GEOTECHNICAL ENGINEERING CRITERIA
POINT THOMSON DEVELOPMENT AREA

EXXON COMPANY, U.S.A.

April, 1984

NORTHERN TECHNICAL SERVICES

ANCHORAGE, ALASKA

NORTEC

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April 10, 1984

Exxon Company, U.S.A.
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Attention: Mr. J.C. Symmes

Subject: Report
Geotechnical Engineering Criteria
Point Thomson Development Area
Winter Geotechnical Study, Alaska
PTD-8301

Gentlemen:

Please find enclosed 30 copies of our Report, Geotechnical Engineering Criteria, Point Thomson Area.

Sincerely,

NORTHERN TECHNICAL SERVICES, INC.

William D Pyle
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Project Manager

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Senior Engineer

WDP/pgh
006-011

Enclosure

GEOTECHNICAL ENGINEERING CRITERIA
POINT THOMSON DEVELOPMENT AREA

EXXON COMPANY, U.S.A

Prepared by

NORTHERN TECHNICAL SERVICES, INC.
Anchorage, Alaska

April, 1984

TABLE OF CONTENTS

LIST OF FIGURES

region and soil type. The properties of each distinct group were tabulated.

5. Develop foundation design criteria. Design criteria are presented for gravel islands, shallow and pile foundations using soil profiles and properties representative of the PTD area.

SOIL TYPES AND DISTRIBUTION

The soils that will influence geotechnical design of facilities within the PTD area are deposits of Holocene and Pleistocene age. The Holocene deposits consist primarily of sand and silt. In general, the sand is silty (SM) and the silt is sandy and non-plastic (ML). Nevertheless, clean sand (SP) and slightly plastic clayey silt and silty clay (ML-CL) are occasionally encountered. The Holocene deposits appear to be normally consolidated to slightly overconsolidated. The relative densities of the granular, non-plastic soils and consistencies of the plastic soils are typically loose to medium dense and soft to medium stiff, respectively. The Pleistocene deposits are primarily clayey silt (ML-CL), silty clay (CL), clean sand (SP) and sandy gravel (GP). These deposits are moderately to heavily overconsolidated. The granular soils are dense to very dense and the fine-grained soils are stiff to hard.

Since the engineering properties of the Holocene and Pleistocene soils differ so significantly, the areal extent and thickness of these deposits is an important geotechnical design consideration. Figures 1 through 17 depict the elevation of the Holocene/Pleistocene interface, the thickness of the Holocene deposits and soil stratigraphy (cross sections and generalized soil profiles) within the PTD area. These illustrations should be considered only approximations of the actual soil conditions, as their accuracy is limited by the wide spacing of the borings and scarcity of information in certain areas (especially seaward of the barrier islands). Nevertheless, these interpretations are a useful starting point for conceptual design and can be supplemented by site-specific investigations as the need arises.

SOIL PROFILES

Figures 1 and 2 illustrate the areal distribution and thickness of the Holocene age soils that will impact the design of facilities within the PTD area. Figures 3 through 13 show the soil stratigraphy in several cross sections taken approximately parallel to and perpendicular to the coastline. These cross sections illustrate only the primary features of the soil stratigraphy; i.e., the Holocene/ Pleistocene interface and the major coarse (sands and gravels) and fine-grained (silt and clay) soil strata within these deposits. Figures 14 through 17 show generalized soil profiles through various parts of the area. These profiles depict the soil types, average relative density and consistency characteristics of the major soil strata. The soil classification system used in the cross sections and profiles is shown on Figure 18.

The following general observations may be made regarding the soil conditions in the PTD area:

1. The Holocene deposits are the deepest, weakest and most compressible in the west lagoon area (in the vicinity of borings H-4, H-5 and H-9) and tend to be thinner toward the north, east and south. Seaward of the barrier islands and throughout the eastern study area, the Holocene soils extend only a few feet below mudline.

2. The Holocene is a heterogeneous deposit. Soil types vary from coarse sands to silt and, occasionally,

clays. They also vary in relative density/consistency from loose/soft to medium dense/stiff.

3. The top surface of the Pleistocene deposit is relatively flat throughout the PTD area, except near the shoreline, where it dips seaward.

4. The uppermost portion of the Pleistocene deposit consists primarily of stiff to hard silts and clays. The silts and clays are underlain by dense to very dense sands and gravels. The top surface of the sands and gravels generally dips sharply seaward, except in the vicinity of boring H-11, where sands and gravels are exposed at mudline. The silt/clay and sand/gravel strata are both practically homogeneous.

SOIL PROPERTIES

Statistical analyses have been performed on the relevant soil property data by stratum, boring and region. Worksheets used in the analyses are presented in the Appendix to this report. In most cases, differences in the computed statistical parameters between individual strata and borings precluded further groupings on a purely statistical basis. However, for the purpose of establishing representative soil profiles and geotechnical design criteria, statistical analyses must be tempered by geologic and engineering judgement. This is especially true since the field and laboratory investigations were not specifically designed for statistical analysis of the data. It may be noted; for example, that the sizes of the data sets are small and variable and often, for valid reasons, testing has been concentrated on the unusual portions of the soil strata rather than the typical portions. Therefore, the statistical parameters may not always be indicative of the true soil properties.

TABLE 1
GEOTECHNICAL ENGINEERING PARAMETERS (3)
IN SITU SOILS

Location	Offshore				Onshore	
Age	Holocene		Pleistocene		Holocene/Pleistocene	
Soil Type	SM & SP	ML & CL	CL & ML	GP & SP	Ice-Rich	Ice-Poor
Density						
Dry Density, pcf	108	92	107	120	<70	130
Moisture Content, %	21	32	22	15	>50	10
Total Unit Weight, pcf	131	121	131	138	<105	143
Buoyant Unit Weight, pcf	67	57	67	74	---	---
Shear Strength						
In Situ Undrained Shear Strength, ksf	---	0.75	2.5	---	---	---
Strength gain with Effective confining pressure (1)	---	0.5	0.5	---		
Effective Friction Angle (deg.)	36	36	34	38	---	---
Effective Cohesion, ksf	0	0	0	0	---	---
Compressibility						
Ave. Compression Ratio (2)	0.03	0.05	0.025	0.01	---	---
Coefficient of Consolidation ft^2/day	---	2.5	4.0	---	---	---
Thermal Properties						
Active Layer Thickness, ft.	5-10 (barrier is.)	---	---	---	1 - 3	5 - 8
Thaw Strain, %	10	20	10	≤ 8	≥ 30	≤ 8
Salinity, ppt	35 - >100	35 - 42	35 - 42	35 - 42	2	5- 10

Notes:

(1) Strength gain with effective confining pressure = $\frac{\Delta S_u}{\Delta \bar{\sigma}_c}$

ΔS_u = increase in undrained shear strength

$\Delta \bar{\sigma}_c$ = increase in effective confining pressure due to consolidation

(2) Ave. Compression Ratio = $\frac{\Delta \epsilon_v}{\log_{10}\left(\frac{\bar{\sigma}_{vo}+\Delta\bar{\sigma}_v}{\bar{\sigma}_{vo}}\right)}$

$\bar{\sigma}_{vo}$ = initial effective vertical stress

$\Delta \bar{\sigma}_v$ = effective vertical stress increase

$\Delta \epsilon_v$ = vertical strain due to $\Delta \bar{\sigma}$

(3) Values are representative of all soils tested in the study area.

TABLE 2

GEOTECHNICAL ENGINEERING PARAMETERS
GRAVEL ISLAND FILL

Placement: Environment	Above MWL (Compacted)			Below MWL (Uncompacted)		
: Ice Content	10%	25%	Ice-Free	10%	25%	Ice-Free
Density						
Dry Density, pcf	102	76	132	91	68	128
Moisture Content, %	10	25	2	31	54	12
Total Unit Weight, pcf	112	95	135	119	105	144
Buoyant Unit Weight, pcf	---	---	---	55	41	80
Shear Strength						
Effective Friction Angle deg.	30	30	40	25	25	36
Effective Cohesion, ksf	0	0	0	0	0	0
Thermal Properties						
Active Layer Thickness, ft.	5-8	5-8	---	---	---	---
Thaw Strain, %	15	35	---	23	42	---
Salinity, ppt	5-10	5-10	---	27	23	35

effective stresses within the soil mass which relate directly to strength and consolidation deformation.

Shear Strength

The shear strength of a soil is a fundamental engineering parameter which is the basis for calculation of ultimate load carrying capacity. Most theories of soil behavior are based upon the effective stress principal and the Mohr-Coulomb failure criterion, in which shear strength is characterized by an angle of internal friction (ϕ) and a cohesion intercept (c).

The shear strength of a soil is a function of the pore water pressure response (and, hence, permeability). Therefore, most analyses are conducted assuming either drained or undrained behavior. Drained behavior implies that the soil is sufficiently permeable (or the loading is sufficiently slow) to prevent the buildup of pore pressures; in which case, the soil shear strength increases in direct proportion to increases in the confining pressure (e.g., the added weight of a newly constructed gravel island). Undrained behavior implies that the soil is so impermeable (or the loading so rapid) that increases in the confining pressure are carried wholly by the pore water; therefore, effective stresses are unchanged and shear strengths remain constant.

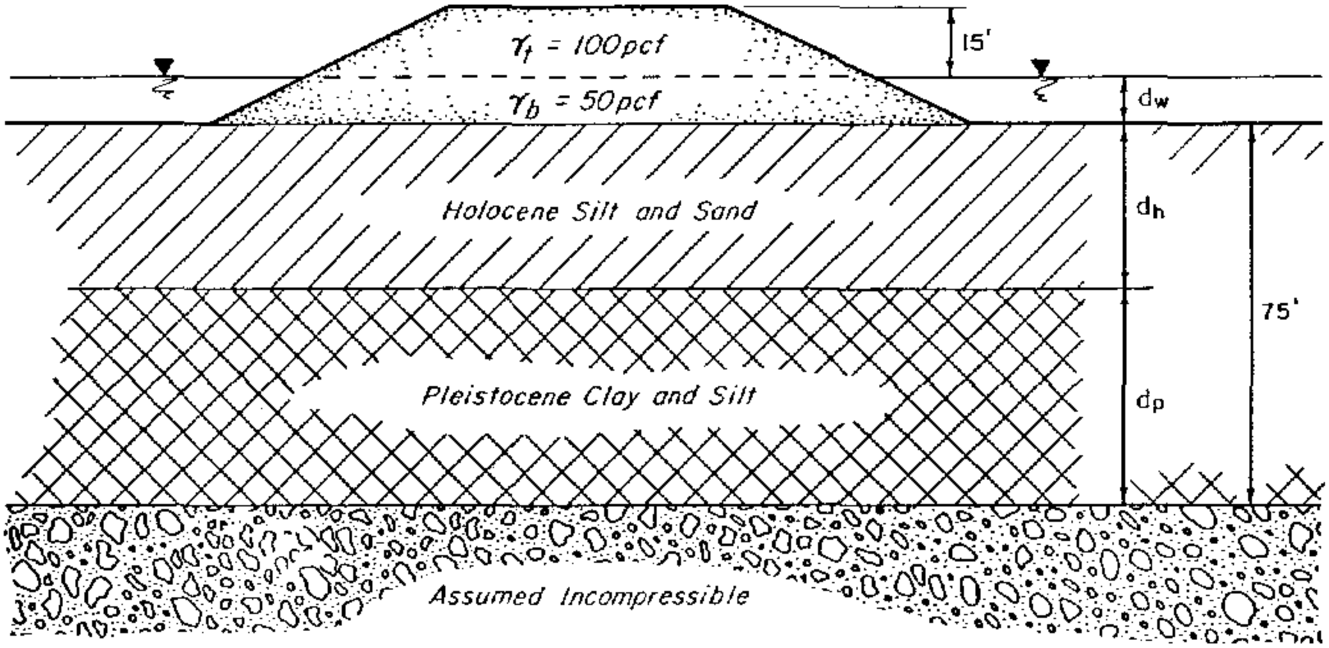
Drained and undrained analyses are also referred to as effective stress and total stress analyses, respectively. The undrained shear strengths will increase from the in situ values if the effective confining pressure increases, for example, due to consolidation under the weight of a gravel island. Since the rates of consolidation are fairly rapid for all the soil types tested, the strength increases will also occur rapidly. Thus, the construction of a gravel island will cause a strength increase in the underlying soil, much of which will be effective by the time the island construction is completed. Subsequent short-term loads (e.g., ice loads) will be resisted by the increased shear strength in the underlying soils. Resistance to long-term loads should be analyzed using the effective stress (drained) strength parameters.

The shear strength parameters for the geotechnical criteria shown on Table 1 were selected on the basis of data reported by HLA (1982) and NORTEC (1983).

Consolidation

Consolidation behavior can be described in terms of the compression ratio and the coefficient of consolidation. The compression ratio is used to estimate the total settlement due to primary consolidation. The coefficient of consolidation is used to estimate the rate at which the predicted settlement will occur. The compression ratio typically decreases with increasing dry density. The coefficient of consolidation decreases with increasing percentages of clay-sized particles. Overconsolidation typically causes nearly an order of magnitude decrease in the compression ratio and a similar increase in the coefficient of consolidation.

The criteria of Table 1 can be used to estimate the consolidation behavior of the subsea soil under the weight of a gravel island. One-dimensional linear consolidation theory was used to predict total settlements of the subsea soil and the times required to achieve 90 percent of the predicted settlements. The island fill properties used in the calculations were given in Table 2. The results of these calculations are presented on Figure 19.



	Estimated Total Settlement, Ft.	Estimated Time for 90 % Consolidation
W. Lagoon d_w = 10' d_h = 30' d_p = 45'	1.6	2-3 months
E. Lagoon d_w = 10' d_h = 10' d_p = 65'	0.8	1-2 months
N. of Barrier Isls. d_w = 30' d_h = 5' d_p = 70'	1.0	4-6 months

ESTIMATED SETTLEMENTS FOR GRAVEL ISLANDS

Figure 19.

Thermal Characteristics

Thermal soil properties of importance to island, facility and pipeline design are salinity, thaw strain and active layer thickness. Salinity of the pore water depresses the soil freeze/thaw temperature and causes warm permafrost to contain both ice and unfrozen water. Saline permafrost will have a lower shear strength than freshwater permafrost at the same temperature. Permafrost thaw strain properties directly influence pipeline and wellbore subsidence estimates. The thickness of the active layer is important in determining frost heave loadings on elevated pipeline supports, piles or other structures.

The salinity criteria presented in Table 1 are calculated values based upon measured electrical conductivities. Thaw strain values are based upon permafrost sample tests. Active layer thicknesses have been estimated using the recent Woodward-Clyde geophysical study results for the PTD area (Woodward-Clyde, 1983).

Island Fill Properties

Geotechnical criteria for gravel island fill are presented in Table 2. The relevant parameters are density, shear strength and thermal properties. The recommended density parameters for 10 percent ice content gravel are based upon in situ measurements at Duck Island Pad #2 (Harding Lawson Associates, 1982). Ice contents reported at Point Thomson gravel sources, however, are closer to 25 percent (Harding Lawson Associates, 1982). The use of a 25 percent ice content gravel, rather than a 10 percent ice content material, will result in significantly lower placement densities. Fill volume requirements also will be increased if ice loading governs the island design. Experience indicates that fill with a 10 percent ice content cannot be compacted to densities that would be considered acceptable for thawed fill, regardless of compactive effort. The compacted dry densities of higher ice content gravel will be even lower.

The properties of a gravel island fill constructed during the summer months should be somewhere between those estimated for gravels with 10 and 25 percent ice content. The ice content of the fill after placement will not be significantly less than for a winter-constructed fill. However, the sea water and the gravel are somewhat warmer in the summer than in the winter, so that both the below-water and above-water portions of the fill will probably be somewhat more dense at the end of construction. Also, recompaction of the active layer in the fill before it starts to freeze again in the fall would result in reduced thaw-settlement and better trafficability during subsequent breakup.

The fill friction angles shown in Table 2 for gravel containing ice are based on our knowledge of a very limited number of laboratory tests, the results of which are proprietary. The cohesion component of strength has been neglected due to considerable uncertainty as to its magnitude and how it may be affected by creep under sustained loads. A material factor of 1.2 is recommended for use with the tangent of the fill friction angle in strength analyses.

FOUNDATION DESIGN CRITERIA

Facilities located on a production island will require foundations which are suited to the loads being supported and the settlements that the structures can tolerate. Deep piles (50+ ft. of penetration) may be required for large module support. Lightly loaded structures, such as tanks or warehouses, can be supported by shallow spread footings or mat foundations. Due to the different mechanisms that may cause foundation heave or settlement, differential movements may occur across the dimension of the structure. Therefore, provisions should be made with each type of foundation for jacking and shimming to maintain a level structure.

Offshore and Barrier Island Piles

Piles will probably be used as the primary means of support for large modules on offshore production islands. Piles are considered superior to shallow foundations for this application because piles will derive support from the in situ soils, for which the geotechnical parameters are far less uncertain than the gravel island fill. Piles are also favored because larger loads can be carried by individual foundation elements and the settlements will be smaller and less time dependent.

On the barrier islands, except Flaxman Island, the distribution and properties of bonded permafrost is expected to be highly unpredictable. The data show wide variations in salinity and, in many cases where bonded soils were encountered in the borings, samples were obtained by pushing or with moderate driving resistance. In such relatively warm, saline permafrost, the bonding is expected to be weak and erratic and unbonded brine pockets may occur within otherwise bonded zones. Therefore, it is our opinion, that without site specific data, pile capacity analysis should be based on unbonded soil properties.

Since Flaxman Island is a remnant of an old coastline, the permafrost may be similar to that found onshore, except warmer. If this can be demonstrated, adfreeze pile design for Flaxman Island may be practical.

Installation

Foundation piles can be driven into unfrozen subsea soils using diesel impact hammers. Drivability can be estimated using standard wave equation techniques. Driving through the gravel island fill may be difficult, possibly requiring predrilling through the island to the seafloor. Gravel strata below the mudline may also cause driving problems. For example, driving refusal may be met in thin gravel strata before penetration sufficient to generate the required bearing capacity has been achieved. This situation would require a modification of the piles or the installation procedure such as reinforcing the pile tips, filling the piles with concrete and redriving or drilling out the obstructing material (Note: jetting is not recommended because it causes excessive disturbance and may eliminate any skin friction capacity in the overlying strata.) In areas of thick, near-surface gravel strata, drilled-and-grouted pile installation may be necessary.

Driving into subsea permafrost may also be difficult. The techniques previously mentioned for penetrating thin gravel strata should also be feasible for penetrating warm, saline permafrost. The use of adfreeze piles in warm, saline permafrost is considered impractical because of the long freezeback time required and the uncertainty of the adfreeze strength. Thermal modification is also considered impractical because of the extreme difficulty of controlling the process in such temperature-sensitive permafrost.

Design Criteria for Axial Loads

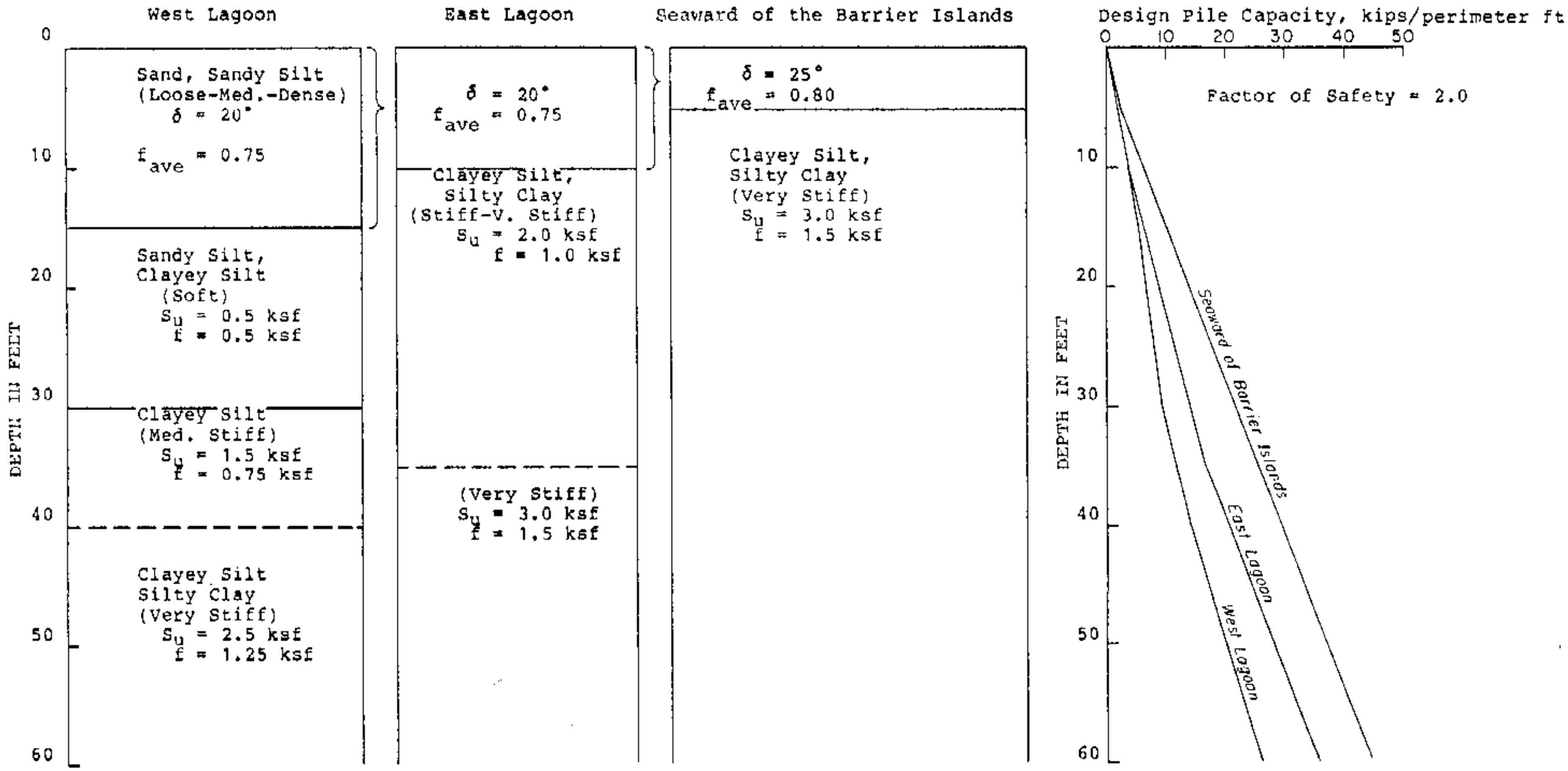
In lieu of site-specific pile load test results, pile capacities in unfrozen subsea soils can be estimated using the recommendations of API RP 2A (American Petroleum Institute, 1982), suggested limits on skin friction and end bearing in granular soils (McClelland, 1974), and interpretations of site soil properties. Design criteria for axially loaded piles in the west lagoon, east lagoon, and seaward of the barrier islands are presented in Figure 20. To be conservative, end bearing was omitted from the analyses. Piles driven into thick strata of

INTRODUCTION

Generalized geotechnical design criteria have been developed for the Point Thomson Development (PTD) area. These criteria are based on data and analyses contained in reports prepared by Harding Lawson Associates (HLA, 1982), Woodward-Clyde Consultants (WCC, 1982) and Northern Technical Services (NORTEC, 1983). The criteria should be used for conceptual design purposes only; site-specific data will be required for final design.

The basic approach used to develop these criteria was to proceed from the broadest generalization of the soil conditions in the area to detailed analyses of the strata, soil properties and foundation design criteria. The methodology may be described as follows:

1. Review the information available for the PTD area.
2. Collate and synthesize the information to formulate an interpretation of the nature and distribution of soils throughout the study area.
3. Perform statistical analysis on the results of laboratory testing of soil properties. These analyses included computation of means and variances by soil type and boring and tests for the validity of combining the data. The statistical data were combined to the extent possible, consistent with geological and engineering judgement.
4. Develop geotechnical design parameters. The soils throughout the PTD area were grouped by location, age,



Notes:

1. Soil-pile friction as recommended by API (1982).
2. Contribution of gravel island fill to pile capacity assumed to be negligible.
3. End bearing ignored--piles encountering gravel and/or permafrost may meet refusal in end-bearing.
4. Warm saline permafrost assumed equivalent to unbonded soil.

Figure 20.

dense sands and gravels could be expected to develop end bearing capacity in the range of 200 to 250 ksf (ultimate) in addition to the purely frictional capacities shown on Figure 20. A factor of safety of 2.0 has been included in the preliminary design curves.

Specific criteria for Barrier Island piles are not presented because of the extreme variability in soil and permafrost conditions, which range from unbonded to well-bonded, from icepoor to massive ice and from fresh to highly saline. For the unbonded condition, pile design criteria can be estimated from the cases shown on Figure 20. For well-bonded non-saline permafrost conditions (Flaxman Island) adfreeze design, as shown on Figure 22 should be appropriate (modified for temperature differences, if necessary). For intermediate cases, pile behavior is highly unpredictable without site-specific data. For example, the zones containing ice-rich, warm, saline permafrost and brine pockets may contribute nothing to pile capacity or even generate downdrag forces due to settlement under the weight of gravel island fill.

A pile capacity larger than that predicted for a given design can usually be developed by increasing the pile diameter or penetration. Available lifting equipment or other construction considerations may constrain the maximum pile diameter. Penetrations may be constrained by gravel strata or permafrost below the mudline. A high end bearing component of strength can be developed in thick gravel strata, so pile designers may want to take advantage of this increased support. The strength and deformation characteristics of warm saline permafrost are uncertain. No pile load test data in offshore permafrost are available to support pile capacity estimates, and the creep behavior of the permafrost may cause long-term pile settlements. We recommend that a pile load test program be performed to provide a design basis for piles embedded in offshore permafrost.

Downdrag

Downdrag loads on a pile (and resulting pile settlement) can be caused by consolidation settlement of the surrounding soil under the weight of a newly-constructed gravel island. Based on available soils data (Table 1) and assuming that piles will be installed at least six months after a production island is built, downdrag due to primary consolidation can be neglected over most of the PTD area. If the piles penetrate fine-grained, highly compressible soils or ice-rich, warm, saline permafrost, a refined analysis should be performed to determine the magnitude of downdrag loads.

Long-term soil movements, due to creep in the gravel island fill or *in situ* soil frost heave, and wellbore thaw subsidence, may also cause pile displacements. The net island surface settlement due to those mechanisms may be on the order of 5 to 6 ft in 20 to 25 years, but a detailed analysis is needed to determine the soil and pile movements expected. Module jacking and leveling systems may have to be developed to compensate for the predicted movements. Settlement-sensitive structures should be located outside the wellbore thaw region to minimize jacking requirements.

Design Criteria for Lateral Loads

Lateral load resistance is developed by the combined bending strength of the pile and lateral bearing against the soil. The unfrozen condition should produce larger deflections at a given load and thus be more conservative than the frozen condition. Lateral load-deflection criteria for use in conventional non-linear P-Y analyses have been estimated assuming that the gravel fill behaves as an unfrozen granular soil with density and strength properties as given in Table 2. The estimated criteria are shown in Figure 21.

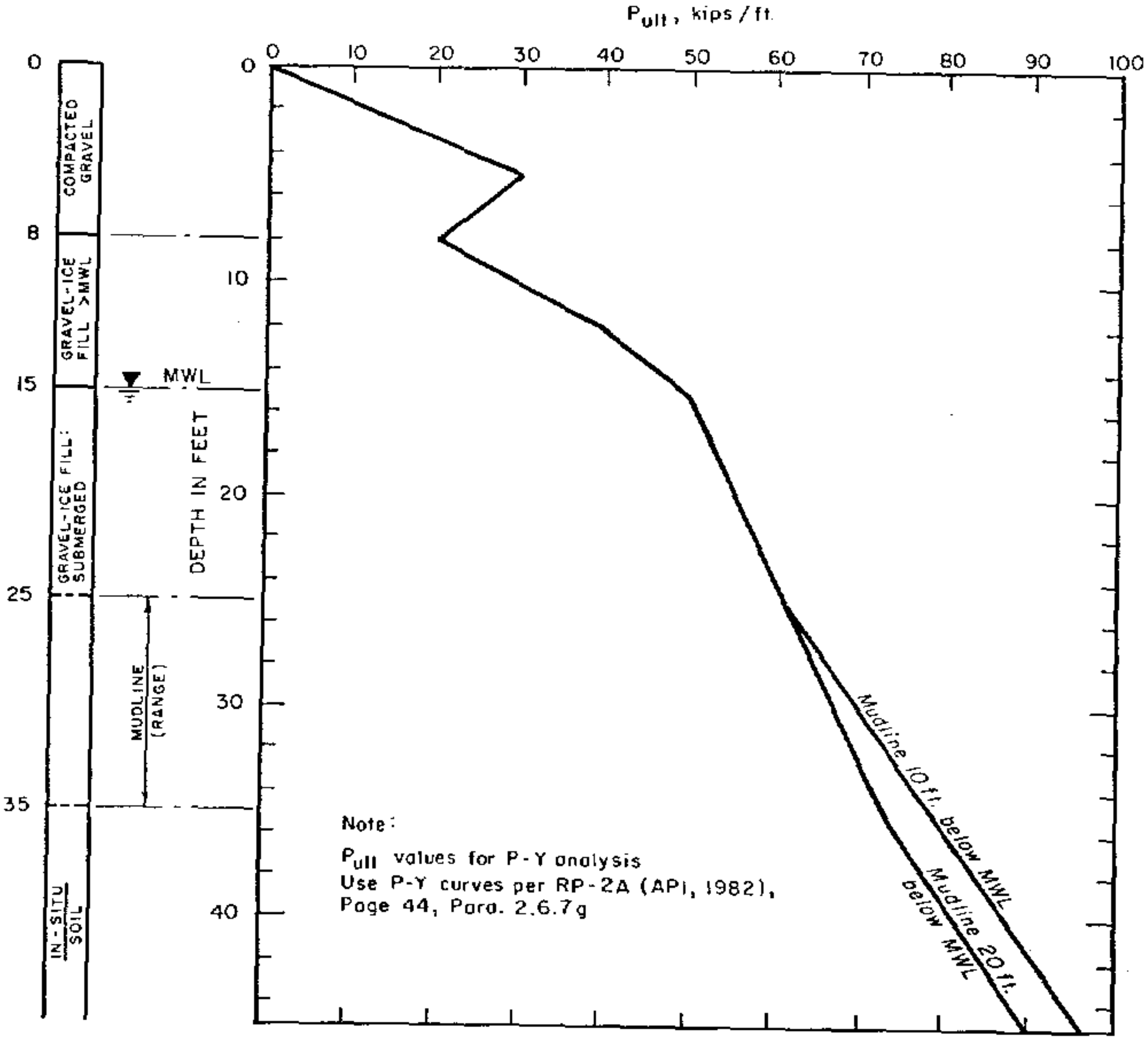
Onshore Piles

In onshore areas, where relatively cold permafrost lies just a few feet below the soil surface, "adfreeze piles" should be used. Adfreeze piles are installed in a predrilled hole, backfilled with a sand-water slurry, and allowed to freeze back before loads are applied. This technique has proven successful at a number of Prudhoe Bay installations, and limited onshore pile load test data exist to support onshore designs.

Design Criteria for Axial Loads

The recommended method for design of axially loaded piles in permafrost is that proposed by Weaver and Morgenstern (1981). This method addresses both ultimate strength and long-term creep settlement of piles in permafrost. It also recognizes the differences in behavior of ice-rich and ice-poor permafrost. (Ice-rich means greater than about 50 percent ice content, by weight) Weaver and Morgenstern (1981) also present ultimate strength and creep data for a wide range of permafrost soil types.

Pile design criteria for axially-loaded adfreeze piles onshore are shown on Figure 22. These criteria were developed for typical onshore permafrost and temperature profiles. Representative strength and creep parameters for the permafrost were selected from the data provided by Weaver and Morgenstern (1981) for similar permafrost soil types. (The parameters selected are consistent with proprietary data for Alaskan North Slope permafrost that we have used on similar pile designs). The allowable adfreeze stresses and pile capacities include a

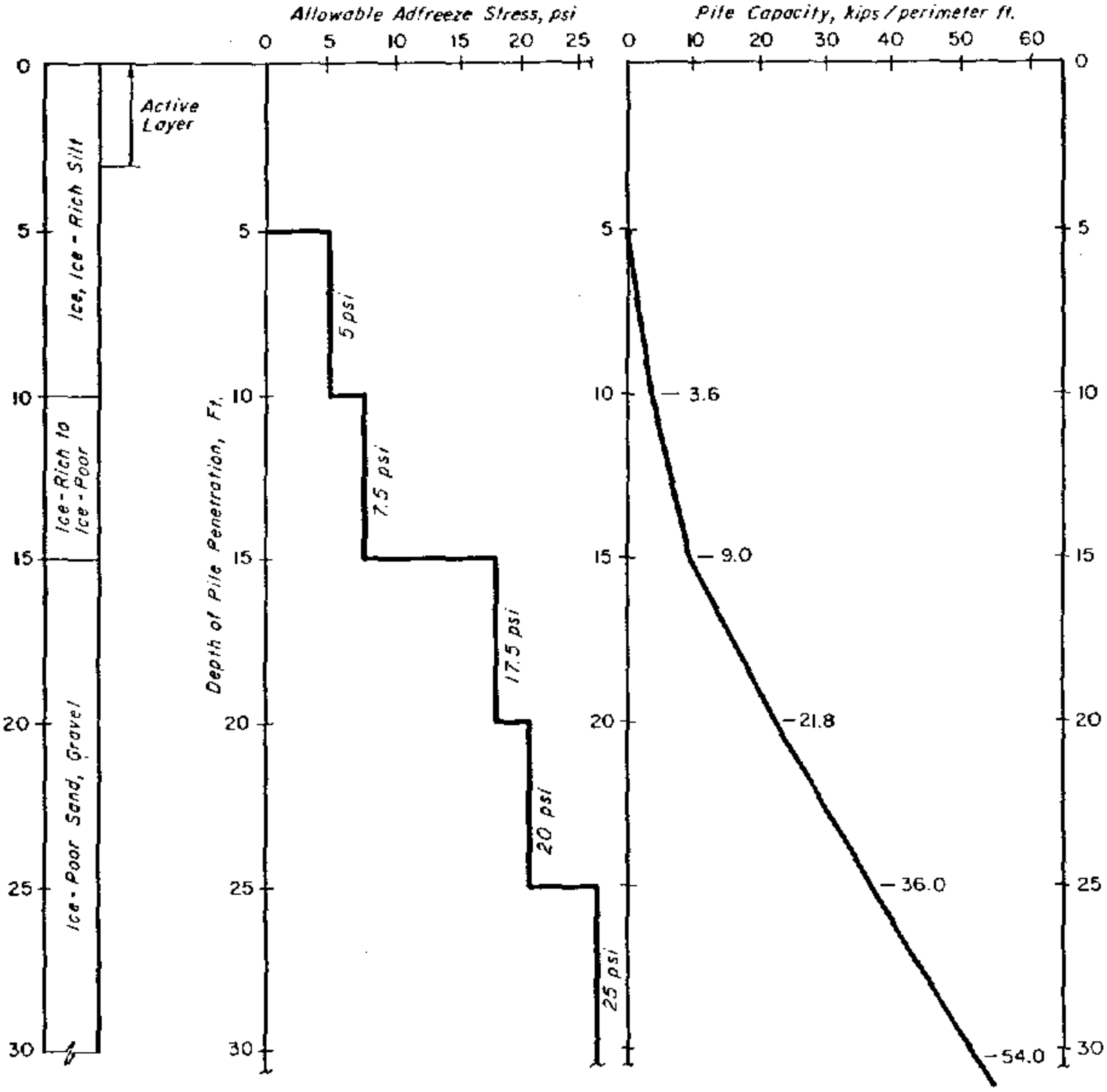


Note:

P_{ult} values for P-Y analysis
Use P-Y curves per RP-2A (API, 1982),
Page 44, Para. 2.6.7g

LATERAL LOAD - DEFLECTION CRITERIA
OFFSHORE PILES

Figure 21.



PILE DESIGN CRITERIA FOR AXIAL LOADS
ADFREEZE PILES ONSHORE

Figure 22.

safety factor of about 2.5 with respect to ultimate strength (the corresponding estimated creep settlement is less than one-half inch in 20 years). A minimum penetration of 15 feet is recommended to resist an assumed frost jacking force of 20 kips per perimeter foot.

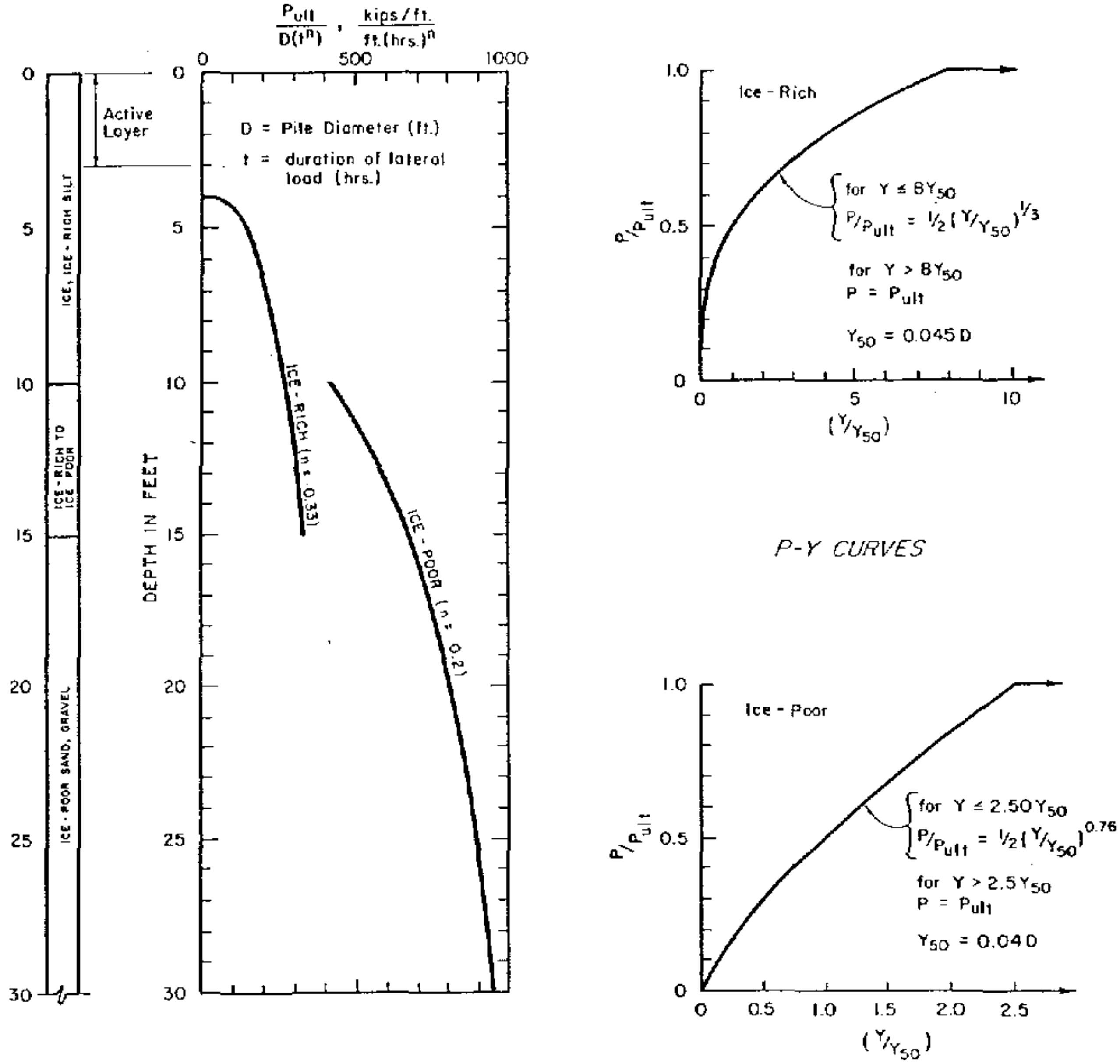
Freezeback times of 30 days and 14 days should be allowed for winter-installed piles for major modules and nonprocess structures, respectively. Site-specific design studies should anticipate any significant departure from the typical permafrost conditions shown on Figure 22 that might affect the required pile embedment. These could include; for example, thicker strata of ice or ice-rich soil, thaw bulbs or warmer-than-average permafrost temperatures.

Design Criteria for Lateral Loads

The behavior of laterally loaded piles in permafrost is a complex phenomenom because, in addition to the factors that influence the behavior in unfrozen soils, the lateral resistance of permafrost is time and temperature dependent. In our analyses, we have used the creep data presented by Weaver and Morgenstern (1981) and the analytical method proposed by Ladanyi (e.g., Ladanyi and Johnston, 1983, 1974 Ladanyi, 1975; Rowley et al., 1973, 1974) to develop lateral load deflection criteria for use in conventional non-linear P-Y analyses. These criteria are presented on Figure 23 for the same typical permafrost and temperature profiles used for axial load criteria shown on Figure 22. Since these criteria are time-dependent, seperate P-Y analyses are required for each design load duration.

Shallow Foundations

Shallow foundations may prove to be an acceptable alternative to pile foundations in some situations. To date, most uses of



LATERAL LOAD – DEFLECTION CRITERIA
ONSHORE PILES

Figure 23.

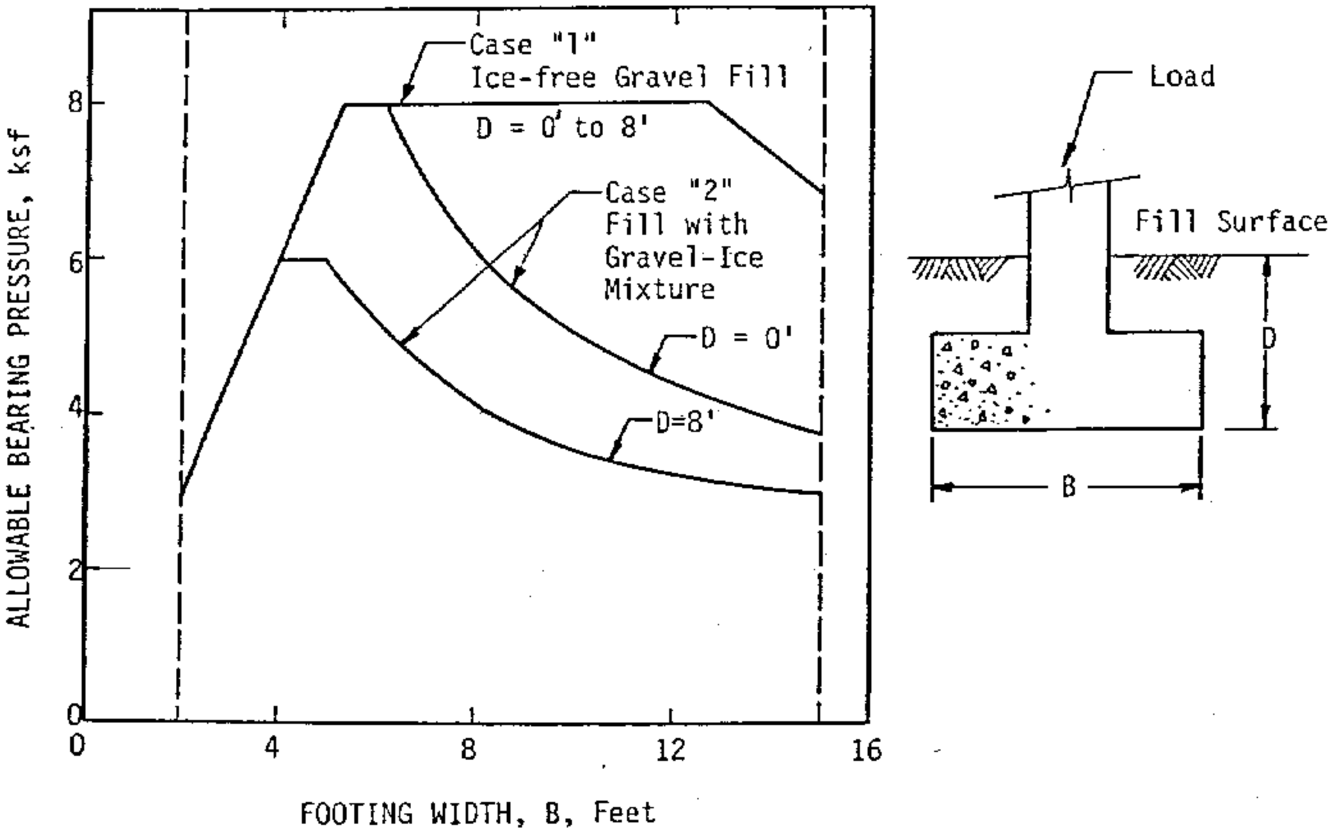
shallow foundations on the North Slope have been for the support for lightly loaded structures. Heavier structures may be supported by shallow footings but the ability to compensate for significant differential settlements might be required in the facility design.

The performance of a shallow foundation is largely dependent on the ice content, gradation, and compaction of the gravel fill. Foundation soils should be compacted and relatively ice-free. Frozen gravel fill will probably maintain the ice content existing at the source (reported by HLA to be about 25 percent). High ice content gravels will be impossible to fully compact and will experience thaw-settlement during the summer. Footings constructed prior to the first summer thaw would require over-excavation to below the depth of thaw (about 5 to 8 ft) and backfilling with compacted gravel with less than 5 percent ice content to minimize thaw settlement. If the fill is well drained and is recompacted with high energy devices after summer thaw, it may be adequate for footing construction.

Shallow foundation design is governed by bearing capacity and settlement in unfrozen soils and creep settlement in frozen soils. HLA has developed the bearing capacity chart shown on Figure 24 based on assumed fill properties and a total allowable settlement of one inch (Harding Lawson Associates, 1982).

For onshore applications, HLA suggests a maximum bearing pressure of 3,000 psf for gravel pads at least 4 ft thick. Typical onshore pads are about 5 ft thick.

Foundation soils should be insulated from the heated structures which they support. The easiest means of foundation insulation is by providing an air space of at least 36 in. below the structure and insulating the structural connections to the footings. A smaller air space may be acceptable if the structure-footing



NOTES:

1. Allowable bearing capacity values include a factor of safety of three for dead plus sustained live loads.
2. For total design loads including wind and seismic, the allowable bearing capacity can be increased by 50%.
3. Allowable bearing capacity is based on a total settlement due to footing pressure of one-inch.
4. Footings should be at least two feet wide, and loaded areas larger than 15 feet wide should be evaluated on an individual basis.

Ref: Harding Lawson Associates, 1982

BEARING CHART FOR SHALLOW SPREAD FOOTINGS

Figure 24.

connection can be adjusted to compensate for differential settlements or if the structure is temporary. Air spaces should be designed to prevent closure by snow drifting. Ducted or refrigerated foundations may be used when a clear air space is impractical.

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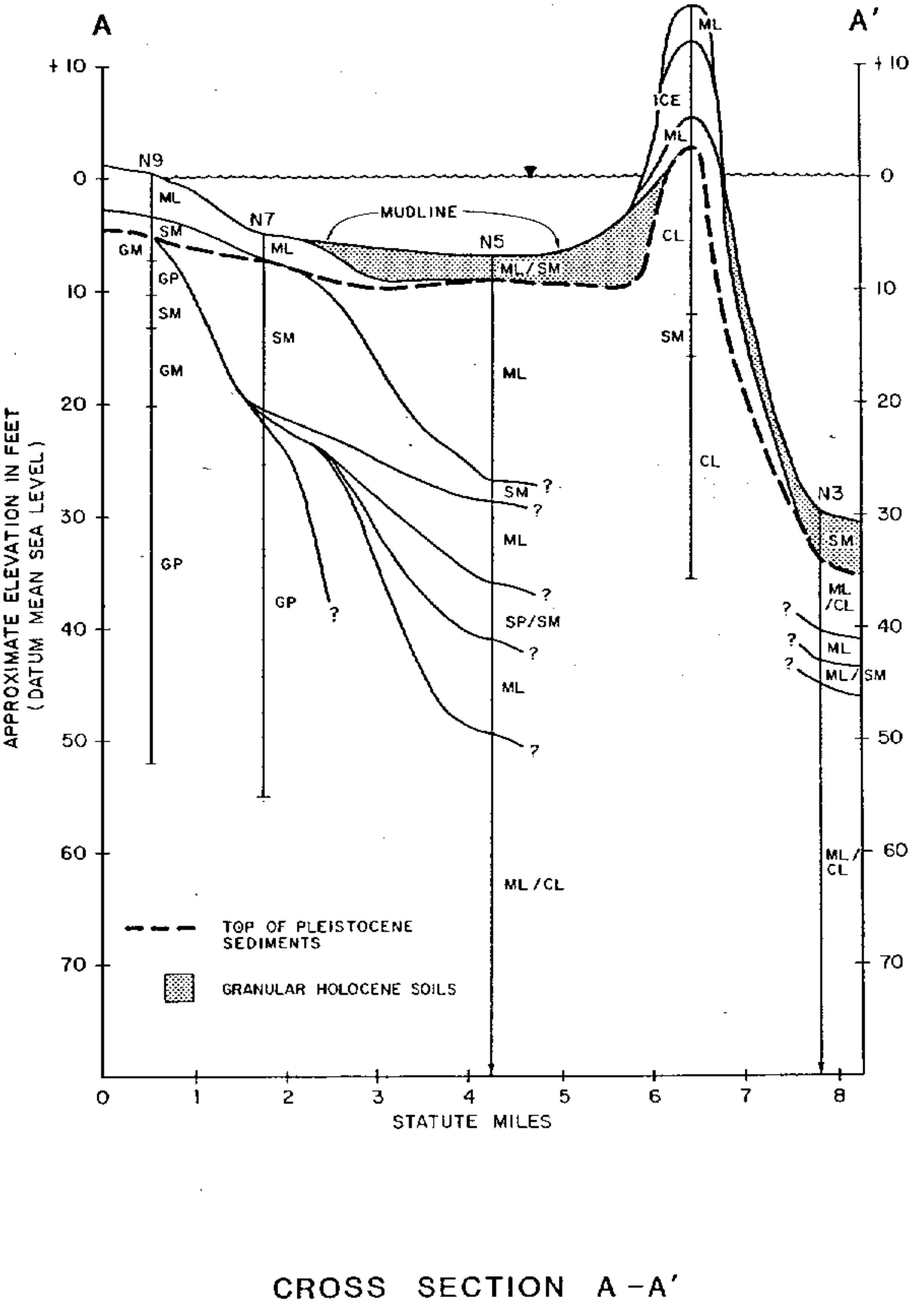
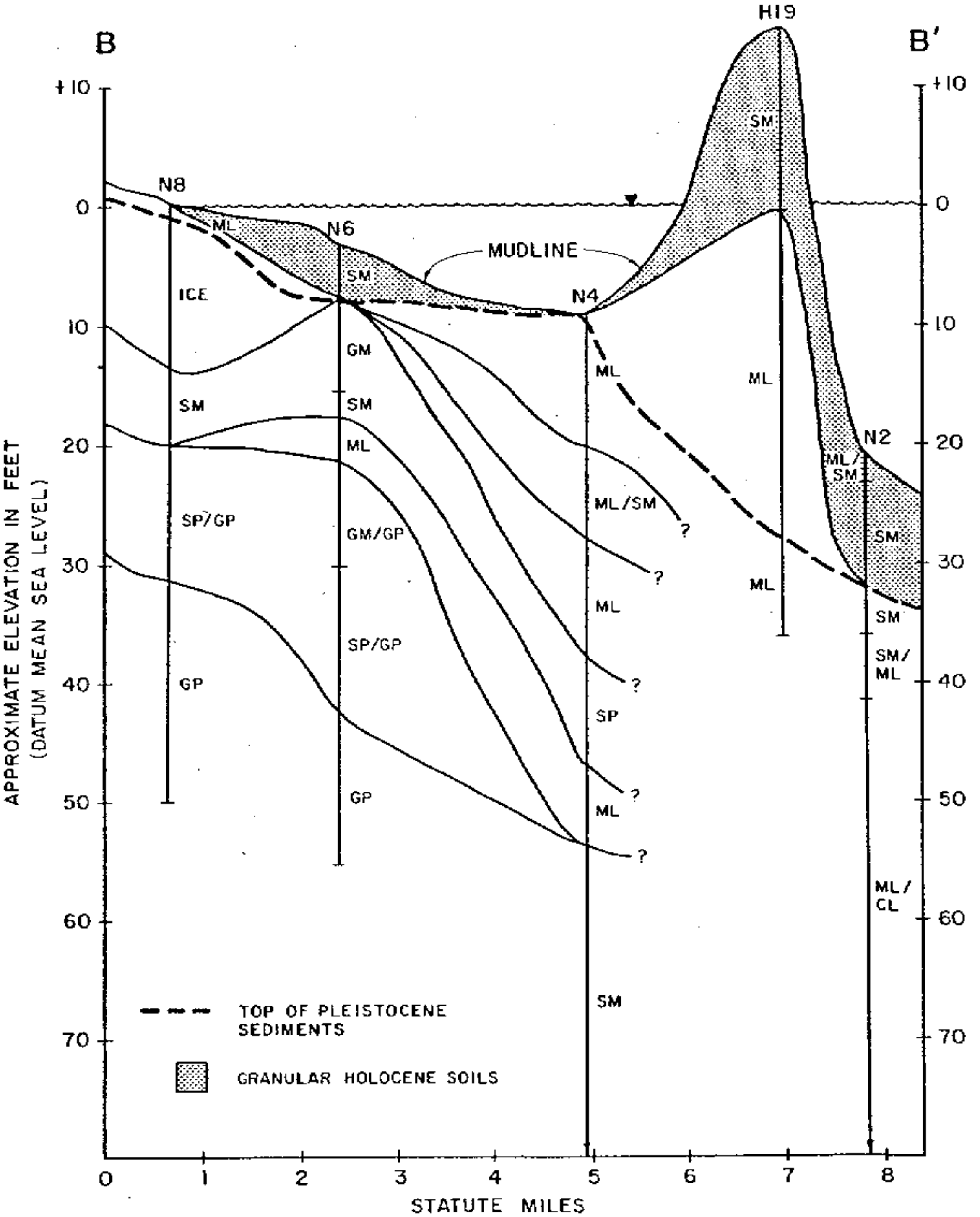


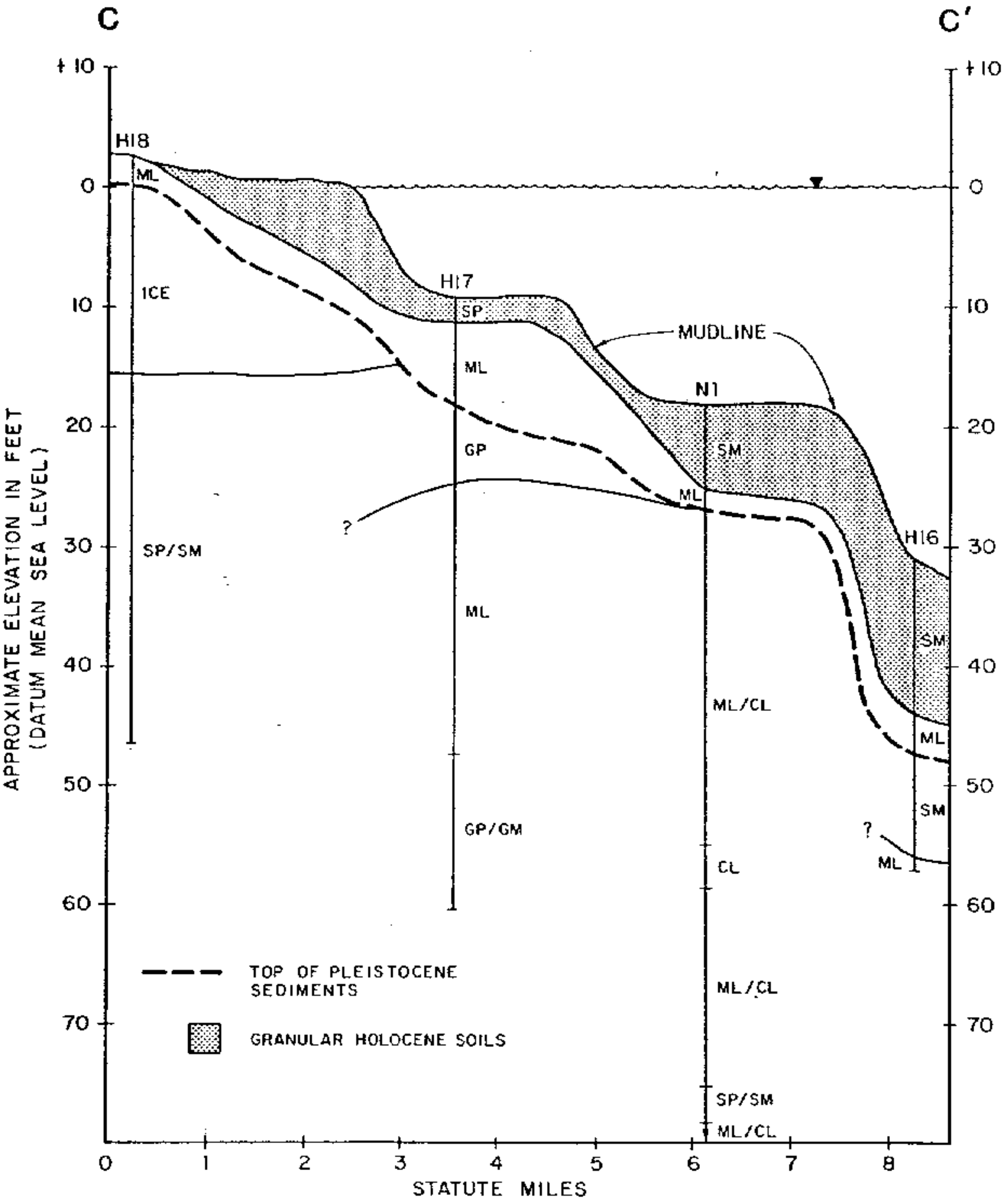
CROSS SECTION A-A'

Figure 3.



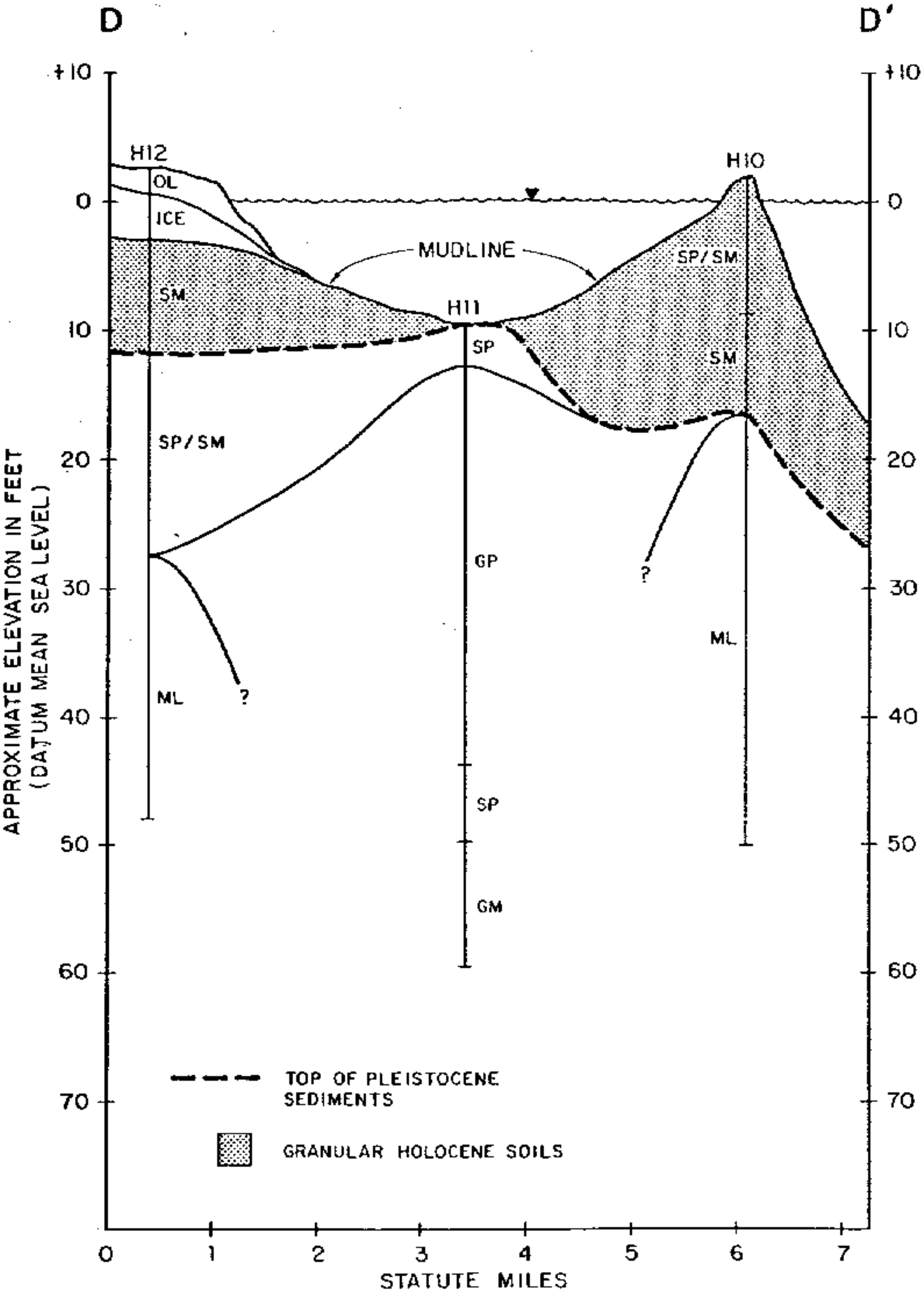
CROSS SECTION B – B′

Figure 4.



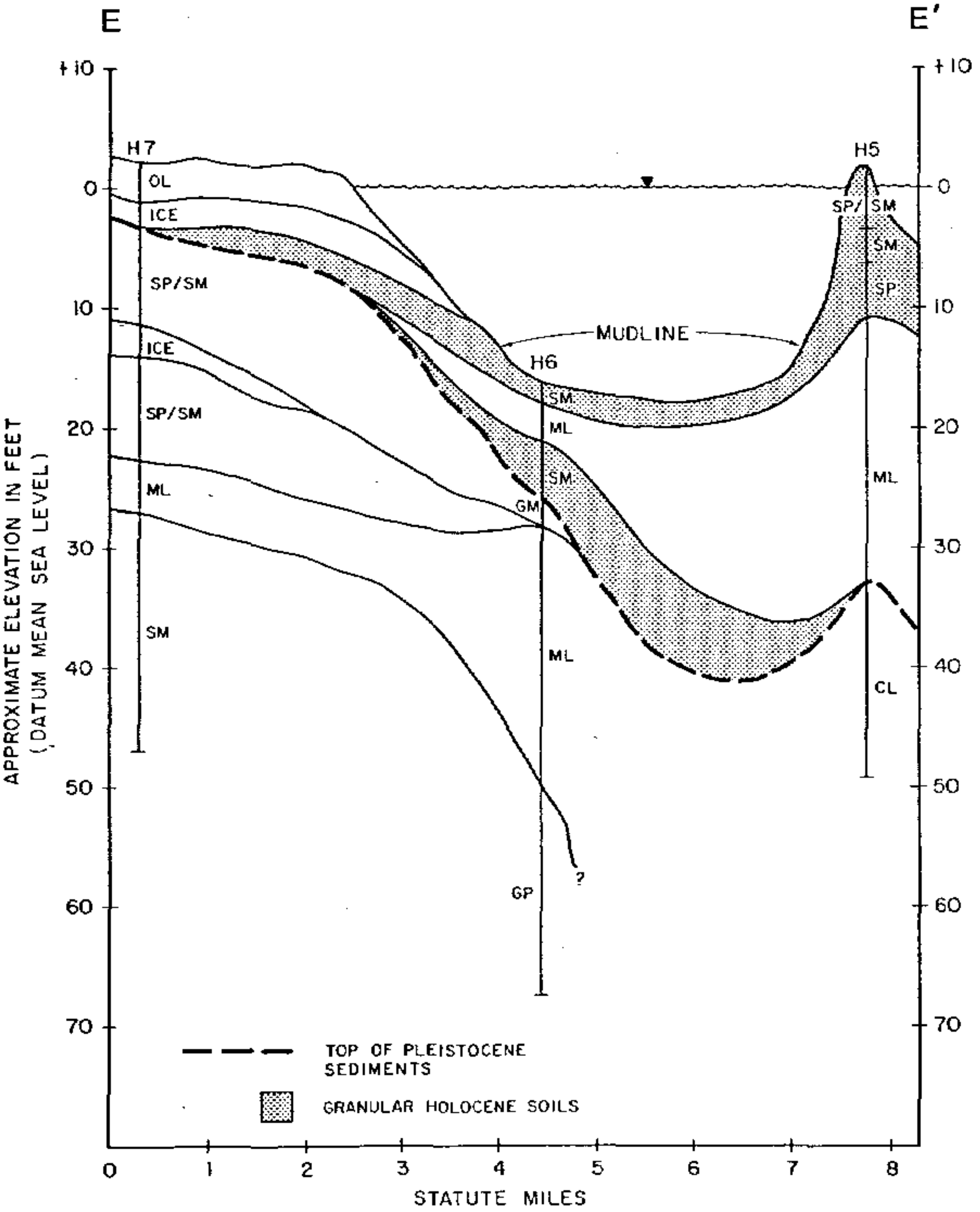
CROSS SECTION C – C′

Figure 5.



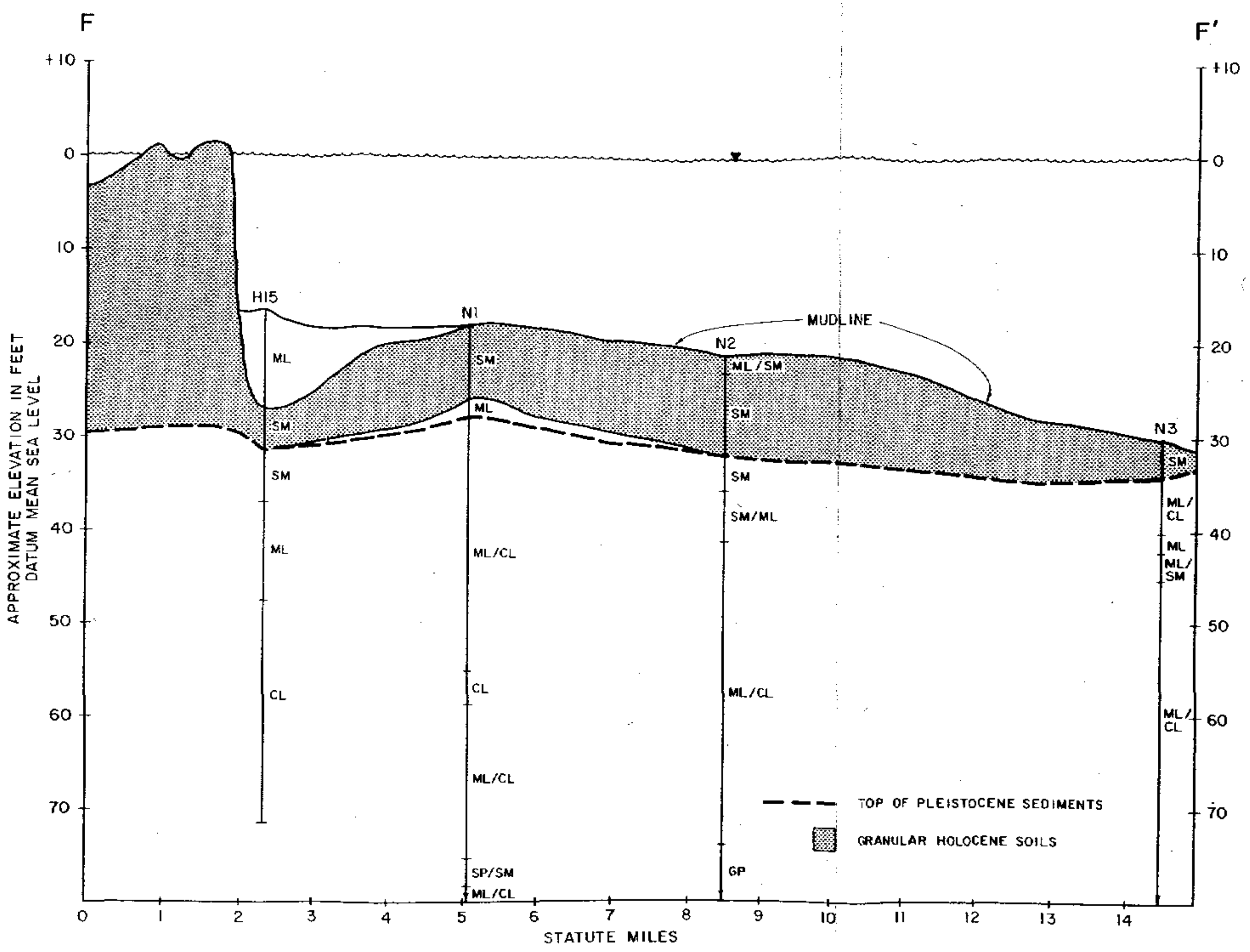
CROSS SECTION D - D'

Figure 6.



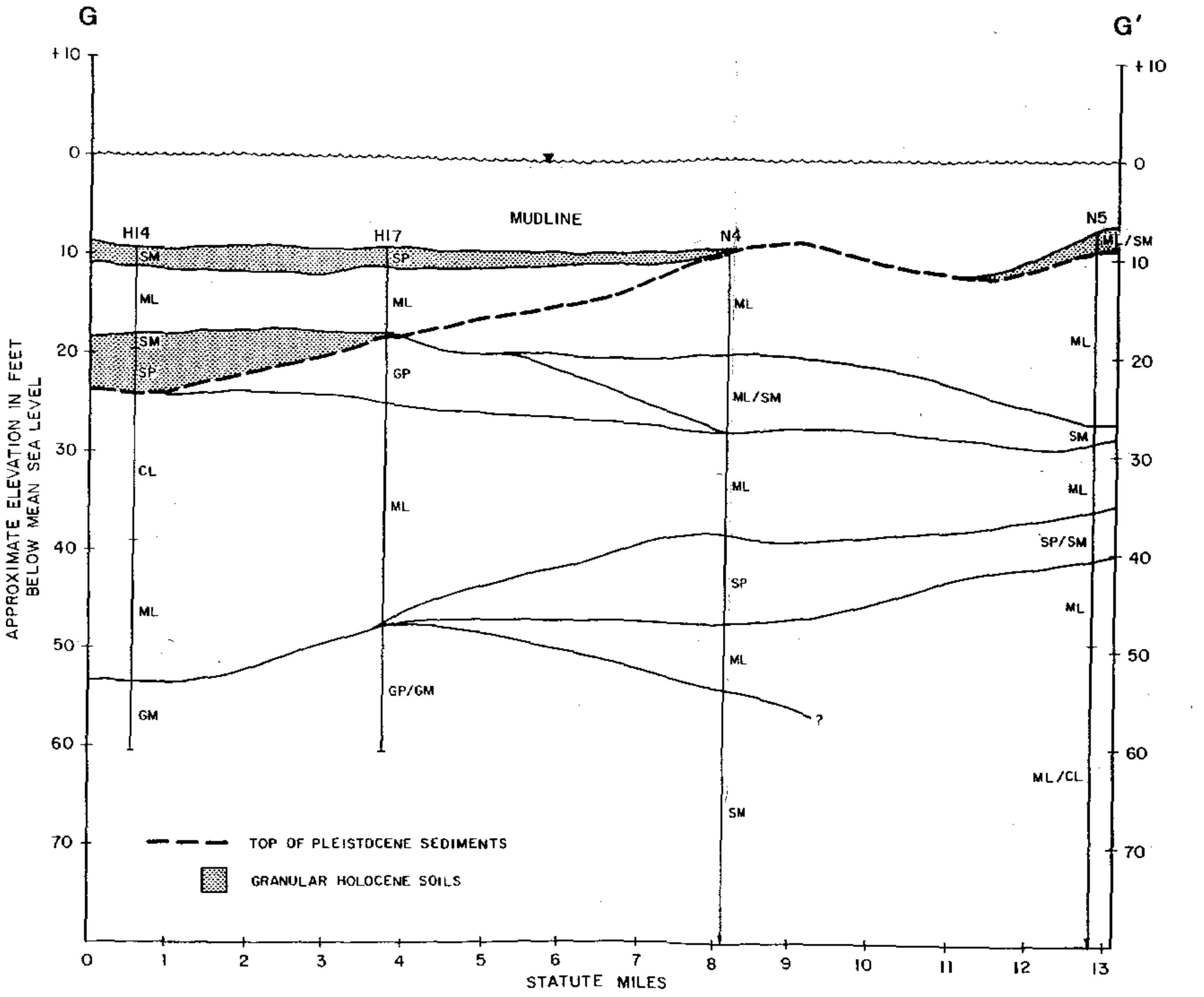
CROSS SECTION E - E'

Figure 7.



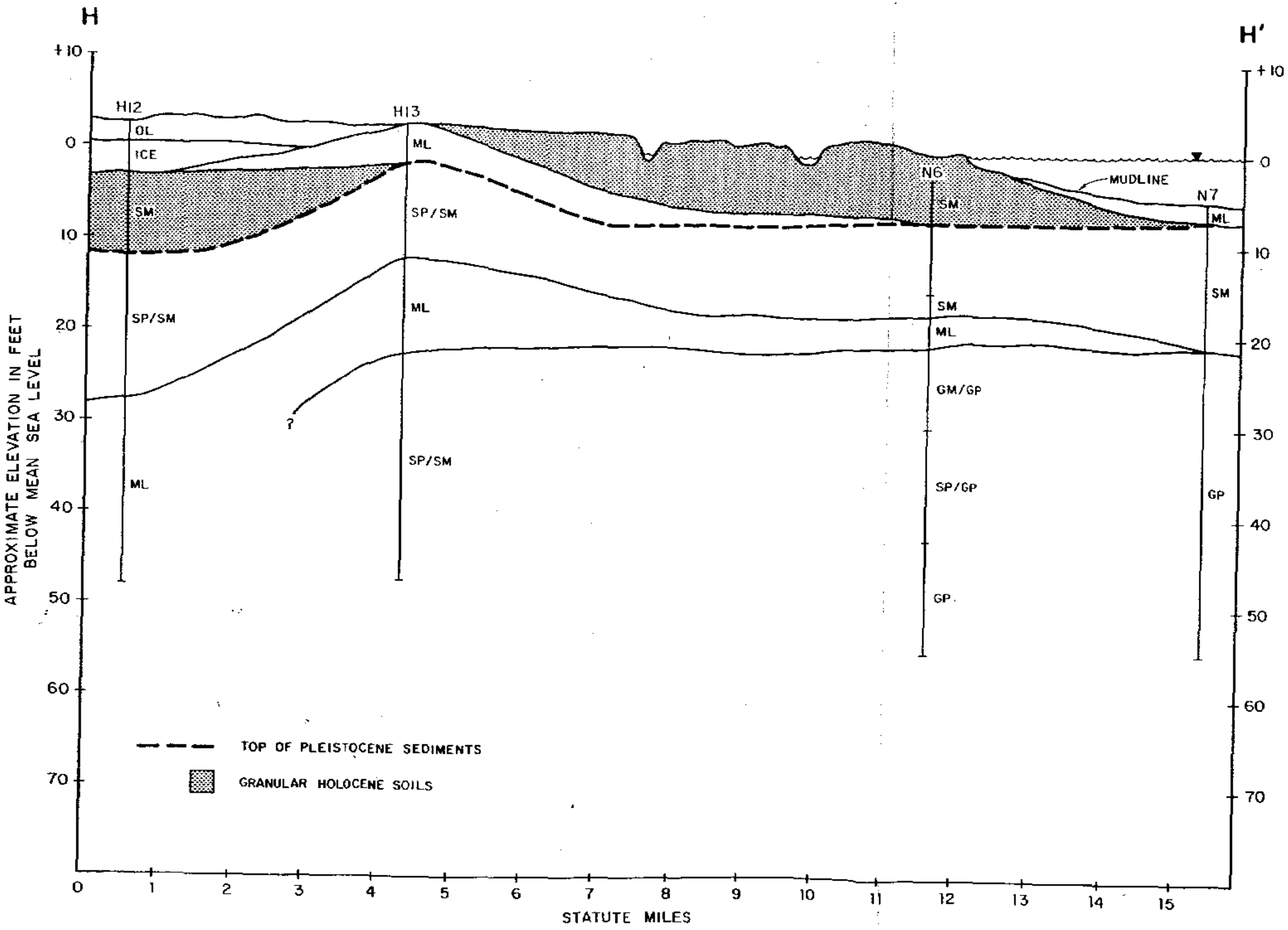
CROSS SECTION F - F'

Figure 8.



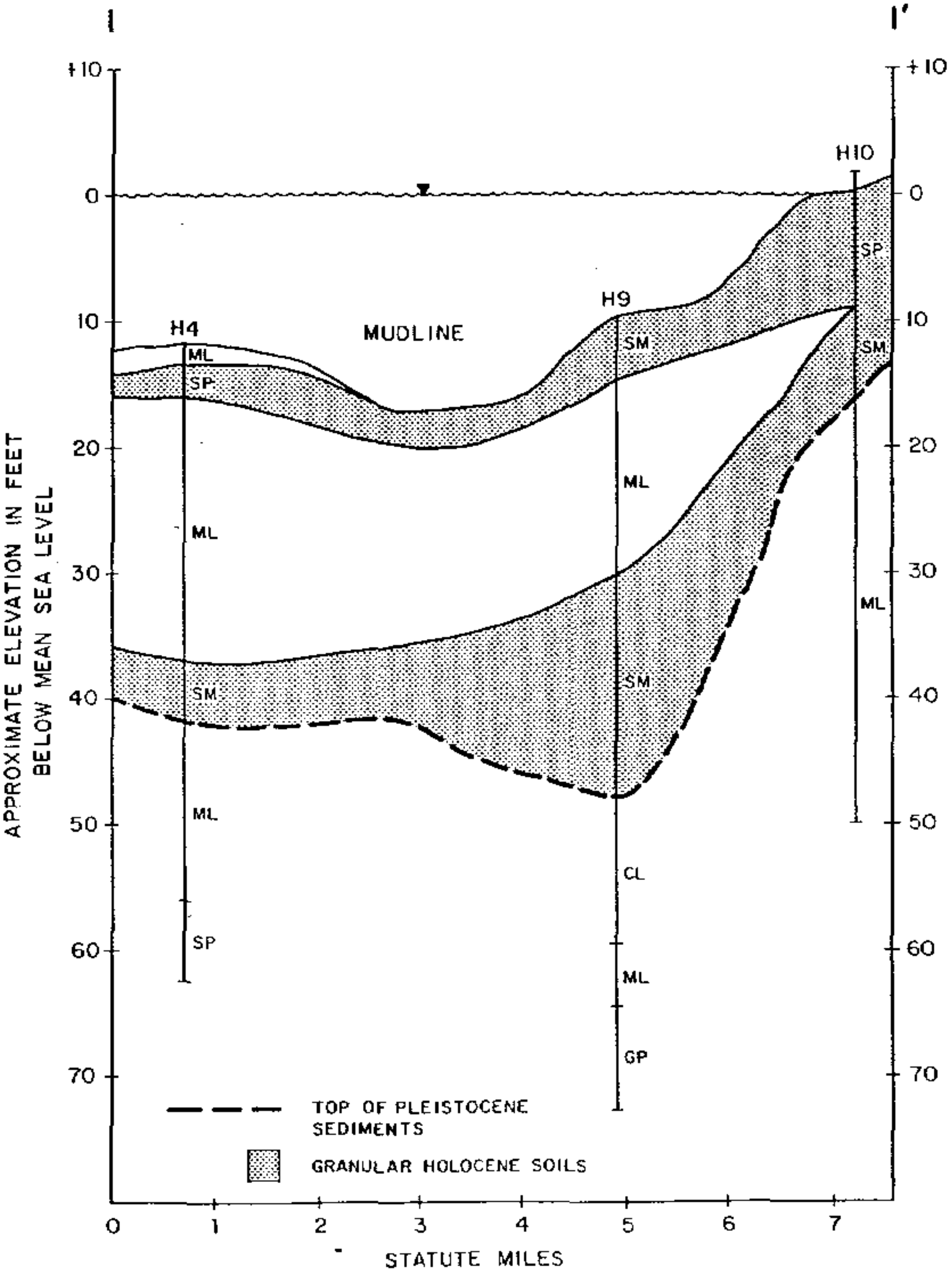
CROSS SECTION G - G'

Figure 9.



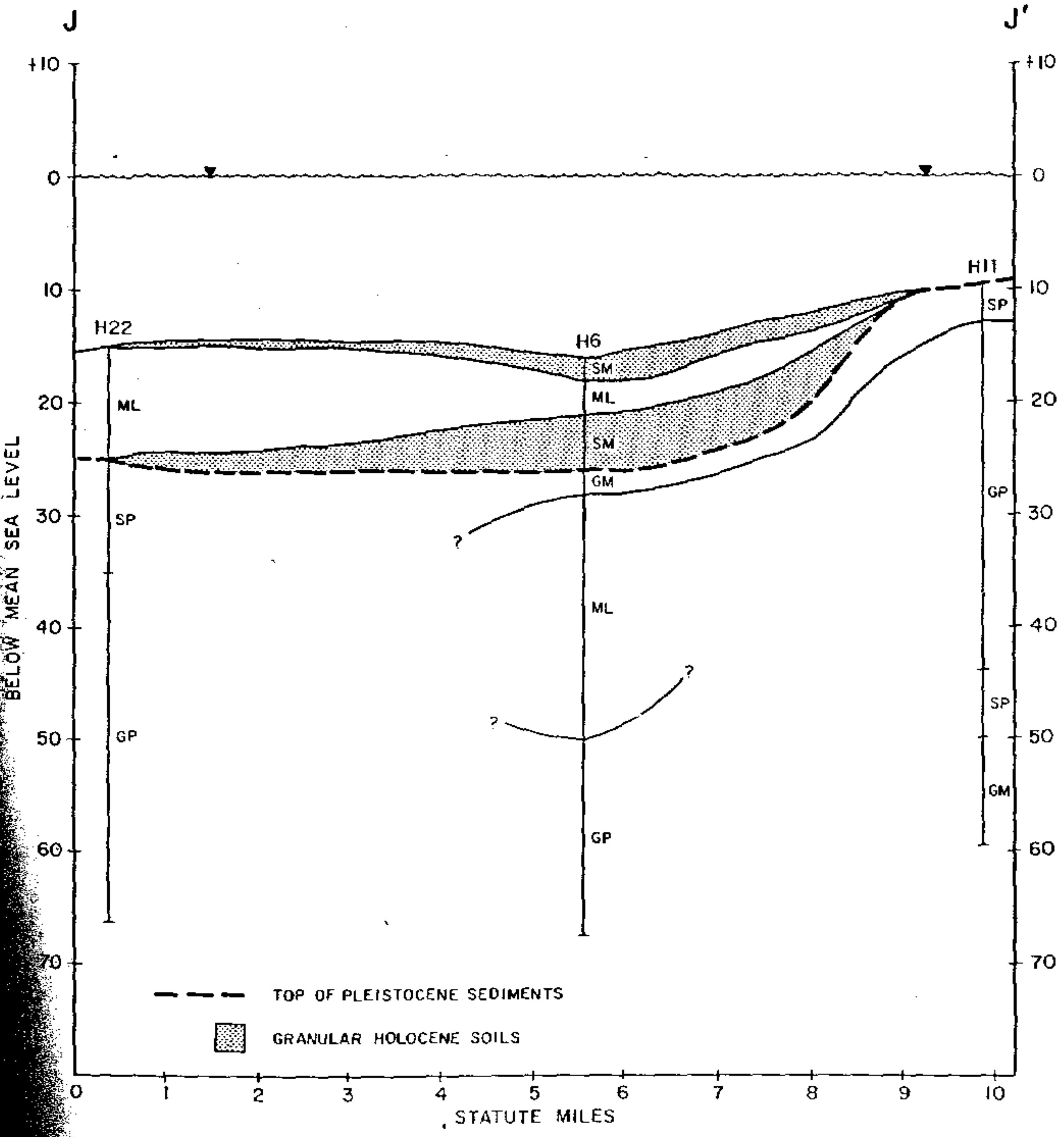
CROSS SECTION H - H'

Figure 10.



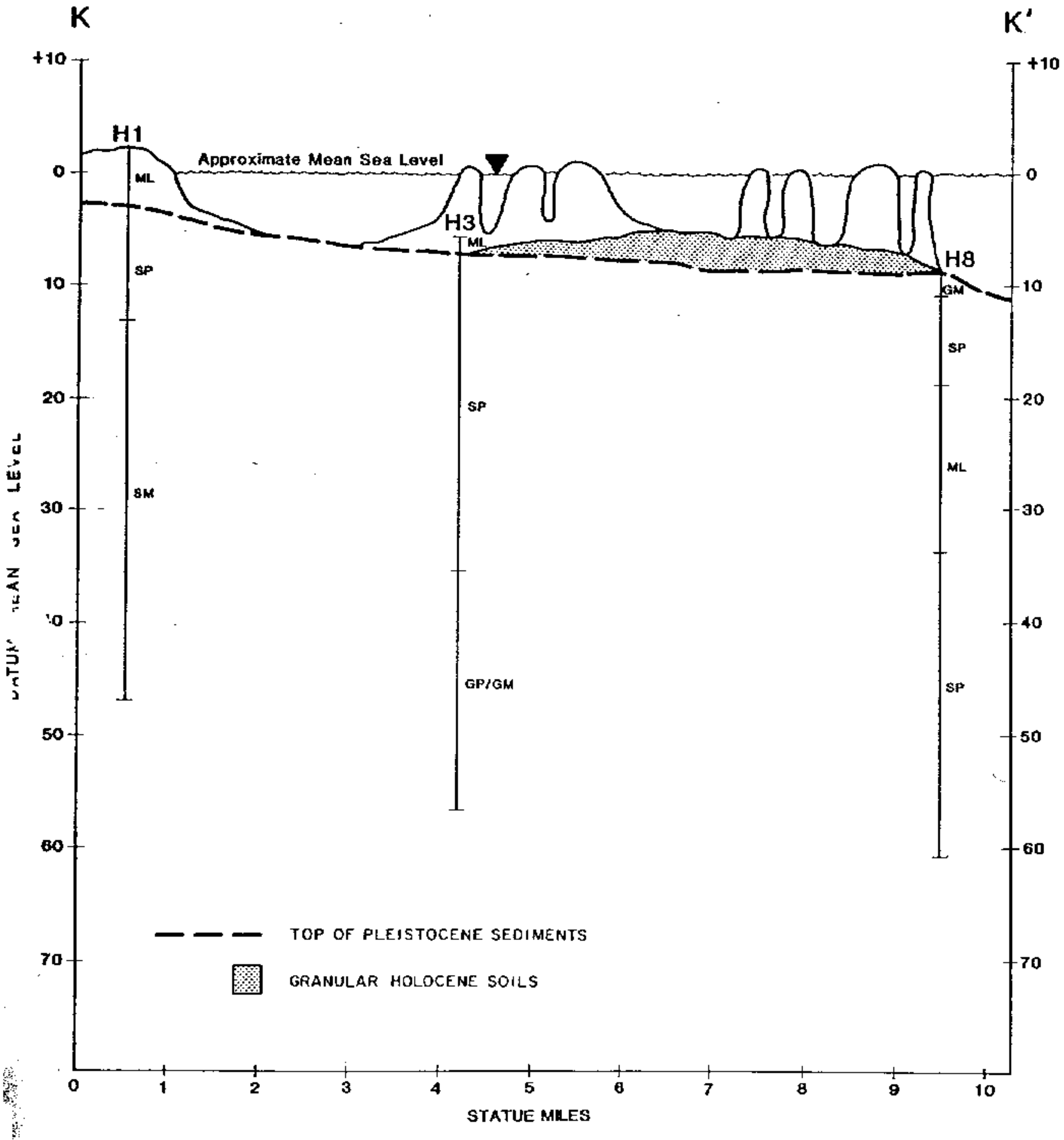
CROSS SECTION I-I'

Figure 11.



CROSS SECTION J – J'

Figure 12



CROSS SECTION K - K'

Figure 13

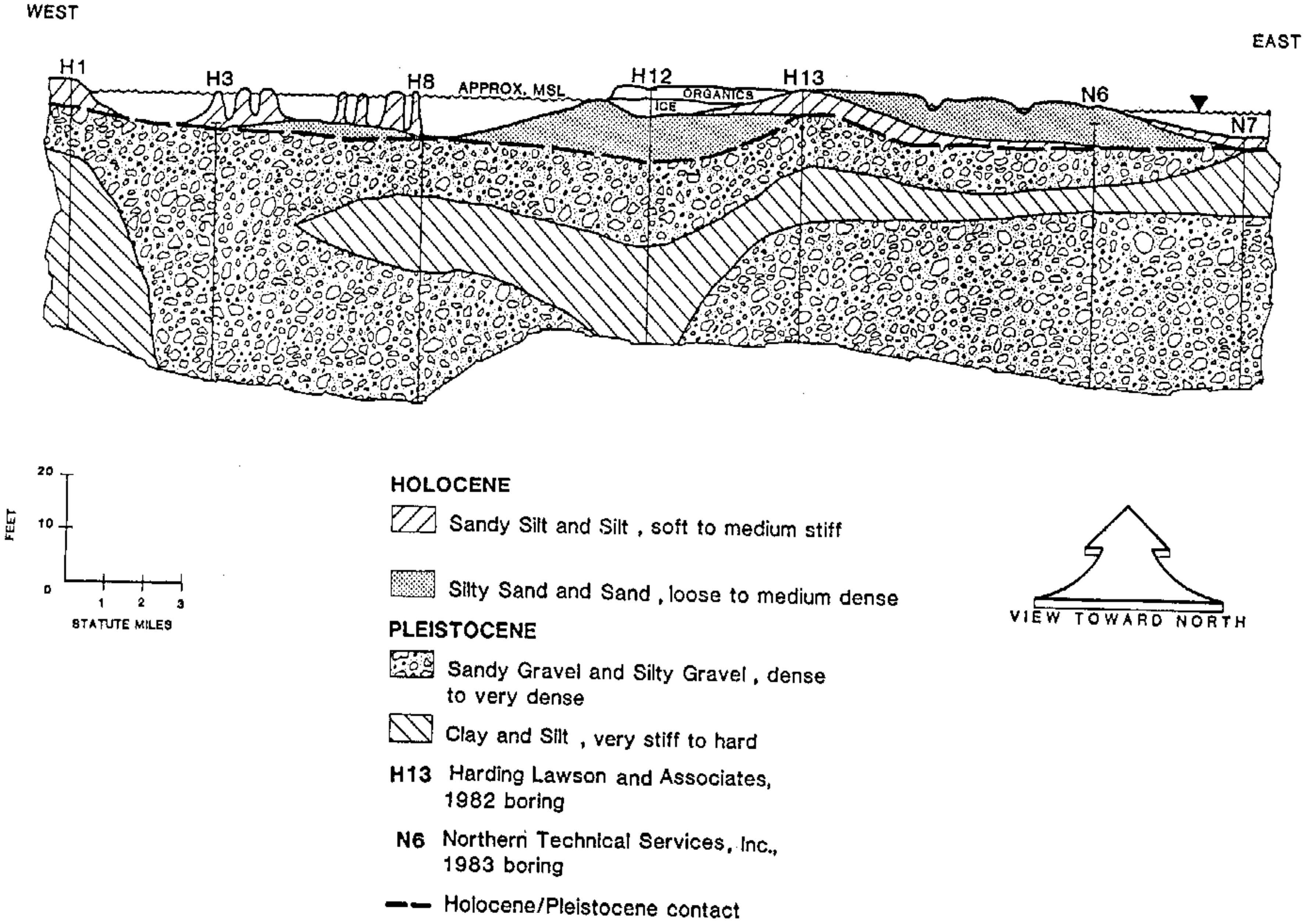

WEST
EAST
H1
H3
H8
APPROX. MSL
H12
ORGANICS
ICE
H13
N6
N7
20
10
0
FEET
1
2
3
STATUTE MILES
HOLOCENE
Sandy Silt and Silt , soft to medium stiff
Silty Sand and Sand , loose to medium dense
PLEISTOCENE
Sandy Gravel and Silty Gravel , dense to very dense
Clay and Silt , very stiff to hard
H13 Harding Lawson and Associates, 1982 boring
N6 Northern Technical Services, Inc., 1983 boring
Holocene/Pleistocene contact
VIEW TOWARD NORTH

Figure 14.

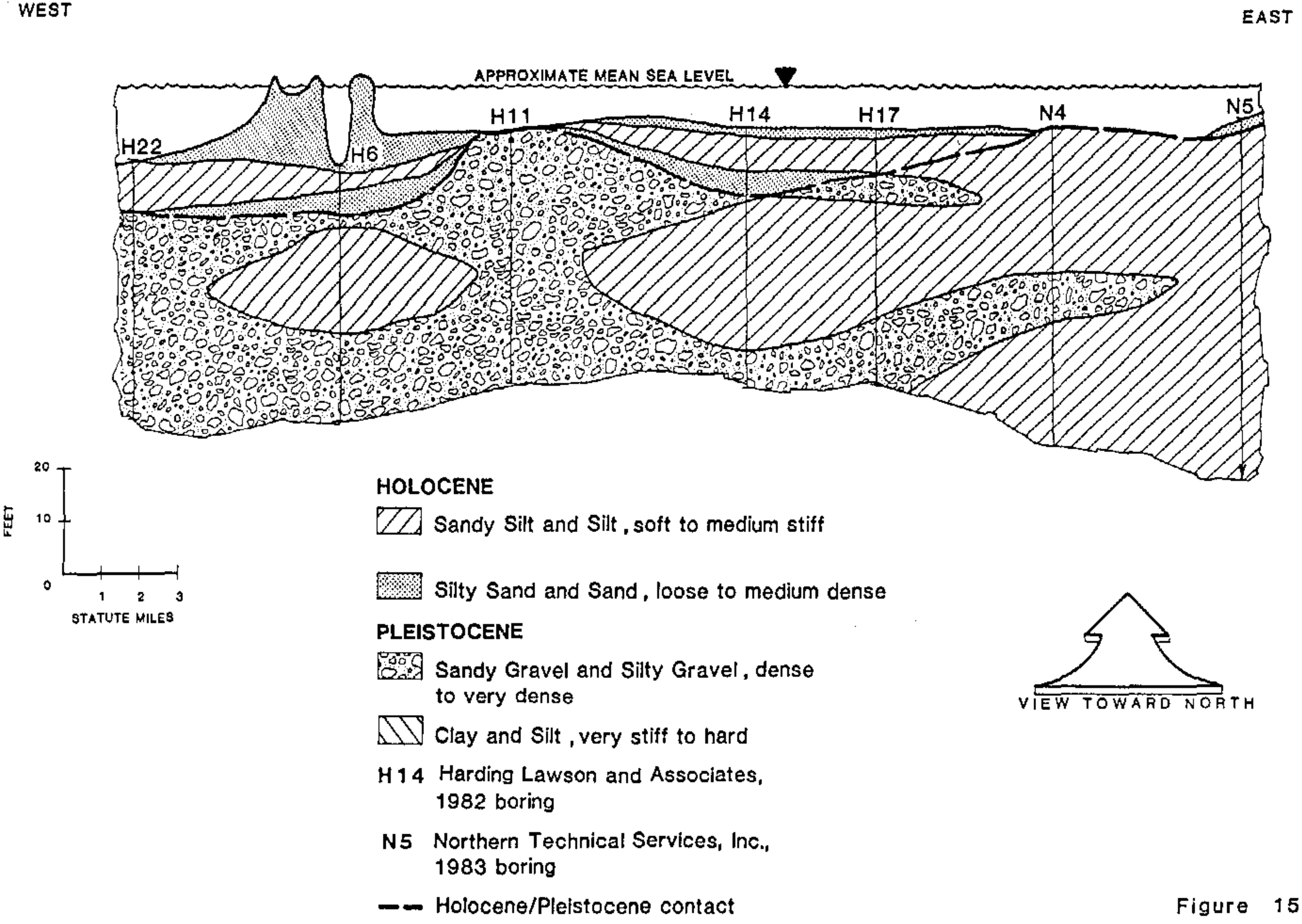

WEST
EAST
APPROXIMATE MEAN SEA LEVEL
H22
H6
H11
H14
H17
N4
N5
20
10
0
FEET
1
2
3
STATUTE MILES
HOLOCENE
▨ Sandy Silt and Silt, soft to medium stiff
▒ Silty Sand and Sand, loose to medium dense
PLEISTOCENE
▒ Sandy Gravel and Silty Gravel, dense to very dense
▧ Clay and Silt, very stiff to hard
H14 Harding Lawson and Associates, 1982 boring
N5 Northern Technical Services, Inc., 1983 boring
—— Holocene/Pleistocene contact
VIEW TOWARD NORTH

Figure 15.

.AST

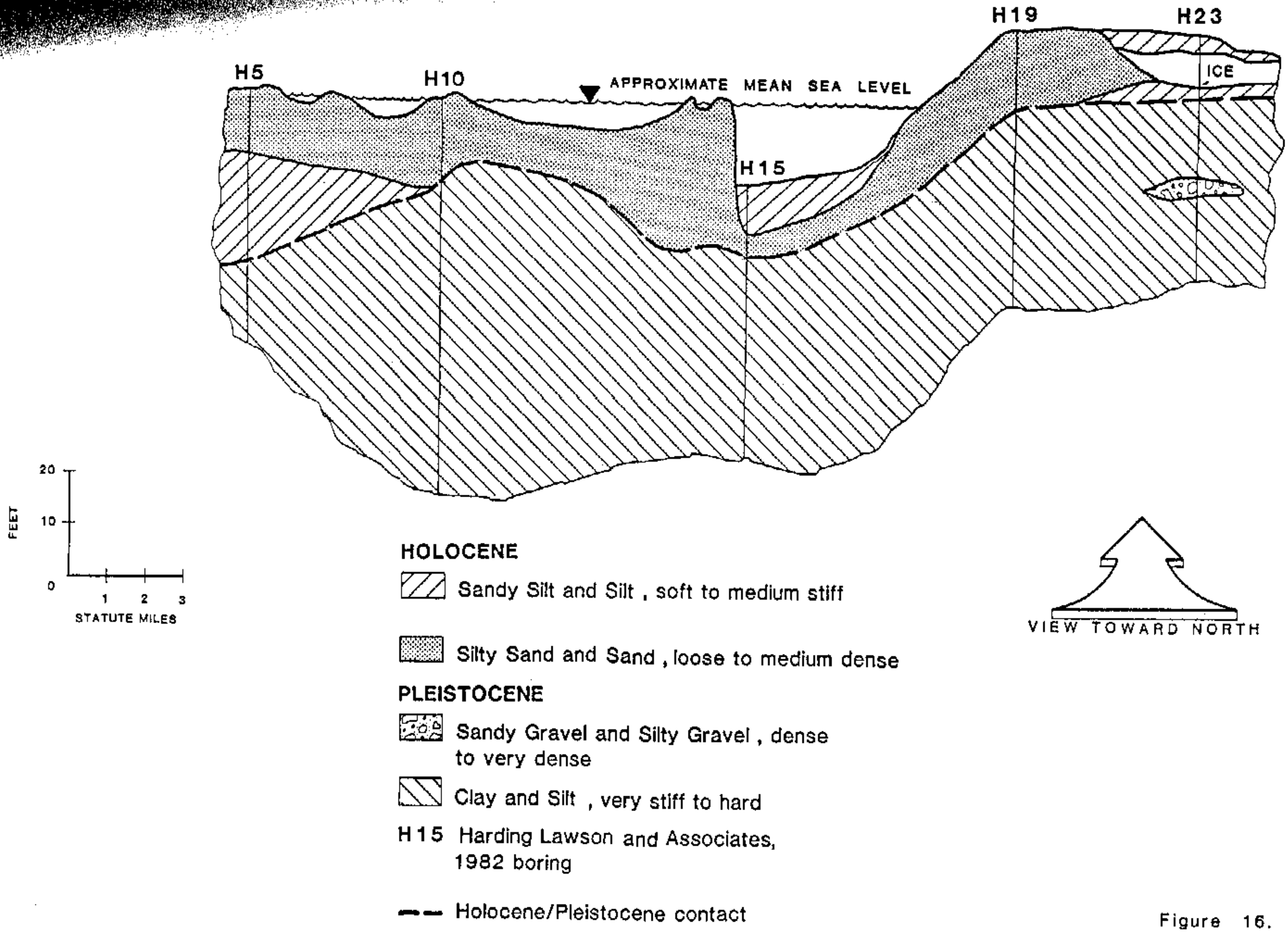


Figure 16.

GENERALIZED SOILS PROFILE SEAWARD OF THE BARRIER ISLANDS

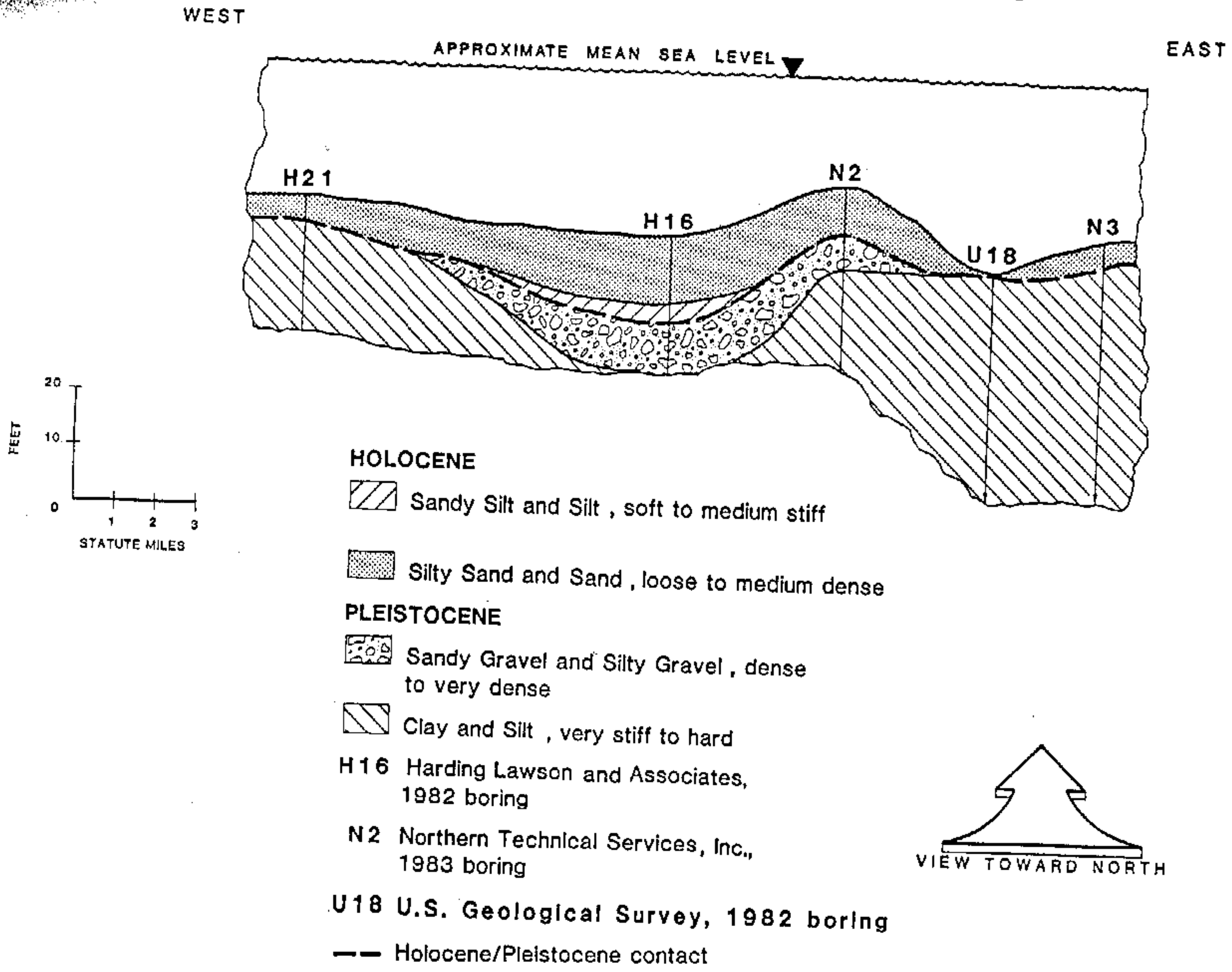
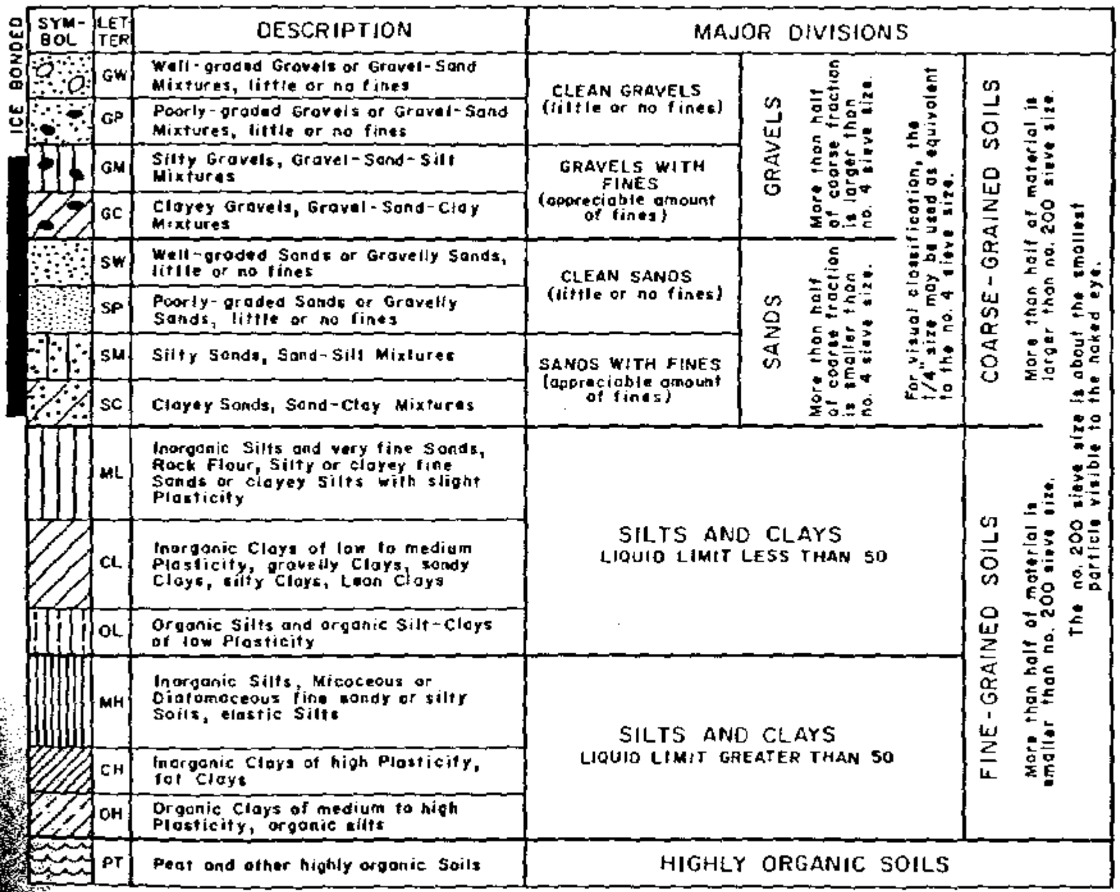


Figure 17.

SOIL CLASSIFICATION CHART



	SYMBOL	LETTER	DESCRIPTION	MAJOR DIVISIONS						
ICE BONDED		GW	Well-graded Gravels or Gravel-Sand Mixtures, little or no fines	CLEAN GRAVELS (little or no fines)	GRAVELS	More than half of coarse fraction is larger than no. 4 sieve size.	For visual classification, the 1/4" size may be used as equivalent to the no. 4 sieve size.	COARSE-GRAINED SOILS	More than half of material is larger than no. 200 sieve size.	The no. 200 sieve size is about the smallest particle visible to the naked eye.
		GP	Poorly-graded Gravels or Gravel-Sand Mixtures, little or no fines							
		GM	Silty Gravels, Gravel-Sand-Silt Mixtures	GRAVELS WITH FINES (appreciable amount of fines)						
		GC	Clayey Gravels, Gravel-Sand-Clay Mixtures							
		SW	Well-graded Sands or Gravelly Sands, little or no fines	CLEAN SANDS (little or no fines)	SANDS	More than half of coarse fraction is smaller than no. 4 sieve size.				
		SP	Poorly-graded Sands or Gravelly Sands, little or no fines							
		SM	Silty Sands, Sand-Silt Mixtures	SANDS WITH FINES (appreciable amount of fines)						
		SC	Clayey Sands, Sand-Clay Mixtures							
		ML	Inorganic Silts and very fine Sands, Rock Flour, Silty or clayey fine Sands or clayey Silts with slight Plasticity	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50				FINE-GRAINED SOILS	More than half of material is smaller than no. 200 sieve size.	
		CL	Inorganic Clays of low to medium Plasticity, gravelly Clays, sandy Clays, silty Clays, Lean Clays							
		OL	Organic Silts and organic Silt-Clays of low Plasticity							
		MH	Inorganic Silts, Micaceous or Diatomaceous fine sandy or silty Soils, elastic Silts	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50						
		CH	Inorganic Clays of high Plasticity, fat Clays							
		OH	Organic Clays of medium to high Plasticity, organic silts							
		PT	Peat and other highly organic Soils	HIGHLY ORGANIC SOILS						

UNIFIED SOIL CLASSIFICATION SYSTEM

APPENDIX

STATISTICAL ANALYSIS WORKSHEETS

Summary of Results

3) Comparison of HLA and NT Borings – 5b Layer

a) Using F test, found no significant differences between moisture content variances of NT Borings 1, 2, 3, 5 and HLA Borings 2, 4, 6, 8, 9, 14, 15, 17, 21 in 5 b Layer ($\alpha = .05$

b) Using t test with pooled variance, found significant difference between mean moisture contents of NT Borings 1, 2, 3, 5 and HLA Borings 2, 4, 6, 8, 9, 14, 15, 17, 21 in 5 b Layer ($\alpha = .05$; $p << .005$).
Conclusion: NT Borings should not be combined with HLA Borings (i.e. within the gravel layer there should be two subdivisions by area).

Summary of Results (Cont'd)

4) Comparison of HLA Borings - 5a Layer

a) Using Single Classification ANOVA for Unequal Sample Sizes, found significant differences between moisture content variances of Borings 2, 4, 5, 6, 9, 14, 15, 17 and 22 ($\alpha = .05$). Borings 3 and 20 each contained only one observation and were therefore excluded from these analyses. Because variances were significantly different between Borings, cannot use parametric methods that assume samples come from the same normally distributed population.

b) Using the non-parametric Kruskal-Wallis one-way analysis of variance by ranks, median moisture contents were significantly different for Borings 2, 4, 5, 6, 9, 14, 15, 17 and 22 ($\alpha = .05$). The test statistic was not corrected for ties because it was already significant at $\alpha = .05$ (correction for ties is used when the test statistic H reveals no significant difference).

c) Used multiple comparison procedure (non-parametric method) to compare median moisture contents individually. This procedure uses higher alpha values (e.g. $\alpha = .15, .20, .25$) than those customarily used in single-comparison inference procedures.
When $\alpha = .25$, there were significant differences between Borings 4 and 9, 4 and 14 (also significantly different at $\alpha = .15$), and 5 and 14. ause se results and that Borings 4 and 5 showed the highest mean values for moisture content ($\bar{X}_4 = 41.33$, $\bar{X}_5 = 40.50$), by separately analyzing the #4+5 Borings, the heterogeneity of the 5a Layer would be better described in terms of 2 subgroupings.

Summary of Results (Cont'd)

d) Comparison of Group 1 (Borings 4 + 5) and Group 2 (Borings 2, 6, 9, 14, 15, 17, 22)

i. Using F test, found <u>no</u> significant differences between moisture content variances <u>within</u> Group 1 (Borings 4 and 5) at $\alpha = .05$. Using t test with pooled variance, found <u>no</u> significant difference between mean moisture contents of Borings 4 and 5. ($\alpha = .05$).
<u>Conclusion</u>: Group 1 is homogeneous; combine borings 4 and 5 for subsequent analysis.

ii. Using Single Classification ANOVA for Unequal Sample Sizes, found <u>no</u> significant difference between moisture content variances of Borings 2, 6, 9, 14, 15, 17 and 22 ($\alpha = .05$).
Using Multiple Comparison of Pairs of Means (unequal sample sizes; unplanned comparisons) - GT2 Method, found <u>no</u> significant difference between mean moisture contents for Borings 2, 6, 9, 14, 15, 17 and 22 ($\alpha = .05$)
<u>Conclusion</u>: Group 2 is homogeneous: combine Borings 2, 6, 9, 14, 15, 17 and 22 for subsequent analysis.

iii. Using F test, found <u>no</u> significant differences between moisture content variances in Group 1 and Group 2 ($\alpha = .05$). Using t test with pooled variance, found significant difference between mean moisture content of Group 1 and Group 2 ($\alpha = .05$).
<u>Conclusion</u>: The 5a Layer HLA Borings should be divided into at least 2 groups where Group 1 = Borings 4 and 5
Group 2 = Borings 2, 6, 9, 14, 15, 17 and 22.
The mean moisture content should be reported separately for these 2 groups.

Summary of Results (Cont'd)

5) Comparison of HLA Borings – 3/4 Layer

a) Using Single Classification ANOVA for Unequal Sample Sizes, found significant differences between moisture content variances of Borings 2, 4, 6, 9, 10, 14, 15, 16, 17, 21, and 22 ($\alpha = .05$). Boring 20 contained only one observation and was therefore excluded from these analyses. Because variances were significantly different between Borings, cannot use parametric methods that assume samples come from the same normally distributed population.

b) Using the non-parametric Kruskal-Wallis one-way analysis of variance by ranks, median moisture contents were significantly different for Borings 2, 4, 6, 9, 10, 14, 15, 16, 17, 21 and 22 ($\alpha = .05$). The test statistic was not corrected for ties because it was already significant at $\alpha = .05$ (correction for ties is used when the test statistic H reveals no significant difference).

c) Used multiple comparison procedure (non-parametric method) to compare median moisture contents individually. This procedure uses higher alpha values (e.g. $\alpha = .15, .20, .25$) than those customarily used in single-comparison inference procedures.
When $\alpha = .15$, there were significant differences between Borings 15 and 17, 16 and 17, 17 and 22, and 16 and 21. At $\alpha = .25$, Borings 15 and 21 also differed significantly. Because of these results, their spatial location, and that Borings 15, 16 and 22 showed the highest mean values for moisture content ($\overline{X}_{15} = 27.10$, $\overline{X}_{16} = 29.97$, $\overline{X}_{22} = 26.80$), by separately analyzing the #15, 16, 22 Borings the heterogeneity of the 3/4 Layer would

Summary of Results (Cont'd)

better described in terms of 3 subgroupings.

Comparison of Group 1 (Borings 2, 4, 6, 9, 10, 14, 17, 21), up 2 (Borings 15 + 16) and Group 3 (Boring 22).

i. Using Single Classification ANOVA for Unequal Sample Sizes, found <u>no</u> significant difference between moisture content variances of Borings 2, 4, 6, 9, 10, 14, 17, and 21 ($\alpha = .05$). Using Multiple Comparison of Pairs of Means (unequal sample sizes; unplanned comparisons) - GT2 Method, found HLA 4 differed significantly from HLA 17 ($\alpha = .05$). Due to these results and spatial location, moved HLA 4 to Group 3.

Comparison of Group 1 (Borings 2, 6, 9, 10, 14, 17, 21), oup 2 (Borings 15 + 16) and Group 3 (Borings 4 + 22).

i. Using Single Classification ANOVA for Unequal Sample Sizes, found <u>no</u> significant difference between moisture content variances <u>within</u> Group 1 orings 2, 6, 9, 10, 14, 17 and 21) ($\alpha = .05$). Using Multiple Comparison of Pairs of Means (unequal sample sizes; unplanned comparisons) - GT2 Method, found <u>no</u> significant difference between mean moisture contents for Borings 2, 6, 9, 10, 14, 17 and 21 ($\alpha = .05$).
<u>Conclusion</u>: Group 1 is homogeneous; combine Borings 2, 6, 9, 10, 14, 17 and 21 for subsequent analysis.

ii. Using F test, found <u>no</u> significant differences between moisture content variances <u>within</u> Group 2 (Borings 15 + 16) at $\alpha = .05$. Note, however, that small sample size ($n_{15} = 3$, $n_{16} = 3$)

Summary of Results (Cont'd)

caused the critical value (F_{CRIT}) to be quite high (i.e. much more variation is "allowed" before the test would show significant differences). Using t test, found <u>no</u> significant difference between mean moisture contents for Borings 15 and 16 ($\alpha = .05$).
<u>Conclusion</u>: Group 2 is homogeneous; combine Borings 15 and 16 for subsequent analysis.

iii. Using F test, found <u>no</u> significant differences between moisture content variances <u>within</u> Group 3 (Borings 4 and 22) at $\alpha = .05$. Note, however, that small sample size ($n_4 = 3$, $n_{22} = 3$) caused the critical value (F_{CRIT}) to be quite high (i.e. much more variation is "allowed" before the test would show significant differences). Using t test, found <u>no</u> significant difference between mean moisture contents for Borings 4 and 22 ($\alpha = .05$).
<u>Conclusion</u>: Group 3 is homogeneous; combine Borings 4 and 22 for subsequent analysis.

iv. Using Single Classification ANOVA for Unequal Sample Sizes, found significant differences between moisture content variances of Groups 1, 2 and 3 ($\alpha = .05$). Because variances were significantly different between Borings, cannot use parametric methods that assume samples come from the same normally distributed population.

v. Using the non-parametric Kruskal-Wallis one-way analysis of variance by ranks, median moisture contents were significantly different for Groups 1, 2 and 3 ($\alpha = .05$). The test statistic was not corrected for ties because it was already

Summary of Results (Cont'd)

significant at $\alpha = .05$ (correction for ties is used to increase the test statistic when it reveals no significant difference).

vi. Used multiple comparison procedure (non-parametric method) to compare median moisture contents individually. This procedure uses higher alpha values (e.g. $\alpha = .15, .20, .25$) than those customarily used in single-comparison inference procedures. At $\alpha = .15$ (only significance level used when number of groups is small), there were significant differences between Groups 1 and 2, and 1 and 3. Conclusion: The 3/4 Layer HLA Borings should be divided into at least 3 groups where

Group 1 = Borings 2, 6, 9, 10, 14, 17 and 21
Group 2 = Borings 15 and 16
Group 3 = Borings 4 and 22

The mean moisture content should be reported separately for these 3 groups.

Although Groups 2 and 3 were not significantly different, it makes no sense to combine these 2 groups when spatial location is considered.

Ties 2 2
2 2/16
4
2
2

1 of 2

HLA Borings — 3/4 Layer [Holocene Sands]

LA Boring	Moisture Content	Rank	x_i^2		Soil Class	Dick's Class
2	23.4	25.5		$s^2 = .26$	SP	3a
5	22.8	20.5			SP	↓
= 22.80	22.0	10		$s = .51$	SP	
	23.0	23			SPSM	
	22.8	20.5			SP	
	Σ 114.00		Σ 2600.24			
4	22.7	18.5		$s^2 = 4.88$	SP	
n = 3	24.5	30			SP	
= 24.77	27.1	37		$s = 2.21$	SM	
	Σ 74.3		Σ 1849.95			
2	22.5	15.5		$s^2 = 0$	SM	
$\bar{x} = 22.50$	22.5	15.5			SM	
	Σ 45.0		Σ 1012.5	$s = 0$		
	23.7	28			SM	
= 23.03	22.5	15.5		$s^2 = .96$	↓	
	22.1	11.5				
	24.7	31		$s = .98$		
	22.5	15.5				
	22.7	18.5				
	Σ 138.2		Σ 3187.98			
	19.4	1		$s^2 = 6.81$	SM	
3	23.2	24			↓	
= 22.33	24.4	29		$s = 2.61$		
	Σ 67.0		Σ 1509.96			
	21.7	7.5		$s^2 = 2.92$	SM	
23.00	21.6	6			↓	
	25.2	35		$s = 1.71$		
	23.5	27				
	Σ 92.0		Σ 2124.74			

2 of 2

HLA Borings - 3/4 Layer (Cont'd)

	Moisture Content	Rank	x_i^2		Soil Class	
5	27.3	38		$s^2 = 1.02$	SM	
3	26.0	36			↓	
27.10	28.0	39		$s = 1.01$		
	Σ81.3		Σ2205.29			
	25.1	33.5		$s^2 = 17.98$	SM	
n=3 x̄=29.97	31.9	41				
	32.9	42		$s = 4.24$	↓	
	Σ89.9		Σ2730.03			
	21.8	9			SP	
4 3	19.9	3		$s^2 = 1.90$		
20	22.4	13		$s = 1.38$	↓	
	19.6	2				
	Σ83.7		Σ1757.17			
	~~42.9~~			$s^2 =$	SM	Exclude
1	Σ42.9		Σ1840.41	$s =$		
42.9						
1	23.4	25.5			SPSM	
	22.9	22		$s^2 = .96$		
6 22.03	21.3	5				
	21.7	7.5		$s = .98$		
	22.1	11.5				
	20.8	4			↓	
	Σ132.2		Σ2917.6			
	30.5	40		$s^2 = 10.30$	SM	
3 30	24.8	32				
	25.1	33.5		$s = 3.21$	↓	
	Σ80.4		Σ2175.30			

1 of 10

Comparison of HLA Borings - 3/4 Layer

a = 11

	n	Σx_i	Σx_i^2	$\bar{x}$	s^2	s	$s^2_{\bar{x}_i} = \frac{1.64}{n_i}$
	5	114.0	2600.24	22.80	126	.51	.3360
	3	74.3	1849.95	$\boxed{24.77}$	4.88	2.21	
	2	45.0	1012.50	22.50	0	0	.840
	6	138.2	3187.98	23.03	.96	.98	.280
	3	67.0	1509.96	22.33	6.81	2.61	.56
	4	92.0	2124.74	23.00	2.92	1.71	.42
	3	81.3	2205.29	27.10'	1.02	1.01	
	3	89.9	2730.03	29.97	17.98	4.24	
	4	83.7	1757.17	20.93	1.90	1.38	.42
	6	132.2	2917.60	22.03	.96	.98	.28
22	3	80.4	2175.30	$\boxed{26.80}$	10.30	3.21	
Σ	42	998.0	24070.76				

$$\frac{(\Sigma x_i)^2}{n} = \frac{(114)^2}{5} + \frac{(74.3)^2}{3} + \frac{(45)^2}{2} + \frac{(138.2)^2}{6} + \frac{(67)^2}{3} + \frac{(92)^2}{4} +$$

$$\frac{(81.3)^2}{3} + \frac{(89.9)^2}{3} + \frac{(83.7)^2}{4} + \frac{(132.2)^2}{6} + \frac{(80.4)^2}{3} = 23963.59$$

$$CT = \frac{(\Sigma \Sigma x_i)^2}{\Sigma n} = \frac{(998)^2}{42} = 23714.38$$

$$\Sigma x_i^2 - CT = 24070.76 - 23714.38 = 356.38 = SS_{TOTAL}$$

Comparison of HLA Borings - 3/4 Layer (Cont'd)

$\sum\left(\frac{(\sum x_i)^2}{n}\right) - CT = 23963.59 - 23714.38 = 249.21 = SS_{groups}$

$SS_{WITHIN} = SS_{TOTAL} - SS_{groups} = 356.38 - 249.21 = 107.17$

Source of Variation	d.f.	SS	MS	F_s
Among Groups (Borings) $(a = 11) \rightarrow a-1$	10	249.21	24.92	7.21***
Within Groups $(\sum n - a)$	31	107.17	3.46	
T[illegible]l	41	356.38		

F[illegible]$(10, 31) \cong 2.16$

Variances are significantly
different at $\alpha = .05$.
Must do non-parametric method.

[illegible] - Wallis oneway analysis of variance by ranks:

[illegible]ing	n_i	R_i	$\bar{R}_i$
2	5	99.5	19.90
4	3	85.5	28.50
6	2	31.0	15.50
9	6	120.0	20.00
10	3	54.0	18.00
14	4	75.5	18.88
15	3	113.0	37.67
16	3	116.5	38.83
[illegible]	4	27.0	6.75
[illegible]	6	75.5	12.58
[illegible]	3	105.5	35.17
	n = 42	903	

d.f. → 11-1 = 10 d.f.

$\chi^2_{.05(10)} = 18.31$

Kruskal-Wallis test statistic H

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

$$= \frac{(99.5)^2}{5} + \frac{(85.5)^2}{3} + \frac{(31)^2}{2} + \frac{(120)^2}{6} + \frac{(54)^2}{3} + \frac{(75.5)^2}{4} + \frac{(113)^2}{3} + \frac{(116.5)^2}{3} + \frac{(27)^2}{4} + \frac{(75.5)^2}{6} + \frac{(105.5)^2}{3} =$$

$$\frac{12}{42(43)}\left[23317.1542\right] - 3(43) =$$

$$154.93 - 129 = 25.93$$

Comparison of HLA Borings - 3/4 Layer (Cont'd)

ed to correct for ties (i.e. increase H_{CALC}) since e is already significant at $\alpha = .05$

Kruskal - Wallis, conclude medians are ficantly different ($\alpha = .05$)

Compare Each Boring, do Multiple Comparison Test:

11 (11)(10)/2 = 55 comparisons

$\alpha = .15, .20$ or $.25$ for multiple comparisons

$.15)/11(10) = z_{.0014} \cong 2.98 \quad \alpha = .15 \quad \bar{R}_i - \bar{R}_j \leq 2.98\sqrt{\frac{42(43)}{12}\left(\frac{1}{n_i}+\frac{1}{n_j}\right)}$

$z_{.0023} \rightarrow \alpha = .25 \qquad 2.84$

ed	Diff. in Means of Ranks	$\frac{1}{n_i} + \frac{1}{n_j}$	Signif. Value $\alpha = .15$	Signif. Value ($\alpha = .25$)
17	13.15	.2 + .25 = .45	24.52	23.37
17	21.75	.33 + .25 = .58	27.84	26.53
17	8.75	.5 + .25 = .75	31.66	30.17
17	13.25	.17 + .25 = .42	23.69	22.58
17	11.25	.33 + .25 = .58	27.84	26.53
17	12.13	.25 + .25 = .50	25.85	24.64
17	30.92**	.33 + .25 = .58	27.84	26.53
17	32.08**	.33 + .25 = .58	27.84	26.53
21	5.83	.25 + .17 = .42	23.69	22.58
2	28.42**	.25 + .33 = .58	27.84	26.53
1	25.09*	.33 + .17 = .50	25.85	24.64
21	26.25**	.33 + .17 = .50	25.55	24.64
2	22.59	.17 + .33 = .50	25.85	24.64
15	22.17	.5 + .33 = .83	33.31	31.74
16	23.33	.5 + .33 = .83	33.31	31.74
15	19.67	.33 + .33 = .66	29.70	28.31
16	20.83	.33 + .33 = .66	29.70	28.31
2	17.17	.33 + .33 = .66	29.70	28.31

Comparison of HLA Borings – 3/4 Layer (Cont'd)

plit into 3 (more homogeneous) groupings
↳ considering spatial location when groupings formed

oup 1	Group 2	Group 3
,9, 10, 14, 17, 21	15, 16	→ 22

ting for differences within Group 1

Borings	$s^2_{\bar{x}_i}$	n	Σx_i	Σx_i^2	$\bar{x}$	s^2	s
2	.3880	5	114.0	2600.24	22.80	.26	.51
4	.6467	3	74.3	1849.95	24.77	4.88	2.21
6	.9700	2	45.0	1012.50	22.50	0	0
9	.3233	6	138.2	3187.98	23.03	.96	.98
10	.6467	3	67.0	1509.96	22.33	6.81	2.61
14	.4850	4	92.0	2124.74	23.00	2.92	1.71
17	.4850	4	83.7	1757.17	20.93	1.90	1.38
21	.3233	6	132.2	2917.60	22.03	.96	.98
		33	746.4	16960.14			

$$\frac{(\Sigma x_i)^2}{n} = 23963.59 - 7051.95 = 16911.64$$

$$CT = \frac{(\Sigma \Sigma x_i)^2}{\Sigma n} = \frac{(746.4)^2}{33} = 16882.21$$

$$\Sigma x_i^2 - CT = 16960.14 - 16882.21 = 77.93 = SS_{TOTAL}$$

Comparison of HLA Borings – 3/4 Layer (Cont'd)

lit into 3 (more homogeneous) groups

$\left(\frac{(\Sigma x_i)^2}{n}\right) - CT = 16911.64 - 16882.21 = 29.43 = SS_{groups}$

$S_{WITHIN} = SS_{TOTAL} - SS_{GROUPS} = 77.93 - 29.43 = 48.50$

Source of Variation	d.f.	SS	MS	F_s
Among Groups (Borings) $(a=8) \rightarrow a-1$	7	29.43	4.20	2.16
Within Groups $(\Sigma n - a)$	25	48.50	1.94	
Total	32	77.93		

$F_{.05}(7, 25) \cong 2.41$ Variances are <u>not</u> significantly different at $\alpha = .05$.

ultiple Comparison of Pairs of Means
(Unequal Sample Size; Unplanned Comparisons)

led variance $= MS_{WITHIN} = \frac{\Sigma(n_i - 1)s_i^2}{\Sigma(n_i - 1)} =$

$\frac{(.26) + 2(4.88) + 1(0) + 5(.96) + 2(6.81) + 3(2.92) + 3(1.90) + 5(.76)}{4+2+1+5+2+3+3+5} =$

$\frac{49.48}{25} = 1.94$ $v = \Sigma(n_i - 1) = 25$

T2 Method $k = a = 8$ $\alpha = .05$
$v = 25$

$[k(k-1)/2, v] = m_{.05}[28, 25]$ For table $m_{.05}[8, 25] \cong 3.462$ Table 21 Sokal + Rohlf

4.374

Comparison of HLA Borings – 3/4 Layer (Cont'd)

into 3 (more homogeneous) groups

$\frac{MS_{WITHIN}}{n_i}$ lower limit $= l_i = \bar{x}_i - \sqrt{\tfrac{1}{2}}\,(m_\alpha[8,25])(s^2_{\bar{x}_i})^{1/2}$

upper limit $= u_i = \bar{x}_i + \sqrt{\tfrac{1}{2}}\,(m_\alpha[8,25])(s^2_{\bar{x}_i})^{1/2}$

A	HLA4	HLA6	HLA9	HLA10	HLA14	HLA17	HLA21
[illegible]	26.7386	24.9110	24.4219	24.2986	24.7048	22.6348	23.4219
.2351	22.8014	20.0890	21.6381	20.3614	21.2952	19.2252	20.6381
5249	1.9686	2.4110	1.3919	1.9686	1.7048	1.7048	1.3919

HLA 4 differs significantly from HLA17 ($\alpha = .05$)
cided that HLA4 should be moved to Group 3
due to these results and spatial location.

Group 1	Group 2	Group 3
2, 6, 9, 10, 14, 17, 21	15, 16	4, 22

Testing for differences within Group 1
n Boring #4

$\frac{(\Sigma x_i)^2}{n} = 16911.64 - 1840.16 = 15071.48$

$T = \frac{(672.1)^2}{30} = 15057.28$ $\qquad \Sigma x_i^2 - CT = 15110.19 - 15057.28 = 52.91 = SS_{TOTAL}$

$\left(\frac{(\Sigma x_i)^2}{n}\right) - CT = 15071.48 - 15057.28 = 14.2 = SS_{groups}$

$_{ITHIN} = SS_{TOTAL} - SS_{GROUPS} = 52.91 - 14.2 = 38.71$

Comparison of HLA Borings – 3/4 Layer (Cont'd)

of Variation	d.f.	SS	MS	F_s
Groups (Borings) $(a=7) \to a-1$	6	14.2	2.37	1.41
in Groups $(\Sigma n - a)$	23	38.71	1.68	
l	29	52.91		

$_{.05}(6,23) \cong 2.52$ Variances are <u>not</u> significantly different at $\alpha = .05$

ple Comparison of Pairs of Means
nequal Sample Size; Unplanned Comparisons)

l variance $= MS_{WITHIN} = 1.68$ $v = 23$

Method $k = 7$ $\alpha = .05$

$(k-1)/2, v] = m_{,05}[21, 23]$ For table use k $m_{,05}[7, 23] \cong 3.369$ Table 21 Sokal + Rohlf

LA 2	HLA 6	HLA 9	HLA 10	HLA 14	HLA 17	HLA 21
4.1809	24.6834	24.2906	23.6641	24.5439	22.4739	23.2906
21.4191	20.3166	21.7694	20.9959	21.4561	19.3861	20.7694
1.3809	2.1834	1.2606	1.3341	1.5439	1.5439	1.2606

Evident all ranges overlap extensively.

Conclusion: Group 1 Borings are homogeneous.

Comparison of HLA Borings - 3/4 Layer (Cont'd)

for differences within Group 2.

n	Σx_i	Σx_i^2	s^2	s	$\bar{x}$
3	81.3	2205.29	1.02	1.01	27.10
3	89.9	2730.03	17.98	4.24	29.97

$^2 = s_2^2$ $F_s = \frac{17.98}{1.01} = 17.80$ $F_{CRIT}(.05/2;\ 2,2) \cong 39.0$

$^2 = s_2^2$

Variances of Borings 15 and 16 do not differ signif.
.05)

for difference in means:

$= \frac{\bar{x}_1 - \bar{x}_2}{sp\sqrt{\frac{1}{N_1}+\frac{1}{N_2}}} = \frac{29.97-27.10}{3.08\sqrt{1/3+1/3}} = 1.14$ $t_{CRIT}(.05/2;\ 4) \cong 2.776$

This formula actually not necessary since sample sizes equal.

$= \frac{(N_1-1)s_1^2 + (N_2-1)s_2^2}{N_1+N_2-2} = \frac{2(1.02)+2(17.98)}{3+3-2} = \frac{38}{4} = 9.5$

$= 3.08$ Means do not differ significantly $(\alpha = .05)$

Conclusion: Group 2 is homogeneous

Testing for differences within Group 3.

ring	n	Σx_i	Σx_i^2	s^2	s	$\bar{x}$
4	3	74.3	1849.95	4.88	2.21	24.77
2	3	80.4	2175.30	10.3	3.21	26.80

Comparison of HLA Borings - 3/4 Layer (Cont'd)

$^2 = s_2^2$ $\quad F_S = \frac{10.3}{4.88} = 2.11 \quad F_{CRIT}(.05/2;2,2) \approx 39.0$

ariances of Borings 4 and 22 do <u>not</u> differ ignif. ($\alpha = .05$)

or difference in means:

$$= \frac{\bar{X}_1 - \bar{X}_2}{s_p\sqrt{\frac{1}{N_1}+\frac{1}{N_2}}} = \frac{26.8-24.77}{2.755\sqrt{\frac{1}{3}+\frac{1}{3}}} = .9024 \quad t_{CRIT}(.05/2;4) = 2.776$$

This formula not necessary since sample sizes equal.

$$\frac{(N_1-1)(s_1^2) + (N_2-1)s_2^2}{N_1+N_2-2} = \frac{2(10.3)+2(4.88)}{4} = 7.59$$

2.755 Means do not differ significantly ($\alpha = .05$)

Conclusion Group 3 is homogeneous

esting for differences between Group 1, 2 + 3.

n	Σx_i	Σx_i^2	$\bar{x}$	s^2	s	$s_{\bar{x}_i}^2 = 3.59/n_i$
30	672.1	15110.19	22.40	1.82	1.35	.1197
6	171.2	4935.32	28.53	10.08	3.18	.5983
6	154.7	4025.25	25.78	7.31	2.70	.5983
42	998.0	24070.76				

$$\left(\frac{(\Sigma x_i)^2}{n}\right) = \frac{(672.1)^2}{30} + \frac{(171.2)^2}{6} + \frac{(154.7)^2}{6} = 23930.87$$

$$= \frac{(\Sigma\Sigma x_i)^2}{\Sigma n} = \frac{(998)^2}{42} = 23714.38$$

$x_i^2 - CT = 24070.76 - 23714.38 = 356.38 = S$[illegible] arison of HLA Borings - 3/4 Layer ((ont'd)

$- CT = 23930.87 - 23714.38 = 216.49 = SS_{groups}$

$_{TOTAL} - SS_{GROUPS} = 356.38 - 216.49 = 139.89$

f Variation	df	SS	MS	Fs
roups' =3)→a-1	2	216.49	108.25	30.15
Groups (Σn-a)	39	139.89	3.59	
	41	356.38		

$_{.05(2,39)} \cong 3.23$

Variances significantly different at $\alpha = .05$
Do non-parametric method.

Wallis one-way analysis of variance by ranks

n_i	R_i	$\bar{R}_i$
30	482.5	16.08
6	229.5	38.25
6	191.0	31.83
42		

$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$

$\frac{(482.5)^2}{30} + \frac{(229.5)^2}{6} + \frac{(191)^2}{6} =$

22618.75

d.f. → 3-1 = 2 d.f.

$\chi^2_{.05(2)} = 5.99$

clude medians are significantly different $(\alpha = .05)$.

$H = \frac{12}{42(43)}(22618.75) - 3(43) =$

$150.29 - 129 = 21.29$

$\boxed{\text{Small K Use .15 ONLY}}$

ltiple Comparison Test: k = 3 3(2)/2 = 3 comparisons

$.15/3(2) = z = .025 \cong 1.95 \quad \alpha = .15 \quad \bar{R}_i - \bar{R}_j \leq 1.95\sqrt{\frac{42(43)}{12}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$

ps Compared	Diff. in Means of Ranks	$\frac{1}{n_i} + \frac{1}{n_j}$	Signif $\alpha = .15$
1, 2	22.17**	.03 + .17 = .20	10.6984
1, 3	15.75**	.03 + .17 = .20	10.6984
2, 3	6.42	.17 + .17 = .34	13.9490

HLA Borings - 5a Layer [Holocene Silts + Clays]

07

Moisture Content	Rank	x_i^2	Soil Class
33.4	39 ~~38~~	1115.56	ML
26.3	5	691.69	
31.2	26	973.44	
30.6	21	936.36	
29.0	17	841.00	
32.5	30	1056.25	
38.6	54 ~~53~~	1489.96	
38.8	55.5 ~~54.5~~	1505.44	
28.7	16	823.69	
35.7	47 ~~46~~	1274.49	
46.2	75 ~~74~~	2134.44	
42.4	67 ~~66~~	1797.76	
55.5	84 ~~83~~	3080.25	
Σ 468.9		Σ 17720.33	

$$s^2 = \frac{\Sigma x_i^2 - (\Sigma x_i)^2/N}{N-1}$$

$$s^2 = \frac{17720.33 - (468.9)^2/13}{12}$$

$$s^2 = 67.29$$

$$s = 8.20$$

Exclude

~~37.9~~		~~1436.41~~	ML
Σ 37.9		Σ 1436.41	

7.9

0

=41.33

26.4	6.5	ML
43.8	73 ~~72~~	
41.6	64 ~~63~~	
41.0	62 ~~61~~	
38.8	55.5 ~~54.5~~	
36.3	49 ~~48~~	OL
43.7	71.5 ~~70.5~~	OL
47.5	76 ~~75~~	ML
48.7	78 ~~77~~	
45.5	74 ~~73~~	
Σ 413.3		Σ 17,457.97

$$s^2 = 41.86$$

$$s = 6.47$$

A Borings - 5a Layer (Cont'd)

Moisture Content	Rank	x_i^2	Soil Class
33.0	34		ML
34.8	43 ~~42~~		ML
52.0	80 ~~79~~		ML
38.4	53 ~~52~~		ML
35.5	46 ~~45~~		ML
39.5	58 ~~57~~		CL
36.6	50 ~~49~~		CL
42.3	66 ~~65~~		CL
52.4	82 ~~81~~		ML

Σ 364.5

Σ 15,173.71

$s^2 = 51.43$

$s = 7.17$

SMML

ML

31.6	27	
29.2	18	
30.4	20	
34.7	42 ~~41~~	
33.4	39 ~~38~~	
32.3	29 ~~29~~	

93

Σ 191.6

Σ 6138.3

$s^2 = 3.96$

$s = 1.99$

ML

22.6	1	
28.2	13	
28.2	13	
26.4	6.5	
34.2	41 ~~40~~	
28.4	15	
27.4	10.5	
35.0	44.5 ~~43.5~~	
28.2	13	
37.0	51.5 ~~50.5~~	
41.8	65 ~~64~~	
40.7	~~60~~ 61	
51.3	~~78~~ 79	
37.6	~~50.5~~ 51.5	

33.31

$s^2 = 60.06$

$s = 7.75$

Σ 16,318.82

Σ 466.4

1. HLA Borings – 5a Layer (Cont'd)

HLA Boring	Moisture Content	Rank	x_i^2		Soil Class
4	27.1	9			ML
7	26.7	8			
30.47	31.1	24		$s^2 = 6.76$	
	33.1	36			
	33.1	36		$s = 2.60$	
	31.1	24			
	31.1	24			↓
	Σ 213.3		Σ 6540.15		
	32.8	33			ML
	35.0	~~43.5~~ 44.5			
	36.0	~~47~~ 48			
7.77	39.0	~~56~~ 57		$s^2 = 28.09$	
	43.2	~~68~~ 69			
	40.5	~~58.5~~ 59.5		$s = 5.30$	
	47.8	~~76~~ 77			
	33.4	~~38~~ 39			
	32.2	28			↓
	Σ 339.9		Σ 13,061.57		
	32.6	31.5			CLML
	32.6	31.5			CLML
7.77	29.7	19		$s^2 = 66.10$	CLML
	43.4	~~69~~ 70			ML
	33.1	36		$s = 8.13$	ML
	52.5	~~82~~ 83			ML
	40.5	~~58.5~~ 59.5			ML
	Σ 264.4		Σ 10,383.28		
	~~53.8~~			Exclude	
3.8	Σ 53.8		Σ 2894.44		ML

HLA Borings - 5 a Layer (Cont'd)

Moisture Content	Rank	x_i^2
24.5	2	
25.8	4	
27.4	10.5	
25.0	3	
30.7	22	
42.7	~~67~~ 68	
43.7	~~70.5~~ 71.5	
41.4	~~62~~ 63	
52.3	~~80~~ 81	
Σ 313.5		Σ11,766.37

4.83

$s^2 = 105.68$

$s = 10.28$

Soil Class

ML

↓

CL

roups

$2(8) + 3(4) = 28$

~~33.1~~

Method of Sokal
+ Rohlf (1981) and
Daniel (1978)

1 of 8

Comparison of HLA Borings - 5a Layer

$a = 9$

Boring	n	Σx_i	Σx_i^2	$\bar{x}$	s^2	s	
2	13	468.9	17720.33	36.07	67.29	8.20	
~~3~~	~~1~~	~~37.9~~	~~1436.41~~	~~37.90~~	~~—~~	~~—~~	Exclud
4	10	413.3	17457.97	41.33	41.81	6.47	
	9	364.5	15173.71	40.50	51.43	7.17	
	6	191.6	6138.30	31.93	3.96	1.99	
	14	466.4	16318.82	33.31	60.06	7.75	
	7	213.3	6540.15	30.47	6.76	2.60	
	9	339.9	13061.57	37.77	28.09	5.30	
	7	264.4	10383.28	37.77	66.10	8.13	
	~~1~~	~~53.8~~	~~2894.44~~	~~53.80~~	~~—~~	~~—~~	Exclude
	9	313.5	11766.37	34.83	105.68	10.28	
	84	3035.8	114560.50				

$$= \frac{(468.9)^2}{13} + \frac{(413.3)^2}{10} + \frac{(364.5)^2}{9} + \frac{(191.6)^2}{6} + \frac{(466.4)^2}{14} + \frac{(213.3)^2}{7} +$$

$$\frac{(339.9)^2}{9} + \frac{(264.4)^2}{7} + \frac{(313.5)^2}{9} = 110656.47$$

$$\frac{(\Sigma\Sigma x_i)^2}{\Sigma n} = \frac{(3035.8)^2}{84} = 109715.26$$

$$- CT = 114560.50 - 109715.26 = 4845.24 = SS_{TOTAL}$$

Comparison of HLA Borings - 5a Layer (Cont'd)

$\frac{x_i)^2}{n}\Big) - CT = 110656.47 - 109715.26 = 941.21 = SS_{groups}$

$_{N} = SS_{TOTAL} - SS_{groups} = 4845.24 - 941.21 = 3904.03$

of Variation	df	SS	MS	F_s
Groups (Borings) (a=9) → a−1	8	941.21	117.65	2.26
Groups (Σn−a)	75	3904.03	52.05	
	83	4845.24		

$_{05}(8,75) \cong 2.08$ Variances significantly different at $\alpha = .05$.

Must do non-parametric metho

- Wallis one-way analysis of variance by ranks:

ring	n_i	R_i	$\bar{R}_i$
	13	536.50	41.27
	10	609.50	60.95
	9	512.00	56.89
	6	175.00	29.17
	14	465.50	33.25
	7	161.00	23.00
	9	455.00	50.56
	7	330.50	47.21
	9	325.00	36.11

Kruskal-Wallis test statistic H

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

$$\frac{(536.5)^2}{13} + \frac{(609.5)^2}{10} + \frac{(512)^2}{9} +$$

$$\frac{(175)^2}{6} + \frac{(465.5)^2}{14} + \frac{(161)^2}{7} +$$

$$\frac{(455)^2}{9} + \frac{(330.5)^2}{7} + \frac{(325)^2}{9} \Rightarrow$$

d.f. → 9−8 = 8 d.f.

$$\frac{12}{84(85)}(163045.33) - 3(85) =$$

$$274.03 - 255 = 19.03$$

$^2_{.05(8)} = 15.507$

ed to correct for ties (i.e. increase H_{CALC}) since is already significant at $\alpha = .05$.

Comparison of HLA Borings - 5a Layer (Cont'd)

m Kruskal-Wallis, medians are significantly different at $\alpha = .05$.

Compare each boring, do <u>Multiple Comparisons Test</u>:

$k = 9 \quad 9(8)/2$ comparisons

Use $\alpha = .15, .20$ or $.25$ for multiple comparisons

$^{4}(.15)/9(8) = z_{.0021} \cong 2.85 \qquad \begin{matrix}\alpha = .15\\ \alpha = .25\end{matrix} \quad \bar{R}_i - \bar{R}_j \le \begin{matrix}2.85\\ 2.7\end{matrix}\sqrt{\frac{84(85)}{12}\left(\frac{1}{n_i}+\frac{1}{n_j}\right.}$

gs red	Diff. in Means of Ranks	$\frac{1}{n_i} + \frac{1}{n_j}$	$\alpha = .15$ Signif. Value	$\alpha = .25$
4	19.68	.08 + .1 = .18	29.49	27.94
5	4.06	.1 + .11 = .21	31.86	30.18
6	31.78	.1 + .17 = .27	36.12	34.22
9	27.70**	.1 + .07 = .17	28.66	27.15
14	37.95*	.1 + .14 = .24	34.06	32.26
,15	10.39	.1 + .11 = .21	31.86	30.18
,17	13.74	.1 + .14 = .24	34.06	32.26
22	24.84	.1 + .11 = .21	31.86	30.18
,9	23.64	.11 + .07 = .18	29.49	27.94
,14	33.89**	.11 + .14 = .25	34.76	32.93
,15	17.31	.07 + .11 = .18	29.59	28.03
,15	27.56	.14 + .11 = .25	34.96	33.12
,17	13.96	.07 + .14 = .21	31.86	30.18
,17	24.21	.14 + .14 = .28	36.79	34.85
,9	8.02	.08 + .07 = .15	26.92	25.51
,14	18.27	.08 + .14 = .22	32.82	31.09
,6	27.72	.11 + .17 = .28	36.79	34.85
,15	21.39	.17 + .11 = .28	36.79	34.85

Adjustment for ties changes critical value by a negligible amount.

Comparison of HLA Borings - 5a Layer (Cont'd)

Comparison of HLA Borings - 5a Layer
Split into 2 (more homogeneous) groupings.

roup 1	Group 2
4, 5	2, 6, 9, 14, 15, 17, 22

esting for differences within Group 1

Borings	n	Σx_i	Σx_i^2	s^2	s	$\bar{X}$
4	10	413.3	17457.97	41.81	6.47	41.33
5	9	364.5	15173.71	51.43	7.17	40.50

ances:

$$s_4^2 = \frac{17457.97 - (413.3)^2/10}{9} = 41.81$$

$$s_5^2 = \frac{15173.71 - (364.5)^2/9}{8} = 51.43$$

$H_0: s_4^2 = s_5^2$

$H_A: s_4^2 \neq s_5^2$

$F_S = \frac{51.43}{41.81} = 1.23$ $F_{CRIT}(.05/2;\ 8,9) = 4.10$

Variances of Borings 4 and 5 are not significantly different for moisture contents ($\alpha = .05$).

Test for difference in means: $H_0: \bar{X}_4 = \bar{x}_5$
$H_A: \bar{x}_4 \neq \bar{x}_5$

$$= \frac{\bar{x}_4 - \bar{x}_5}{sp\sqrt{1/N_4 + 1/N_5}} = \frac{41.33 - 40.5}{6.81\sqrt{1/10 + 1/9}} = (.83)(.3196) = .2653$$

$t_{CRIT}(.05/2;\ 17) = 2.11$

next page

Comparison of HLA Borings - 5a Layer (Cont'd)

A Borings split into 2 (more homogenous) groups.

$$= \frac{(N_5 - 1)s_5^2 + (N_4 - 1)s_4^2}{N_5 + N_4 - 2} = \frac{8(51.43) + 9(41.81)}{10 + 9 - 2} = 46.34$$

= 6.81

Mean Moisture Contents are not significantly ifferent in Borings 4 and 5 ($\alpha = .05$).

Conclusion : Group 1 Borings are homogeneous.

esting for Differences within Group 2

rings	$s^2_{\bar{x}_i}$	n	Σx_i	Σx_i^2	s^2	s	$\bar{x}$
2	4.1315	13	468.9	17720.33	67.29	8.20	36.07
6	8.9517	6	191.6	6138.30	3.96	1.99	31.93
9	3.8364	14	466.4	16318.82	60.06	7.75	33.31
4	7.6729	7	213.3	6540.15	6.76	2.60	30.47
5	5.9678	9	339.9	13061.57	28.09	5.30	37.77
17	7.6729	7	264.4	10383.28	66.10	8.13	37.77
2	5.9678	9	313.5	11766.37	105.68	10.28	34.83
		Σ 65	Σ 2258.0	Σ 81928.82			

$$\frac{(\Sigma x_i)^2}{n} = 110656.47 - \left[\frac{(413.3)^2}{10} + \frac{(364.5)^2}{9}\right] = 78812.53$$

$$CT = \frac{(2258)^2}{65} = 78439.45$$

$$\Sigma x_i^2 - CT = 81928.82 - 78439.45 = 3489.37 = SS_{TOTAL}$$

Comparison of HLA Borings - 5a Layer (Cont'd)

Borings Split into 2 (more homogeneous) groups

$\left.\frac{(\Sigma x_i)^2}{n}\right) - CT = 78812.53 - 78439.45 = 373.08 = SS_{groups}$

$_{N} = SS_{TOTAL} - SS_{groups} = 3489.37 - 373.08 = 3116.29$

ce of Variation	d.f.	SS	MS	F_s
mong Groups (Borings) $(a = 7) \rightarrow a - 1$	6	373.08	62.18	1.16
ithin Groups $(\Sigma n - a)$	58	3116.29	53.73	
Total	64	3489.37		

$F_{.05}(6,58) \cong 2.25$ Variances are <u>not</u> significantly different at $\alpha = .05$.

ple Comparison of Pairs of Means
(Unequal Sample Sices; Unplanned Comparisons)

ed variance $= MS_{WITHIN} = \frac{\Sigma(n_i - 1)s_i^2}{\Sigma(n_i - 1)} =$

$\frac{7.29) + 5(3.96) + 13(60.06) + 6(6.76) + 8(28.09) + 6(66.10) + 8(105.68)}{12 + 5 + 13 + 6 + 8 + 6 + 8}$

$\frac{39}{} = 53.71 \qquad v = 58 = \Sigma(n_i - 1)$

Method $\qquad k = a = 7 \qquad \alpha = .05$

$v = 58$

$k(k-1)/2, v] = m_{.05}[21, 58]$ For table: $m_{.05}[7, 58] \cong 3.16$ Table 21 Sokal + Rohlf

$= \frac{MS_{within}}{n_i}$

lower limit $= l_i = \bar{x}_i - \sqrt{\frac{1}{2}(m_\alpha[7,58])}(s^2_{\bar{x}_i})^{1/2}$

upper limit $= u_i = \bar{x}_i + \sqrt{\frac{1}{2}(m_\alpha[7,58])}(s^2_{\bar{x}_i})^{1/2}$

Comparison of HLA Borings - 5a Layer (Cont'd)

Borings Split into 2 (more homogeneous) groups

HLA 2	HLA 6	HIA 9	HLA 14	HLA 15	HLA 17	HLA 22
40.6118	38.6154	37.6866	36.6594	43.2286	43.9594	40.2886
31.5282	25.2446	28.9334	24.2806	32.3114	31.5806	29.3714
4.5418	6.6854	4.3766	6.1894	5.4586	6.1894	5.4586

vident from Table that all ranges overlap xtensively.

herefore, i mean moisture contents for Boring 2, 6, 9, 14, 15, 17, 22 are <u>not</u> significantly different ($\alpha = .05$)

Conclusion: Group 2 Borings are homogeneous.

esting for differences between Group 1 and 2

e no significant differences <u>within</u> HLA up 1 (Borings 4 + 5) and HLA Group 2 (Borings 6, 9, 14, 15, 17, 22) in moisture content levels, mbined all Group 1 borings; also combined Group 2 borings to test for differences tween the 2 groups.

up	n	Σx_i	Σx_i^2	s^2	s	$\bar{x}$
	19	777.8	32631.68	43.94	6.63	40.94
	65	2258.0	81925.82	54.52	7.38	34.74

$s_1^2 = s_2^2$

$s_1^2 \neq s_2^2$

$F_s = \frac{54.52}{43.94} = 1.24$ $F_{CRIT}(.05/2; 64, 18) \cong 2.34$

Variances of Group 1 + 2 do not differ significantly for moisture content ($\alpha = .05$)

Comparison of HLA Borings - 5a Layer (Cont'd)
HLA Borings Split into 2 (more homogeneous) groups
for difference in means:

$H_0 : \bar{x}_1 = \bar{x}_2$

$H_A : \bar{x}_1 \neq \bar{x}_2$

$$\frac{\bar{x}_1 - \bar{x}_2}{s_p\sqrt{1/N_1 + 1/N_2}} = \frac{40.94 - 34.74}{7.2248\sqrt{1/19 + 1/65}}$$

$$= \frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2} = \frac{(18)(43.94) + (64)(54.52)}{19 + 65 - 2} = 52.1976$$

7.2248

3.2905 $t_{CRIT(.05/2\,;\,82)} \cong 1.99$

Group 1 and Group 2 mean moisture contents are significantly different ($\alpha = .05$).

HLA Borings - 5b Layer [Pleistocene Silts & Clays]

	Moisture Content	Rank	x_i^2		Soil Class
	29.0	82	841.0	$s^2 = \frac{\sum x_i^2 - (\sum x_i)^2/N}{N-1}$	ML
	26.3	73.5	691.7	$= \frac{4851.2 - (182.4)^2/7}{6}$	ML
.06	21.2	22	449.4		ML
	21.1	21	445.2		ML
	26.3	73.5	691.7	$= 16.4$	ML
	32.5	84	1056.2		ML
	26.0	69	676.0	$s = 4.05$	ML
	$\Sigma = 182.4$		$\Sigma = 4851.2$		
	22.3	27	497.3	$s^2 = \frac{2652.3 - (115.1)^2/5}{4}$	ML
6	22.8	35.5	519.8		ML
23.02	24.4	53.5	595.4		ML
	23.1	41	533.6	$= .67$	ML
	22.5	30	506.2	$s = .82$	ML
	$\Sigma = 115.1$		$\Sigma = 2652.3$		
	24.1	49	580.8		ML
12	22.5	30	506.2	$s^2 = \frac{6896.4 - (287)^2/12}{11}$	ML
23.92	25.1	58	630.0		ML
	23.3	43.5	542.9		ML
	26.2	71.5	686.4	$= 2.94$	ML
	23.0	38.5	529.0		ML
	26.4	75.5	697.0	$s = 1.71$	ML
	23.1	41	533.6		ML
	23.1	41	533.6		ML
	20.4	15.5	416.2		ML
	25.5	63	650.2		ML
	24.3	51	590.5		ML
	$\Sigma = 287.0$		$\Sigma = 6896.4$		

HLA Borings - 5b Layer (Cont'd)

	Moist. Content	Rank	x_i^2		Soil Class
	25.6	64	655.4	$s^2 = \frac{5132.4-(202.1)^2/8}{7}$	ML
	24.1	49	580.8		ML
5.26	22.6	32.5	510.8		ML
	26.0	69	676.0	$= 3.84$	ML
	25.3	62	640.1		ML
	28.8	81	829.4	$s = 1.96$	ML
	26.4	75.5	697.0		ML
	23.3	43.5	542.9		ML
	$\Sigma = 202.1$		$\Sigma = 5132.4$		
	27.6	80	761.8	$s^2 = \frac{2522.4-(98.5)^2/4}{3}$	CL
	29.3	83	858.4		CL
4.6	25.1	58	630.0		ML
	16.5	1	272.2	$= 32.28$	ML
	$\Sigma = 98.5$		$\Sigma = 2522.4$	$s = 5.68$	
	19.5	11.5	380.2	$s^2 = \frac{4438.4-(198.5)^2/9}{8}$	CL
9	19.5	11.5	380.2		CL
2.06	18.1	3.5	327.6		CL
	20.4	15.5	416.2	$= 7.55$	CL
	22.9	37	524.4		CL
	22.8	35.5	519.8	$s = 2.75$	ML
	25.1	58	630.0		CL
	25.1	58	630.0		ML
	25.1	58	630.0		ML
	$\Sigma = 198.5$		$\Sigma = 4438.4$		
	18.4	5.5	338.6	$s^2 = \frac{1476.8-(65.9)^2/3}{2}$	ML
3	21.5	24.5	462.2		ML
21.97	26.0	69.0	676.0	$s^2 = 14.60$	CL
	$\Sigma = 65.9$		$\Sigma = 1476.8$		
				$s = 3.82$	

HLA Borings – 5b Layer (Cont'd)

ng.	Moist. Content	Rank	x_i^2		Soil Class
	18.1	3.5	327.6		ML
7	22.7	34	515.3	$s^2 = \frac{3411.3-(153.5)^2/7}{6}$	ML
21.93	21.4	23	458.0		ML
	18.4	5.5	338.6		ML
	24.7	55	610.1	= 7.54	CL
	23.9	46	571.2		CL
	24.3	52	590.5	s = 2.75	ML
	Σ = 153.5		Σ = 3411.3		
	20.6	19	424.4		CL
	20.5	17.5	420.2		CL
$\overline{50}$	20.1	14	404.0		CL
~~23.31~~	19.3	10	372.5		ML
29	19.6	13	384.2		ML
= 22.59	18.9	8	357.2		ML
	20.5	17.5	420.2		ML
	20.8	20	432.6		ML
	21.5	24.5	462.2		ML
	19.2	9	368.6		ML
	16.8	2	282.2		ML
	25.7	65	660.5		ML
	27.3	79	745.3		ML
	24.0	47	576.0		ML
	26.6	77	707.6		ML
	22.4	28	501.8		ML
	25.2	61	635.0		ML
	25.9	66.5	670.8		ML
	25.9	66.5	670.8		ML
	27.0	78	729.0		ML
	24.4	53.5	595.4		CL
	23.7	45	561.7		CL
	23.0	38.5	529.0		CL
	26.2	71.5	686.4		CL

HLA Borings – 5 b Layer (Cont'd)

Moist Content	Rank	x_i^2	Soil Class
24.1	49	580.8	CL
22.5	30	506.2	CL
18.7	7	349.7	CL
~~44.2~~		~~1953.6~~	~~CLML~~
22.0	26	484.0	CL
22.6	33.5	510.8	CL —
~~Σ = 699.2~~		~~Σ = 16982.7~~	
Σ = 655		Σ = 15029.1	

~~$s^2 = \frac{16982.7 - (699.2)^2/30}{29}$~~

~~$= 23.68$~~

~~$s = 4.87$~~

$s^2 = \frac{15029.1 - (655)^2/29}{28}$

$= 8.40$

$s = 2.90$

Methods from Sokal +
Rohlf (1981) and
Daniel (1978).

Comparison of HLA Borings (5 b Layer) $a = 9$

Boring	n	Σx_i	Σx_i^2	$\bar{x}$	s^2	s
2	7	182.4	4851.2	26.06	16.4	4.05
4	5	115.1	2652.3	23.02	.67	.82
6	12	287.0	6896.4	23.92	2.94	1.71
8	8	202.1	5132.4	25.26	3.84	1.96
1	4	98.5	2522.4	24.60	32.28	5.68
4	9	198.5	4438.4	22.06	7.55	2.75
5	3	65.9	1476.8	21.97	14.60	3.82
7	7	153.5	3411.3	21.93	7.54	2.75
1	29	655.0	15029.1	22.59	8.40	2.90
$\Sigma \Rightarrow$	84	1958.0	46410.3			

$$\Sigma \frac{(\Sigma x_i)^2}{n} = \frac{(182.4)^2}{7} + \frac{(115.1)^2}{5} + \frac{(287)^2}{12} + \frac{(202.1)^2}{8} + \frac{(98.5)^2}{4} + \frac{(198.5)^2}{9} +$$

$$\frac{(65.9)^2}{3} + \frac{(153.5)^2}{7} + \frac{(655)^2}{29} = 45783.25$$

$$CT = \frac{(\Sigma\Sigma x_i)^2}{\Sigma n} = \frac{(1958)^2}{84} = 45640.05$$

$$\Sigma x_i^2 - CT = 46410.3 - 45640.05 = 770.25 = SS_{TOTAL}$$

$$\Sigma \left(\frac{(\Sigma x_i)^2}{n}\right) - CT = 45783.25 - 45640.05 = 143.20 = SS_{groups}$$

Comparison of HLA Borings (5b Layer) (Cont'd)

$SS_{WITHIN} = SS_{TOTAL} - SS_{GROUPS} = 770.25 - 143.20 = 627.05$

Source of Variation	df	SS	MS	F_s
Among Groups (Borings) $(a=9) \rightarrow a-1$	8	143.20	17.90	2.14
Within Groups $(\Sigma n - a)$	75	627.05	8.36	
Total	83	770.25		

$F_{.05}(8, 75) \cong 2.08$

Significantly different at $\alpha = .05$

Must do non-parametric method.

Kruskal-Wallis

one-way analysis of variance by ranks

HLA Boring	n_i	R_i	$\bar{R}_i$
2	7	425	60.71
4	5	187	37.40
6	12	577.5	48.13
8	8	476.5	59.56
9	4	222	55.50
14	9	288.5	32.06
15	3	99	33.00
17	7	219	31.29
21	29	1075.5	37.09

Kruskal-Wallis test statistic H

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

$$= \frac{12}{84(85)} \left[\frac{(425)^2}{7} + \frac{(187)^2}{5} + \frac{(577.5)^2}{12} + \frac{(476.5)^2}{8} + \frac{(222)^2}{4} + \frac{(288.5)^2}{9} + \frac{(99)^2}{3} + \frac{(219)^2}{7} + \frac{(1075.5)^2}{29} \right] - 3(84+1) =$$

k-1 d.f. → 9-1 = 8 d.f.

$$.00168(160544.9) - 3(85) = 269.82 - 255$$
$$= 14.82$$

$\chi^2_{.05(8)} = 15.507$

Correction for ties:

Comparison of HLA Borings (5b Layer) (Cont'd)

rrection for ties:

$1 - \frac{\Sigma T}{N^3 - N}$ $\quad T = t^3 - t$ $\quad = 1 - \frac{(2^3-2)15 + (3^3-3)4 + (5^3-5)}{84^3 - 84}$

$t = 30 + 3 + 3 + 3 + 5 + 3 = 47$

$= 2(15) + 3(4) + 5(1)$

$= 1 - \frac{90 + 96 + 120}{592620} = .99948$

$_c = \frac{H}{1 - \Sigma T / N^3 - N} = \frac{14.82}{.99948}$

$= 14.8277$

Medians of the populations are not significantly different at $\alpha = .05$

$.10 < P < .05$ Because of P Value Do Multiple Comparisons Test:

$k = 9$ $\quad 9(8)/2$ comparisons

Use $\alpha = .15, .20$ or $.25$ for multiple comparisons

$z(.15)/9(8) = z_{.0021} \cong 2.85$ $\quad \alpha = .15 \; \bar{R}_i - \bar{R}_j \le \underset{2.7}{2.85} \sqrt{\frac{84(85)}{12}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$

$\alpha = .25$

Borings Compared	Diff. in Means of Ranks	$\frac{1}{n_i} + \frac{1}{n_j}$	$\alpha = .15$ Signif. Value	$\alpha = .25$	Adjust for ties
2, 4	23.31	.14 + .20 = .34	40.54	38.4	40.53
2, 6	12.58	.14 + .08 = .22	32.61	—	negligible
2, 8	11.15	.14 + .13 = .27	36.12	34.22	
2, 9	5.21	.14 + .25 = .39	43.41	41.13	
2, 14	28.65	.14 + .11 = .25	34.76	32.93	
2, 15	27.71	.14 + .33 = .47	47.66	45.15	
2, 17	29.42	.14 + .14 = .28	36.79	34.85	
2, 21	23.62	.14 + .03 = .17	28.66	27.15	
8, 21	22.47	.13 + .03 = .16	27.81	26.34	
6, 21	11.04	.08 + .03 = .11	23.06	21.84	

No significant difference in median levels of moisture content among HLA Borings.

$$\le \underset{2.7}{2.85} \sqrt{\frac{84(84^2-1) - \left[(2^3)15 + (3^3)4 + 5(1)\right] - 47}{12(83)}\left[\frac{1}{n_i} + \frac{1}{n_j}\right]}$$

$$\le 2.85 \sqrt{\frac{592620 - (233 - 47)}{12(83)}\left[\quad\right]} = \sqrt{594.51\left[\quad\right]}$$

1 of 2

NT Borings - 5b Layer

NT oring	Moisture Content	x_i^2		Soil Class
1	25	625	$s^2=\frac{\Sigma x_i^2-(\Sigma x_i)^2/N}{N-1}$	MLCL
	18	324		MLCL
$n_1=12$	21	441		MLCL
$\bar{x}_1=20.83$	21	441	$=\frac{5300-(250)^2/12}{11}$	MLCL
	23	529		MLCL
	18	324	$= 8.3\bar{3}$	MLCL
	18	324		MLCL
	19	361	$s = 2.89$	CL
	21	441		MLCL
	19	361		MLCL
	~~21~~			~~SPSM~~
	27	729		ML
	20	400		ML
	$\Sigma x_i=250$	$\Sigma=5300$		
2	25	625	$s^2=\frac{8023-(355)^2/16}{15}$	MLCL
	22	484		MLCL
$_2=16$	20	400		MLCL
$_2=22.19$	20	400	$= 9.76$	MLCL
	28	784		MLCL
	26	676	$s = 3.12$	ML
	23	529		ML
	18	324		CLML
	15	225		CLML
	21	441		ML
	23	529		ML
	22	484		ML
	23	529		ML
	22	484		ML
	25	625		ML
	22	484		MLCL
	$\Sigma=355$	$\Sigma=8023$		
	18	324		MLCL
$_3=19$	17	289		MLCL
$_3=19.74$	18	324		MLCL

NT- Borings -5b Layer

NT Boring	Moist Cont.	x_i^2		Soil Class.
3	19	361	$s^2 = \frac{7521-(375)^2/19}{18}$	MLCL
	18	324		MLCL
	22	484		MLCL
	21	441	$= 6.65$	MLCL
	18	324		MLCL
	24	576	$s = 2.58$	MLCL
	14	196		MLCL
	17	289		MLCL
	18	324		MLCL
	23	529		MLCL
	23	529		MLCL
	21	441		MLCL
	21	441		MLCL
	22	484		MLCL
	21	441		MLCL
	20	400		MLCL
	Σ=375	Σ=7521		
5	20	400	$s^2 = \frac{5804-(274)^2/13}{12}$	ML
$n_4 = 13$	22	484		ML
$\bar{x}_4 = 21.08$	23	529		MLCL
	21	441	$= 2.41$	MLCL
	20	400		MLCL
	22	484	$s = 1.55$	MLCL
	22	484		MLCL
	19	361		MLCL
	20	400		MLCL
	22	484		MLCL
	23	529		MLCL
	22	484		MLCL
	18	324		CLML
	Σ=274	Σ=5804		

For all of 5b

$\Sigma = 1254$ $\bar{x} = 20.9$

$n = 60$

$$s^2 = \frac{26648-(1254)^2/60}{59} = 7.45$$

$s = 2.73$

Method of
Sokal + Rohlf
(1981)

Comparison of NT Borings (5b Layer)

Excluded Boring #4 from Analysis

$a = 4$

NT Boring	n	Σx_i	Σx_i^2
1	12	250	5300
2	16	355	8023
3	19	375	7521
5	13	274	5804
	$\Sigma = 60$	$\Sigma = 1254$	$\Sigma = 26648$

$$\Sigma\frac{(\Sigma x_i)^2}{n} = \frac{250^2}{12} + \frac{355^2}{16} + \frac{375^2}{19} + \frac{274^2}{13} = 26261.3$$

$$CT = \frac{(\Sigma x_i)^2}{\Sigma n} = \frac{(1254)^2}{60} = 26208.6$$

$$\Sigma x_i^2 - CT = 26648 - 26208.6 = 439.4 = SS_{TOTAL}$$

$$\Sigma\left(\frac{(\Sigma x_i)^2}{n}\right) - CT = 26261.3 - 26208.6 = 52.7 = SS_{groups}$$

$$SS_{WITHIN} = SS_{TOTAL} - SS_{groups} = 439.4 - 52.7 = 386.7$$

Source of Variation	df	SS	MS	F_s
Among Groups (Borings) ($a=4$) $\rightarrow a-1$	3	52.7	17.57	2.54
Within Groups ($\Sigma n - a$)	56	386.7	6.91	
Total	59	439.4		

Not signif. at $\alpha = .05$
No difference in variance
Can do parametric method — comparison of means.

$$F_{.05\,(3,56)} \cong 2.80$$

Comparison of NT Borings (5 b Layer) (Cont'd)

ummary

Boring	n	$\bar{x}$	s^2	s	$s^2_{\bar{x}_i}$
1	12	20.83	8.33	2.89	~~1.7380~~ .5754
2	16	22.19	9.76	3.12	~~2.3173~~ .4315
3	19	19.74	6.65	2.58	~~2.7518~~ .3634
5	13	21.08	2.41	1.55	~~1.8828~~ .5311

Multiple Comparison of Pairs of Means (Unequal Sample Sizes; Unplanned Comparisons)

$$\text{Pooled variance} = MS_{\text{WITHIN}} = \frac{\Sigma(n_i-1)s_i^2}{\Sigma(n_i-1)} =$$

$$\frac{11(8.33)+15(9.76)+18(6.65)+12(2.41)}{11+15+18+12} = \frac{386.65}{56} = 6.9045$$

$v = 56$

GT2 Method

$k = a = 4 \quad \alpha = .05$

$v = \Sigma(n_i - 1)$

$$m_\alpha[k(k-1)/2, v] = m_{.05}[6,56] \xrightarrow{\text{For table}} m_{.05}[4,56] \cong 2.7248$$ Table 21 Sokal + Rohlf

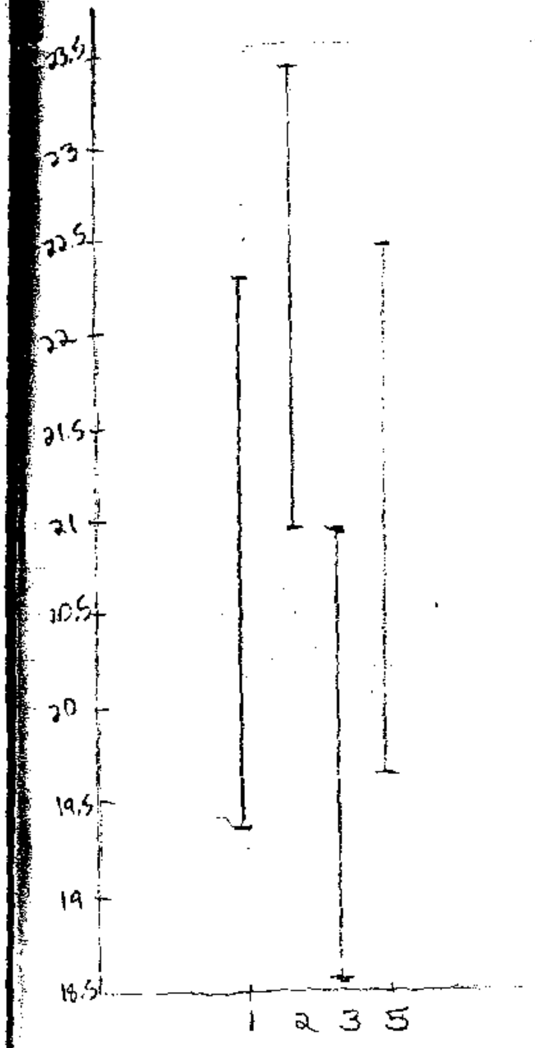
$$s^2_{\bar{x}_i} = \frac{MS\text{-within}}{n_i}$$

wer limit $= l_i = \bar{x}_i - \sqrt{\tfrac{1}{2}(m_\alpha[4,56])}(s^2_{\bar{x}_i})^{1/2}$

pper limit $= u_i = \bar{x}_i + \sqrt{\tfrac{1}{2}}(m_\alpha[4,56])(s^2_{\bar{x}_i})^{1/2}$

Comparison of NT Borings (5b Layer) (Cont'd)

NT 1	NT 2	NT 3	NT 5
~~23.37~~	~~25.12~~	~~22.94~~	~~23.72~~
22.2915	23.4356	20.9015	22.4841
~~18.79~~	~~19.26~~	~~16.57~~	~~18.72~~
19.3685	20.9244	18.5785	19.6759
~~2.54~~	~~2.73~~	~~2.20~~	~~2.64~~
1.4615	1.2656	1.1615	1.4041



Of the Nortec Borings, Boring 2 is, significantly different (barely) from Boring 3 for moisture content (α=.05) however, neither Boring 2 or 3 is distinct from the other Borings.

May wish to separate Boring 2 or Boring 3 from the group based on other parameters.

NT Borings 1, 2, 3 + 5   1 of 1
HLA Borings 2, 4, 6, 8, 9, 14, 15, 17 and 21

Comparison of HLA and NT Borings (5b Layer)

Since no significant differences within HLA and NT borings in moisture content levels, combined all HLA borings; also combined all NT borings to test for differences between the 2 groups (i.e. HLA and NT).

Borings	n	Σx_i	Σx_i^2	s^2	s	$\bar{x}$
NT	60	1254.0	26648.0	7.45	2.73	20.90
HLA	84	1958.0	46410.3	9.28	3.05	23.31

Variances:

$H_0: s^2_{NT} = s^2_{HLA}$
$H_A: s^2_{NT} \neq s^2_{HLA}$

$$s^2_{NT} = \frac{26648 - (1254)^2/60}{59} = 7.45$$

$$s^2_{HLA} = \frac{46410.3 - (1958)^2/84}{83} = 9.28$$

F test $\quad F_s = \frac{9.28}{7.45} = 1.25 \qquad F_{CRIT}(.05/2; 83, 59) \cong 1.64$

Variances of HLA and NT borings are not significantly different for moisture contents ($\alpha = .05$).

$$t = \frac{\bar{X}_{HLA} - \bar{X}_{NT}}{s_p\sqrt{1/N_{HLA} + 1/N_{NT}}} = \frac{23.31 - 20.9}{2.92\sqrt{1/84 + 1/60}} = 4.884$$

$H_0: \bar{X}_{NT} = \bar{X}_{HLA}$
$H_A: \bar{X}_{NT} \neq \bar{X}_{HLA}$

$$_p^2 = \frac{\Sigma x_i^2 - [(\Sigma X_i)^2/N_i] + \Sigma x_j^2 - [(\Sigma X_j)^2/N_j]}{N_i + N_j - 2}$$

$t_{CRIT}(.05/2; 142) \cong 1.97$
$t_{CALC} = 4.884$

$$= \frac{(N_i - 1)s_i^2 + (N_j - 1)s_j^2}{N_1 + N_2 - 2} = \frac{59(7.45) + 83(9.28)}{144 - 2} = 8.52$$

$s_p = 2.92$

ean Moisture Contents are significantly diff. ($\alpha = .05$)

Statistical Analysis : Undrained Shear Strength & Compression Ratio

Undrained Shear Strength

Pleistocene ML, CL :

NORTEC DATA : $N = 31$

$\bar{x} = 2.95$ ksf

$s = 2.06$ ksf

$\Sigma x = 91.5$

$\Sigma x^2 = 397.2$

HLA DATA : $N = 12$

$\bar{x} = 2.50$ ksf

$s = 1.58$ ksf

$\Sigma x = 30.0$

$\Sigma x^2 = 102.6$

NORTEC + HLA : $N = 43$

$\bar{x} = 2.83$ ksf

$s = 1.93$

$\Sigma x = 121.5$

$\Sigma x^2 = 499.8$

Holocene ML, CL : (HLA Data Only)

$N = 13$

$\bar{x} = 0.69$

$s = 0.39$

$\Sigma x = 9.02$

$\Sigma x^2 = 8.06$

Compression Ratio (Pleistocene ML, CL Only)

NORTEC DATA : $N = 16$

$\bar{x} = 0.030$

$s = 0.009$

$\Sigma x = 0.481$

$\Sigma x^2 = 0.016$

HLA DATA : $N = 4$

$\bar{x} = 0.020$

$s = 0.005$

$\Sigma x = 0.080$

$\Sigma x^2 = 0.002$

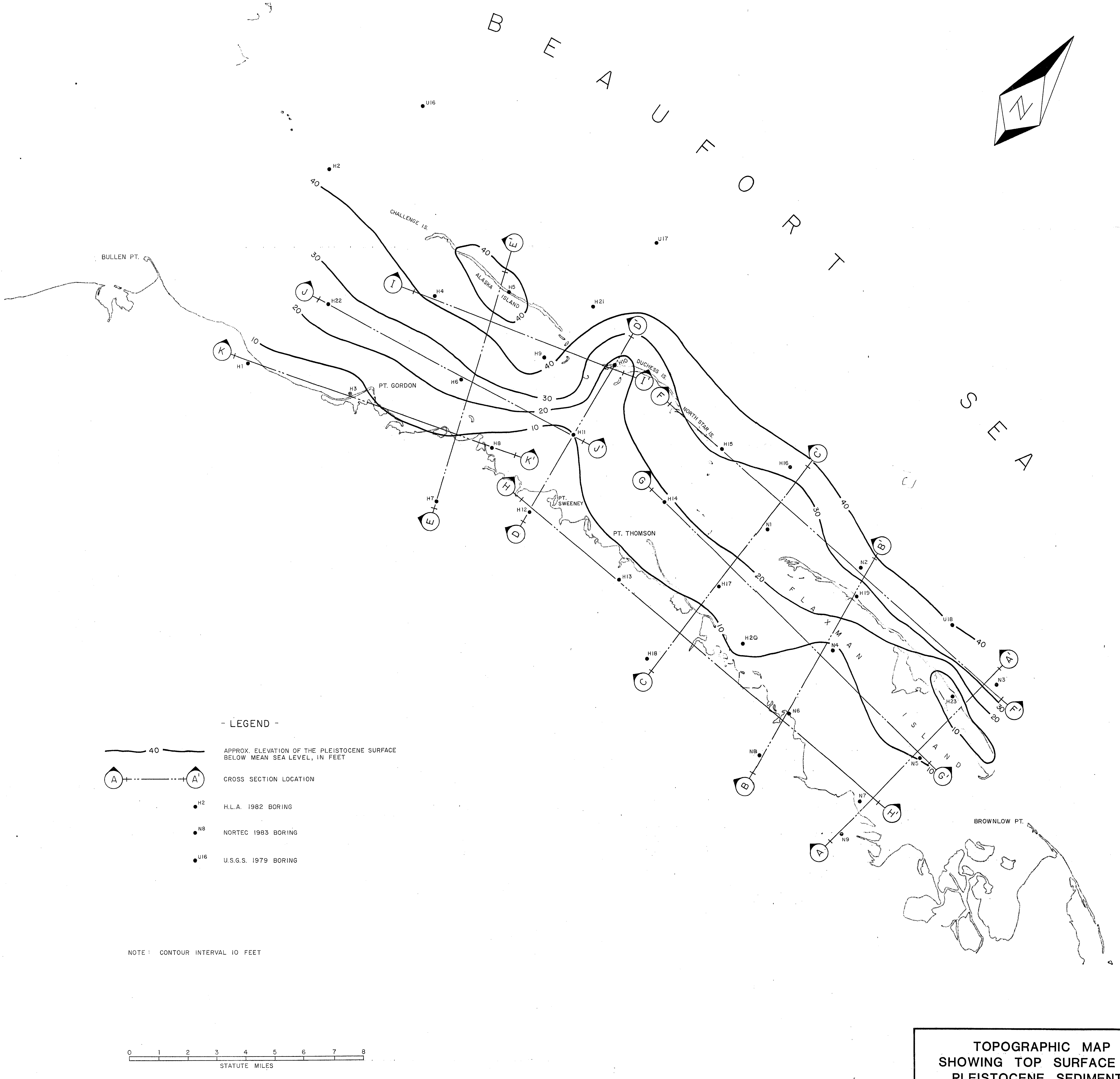
NORTEC + HLA : $N = 20$

$\bar{x} = 0.028$

$s = 0.011$

$\Sigma x = 0.561$

$\Sigma x^2 = 0.018$

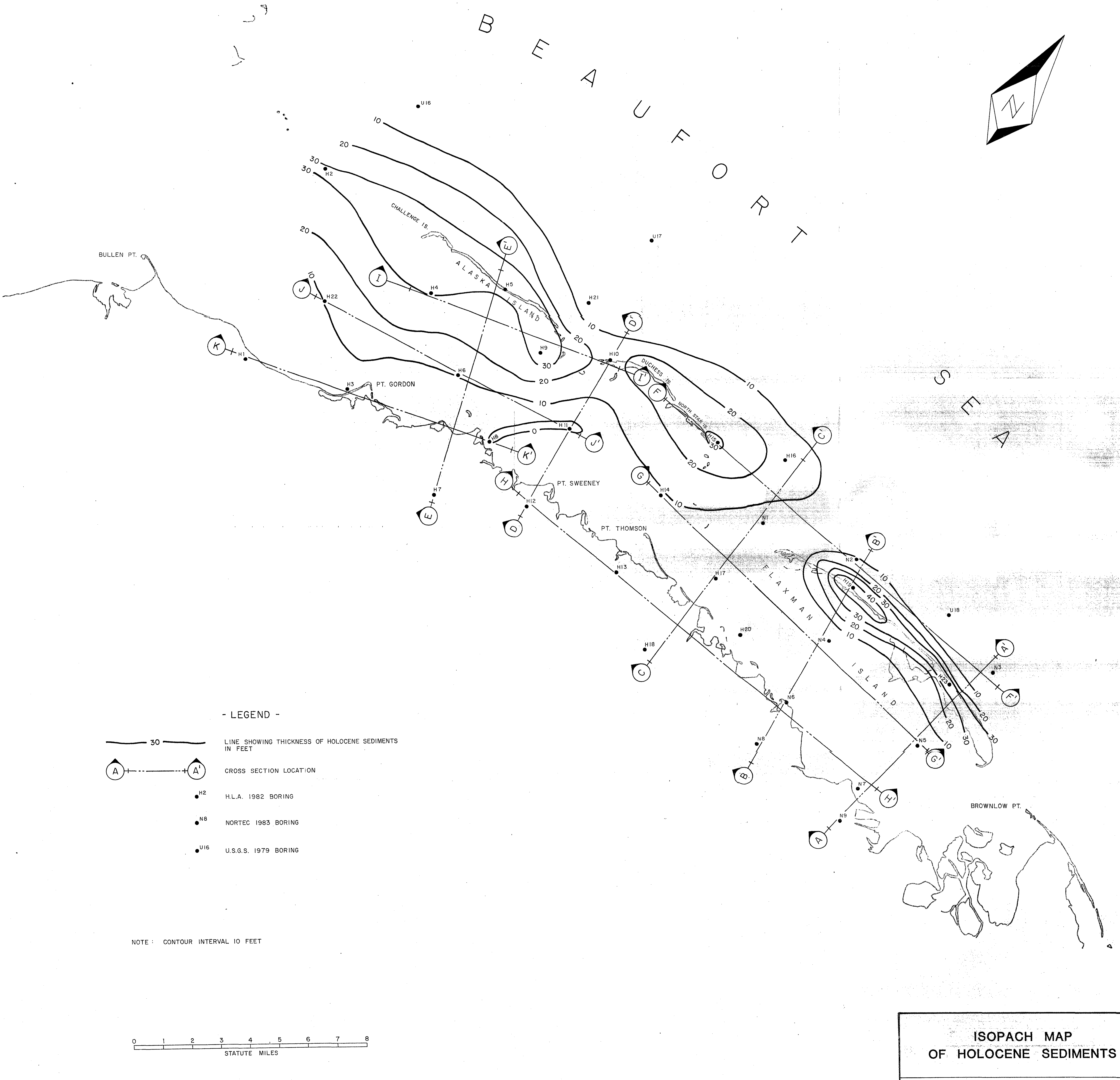


TOPOGRAPHIC MAP SHOWING TOP SURFACE OF PLEISTOCENE SEDIMENTS

EXXON COMPANY, U.S.A.

NORTHERN TECHNICAL SERVICES, INC.

DRAWN BY: AWB	DATE: MAR '84	FIGURE 1
CHECKED BY: WDP	SCALE: AS SHOWN	



ISOPACH MAP
OF HOLOCENE SEDIMENTS

EXXON COMPANY, U.S.A.

NORTHERN TECHNICAL SERVICES, INC.

DRAWN BY: AWB	DATE: MAR '84	FIGURE 2
CHECKED BY: WDP	SCALE: AS SHOWN	