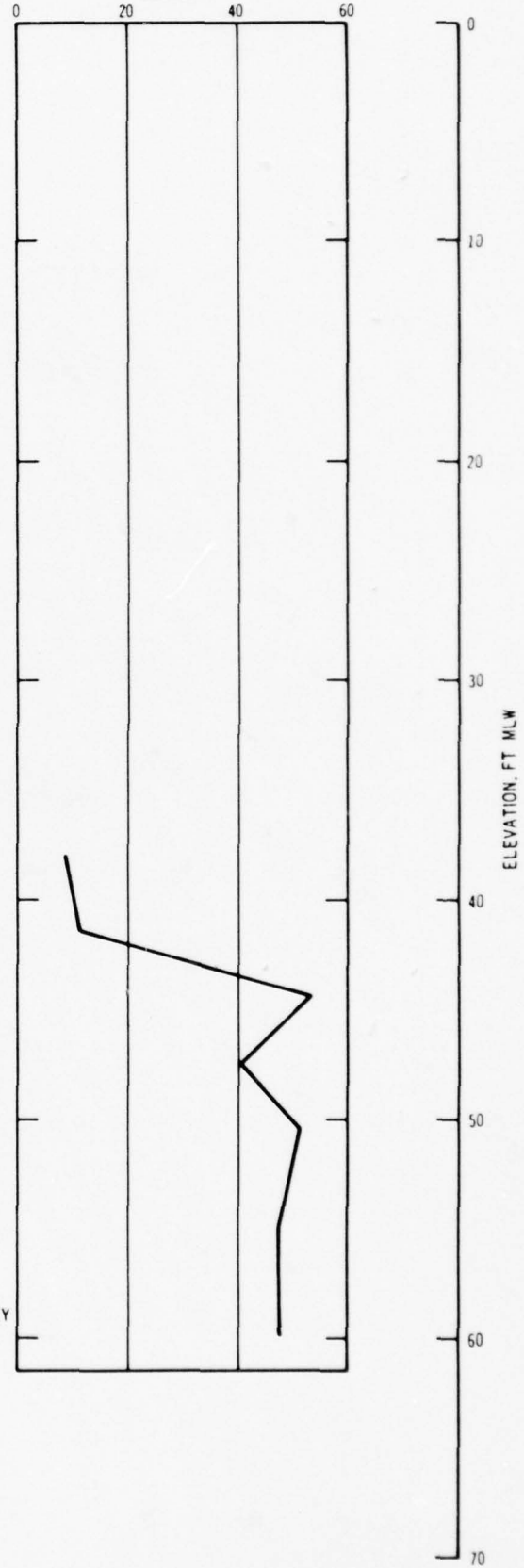


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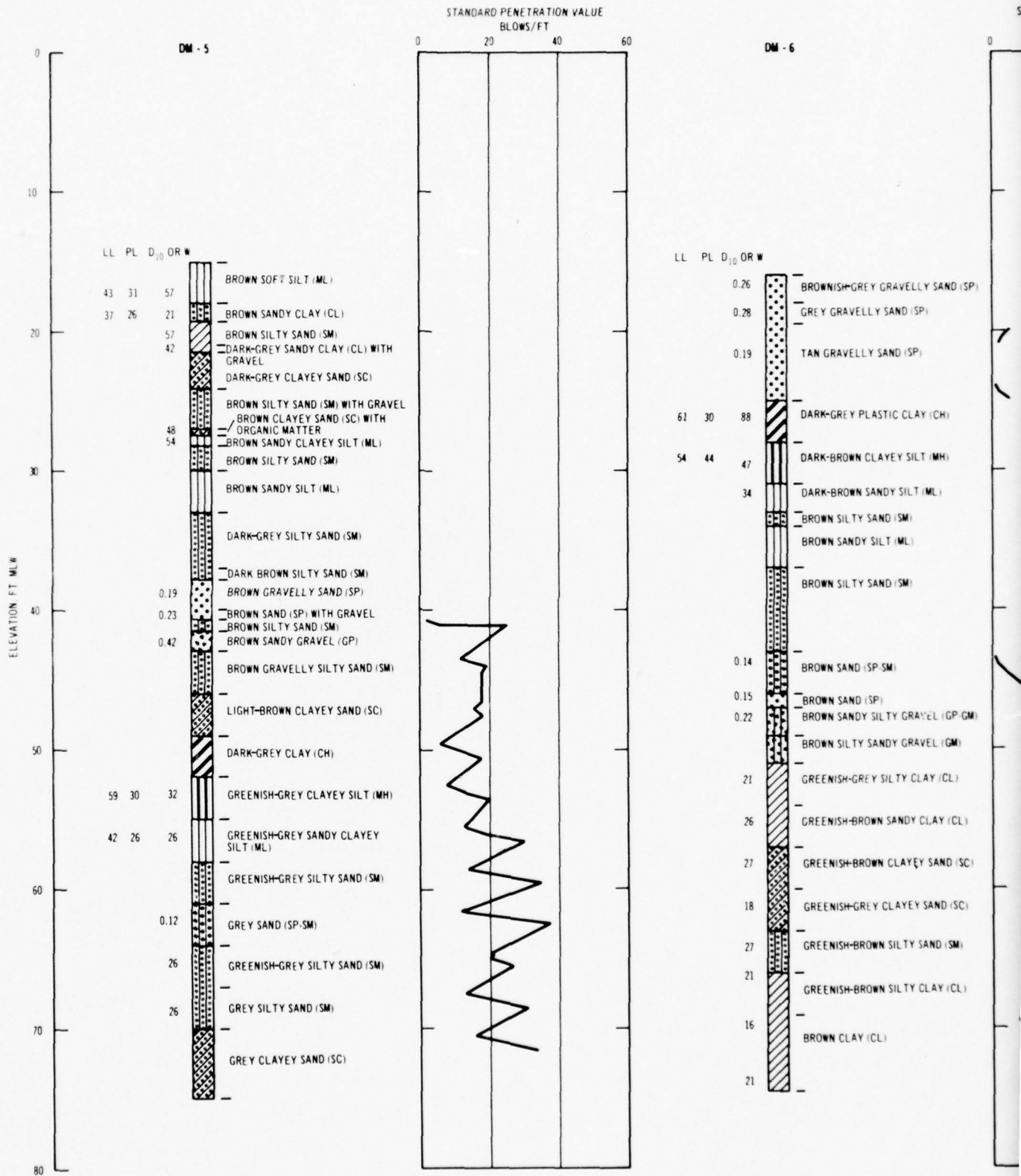


Figure 14. Boring logs DM-5 thro

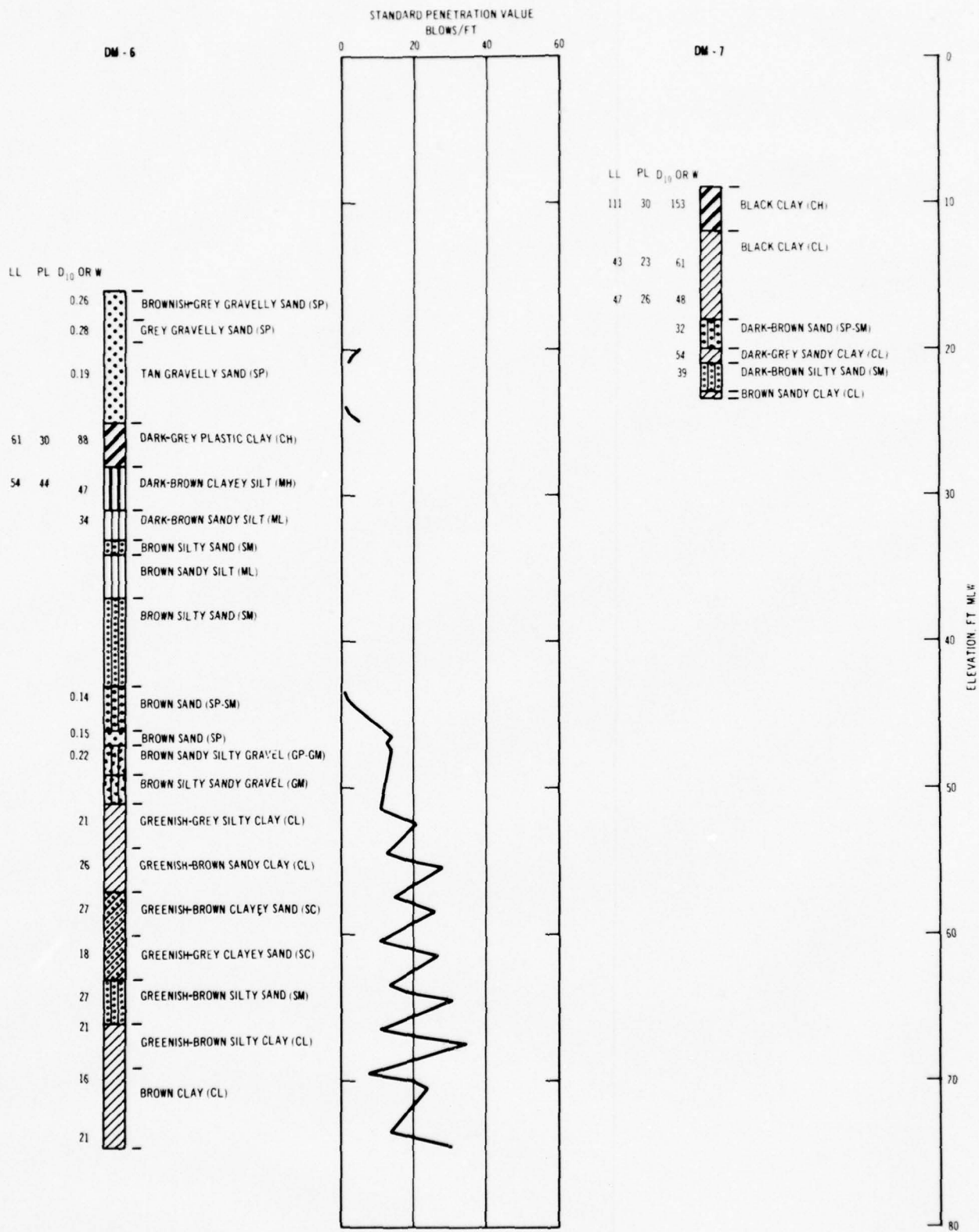


Figure 14. Boring logs DM-5 through DM-7

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 ft mlw</u>	<u>Classifi- cation (USCS)</u>	<u>Atterberg</u>		<u>Shear Strength</u>		
				<u>Limits</u>		<u>Type</u>	ϕ	<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

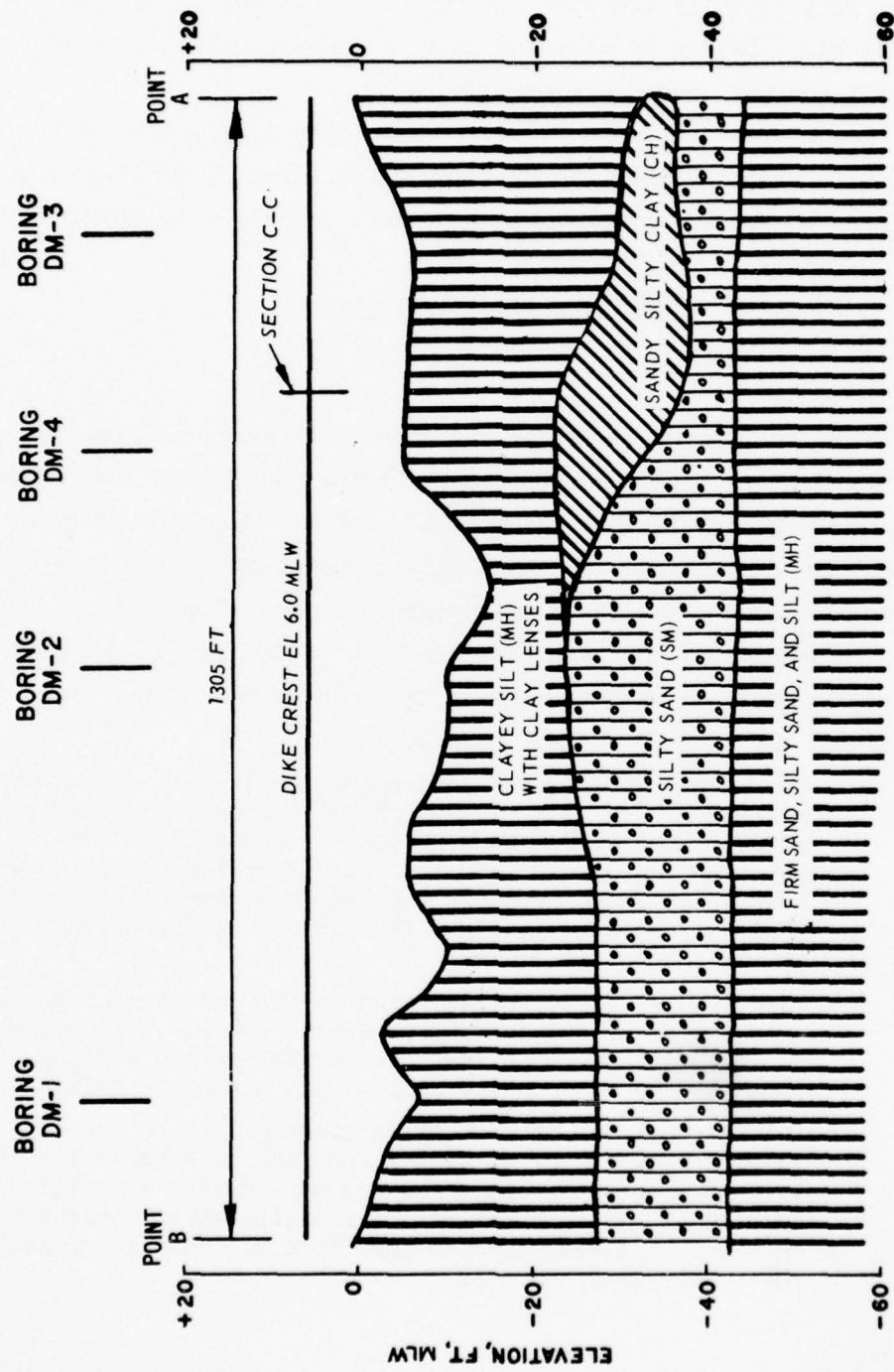


Figure 15. Generalized soil profile, dike reach A-B

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		Consolidated Undrained		Consolidated Drained	
	Q		R		S	
	ϕ Degrees	Cohesion psf	ϕ Degrees	Cohesion psf	ϕ Degrees	Cohesion 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.^{7,8} 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.^{10,11} 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

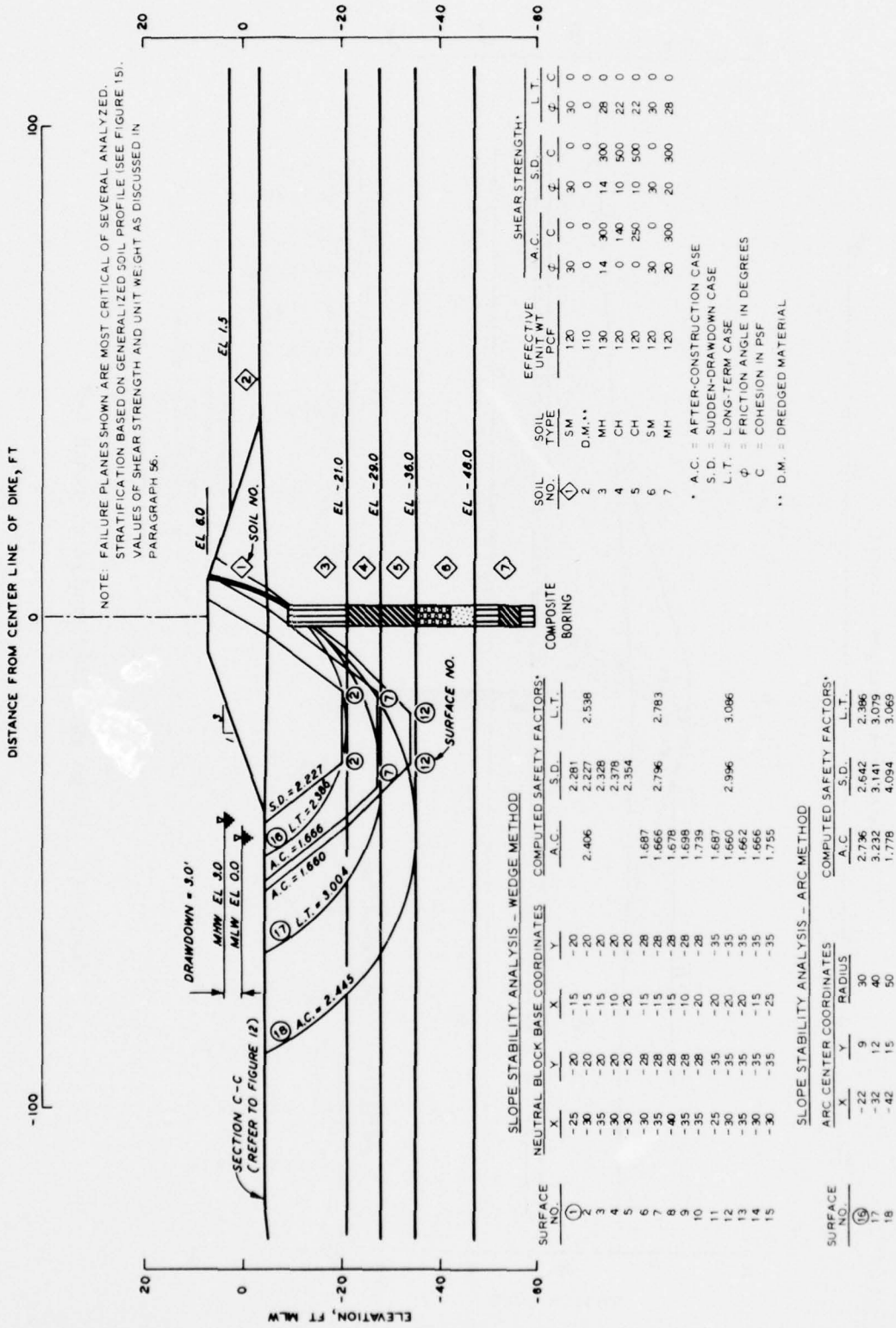


Figure 16. Slope stability analysis, reach A-B

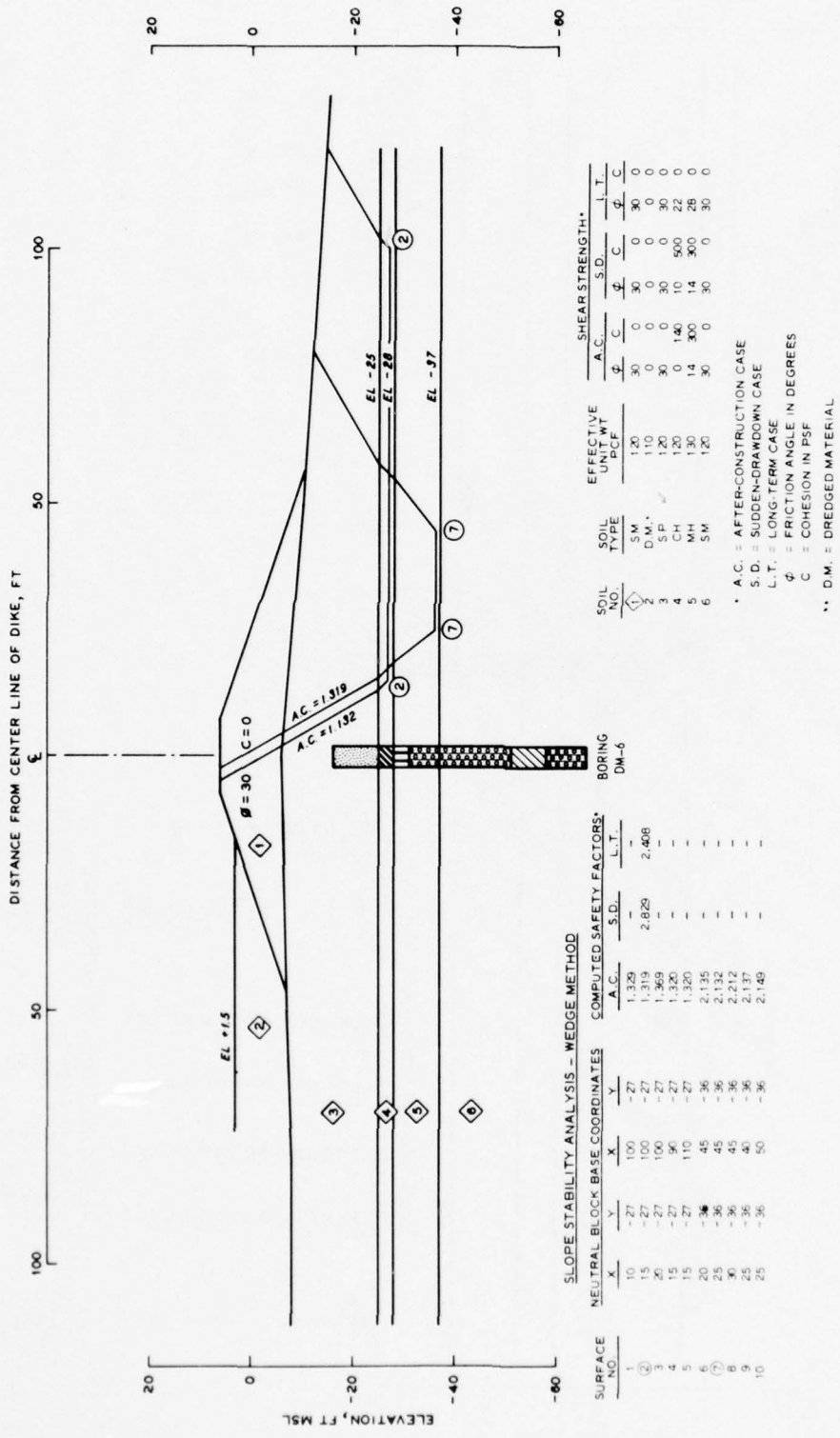


Figure 17. Slope stability analysis, reach E-F

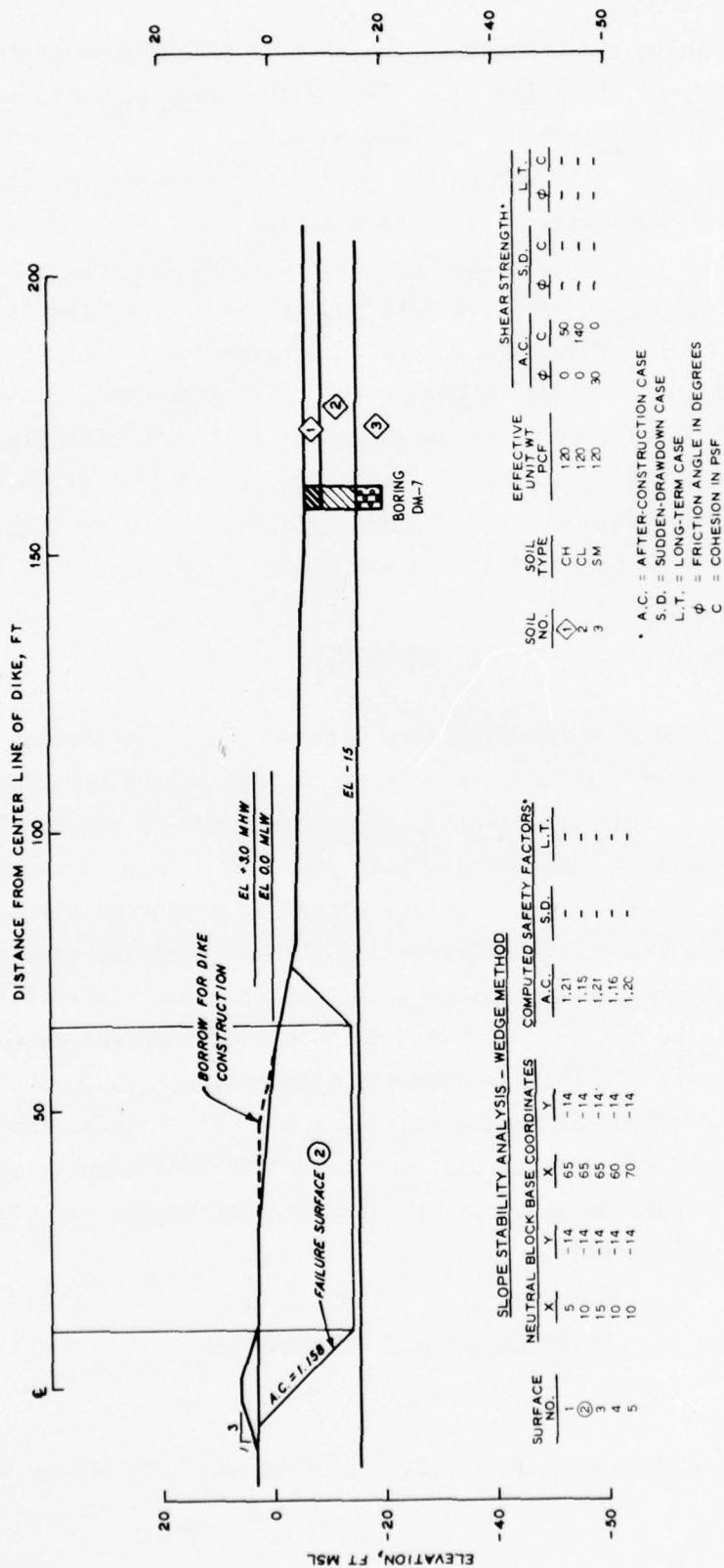


Figure 18. Slope stability analysis, reach C-D

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.¹² This is well below the suggested mean scour velocity of 2.0 fps for fine sand.¹³ 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.¹⁴ 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 1110-2-2300.⁷ 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 mlw 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 mlw within the containment area as described in Part II. This will require an interior pool to approximate el +4.0 ft mlw 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 mlw. 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.

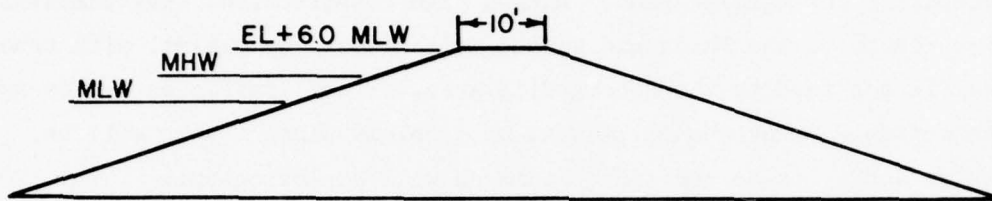
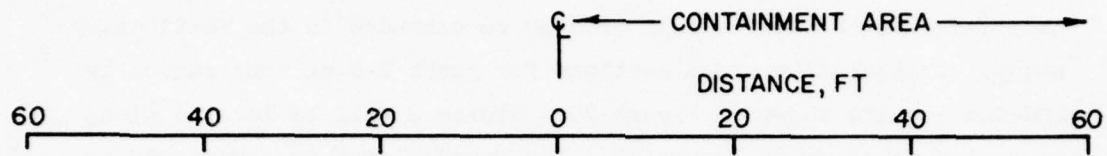
* Conclusions derived from discussions in August 1976 between WES and NPS personnel responsible for the environmental assessment of the Dyke Marsh project.

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.

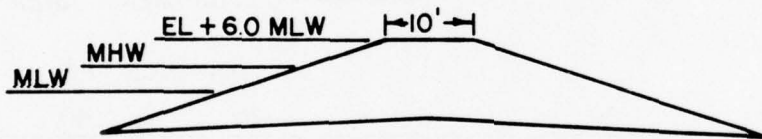
74. Dike construction material should consist of coarse-grained fill such as sand or sand and gravel mixtures. Fill should contain less than 20 percent silt- and clay-sized materials to prevent excessive turbidity during placement. The only definite sources of suitable fill are commercial sand pits. 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

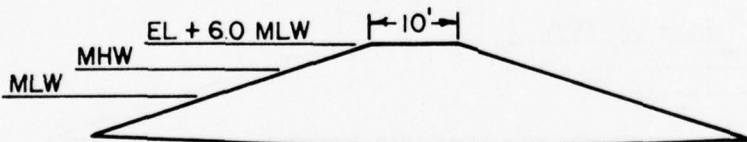
75. Dike reach E-F extends through the water from the tip of the



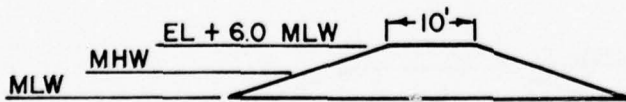
a. Section A-A' (reach A-B)



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

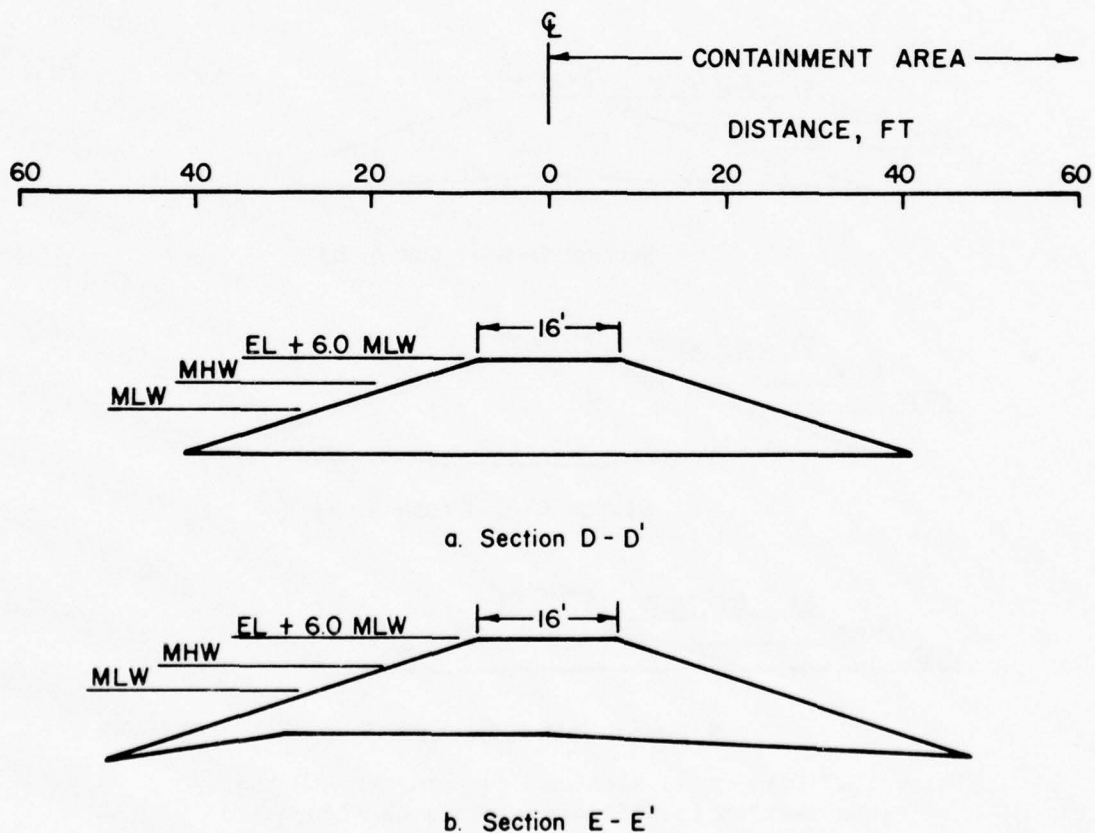


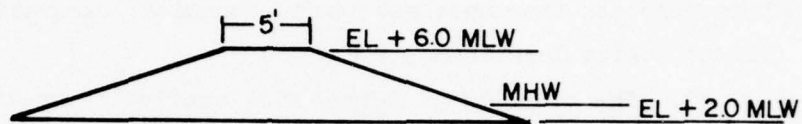
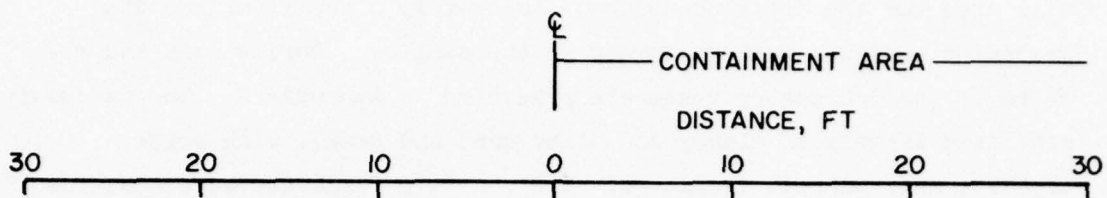
Figure 20. Dike cross sections for reach E-F (cross-section locations are shown in Figure 12)

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.

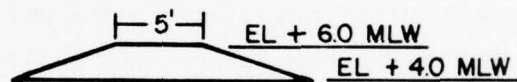
77. The quantity of debris fill available for dike construction is also limited by other considerations. Because the marsh is visited regularly by local residents and organized wildlife societies, it is desirable to maintain a large area for convenient observation of the marsh and access to the river. 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 mlw. 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 mlw 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 mhw 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/yd³. 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.

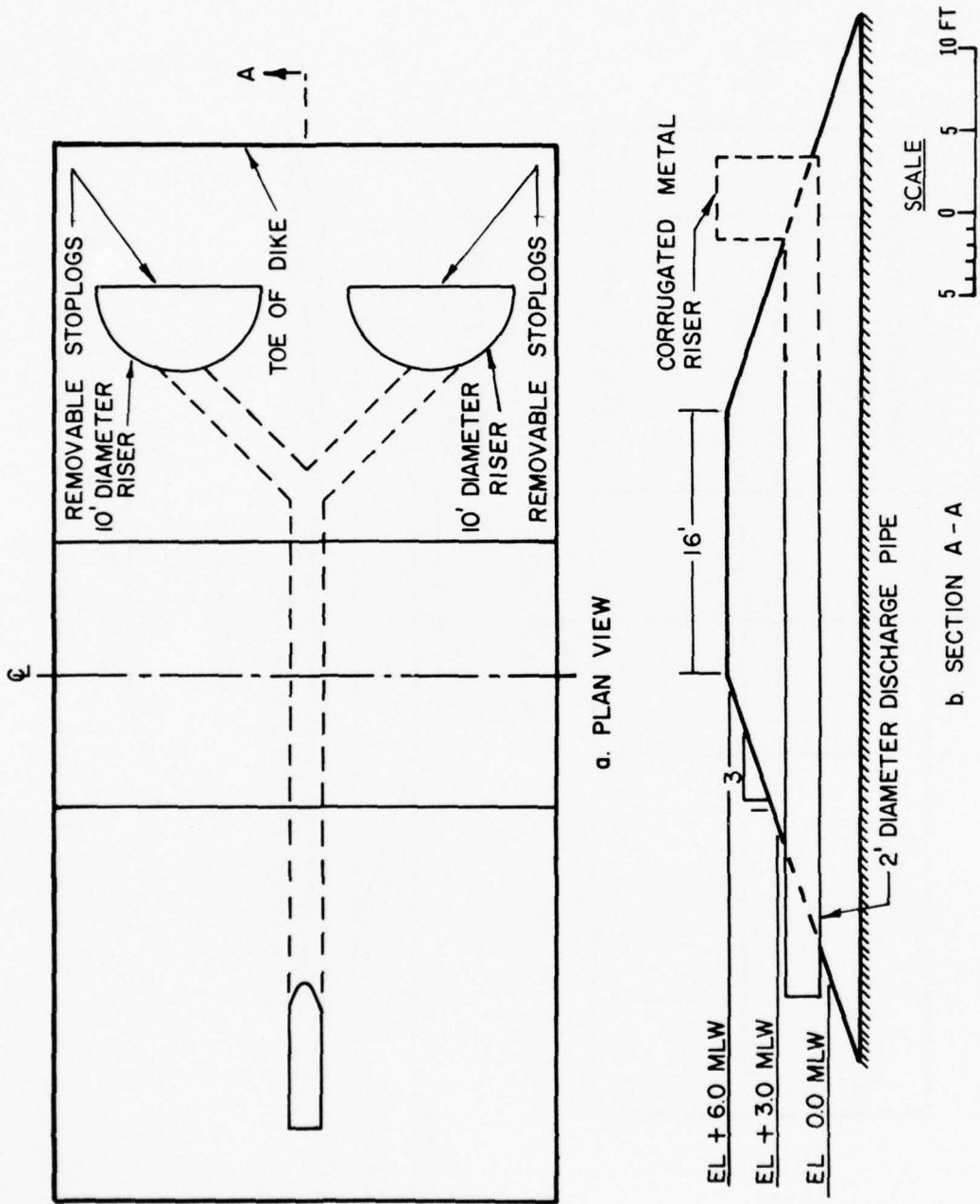
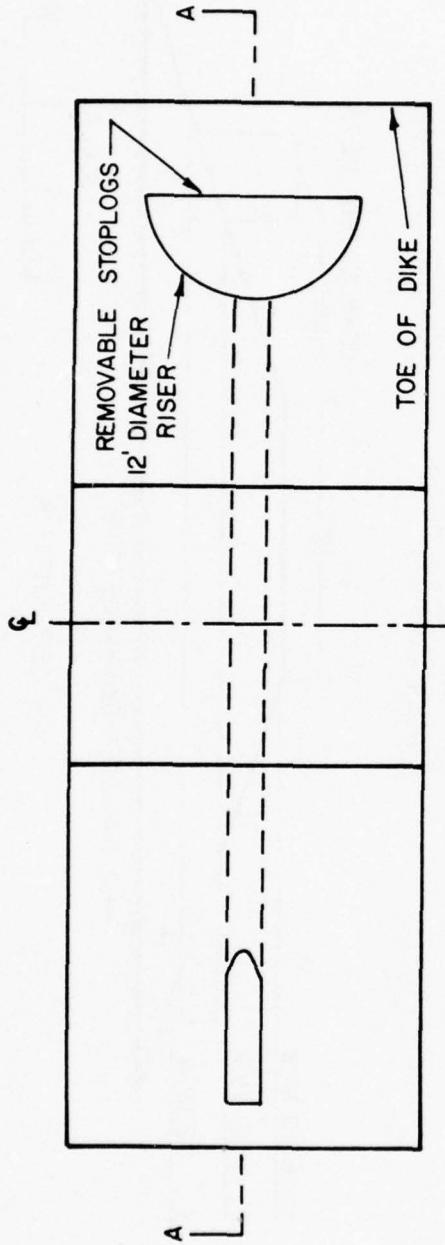
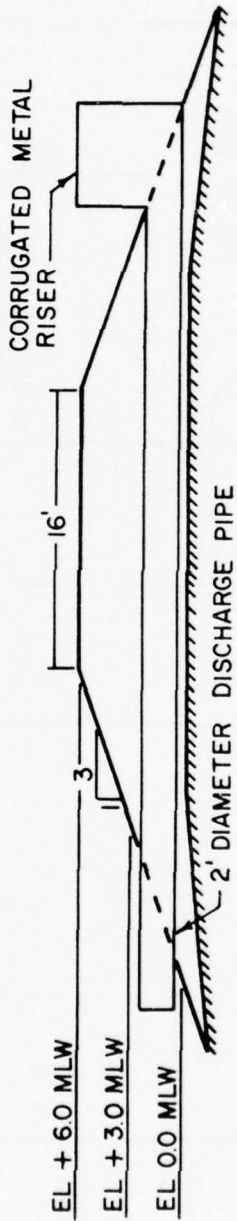


Figure 22. Plan and section for sluice 1



a. PLAN VIEW



b. SECTION A-A

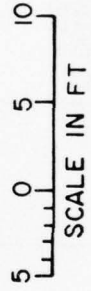


Figure 23. Plan and section for sluice 2

Table 2

Containment Area Construction Costs

Item	Construction Material		Construction		Total \$
	Source	Volume yd ³	Method	Cost/yd ³	
Reach A-B:					
Fill (sand)	Commercial	27,500	Barge Placement	17.30	475,750
Riprap (stone)	Commercial	1,300	Barge Placement	61.40	79,820
Filter cloth	--	--	--	--	5,500
Reach B-C:					
Fill (sand)	Commercial	5,000	Barge Placement	17.30	86,500
Riprap (stone)	Commercial	550	Barge Placement	61.40	33,770
Filter cloth	--	--	--	--	2,500
Reach C-D:					
Fill	Adjacent to dike	3,000	Dragline-Bulldozer	3.00	9,000
Reach D-E:					
Fill	Adjacent to dike	550	Dragline-Bulldozer	3.00	1,650
Reach E-F:					
Fill	Debris fill area	4,000	Truck End-dumped	4.00	16,000
Reach F-A:					
Fill	Adjacent to dike	3,000	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 yd³ 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,¹ 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.

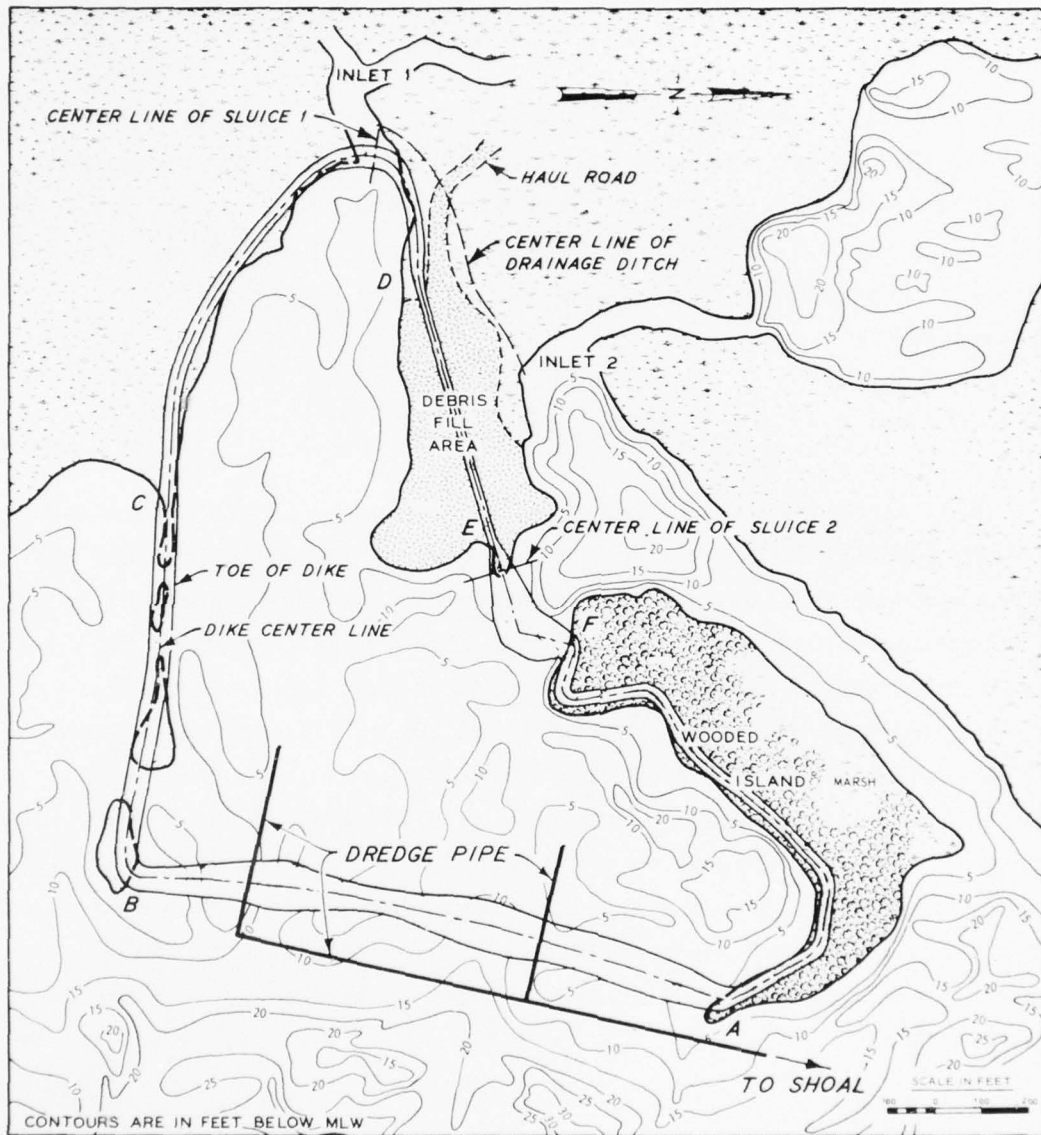


Figure 24. Dredged material placement scheme

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 yd³ per day, a 246,000 yd³ 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 yd³ 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 mhw 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.

REFERENCES

1. Palermo, M. R. and Zeigler, T. W., "Feasibility Study for Dyke Marsh Demonstration Area, Potomac River, Virginia," Technical Report D-76-6, Nov 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
2. National Capitol Region, National Park Service, Department of Interior, "Environmental Assessment of Dyke Marsh," May 1976, George Washington Memorial Parkway, Capitol Region, Washington, D. C.
3. U. S. Army Engineer Waterways Experiment Station, CE, "The Unified Soil Classification System," Technical Memorandum No. 3-357, Apr 1960, Vicksburg, Miss.
4. Office, Chief of Engineers, Department of the Army, "Laboratory Soils Testing," Engineer Manual EM 1110-2-1906, Nov 1970, Washington, D. C.
5. U. S. Army Engineer Waterways Experiment Station, CE, "Prediction of Stable Elevation for a Marsh Created from Dredged Material," Contract Report (in preparation), Vicksburg, Miss.; prepared by Massachusetts Institute of Technology.
6. Huston, J., Hydraulic Dredging, Cornell, Cambridge, Md., 1970.
7. Office, Chief of Engineers, Department of the Army, "Earth and Rock-Fill Dams: General Design and Construction Considerations," Engineer Manual EM 1110-2-2300, Mar 1971, Washington, D. C.
8. Office, Chief of Engineers, Department of the Army, "Stability of Earth and Rock-Fill Dams," Engineer Manual EM 1110-2-1902, Apr 1970, Washington, D. C.
9. Hammer, D. P., "Guidelines for the Design and Construction of Dredged Material Retaining Dikes," Technical Report (in preparation), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
10. Cheek, J. B. "Instruction Manual for Using WES Time-Sharing System for Analysis of Slope Stability (The Circular Arc Method)," Miscellaneous Paper K-73-2, Mar 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
11. _____, "Instruction Manual for Using WES Time-Sharing System for Analysis of Slope Stability; Wedge Method," Miscellaneous Paper K-76-3, Jun 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
12. National Ocean Survey, National Oceanic and Atmospheric Administration, Department of Commerce, "Tidal Current Tables 1976 - Atlantic Coast of North America," 1975, Washington, D. C.

13. Office, Chief of Engineers, Department of the Army, "Hydraulic Design of Flood Control Channels," Engineer Manual EM 1110-2-1601, Jul 1970, Washington, D. C.
14. U. S. Army Coastal Engineering Research Center, "Shore Protection Manual," Vols I and II, 1973, Fort Belvoir, Va.

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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.

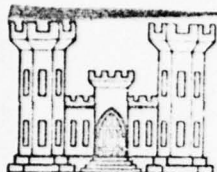
70 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-13)

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

Appendixes A-D on microfiche in pocket.

References: p. 69-70.

I. Containment areas. 2. Dredged material. 3. Dyke Marsh, Va. 4. Marshes. 5. Potomac River. I. Ziegler, Timothy W., joint author. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-13.
TA7.W34 no.D-77-13



DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT D-77-13

DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA POTOMAC RIVER, VIRGINIA

by

Michael R. Palermo and Timothy W. Ziegler

Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1977

Final Report

Approved For Public Release; Distribution Unlimited

- APPENDIX A: LABORATORY TEST RESULTS FOR SHOAL & COLUMN SEDIMENTATION SAMPLES
- APPENDIX B: FIELD INVESTIGATIONS & LABORATORY TESTS FOR RIVERINE SOURCES OF SAND
- APPENDIX C: FIELD INVESTIGATIONS & LABORATORY TESTS--DEBRIS FILL AREA & WOODED ISLAND
- APPENDIX D: LABORATORY TESTS OF FOUNDATION SOILS

Prepared for Office, Chief of Engineers, U. S. Army
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Under DMRP Work Unit 4A17A

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APPENDIX A: LABORATORY TEST RESULTS FOR SHOAL
AND COLUMN SEDIMENTATION SAMPLES

1. This appendix presents the results of laboratory tests performed on undisturbed and bulk samples of sediment taken from the Potomac River near Dyke Marsh, Virginia. Undisturbed samples were taken from ten borings located as shown in Figure 3 of the main text. Analyses performed included laboratory classifications under the Unified Soil Classification System (USCS) and determinations of water content, Atterberg limits, grain-size distribution, specific gravity, and density-void ratio. Results of the tests are presented with the graphic boring logs in Figure 4 of the main text.

2. Individual grain-size analyses were performed on coarse-grained samples and are presented on pages A3 through A13. Results of all Atterberg limits tests performed on fine-grained samples are shown plotted on the plasticity chart on page A14. All samples plotted adjacent to the A-line, the arbitrary boundary between clays and silts. Though the USCS indicates that the fine-grained samples were evenly divided between clays and silts, the material is essentially homogeneous with similar plasticity. A summary of test data is presented in Table A1.

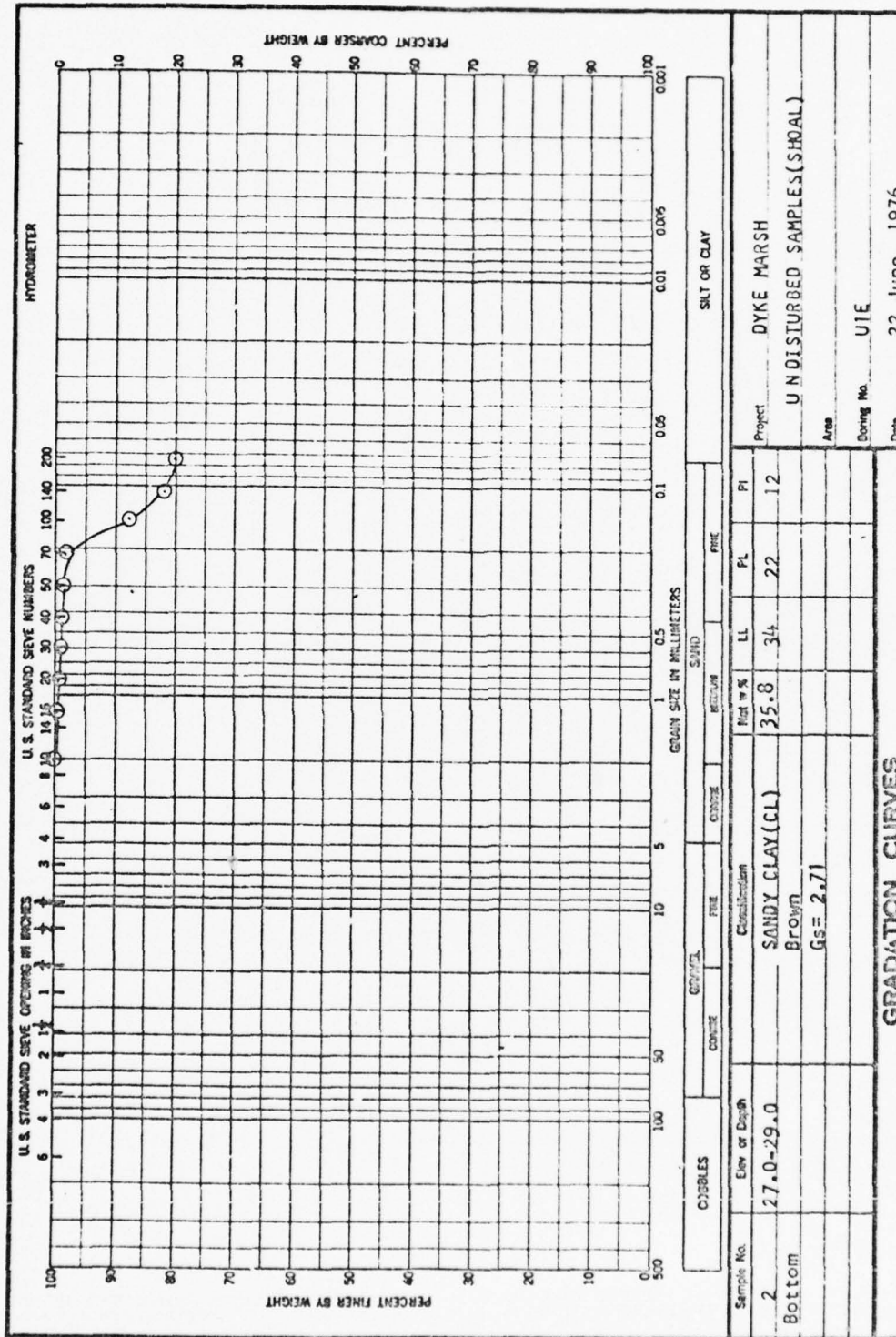
3. A bulk sample of sediment was taken at boring location U-2-C. The bulk sample was used in performing column sedimentation tests for the sizing studies. Two consolidation samples of the sedimented material were taken to estimate final settlements of the marsh substrate. Results of these tests are presented on pages A15 through A36. Hydro-meter analyses performed on samples from the sedimentation column are presented on pages A37 through A54.



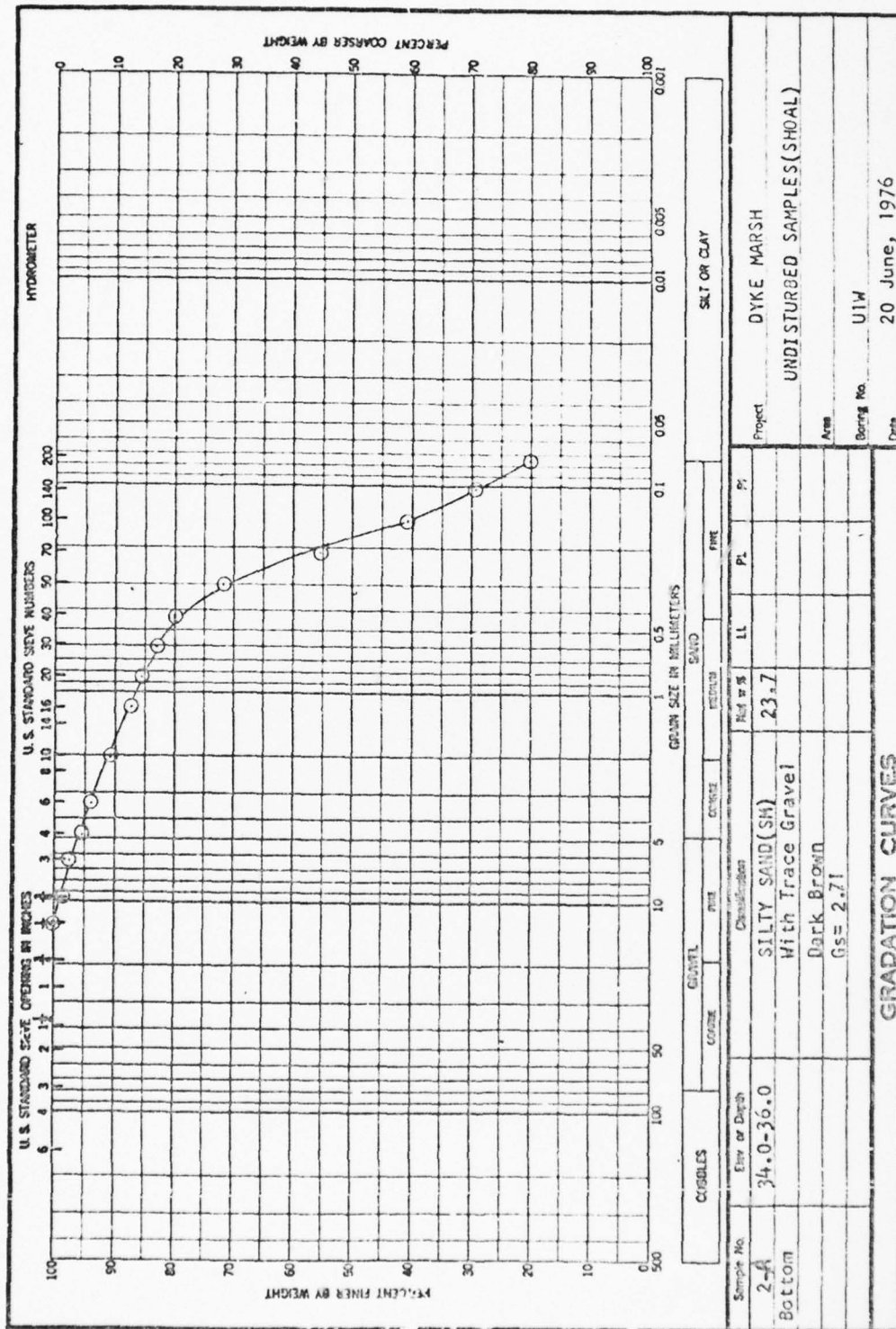
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Table A1
Physical and Engineering Properties of Channel Sediment

Boring	El, ft mlw	USCS	Atterberg Limits			Natural Water Content %	Specific Gravity G _s	Wet Density γ _{wet} pcf	Dry Density γ _{dry} pcf	Void Ratio e
			LL	PL	PI					
U-1-C	-18.5	ML	39	27	12	58.4	2.71	98.3	62.1	1.583
	-21.2					51.4		102.1	67.4	1.393
	-24.0	ML	41	28	13	50.4	2.72	101.6	67.6	1.371
	-26.5	ML	49	29	20	53.0	2.73	99.8	65.2	1.447
	-29.0	ML	48	29	19	53.3	2.72	99.3	64.8	1.450
U-2-C	-17.2	MH	58	35	23	76.9	2.68	89.2	50.4	2.061
	-19.6					85.8		85.0	45.7	2.299
	-22.2	ML	46	31	15	73.1	2.68	90.0	52.0	1.959
	-24.5	ML	32	5	6	64.0	2.68	98.3	60.0	1.715
	-27.0	SP-SM				29.3	2.72	110.5	85.4	0.797
-29.5	SP				25.3	2.72	115.2	91.9	0.688	
Bulk: Sample										
A		MH	58	36	22	57.1	2.67			
B		MH	77	45	32	72.2	2.65			
C		MH	68	43	25	79.2	2.68			
D		MH	75	42	33	70.1	2.68			
E		MH	57	34	23	52.8	2.67			



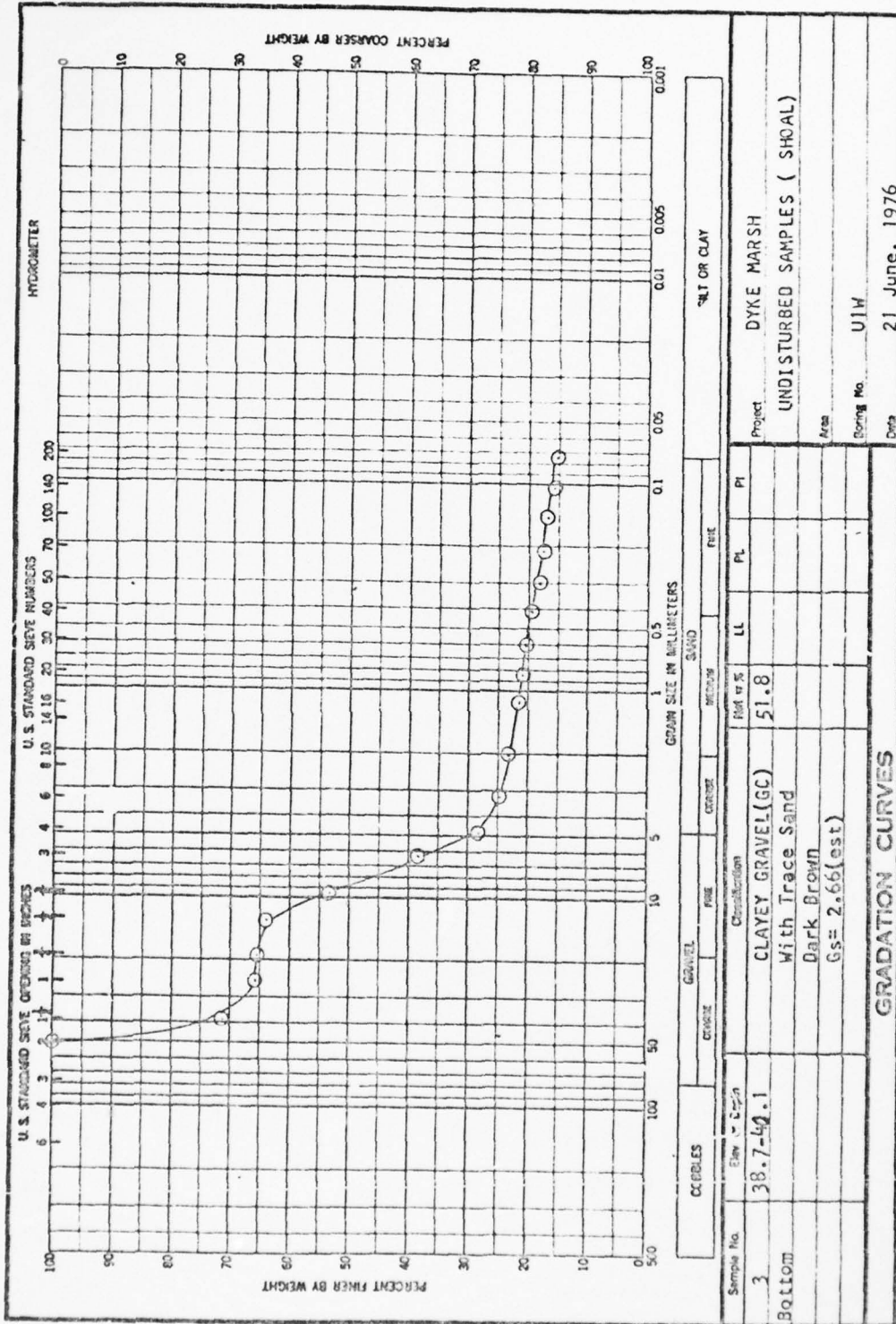
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Sample No. 2-A Bottom	Env. or Depth 34.0-36.0	Description SILTY SAND (SM) With Trace Gravel Dark Brown G _s = 2.71	No. of # 23.7	LL	PL	PI	Project DYKE MARSH UNDISTURBED SAMPLES (SHOAL)	Acct. UITW	Boring No. 20 June, 1976	Date
	COARSE									

GRADATION CURVES

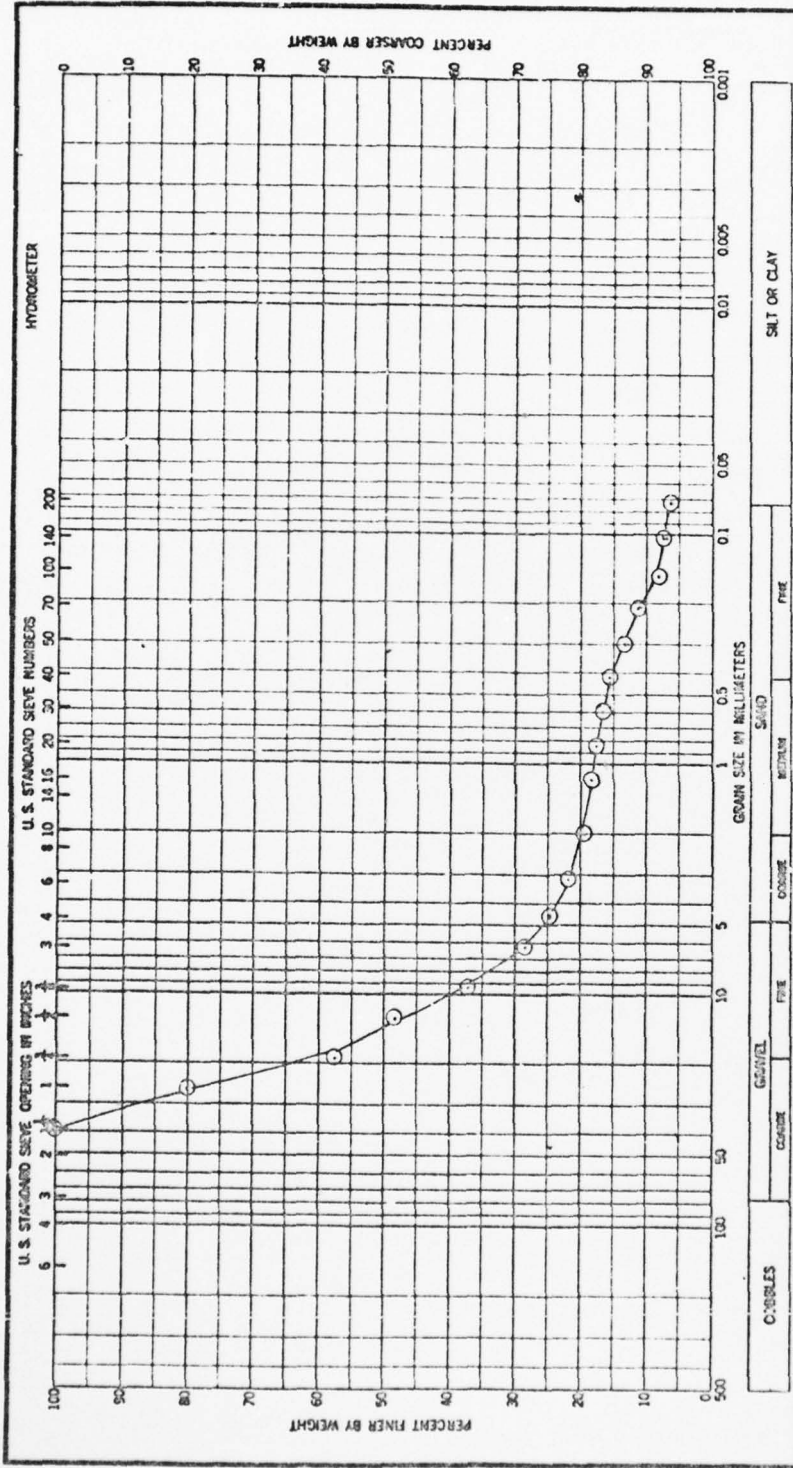
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Sample No.	3	Elev. & Depth	38.7-42.1	Classification	CLAYEY GRAVEL(GC) With Trace Sand Dark Brown Gs = 2.66(est)	Flow or %	51.8	LL		PL		PI	
Bottom													
Project: DYKE MARSH Area: UNDISTURBED SAMPLES (SHOAL) Boring No.: U1W Date: 21 June, 1976													

GRADATION CURVES

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HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES

U.S. STANDARD SIEVE NUMBERS

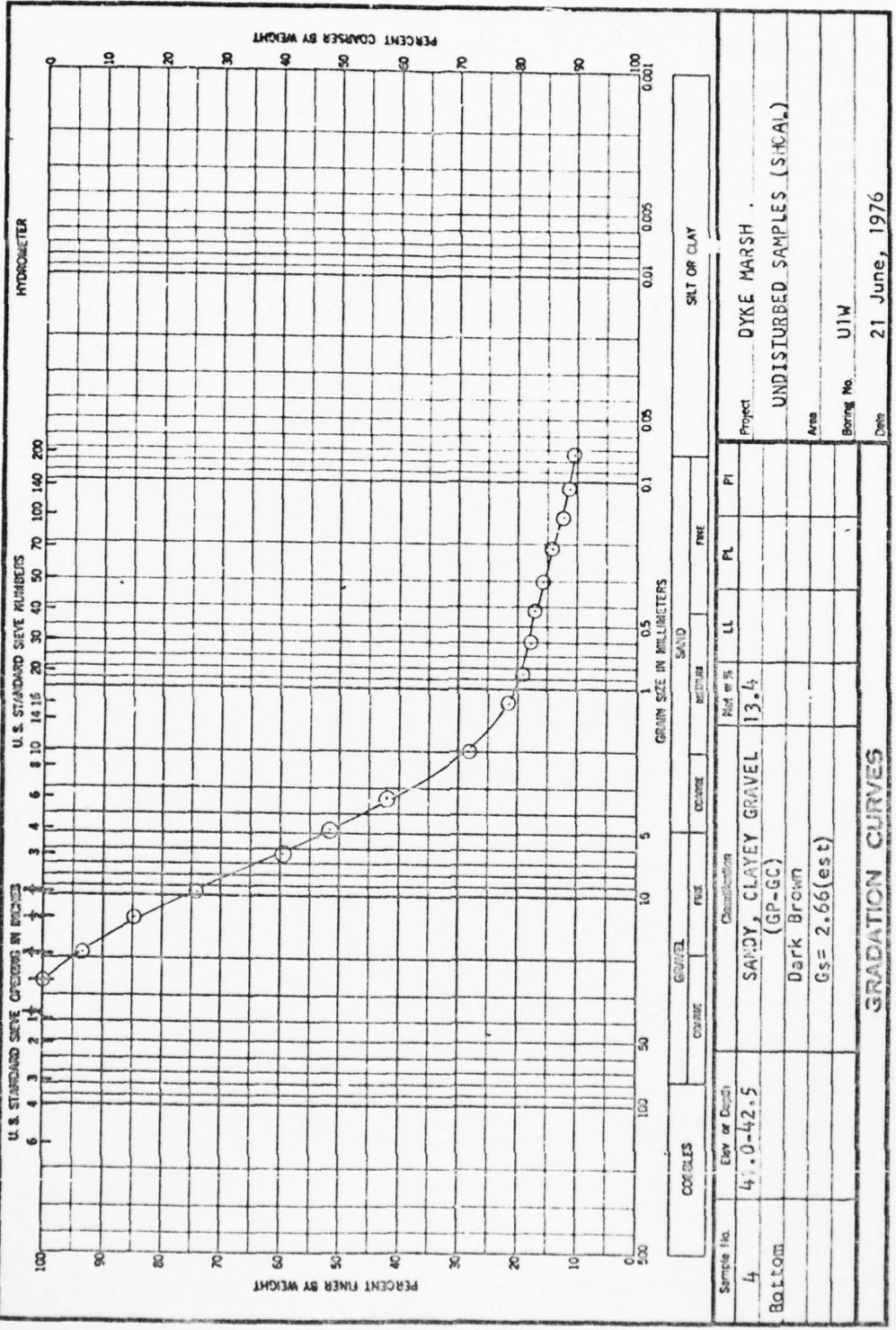
GRAIN SIZE IN MILLIMETERS

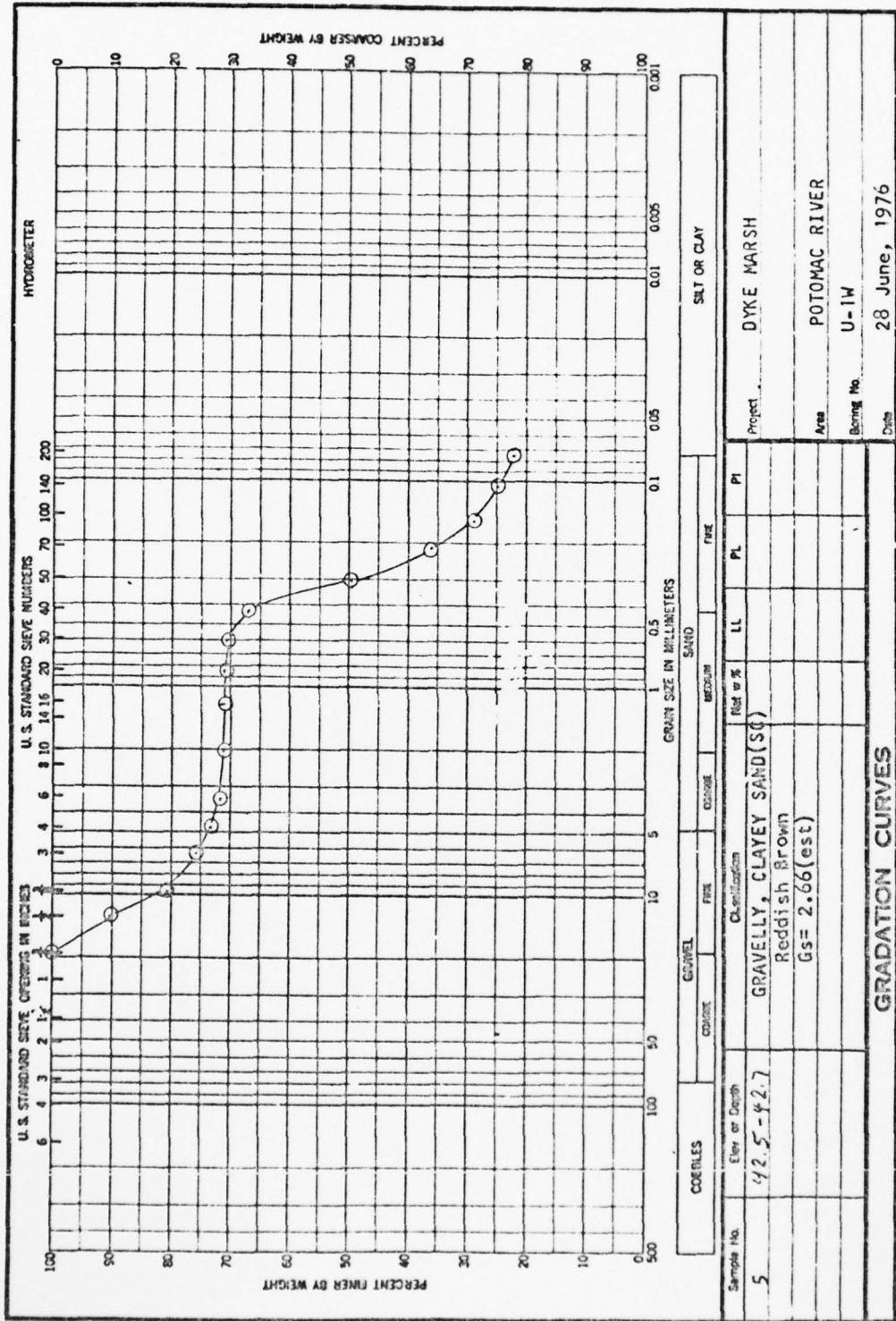
SILT OR CLAY

Sample No.	401-40.5	Classification	SANDY, CLAYEY GRAVEL (GP-SC)
Elev or Depth		Grav	
		Gs = 2.66 (est)	
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	U-1W		
Date	28 June, 1976		

GRADATION CURVES

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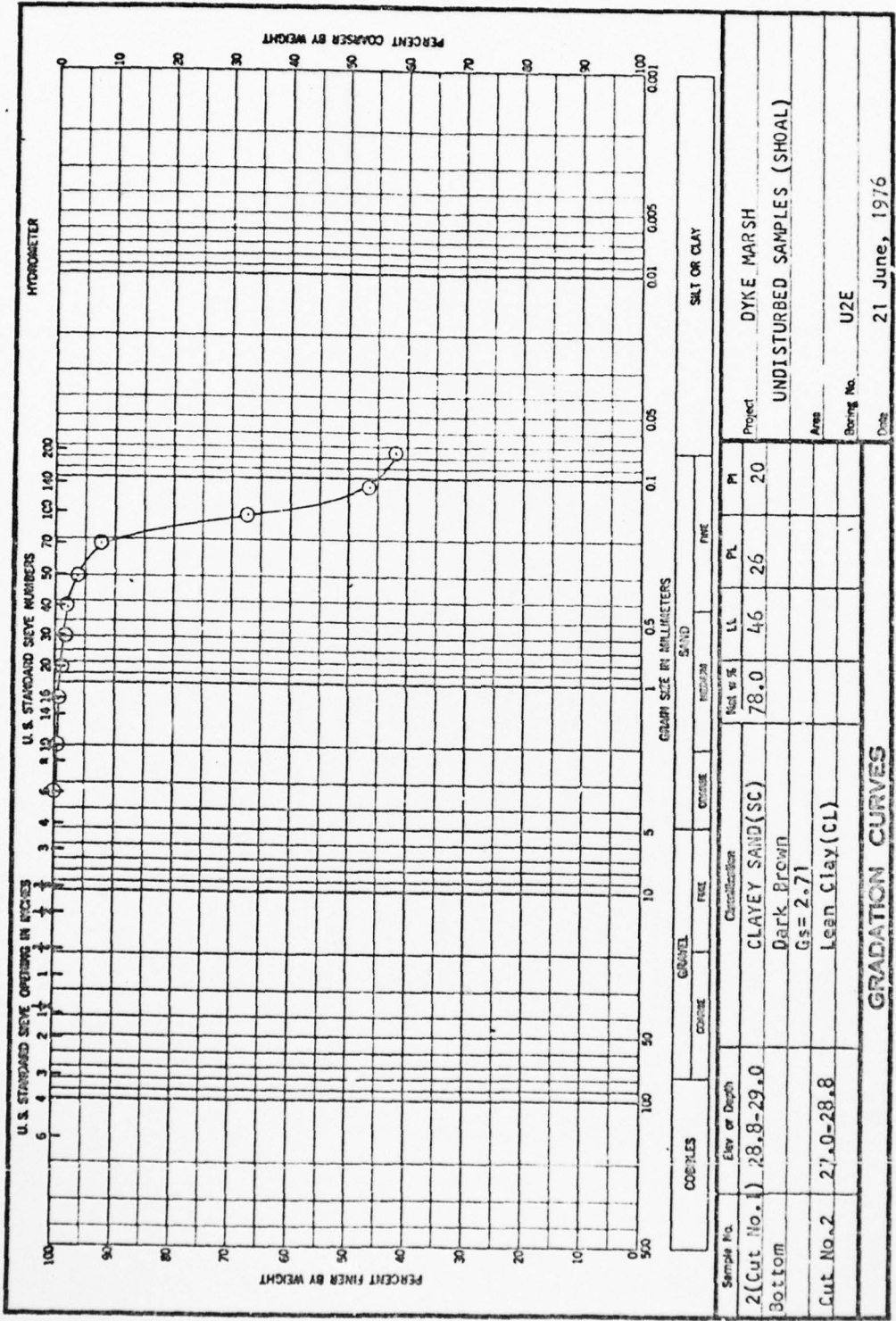


Project: DYKE MARSH
 Area: POTOMAC RIVER
 Boring No.: U-1W
 Date: 28 June, 1976

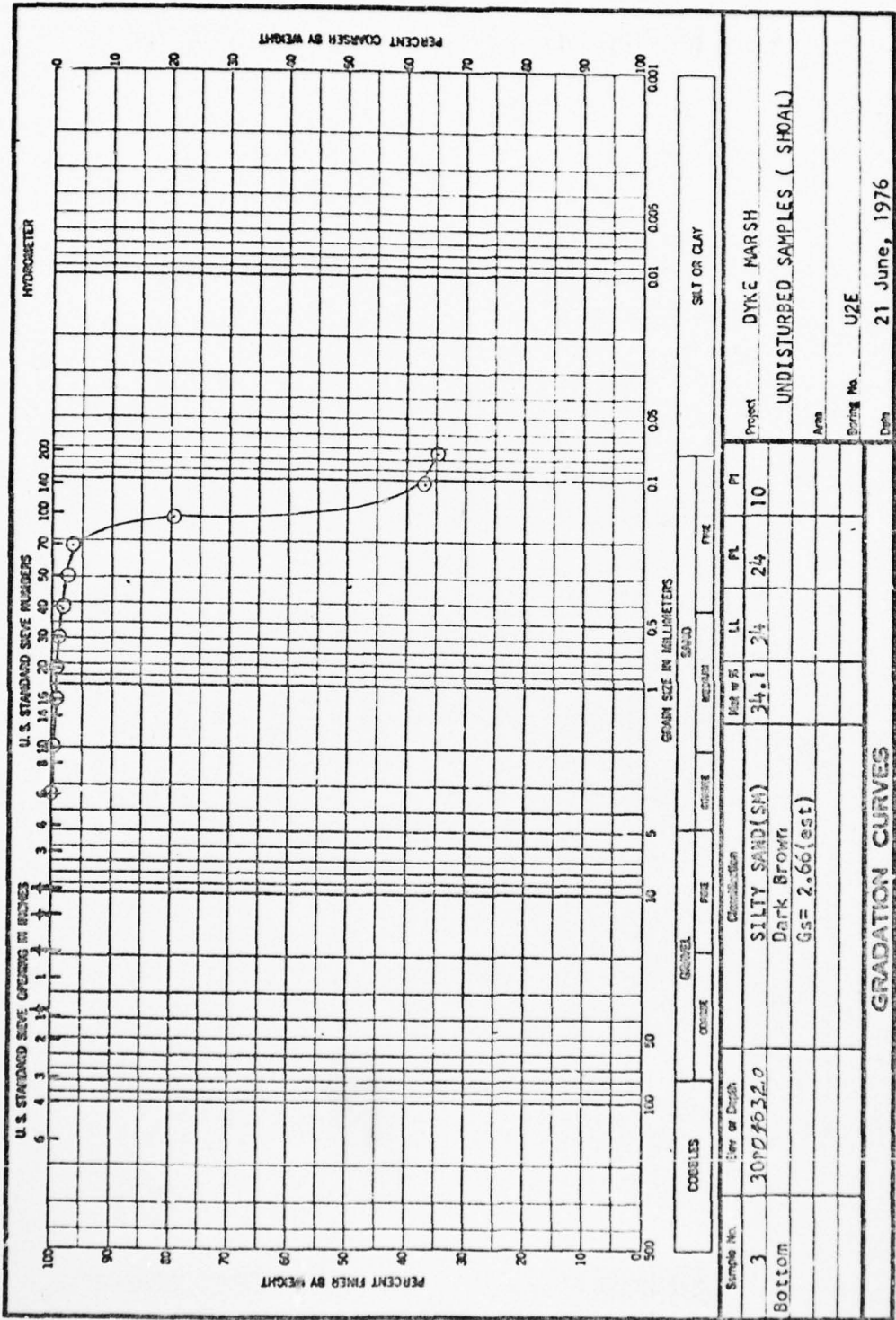
GRADATION CURVES

Sample No. 5
 Elevation of Depth 42.5-42.7
 Classification GRAVELLY, CLAYEY SAND (SC)
 Color Reddish Brown
 Gs = 2.66 (est)

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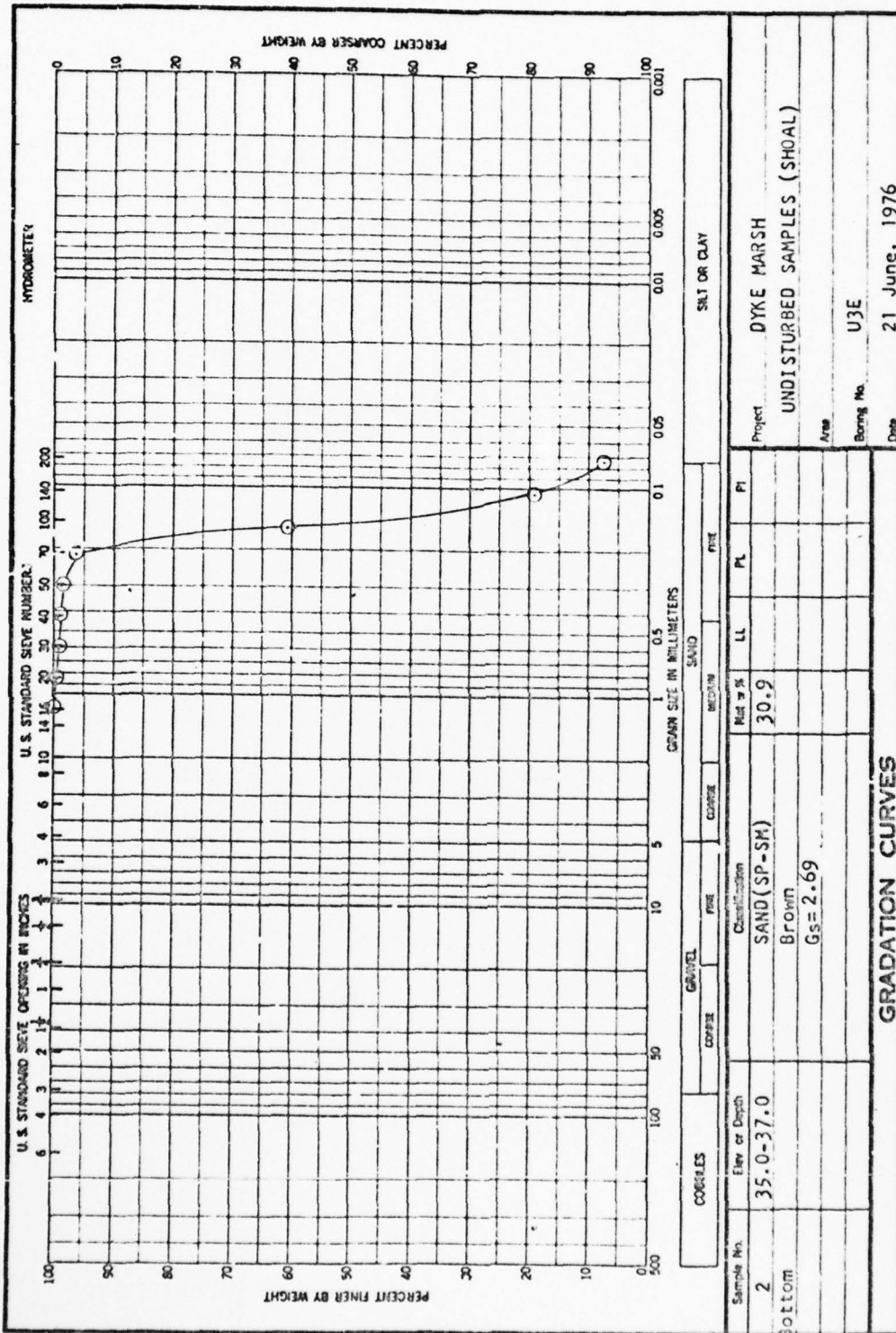
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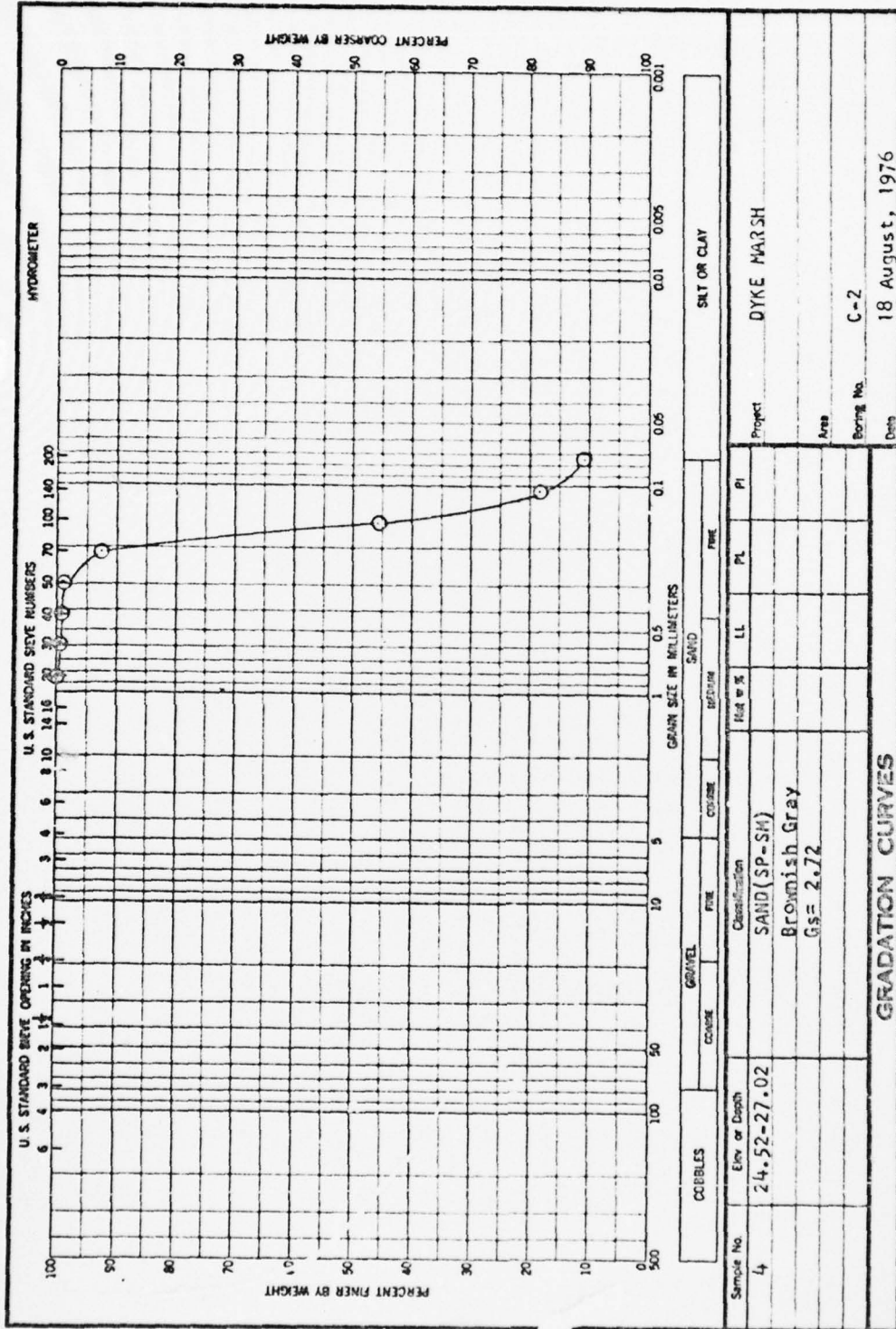
Sample No.	3	Level or Depth	Bottom
Classification	SILTY SAND (SH) Dark Brown Gs = 2.65 (est)		
Moisture Content (%)	34.1	LL	24
Plasticity Index (PI)	10	FL	24
Project	DYKE MARSH		
Area	UNDISTURBED SAMPLES (SHOAL)		
Drift No.	UZE		
Date	21 June, 1976		

GRADATION CURVES

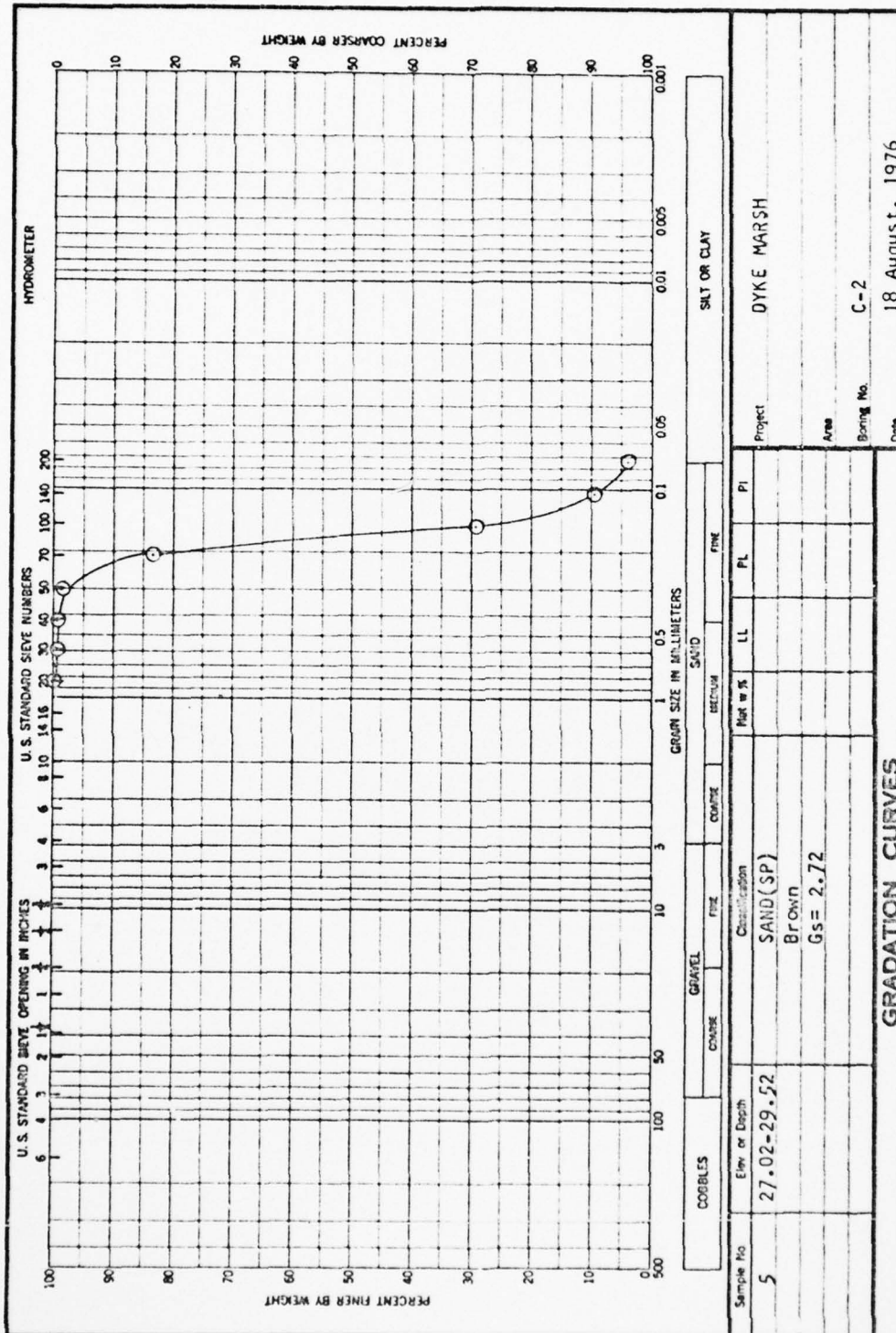
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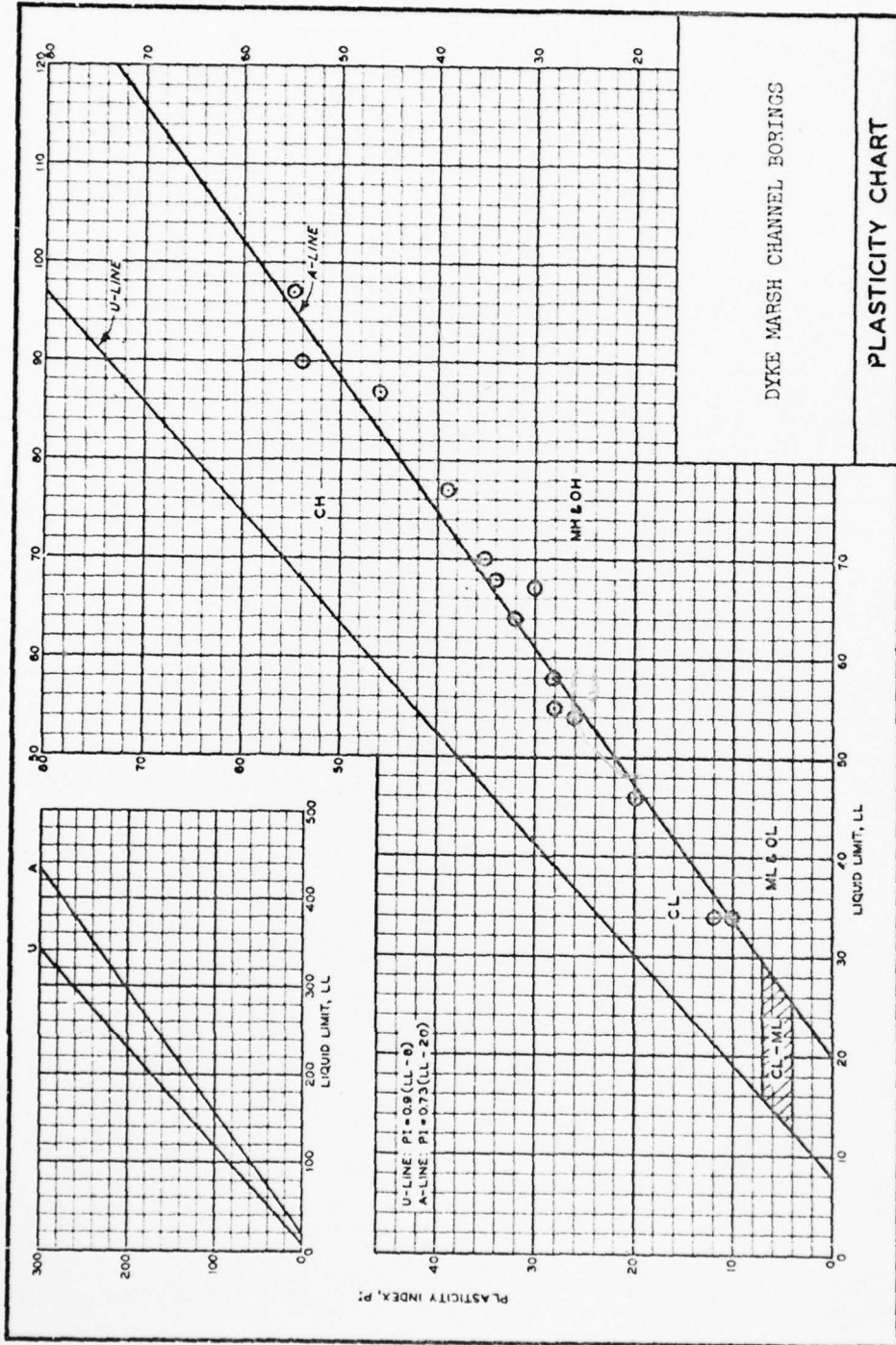
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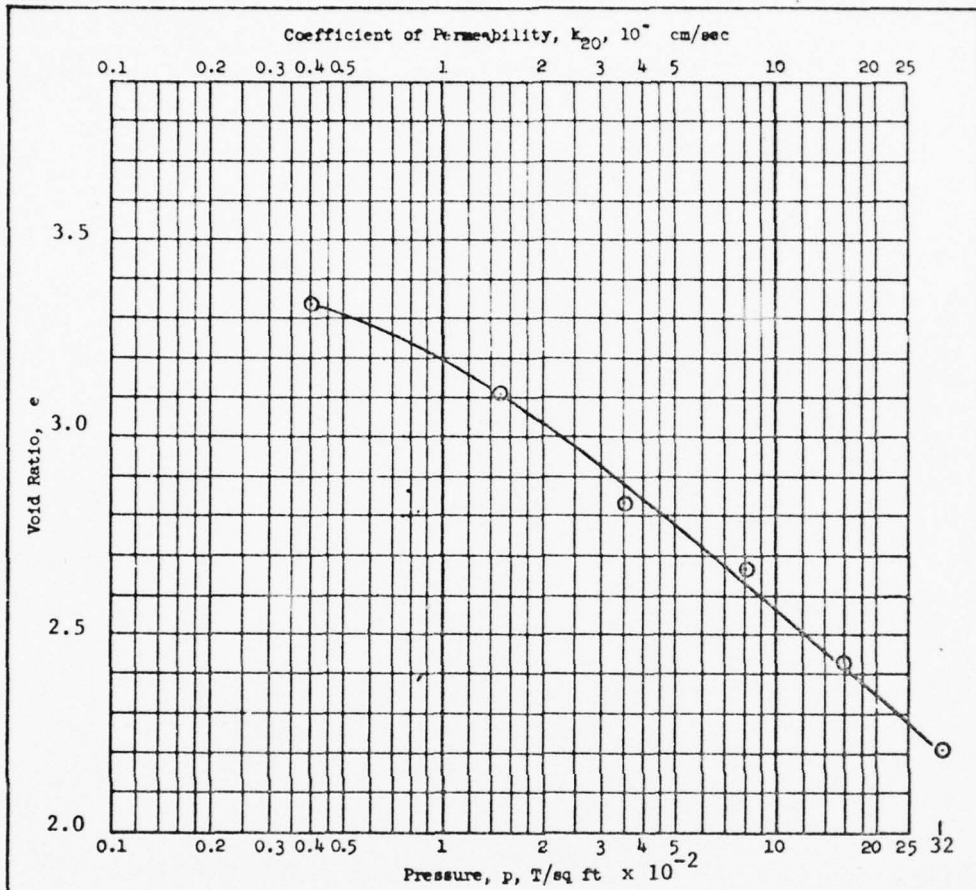


COBBLES		GRAVEL		FINE		SAND		SILT OR CLAY	
Sample No.	Elev. or Depth	Classification		Max w %	LL	PL	PI	Project	
5	27.02-29.52	SAND (SP) BROWN Gs = 2.72						DYKE MARSH	
								Area	C-2
								Boring No.	
								Date	18 August, 1976

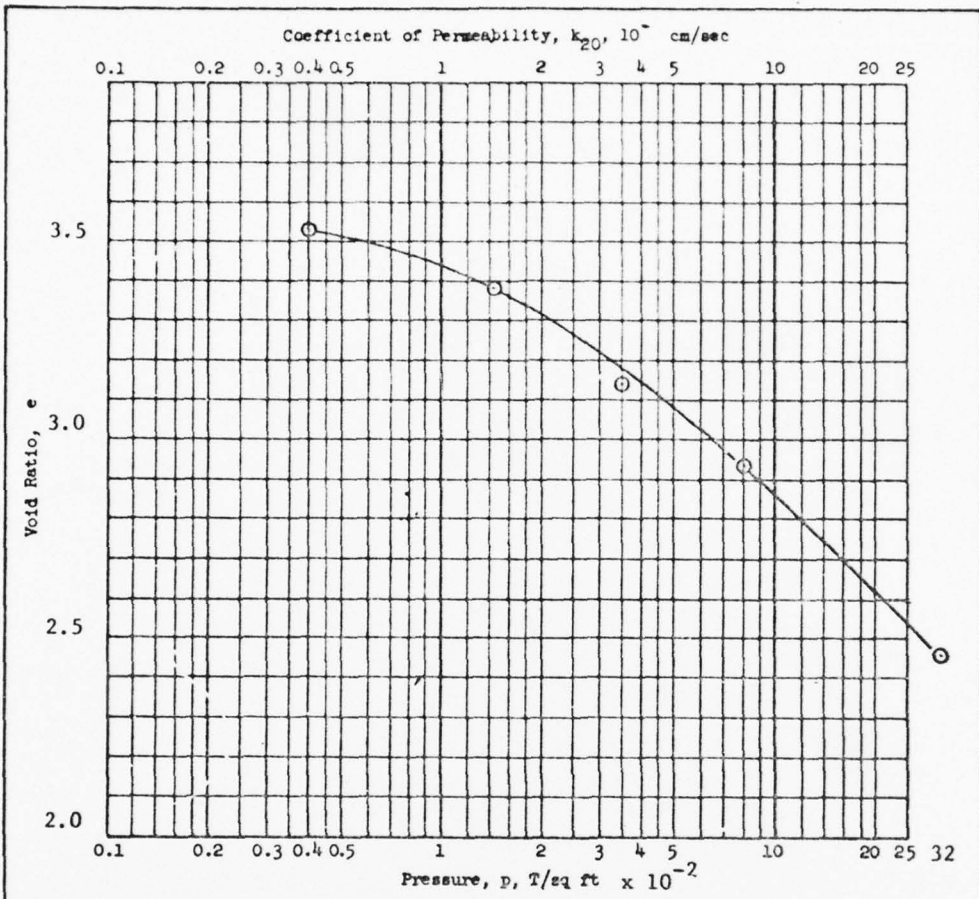
GRADATION CURVES

ENG FORM 2087
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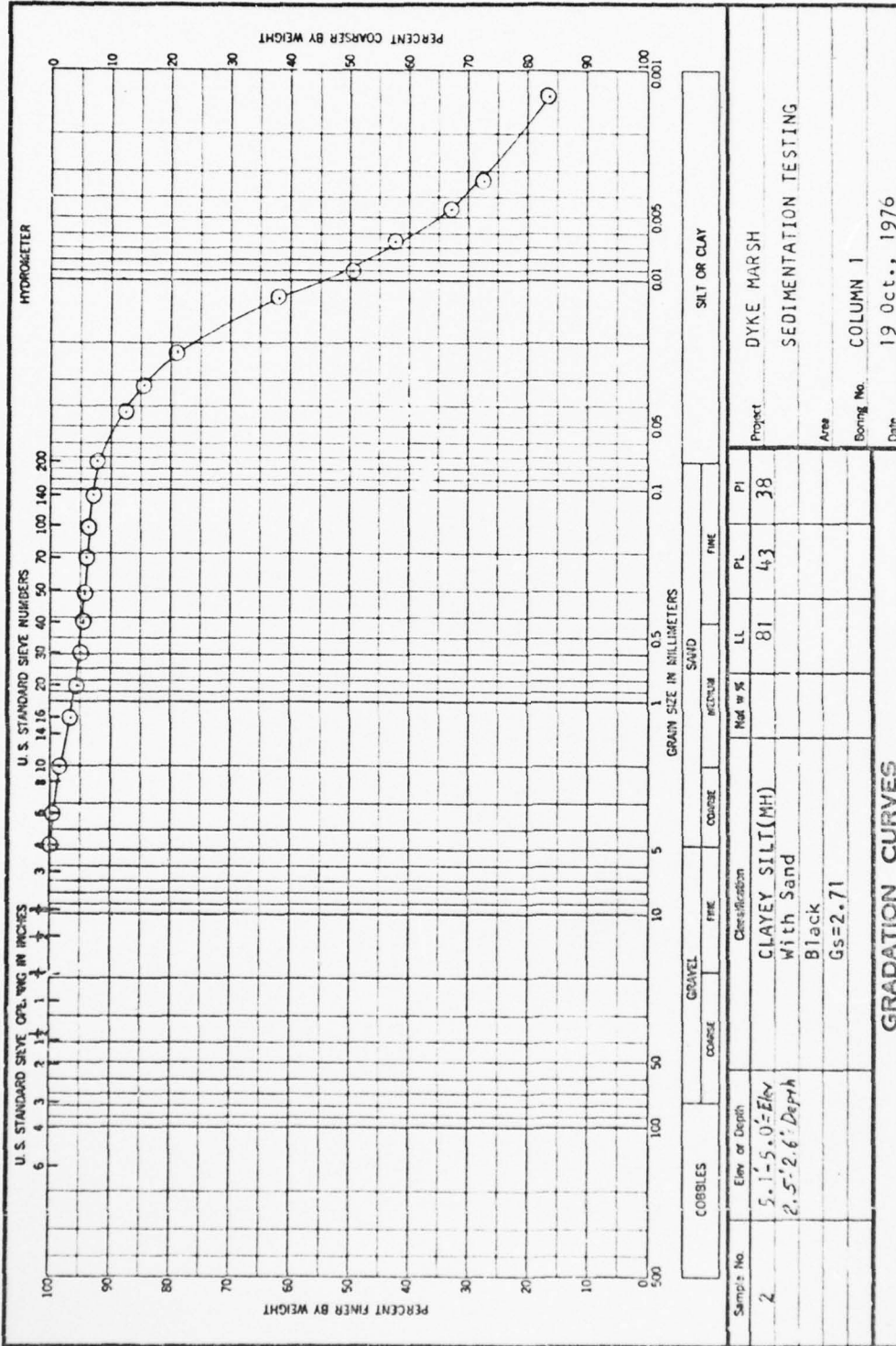




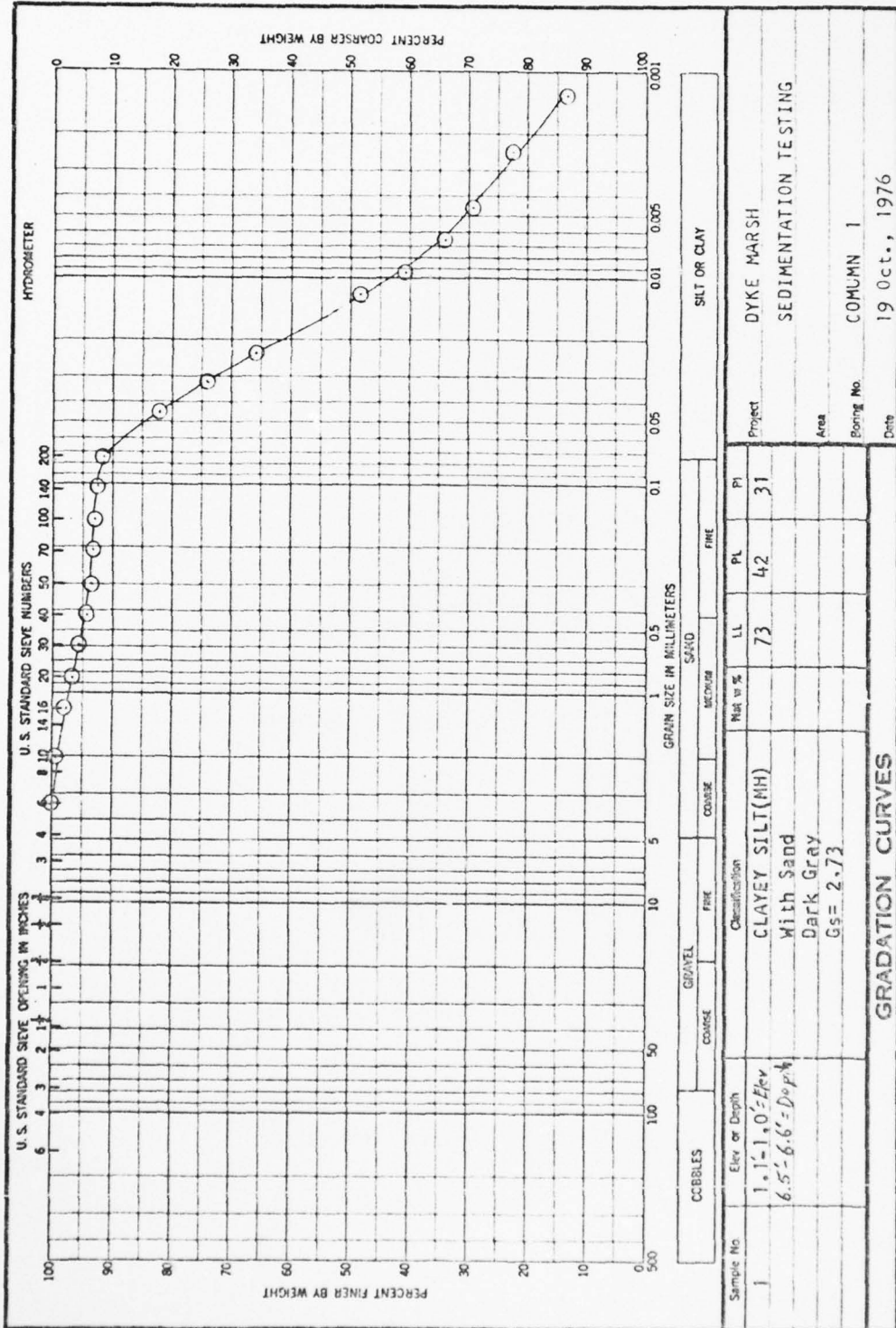
Type of Specimen		Before Test		After Test	
SEDIMENTED		Water Content, w_o	122.74 %	w_f	69.9 %
Diam 2.50 in.	Ht 1.470 in.	Void Ratio, e_o	3.339	e_f	2.202
Overburden Pressure, p_o	T/sq ft	Saturation, S_o	100.4 %	S_f	86.7 %
Preconsol. Pressure, p_c	T/sq ft	Dry Density, γ_d	39.3 lb/ft ³		
Compression Index, C_c		k_{20} at $e_o =$ $\times 10^{-7}$ cm/sec			
LL	G_s	Project Dyke Marsh			
PL	D_{10}	Column Sedimentation Test			
Remarks Sample taken 1.0 ft.		Area			
from bottom of column.		Boring No. --	Sample No. 2 (lower)		
		Depth	Date 7 Nov 76		
		El 1.1 - 1.0 ft.			
CONSOLIDATION TEST REPORT					



Type of Specimen		Before Test		After Test	
SEDIMENTED					
Diam 2.50 in.	Et 1.389 in.	Water Content, w_o	135.4 %	w_f	58.2 %
Overburden Pressure, p_o	T/sq ft	Void Ratio, e_o	3.542	e_f	2.458
Preconsol. Pressure, p_c	T/sq ft	Saturation, S_o	103.6 %	S_f	75.2 %
Compression Index, C_c		Dry Density, γ_d	37.2 lb/ft ³		
Classification		k_{20} at $e_o =$ $\times 10^{-7}$ cm/sec			
LL	G_s	Project Dyke Marsh			
PL	D_{10}	Column Sedimentation Test			
Remarks Sample taken 5.0 ft.		Area			
from bottom of column		Boring No.	Sample No. 1 (upper)		
		Depth El 5.1 to 5.0	Date 7 Nov 76		
CONSOLIDATION TEST REPORT					



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1 MAY 63 2087



Sample No.	1	Elev or Depth	1.1-1.0' Elev 6.5-6.6' Depth	Classification	CLAYEY SILT (MH) With Sand Dark Gray G _s = 2.73	LL	73	PL	42	PI	31
<p style="text-align: center;">GRADATION CURVES</p>											
Project			DYKE MARSH			SILT OR CLAY			SEDIMENTATION TESTING		
Area			COMUMN 1			Booring No.			Date		
						19 Oct., 1976					

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1 MAY 63

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ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RIVE--ETC(U)
OCT 77 M R PALERMO, T W ZEIGLER

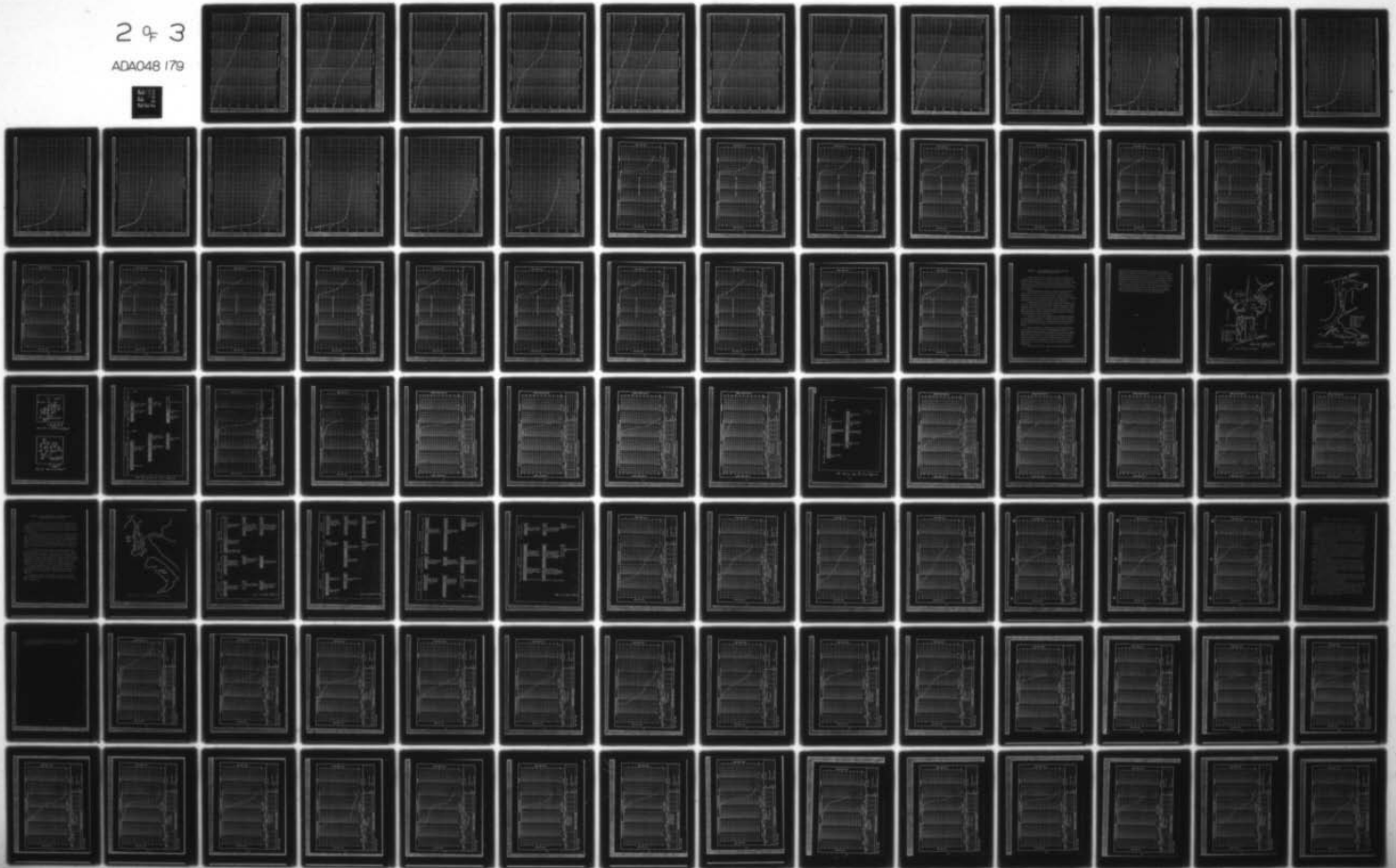
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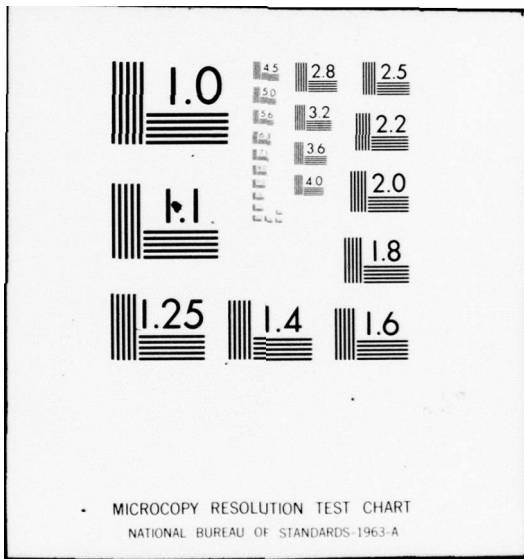
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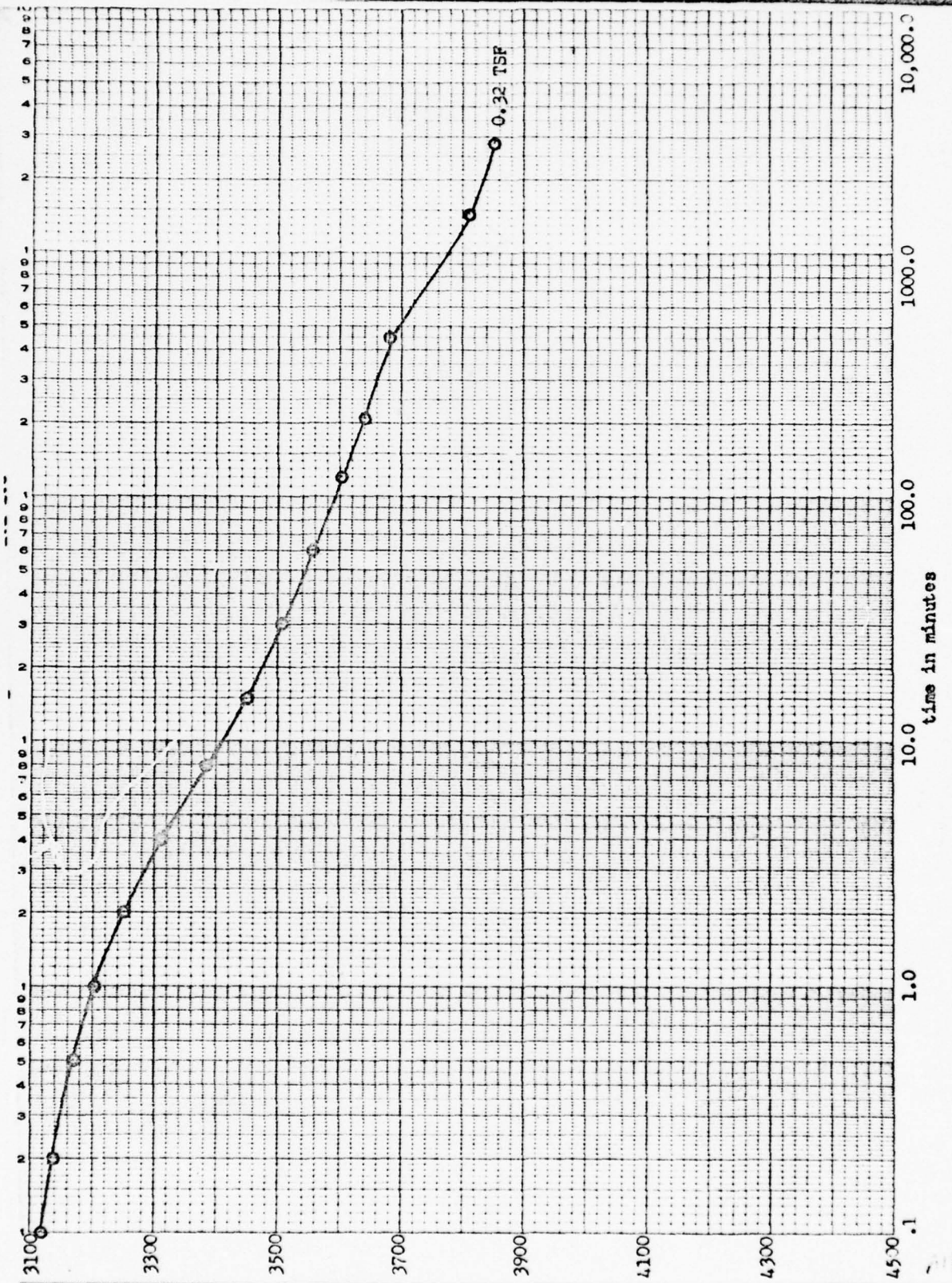
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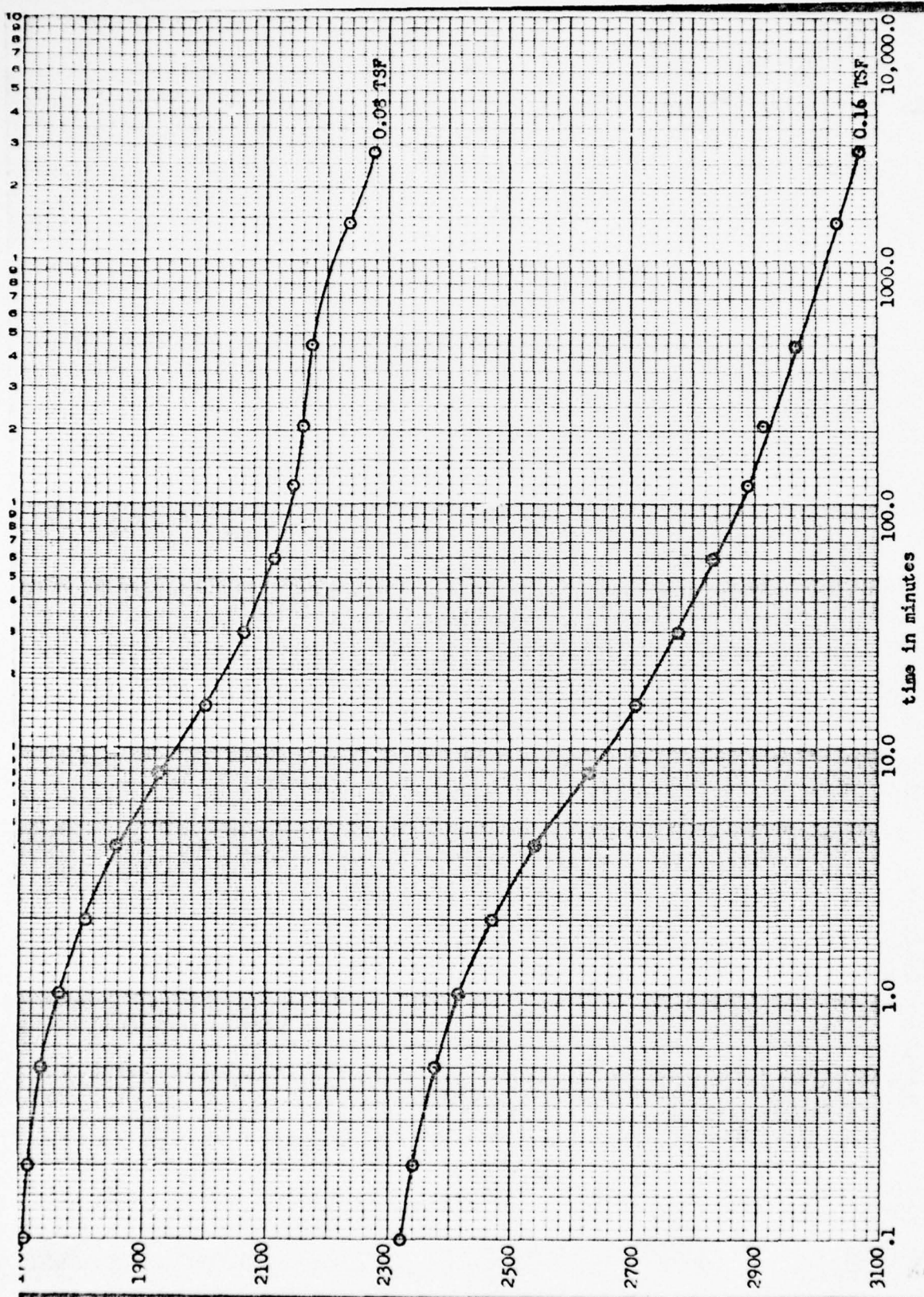
2 of 3

ADA048 179







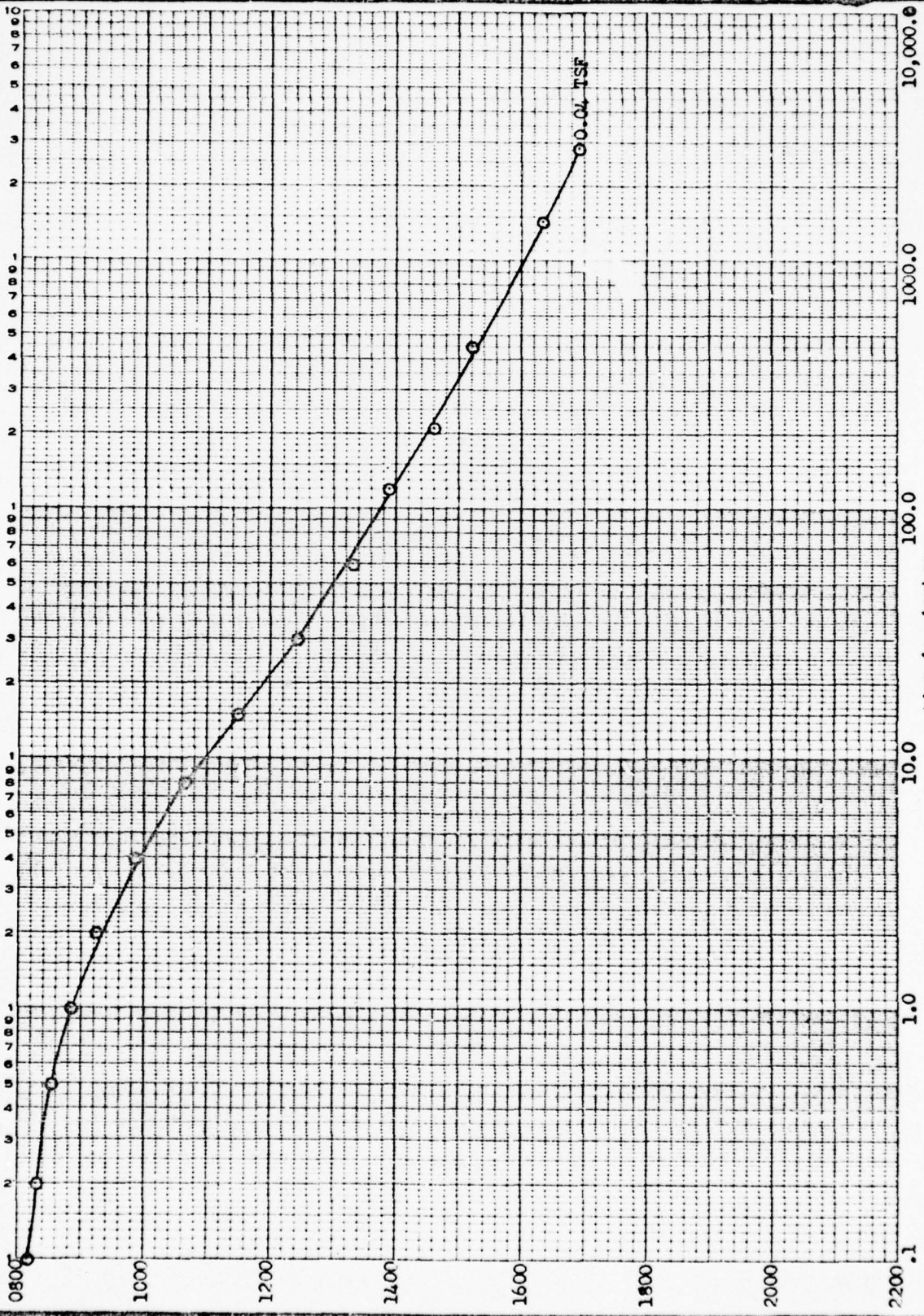


7

1.1-1.0

Sedimentation Testing

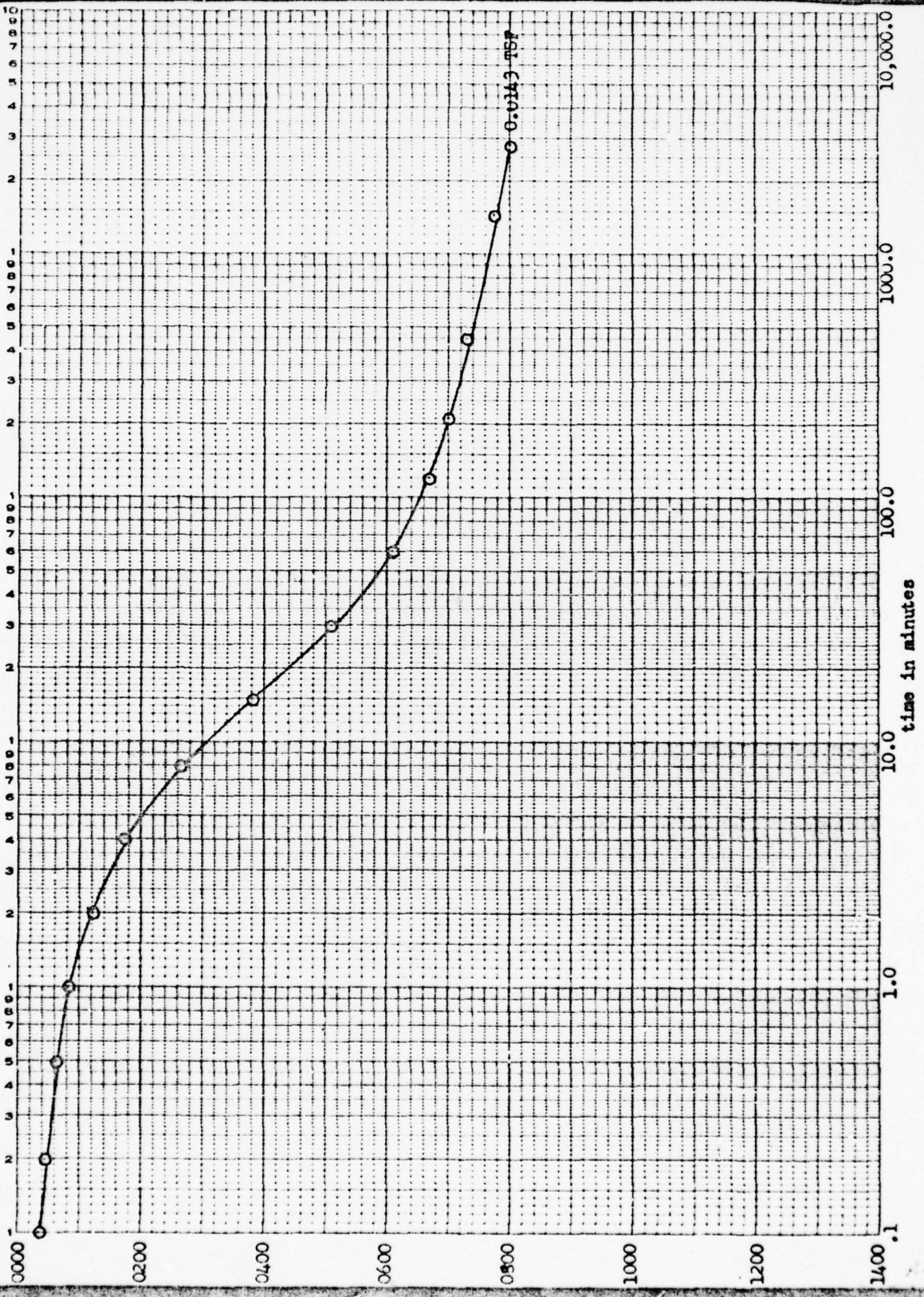
Dial Reading $\times 10^{-4}$



1.1-1.0

Sedimentation Testing

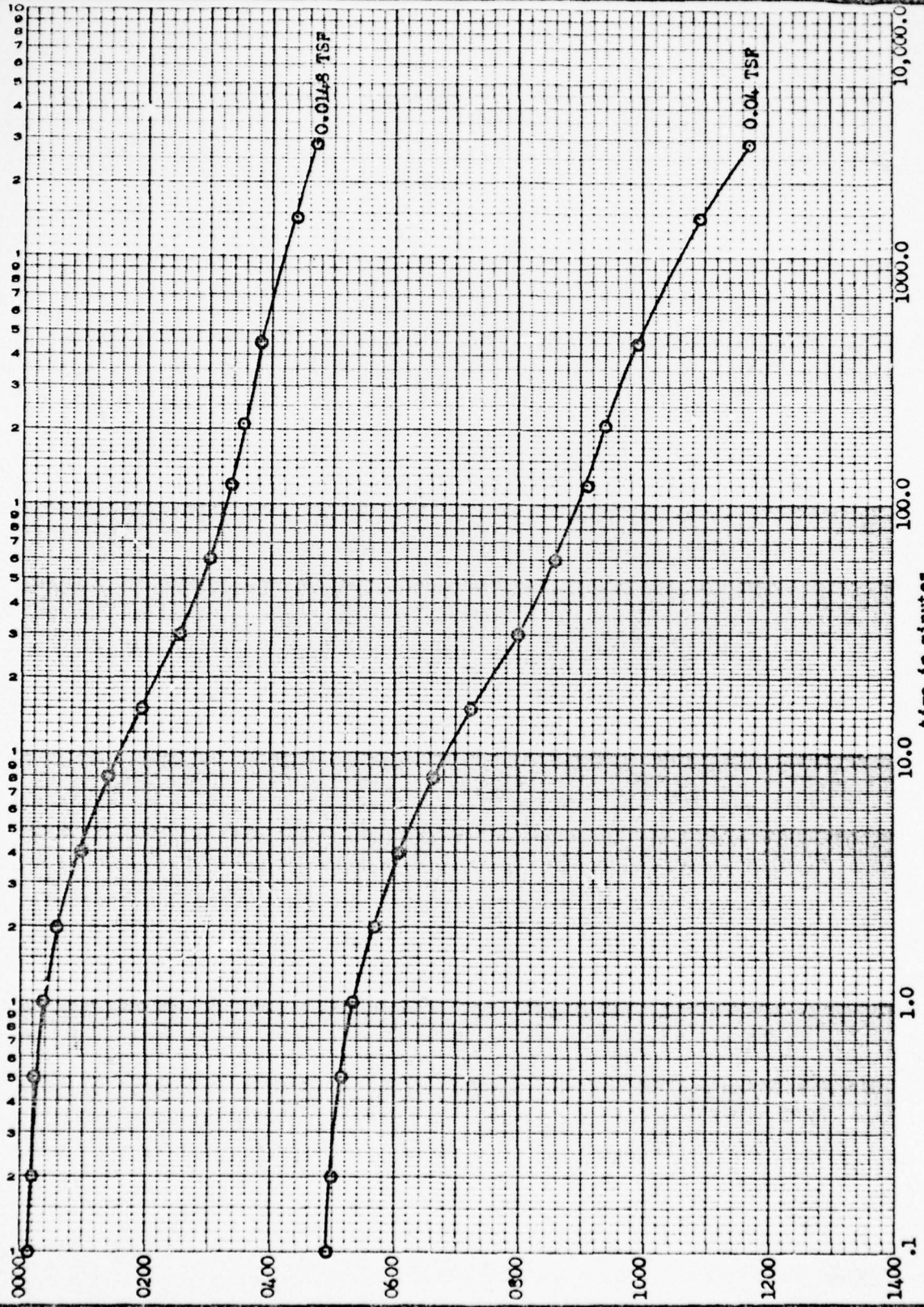
Dial Reading $\times 10^{-4}$



5.1-5.0

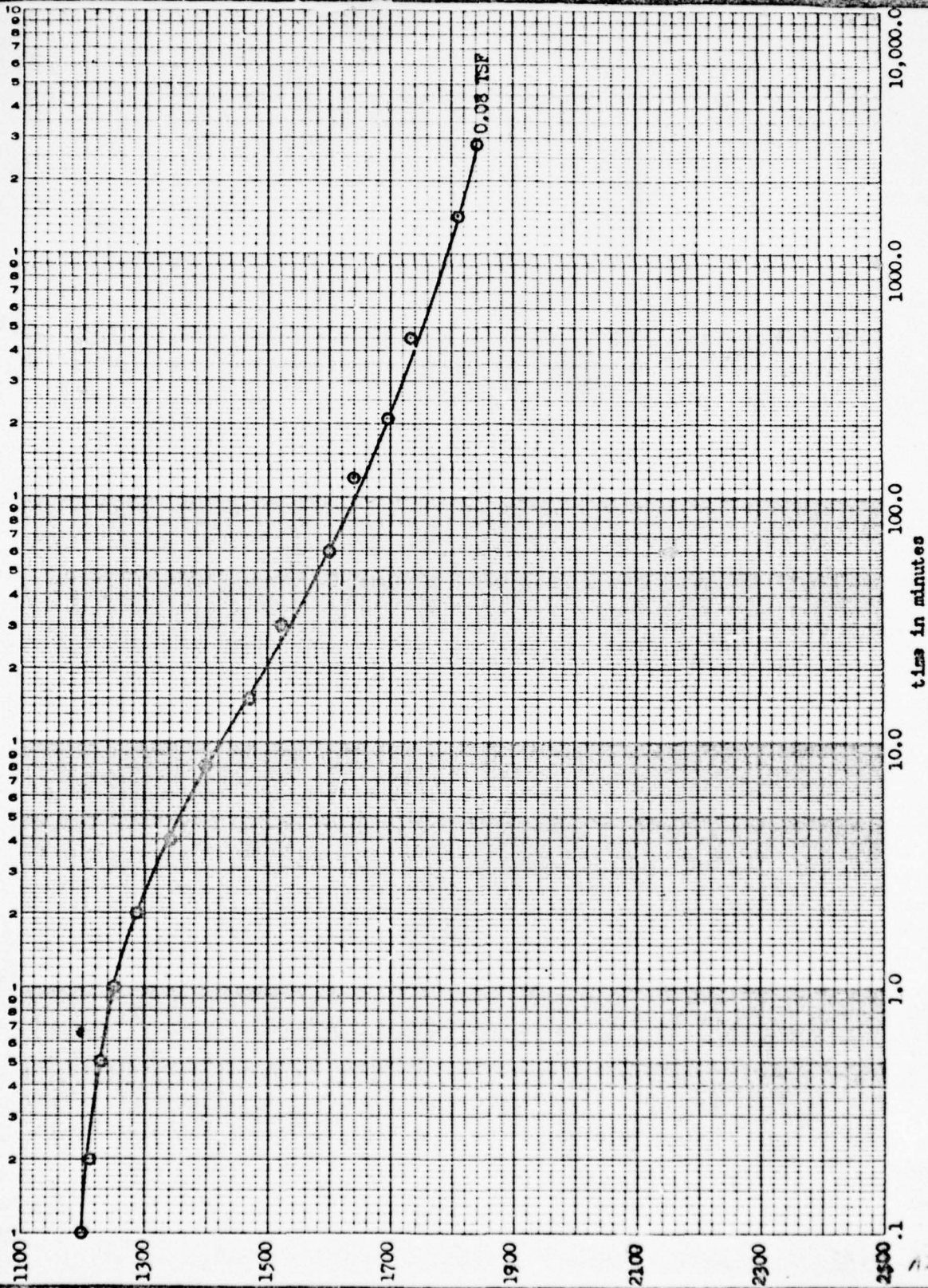
Sedimentation Testing

Dial Reading $\times 10^{-4}$



Dial Reading x 10⁻⁴ Sedimentation Testing

5.1-5.0

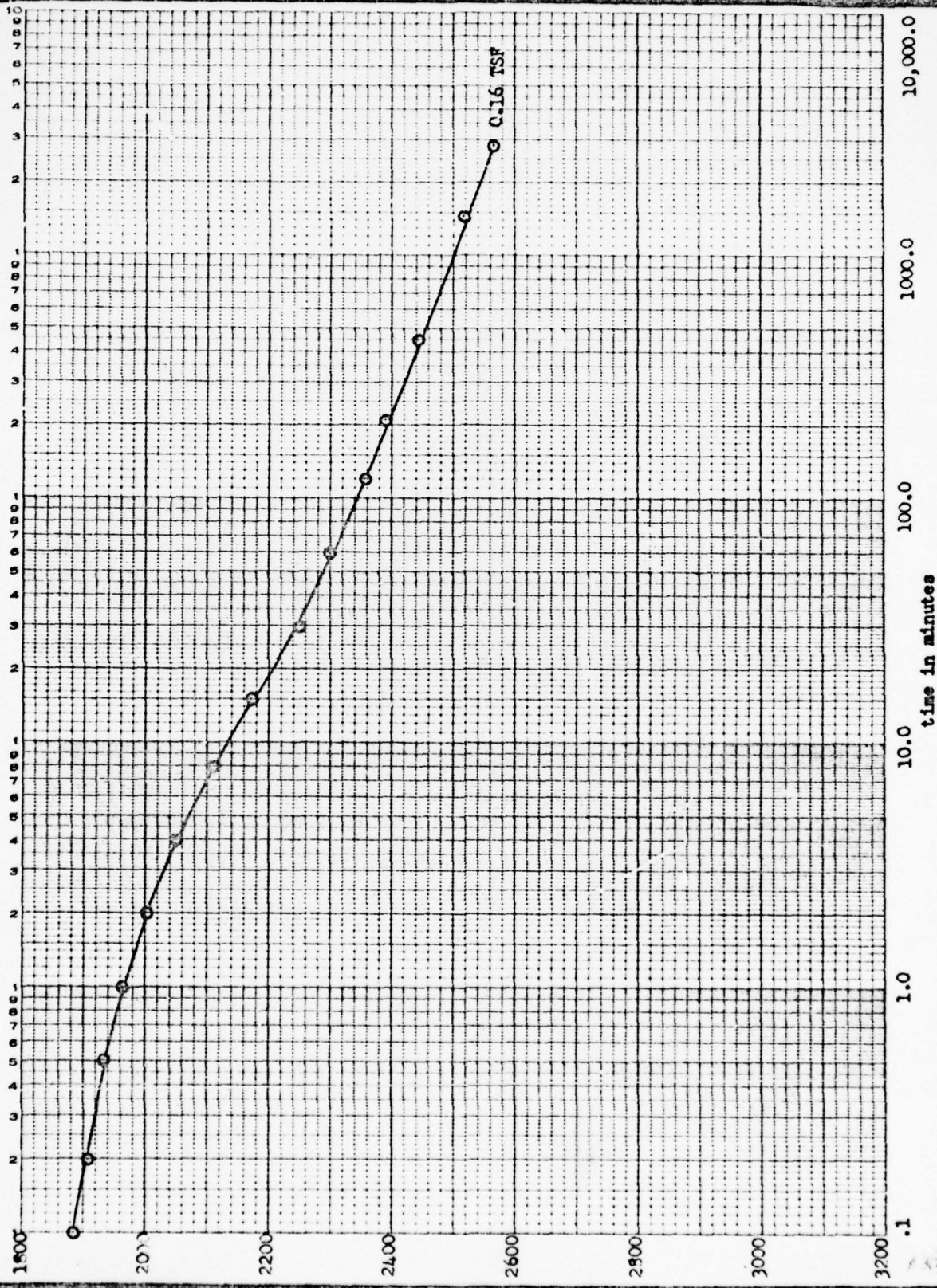


2500

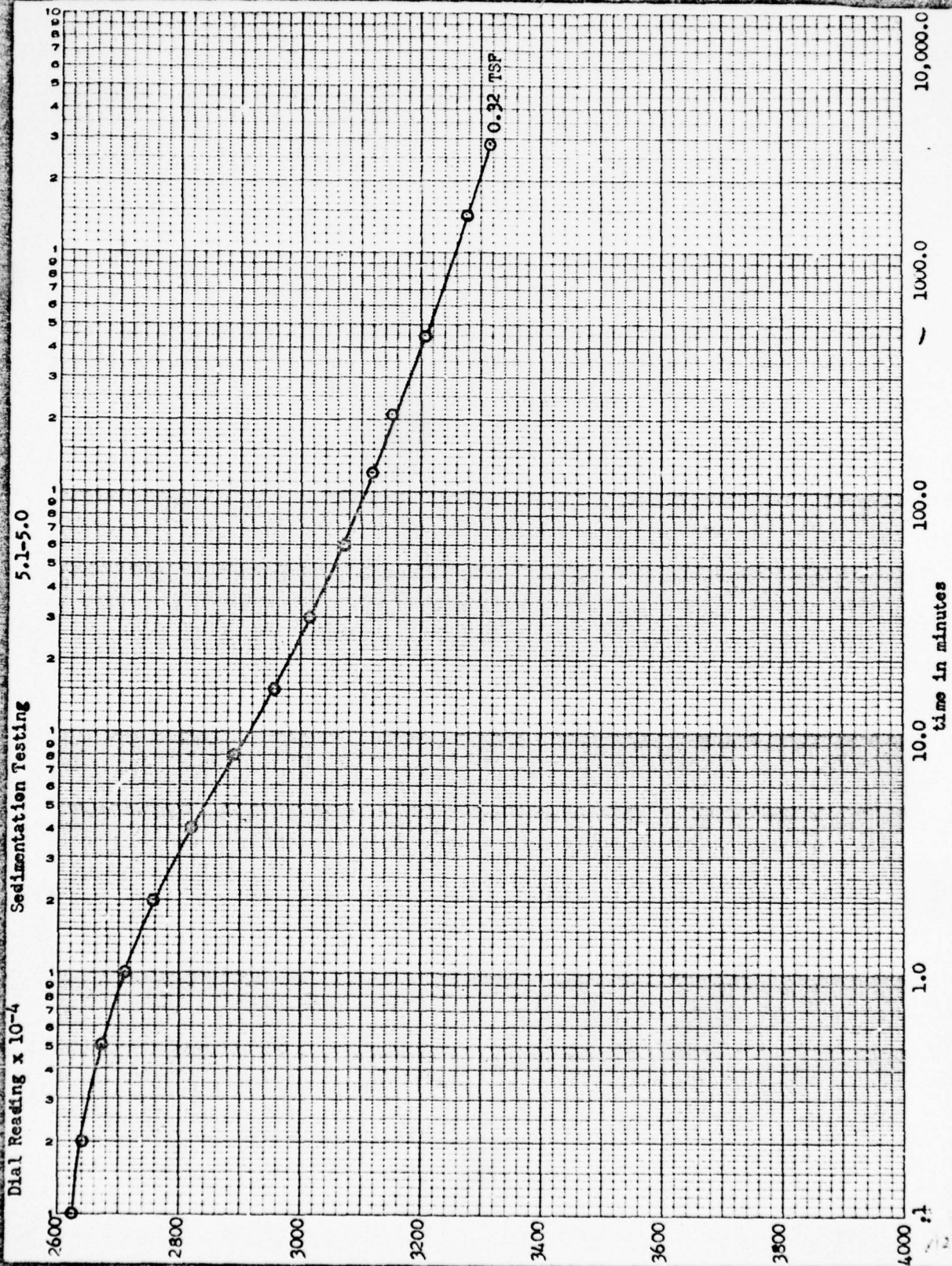
5.1-5.0

Sedimentation Testing

Dial Reading $\times 10^{-4}$



0.16 TSP



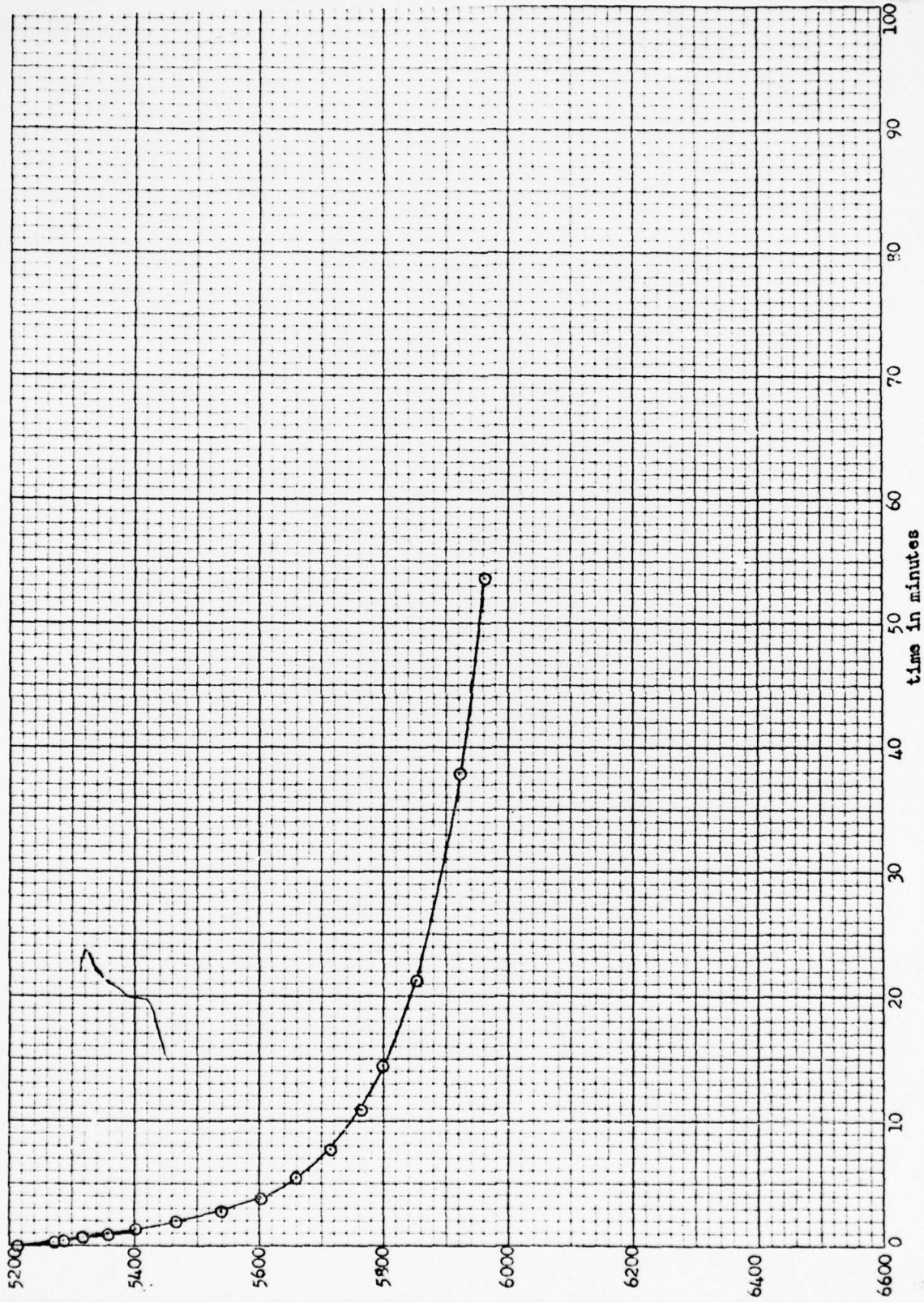
126

5.1-5.0

.32 TSP

Sedimentation Testing

Dial Reading x 10⁻⁴

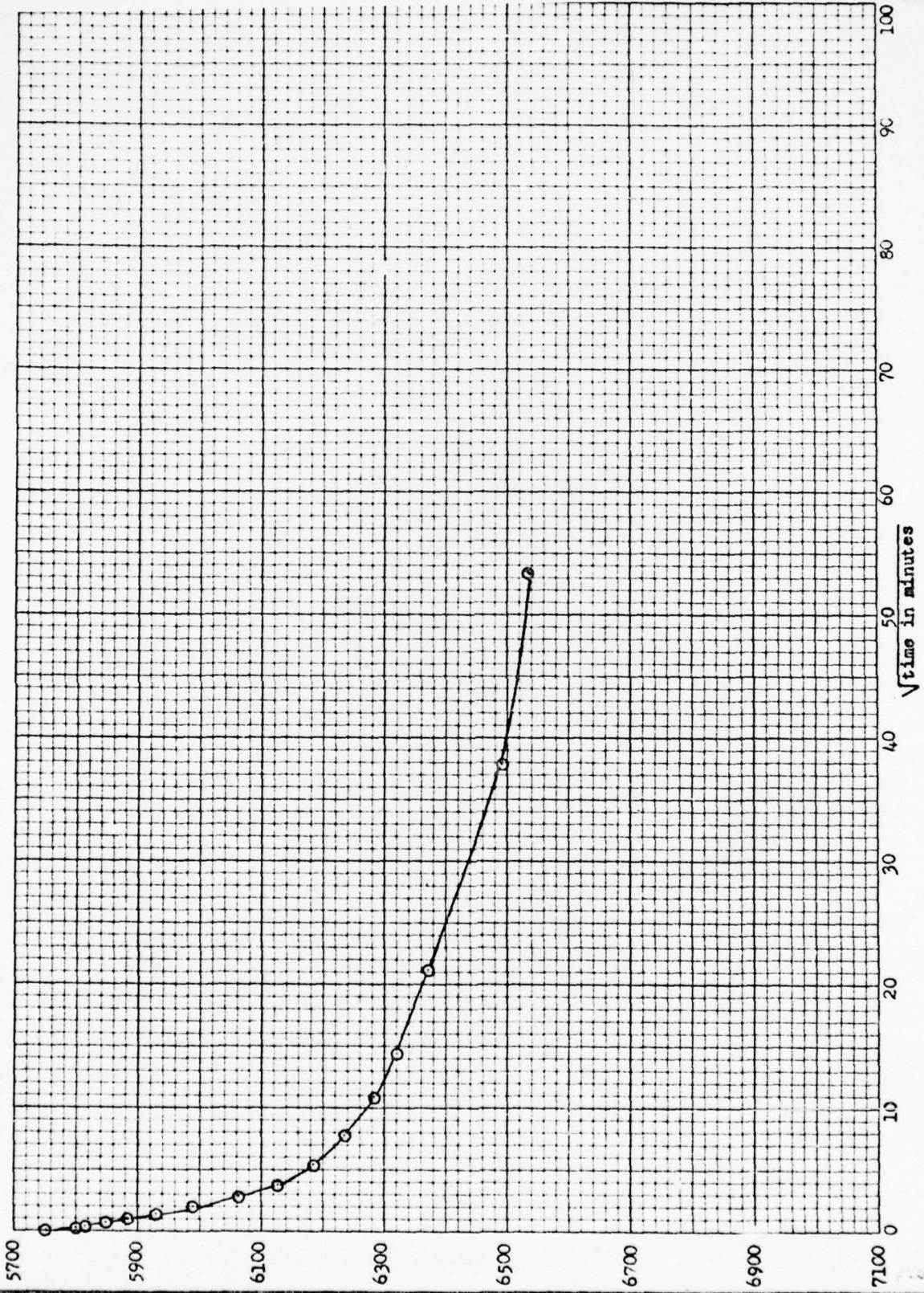


1.1-1.0

.32 TSF

Sedimentation Testing

Dial Reading $\times 10^{-4}$

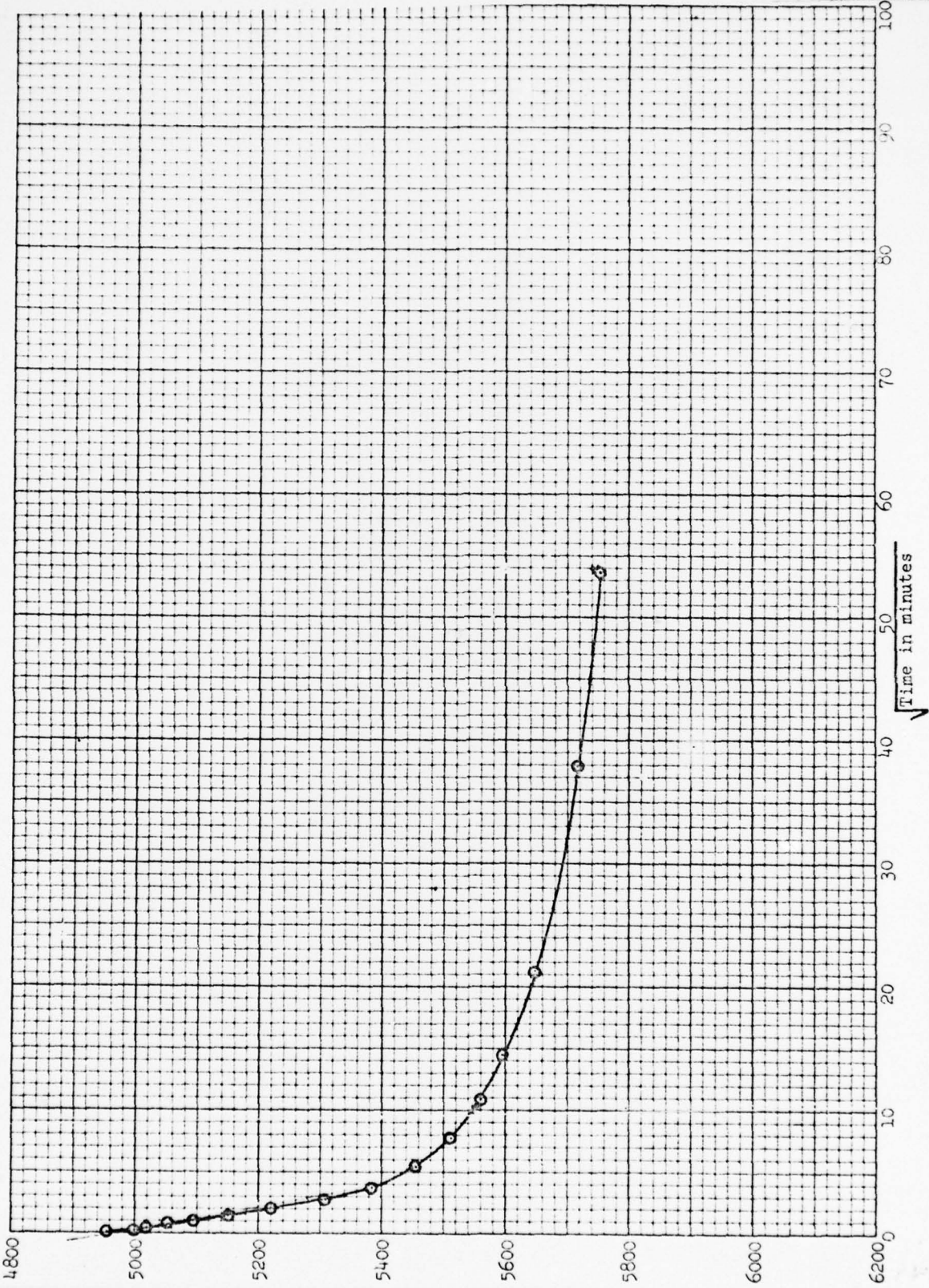


1.1-1.0

0.16

Sedimentation Testing

Dial Reading $\times 10^{-4}$

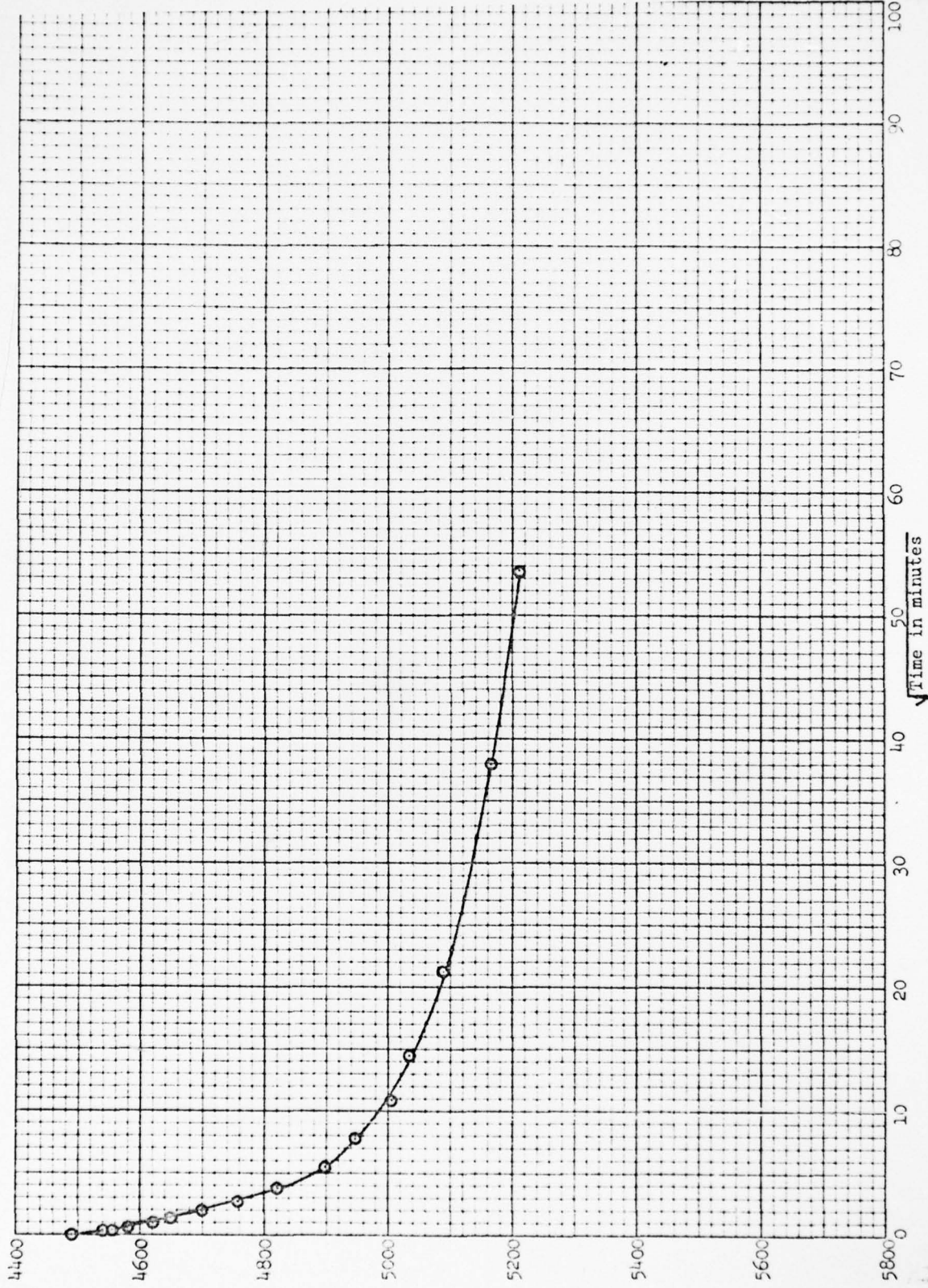


Dial Reading $\times 10^{-4}$

Sedimentation Testing

0.16

5.1-5.0

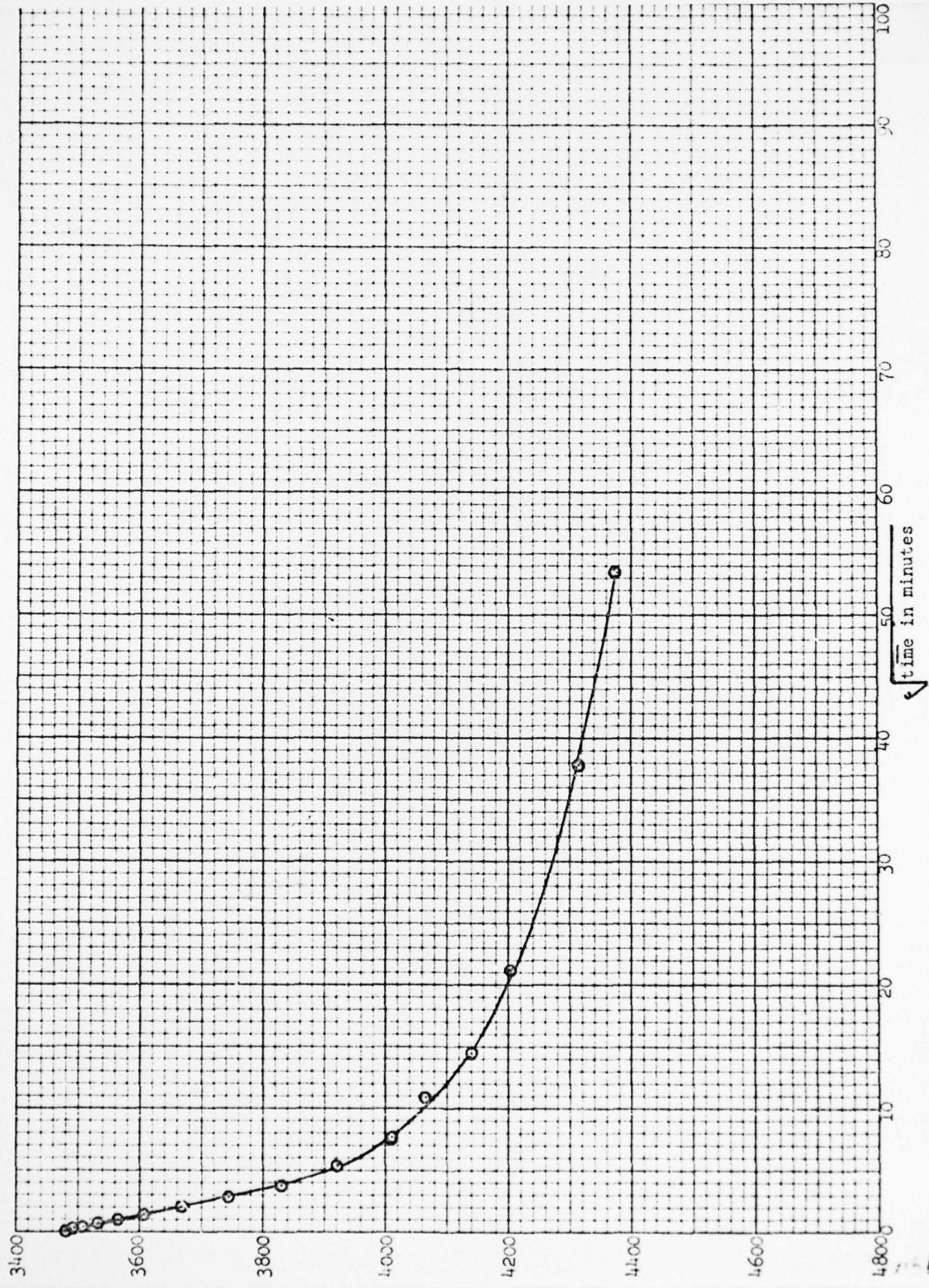


Dial Reading x 10⁻⁴

Sedimentation Testing

Depth: 1.1-1.0

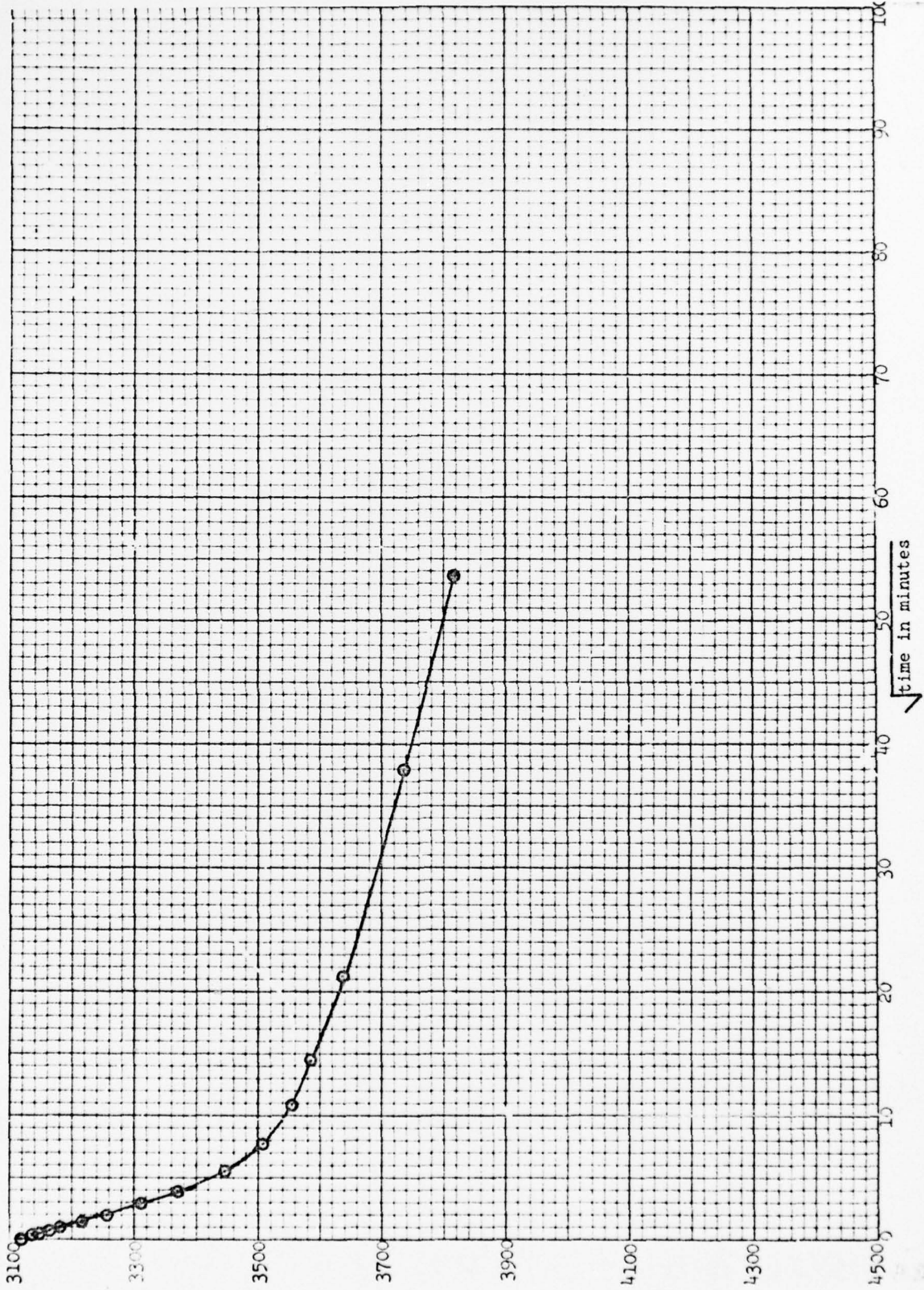
.04 TSF



Dial Reading x 10⁻⁴

Depth: 5.1-5.0

Sedimentation Testing .C4 TSF

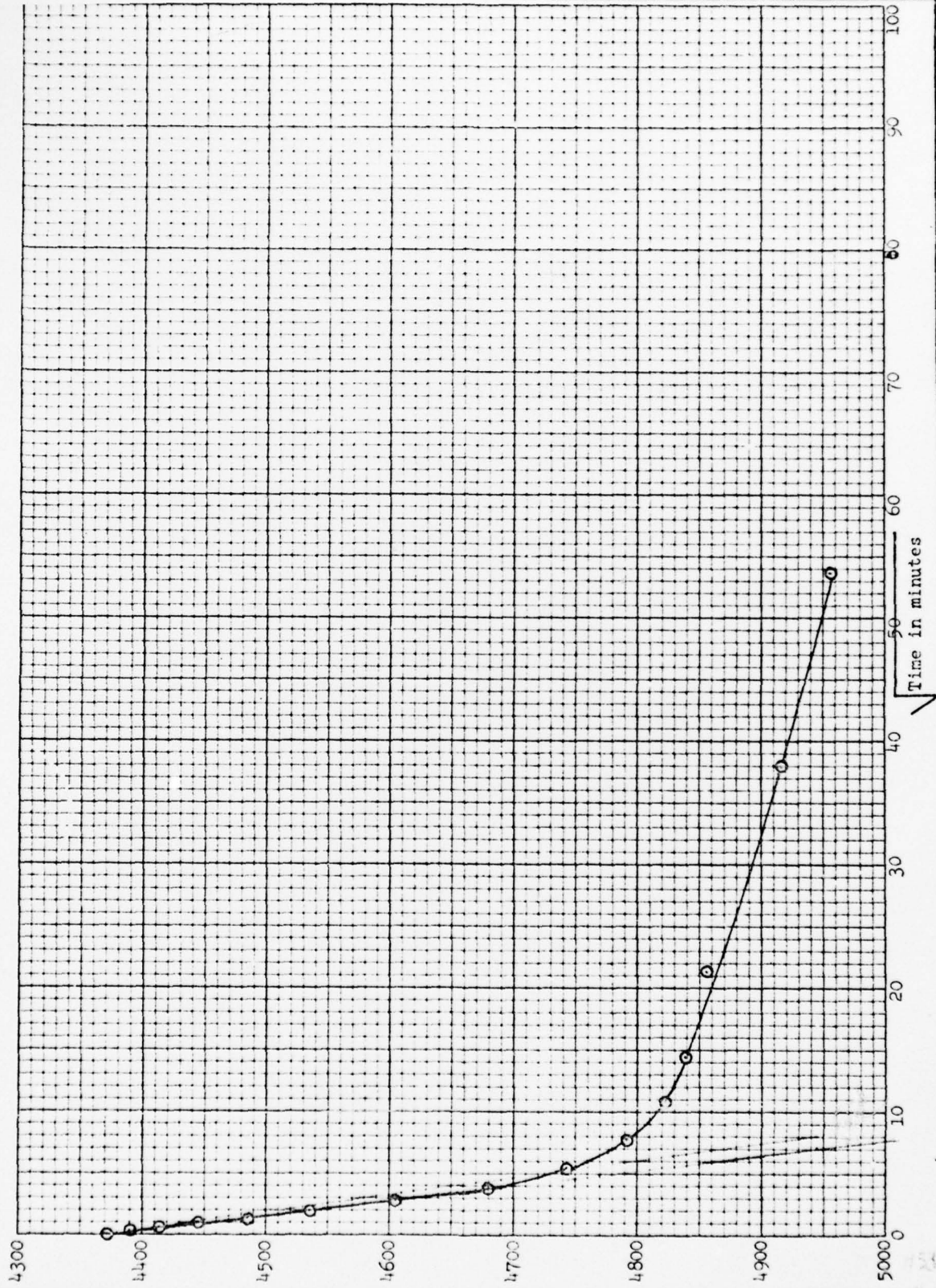


Dial Reading $\times 10^{-4}$

.08 TSF

Sedimentation Testing

1.0-1.1

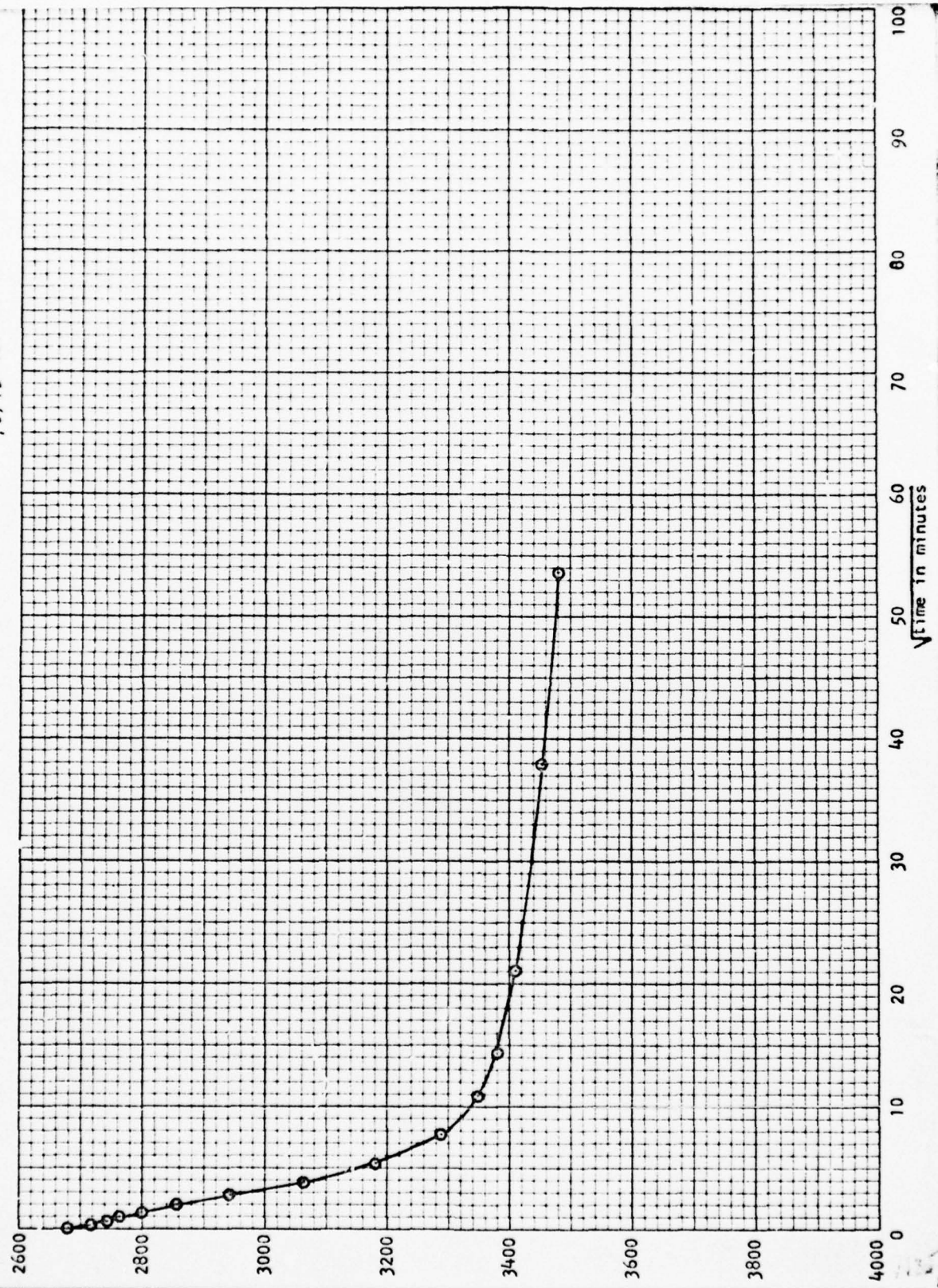


Dial Reading x 10⁻⁴

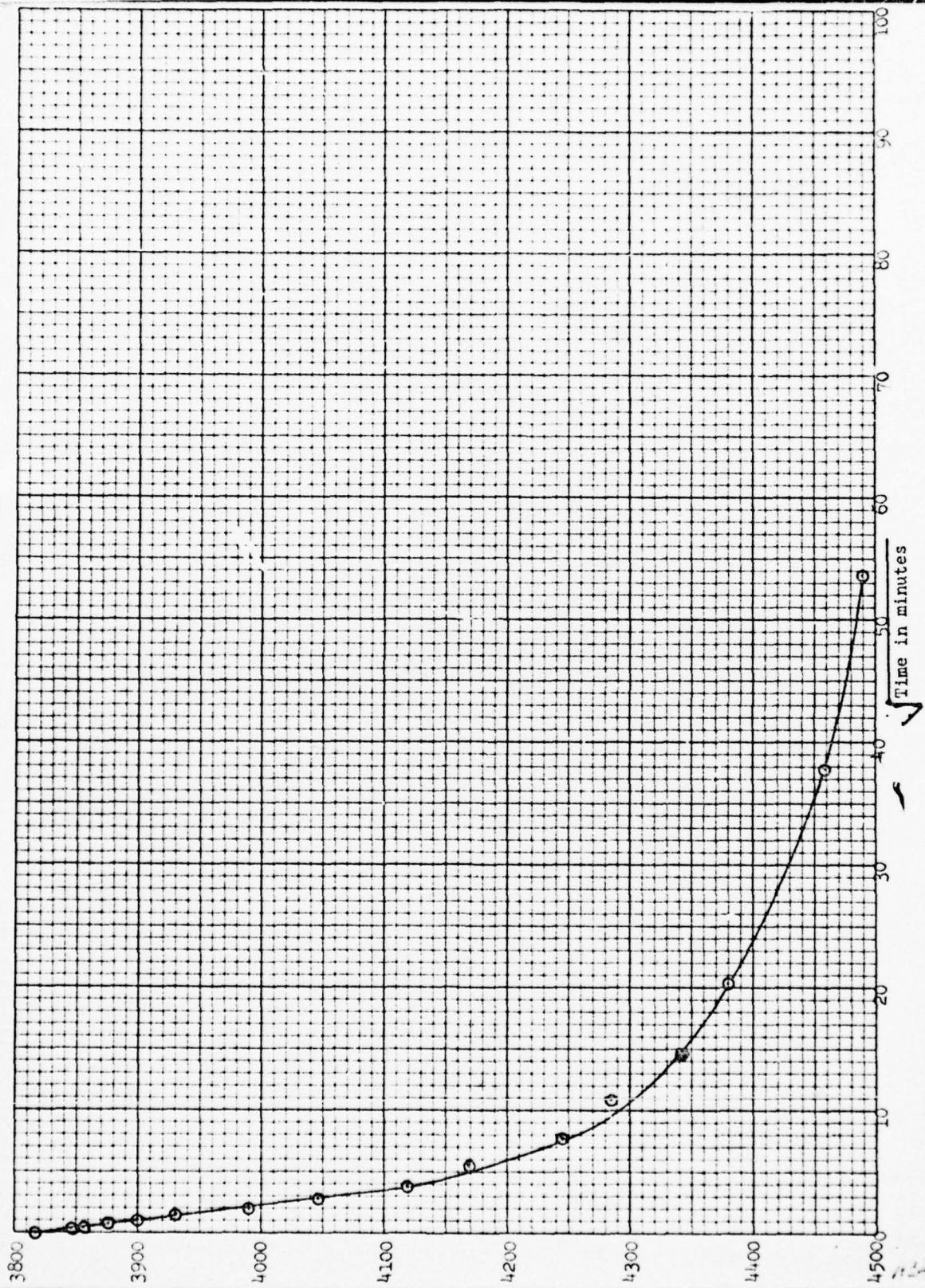
1.0-1.1

Sedimentation Testing

.0148 tsf

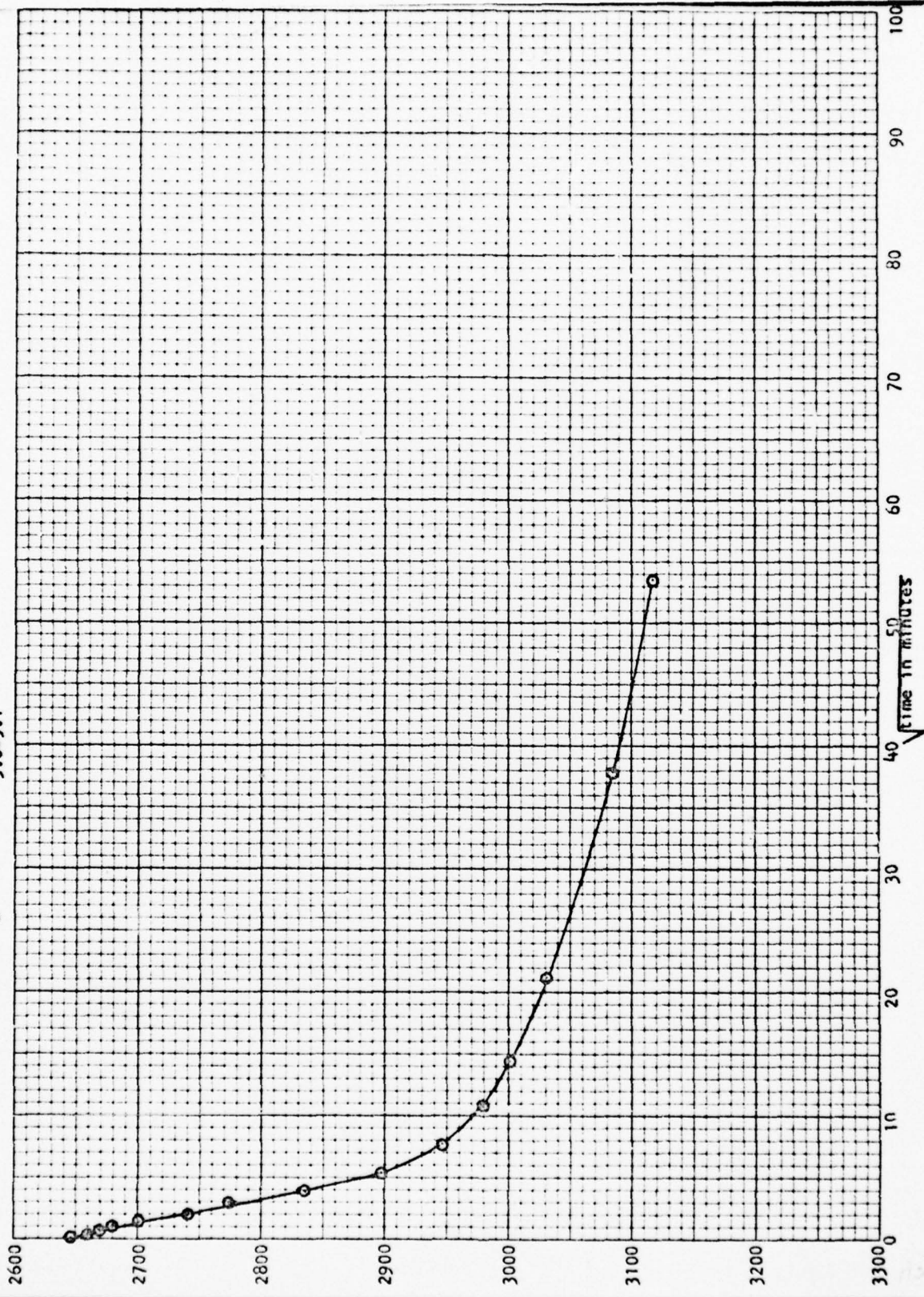


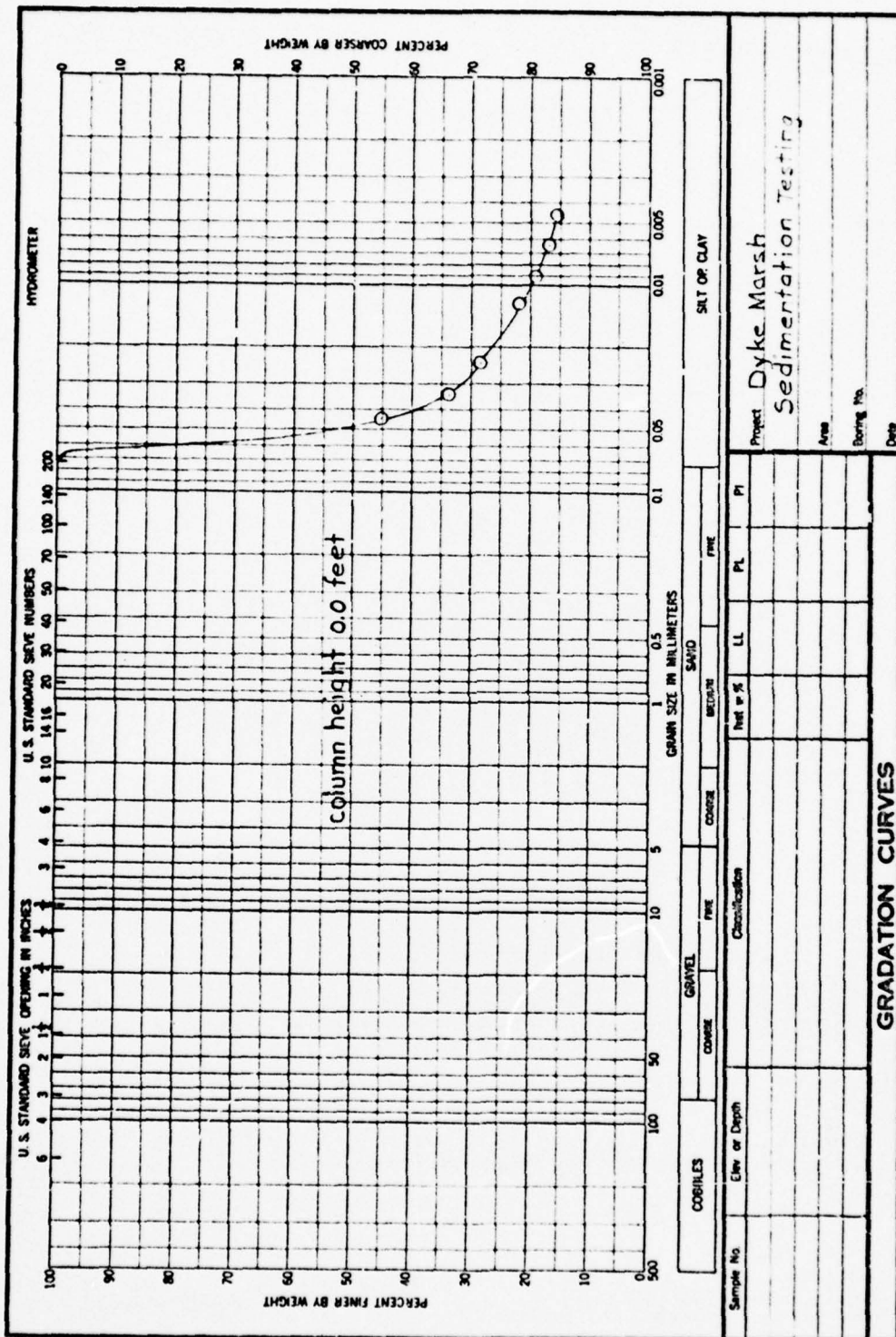
Dial Reading x 10⁻⁴ .08 TSF Sedimentation Testing 5.1-5.0



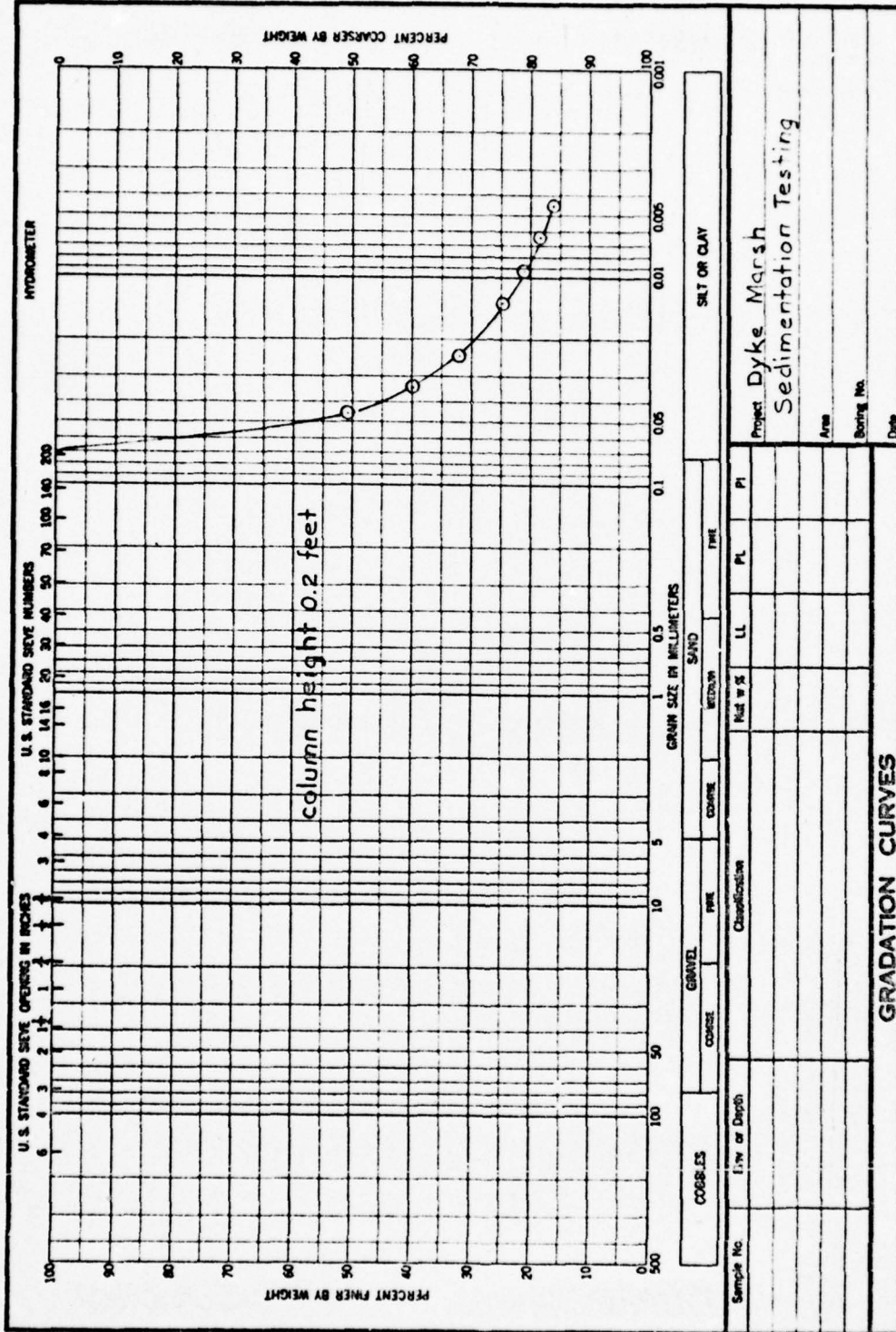
Sedimentation testing .0148 rsf

Dial Reading $\times 10^{-4}$ 5.0-5.1





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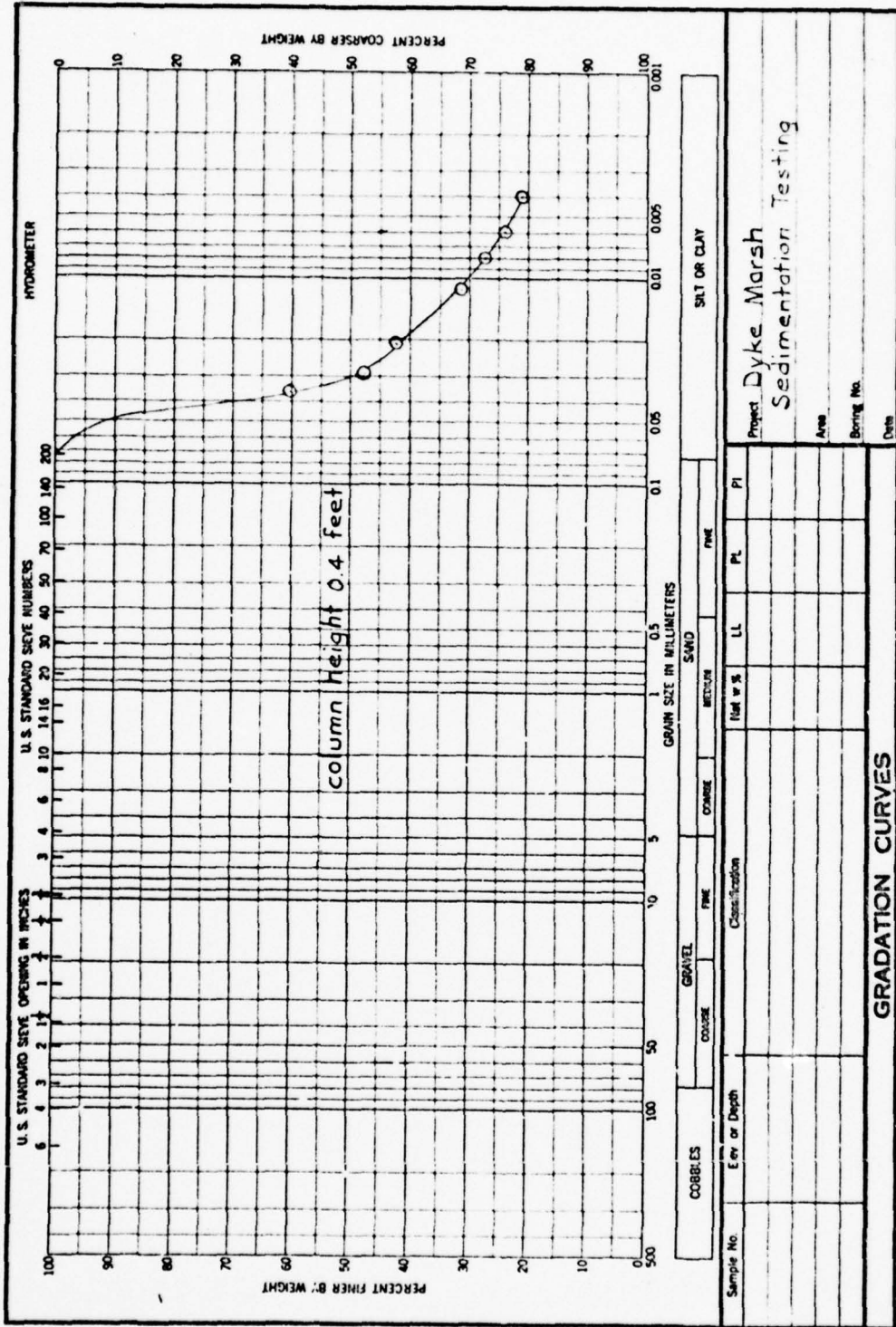


column height 0.2 feet

Sample No.						
1.75 or Depth						
Classification						
Gravel	Coarse	Fine	Sand	Medium	Fine	PI
Project Dyke Marsh Sedimentation Testing						
Area						
Boring No.						
Date						

GRADATION CURVES

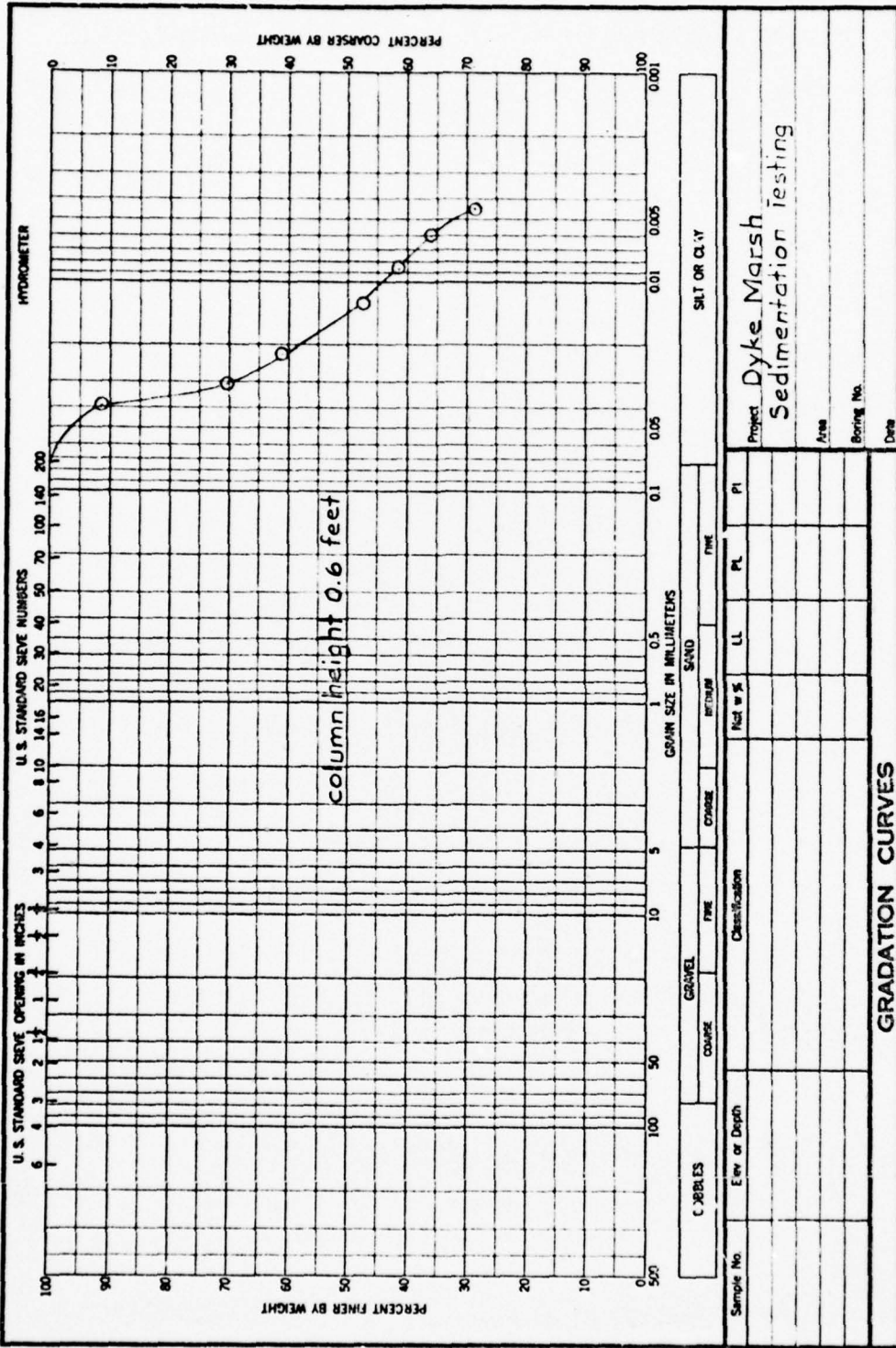
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COBBLES		GRAVEL		SAND		SILT OR CLAY	
COARSE		FINE		MEDIUM		FINE	
Classification		Classification		Classification		Classification	
Sample No.	Elev or Depth	LL	PL	PI			
Project Dyke Marsh Sedimentation Testing				Area			
Boring No.				Date			

GRADATION CURVES

ENG FORM 2087
1 MAY 63



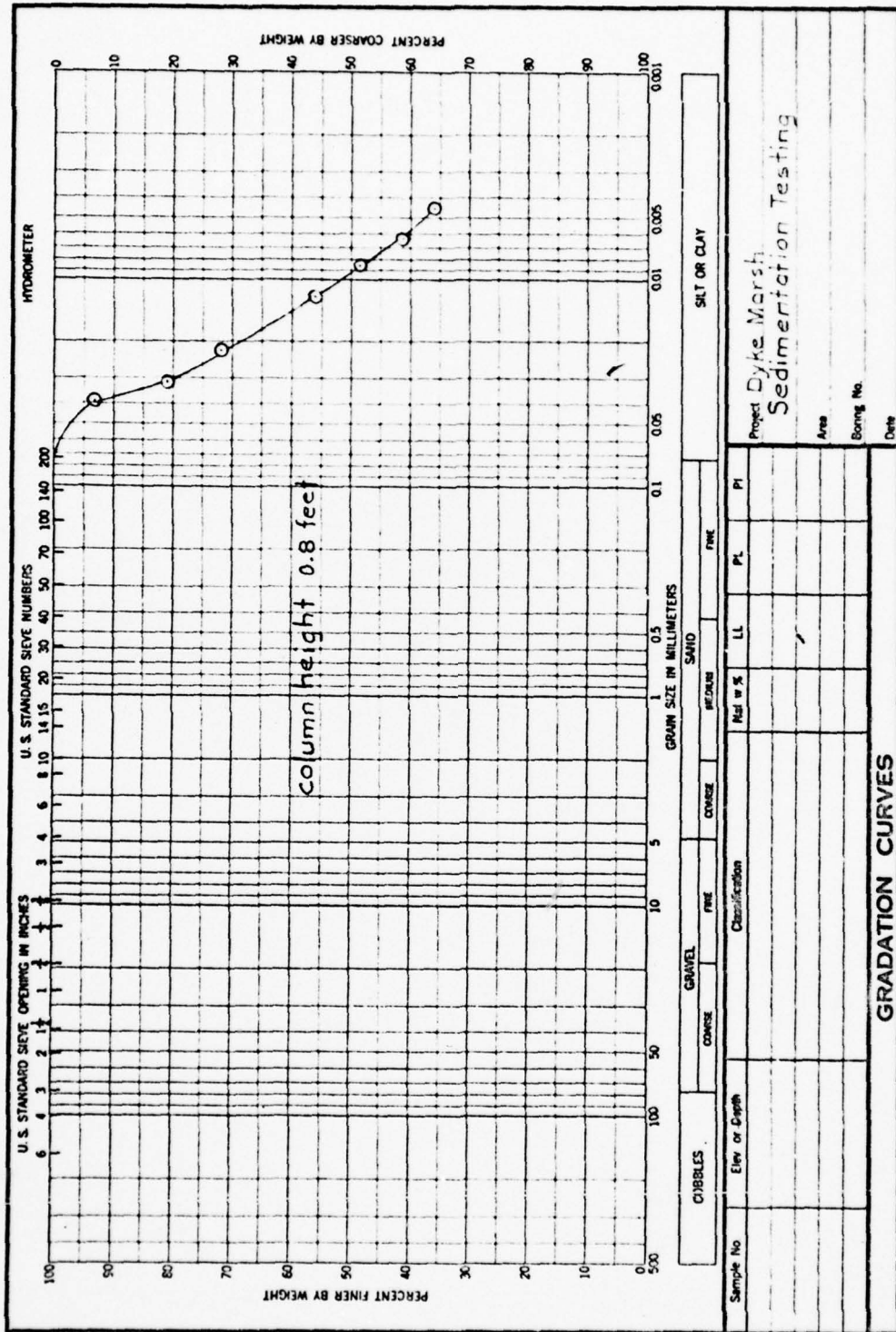
Sample No.	Elev. or Depth	Classification	U.S. STANDARD SIEVE NUMBERS	PERCENT FINER BY WEIGHT
			10	~85
			20	~75
			40	~65
			60	~55
			100	~45
			200	~35

GRAVEL	COARSE	FINE	GRANULAR SAND	FINE	SILT OR CLAY

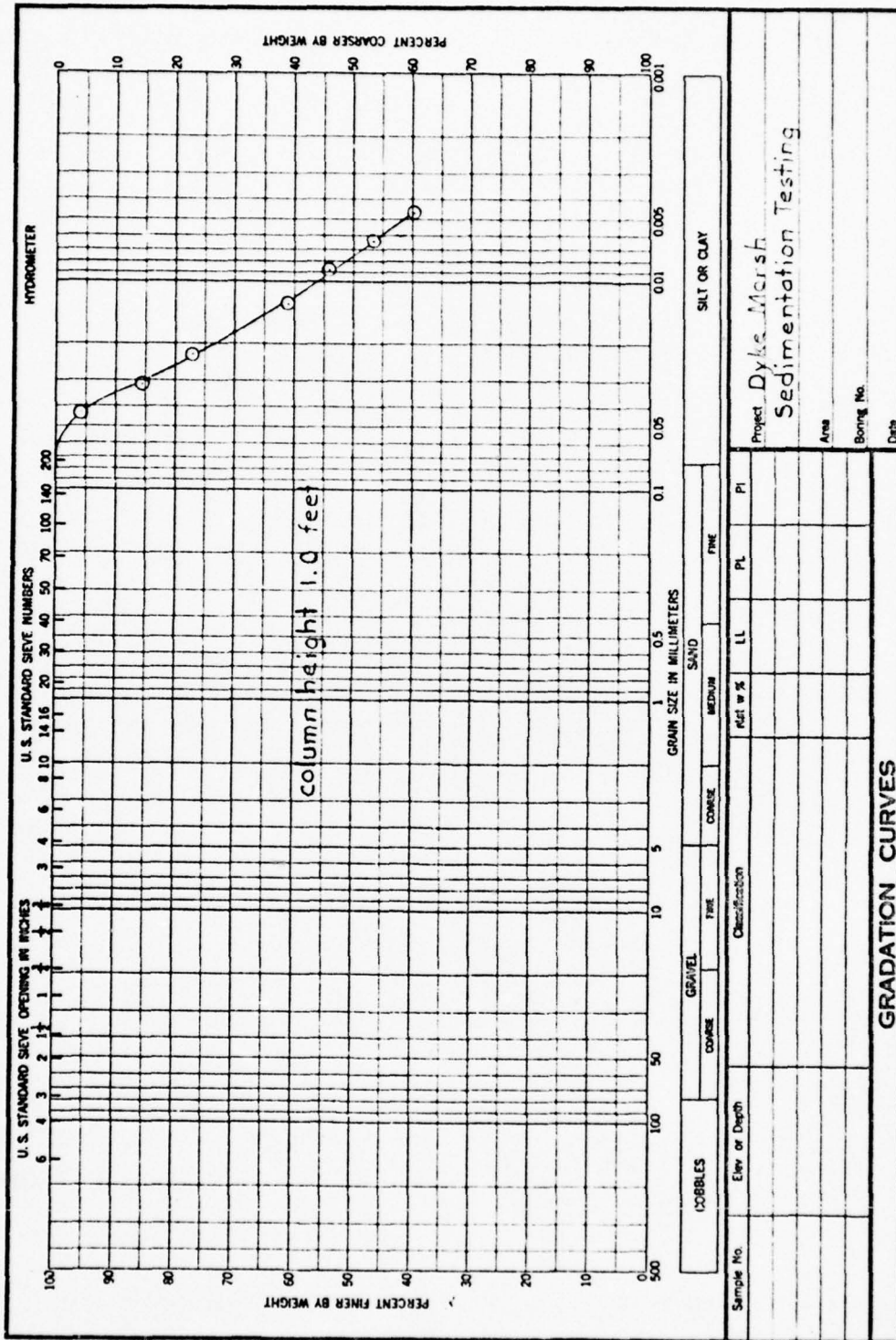
Project	Dyke Marsh
Area	
Boring No.	
Date	

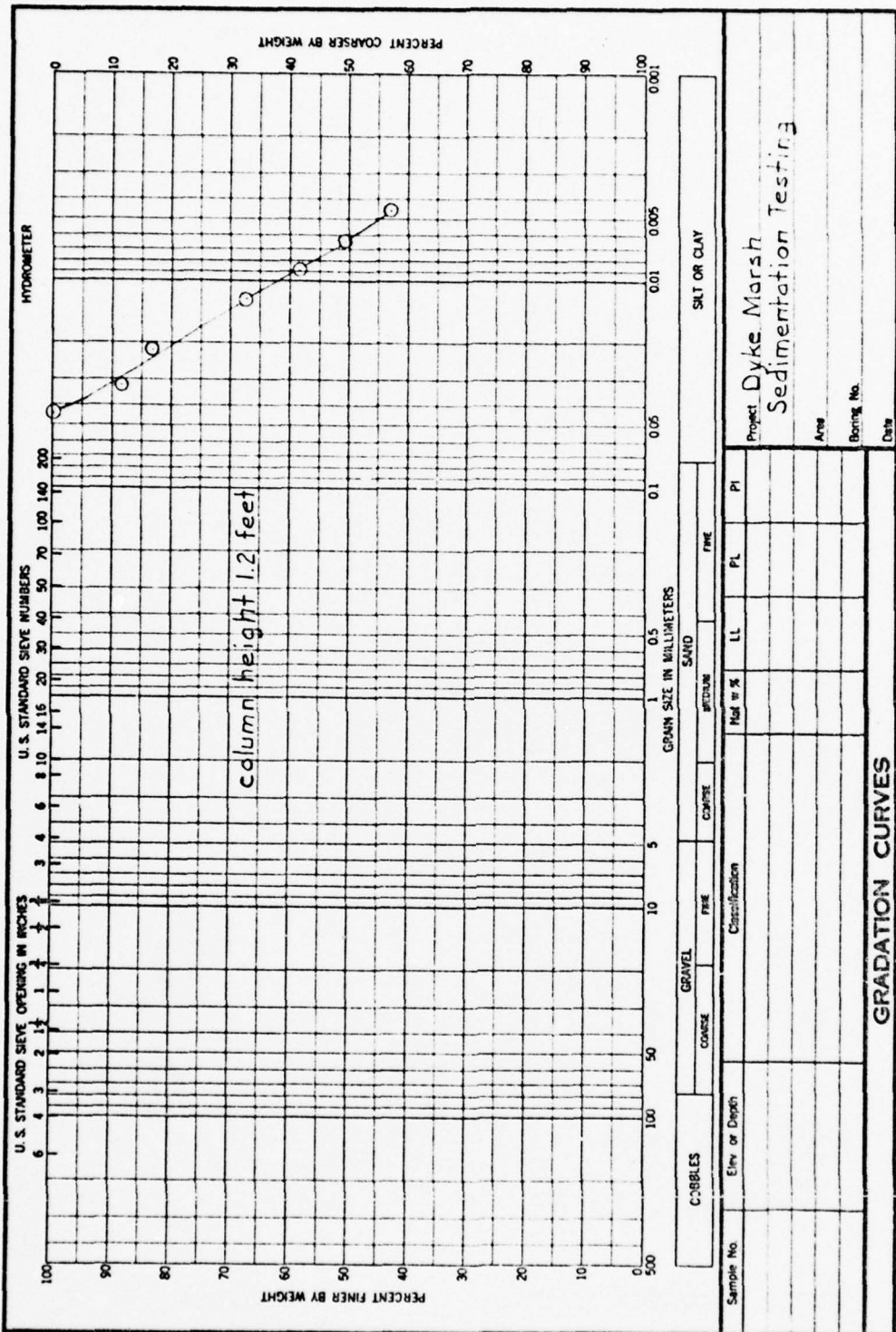
GRADATION CURVES

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1 MAY 63



ENG FORM 1 MAY 63 2087

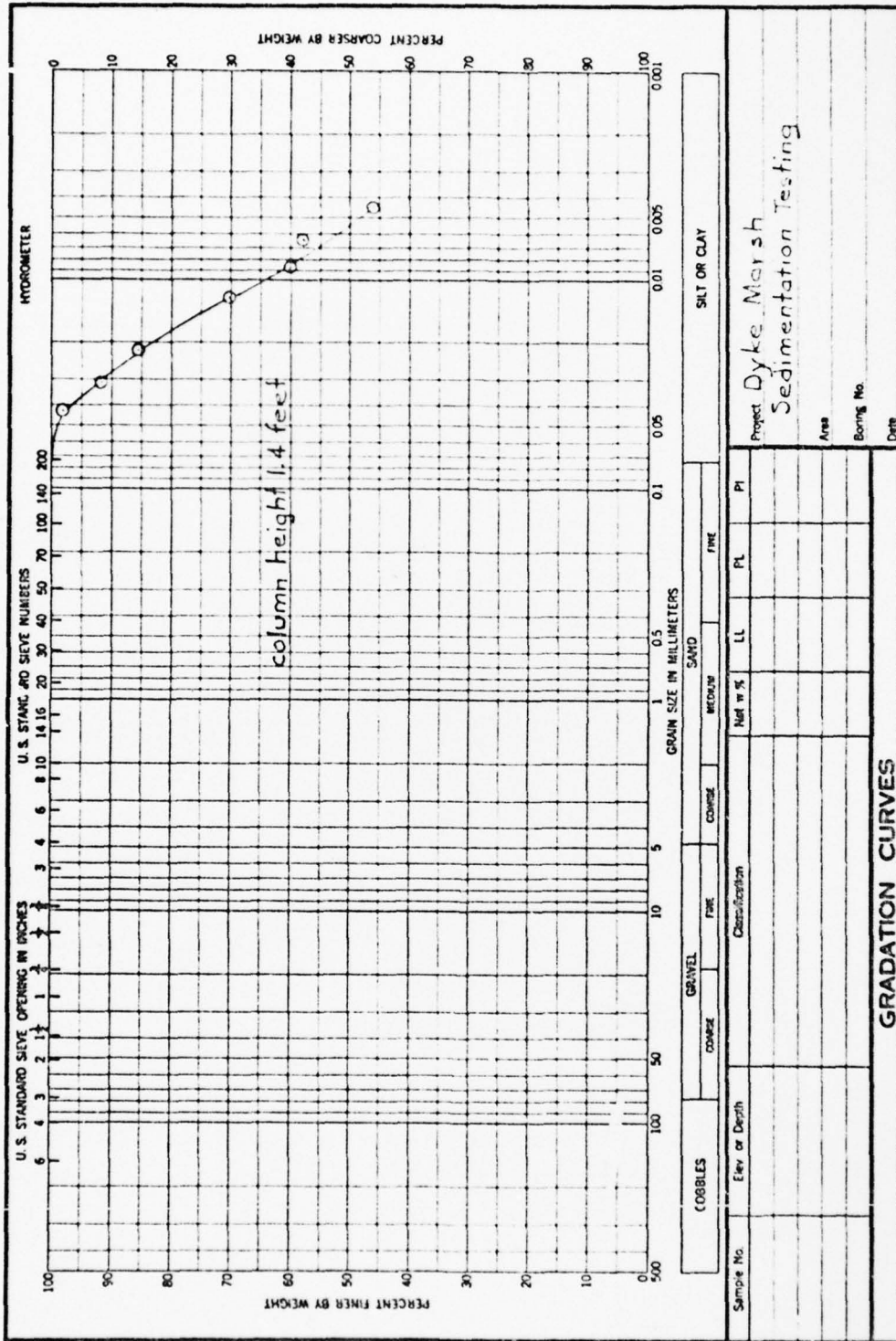




Cobbles		Gravel		Fine Sand		Medium Sand		Fine		Silt or Clay	
Sample No.	Elev or Depth	Classification	LL	PL	PI						
Project Dyke Marsh Sedimentation Testing											
Date											
Boring No.											
Area											

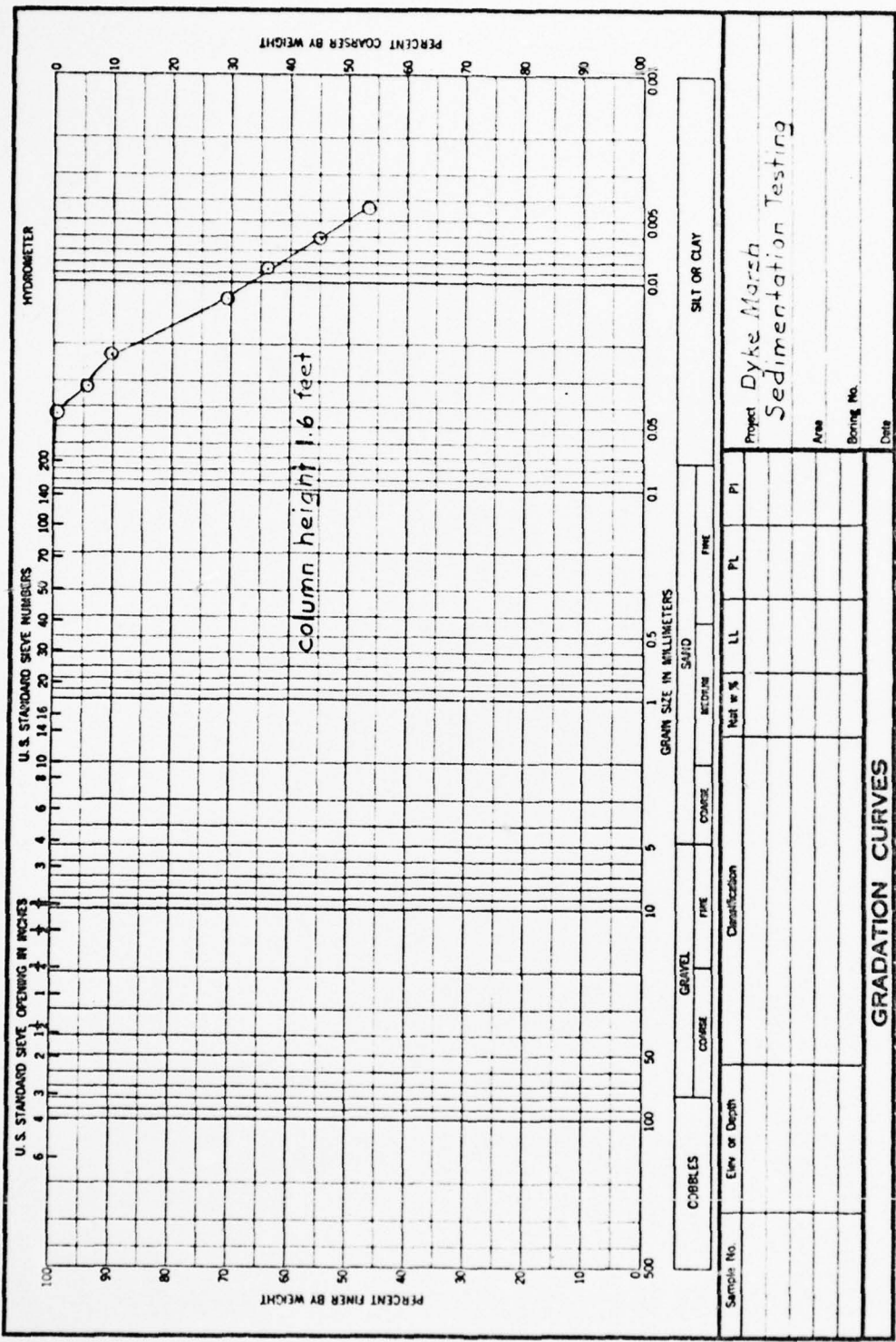
GRADATION CURVES

ENG FORM 1 MAY 63 2087

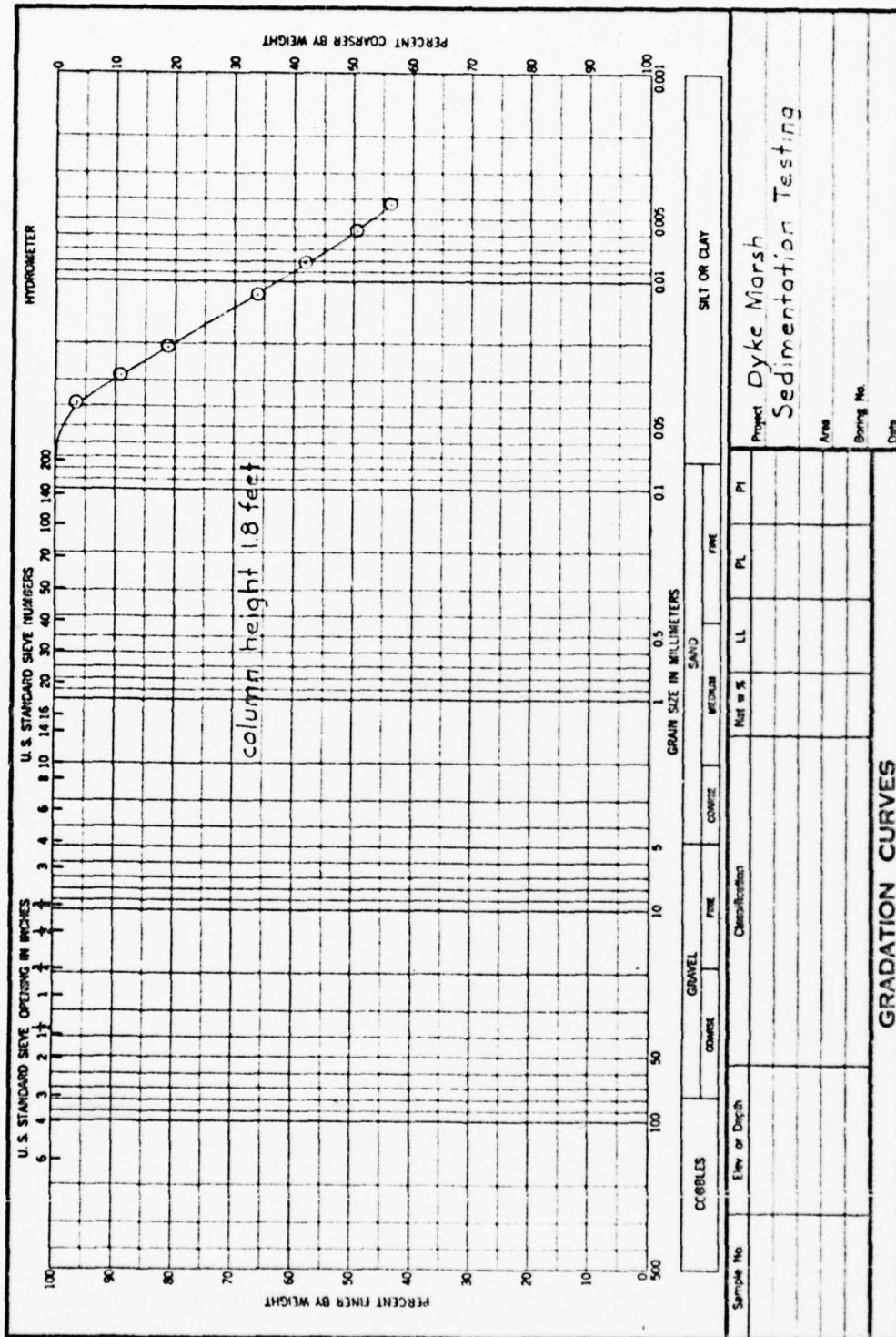


A44

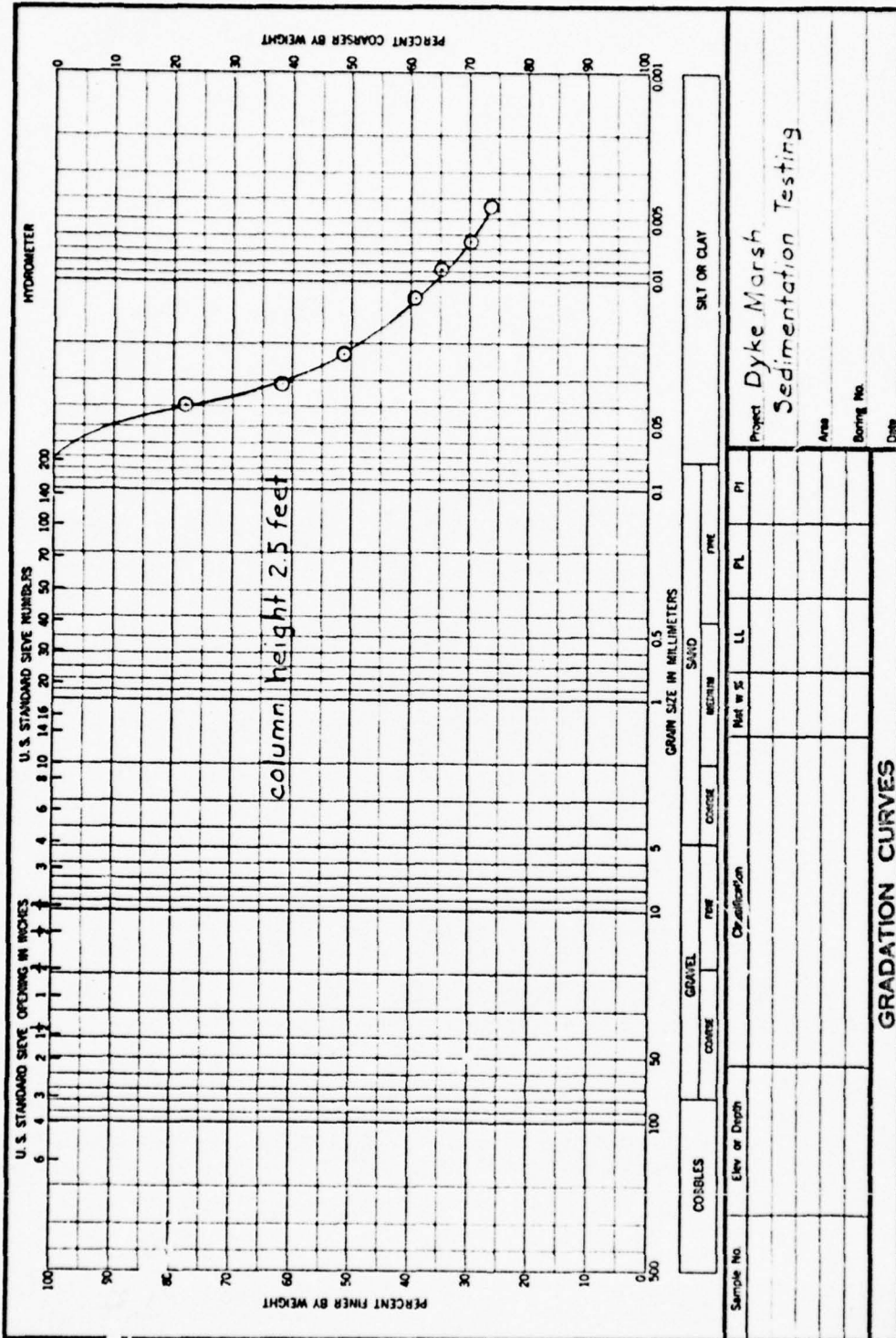
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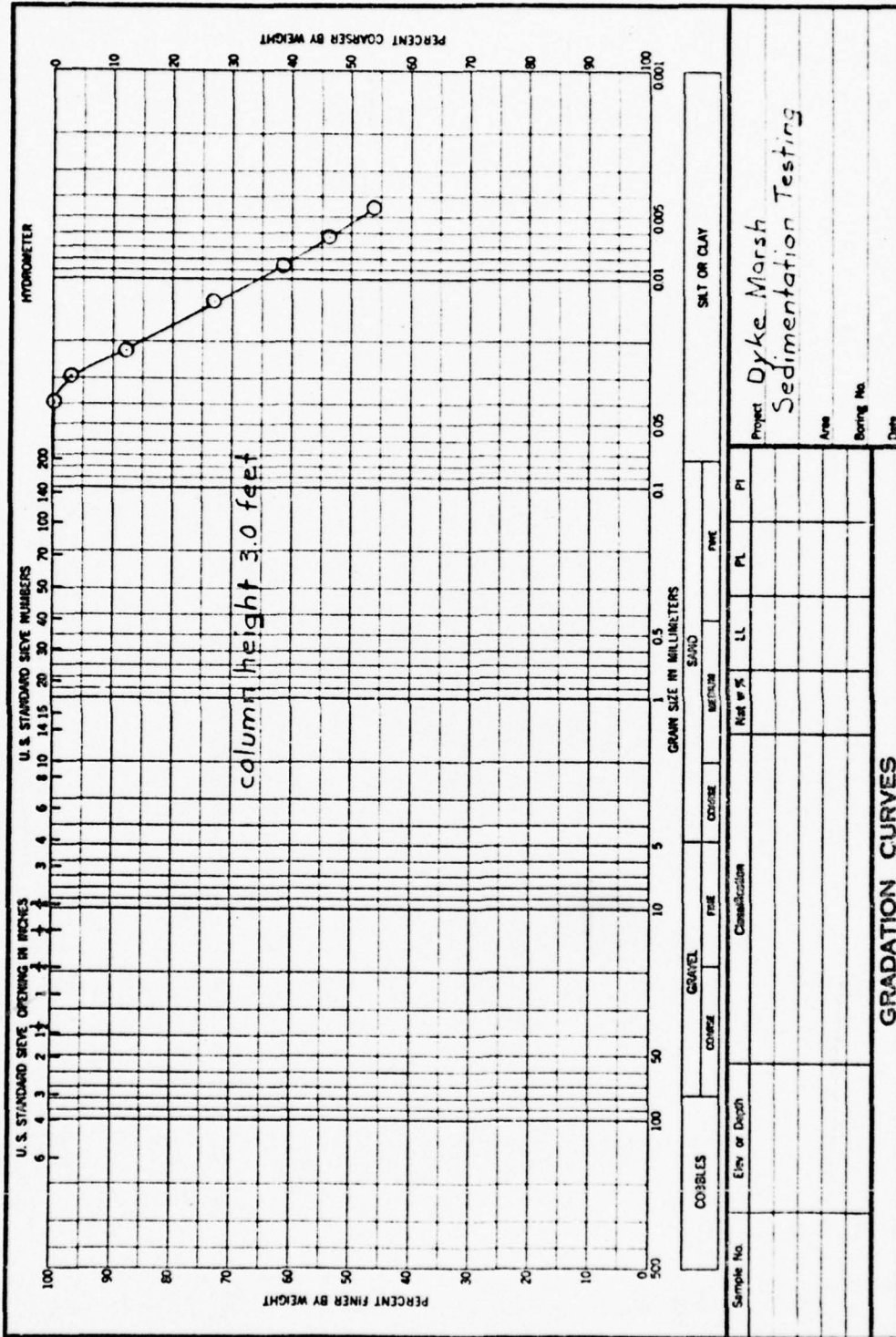


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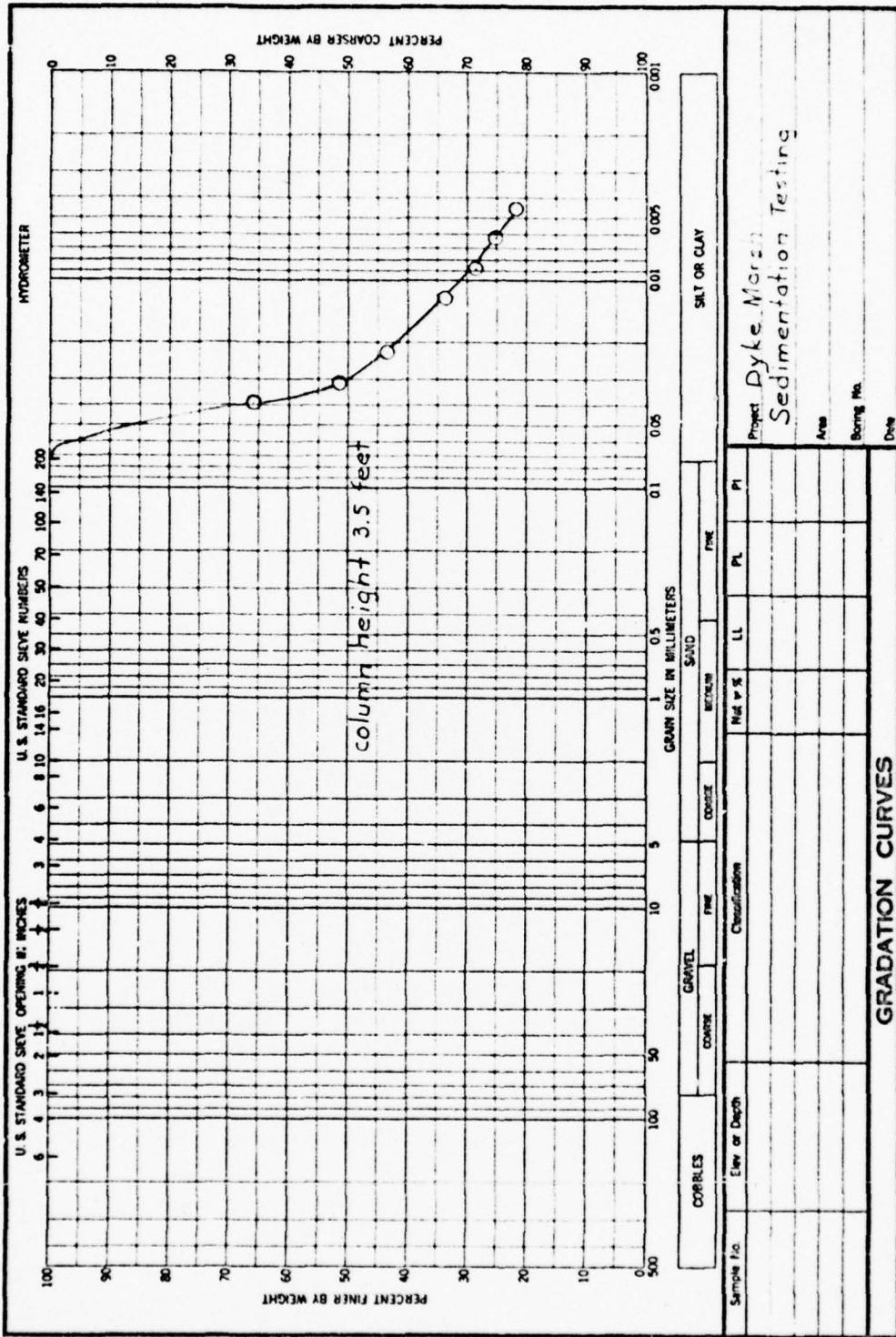


A48

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1 MAY 63

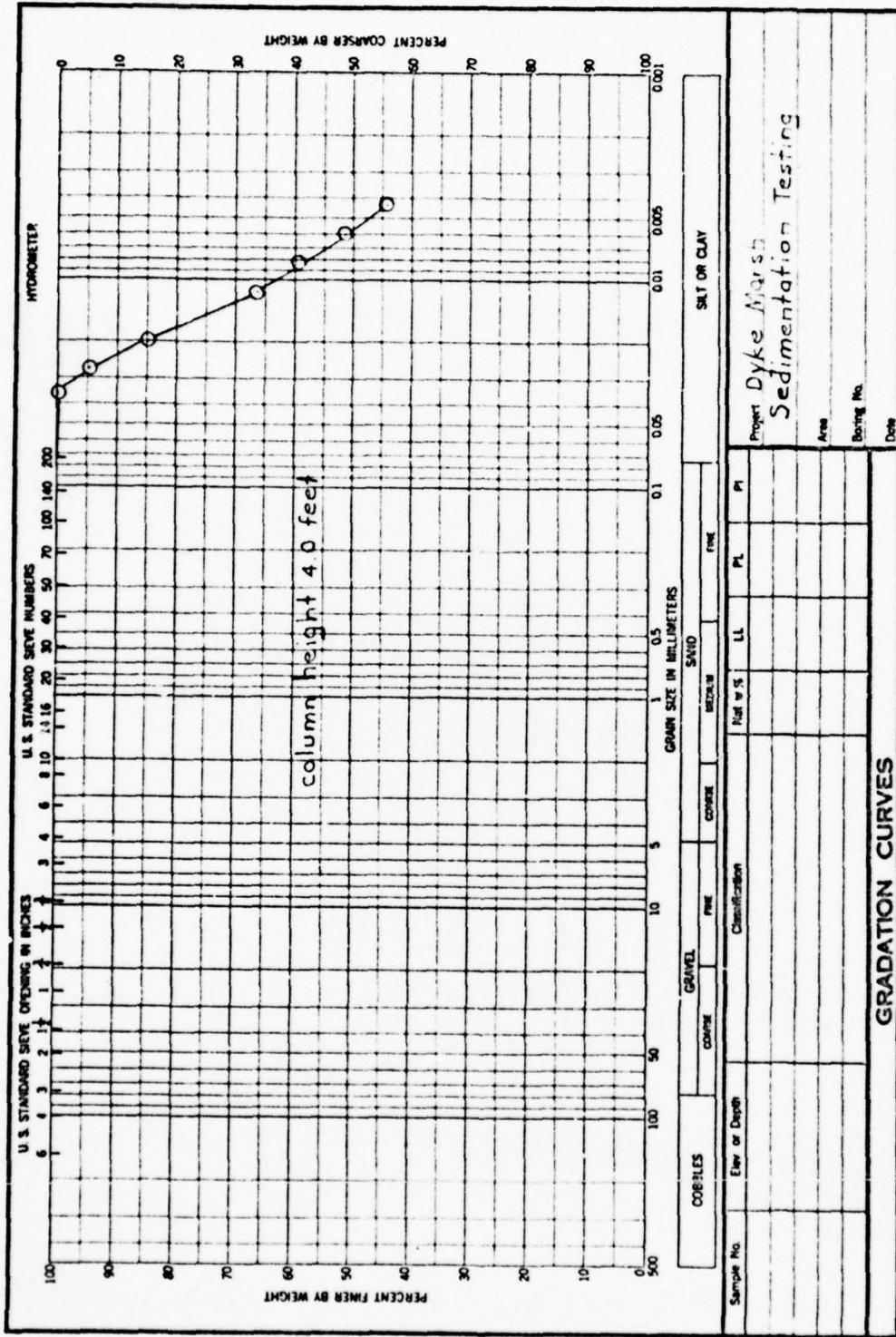


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1 MAY 63

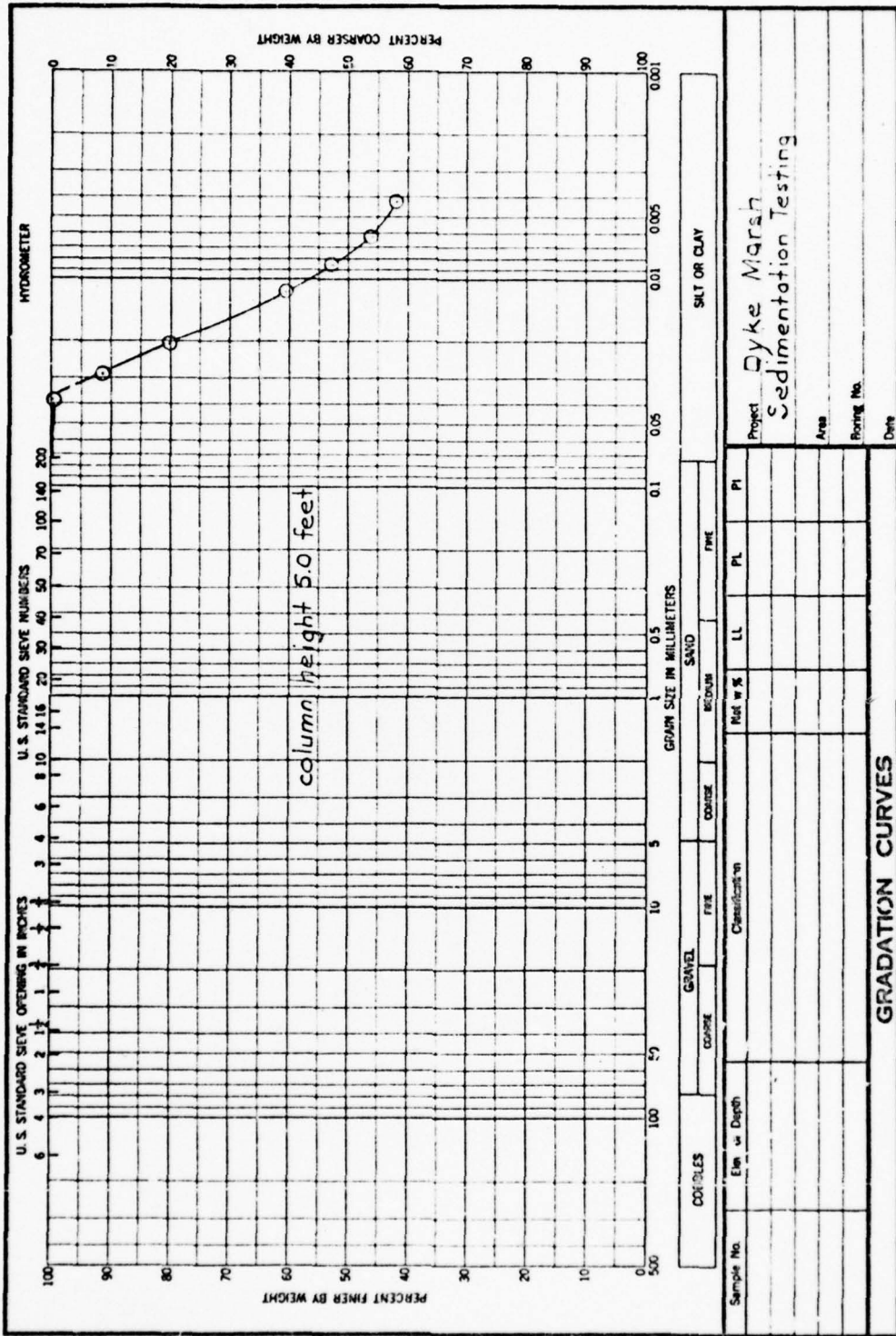


GRADATION CURVES

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1 MAY 63 2037



ENG FORM 1 MAY 63 2087



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1 MAY 63

APPENDIX B: FIELD INVESTIGATIONS AND LABORATORY TESTS
FOR RIVERINE SOURCES OF SAND

1. Borings taken within the navigation channel area (Figure 3 of the main text) revealed that the extensive sand deposits indicated by previous surface sampling were not present with depth. Therefore, field investigations consisting of bottom sampling and probing were made to locate other potential sources of sand in shallow areas outside the navigation channel.

2. Bottom sediments were sampled at various locations along the Potomac River from Oxen Creek, 2-1/2 miles north of Dyke Marsh, to Mockley Point, 4-1/2 miles south of the marsh. Sample locations and descriptions are given in Figures B1 and B2. The majority of the samples consisted of soft clay with only traces of silt or fine sand.

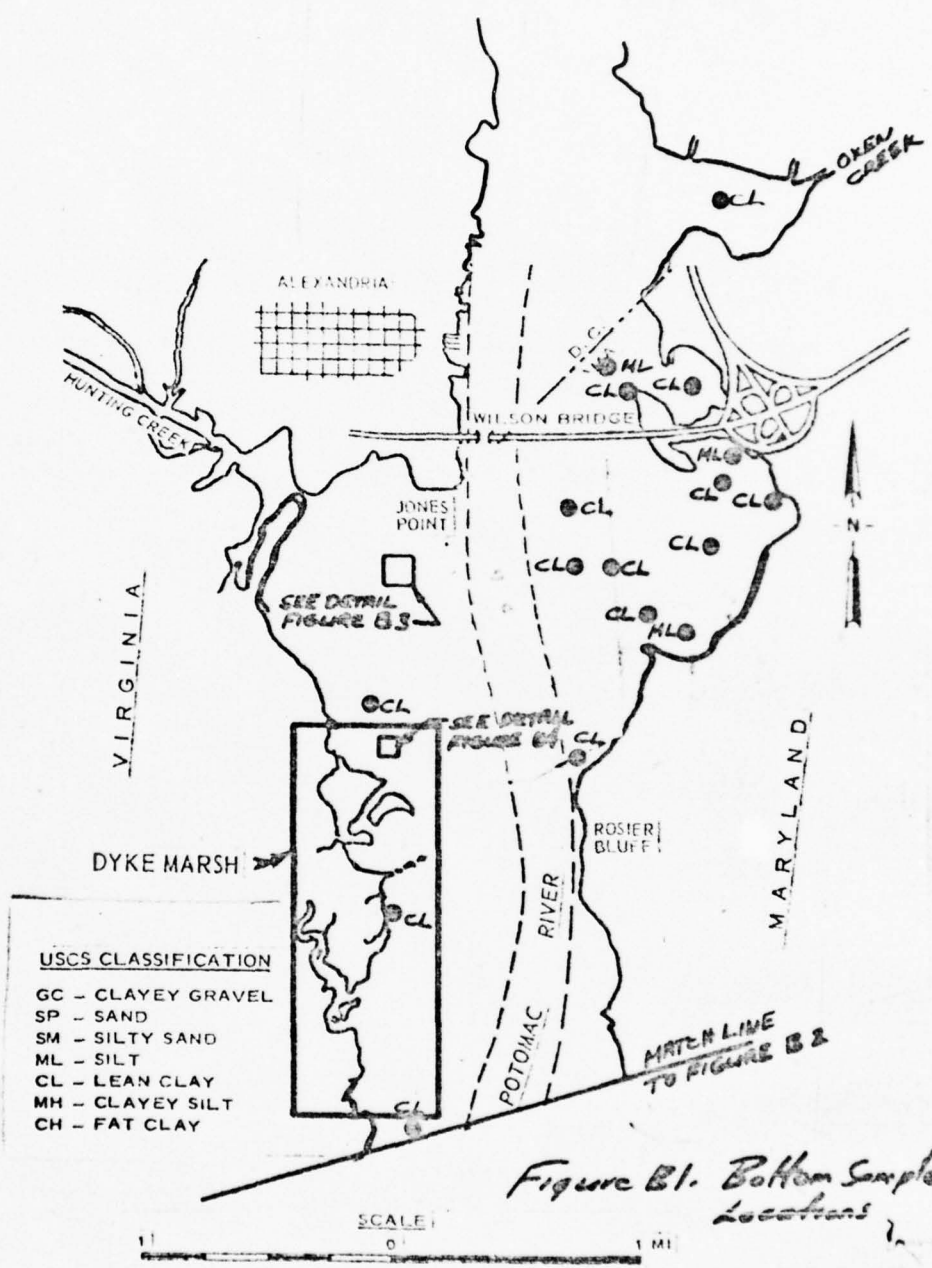
3. The Potomac River in the vicinity of Dyke Marsh generally consists of a wide expanse of shallows with the navigation channel located generally toward the center of the river. Numerous stretches of sandy beach are visible, especially along the Maryland shoreline. However, bottom sampling and probing revealed that short distances off the beach the bottom consists of soft clay and silt.

4. Two areas of sand were located by bottom sampling and probing as shown in Figures B1 and B2. Borings were taken at these locations using a barge-mounted drill rig. Bottom samples were also taken to define the limits of the sand deposits located as shown in Figures B3 and B4.

5. The sand deposit area opposite the mouth of Hunting Creek consisted mainly of fine sand over an area approximately 600 ft². Six general sample borings, numbered H-1 through H-6, and 34 bottom samples were taken and probings made. The borings revealed that the sand deposit was approximately 3 ft thick and underlain by clays and silts. Graphic boring logs are presented in Figure B5. Grain-size analyses were performed on these sand samples and are presented on pages B7 through B12.

6. Two small bars of coarse sand and gravel approximately 100 feet

square were indicated by bottom sampling and probing near the Belle Haven Marina. These areas were less than one-quarter mile north of Dyke Marsh and had configurations as shown in Figure B4. All bottom samples indicated presence of coarse sand that could not be penetrated by probes. Immediately outside the limits of the bars, the bottom consisted of soft clay and silt. Two general sample borings numbered M-1 and M-2 were taken, and analysis revealed that the coarse material was approximately 2 ft thick and underlain by very fine sand, silt, and clay. Graphic logs are presented in Figure B6. Grain-size analyses were performed on the coarse sand and are presented on pages B14 through B18.



- USCS CLASSIFICATION**
- GC - CLAYEY GRAVEL
 - SP - SAND
 - SM - SILTY SAND
 - ML - SILT
 - CL - LEAN CLAY
 - MH - CLAYEY SILT
 - CH - FAT CLAY

Figure B1. Bottom Sample Locations

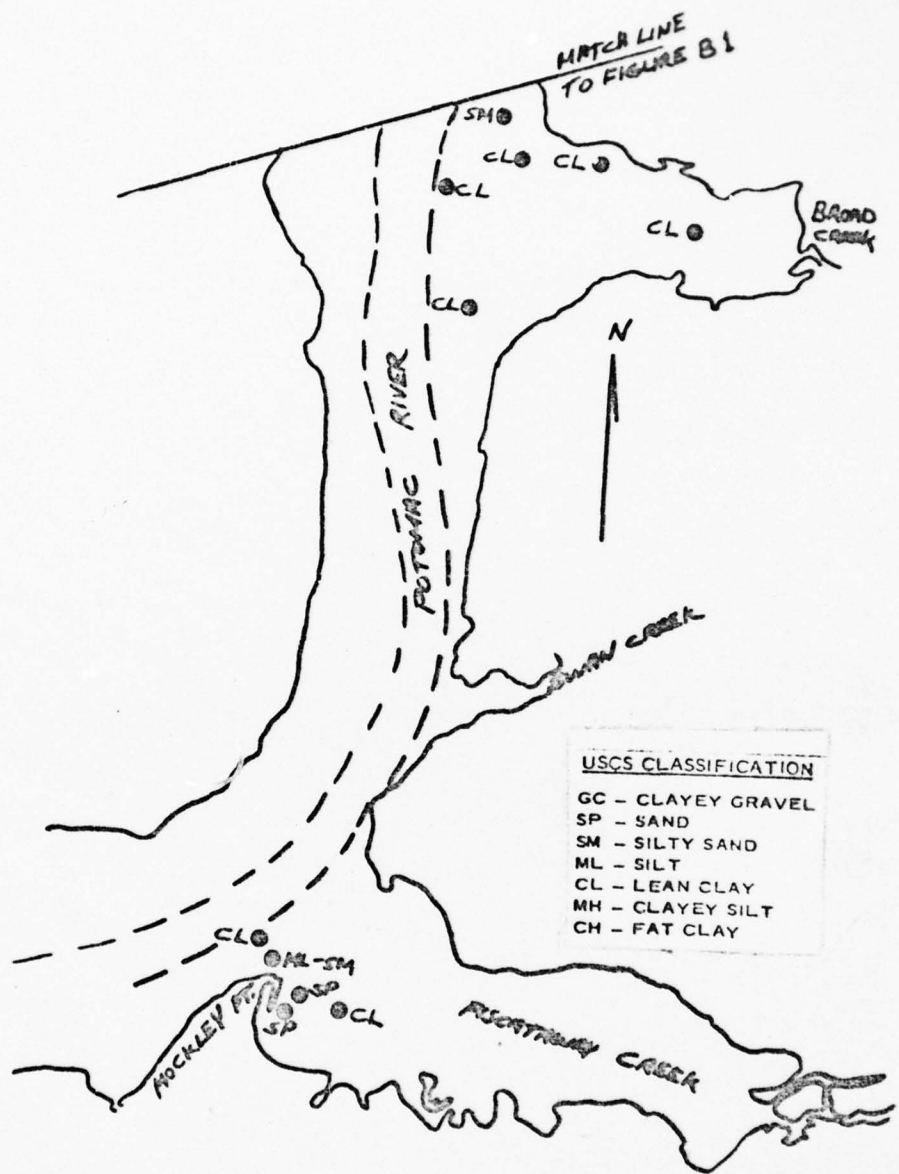


Figure B-2. Bottom Sample Locations

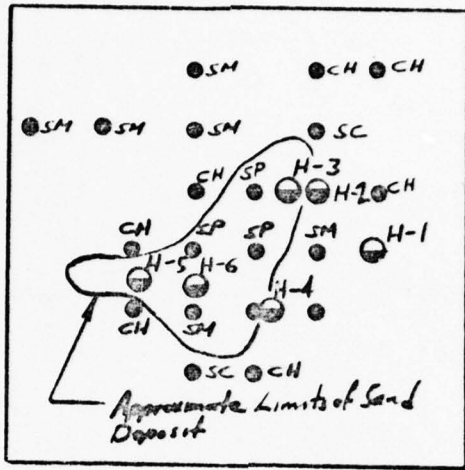


Figure B3. Hunting Creek Sand Deposit

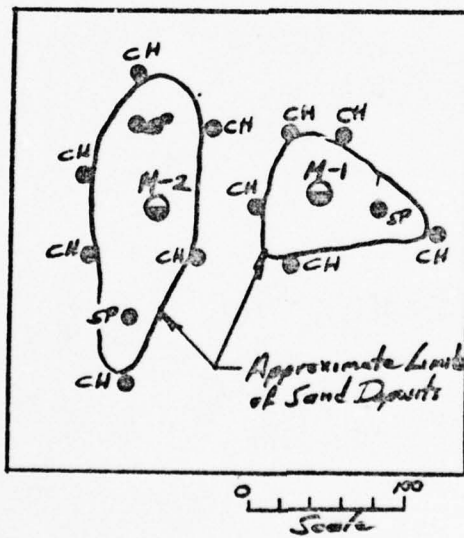
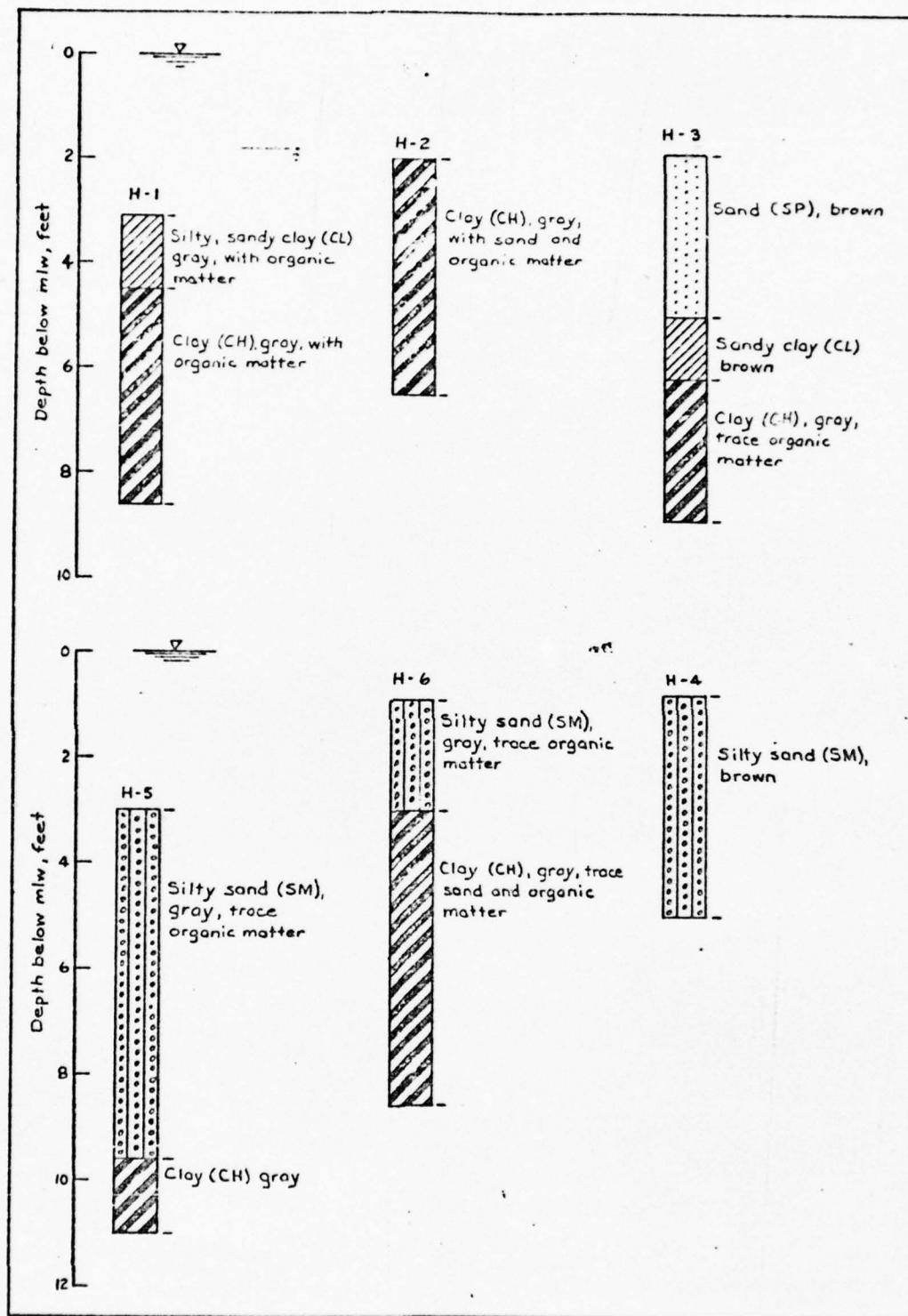
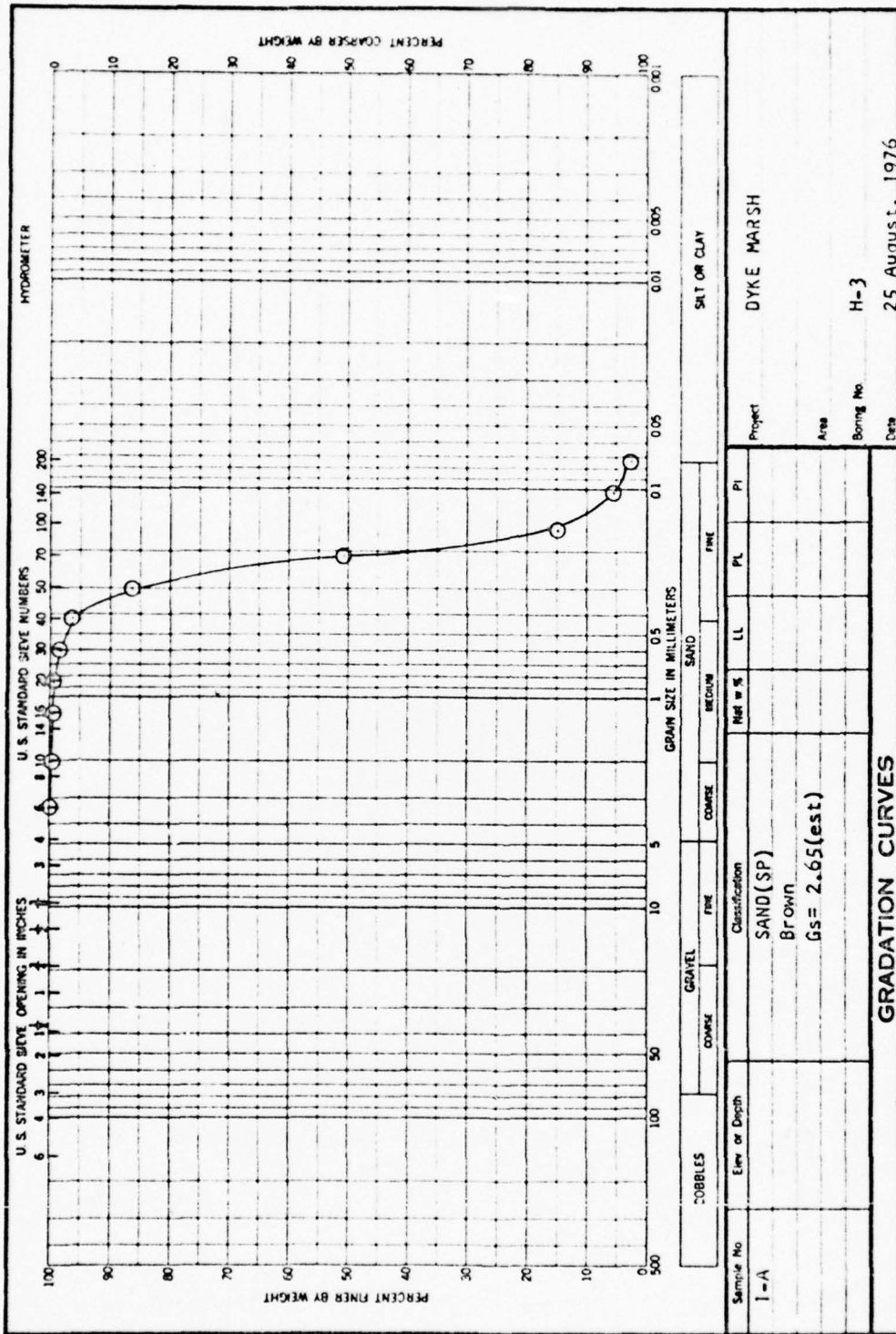


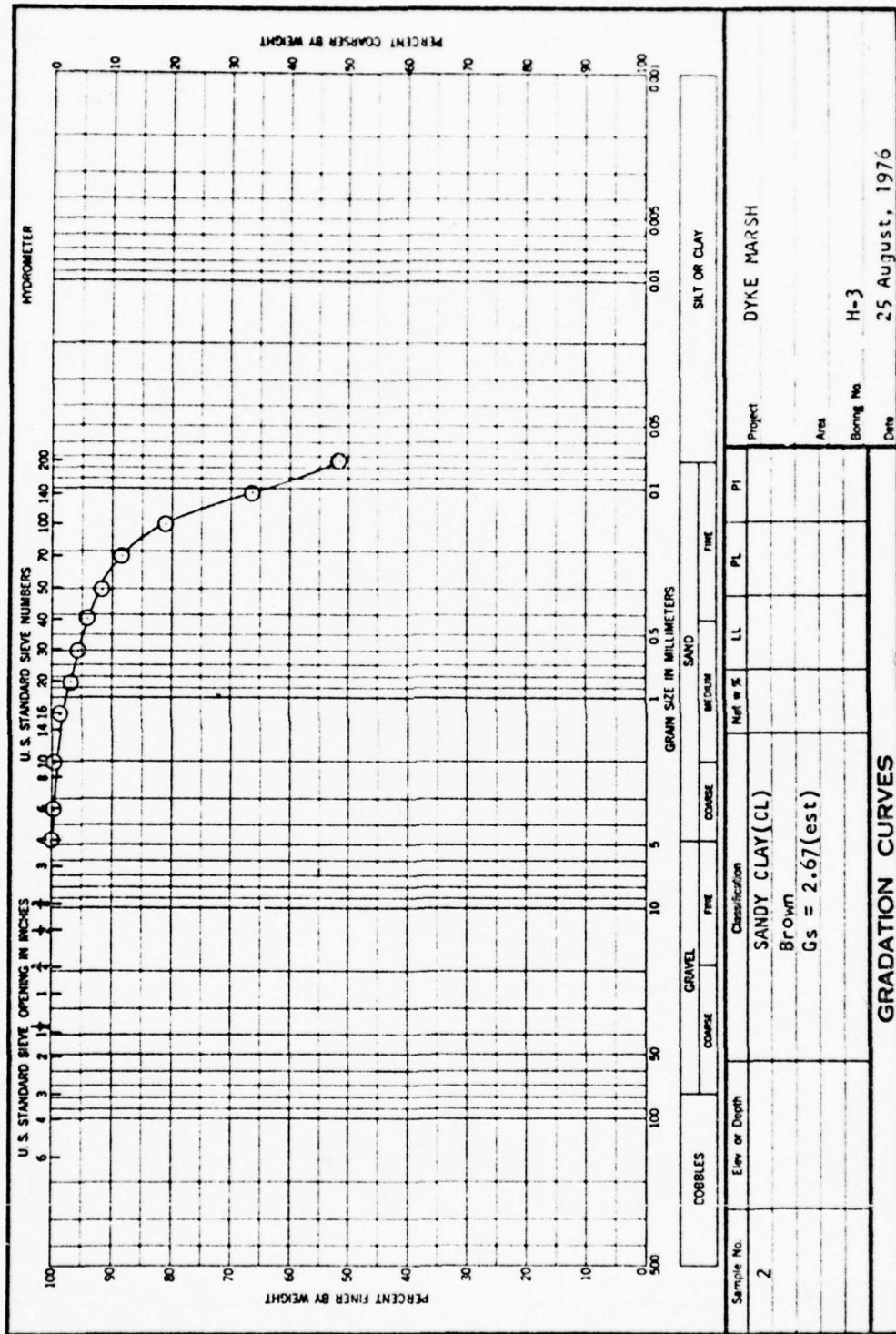
Figure B4. Marina Sand Deposit



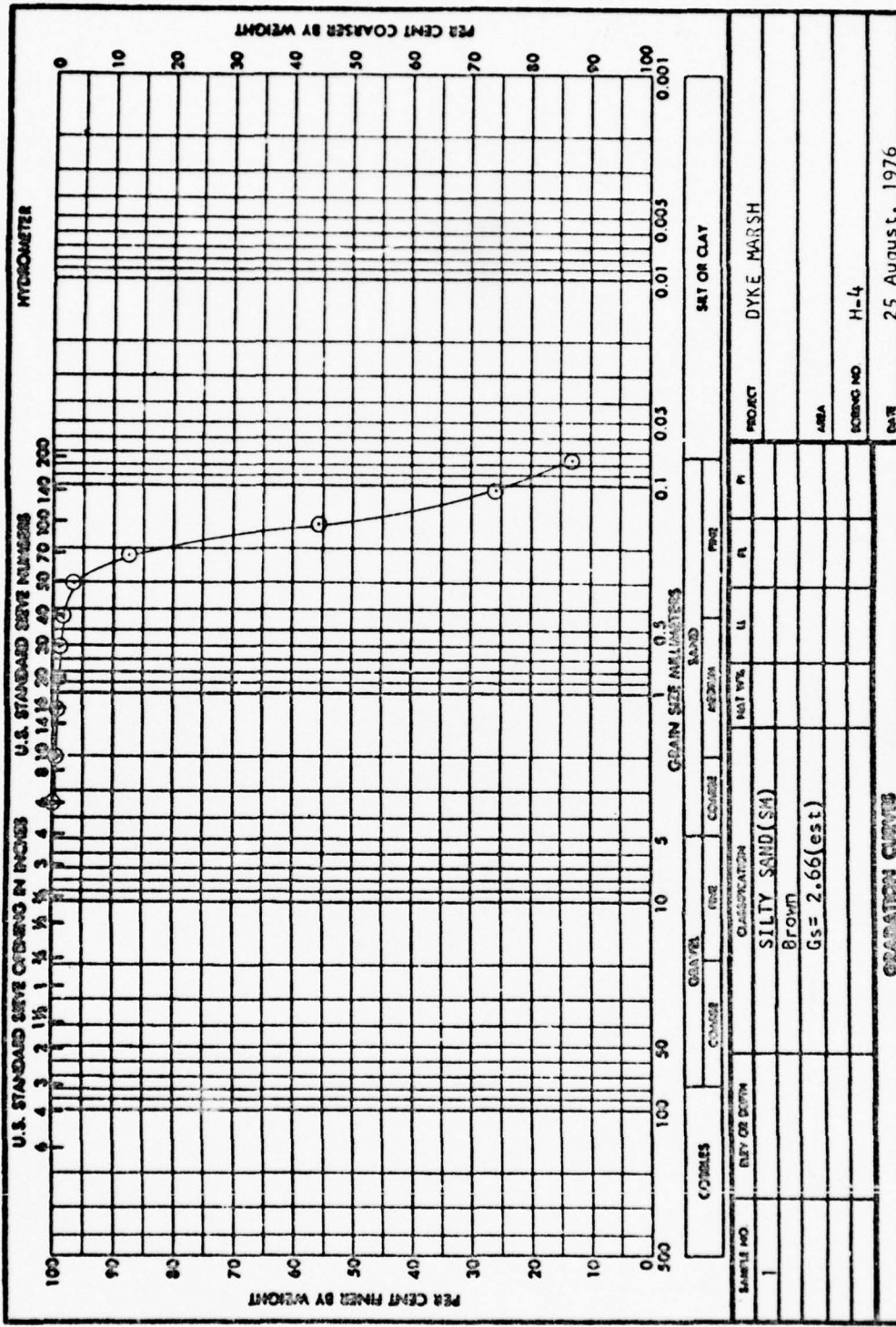
BS. Boring Logs for Sand Deposits



ENG FORM 2087
1 MAY 63



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SAMPLE NO. _____

LOCATION OF DEPTH _____

CLASSIFICATION: **SILTY SAND (SM)**
 Brown
 $G_s = 2.66(\text{est})$

GRADATION CURVE

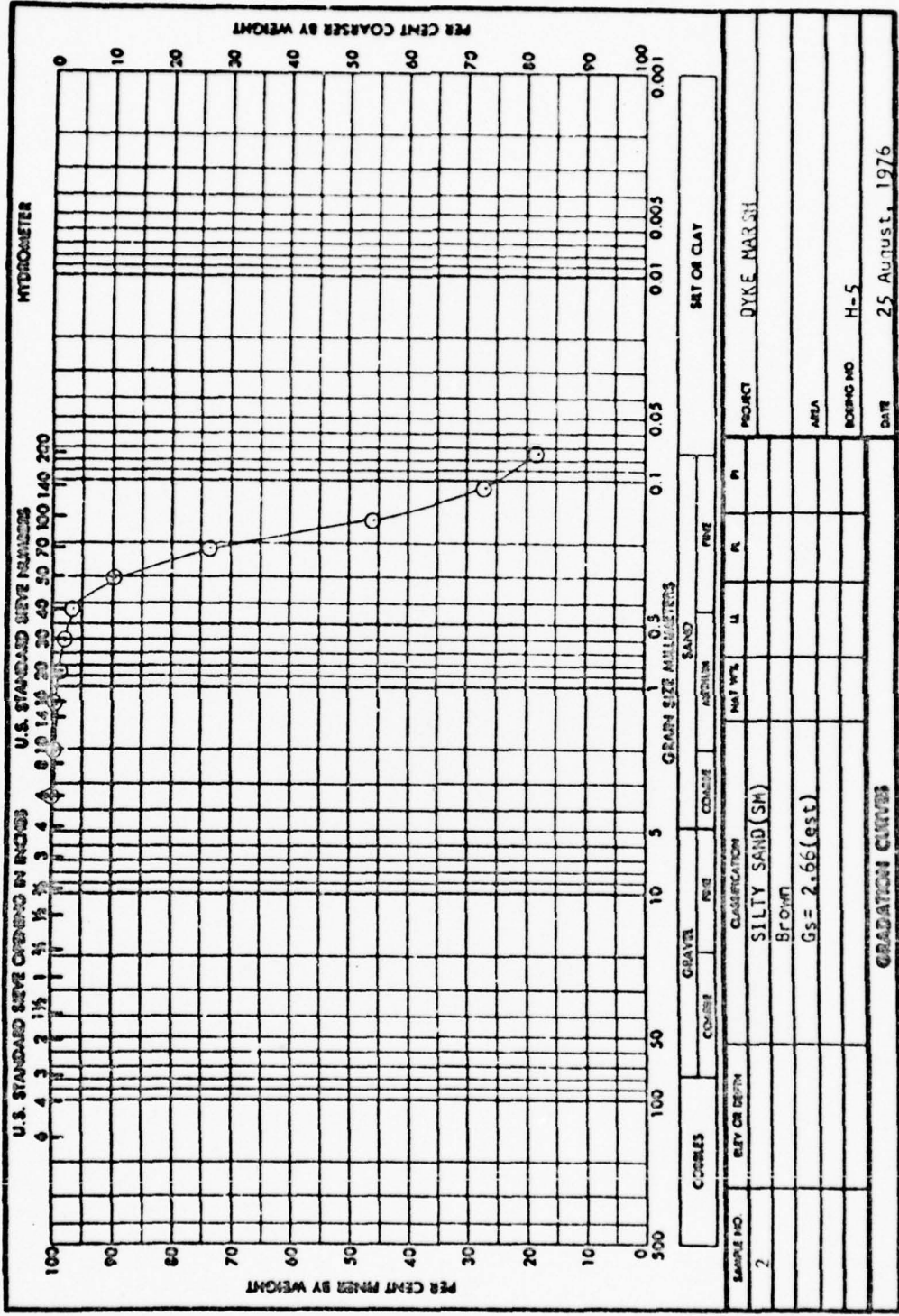
PROJECT: **DYKE MARSH**

AREA: _____

BOREHOLE NO: **H-4**

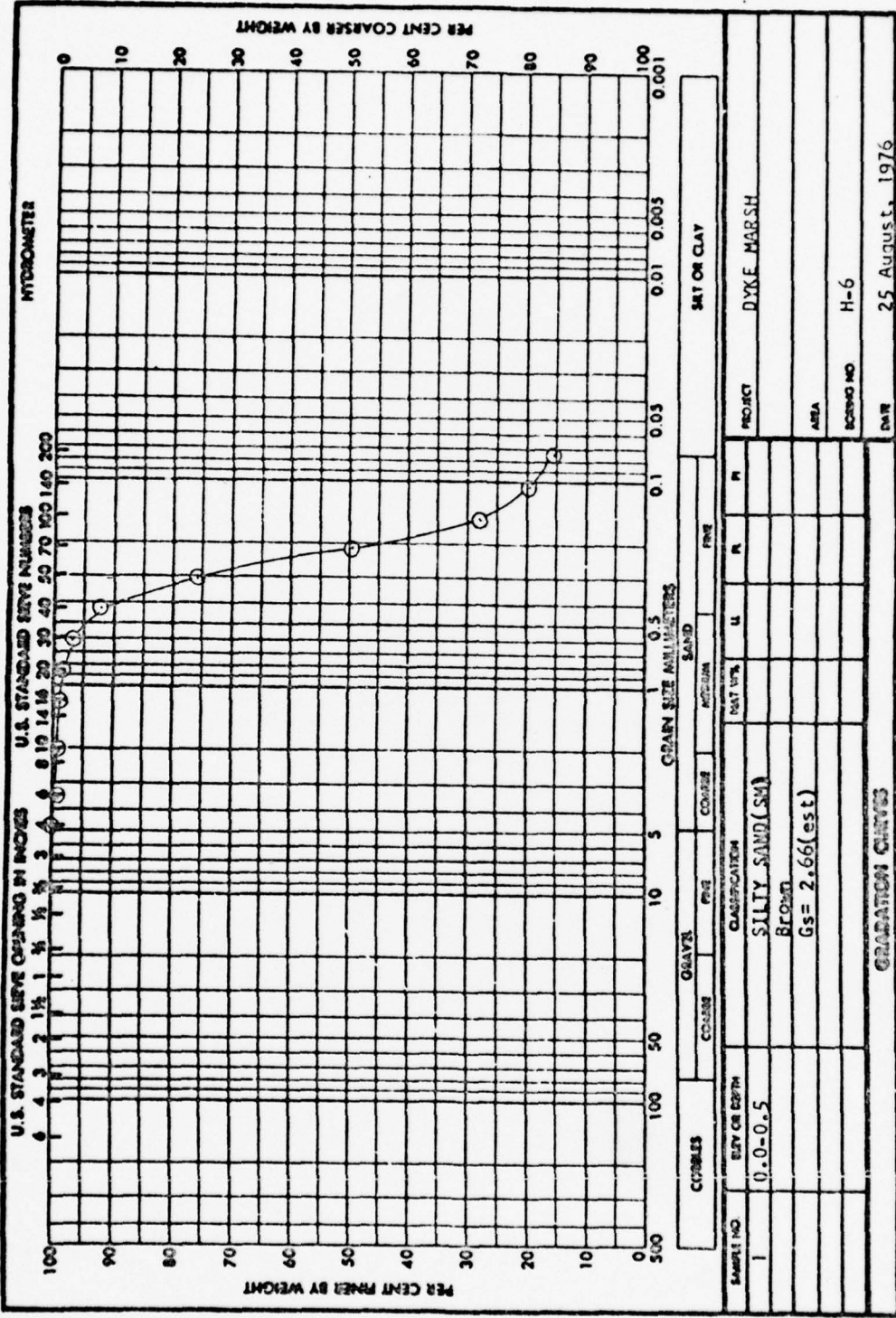
DATE: **25 August, 1976**

U.S. GOVERNMENT PRINTING OFFICE: 1969 O-350-140

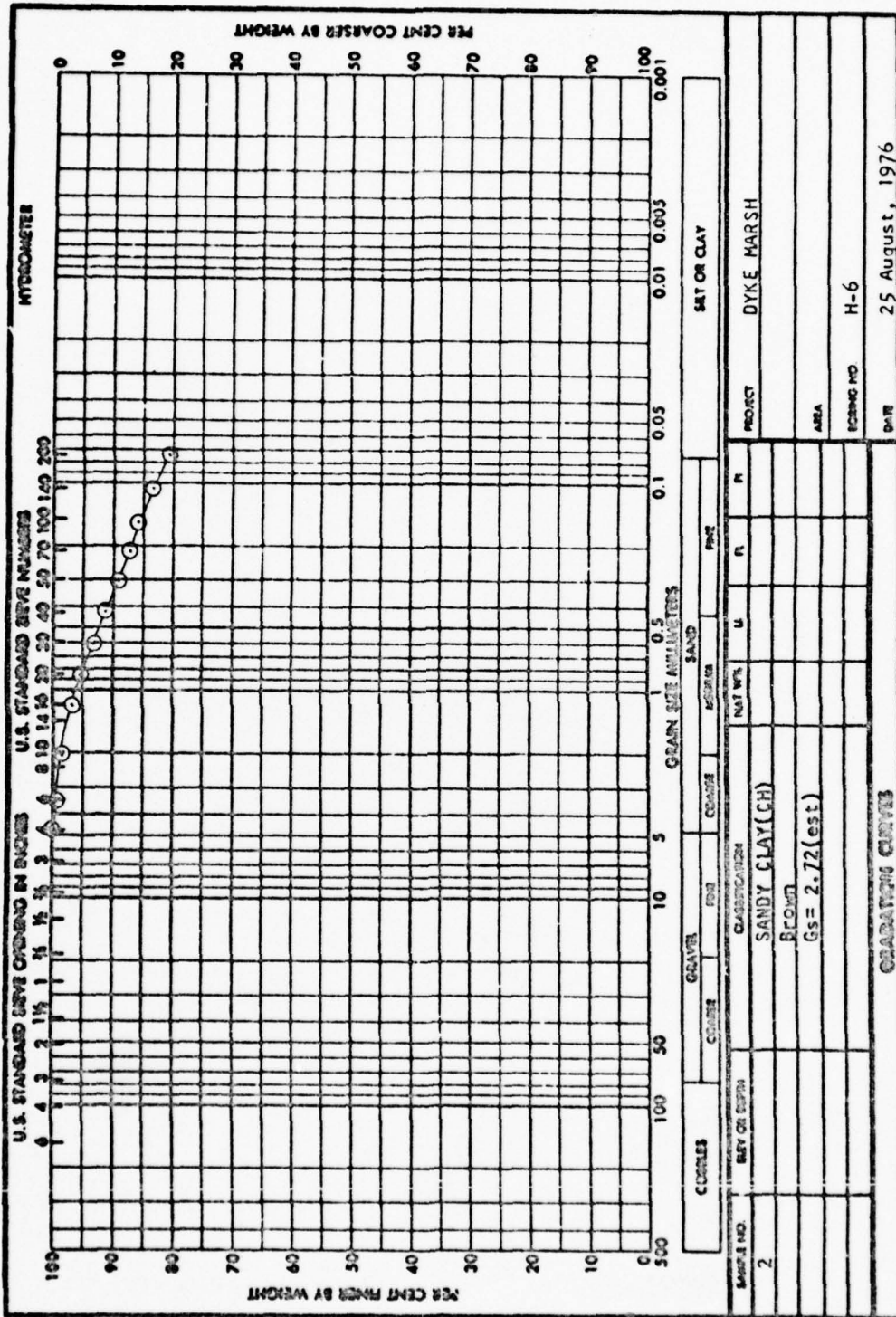


COBBLES		GRAVEL		FINE SAND		SAND		SILT OR CLAY	
COARSE	FINE	COARSE	FINE	ASHES	FINE	COARSE	FINE	COARSE	FINE
SAMPLE NO.	2	REF OR DEPTH		CLASSIFICATION		PROJECT	DIKE MARCH	AREA	
								BOREHOLE NO.	H-5
								DATE	25 August, 1976

ENG FORM 2087
 1 MAY 62
 REPLACES WES FORM NO 1241, SEP 1942, WHICH IS OBSOLETE.
 U.S. GOVERNMENT PRINTING OFFICE: 1969 O-350-124

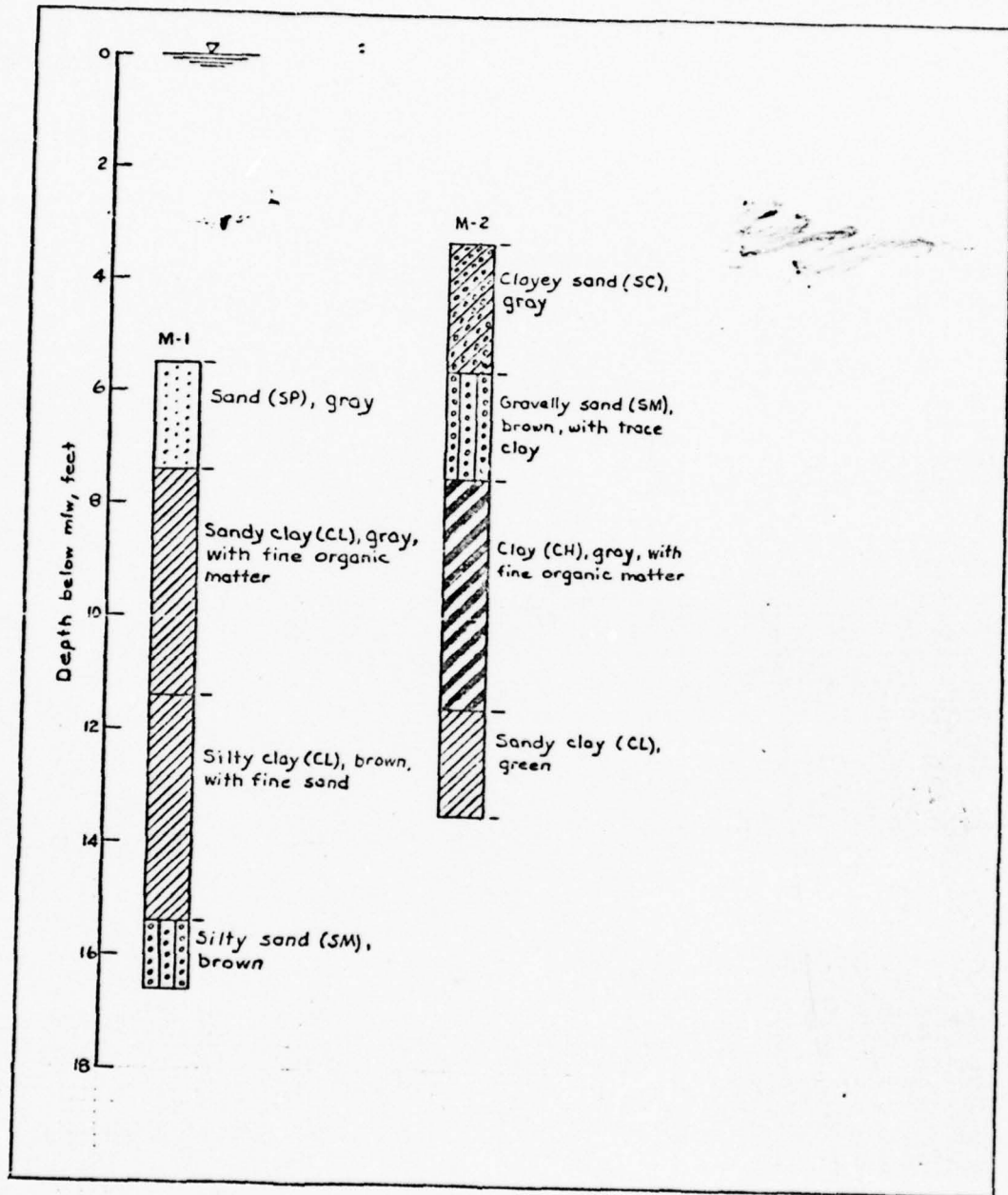


ENG FORM 2097 REFACES WITH FORM NO. 1241, SEP. 1963, WHICH IS OBSOLETE.
 1 MAY 63 U.S. GOVERNMENT PRINTING OFFICE: 1968 O-381-461

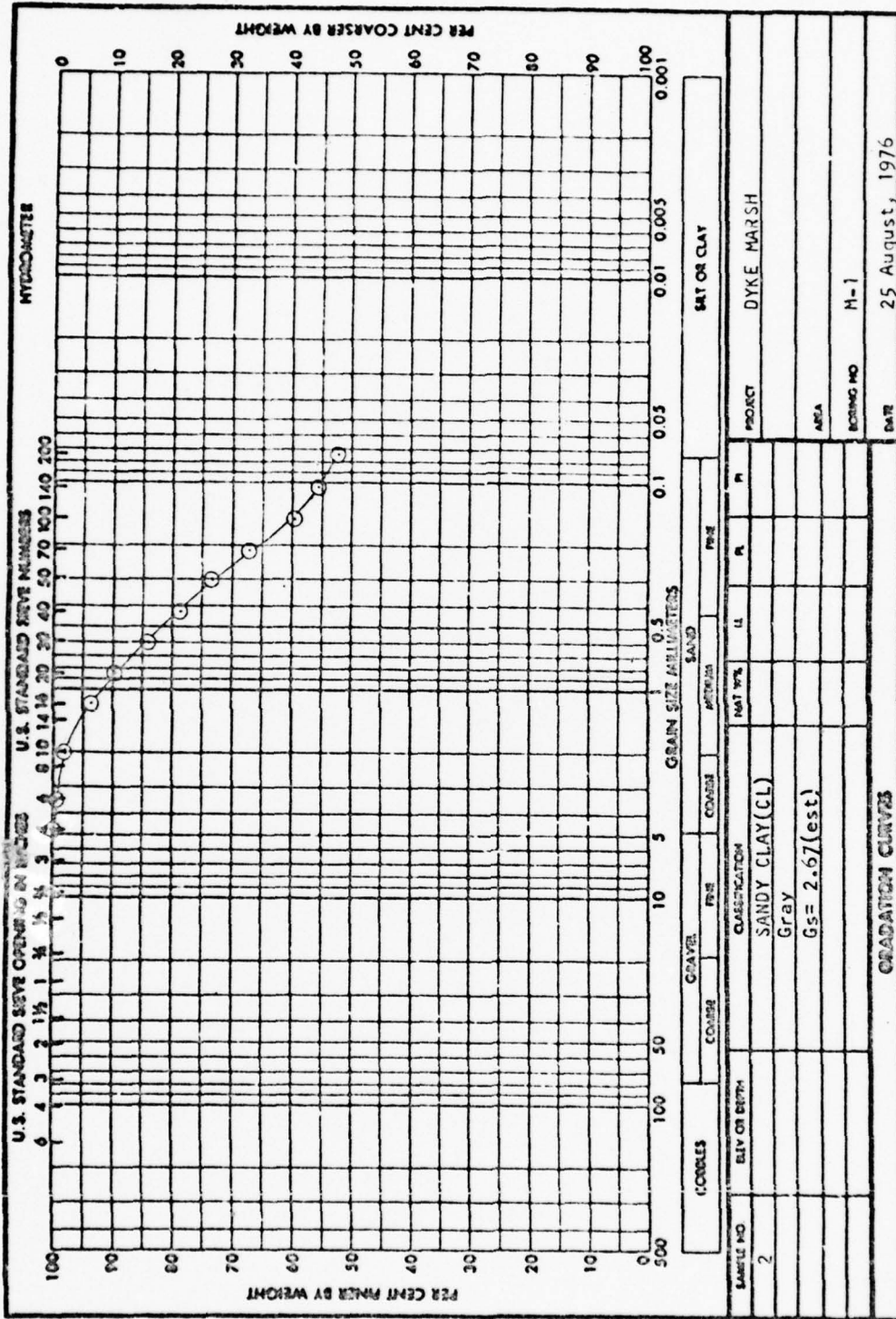


U.S. STANDARD SIEVE OPENING IN INCHES: 6 4 3 2 1 1/2 1 3/4 2 1/2 3 4 5 6 8 10 14 20 30 40 60 100 150 200
 U.S. STANDARD SIEVE NUMBERS: 10 20 30 40 60 100 150 200
 SOIL CLASSIFICATION: SANDY CLAY (CH)
 RECORD
 Gs = 2.72 (est)
 ORGANIC CONTENT: _____
 PROJECT: DYKE MARSH
 AREA: _____
 PCHNG NO: H-6
 DATE: 25 August, 1976
 U.S. GOVERNMENT PRINTING OFFICE: 1965 O-189-184

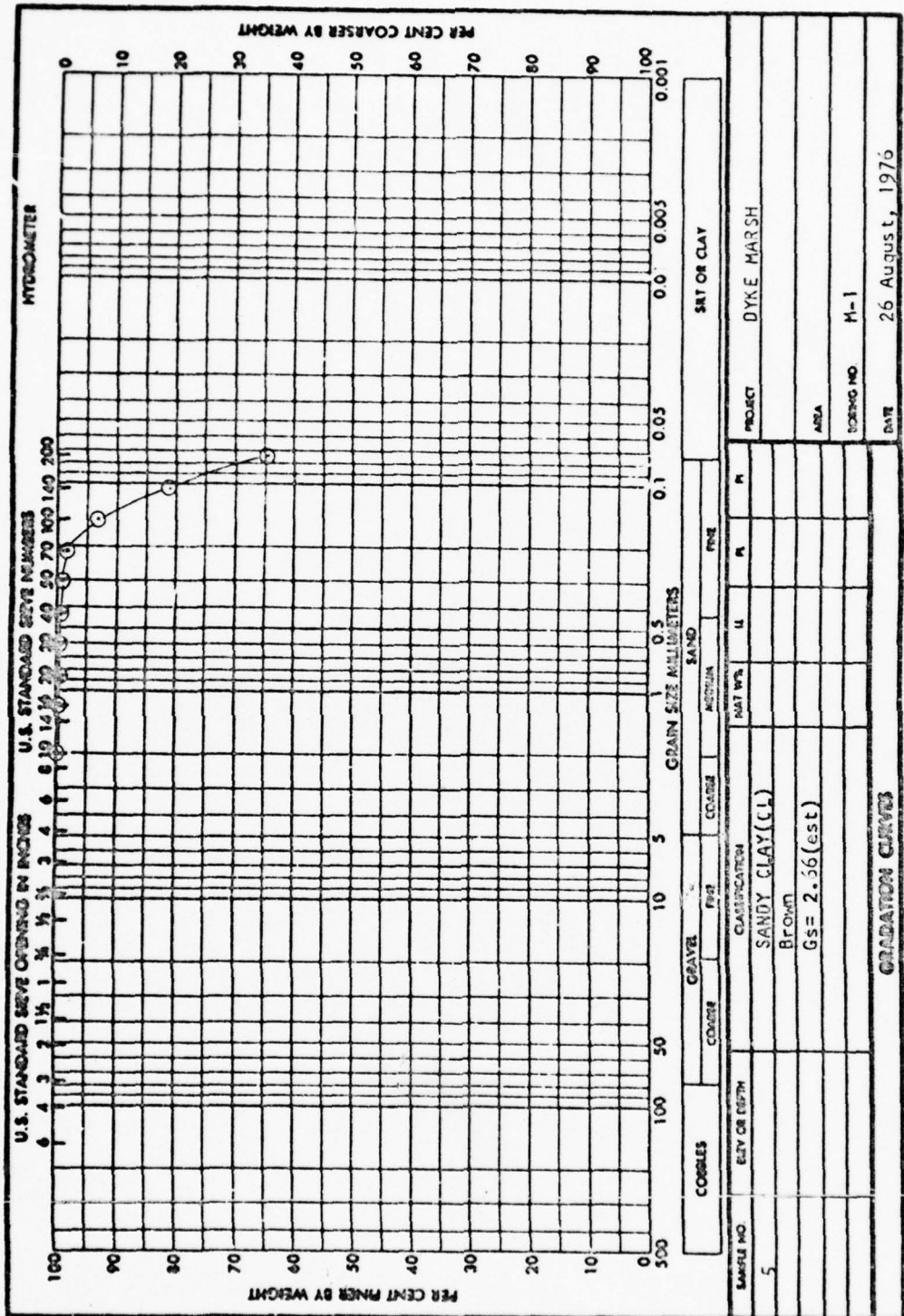
SOIL FORM 2007
 REPLACES WBS FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
 1 MAY 65



B6. Boring Logs for Sand Deposits



SOIL NO. **2087** REPLACES WTS FORM NO. 1261, SEP. 1962, WHICH IS OBSOLETE.
 DATE **25 August, 1976**
 PROJECT **DYKE MARSH**
 AREA
 BORING NO. **M-1**
 DATE



ENG FORM 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
 1 MAY 63 U.S. GOVERNMENT PRINTING OFFICE 168 67-100-100

APPENDIX C: FIELD INVESTIGATIONS AND LABORATORY TESTS--
DEBRIS FILL AREA AND WOODED ISLAND

1. This appendix contains the results of field investigations and laboratory tests conducted to determine the properties of material contained in the debris fill area and along the perimeter of the wooded island adjacent to the proposed demonstration area as shown in Figure 12 of the main text.

2. The debris fill area was formed as a result of dumping building rubble and construction debris from the Washington, D. C. metropolitan area. An access road was constructed from the George Washington Memorial Parkway to the debris fill area, and this road now serves as primary access to the marsh. It is proposed that material from the debris fill be used to construct dike reach E-F as shown in Figure 12 of the main text.

3. Thirty-two general sample borings were taken from the debris fill area as shown in Figure C1. These borings were taken by a truck-mounted rotary drill rig using a conventional auger. The material consists mainly of clayey and silty sand with a mixture of bricks and pieces of asphalt and concrete. The fragments were numerous enough to prevent penetration of most of the auger holes below a depth of a few feet. Graphic logs of the borings are presented in Figures C2 through C5.

4. General samples of sand were taken along the perimeter of the wooded island following the proposed alignment of dike reach A-F as shown in Figure 12 of the main text. Sample locations are shown in Figure C1.

5. Gradation analyses were performed on selected soil samples taken from the debris fill area and wooded island and are presented on pages C7 through C13.

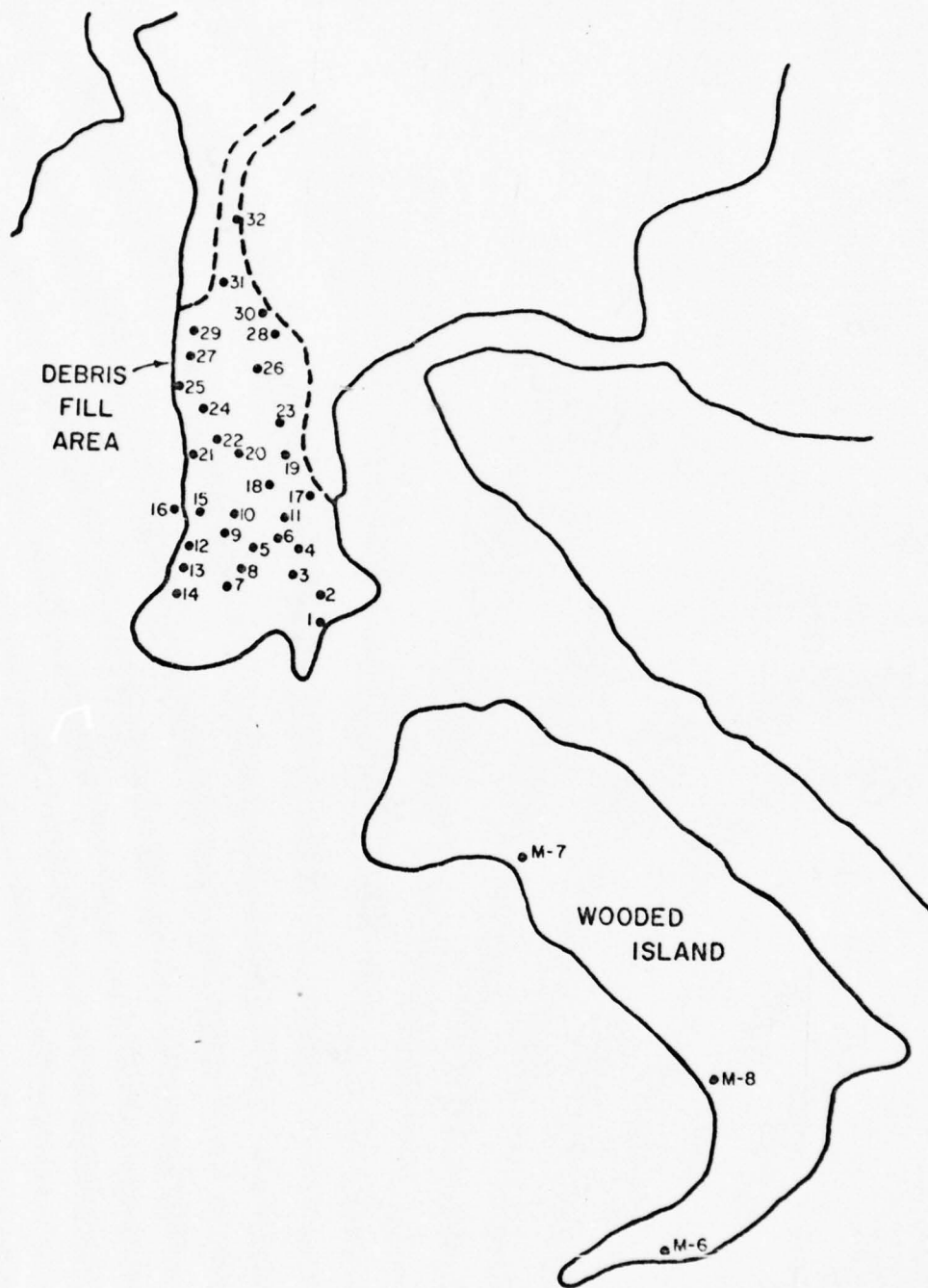


Figure C1. Debris fill and wooded island sample locations

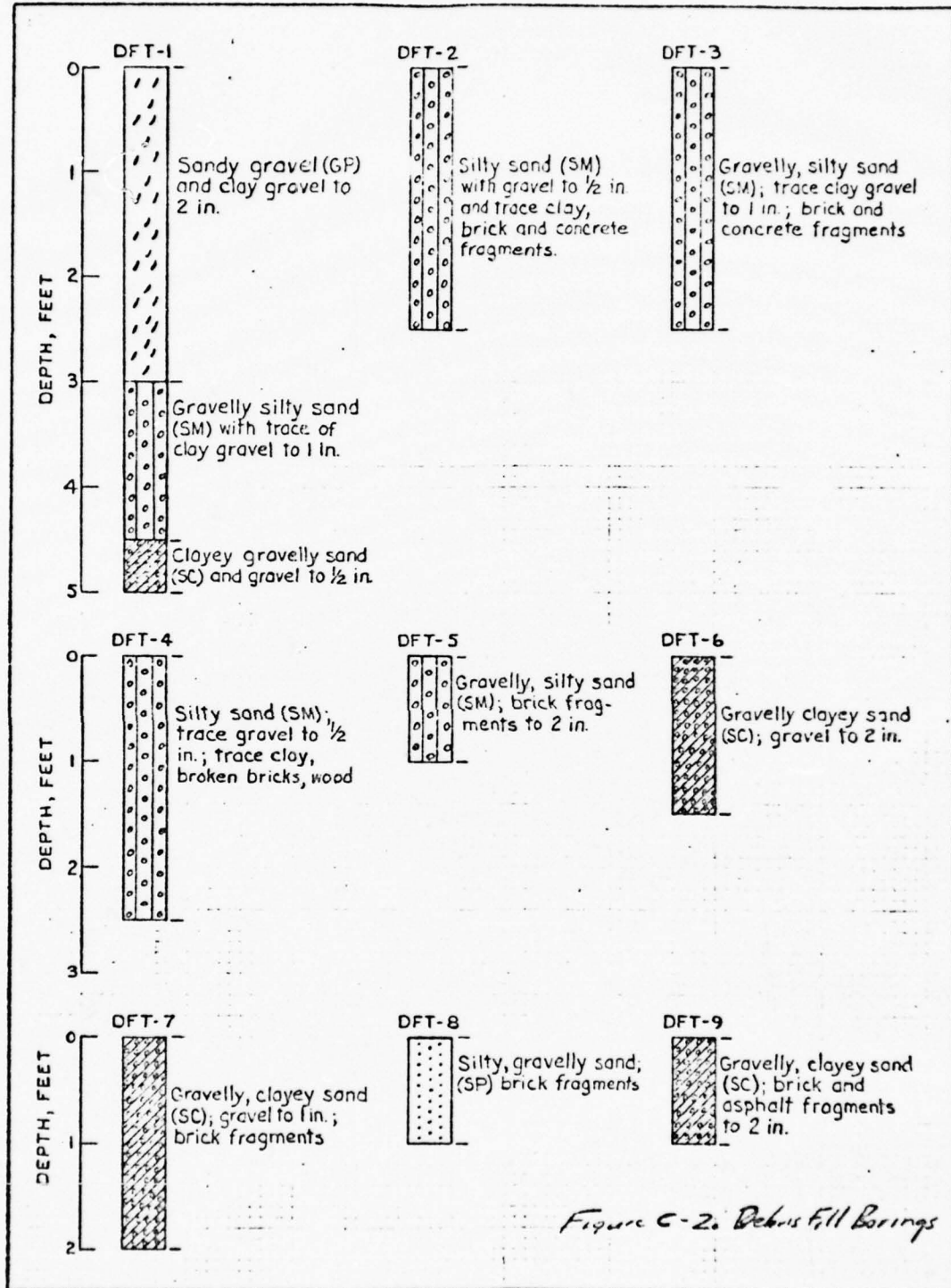


Figure C-2. Debris Fill Borings

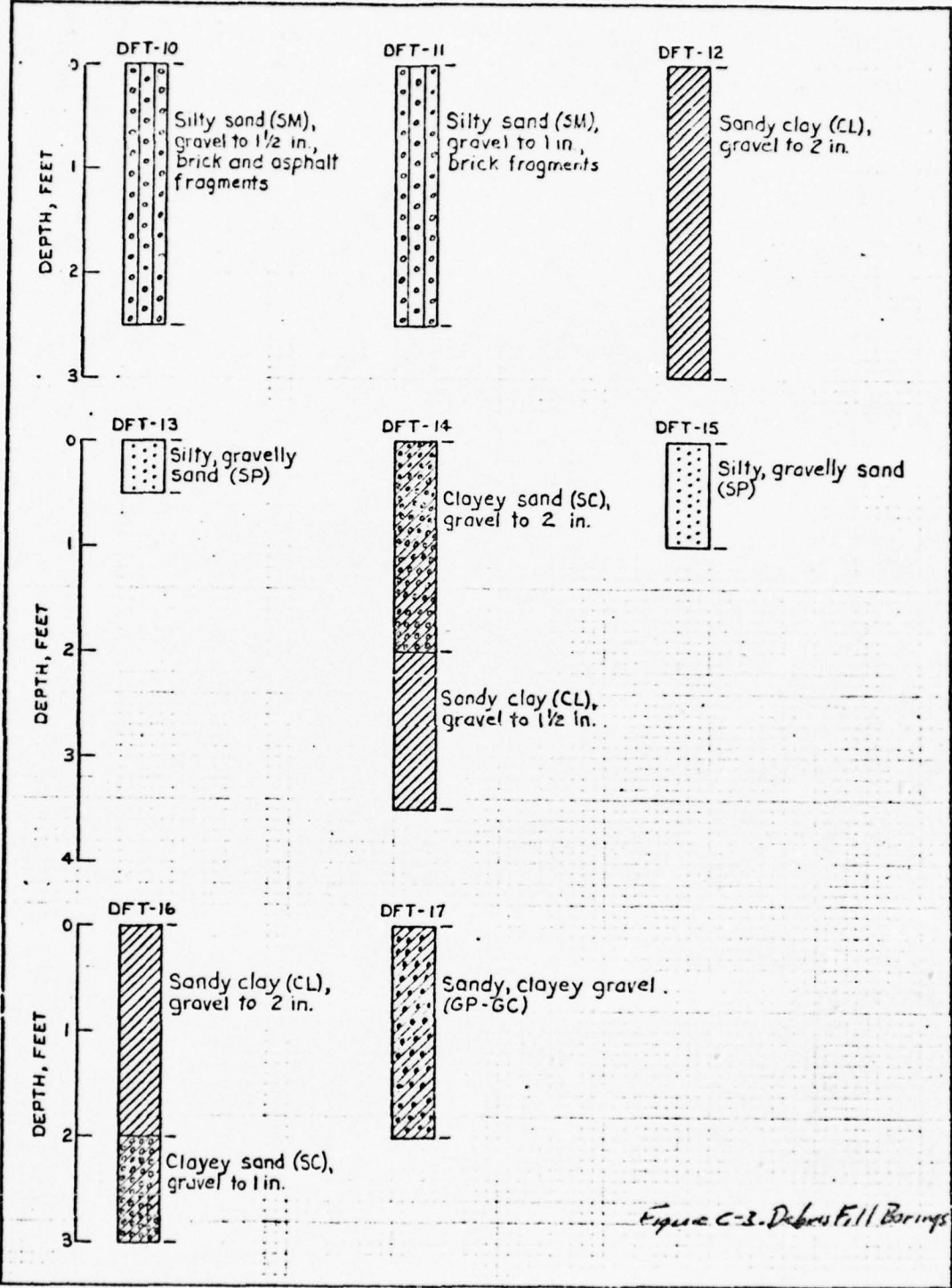


Figure C-3. Debris Fill Borings

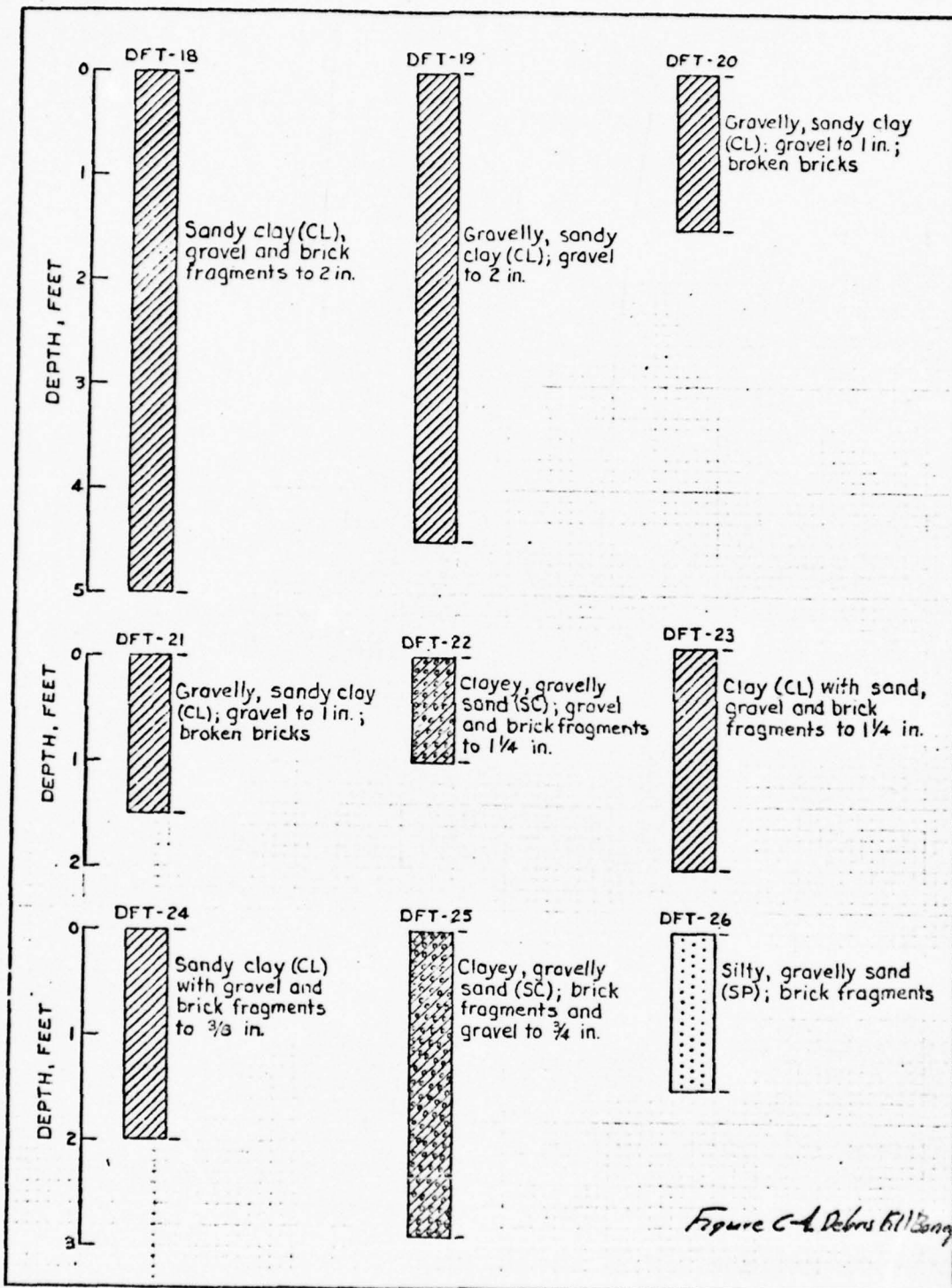


Figure C-4 Debris Fill Soils

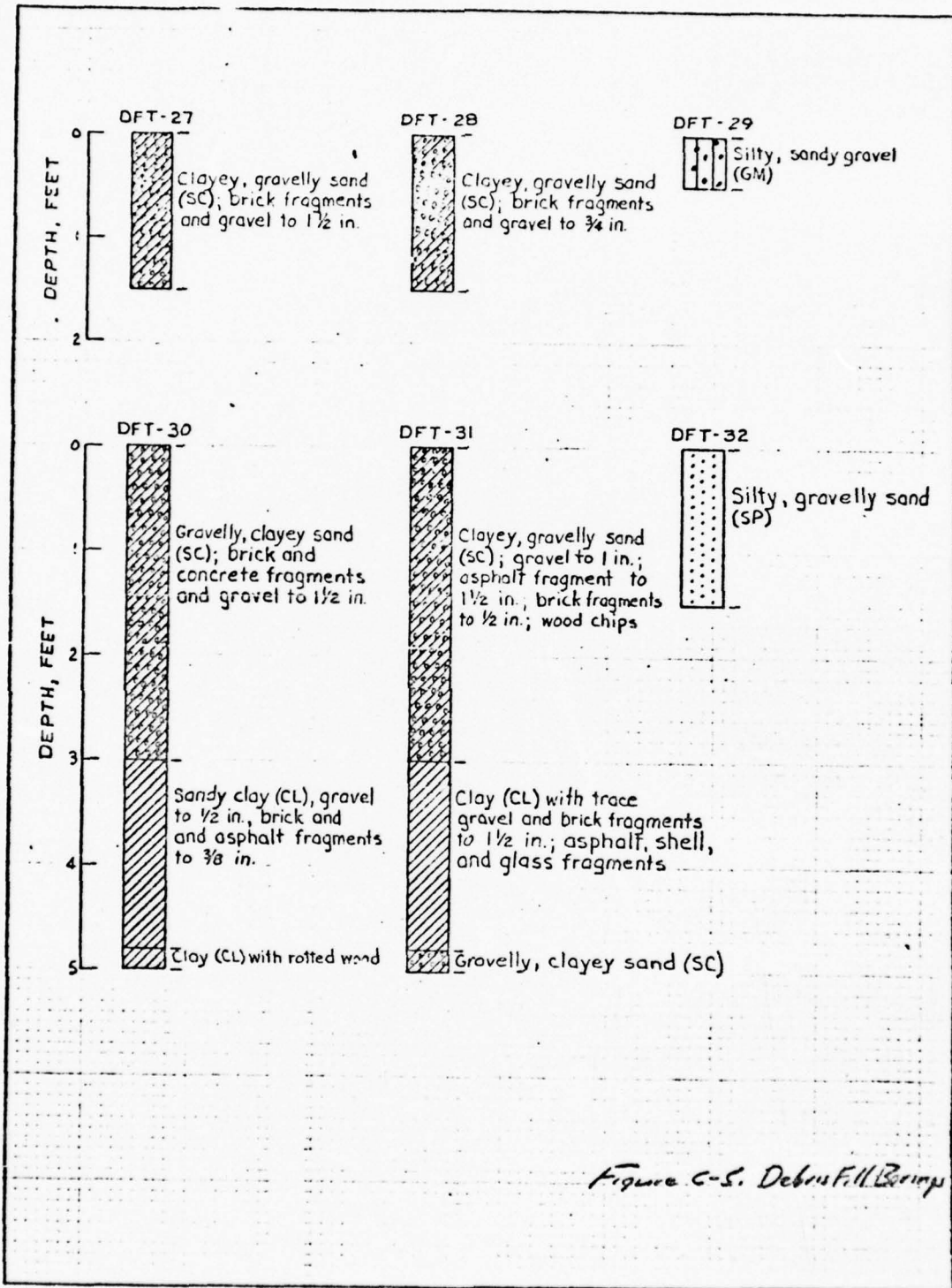
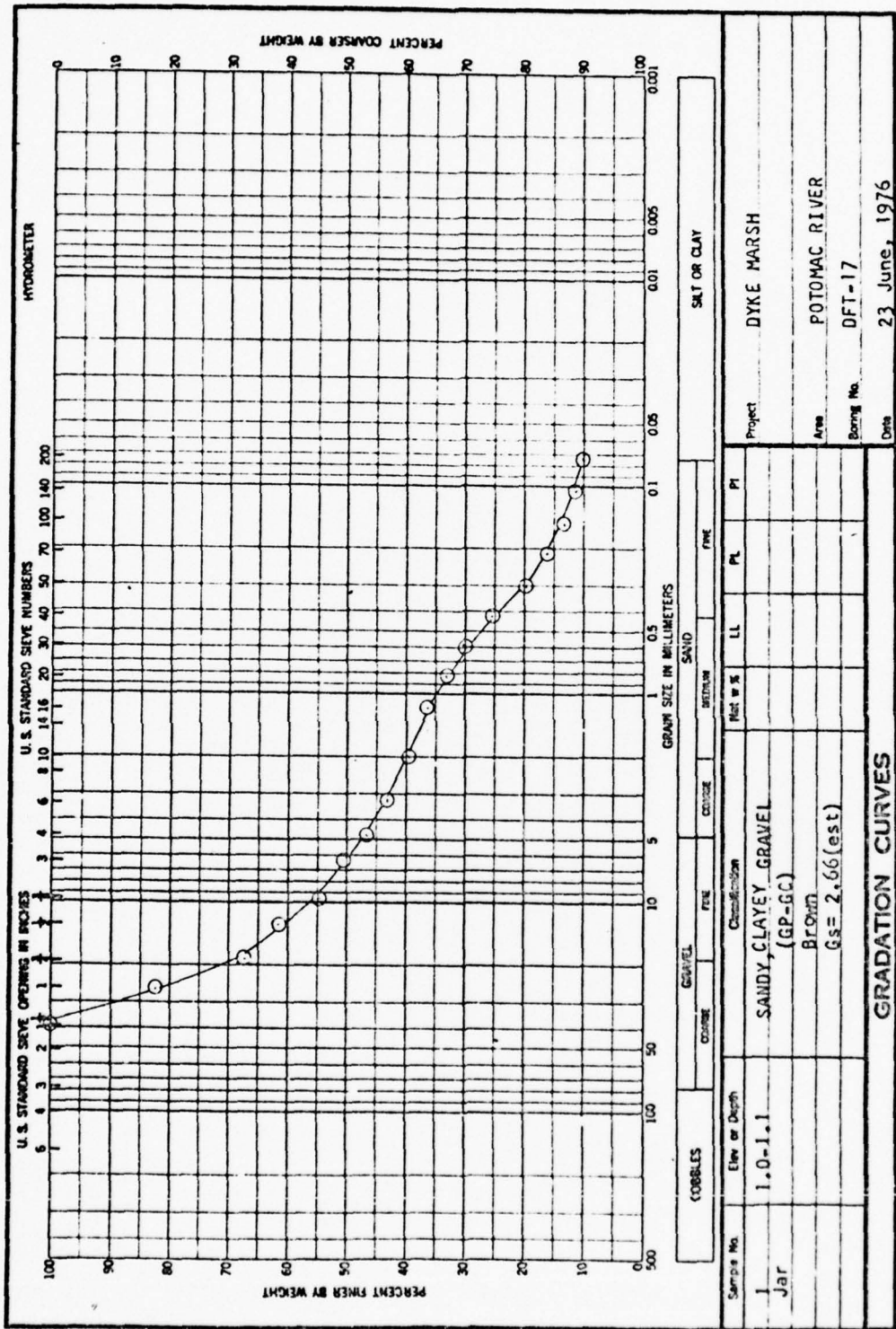
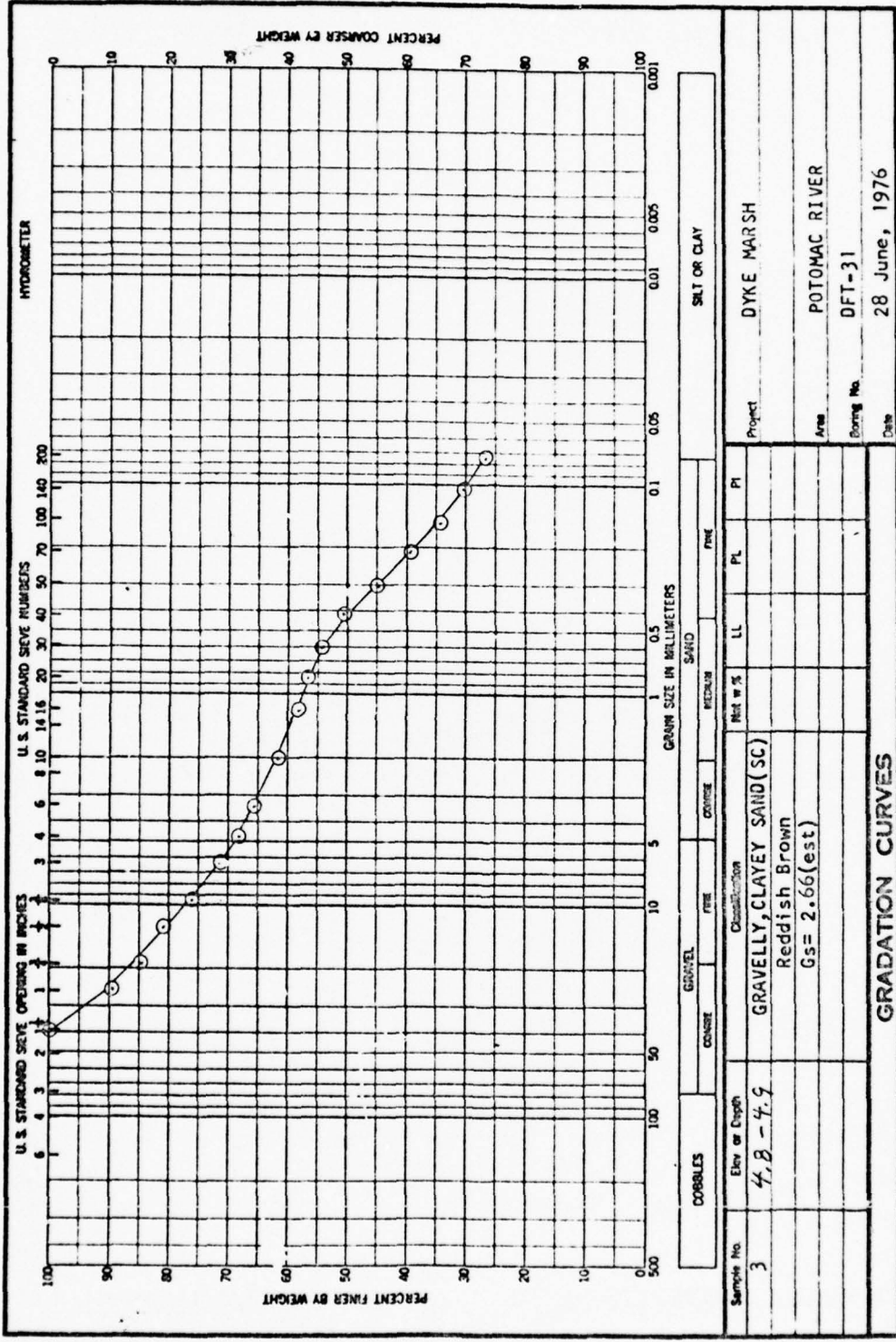


Figure C-5. Debris Fill Borings

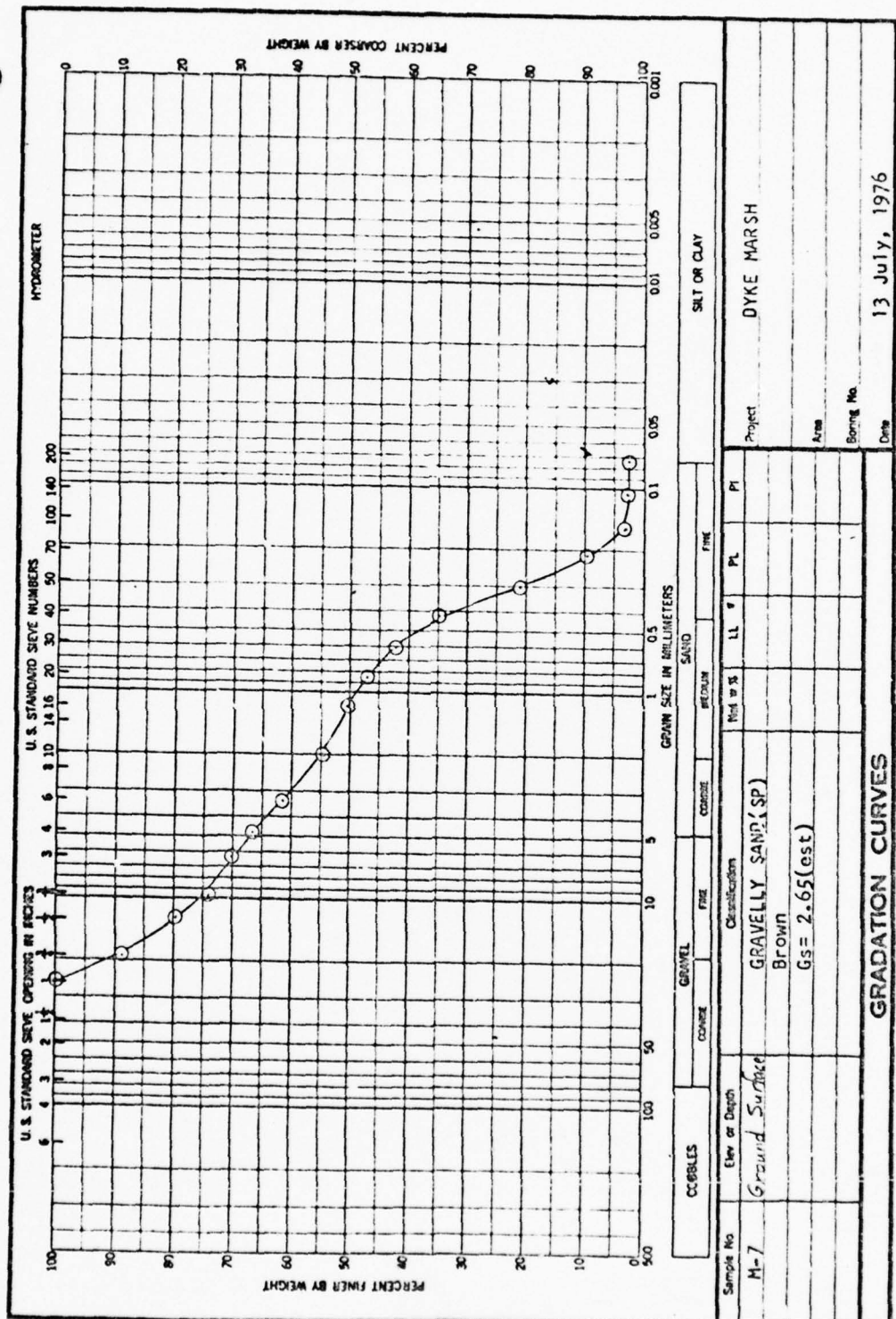


Sample No.	1	Classification	SANDY, CLAYEY GRAVEL (GP-GC) Brown Gs = 2.66 (est)
Elev or Depth	1.0-1.1	Moisture %	
		LL	
		PL	
		PI	
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	DFT-17		
Date	23 June, 1976		

GRADATION CURVES



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GRADATION CURVES

13 July, 1976

Project DYKE MARSH

APPENDIX D: LABORATORY TESTS OF FOUNDATION SOILS

1. Four foundation borings numbered DM-4 through DM-7 were made for the detailed design study to supplement data from the initial feasibility study borings DM-1 through DM-3. The borings were made from a barge-mounted rotary drill rig in 7 to 10 ft of water. Locations of the borings are shown in Figure 11 and graphic boring logs are shown in Figures 13 and 14 of the main text. Individual test data results from borings DM-4 through DM-7 are presented in this appendix. Individual test data results from borings DM-1 through DM-3 were presented in the report of the feasibility study.¹

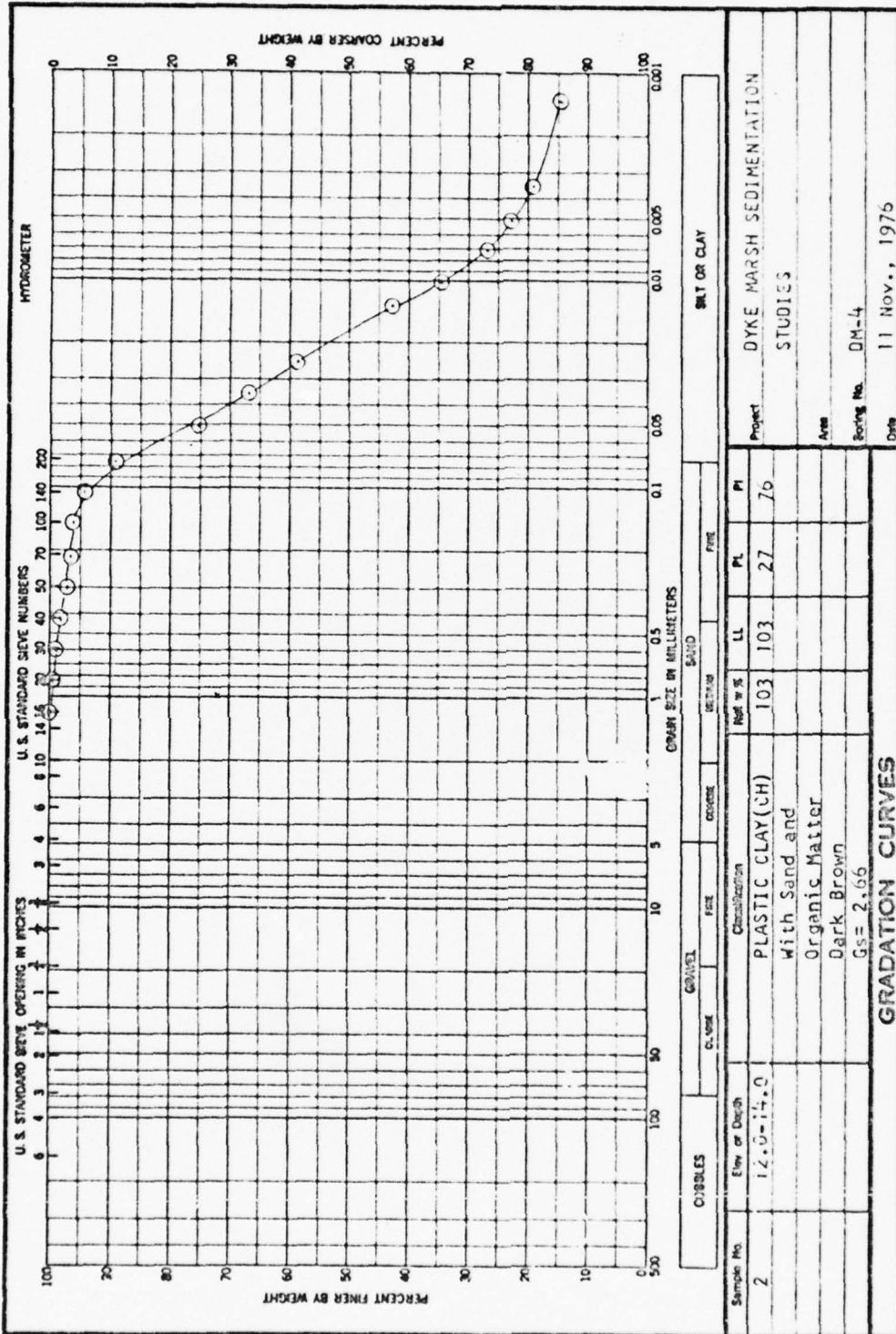
2. Laboratory tests performed on undisturbed and general samples from these borings included classifications under the USCS, grain-size analysis, Atterberg limits, unconfined compression tests, consolidated undrained R triaxial tests, and one conventional consolidation test. Results of the tests were used in analysis of dike slope stability, dike settlement, and foundation settlement following placement of the dredged material substrate.

3. Grain-size analyses were performed on selected coarse-grained samples and are presented on pages D3 through D44. Atterberg limits, shown plotted on the plasticity chart on page D45, are plotted adjacent to the A-line, indicating the foundation material throughout the demonstration area has plasticity properties similar to the channel sediment material, as shown in Appendix A.

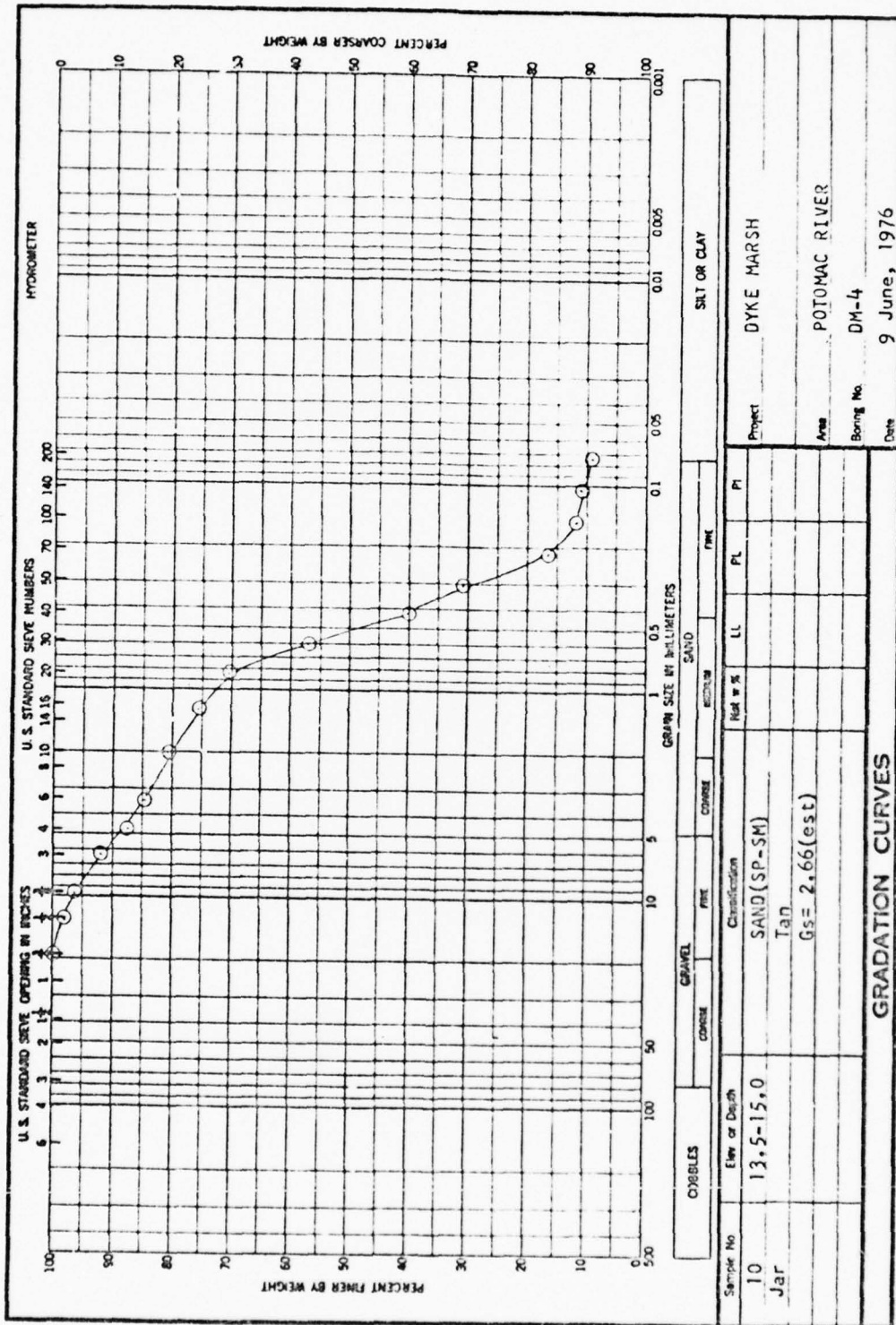
4. Two unconfined compression tests were performed on clay samples from boring DM-4 located in the upper clay layers. One R triaxial test was performed on a silt sample taken from boring DM-6. Results of these tests are presented on pages D46 through D49.

5. Shear strengths for slope stability analysis were selected based on plots of shear strength versus depth for clays presented on page D50 and plots of R triaxial results for silts presented on page D51. Results of tests from borings DM-1 through DM-3 are also shown on these plots. Saturated unit weights for silts were determined from the triaxial tests and are presented on page D51.

6. One conventional consolidation test was performed on the foundation clays. Consolidation test results and time curves are presented on pages D52 through D61.

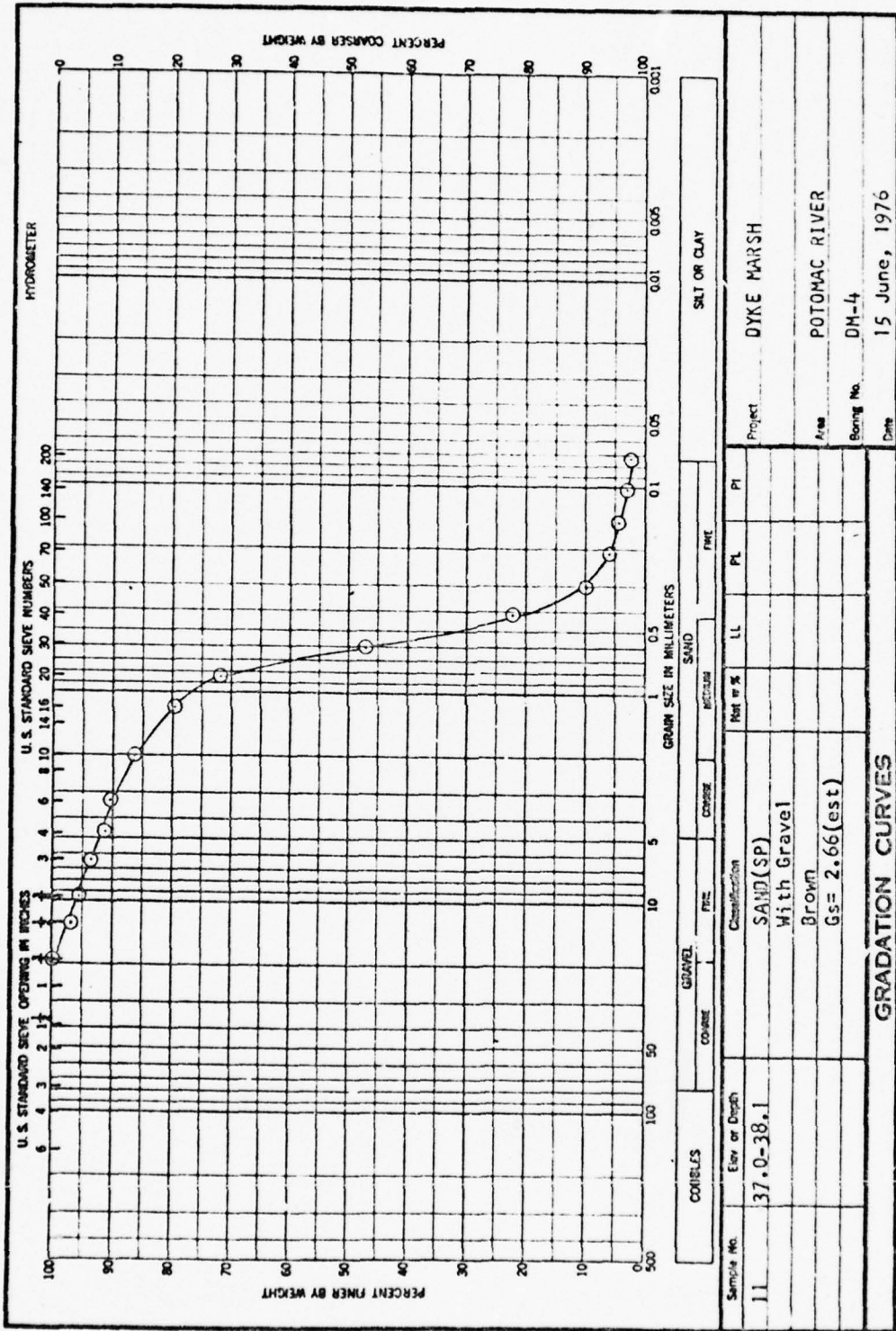


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D4

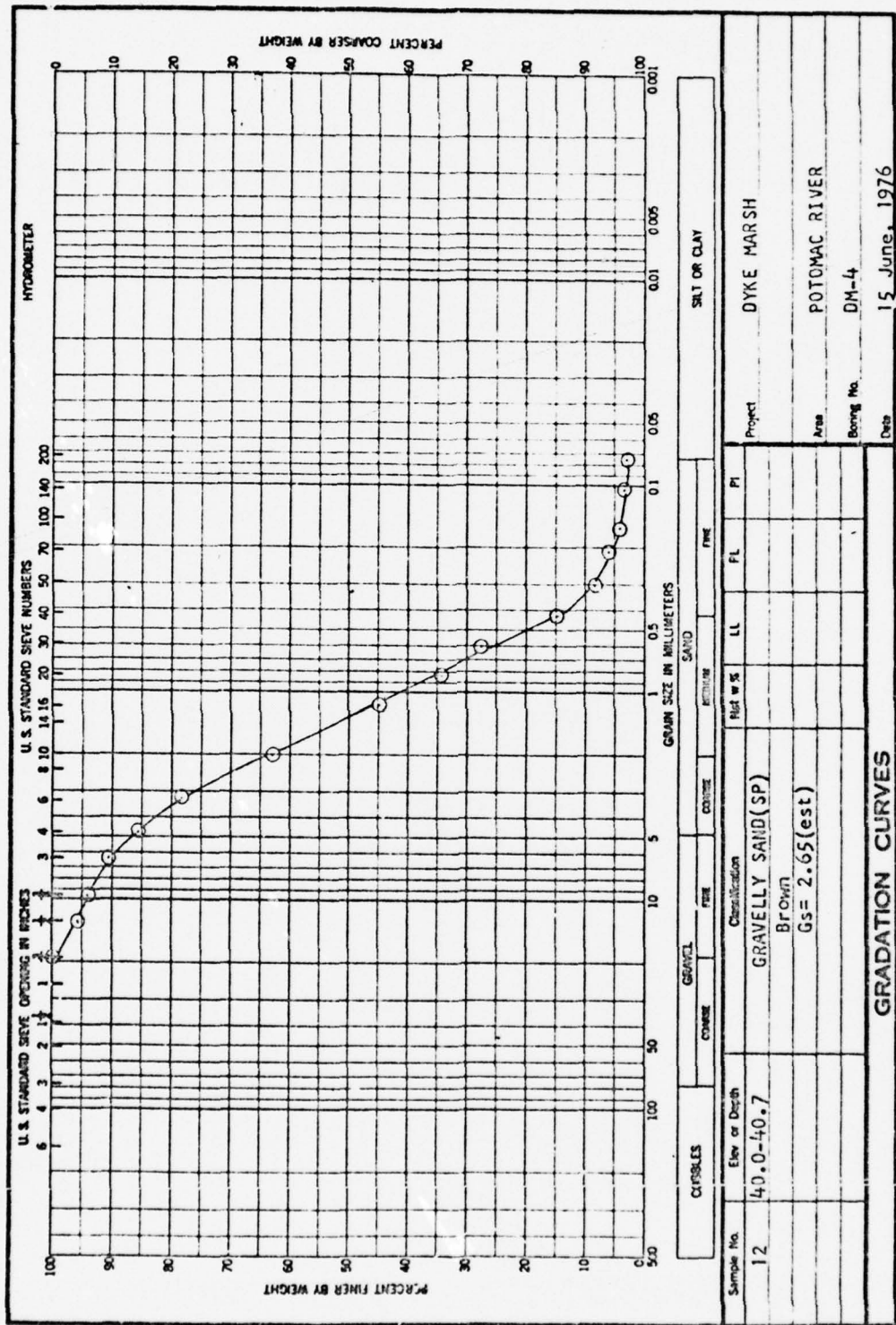
ENG FORM 1 MAY 63 2087



Sample No.	37.0-38.1	Classification	SAND (sp) With Gravel Brown Gs = 2.66 (est)	Moisture		LL		PL		PI	
Est. or Depth											
Project	DYKE MARSH										
Area	POTOMAC RIVER										
Boring No.	DM-4										
Date	15 June, 1976										

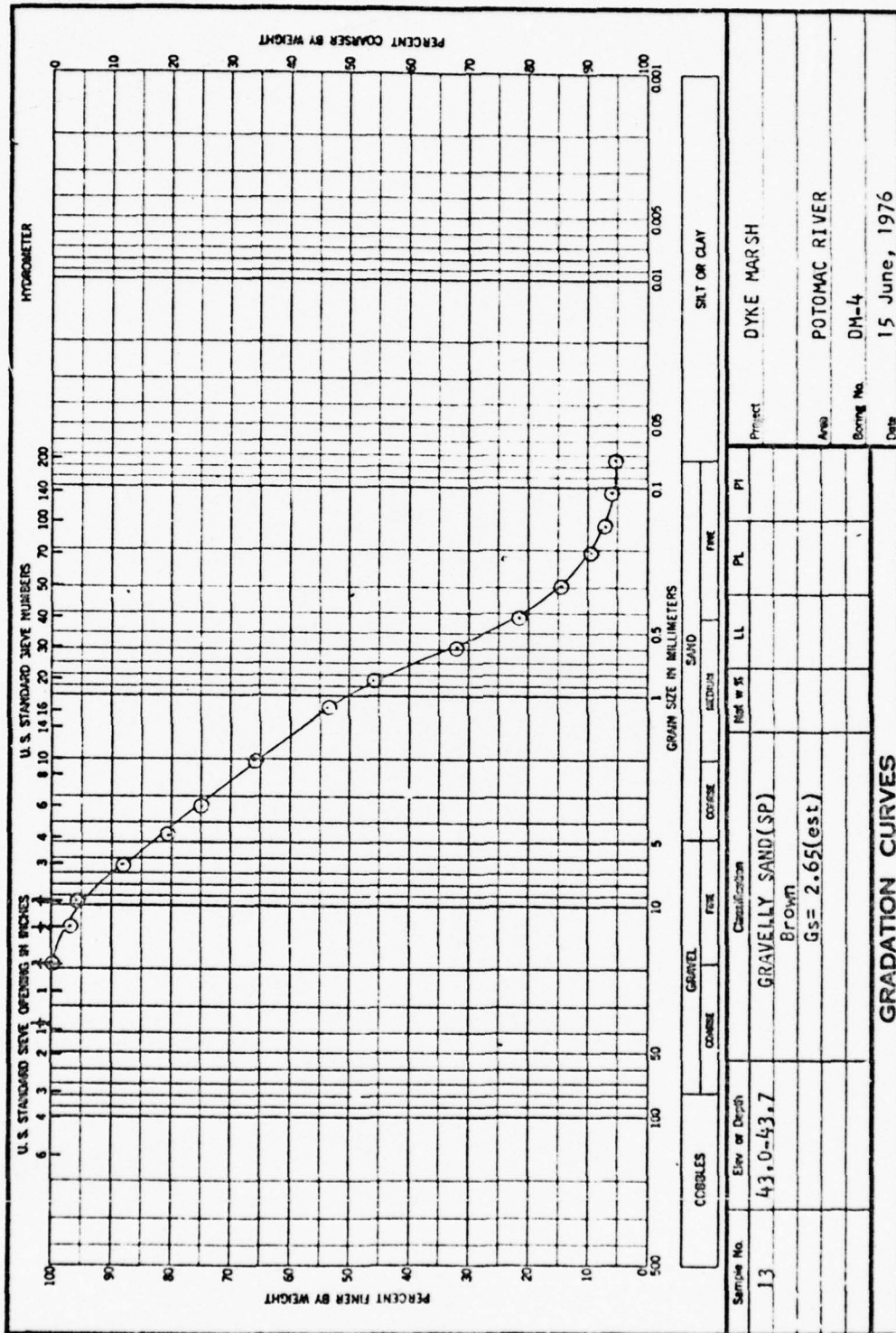
GRADATION CURVES

ENG FORM 1 MAY 63 2007

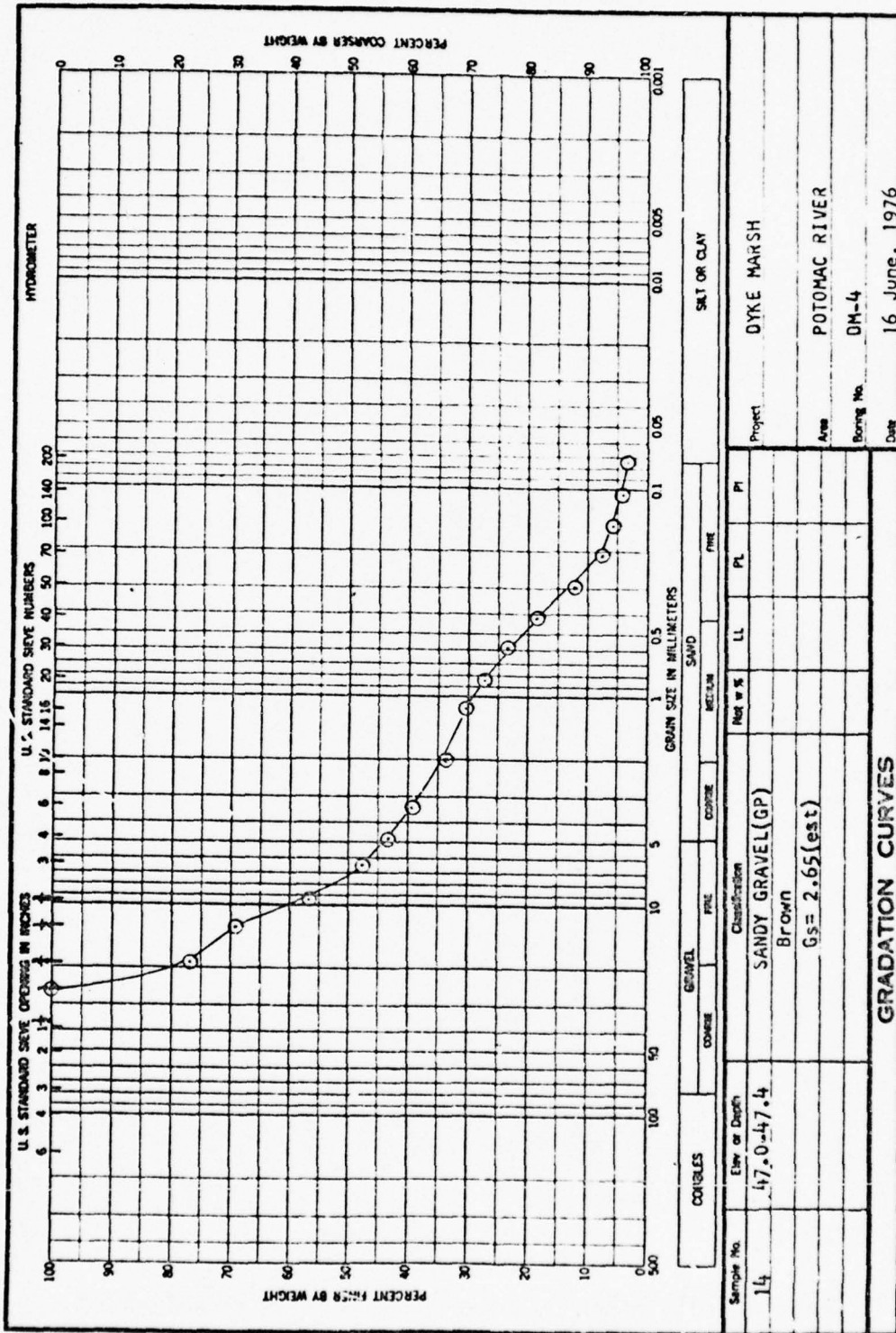


GRADATION CURVES

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1 MAY 63

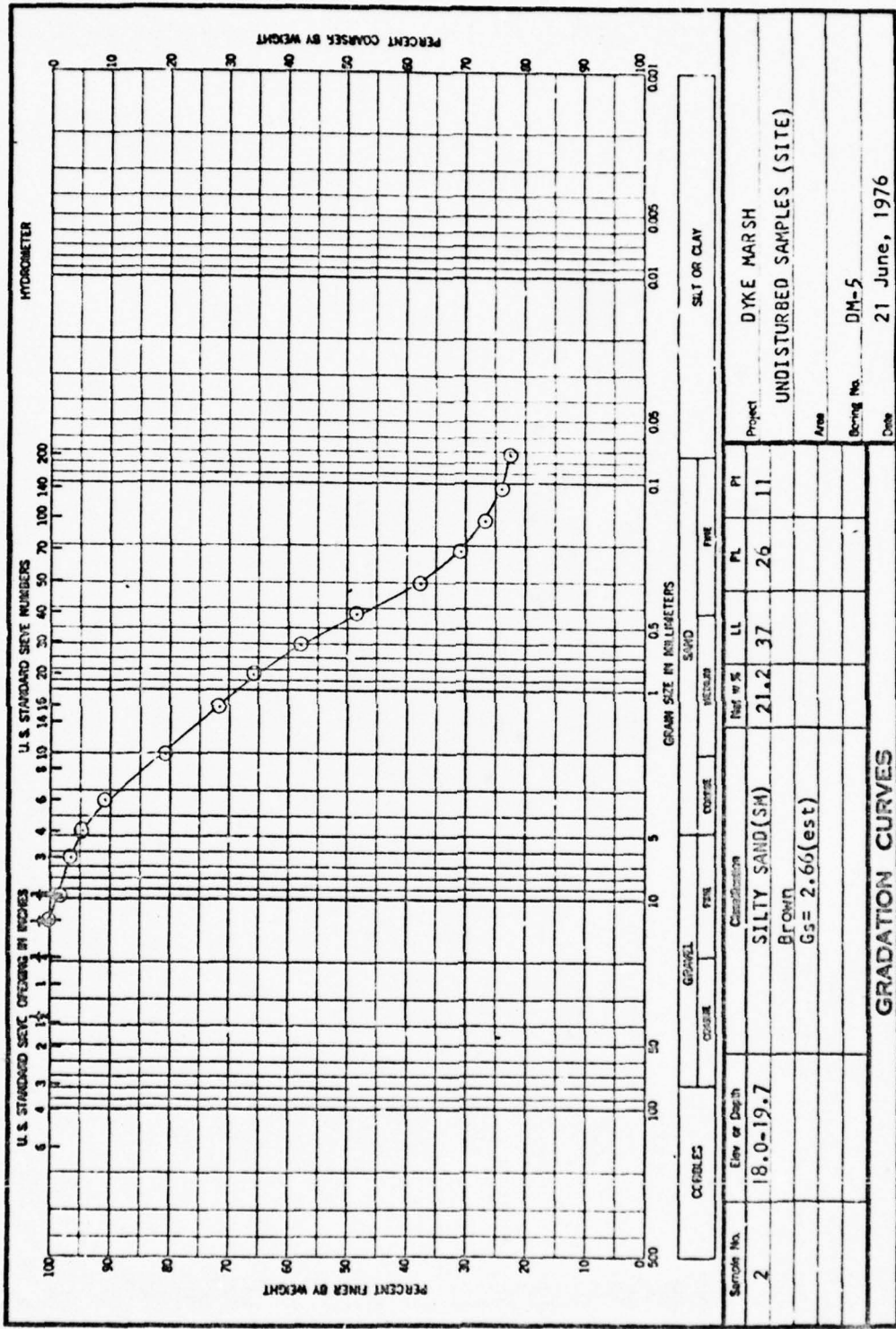


ENG FORM 2087
1 MAY 62



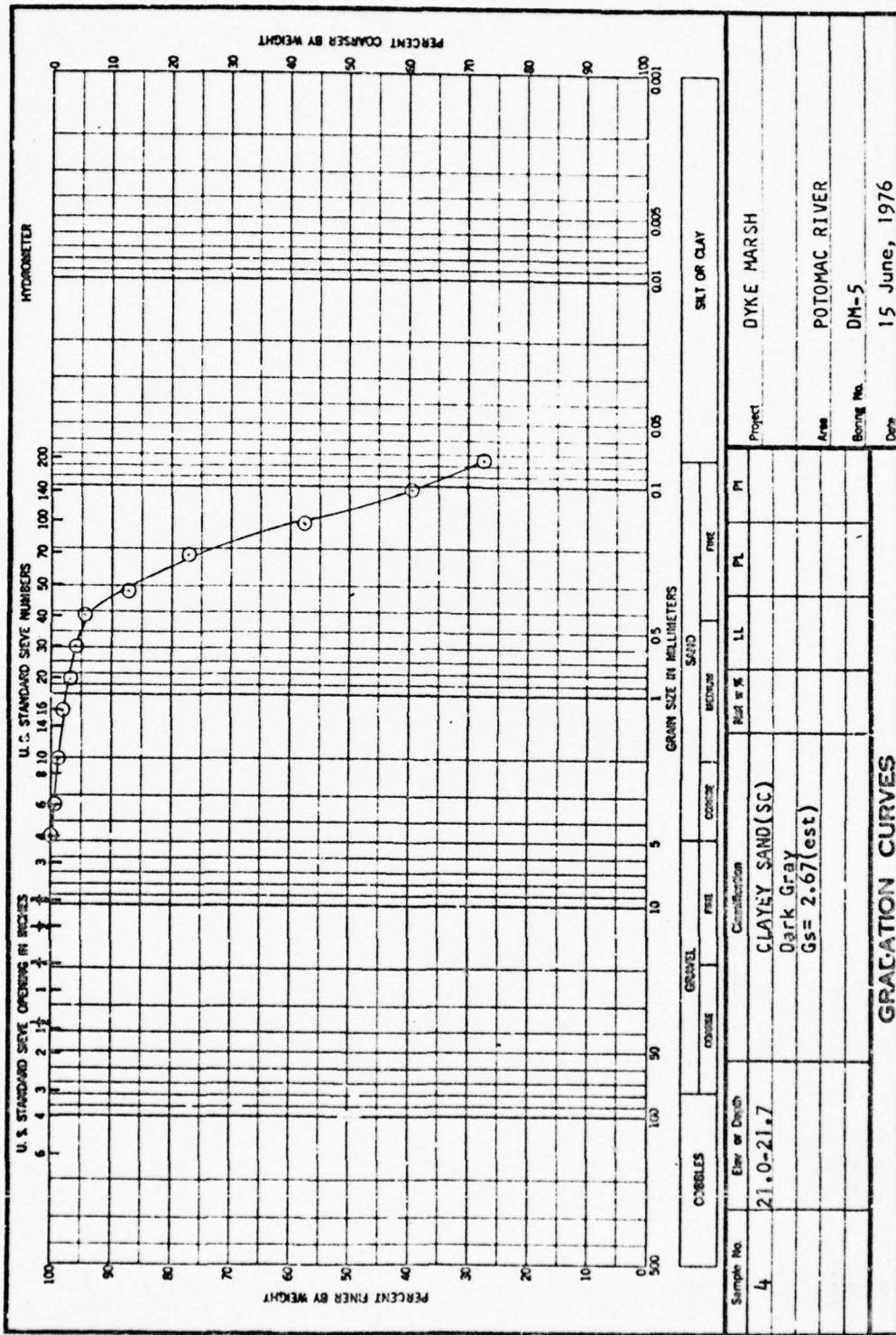
GRAVIMETRIC DATA

ENG FORM 2087
1 MAY 63

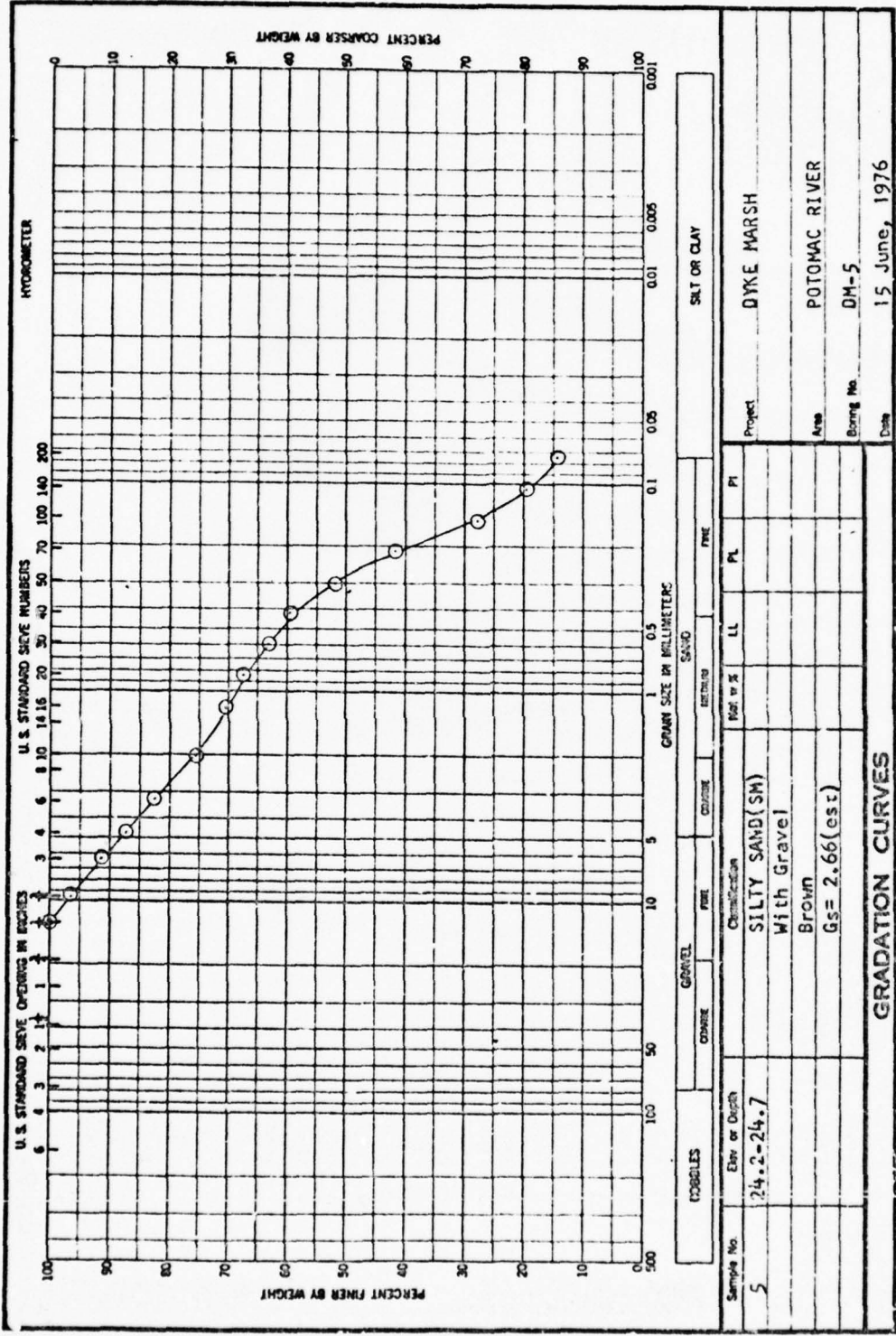


Sample No.	2	U.S. STANDARD SEIVE OPENING IN INCHES	U.S. STANDARD SEIVE NUMBERS	HYDROMETER	PERCENT FINER BY WEIGHT	PERCENT COARSER BY WEIGHT
Site or Depth	18.0-19.7	Classification		SILT OR CLAY		
		SILTY SAND (SM)		DYKE MARSH		
		Brown		UNDISTURBED SAMPLES (SITE)		
		Gs = 2.66 (est)		Area		
		LL	21.2	PI	26	11
GRADATION CURVES						
Project		DM-5				
Date		21 June, 1976				

ENG FORM 1 MAY 63 2187

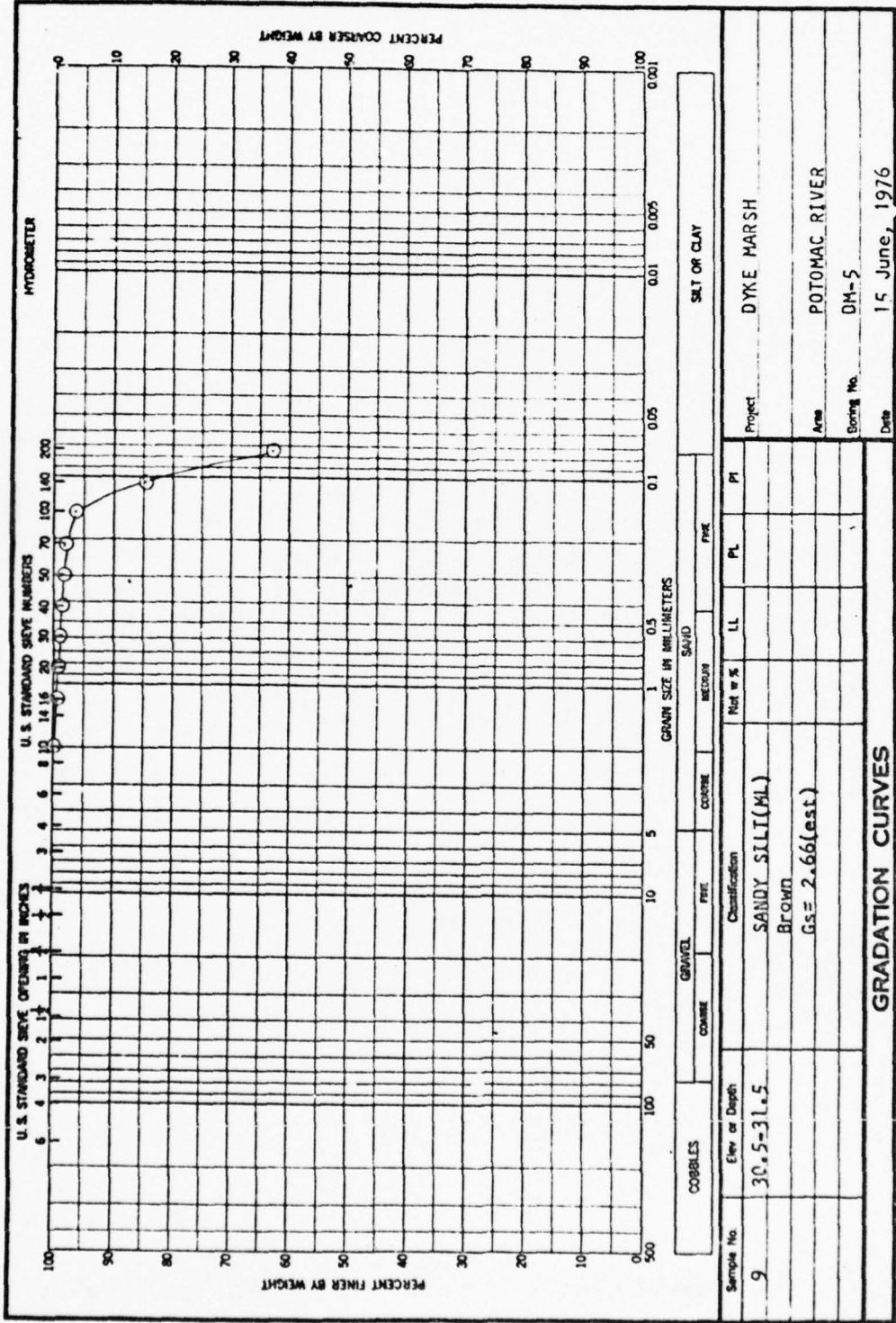


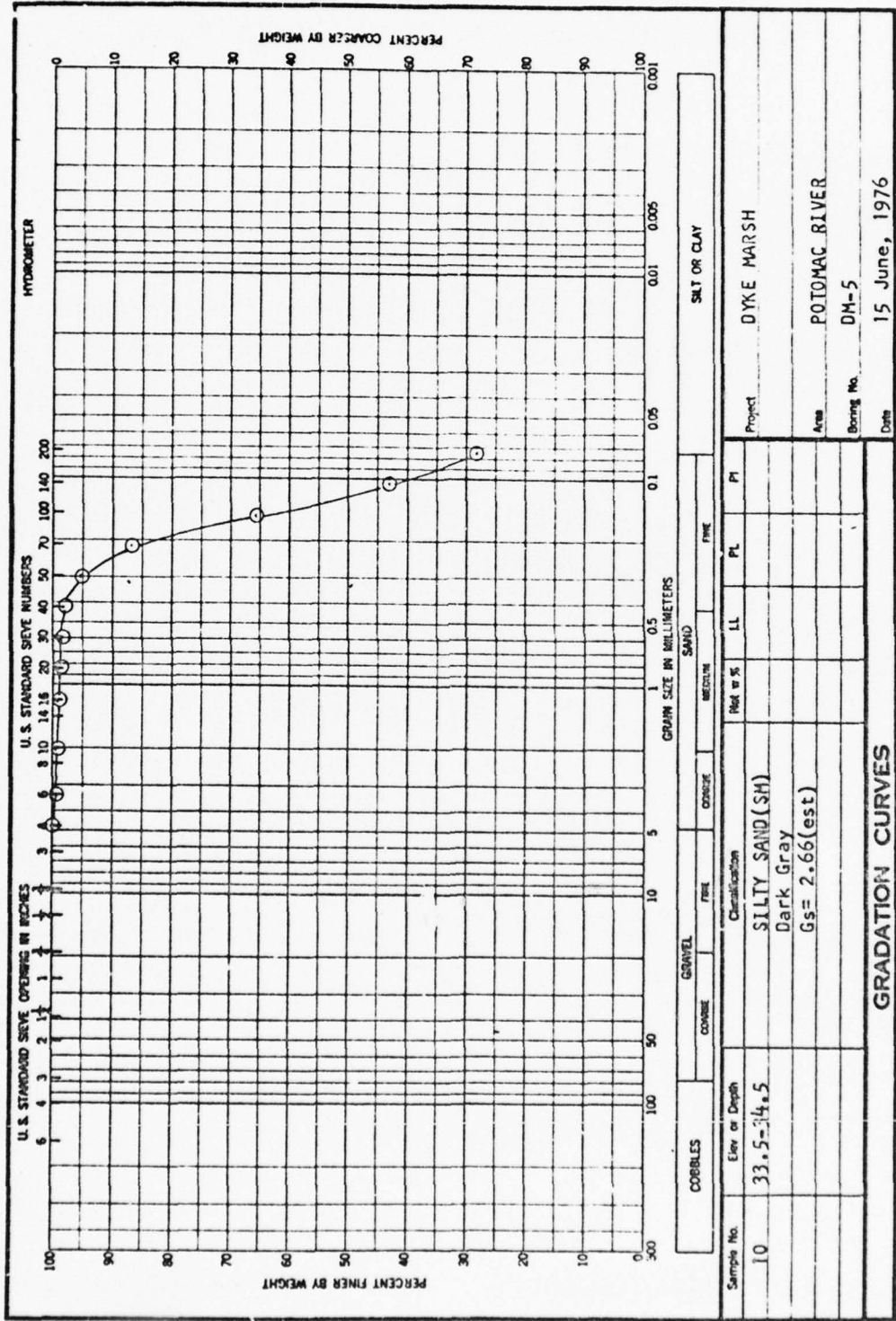
ENG FORM 2087
1 MAY 68



D11

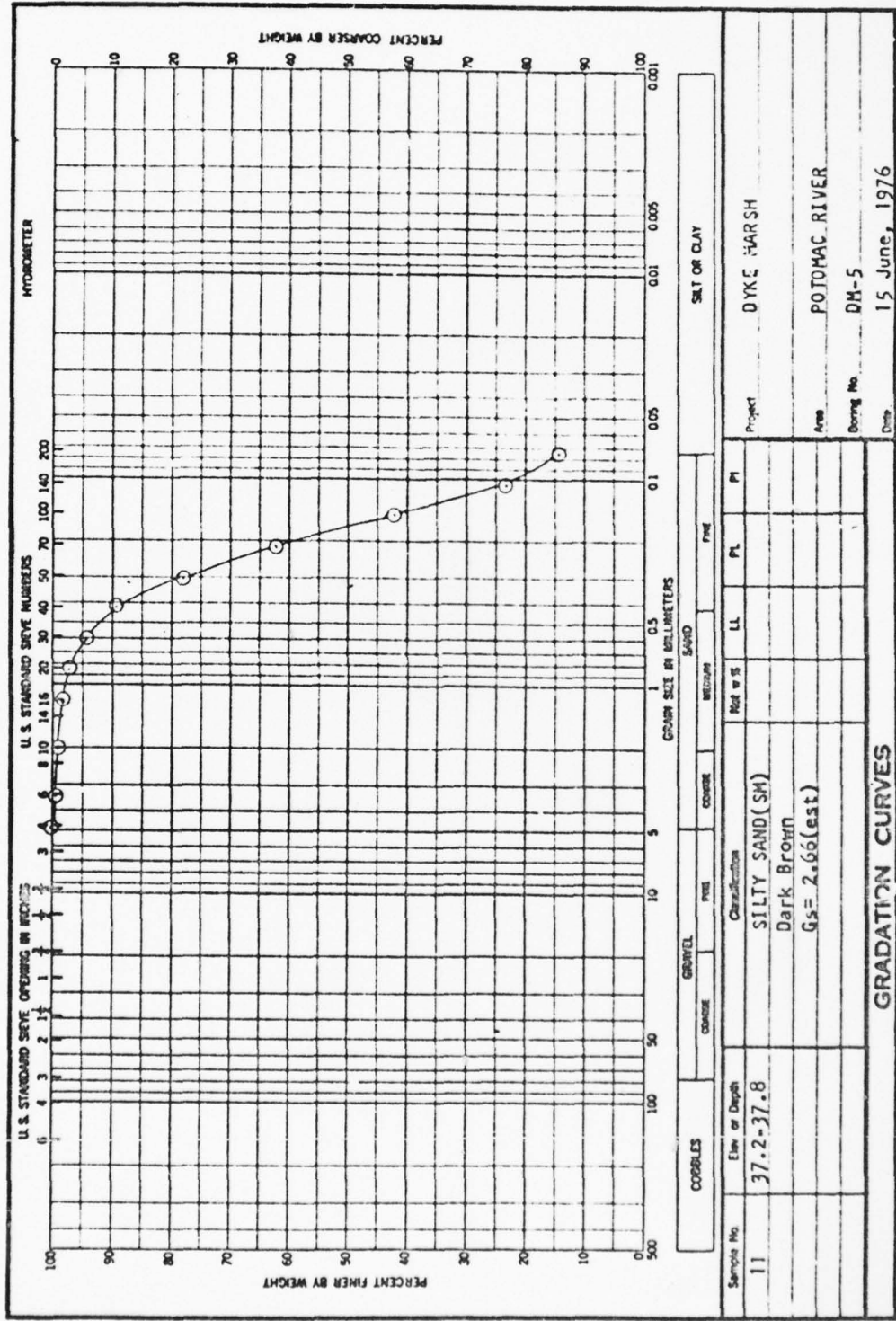
ENG FORM
1 MAY 62 2017





Sample No.	10	Elev or Depth	33.5-34.5	Classification	SILTY SAND(SH) Dark Gray Gs= 2.66(est)	Field w %		LL		PL		PI	
<p>COBBLES</p> <p>GRAVEL</p> <p>SAND</p> <p>SILT OR CLAY</p>													
<p>Project: DYKE MARSH</p> <p>Area: POTOMAC RIVER</p> <p>Boring No: DM-5</p> <p>Date: 15 June, 1976</p>													
<p>GRADATION CURVES</p>													

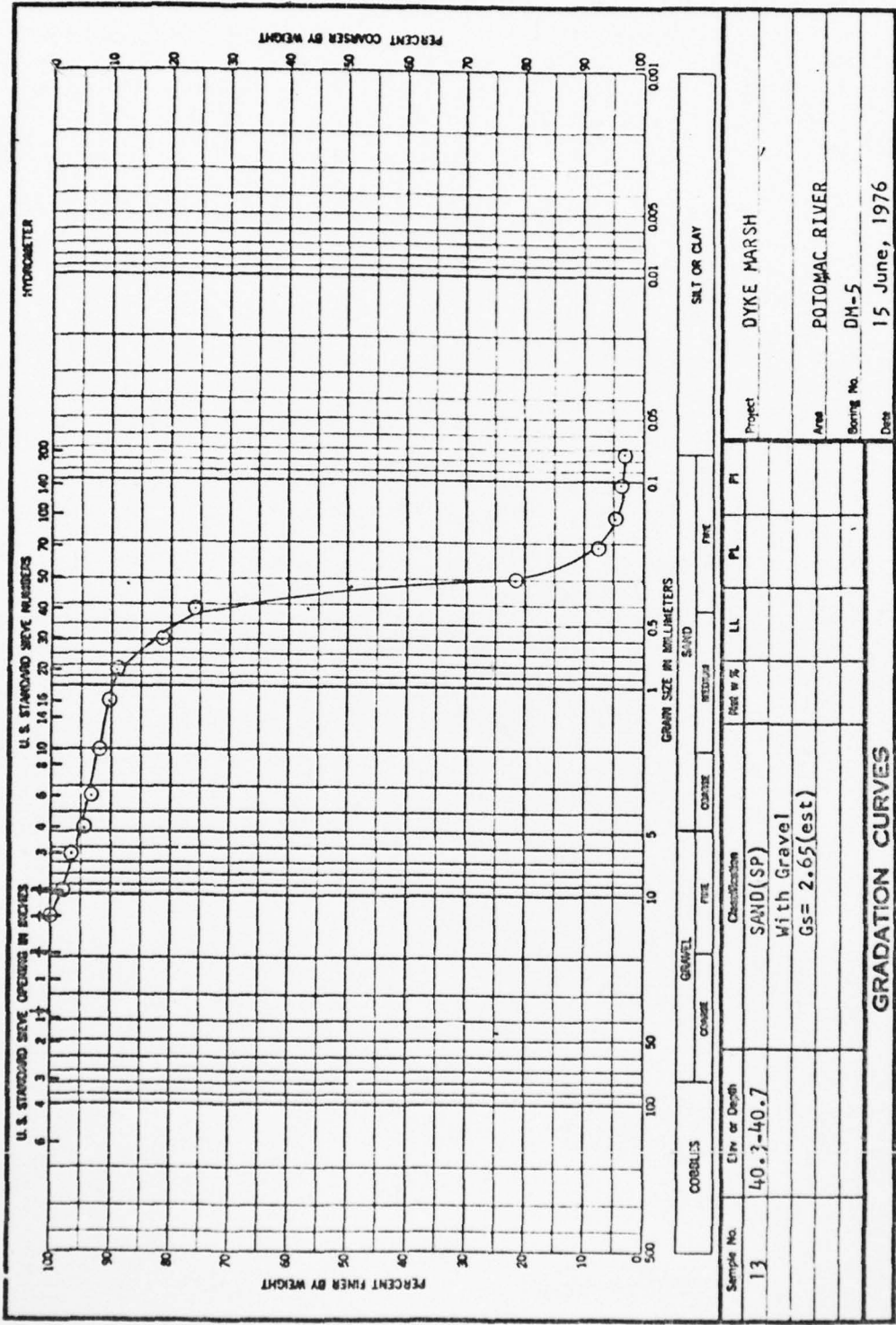
ENG FORM 1 MAY 63 2087



Sample No.	11	Elev or Depth	37.2-37.8
Classification	SILTY SAND (SH) Dark Brown G _s = 2.66 (est)		
Moisture	LL	PL	PI
Silt or Clay	DYKE MARSH		
Area	POTOMAC RIVER		
Drilling No.	DM-5		
Date	15 June, 1976		

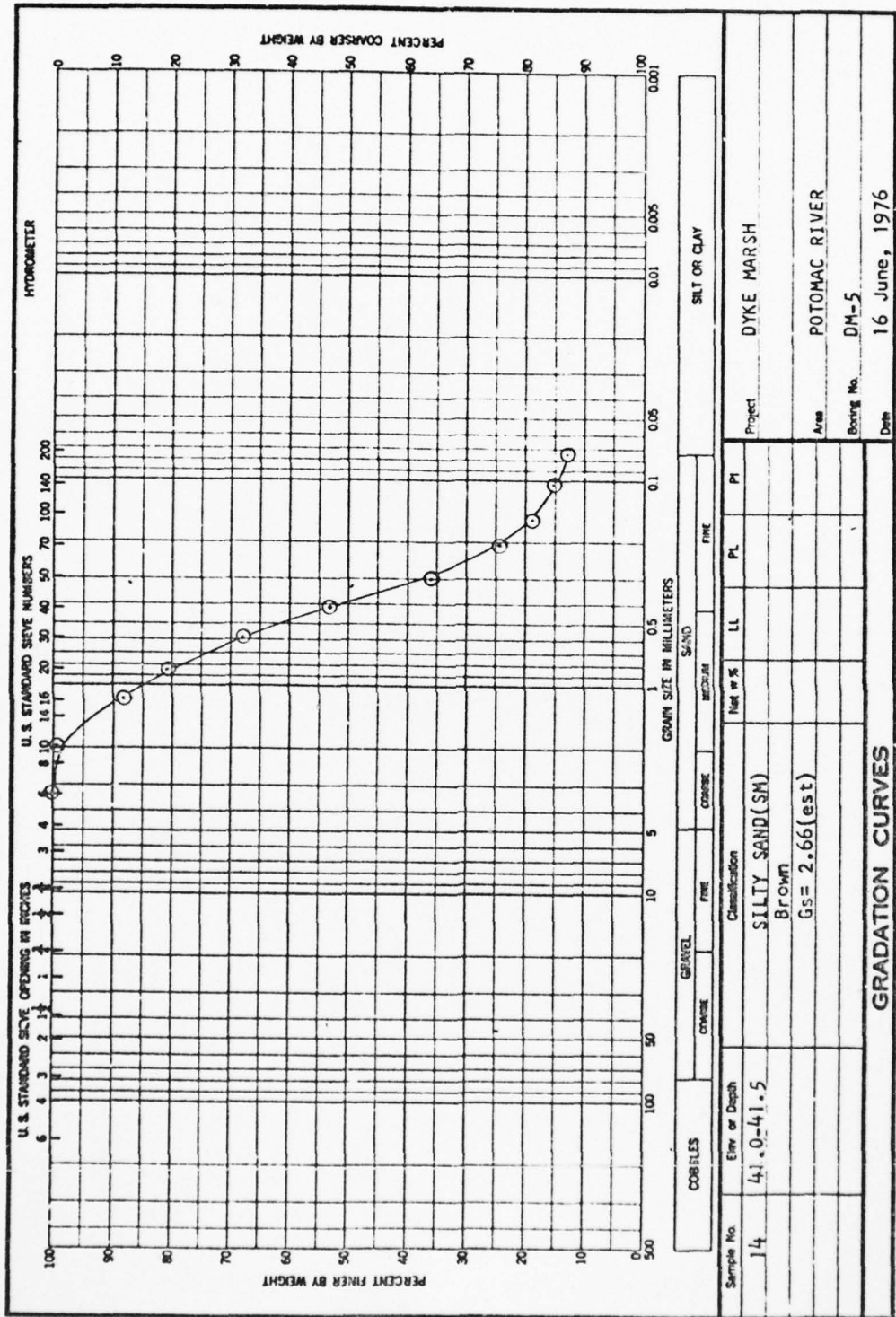
GRADATION CURVES

ENG FORM 2087
1 MAY 63



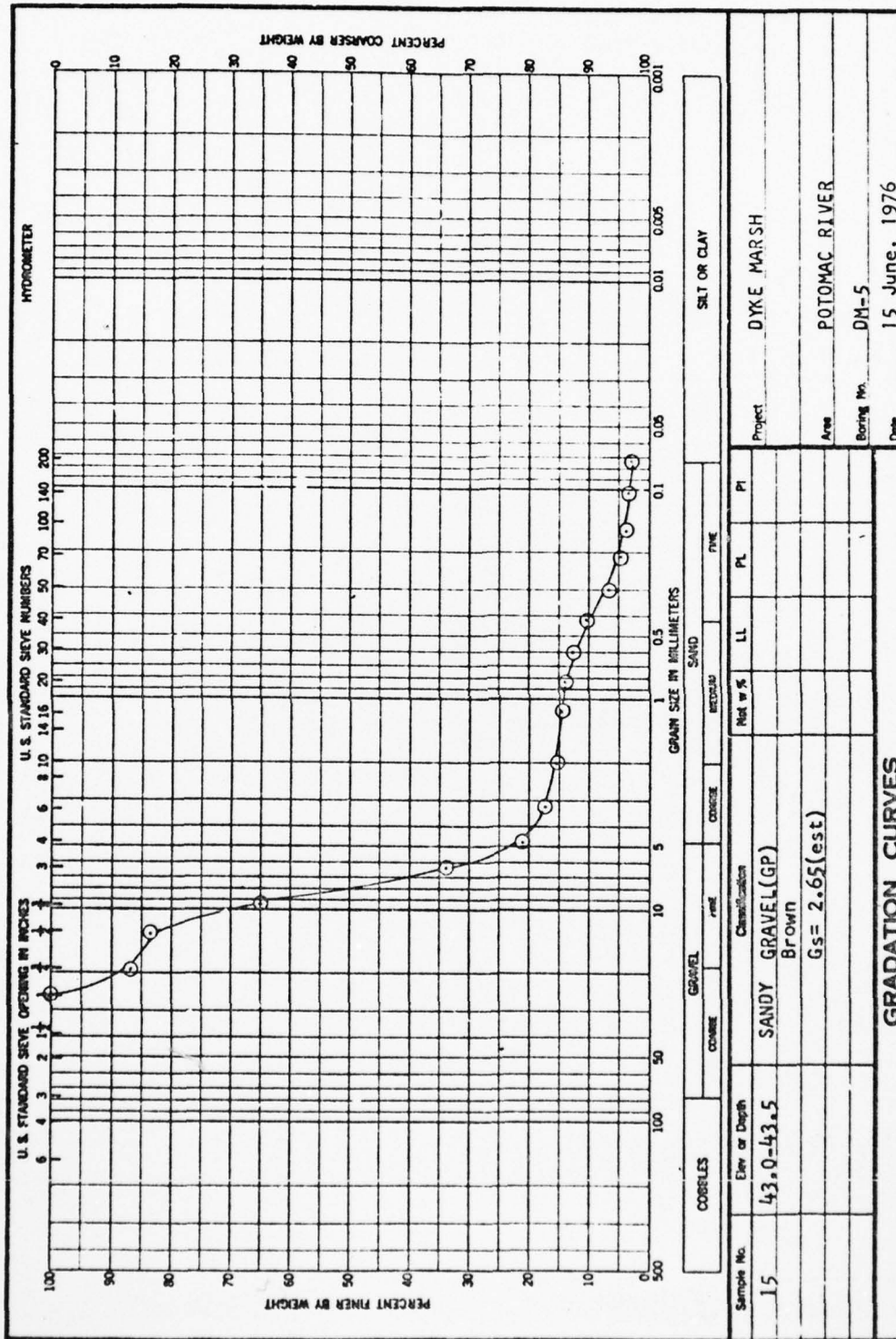
Sample No.	40.7	Classification	SAND (SP) With Gravel Gs = 2.65 (est)
Elv or Depth	?	Moisture	
		Shrinkage	
		LL	
		PL	
		FI	
GRADATION CURVES			
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	DM-5		
Date	15 June, 1976		

ENG FORM
1 MAY 63 2087

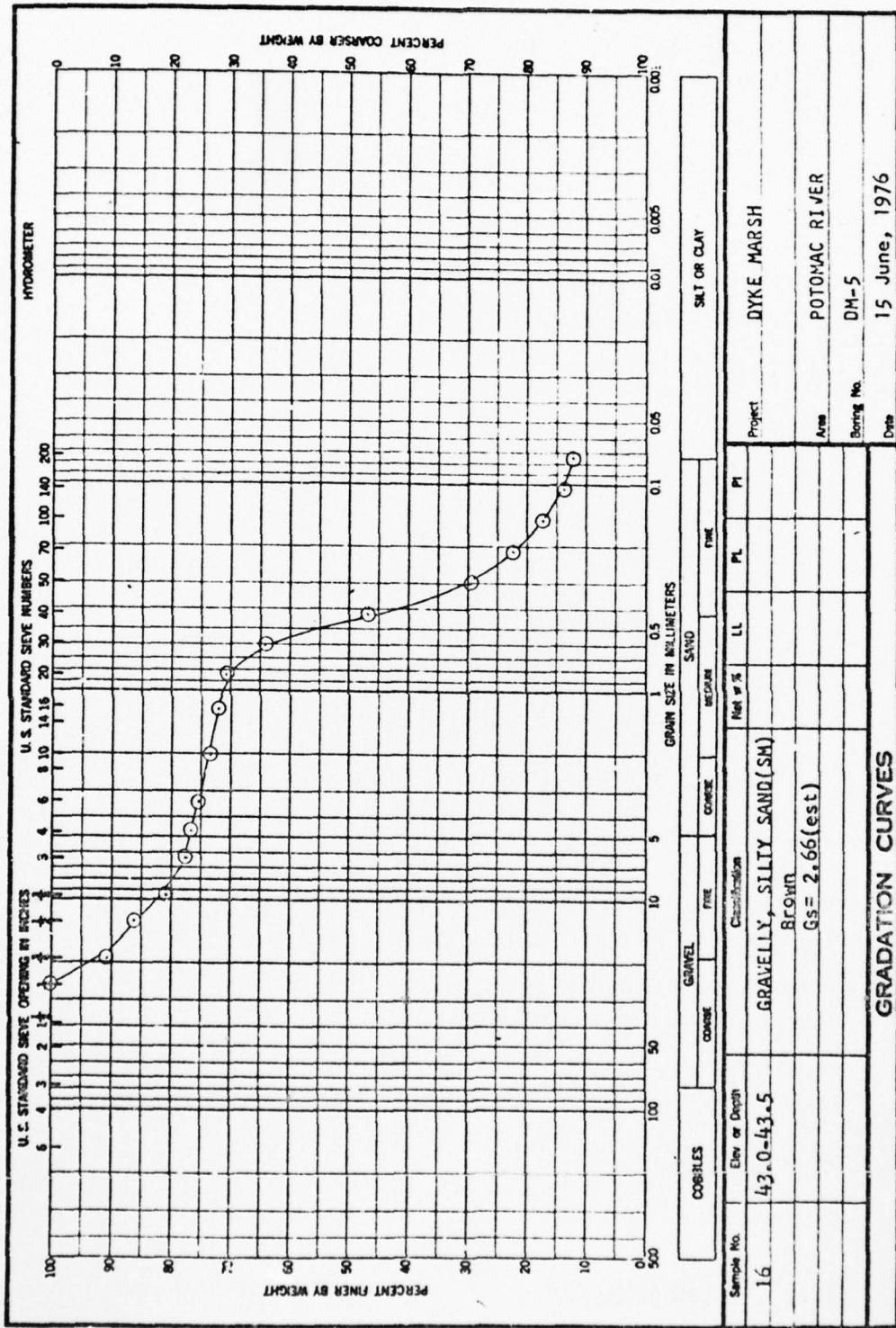


Sample No.	14	Elev or Depth	41.0-41.5
Classification		SILTY SAND (SM)	
Color		Brown	
Gs		2.66(est)	
GRADATION CURVES			
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	DM-5		
Date	16 June, 1976		

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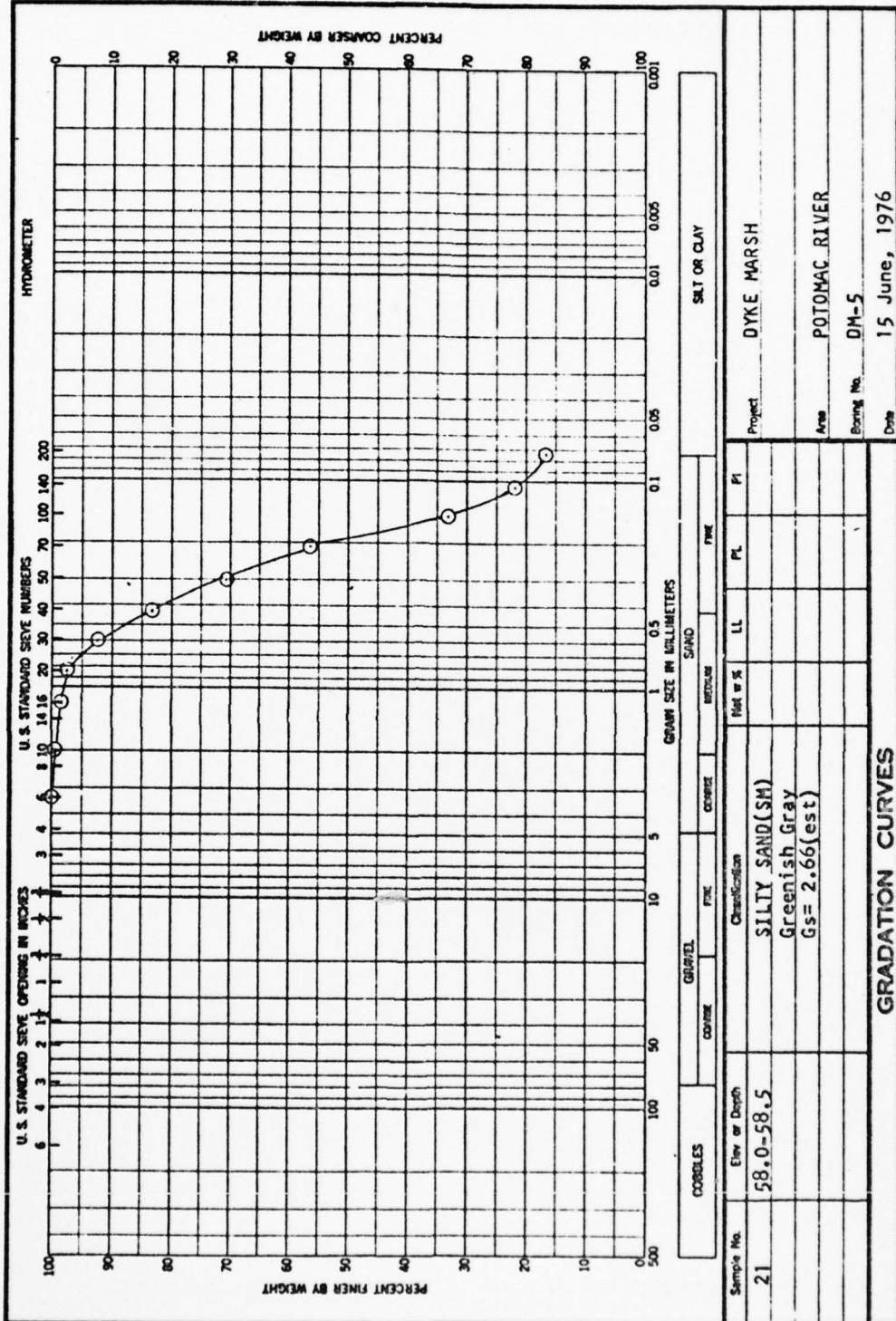
ENG FORM 1 MAY 63 2087

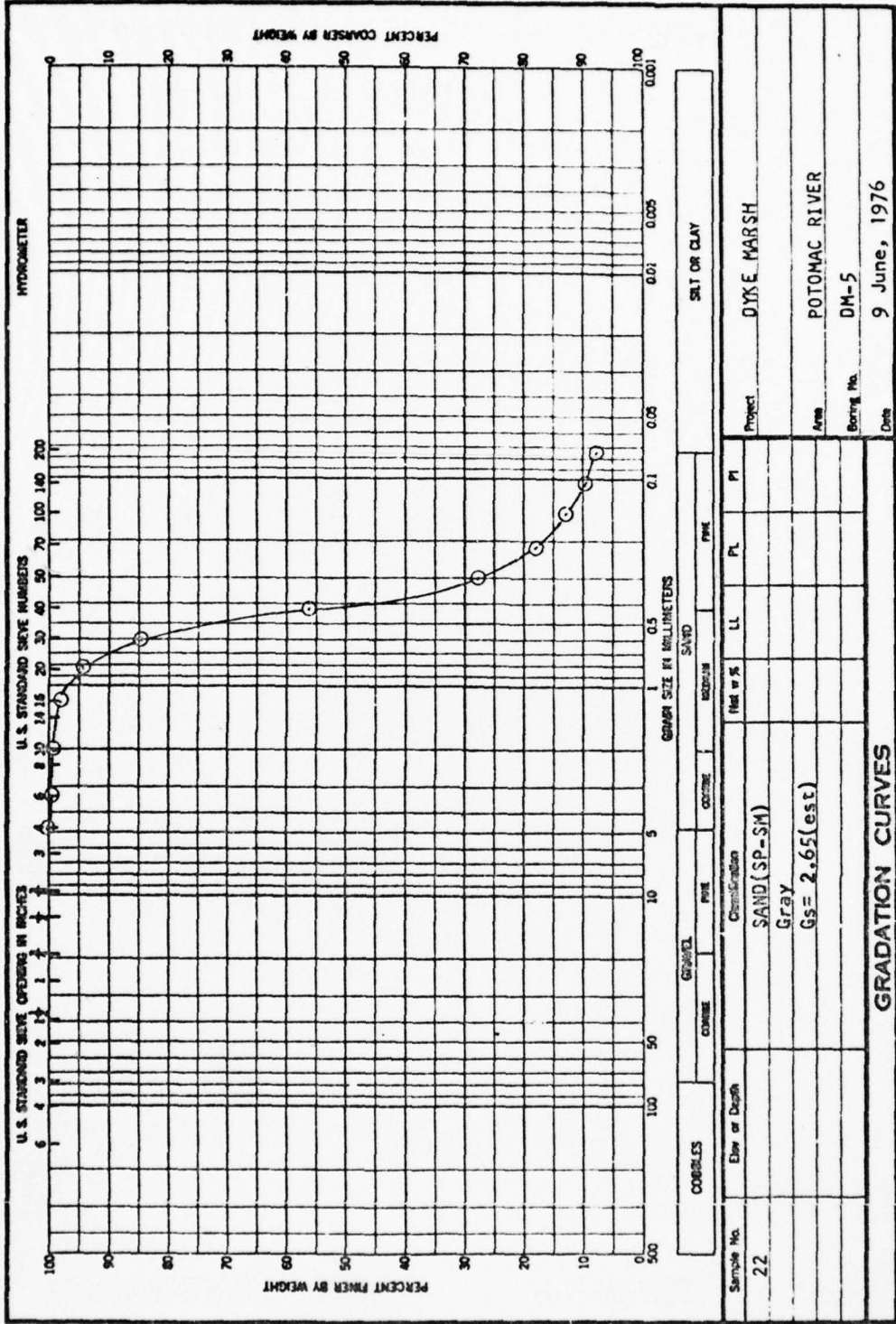


ENG FORM 2007
1 MAY 63

D20

COBBLES		GRAVEL		SAND		SILT OR CLAY	
Sample No.	Elev or Depth	Classification	Net wt %	LL	PL	PI	
16	43-0-43-5	GRAVELLY, SILTY SAND(SM) BROWN Gs = 2.66(est)		8		2.66	
Project		Area		Boring No.		Date	
DYKE MARSH		POTOMAC RIVER		DH-5		15 June, 1976	
GRADATION CURVES							

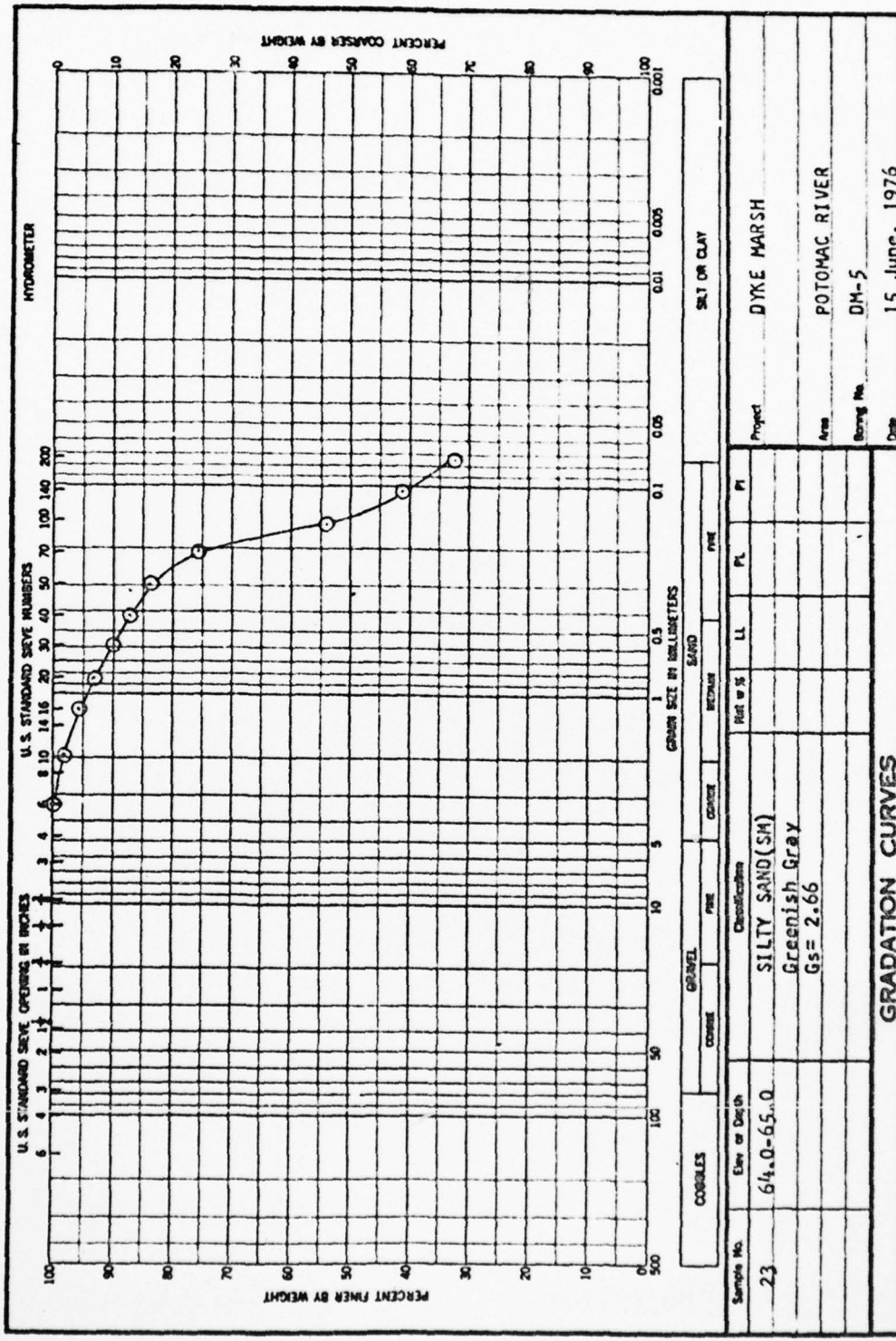




Sample No.	22	Elow or Depth	
Classification	SAND (SP-SM)	Field %	
	Gray	LL	
	Gs = 2.65 (est)	PL	
		PI	
Project		DYKE MARSH	
Area		POTOMAC RIVER	
Boring No.		DM-5	
Date		9 June, 1976	

GRADATION CURVES

ENG FORM 1 MAY 63 2087

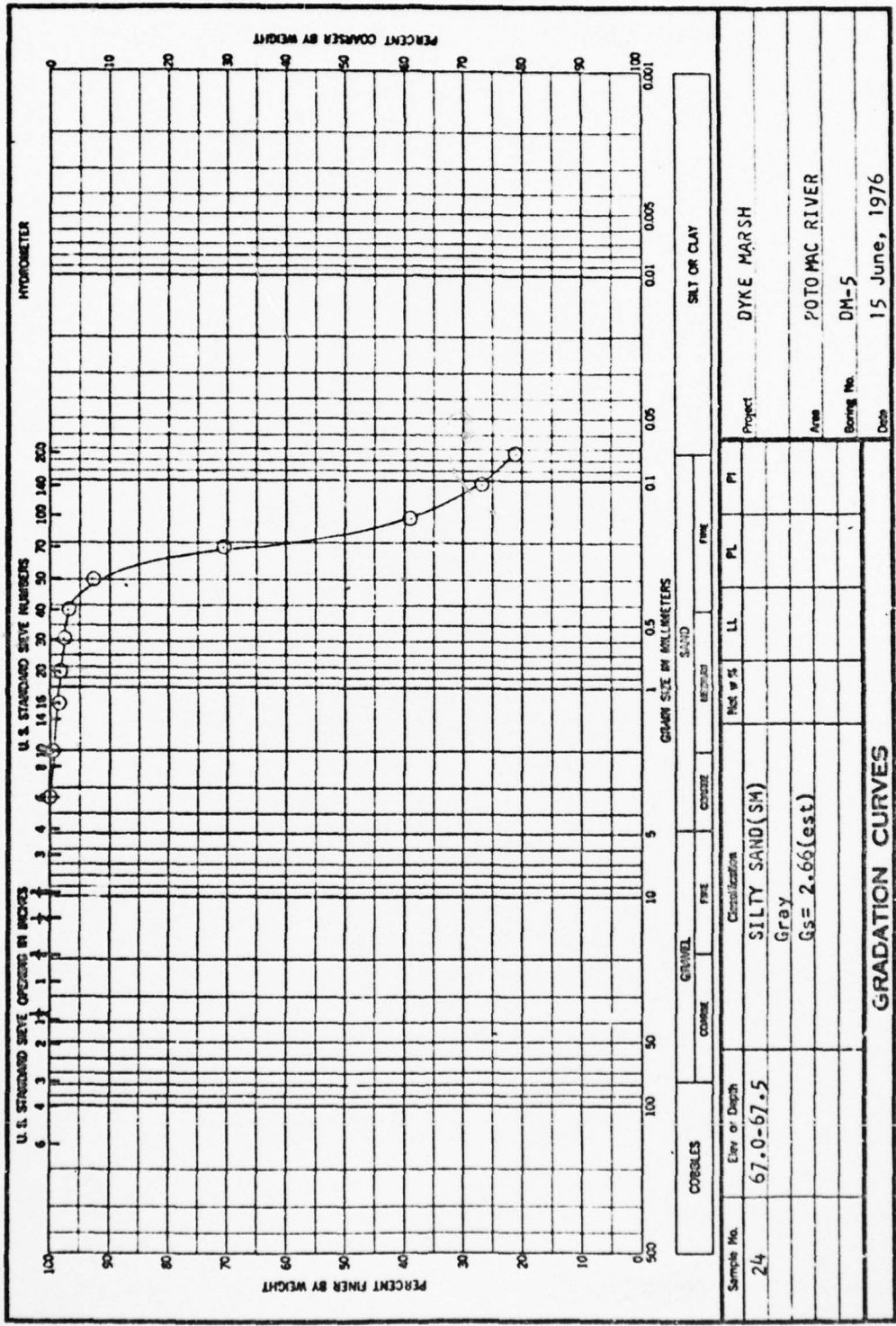


Project: DYKE MARSH
 Area: POTOMAC RIVER
 Boring No: DM-5
 Date: 15 June, 1976

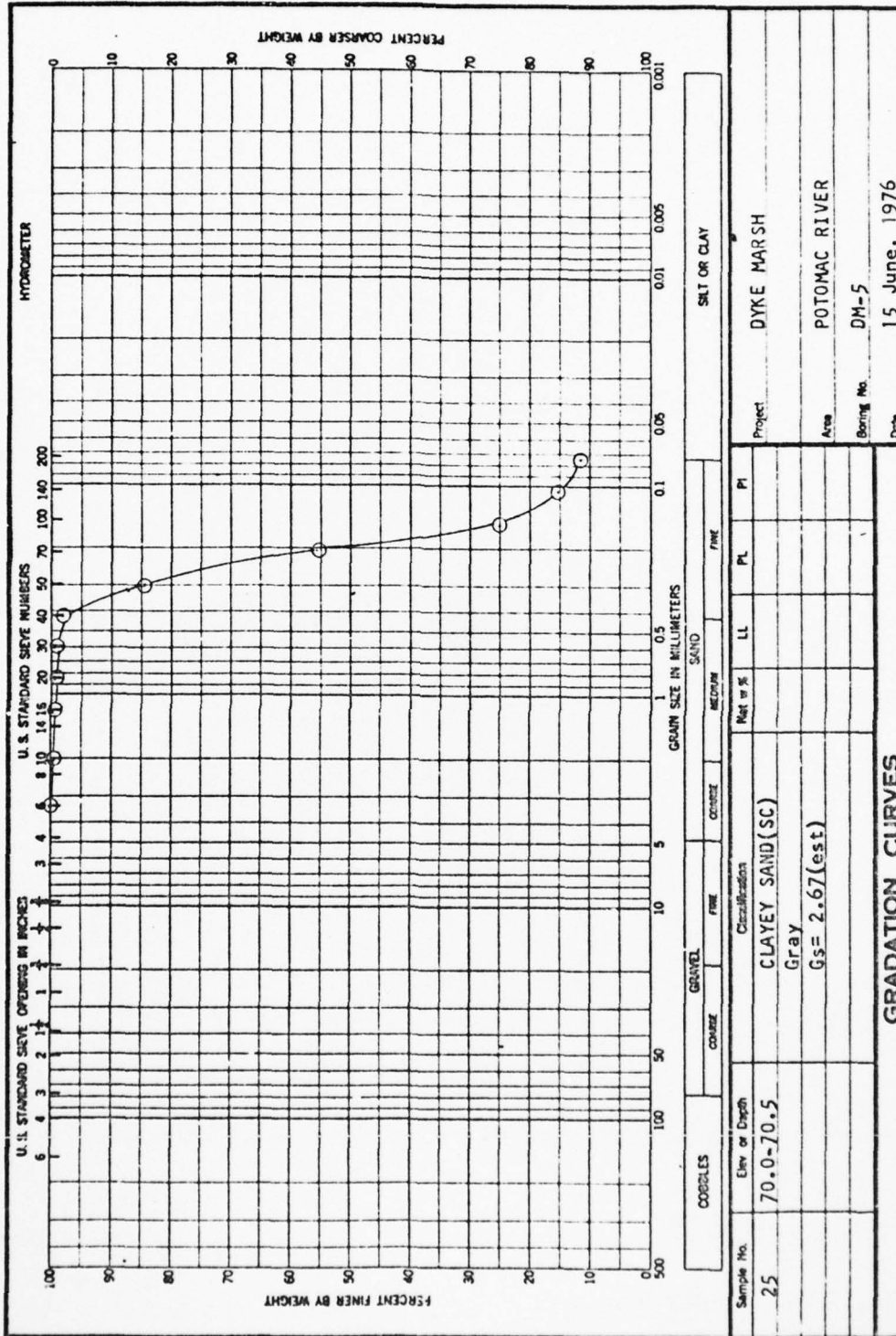
Sample No.	Elev or Depth	Classification	SAND			FINE		
			Coarse	Medium	Fine	Coarse	Medium	Fine
23	64.0-65.0	SILTY SAND (SM) Greenish Gray Gs = 2.66						

GRADATION CURVES

ENG FORM 2087
MAY 68



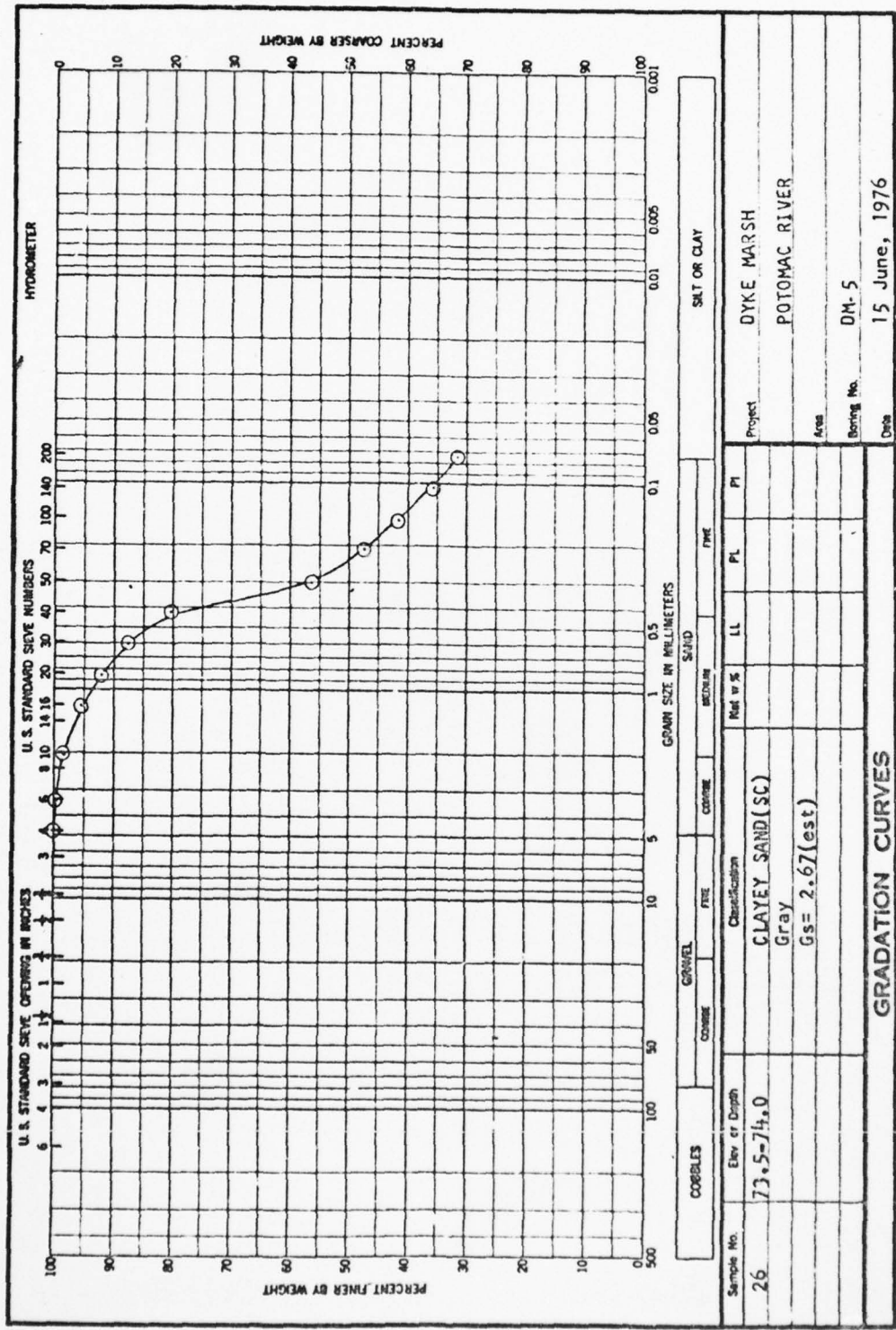
ENG FORM 1 MAY 63 2087



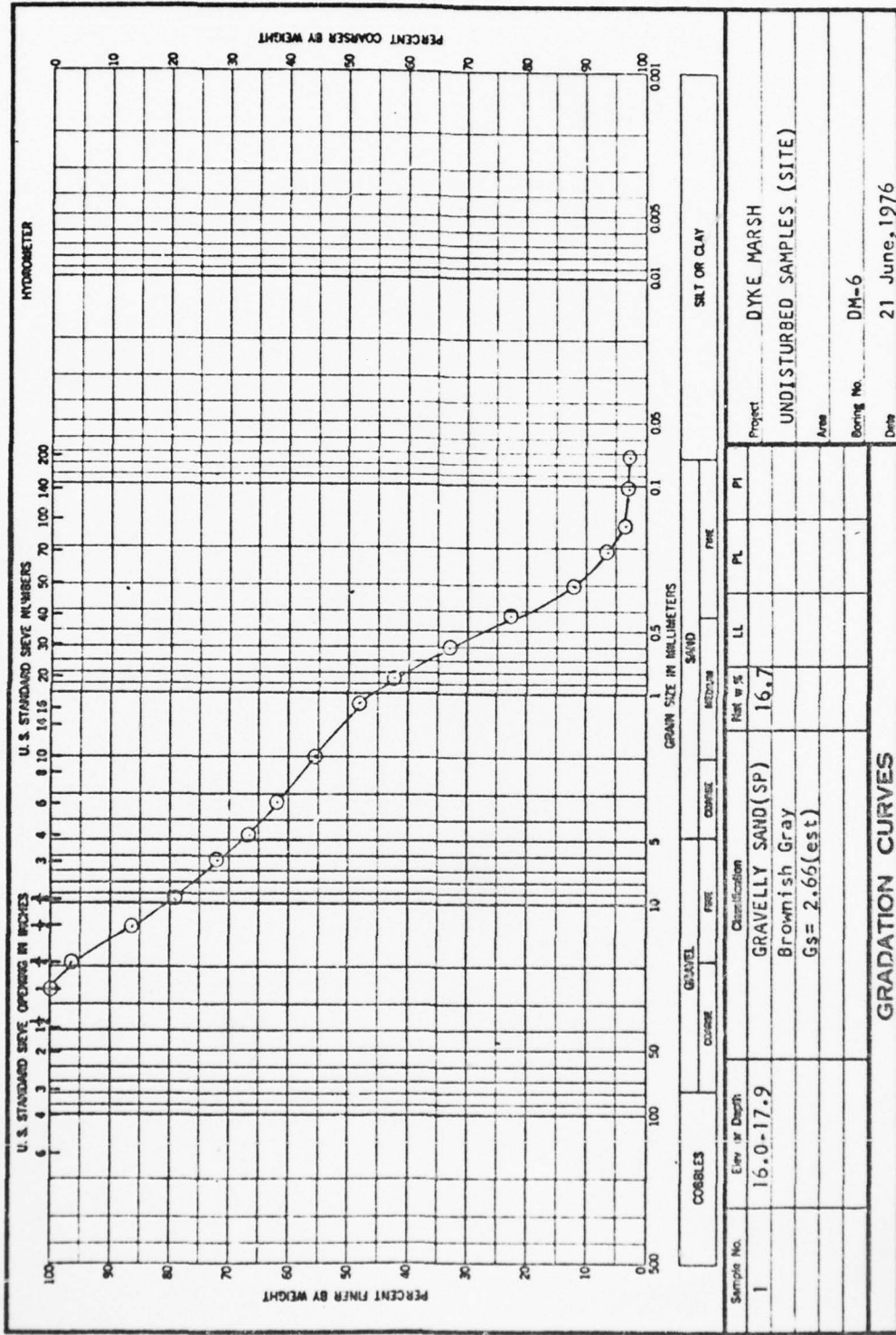
COBBLES		GRAVEL		FINE GRAVEL		SAND		SILT OR CLAY	
Sample No.	Elev or Depth	Classification		Moist w %	LL	PL	PI	Project	
25	70.0-70.5	CLAYEY SAND(SC) Gray G _s = 2.67(est)						DYKE MARSH	
								POTOMAC RIVER	
								DM-5	
								Boring No.	15 June, 1976
								Date	

GRADATION CURVES

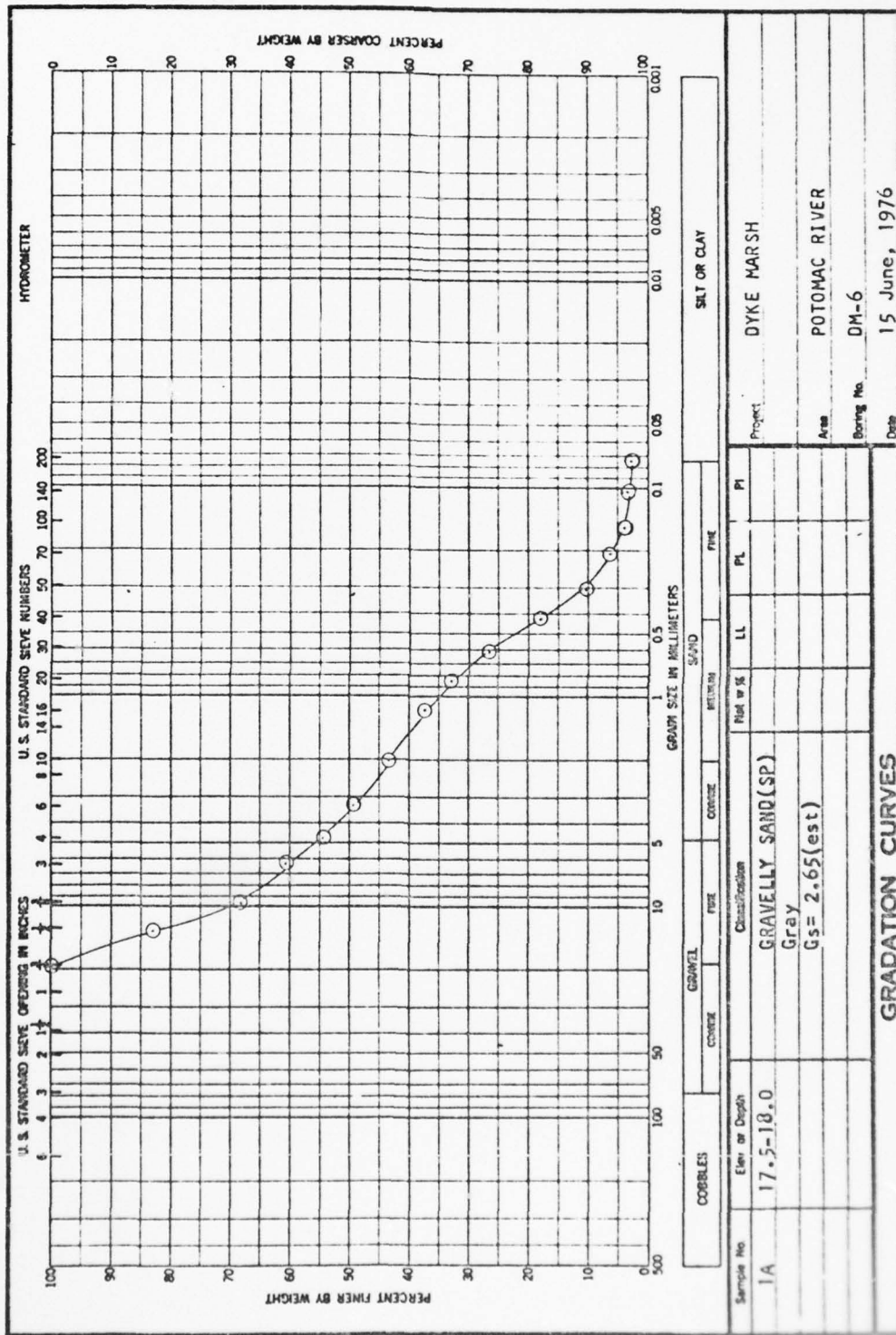
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ENG FORM 1 MAY 65 2087



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1 MAY 63 2087



GRADATION CURVES

Sample No.	1A	Element or Depth	17.5-18.0	Classification	GRAVELLY SAND (SP) Gray Gs = 2.65 (est)	Field %	LL	PL	PI	Project	DYKE MARSH
										Area	POTOMAC RIVER
										Boring No.	DM-6
										Date	15 June, 1976

ENG FORM 2087

AD-A048 179

ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
DETAILED DESIGN FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RIVE--ETC(U)
OCT 77 M R PALERMO, T W ZEIGLER

UNCLASSIFIED

WES-TR-D-77-13

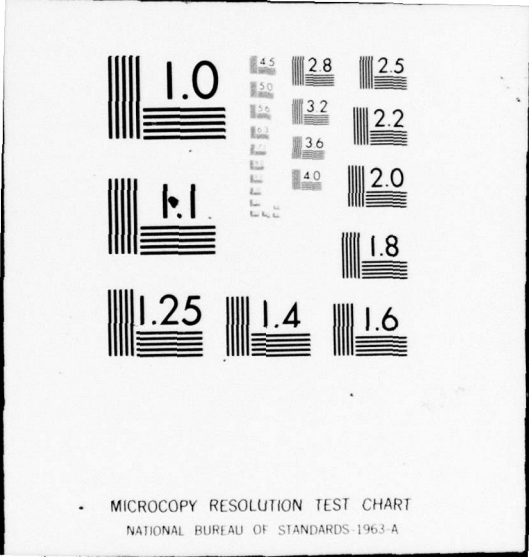
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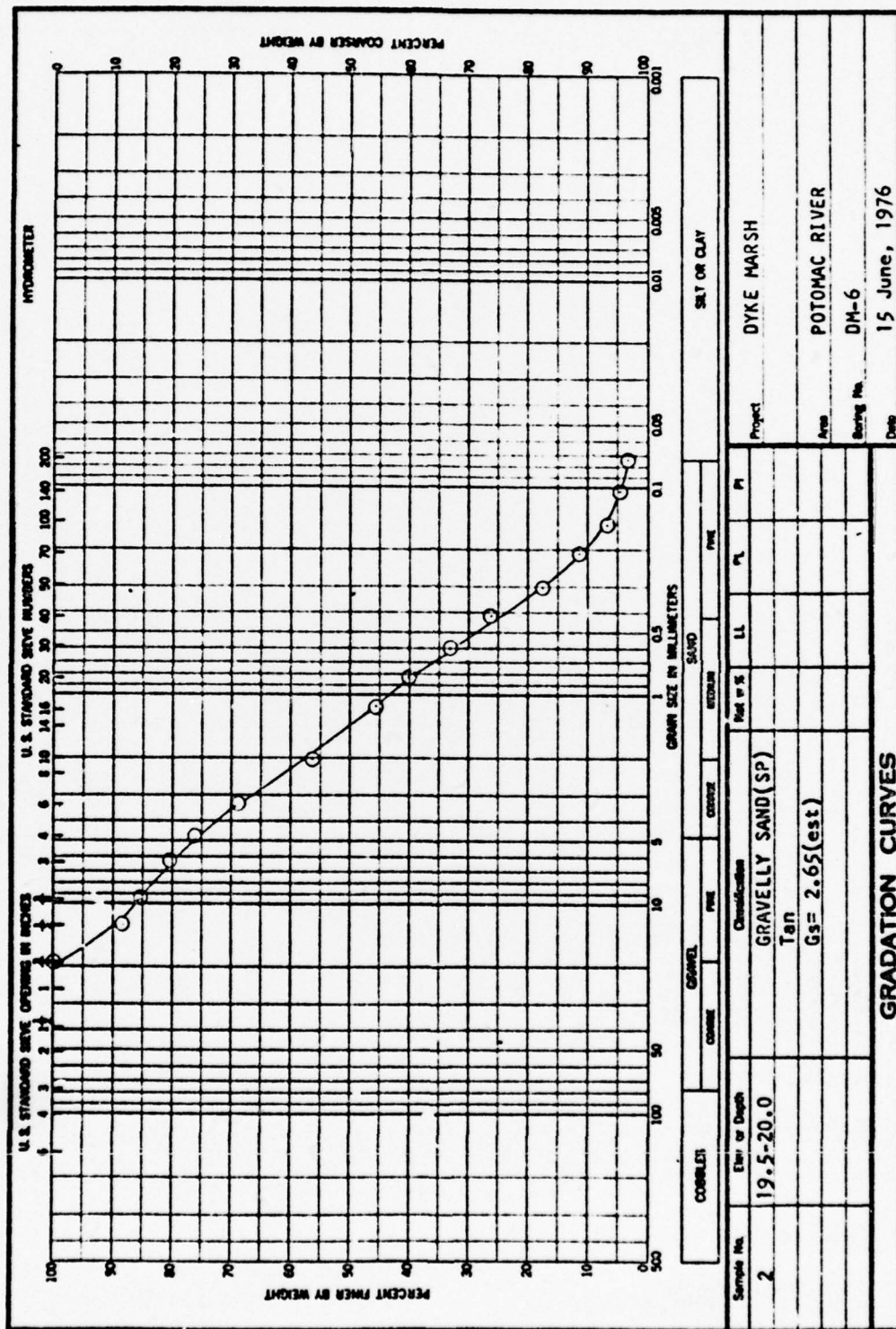
3 of 3

ADA048 179



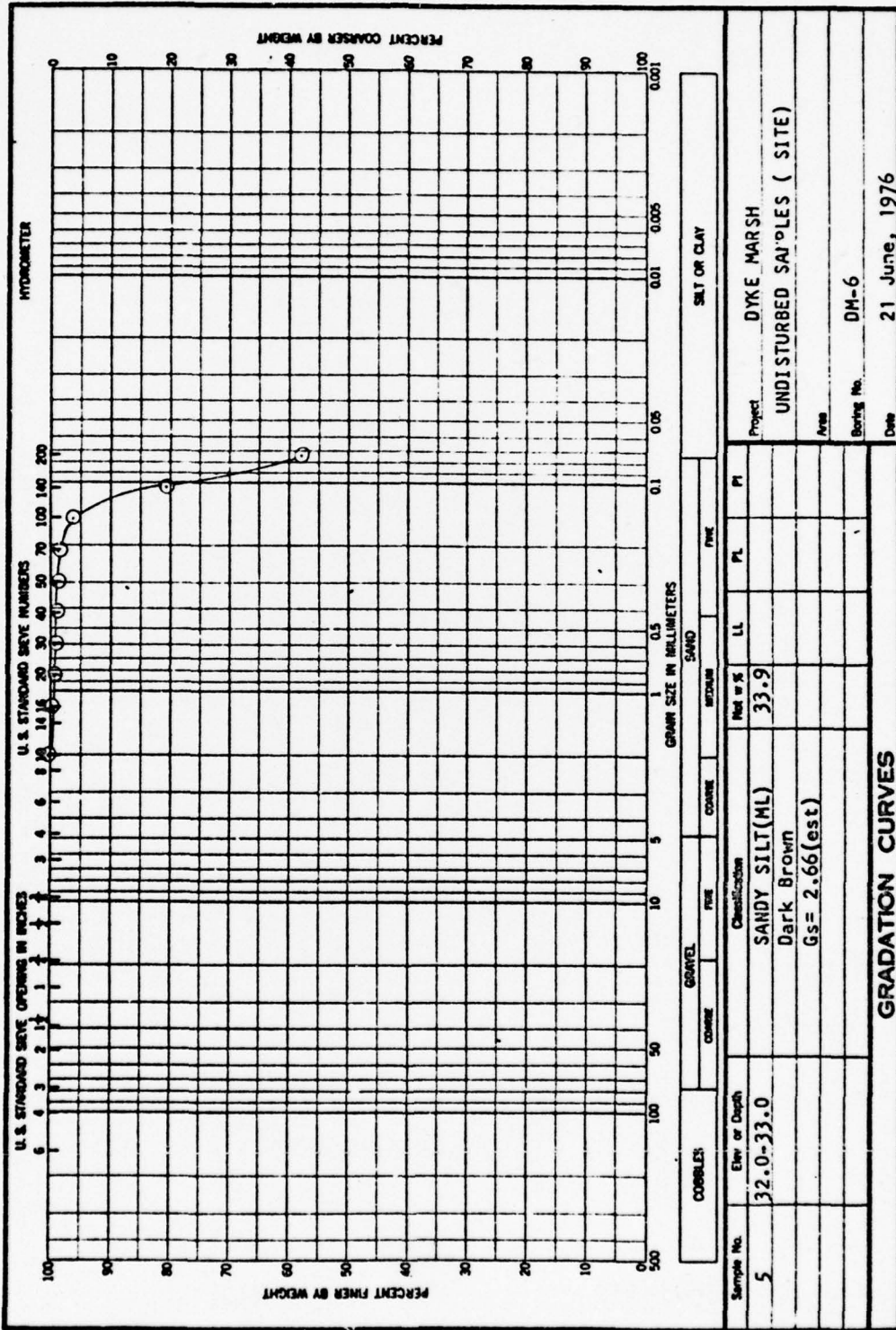
END
DATE
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1 - 78
DDC



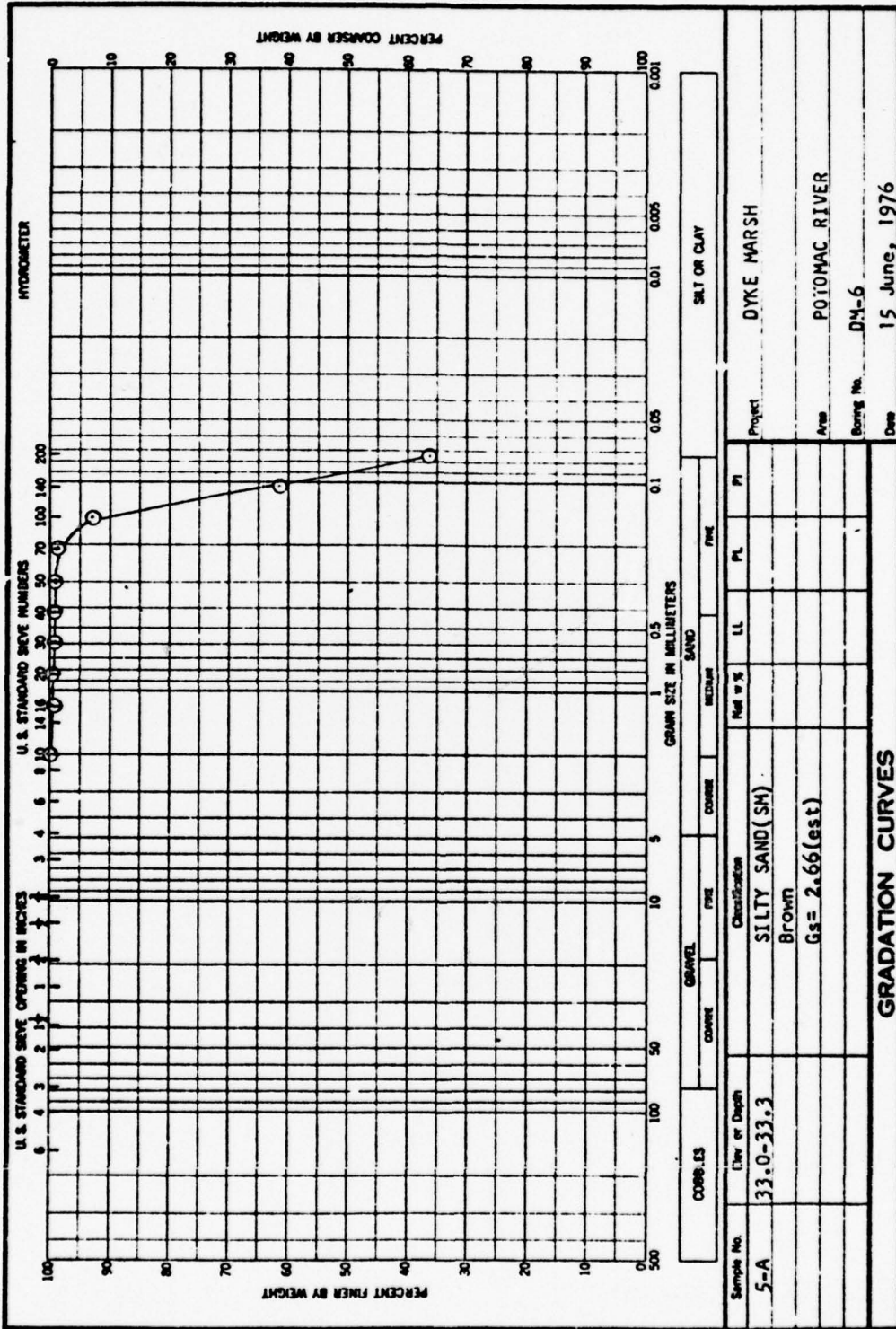


Sample No.	2	Enter or Depth	19.5-20.0
Classification		GRAVELLY SAND (SP)	
Tan		Tan	
Gs = 2.65 (est)		Gs = 2.65 (est)	
GRADATION CURVES			
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	DM-6		
Date	15 June, 1976		

ENG FORM 2087
1 MAY 63

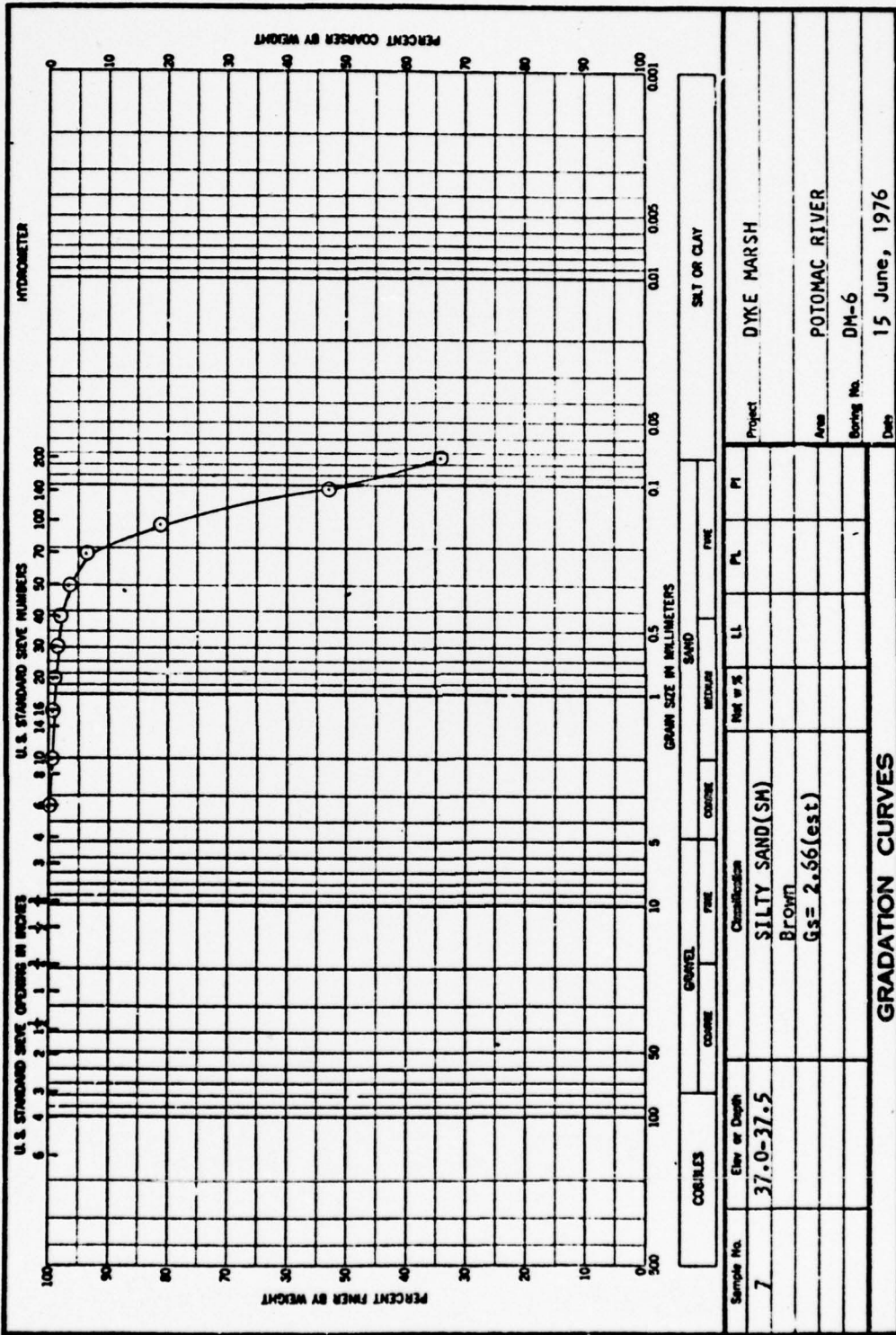


ENG FORM 2087
1 MAY 68



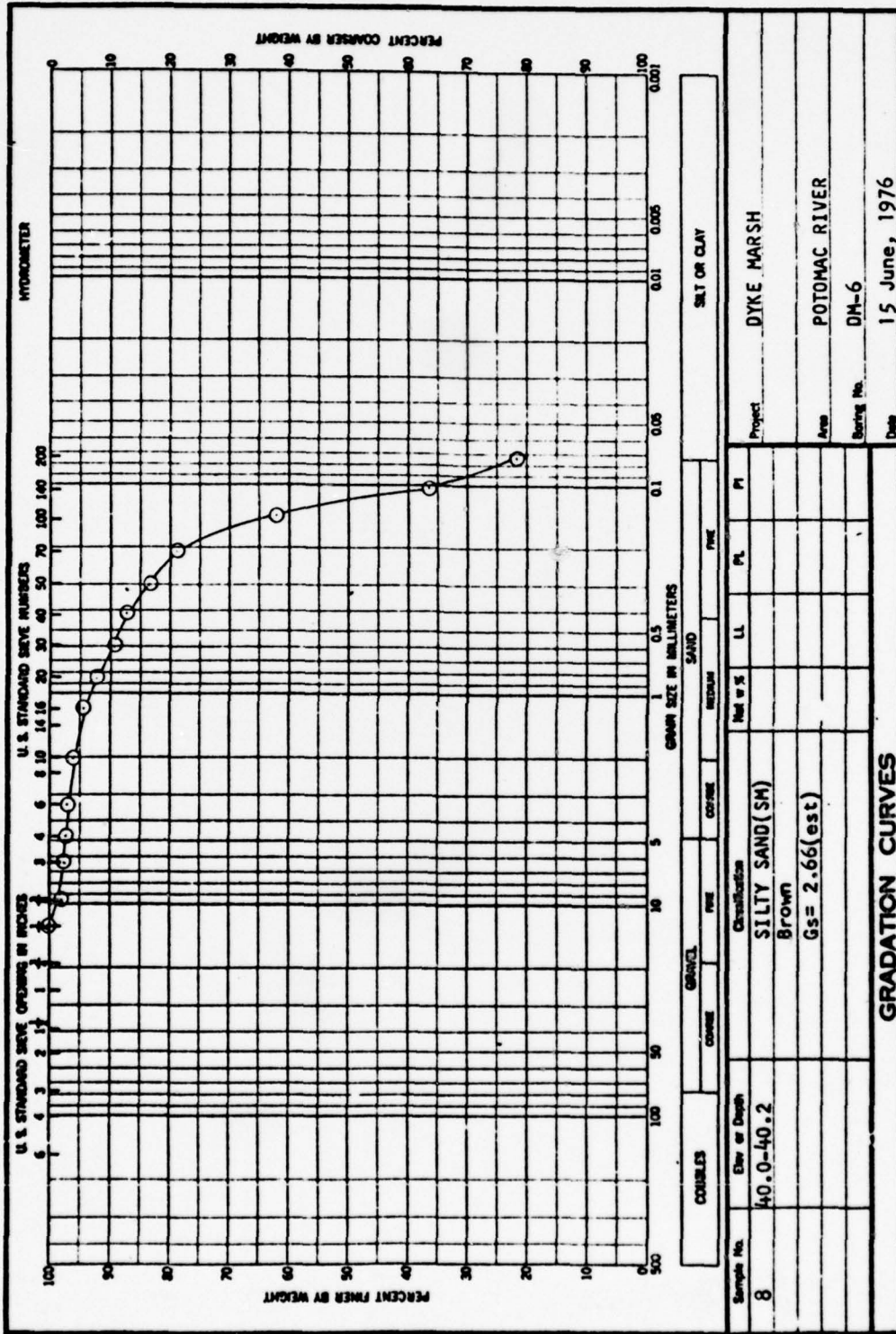
Sample No.	5-A	City or Depth	33.0-33.3
Classification	SILTY SAND(SH) Brown Gs = 2.66(est)		
Moisture Content (%)	LL	PL	PI
GRADATION CURVES			
Project	DYKE MARSH		
Area	POTOMAC RIVER		
Boring No.	DM-6		
Date	15 June, 1976		

ENG FORM 1 MAY 68 2087



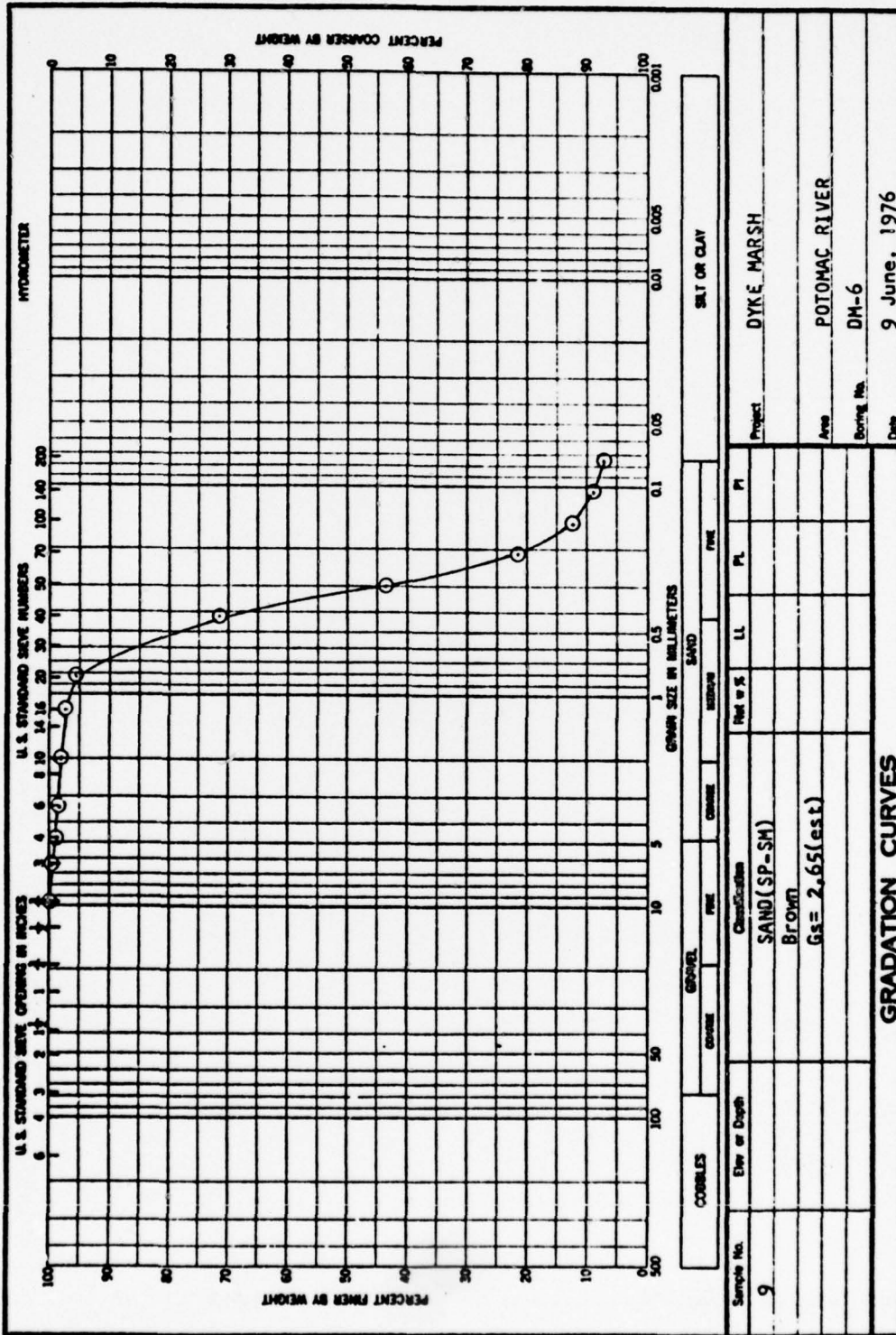
GRADATION CURVES

ENG FORM 1 MAY 63 2007

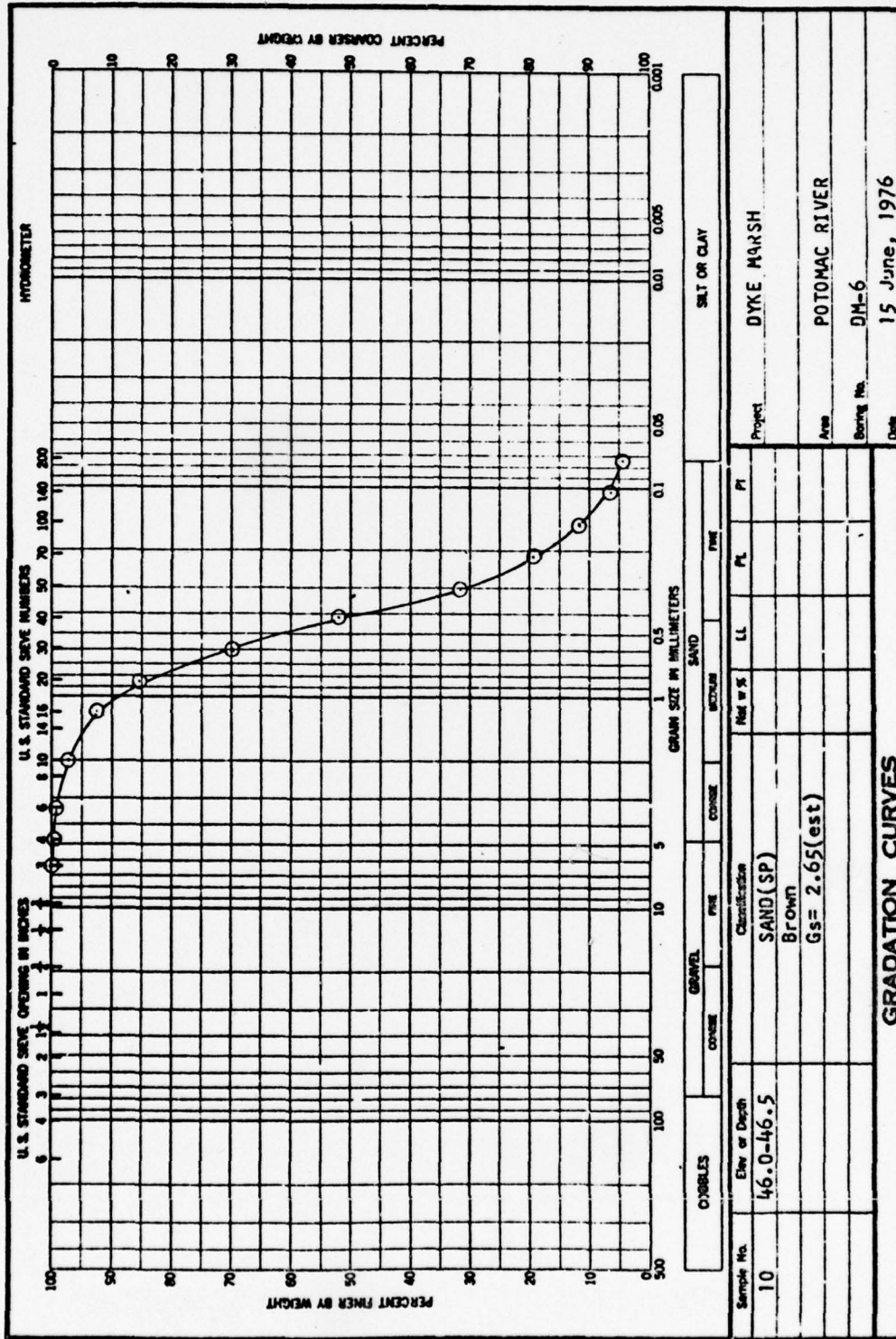


GRADATION CURVES

ENG FORM 2007
MAY 63



ENG FORM 2087
 1 MAY 63

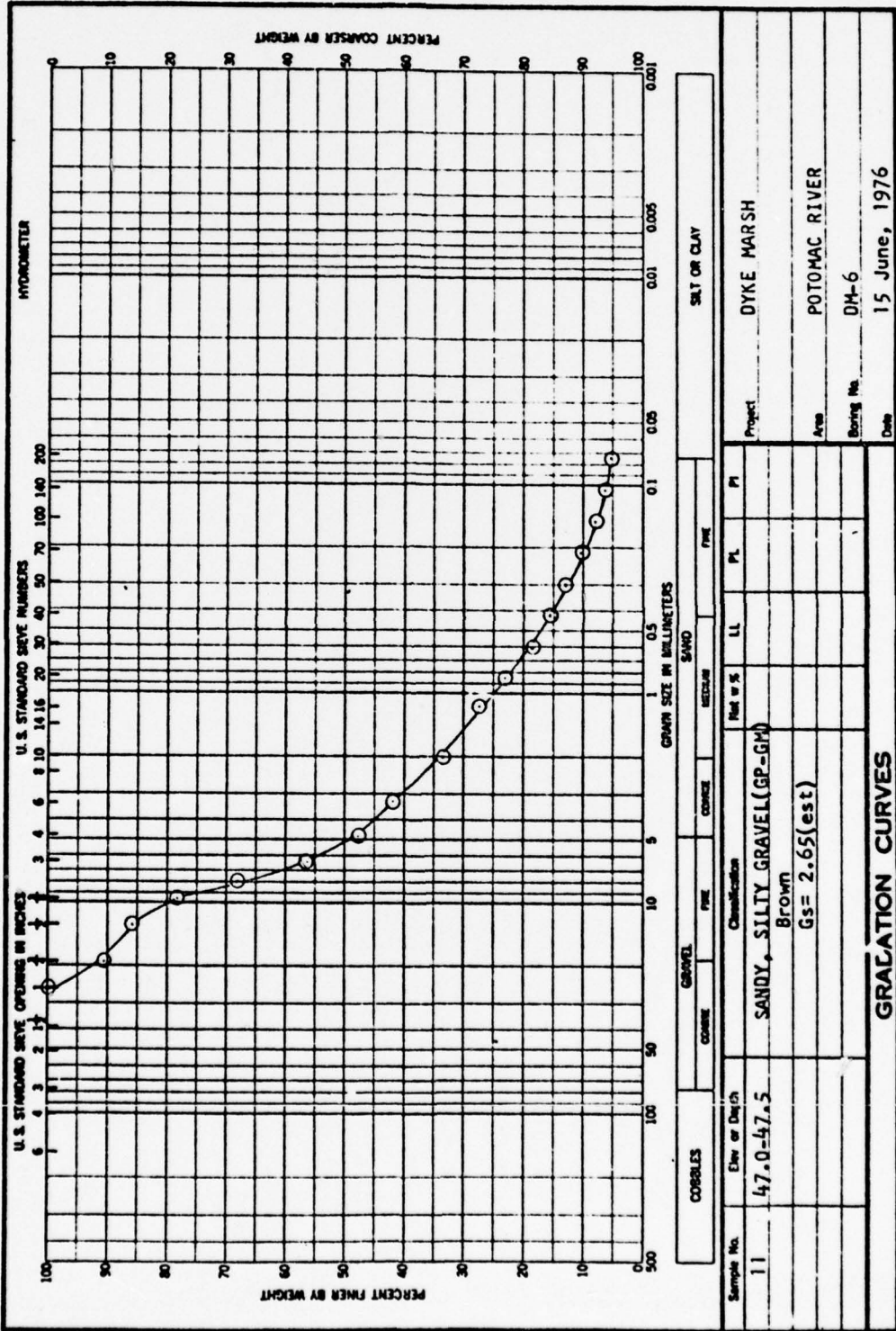


Sample No.	10	Site or Depth	46.0-46.5
Classification	SAND (SP)	Moisture	
	Brown	LL	
	Gs = 2.65 (est)	PL	
		PI	
Project		DYKE MARSH	
Area		POTOMAC RIVER	
Boring No.		DM-6	
Date		15 June, 1976	

GRADATION CURVES

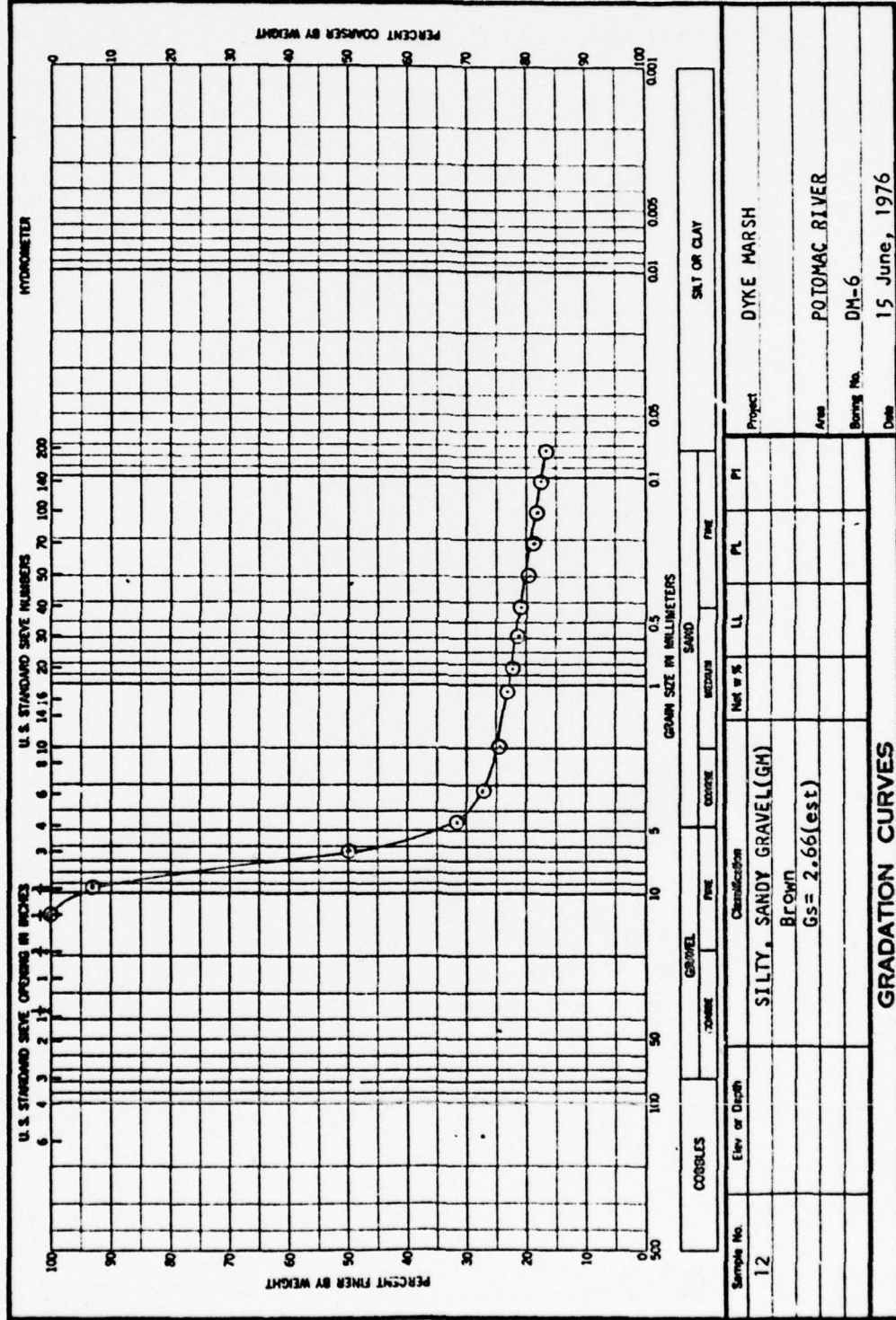
ENG FORM 1 MAY 68 2087

D37



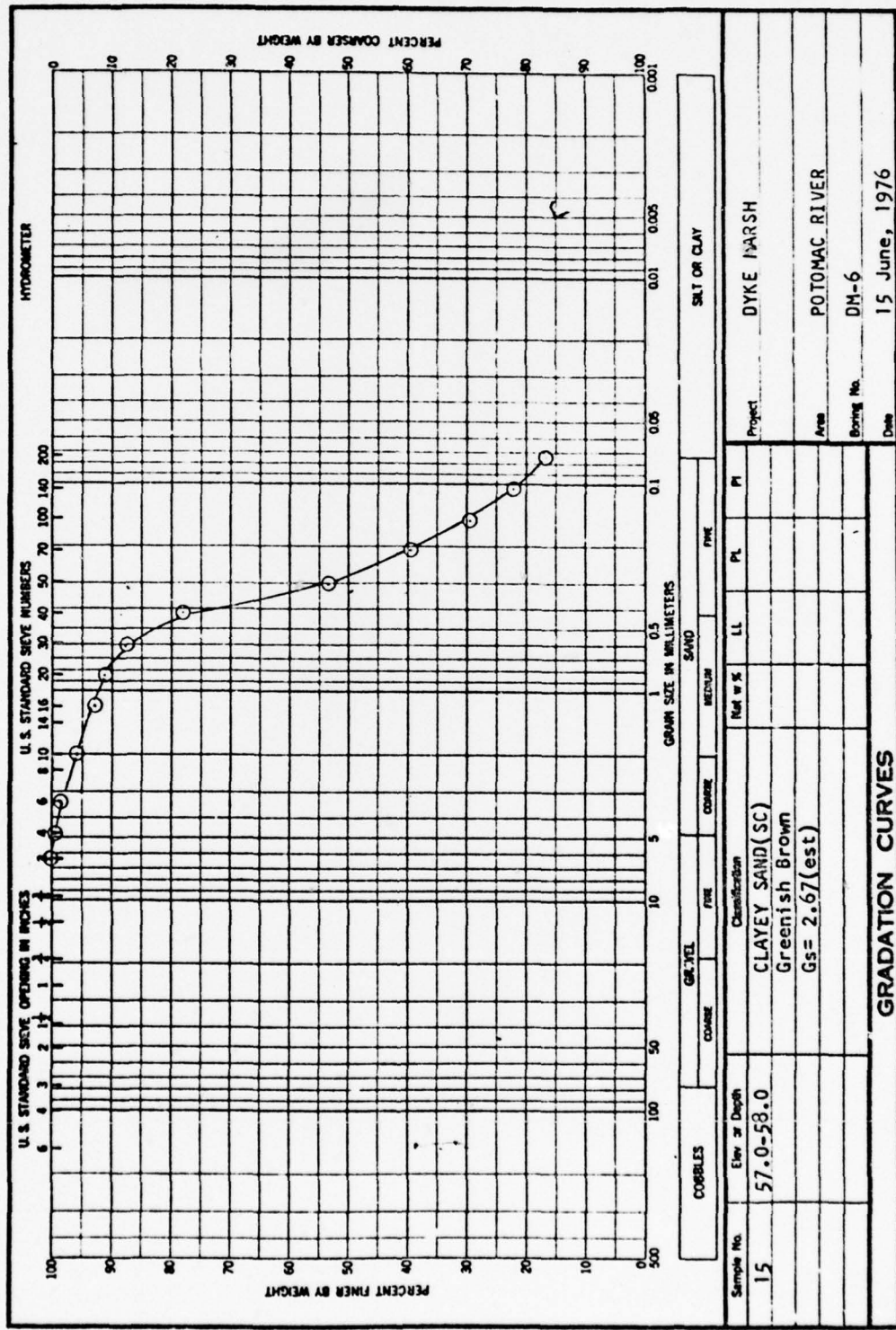
CORRUGLES		GRAVEL		FINE		SAND		SILT OR CLAY	
Sample No.	47.0-47.5	Classification	SANDY, SILTY GRAVEL (GP-GM)		Flak %	LL	PL	PI	Project
			Brown						DYKE MARSH
			Gs = 2.65 (est)						POTOMAC RIVER
									Boring No. DM-6
									Date 15 June, 1976

GRATATION CURVES



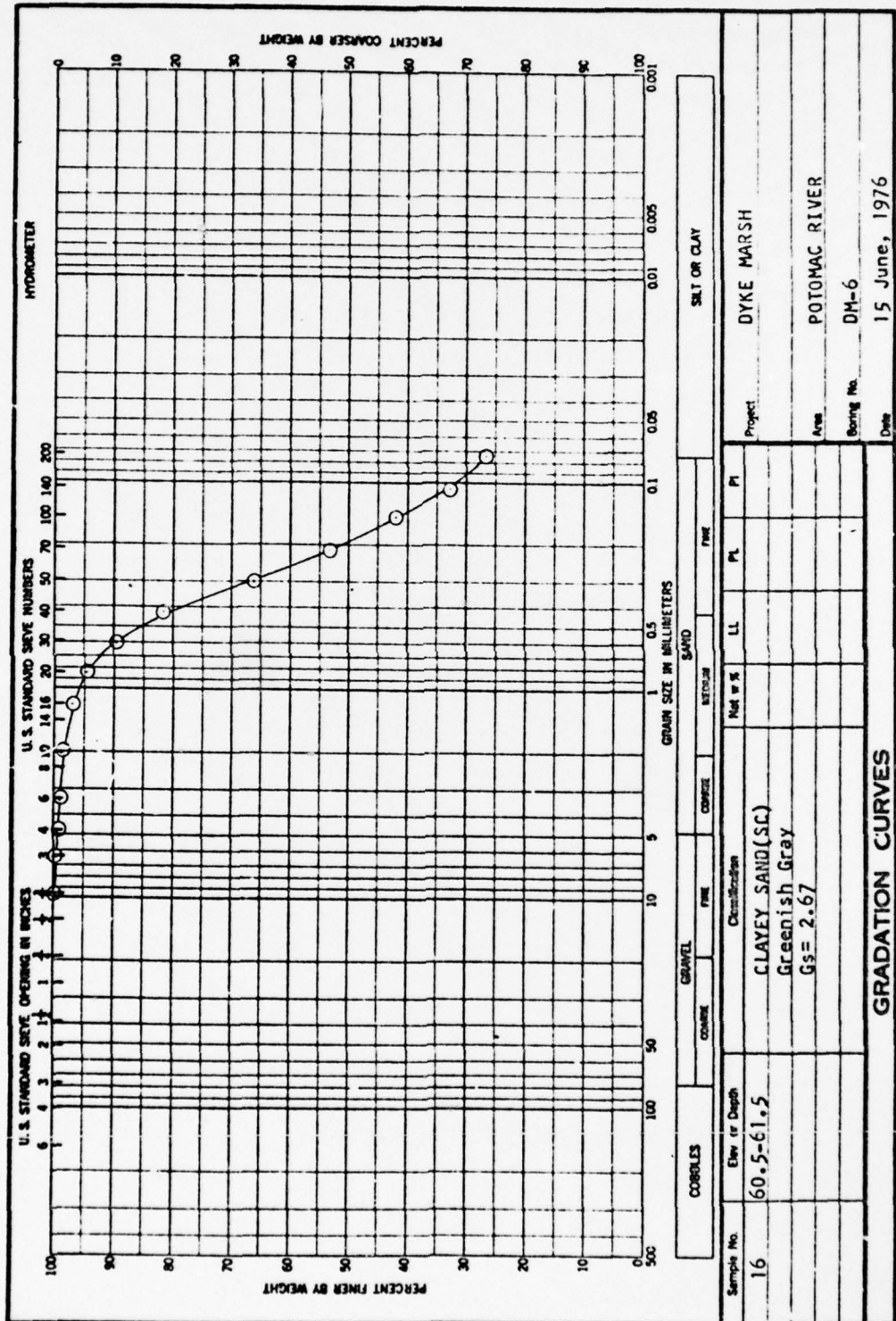
Sample No.	12	Elev or Depth		Classification	SILTY, SANDY GRAVEL (GH) Brown Gs = 2.66 (est)	Net wt %		LL		PL		PI	
GRADATION CURVES													
Project		DYKE MARSH											
Area		POTOMAC RIVER											
Boring No.		DM-6											
Date		15 June, 1976											

ENG FORM 1 MAY 68 2087



GRADATION CURVES

ENG FORM 1 MAY 63 2087

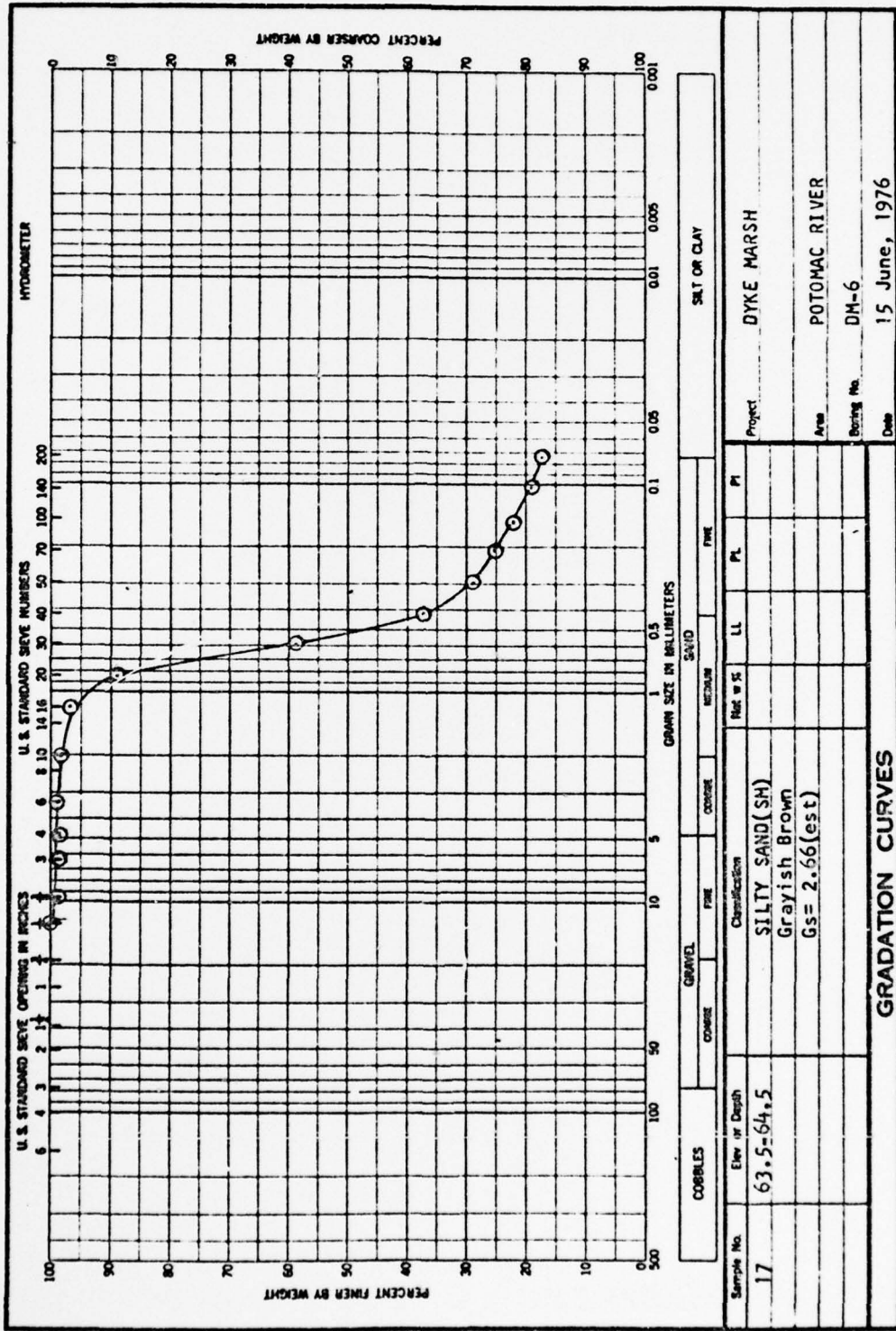


ENG FORM 1 MAY 63 2087

D41

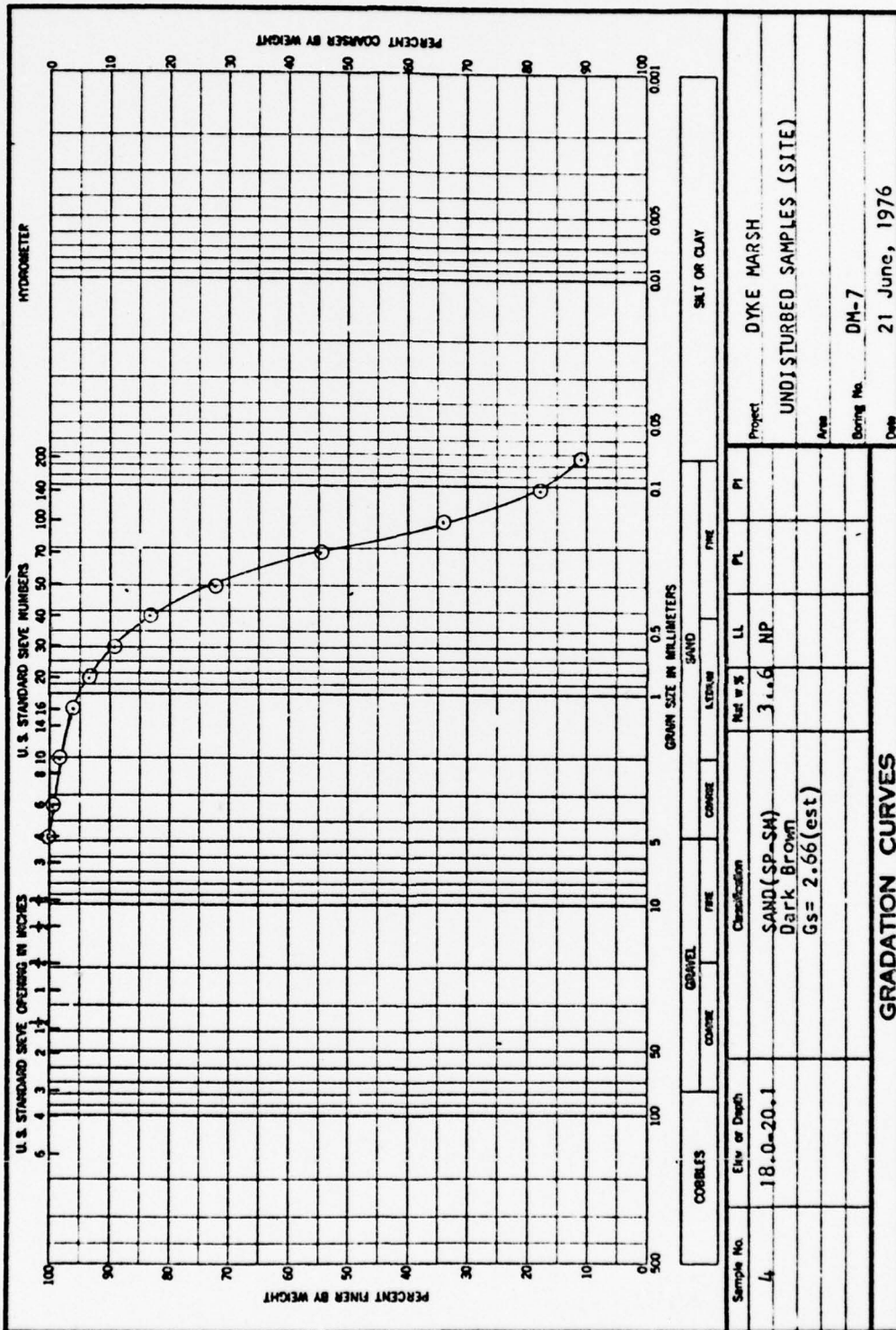
GRADATION CURVES

Sample No.	16	Elev or Depth	60.5-61.5	Classification	CLAYEY SAND (SC) Greenish Gray Gs = 2.67	Moist w %		LL		PL		P1	
Project													DYKE MARSH
Area													POTOMAC RIVER
Boring No.													DM-6
Date													15 June, 1976



D42

ENG FORM 1 MAY 68 2087



Project: DYKE MARSH
 UNDISTURBED SAMPLES (SITE)
 Boring No. DM-7
 Date: 21 June, 1976

GRADATION CURVES

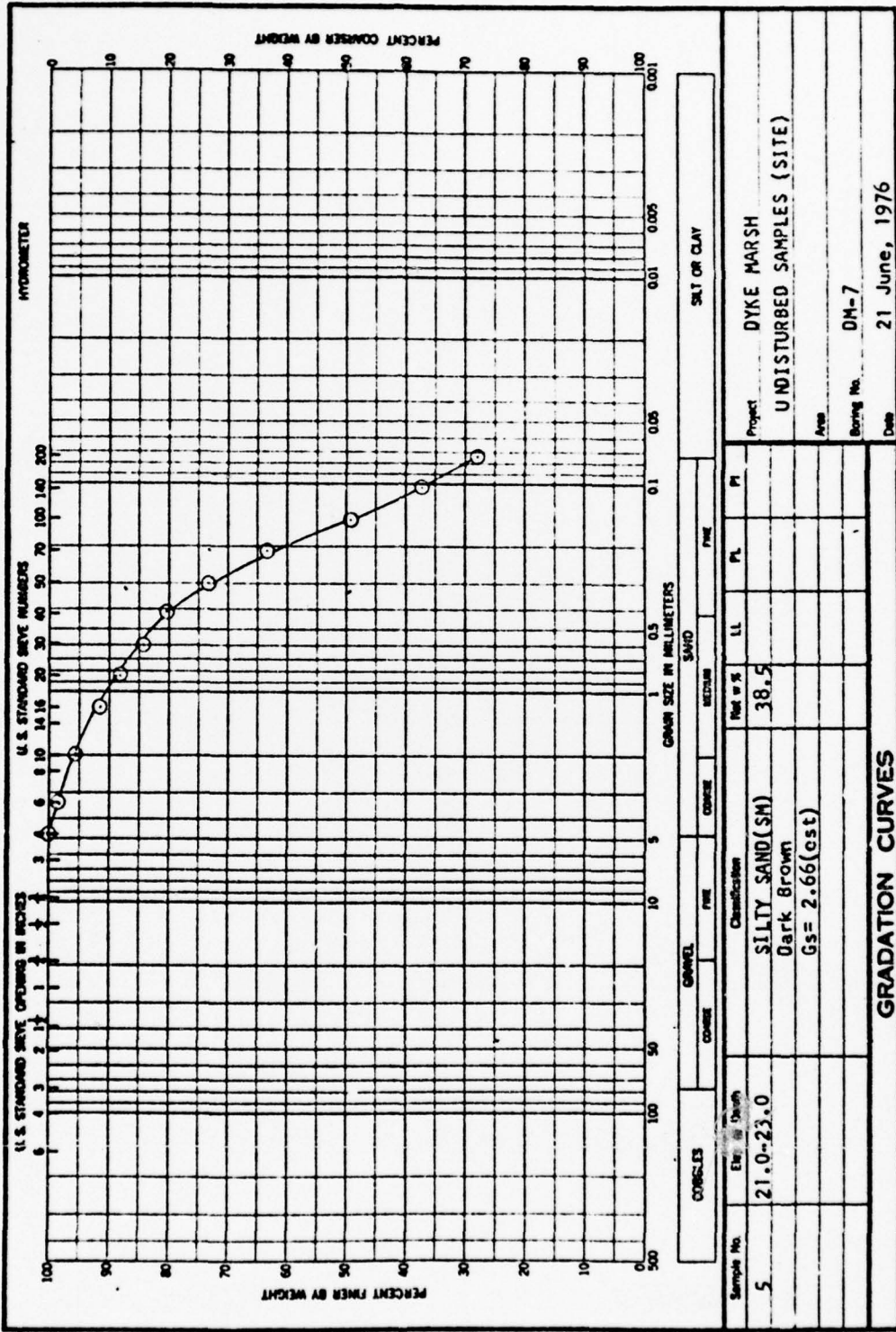
Sample No. 4
 Elev. or Depth 18.0-20.1
 Classification SAND (SP-SM)
 Dark Brown
 Gs = 2.66 (est)

Ref. w % 3.6
 LL NP
 PI

COBBLES GRAVEL FINE SAND SALT OR CLAY
 COURSE COURSE FINE COURSE FINE

U.S. STANDARD SIEVE OPENING IN INCHES
 U.S. STANDARD SIEVE NUMBERS
 PERCENT FINER BY WEIGHT
 PERCENT COARSER BY WEIGHT
 GRAIN SIZE IN MILLIMETERS

ENG FORM 2087
 1 MAY 63

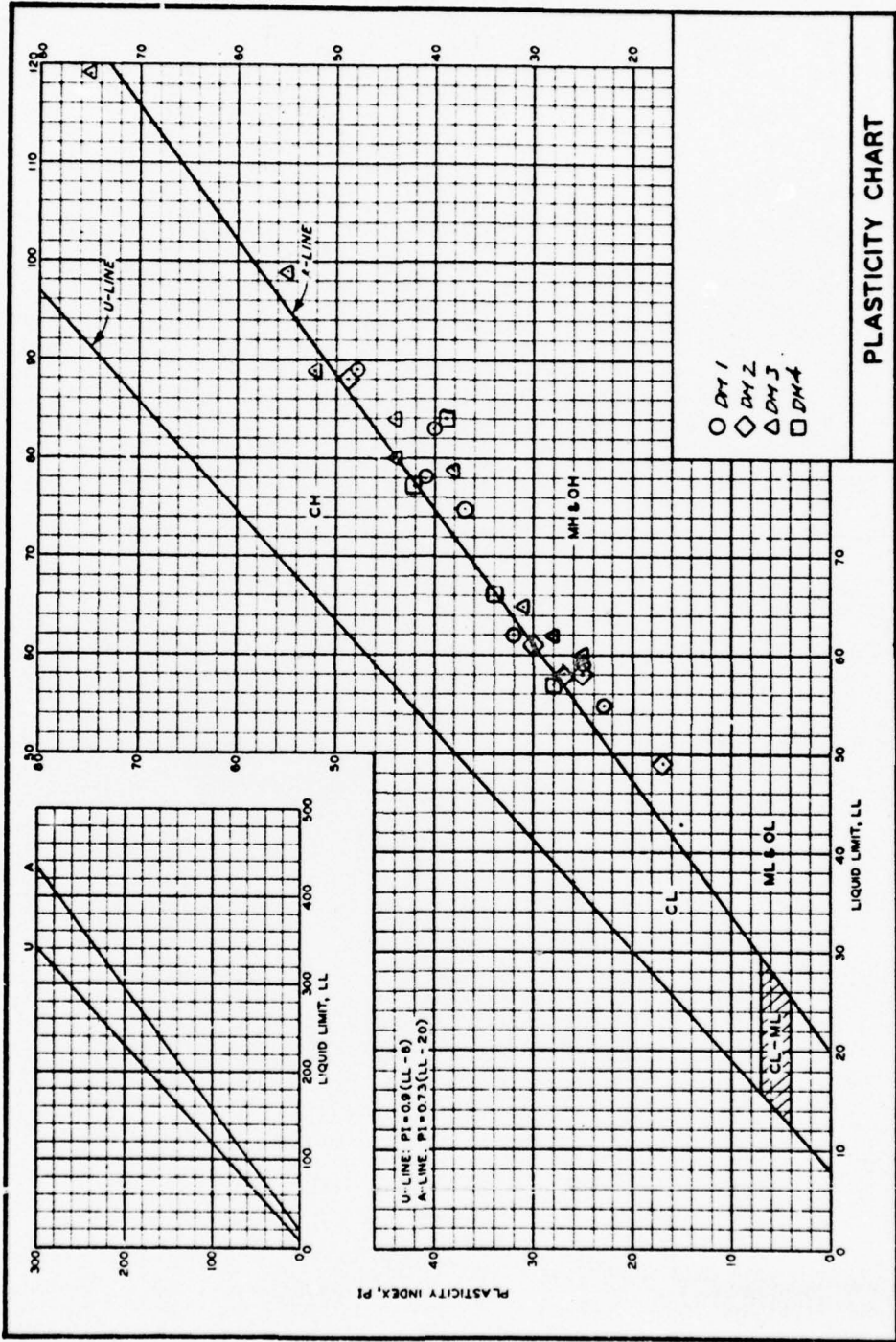


Project: **DYKE MARSH**
UNDISTURBED SAMPLES (SITE)
 Area: _____
 Boring No.: **DM-7**
 Date: **21 June, 1976**

Sample No.	Elev. @ Depth	Classification	GRAVEL			SAND			SILT OR CLAY		
			COARSE	FINE	COARSE	MEDIUM	FINE	PI	PL	PI	
5	21.0-23.0	SILTY SAND(SM) Dark Brown Gs = 2.66(gst)			38.5						

GRADATION CURVES

ENG FORM 2087
1 MAY 63



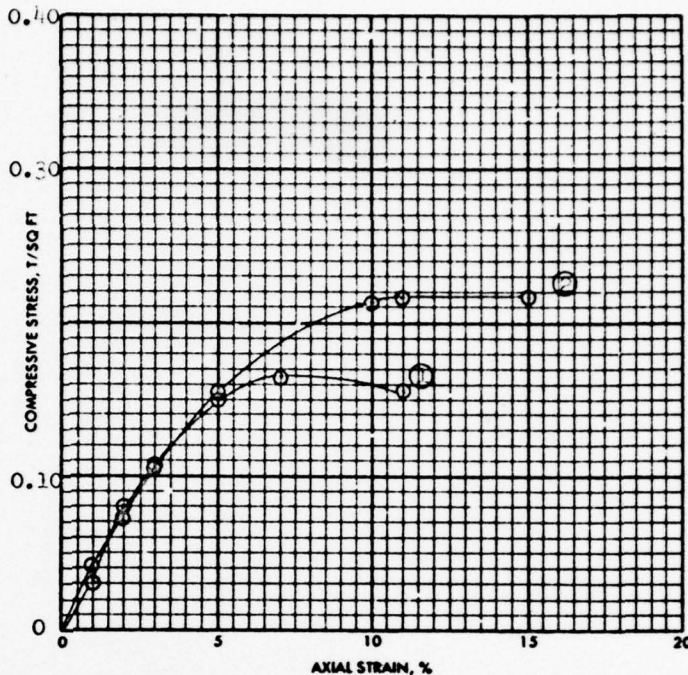
TRANSLUCENT

ENG FORM
JUNE 1975 4334

FAILURE SKETCHES



CONTROLLED STRESS
 CONTROLLED STRAIN



TEST NO.		1	2		
TYPE OF SPECIMEN					
INITIAL	WATER CONTENT	w _c	48.1 %	50.5 %	%
	VOID RATIO	e _v	1.30	1.29	
	SATURATION	S _v	100+ %	100+ %	%
	DRY DENSITY, LB/CU FT	γ _d	75.7	74.2	
TIME TO FAILURE, MIN		t _f	19	19	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT		q _u	0.16	0.22	
UNDRAINED SHEAR STRENGTH, T/SQ FT		s _u	0.082	0.11	
SENSITIVITY RATIO		S _i			
INITIAL SPECIMEN DIAMETER, IN		D _i	1.40	1.38	
INITIAL SPECIMEN HEIGHT, IN.		H _i	3.00	3.00	
CLASSIFICATION <u>SILTY CLAY(CH), gray</u>					
LL		PL	PI	G.	
REMARKS			PROJECT <u>DYKE MARSH</u>		
			AREA		
			BORING NO. <u>DM-4</u>		SAMPLE NO. <u>4A</u>
			DEPTH EL		
			DATE <u>22 July 1976</u>		
			JMS		
UNCONFINED COMPRESSION TEST REPORT					

ENG FORM 3659 (E.M 1110-2-1906) 1 JUN 68

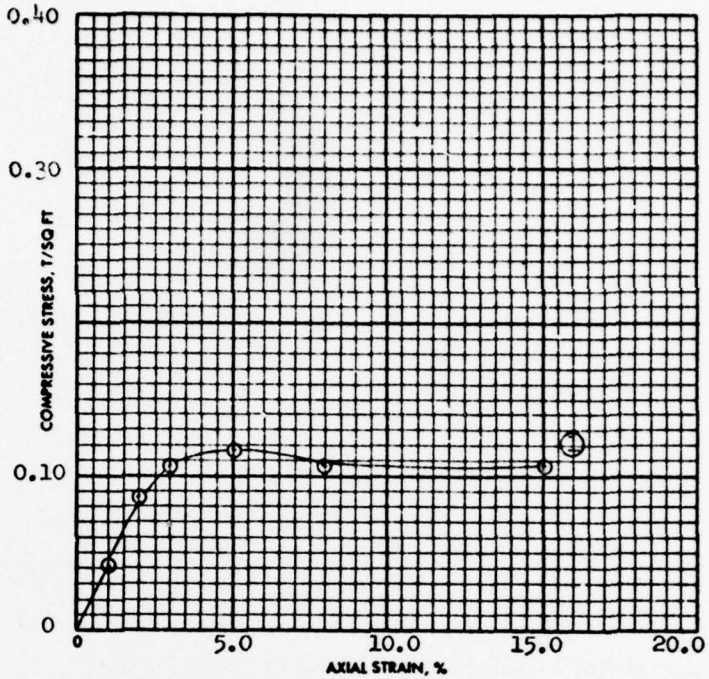
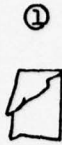
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GPO 1968 OF-214-946

PLATE XI-2

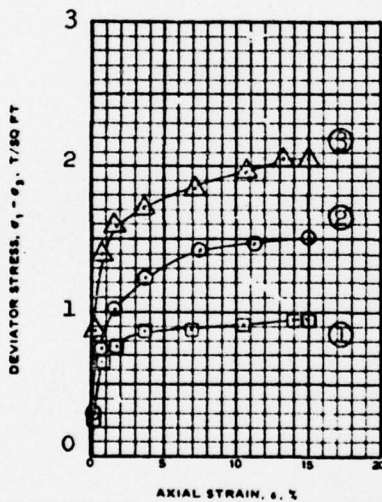
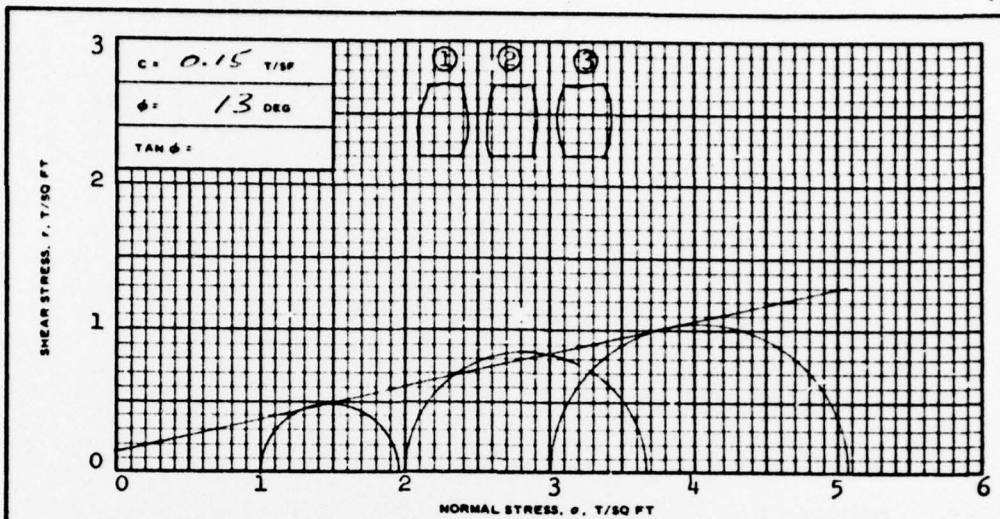
D46

FAILURE SKETCHES



- CONTROLLED STRESS
- CONTROLLED STRAIN

TEST NO.		1			
TYPE OF SPECIMEN					
INITIAL	WATER CONTENT	w _c	86.0	%	%
	VOID RATIO	e _v	2.35		
	SATURATION	S _v	98.8	%	%
	DRY DENSITY, LB/CU FT	γ _d	50.3		
TIME TO FAILURE, MIN		t _f	7		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT		q _v	0.118		
UNDRAINED SHEAR STRENGTH, T/SQ FT		s _v	0.059		
SENSITIVITY RATIO		S _i			
INITIAL SPECIMEN DIAMETER, IN		D _i	1.385		
INITIAL SPECIMEN HEIGHT, IN		H _i	3.00		
CLASSIFICATION PLASTIC CLAY(CH), gray, black & brown; small % fine sand, lignite					
LL	PI	PI	C. 2.70 EST.		
REMARKS		PROJECT DIKE MARSH			
		AREA			
		BORING NO.	DM-4	SAMPLE NO.	5A
		DEPTH EL		DATE	22 July 1976
		JMS UNCONFINED COMPRESSION TEST REPORT			



SPECIMEN NO.		1	2	3
INITIAL	WATER CONTENT, %	w _o 61.2	78.7	49.3
	DRY DENSITY LB./CU FT	γ _d 61.1	51.6	68.8
	SATURATION, %	s _o 95.3	94.8	93.4
BEFORE SHEAR	WATER CONTENT, %	w _c 52.6	59.2	41.2
	DRY DENSITY LB./CU FT	γ _d 68.8	66.7	79.3
	SATURATION, %	s _c 99.6	100+	100+
VOID RATIO		e _o 1.70	2.19	1.39
VOID RATIO		e _c 1.39	1.47	1.08
FINAL BACK PRESSURE, T/50 FT		u _o 5.04	5.04	5.04
MINOR PRINCIPAL STRESS, T/50 FT		σ ₃ 1.0	2.0	3.0
MAXIMUM DEVIATOR STRESS, T/50 FT		(σ ₁ - σ ₃) _{MAX} 0.95	1.65	2.06
TIME TO (σ ₁ - σ ₃) _{MAX} , MIN		t _i 875	882	894
ULTIMATE DEVIATOR STRESS, T/50 FT		(σ ₁ - σ ₃) _{ULT}		
INITIAL DIAMETER, IN.		D _o 1.40	1.38	1.37
INITIAL HEIGHT, IN.		H _o 3.00	3.00	3.00

CONTROLLED- **strain** TEST

DESCRIPTION OF SPECIMENS **SILT(MI), gray and brown; silty sand layers**

LL	PL	Pi	G _s 2.64	TYPE OF SPECIMEN	TYPE OF TEST R
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REMARKS See attached sheet for effective values.

PROJECT **DYKE MARSH**

BORING NO. **DM-6** SAMPLE NO. **4**

DEPTH FLEW

LABORATORY **USAEWES** DATE **27 July 1976**

JMS **TRIAXIAL COMPRESSION TEST REPORT**

Sheet 1 of 2.

Based on Max. σ_1/σ_3

SHEAR STRESS, τ , T/50 FT

Effective NORMAL STRESS, σ' , T/50 FT

C =	T/50 FT
$\phi =$	DEG
TAN $\phi =$	

Induced Pore Pressure, u , T/50 FT

AXIAL STRAIN, ϵ , %

SPECIMEN NO.		
INITIAL	WATER CONTENT, %	w_0
	DRY DENSITY LB/ CU FT	γ_{d_0}
	SATURATION, %	s_0
	VOID RATIO	e_0
BEFORE SHEAR	WATER CONTENT, %	w_c
	DRY DENSITY LB/ CU FT	γ_{d_c}
	SATURATION, %	s_c
	VOID RATIO	e_c
FINAL BACK PRESSURE, T/50 FT		u_0
MINOR PRINCIPAL STRESS, T/50 FT		σ_3
MAXIMUM DEVIATOR STRESS, T/50 FT		$(\sigma_1 - \sigma_3)_{MAX}$
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f
ULTIMATE DEVIATOR STRESS, T/50 FT		$(\sigma_1 - \sigma_3)_{ULT}$
INITIAL DIAMETER, IN.		D_0
INITIAL HEIGHT, IN.		H_0

CONTROLLED- TEST			
DESCRIPTION OF SPECIMENS			
LL	PL	PI	GI
TYPE OF SPECIMEN		TYPE OF TEST	
REMARKS:			
PROJECT DYKE MARSH			
BORING NO. DM-6		SAMPLE NO. 4	
DEPTH/ELEV			
LABORATORY USAEWES		DATE 27 July 1976	
JMS TRIAXIAL COMPRESSION TEST REPORT			

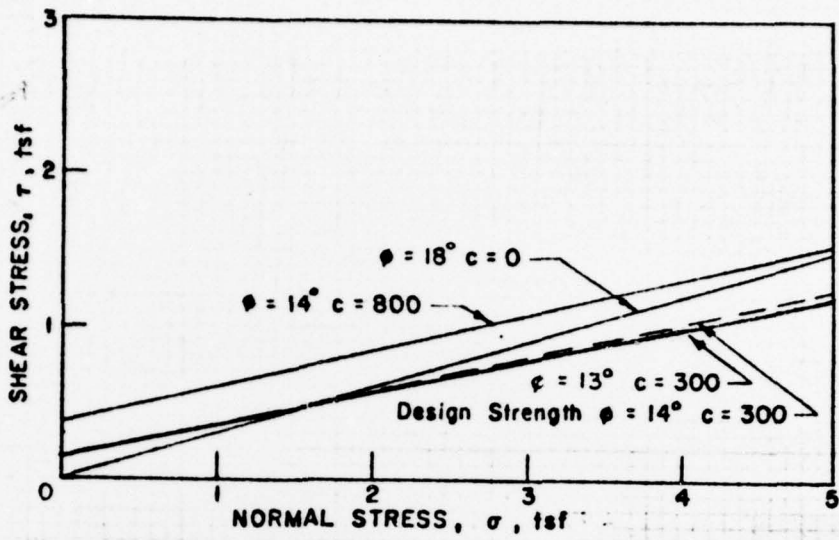
Sheet 2 of 2.

ENG FORM NO. 2089
REV JUNE 1970

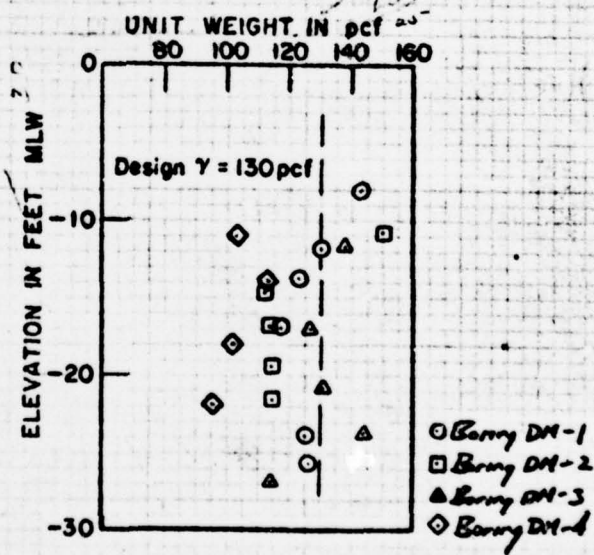
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TRANSLUCENT

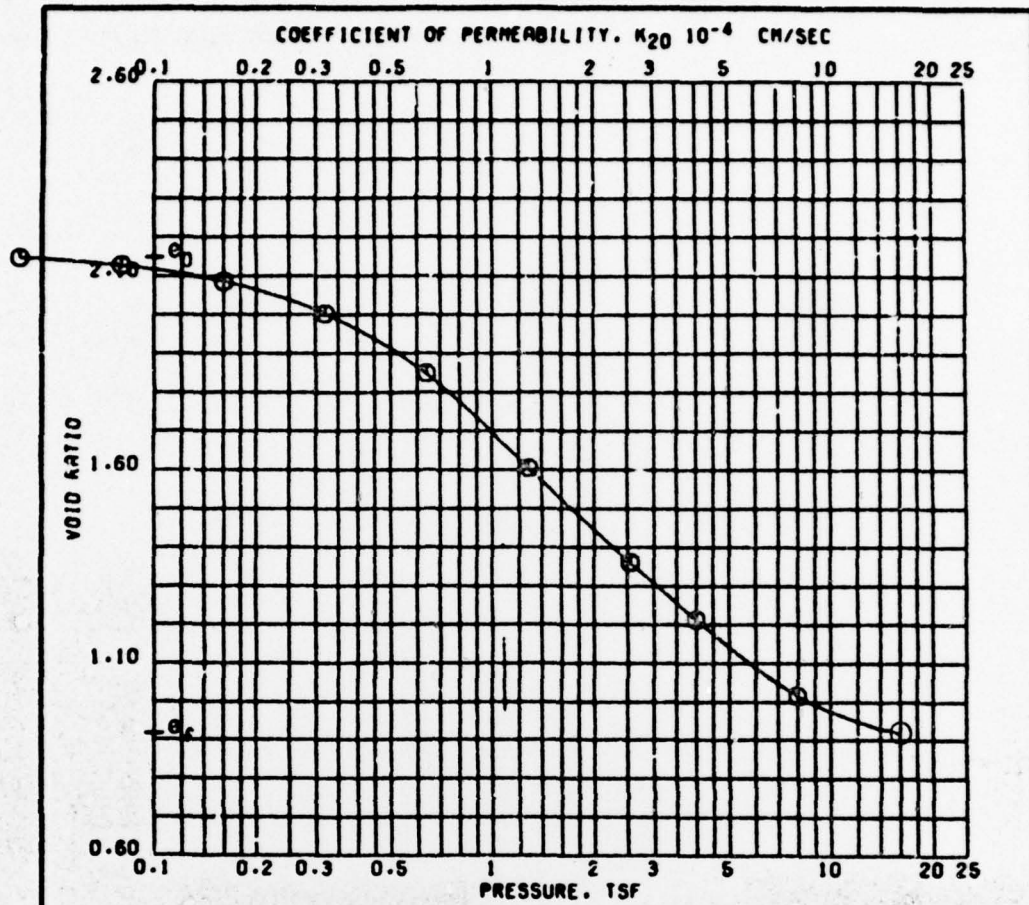
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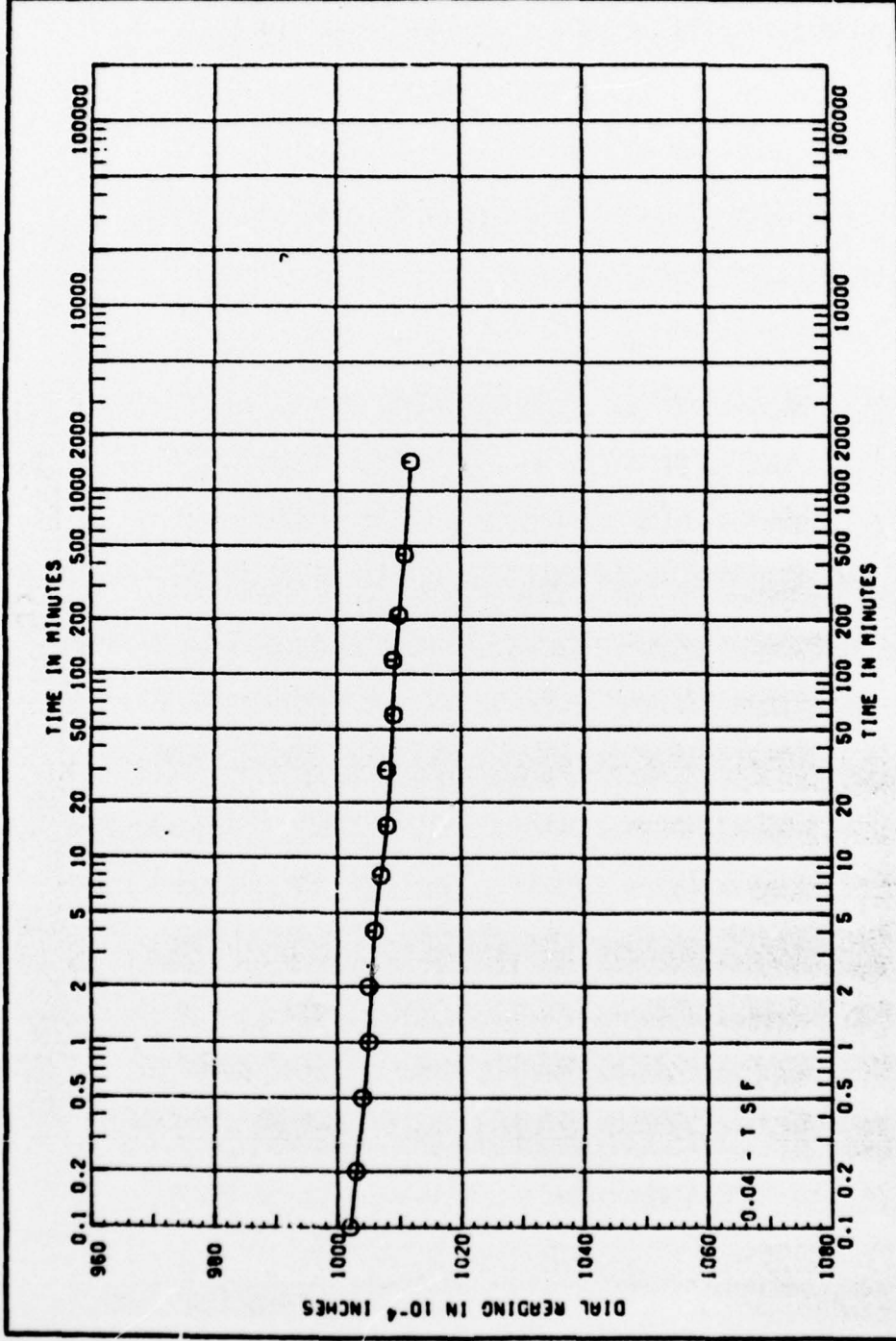
Consolidated undrained strength for silt



Saturated unit weight for silt

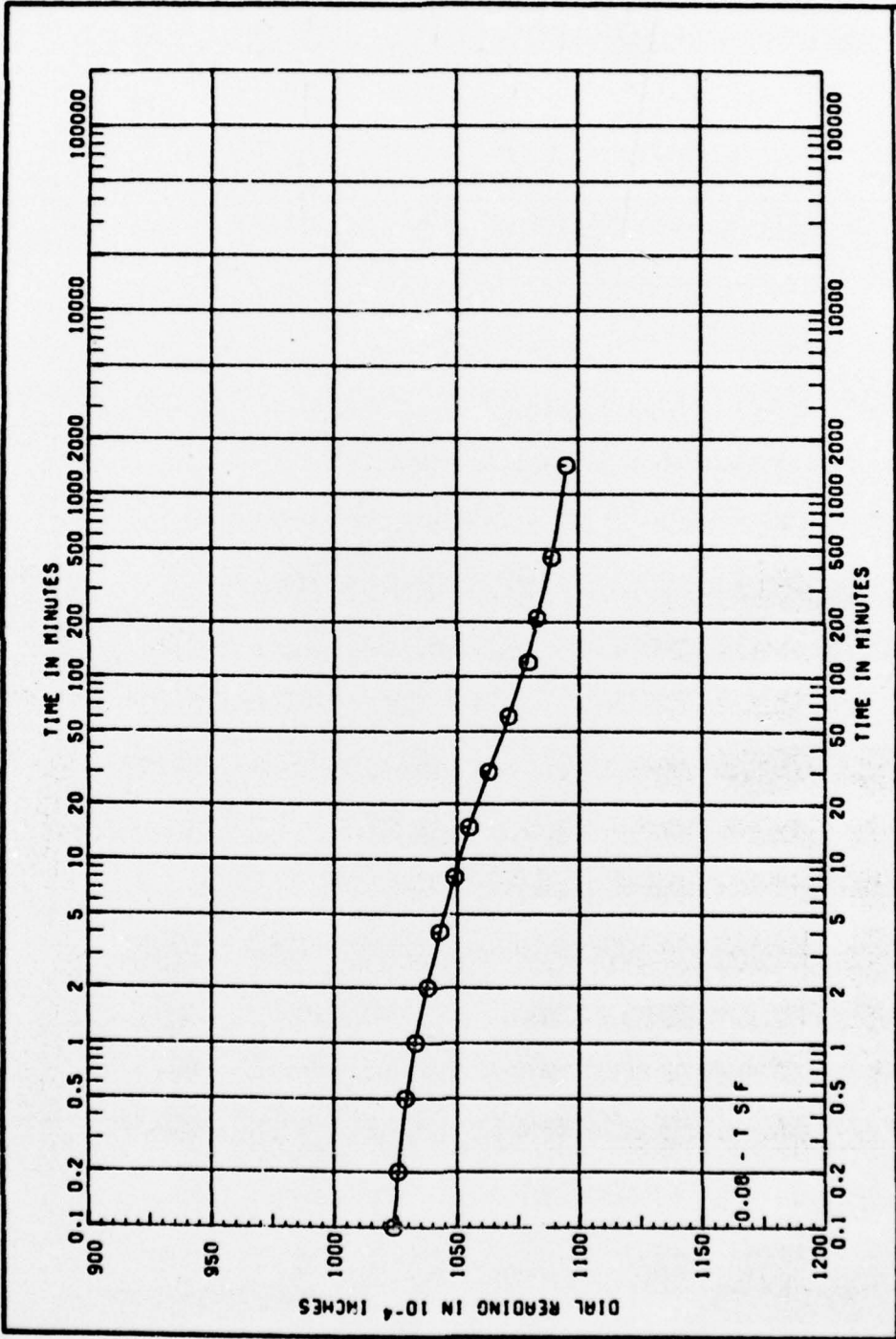


		BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE. TSF	0.14	WATER CONTENT. %	78.0
PRECONSOL. PRESSURE. TSF	0.45	DRY DENSITY. PCF	86.6
COMPRESSION INDEX	0.81	SATURATION. %	100.0
TYPE SPECIMEN	UNDISTURBED	VOID RATIO	2.148
DIA. IN 2.50	HT. IN 1.397	BACK PRESSURE. TSF	
CLASSIFICATION PLASTIC CLAY (CH). DARK GRAY			
LL 103	PL 27	PI 76	PROJECT DYKE HARM SEDIMENTATION STUDIES
GS 2.66	D ₁₀		
REMARKS	INITIAL VOID RATIO	BORING NO. DM4	SAMPLE NO. 2
	HELD CONSTANT BY P = 0.011 TSF	DEPTH/ELEV - - -14.0	DATE 04 NOV 76
AFTER INUNDATION		CONSOLIDATION TEST REPORT	



**CONSOLIDATION TEST
TIME CURVES**

PROJECT DYKE HARM SEDIMENTATION STUDIES	
BORING DM4	SAMPLE NO. 2
DEPTH/ELEV - -	DATE 04 NOV 76



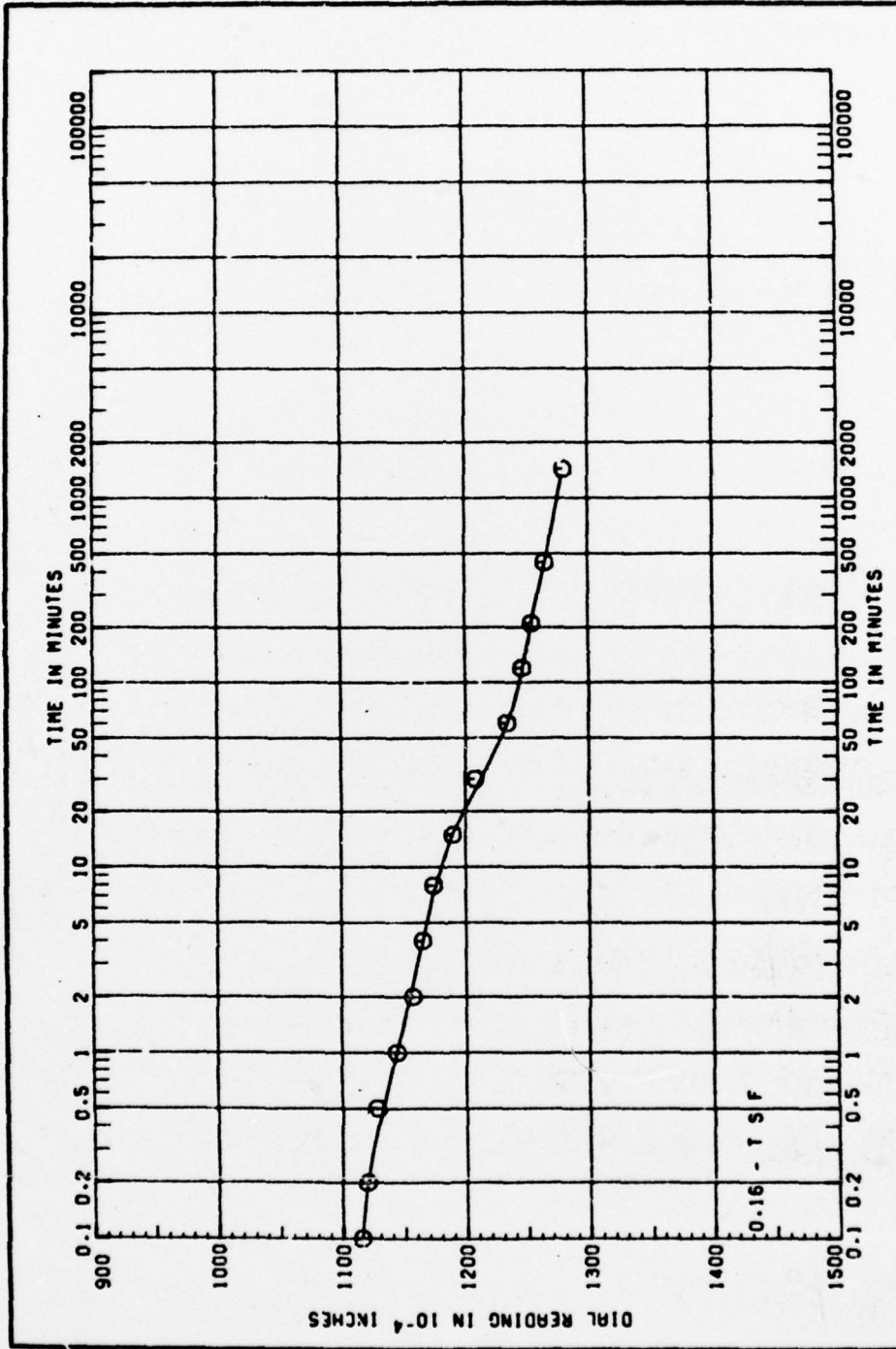
CONSOLIDATION TEST
TIME CURVES

PROJECT DYKE MARK SEDIMENTATION STUDIES

BORING DM4 SAMPLE NO. 2

DEPTH/ELEV - - DATE 04 NOV 76

SHEET 3 OF 11

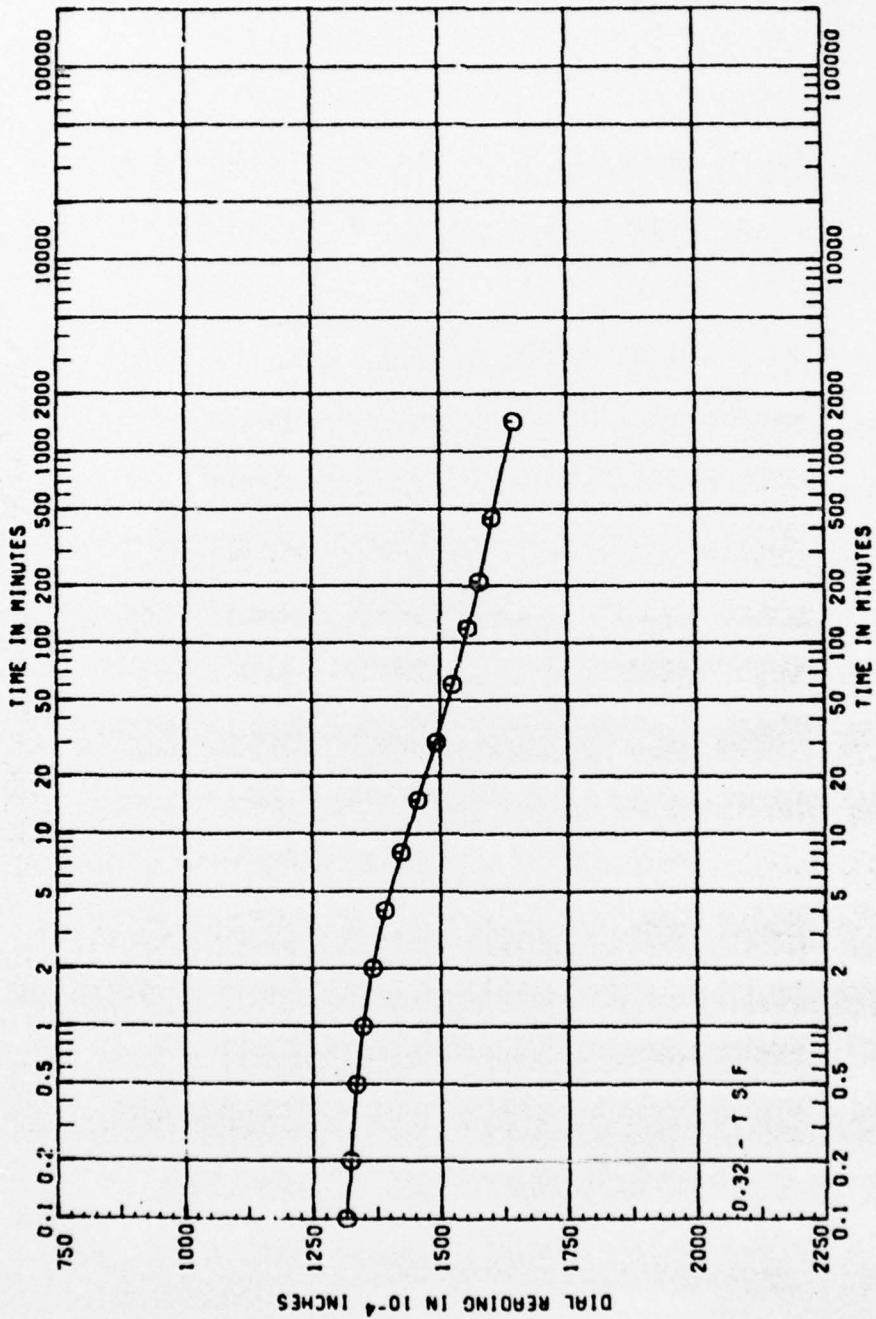


PROJECT DYKE HARM SEDIMENTATION STUDIES

CONSOLIDATION TEST
TIME CURVES

BORING	DM4
SAMPLE NO.	2
DEPTH/ELEV	-
DATE	04 NOV 76

150

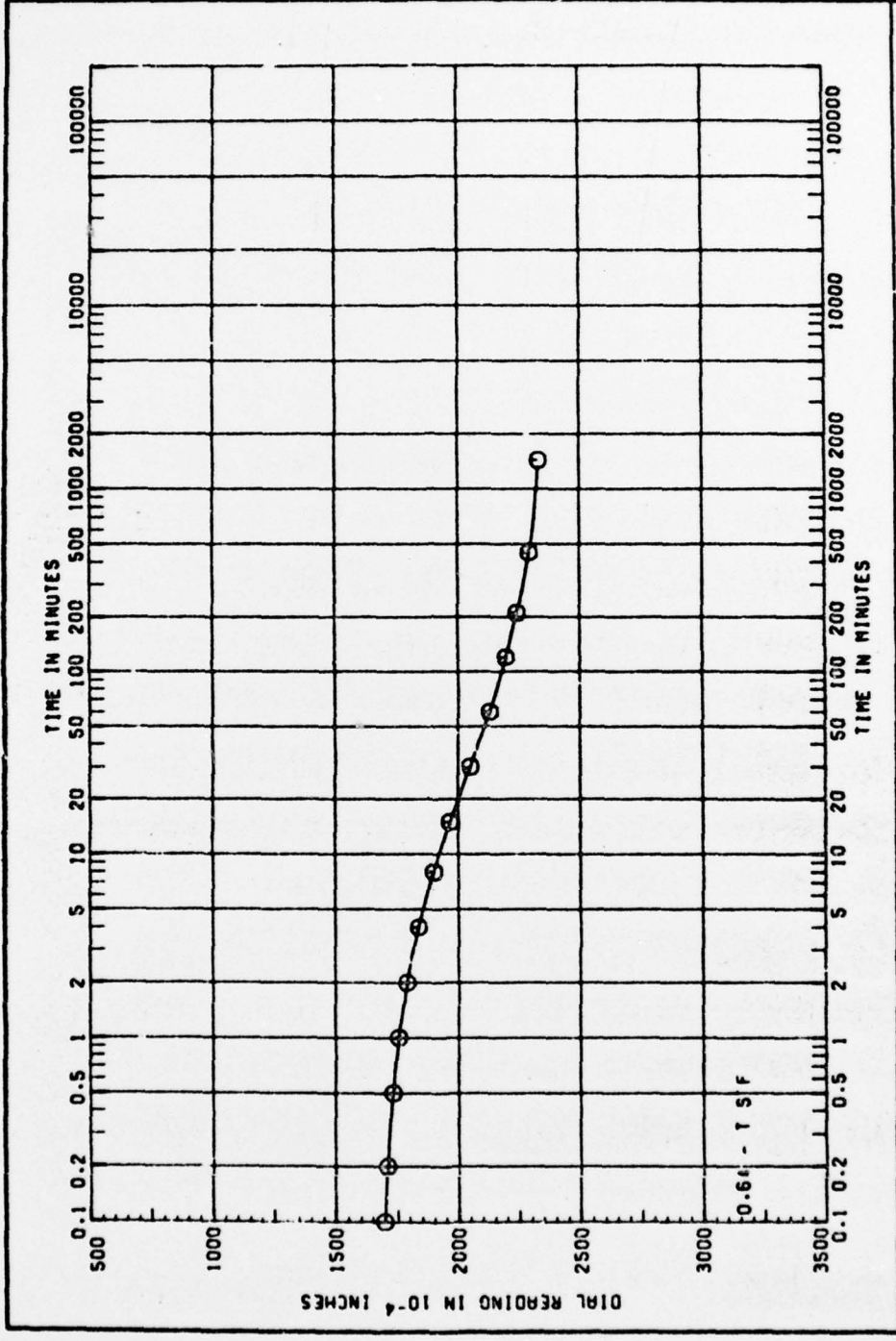


0.32 - T S F

CONSOLIDATION TEST
TIME CURVES

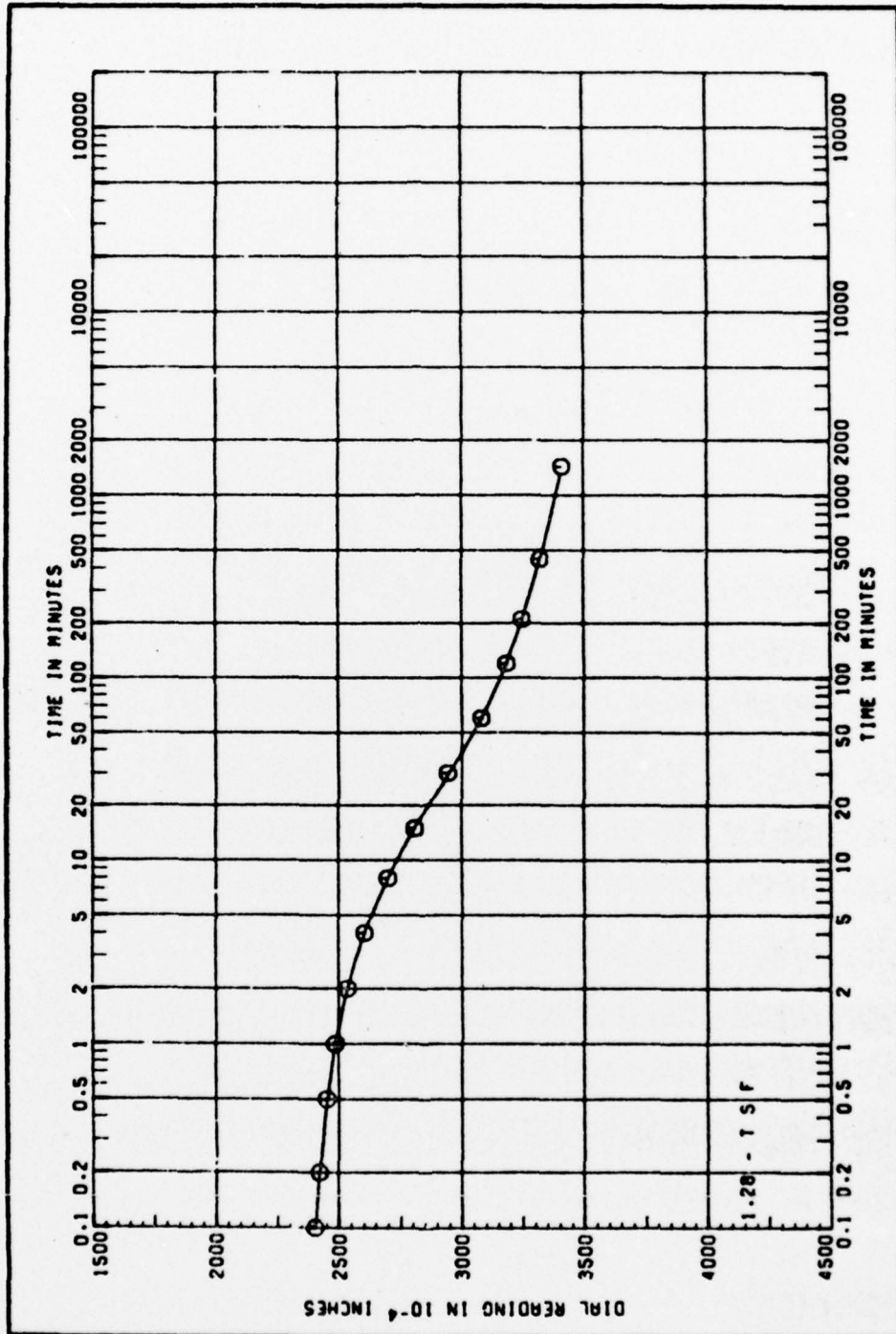
PROJECT DYKE MARK SEDIMENTATION STUDIES	
BORING DM4	SAMPLE NO. 2
DEPTH/ELEV - -	DATE 04 NOV 76

259



CONSOLIDATION TEST
TIME CURVES

PROJECT DYKE HARM SEDIMENTATION STUDIES	
BORING DM4	SAMPLE NO. 2
DEPTH/ELEV - -	DATE 04 NOV 76



CONSOLIDATION TEST
TIME CURVES

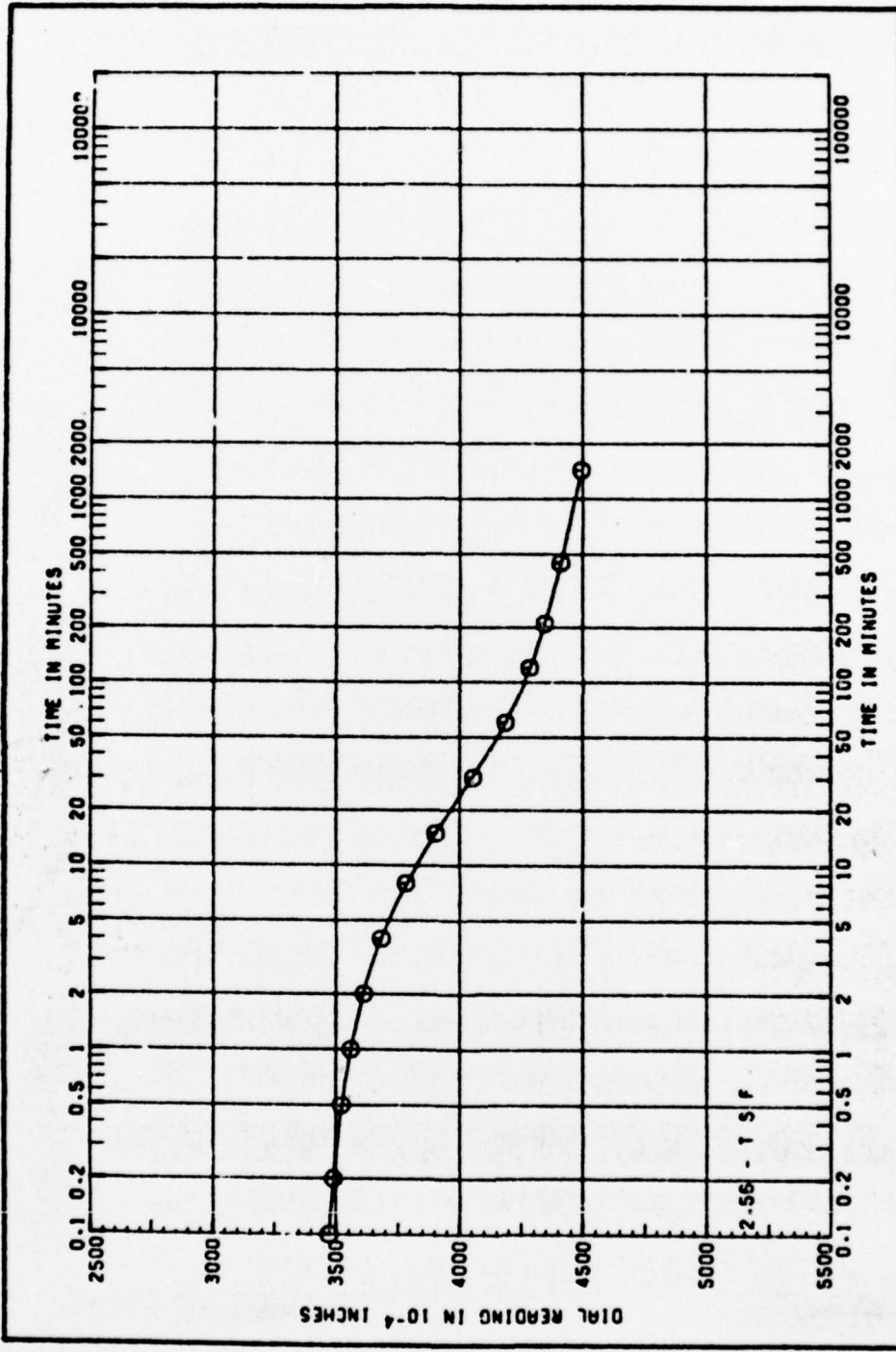
PROJECT DYKE MARK SEDIMENTATION STUDIES

BORING DM4 SAMPLE NO. 2

DEPTH/ELEV - - DATE 04 NOV 76

SHEET 7 OF 11

250



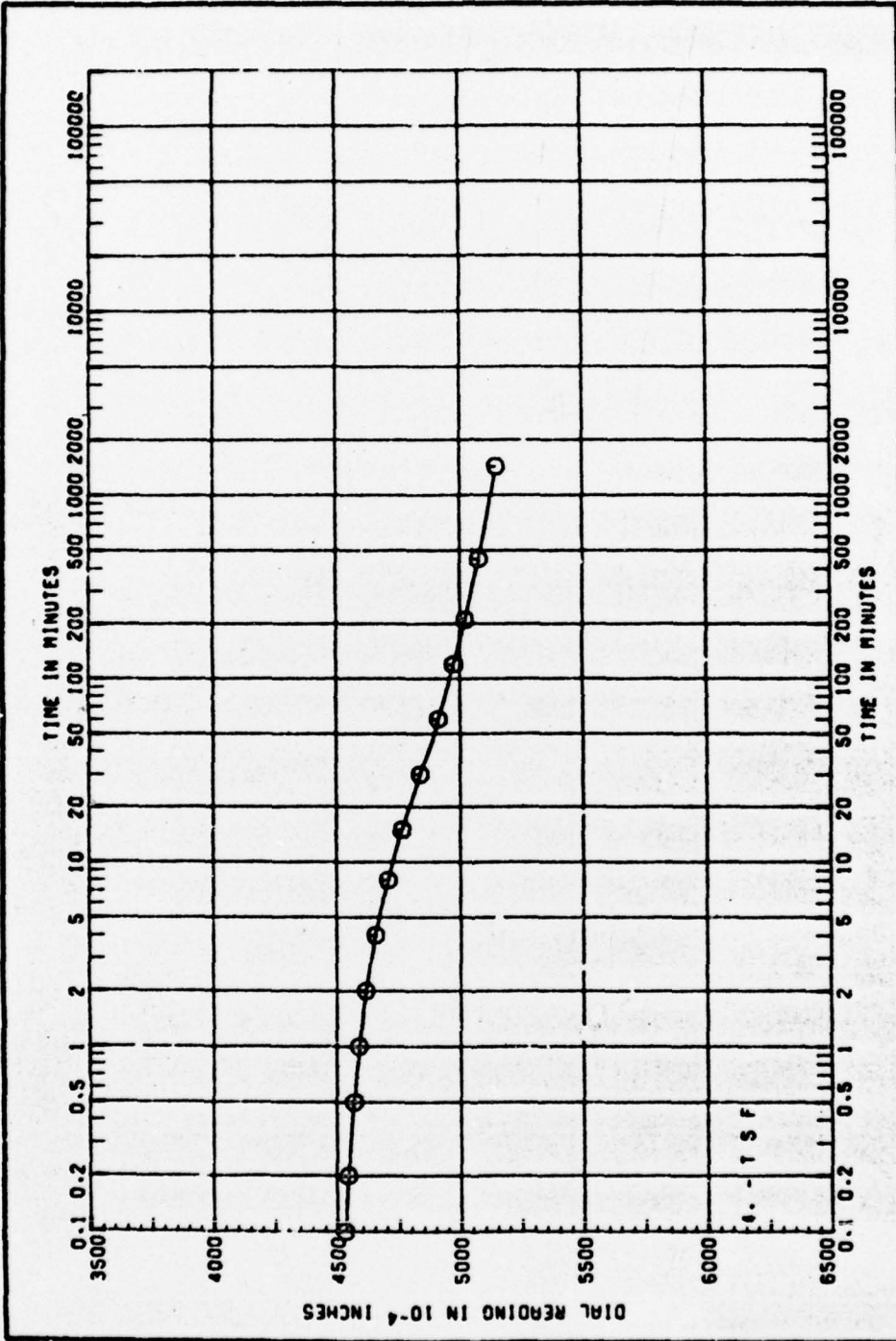
CONSOLIDATION TEST
TIME CURVES

PROJECT DYKE HARM SEDIMENTATION STUDIES

BORING UM4 SAMPLE NO. 2

DEPTH/ELEV - - DATE 04 NOV 76

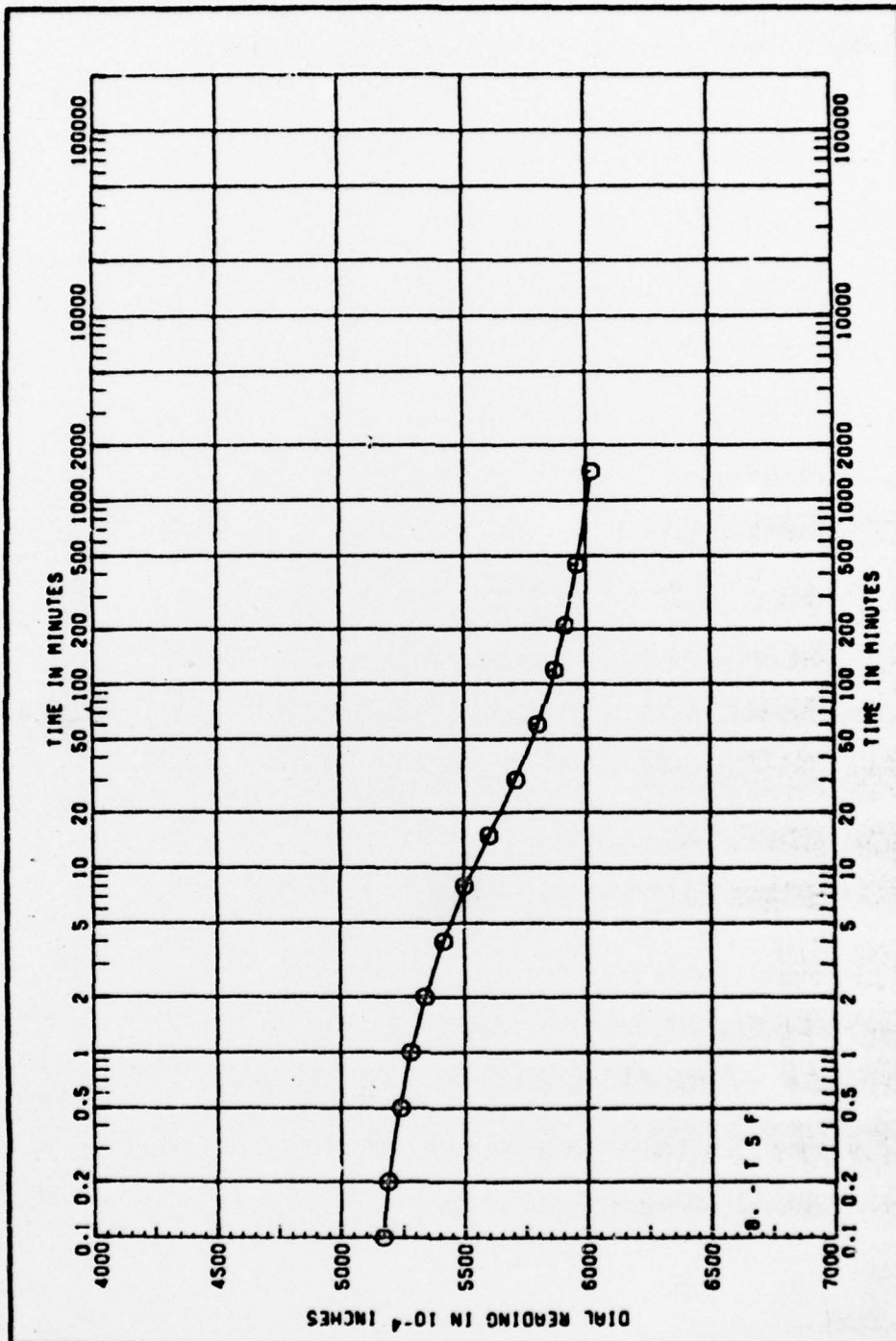
SHEET 8 OF 11



PROJECT DYKE MARK SEDIMENTATION STUDIES

BORING	DIR4	SAMPLE NO.	2
DEPTH/ELEV	- -	DATE	04 NOV 76

CONSOLIDATION TEST
TIME CURVES

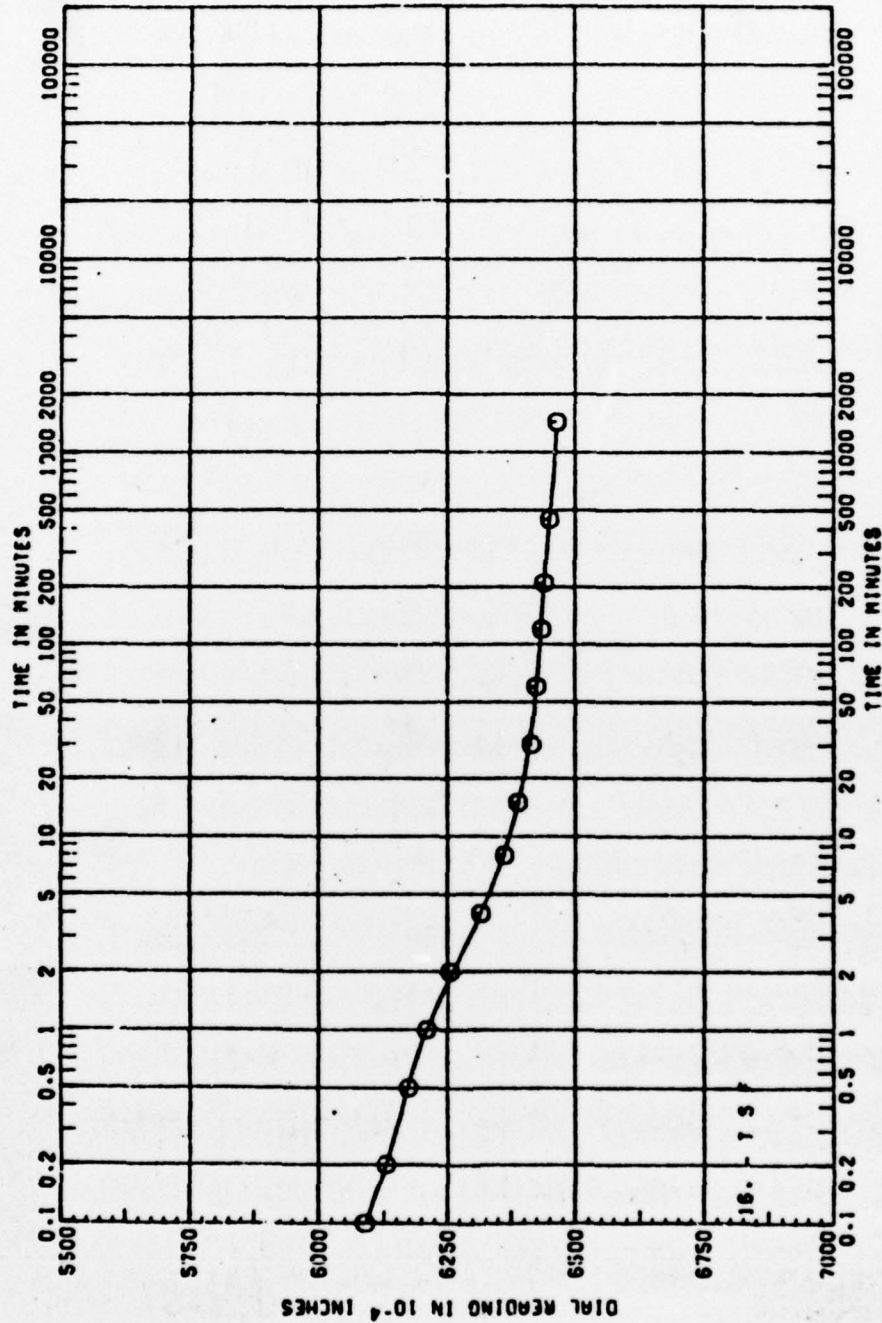


CONSOLIDATION TEST
TIME CURVES

PROJECT DYKE HARM SEDIMENTATION STUDIES

BORING DM4 SAMPLE NO. 2

DEPTH/ELEV - - DATE 04 NOV 76



D61

CONSOLIDATION TEST
TIME CURVES

PROJECT DYKE HARM SEDIMENTATION STUDIES

BORING DR4 SAMPLE NO. 2

DEPTH/ELEV. - - DATE 04 NOV 76