WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

PHILLIPS BROOK, MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

EMBANKMENTS AND FOUNDATIONS

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASS.

APRIL 1973

14

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

30 April 1973

SUBJECT: Nookagee Lake, Phillips Brook, North Nashua River Basin - Design Memorandum No. 8, Embankments and Foundations

HQDA (DAEN-CWE-B)
WASH DC 20314

In accordance with ER 1110-2-1150, there is submitted for review and approval Design Memorandum No. 8, Embankments and Foundations, for the Nookagee Lake Project, located in the North Nashua River Basin, Massachusetts.

FOR THE DIVISION ENGINEER:

Incl (10 cys)
as

JOHN Wm. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT
North Nashua River Basin - Merrimack River
Massachusetts

DESIGN MEMORANDA INDEX

		Whitmanville Lake Whitman River			Nookagee Lake Phillips Brook		
No.	Title	Scheduled Submission	Submission	Approved	Scheduled Submission	Submission	Approved
1	*Hydrology	May 1970	7 May 1970	10 Jul 1970	May 1970	7 May 1970	10 Jul 1970
1	*Hydrology (Revised)	Jul 1971	15 Jul 1971	2 Nov 1971	Jul 1971	15 Jul 1971	2 Nov 1971
2	General Design	Jul 1971	31 Aug 1971	6 Jan 1972	Mar 1972	22 Dec 1972	
3	Public Use - Land Use Requirement Plan	(To be submitted as an appendix to GDM)					
4	Relocations	Sep 1971	24 Sep 1971	11 Jan 1972	Jan 1973	1 Feb 1973	
5	Real Estate	Apr 1972	15 Sep 1972		Feb 1973		
6	*Concrete Materials	Nov 1970	26 Feb 1971	29 Mar 1971	Nov 1970	26 Feb 1971	29 Mar 1971
7	Site Geology	Dec 1970	31 Mar 1971	29 Apr 1971	Feb 1972	29 Feb 1972	17 Nov 1972
8	Embankments and Foundations	Aug 1971	20 Sep 1971	12 Jan 1972	Jan 1973	30 Apr 1973	
9	Hydraulic Analysis	Mar 1973			Mar 1973		
10	Detailed Design of Structures	**Jun 1972			Sep 1973		

* Joint Submission for Both Projects

** To be completed upon receipt of construction funds

NOOKAGEE LAKE

DESIGN MEMORANDUM NO. 8

EMBANKMENTS and FOUNDATIONS

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WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE
PHILLIPS BROOK, MASSACHUSETTS

DESIGN MEMORANDUM NO. 8
EMBANKMENTS AND FOUNDATIONS
APRIL 1973

A. INTRODUCTION

1. Location and Description of Project. The Nookagee Lake Project is located on Phillips Brook in the Town of Westminster and Ashburnham, Massachusetts about 3.1 miles above the confluence of the brook with the North Nashua River. (Plate 8-1) The project consists of a rolled earthfill dam with a side channel spillway and appurtenant structures. (Plate 8-2)

2. Pertinent Data.

a. Purpose. Flood control, water quality control and limited recreation.

b. Drainage Area at Damsite. 10.8 square miles.

c. Project Elevations, Mean Sea Level.

(1)	Top of Dam	846.5
(2)	Maximum Surcharge Pool	841.7
(3)	Spillway Crest	835.0
(4)	Water Quality Control Pool	816.0
(5)	Conservation Pool	790.0
(6)	Recreation Pool (Limited)	790.0 to 816.0

d. Dam

(1)	Maximum height above stream bed	105 feet
(2)	Length	2,000 feet

3. General Notes. The results of subsurface investigations and soils engineering studies undertaken for the design of the dam embankment are discussed in this design memorandum. The subsurface investigations included programs of subsurface explorations and laboratory tests conducted to determine the distribution and characteristics of foundation and embankment materials and to determine soil conditions pertinent to excavations and to the design and construction of the dam embankment and other project features. Soils engineering studies were conducted on the basis of data obtained from these investigations to develop safe and economical earthwork designs and construction methods.

B. SUBSURFACE INVESTIGATIONS

4. Subsurface Explorations. Subsurface explorations were conducted in accordance with current criteria and practices as set forth in Corps of Engineers Manuals EM 1110-2-1801, "Geological Investigations" and EM 1110-2-1803, "Subsurface Investigations - Soils." The majority of the explorations were drive-sample borings. Undisturbed sampling procedures were attempted unsuccessfully in one drill hole in the dam foundation area. The subsurface exploration program completed to date is considered adequate for the design of the dam embankment. The locations, types and general purposes of the explorations are discussed in Design Memorandum No. 7 "Site Geology."

5. Laboratory Tests. All soil samples were visually classified according to the Unified Soil Classification System. This visual classification was confirmed for representative samples by grain size analyses and determinations of Atterberg Limits. Selected samples were tested to determine natural moisture content, compaction characteristics, permeability, consolidation characteristics and shear strength. All laboratory tests were performed in accordance with the provisions of EM 1110-2-1906 "Laboratory Soils Testing."

6. Presentation of Data. Summarized soil test results are presented in Appendix A. Detailed shear, consolidation and compaction test reports are included in Appendix B. Log profiles of the dam embankment foundation, based upon engineering soil reports, are shown on Plates 8-4 through 8-8. These engineering soil reports were prepared for all pertinent explorations by the design soil engineer with the aid of laboratory test data and the assistance of an experienced soils classifier. The reports include descriptions of the soils and soil strata based on the engineer's examination of the samples and his interpretation of the test results

and exploration records. The descriptions cover soil consistency, estimated or measured percentages of the soil components, color, stratification, presence of foreign material, geological names and other information of significance in establishing soil characteristics for design and construction purposes. Selected laboratory test data are shown on Plates 8-10 and 8-11.

C. CHARACTERISTICS OF FOUNDATION SOILS

7. Distribution and Description.

a. General. Reference is made to the engineering log profiles (Plates 8-4 through 8-8) for details of the distribution and description of embankment foundation soils. The embankment foundation area is capped with from 1 to 2 feet of topsoil and forest litter overlying from 5 to 30 feet of highly variable glacial outwash and alluvial deposits. On both abutments, these overlie a very compact glacial till deposit, extending to the bedrock surface. In the valley, the till deposit becomes thinner and intermittent and is overlain by a deposit of stratified sandy silt and silty fine sand up to 60 feet thick. For convenience, these deposits will be referred to hereafter as follows:

Zone A - Glacial outwash and alluvial deposits

Zone B - Stratified sandy silt and silty fine sand deposit

Zone C - Glacial till deposit

b. Zone A. The soils in this zone consist of roughly and erratically stratified, highly variable, moderately compact to compact, non-plastic, gravelly silty sand and silty sandy gravel with a few lense and pockets of gravelly sandy silt. Cobbles and boulders are scattered throughout the zone with occasional local concentrations. Gravel contents of the sands range from 0 to 50 percent. Silt contents of all the soils vary widely from less than 5 percent to 50 percent of the component passing the No. 4 Sieve. There are occasional strata of soils having gradations typical of those in the glacial till deposit (Zone C).

c. Zone B. The soils in this zone generally consist of stratified, very compact, non-plastic, sandy silt and silty fine sand. The thicknesses of the strata range from 1/32 inch to several inches. There are occasional layers of relatively clean fine and medium to fine sands. There are also a few layers of soils having gradations typical of those in Zone C. Although this zone is generally free of cobbles and boulders, a concentration

of cobbles 12 feet thick was encountered in one boring within this zone. Natural water contents of samples from this zone indicate in-situ dry unit weight ranging from 105 to 130 p.c.f. and averaging about 115 p.c.f.

d. Zone C. The soils in this zone consist principally of unstratified, compact to very compact, cobbly, bouldery, gravelly silty sand. These soils are non-plastic except for a few small inclusions of gravelly sandy clay and gravelly silty clayey sand. Gravel contents generally range from about 5 to 25 percent. Fine contents range from 30 to 60 percent of the component passing the No. 4 Sieve. Natural water contents of samples from this zone indicate in-situ dry unit weights ranging from 115 to 140 p.c.f. and averaging about 131 p.c.f.

8. Permeability Characteristics. Permeability tests were not performed on samples of embankment foundation soils. The following ranges of permeability characteristics have been estimated on the basis of visual examination of the samples and their grain size curves:

Zone	K_v cm/sec	K_h/K_v
A	1 to 1000 x 10^{-4}	9
B	1 to 100 x 10^{-4}	16
C	0.1 to 1.0 x 10^{-4}	4

9. Consolidation Characteristics. Consolidation tests were not performed on samples of the embankment foundation soils. The soils in Zones A and C are of types normally exhibiting low to very low compressibility. The Zone B soils, although normally of higher compressibility, are also considered to be of low compressibility in this case due to their high in-situ densities. Little or no post construction foundation settlement is anticipated under the proposed embankment loading.

10. Shear Strengths. Shear tests were not performed on samples of embankment foundation soils. The following shear strength parameters represent conservative estimates based on examination of the samples and their grain size curves together with experience with similar materials:

Zone	ø degrees	C T.S.F.
A	35	0
B*	25	0
C	30	0

*Also applicable for possible silt layers in Zone A.

D. CHARACTERISTICS OF FOUNDATION BEDROCK

11. Bedrock Foundation for Dam Embankment. The bedrock consists of granitic schist with scattered zones of fine-grained granite and numerous but generally thin pods and lenses of pegmatite. Biotite mica occurs abundantly throughout in thick, felted, concentrations and talc occurs locally as thick lenses in the schist. The schist and the granite are generally dark gray, hard, fine-grained and fresh. The pegmatite ranges from light gray to pink and is very coarse-grained, hard and fresh. Foliation in the schist is generally horizontal or dips at very low angles. The upper zones of the rock to depths in the order of fifteen (15) to twenty (20) feet are very closely jointed with joints which are horizontal or dipping at low angle. Secondary joints dipping at approximately 30°, 45°, and 60° are also common throughout. Weathering has progressed commonly along the foliation planes and joints to depths of ten (10) feet and more rarely to depths up to 30 feet. The bedrock surface is rough and irregular with numerous shallow ridges and troughs typical of schist. A double-line grout curtain will be constructed in the bedrock along the eastern edge of the upstream impervious blanket and in the shallow bedrock on the left abutment under the cut-off for the embankment.

12. Bedrock Foundation for Concrete Structures. Foundations for the spillway weir and associated walls are located generally well below the surficial zone of loose and weathered rock. At such depth the rock is hard, generally sound and should require only nominal treatment such as removal of loose joint blocks and clean-out of slightly weathered seams to provide satisfactory foundation for the proposed structures. Pre-splitting will be required and line-drilling will be utilized as feasible to control breakage for final excavations. A single line grout curtain will

be constructed in rock under the spillway walls and weir. Drain holes will be provided as required beneath structures, walls and slabs. Detailed discussion of bedrock conditions in relation to concrete structures is included in Design Memorandum No. 7, "Site Geology" and Design Memorandum No. 9 "Detailed Design of Structures."

E. CHARACTERISTICS OF EMBANKMENT MATERIALS

13. General. The required project excavations will not provide sufficient material for the construction of the dam embankment. Reconnaissance for sources of borrow resulted in the location of several glacial till deposits near the site. Of these potential sources, the deposit in Area A (see Plate 8-9) was selected on the basis of the adequacy of the material therein as to quantity and quality; its potential for economical development as a borrow area and the lesser environmental impact of its selection as compared to other sources. The reconnaissance indicated that there were no economically feasible borrow sources of embankment drainage materials and gravel bedding near the site. These materials, consequently, will be furnished by the contractor from commercial sources within a 15-mile haul.

14. Impervious Embankment Material.

a. General. Impervious embankment material will be obtained from a borrow area developed in the glacial till deposit in Area A. This area is located on the right wall of the valley about 4,000 feet downstream of the damsite. The area is undeveloped and covered for the most part by a moderately heavy growth of brush. Its topography lends itself to the development of drainage and sedimentation systems for the control of waterborne silt during and after construction. Borrow operations in this area are considered to have a potential environmental impact no greater than that in any of the other practicable sources near the damsite.

b. Distribution and Description. The overburden in Area A consists of a 1 to 2-foot capping of topsoil and forest debris overlying compact to very compact, bouldery, cobbly, gravelly silty sand. Gravel contents range from 5 to 35 percent with silt contents varying from 30 to 55 percent of the component passing the No. 4 Sieve. The material is generally non-plastic. Stone counts made during the excavation of test pits indicate that oversize stone may account for as much as 10 percent of the volume of impervious embankment material obtained from this source. In view of this, it is planned to specify removal of oversize stone by screening.

c. Permeability Characteristics. Permeability tests were performed on two samples of impervious embankment material. On the basis of the results of these tests and of visual examination of other samples and their grain size curves, it is estimated that the vertical coefficient of permeability of compacted impervious embankment material will range from 0.1 to 1.0×10^{-4} cm/sec. The horizontal coefficient is expected to be about four times the vertical.

d. Consolidation Characteristics. A consolidation test was performed on a sample considered representative of the impervious embankment material (BT 2, B-3). The test specimen was prepared at a water content two percent above optimum and compacted to 97 percent of maximum test density. The test results indicate a compression index (C_c) of 0.040 and a coefficient of consolidation (C_v) of 0.57 cm^2/sec. at a loading equivalent to the maximum embankment load. On the basis of the test results and experience with compacted fills of similar materials, it is anticipated that most of the settlement within the fill will occur during construction and that post-construction settlement will be negligible.

e. Compaction Characteristics. Standard compaction tests were performed on two representative samples of impervious embankment material with the following results:

Sample	Group Letter Symbol	Maximum Dry Density	Optimum Water Content
BT-1, B-6	SM	122.0	10.9
BT-2, B-3	SM	124.6	9.8

In-situ densities as indicated by natural water contents average over 100 percent of maximum dry densities. Natural water contents generally range from optimum to about four percent above optimum. It is anticipated that with adequate drainage of the borrow area during excavation and a minor amount of moisture conditioning during placement, placement moisture contents can be held within a specified range of from two percent below to two percent above optimum.

f. Shear Strengths. Sample BT-2, B-3 was selected for shear testing as being typical of the impervious embankment material to be obtained from Area A. Triaxial Q and R type tests and direct shear S type tests were performed on specimens prepared at the following water contents and densities:

Test	Water Content (Moulding)	Density
1	Optimum W. C. - 2%	97% max.
2	Opbimum W. C.	97% max.
3	Optimum W. C. + 2%	97% max,
4	Optimum W. C.	100% max.

The Q and R tests were run at controlled strain rates of 0.2 and 1.0 percent per minute, respectively. Specimens for the R tests were saturated by the back pressure method. Detailed shear test reports (ENG Forms 2089 and 2092) are included in Appendix B. Shear strength envelopes for the test and design strengths are shown on Plate 8-12.

15. Random Embankment Material. Random embankment material will be obtained from the required earth excavations for the outlet works and the spillway channels. These excavations will be made in Zones A and C of the foundation (See Par. 7). While the material will be highly variable in character, it has been assigned the same physical characteristics as the impervious embankment material for design purposes.

16. Embankment Drainage Materials and Gravel Bedding.

a. General. As discussed in Paragraph 13, embankment drainage materials and gravel bedding will be furnished by the contractor from commercial sources. Embankment drainage materials include those for pervious fill, drainage fill and gravel fill.

b. Gradation Specifications.

(1) Investigations of the potential sources of embankment drainage materials and gravel bedding indicate that the following gradation specifications can be satisfied by materials available from commercial and undeveloped sources within a 15-mile haul. The specifications for materials functioning as filters have been established according to the filter design criteria set forth in EM 1110-2-1901, "Seepage Control."

(2) Gravel Bedding. Gravel bedding material shall consist of bank-run sandy gravel or gravelly sands. The material shall be reasonably well-graded between the following limits:

Sieve Size (U.S. Standard)	Percent Passing by Dry Weight
6-inch	100
1-inch	50-85
No. 4	30-60
No. 16	15-40
No. 200	0-5

(3) Gravel Fill. Gravel fill material shall meet all requirements specified for gravel bedding with the additional requirement that no more than 10 percent, by dry weight, of the component passing the No. 4 Sieve shall pass the No. 200 Sieve.

(4) Pervious Fill. Pervious fill material shall consist of approved bank-run, reasonably well-graded gravelly sand or sandy gravel. Of the component passing the 3-inch Sieve, between 30 and 75 percent shall pass the No. 4 Sieve. Of the component passing the No. 4 Sieve, between 10 and 50 percent shall pass the No. 40 Sieve and no more than 10 percent shall pass the No. 200 Sieve.

(5) Drainage Fill. Drainage fill material shall consist of sand processed as required to meet the following gradation requirements:

Sieve Size (U.S. Standard)	Percent Passing by Dry Weight
3/8-inch	100
No. 4	95-100
No. 16	55-80
No. 50	10-25
No. 100	2-8
No. 200	0-2

NOTE: This gradation specification is the same as that used by the Massachusetts Department of Public Works for fine concrete aggregate.

c. Permeability. Permeability tests were not performed on samples of embankment drainage materials. On the basis of the specified gradations and experience with similar materials, the following permeability characteristics have been assigned to compacted fills of these materials.

Material	K_v cm/sec	K_h/K_v
Gravel Fill	over 100×10^{-4}	9
Pervious Fill	over 100×10^{-4}	9
Drainage Fill	over 200×10^{-4}	9

d. Shear Strengths. Shear tests were not performed on samples of embankment drainage materials. On the basis of the specified gradations and experience with similar materials, the following shear strength parameters have been assigned to compacted fills of these materials:

Material	ϕ degrees	c - T/sq. ft.
Gravel Fill	35	0
Pervious Fill	35	0
Drainage Fill	35	0

17. Rock Protection. Rock for rock protection and riprap will be available from required excavations in rock. The rock consists mainly of granitic schist with scattered thin zones of fine granite and very coarse pegmatite. The essentially horizontal foliation and close jointing will tend to result in producing thin, flat, slabby fragment shapes particularly in the upper, shallow zones of the excavations. Breakdown of highly micaceous phases and pegmatitic zones in the rock during blasting and handling will tend to produce considerable fines. Fines will also result from weathered zones in the rock and mud-filled seams. Field segregation and wasting of dirty rock would be very difficult during construction and losses from wastage would not be within tolerable limits. It is, therefore, considered necessary to process the blasted rock over a 4-inch bar grizzly to remove the surplus fines. The surplus fines will be utilized in the random fill section of the downstream berm. It is estimated that the rock will bulk by a factor of 1.4 over in-situ volume. Losses incurred in blasting and handling will largely offset bulking and a factor of 1.0 of the in-situ volume is

considered realistic for estimates of the quantity of available usable rock. If additional rock is required above the quantity available from currently planned excavations, it can be obtained by quarrying from the hillside upstream from or above the spillway approach channel. All precautions will be taken to avoid encroachment which might damage scenic or other aesthetic values on Buck Hill.

F. DESIGN OF EMBANKMENT

18. Design Criteria. The design of the embankment for this project was developed in accordance with the criteria set forth in EM 1110-2-2300, "Earth Embankments" and other manuals and publications referred to therein.

19. Materials for Embankment Construction.

a. General. The quantities of embankment materials available from the required and borrow excavations and their proposed utilization are indicated on the preliminary materials usage chart (Plate 8-25). The quantities shown are subject to modification during the preparation of contract plans and specifications. The embankment has been designed so that most of the materials from the required excavations can be utilized in the embankment without stockpiling.

b. Required Earth Excavations. It is estimated that about 210,000 c.y. of suitable random fill material will be available from the required earth excavations.

c. Required Rock Excavations. It is estimated that about 56,000 c.y. of rock excavation will be required for this project. It is expected that after screening, this will furnish an equivalent volume of rock protection material and from 10,000 to 20,000 c.y. of rock fines. The fines will be incorporated into the random fill portion of the downstream berm.

d. Borrow Excavations. About 1,080,000 c.y. of earth borrow will be required for the embankment. This will be obtained from a borrow area developed in Area A.

e. Contractor Furnished Materials. Gravel bedding, gravel fill, pervious fill and drainage fill materials will be furnished by the contractor.

20. Selection of Embankment Section. The selection of the dam embankment section was heavily influenced by the availability of large quantities of impervious fill material from a nearby borrow source, the great depth of excavation required for the construction of any foundation cut-off in the valley and the presence of a stratified sandy silt and silty fine sand deposit in part of the foundation. The selected section is shown on Plate 8-15. This section consists of a large impervious fill zone with a contiguous impervious upstream blanket, a downstream zone and berm of random fill, an inclined internal drain of pervious fill with a contiguous horizontal drainage blanket of pervious fill and drainage fill and layers of gravel bedding and rock protection. A foundation toe drain of drainage fill is included in the valley.

21. Slope Protection. About 68,000 cubic yards of rock protection material will be required. About 56,000 cubic yards of this will be available from the required rock excavations as presently laid out. The possible 12,000 cubic yards deficit will be made up by either revising the rock excavation lines or through the establishment of a small rock borrow area. The proposed 3-foot rock protection layer on the upstream slope will furnish more than adequate protection against the action of waves up to the maximum expected height of 1.7 feet.

22. Seepage Control.

a. Seepage through the embankment will be controlled by the arrangement and differences in permeability of the impervious fill zone and the internal drain and horizontal drainage blanket.

b. Foundation Seepage. Seepage through the overburden in the dam foundation will be controlled, in the valley, by an impervious upstream blanket dimensioned so as to limit the foundation seepage gradient to 10 percent for the maximum pool. On the abutments, foundation seepage will be controlled by shallow impervious foundation cutoffs to the Zone C foundation soils or bedrock. These cutoffs will be contiguous with similar cutoffs along the sides of the blanket. A foundation toe drain will be provided in the valley to control the emergence of foundation seepage. This drain will be provided with a perforated collector pipe to facilitate seepage measurements.

c. Seepage Along Bedrock Surfaces. The embankment will be in contact with the bedrock surface at the extreme left abutment. In order to avoid the detrimental effects of seepage along bedrock surfaces against which impervious fill is to be placed, such surfaces will be prepared by:

(1) The removal of all soil and loose rock fragments

(2) The removal of all overhangs and irregularities in the bedrock surface which could interfere with the proper placement and compaction of the impervious fill material.

(3) The cleaning and mortaring of all cracks and openings in the bedrock surface.

d. Quantity of Seepage. It is estimated that the total quantity of seepage through the embankment and its foundation will be on the orders of magnitude indicated below:

Pool	Q - cfs
Conservation, El. 790	0.3
Water Quality, El. 816	0.6
Maximum, El. 841.5	0.8

23. Embankment Stability

a. General. The embankment section for the dam has been analyzed for stability against shear failure by the sliding wedge and the modified Swedish circular arc methods. In using the latter method, the effects of forces on the vertical sides of the slices have been ignored. The design shear strengths and unit weights used in the analyses were selected on the basis of laboratory test results and experience.

b. Conditions Analyzed. The conditions for which stability analyses were done are those prescribed and discussed in EM-1110-2-1902, "Stability of Earth and Rock-Fill Dams." Special assumptions considered for certain of these conditions are discussed below.

(1) Case I - End-of-Construction. Two possible foundation situations were considered in the sliding wedge analysis of the end-of-construction condition. In one instance, the presence of a shallow layer of relatively weak silt in the embankment foundation was assumed. In the other, it was assumed that there was a silt layer at the top of foundation zone B subjected to an artesian head of 10 feet above the ground surface. Neither the shallow silt layer or the artesian condition were considered in the circle analysis.

(2) Cases II and III - Sudden Drawdown. In establishing the minimum pool elevation for the drawdown cases, consideration was given to the fact that continuous drawdown from maximum or spillway pool levels will seldom proceed below the water quality pool level (Elev. 816) and only under exceptional conditions to the conservation pool level (Elev. 790). For purposes of these analyses, it has been assumed that continuous sudden drawdown may proceed to Elev. 780 or 10 feet below the conservation pool.

c. Selection of Design Values.

(1) Unit Weights. Impervious and random fill materials will be compacted with a sheepsfoot roller, as described in Paragraph 28, in accordance with a compaction specification previously used by this Division for embankments of similar materials. Fills compacted in accordance with this specification have averaged about 98 percent of maximum test density. The design unit weights for compacted impervious and random fills, therefore, have been selected on the basis of compaction test densities adjusted for the anticipated degree of compaction and to include the weight of the average stone content. Unit weights of the other embankment materials have been selected on the basis of experience with similar materials. Unit weights for the foundation soils have been selected on the basis of experience supplemented by such test data as natural water contents and specific gravities. The selected design unit weights are tabulated below:

Material	Dry	Moist	Saturated	Bouyant
Rock Protection and Gravel Bedding	116	120	140	77.6
Impervious and Random Fills	128	140	145	82.6
Pervious and Drainage Fills	130	140	145	82.6
Foundation - Zone A	-	-	140	77.6
Foundation - Zone B	-	-	135	72.6
Foundation - Zone C	-	-	145	82.6

(2) Shear Strength. The design shear strength parameters for impervious fill have been selected on the basis of laboratory shear test results. As a significant portion of the random fill material will be similar in character to the impervious fill material, random and impervious fills have been considered identical with respect to design shear strength. The design shear strength parameters

for other embankment fills and the foundation soils have been selected on the basis of experience with similar materials. The selected design shear strength parameters are tabulated below:

Material	Design Shear Strength Parameters					
	Q		Combined R&S		S	
	ø	c	ø	c	ø	c
Rock Protection	-	-	-	-	40°	0
Gravel Bedding	-	-	-	-	35°	0
Pervious and Drainage Fills	-	-	-	-	35°	0
Impervious and Random Fills	33°	0.20 TSF	19° 27°	0.70TSF(a) 0.35TSF(b)	34°	0
Foundation		-			-	
Zone A	-	-	-	-	35°	0
Zone B	-	-	-	-	25°	0
Zone C	(Same as Impervious and Random Fills)					

(a) For sudden drawdown (Cases II and III). Use S shear strength where normal stresses are less than 2.1 T.S.F.

(b) For partial pool and steady seepage (Cases IV, V and VI) Use S shear strength where normal stresses are less than 2.1 T.S.F.

(3) Seismic Coefficient. The Nookagee project is located within Seismic Zone 2. The appropriate seismic coefficient for this zone is 0.10. (See Fig. 6, EM 1110-2-1902).

d. Sections Analyzed. The upstream and downstream portions of the dam embankment at Station 10+20 were selected for stability analysis since the maximum embankment height occurs at this location together with a significant thickness of the weaker Zone B foundation soils.

e. Use of Computer. A GE 427 electronic computer was used in these stability analyses. Critical circles and sets of planes for each case were checked manually.

f. Results. Summaries of the results of the embankment stability analyses are shown on Plates 8-17 through 8-19. Typical analyses are shown on Plates 8-19 through 8-24. The minimum factors of safety against shear failure are tabulated below. These are considered adequate and indicate that the selected embankment section is safe against shear failure.

Condition	Minimum Factor of Safety	Criteria
I. End of Construction		
a. D/S-Wedge		
(1) Shallow Silt Layer	2.1	1.3
(2) Artesian Condition	2.0	1.3
b. D/S Circle	1.7	1.3
II. Sudden Drawdown from Max. Pool (Circle)	1.3	1.0
III. Sudden Drawdown from Spillway Crest (Circle)	1.3	1.2
IV. Partial Pool (Circle) Pool at Elev. 776.5	1.6	1.5
V. Steady Seepage from Max. Storage Pool		
(Circle)	1.6	1.5
(Wedge)	1.9	1.5
VI. Steady Seepage from Surcharge Pool		
(Circle)	1.5	1.4
(Wedge)	1.8	1.4

Condition	Minimum Factor of Safety	Criteria
VII Earthquake		
Case I	1.2 (Circle)	1.0
IV	1.0 (Circle)	1.0
V	1.0 (Circle)	1.0
VI	1.0 (Circle)	1.0

24. Settlements. Consolidation test results indicate that settlements within the impervious fill zone of the dam embankment may approach a maximum of 3 feet but that practically all of the settlement will take place during construction. The other embankment materials and most of the foundation soils are of types exhibiting low compressibility. Portions of the foundation Zone B soils are somewhat compressible but in this instance appear to have been preconsolidated and to be well drained by the interbedded sand layers. Settlements within the embankment and in its foundation, therefore, are expected to occur mostly during construction with little significant post-construction settlement.

25. Instrumentation. No instrumentation is planned for the dam embankment. Data from the consolidation test and experience with similar embankment materials indicate that construction pore pressures will be insignificant. The character of the embankment materials is such that significant horizontal or vertical movements are not anticipated.

26. Disposal of Unsuitable Materials. All topsoil and other surficial deposits of organic soils will be removed from the embankment foundation area and, to the extent practicable, salvaged for use as topsoil. Any of these materials not thus salvaged will be placed in the spoil fill along the upstream toe of the embankment or in designated spoil areas. No spoil area will be located within 100 feet of the downstream toe of the dam.

27. Construction Considerations.

a. Dewatering. Dewatering will be required for all areas in which compacted fill is to be constructed including the foundation toe drain and the conduit. The dewatering of other areas will be required to the extent necessary to facilitate construction operations. All earth excavations will be done in the dry except that for the inspection trench at the upstream edge of the impervious blanket. It

is anticipated that the required dewatering generally can be accomplished by normal methods such as ditching, cofferdamming and open pumping. Well points may be necessary for the construction of the foundation toe drain in the valley.

b. Rate of Embankment Construction. The topography of the site and the length of the dam embankment are such that embankment construction in partial reaches is neither practicable nor desirable. Full length embankment construction therefore will be required. Generally, it will be required that all zones of embankment fill be constructed to the same level at all times except for a slight drainage slope. Exceptions will be permitted to allow the advance construction of the permanent cofferdam and of the downstream random, pervious and drainage fills, so as to permit direct utilization of materials from the required excavations.

c. Construction of Service Bridge Pier and Abutment. The service bridge pier and abutment will be founded on embankment fill. In order to avoid any possible movement of these structures due to fill deflections during construction, the foundations will not be started until the embankment has been completed to within 3 feet of the top of the dam.

28. Methods of Fill Compaction.

a. Impervious and Random Fills. Impervious and random fill materials will be spread in layers of not more than 8 inches loose thickness at moisture contents within 2 percentage points of optimum. Each layer will be compacted by at least 6 complete passes of a tamping roller. The roller will consist of a heavy-duty double drum unit with a minimum drum diameter and length of 60 inches. The roller will be of a type weighing no more than 2,000 pounds per foot of drum length, empty, and at least 3,500 pounds per foot of drum length, weighted.

b. Other Fills. Pervious, drainage and gravel fills will be spread in layers of no more than 6 inches loose thickness at such moisture contents that excessive dust or rutting will not occur. Each layer will be compacted by at least 6 coverages of the tread of a crawler type tractor of a type weighing at least 35,000 pounds and exerting a tread pressure of at least 9 pounds per square inch.

G. PERMANENT CUT SLOPES

29. Earth Cut Slopes. Layers of rock protection and gravel bedding will be constructed on the permanent earth cut slopes of the spillway, intake and outlet channels which are subject to damage from the action of waves, currents, run-off, seepage or frost. Elsewhere, these slopes will be topsoiled and seeded. The final earth cut slopes in the borrow area will be finished to slopes of 1 on 3, or flatter, and topsoiled and seeded.

30. Rock Cut Slopes. Foliation and major jointing are essentially horizontal or dipping at very low angles in the granitic schist which constitutes the main bedrock in the areas of rock excavation for spillway and discharge channel. For this reason, there is no particularly favorable orientation for alignment of excavations in regard to bedrock structure. The permanent cuts in the rock are up to approximately 40 feet in depth below the rock surface and throughout most of the excavation the depth of cut ranges from 30 to 35 feet. Side slopes of 4 vertical on 1 horizontal are considered reasonable. Because much of the excavations will be in the upper closely jointed and weathered zones of the bedrock, overbreak and ravelling along the crest of the excavation must be expected. Likewise in scattered areas where the foliation is variable and contorted or where pegmatite zones are encountered in the schist, breakage cannot be precisely controlled and overbreak and fallout will occur. Close control of breakage will be attempted, however, by presplitting methods and locally by line drilling for final structure excavations.

H. FOUNDATIONS FOR CONCRETE STRUCTURES

31. General. The spillway weir and wingwalls will be founded on bedrock as described in Paragraph 12. The gate tower and outlet conduit will be founded on earth as described below. The service bridge pier and abutment will be founded on embankment fill as discussed in subparagraph 27c.

32. Gate Tower. The gate tower will be founded in the glacial till deposit on the right abutment - (Foundation Zone C as described in paragraph 7). In view of the high natural densities and other characteristics of these soils, little or no settlement of the tower is anticipated at the proposed loadings.

33. Outlet Conduit. Within the embankment foundation, the conduit will be constructed in the glacial till deposit (Foundation Zone C). Beyond the downstream toe of the embankment, the conduit will be in

stratified soils typical of Foundation Zone B. The in-situ densities of the foundation soils for the conduit are very high and significant settlements of the conduit are not anticipated. To allow for possible settlement and foundation spreading during construction of the embankment over the conduit, however, the conduit design will include the following special features. The conduit joints will be provided with collars and waterstops designed so as to assure the integrity of the conduit at joint movements up to 12 inches. The invert grades of the conduit will be established so as to allow for differential settlements of up to 12 inches between the embankment toes and the embankment centerline.

I. ENVIRONMENTAL CONSIDERATIONS

34. General. The overall environmental impact of this project is discussed in Design Memorandum No. 2, General Design. The following discussion is limited to the major effects of the construction operations upon the environment of the project site and the methods proposed to alleviate them.

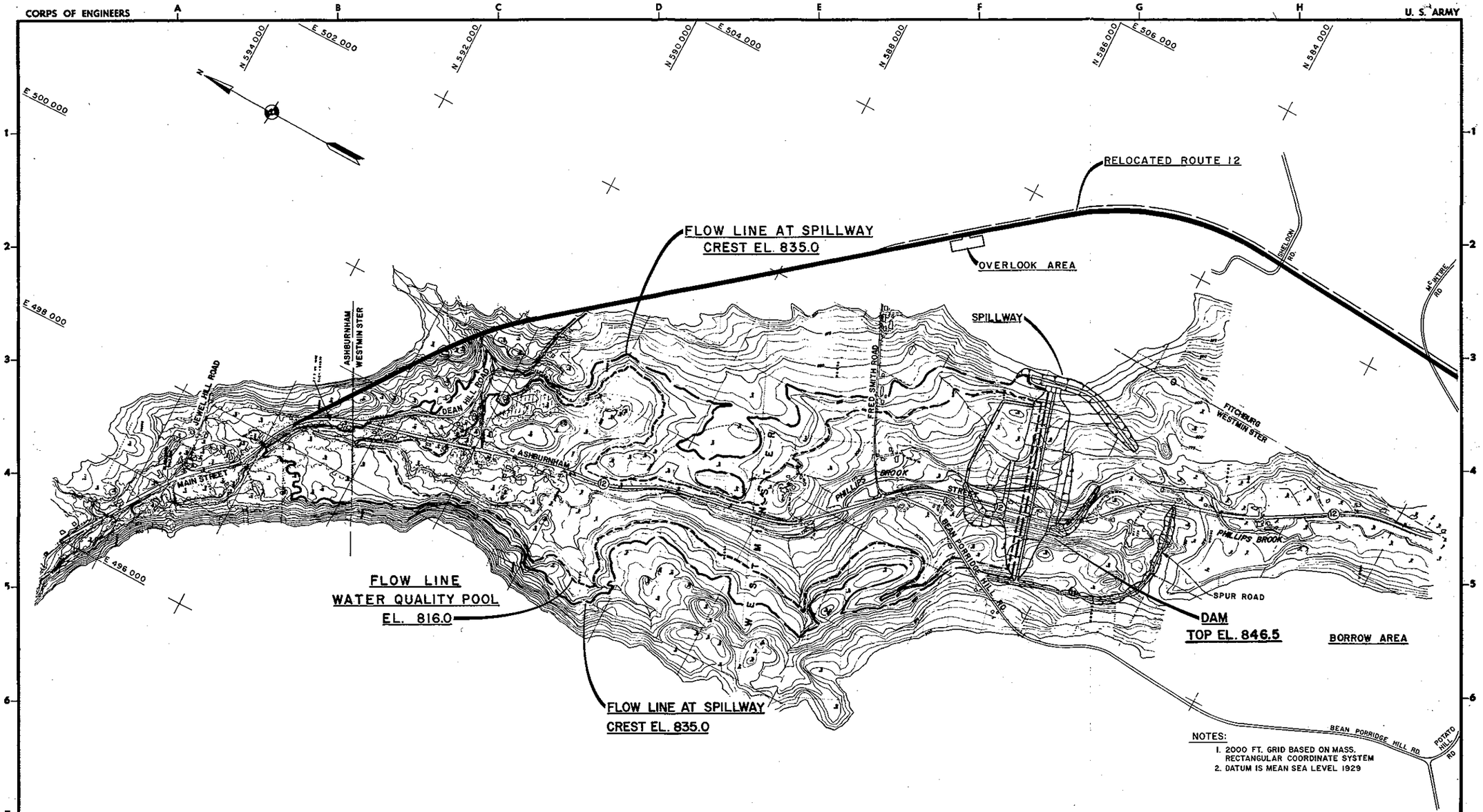
35. Vegetative Cover. Large portions of the existing vegetative cover at the damsite and in the borrow area will be destroyed or disturbed during construction. In order to avoid excessive erosion in the affected areas, provision will be made for the expeditious establishment of a grass cover wherever practicable. In general, it is intended that all permanent earth cut surfaces exposed during a construction season will be topsoiled and seeded by the end of that season.

36. Silting. Minor amounts of fine soil particles will tend to enter the stream from exposed earth cut and fill surfaces during construction. Provisions will be made to alleviate this problem to the maximum extent practicable. The chief provisions to this end will include the installation of drainage ditches with settling basins in and around the excavation areas. Provision will also be made for the possible construction of a low weir in the stream to form a settling basin downstream of the project.

J. COST ESTIMATE

37. The latest detailed cost estimate for this project is presented in Appendix C.

CORPS OF ENGINEERS U. S. ARMY



NOTES:

1. 2000 FT. GRID BASED ON MASS. RECTANGULAR COORDINATE SYSTEM
2. DATUM IS MEAN SEA LEVEL 1929

RESERVOIR PLAN

SCALE: 1" = 400'

GRAPHIC SCALE

1" = 400' 400' 0 400' 800'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY J D M | CK. BY

SUBMITTED:

CHIEF, SECTION

APPROVAL RECOMMENDED:

CHIEF, TECH. ENG. BRANCH

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
RESERVOIR PLAN

PHILLIPS BROOK MASSACRUSETTS

APPROVED DATE

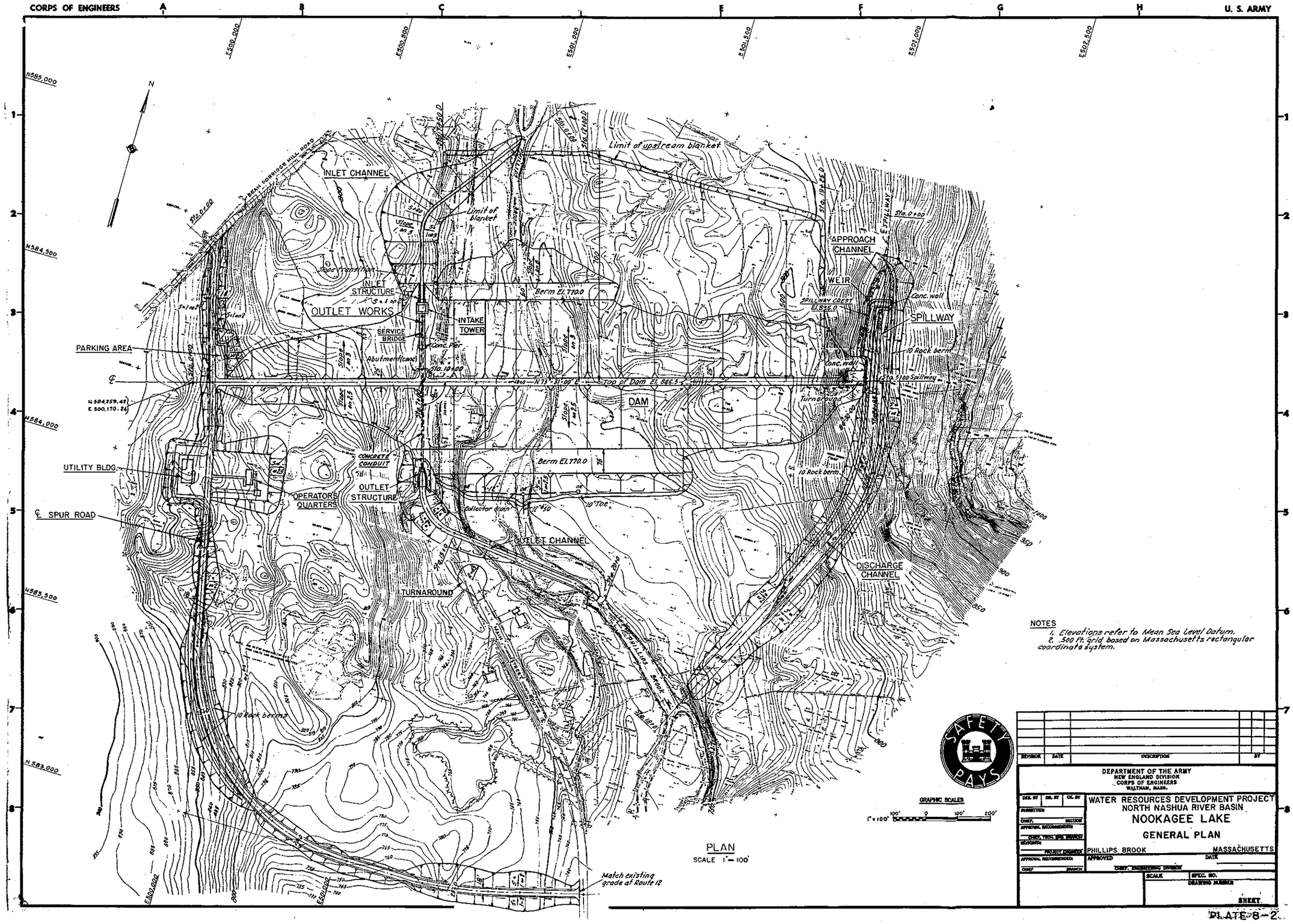
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER

SHEET

PLATE 8-1

CORPS OF ENGINEERS U. S. ARMY



NOTES
1. Elevations refer to Mean Sea Level Datum.
2. 500 Ft. grid based on Massachusetts rectangular coordinate system.

PLAN
SCALE 1" = 100'

GRAPHIC SCALES
1" = 100'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
GENERAL PLAN

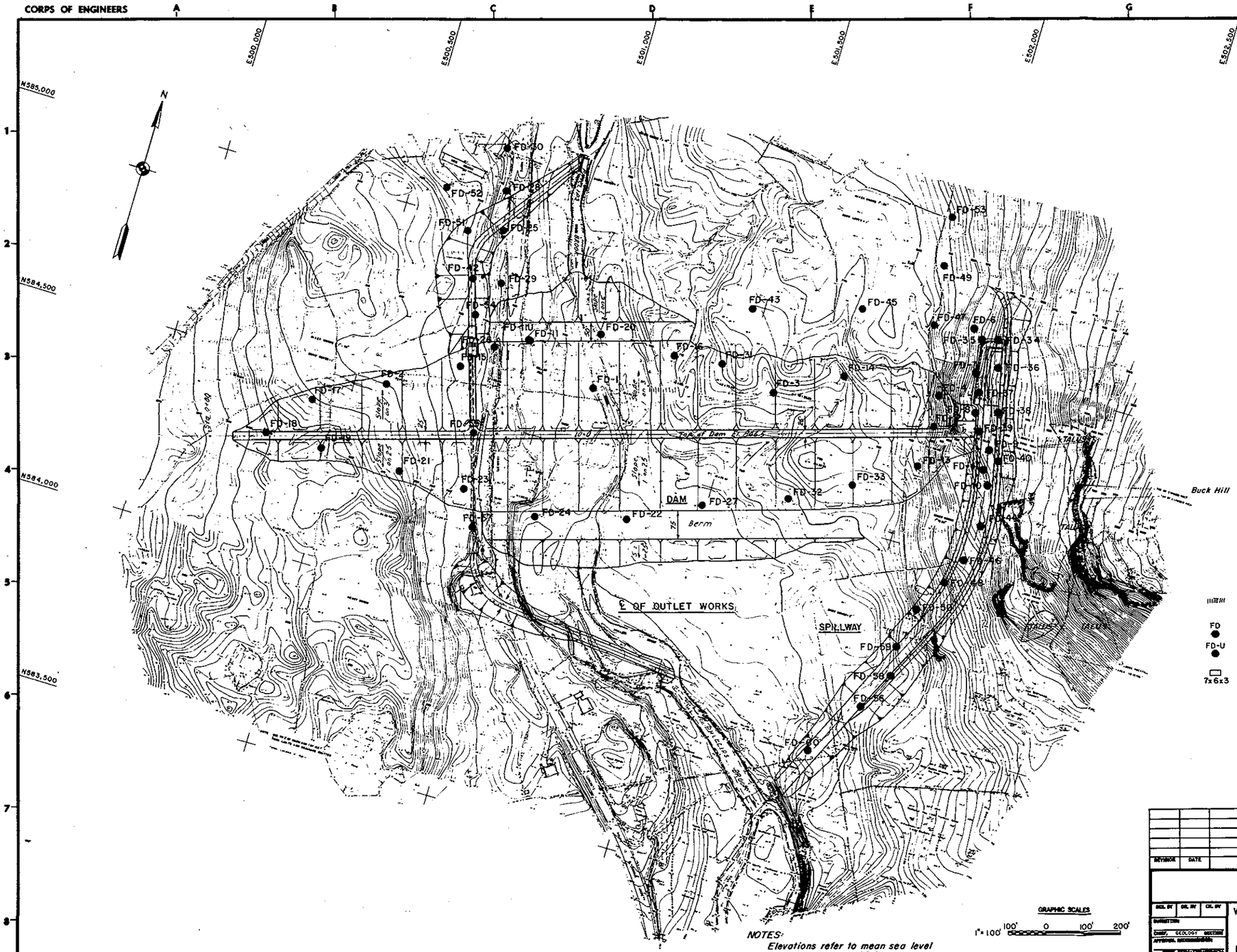
PHILLIPS BROOK MASSACHUSETTS

DATE

SCALE SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-2

CORPS OF ENGINEERS U. S. ARMY



LEGEND

- BEDROCK OUTCROP AND BOUNDARY FOR AREA OF OUTCROP
- FD — FOUNDATION TEST BORING
- FD-U — UNDISTURBED SAMPLE BORING
- 7x6x3 — LARGE BOULDER WITH APPROXIMATE DIMENSIONS OF EXPOSED SURFACES

GRAPHIC SCALES

1" = 100' 100' 0 100' 200'

NOTES:
Elevations refer to mean sea level
Contour interval is 2 feet
Plane coordinates refer to Massachusetts Rectangular System
Topography by NED survey dated April 1969

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
PLAN OF FOUNDATION EXPLORATIONS

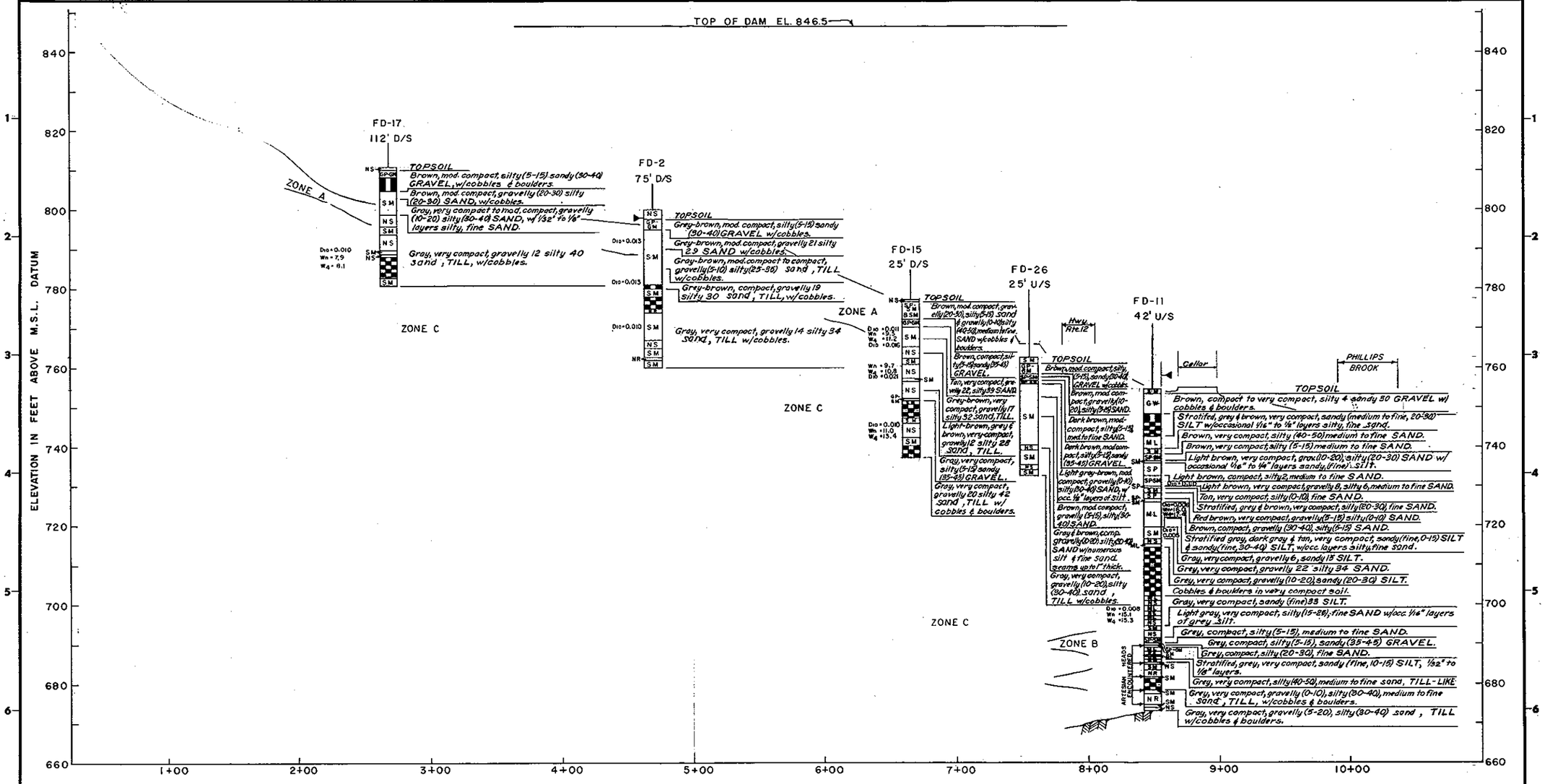
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE 1" = 100' SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-3

CORPS OF ENGINEERS — U. S. ARMY



ENGINEERING LOG PROFILE - LOOKING UPSTREAM

SCALE HOR. 1" = 30'
VERT. 1" = 10'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY J B M | CK. BY

SUBMITTED: CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED: CHIEF, F & M BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED:

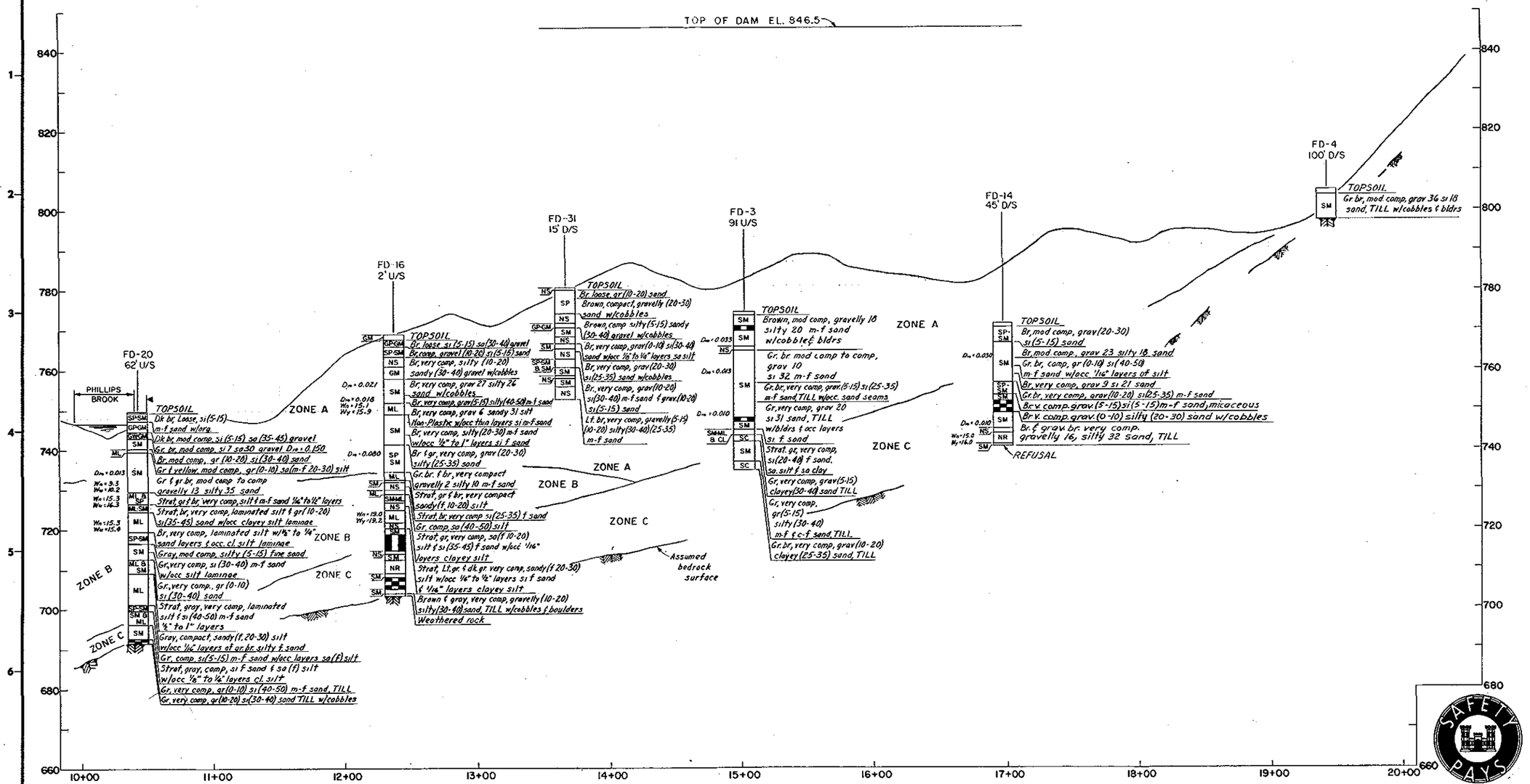
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
ENGINEERING LOG PROFILE A (PART I)
(200 FEET UPSTREAM)
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO. ENG. 19-018-
DRAWING NUMBER
SHEET

PLATE 8-4

CORPS OF ENGINEERS — U. S. ARMY



ENGINEERING LOG PROFILE - LOOKING UPSTREAM

SCALE HOR. 1" = 30'
VERT. 1" = 10'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY R.D.P. | CK. BY

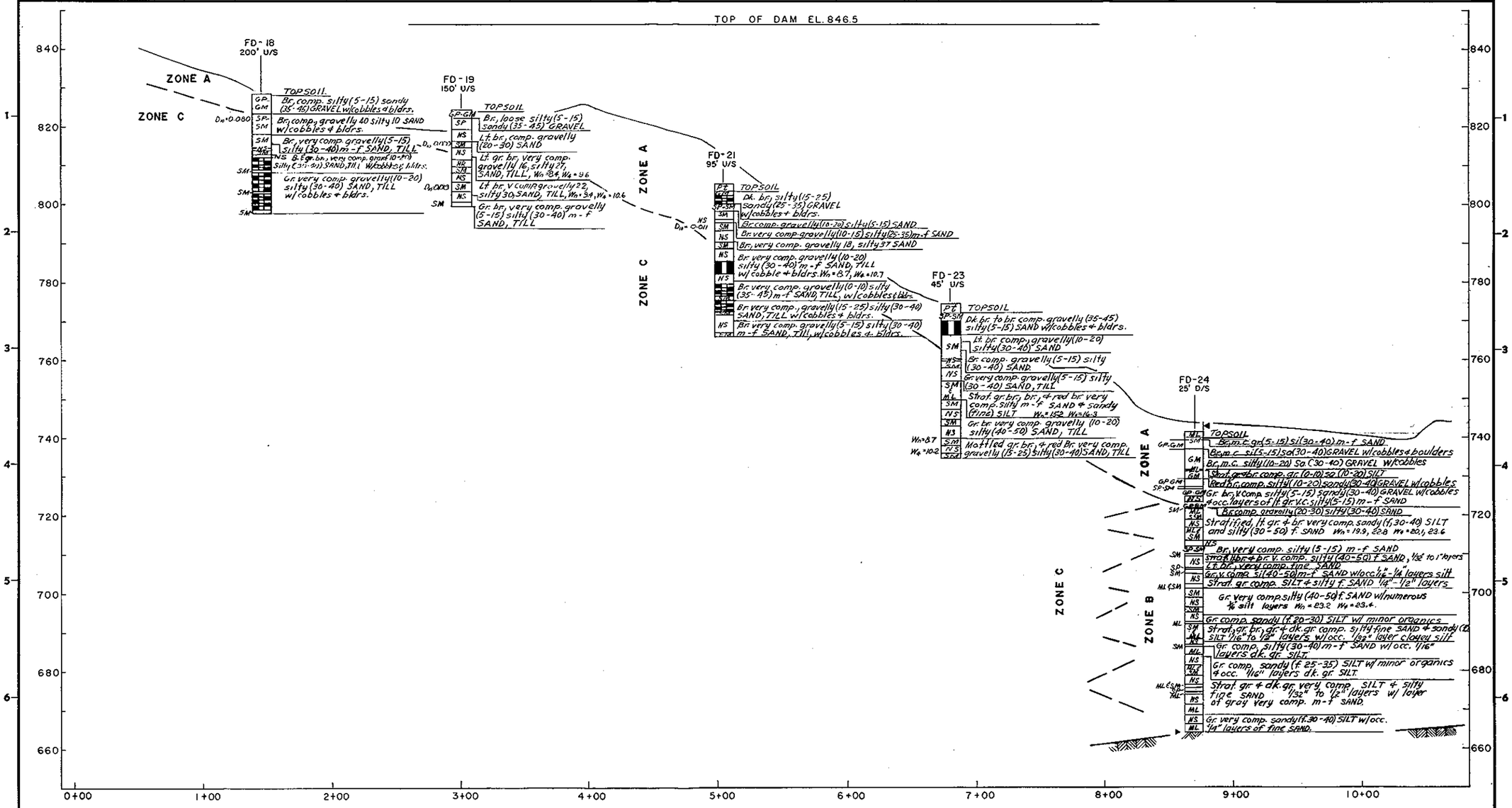
SUBMITTED: CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED: CHIEF, F & M BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED:

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
ENGINEERING LOG PROFILE A (PART 2)
(200 FEET UPSTREAM)
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO. ENG. 19-016-
DRAWING NUMBER
SHEET

CORPS OF ENGINEERS — U. S. ARMY



ENGINEERING LOG PROFILE - LOOKING UPSTREAM

SCALE HOR. 1"=30' VERT. 1"=10'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED: CHIEF, F & M BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED:

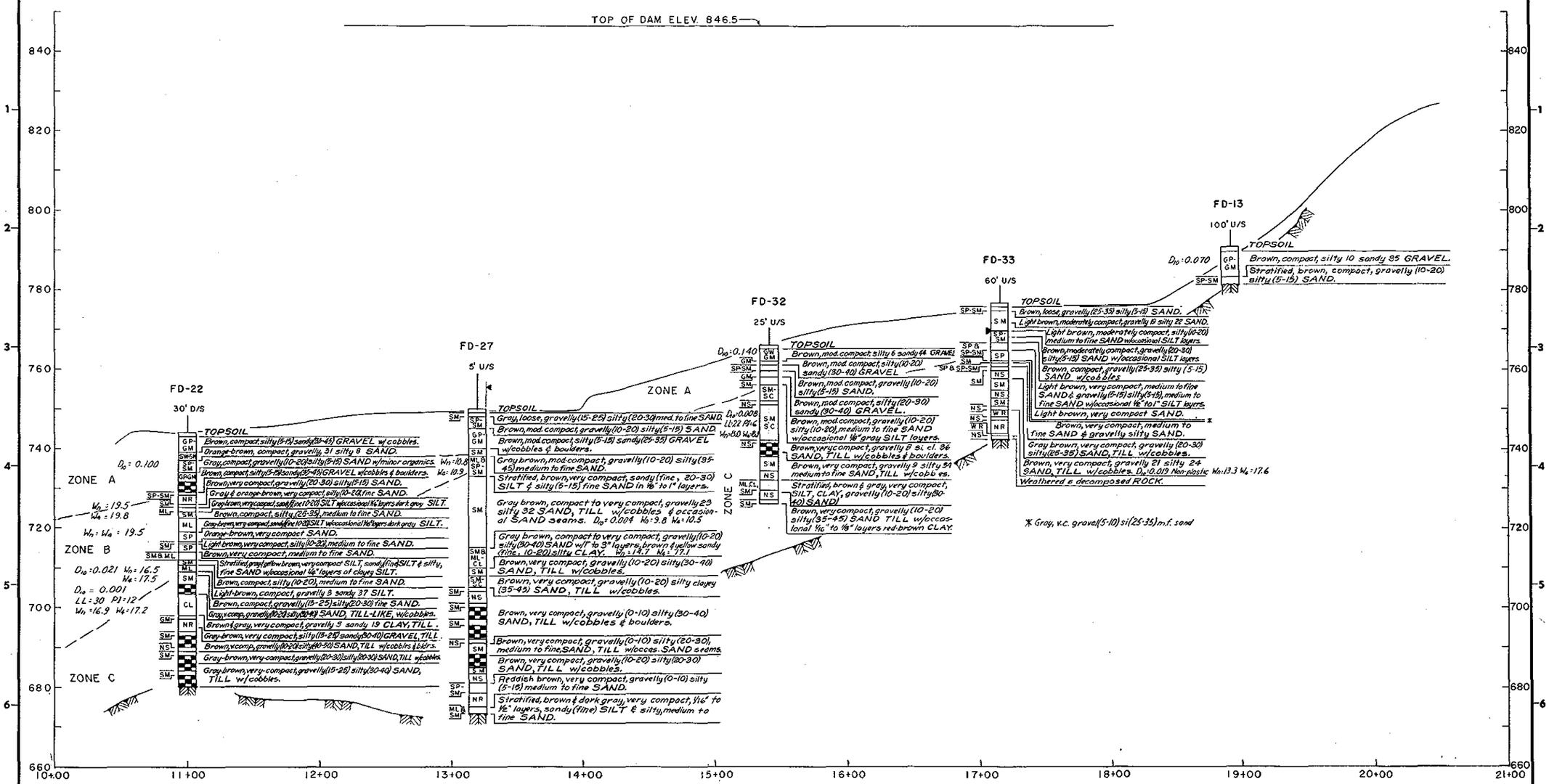
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
ENGINEERING LOG PROFILE B (PART I)
(200 FEET DOWNSTREAM)
PHILLIPS BROOK MASSACHUSETTS

APPROVED CHIEF, ENGINEERING DIVISION DATE

SCALE | SPEC. NO. ENG. 19-016-
DRAWING NUMBER
SHEET 1

PLATE 8-6

CORPS OF ENGINEERS — U. S. ARMY



ENGINEERING LOG PROFILE - LOOKING UPSTREAM

SCALE HOR. 1" = 30'
VERT. 1" = 10'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED: CHIEF, F & M BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED:

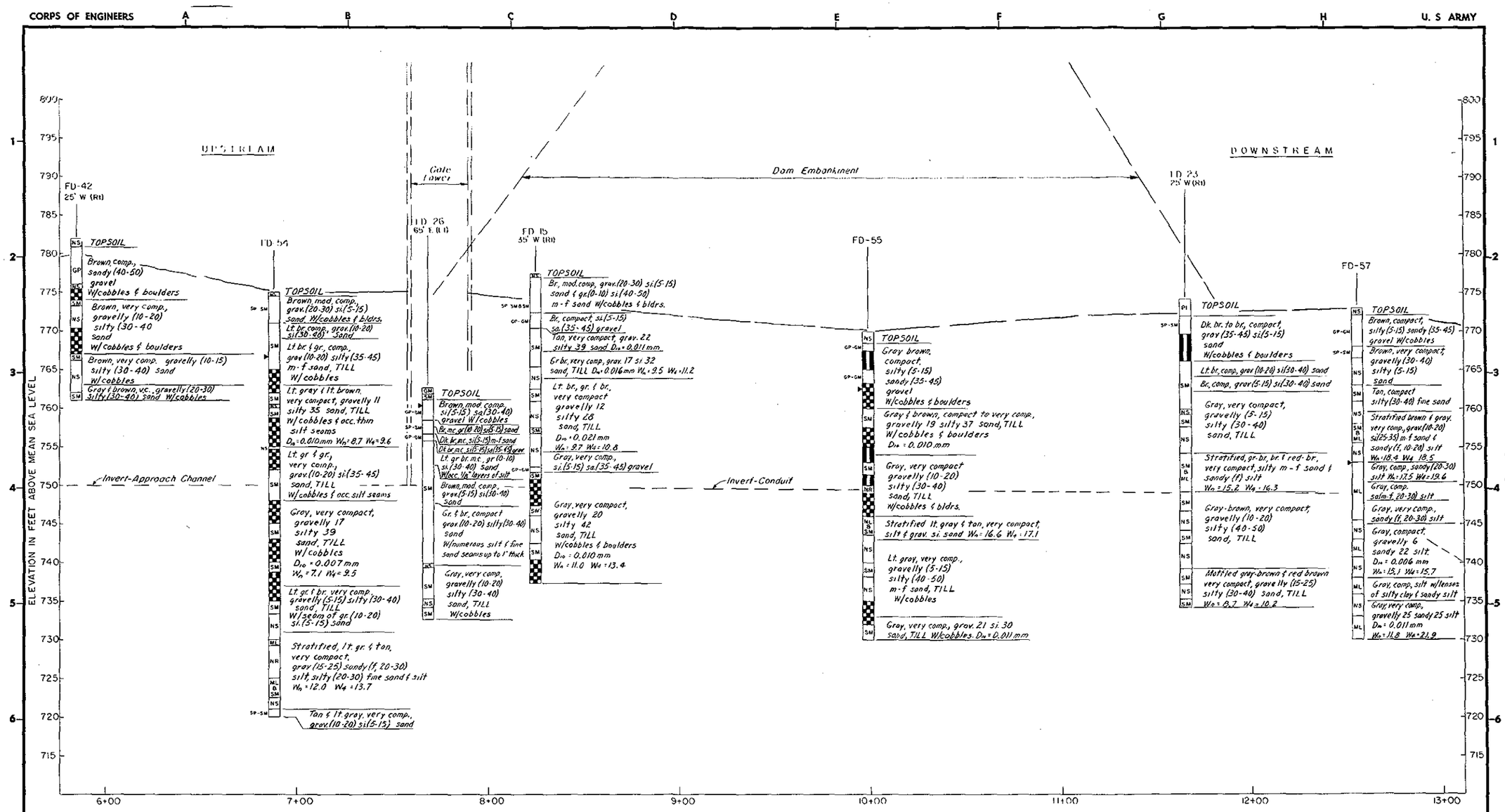
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
ENGINEERING LOG PROFILE B (PART 2)
(200 FEET DOWNSTREAM)
PHILLIPS BROOK MASSACHUSETTS

APPROVED: CHIEF, ENGINEERING DIVISION
DATE

SCALE
SPEC. NO. ENG. 19-016-
DRAWING NUMBER
SHEET

PLATE 8-7

CORPS OF ENGINEERS — U. S ARMY



SECTION AT STA. 7+00

SCALE: HORZ 1" = 20'
VERT 1" = 5'

GRAPHIC SCALES
1" = 5' 5 0 5 10
1" = 20' 20' 0 20 40

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

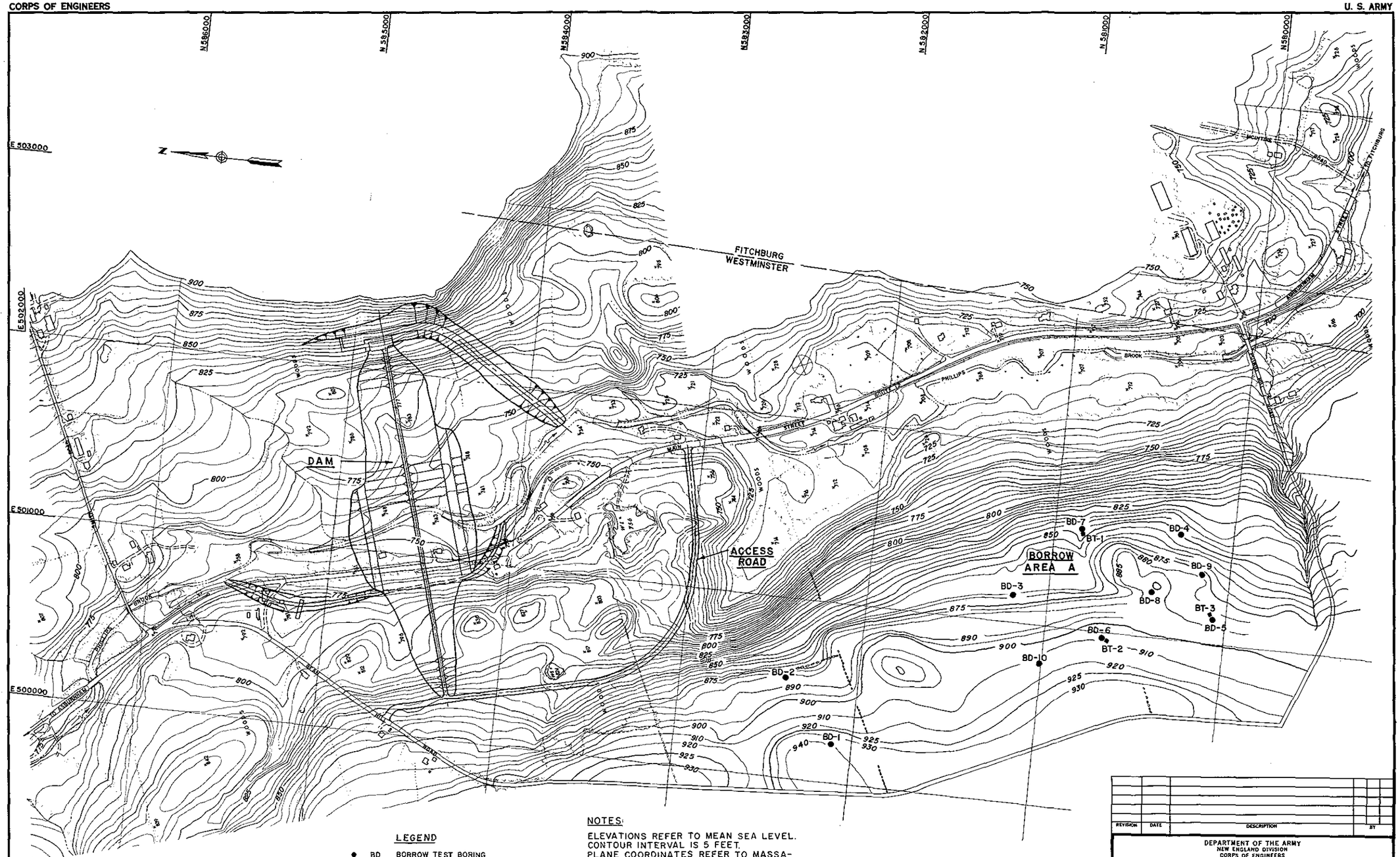
DES. BY | DR. BY R.D.P. | CK. BY

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
OUTLET WORKS
ENGINEERING LOG PROFILE
PHILLIPS BROOK MASSACHUSETTS

SUBMITTED: CHIEF, SECTION
APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF BRANCH
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-8



LEGEND

- ● BD BORROW TEST BORING
- ■ BT BORROW TEST PIT
- /// BEDROCK OUTCROP

NOTES:

ELEVATIONS REFER TO MEAN SEA LEVEL.
CONTOUR INTERVAL IS 5 FEET.
PLANE COORDINATES REFER TO MASSACHUSETTS RECTACTANGULAR SYSTEM.
TOPOGRAPHY FROM NED PHOTOGRAMMETRY DATED MARCH 1968, EXCEPT ABOVE EL. 775 IN VICINITY OF BORROW AREA WHERE TOPOGRAPHY IS A COMPOSITE *SKETCH FROM MASSACHUSETTS HIGHWAY* DEPT. PHOTOGRAMMETRY AND U.S.G.S. FITCHBURG QUAD.

GRAPHIC SCALE
1" = 200' 200' 0 200 400'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

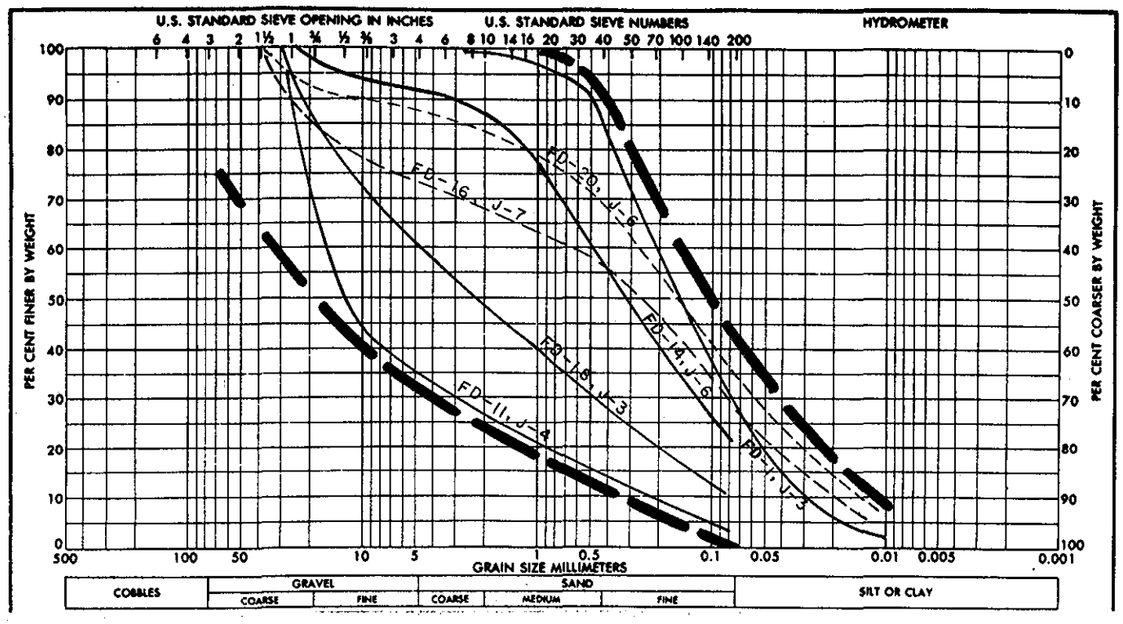
DES. BY | DR. BY J B H | CK. BY

SUBMITTED:
CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED:
CHIEF, F & M BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, PROJECT BRANCH

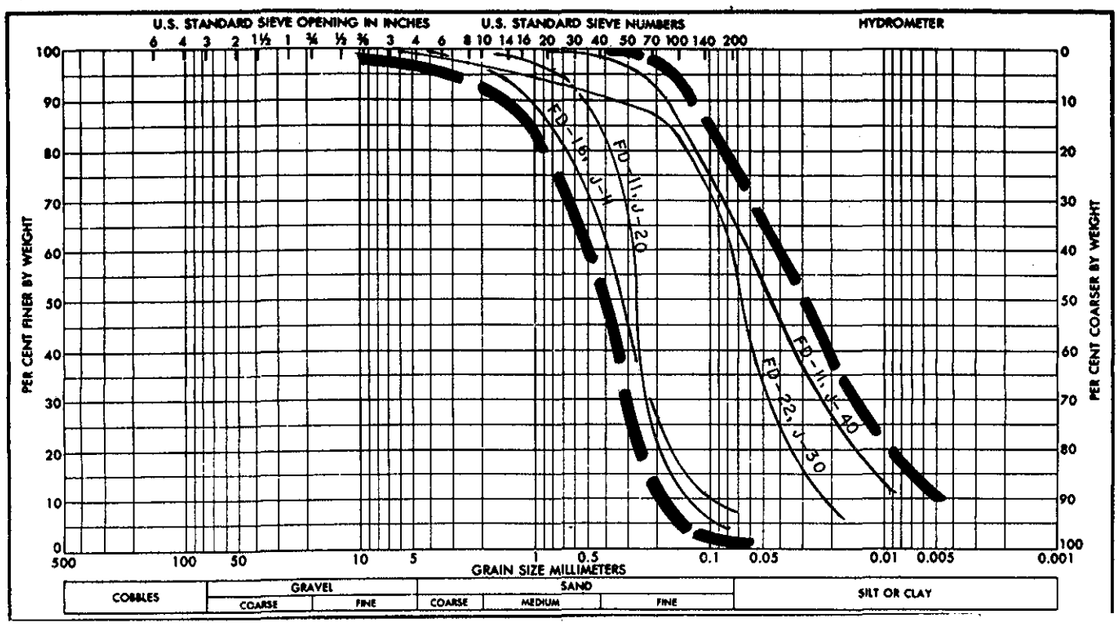
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
PLAN OF BORROW EXPLORATIONS
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

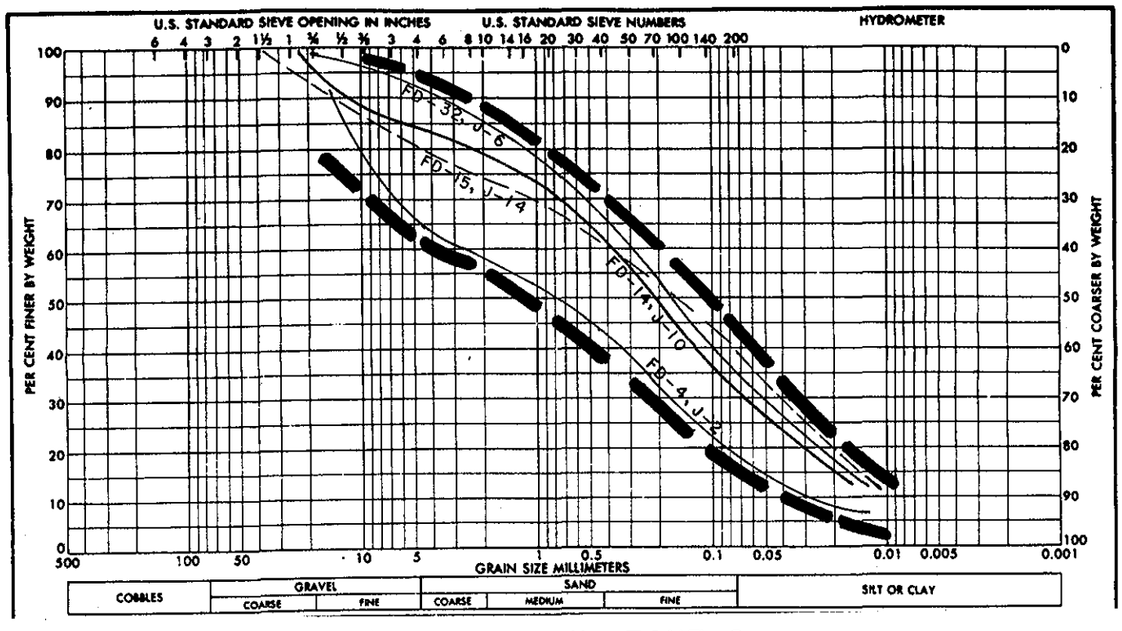
SCALE: 1" = 200' | SPEC. NO.
DRAWING NUMBER
SHEET



FOUNDATION — ZONE A



FOUNDATION — ZONE B



FOUNDATION — ZONE C

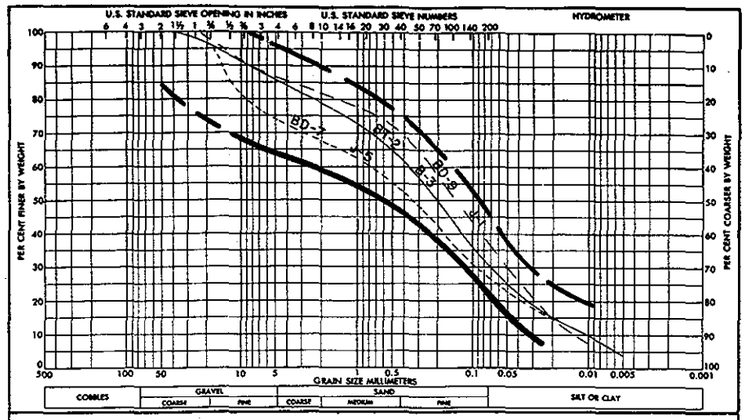
WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

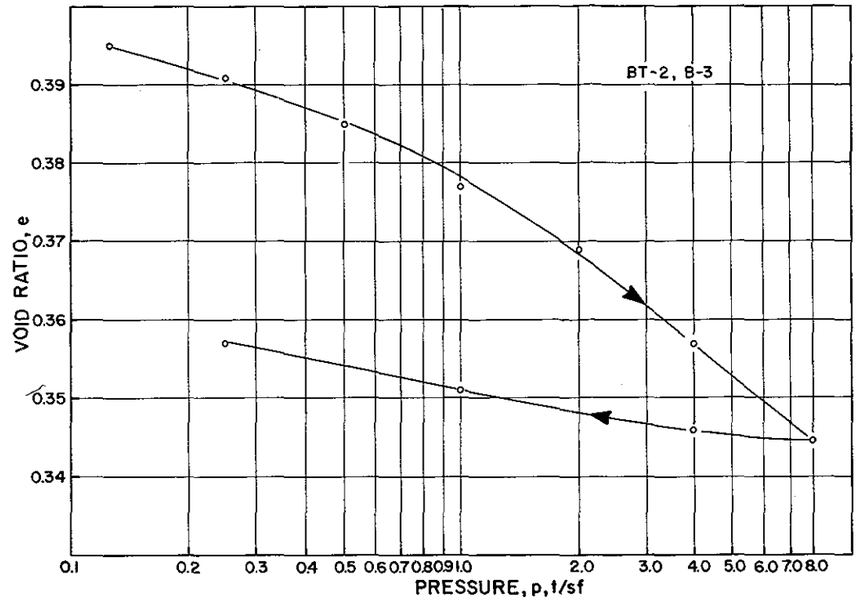
SELECTED TEST DATA-FOUNDATION MATERIALS

PHILLIPS BROOK MASSACHUSETTS

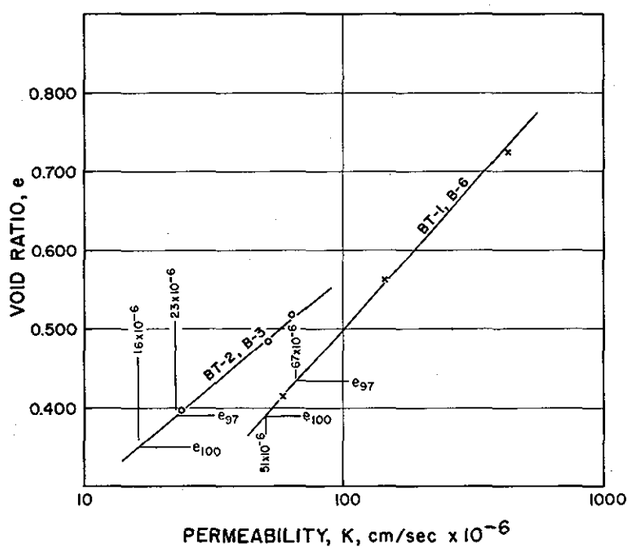


IMPERVIOUS EMBANKMENT MATERIAL

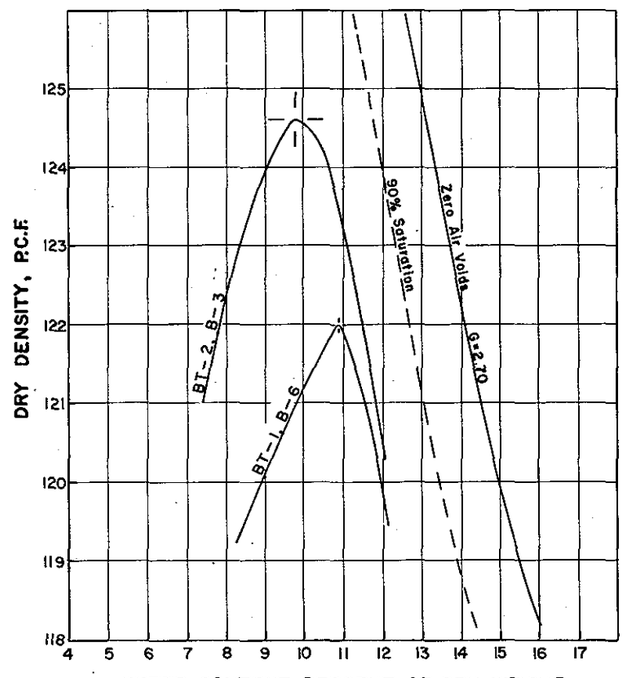
GRADATION RANGE



CONSOLIDATION TEST RESULTS



PERMEABILITY TEST RESULTS

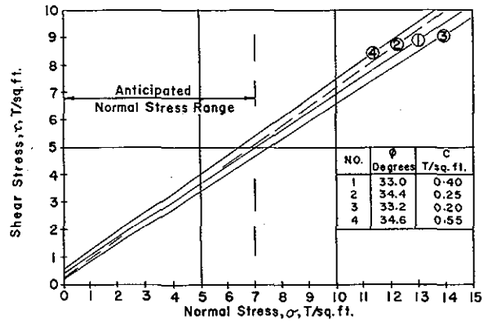


STANDARD COMPACTION TEST CURVES
(Minus No. 4 Sieve)

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

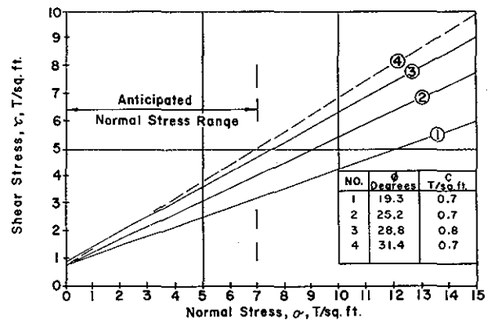
NOOKAGEE LAKE
SELECTED TEST DATA
IMPERVIOUS EMBANKMENT MATERIAL
PHILLIPS BROOK MASSACHUSETTS

TEST RESULTS (BT-2, B-3)



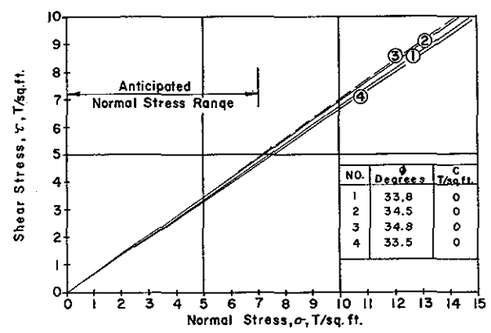
NO.	φ Degrees	C T/sq. ft.
1	33.0	0.40
2	34.4	0.25
3	33.2	0.20
4	34.6	0.55

Q. TESTS – TRIAXIAL



NO.	φ Degrees	C T/sq. ft.
1	19.3	0.7
2	25.2	0.7
3	28.8	0.8
4	31.4	0.7

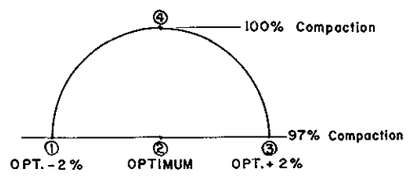
R. TESTS – TRIAXIAL



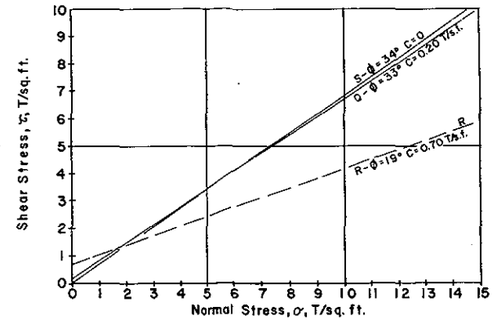
NO.	φ Degrees	C T/sq. ft.
1	33.8	0
2	34.5	0
3	34.8	0
4	33.5	0

S. TESTS – DIRECT SHEAR

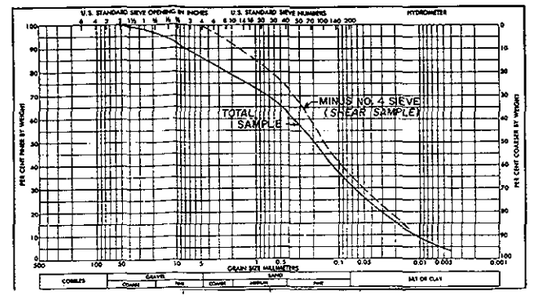
COMPACTION KEY



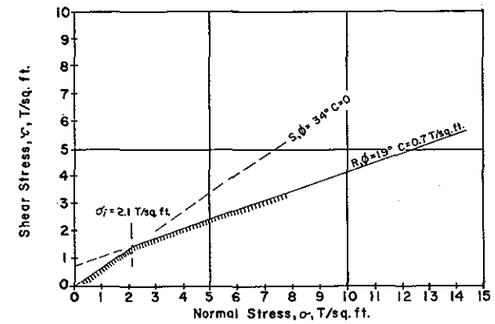
DESIGN SHEAR STRENGTHS



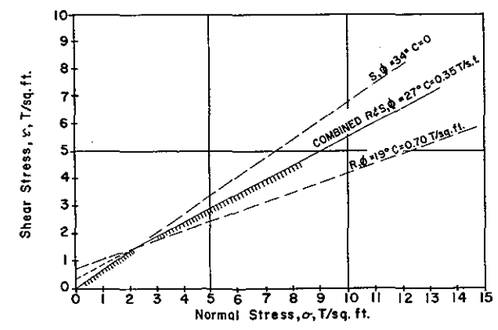
GENERAL



GRADATION CURVES
(BT-2, B-3)



DESIGN ENVELOPE FOR CASES II & III



DESIGN ENVELOPE FOR CASES IV V & VI

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

SELECTED SHEAR STRENGTH DATA
IMPERVIOUS EMBANKMENT MATERIAL

PHILLIPS BROOK MASSACHUSETTS

WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

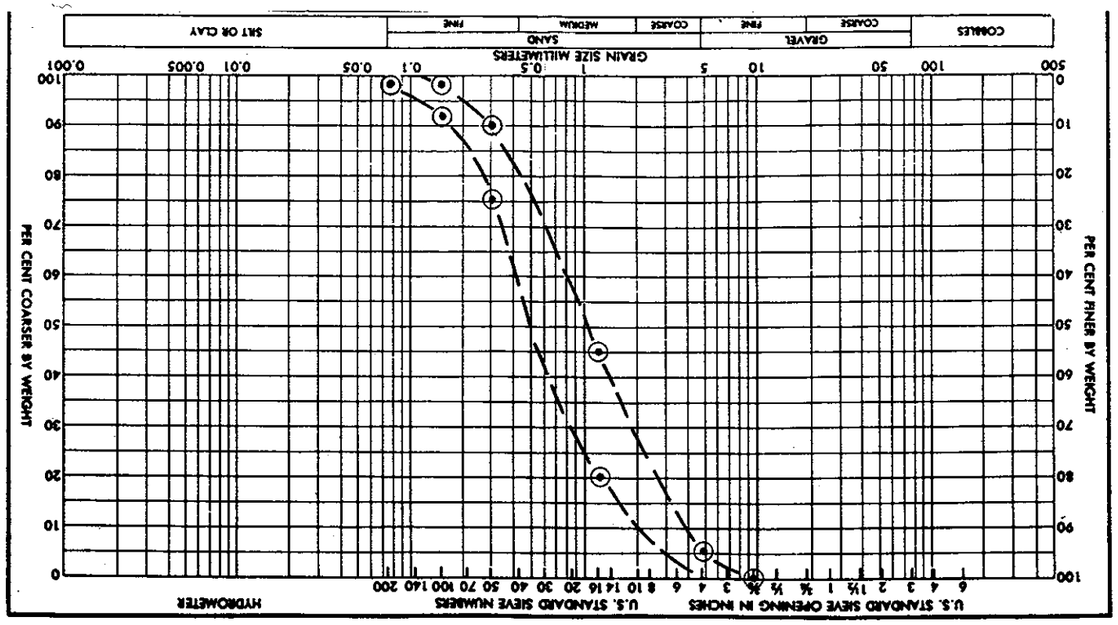
NOOKAGEE LAKE

GRADATION SPECIFICATIONS

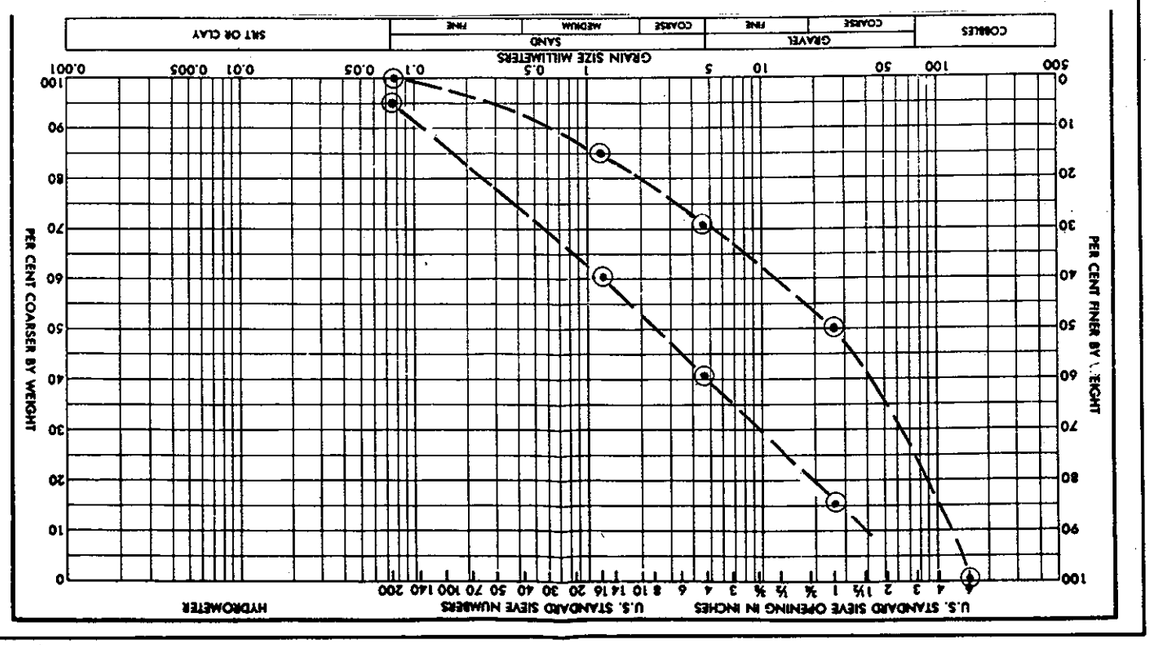
PHILLIPS BROOK MASSACHUSETTS

PLATE 8-13

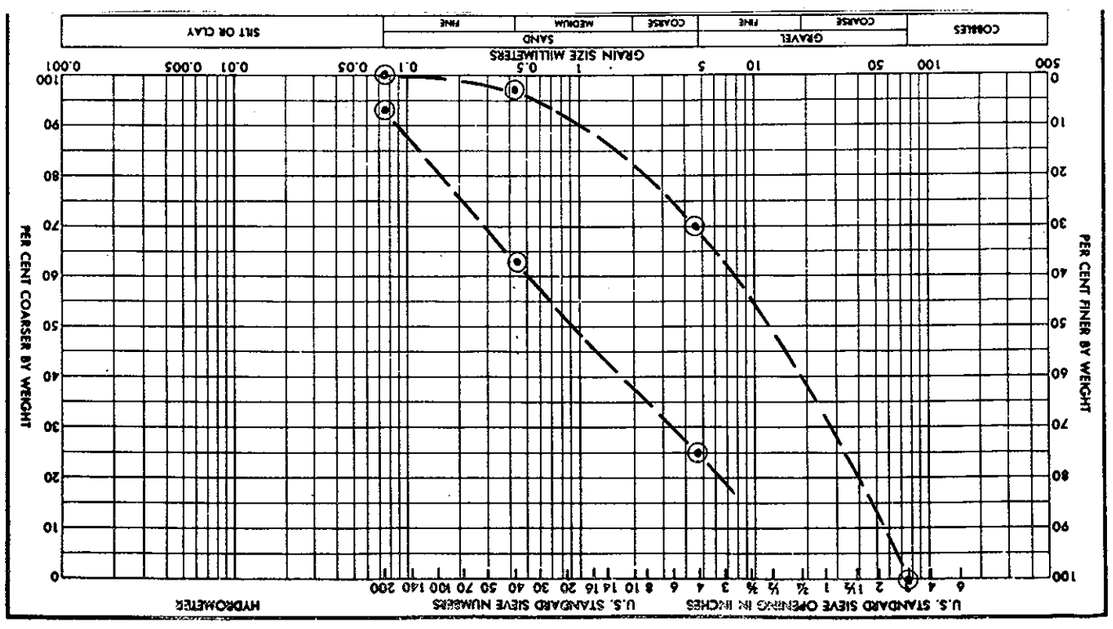
DRAINAGE FILL

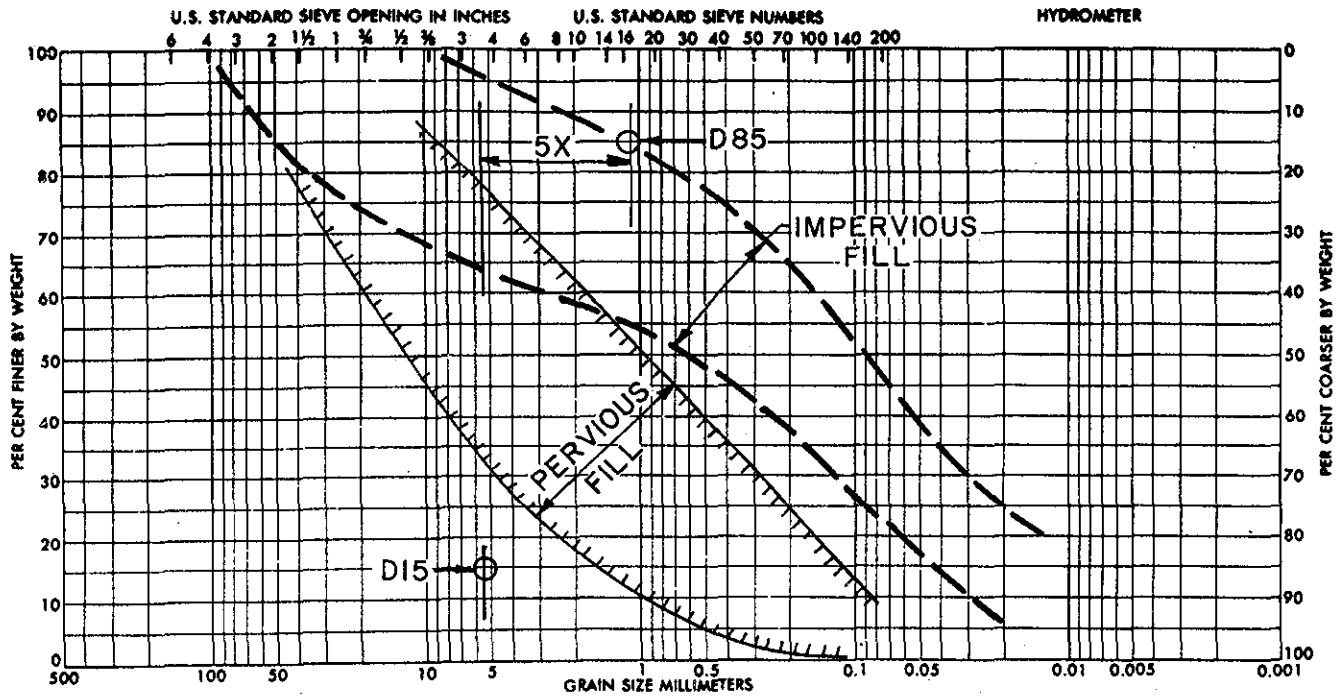


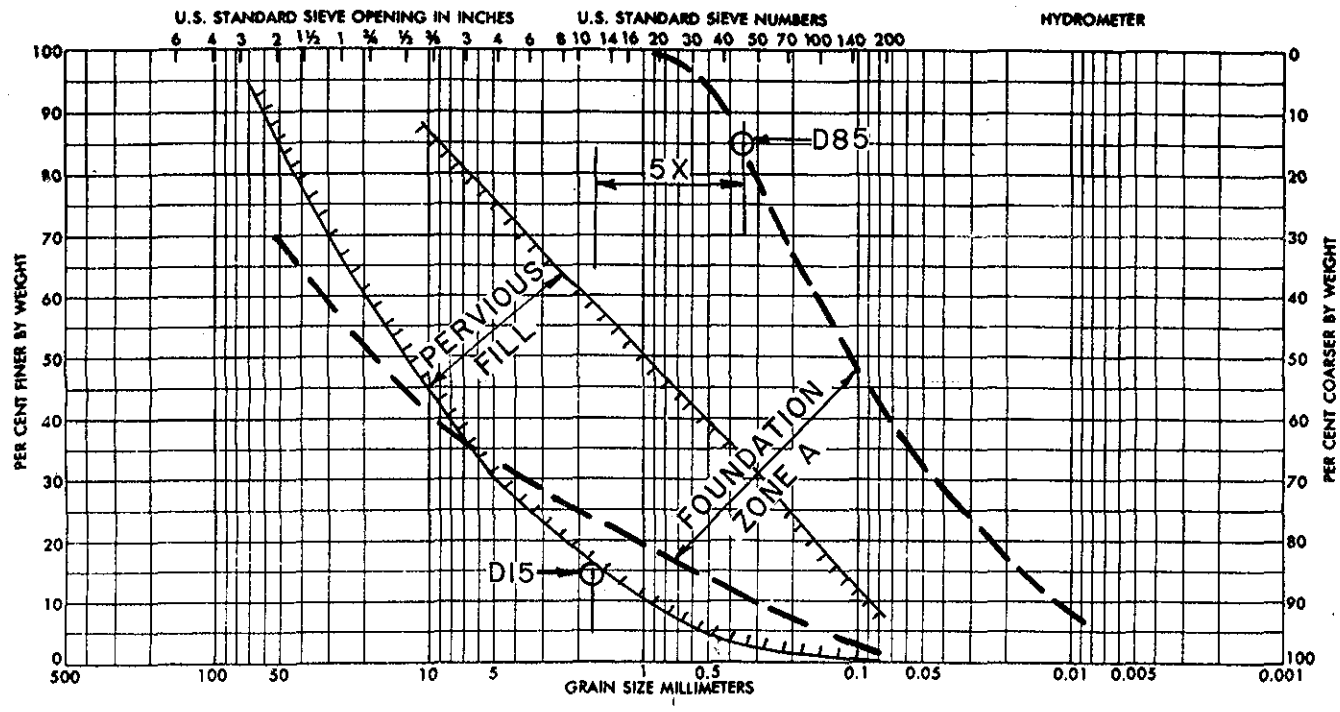
GRAVEL BEDDING & GRAVEL FILL

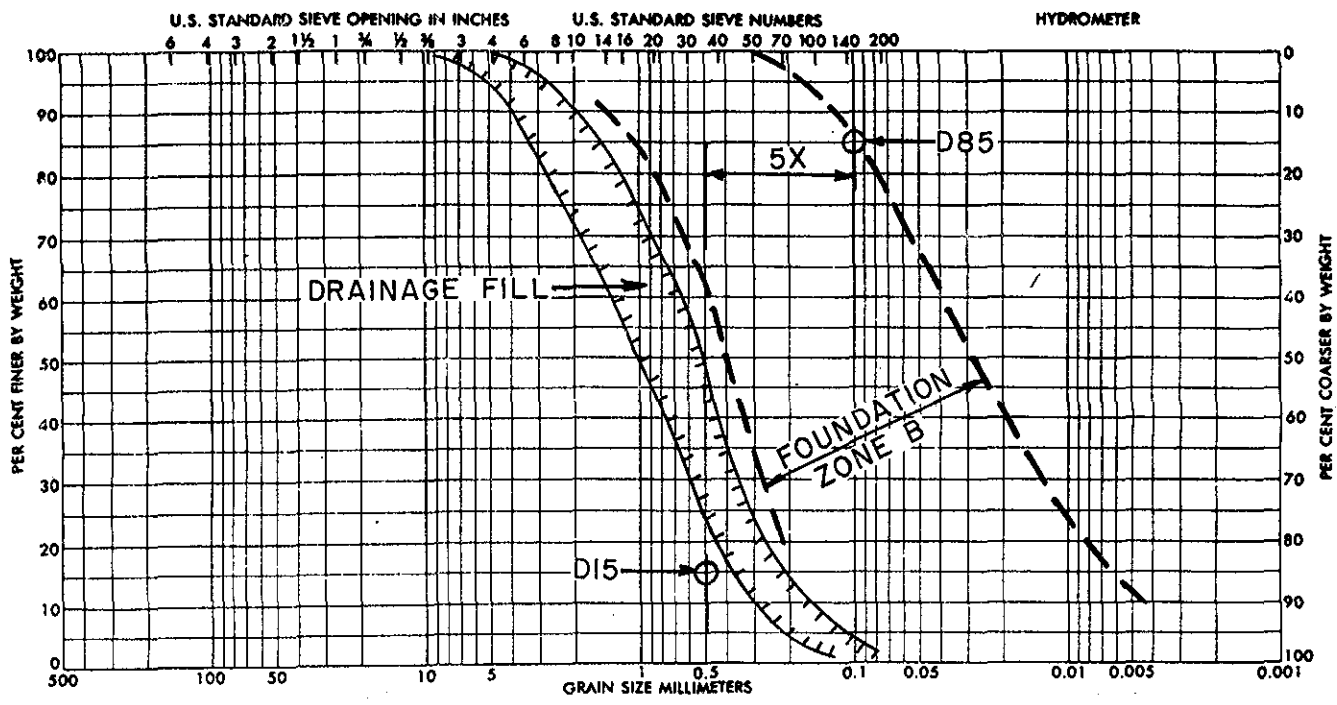


PERVIOUS FILL









WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

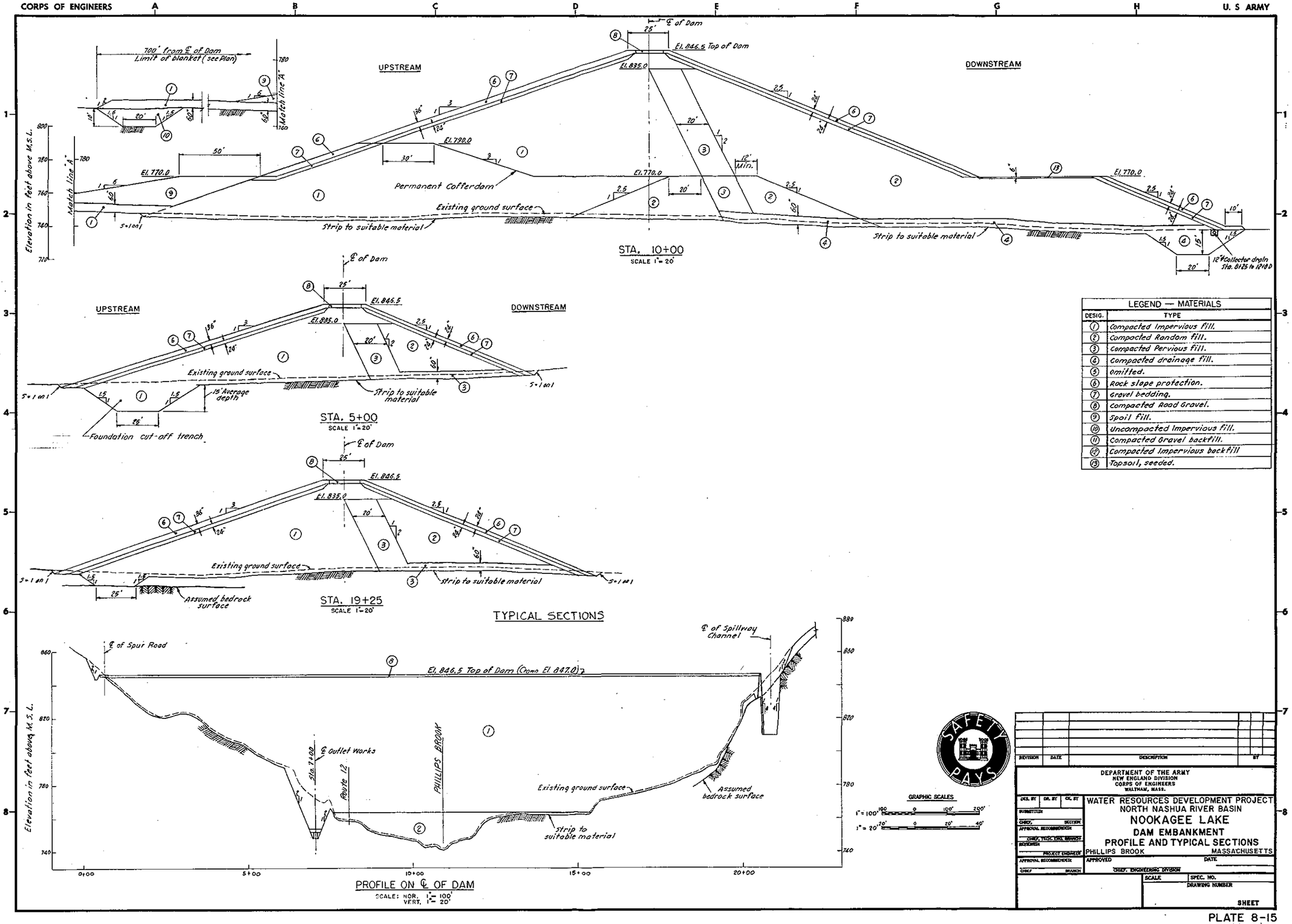
NOOKAGEE LAKE

FILTER STUDIES

PHILLIPS BROOK MASSACHUSETTS

PLATE 8-14

CORPS OF ENGINEERS — U. S ARMY



LEGEND — MATERIALS	
DESIG.	TYPE
1	Compacted Impervious fill.
2	Compacted Random fill.
3	Compacted Pervious fill.
4	Compacted drainage fill.
5	Omitted.
6	Rock slope protection.
7	Gravel bedding.
8	Compacted Road Gravel.
9	Spoil fill.
10	Uncompacted Impervious fill.
11	Compacted Gravel backfill.
12	Compacted Impervious backfill
13	Topsoil, seeded.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECHNICAL BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

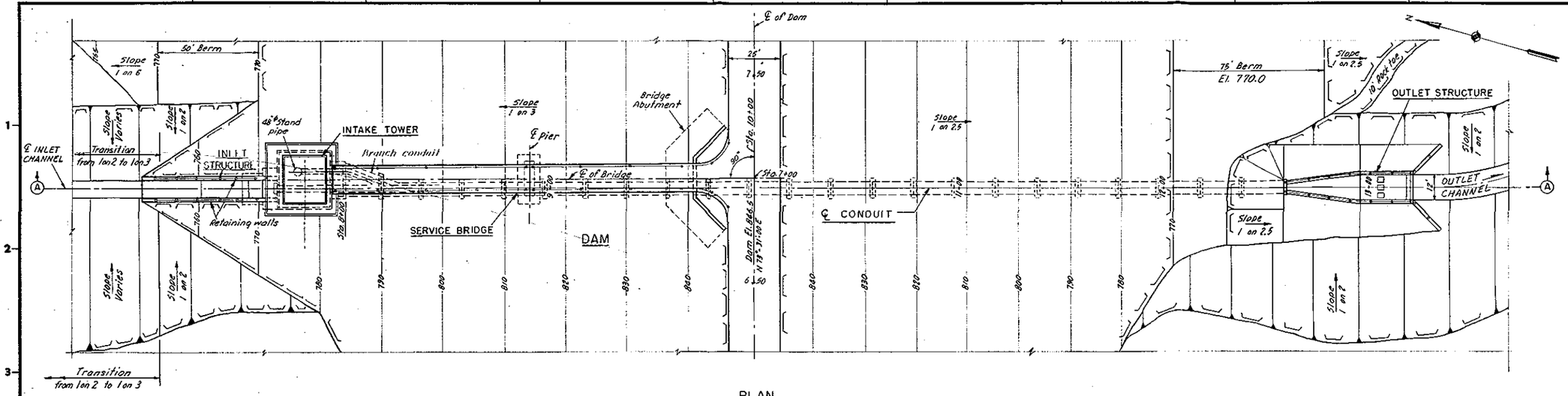
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
DAM EMBANKMENT
PROFILE AND TYPICAL SECTIONS
PHILLIPS BROOK MASSACHUSETTS

APPROVED
CHIEF, ENGINEERING DIVISION
DATE

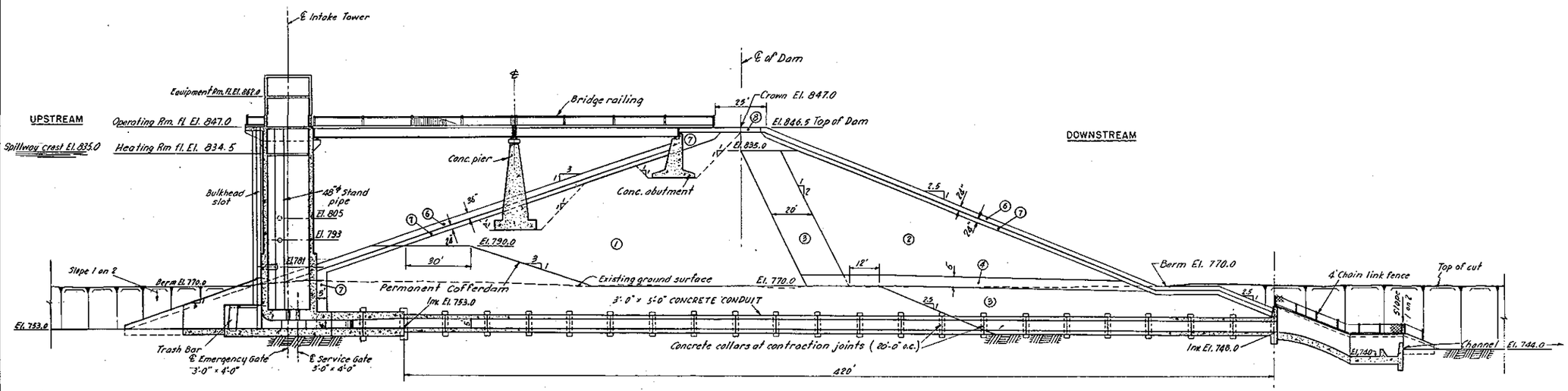
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-15

CORPS OF ENGINEERS A B C D E F G H U. S ARMY



PLAN
SCALE 1"=20'



SECTION A–A
SCALE 1"=20'

GRAPHIC SCALES
1" = 20' 20' 0 20' 40'

NOTE:
For Legend-Material, see Plate 2-4

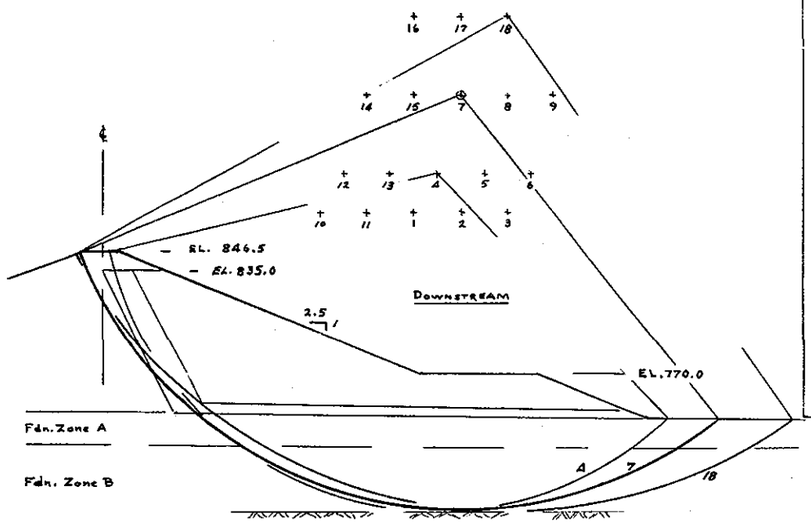
REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
OUTLET WORKS
PLAN AND SECTION
PHILLIPS BROOK MASSACHUSETTS
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE 1" = 20' | SPEC. NO.
DRAWING NUMBER
SHEET



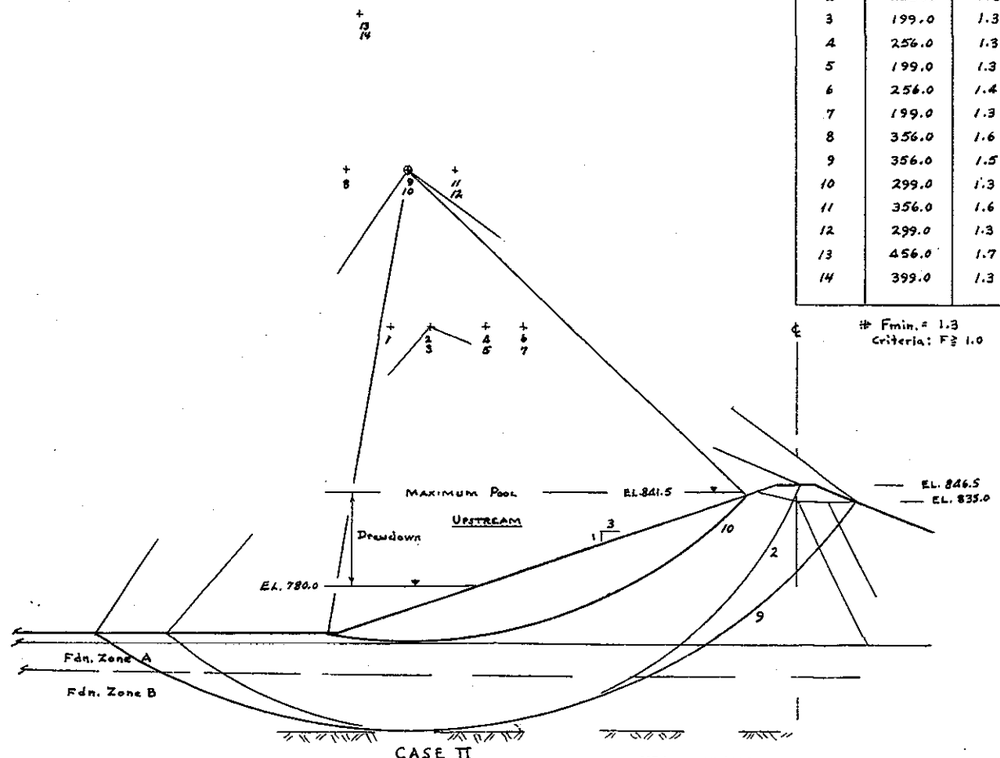
CIRCLE	RADIUS	F
1	191.0	1.8
2	191.0	1.9
3	191.0	2.0
4	216.0	1.8
5	216.0	1.8
6	216.0	1.9
7	266.0	1.7 #
8	266.0	1.8
9	266.0	1.9
10	191.0	2.1
11	191.0	2.0
12	216.0	2.0
13	216.0	1.9
14	266.0	2.0
15	266.0	1.8
16	316.0	1.9
17	316.0	1.8
18	316.0	1.8

$F_{min.}$ = 1.7
Criteria: F ≥ 1.3

CASE I
END-OF-CONSTRUCTION
STA. 10+20

DESIGN UNIT WEIGHTS AND SHEAR STRENGTHS

ZONE	UNIT WEIGHT pcf			SHEAR STRENGTH					
				Q		R		S	
	Moist	Sat.	Bouy.	Ø-Degr.	C-T.S.F.	Ø-Degr.	C-T.S.F.	Ø-Degr.	C-T.S.F.
Impervious & Random Fills	140.0	145.0	82.6	33.0	0.20	19.0	0.70	34.0	0
Pervious Fill	140.0	145.0	82.6	–	–	–	–	35.0	0
Foundation Zone A	–	140.0	77.6	–	–	–	–	35.0	0
Foundation Zone B	–	135.0	72.6	–	–	–	–	25.0	0



CIRCLE	RADIUS	F
1	256.0	1.4
2	256.0	1.3
3	199.0	1.3
4	256.0	1.3
5	199.0	1.3
6	256.0	1.4
7	199.0	1.3
8	356.0	1.6
9	356.0	1.5
10	299.0	1.3 #
11	356.0	1.6
12	299.0	1.3
13	456.0	1.7
14	399.0	1.3

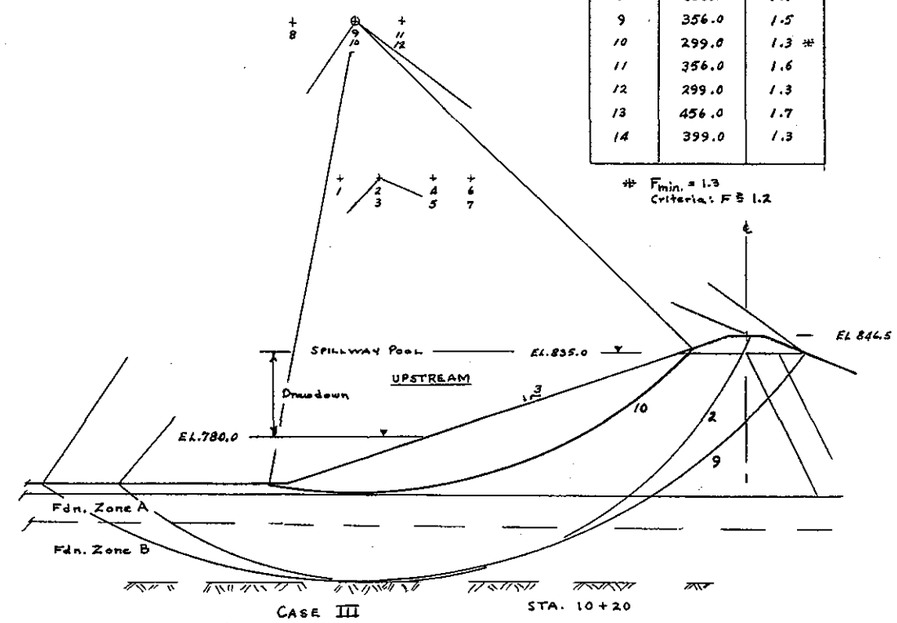
$F_{min.}$ = 1.3
Criteria: F ≥ 1.0

CASE II
SUDDEN DRAWDOWN FROM
MAXIMUM POOL

STA. 10+20

CIRCLE	RADIUS	F
1	256.0	1.4
2	256.0	1.3
3	199.0	1.3
4	256.0	1.4
5	199.0	1.3
6	256.0	1.5
7	199.0	1.3
8	356.0	1.6
9	356.0	1.5
10	299.0	1.3 #
11	356.0	1.6
12	299.0	1.3
13	456.0	1.7
14	399.0	1.3

$F_{min.}$ = 1.3
Criteria: F ≥ 1.2



CASE III
SUDDEN DRAWDOWN FROM
SPILLWAY POOL

STA. 10+20

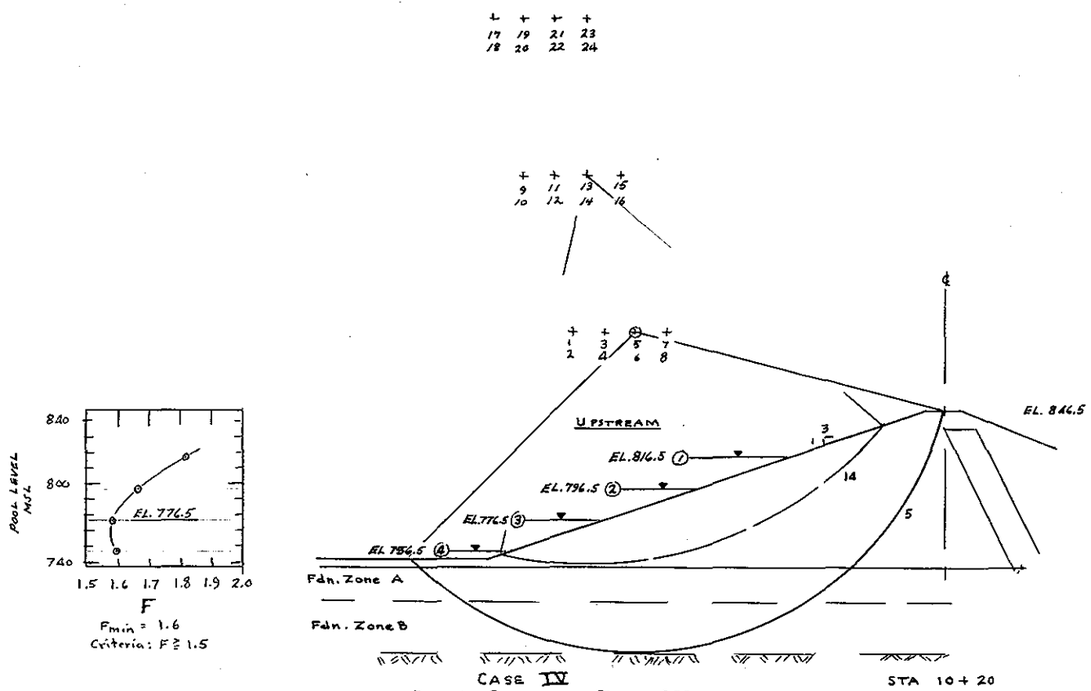
0 50 100 FT.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

SUMMARY OF STABILITY ANALYSIS NO. 1 (CIRCLES)

PHILLIPS BROOK MASSACHUSETTS



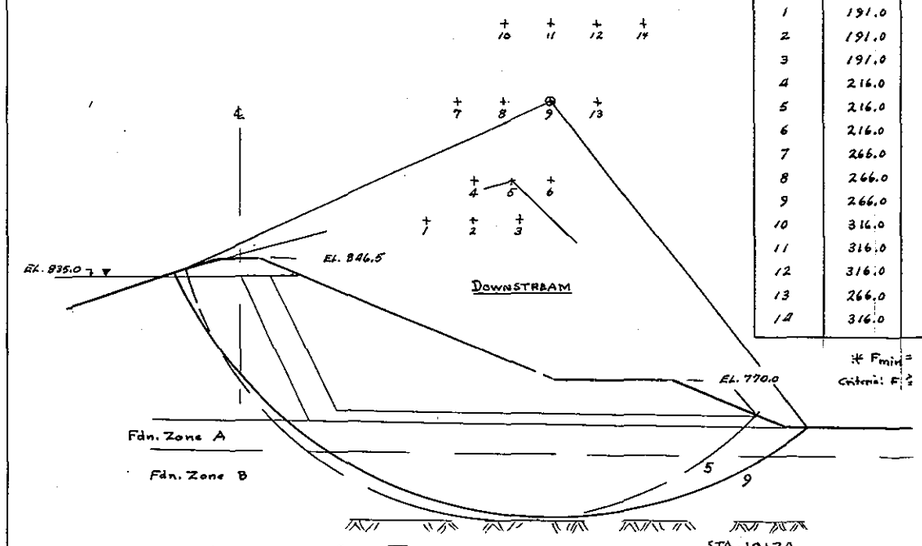
CASE IV
PARTIAL POOL WITH STEADY SEEPAGE

STA 10 + 20

Fmin = 1.6
Criteria: F ≥ 1.5

CIRCLE	RADIUS	F			
		Pool 1	Pool 2	Pool 3	Pool 4
1	206.0	2.0	1.8	1.7	1.6
2	149.0	2.2	2.1	1.9	2.1
3	206.0	1.9	1.7	1.6	1.6
4	149.0	2.3	2.0	1.9	2.2
5	206.0	1.8	1.7	1.6 *	1.6
6	149.0	2.2	2.0	1.9	2.2
7	206.0	1.8	1.7	1.6	1.6
8	149.0	2.2	2.0	2.0	2.3
9	306.0	2.1	1.9	1.8	1.8
10	249.0	2.1	2.0	1.9	2.0
11	306.0	2.0	1.8	1.7	1.7
12	249.0	2.1	1.9	1.9	2.0
13	306.0	1.9	1.8	1.7	1.7
14	249.0	2.0	1.9	1.9	2.1
15	306.0	2.0	1.8	1.8	1.8
16	249.0	2.0	1.9	1.9	2.1
17	406.0	2.2	2.1	2.0	1.9
18	349.0	2.1	2.0	1.9	2.0
19	406.0	2.2	2.0	1.9	1.9
20	349.0	2.0	1.9	1.9	2.0
21	406.0	2.2	2.0	2.0	1.9
22	349.0	2.0	1.9	1.9	2.0
23	406.0	2.2	2.1	2.0	2.0
24	349.0	2.0	1.9	2.0	2.1

* Fmin. = 1.6 Pool at EL. 776.5
Criteria: F ≥ 1.5

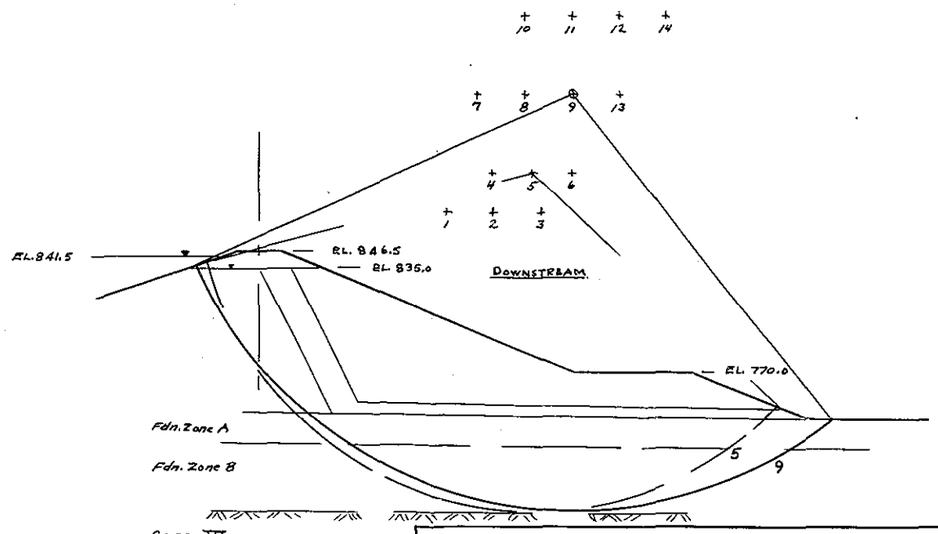


CASE V
STEADY SEEPAGE - MAXIMUM STORAGE POOL
AT SPILLWAY CREST
EL. 835.0

STA. 10+20

CIRCLE	RADIUS	F	
		CASE V	CASE VI
1	191.0	1.8	1.7
2	191.0	1.6	1.6
3	191.0	1.7	1.7
4	216.0	1.7	1.6
5	216.0	1.6	1.6
6	216.0	1.7	1.7
7	266.0	1.8	1.8
8	266.0	1.6	1.6
9	266.0	1.6 *	1.5 *
10	316.0	1.7	1.7
11	316.0	1.6	1.6
12	316.0	1.6	1.6
13	266.0	1.6	1.6
14	316.0	1.7	1.7
* Fmin =		1.6	1.5
Criteria: F ≥		1.5	1.4

0 50 100 FT.



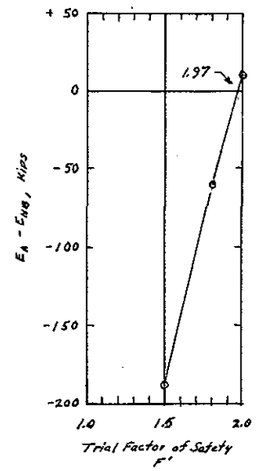
CASE VI
STEADY SEEPAGE - SURCHARGE POOL
EL. 841.5

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

SUMMARY OF STABILITY ANALYSIS NO.2 (CIRCLES)

PHILLIPS BROOK MASSACHUSETTS



COMPUTATION – E_P

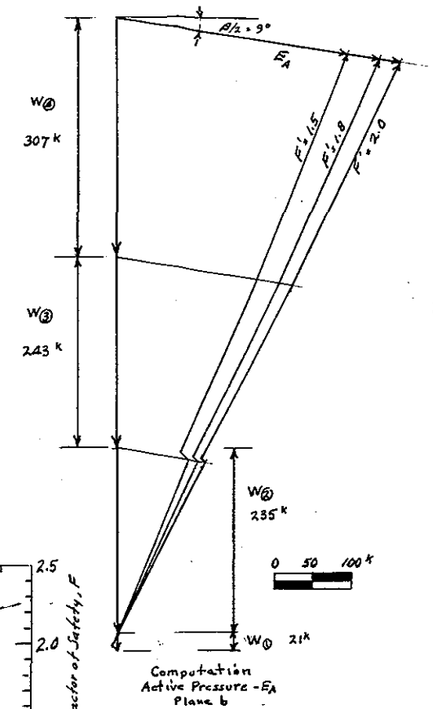
$E_P = \frac{1}{2}\gamma z^2 K_P = \frac{1}{2}(.078)(20)^2 K_P$

$= 15.5\ K_P$

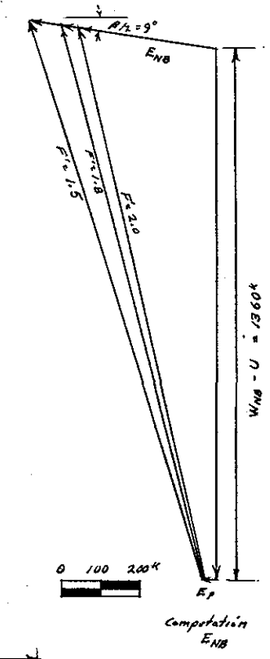
$K_P = \tan^2(45° + \frac{\phi_D}{2})$

$\phi' = 35°$

F	ϕ_D	K_P	E_P
1.5	25°	2.46	37.8k
1.8	21.2°	2.13	33.0k
2.0	19.3°	1.98	30.7k

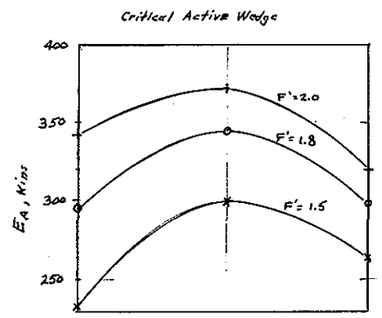


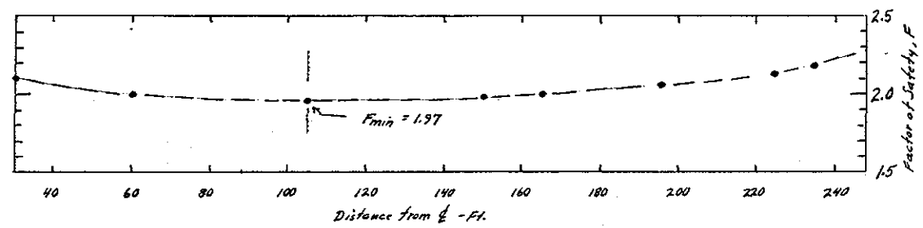
Computation
Active Pressure - E_A
Plane b

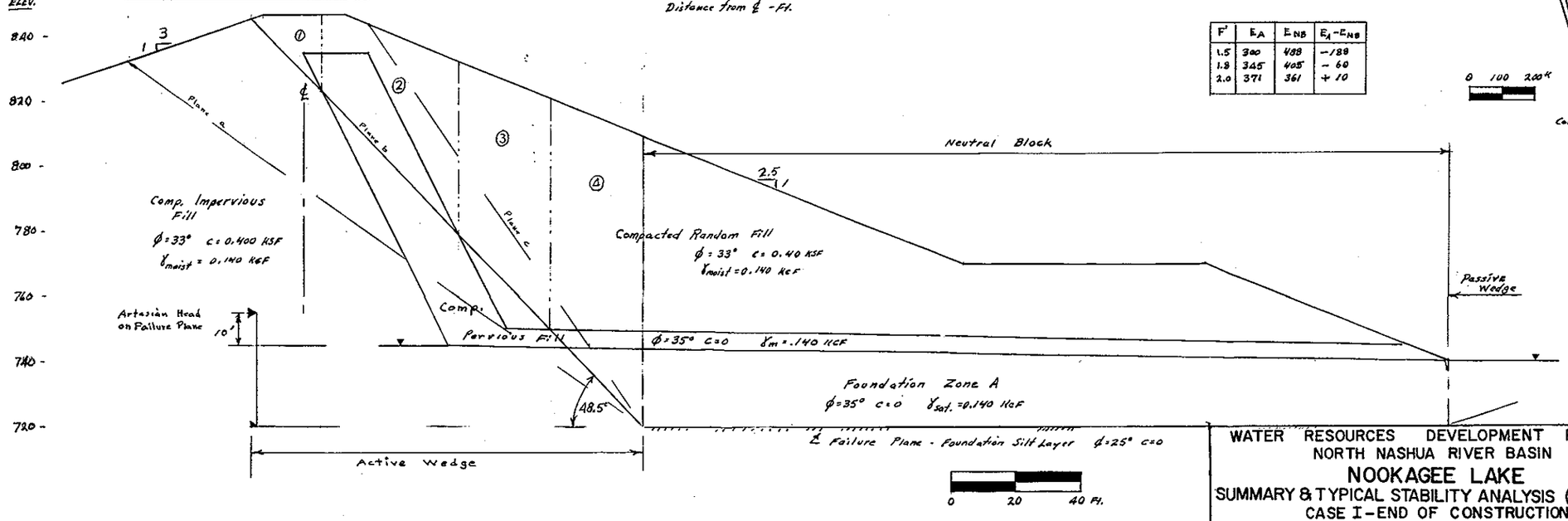


Computation
E_{NB}

F'	E_A	E_{NB}	$E_A - E_{NB}$
1.5	300	488	-188
1.8	345	405	- 60
2.0	371	361	+ 10



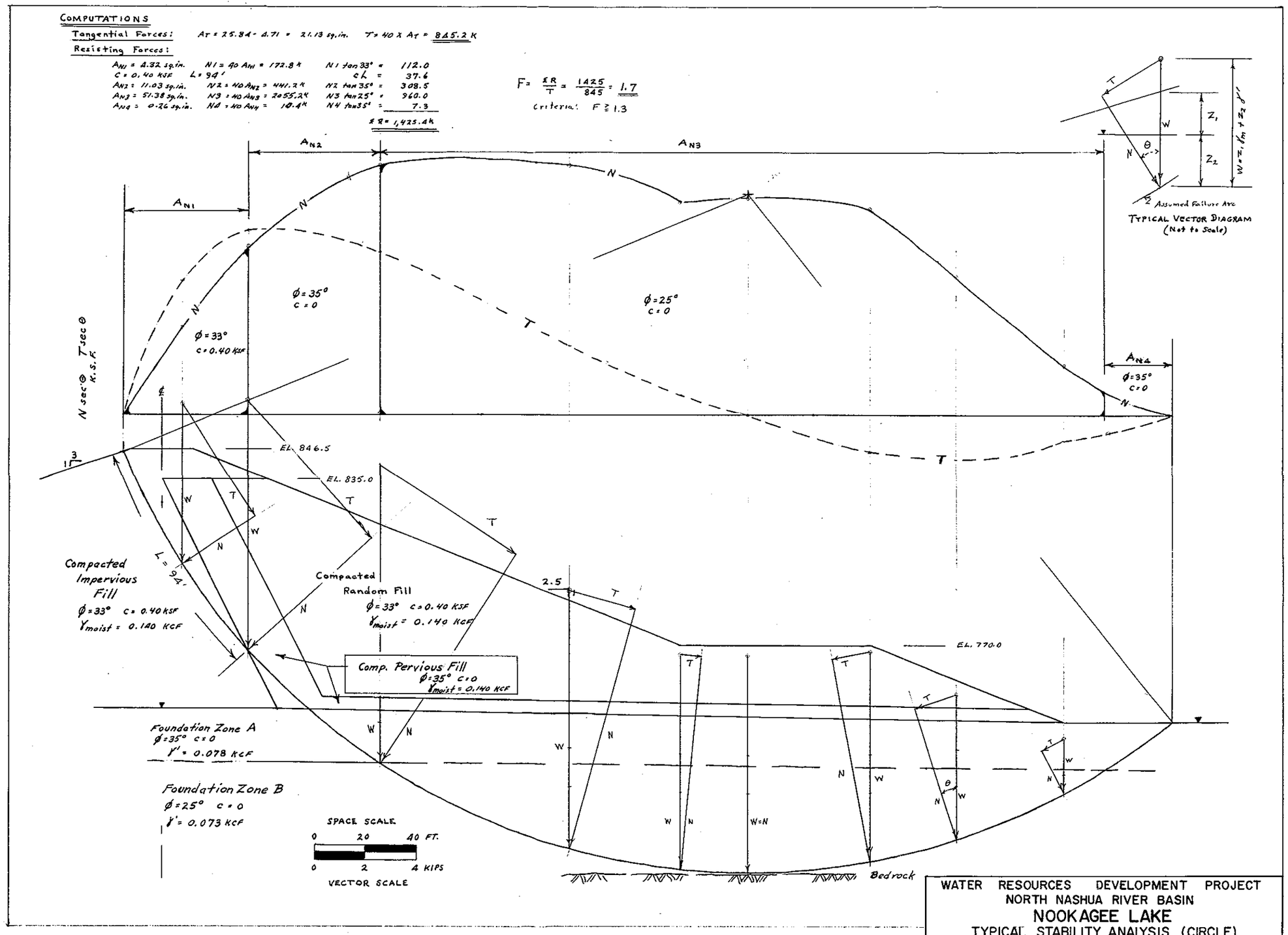




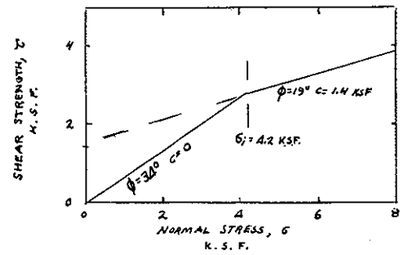
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

SUMMARY & TYPICAL STABILITY ANALYSIS (WEDGE)
CASE I – END OF CONSTRUCTION
DEEP FOUNDATION SILT LAYER
PHILLIPS BROOK MASSACHUSETTS



WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
TYPICAL STABILITY ANALYSIS (CIRCLE)
CASE I - END OF CONSTRUCTION (D/S)
PHILLIPS BROOK MASSACHUSETTS



DESIGN SHEAR STRENGTH ENVELOPE
IMPERVIOUS FILL

VECTOR SCALE FACTORS		
Zone	Unit Wt. p.c.f.	Scale Factor
Impervious Fill		
⊕ Saturated	145.0	1.45
Bouyant	82.6	0.83

COMPUTATIONS

Tangential Forces

$A_T = 6.56 - 0.05 = 6.51$ sq. in.

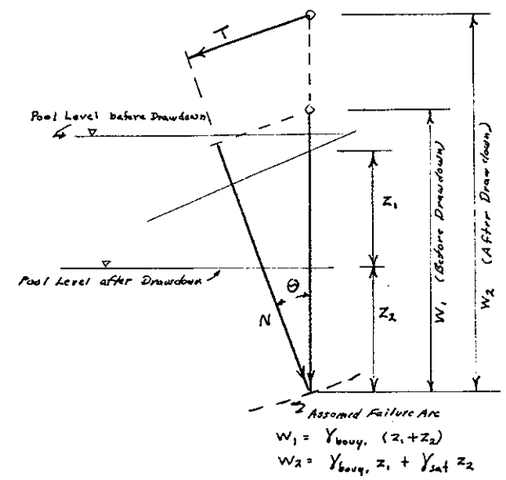
$T = 40 \times 6.51 = \underline{\underline{260.4 \text{ Kips}}}$

Resisting Forces

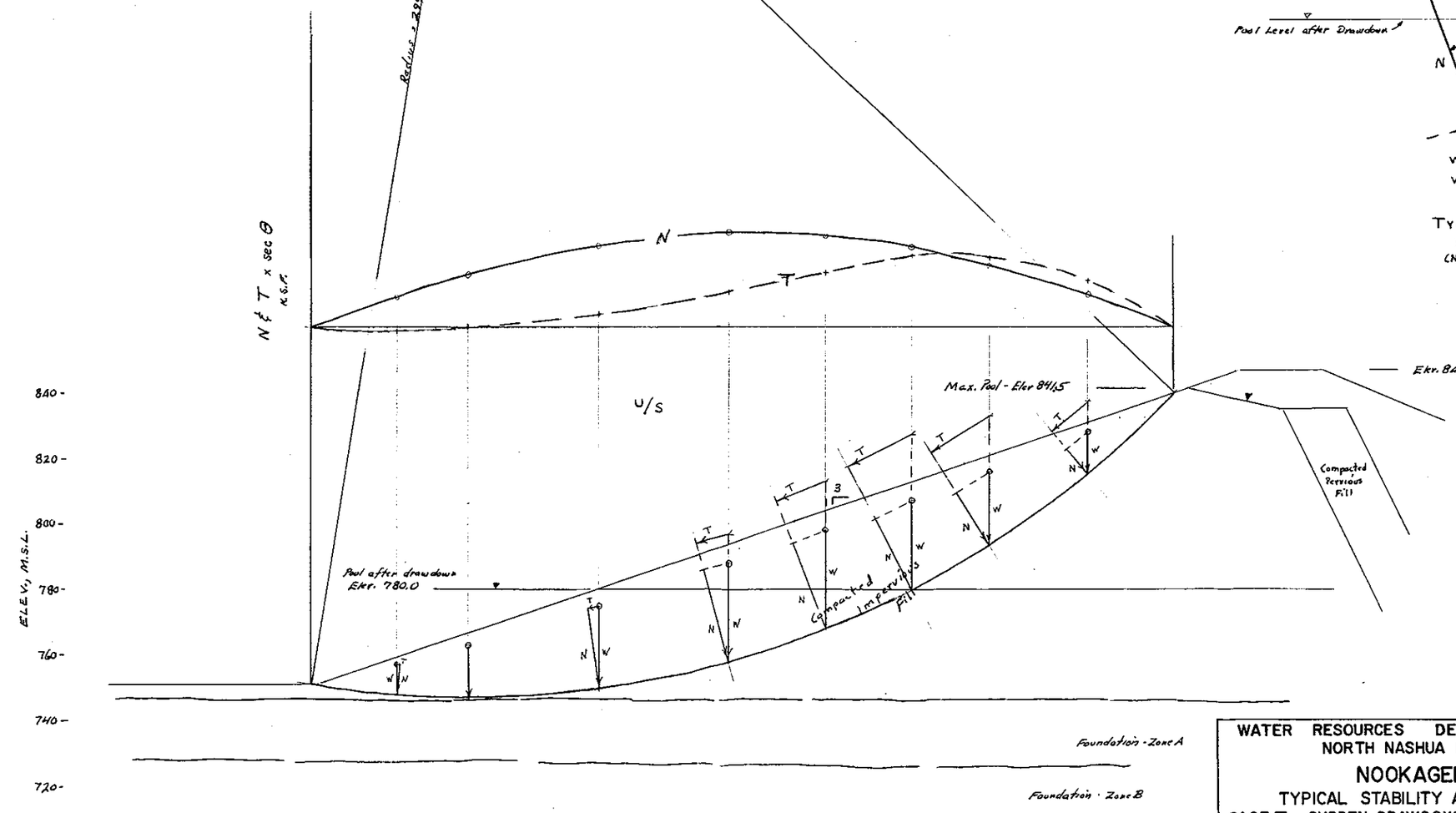
$A_N = 12.25$ sq. in. $\quad N = 40 \times 12.25 = \underline{490.0 \text{ Kips}}$

$$F = \frac{R}{T} = \frac{490.0 \tan 34^\circ}{260.4} = \frac{330.0}{260.4} = \underline{\underline{1.26}}$$

Criteria; $F \geq 1.0$



TYPICAL VECTOR DIAGRAM
(Not to Scale)

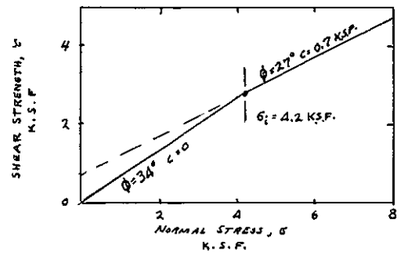


SPACE SCALE
0 20 40 FT.
0 2 4 KIPS
VECTOR SCALE

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

TYPICAL STABILITY ANALYSIS (CIRCLE)
CASE II - SUDDEN DRAWDOWN FROM MAXIMUM POOL
PHILLIPS BROOK MASSACHUSETTS



DESIGN SHEAR STRENGTH ENVELOPE
IMPERVIOUS FILL

VECTOR SCALE FACTORS		
Zone	Unit Wgt. pcf	Scale Factor
Impervious Fill Moist	140.0	1.40
Buoyant	82.6	0.83
Foundation - A Buoyant	77.6	0.78
Foundation - B Buoyant	72.6	0.73

COMPUTATIONS

Tangential Forces

A_T = 21.00 − 3.93 = 17.07 sq. in.
T = 40 × 17.07 = 682.8 K.ips

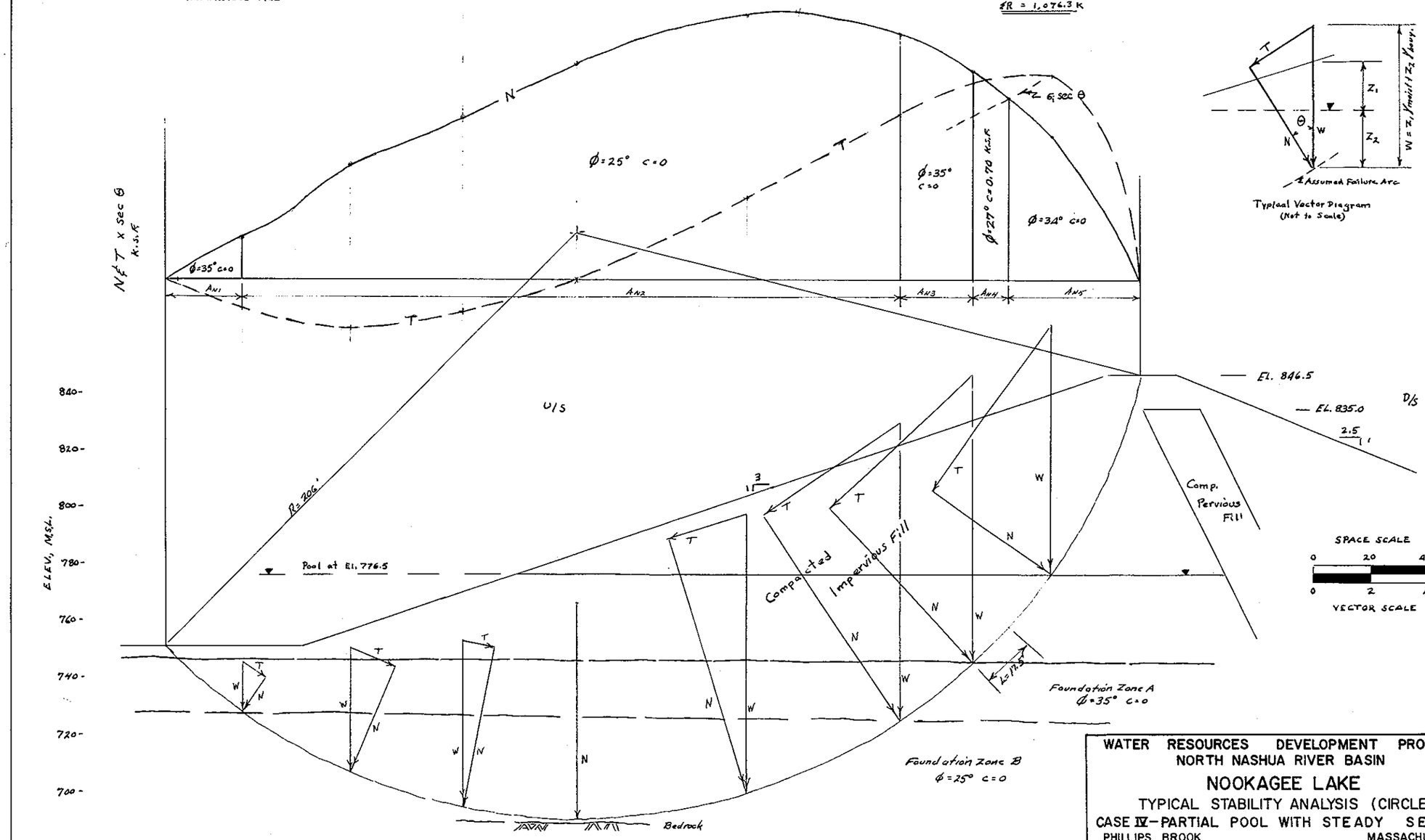
Resisting Forces

A_{N1} = 0.55 sq. in.	N1 = 40 × 0.55 = 22.0 K	N1 tan 35° = 15.4 K
A_{N2} = 39.60 sq. in.	N2 = 40 × 39.60 = 1584.0 K	N2 tan 25° = 740.0 K
A_{N3} = 5.30 sq. in.	N3 = 40 × 5.30 = 212.0 K	N3 tan 35° = 148.8 K
A_{N4} = 2.15 sq. in.	N4 = 40 × 2.15 = 86.0 K	N4 tan 27° = 43.9 K
cL = 0.7 × 17.5 = 12.2 K		cL 12.2 K
A_{N5} = 4.30 sq. in.	N5 = 40 × 4.30 = 172.0 K	N5 tan 34° = 116.0 K

ΣR = 1,076.3 K

$F = \frac{\Sigma R}{T} = \frac{1076}{683} = 1.58$

Criteria: F ≥ 1.5

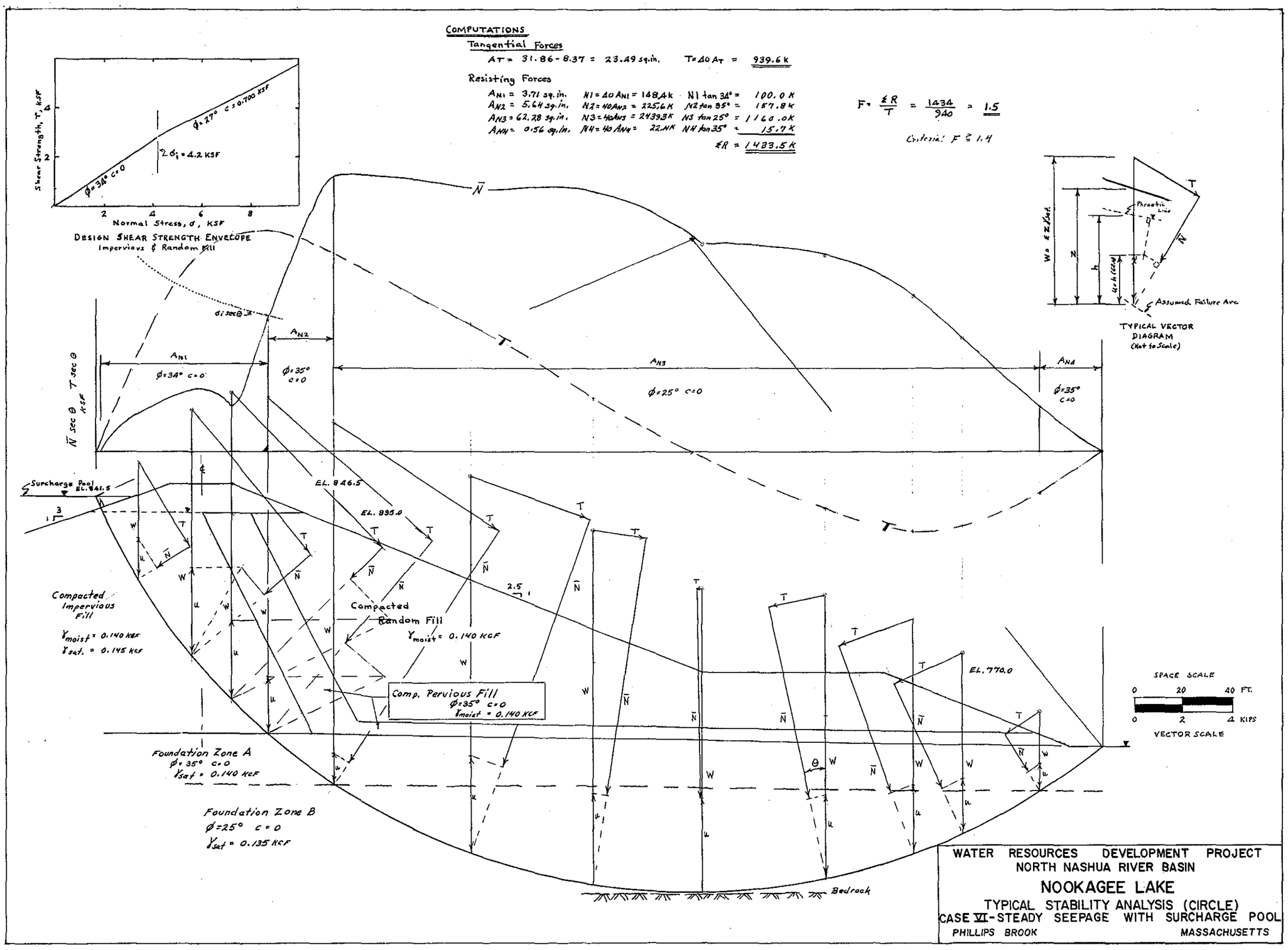


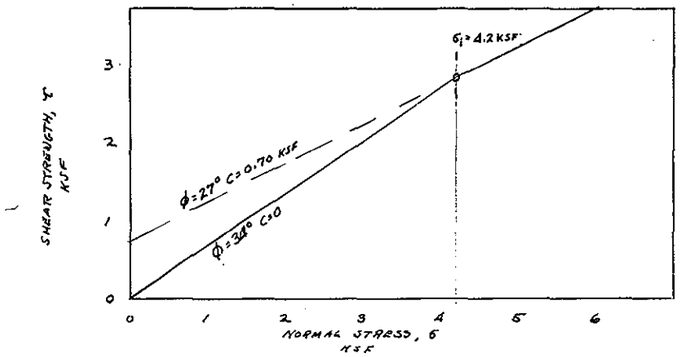
Typical Vector Diagram
(Not to Scale)

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

TYPICAL STABILITY ANALYSIS (CIRCLE)
CASE IV – PARTIAL POOL WITH STEADY SEEPAGE
PHILLIPS BROOK MASSACHUSETTS


COMPUTATIONS
Tangential Forces
AT = 31.86 - 8.37 = 23.49 sq.in. T = 40 AT = 939.6 K
Resisting Forces
AN1 = 3.71 sq.in. N1 = 40 AN1 = 148.4k N1 tan 34° = 100.0 K
AN2 = 5.64 sq.in. N2 = 40 AN2 = 225.6K N2 tan 35° = 157.8 K
AN3 = 62.28 sq.in. N3 = 40 AN3 = 2439.3K N3 tan 25° = 1160.0 K
AN4 = 0.56 sq.in. N4 = 40 AN4 = 22.4K N4 tan 35° = 15.7 K
ΣR = 1433.5 K
F = ΣR / T = 1434 / 940 = 1.5
Criteria: F ≧ 1.4
Shear Strength, τ, KSF
Normal Stress, σ, KSF
φ=34° c=0
φ=27° c=0.700 KSF
2σ1 = 4.2 KSF
DESIGN SHEAR STRENGTH ENVELOPE
Impervious & Random Fill
N̄ sec θ T sec θ KSF
AN1
φ=34° c=0
AN2
φ=35° c=0
AN3
φ=25° c=0
AN4
φ=35° c=0
Surcharge Pool EL. 841.5
EL. 846.5
EL. 835.0
EL. 770.0
Compacted Impervious Fill
γmoist = 0.140 KCF
γsat. = 0.145 KCF
Compacted Random Fill
γmoist = 0.140 KCF
Comp. Pervious Fill
φ=35° c=0
γmoist = 0.140 KCF
Foundation Zone A
φ=35° c=0
γsat = 0.140 KCF
Foundation Zone B
φ=25° c=0
γsat = 0.135 KCF
Bedrock
TYPICAL VECTOR DIAGRAM (Not to Scale)
Phreatic Line
Assumed Failure Arc
SPACE SCALE
0 20 40 FT.
0 2 4 KIPS
VECTOR SCALE
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
TYPICAL STABILITY ANALYSIS (CIRCLE)
CASE VI - STEADY SEEPAGE WITH SURCHARGE POOL
PHILLIPS BROOK
MASSACHUSETTS



DESIGN SHEAR STRENGTH ENVELOPE
IMPERVIOUS FILL

VECTOR SCALE FACTORS		
Zone	Unit Wt.	Scale Factor
Impervious Fill		
Moist	140.0	1.40
Saturated	145.0	1.45
Bouyant	82.6	0.82
Foundation - Zone A		
Saturated	140.0	1.40
Bouyant	77.6	0.78
Foundation - Zone B		
Saturated	135.0	1.35
Bouyant	72.6	0.73

COMPUTATIONS

Tangential Forces

$A_T = 26.70 - 1.90 = 24.80$ sq. in.
$T = 40 \times 24.8 = \underline{992.0}$ Kips

Resisting Forces

$A_{N1} = 0.01$ sq. in. $N_1 = 40 \times .01 = 0.4$ K
$N1 \tan 34° = \underline{0.3}$ Kips

$A_{N2} = 0.53$ sq. in. $N_2 = 40 \times 0.53 = 21.2$ Kips
$N2 \tan 35° = \underline{14.8}$ Kips

$A_{N3} = 39.43$ sq. in $N_3 = 40 \times 39.43 = 1577.2$ Kips
$N3 \tan 25° = \underline{735.0}$ Kips

$A_{N4} = 4.78$ sq. in. $N_4 = 40 \times 4.78 = 191.2$ Kips
$N4 \tan 35° = \underline{134.0}$ Kips

$A_{N5} = 1.18$ sq. in $N_5 = 40 \times 1.18 = 47.2$ Kips
$N5 \tan 27° = \underline{24.0}$ Kips

$cL = 0.7 \times 10 = \underline{7.0}$ Kips

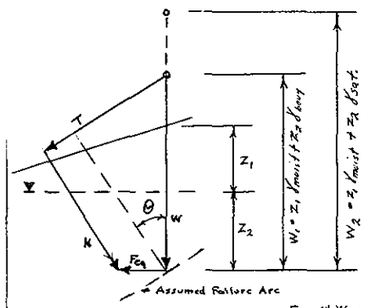
$A_{N6} = 4.64$ sq. in. $N_6 = 40 \times 4.64 = 185.6$ Kips
$N6 \tan 34° = \underline{125.0}$ Kips

$\Sigma R = 0.3 + 14.8 + 735.0 + 134.0 + 24.0 + 7.0 + 125.0$
$= \underline{1040.1}$ Kips

$F = \frac{\Sigma R}{T} = \frac{1040}{992} = \underline{1.05}$

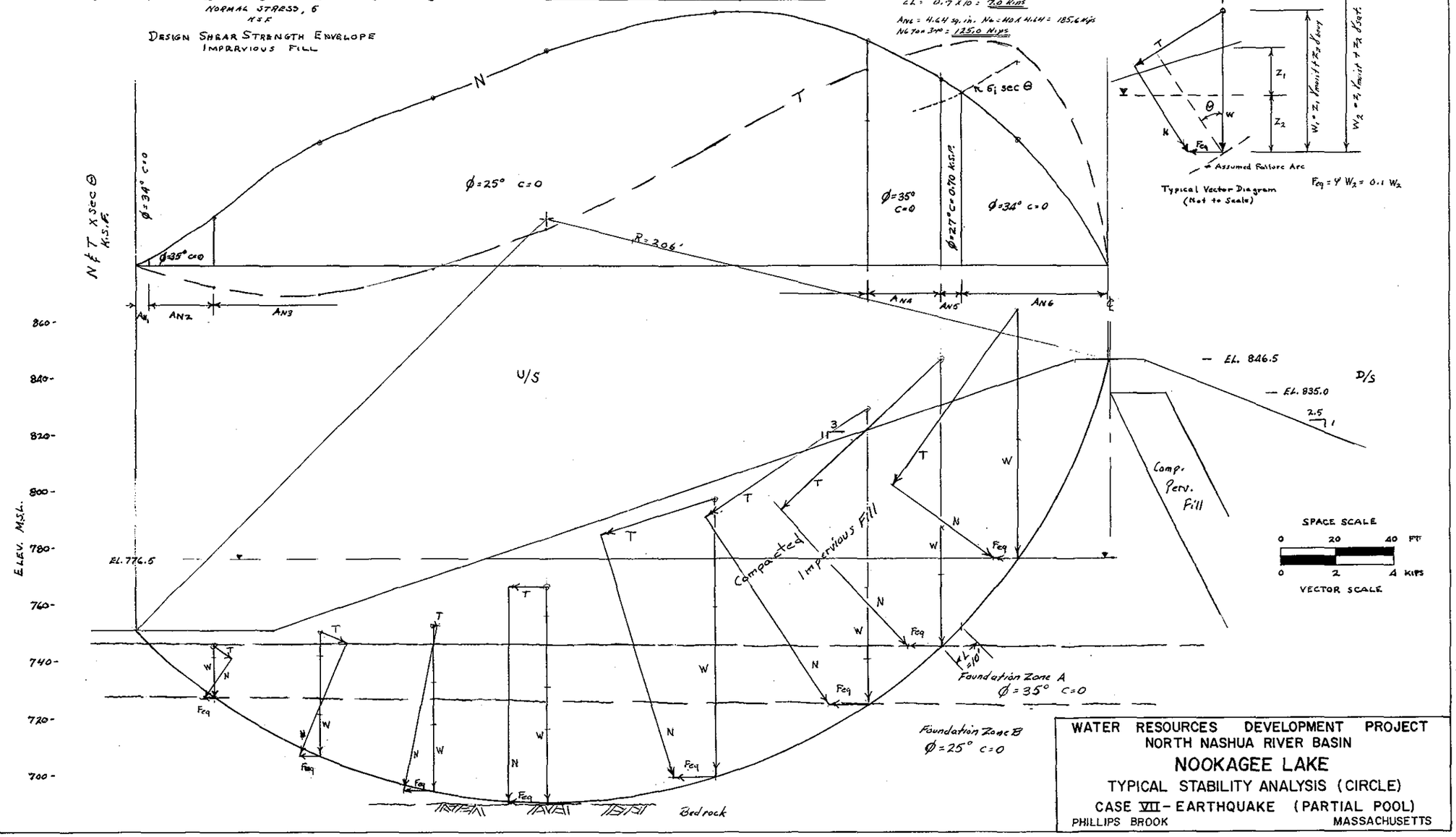
criteria: $F \geq 1.0$

$\Psi = 0.10$



Typical Vector Diagram
(Not to Scale)

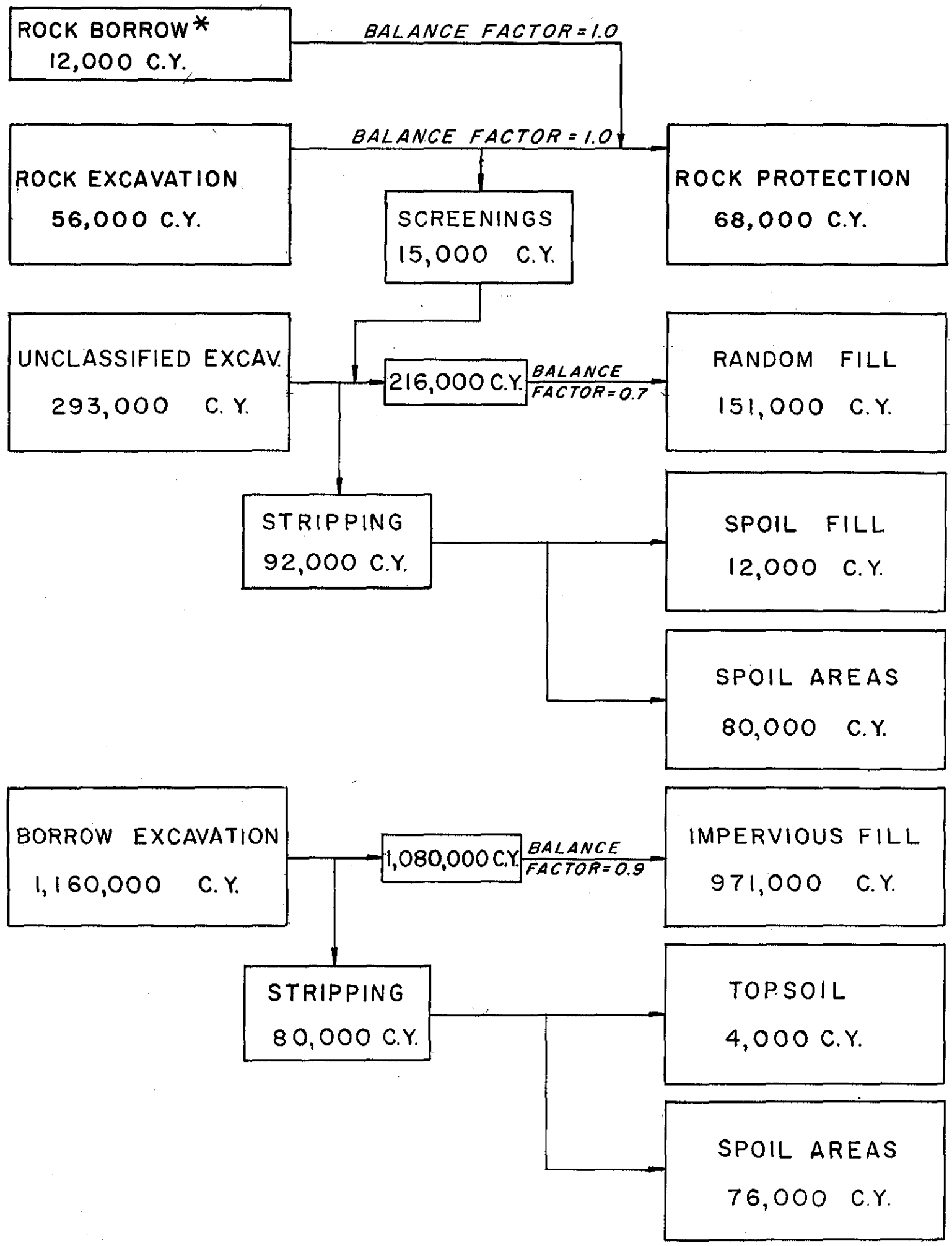
$F_{eq} = \Psi W_2 = 0.1 W_2$



WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

TYPICAL STABILITY ANALYSIS (CIRCLE)
CASE VII - EARTHQUAKE (PARTIAL POOL)
PHILLIPS BROOK MASSACHUSETTS



CONTRACTOR FURNISHED MATERIAL

GRAVEL BEDDING	55,000 C.Y.
GRAVEL FILL	3,000 C.Y.
PERVIOUS FILL	77,000 C.Y.
DRAINAGE FILL	86,000 C.Y.
ROAD GRAVEL	4,000 C.Y.

* MAY BE OBTAINED BY ENLARGING REQUIRED EXCAVATIONS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
MATERIALS USEAGE CHART
(PRELIMINARY)
PHILLIPS BROOK MASSACHUSETTS

APPENDIX A

SUMMARY OF LABORATORY TEST RESULTS

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-1	748.3	J-3	7.5-10.0	SM	0	71	29	0.030													
		J-5	15.0-20.0	SM	3	69	28	0.022													
FD-2	801.2	J-2	5.0-10.0	SM	21	50	29	0.013													
		J-5	15.0-19.0	SM	19	51	30	0.013													
		J-8	30.0-33.0	SM	14	52	34	0.010													
FD-3	775.5	J-3	4.0- 9.0	SM	18	62	20	0.033													
		J-5	15.0-18.0	SM	10	58	32	0.013													
		J-10	23.0-25.0	SM	20	49	31	0.010													
FD-4	802.9	J-2	1.3- 4.4	SM	36	46	18	0.033													
FD-6	836.9	J-4	5.0- 9.4	SM	36	46	18														
FD-11	754.6	J-4	1.2- 3.1	GW	66	30	4	0.100													
		J-20	20.0-21.8	SP	0	98	2	0.110													
		J-22	21.8-23.3	SP-SM	7	87	6	0.110													
		J-35	33.0-35.0	ML	6	15	79	0.006													
		J-36R	33.0-35.0	ML								16.0	17.4								
		J-37	35.0-38.0	SM	22	44	34	0.005													
		J-40	52.4-53.6	ML	0	33	67	0.008													
		J-41R	52.4-53.6	ML								15.1	15.3								
FD-13	791.0	J-2	1.2- 5.0	GP-GM	55	35	10	0.070													
FD-14	777.1	J-3	5.0- 9.0	SM	22	60	18	0.030													
		J-6	11.0-15.0	SM	9	70	21														
		J-10	22.6-25.0	SM	16	52	32	0.010													
		J-11R	22.6-25.0	SM								15.0	16.0								

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NOOKAGEE LAKE

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-15	777.4	J-3	7.0-10.0	SM	22	39	39	0.011													
		J-4	10.0-12.0	SM	16	52	32	0.015													
		J-5R	10.0-12.0	SM								9.5	11.2								
		J-6	15.0-16.5	SM	12	60	28	0.021													
		J-7R	15.0-16.5	SM								9.7	10.8								
		J-14	30.0-31.3	SM	20	38	42	0.010													
		J-15R	30.0-31.3	SM								11.0	13.4								
FD-16	769.0	J-7	11.0-13.0	SM	27	47	26	0.021													
		J-11	17.0-20.0	ML	6	31	63	0.018													
		J-12R	17.0-20.0	ML					N-P			15.1	15.9								
		J-16	27.5-30.0	SP-SM	2	88	10	0.080													
		J-25R	45.0-47.0	ML								19.0	19.2								
FD-17	810.9	J-7	15.0-17.0	SM	12	48	40	0.010													
		J-8R	15.0-17.0	SM								7.9	8.1								
FD-18	828.1	J-3	5.0-10.0	SP-SM	41	49	10	0.080													
FD-19	824.4	J-4	8.0-10.0	SM	16	57	27	0.020													
		J-5R	8.0-10.0	SM								8.4	9.6								
		J-6	15.0-16.5	SM	21	49	30	0.013													
		J-7R	15.0-16.5	SM								9.4	10.6								
FD-20	749.8	J-3	5.0- 6.5	GW-GM	63	30	7	0.150													
		J-6	10.0-15.0	SM	13	52	35	0.013													
		J-7R	10.0-15.0	SM								9.3	10.2								
		J-13R	20.0-23.0	ML&SP								15.3	16.3								
		J-17R	25.0-27.0	ML								21.1	21.1								
		J-19R	27.0-30.0	ML								15.3	15.4								

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* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	- NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	- NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-21	804.9	J-8	10.0-12.0	SM	18	45	37	0.011													
		J-10R	15.0-16.5	SM								8.7	10.7								
FD-22	744.1	J-4	5.0- 7.0	SW-SM	31	61	8	0.100													
		J-13R	18.8-20.0	ML								19.5	19.8								
		J-17R	21.5-23.0	ML								19.5	19.5								
		J-30	33.3-35.0	ML	3	37	60	0.021													
		J-31R	33.3-35.0	ML								16.5	17.5								
		J-38	40.5-43.0	CL	3	19	78	<0.001	30	18		16.9	17.2								
FD-23	774.2	J-12R	20.0-25.0	SM&ML								15.2	16.3								
		J-18R	35.0-37.0	SM								8.7	10.2								
FD-24	741.5	J-17R	20.4-23.0	ML								19.9	20.1								
		J-19R	25.0-27.5	ML								22.8	23.6								
		J-28R	40.0-42.5	SM								23.2	23.4								
FD-27	750.2	J-7R	12.0-15.0	ML								10.8	10.9								
		J-11R	17.0-20.0	SM								9.8	10.5								
		J-14	22.0-25.0	SM	24	44	32	0.004													
		J-25R	35.0-38.4	SM&CL								14.7	17.1								
FD-32	766.5	J-1	1.0- 4.0	GW-GM	50	44	6	0.140													
		J-6	10.0-12.5	SM-SC	8	56	36	0.008	22	16											
		J-9R	12.5-14.0	SM								8.0	8.1								
		J-20	28.0-30.0	SM	9	57	34	0.010	N-P												
		J-23R	30.0-31.8	SM								12.8	13.4								

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* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	- NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	- NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-33	776.9	J-19	20.0-22.0	SM	21	55	24	0.019													
		J-20R	20.0-22.0	SM					N-P												
		J-22R	24.0-25.0	SM								16.3	17.9								
FD-54	775±	J-7	13.0-14.8	SM	11	54	35	0.010				8.7	9.6								
		J-13	30.0-32.0	SM	17	44	39	0.007													
		J-14R	30.0-32.0	SM								7.1	9.5								
		J-17	45.0-45.7	ML&SM								12.0	13.7								
FD-55	770±	J-5	24.0-26.4	ML&SM								16.6	17.1								
		J-7	38.0-40.0	SM	21	49	30	0.011													
FD-57	773±	J-4	10.0-12.1	SM								18.4	18.5								
		J-6	20.0-22.5	ML								17.5	19.6								
		J-9	30.0-32.4	ML	6	22	72	0.006				15.1	15.7								
		J-12	40.0-43.0	ML	25	21	54	0.011				11.8	21.9								

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* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
BD-4	810.5±	J-1	0.5- 5.0	SM	12	50	38	0.010			2.70										
		J-2R	0.5- 5.0	SM								13.3	14.1								
		J-5	9.0-10.0	GM	35	31	34	0.007													
		J-7R	10.0-11.3	GM								9.5	10.0								
		J-8	20.5-22.6	SM	11	44	45	0.007													
		J-9R	20.5-22.6	SM					N-P			10.7	11.9								
		J-12	30.0-31.2	SM	12	50	38	0.002			2.71										
		J-13R	30.0-31.2	SM					18	15		7.1	10.1								
BD-5	850±	J-1	1.0- 5.0	SM	17	55	28	0.013													
		J-2R	1.0- 5.0	SM								9.4	11.6								
		J-5	14.0-18.0	ML	7	35	58	0.004			2.72										
		J-6R	14.0-18.0	ML					N-P			16.8	19.2								
		J-9	25.0-26.4	SM	17	50	33	0.012													
		J-10R	25.0-26.4	SM					N-P			9.7	10.3								
BD-6	871±	J-1	1.0- 5.0	SM	17	50	33	0.010													
		J-2R	1.0- 5.0	SM					N-P			11.8	12.9								
		J-10	20.0-22.0	SM	26	43	31	0.012													
		J-11R	20.0-22.0	SM					N-P			11.1	13.8								
BD-7	855±	J-2	5.0- 8.0	SM	29	31	40	0.012													
		J-5	15.0-16.0	SM	27	46	27	0.010													
BD-8	895±	J-4R	2.8- 5.0	SM								16.3	17.9								
		J-5	5.0-10.0	SM	18	43	39	0.013													
		J-6R	5.0-10.0	SM					N-P												
		J-8R	10.0-12.0	SM								13.5	15.1								
		J-11	20.0-22.0	SM	16	53	31	0.013													
		J-12R	20.0-22.0	SM					N-P		2.71										
		J-16	26.7-28.0	SM	13	46	41	0.010													
		J-17R	26.7-28.0	SM					N-P												

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* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
BD-9	885±	J-1	0.6- 5.0	SM	13	49	38	0.011													
		J-5	10.0-13.0	SM	31	37	32	0.008													
		J-13R	26.0-28.5	SM								11.1	14.9								
BD-10	910±	J-5	20.0-23.7	SM	22	56	22	0.030													
		J-8R	25.0-27.7	SM								8.5	13.0								

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* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

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SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. [redacted] OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
BT-1	855±	J-1	2.0- 5.0	GM	52	35	13	0.050	N-P												
		J-2R	2.0- 5.0	GM								4.8	11.1								
		J-5R	5.0-10.0	SM								8.6	12.5								
		B-6	5.0-10.0	SM	25	52	23	0.016	N-P		2.72			10.9	122.0						X
		J-7	10.0-12.0	SM	24	53	23	0.016	N-P												
		J-8R	10.0-12.0	SM								10.3	12.9								
BT-2	905±	J-2R	1.0-12.0									13.6	15.3								
		B-3	1.0-12.0	SM	14	56	30	0.011	N-P		2.70			9.8	124.6				X	X	X
BT-3	890±	J-1	2.0-10.0	GM	43	37	20	0.021	N-P												
		J-2R	2.0-10.0	GM								9.8	15.6								
		J-4	10.0-12.0	SM	13	52	35	0.010	N-P												
		J-5R	10.0-12.0	SM								8.2	11.3								

PAGE NO. 7 A

NED FORM JUL 63 510

* PROVIDENCE VIBRATED DENSITY TEST

NOOKAGEE LAKE

APPENDIX B

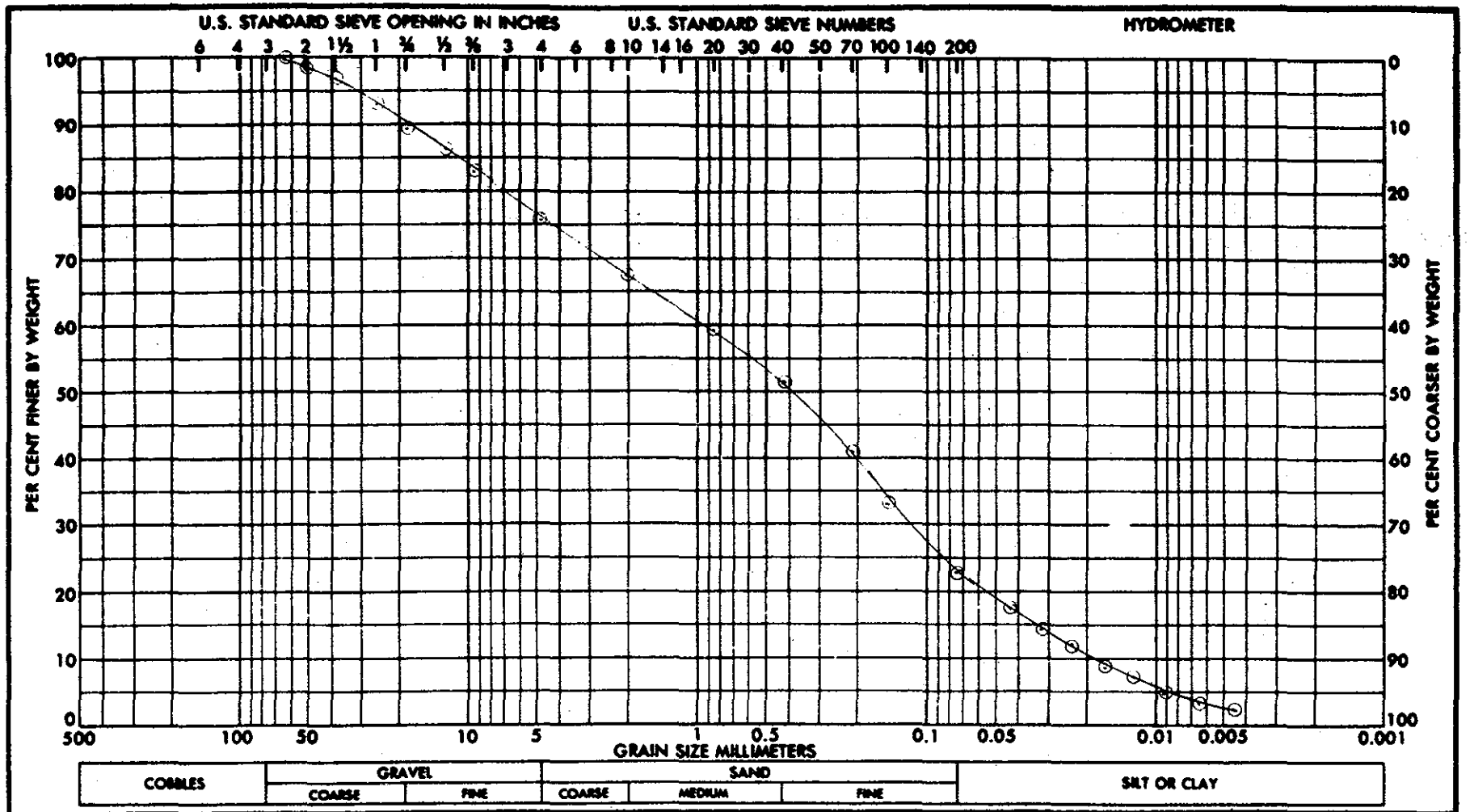
DETAILED SHEAR, CONSOLIDATION and COMPACTION TEST REPORTS

APPENDIX B

DETAILED SHEAR, CONSOLIDATION AND COMPACTION TEST REPORTS

NOCKAGEE LAKE

Plate No.	Title
	BT-1, B-6
B-1	Gradation Curve
B-2	Compaction Test Report
	BT-2, B-3
B-3	Gradation Curve
B-4	Consolidation Test Report
B-5	Compaction Test Report
B-6	Q Triax. Test Report - 97% Compaction - Opt. minus 2%
B-7	Q Triax. Test Report - 97% Compaction - Optimum
B-8	Q Triax. Test Report - 97% Compaction - Optimum plus 2%
B-9	Q Triax. Test Report - 100% Compaction - Optimum
B-10	R Triax. Test Report - 97% Compaction - Opt. minus 2%
B-11	R Triax. Test Report - 97% Compaction - Opt. minus 2%
B-12	R Triax. Test Report - 97% Compaction - Optimum
B-13	R Triax. Test Report - 97% Compaction - Optimum
B-14	R Triax. Test Report - 97% Compaction - Opt. plus 2%
B-15	R Triax. Test Report - 97" Compaction - Opt. plus 2%



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
B-6	5.0'-10.0'	Gravelly silty SAND (SM)		NP	NP	NP

PROJECT Nookagee Lake

AREA

BORING NO. BT-1

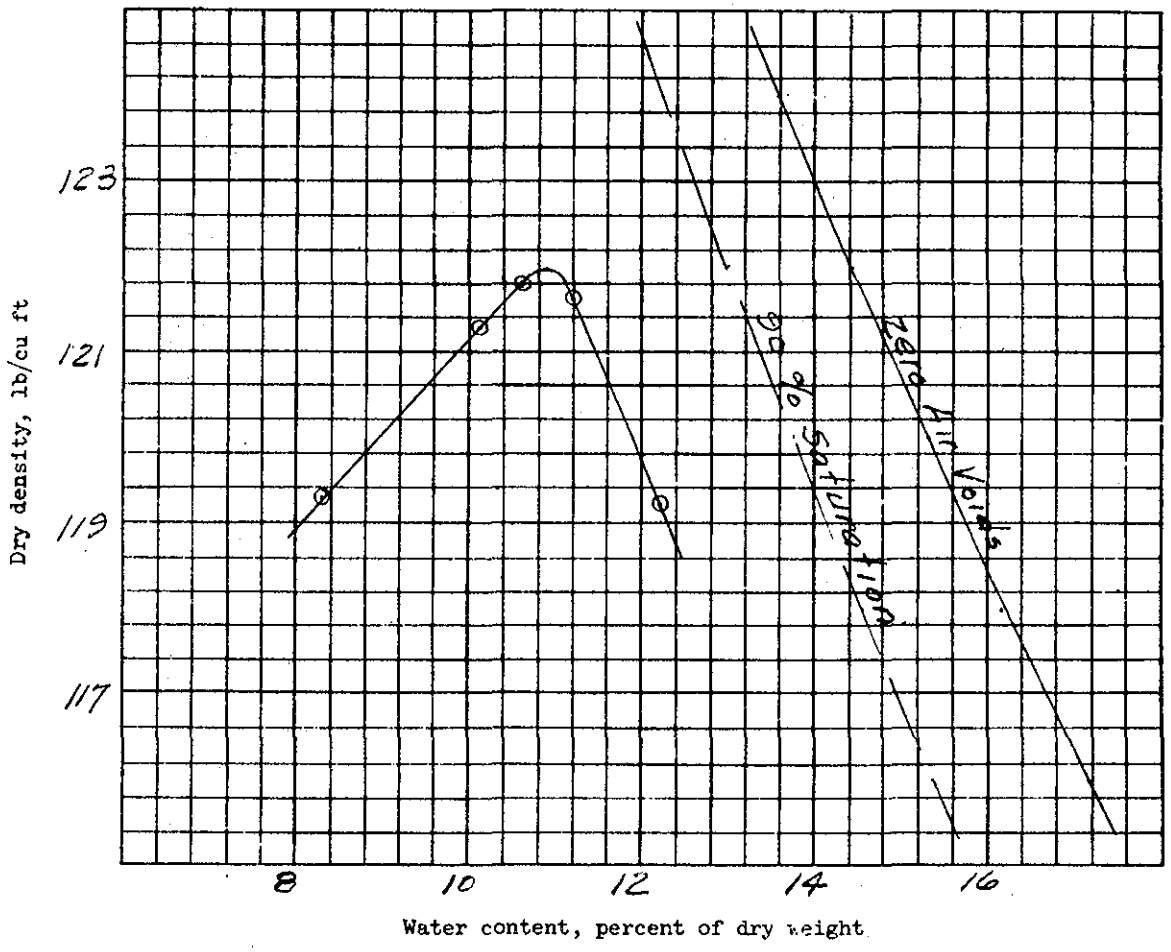
DATE Sept. 1971

GRADATION CURVES

PLATE NO. B-1

ENG FORM 1 MAY 63 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.

U.S. GOVERNMENT PRINTING OFFICE : 1963 OF—760-126



Standard compaction test

25 blows per each of 3 layers, with 5.5 lb rammer and

12 inch drop. 4.0 inch diameter mold

Sample No.	~~Elev or~~ Depth	Classification	G	LL	PL	% > No. 4	% > 3/4 in
B-6	5.0'-10.0	Gravelly silty SAND (SM)	2.72	NP	NP	24.8	10.4

Sample No.	B-6			
Natural water content, percent				
Optimum water content, percent	10.9			
Max dry density, lb/cu ft	122.0			

Remarks Test run on -No4 material.

Project Nookagee Lake

Area

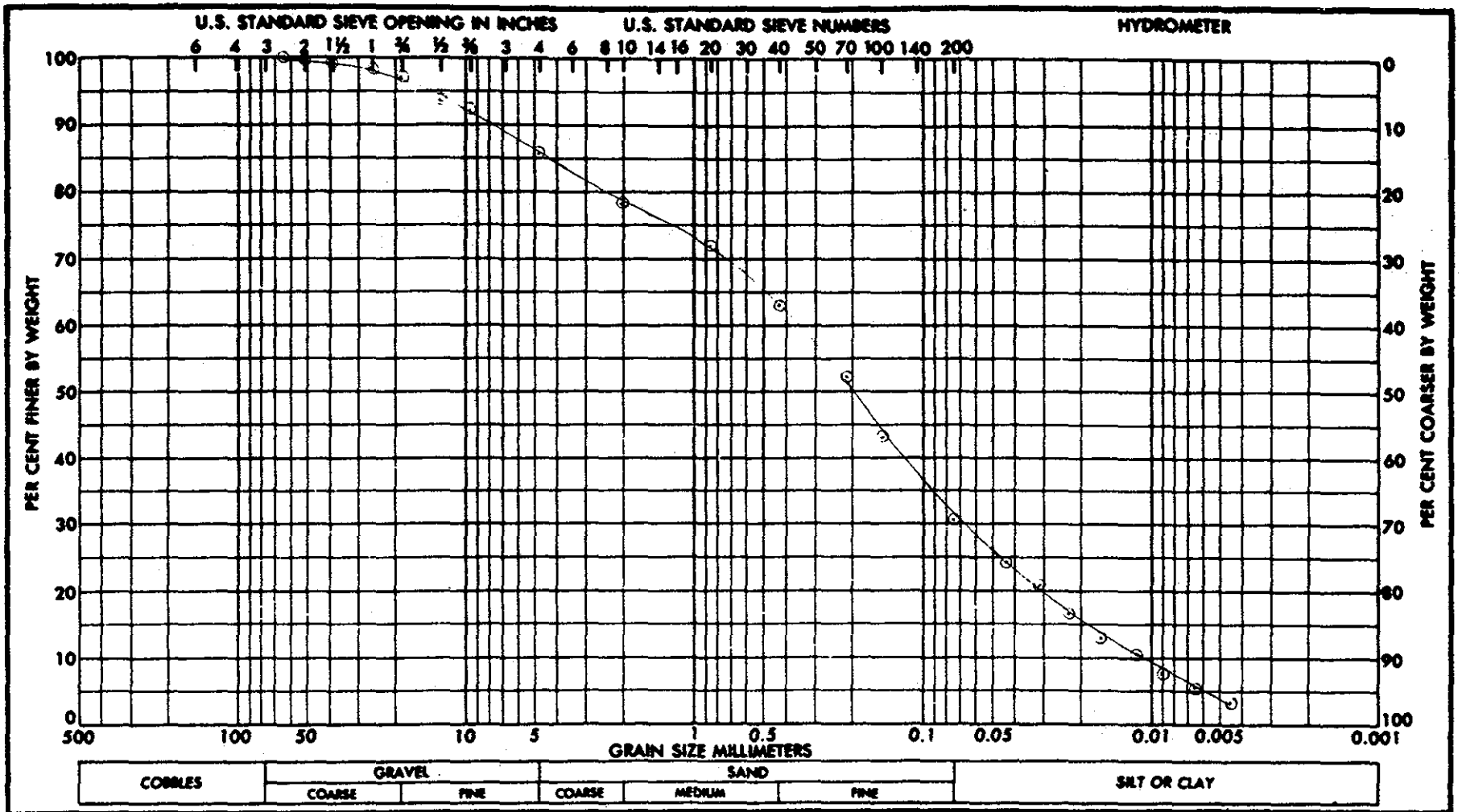
Boring No. BT-1 Date Aug. 1971

COMPACTION TEST REPORT

ENG FORM 1 JUN 65 2091

PREVIOUS EDITIONS ARE OBSOLETE

PLATE NO. B-2



SAMPLE NO.	ELEV-OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
B-3	1.0'-12.0'	Gravelly silty SAND (SM)		NP	NP	NP

PROJECT Nookagee Lake

AREA

BORING NO. BT-2

DATE Sept. 1971

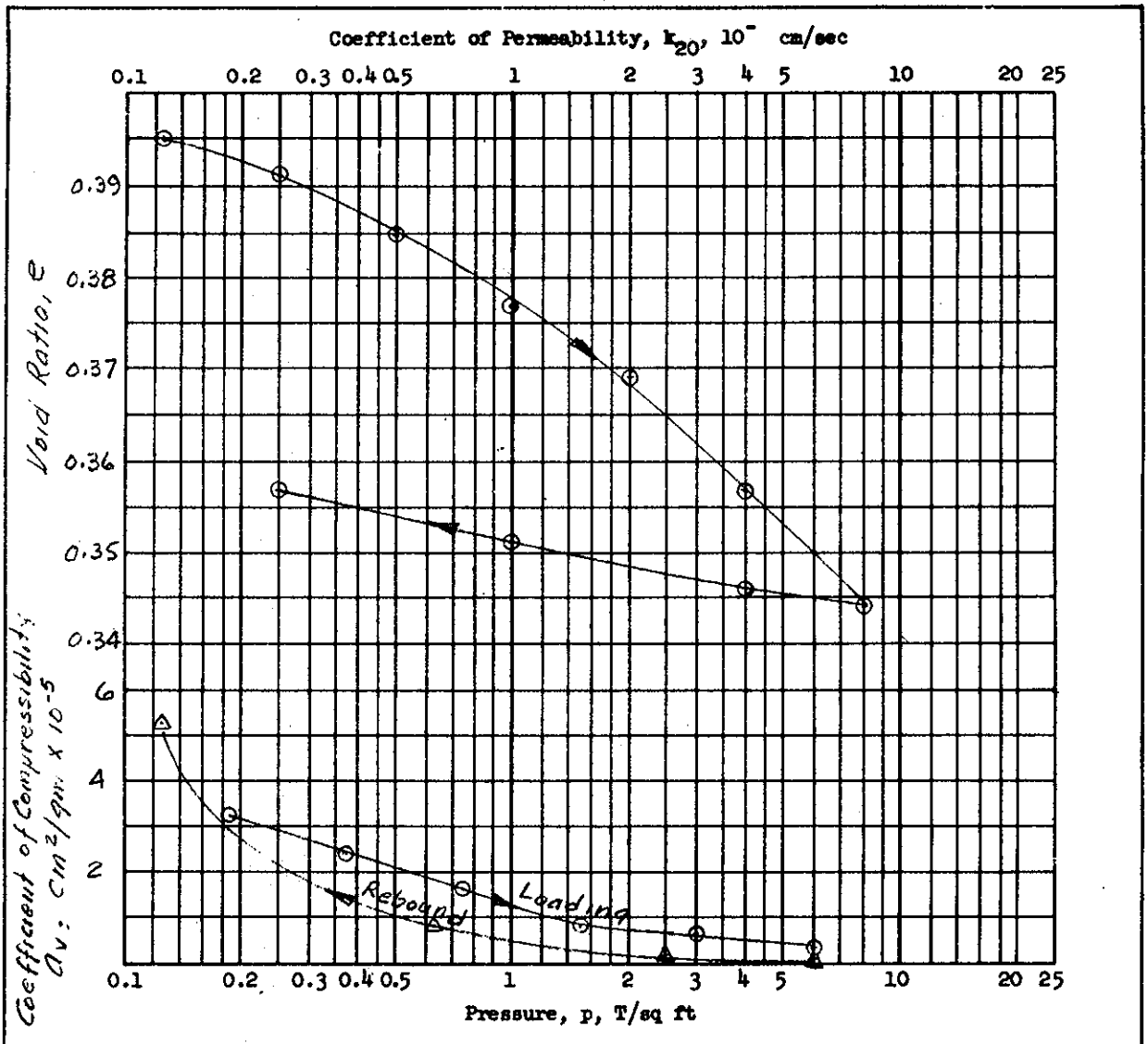
GRADATION CURVES

PLATE NO. B-3

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.

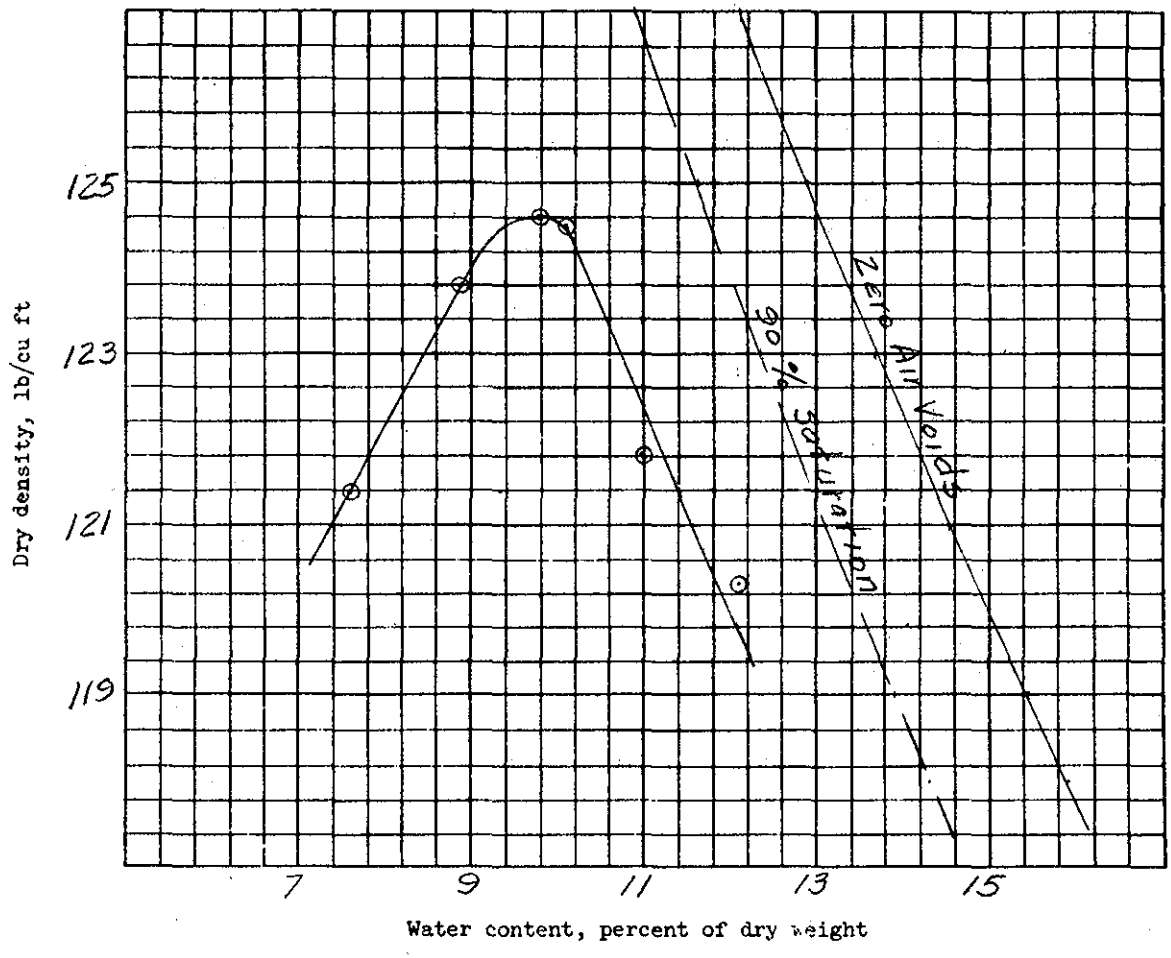
U.S. GOVERNMENT PRINTING OFFICE : 1963 O-7—709-136



Type of Specimen Remolded		Before Test		After Test	
Diam 4.45 in.	Ht 1.0 in.	Water Content, w_o	11.7 %	w_f	13.1 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.403	e_f	0.370
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	78.7 %	S_f	95.5 %
Compression Index, C_c 0.040		Dry Density, γ_d	120.1 lb/ft^3		
Classification Gravelly silty SAND (SM)		k_{20} at e_o =	$\times 10^{-}$ cm/sec		
LL NP	G_s 2.70	Project Nookagee Lake			
PL NP	D_{10} 0.012				
Remarks Test run on - No 4 material molded at approx. water content of 11.8% and approx. dry density of 121.0 pcf, opt. water content plus 2% and 97% of max. density as determined from std comp. test. Sheet 1 of 2		Area			
		Boring No. BT-2		Sample No. B-3	
		Depth El 1.0'-12.0'		Date Nov. 1971	

CONSOLIDATION TEST REPORT

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE.



Standard compaction test

25 blows per each of 3 layers, with 5.5 lb rammer and

12 inch drop. 4.0 inch diameter mold

Sample No.	~~Elev or~~ Depth	Classification	G	LL	PL	% > No. 4	% > 3/4 in
B-3	1.0'-12.0'	Gravelly silty SAND (SM)	2.70	NP	NP	14.7	3.2

Sample No.	B-3			
Natural water content, percent				
Optimum water content, percent	9.8			
Max dry density, lb/cu ft	124.6			

Remarks Test run on -No 4 Material

Project Nookagee Lake

Area

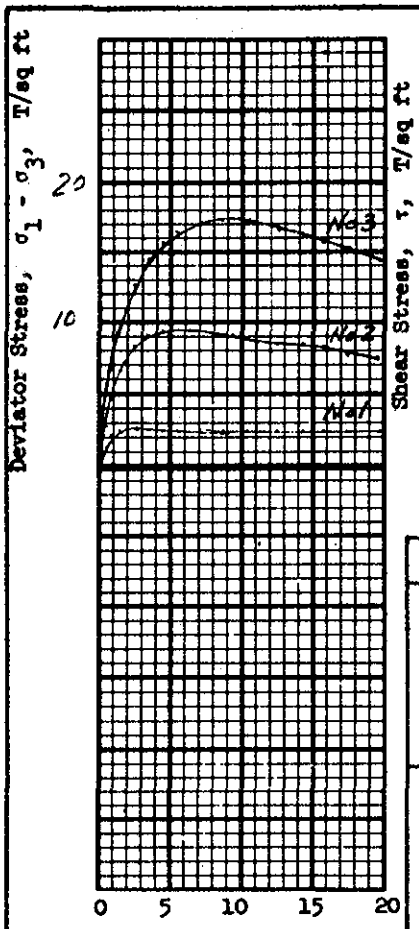
Boring No. BT-2 Date Aug. 1971

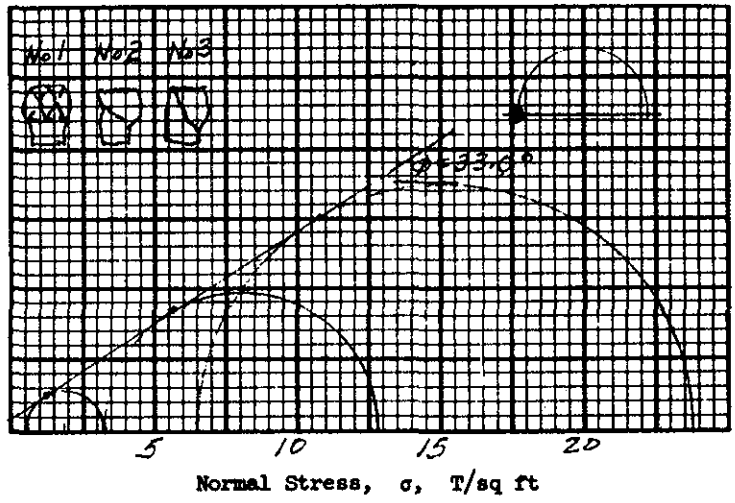
COMPACTION TEST REPORT

ENG FORM 1 JUN 65 2091

PREVIOUS EDITIONS ARE OBSOLETE

PLATE NO. B-5





Test No.			1	2	3	
Initial	Water content	w_o	7.9 %	8.0 %	8.0 %	%
	Void ratio	e_o	0.398	0.398	0.398	
	Saturation	S_o	53.8 %	54.4 %	54.4 %	%
	Dry density, lb/cu ft	γ_d	120.3	120.3	120.3	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	— %	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	2.67	9.43	17.24	
Time to failure, min		t_f	3.0	6.4	9.6	
Rate of strain, percent/min			0.99	0.99	0.99	
			—	—	—	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	2.32*	8.34*	16.02*	
Initial diameter, in.		D_o	2.80	2.80	2.80	
Initial height, in.		H_o	6.32	6.33	6.32	

Shear Strength Parameters

ϕ = 33.0 °

tan ϕ = 0.650

c = 0.40 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Type of test Q | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks *Stress @ 15% Strain
Specimens molded in/-No 4. Nat'l at approx. water content of 7.8 % and approx. dry density of 120.9 pcf, 97% of max. density and opt. minus 2% water content as determined from Std compaction test curve.

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

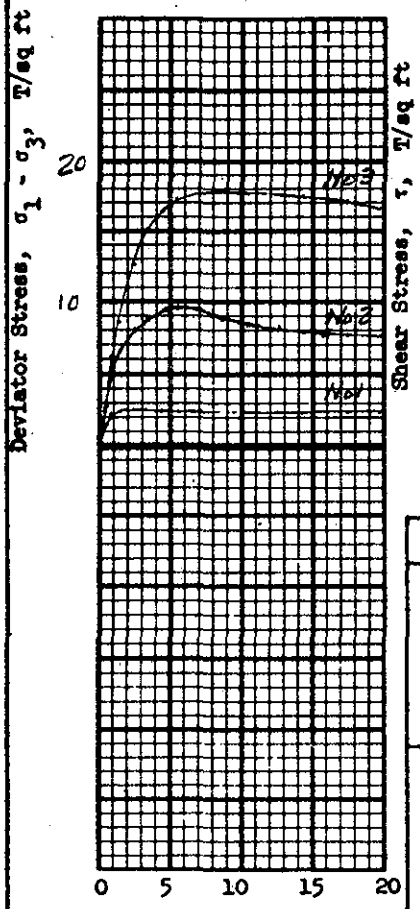
Depth ~~El~~ 1.0' - 12.0' | Date Oct. 1971

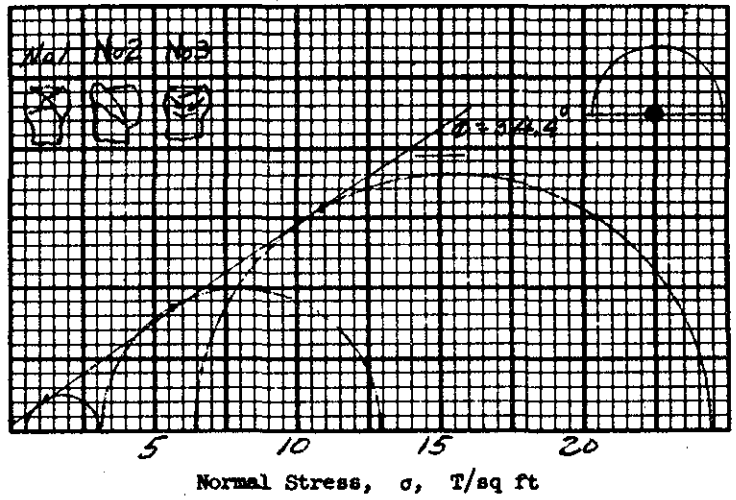
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-6





Test No.			1	2	3	
Initial	Water content	w_o	9.6 %	9.7 %	9.6 %	%
	Void ratio	e_o	0.395	0.392	0.391	
	Saturation	S_o	65.8 %	66.5 %	66.4 %	%
	Dry density, lb/cu ft	γ_d	120.6	120.9	120.9	
Before Shear	Water content	w_c	– %	– %	– %	%
	Void ratio	e_c	–	–	–	
	Saturation	S_c	– %	– %	– %	%
	Final back pressure, T/sq ft	u_o	–	–	–	
Final	Water content	w_f	– %	– %	– %	%
	Void ratio	e_f	–	–	–	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	2.55	9.56	17.89	
Time to failure, min		t_f	3.2	5.6	8.8	
Rate of strain, percent/min			0.99	0.99	0.99	
			–	–	–	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	2.34*	7.94*	17.33*	
Initial diameter, in.		D_o	2.80	2.80	2.80	
Initial height, in.		H_o	6.32	6.31	6.30	

Shear Strength Parameters

ϕ = 34.4 °

tan ϕ = 0.685

c = 0.25 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Type of test Q | Type of specimen Remolded

Classification Gravelly Silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks *Stress @ 15% strain. Specimens molded w/-No4 mat'l at approx. water content of 9.8% and approx. dry density of 120.9 pcf, opt water content and 97% of max. density as determined from std compaction test.

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

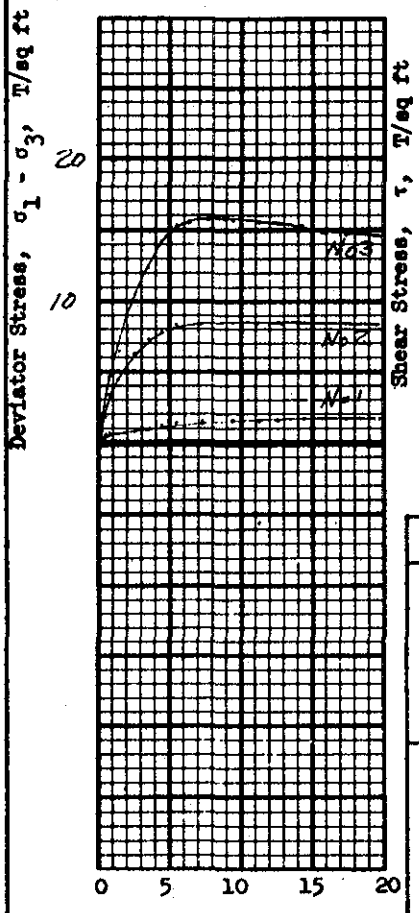
Depth Et 1.0'-12.0' | Date Oct. 1971

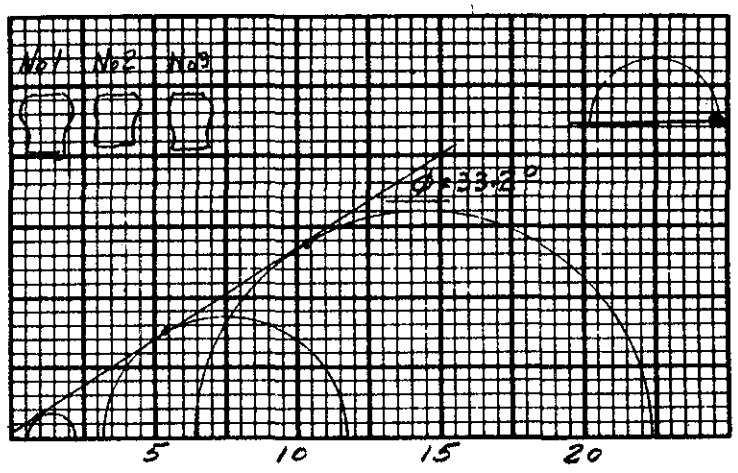
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-7





Test No.			1	2	3	
Initial	Water content	w_o	11.7 %	11.5 %	11.9 %	%
	Void ratio	e_o	0.392	0.392	0.394	
	Saturation	S_o	80.6%	78.9%	81.3%	%
	Dry density, lb/cu ft	γ_d	120.8	120.8	120.6	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	— %	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	1.67*	8.48	15.88	
Time to failure, min		t_f	15.1	11.2	8.0	
Rate of strain, percent/min			0.99	0.99	1.00	
			—	—	—	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	—	8.44*	15.08*	
Initial diameter, in.		D_o	2.81	2.80	2.81	
Initial height, in.		H_o	6.27	6.32	6.26	

Shear Strength Parameters

ϕ = 33.2 °

tan ϕ = 0.635

c = 0.20 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Type of test Q | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks *Stress @ 15% Strain
Specimens molded w/ -No4 mat'l at approx. water content of 11.8 % and approx. dry density of 120.9 pcf, 97% of max. density and opt plus 2% as determined from std compaction test curve.

Project Naokagee Lake

Area

Boring No. BT-2 | Sample No. B-3

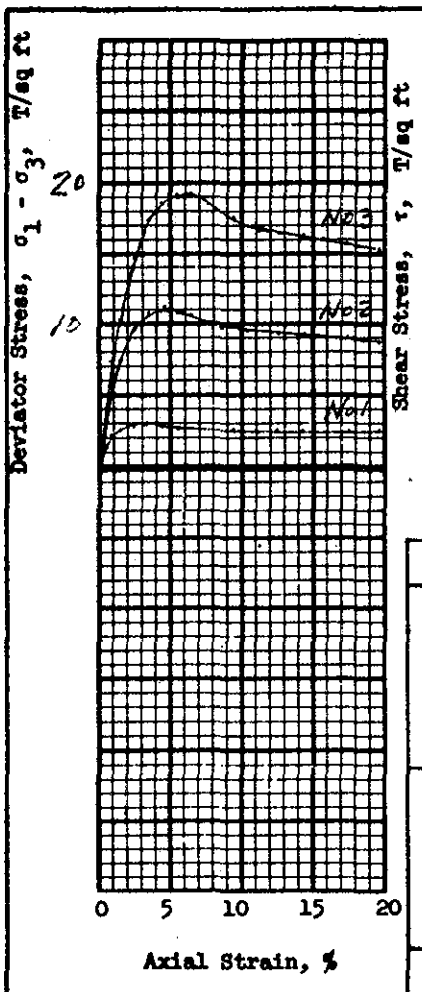
Depth 1.0'-12.0' | Date Oct. 1971

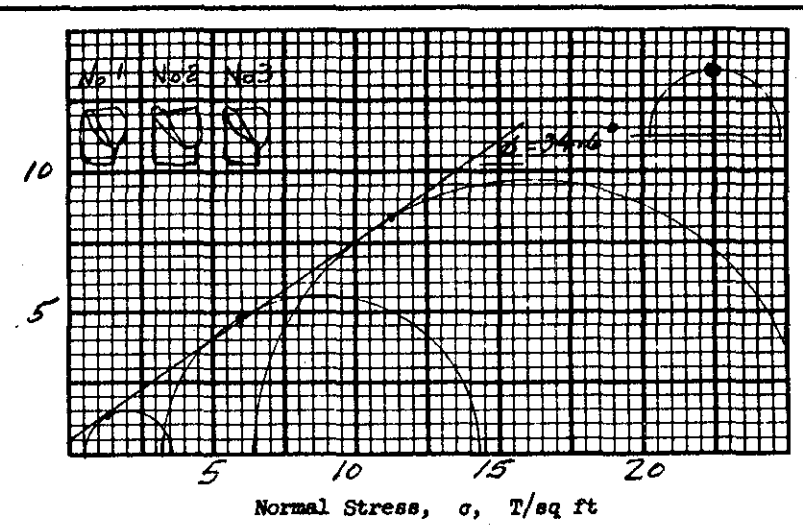
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-8





Test No.			1	2	3	
Initial	Water content	w_o	9.5 %	9.6 %	9.7 %	%
	Void ratio	e_o	0.354	0.350	0.353	
	Saturation	S_o	72.7 %	74.2 %	73.6 %	%
	Dry density, lb/cu ft	γ_d	124.2	124.6	124.3	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	— %	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	3.00	11.01	19.12	
Time to failure, min		t_f	3.2	4.8	6.4	
Rate of strain, percent/min			0.99	0.99	0.99	
			—	—	—	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	2.50*	9.21*	16.16*	
Initial diameter, in.		D_o	2.80	2.80	2.80	
Initial height, in.		H_o	6.31	6.29	6.30	

Shear Strength Parameters

ϕ = 34.6°

tan ϕ = 0.690

c = 0.55 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Type of test Q | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

Remarks *Stress @ 15% Strain. Specimens molded w/ -No4 mat'l at approx. water content of 9.8% and approx. dry density of 124.6 pcf, max density and opt. water content as determined from std compaction test curve.

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

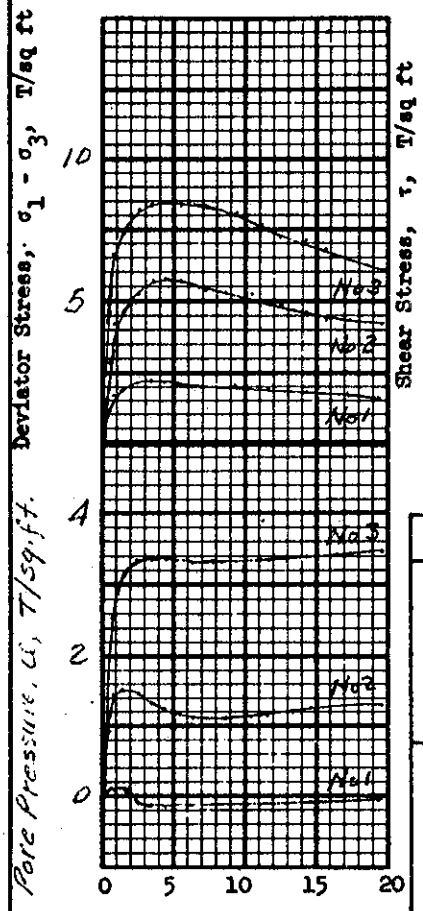
Depth Ft 1.0'-12.0' | Date Oct. 1971

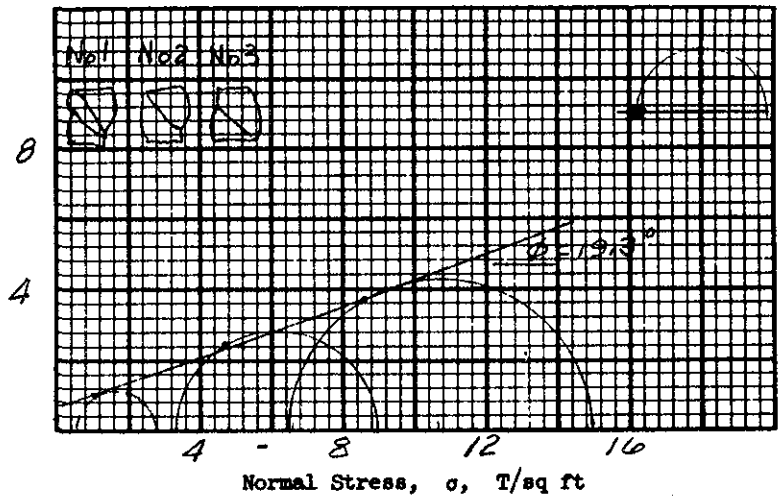
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 68 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

PLATE NO. B-9

TRANSLUCENT





Test No.			1	2	3	
Initial	Water content	w_o	8.1 %	8.1 %	8.1 %	%
	Void ratio	e_o	0.399	0.396	0.402	
	Saturation	S_o	54.9 %	55.0 %	54.2 %	%
	Dry density, lb/cu ft	γ_d	120.2	120.5	120.0	
Before Shear	Water content	w_c	16.3 %	15.3 %	14.8 %	%
	Void ratio	e_c	0.439	0.413	0.398	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	16.3 %	15.3 %	14.8 %	%
	Void ratio	e_f	0.439	0.413	0.398	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	2.19	5.72	8.49	
Time to failure, min		t_f	21.1	26.9	26.9	
Rate of strain, percent/min			0.16	0.16	0.16	
Pore Pressure, T/sq ft @ max. deviator stress		u	-0.17	+1.20	+3.37	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	1.79*	4.44*	6.92*	
Initial diameter, in.		D_o	2.80	2.80	2.80	
Initial height, in.		H_o	6.33	6.31	6.34	

Shear Strength Parameters

ϕ = 19.3 °

tan ϕ = 0.350

c = 0.7 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test R	Type of specimen Remolded			
Classification Gravelly Silty SAND (SM)				
LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

Remarks *Stress @ 15% strain. Specimens molded w/ -No4 max'l at approx. water content of 7.8% and approx. dry density of 120.9 pcf opt. minus 2% water content and 97% of max. density as determined from St'd compaction test curve.

Sheet 1 of 2

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

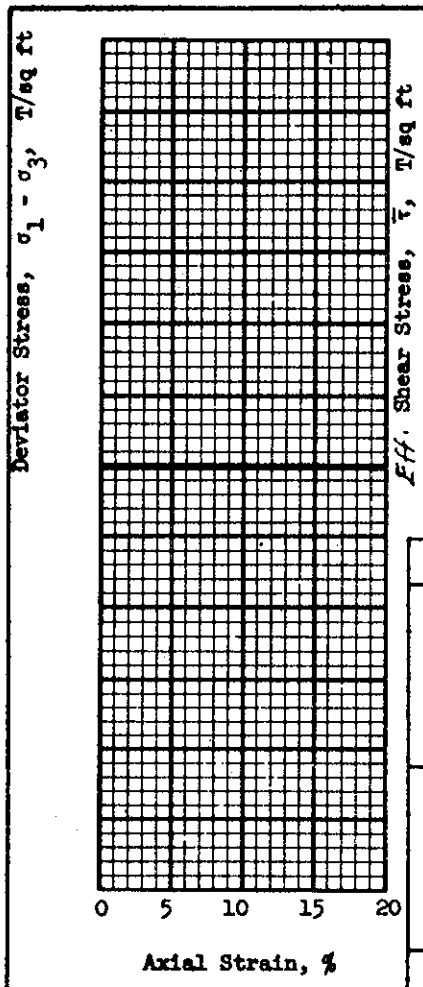
Depth ~~Bl~~ 1.0'-12.0' | Date Oct. 1971

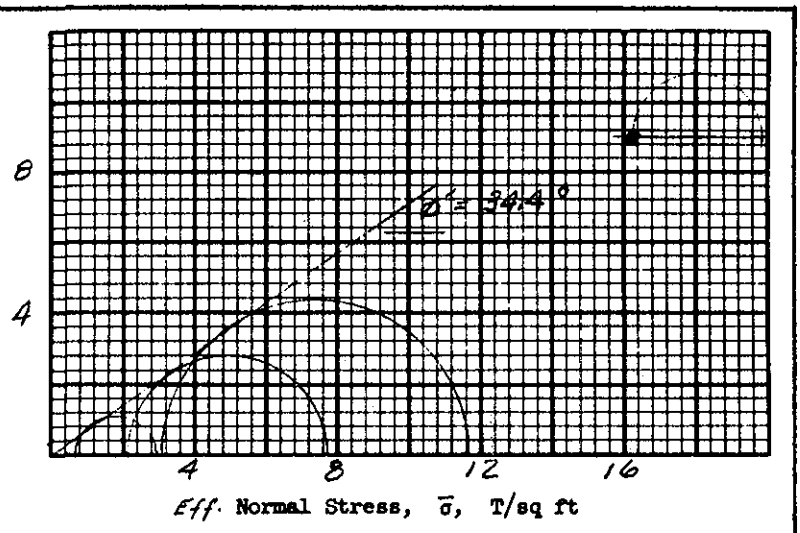
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE B-10





Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff.		$\bar{\sigma}_3$	0.71	2.04	3.12	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major principal stress, T/sq.ft. Eff.		$\bar{\sigma}_1$	2.89	7.76	11.60	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Shear Strength Parameters

$\phi' =$ 34.4 °

$\tan \phi' =$ 0.685

$c' =$ 0 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test $\bar{R}$ | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

Remarks See Sheet 1 of 2 for other data.

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

Depth 1.0' - 12.0' | Date Oct. 1971

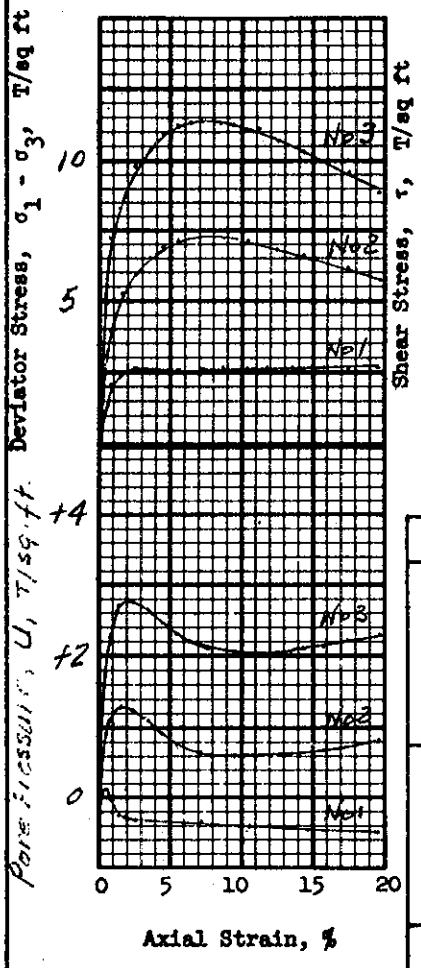
Sheet 2 of 2

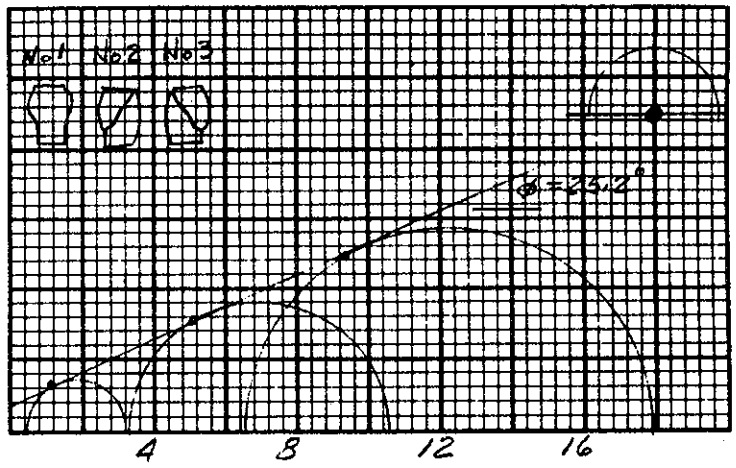
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-11





Test No.			1	2	3	
Initial	Water content	w_o	9.8 %	9.6 %	9.8 %	%
	Void ratio	e_o	0.392	0.398	0.394	
	Saturation	S_o	67.1 %	65.2 %	67.1 %	%
	Dry density, lb/cu ft	γ_d	120.8	120.3	120.6	
Before Shear	Water content	w_c	15.9 %	15.0 %	14.8 %	%
	Void ratio	e_c	0.428	0.403	0.400	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	15.9 %	15.0 %	14.8 %	%
	Void ratio	e_f	0.428	0.403	0.400	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	2.61	7.29	11.41	
Time to failure, min		t_f	15.4	43.2	43.2	
Rate of strain, percent/min			0.16	0.16	0.16	
Pore Pressure, T/sq ft @ max. deviator stress		U	-0.33	+0.67	+2.15	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	2.58	6.46*	10.10*	
Initial diameter, in.		D_o	2.80	2.80	2.80	
Initial height, in.		H_o	6.31	6.32	6.31	

Shear Strength Parameters

ϕ = 25.2 °

tan ϕ = 0.470

c = 0.7 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test R | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

Remarks *Stress @ 15% Strain
Specimens molded w/ No 4 mat'l at approx. water content of 9.8% and approx. dry density of 120.9 pcf. Opt. water content and 97% of max. density as determined from std compaction test curve

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

Depth ~~El~~ 1.0' - 12.0' | Date Oct 1971

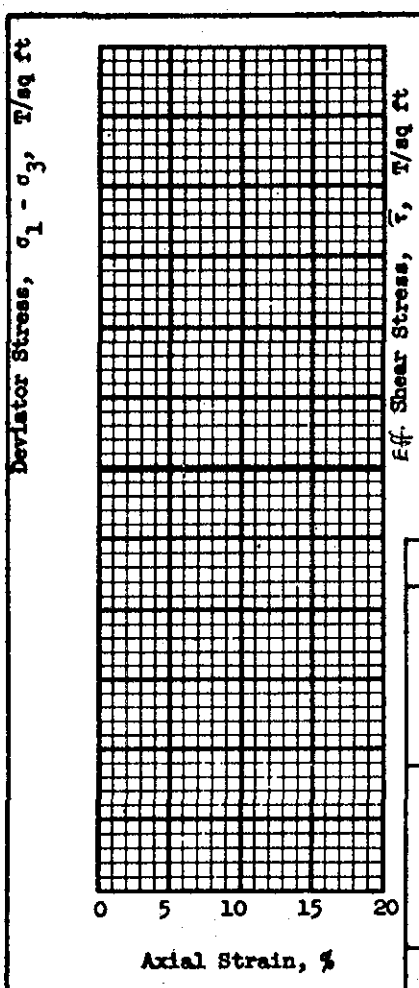
Sheet 1 of 2

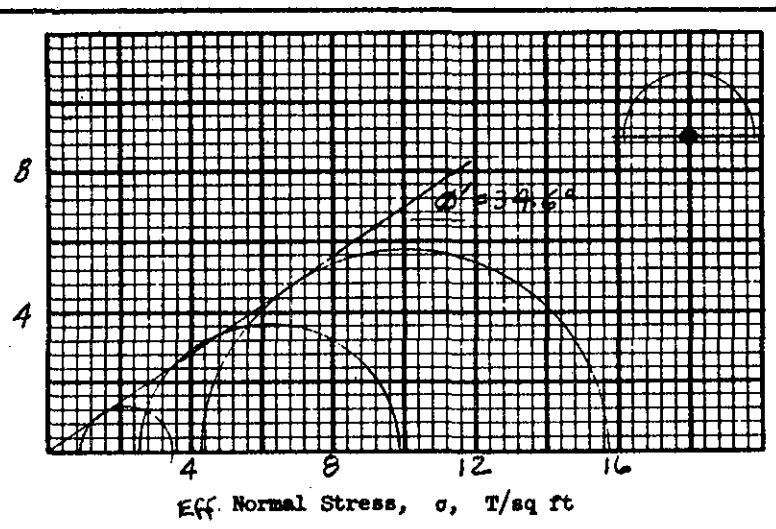
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-12





Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff.		$\bar{\sigma}_3$	0.87	2.57	4.33	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major Principal Stress, T/sq ft. Eff.		$\bar{\sigma}_1$	3.48	9.86	15.73	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Shear Strength Parameters

$\phi' =$ 34.6 °

$\tan \phi' =$ 0.690

$c' =$ 0 T/sq ft

Method of saturation Back pressure

☐ Controlled stress

☒ Controlled strain

Type of test $\bar{R}$ | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks See Sheet 1 of 2 for other data.

Sheet 2 of 2

Project Nookagee Lake

Area

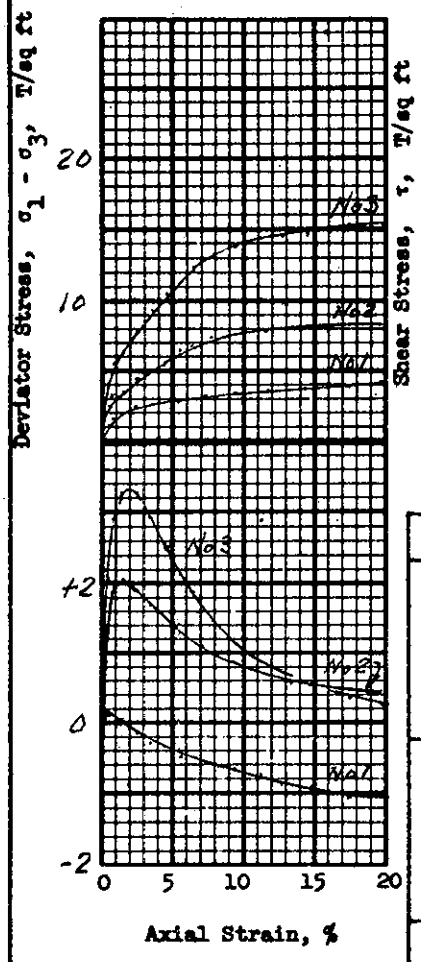
Boring No. BT-2 | Sample No. B-3

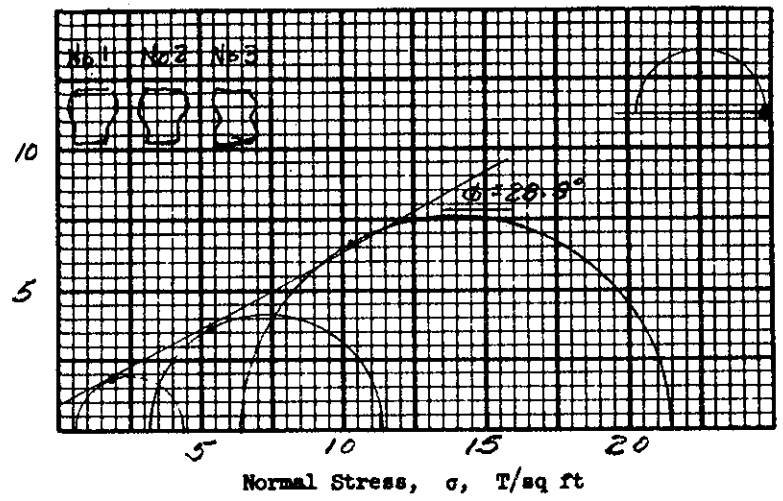
Depth Ft 1.0'-12.0' | Date Oct. 1971

TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT





Test No.			1	2	3	
Initial	Water content	w_o	11.7 %	11.6 %	11.7 %	%
	Void ratio	e_o	0.381	0.395	0.396	
	Saturation	S_o	82.6 %	79.4 %	79.4 %	%
	Dry density, lb/cu ft	γ_d	121.8	120.6	120.4	
Before Shear	Water content	w_c	14.9 %	14.4 %	13.8 %	%
	Void ratio	e_c	0.400	0.388	0.371	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	14.9 %	14.4 %	13.8 %	%
	Void ratio	e_f	0.400	0.388	0.371	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	3.86*	8.10*	14.97*	
Time to failure, min		t_f	90.0	90.6	89.9	
Rate of strain, percent/min			0.17	0.17	0.17	
Pore Pressure, T/sq.ft. @ max. deviator stress		u	-0.93	+0.57	+0.54	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	—	—	—	
Initial diameter, in.		D_o	2.81	2.81	2.81	
Initial height, in.		H_o	6.22	6.30	6.28	

Shear Strength Parameters

ϕ = 28.8 °

tan ϕ = 0.550

c = 0.8 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test R | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks *Stress @ 15% Strain. Specimens molded w/ -No4 mat'l at approx. water content of 11.8% and approx. dry density of 120.9 pcf, 97 % of max density and opt plus 2 % water content as determ. from std compaction test curve

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

Depth 1.0'-12.0' | Date Oct. 1971

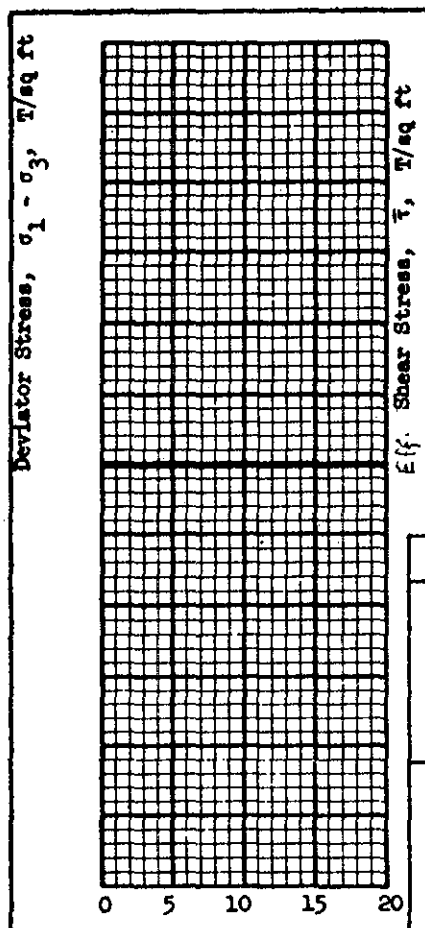
TRIAXIAL COMPRESSION TEST REPORT

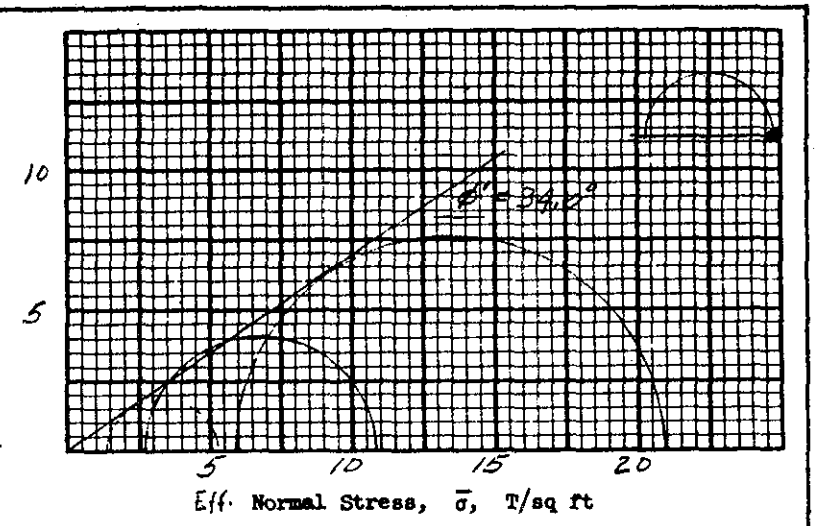
Sheet 1 of 2

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

PLATE NO. B-14

TRANSLUCENT





Shear Strength Parameters

ϕ = 34.0°

tan ϕ = 0.675

c = 0 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff.		$\bar{\sigma}_3$	1.47*	2.67*	5.94*	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major Principal Stress, T/sq.ft. Eff		$\bar{\sigma}_1$	5.32*	10.76*	20.91*	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Type of test $\bar{R}$ | Type of specimen Remolded

Classification Gra. silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks *Stress @ 15% strain. See Sheet 1 of 2 for other data

Sheet 2 of 2

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

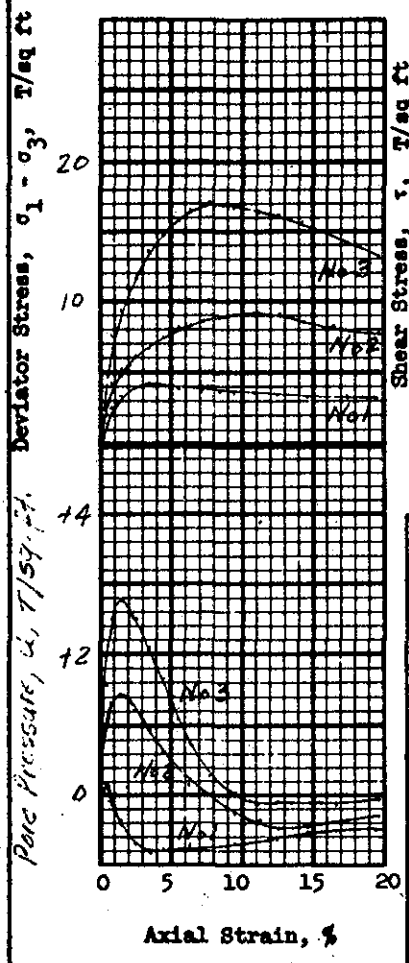
Depth ~~El~~ 1.0'-12.0' | Date Oct. 1971

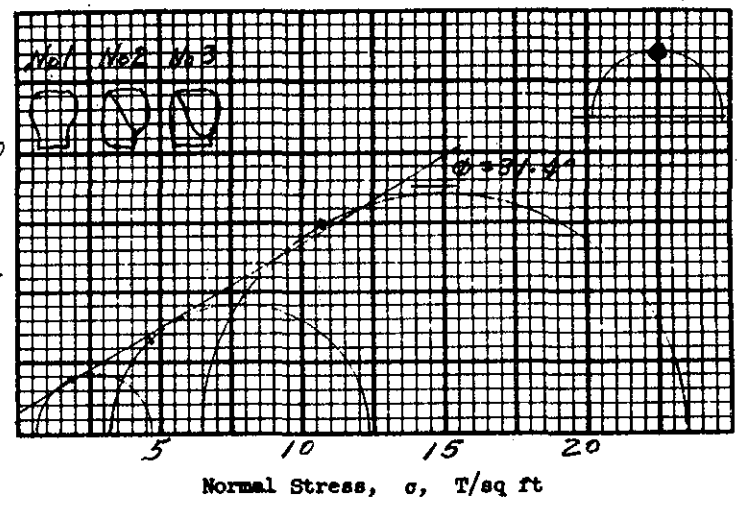
TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT

PLATE NO. B-15





Test No.			1	2	3	
Initial	Water content	w_o	9.8 %	9.7 %	9.7 %	%
	Void ratio	e_o	0.361	0.358	0.362	
	Saturation	S_o	73.4 %	73.3 %	72.5 %	%
	Dry density, lb/cu ft	γ_d	123.5	123.9	123.5	
Before Shear	Water content	w_c	14.7 %	13.7 %	13.7 %	%
	Void ratio	e_c	0.397	0.370	0.369	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	14.7 %	13.7 %	13.7 %	%
	Void ratio	e_f	0.397	0.370	0.369	
Minor principal stress, T/sq ft		σ_3	0.54	3.24	6.48	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	4.13	9.13	17.01	
Time to failure, min		t_f	21.1	67.2	48.0	
Rate of strain, percent/min			0.16	0.16	0.16	
Pore Pressure, T/sq.ft. @ max deviator stress		u	-0.81	-0.40	+0.30	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	3.25*	8.45*	15.58*	
Initial diameter, in.		D_o	2.81	2.80	2.81	
Initial height, in.		H_o	6.33	6.32	6.33	

Shear Strength Parameters

ϕ = 31.4 °

tan ϕ = 0.610

c = 0.7 T/sq ft

Method of saturation: Back pressure

☐ Controlled stress

☒ Controlled strain

Type of test: R | Type of specimen: Remolded

Classification: Gravelly silty SAND (SM)

LL	PL	PI	D_{10}	G_s
NP	NP	NP	0.012	2.70

Remarks: * Stress @ 15% Strain. Specimens molded w/ -No4 mat'l at approx. water content of 9.8 % and approx dry density of 124.6 pcf, opt. water content and max. density as determined from std compaction test curve.

Sheet 1 of 2

Project: Nookagee Lake

Area:

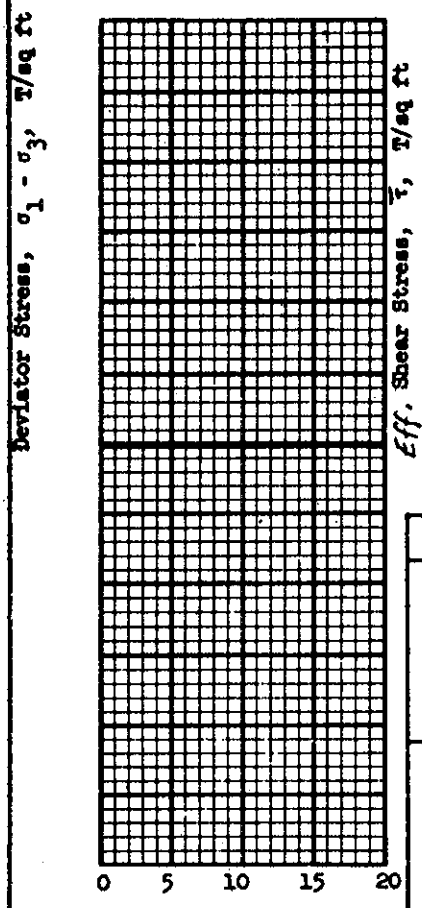
Boring No. BT-2 | Sample No. B-3

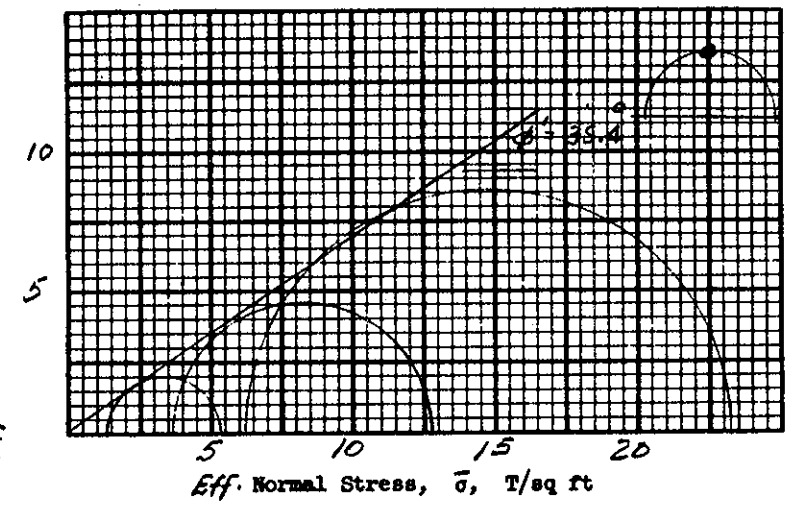
Depth El. 1.0' - 12.0' | Date Oct. 1971

TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT





Shear Strength Parameters

$\phi' =$ 35.4°

$\tan \phi' =$ 0.710

$c' =$ 0 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff		$\bar{\sigma}_3$	1.35	3.64	6.18	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major principal Stress, T/sq ft Eff.		$\bar{\sigma}_1$	5.48	12.77	23.19	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Type of test $\bar{R}$ | Type of specimen Remolded

Classification Gravelly silty SAND (SM)

LL NP | PL NP | PI NP | D_{10} 0.012 | G_s 2.70

Remarks See Sheet 1 of 2 for other data.

Project Nookagee Lake

Area

Boring No. BT-2 | Sample No. B-3

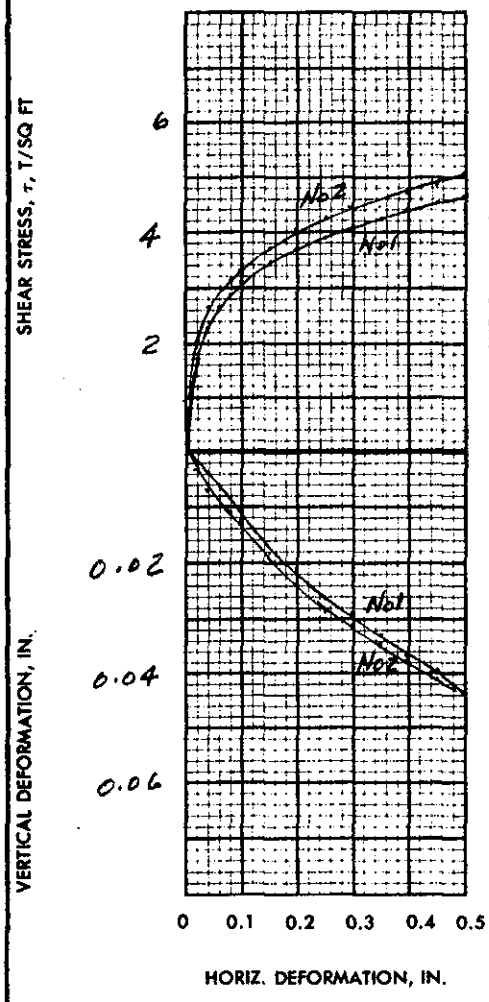
Depth ft 1.0' - 12.0' | Date Oct. 1971

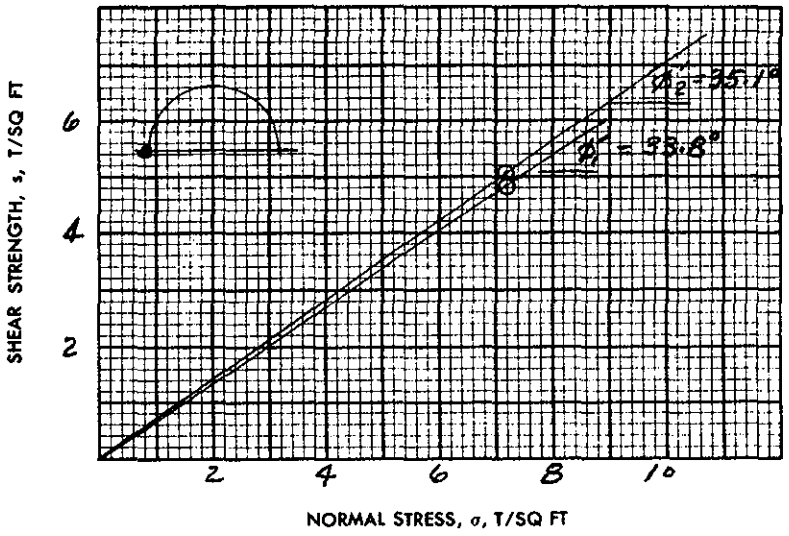
Sheet 2 of 2

TRIAXIAL COMPRESSION TEST REPORT

ENG FORM 1 JUN 69 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

TRANSLUCENT





TEST NO.			1	2		
INITIAL	WATER CONTENT	w_o	8.1 %	8.1 %	%	%
	VOID RATIO	e_o	0.389	0.385		
	SATURATION	S_o	55.8%	56.4%	%	%
	DRY DENSITY, LB/CU FT	γ_d	121.1	121.5		
VOID RATIO AFTER CONSOLIDATION		e_c	0.357	0.366		
TIME FOR 50 PERCENT CONSOLIDATION, MIN		t_{50}	0.6	0.7		
FINAL	WATER CONTENT	w_f	14.5%	13.2%	%	%
	VOID RATIO	e_f	0.241	0.251		
	SATURATION	S_f	100 %	100 %	%	%
NORMAL STRESS, T/SQ FT		σ	7.20	7.20		
MAXIMUM SHEAR STRESS, T/SQ FT		τ_{max}	4.83	5.06		
ACTUAL TIME TO FAILURE, MIN		t_f	105	103		
RATE OF STRAIN, IN./MIN			0.005	0.005		
ULTIMATE SHEAR STRESS, T/SQ FT		τ_{ult}	—	—		

SHEAR STRENGTH PARAMETERS

ϕ' = 33.8°

TAN ϕ' = 0.670

c' = 0 T/SQ FT

☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TYPE OF SPECIMEN Remolded		3.0 IN. SQUARE	0.5 IN. THICK
CLASSIFICATION Gravelly silty SAND (SM)			
LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

REMARKS Specimens molded with - No 4 mat'l. Specimens molded at approx. water content of 7.8% and approx. dry density of 120.9 pcf, opt. water content - 2% and 97% of max. density as determined from std. compaction test curve.

PROJECT Nookagee Lake

AREA

BORING NO. BT-2 SAMPLE NO. B-3

DEPTH EL 1.0'-12.0' DATE Oct. 1971

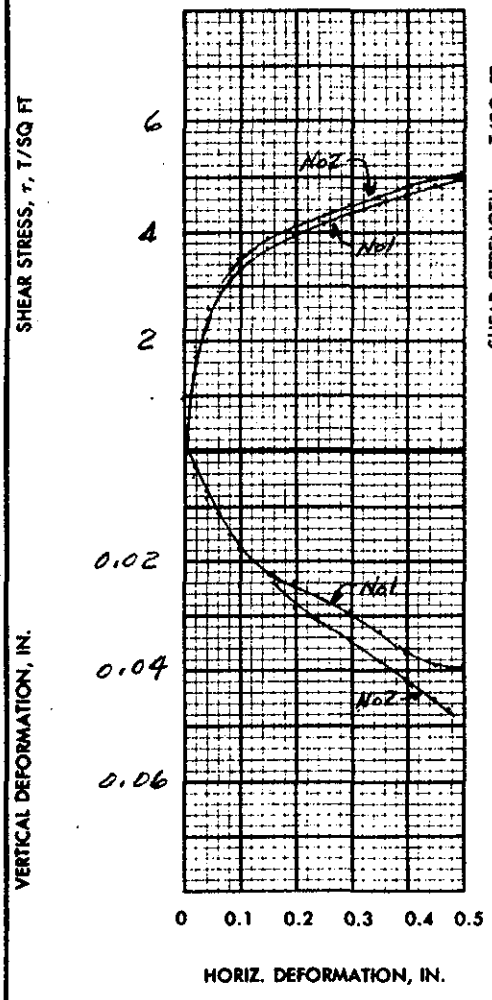
DIRECT SHEAR TEST REPORT

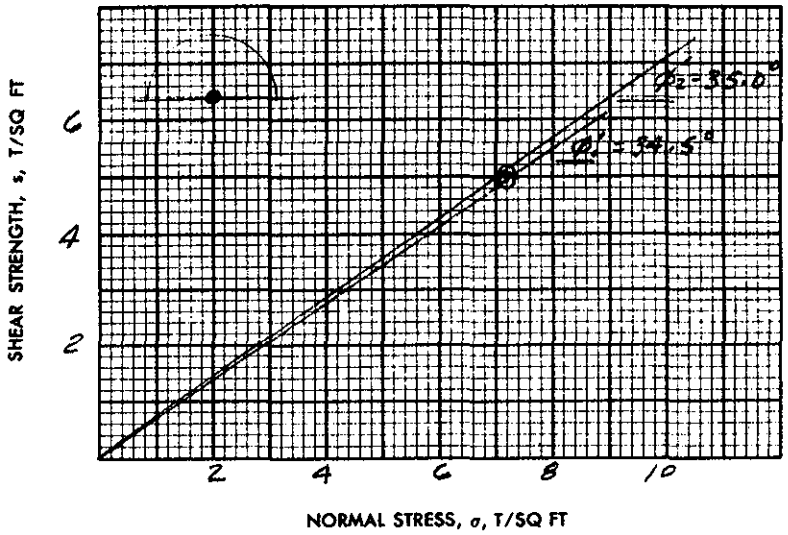
ENG FORM 1 JUN 65 2092 (EM 1110-2-1906) PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

GPO : 1966 OF—214-945

PLATE IX-3

PLATE B-18





TEST NO.			1	2		
INITIAL	WATER CONTENT	w_o	9.6 %	9.6 %	%	%
	VOID RATIO	e_o	0.383	0.377		
	SATURATION	S_o	67.6%	68.6%	%	%
	DRY DENSITY, LB/CU FT	γ_d	121.6	122.1		
VOID RATIO AFTER CONSOLIDATION		e_c	0.312	0.320		
TIME FOR 50 PERCENT CONSOLIDATION, MIN		t_{50}	0.7	0.6		
FINAL	WATER CONTENT	w_f	13.3%	13.2%	%	%
	VOID RATIO	e_f	0.209	0.212		
	SATURATION	S_f	100+%	100+%	%	%
NORMAL STRESS, T/SQ FT		σ	7.20	7.20		
MAXIMUM SHEAR STRESS, T/SQ FT		τ_{max}	4.96	5.04		
ACTUAL TIME TO FAILURE, MIN		t_f	106	105		
RATE OF STRAIN, IN./MIN			0.005	0.005		
ULTIMATE SHEAR STRESS, T/SQ FT		τ_{ult}	—	—		

SHEAR STRENGTH PARAMETERS

ϕ' = 34.5°

TAN ϕ' = 0.689

c' = 0 T/SQ FT

☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TYPE OF SPECIMEN Remolded — 3.0 IN. SQUARE — 0.5 IN. THICK

CLASSIFICATION Gravelly silty SAND (SM)

LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

REMARKS Specimens molded with No4 mat'l. Specimens molded at approx. water content of 9.8% and approx. dry density of 120.9 pcf. Opt. water content and 97% of max. density as determined from Std compaction curve.

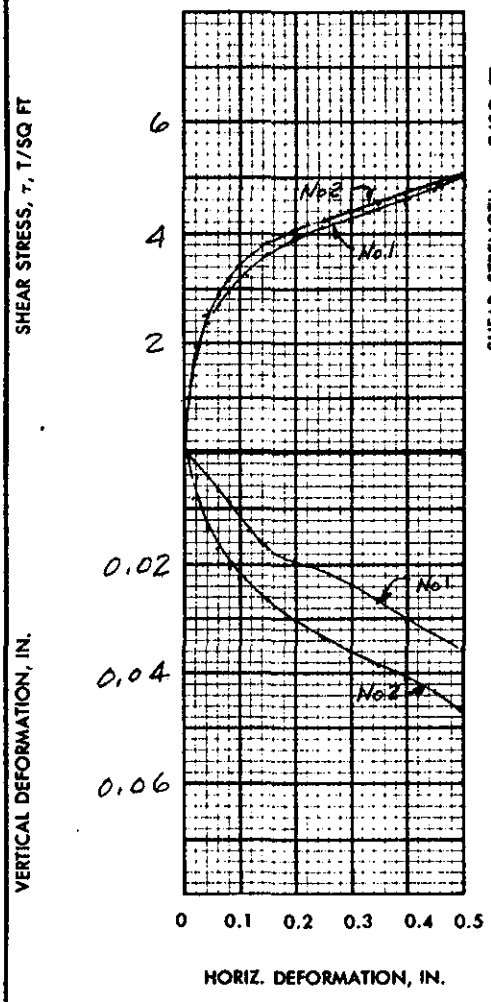
PROJECT Nookagee Lake

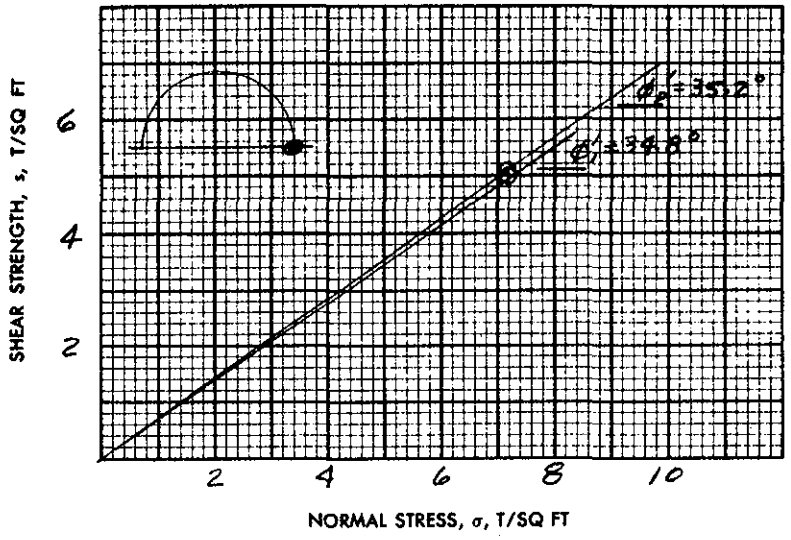
AREA

BORING NO. BT-2 — SAMPLE NO. B-3

DEPTH EL. 1.0'-12.0' — DATE Oct. 1971

DIRECT SHEAR TEST REPORT





TEST NO.			1	2		
INITIAL	WATER CONTENT	w_o	11.6 %	11.6%	%	%
	VOID RATIO	e_o	0.391	0.391		
	SATURATION	S_o	80.2%	80.2%	%	%
	DRY DENSITY, LB/CU FT	γ_d	120.9	120.9		
VOID RATIO AFTER CONSOLIDATION		e_c	0.313	0.349		
TIME FOR 50 PERCENT CONSOLIDATION, MIN		t_{50}	0.7	0.6		
FINAL	WATER CONTENT	w_f	13.2 %	13.7%	%	%
	VOID RATIO	e_f	0.218	0.226		
	SATURATION	S_f	100, %	100%	%	%
NORMAL STRESS, T/SQ FT		σ	7.20	7.20		
MAXIMUM SHEAR STRESS, T/SQ FT		τ_{max}	5.00	5.08		
ACTUAL TIME TO FAILURE, MIN		t_f	107	102		
RATE OF STRAIN, IN./MIN			0.005	0.005		
ULTIMATE SHEAR STRESS, T/SQ FT		τ_{ult}	—	—		

SHEAR STRENGTH PARAMETERS

ϕ' = 34.8°

TAN ϕ' = 0.694

c' = 0 T/SQ FT

☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TYPE OF SPECIMEN Remolded 3.0 IN. SQUARE 0.5 IN. THICK

CLASSIFICATION Gravelly silty SAND (SM)

LL NP	PL NP	PI NP	D_{10} 0.012	G_s 2.70

REMARKS Test run on No.4 mat'l. Specimens molded at approx. water content of 11.8% and approx. dry density of 120.9 pcf, 97% of max. density and opt. plus 2% as determined from Std Comp. curve

PROJECT Nookagee Lake

AREA

BORING NO. BT-2 SAMPLE NO. B-3

DEPTH 1.0' - 12.0' DATE Oct. 1971

DIRECT SHEAR TEST REPORT

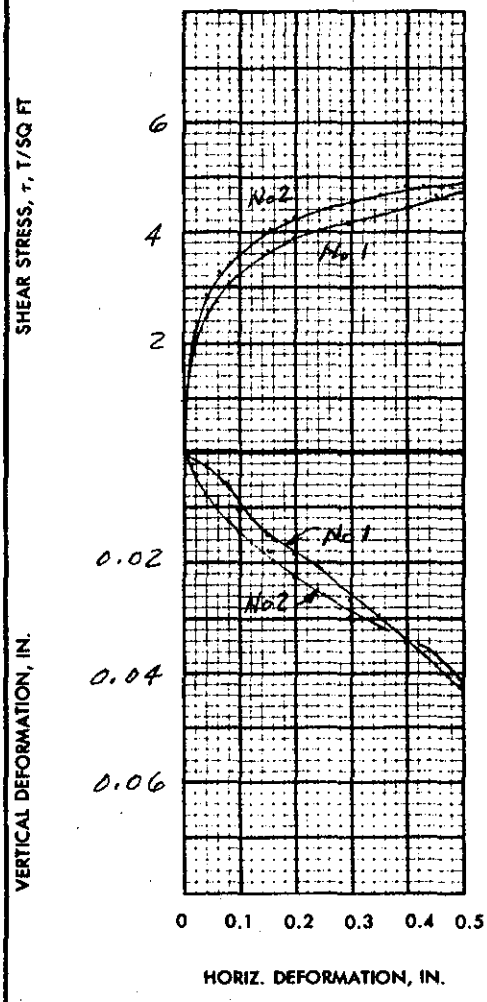
B-20

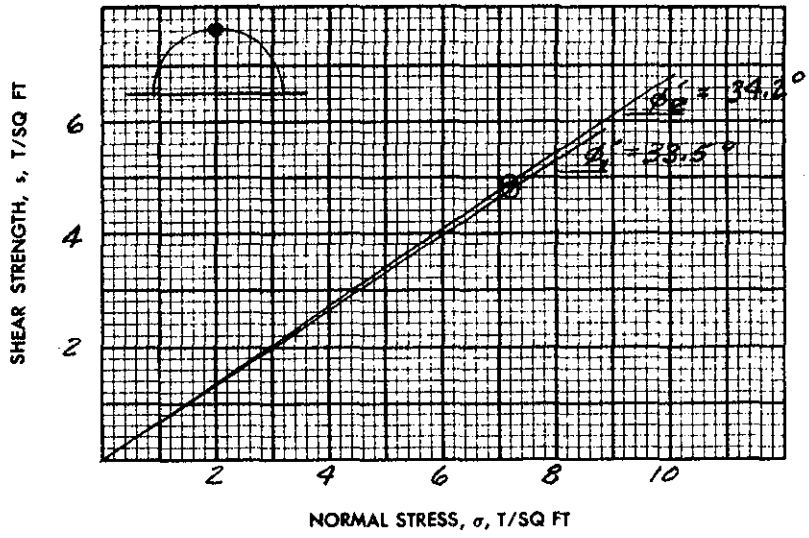
ENG FORM 1 JUN 65 2092 (EM 1110-2-1906) PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

GPO : 1966 OF—214-945

PLATE IX-3

PLATE NO. -20





TEST NO.			1	2		
INITIAL	WATER CONTENT	w_o	9.6%	9.6%	%	%
INITIAL	VOID RATIO	e_o	0.347	0.348		
INITIAL	SATURATION	S_o	74.6%	74.4%	%	%
INITIAL	DRY DENSITY, LB/CU FT	γ_d	124.8	124.8		
VOID RATIO AFTER CONSOLIDATION		e_c	0.282	0.318		
TIME FOR 50 PERCENT CONSOLIDATION, MIN		t_{50}	0.8	0.6		
FINAL	WATER CONTENT	w_f	13.0%	12.0%	%	%
FINAL	VOID RATIO	e_f	0.176	0.213		
FINAL	SATURATION	S_f	100+%	100+%	%	%
NORMAL STRESS, T/SQ FT		σ	7.20	7.20		
MAXIMUM SHEAR STRESS, T/SQ FT		τ_{max}	4.76	4.89		
ACTUAL TIME TO FAILURE, MIN		t_f	103	104		
RATE OF STRAIN, IN./MIN			0.005	0.005		
ULTIMATE SHEAR STRESS, T/SQ FT		τ_{ult}	—	—		

SHEAR STRENGTH PARAMETERS

ϕ' = 33.5°

TAN ϕ' = 0.661

c' = 0 T/SQ FT

☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TYPE OF SPECIMEN Remolded — 3.0 IN. SQUARE — 0.5 IN. THICK

CLASSIFICATION Gravelly silty SAND (SM)

LL	PL	PI	D_{10}	G_s
NP	NP	NP	0.012	2.70

REMARKS Test run on No 4 mat'l. Specimen molded at approx. water content of 9.8% and approx. dry density of 124 pcf, max. density and optimum water content as determined from Std. Compaction test curve

PROJECT Nookagee Lake

AREA

BORING NO. BT-2 — SAMPLE NO. B-3

DEPTH Et 1.0'-12.0' — DATE Oct. 1971

DIRECT SHEAR TEST REPORT

APPENDIX C

DETAILED COST ESTIMATE

DETAILED COST ESTIMATE
(July 1972 Price Level)

	Description	Quantity	Unit	Unit Price	Estimated Amount
01.	Lands and Damages				
	Lands, Acquisition & Resettlement				$ 1,500,000
02.	Relocations				
	Roads	1	Job	L.S.	1,143,000
	Telephone	1	Job	L.S.	53,600
	Electric	1	Job	L.S.	29,000
	Sub-Total				1,225,600
	Contingencies				184,400
	TOTAL RELOCATIONS				$ 1,410,000
03.	Reservoir				
	Log Boom	1	Job	L.S.	$ 10,000
	Reservoir Clearing	175	Ac.	$900	157,500
	Grubbing & Stripping	166	Ac.	$2,400	398,400
	Contingencies				84,100
	TOTAL RESERVOIR				$ 650,000
04.	Dam				
	Preparation of Site	1	Job	L.S.	$ 15,000
	River Diversion	1	Job	L.S.	10,000
	Control of Waters	1	Job	L.S.	95,000
	Unclassified Excavation General	293,000	C.Y.	$1.00	293,000
	Unclassified Excavation Borrow	1,160,000	C.Y.	$1.30	1,508,000
	Rock Excavation - Open Cut	56,000	C.Y.	$4.20	235,200
	Hand Cleaned Bedrock Surface	100	Sq.	$35.00	3,500

Description	Quantity	Unit	Unit Price	Estimated Amount
04. Dam				
Compacted Impervious Fill	720,000	C.Y.	$ .40	$ 288,000
Compacted Random Fill	370,000	C.Y.	.40	148,000
Compacted Pervious Fill	77,000	C.Y.	.40	30,800
Backfill Gravel	3,000	C.Y.	6.50	19,500
Compacted Drainage Fill	86,000	C.Y.	5.00	430,000
Compacted Impervious Backfill	8,000	C.Y.	6.00	48,000
Road Gravel	3,700	C.Y.	3.20	11,840
Gravel Bedding	55,000	C.Y.	2.00	110,000
Spoil Fill	12,000	C.Y.	.40	4,800
Uncompacted Impervious Fill	24,000	C.Y.	.20	4,800
Additional Embankment Rolling	200	Hrs.	30.00	6,000
Rock Protection	68,000	C.Y.	3.10	210,800
Foundation Grouting	1	Job	L.S.	25,000
Concrete - Walls & Weir	1,830	C.Y.	75.00	137,250
Concrete - Spillway Lining	570	C.Y.	90.00	51,300
Concrete Intake Tower to El. 845	1,020	C.Y.	80.00	81,600
Concrete Intake Tower above El. 845	80	C.Y.	180.00	14,400
Concete - Inlet Structure	140	C.Y.	90.00	12,600
Concrete - Stilling Basin	230	C.Y.	90.00	20,700
Concrete - Transition & Conduit	1,140	C.Y.	90.00	102,600
Concrete - Bridge Abutment & Piers	490	C.Y.	75.00	36,750
Concrete - Service Bridge Deck	90	C.Y.	110.00	9,900
Cement	8,400	Bbl.	6.50	54,600
Steel Reinforcement	330,000	Lbs.	.25	82,500
Rubber Water Stop	400	L.F.	5.00	2,000
Anchors	130	ea.	50.00	6,500
Structural Steel - Misc.	7,000	Lbs.	.60	4,200
Structural Steel Service Bridge	1	Job	L.S.	75,000
Aluminum	8,800	Lbs.	3.00	26,400
Misc. Metals	8,000	Lbs.	2.00	16,000
Intake Tower - Superstructure	1	Job	L.S.	5,000
Gate Vent System	1	Job	L.S.	10,000
Float Well & Accessories	1	Job	L.S.	6,000
Heating & Ventilating System	1	Job	L.S.	4,000
Hydraulic Gates & Machinery	1	Job	L.S.	70,000
Emergency Stop Gate	1	Job	L.S.	10,000
Elevator	1	Job	L.S.	25,000
Water Quality System Pipes and Gates	1	Job	L.S.	30,000
Crane and Hoist	1	Job	L.S.	5,000

	Description	Quantity	Unit	Unit Price	Estimated Amount
04.	Dam				
	Diesel Engine	1	Job	L.S.	$ 6,000
	Sump Pump	1	Job	L.S.	2,000
	Electric Work	1	Job	L.S.	25,000
	Tile Gage	1	Job	L.S.	2,000
	4' Chain Link Fence	1,300	L.F.	4.00	5,200
	18' Double Swing Gate	1	Ea.	400.00	400
	Topsoiling	4,000	C.Y.	7.00	28,000
	Seeding	5	Ac.	800.00	4,000
	Guide Rail	4,000	L.F.	3.00	12,000
	Sub-Total				4,481,140
	Contingencies (15%)				668,860
	TOTAL DAM				$5,150,000
08.	Roads				
	Roads	1	Job	L.S.	4,300
	Contingencies				700
	TOTAL ROADS				$ 5,000
14.	Recreation Facilities				
	Recreation	1	Job	L.S.	13,000
	Contingencies				2,000
	TOTAL RECREATION FACILITIES				$ 15,000
19.	Building, Grounds and Utilities				
	Bldg., Grounds & Util.	1	Job	L.S.	113,000
	Contingencies				17,000
	TOTAL BUILDING, GROUNDS & UTILITIES				$ 130,000

	Description	Quantity	Unit	Unit Price	Estimated Amount
20.	Permanent Operating Equipment				
	Perm. Oper. Equipment	1	Job	L.S.	$ 52,000
	Contingencies				8,000
	TOTAL PERMANENT OPERATING EQUIPMENT				$ 60,000
30.	Engineering & Design				$ 910,000
31.	Supervision & Administration				$ 670,000
	TOTAL PROJECT FIRST COST				$10,500,000