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SOIL AND FOUNDATION ENGINEERS

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REPORT

TO

DEPARTMENT OF HIGHWAYS, ONTARIO

ON

FINAL FOUNDATION INVESTIGATION

PROPOSED CROSSING OF THE RE-ALIGNED WELLAND CANAL

MAIN STREET EAST TUNNEL

WELLAND

ONTARIO

VOLUME I

SOIL AND BEDROCK CONDITIONS

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ABSTRACT

This report forms Volume I of the final foundation investigation report and details the soil and bedrock conditions at the site of the proposed tunnel crossing of the re-aligned Welland Canal along Main Street East in the eastern outskirts of Welland, Ontario.

The generally flat site is underlain by some 40 to 120 feet of hard to stiff reddish-brown clayey silt which has been desiccated to a depth of about 15 feet. Within this extensive clayey silt deposit between about elevation 525 and 560 the borings encountered a thick but discontinuous zone of dense silt to sandy silt. In the central portion of the site the clayey silt stratum is underlain by some 5 to 30 feet of stiff to very stiff reddish-brown silty clay which, particularly in the lower part of the stratum, has an occasionally irregularly layered structure. The silty clay is underlain at a depth of between 70 and 115 feet by very dense generally silty till containing occasional gravelly zones followed at about elevation 485 to 495 by dolomitic limestone bedrock. The upper 5 to 10 feet of the bedrock is weathered and generally fractured.

The undrained shear strength and the effective strength parameters of both the clayey silt and silty clay strata are discussed. The effect of the irregular layering on the shear strength of the clay stratum is considered in detail and a comparison of this effect is made with data obtained for a banded silty clay stratum encountered at adjacent sites.

The modulus of deformation "E" for prepared samples of the basal till is about 840 tons/sq.ft. and the rebound modulus "E_R" (i.e., for the unloading condition) is about 3,250 tons/sq.ft.

Based on pressure packer permeability tests the equivalent coefficient of permeability of the upper weathered portion of the bedrock is about 10^{-3} cm./sec. and the equivalent coefficient of permeability for the sound bedrock is about 10^{-5} cm./sec.

INTRODUCTION

H. Q. Golder & Associates Ltd. have been retained by the Department of Highways, Ontario, letter of authorization dated October 13, 1967, to carry out a final foundation investigation at the site of a proposed tunnel to carry Main Street East under the re-aligned Welland Canal in the eastern outskirts of the City of Welland, Ontario. This investigation compliments that carried out during December, 1966 and January, 1967, (our report 66134, dated May, 1967) which was a preliminary investigation providing general soils data for a feasibility study by the Department of a proposed crossing of the re-aligned canal.

The purpose of the present investigation was to determine the detailed soil and groundwater conditions at the site, to determine by means of a full scale pumping test the hydraulic characteristics of the bedrock till aquifer underlying the site, and to provide recommendations for earthworks and foundation design.

This report presents the factual results of the soil investigation carried out at the site and forms Volume I of our complete report presented in three volumes as follows:

Volume I - Soil and Bedrock Conditions

Volume II - Groundwater Conditions and Pumping Test Results

Volume III - Foundations and Excavations

FIELD INVESTIGATION

The field work for the final foundation investigation was carried out between October 25, 1967 and January 5, 1968. During this period a total of 14 sampled boreholes were put down to determine the soil conditions at the site and 10 unsampled boreholes were put down for the installation of piezometers in conjunction with a pumping test carried out at the site. The borings were put down using the following drilling equipment:

- a) 1 continuous flight power auger supplied and operated by the F. E. Johnston Drilling Co. Ltd.
- b) 2 Diamond machine drillrigs supplied and operated by the F. E. Johnston Drilling Co. Ltd.
- c) 1 Diamond Machine drillrig supplied and operated by Peninsula Soil Investigations.
- d) 1 Diamond Machine drillrig supplied and operated by Master Soil Investigation Limited.
- e) 1 Diamond Machine drillrig supplied and operated by P.V.K. and Sons.

Sampled Boreholes

The fourteen sampled boreholes put down at the site may be divided into two types. Boreholes T-101 to T-108 inclusive were primarily to determine the extent and strength characteristics of the silty clay to clayey silt overburden in the areas of the roadway approach cut sections and were generally terminated in the till stratum at a depth of between 85 and 120 feet below ground surface. Borehole T-101 however, was taken 10 feet into

the bedrock for the installation of a piezometer in conjunction with the pumping test. Boreholes T-121 to T-126 inclusive were put down along the actual tunnel section and were taken to a depth of between about 120 and 150 feet below ground surface or some 20 to 50 feet into the bedrock.

The borings were carried to a depth of between 50 and 70 feet using a continuous flight power auger. Augering was stopped when the uncased augerholes began to slough or cave. Below this depth the borings were cased and completed by diamond machine drillrigs using conventional wash boring techniques. Bedrock was proved in Boreholes T-121 to T-126 inclusive by diamond core drilling in BXL size to a depth generally of about 20 feet, below the bedrock surface. In Borehole T-123 however, the bedrock was cored for a depth of about 50 feet. Pressure packer permeability tests were carried out in all of the holes cored in bedrock.

Disturbed samples of the overburden were obtained for identification purposes using a standard 2 inch O.D. split spoon sampler which was driven during the course of standard penetration testing in the boreholes. In addition, relatively undisturbed samples of the cohesive portion of the overburden were obtained using 2 and 3 inch diameter thin walled tube samplers supplemented, where necessary, with 2 and 3 inch diameter thin walled piston samplers.

Representative samples of the groundwater from the upper overburden deposits were obtained by bailing in 4 of the open augerholes before wash boring operations began. Groundwater samples from the lower till and bedrock were obtained during the pumping test carried out at the site. These samples were forwarded to the Chemical Division of the Department of Highways, Ontario for chemical analysis.

Piezometers were installed in each of the boreholes completed before the end of the full scale pumping test (December 19, 1967). As many as three (3) piezometers were sealed into each borehole to determine the piezometric level within each soil stratum encountered.

A detailed log for each of the boreholes put down during the course of the final foundation investigation is presented on the Record of Borehole sheets following the text of this volume of the report. Revised logs for the borings put down during the preliminary foundation investigation (boreholes T-1 to T-9 inclusive) are also given. The revision to the previously issued logs (our report 66134 dated May, 1967) was made to distinguish between silty CLAY and clayey SILT strata, previously undifferentiated, on the basis of plasticity, the silty clay samples having a liquid limit invariably in excess of 30, the clayey silt samples being

below this limit. It was also determined that the effective or drained strength characteristics for the two strata were quite different, the effective strength parameters being apparently dependent on the clay content of the material. Further, the piezometer numbering system was revised for convenience during the pumping test.

The locations of the sampled boreholes put down during the investigation together with a section of the inferred soil stratigraphy along the Main Street East centreline are presented on Figures 1-1A and 1-1B. A soil stratigraphy section to natural scale is plotted on Figure 1-2.

Samples obtained during the investigation were brought to our laboratory for detailed examination and testing. Initially, laboratory testing was concentrated on the determination of the drained shear strength (effective stress) characteristics of the cohesive overburden deposits. However, as these characteristics appear to be dependent upon the clay content of the deposit the laboratory testing program was extended to include extensive identification testing. The results of the laboratory testing are presented in the Record of Borehole sheets and on Figures 1-3 and 1-5 to 1-38 inclusive.

Unsampled Boreholes

In addition to the sampled borings put down to determine the soil and bedrock conditions at the site 10 unsampled borings were put down for the installation of piezometers in conjunction with the pumping test. The borings for the piezometer installations were advanced by augering with a continuous flight power auger to the maximum depth which could be safely achieved with the equipment, generally a depth of about 110 feet, or to auger refusal. The augerholes were then cased and taken to bedrock using a diamond machine drillrig employing conventional wash boring techniques. Bedrock was cored in AXT or BXL size for a depth of about 10 feet.

Following completion of each boring a piezometer was sealed into the bedrock to determine the stabilized groundwater level at the location and to measure the drawdown achieved by pumping from the well; with certain exceptions, a second piezometer was sealed into the till overlying the bedrock.

A detailed log for each piezometer installation is presented on the Record of Borehole sheets following the text of this volume of the report. The soil stratigraphy given on these logs is based on visual examination of augerings and wash water return together with the observed resistance to auger and casing penetration. The locations of the unsampled borings are shown on

Figure 1-1A and 1-1B.

A more detailed discussion of the boreholes put down for piezometer installation purposes is given in Volume II of the final foundation investigation report.

Locations and Elevations

The locations and elevations of the borings put down during the course of the preliminary and final foundation investigations were supplied by the Department of Highways, Ontario. The elevations given in this report are referred to Geodetic Datum (1966).

SITE TOPOGRAPHY

The site of the proposed Main Street East tunnel crossing of the re-aligned Welland Canal is located in the Township of Crowland at the eastern limit of the City of Welland, Ontario. The topography across the site is generally flat to gently undulating with ground surface varying between elevation 595 and 605. The lower lying portions of the site were covered by as much as 1 foot of ponded surface water during the period of the investigation. The grade of the existing Main Street East or County Road Number 11 is slightly above the surrounding ground surface and the road is bounded on both sides by open ditches.

The site is a sparsely populated suburban residential area and the majority of the structures within the 2,000 foot wide St. Lawrence Seaway Authority canal right-of-way had been demolished or moved at the time of the field investigation.

GEOLOGY

Overburden

Due to the complex Pleistocene geology in the Welland area the overburden is characterized by thick, discontinuous deposits of glacio-lacustrine silts and clays which were laid down in the several glacial lakes occupying the Lake Erie basin during the latter stages of the Wisconsin Period of Glaciation. At the water level, lateral extent and direction of discharge of these glacial lakes varied greatly during fluctuations in the ice front, the resulting glacio-lacustrine deposits can, within a few hundred feet, vary from stratified clay to massive silty material containing gravel and cobbles. In addition, outwash streams from the retreating glacier resulted in local, discontinuous deltaic silt and sand strata within the complex series of glacio-lacustrine silts and clays. The pattern of deposition in relation to the geo-chronology of the Lake Erie basin is discussed in detail below.

The majority of Pleistocene deposition at the Main Street East tunnel site occurred in glacial lakes which occupied the Lake Erie basin during the latter stages of the Wisconsin Period of Glaciation. The water level in these glacial lakes during various glacial events is presented graphically on Figure 1-4. As shown on this figure the initial ponding in the Lake Erie basin occurred during the Fort Wayne Maxim and all deposition at the site (which is at about elevation 600) ended during the formation of Early Lake Erie as the level of this lake was at about elevation 540. No deposition occurred at the site during the initial lake stages as the glaciers had not retreated from the Niagara Peninsula during the Maumee, Arkona and Wittlesey pondings.

The first retreat of the Wisconsin glacier from the Welland area occurred during the glacial stage referred to as the "Two Creeks Interval". During this glacial retreat, outwash streams from the melting glacier emptied into the receding Middle Lake Warren and probably deposited some deltaic silts and sands in localized areas over very dense basal till. At the maximum extent of glacial retreat a very low stage of the Lake Erie basin occurred as the water from the Upper Great Lakes basins probably emptied into the Lake Ontario basin through the area of the Kewartha Lakes. This resulted in little or no deposition within the Lake Erie basin.

During the latter stages of the "Two Creeks Interval" and during the "Valders Substage" the Wisconsin glacier advanced southward to the area of the Niagara Escarpment. This resulted in the ponding in the Lake Erie basin of glacial Lake Wayne and, at the maximum extent of glacial advance, Lowest Lake Warren. It is probably during these pondings that the lower portion of the glacio-lacustrine silts and clays were deposited. In addition, it is probable that relatively coarse grained clayey silt with some sand and gravel was deposited in Lake Wayne since this lake emptied eastward through Syracuse, New York and the velocity of lake flow in the vicinity of the site was probably appreciable. In Lowest Lake Warren which emptied westward finer grained and occasionally layered silty clay was probably deposited.

The final retreat of the glacier from the Niagara Escarpment began at the end of the "Valders Substage". As during the previous glacial retreat melt-water outwash streams from the glacier probably formed deltaic deposits of silts and sands in the ponded lake occupying the Lake Erie basin. As the direction of deposition of these glacial outwash deltaic or alluvial "fans"

was probably oriented along a generally north-south axis it is possible that along an east-west axis the sands and silts are (over a limited lateral extent) discontinuous.

Following the initial retreat of the glacier to below the Niagara Escarpment and during the period of glacial lakes Grassmere and Lundy it is probable that the upper portion of the glacio-lacustrine clays and silts were deposited. Although the outfall of these glacial lakes was westward, the inflow of melt-water from the retreating glaciers together with the possibility of "rafted" ice sheets floating on the glacial lakes resulted in the deposition of generally cohesive material containing sand and gravel. Such "rafted" ice sheets from the retreating glacier could also result in the presence of cobbles or boulders in the overburden and a generally till-like gradation of the soil.

The last major geological period of deposition at the proposed tunnel site was during the late stages of Lake Lundy and early stages of Early Lake Algonquin. The relatively low water level in these western draining lakes probably resulted in generally clayey and probably stratified backwater deposits overlying the relatively coarser till-like material.

Following the Early Lake Algonquin stage and the development of the present eastern drainage pattern of the Great Lakes System the water level in the Lake Erie basin fell to about its present level ending Pleistocene deposition in the Welland area.

Bedrock

The area of the site is underlain at a depth of about 100 to 140 feet by dolomitic limestone bedrock of the Salina Formation, Devonian Period. The bedrock contains numerous interbedded siltstone and calcareous shale layers and gypsum inclusions which may be as much as 12 inches thick. The bedding planes of the bedrock dip slightly southward and pass under the present Lake Erie basin.

SOIL CONDITIONS

The occurrence and index properties of the various soil strata underlying the proposed Main Street East tunnel site have been detailed in the preliminary foundation investigation report (our report 66134, dated May, 1967) and reference should be made to this report. The borings put down during the present investigation have confirmed in general the previously determined soil conditions at the site and have established the boundaries between soil strata in more detail. Stratigraphic sections of the inferred soil conditions at the site are presented on Figures 1-1A,B and 1-2. Figure 1-2 shows the actual relationship of the various strata as the vertical and horizontal scales of the drawing are equal.

In general, the site is covered by about 1 foot of soft black clayey topsoil underlain by an extensive deposit of very stiff to stiff reddish-brown clayey silt. The deposit varies in thickness from about 40 feet at the west end of the site to about 120 feet in the eastern portion of the site. The clayey silt contains a trace to some sand and gravel. Dispersed throughout the deposit there are occasional cobbles and 1 inch to 2 foot thick seams and layers of silt and sandy silt. Gradation limits for typical samples of the clayey silt stratum are presented on Figure 1-5.

The upper 10 to 20 feet of the stratum consists of occasionally layered mottled brown clayey silt to silty clay. The layered structure has, however, generally been destroyed by desiccation. This 10 to 20 foot thick desiccated zone forms a hard crust over the clayey silt stratum.

As shown on the summary plot of engineering properties (Figure 1-3) and the plasticity chart (Figure 1-6) the clayey silt is of low plasticity having a liquid limit of generally less than 30 and a plasticity index of less than 15. The average in situ water content of the clayey silt increases from about 10 percent below the desiccated crust to about 25 percent at the maximum depth of the deposit.

Underlying the clayey silt in the western portion of the site and within the clayey silt deposit along the remainder of the proposed tunnel the borings encountered a thick but discontinuous silt stratum. This upper silt stratum is as much as 30 feet in thickness and, where encountered, is located within a vertical zone extending from about elevation 525 to elevation 560. The upper silt consists generally of dense to very dense silt to sandy silt with a trace to some clay and gravel. Although the deposit exhibits little or no stratification occasional clayey silt seams were encountered within the generally cohesionless silts.

Grading curves for typical samples of the upper silt to sandy silt are presented on Figures 1-28 to 1-30. The standard penetration resistance, "N values" and in situ water contents for the stratum are summarized on Figure 1-3.

The extensive clayey silt stratum or, on occasion, the upper silt to sandy silt deposit is underlain at a depth of about 50 to 90 feet by a stratum of stiff to very stiff reddish-brown silty clay. The silty clay stratum extends continuously along the Main Street East centreline from about station 15+00 to station 34+00 and in this area varies in thickness from about 5 to 35 feet. Layering is evident in dried samples taken close to the base of the stratum. This layering is not evident in all samples, but where it occurs the samples frequently contain gravel sized particles up to 1 in. or more in size and randomly dispersed. The stratum throughout contains a trace to some sand and gravel and occasional cobbles, silt seams and clayey silt zones. Gradation limits for the majority of the silty clay stratum and a comparison between the gradation of the silty clay and clayey silt strata are presented on Figure 1-5.

As shown on the summary plot of engineering properties (Figure 1-3) and the Plasticity Chart (Figure 1-6) the

silty clay is a glacial clay of generally medium plasticity. The liquid limit of the silty clay varies from 30 to about 55 and the corresponding plasticity index is between about 15 and 32. The in situ water content of the silty clay ranges between about 20 and 35 percent but does not vary appreciably with depth.

The silty clay stratum is underlain in the vicinity of the proposed western tunnel portal by a lower silt to sandy silt deposit similar in gradation to the previously described upper silt stratum. The lower 10 to 20 foot thick localized silt deposit consists of compact to very dense (generally dense) reddish-brown silt to sandy silt with a trace of clay and gravel. Grading curves for typical samples of the lower silt deposit are presented on Figure 1-33. The standard penetration resistance, "N values", and the in situ water contents of the deposit are summarized in Figure 1-3.

Underlying the silts, clayey silt and silty clay strata the borings encountered a deposit of very dense glacial till. As shown on Figures 1-1A,B and 1-2 the upper surface of the till is quite erratic varying between about elevations 490 and 530. The corresponding thickness of till (where the till was completely penetrated by the borings) varies between about 1 foot and 40 feet. The till consists generally of very dense reddish-brown sandy silt to silty sand with some cobbles and

boulders dispersed throughout. Within the generally silty till the borings encountered gravelly zones up to 15 feet thick consisting of very dense grey sand and gravel to silty sand and gravel with a trace of clay. These gravelly zones appear to occur at random throughout the till deposit and do not appear to be continuous over more than a short horizontal distance. Grading curves for typical samples of the silty portion of the till are presented in Figures 1-34 to 1-36 and grading curves for typical samples of the gravelly zones are presented on Figures 1-37 and 1-38. The standard penetration resistance and the in situ water content of the till are summarized on Figure 1-3.

The shear strength of the cohesive overburden deposits and the till together with the effects of irregular layering on the shear strength characteristics of portions of the silty clay are discussed in detail below.

DRAINED SHEAR STRENGTH OF COHESIVE STRATA

The effective stress shear strength parameters (c' and ϕ') for the clayey silt and silty clay strata encountered at the proposed Main Street East Tunnel site were determined in the laboratory by consolidated drained triaxial tests (S tests) on relatively undisturbed 2 and 3 inch diameter samples.

The larger 3 inch diameter samples were trimmed in the laboratory to 2 inch diameter prior to testing.

Stress controlled and strain controlled consolidated drained triaxial tests were carried out. For the stress controlled tests the major principal stress (σ_1) was applied by means of a dead load loading frame with load increments applied at 24 hour intervals. For the strain controlled tests the major principal stress was applied by means of a continuously moving ram which advanced at a strain rate of 0.5 percent per hour. The individual drained triaxial test series results are presented on Figures 1-9 to 1-16 inclusive.

It should be noted that consolidated drained triaxial tests were scheduled on samples additional to those shown on the figures. These additional samples were, on examination, found to include gravel fragments up to 2 inches in diameter. The presence of this gravel made trimming of the samples extremely difficult and such samples were excluded from the testing program.

The effective stress parameters obtained for the clayey silt and silty clay strata are considered separately.

(i) Clayey Silt Stratum

The results of the consolidated drained triaxial

tests (S tests) carried out on samples of the generally very stiff clayey silt stratum are summarized on Figure 1-18. Also presented on Figure 1-18 are the results of consolidated undrained triaxial tests with pore pressure measurements (\bar{R} tests) carried out on samples obtained during the course of the preliminary foundation investigation. The corresponding stress paths which developed during the course of the tests are presented on Figures 1-21 and 1-22 (\bar{R} tests and S tests respectively). The stress condition at the maximum deviator stress, $(\sigma'_1 - \sigma'_3)_{\text{max.}}$, is indicated on each of the summary plots together with the strength envelope at the maximum deviator stress.

As can be seen from Figure 1-18 the consolidated drained and undrained triaxial test results agree very closely and the average strength envelope at the maximum deviator stress corresponds to an effective angle of shear resistance (ϕ') equal to 31.5° . The maximum deviator stress occurred at an average axial strain of about 11 percent of the initial sample length. (Fig. 1-17, Table)

It should be noted that the above figures have not been corrected to account for the possible stiffening effect of the membrane and side filter drains placed around

the sample during testing. The effect of the membrane and drains would possibly reduce the principal effective stress by about 2 lb/sq.in. (Bishop, Henkel. "The Measurement of Soil Properties in the Triaxial Test", 1962.) For consolidated drained triaxial tests this correction does not vary the effective angle of shearing resistance (ϕ') but decreases any cohesion intercept (c') by about 0.5 lb/sq.in. For the stress range anticipated at the proposed tunnel site which corresponds to a minor principal stress (σ_3') of about 30 to 40 lb/sq.in. the membrane correction may be applied by reducing the effective angle of shearing resistance (ϕ') to about 31° and assuming the cohesion (c') to be zero.

(ii) Silty Clay Stratum

The results of the consolidated drained triaxial tests (S tests) carried out on samples of the stiff to very stiff silty clay stratum together with the results of consolidated undrained triaxial tests with pore pressure measurement (\bar{R} tests) carried out during the course of the preliminary investigation are summarized on Figure 1-19. The corresponding stress paths which developed during the tests are presented on Figures 1-23 and 1-24 (\bar{R} and S tests respectively). The stress conditions at maximum deviation stress, $(\sigma_1' - \sigma_3')$ max., is shown on each of the summary plots together with the strength envelope at the maximum deviator stress.

As indicated on Figure 1-19 there is good agreement between the results of the consolidated drained and undrained triaxial tests. The average strength envelope for the silty clay stratum gives an effective angle of shearing resistance (ϕ') of 24° with a corresponding cohesion intercept (c') of about 300 lb/sq.ft. As discussed previously, the effect of the membrane and filter drains placed around the test samples would be to reduce the apparent cohesion slightly to a value of cohesion, (c') of 230 lb/sq.ft.

It should be noted that testing was carried out on both the massive and the irregularly layered portions of the silty clay stratum and that the structure of the deposit has apparently little or no effect on the drained shear strength parameters of the material. This is in contrast to the results of consolidated undrained triaxial tests with pore pressure measurement carried out by the Department (D.H.O. Preliminary Foundation Investigation report W.J. 66-F-111) on samples of a markedly banded silty clay stratum encountered at the proposed Forkes Road tunnel crossing of the re-aligned Welland Canal in Welland, Ontario and which are presented on Figures 1-20 and 1-25. Also shown on Figure 1-20 are the results of consolidated drained and undrained triaxial tests carried out on samples of a heavily stratified

silty clay stratum encountered in a test shaft put down at the original Main Street tunnel crossing or the existing Welland Canal. These latter tests were carried out on samples cut from a block sample and trimmed at 45° to the plane of stratification.

As shown on Figure 1-20 the tests carried out on samples of the banded silty clay from both of the adjacent sites gave the same average strength envelope at maximum deviator stress. This strength envelope corresponds to an effective angle of shearing resistance (ϕ') of 17.5° and an apparent cohesion intercept (c') of 350 lb/sq.ft. These results indicate that the banded silty clay encountered at the previous sites has an appreciably lower effective angle of shearing resistance than does the irregularly layered silty clay encountered at the presently proposed site. Further, for the irregularly layered silty clay the axial strain at maximum deviator stress was consistently greater than 7 percent of the initial sample height (Figure 1-17, Table). At the proposed Forkes Road tunnel site the axial strain at $(\sigma'_1 - \sigma'_3)_{\text{max.}}$ was consistently less than 7 percent of the initial sample length.

UNDRAINED SHEAR STRENGTH OF COHESIVE STRATA

The undrained shear strength (C_u) of the cohesive overburden was determined by in situ field vane tests and by laboratory undrained triaxial compression tests. The results of these

tests are presented on the Record of Borehole sheets and are summarized on Figure 1-3.

(i) Clayey Silt Stratum

The undrained shear strength characteristics of the extensive clayey silt stratum have been discussed in detail in the preliminary foundation investigation report (our report 66134, dated May, 1967). As the field vane and laboratory strength data obtained during the present investigation falls within the limits of the extensive data obtained during the course of the preliminary foundation investigation the following discussion summarizes the previously presented information.

The test results indicate that the undrained shear strength in the desiccated crust is consistently greater than 3,000 lb/sq.ft. Below this desiccated zone the undrained shear strength varies generally from about 1,500 lb/sq.ft. to 2,500 lb/sq.ft. with a few triaxial test results indicating an undrained shear strength of as low as 1,000 lb/sq.ft. These low triaxial test results are considered to be caused by some sampling disturbance and the presence of occasional pieces of coarse gravel which were observed to be in the test samples. Based on the field vane and triaxial test results it may be concluded that the average undrained shear strength of the extensive clayey silt

stratum is about 2,000 lb/sq.ft. and the consistency of the deposit is stiff to very stiff.

Standard penetration tests carried out in the reddish-brown clayey silt stratum gave "N-values" ranging between about 12 and 50 blows/ft. with an average value of about 28 blows/ft. Based on an approximate empirical correlation between "N-values" and undrained shear strength the standard penetration tests results indicate the consistency of the clayey silt stratum is stiff to hard with a minimum undrained shear strength of about 1,500 lb/sq.ft. and an average undrained shear strength of about 3,000 to 4,000 lb/sq.ft.

The sensitivity of the clayey silt stratum, defined as the ratio of in situ shear strength to remoulded shear strength, is about 2 to 3.

(ii) Silty Clay Stratum

The in situ field vane and triaxial compression test results indicate that the undrained shear strength of the silty clay stratum encountered at depth varies generally between about 1,000 lb/sq.ft. and 2,000 lb/sq.ft. Four (4) triaxial test results, out of a total of 30 strength determinations, gave undrained shear strengths of less than 900 lb/sq.ft. and as low as 600 lb/sq.ft. These low test results occur in boreholes T-3,

T-105 and T-124, at apparently random elevations and are interspersed vertically among measured undrained shear strengths of greater than 1,000 lb/sq.ft.: there is no distinct pattern of a soft horizontal zone throughout the silty clay stratum. However, all of the measured undrained shear strengths of less than about 800 lb/sq.ft. were obtained in the lower 5 feet of the silty clay stratum and all occur within zones exhibiting an irregularly layered structure.*

As undrained shear strength values of less than about 1,000 lb/sq.ft. do not appear to be consistent with the majority of the strength data available, a study was made of the individual borings in which the relatively low strength values were recorded. Following is a table of the undrained shear strength in the pertinent portion of these borings:

TABLE I				
Borehole	Sample	Undrained Shear Strength lb/sq.ft.	Total Unit Weight lb/cu.ft.	Axial Strain at Failure Percent
T-3	17	850	111	4
T-101	33	1,200	117	6
T-105	34	820	132	20
T-105	35	580	130	18
T-124	25	950	116	20
T-124	26	680	123	15

* The presence of an irregularly layered structure does not necessarily indicate a low undrained shear strength since strength values of greater than 1,000 lb/sq.ft. were determined for irregularly layered samples.

From the Table I it can be seen that in Boreholes T-105 and T-124 the undrained shear strengths of the silty clay apparently decrease with depth yet the corresponding total unit weights increase. These facts are inconsistent and it is considered that some factor apart from the undrained strength characteristics of the silty clay stratum as a whole influenced the results of the tests on samples 34 and 35 from Borehole T-105 and sample 26 from Borehole T-124. A significant factor is the presence of gravel which was encountered throughout the silty clay stratum but which varied in size from sample to sample. The presence of a single piece of medium or coarse gravel within a 2 inch diameter test sample would be sufficient to reduce considerably the undrained shear strength of that sample, since the effective area and stress distribution within the sample would change, and yet the total unit weight of the sample would be high. Table I further shows that the undrained shear strengths of less than about 1,000 lb/sq.ft. recorded in Boreholes T-105 and T-124 correspond to large axial strains at failure which indicates some disturbance probably occurred during sampling.

It appears that the undrained shear strengths measured in samples 34 and 35 from Borehole T-105 and samples 25 and 26 from Borehole T-124 are not representative of the undrained shear strength of the silty clay in situ.

The undrained shear strength of 850 lb/sq.ft. measured in sample 17 from Borehole T-3 corresponds to a reasonably low total unit weight and small axial strain at failure. This test result could be considered representative of the undrained shear strength. It should be noted however, that an in situ field vane test carried out immediately beneath sample 17 gave an undrained shear strength in excess of 2,000 lb/sq.ft. The undrained shear strength determined for sample 17, Borehole T-3, is probably representative only of a local zone within the generally stiff to very stiff silty clay stratum.

(iii) Comparison with Banded Silty Clay from
Adjacent Sites

A comparison was made between the index properties and strength characteristics of the irregularly layered silty clay encountered at depth beneath the present site and those of a banded silty clay which occurs at approximately the same elevation at adjacent sites. The following sites were used for comparison:

- (a) Main Street Tunnel Crossing of Existing Welland Canal
-Welland, Ontario (hereafter referred to as original
tunnel site)

Reference - H.Q.G.A. Report 64005, dated November, 1964
"Soil Conditions"
- H.Q.G.A. Report 6375, dated July, 1964
"Trial Shaft"

- (b) Forkes Road Crossing of the Proposed Welland Canal
(hereafter referred to as Forkes Road Site)

Reference - D.H.O. Report W.J. 66-F-111, dated
September, 1967
"Preliminary Foundation Investigation
Report"

The results of the comparison of index properties and strength characteristics determined at the three sites are summarized in Table II.

From Table II it can be seen that the irregularly layered silty clay encountered at the present site differs from the banded silty clay at both the original tunnel site and the Forkes Road site in occurrence, gradation and structure. The liquid limit and in situ water content of the irregularly layered material are considerably less than those of the banded silty clay and both the undrained shear strength and effective angle of shearing resistance of the silty clay underlying the present site are greater than the strength recorded at the adjacent sites. Thus it may be concluded that the irregularly layered silty clay at this site and the banded silty clay encountered at adjacent sites do not have similar characteristics, the irregularly layered clay at this site being a stronger material.

TABLE II
SUMMARY OF LABORATORY AND IN SITU TESTING
SILTY CLAY STRATA
KNOWN SITES INVESTIGATED IN WELLAND AREA
(Excluding Tests on Block Samples in Test Shaft)

GENERAL HEADING FOR COMPARISON	SPECIFIC POINT COMPARED	PRESENT SITE	ORIGINAL MAIN ST. TUNNEL SITE	PROPOSED FORKES RD. TUNNEL SITE
OCCURENCE	Elevations between which stratum encountered	550 - 490	540 - 490	545 - 480
	Thickness of stratum (feet)	0 - 30	30 - 50	25 - 50
		Discontinuous	Continuous	Continuous
DESCRIPTION	Gradation	reddish-brown silty clay-trace to some sand and gravel-occ. cobbles	red-brown and grey sensitive silty clay	red-brown and grey silty clay to clay
	Structure	irregularly layered (generally in lower portion) to massive	distinctly layered in upper 5-10 feet and lower 10-25 feet	distinctly layered in upper 5-10 feet and lower 10-20 feet
LIQUID LIMIT Note: $w_L < 30$ considered to be clayey silt layer	Total number of values considered	35	118	156
	Percent of liquid limits > 60	0%	20%	12%
	Percent of liquid limits > 50	10%	37%	48%
	Percent of liquid limits > 40	35%	63%	90%
IN SITU WATER CONTENT	Total number of values considered	54	300	250
	Percent of values $> 50\%$	3%	2%	2%
	Percent of values $> 40\%$	5%	30%	35%
	Percent of values $> 30\%$	40%	60%	90%
EFFECTIVE STRESS PARAMETERS	Effective angle of shearing resistance ϕ'	24°	$17\frac{1}{2}^\circ$	$17\frac{1}{2}^\circ$
	Cohesion intercept (C') (lb/sq.ft.)	230	350	350
UNDRAINED SHEAR STRENGTH from in situ vanes (lb/sq.ft.)	Lowest strength recorded	1,450	900	600
	Average of lowest 10% of strengths	1,550	1,200	800
	Highest strength recorded	$> 2,000$	$> 2,000$	1,700
	Average of highest 10% of strengths	2,000	1,800	1,400
	Average strength (Minimum)	1,800	1,500	1,000
UNDRAINED SHEAR STRENGTH from Triaxial Tests (lb/sq.ft.)	Lowest strength recorded	580	250	250
	Average of lowest 10% of strengths	1,800	1,500	600
	Highest strength recorded	2,400	2,000	1,700
	Average of highest 10% of strengths	2,100	1,700	1,200
	Average strength (Minimum)	1,200	800	800
	Typical strain at failure	15% - 20%	10% - 15%	5% - 10%

MODULUS OF DEFORMATION OF THE BASAL TILL

The modulus of deformation "E" of the silty portion of the basal till was determined in the laboratory by cyclic loading triaxial compression tests on prepared samples of the till. The results of this testing together with a grading curve for the prepared composite sample is presented on Figure 1-7. Test specimens 1 and 2 were prepared at initial water contents of about 6 and 8 percent respectively and, as shown on Figure 1-7, each sample was cycled at 6 different compressive stresses and was then loaded to failure.

The modulus of deformation "E" and the rebounded modulus of deformation " E_R " used in this report are defined following the text of the report. The modulus of deformation of the till computed from the cyclic loading test results ranges between about 400 and 1,500 tons/sq.ft. with an average value of about 850 tons/sq.ft. The rebounded modulus of deformation " E_R " calculated on the unloading portion of each cycle varies between about 2,300 and 4,000 tons/sq.ft. with an average value of about 3,250 tons/sq.ft.

Although the prepared laboratory samples were compacted to only about 95 percent of the unit weight anticipated

for the very dense glacial till the above values appear to be relatively insensitive to minor density changes and are considered to be representative of the in situ material.

BEDROCK CONDITIONS

General

The basal Pleistocene overburden deposit at the site (i.e., the till) is underlain at a depth of between 105 and 120 feet by dolomitic limestone bedrock of the Salina Formation. The bedrock surface is generally flat across the site but slopes gently downward from about elevation 495 at the west end of the site to about elevation 485 at the east end. Within the actual proposed tunnel section however the bedrock surface is slightly erratic dipping down to about elevation 481 at the proposed re-aligned Welland Canal centreline and rising to about elevation 497 at the eastern tunnel entrance.

To the maximum depth of exploration (50 feet below the bedrock surface) the bedrock consists of fairly sound to sound grey dolomitic limestone with some interbedded shale layers and numerous gypsum inclusions. The interbedded shale layers vary in thickness from a few inches to about 6 feet whereas the gypsum inclusions are less than 1 foot in thickness and the majority of the inclusions occur as very thin partings within the bedrock mass.

Small fractures and occasional small holes about 1/16 inch in diameter were encountered throughout the bedrock and in borehole E-1 a 2 foot void was encountered near the top of the rock.

The upper 5 to 10 feet of the bedrock is weathered and is generally slightly fractured. A 1 to 4 foot thick fractured shale layer frequently forms the lower boundary of this upper weathered zone.

Bedrock Permeability

Pressure packer permeability tests were carried out in the bedrock in Boreholes T-121 to T-126 inclusive to determine the coefficient of permeability of both the weathered and underlying sound portions of the rock. Since the bedrock contains numerous fissures water lost during pressure packer tests probably represents the "take" within fissures rather than the permeability of the sound rock matrix. The permeability calculated from the pressure packer tests therefore represents an equivalent coefficient of permeability of the entire rock mass rather than a coefficient of permeability of the matrix. The equivalent coefficients of permeability of the bedrock mass calculated from the pressure packer test results are presented on the Record of Borehole sheets and are summarized on Figure 1-8.

Based on the pressure packer test results the equivalent coefficient of permeability of the upper weathered portion of the bedrock is between about 1×10^{-3} and 5×10^{-4} cm./sec. The equivalent coefficient of permeability of the lower sound portion of the rock varies from about 1×10^{-4} cm./sec. to less than 10^{-6} cm./sec. and, in general, the rock becomes less permeable with depth. The average equivalent coefficient of permeability for the upper 40 to 50 feet of the sound rock is about 1×10^{-5} cm./sec.

As the pressure packer permeability test results indicated that the upper weathered portion of the bedrock is about 100 times more permeable than the underlying sound bedrock, it can be concluded that the majority of horizontal water transport through the bedrock will occur within the upper 5 to 10 foot weathered zone.

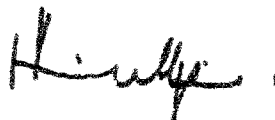
GROUNDWATER CONDITIONS

During the course of the present and preliminary foundation investigations, it was observed that the upper bedrock, till and lower silt deposit form an aquifer in which the piezometric groundwater level is independent of the water level in the overlying clays and silts. At the time of the investigation the piezometric groundwater level in the aquifer was at elevation 576 or some 25 to 30 feet below ground surface. At the same

time the piezometric water level in the overlying clays and silts was at about ground surface. The stabilized groundwater conditions at the site together with the results of a pumping test carried out in conjunction with the final foundation investigation are detailed in Volume II of this report.



J. B. Davis, P. Eng.



V. Milligan, P. Eng.

JBD:jg
67106
April 18, 1968.

LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

<i>AS</i>	auger sample
<i>CS</i>	chunk sample
<i>DO</i>	drive open
<i>DS</i>	Denison type sample
<i>FS</i>	foil sample
<i>RC</i>	rock core
<i>ST</i>	slotted tube
<i>TO</i>	thin-walled, open
<i>TP</i>	thin-walled, piston
<i>WS</i>	wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch diameter, 60 degree cone one foot, where the cone is attached to 'A' size drill rods and casing is not used.

Standard Penetration Resistance, *N*: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch drive open sampler one foot.

<i>WH</i>	sampler advanced by static weight—weight, hammer
<i>PH</i>	sampler advanced by pressure—pressure, hydraulic
<i>PM</i>	sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) *Cohesionless Soils*

<i>Relative Density</i>	<i>N, blows/ft.</i>
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) *Cohesive Soils*

<i>Consistency</i>	<i>c_u, lb./sq. ft.</i>
Very soft	Less than 250
Soft	250 to 500
Firm	500 to 1,000
Stiff	1,000 to 2,000
Very stiff	2,000 to 4,000
Hard	over 4,000

IV. SOIL TESTS

<i>C</i>	consolidation test
<i>H</i>	hydrometer analysis
<i>M</i>	sieve analysis
<i>MH</i>	combined analysis, sieve and hydrometer ¹
<i>Q</i>	undrained triaxial ²
<i>R</i>	consolidated undrained triaxial ²
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test

NOTES:

¹Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

²Undrained triaxial tests in which pore pressures are measured are shown as \bar{Q} or \bar{R} .

LIST OF SYMBOLS

I. GENERAL

π	= 3.1416
e	= base of natural logarithms 2.7183
$\log_e a$ or $\ln a$	natural logarithm of a
$\log_{10} a$ or $\log a$	logarithm of a to base 10
t	time
g	acceleration due to gravity
V	volume
W	weight
M	moment
F	factor of safety

II. STRESS AND STRAIN

u	pore pressure
σ	normal stress
σ'	normal effective stress ($\bar{\sigma}$ is also used)
τ	shear stress
ϵ	linear strain
ϵ_{xy}	shear strain
ν	Poisson's ratio (μ is also used)
E	modulus of linear deformation (Young's modulus)
G	modulus of shear deformation
K	modulus of compressibility
η	coefficient of viscosity

III. SOIL PROPERTIES

(a) Unit weight

γ	unit weight of soil (bulk density)
γ_s	unit weight of solid particles
γ_w	unit weight of water
γ_d	unit dry weight of soil (dry density)
γ'	unit weight of submerged soil
G_s	specific gravity of solid particles $G_s = \gamma_s / \gamma_w$
e	void ratio
n	porosity
w	water content
S_r	degree of saturation

(b) Consistency

w_L	liquid limit
w_P	plastic limit
I_P	plasticity index
w_s	shrinkage limit
I_L	liquidity index = $(w - w_P) / I_P$
I_C	consistency index = $(w_L - w) / I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
D_r	relative density = $(e_{max} - e) / (e_{max} - e_{min})$

(c) Permeability

h	hydraulic head or potential
q	rate of discharge
v	velocity of flow
i	hydraulic gradient
k	coefficient of permeability
j	seepage force per unit volume

(d) Consolidation (one-dimensional)

m_v	coefficient of volume change = $-\Delta e / (1+e) \Delta \sigma'$
C_c	compression index = $-\Delta e / \Delta \log_{10} \sigma'$
c_c	coefficient of consolidation
T_v	time factor = c_v / d^2 (d , drainage path)
U	degree of consolidation

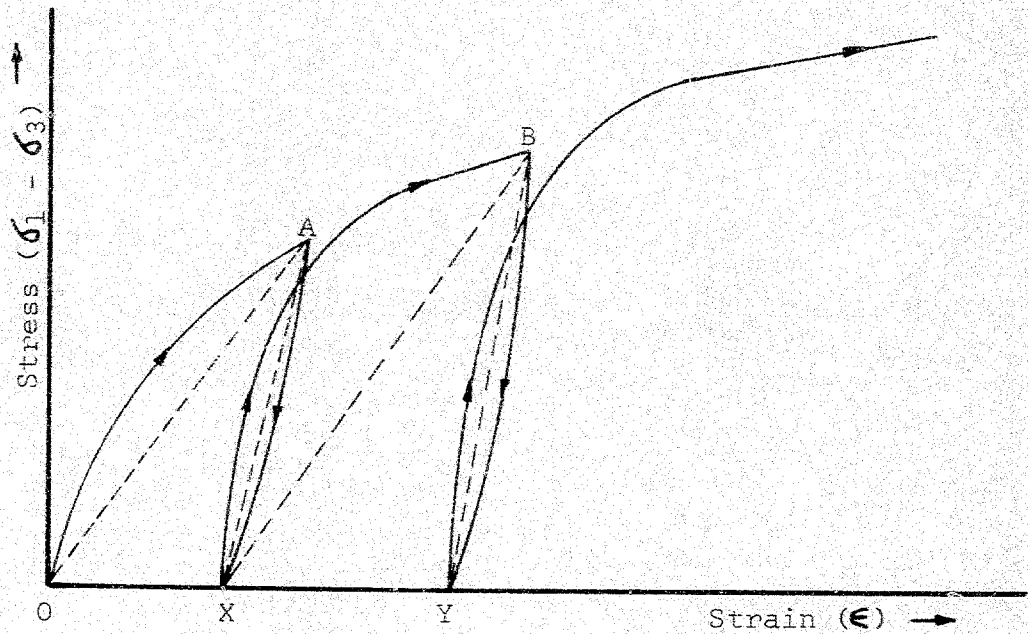
(e) Shear strength

τ_f	shear strength
c'	effective cohesion
ϕ'	effective angle of shearing resistance, or friction
c_u	apparent cohesion*
ϕ_u	apparent angle of shearing resistance, or friction
μ	coefficient of friction
S_r	sensitivity

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = c_u$ is taken as half the undrained compressive strength.

DEFINITION OF E-VALUE

(E is the Modulus of Deformation)



Modulus Determined at Peak Stress of First Cycle (i.e. point A)

E = Modulus of Deformation
 = Slope of Line A-0
 = $\frac{\text{Stress at A}}{\text{Strain at A}}$

E_R = Rebounded Modulus
 = Slope of Line A-X
 = $\frac{\text{Stress at A}}{\text{Strain at A} - \text{Strain at X}}$

Modulus Determined at Peak Stress of Second Cycle (i.e. point B)

E = Modulus of Deformation
 = Slope of Line B-X
 = $\frac{\text{Stress at B}}{\text{Strain at B} - \text{Strain at X}}$

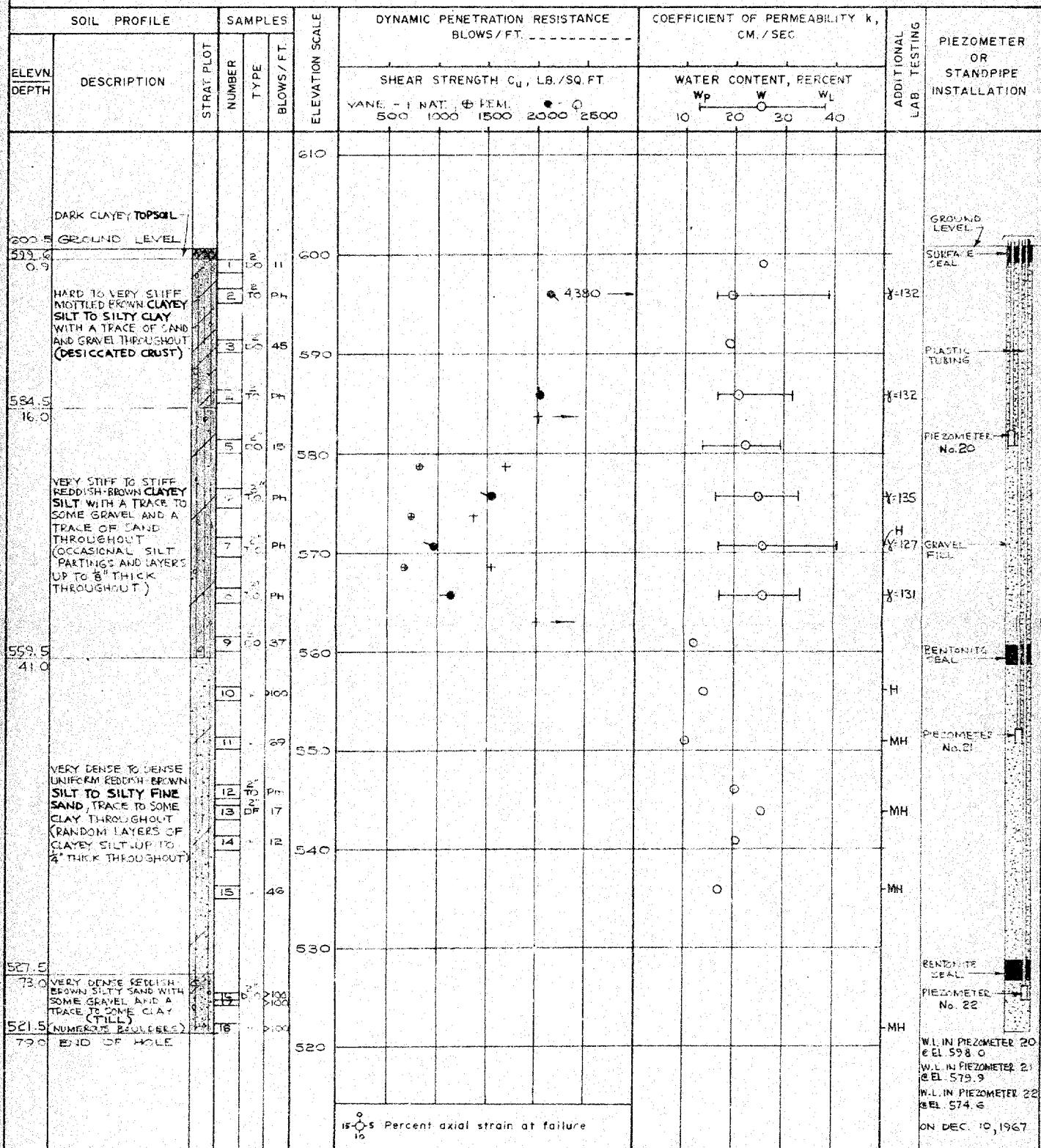
E_R = Rebounded Modulus
 = Slope of Line B-Y
 = $\frac{\text{Stress at B}}{\text{Strain at B} - \text{Strain at Y}}$

RECORD OF BOREHOLE T-1

LOCATION See Figure 1-1 BORING DATE DEC 28, 1966 - JAN. 5, 1967 DATUM GEOLOGIC

BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" & NX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES



GOLDER & ASSOCIATES

DRAWN *[Signature]*
CHECKED *[Signature]*

RECORD OF BOREHOLE T-2

LOCATION

See Figure 1-1

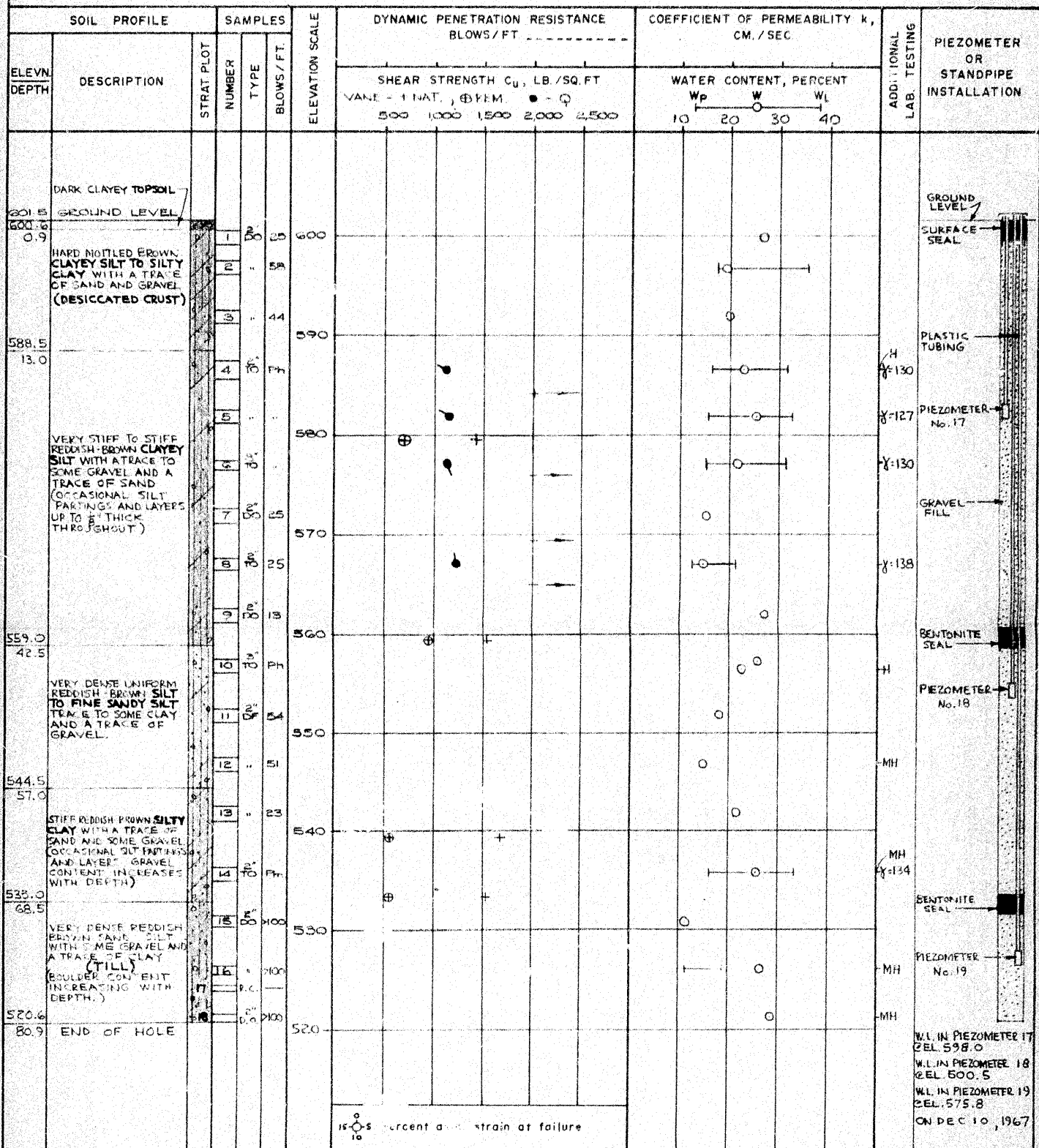
BORING DATE DEC. 30 1966 - JAN. 10, 1967 DATUM GEODETIC

BOREHOLE TYPE POWER AUGER

BOREHOLE DIAMETER 4.5"

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

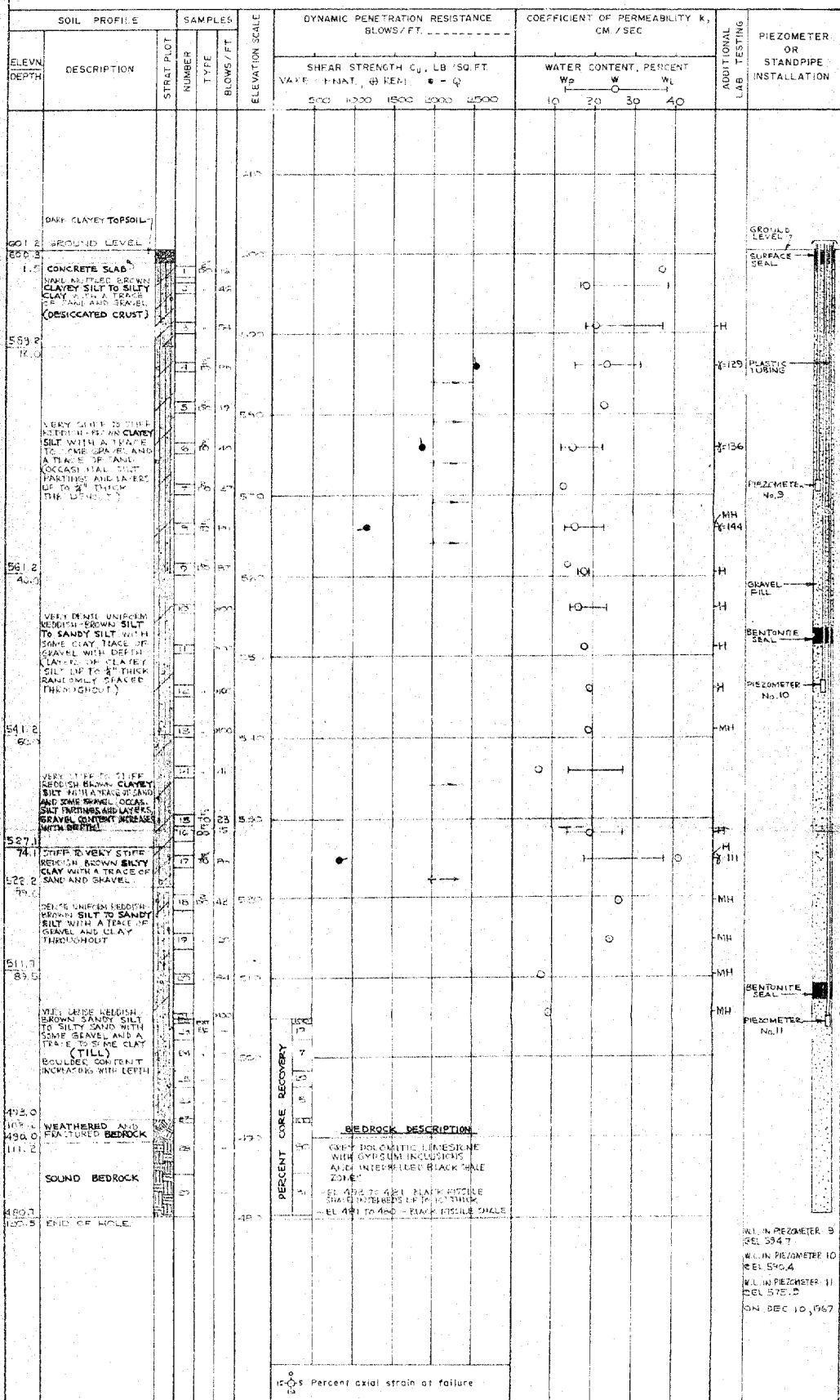
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *MCW*
CHECKED *J.P.S.*

RECORD OF BOREHOLE T-3

LOCATION	See Figure 1-1	BORING DATE	DEC. 12 - 17, 1966	DATUM	GEODETIC
BOREHOLE TYPE		POWER AUGER	% WATER BODIES	BOREHOLE DIAMETER	4.0" EX BK CASING
SAMPLER HAMMER WEIGHT 140 LB.		DROP 30 INCHES		PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES	
<div style="display: flex; justify-content: space-between;"> <div> <p>1. 10' - 11' - 12' - 13' - 14' - 15' - 16' - 17' - 18' - 19' - 20' - 21' - 22' - 23' - 24' - 25' - 26' - 27' - 28' - 29' - 30' - 31' - 32' - 33' - 34' - 35' - 36' - 37' - 38' - 39' - 40' - 41' - 42' - 43' - 44' - 45' - 46' - 47' - 48' - 49' - 50' - 51' - 52' - 53' - 54' - 55' - 56' - 57' - 58' - 59' - 60' - 61' - 62' - 63' - 64' - 65' - 66' - 67' - 68' - 69' - 70' - 71' - 72' - 73' - 74' - 75' - 76' - 77' - 78' - 79' - 80' - 81' - 82' - 83' - 84' - 85' - 86' - 87' - 88' - 89' - 90' - 91' - 92' - 93' - 94' - 95' - 96' - 97' - 98' - 99' - 100' - 101' - 102' - 103' - 104' - 105' - 106' - 107' - 108' - 109' - 110' - 111' - 112' - 113' - 114' - 115' - 116' - 117' - 118' - 119' - 120' - 121' - 122' - 123' - 124' - 125' - 126' - 127' - 128' - 129' - 130' - 131' - 132' - 133' - 134' - 135' - 136' - 137' - 138' - 139' - 140' - 141' - 142' - 143' - 144' - 145' - 146' - 147' - 148' - 149' - 150' - 151' - 152' - 153' - 154' - 155' - 156' - 157' - 158' - 159' - 160' - 161' - 162' - 163' - 164' - 165' - 166' - 167' - 168' - 169' - 170' - 171' - 172' - 173' - 174' - 175' - 176' - 177' - 178' - 179' - 180' - 181' - 182' - 183' - 184' - 185' - 186' - 187' - 188' - 189' - 190' - 191' - 192' - 193' - 194' - 195' - 196' - 197' - 198' - 199' - 200' - 201' - 202' - 203' - 204' - 205' - 206' - 207' - 208' - 209' - 210' - 211' - 212' - 213' - 214' - 215' - 216' - 217' - 218' - 219' - 220' - 221' - 222' - 223' - 224' - 225' - 226' - 227' - 228' - 229' - 230' - 231' - 232' - 233' - 234' - 235' - 236' - 237' - 238' - 239' - 240' - 241' - 242' - 243' - 244' - 245' - 246' - 247' - 248' - 249' - 250' - 251' - 252' - 253' - 254' - 255' - 256' - 257' - 258' - 259' - 260' - 261' - 262' - 263' - 264' - 265' - 266' - 267' - 268' - 269' - 270' - 271' - 272' - 273' - 274' - 275' - 276' - 277' - 278' - 279' - 280' - 281' - 282' - 283' - 284' - 285' - 286' - 287' - 288' - 289' - 290' - 291' - 292' - 293' - 294' - 295' - 296' - 297' - 298' - 299' - 300' - 301' - 302' - 303' - 304' - 305' - 306' - 307' - 308' - 309' - 310' - 311' - 312' - 313' - 314' - 315' - 316' - 317' - 318' - 319' - 320' - 321' - 322' - 323' - 324' - 325' - 326' - 327' - 328' - 329' - 330' - 331' - 332' - 333' - 334' - 335' - 336' - 337' - 338' - 339' - 340' - 341' - 342' - 343' - 344' - 345' - 346' - 347' - 348' - 349' - 350' - 351' - 352' - 353' - 354' - 355' - 356' - 357' - 358' - 359' - 360' - 361' - 362' - 363' - 364' - 365' - 366' - 367' - 368' - 369' - 370' - 371' - 372' - 373' - 374' - 375' - 376' - 377' - 378' - 379' - 380' - 381' - 382' - 383' - 384' - 385' - 386' - 387' - 388' - 389' - 390' - 391' - 392' - 393' - 394' - 395' - 396' - 397' - 398' - 399' - 400' - 401' - 402' - 403' - 404' - 405' - 406' - 407' - 408' - 409' - 410' - 411' - 412' - 413' - 414' - 415' - 416' - 417' - 418' - 419' - 420' - 421' - 422' - 423' - 424' - 425' - 426' - 427' - 428' - 429' - 430' - 431' - 432' - 433' - 434' - 435' - 436' - 437' - 438' - 439' - 440' - 441' - 442' - 443' - 444' - 445' - 446' - 447' - 448' - 449' - 450' - 451' - 452' - 453' - 454' - 455' - 456' - 457' - 458' - 459' - 460' - 461' - 462' - 463' - 464' - 465' - 466' - 467' - 468' - 469' - 470' - 471' - 472' - 473' - 474' - 475' - 476' - 477' - 478' - 479' - 480' - 481' - 482' - 483' - 484' - 485' - 486' - 487' - 488' - 489' - 490' - 491' - 492' - 493' - 494' - 495' - 496' - 497' - 498' - 499' - 500' - 501' - 502' - 503' - 504' - 505' - 506' - 507' - 508' - 509' - 510' - 511' - 512' - 513' - 514' - 515' - 516' - 517' - 518' - 519' - 520' - 521' - 522' - 523' - 524' - 525' - 526' - 527' - 528' - 529' - 530' - 531' - 532' - 533' - 534' - 535' - 536' - 537' - 538' - 539' - 540' - 541' - 542' - 543' - 544' - 545' - 546' - 547' - 548' - 549' - 550' - 551' - 552' - 553' - 554' - 555' - 556' - 557' - 558' - 559' - 560' - 561' - 562' - 563' - 564' - 565' - 566' - 567' - 568' - 569' - 570' - 571' - 572' - 573' - 574' - 575' - 576' - 577' - 578' - 579' - 580' - 581' - 582' - 583' - 584' - 585' - 586' - 587' - 588' - 589' - 590' - 591' - 592' - 593' - 594' - 595' - 596' - 597' - 598' - 599' - 600' - 601' - 602' - 603' - 604' - 605' - 606' - 607' - 608' - 609' - 610' - 611' - 612' - 613' - 614' - 615' - 616' - 617' - 618' - 619' - 620' - 621' - 622' - 623' - 624' - 625' - 626' - 627' - 628' - 629' - 630' - 631' - 632' - 633' - 634' - 635' - 636' - 637' - 638' - 639' - 640' - 641' - 642' - 643' - 644' - 645' - 646' - 647' - 648' - 649' - 650' - 651' - 652' - 653' - 654' - 655' - 656' - 657' - 658' - 659' - 660' - 661' - 662' - 663' - 664' - 66</p></div></div>					



VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *— m.w.*
CHECKED *126*

RECORD OF BOREHOLE T-4

LOCATION

See Figure 1-1

BORING DATE DEC 12 - 13, 1966

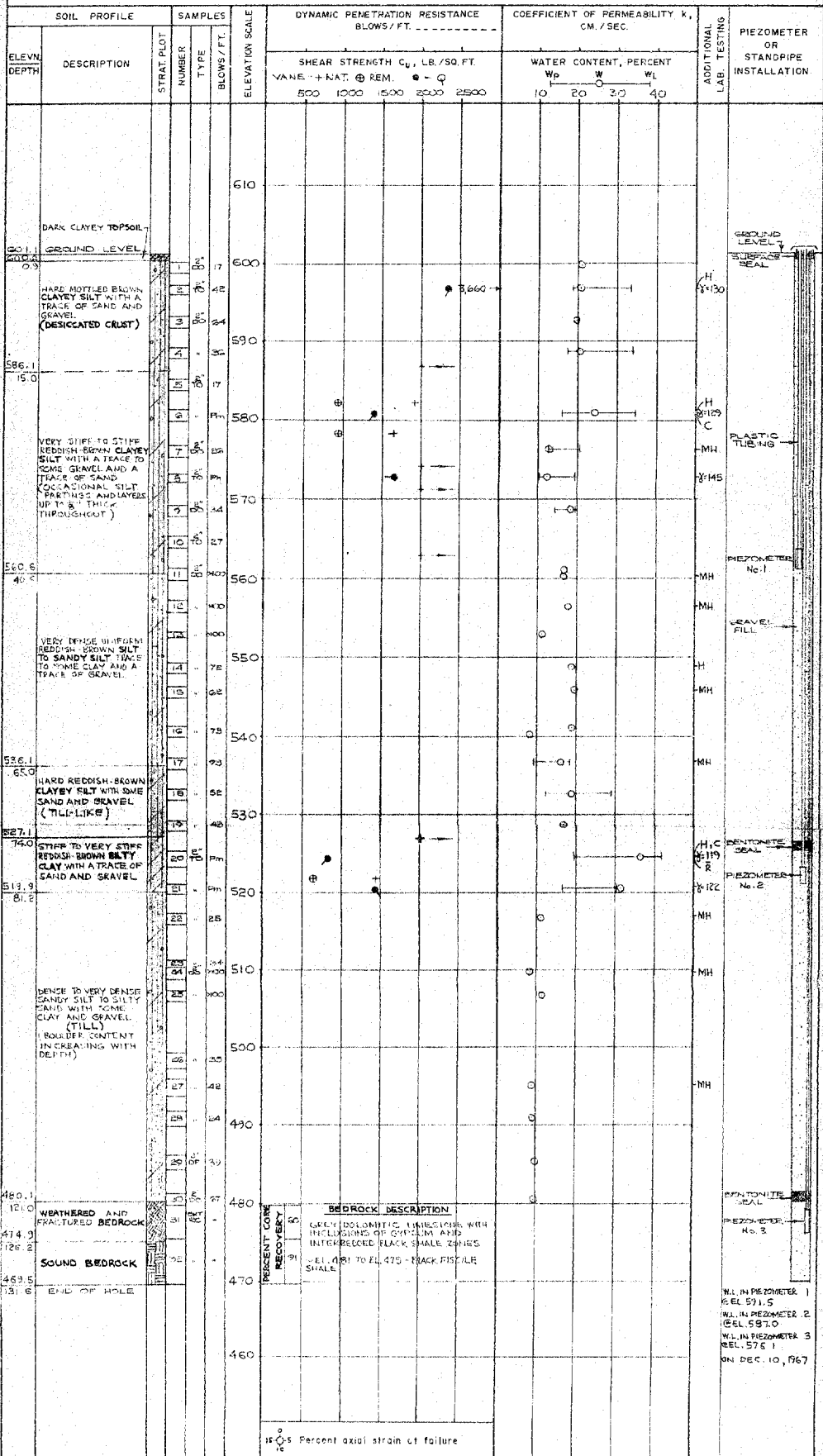
DATUM GEODETIC

BOREHOLE TYPE POWER AUGER & WASH BORING

BOREHOLE DIAMETER 4.5" NX, BX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

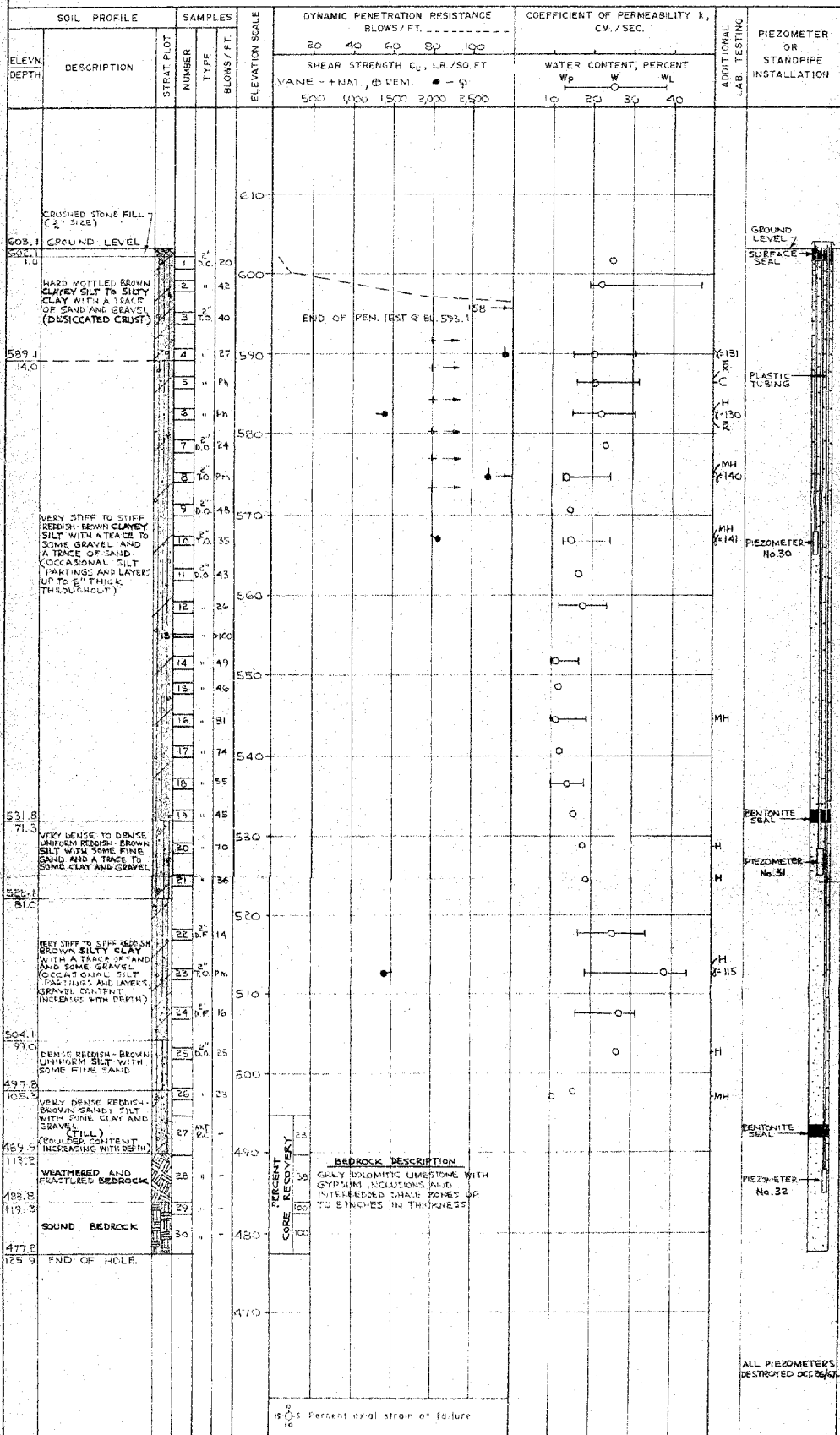
PEN. TEST HAMMER WEIGHT - LB DROP - INCHES



15% Percent axial strain at failure

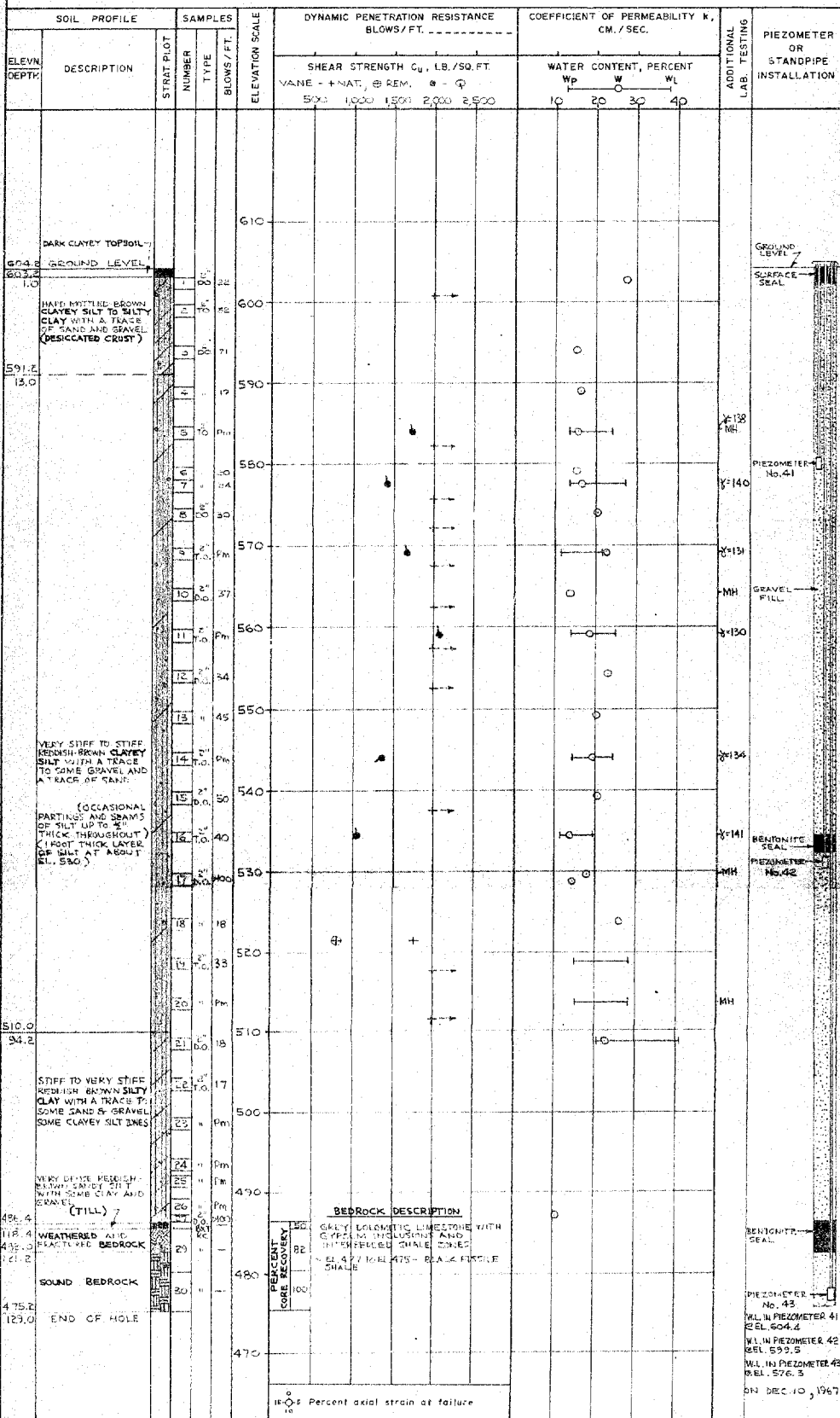
RECORD OF BOREHOLE T-5

LOCATION See Figure 1-1 BORING DATE DEC. 8-16, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" A.X. B.X. CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



RECORD OF BOREHOLE T-6

LOCATION See Figure 1-1 BORING DATE DEC. 14-31, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" NX, BX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES



RECORD OF BOREHOLE T-7

LOCATION	See Figure 1-1	BORING DATE	DEC. 20, 1966 - JAN. 3, 1967	DATUM	GEODETIC
BOREHOLE TYPE	POWER AUGER & WASH BORING		BOREHOLE DIAMETER	4.5" & NX CASING	
SAMPLER HAMMER WEIGHT	140 LB.	DROP	30 INCHES	PEN. TEST HAMMER WEIGHT	— LB. DROP — INCHES

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT.		COEFFICIENT OF PERMEABILITY k , CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C_u , LB./SQ. FT. VANE - + NAT. - REM. • - Q 500 1,000 1,500 2,000 2,500			
604.4 603.4 1.0	DARK CLAYEY TOPSOIL GROUND LEVEL	1	Ph	15	610				
591.4 13.0	HARD MITTLED BROWN CLAYEY SILT TO SILTY CLAY WITH A TRACE OF SAND AND GRAVEL (DESICCATED CRUST)	2	Ph	15	600	5,060			GROUND LEVEL SURFACE SEAL
		3	Ph	61					
		4	Ph	15	590				
		5	Ph	15					
		6	Ph	15	580				
		7	Ph	15					
		8	Ph	15	570				
		9	Ph	15					
		10	Ph	15	560				
		11	Ph	15					
		12	SS	15	550				
		13	Ph	15					
		14	Ph	15					
		15	Ph	15	540				
		16	Pm	15					
		17	Pm	15	530				
		18	Pm	15					
		19	Pm	15	520				
		20	Pm	15					
		21	Pm	15	510				
		22	Pm	15					
496.9 107.5		23	Pm	15	500				
		24	Pm	60	490				
488.4 116.0	VERY DENSE YELLOW BROWN SANDY SILT TO SILTY SAND WITH SOME CLAY AND GRAVEL (TILL) (VERY BOULDERY) END OF HOLE	25	NO	NO	480				

GROUND
LEVEL
SURFACE
SEAL

PLASTIC
TUBING

GRAVEL
FILL

BENTONITE
SEAL

PIEZOMETER
No. 44

PIEZOMETER
No. 45

W.L. IN PIEZOMETER 44
ELEV. 601.2

W.L. IN PIEZOMETER 45
ELEV. 587.9

ON DEC. 10, 1967

15-0-5 Percent axial strain at failure

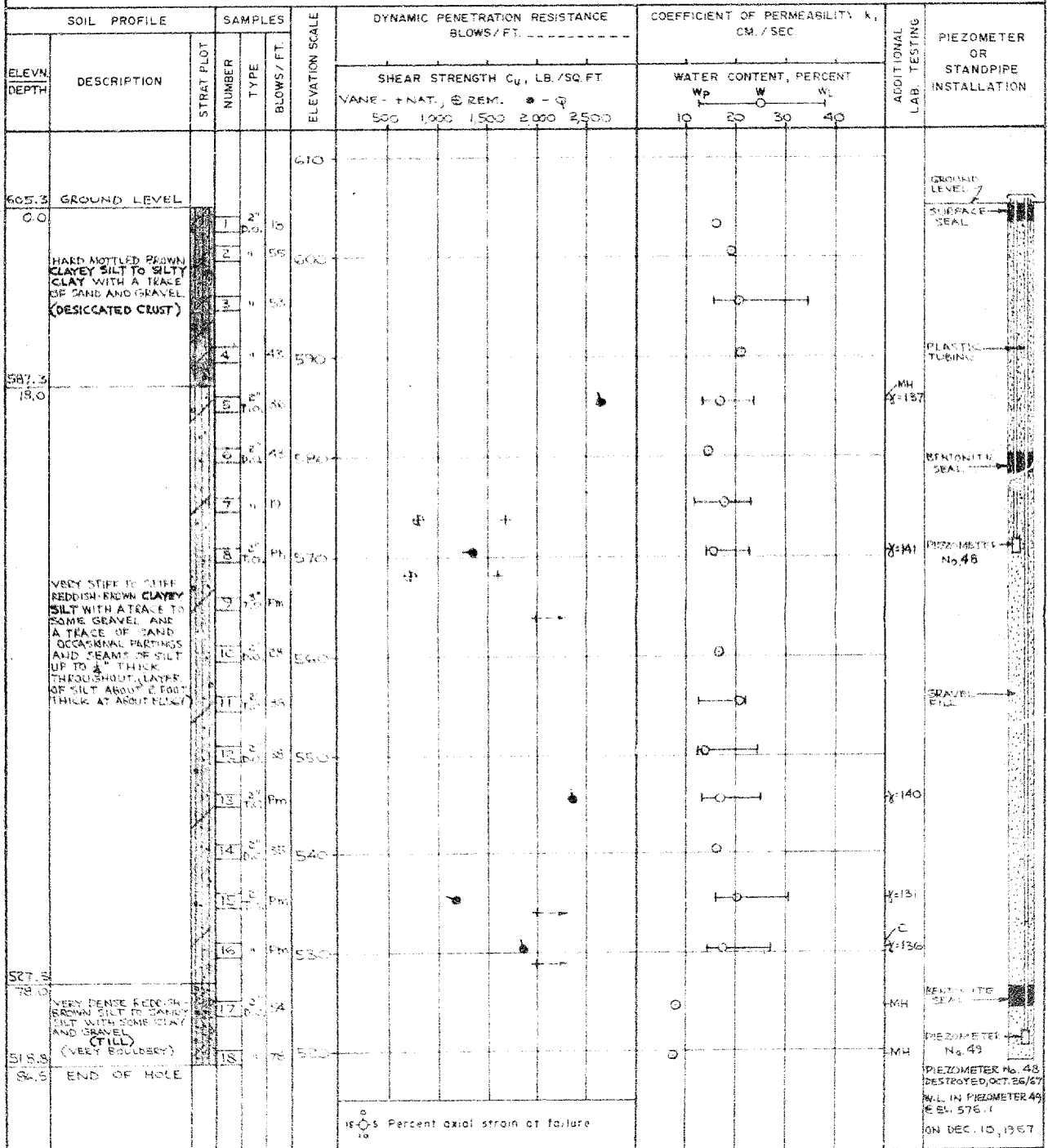
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN MD
CHECKED BD

RECORD OF BOREHOLE T-8

LOCATION See Figure 1-1 BORING DATE DEC. 22, 1966 - JAN. 5, 1967 DATUM GEOBOTIC
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" & NX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT --- LB. DROP --- INCHES



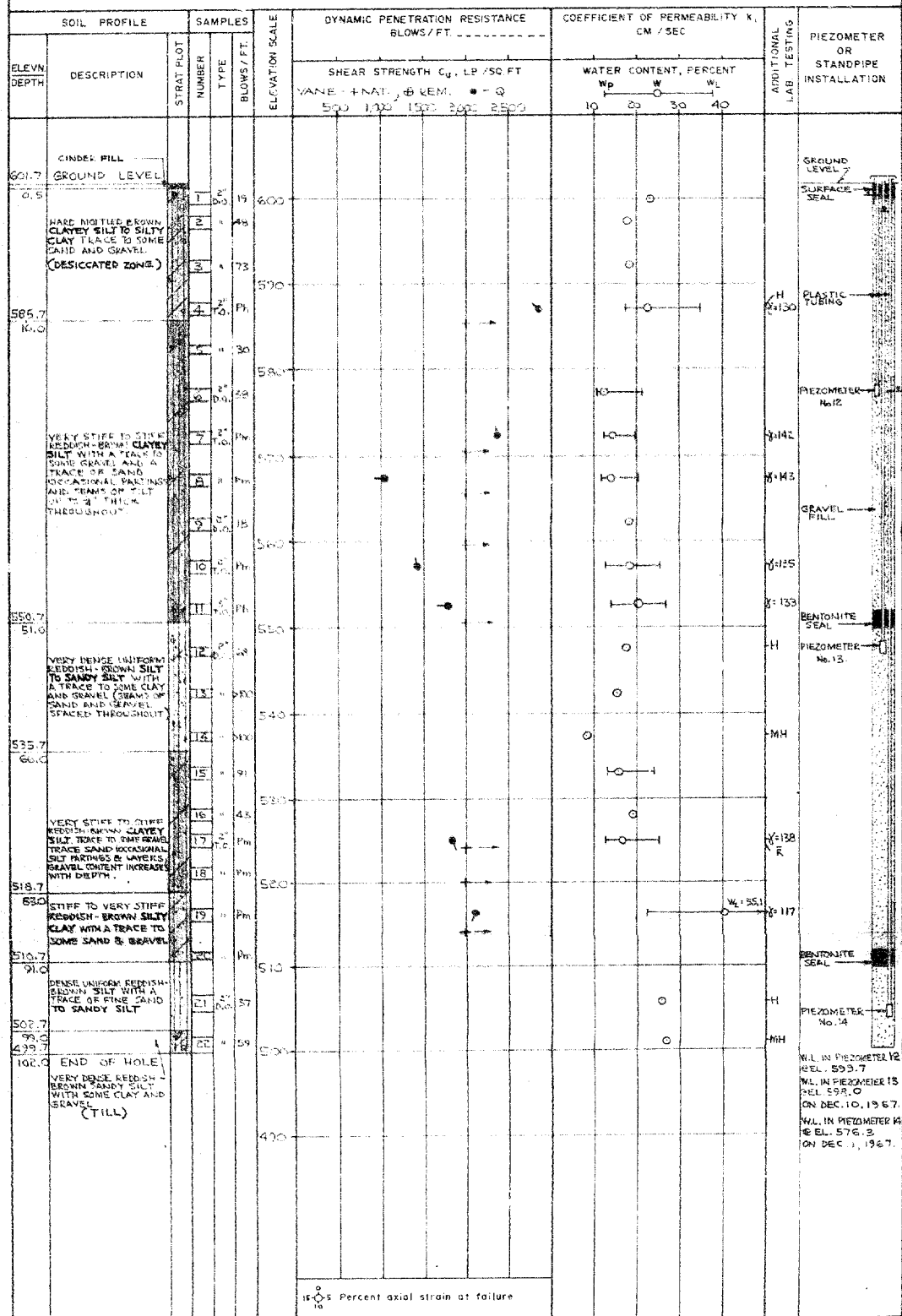
VERTICAL SCALE
1 INCH TO 10'-0"

COLDER & ASSOCIATES

DRAWN *MW*
CHECKED *AB*

RECORD OF BOREHOLE T-9

LOCATION See Figure 1-1 BORING DATE JAN. 4-10, 1947 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" \pm NX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB DROP — INCHES



VERTICAL SCALE
 1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *M.W.*
 CHECKED *J.P.*

RECORD OF BOREHOLE T-101

LOCATION See Figure 1-1 BORING DATE NOV. 8 - DEC. 19 1967 DATUM GEODETIC (1966)

BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" IN. & EX. CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT.					COEFFICIENT OF PERMEABILITY K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
ELEV. DEPTH	DESCRIPTION	STRAT. PLCT NUMBER	TYPE	BLOWS/FT.	SHEAR STRENGTH C_u , LB./SQ. FT.					WATER CONTENT, PERCENT						
					500	1000	1500	2000	2500	W_p	W	W_L			W_i	
ELEVATION SCALE																
• - Q.																
500 1000 1500 2000 2500																
Wp W WL Wi																
0 20 30 40																
BLACK CLAYEY TOPSOIL																
604.7	GROUND LEVEL				610										GROUND LEVEL	
604.7	DENSE GRAY SILT (PH)	1	2"	55							0				GROUND LEVEL	
586.7	HARD MOTTLED BROWN CLAYEY SILT TO SILTY CLAY WITH A TRACE TO SOME SAND & GRAVEL IRREGULARLY LAYERED STRUCTURE. BELOW ABOUT ELEV. 596 (DESICCATED CRUST)	2	"	58	600						0					
586.7		3	"	48							0					
586.7		4	TO Ph	590											SAND FILL	
586.7		5	0.0	25							0					
586.7		6	5"	PH	580										PLASTIC TUBING	
586.7		7	2"	21							0					
586.7	VERY STIFF TO STIFF REDDISH-BROWN CLAYEY SILT WITH A TRACE TO SOME SAND & GRAVEL, OCCASIONAL SILT TO SANDY SILT PARTINGS AND LAYERS UP TO 2" THICK DISPERSED THROUGHOUT	8	3"	Ph	570										PIEZOMETER NO. 27	
586.7		9	0.0	14							0					
586.7		10	5"	Ph	560											
586.7		11	2"	23							0					
586.7		12	3"	Ph	550						0				PIEZOMETER NO. 27	
586.7		13	2"	23							0					
586.7		14	5"	Ph	540											
586.7		15	0.0	17												
586.7		16	"	16							0					
586.7	DENSE TO VERY DENSE REDDISH-BROWN NON- STRATIFIED SILT TO SANDY SILT WITH A TRACE OF CLAY. OCCAS. CLAYEY SILT LAYERS UP TO ABOUT 6" THICK	17	"	46	530						0	N.P.			MH	
586.7		18	"	83							0	N.P.				
586.7		19	TO Ph	520							0				PIEZOMETER NO. 27	
586.7		20	0.0	14							0					
586.7	VERY STIFF TO STIFF REDDISH-BROWN CLAYEY SILT WITH A TRACE TO SOME SAND & GRAVEL, OCCASIONAL COBBLES	21	TO Ph		510						10	1			PIEZOMETER NO. 27	
586.7		22	"	Ph												
586.7		23	0.0	52							0					
586.7		24	TO Ph		500						0				SAND FILL	
494.7		25	0.0	10							0					
494.7	STIFF TO VERY STIFF REDDISH-BROWN SILTY CLAY WITH SOME SAND AND GRAVEL	26	TO Ph		490						0					
486.2		27	0.0	85												
486.2	WEATHERED AND SLIGHTLY FRACTURED BEDROCK	28	0.0	85											GRAVEL FILL	
476.7	FAIRLY SOUND BEDROCK	29	0.0	85											PIEZOMETER NO. 27	
474.6	END OF HOLE															
130.1																
					VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND WITH SOME CLAY AND GRAVEL (TILL)											
					BEDROCK DESCRIPTION											
					EL. 484.7 TO 483.5 WEATHERED GRAY SILTSTONE BEDROCK WITH NUMEROUS GYTTUML INCLUSIONS											GRAVEL FILL
					EL. 483.5 TO 482.4 WEATHERED AND SLIGHTLY FRACTURED DARK GRAY SHALE BEDROCK - FRACTURES FILLED WITH GYTTUML											BENTONITE SEAL
					EL. 482.4 TO 481.7 WEATHERED GRAY SILTSTONE BEDROCK WITH OCCASIONAL INTERBEDDED SHALE LAYERS AND NUMEROUS GYTTUML INCLUSIONS											PIEZOMETER NO. 27
					EL. 477.7 TO 476.6 FAIRLY SOUND DARK GRAY SHALE BEDROCK											PIEZOMETER NO. 27
					PERCENT CORE RECOVERY											
					85											
					100											
					Percent axial strain at failure											
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PERCENT CORE
RECOVERY

EL. 486.2 TO 486.3 - WEATHERED GREY BROMITIC
LIMESTONE BEDROCK WITH NUMEROUS
GYSDUM INCLUSIONS

EL. 486.3 TO 486.4 - WEATHERED AND SLIGHTLY FRACTURED
DARK GRAY SHALE BEDROCK - FRACTURED FILLED
WITH GYSDUM

EL. 486.4 TO 486.5 - WEATHERED GREY BROMITIC
LIMESTONE BEDROCK WITH OCCASIONAL
INTERBEDDED SHALE LAYERS AND
NUMEROUS GYSDUM INCLUSIONS

EL. 476.7 TO 474.6 - FAIRLY SOUND DARK GRAY SHALE
BEDROCK

150% Percent axial strain at failure

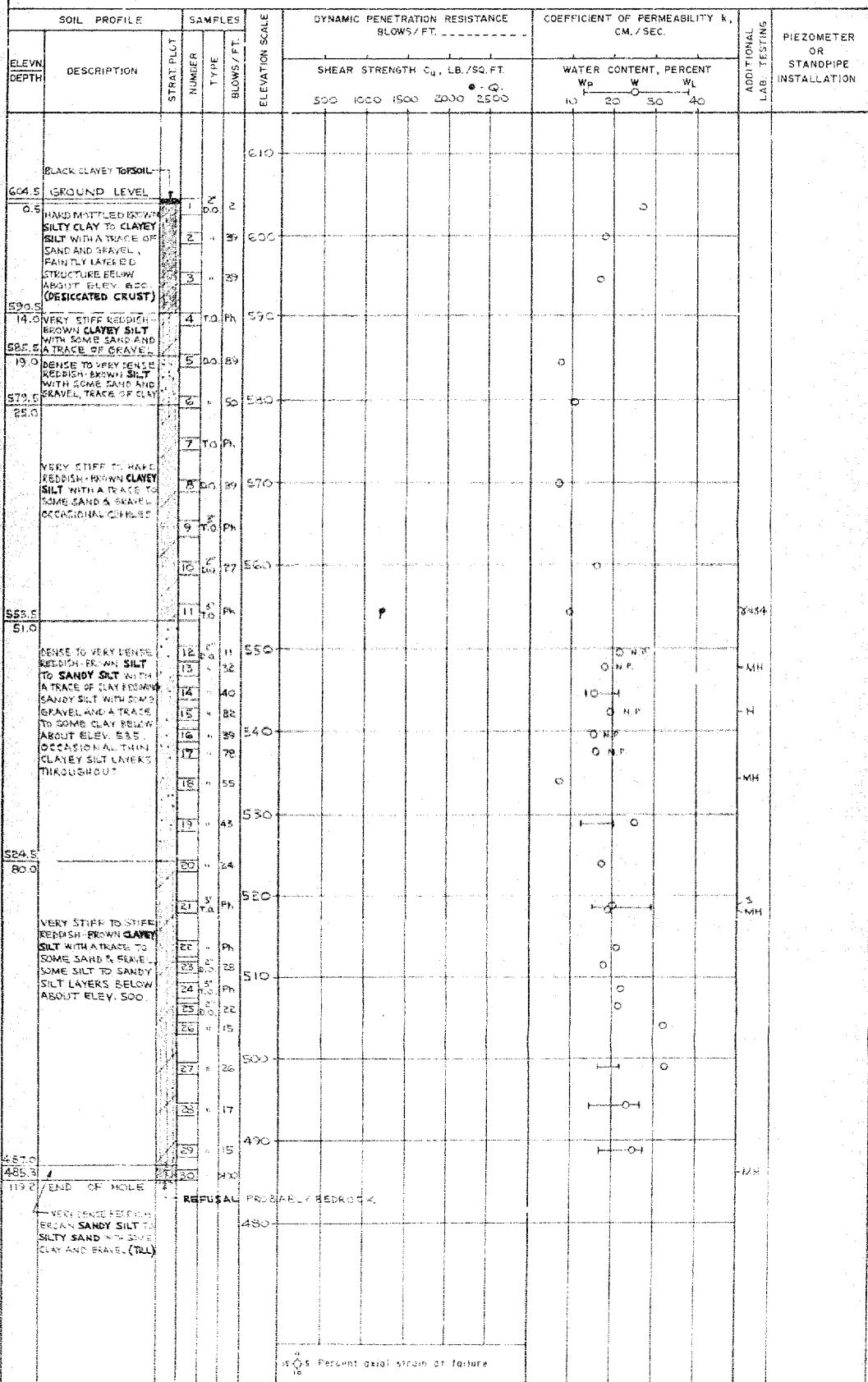
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J. A. J. M. W.
CHECKED J. A. J. M. W.

RECORD OF BOREHOLE T-102

LOCATION See Figure 1-1 BORING DATE NOV 7 - DEC 13 1967 DATUM GEODETIC (1944)
BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" HX CASING
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT --LB. DROP -- INCHES



VERTICAL SCALE
1 INCH TO 10 FT

GOLDER & ASSOCIATES

DRAWN J.A. 6/68
CHECKED

RECORD OF BOREHOLE T-103

LOCATION See Figure 1-1 BORING DATE NOV. 6 - DEC. 20, 1967 DATUM GEODETIC (1968)

BOREHOLE TYPE POWER AUGER $\frac{1}{2}$ WASH BORING BOREHOLE DIAMETER 4 5/8" BX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES

SOIL PROFILE			SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE	COEFFICIENT OF PERMEABILITY K, CM. / SEC.			ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FT.	SHEAR STRENGTH C _u , LB. / SQ. FT.	WATER CONTENT, PERCENT				
								W _p	W	W _L		
								10	20	30	40	
	BLACK CLAYEY TOPSOIL											
604.4	GROUND LEVEL											
599.4	0.7 FIRM TO VERY STIFF MOTTLED BROWN SILTY CLAY (FILL)		1	2"	4				0			
590.4			2	"	5				0			
580.4	HARD REDDISH-BROWN LAYERED SILTY CLAY TO CLAYEY SILT WITH A TRACE OF SAND AND GRAVEL. NUMEROUS SAND AND SILT SEAMS THROUGHOUT.		3	"	56				0			
570.4			4	T.O.	Ph							
560.4			5	3"	>100							
550.4			6	2"	51				0			
540.4			7	"	43				0			
530.4	HARD REDDISH-BROWN CLAYEY SILT WITH A TRACE TO SOME SAND AND GRAVEL. OCCASIONAL SILT SEAMS THROUGHOUT. OCCASIONAL COBBLES.		8	T.O.	Ph							
520.4			9	D.O.	27				0			
510.4			10	3"	Ph							
500.4			11	2"	39				0			
490.4			12	"	>100				10-1			
480.4			13	"	81				O.N.P.			
470.4			14	"	>100				O.N.P.			MH
460.4	VERY DENSE REDDISH BROWN SILT TO SANDY SILT WITH A TRACE OF CLAY AND GRAVEL.		15	"	>100				O.N.P.			
450.4			16	"	>100				O.N.P.			
440.4			17	"	52				O.N.P.			
430.4	VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND WITH SOME CLAY AND GRAVEL (TILL)		18	"	>100				0			
420.4			19	"	>100							
410.4	VERY DENSE GREY SILTY SAND & GRAVEL WITH A TRACE TO SILTY CLAY (TILL)		20	"	>100							MH
400.4	END OF HOLE.											

Percent axial strain at failure

VERTICAL SCALE
1 INCH TO 10'-0"

COLDER & ASSOCIATES

DRAWN J.A. Schaefer
CHECKED J.B. Schaefer

RECORD OF BOREHOLE T-104

LOCATION	See Figure 1-1	BORING DATE	NOV 16 - NOV 24, 1967	DATUM	CEMETERY (1966)
	BOREHOLE TYPE	POWER AUGER & WASH BORING	BOREHOLE DIAMETER	4.5" AND 5X CASING	
	SAMPLER HAMMER WEIGHT 140 LB	DROP 30 INCHES	PEN. TEST HAMMER WEIGHT — LB	DROP — INCHES	

SOIL PROFILE				SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FT.					COEFFICIENT OF PERMEABILITY k , CM. / SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEVATION DEPTH	DESCRIPTION	STRAT. PLCT NUMBER	TYPE	BLOWS / FT.	SHEAR STRENGTH C_u , LB. / SQ. FT.					WATER CONTENT, PERCENT							
					500		1000	1500	2000	2500	W_p	W	W_L				
603.8	GROUND LEVEL															GROUND LEVEL	
590.8	VERY STIFF TO HARD MOTTLED BROWN SILTY CLAY TO CLAYEY SILT WITH A TRACE OF SAND AND GRAVEL. FAINTLY LAYERED STRUCTURE BELOW ABOUT EL. 589 (DESICCATED CRUST)	1	2"	10													
590.8	VERY STIFF TO HARD REDDISH BROWN LAYERED SILTY CLAY TO CLAYEY SILT WITH A TRACE OF SAND AND GRAVEL. SOME SILT TO SANDY SILT SEAMS	4	4.0	28												SAND FILL	
580.3		6	2"	44												PIEZOMETER NO. 22	
580.3		7	4"	31													
580.3		8	TO	Ph												BENTONITE SEAL	
570.0		9	6"	22													
570.0		10	4"	11												PIEZOMETER NO. 23	
560.0		11	2"	11													
560.0		12	"	29													
550.0		13	"	41													
541.8		14	TO	Ph													
541.8		15	"	8												SAND FILL	
541.8	STIFF REDDISH BROWN SILTY CLAY WITH A TRACE OF SAND, GRAVEL, OCCASIONAL SILT SEAMS FAINTLY LAYERED STRUCTURE	16	6.0	12													
523.5		17	TO	Ph												S.H.	
523.5		18	6.0	17												BENTONITE SEAL	
523.5	VERY DENSE REDDISH- BROWN SILT TO SANDY SILT WITH A TRACE OF CLAY AND GRAVEL (FAINTLY STRATIFIED STRUCTURE BELOW ABOUT ELEV. 518)	19	"	>100												MH	
523.5		20	"	>100												PIEZOMETER NO. 23	
506.8		21	"	>100												SAND FILL	
506.8	VERY DENSE REDDISH- BROWN SILTY SAND TO SANDY SILT WITH SOME CLAY & GRAVEL (TRAIL)	22	"	>100												MH	
502.9																	
100.9	END OF HOLE																

WL IN PIEZOMETER 22
@ EL. 530.8
WL IN PIEZOMETER 23
@ EL. 576.0
ON DEC. 10, 1967

0
100% Percent axial strain at failure

15-15 percent axial strain at failure

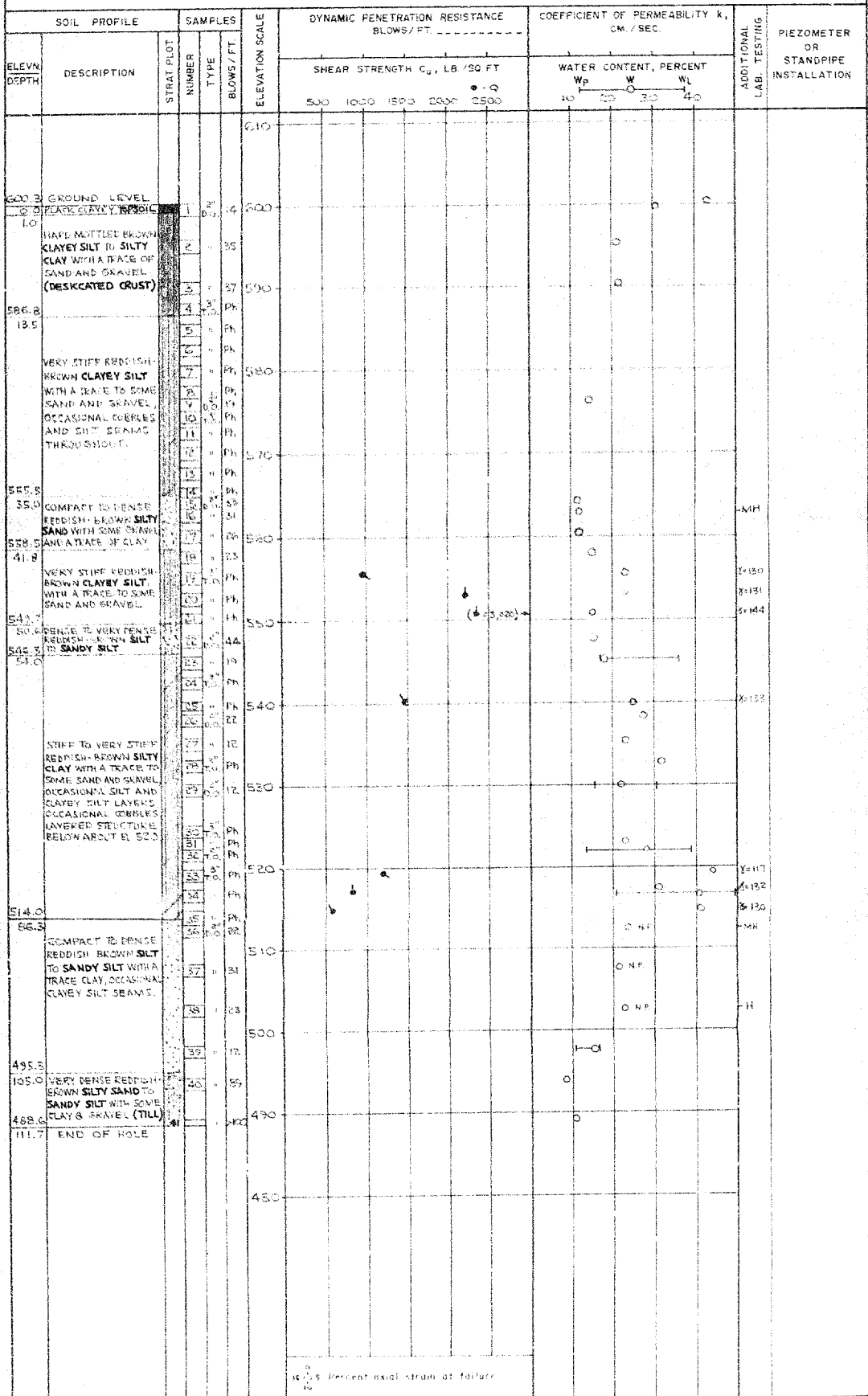
VERTICAL SCALE
1 INCH TO 10' 0"

COLDER & ASSOCIATES

DRAWN J.A.
CHECKED W.D.

RECORD OF BOREHOLE T-105

LOCATION	See Figure 1-1	BORING DATE	NOV. 21 - DEC. 5, 1967	DATUM	GEODETIC (1985)
BOREHOLE TYPE		POWER AUGER & WASH BORING		BOREHOLE DIAMETER	
				4.5" A NX CASING	
SAMPLER HAMMER WEIGHT		140 LB.		DROP 30 INCHES	
				PEN. TEST HAMMER WEIGHT --- LB. DROP --- INCHES	



VERTICAL SCALE
1 INCH TO 10' - 0"

CONFIDENTIAL

DRAWN ... A. J. K.

CHECKED -

RECORD OF BOREHOLE T-106

LOCATION See Figure 1-1 BORING DATE NOV. 9 - DEC. 20, 1967 DATUM GEODTIC (1966)
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" & NX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS / FT					COEFFICIENT OF PERMEABILITY K, CM / SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FT	SHEAR STRENGTH C _u , LB / SQ. FT.					WATER CONTENT, PERCENT					
						e - Q _u					W _p W W _L					
						500	1000	1500	2000	2500	10	20	30	40		
	BLACK CLAYEY TOPSOIL					610										
600.8	GROUND LEVEL															
595.3	STIFF (SEEMING HARD) YELLOW AND BROWN SILT, MOTTLED BROWN SILTY CLAY TO CLAYEY SILTY CLAY WITH A TRACE OF SOME SAND & GRAVEL. FAINTLY LAYERED STRUCTURE (DESICCATED CRUST)		1	0.0	4	600										
			2	"	15											
			3	"	40	550										
585.3			4	TO	PH											
580.3			5	DO	25											
			6	"	23	520										
			7	"	37											
	VERY STIFF TO HARD REDDISH BROWN CLAYEY SILT WITH A TRACE TO SOME SAND AND GRAVEL. OCCASIONAL COBBLES AND SILT GRAVEL THROUGHOUT		8	TO	PH	470										
			9	"	PH											
			10	DO	54											
			11	"	PH	560										
			12	"	PH											
541.3			13	"	PH	550										
531.3	VERY DENSE REDDISH-BROWN SILT & SANDY SILT WITH A TRACE OF GRAVEL. OCCASIONAL COBBLES AND CLAYEY SILT SEAMS.		14	"	N.P.											
			15	"	PH	540										
536.8			16	"	PH											
540.0			17	"	PH											
	VERY STIFF TO HARD REDDISH BROWN CLAYEY SILT WITH SOME SAND AND A TRACE OF SOME GRAVEL		18	TO	PH	530										
520.0			19	"	PH											
500.8			20	DO	20	520										
510.7	STIFF TO VERY STIFF REDDISH-BROWN IRREGULARLY LAYERED SILTY CLAY WITH A TRACE TO SOME SAND, OCCASIONAL SILT SEAMS.		21	TO	PH											
500.4			22	"	54											
	DENSE TO VERY DENSE REDDISH-BROWN SILT WITH SOME SAND AND A TRACE TO SOME CLAY		23	"	60	500										
495.8			24	"	34											
105.0	VERY DENSE GREY SILTY SAND & GRAVEL WITH A TRACE TO SOME CLAY (TILL)		25	"	PH	490										
490.3																
110.5	END OF HOLE															

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Percent axial strain at failure

VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN S.A.
CHECKED S.A.

RECORD OF BOREHOLE T-107A

LOCATION See Figure 1-1 BORING DATE DEC. 11 - 23, 1967 DATUM GEODETIC (1966)
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" # NX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES

SOIL PROFILE					DYNAMIC PENETRATION RESISTANCE BLOWS/FT. -----					COEFFICIENT OF PERMEABILITY K, CM./SEC					ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
ELEV. DEPTH	DESCRIPTION	STRAT PLOT NUMBER	TYPE	BLOWS/FT	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ FT.					WATER CONTENT, PERCENT						
						500	1000	1500	2000	2500	W _p	W	W _L	10			20
					610												
	BLACK CLAYEY TOPSOIL																
600.7	GROUND LEVEL																
595.7	HARD MOTTLED BROWN SILTY CLAY TO CLAYEY SILT WITH A TRACE OF SAND & GRAVEL, FAINTLY LAYERED STRUCTURE BELOW ABOUT ELEV. 587 (DESICCATED CRUST)	1	NO	12	600.0												
590.7		2	NO	44													
587.7		3	NO	38	590.0												
580.7		4	NO	Ph													
575.7		5	NO	21	580.0												
570.7	VERY FINE TO MEDIUM REDDISH-BROWN CLAYEY SILT WITH A TRACE OF SAND & GRAVEL, OCCASIONAL GORRLES	6	NO	16													
565.7		7	NO	15													
560.7		8	NO	27	570.0												
555.7		9	NO	64													
550.7		10	NO	25	560.0												
545.7		11	NO	20													
540.7		12	NO	21	550.0												
535.7		13	NO	14													
530.7		14	NO	Ph												6-123	
525.7		15	NO	23	540.0												
520.7	STIFF TO VERY STIFF REDDISH-BROWN SILTY CLAY WITH A TRACE OF SAND AND GRAVEL, OCCASIONALLY FAINTLY LAYERED STRUCTURE	16	NO	21													
515.7		17	NO	18	530.0												
510.7		18	NO	12													
505.7		19	NO	16	520.0												
500.7		20	NO	Ph												6-187	
495.7	VERY DENSE REDDISH BROWN SILTY SAND TO SANDY SILT WITH SOME CLAY AND GRAVEL, OCCASIONAL GORRLES (TILL)	21	NO	40	510.0												
490.7		22	NO	72												6-187	
485.7	END OF HOLE																

15-10-5 Percent axial strain at failure

15 10 5 Percent axial strain at failure

RECORD OF BOREHOLE T-108

LOCATION	See Figure 1-1	BORING DATE	DEC 5 - 21, 1967	DATUM	GEODETIC (1966)
	BOREHOLE TYPE	POWER AUGER & WASH BORING	BOREHOLE DIAMETER	4.5" AND NX CASING	
	SAMPLER HAMMER WEIGHT	140 LB. DROP 30 INCHES	PEN. TEST HAMMER WEIGHT	--- LB. DROP --- INCHES	

SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT.		COEFFICIENT OF PERMEABILITY K, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ. FT.	WATER CONTENT, PERCENT W _p W W _L		
								10 20 30 40		
601.8	GROUND LEVEL									
600.0	2.0' SAND & GRAVEL (TILL)		1	Ph	2	600				
598.5	VERY STIFF TO HARD BOTTLED UP, CLAYEY SILT TO SILTY CLAY WITH A TRACE OF SAND, GRAVEL AND GRAVEL. FAINTLY LAYERED STRUCTURE BELOW AS AT FLOW, 594 (DESICCATED CRUST)		2	Ph	3	598				
596.5			3	Ph	4	596				
594.5			4	Ph	5	594				
592.5			5	Ph	6	592				
590.5			6	Ph	7	590				
588.5			7	Ph	8	588				
586.5			8	Ph	9	586				
584.5			9	Ph	10	584				
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574.5			14	Ph	15	574				
572.5			15	Ph	16	572				
570.5			16	Ph	17	570				
568.5			17	Ph	18	568				
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564.5			19	Ph	20	564				
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556.5			23	Ph	24	556				
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520.5			41	Ph	42	520				
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516.5			43	Ph	44	516				
514.5			44	Ph	45	514				
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510.5			46	Ph	47	510				
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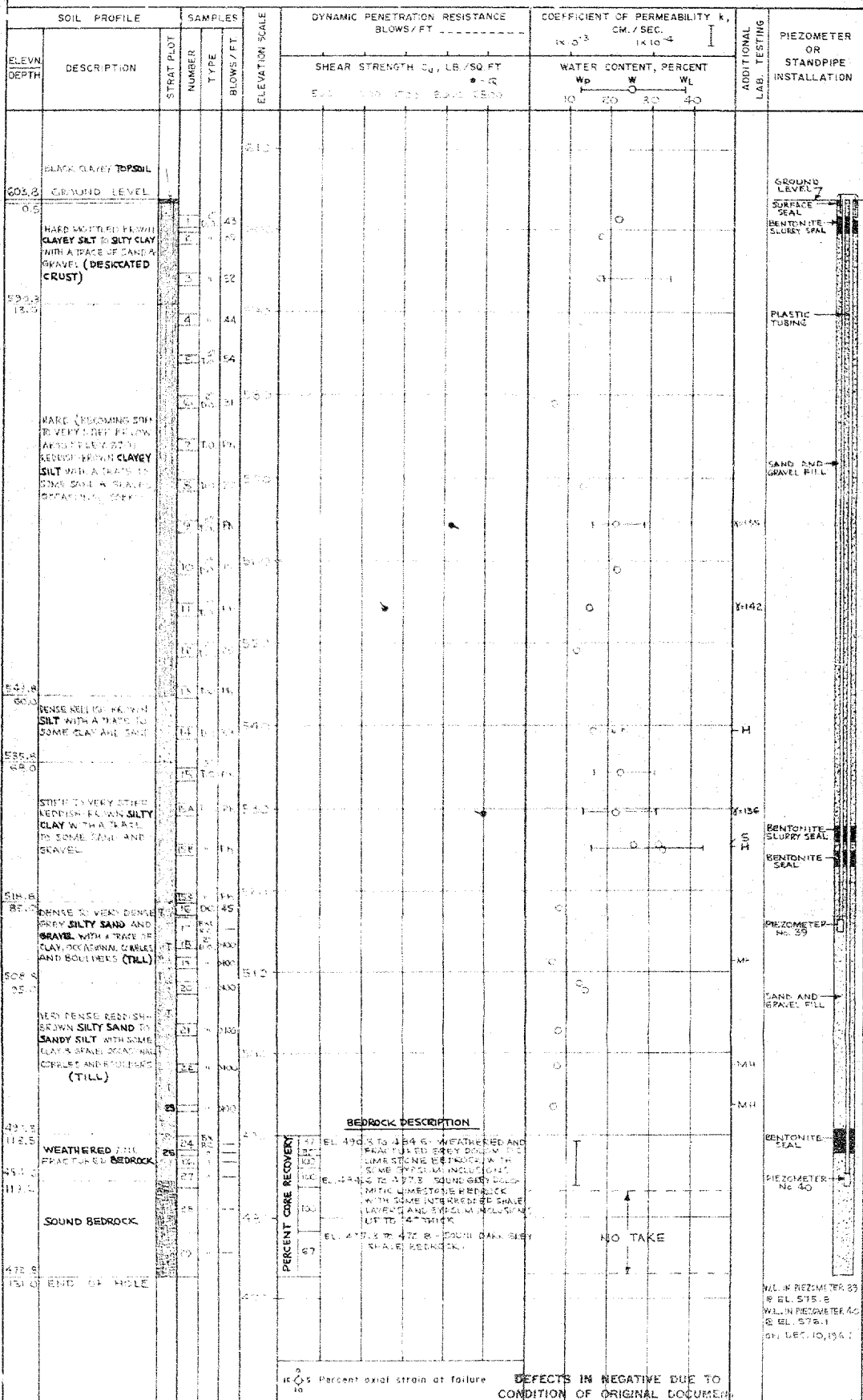
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J. A. J. [signature]
CHECKED [signature]

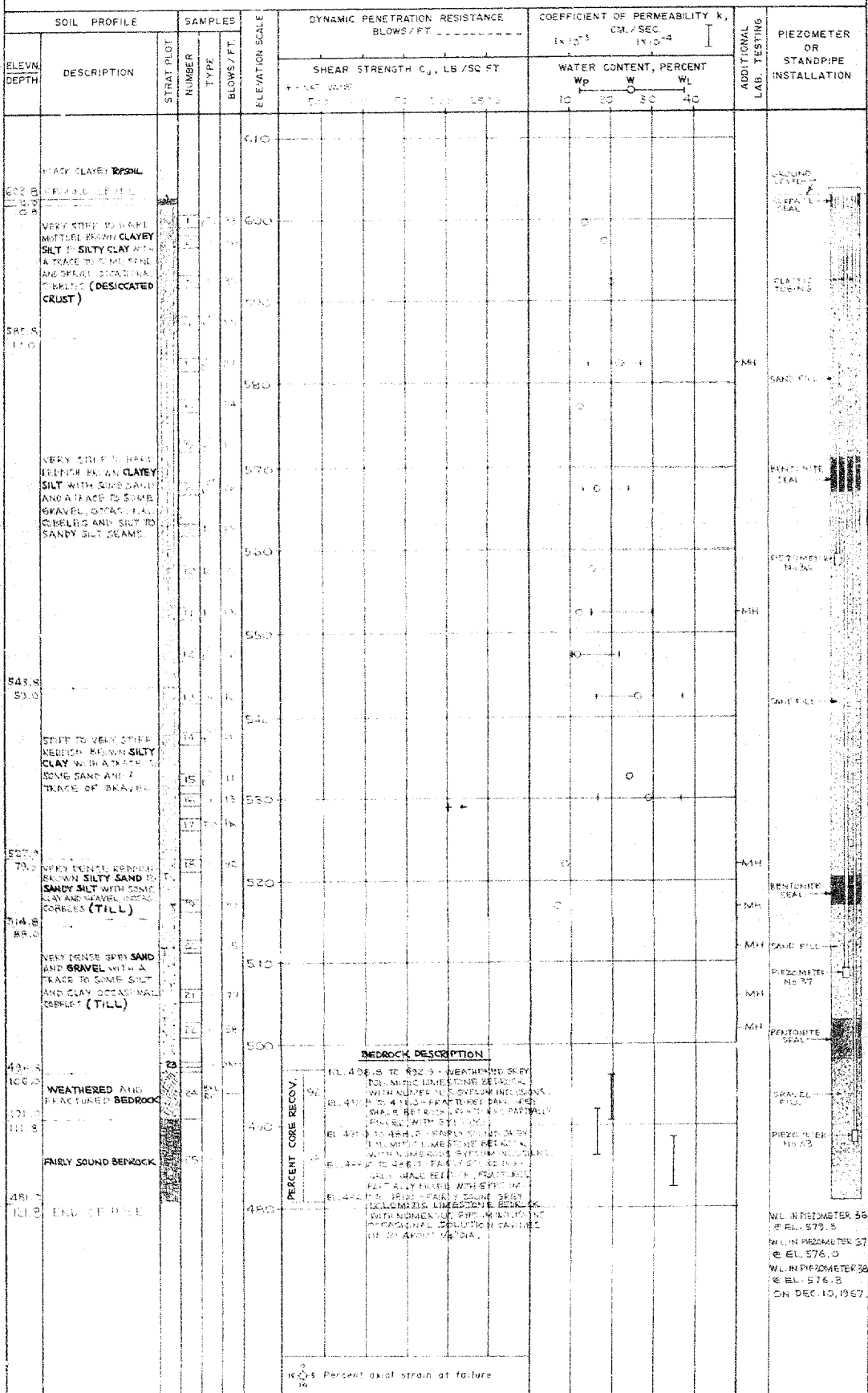
RECORD OF BOREHOLE T-121

LOCATION See Figure 1-1 BORING DATE NOV. 1 - 20 1967 DATUM GEODETIC (1960)
 BOREHOLE TYPE POWER AUGER 3 WAY H. BURNING BOREHOLE DIAMETER 4.5" X 5 BY CASING
 SAMPLER HAMMER WEIGHT 142 LB. DROP 20 INCHES PEN. TEST HAMMER WEIGHT --- LB. DROP --- INCHES



RECORD OF BOREHOLE T-122

LOCATION See Figure 1-1 BORING DATE NOV. 22, 1967 DATUM GEOLOGIC (1960)
 BOREHOLE TYPE POWER PILE & WASH BOX NO. BOREHOLE DIAMETER 11.5" MAX. & 8" CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO

GOLDER & ASSOCIATES

DRAWN BY A. J. BULL
CHECKED BY J. D. BULL

RECORD OF BOREHOLE T-123

LOCATION	See Figure 1-1	BORING DATE	NUTS & BELT TIGHTEN	DATUM	SEEDGYC (1960)
BOREHOLE TYPE	DRILL AND BLOW	WASH BIT IN	BOREHOLE DIAMETER	4 INCHES EX LAIN	
SAMPLER HAMMER WEIGHT 140 LB	DRILL ROD INCHES		PEN. TEST HAMMER WEIGHT - LB	GRN - INCHES	

[illegible]

VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN LAZAR
CHECKED LAZAR

RECORD OF BOREHOLE T-124

LOCATION	See Figure 1-1	BORING DATE	NOV. 1, 1977	DATUM	GEODETIC (1986)
BOREHOLE TYPE	POWER AUGER & WASH BORING		BOREHOLE DIAMETER	4.5" HX 8 BX CASING	
SAME 50 HAMMER WEIGHT 140 LB. DROP 12 INCHES			PEN. TEST HAMMER WEIGHT --- LB. DROP --- INCHES		

[illegible]

VERTICAL SCALE

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COLLIER & ASSOCIATES

DRAWN J. A. & M. W.

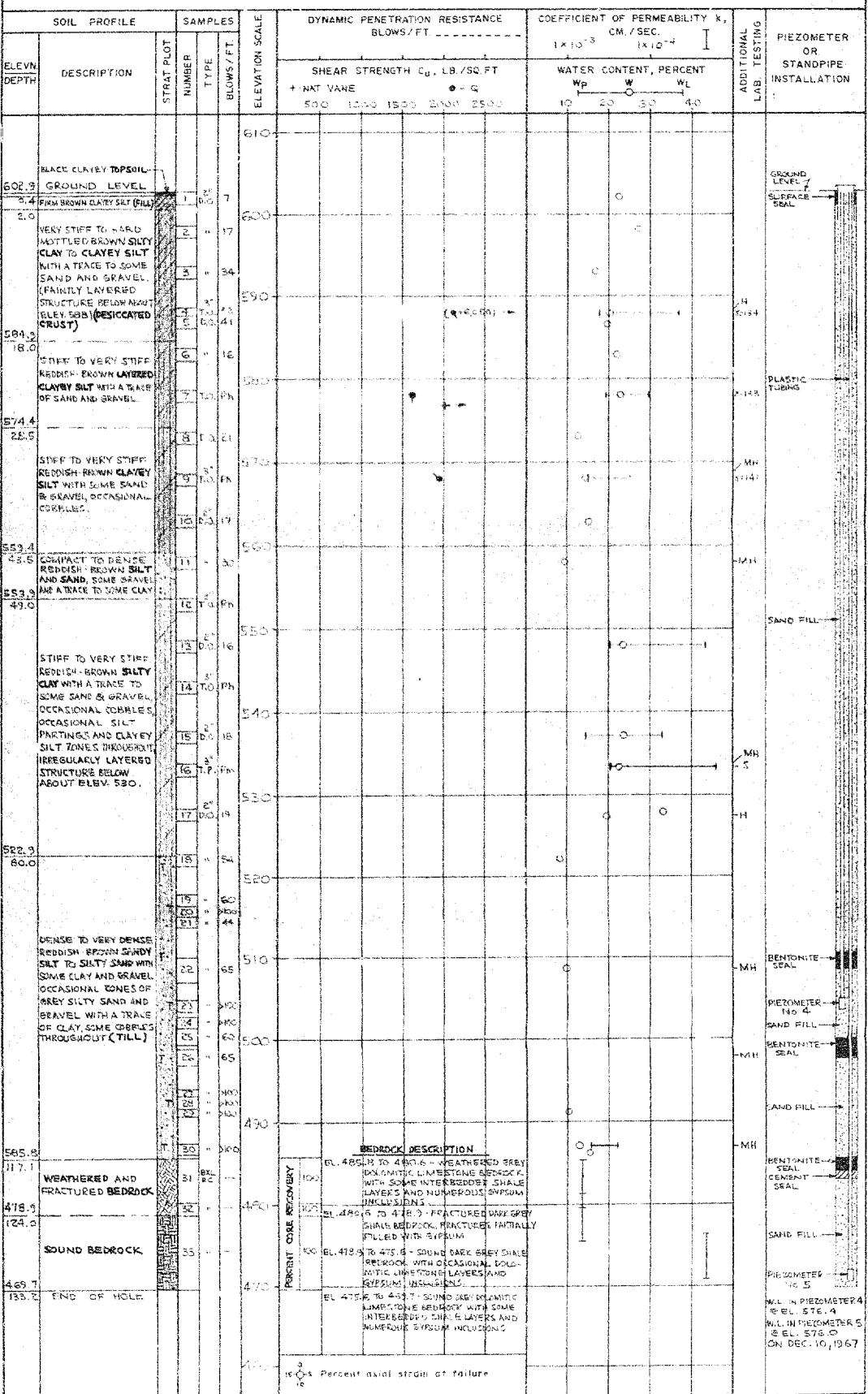
CHECKED 132.....

RECORD OF BOREHOLE T-125

LOCATION See Figure 1-1 BORING DATE OCT 27 - NOV 10, 1967 DATUM GEODETIC (1966)

BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" NX NX #BX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES



VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

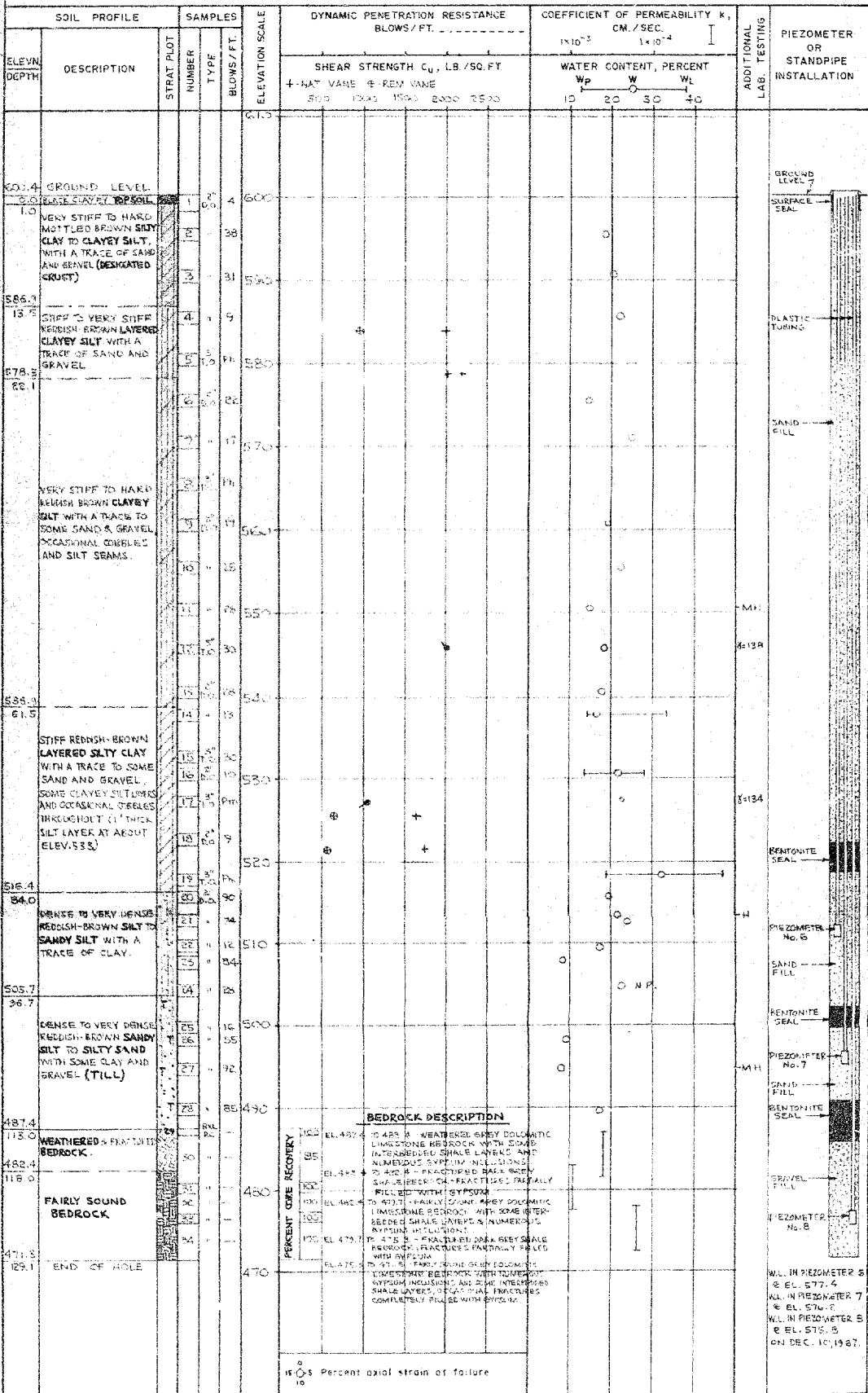
DRAWN J.A. (J.M.)
CHECKED J.M.

RECORD OF BOREHOLE T-126

LOCATION See Figure 1-1 BORING DATE OCT 26 - NOV 8, 1967 DATUM GEODETIK (1966)

BOREHOLE TYPE POWER AUGER AND WASH BORING BOREHOLE DIAMETER 4.5" HX AND P-CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT ---- LB. DROP -- INCHES



RECORD OF BOREHOLE E-1

PROJECT No. 92-11002

LOCATION See Figure 1-1 BORING DATE NOV. 22 - DEC. 1, 1967 DATUM GEODETIC (1966)
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" NX 4 BX CASING
 SAMPLER HAMMER WEIGHT - LB. DROP - INCHES PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT		COEFFICIENT OF PERMEABILITY k, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE	BLOWS/FT	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ. FT	WATER CONTENT, PERCENT W _p W W _L		
601.7	GROUND LEVEL				610				
594.7	PROBABLY HAVE MOTTLED BROWN SILTY CLAY TO CLAYEY SILT (DISCONTINUOUS CORRELS)				600				GROUND LEVEL 7 SURFACE SEAL
584.7					590				
574.7	PROBABLY VERY SILTY TO BROWN AND BROWN BROWN CLAYEY SILT, OCCASIONAL CORRELS				580				PLASTIC TUBING
564.7					570				
554.7	PROBABLY VERY SILTY TO BROWN AND BROWN BROWN CLAYEY SILT, OCCASIONAL CORRELS				560				SAND FILL
544.7					550				
534.7					540				
524.7	PROBABLY VERY SILTY TO BROWN AND BROWN BROWN CLAYEY SILT, OCCASIONAL CORRELS				530				
514.7					520				
504.7					510				
494.7	PROBABLY VERY SILTY TO BROWN AND BROWN BROWN CLAYEY SILT, OCCASIONAL CORRELS				500				BENTONITE SEAL
484.7					490				PIEZOMETER No. 23
474.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				480				SAND FILL
464.7					470				BENTONITE SEAL
454.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				460				GRAVEL FILL
444.7					450				PIEZOMETER No. 24
434.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				440				
424.7					430				
414.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				420				
404.7					410				
394.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				400				
384.7					390				
374.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				380				
364.7					370				
354.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				360				
344.7					350				
334.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				340				
324.7					330				
314.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				320				
304.7					310				
294.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				300				
284.7					290				
274.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				280				
264.7					270				
254.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				260				
244.7					250				
234.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				240				
224.7					230				
214.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				220				
204.7					210				
194.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				200				
184.7					190				
174.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				180				
164.7					170				
154.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				160				
144.7					150				
134.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				140				
124.7					130				
114.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				120				
104.7					110				
94.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				100				
84.7					90				
74.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				80				
64.7					70				
54.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				60				
44.7					50				
34.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				40				
24.7					30				
14.7	PROBABLY WEATHERED AND FRACTURED BEDROCK				20				
4.7					10				
					0				

GROUND LEVEL 7

SURFACE SEAL

PLASTIC TUBING

SAND FILL

BENTONITE SEAL

PIEZOMETER No. 23

SAND FILL

BENTONITE SEAL

GRAVEL FILL

PIEZOMETER No. 24

N.I. IN PIEZOMETER 23 @ EL. 577.1

W.I. IN PIEZOMETER 24 @ EL. 576.4

ON DEC. 10, 1947

BEDROCK DESCRIPTION

EL. 482.4 TO 474.7: BADLY WEATHERED AND FRACTURED BEDROCK. LUMINOUS BEDROCK WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILICUM INCLUSIONS.

EL. 474.7 TO 470.2: BADLY WEATHERED BEDROCK WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILICUM INCLUSIONS.

EL. 470.2 TO 464.7: OPEN, VOID.

EL. 464.7 TO 454.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 454.7 TO 444.7: OPEN, VOID.

EL. 444.7 TO 434.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 434.7 TO 424.7: OPEN, VOID.

EL. 424.7 TO 414.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 414.7 TO 404.7: OPEN, VOID.

EL. 404.7 TO 394.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 394.7 TO 384.7: OPEN, VOID.

EL. 384.7 TO 374.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 374.7 TO 364.7: OPEN, VOID.

EL. 364.7 TO 354.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 354.7 TO 344.7: OPEN, VOID.

EL. 344.7 TO 334.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 334.7 TO 324.7: OPEN, VOID.

EL. 324.7 TO 314.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 314.7 TO 304.7: OPEN, VOID.

EL. 304.7 TO 294.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 294.7 TO 284.7: OPEN, VOID.

EL. 284.7 TO 274.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 274.7 TO 264.7: OPEN, VOID.

EL. 264.7 TO 254.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 254.7 TO 244.7: OPEN, VOID.

EL. 244.7 TO 234.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 234.7 TO 224.7: OPEN, VOID.

EL. 224.7 TO 214.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 214.7 TO 204.7: OPEN, VOID.

EL. 204.7 TO 194.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 194.7 TO 184.7: OPEN, VOID.

EL. 184.7 TO 174.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 174.7 TO 164.7: OPEN, VOID.

EL. 164.7 TO 154.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 154.7 TO 144.7: OPEN, VOID.

EL. 144.7 TO 134.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 134.7 TO 124.7: OPEN, VOID.

EL. 124.7 TO 114.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 114.7 TO 104.7: OPEN, VOID.

EL. 104.7 TO 94.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 94.7 TO 84.7: OPEN, VOID.

EL. 84.7 TO 74.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 74.7 TO 64.7: OPEN, VOID.

EL. 64.7 TO 54.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 54.7 TO 44.7: OPEN, VOID.

EL. 44.7 TO 34.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 34.7 TO 24.7: OPEN, VOID.

EL. 24.7 TO 14.7: BADLY WEATHERED AND FRACTURED BEDROCK.

EL. 14.7 TO 4.7: OPEN, VOID.

EL. 4.7 TO 0: BADLY WEATHERED AND FRACTURED BEDROCK.

PERCENT CORE RECOVERY

25

50

75

100

IF $\frac{D}{10}$ Percent axial strain at failure

BEDROCK DESCRIPTION

EL. 424.4 TO 474.4 EASILY WEATHERED AND FRACTURED (FEE) DIOLOMITE LIMESTONE BEDROCK WITH SOME INTERESTING SHALE LAYERS AND DISCONTINUOUS SILTUM INCLUSIONS
 EL. 474.4 TO 494.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 494.4 TO 504.4 OBSERVED
 EL. 504.4 TO 514.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 514.4 TO 524.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 524.4 TO 534.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 534.4 TO 544.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 544.4 TO 554.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 554.4 TO 564.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 564.4 TO 574.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 574.4 TO 584.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 584.4 TO 594.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 594.4 TO 604.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS
 EL. 604.4 TO 614.4 EASILY WEATHERED SILTUM WITH SOME INTERESTING SHALE LAYERS AND NUMEROUS SILTUM INCLUSIONS

100 Percent axial strain at failure

VERTICAL SCALE
 1 INCH TO 10' 0"

GOLDER & ASSOCIATES

DRAWN J.A. #20
 CHECKED J.E. #20

RECORD OF BOREHOLE E-2A

LOCATION See Figure 1-1 BORING DATE DEC. 5-12, 1967 DATUM GEODETIC (1966)
BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" AND NK CASING
SAMPLER HAMMER WEIGHT - LB. DROP - INCHES PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES		BLOWS/FT.	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FT. -----	COEFFICIENT OF PERMEABILITY k, CM./SEC.			ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEVATION DEPTH	DESCRIPTION	STRAT. PLCT NUMBER	TYPE			SHEAR STRENGTH C _u , LB./SQ. FT.	WATER CONTENT, PERCENT W _p W W _L				
601.9	GROUND LEVEL				610						
600.0	CRUSHED STONE (FILL)				600						GROUND LEVEL SURFACE SEAL
486.0	PROBABLY HARD MOTTLED BROWN SILTY CLAY TO CLAYEY SILT (VERMICULATED CRUST)				590						
456.0	PROBABLY VERY STIFF TO HARD REDDISH BROWN CLAYEY SILT				580						PLASTIC TUBING
456.0					570						1" I.D. IRON PIPE
456.0					560						
456.0	PROBABLY VERY DENSE REDDISH BROWN AND TO SANDY SILT OCCASIONAL COBBLES				550						GRAVEL FILL
585.0					540						
585.0					530						
585.0					520						
585.0	PROBABLY VERY STIFF TO STIFF REDDISH- BROWN CLAYEY SILT TO SILTY CLAY				510						
585.0					500						
492.4					490						
492.5	PROBABLY VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND (FILL)				480						BENTONITE SEAL
487.3	WEATHERED AND FRACTURED BEDROCK	1	AXL EC		470						
481.6					460						
481.6	FRACTURED BEDROCK	2			450						GRAVEL FILL
471.3		3			440						PIEZOMETER No. 26
130.6	END OF HOLE				430						WL IN PIEZOMETER 26 @ EL. 576.0 ON DEC. 10, 1967

100

5

Percent axial strain at failure

EL. 492.5 TO 486.0 - WEATHERED AND FRACTURED
GREY DOLOMITIC LIMESTONE BEDROCK
WITH OCCASIONAL INTERBEDDED SHALE
LAYERS AND NUMEROUS SYNGRANULAR
INCLUSIONS.

EL. 486.0 TO 471.3 - FRACTURED GREY DOLOMITIC
LIMESTONE BEDROCK WITH OCCASIONAL
SHALE LAYERS AND NUMEROUS SYNGRANULAR
INCLUSIONS.

EL. 471.3 TO 470.0 - FRACTURED DARK GREY SHALE
BEDROCK.

EL. 470.0 TO 456.0 - FRACTURED GREY DOLOMITIC
LIMESTONE BEDROCK WITH NUMEROUS
SYNGRANULAR INCLUSIONS. OCCASIONAL
SMALL SILENT CAVITIES (2" DIA.)

BEDROCK DESCRIPTION

EL. 492.5 TO 486.0 - WEATHERED AND FRACTURED
GREY DOLOMITIC LIMESTONE BEDROCK
WITH OCCASIONAL INTERBEDDED SHALE
LAYERS AND NUMEROUS SYNGENETIC
INCLUSIONS.

EL. 481.6 TO 477.3 - FRACTURED GREY DOLOMITIC
LIMESTONE BEDROCK WITH OCCASIONAL
SHALE LAYERS AND NUMEROUS SYNGENETIC
INCLUSIONS.

EL. 477.3 TO 474.3 - FRACTURED DARK GREY SHALE
BEDROCK.

EL. 474.3 TO 471.3 - FRACTURED GREY DOLOMITIC
LIMESTONE BEDROCK WITH NUMEROUS
SYNGENETIC INCLUSIONS, OCCASIONAL
SMALL BENTONITE CAVITIES (1" DIA.)

PERCENT COKE RECOVERY

58
67
88

0
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

Percent axial strain at failure

VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J.A. & M.D.
CHECKED J.C.

RECORD OF BOREHOLE S-1

LOCATION See Figure 1-1 BORING DATE NOV 25 - 30, 1967 DATUM GEODETIC (1968)
BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" NX # BX CASING
SAMPLER HAMMER WEIGHT - LB. DROP - INCHES PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FT.	COEFFICIENT OF PERMEABILITY k , CM. / SEC			ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEVATION DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE		SHEAR STRENGTH C_u , LB. / SQ. FT.	WATER CONTENT, PERCENT W_p W W_L				
601.7	GROUND LEVEL			610						
600.0	CRUSHED PLANE FILL			600						GROUND LEVEL SURFACE SEAL
488.7	PROBABLY HARD MOTTLED BROWN CLAYEY SILT TO SILTY CLAY (DEBRICATED CRUST)			570						
485.0				560						SAND FILL
	PROBABLY VERY STIFF TO HARD REDDISH-BROWN CLAYEY SILT OCCASIONAL CORBBLES.			570						PLASTIC TUBING
554.7				560						
551.0	PROBABLY DENSE TO VERY DENSE REDDISH-BROWN SILT TO SANDY SILT			550						
538.7				540						
535.0				530						
	PROBABLY VERY STIFF TO STIFF REDDISH- BROWN CLAYEY SILT TO SILTY CLAY			520						
505.7				510						
505.0	PROBABLY VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND, SOME CORBBLES BELOW ABOUT EL. 492 (TILL)			500						BENTONITE SEAL
483.0				490						SAND FILL
482.0				480						PIEZOMETER NO. 50
474.0	WEATHERED AND FRACTURED BEDROCK	1	REL R2	480						BENTONITE SEAL
471.2	FAIRLY SOUND BEDROCK	2		470						GRAVEL FILL
430.5	END OF HOLE	3		470						PIEZOMETER NO. 51

BEDROCK DESCRIPTION

100 EL. 488.0 TO 477.5 - WEATHERED AND SUBSTLY
FRACTURED GREY DALMANITE LIMESTONE
BEDROCK WITH SOME INTERBEDDED
SHALE LAYERS AND SYSTEM INCLUSIONS
5 TO 474.0 - FRACTURED DARK GREY
SHALE BEDROCK
EL. 474.0 TO 471.2 - FAIRLY SOUND GREY DALMANITE
LIMESTONE BEDROCK WITH INTERBEDDED
SHALE LAYERS AND SOME SYSTEM
INCLUSIONS.

PERCENT CORE
RECOVERY

0
100-5 Percent axial strain at failure

W.L. IN PIEZOMETER 50
@ EL. 575.6
ON DEC. 10, 1967
W.L. IN PIEZOMETER 51
@ EL. 576.2
ON DEC. 1, 1967
PIEZOMETER NO. 51
DESTROYED DEC. 1/67.

RECORD OF BOREHOLE S-1A

LOCATION See Figure 1-1

BORING DATE DEC. 8-12, 1967

DATUM GEODETIC (1966)

BOREHOLE TYPE POWER AUGER $\frac{1}{2}$ " WASH BORINGBOREHOLE DIAMETER 4.5" NX $\frac{1}{2}$ " BX CASING

SAMPLER HAMMER WEIGHT - LB. DROP - INCHES

PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT.		COEFFICIENT OF PERMEABILITY K, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ. FT.				WATER CONTENT, PERCENT W _p W W _L
601.7 1.0	GROUND LEVEL REINFORCED CONCRETE				610					GROUND LEVEL SURFACE SEAL
	PROBABLY HARD MOIST BROWN CLAYEY SILT TO SILTY CLAY (DECATIZED 41.5%)				600					
586.7 15.0					590					
	PROBABLY VERY STIFF TO HARD REDDISH-BROWN CLAYEY SILT OCCASIONAL COBBLES				580					PLASTIC TUBING
					570					
564.7 45.0					560					GRAVEL FILL
	PROBABLY DENSE & HARD REDDISH-BROWN SANDY SILT TO SANDY SILT				550					
536.7 65.0					540					5" I.D. IRON PIPE
	PROBABLY VERY STIFF & STIFF REDDISH-BROWN CLAYEY SILT TO SILTY CLAY OCCASIONAL COBBLES				530					
					520					
					510					
501.7 60.0					500					
	PROBABLY VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND OCCASIONAL COBBLES (FILL)				490					
484.0 17.0	WEATHERED & DISSEMINATED FRACTURED BEDROCK	1	472		480					BENTONITE SEAL
478.7 23.0	FAIRLY SOUND BEDROCK	2			470					GRAVEL FILL
473.0		3								PIEZOMETER No. 59
428.7	END OF HOLE									
						BEDROCK DESCRIPTION				
						EL. 484.0 TO 480.0 - WEATHERED AND SLIGHTLY FRACTURED GREY DOLOMITE LIMESTONE BEDROCK WITH SOME INTERBEDDED SHALE LAYERS AND SYLITUM INCLUSIONS				
						EL. 480.0 TO 475.0 - SLIGHTLY FRACTURED DARK GREY SHALE BEDROCK				
						EL. 475.0 TO 473.0 - FAIRLY SOUND INTERBEDDED GREY DOLOMITE LIMESTONE BEDROCK AND SHALE BEDROCK WITH SOME SYLITUM INCLUSIONS				
						0 10 5 Percent axial strain at failure				
<div>W.L. IN PIEZOMETER 59 @ EL. 576.0 ON DEC. 12, 1967</div>										

BEDROCK DESCRIPTION

EL. 430.0 TO 480.0 - WEATHERED AND
SLIGHTLY FRACTURED GREY DOLOMITIC
LIMESTONE BEDROCK WITH SOME
INTERBEDDED SHALE LAYERS
AND SYNGENETIC INCLUSIONS
EL. 480.0 TO 495.0 - SLIGHTLY FRACTURED
DARK GREY SHALE BEDROCK
EL. 495.0 TO 475.0 - FAIRLY SOUND INTERBEDDED
GREY DOLOMITIC LIMESTONE BEDROCK AND
SHALE BEDROCK WITH SOME
SYNGENETIC INCLUSIONS

PROBABLE
CORE
SAMPLES

10
5
Percent axial strain at failure

W.L. IN PIEZOMETER 59
@ EL. 576.0
ON DEC. 12, 1967

VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J.A. [signature]
CHECKED [signature]

RECORD OF BOREHOLE S-2

LOCATION See Figure 1-1 BORING DATE NOV. 27 - DEC 2, 1967 DATUM GEODETIC (1966)
 BOREHOLE TYPE POWER AUGER $\frac{1}{2}$ WASH BORING BOREHOLE DIAMETER 4.5", NX $\frac{1}{2}$ BX CASING
 SAMPLER HAMMER WEIGHT - LB. DROP - INCHES PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE BLOWS/FT. -----		COEFFICIENT OF PERMEABILITY K, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C_u , LB./SQ. FT.	WATER CONTENT, PERCENT Wp W WL		
601.6 0.0	GROUND LEVEL					610				GROUND LEVEL
586.6 15.0	PROBABLY HARD MOTTLED BROWN CLAYEY SILT TO SILTY CLAY (DESICCATED CRUST)					600				SURFACE SEA
562.6 39.0	PROBABLY VERY STIFF TO HARD REDDISH BROWN CLAYEY SILT, OCCASIONAL COBBLES.					590				
						580				PLASTIC TUBING
						570				
						560				SAND FILL
						550				
						540				
						530				
						520				
						510				
						500				BENTONITE SEAL
498.6 103.0	PROBABLY VERY DENSE REDDISH-BROWN SILTY SAND TO SANDY SILT, OCCASIONAL COBBLES (TILL)					490				PIEZOMETER No. 52
485.6 116.0	WEATHERED AND FRACTURED BEDROCK		1	SL NC		480				BENTONITE SEAL
479.1 122.5			2							SAND FILL
471.8 129.8	FAIRLY FINE BEDROCK		3							PIEZOMETER No. 53
	END OF HOLE					470				PLASTIC TUBING IN PIEZOMETERS 52, 53 KINNED DURING INSTALLATION.

BEDROCK DESCRIPTION

PERCENT COKE RECOVERY	86	EL. 485.6 TO 481.8 - WEATHERED GRAY DOLOMITIC LIMESTONE BEDROCK WITH SOME SYNGRAN INCLUSIONS.
	100	EL. 481.8 TO 480.0 - WEATHERED WHITE SYNGRAN BEDROCK WITH SOME DOLOMITIC LIMESTONE INCLUSIONS.
	27	EL. 480.0 TO 450.0 - FRACTURED DARK GRAY SHALE SANDY SILT.
		EL. 450.0 TO 479.1 - WEATHERED GRAY DOLOMITIC LIMESTONE BEDROCK, SOME SYNGRAN INCLUSIONS.

EL. 479.1 TO 471.8 - FAIRLY SOUND DARK GRAY
SANDY DOLOMITIC0
100.5 Percent axial strain at failureVERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J.A. & M.W.
CHECKED J.A. & M.W.

RECORD OF BOREHOLE S-3

LOCATION	See Figure 1-1	BORING DATE	NOV. 27- DEC. 7, 1967	DATUM	GEODETIC (1966)
BOREHOLE TYPE		POWER AUGER & WASH BORING	BOREHOLE DIAMETER		4.5" NX & BX CASING
SAMPLER HAMMER WEIGHT - LB. DROP - INCHES			PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES		

SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE BLOWS/FT. -----		COEFFICIENT OF PERMEABILITY k, CM./SEC.		ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ. FT.	WATER CONTENT, PERCENT W _p W W _L			
402.3 0.0	GROUND LEVEL				410					GROUND LEVEL SURFACE SEAL
427.3 15.0	PROBABLY HARD MOTTLED BROWN CLAYEY SILT TO SILTY CLAY (DESIGNATED CRUST)				430					
					450					
					470					PLASTIC TUBING
	PROBABLY VERY STIFF TO HAVE REDDISH BROWN CLAYEY SILT OCCASIONAL CORRUS.				490					
					510					
454.3 52.0	PROBABLY DENSE TO VERY DENSE REDDISH-BROWN SILT TO SANDY SILT				530					SAND FILL
					550					
					570					
482.3 80.0					590					
					610					
	PROBABLY VERY STIFF TO STIFF REDDISH BROWN CLAYEY SILT TO SILTY CLAY OCCASIONAL COBBLES				630					
					650					
					670					
492.3 110.0	PROBABLY VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND (TILL)				690					BENTONITE SEAL
485.3 117.0	WEATHERED BEDROCK	1	BY RC		710					PIEZOMETER NO. 54
478.5 124.3		2	"		730					BENTONITE SEAL
473.3	FAIRLY SOUND BEDROCK	3	"		750					SAND FILL
472.0	END OF HOLE				770					PIEZOMETER NO. 55
					790					PLASTIC TUBING IN PIEZOMETERS 54, 55 KINKED DURING INSTALLATION

BEDROCK DESCRIPTION

EL. 485.3 TO 478.5 - WEATHERED GREY
DULACITE LIMESTONE BEDROCK
WITH OCCASIONAL INTERBEDDED
SHALE LAYERS AND NUMEROUS
SILTY LAYERS AND LENSES
UP TO 4" THICK

EL. 478.5 TO 472.0 - FAIRLY SOUND DARK
GRAY SHALE BEDROCK WITH
OCCASIONAL STYROL FILLER
FRACTURES.

Percent axial strain at failure

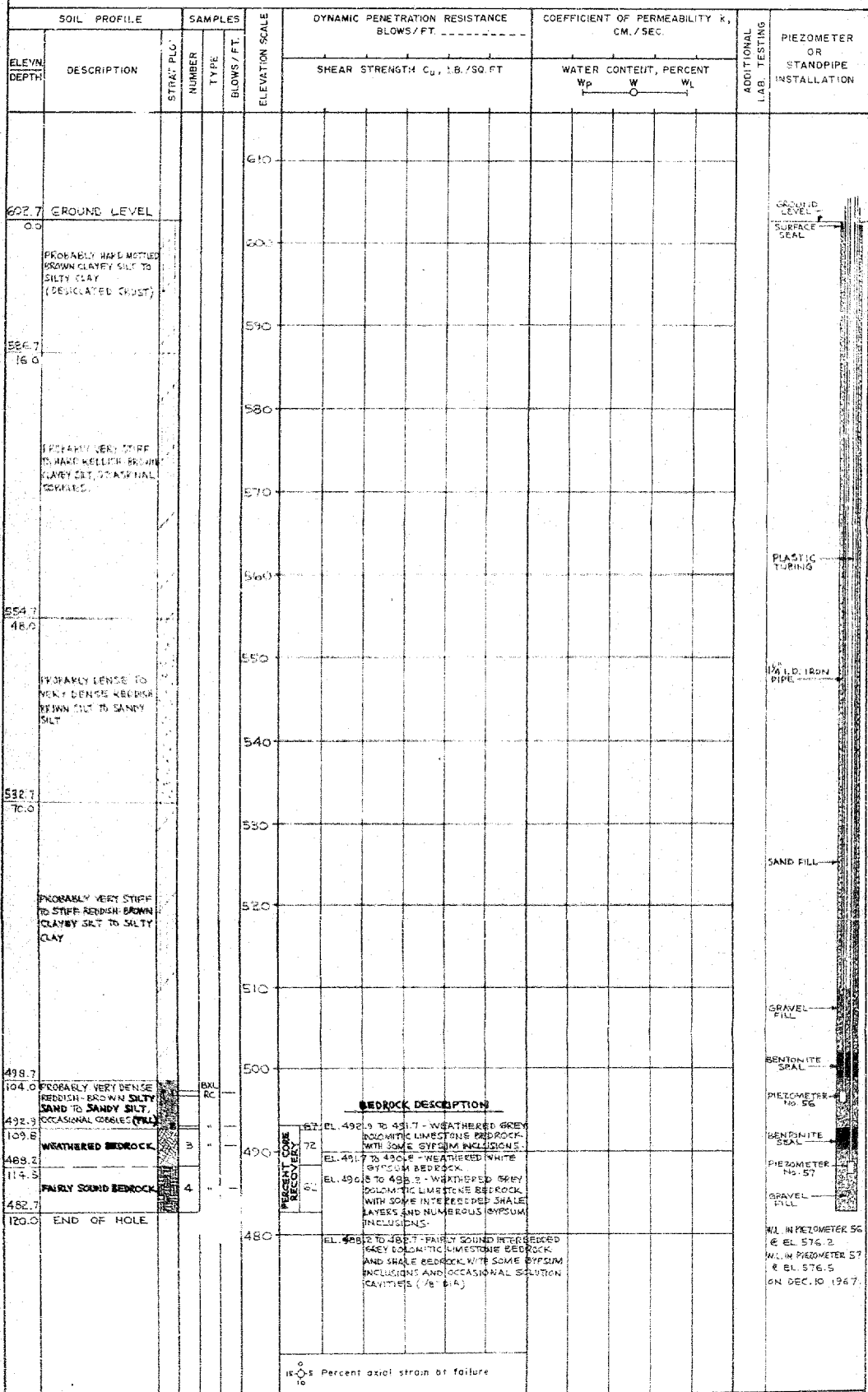
VERTICAL SCALE
1 INCH TO 10' 0"

GOLBERG & ASSOCIATES

DRAWN J. A. J. M. L.
CHECKED J. A. J. M. L.

RECORD OF BOREHOLE S-4

LOCATION See Figure 1-1 BORING DATE NOV 25 - DEC 9, 1967 DATUM GEODETIC (1966)
 BOREHOLE TYPE POWER AUGER & WASH BORING BOREHOLE DIAMETER 4.5" NX 4" BX CASING
 SAMPLER HAMMER WEIGHT - 15 LB DROP - INCHES PEN. TEST HAMMER WEIGHT - LB DROP - INCHES



VERTICAL SCALE

1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J.A.

CHECKED J.A.

RECORD OF BOREHOLE N-1

LOCATION See Figure 1-1

BORING DATE DEC. 1-15, 1967

DATUM

GEODETTIC (1966)

BOREHOLE TYPE POWER AUGER & WASH BORING

BOREHOLE DIAMETER 4.5" NX 8" CASING

SAMPLER HAMMER WEIGHT - LB. DROP - INCHES

PEN. TEST HAMMER WEIGHT - LB. DROP - INCHES

SOIL PROFILE		SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FT. -----		COEFFICIENT OF PERMEABILITY k_v , CM. / SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FT.	SHEAR STRENGTH C_u , LB./SQ. FT.	WATER CONTENT, PERCENT W_p W W_L			
					610						
601.7 0.0	GROUND LEVEL				600						GROUND SURFACE SEAL
	PROBABLY HARD MEDIUM BROWN CLAYEY SILT TO SILTY CLAY (DESICATED CRUST)				590						
585.7 16.0					580						PLASTIC TUBING
	PROBABLY VERY STIFF TO HARD REDDISH- BROWN CLAYEY SILT, OCCASIONAL COBBLES				570						1/2" I.D. IRON PIPE
556.7 45.0					560						
	PROBABLY VERY DENSE REDDISH-BROWN SILT TO SANDY SILT				550						
535.7 66.0					540						SAND FILL
	PROBABLY VERY STIFF TO HARD REDDISH- BROWN CLAYEY SILT, OCCASIONAL COBBLES				530						
522.7 79.0					520						
	PROBABLY VERY DENSE REDDISH-BROWN SILT SAND TO SANDY SILT, SOME COBBLES, OCCASIONAL BOULDERS				510						
480.7 121.0	END OF HOLE				500						
					490						BENTONITE SEAL
					480						SAND AND GRAVEL FILL
											PIEZOMETER No. 60
											PIEZOMETER GOING NOT RESPONDING TO FLUSHING ON DEC. 20, 1967.

0

10

15

Percent axial strain at failure

15% ± Percent axial strain at failure

VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN 4A (M)
CHECKED 160

RECORD OF BOREHOLE N-2

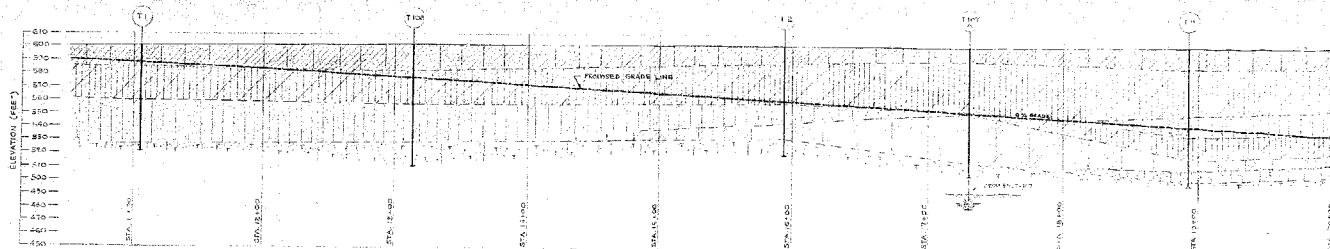
LOCATION	See Figure 1-1	BORING DATE	NOV. 30 - DEC. 14, 1967	DATUM	GEODETIC (1966)
BOREHOLE TYPE	POWER AUGER & WASH BORING	BOREHOLE DIAMETER	4.5" NA & BX CASING		
SAMPLER HAMMER WEIGHT - LB.	DROP - INCHES	PEN. TEST HAMMER WEIGHT	- LB. DROP - INCHES		

SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE BLOWS/FT.		COEFFICIENT OF PERMEABILITY K, CM./SEC.		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH C _u , LB./SQ.FT.			
					610				
600.4 0.0	GROUND LEVEL				600				GROUND LEVEL - 7
589.4 11.0	PROBABLY HARD MOTTLED BROWN CLAYEY SILT TO SILTY CLAY (DESICCATED CRUST)				590				
					580				
	PROBABLY VERY STIFF TO HARD REDDISH- BROWN CLAYEY SILT				570				PLASTIC TUBING
					560				SAND FILL
555.4 45.0					550				
	PROBABLY DENSE TO VERY DENSE REDDISH- BROWN SILT TO SANDY SILT, OCCASIONAL CORBELLS.				540				
					530				
530.4 70.0					520				
	PROBABLY VERY STIFF TO STIFF REDDISH- BROWN CLAYEY SILT TO SILTY CLAY.				510				
					500				
498.4 102.0	PROBABLY VERY DENSE REDDISH-BROWN SANDY SILT TO SILTY SAND, OCCASIONAL CORBELLS (TILL)				490				CAVE - IN MATERIAL
485.3 114.5	WEATHERED BEDROCK	1	ART RC		480				SAND FILL
479.4 121.0	END OF HOLE	2	"		470				PIEZOMETER - NO. 61
				BEDROCK DESCRIPTION					
				EL. 485.3 TO 482.2 - WEATHERED GREY DOLOMITIC LIMESTONE BEDROCK WITH SOME GYPSUM INCLUSIONS					
				EL. 482.2 TO 482.4 - WEATHERED DARK GREY SHALE BEDROCK					
				EL. 482.4 TO 479.4 - WEATHERED GREY DOLOMITIC LIMESTONE BEDROCK WITH SOME GYPSUM INCLUSIONS					
				9 15-25 Percent axial strain at failure					
NOTE: CASING LEFT IN HOLE AT ELEV. 492 TO PROTECT PLASTIC TUBING DURING THE PERIOD OF PUMPING TEST. PIEZOMETER #61 DESTROYED DURING RECOVERY OF CASING ON DEC. 22, 1967.									

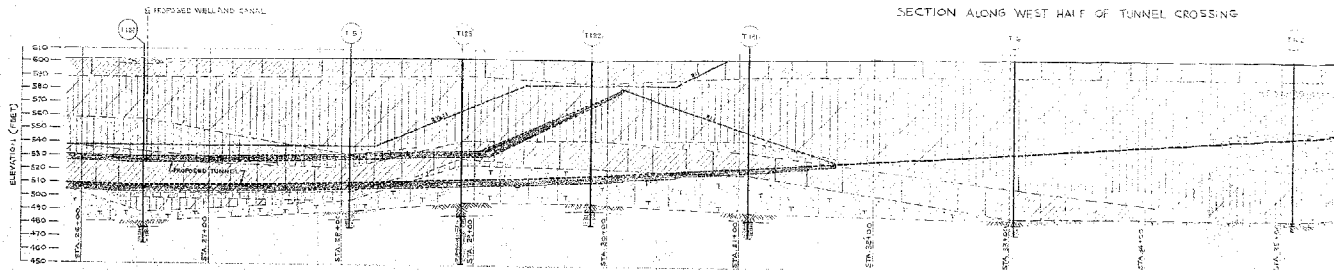
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN J. A. Felt
CHECKED 152



SECTION ALONG WEST HALF OF TUNNEL CROSSING

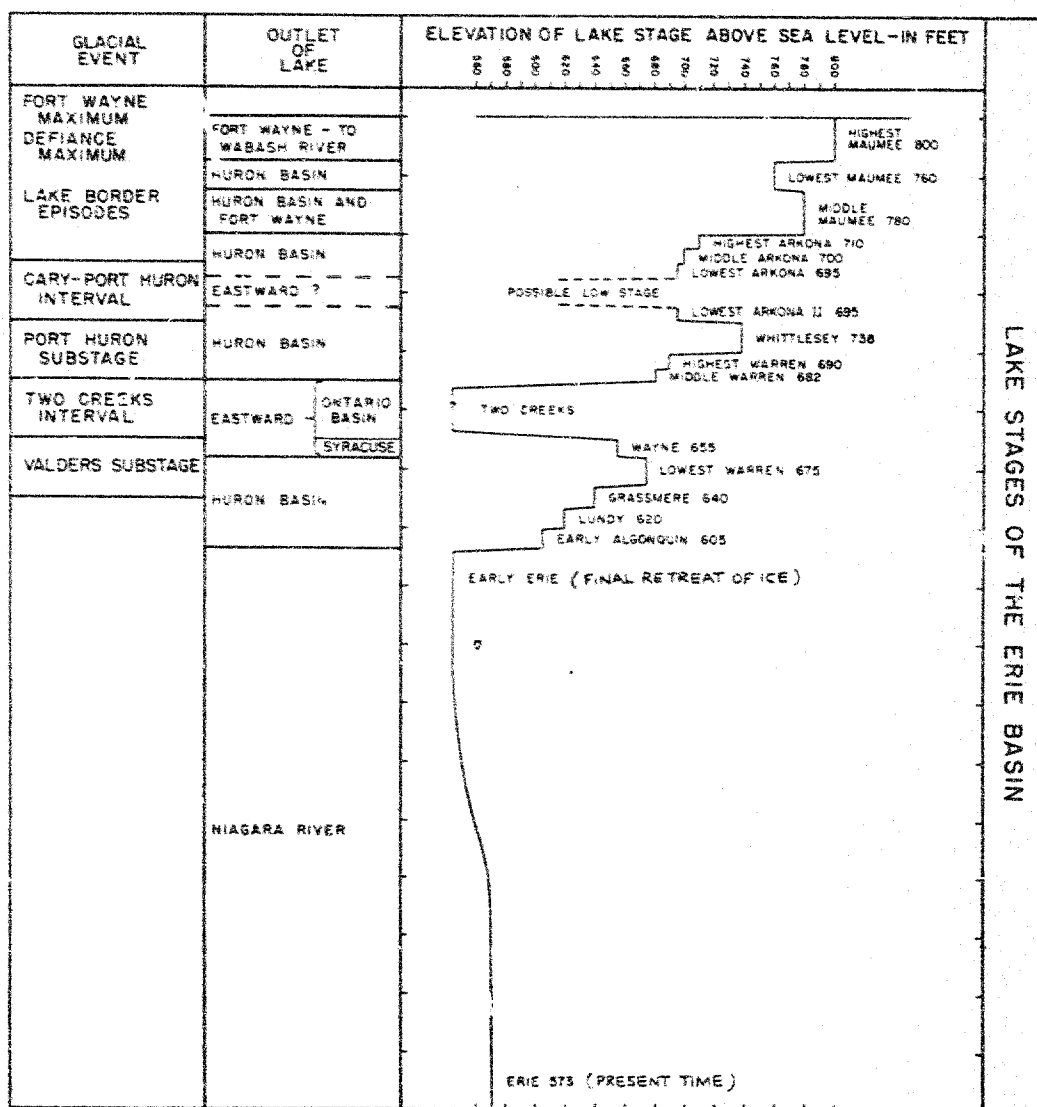


SECTION ALONG EAST HALF OF TUNNEL CROSSING

SCALE: 1" TO 40'

EARLY STAGES OF THE ERIE BASIN

FIGURE 1 - 4



REFERENCE: HOUGH, J. L., 1958. GEOLOGY OF THE GREAT LAKES
(URBANA: UNIVERSITY OF ILLINOIS PRESS)

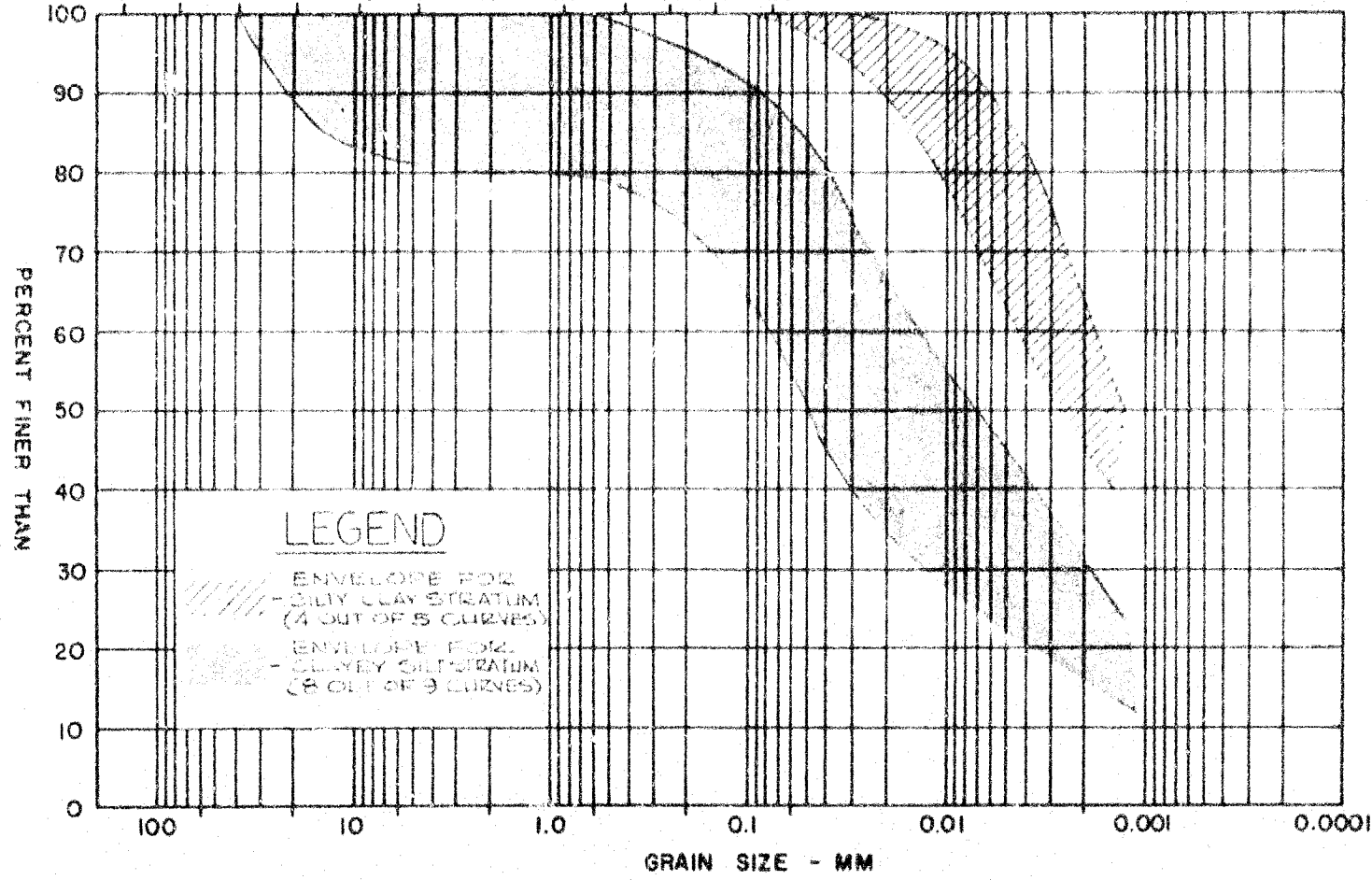
GRADATION ENVELOPES
CLAYEY SILT AND SILTY CLAY STRATA

FIGURE 1-5

M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES/IN.

6" 3" 1 1/2" 3/4" 3/8" 4 10 20 40 60 100 200

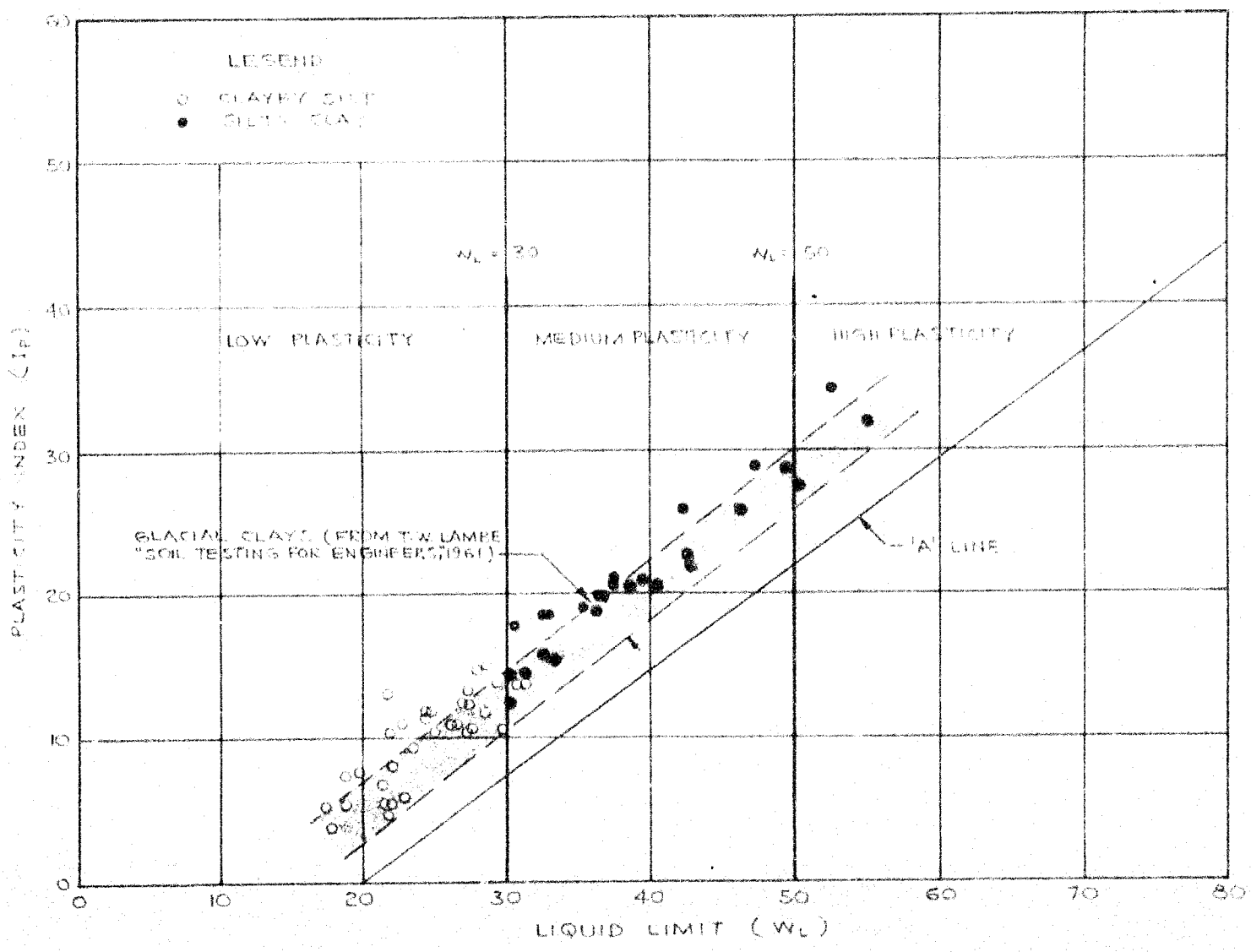


COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

GOLDER & ASSOCIATES

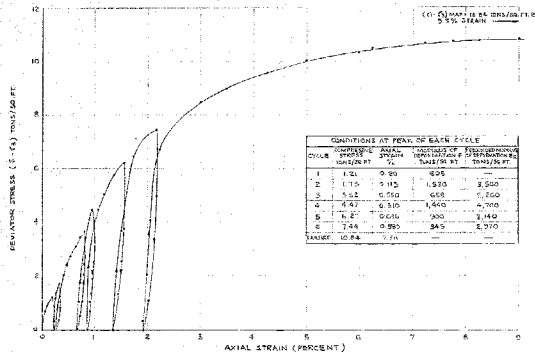
PLASTICITY CHART
CLAYEY SILT AND SILTY CLAY STRATA

FIGURE 1-6



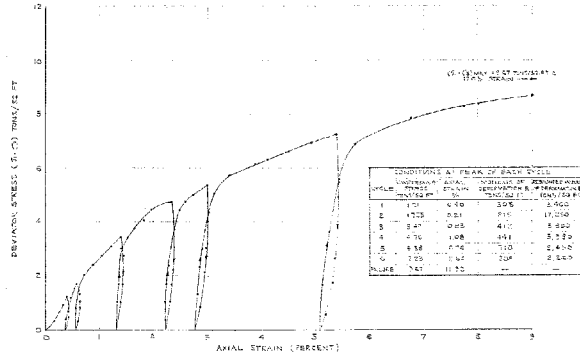
GOLDER & ASSOCIATES

TEST No. 1



NOTE: 1) INITIAL WATER CONTENT OF SAMPLE 6.1%
2) TOTAL UNIT WEIGHT OF SAMPLE 129 LB./CU. FT.

TEST No. 2

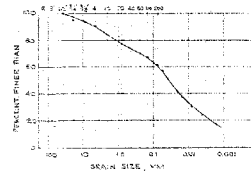


NOTE: 1) INITIAL WATER CONTENT OF SAMPLE 7.5%
2) TOTAL UNIT WEIGHT OF SAMPLE 135 LB./CU. FT.

RESULTS OF CYCLIC LOADING TESTS
COMPOSITE SAMPLE OF TILL

FIGURE 1-7

COARSE GRAVEL SIZE SAND SIZE FINE SAND GRAIN SIZE
W/1 GRAIN SIZE SCALE



GRAIN SIZE DISTRIBUTION OF TEST SAMPLE

NOTES ON TESTING PROCEDURE

- 1) TESTS PERFORMED ON COMPOSITE SAMPLE OF SILTY PORTION OF TILL
- 2) SAMPLES COMPACTED BY MODIFIED HANDBOOK COMPACTION METHOD
- 3) SAMPLE SIZE 6" DIA. X 4" HIGH
- 4) TOTAL CELL PRESSURE DURING TESTS, 6% X 45 LB./SQ. IN.

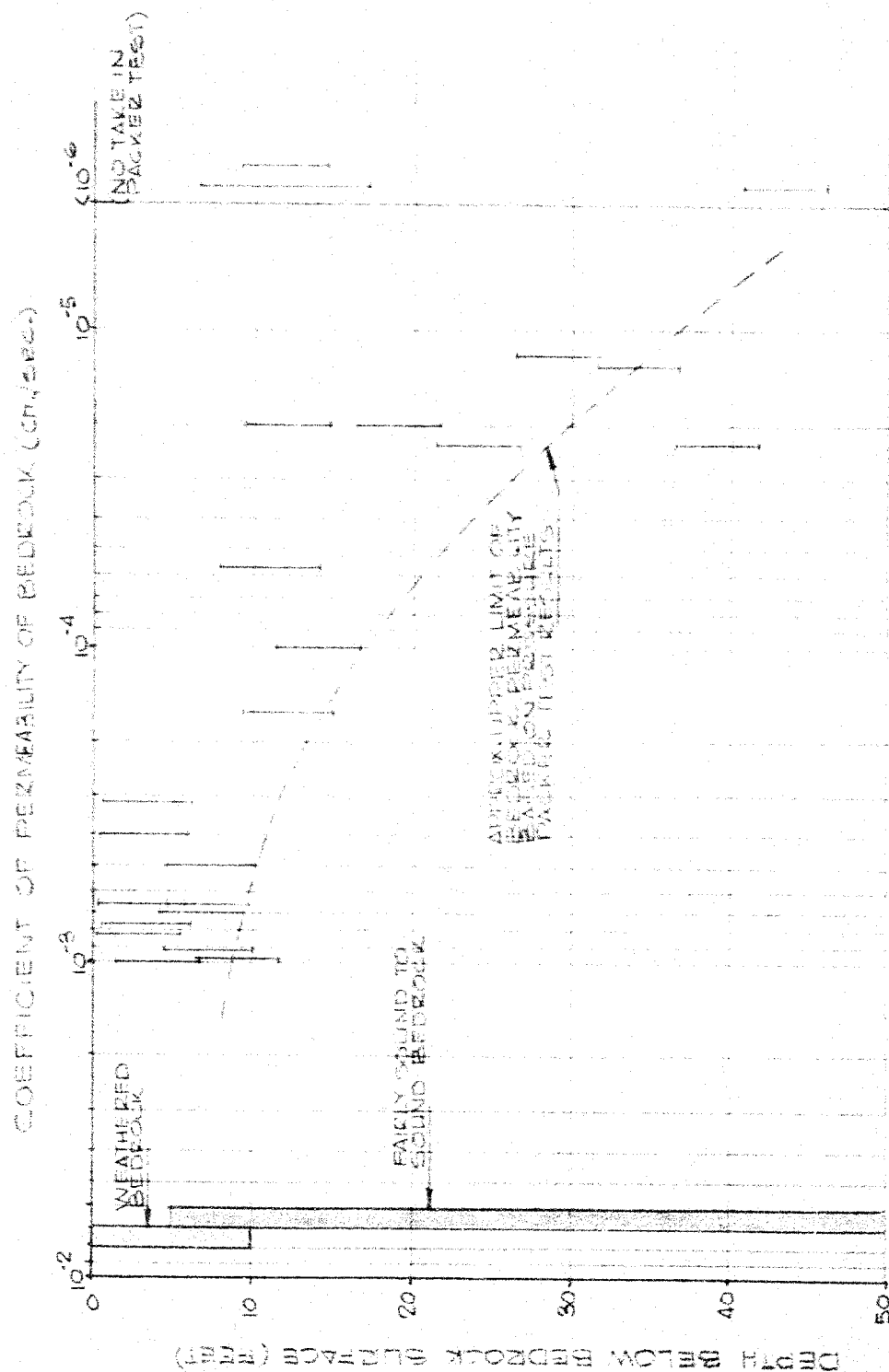
Drawn: APRIL 7, 1969.

GOLDER & ASSOCIATES

Made
Cncl.
Appd.

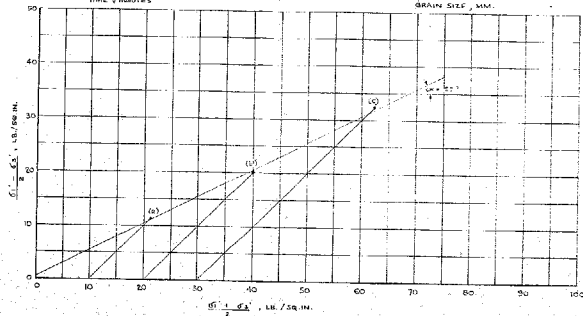
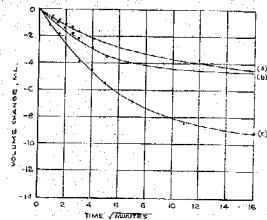
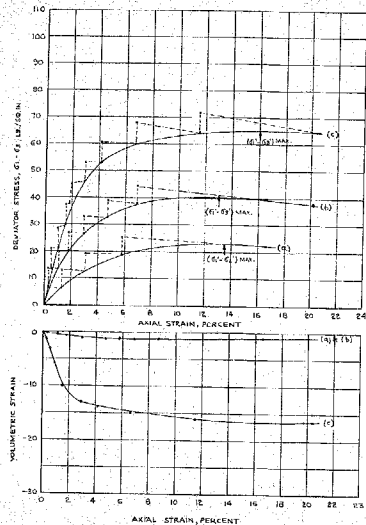
SUMMARY PLOT OF BEDROCK PERMEABILITY BASED ON PRESSURE PACKED TEST RESULTS

FIGURE 1-8

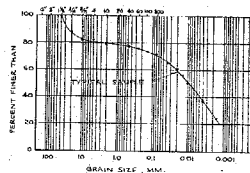


GOLDER & ASSOCIATES

Made ☒
Chkd ☒
Appd ☒



COBBLE GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
M.I.T. GRAIN SIZE SCALE



CONSOLIDATED GRAINED TRIAXIAL COMPRESSION S. TESTS

FIGURE 1-9

(CLAYEY SILT STRATUM)

TABLE				
TEST NUMBER				
	(a)	(b)	(c)	(d)
BORERHOLE NUMBER	T-107	T-102	T-102	
SAMPLE NUMBER	21	21	21	
SAMPLE DEPTH, FT.	87.0	87.6	88.0	
SAMPLE DIAMETER, IN.	2	2	2	
SAMPLE HEIGHT, IN.	4	4	4	
TOTAL CELL PRESSURE, σ_3 , LB./SQ. IN.	11.3	22.5	33.7	
BACK PRESSURE, LB./SQ. IN.	0	0	0	
EFFECTIVE CELL PRESSURE, σ'_3 , LB./SQ. IN.	11.3	22.5	33.7	
PARAMETER "B"	0.17	0.18	0.22	
VOLUME CHANGE, CONSOLIDATION, M.L.	0.240	0.000	0.000	
LOAD INCREMENTS, LB./SQ. IN.				
	1.	5.45	6.05	6.05
	2.	12.51	13.13	13.13
	3.	13.4	13.75	13.75
	4.	26.0	26.3	26.3
	5.	32.46	34.7	
	6.	38.5	41.1	
	7.	44.1	50.8	
	8.		50.5	
	9.		63.1	
	10.		71.6	
INCREASED LOAD AT 24 HOUR INTERVALS				
TIME TO FAILURE, DAYS	3	7	10	
AVERAGE RATE OF STRAIN, IN./MIN.	-	-	-	
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB./SQ. IN.	71.0	43.2	45.0	
AXIAL STRAIN AT FAILURE, PERCENT	11.4	15.0	16.0	
INITIAL WATER CONTENT, PERCENT	19.2	18.4	19.8	
FINAL WATER CONTENT, PERCENT	16.0	16.3	16.5	
DRY DENSITY, LB./CU. FT.	113.8	112.2	112.5	
LIQUID LIMIT, WL	23.5	-	-	
PLASTIC LIMIT, WP	15.7	-	-	
REMARKS:				

DATE: 10/10/60

CONSOLID & ASSOCIATES

Drawn: J.E.C.

CONSOLIDATED DRAINED TRIAXIAL COMPRESSION S TESTS

FIGURE 1-10

(CLAYEY SILT STRATUM)

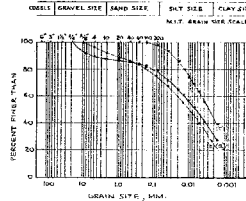
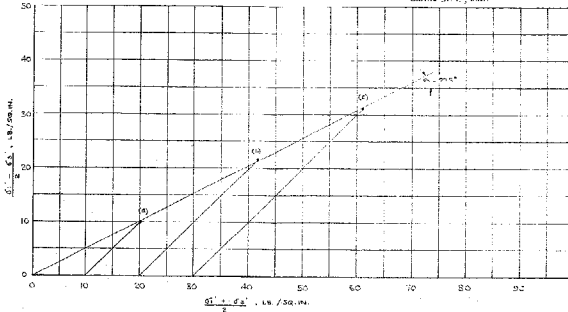
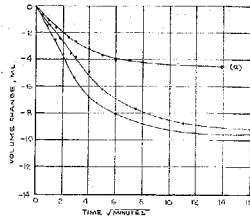
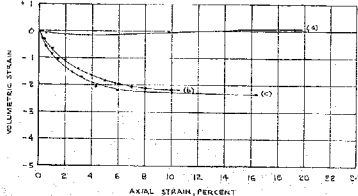
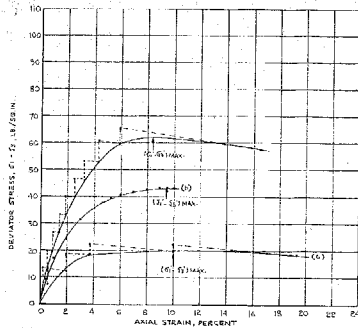


TABLE I				
TEST NUMBER				
BOREHOLE NUMBER	(a)	(b)	(c)	(d)
SAMPLE NUMBER	23	22	22	
SAMPLE DEPTH, FT.	55.4	76.5	49.0	
SAMPLE DIAMETER, IN.	5	2	2	
SAMPLE HEIGHT, IN.	4	4	4	
TOTAL CELL PRESSURE, σ_3 , LB/SQ. IN.	1.0	0.5	3.1	
BACK PRESSURE, LB/SQ. IN.	4	4	4	
EFFEKTIVE CELL PRESSURE, σ'_3 , LB/SQ. IN.	1.0	0.5	3.1	
PARAMETER "a"	0.01	0.01	0.01	
VOLUME CHANGE, CONSOLIDATION, ML	1.02	0.02	0.02	
LOAD INCREMENTS, LB/SQ. IN.				
	1.	0.5	0.5	
	2.	0.5	0.5	
	3.	0.5	0.5	
	4.	0.5	0.5	
	5.	0.5	0.5	
	6.	0.5	0.5	
	7.	0.5	0.5	
	8.	0.5	0.5	
	9.	0.5	0.5	
	10.	0.5	0.5	
TIME TO FAILURE, DAYS	5	1	10	
AVERAGE RATE OF STRAIN, IN./MIN.	0.0004	0.0004	0.0004	
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB/SQ. IN.	10.1	4.5	10.0	
AXIAL STRAIN AT FAILURE, PERCENT	12.1	2.5	8.4	
INITIAL WATER CONTENT, PERCENT	19.7	20.4	16.4	
FINAL WATER CONTENT, PERCENT	19.1	17.0	13.4	
DRY DENSITY, LB/CU. FT.	11.0	11.2	11.4	
LIQUID LIMIT, WL	27.8	27.7	24.1	
PLASTIC LIMIT, WP	14.8	14.1	15.2	

REMARKS:
TESTS (a) AND (b) ARE DEAD LOAD
TEST (c) IS MACHINE LOADED

DATE: 2/24/60

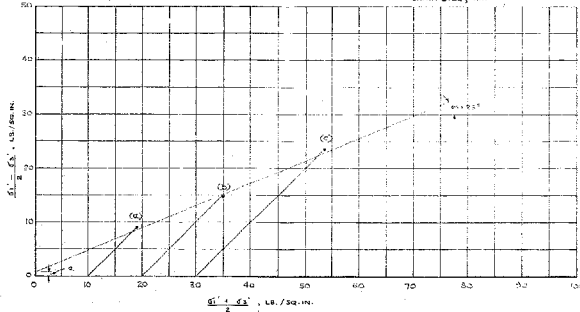
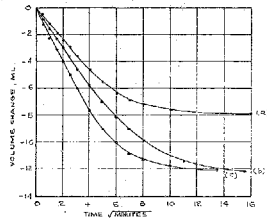
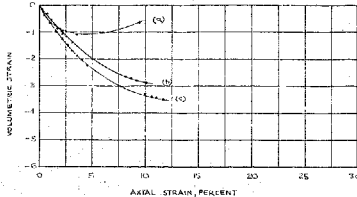
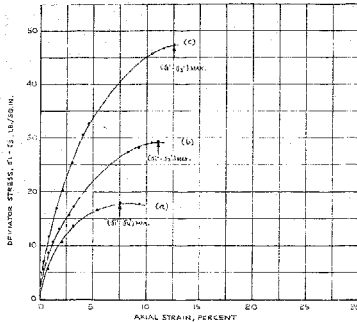
GOLDER & ASSOCIATES

Drawn: 2/24/60
Chd: 2/24/60

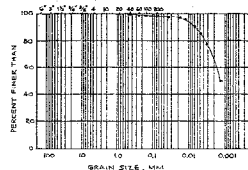
CONSOLIDATED DRAINED TRIAXIAL COMPRESSION S TESTS

FIGURE 1-11

(SILTY CLAY STRATUM)



COARSE GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
MULT. GRAIN SIZE SCALE



TEST NUMBER	(A)	(B)	(C)	(D)
BOREHOLE NUMBER	104	104	104	
SAMPLE NUMBER	17	17	17	
SAMPLE DEPTH, FT.	74.7	76.0	75.5	
SAMPLE DIAMETER, IN.	1.38	1.35	1.36	
SAMPLE HEIGHT, IN.	4.00	3.99	4.00	
TOTAL CELL PRESSURE, σ_3 , LB./SQ. IN.	5.0	5.0	4.5	
BACK PRESSURE, LB./SQ. IN.	15	15	15	
EFFECTIVE CELL PRESSURE, σ'_3 , LB./SQ. IN.	10	10	10	
PARAMETER "B"	0.38	0.38	0.38	
VOLUME CHANGE, CONSOLIDATION, ML	0.001	0.001	0.001	
LOAD INCREMENTS, LB.				
TIME TO FAILURE, DAYS	1	172	175	
AVERAGE RATE OF STRAIN, IN./MIN.	0.0000000000000000	0.0000000000000000	0.0000000000000000	
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB./SQ. IN.	18.1	23.5	44.5	
AXIAL STRAIN AT FAILURE, PERCENT	15	14	12.7	
INITIAL WATER CONTENT, PERCENT	25.3	26.7	26.7	
FINAL WATER CONTENT, PERCENT	24.5	25.1	26.2	
DRY DENSITY, LB./CU. FT.	26.7	26.4	26.5	
LIQUID LIMIT, WL	26.6	27.5	27.5	
PLASTIC LIMIT, WP	15.5	15.2	15.1	
REMARKS:				

DATE: 10/10/60

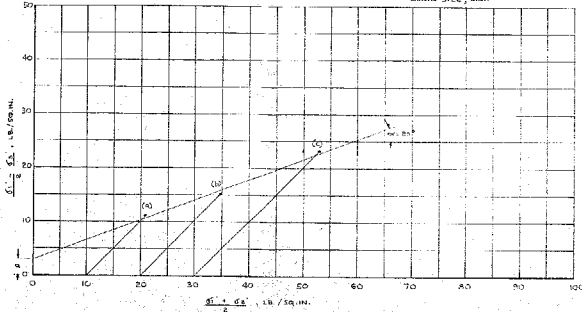
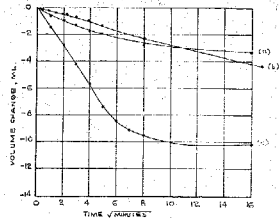
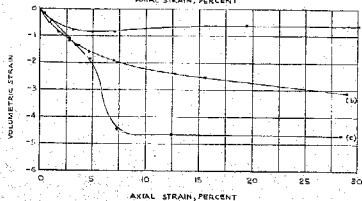
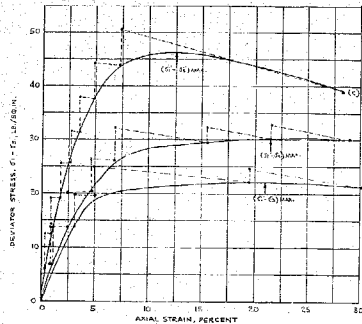
GOLDER & ASSOCIATES

Drawn: J. H. G.
Chk'd: J. H. G.
App'd: J. H. G.

CONSOLIDATED DRAINED TRIAXIAL COMPRESSION S TESTS

FIGURE 1-12.

(SILTY CLAY STRATUM)



COBBLE GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
N.I.T. GRAIN SIZE SCALE

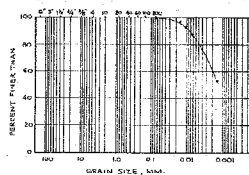


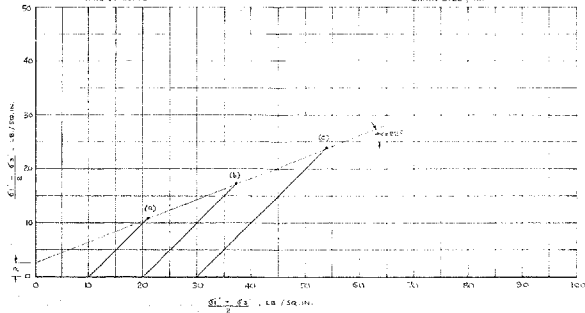
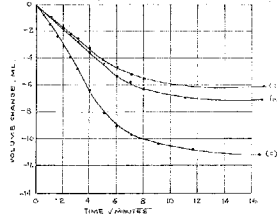
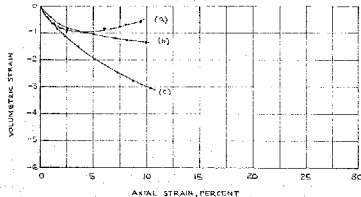
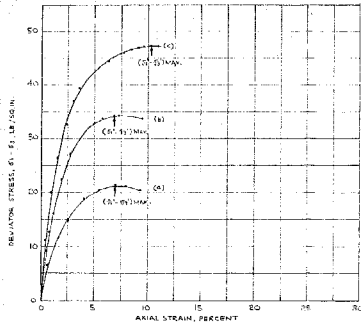
TABLE				
TEST NUMBER	(a)	(b)	(c)	(d)
BORERHOLE NUMBER	121	121	121	
SAMPLE NUMBER	5.6	15.6	15.6	
SAMPLE DEPTH, FT.	26.2	26.2	26.2	
SAMPLE DIAMETER, IN.	2	2	2	
SAMPLE HEIGHT, IN.	4	4	4	
TOTAL CELL PRESSURE, σ_3 , LB./SQ. IN.	13	24	23	
BACK PRESSURE, LB./SQ. IN.	13	13	13	
EFFECTIVE CELL PRESSURE, σ'_3 , LB./SQ. IN.	10	10	10	
PARAMETER "B"	0.78	0.78	0.78	
VOLUN. CHANGE, CONSOLIDATION, ML.	0.018	0.018	0.018	
LOAD INCREMENTS, LB./SQ. IN.				
	1.	7.07	0.05	0.71
	2.	15.59	15.40	17.12
	3.	17.75	17.25	18.50
	4.	25.85	24.1	25.1
	5.	23.4	21.0	21.45
	6.	30.0	30.45	
	7.	32.7	45.0	
	8.		30.2	
TIME TO FAILURE, DAYS	5	7	2	
AVERAGE RATE OF STRAIN, IN./MIN.	—	—	—	
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB./SQ. IN.	21.8	23.0	46.7	
AXIAL STRAIN AT FAILURE, PERCENT	21.0	21.5	18.5	
INITIAL WATER CONTENT, PERCENT	20.6	22.3	21.3	
FINAL WATER CONTENT, PERCENT	24.0	23.0	23.3	
DRY DENSITY, LB./CU. FT.	101.2	95.4	95.7	
LIQUID LIMIT, WL	—	42.5	—	
PLASTIC LIMIT, WP	—	16.5	—	
REMARKS:				

DATE: 10/1/68

GOLDER & ASSOCIATES

Drawn: J.S.
Chd: J.S.
App: J.S.

(SILTY CLAY STRATUM)



GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
MAY GRAIN SIZE SCALE

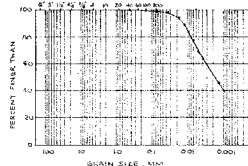


TABLE				
TEST NUMBER				
BOREHOLE NUMBER	125	105	125	125
SAMPLE NUMBER	27	27	27	27
SAMPLE DEPTH, FT	40.5	40.5	40.5	40.5
SAMPLE DIAMETER, IN.	2	2	2	2
SAMPLE HEIGHT, IN.	4	4	4	4
TOTAL CELL PRESSURE, σ_3 , LB./SQ. IN.	12	22	27	27
BACK PRESSURE, LB./SQ. IN.	0	0	0	0
EFFECTIVE CELL PRESSURE, σ'_3 , LB./SQ. IN.	12	22	27	27
PARAMETER "R"	0.17	0.17	0.17	0.17
VOLUME CHANGE, CONSOLIDATION, %	0	0	0	0
LOAD INCREMENTS, LB.	0	0	0	0
TIME TO FAILURE, DAYS	1	1	1	1
AVERAGE RATE OF STRAIN, IN./MIN.	0.0001	0.0001	0.0001	0.0001
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB./SQ. IN.	21.6	24.4	27.5	27.5
AXIAL STRAIN AT FAILURE, PERCENT	7.3	7.3	10.2	10.2
INITIAL WATER CONTENT, PERCENT	23.5	20.4	27.5	27.5
FINAL WATER CONTENT, PERCENT	22.2	27.4	28.2	28.2
DRY DENSITY, LB./CU. FT.	99.3	114.1	104.4	104.4
LIQUID LIMIT, WL	45.0	44.0	44.0	44.0
PLASTIC LIMIT, WP	21.4	21.4	21.4	21.4
REMARKS				

DATE April 1, 1968

GOLDER & ASSOCIATES

Drawn: J. L. B.
Calc: J. L. B.
Appd: J. L. B.

(SILTY CLAY STRATUM)

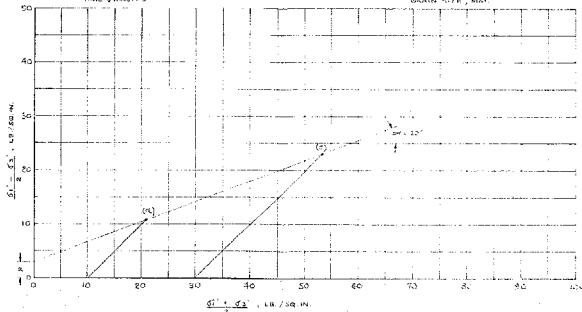
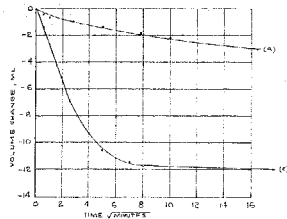
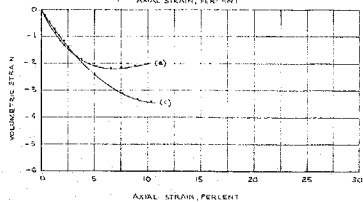
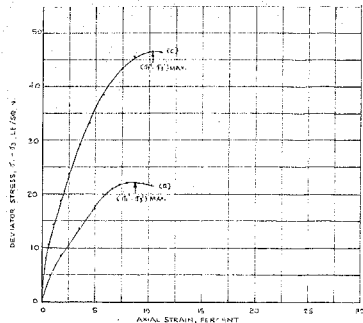
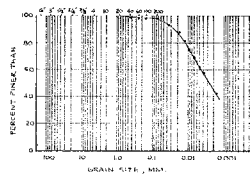


TABLE GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
WITH GRAIN SIZE SCALE



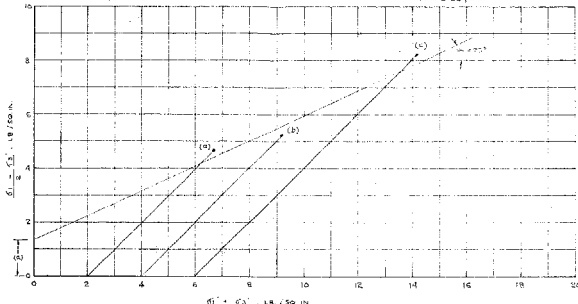
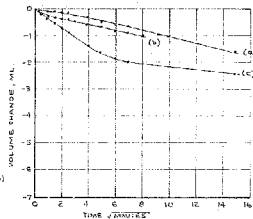
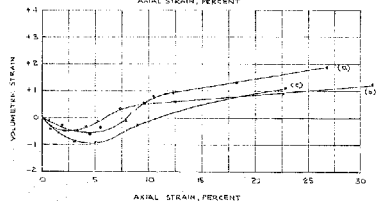
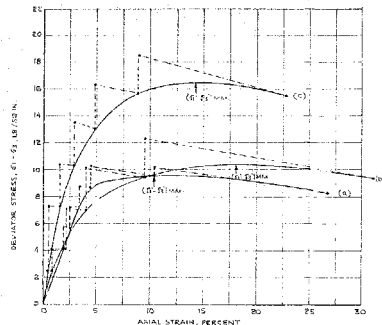
TEST NUMBER	(A)	(B)	(C)	(D)
BORPHALE NUMBER	121	122		
SAMPLE NUMBER	5.0	5.0		
SAMPLE DEPTH, FT	74.0	77.0		
SAMPLE DIAMETER, IN	2.0	2.0		
SAMPLE HEIGHT, IN	5	5		
TOTAL CELL PRESSURE, σ_3 , LB/SQ IN	10	10		
BACK PRESSURE, u , LB/SQ IN	5	5		
EXCESSIVE CELL PRESSURE, σ'_3 , LB/SQ IN	5	5		
PARAMETER σ'_3	0.30	0.30		
VOLUME CHANGE, CONSOLIDATION, %	0.00	0.00		
LOAD INCREMENTS, LB				
TIME TO FAILURE, DAYS	1	1		
AVERAGE RATE OF STRAIN, IN./MIN.	0.0024	0.0024		
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB/SQ IN	45.0	46.0		
AXIAL STRAIN AT FAILURE, PERCENT	10.0	10.0		
INITIAL WATER CONTENT, PERCENT	50.5	50.6		
FINAL WATER CONTENT, PERCENT	28.4	28.2		
DRY DENSITY, LB./CU FT	75.1	75.3		
LIQUID LIMIT, WL	50.5	50.4		
PLASTIC LIMIT, WP	25.0	25.0		
REMARKS:				

DATE: 10/1/66

GOLDER & ASSOCIATES

Drawn: JMB
Chkd: JMB
Appd: JMB

(SILTY CLAY STRATUM)



GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
M.I.T. GRAIN SIZE SCALE

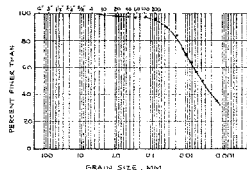


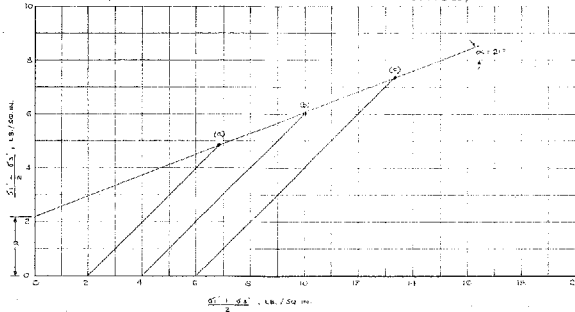
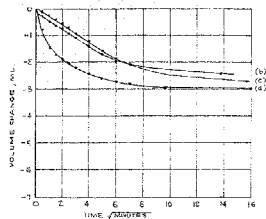
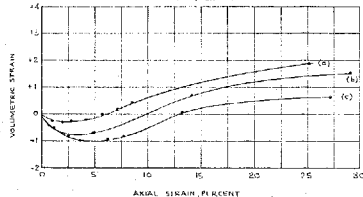
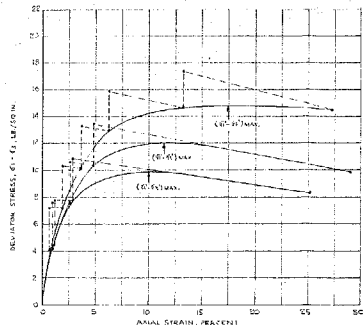
TABLE				
TEST NUMBER				
BURSTHOLE NUMBER	125	126	127	
SAMPLE NUMBER	25	26	27	
SAMPLE DEPTH, FT	80.4	80.8	81.5	
SAMPLE DIAMETER, IN.	3.55	3.55	3.55	
SAMPLE HEIGHT, IN.	3.11	3.10	3.04	
TOTAL CELL PRESSURE, σ_3 , LB/SQ IN.				
BACK PRESSURE, LB/SQ IN.	3	3	3	
EFFECTIVE CELL PRESSURE, σ_3' , LB/SQ IN.	2	4	3	
PARAMETER "B"	0.37	0.44	0.37	
VOLUME CHANGE, CONSOLIDATION, %	0.00	0.00	0.00	
LOAD INCREMENTS, LB/SQ IN.				
	1.	4.00	2.50	4.00
	2.	5.00	4.00	7.00
	3.	7.00	7.00	10.00
	4.	8.00	10.00	15.00
	5.	10.00	15.00	20.00
	6.	12.00	18.00	
TIME TO FAILURE, DAYS				
AVERAGE RATE OF STRAIN, IN./MIN.	1	8	7	
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB/SQ IN.	15	10.5	10.5	
AXIAL STRAIN AT FAILURE, PERCENT	12.5	10.5	10.5	
INITIAL WATER CONTENT, PERCENT	22.1	22.9	23.1	
FINAL WATER CONTENT, PERCENT	24.5	24.5	24.5	
WATER CONTENT, LB/SQ IN.	0.00	0.00	0.00	
LIQUID LIMIT, WL	20.6	20.6	20.6	
PLASTIC LIMIT, WP	18.0	18.0	18.0	
REMARKS:				

DATE: 11/1/54

GOLDER & ASSOCIATES

Drawn: JLL
Chk: JLL
App: JLL

(SILTY CLAY STRATUM)



COARSE GRAVEL SIZE SAND SIZE SILT SIZE CLAY SIZE
NO. 10 GRAIN SIZE SCALE

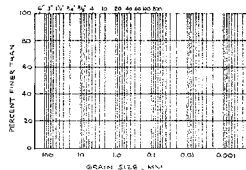


TABLE				
TEST NUMBER				
BORERHOLE NUMBER	105	106	107	108
SAMPLE NUMBER	105	106	107	108
SAMPLE DEPTH, FT.	45.5	45.5	45.5	45.5
SAMPLE DIAMETER, IN.	1.50	1.50	1.50	1.50
SAMPLE HEIGHT, IN.	3.14	3.14	3.14	3.14
TOTAL CELL PRESSURE, σ_3 , LB./SQ. IN.	11	13	15	17
BACK PRESSURE, u , LB./SQ. IN.	0	0	0	0
EFFECTIVE CELL PRESSURE, σ_3' , LB./SQ. IN.	11	13	15	17
PARAMETER "a"	0.47	0.07	0.17	0.17
VOLUME CHANGE, CONSOLIDATION, %, NL.	0.00	0.00	0.00	0.00
LOAD INCREMENTS, LB./SQ. IN.	1	1	1	1
INTEGRATED LOAD AT 24 HOUR INTERVALS	1	4.41	4.30	5.07
	2	7.65	7.55	7.15
	3	15.80	15.54	14.75
	4		15.28	14.50
	5			14.53
	6			13.38
DATE TO FAILURE, DAYS	4	5	7	
AVERAGE RATE OF STRAIN, IN./MIN.				
MAXIMUM DEVIATOR STRESS, $\sigma_1 - \sigma_3$, LB./SQ. IN.	15.8	11.9	14.2	
AXIAL STRAIN AT FAILURE, PERCENT	10.0	11.5	11.5	
INITIAL WATER CONTENT, PERCENT	16.7	22.0	22.0	
FINAL WATER CONTENT, PERCENT	16.4	21.9	21.9	
DRY DENSITY, LB./CU. FT.	112.5	107.7	108.7	
LIQUID LIMIT, WL	66.0	64.2	66.0	
PLASTIC LIMIT, Wp	22.6	13.4	20.6	
REMARKS:				

DATE 10-1-54

GOLDER & ASSOCIATES

DRAWN
CHKD
APPD

SUMMARY OF INDEX PROPERTIES FOR R AND S TRIAxIAL TEST SAMPLES (COHESIVE OVERBURDEN STRATA)

FIGURE 1-17

1. CLAYEY SILT STRATUM

CONSOLIDATED UNDRAINED TRIAXIAL TEST WITH PORE PRESSURE MEASUREMENT (E) (LMA REPORT 66134, DATED MAY 1967)

HOLE	SAMPLE	ELEV.	STRAIN RATE	STRAIN AT (C-C) MAX	LIQUID LIMIT	PLASTIC LIMIT	IN SITU WATER CONTENT	LIQUIDITY INDEX	PLASTICITY INDEX
T-5	5	526.5	18%/HR	16% - 18%	33	16	22%	0.3	17
T-5	6	526.1	18%/HR	14%	31	15	22%	0.3	17
T-7	16	523.2	8%/HR	13%	24	12	17%	0.4	12
T-7	17	522.5	18%/HR	7%	21	14	18%	0.6	7
T-9	17	523.0	18%/HR	10%	25	13	18	0.4	12

2. CLAYEY SILT STRATUM

CONSOLIDATED DRAINED TRIAXIAL TEST (S)
NOTE: D.L. DENOTES DEAD LOAD TEST

HOLE	SAMPLE	ELEV.	STRAIN RATE	STRAIN AT (C-C) MAX	LIQUID LIMIT	PLASTIC LIMIT	IN SITU WATER CONTENT	LIQUIDITY INDEX	PLASTICITY INDEX
T-101	22	507.0	D.L.	8%	26	15	17%	0.1	11
T-101	21	519.0	D.L.	15% - 16%	30	16	17%	0.2	14
T-102	11	511.3	D.L.	10%	30	14	12%	0.0	16
T-103	23	548.0	D.L.	10%	27	15	20%	0.4	10
T-103	20	527.0	95%/HR	2%	27	14	21%	0.5	13

3. SILTY CLAY STRATUM

CONSOLIDATED UNDRAINED TRIAXIAL TEST WITH PORE PRESSURE MEASUREMENT (E) (LMA REPORT 66134, DATED MAY 1967)

HOLE	SAMPLE	ELEV.	STRAIN RATE	STRAIN AT (C-C) MAX	LIQUID LIMIT	PLASTIC LIMIT	IN SITU WATER CONTENT	LIQUIDITY INDEX	PLASTICITY INDEX
T-4	20	513.7	18%/HR	11%	42	20	37%	0.8	22
T-5	23	513.0	45%/HR	8% - 10%	44	19	31%	0.5	25

4. SILTY CLAY STRATUM

CONSOLIDATED DRAINED TRIAXIAL TEST (S)
NOTE: D.L. DENOTES DEAD LOAD TEST

HOLE	SAMPLE	ELEV.	STRAIN RATE	STRAIN AT (C-C) MAX	LIQUID LIMIT	PLASTIC LIMIT	IN SITU WATER CONTENT	LIQUIDITY INDEX	PLASTICITY INDEX
T-104	13	528.0	5%/HR	7% - 12%	40	19	36%	0.8	21
T-12	15E	525.0	D.L.	12% - 22%	43	17	32%	0.6	26
T-107	27	526.0	25%/HR	7% - 10%	43	21	28%	0.3	22
T-103	29	523.0	95%/HR	8% - 10%	51	23	31%	0.3	27
T-104	32	525.0	D.L.	10% - 15%	51	18	23%	0.4	13
T-105	14	517.0	D.L.	10% - 17%	46	21	22%	0.1	25

5. BANDED SILTY CLAY STRATUM

PROPOSED FURKES ROAD TUNNEL SITE - W.P. 242-66
CONSOLIDATED UNDRAINED TRIAXIAL TEST WITH PORE PRESSURE MEASUREMENT (E) - D.H.O. PRELIMINARY INVESTIGATION, W.J. 66-P-111

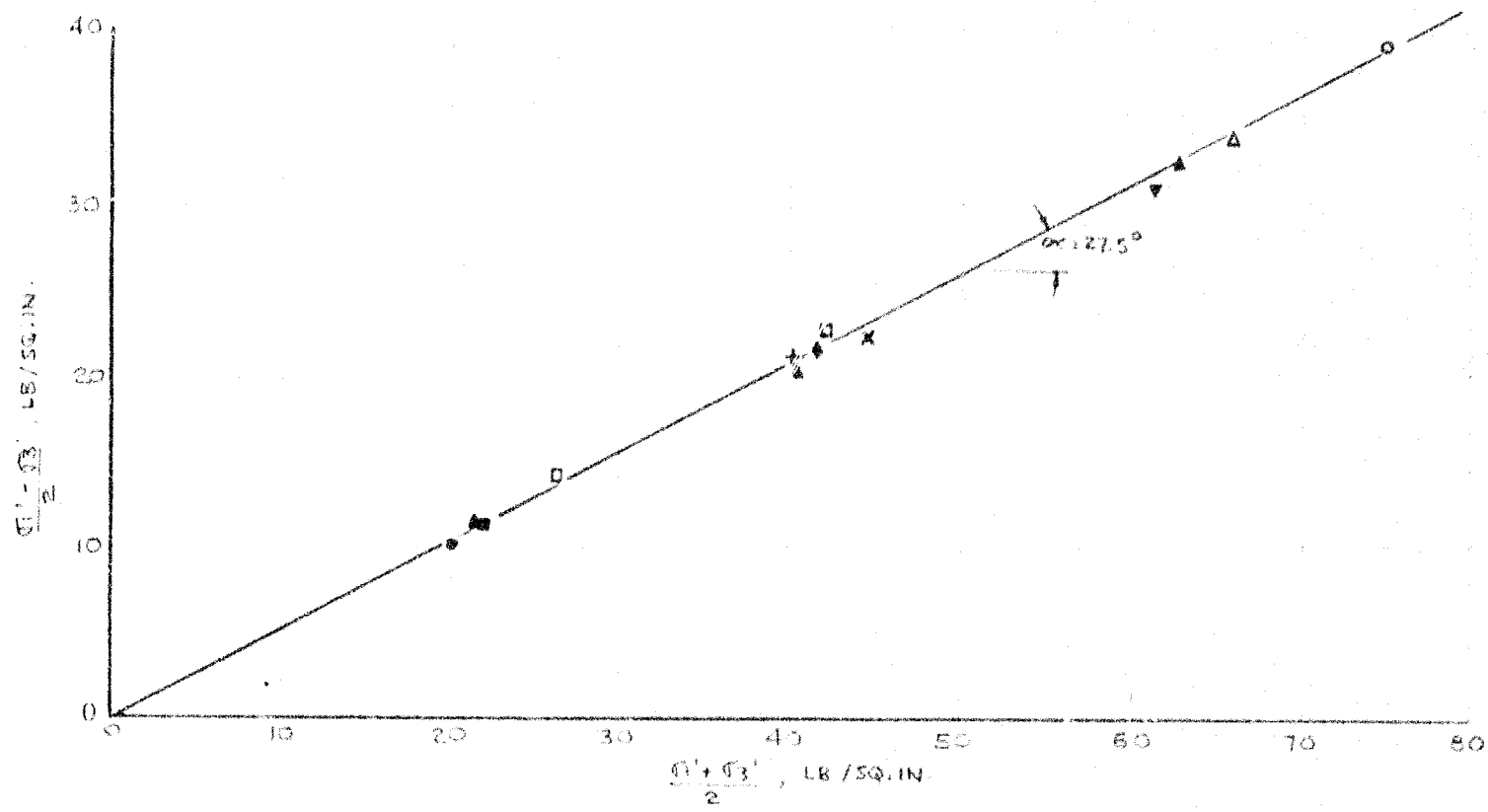
HOLE	SAMPLE	ELEV.	STRAIN RATE	STRAIN AT (C-C) MAX	LIQUID LIMIT	PLASTIC LIMIT	IN SITU WATER CONTENT	LIQUIDITY INDEX	PLASTICITY INDEX	SOIL ZONE
16	11	535.5	1%/HR	1% - 4%	44	22	50%	1.3	22	3
16	12	528.5	1%/HR	3% - 6%	48	22	34%	0.5	26	4
17	21	523.0	1%/HR	2% - 6%	42	21	34%	0.6	21	4
8	24	507.0	1%/HR	4% - 5%	54	25	45%	0.7	29	5
14	13	526.5	1%/HR	2% - 7%	41	32	47%	1.7	9	5
15	15	515.0	1%/HR	4% - 7%	47	22	44%	0.9	25	5

GOLDER & ASSOCIATES

 Made *[Signature]*
 Chkd. *[Signature]*
 Appd. *[Signature]*

SUMMARY OF R AND S TRIAXIAL TESTS
CLAYEY SILT STRATUM
STRESS CONDITIONS AT $(\sigma_1 - \sigma_3)$ MAX.

FIGURE 1-16



LEGEND					
R TESTS			S TESTS		
SYMBOL	HOLE	SA	SYMBOL	HOLE	SA
□	T-5	5	▼	T-101	22
x	T-5	6	▲	T-102	21
+	T-7	16	■	T-122	11
△	T-7	17	●	T-123	23
○	T-9	17	◆	T-123	30

NOTE: 1) FOR INDEX PROPERTIES OF SAMPLES SEE FIG. 1-17.
2) EFFECTIVE STRESS PARAMETERS FOR CLAYEY SILT STRATUM:
 $\phi' = \sin^{-1} \tan \alpha$
 $= 31.5^\circ$
 $c' = 0$ LB/SQ. FT.

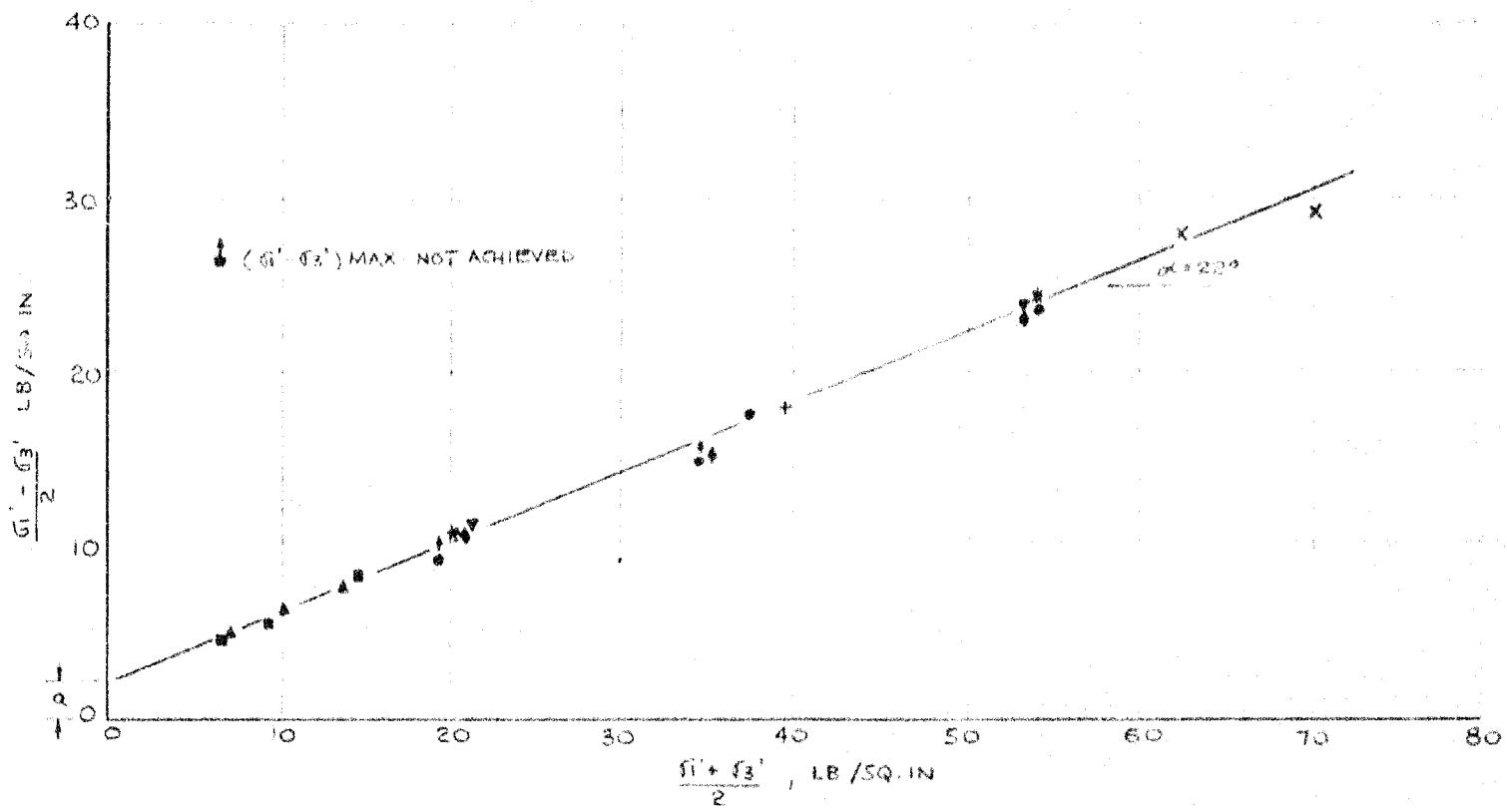
* SINGLE TEST RESULT ; NO SERIES CARRIED OUT.

GOLDER & ASSOCIATES

Mode: 100
Chkd: 100
Appd: 100

SUMMARY OF $\bar{\epsilon}$ AND S TRIAXIAL TESTS
SILTY CLAY STRATUM
STRESS CONDITIONS AT $(\sigma'_1 - \sigma'_3)$ MAX.

FIGURE 1-19



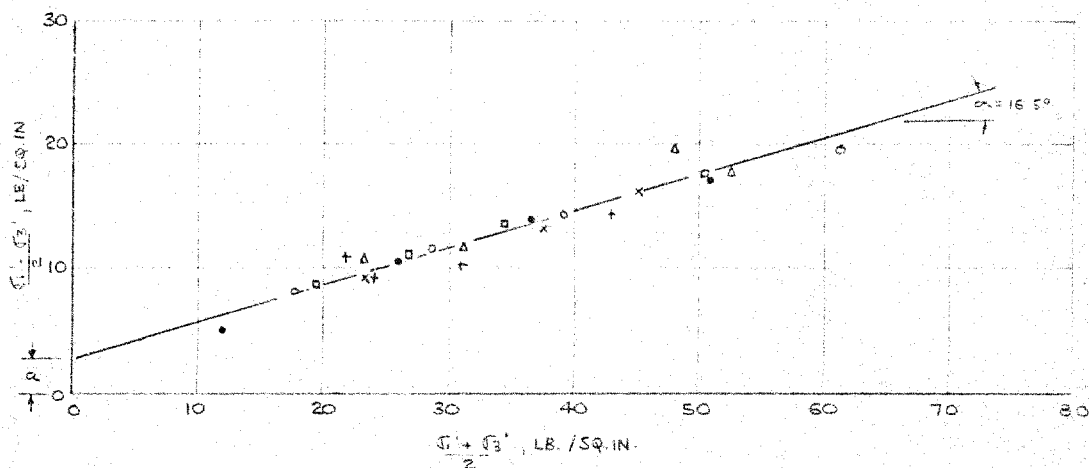
LEGEND					
$\bar{\epsilon}$ TESTS			S TESTS		
SYMBOL	HOLE	SA	SYMBOL	HOLE	SA
+	T-4	20	●	T-104	18
x	T-5	23	◆	T-121	15B
			✕	T-123	27
			▼	T-123	29
			■	T-124	22
			▲	T-125	15

NOTE: 1) FOR INDEX PROPERTIES OF SAMPLES SEE FIG. 1-17.
2) EFFECTIVE STRESS PARAMETERS FOR SILTY CLAY STRATUM:
 $\phi' = \sin^{-1} \tan \alpha$
 $= 24^\circ$
 $c' = q / \cos \phi'$
 $= 300 \text{ LB/SQ. FT.}$

GOLDER & ASSOCIATES

Mode
CHKD
Appd

PROPOSED FORKES ROAD TUNNEL CROSSING OF REALIGNED WELLAND CANAL



LEGEND		
SYMBOL	HOLE	SA
+	16	11
o	18	12
Δ	17	21
□	8	24
x	14	13
•	15	15

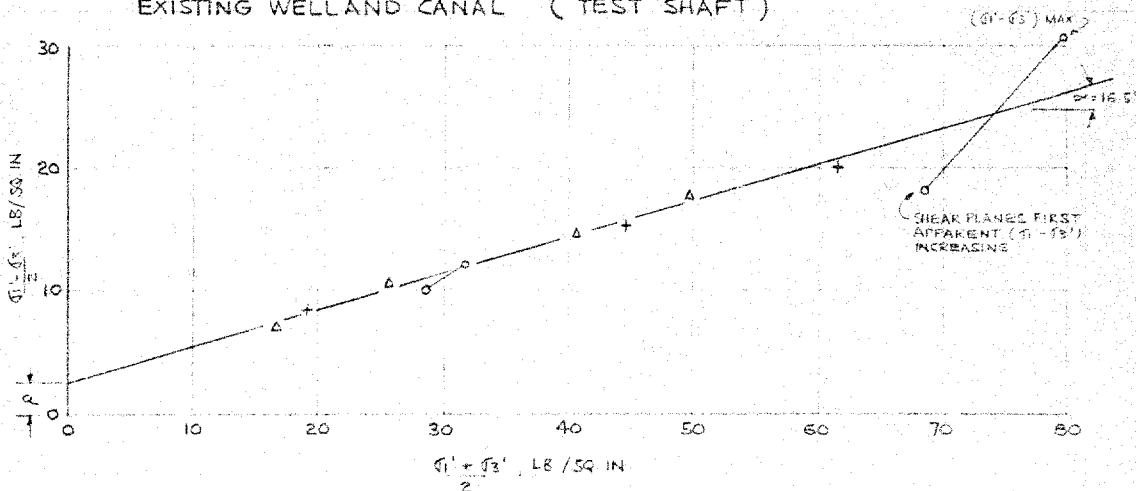
- NOTE: 1) BASED ON DATA OBTAINED FROM D.H.G. PRELIMINARY FOUNDATION REPORT W.J. 66-F-111
2) FOR INDEX PROPERTIES OF SAMPLES SEE FIGS 1-17
3) EFFECTIVE STRESS PARAMETERS FOR BANDED SILTY CLAY STRATUM $\phi' = \sin^{-1} \tan \alpha$

$$\phi' = 17.5^\circ$$

$$c' = \sigma' / \cos \phi'$$

$$= 350 \text{ LB/SQ. FT.}$$

PROPOSED ORIGINAL MAIN STREET TUNNEL CROSSING OF EXISTING WELLAND CANAL (TEST SHAFT)



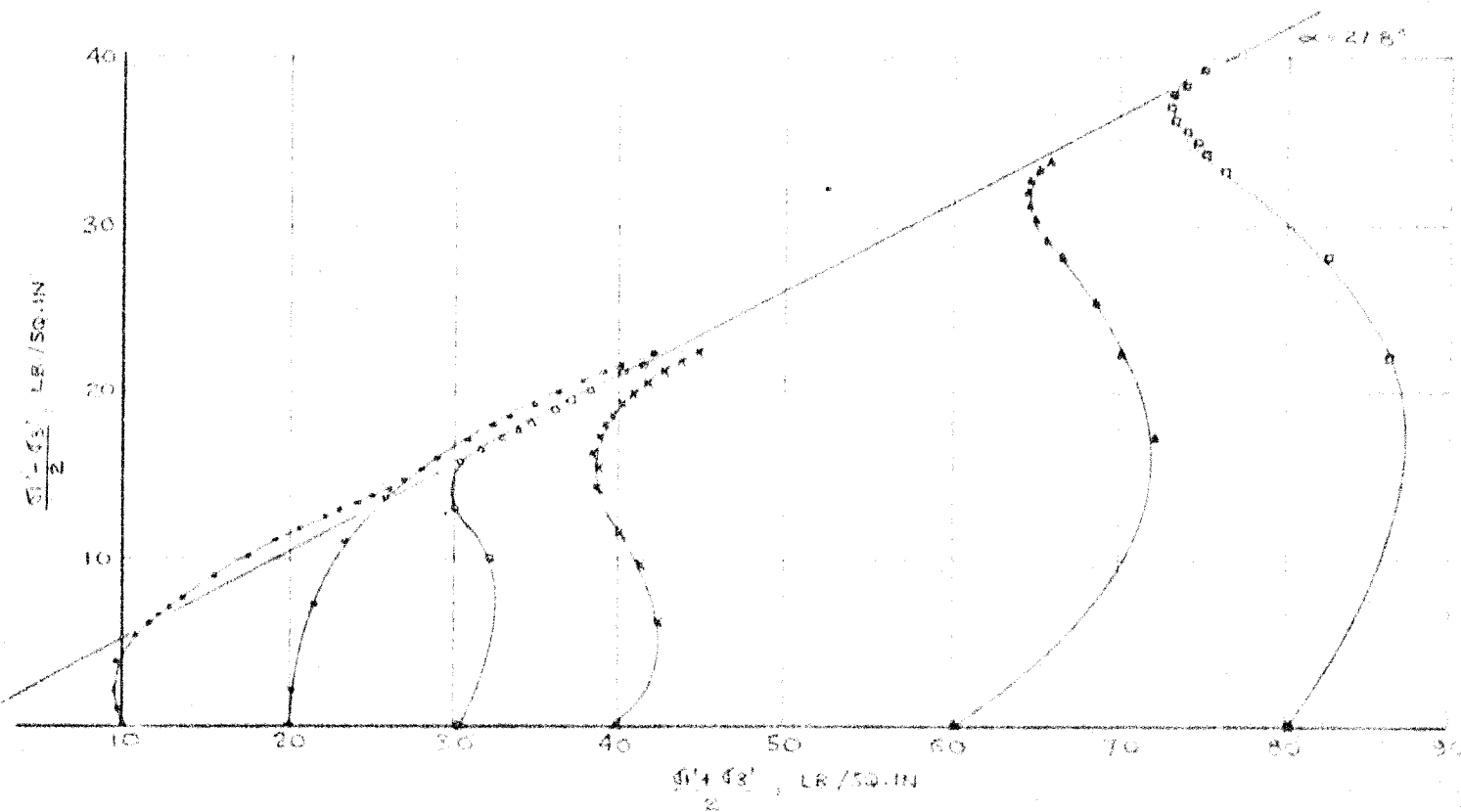
LEGEND		
+	R TRIAXIAL TESTS (H.Q.B.A.)	
o	S TRIAXIAL TESTS (H.Q.B.A.)	
Δ	R TRIAXIAL TESTS (P.H.O.)	

- NOTE: 1) BASED ON DATA OBTAINED FROM OUR REPORT 6373 DATED JULY 1964
2) TESTS CARRIED OUT ON BANDED SILTY CLAY LAYER DISCLOSED BLOCK SAMPLE F, TEST SHAFT
3) SAMPLES TRIMMED AT 45° TO INCLINATIONS OF STRATIFICATION
4) EFFECTIVE STRESS PARAMETERS FOR BANDED SILTY CLAY STRATUM $\phi' = \sin^{-1} \tan \alpha$
- $$\phi' = 17.5^\circ$$
- $$c' = \sigma' / \cos \phi'$$
- $$= 350 \text{ LB/SQ. FT.}$$

SUMMARY OF TRIAXIAL TESTS
BANDED SILTY CLAY STRATUM ENCOUNTERED AT
PREVIOUSLY PROPOSED TUNNEL SITES IN
WELLAND, ONTARIO.

SUMMARY OF TRIAXIAL TESTS CLAYEY SILT STRATUM (SHOWING STRESS PATHS)

FIGURE 1-21



LEGEND		
SYMBOL	HOLE	SA
●	T-5	5
x	T-5	6
o	T-7	16
△	T-7	17
□	T-9	17

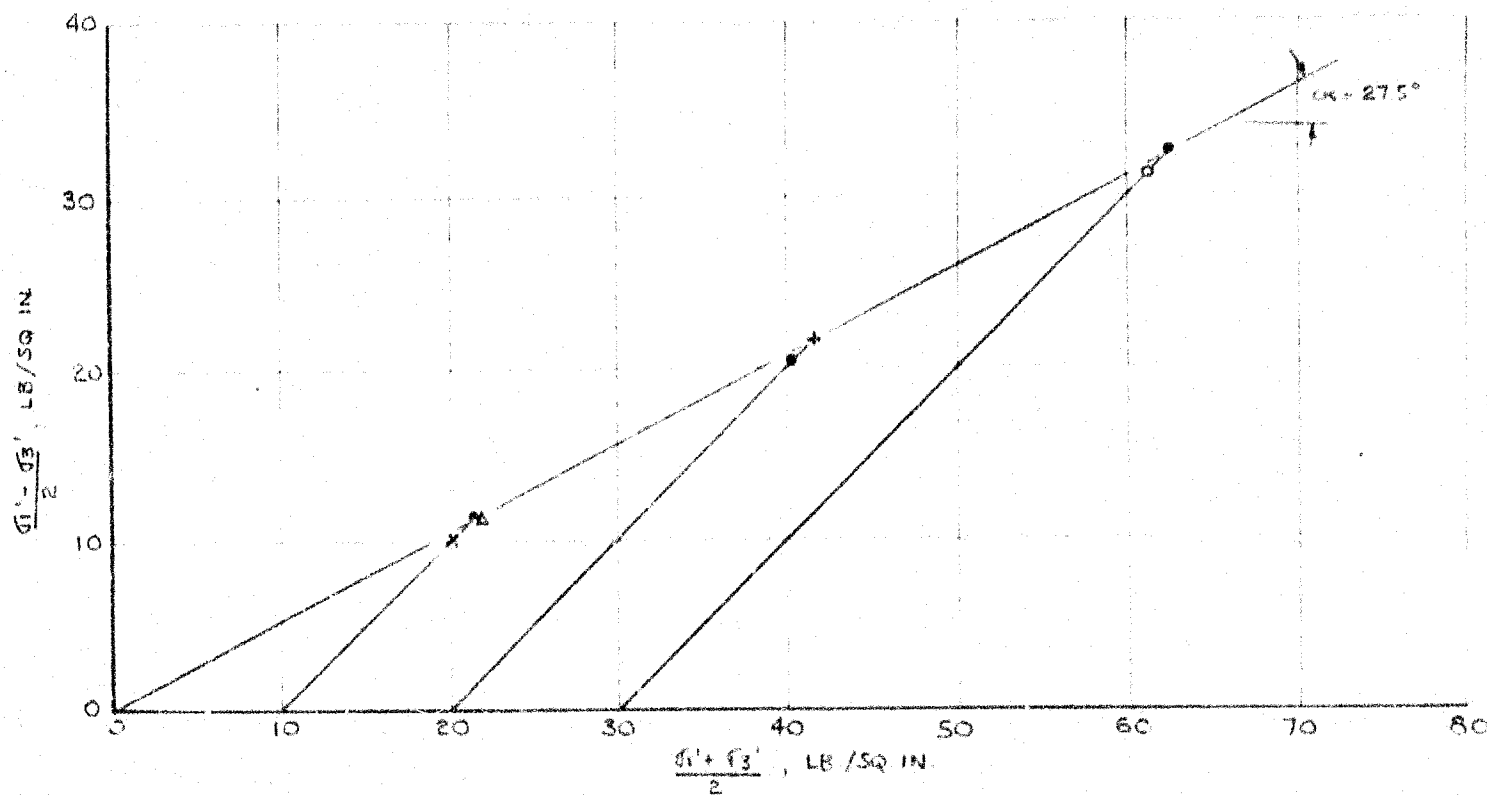
- NOTE: 1) BASED ON DATA FROM OUR REPORT 66124 DATED MAY 1967.
 2) FOR INDEX PROPERTIES OF SAMPLES SEE FIG. 1-17.
 3) EFFECTIVE STRESS PARAMETERS FOR CLAYEY SILT STRATUM
 $\phi' = \sin^{-1} \tan \alpha$
 $\alpha = 32^\circ$
 $c' = 0 \text{ LB/SQ. FT.}$

GOLDER & ASSOCIATES

 Made by [Signature]
 Ckd. [Signature]
 Appd. [Signature]

SUMMARY OF 5 TRIAXIAL TESTS
CLAYEY SILT STRATUM
(SHOWING STRESS PATHS)

FIGURE 1-22



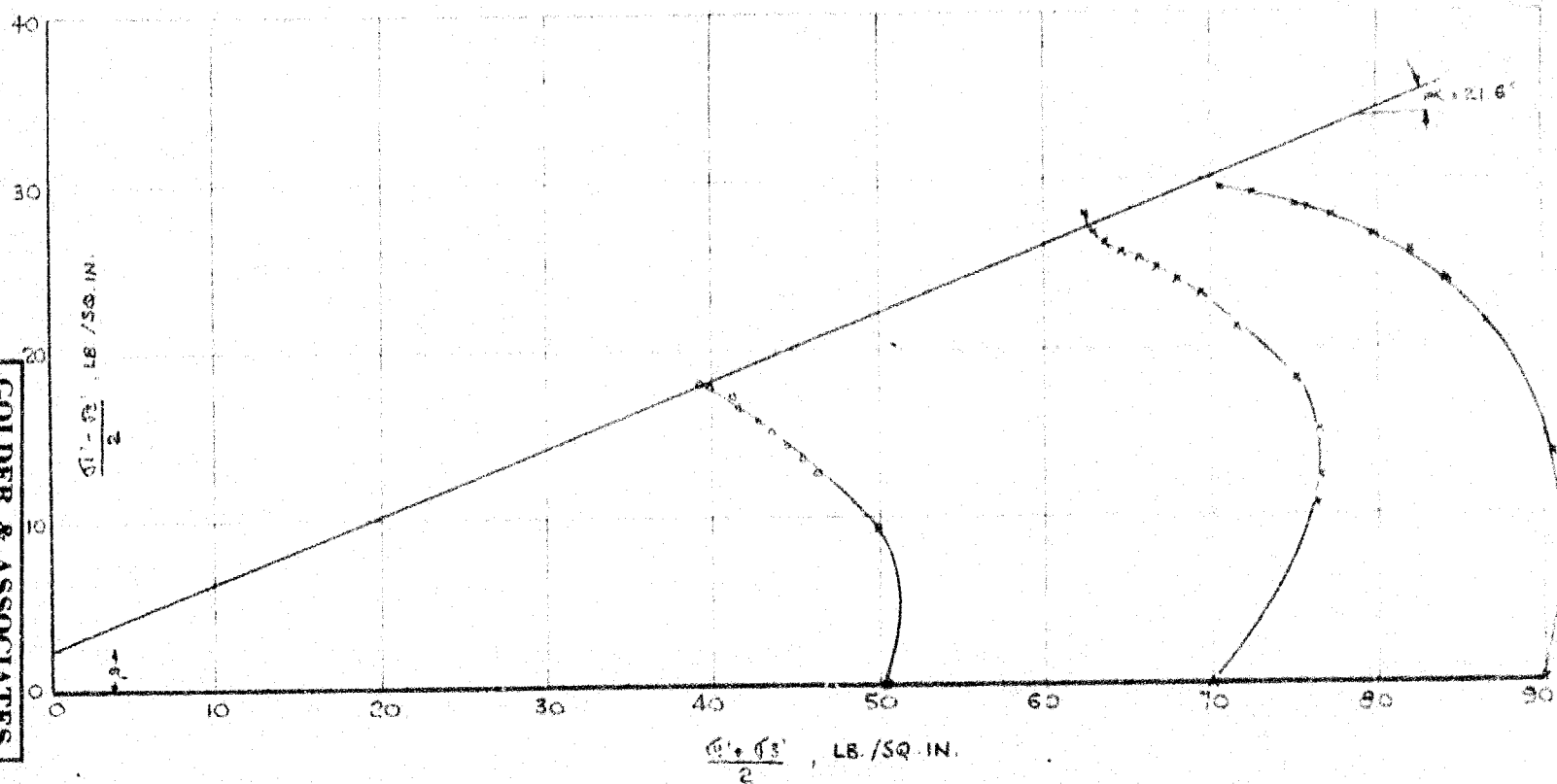
LEGEND		
SYMBOL	HOLE	EA
○	T-101	22
●	T-102	21
x	T-123	23
+	T-123	30
△	T-122	11

- NOTE 1) FOR INDEX PROPERTIES OF SAMPLES
SEE FIG 1-17.
- 2) EFFECTIVE STRESS PARAMETERS
FOR CLAYEY SILT STRATUM
 $\phi' = \sin^{-1} \tan \alpha$
 $= 31.5^\circ$
 $c' = 0 \text{ LB / SQ FT.}$

* SINGLE TEST RESULT, NO SERIES CARRIED OUT.

SUMMARY OF TRIAXIAL TESTS
SILTY CLAY STRATUM
(SHOWING STRESS PATHS)

FIGURE 1-23



LEGEND		
SYMBOL	HOLE	SA
o	T-4	20
x	T-5	23

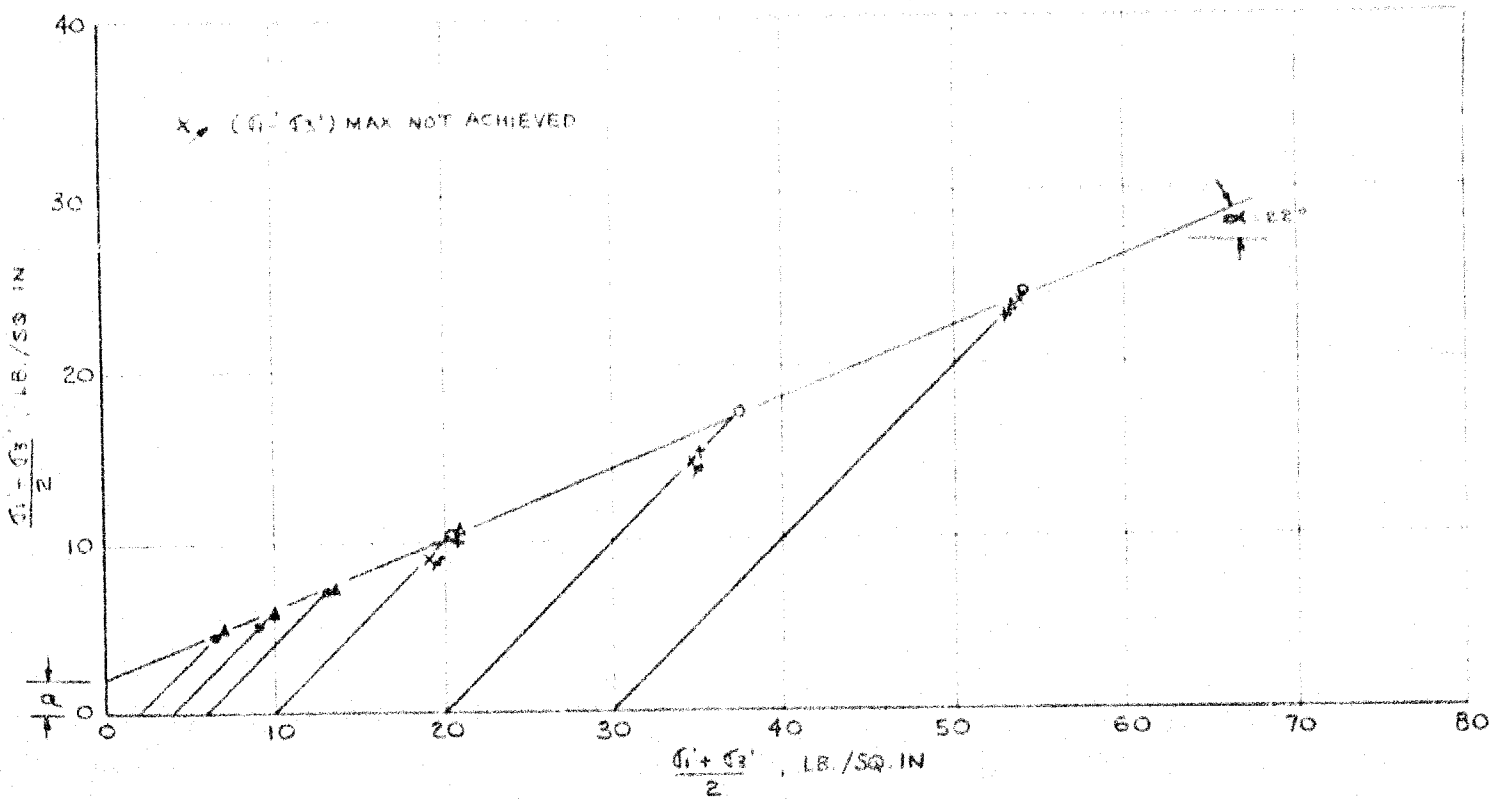
- NOTE: 1) BASED ON DATA FROM OUR REPORT
GG134, DATED MAY 1967.
- 2) FOR INDEX PROPERTIES OF SAMPLES
SEE FIG. 1-17.
- 3) EFFECTIVE STRESS PARAMETERS FOR
SILTY CLAY STRATUM
 $\phi' = \sin^{-1} \tan \alpha$
 $= 23.5^\circ$
 $c' = \alpha / \cos \phi'$
 $= 400 \text{ LB./SQ. FT.}$

GOLDER & ASSOCIATES

Mode *McL*
Chkd *JD*
Appd *JD*

SUMMARY OF 5 TRIAXIAL TESTS
SILTY CLAY STRATUM
(SHOWING STRESS PATHS)

FIGURE 1-24



LEGEND		
SYMBOL	HOLE	SA
x	T-104	18
+	T-121	15 B
o	T-123	27
Δ	T-123	29
•	T-124	22
▲	T-125	16

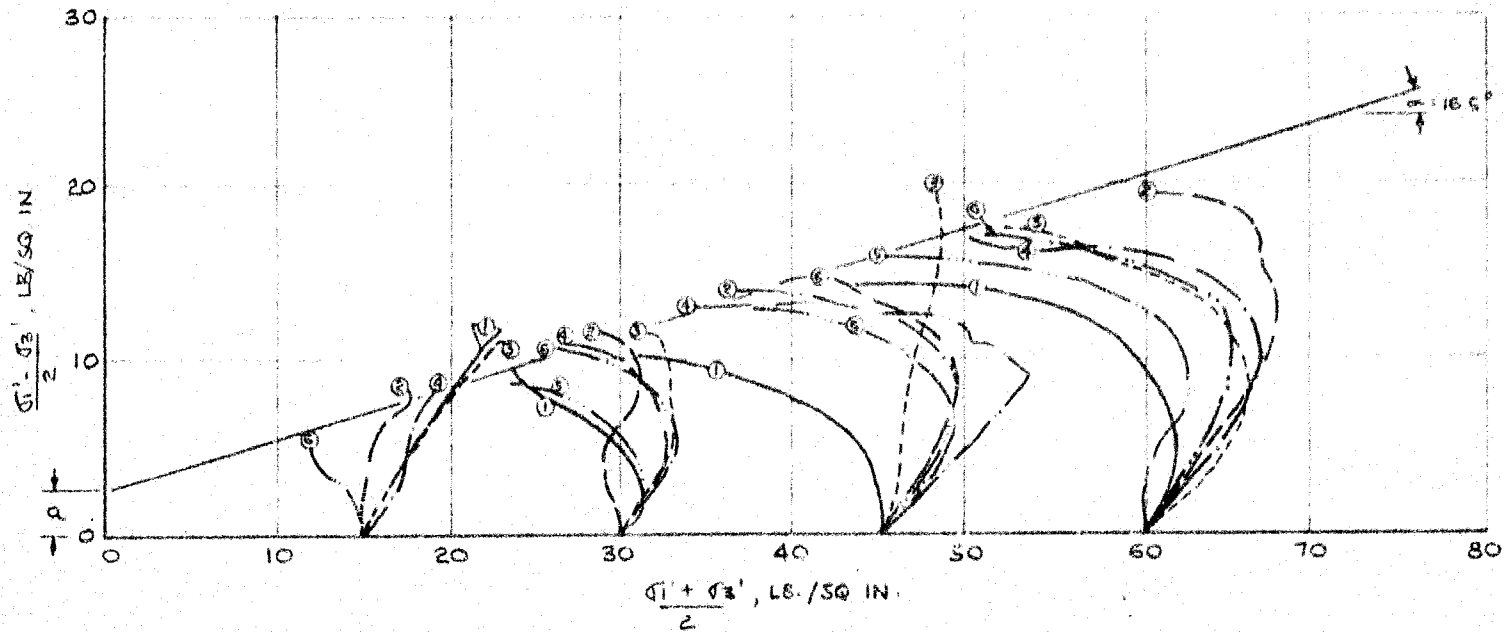
- NOTE: 1) FOR INDEX PROPERTIES OF SAMPLES SEE FIG. 1-17.
2) EFFECTIVE STRESS PARAMETERS FOR SILTY CLAY STRATUM
 $\phi' = \sin^{-1} \tan \phi$
 $= 24^\circ$
 $c' = c / \cos \phi'$
 $= 300 \text{ LB./SQ. FT.}$

GOLDER & ASSOCIATES

Mode *CH*
Ckd *CH*
Appd *CH*

SUMMARY OF TRIAXIAL TESTS
BANDED SILTY CLAY STRATUM
(SHOWING STRESS PATHS)
PROPOSED FORKES ROAD TUNNEL SITE

FIGURE 1-25



LEGEND		
SYMBOL	HOLE	SA.
1	16	11
2	18	12
3	17	21
4	8	24
5	14	13
6	15	15

- NOTE: 1) BASED ON DATA FROM D.H.O. PRELIMINARY REPORT 66-F-III.
2) FOR INDEX PROPERTIES OF SAMPLES SEE FIG. 1-17.
3) EFFECTIVE STRESS PARAMETERS FOR BANDED SILTY CLAY STRATUM

$$\phi' = \sin^{-1} \tan \alpha$$

$$= 17.5^\circ$$

$$c' = \sigma / \cos \phi'$$

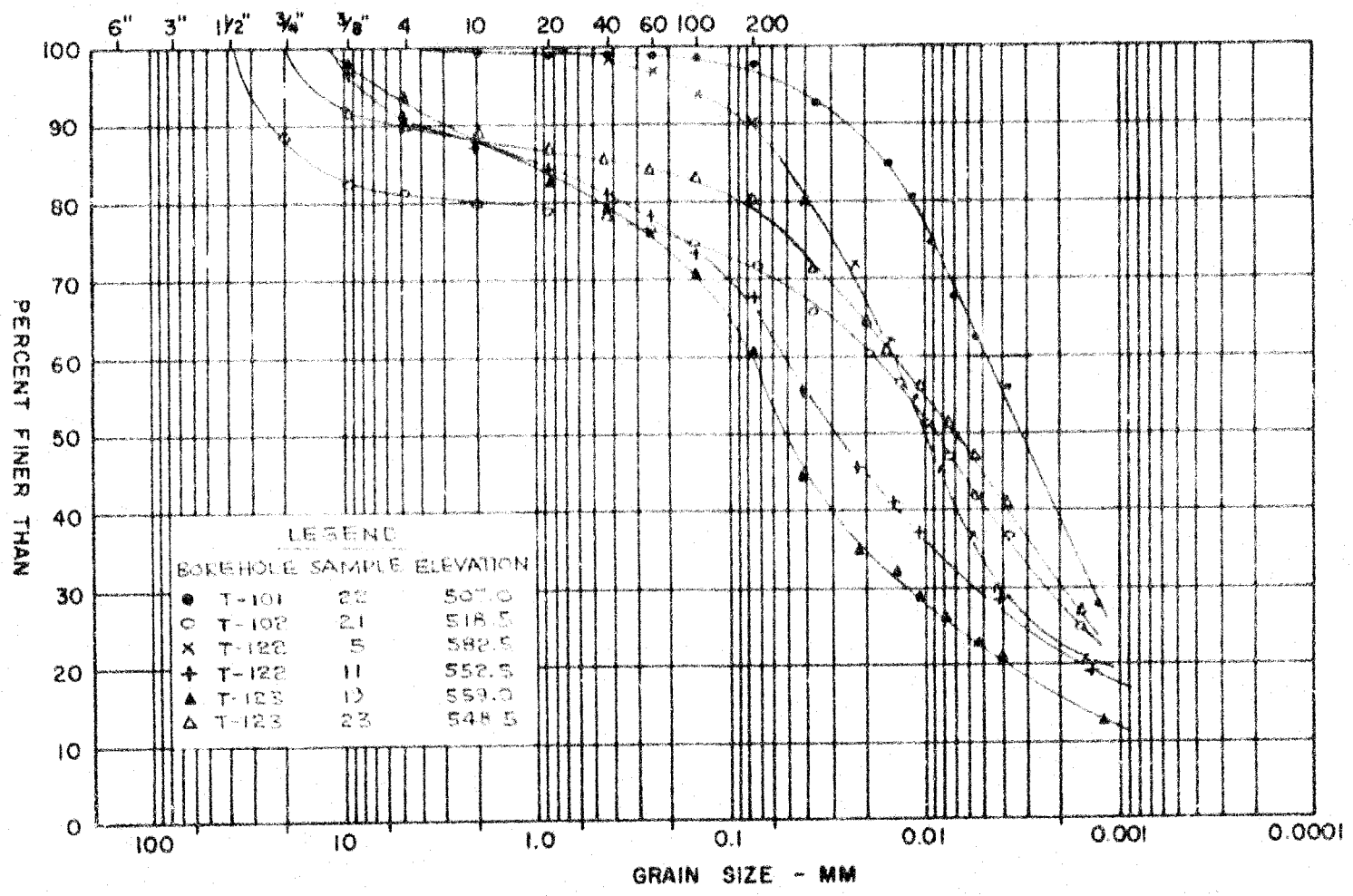
$$= 350 \text{ LB./SQ. FT.}$$

GOLDER & ASSOCIATES

Made: *[Signature]*
Chkd: *[Signature]*
Appd: *[Signature]*

M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES/IN.



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

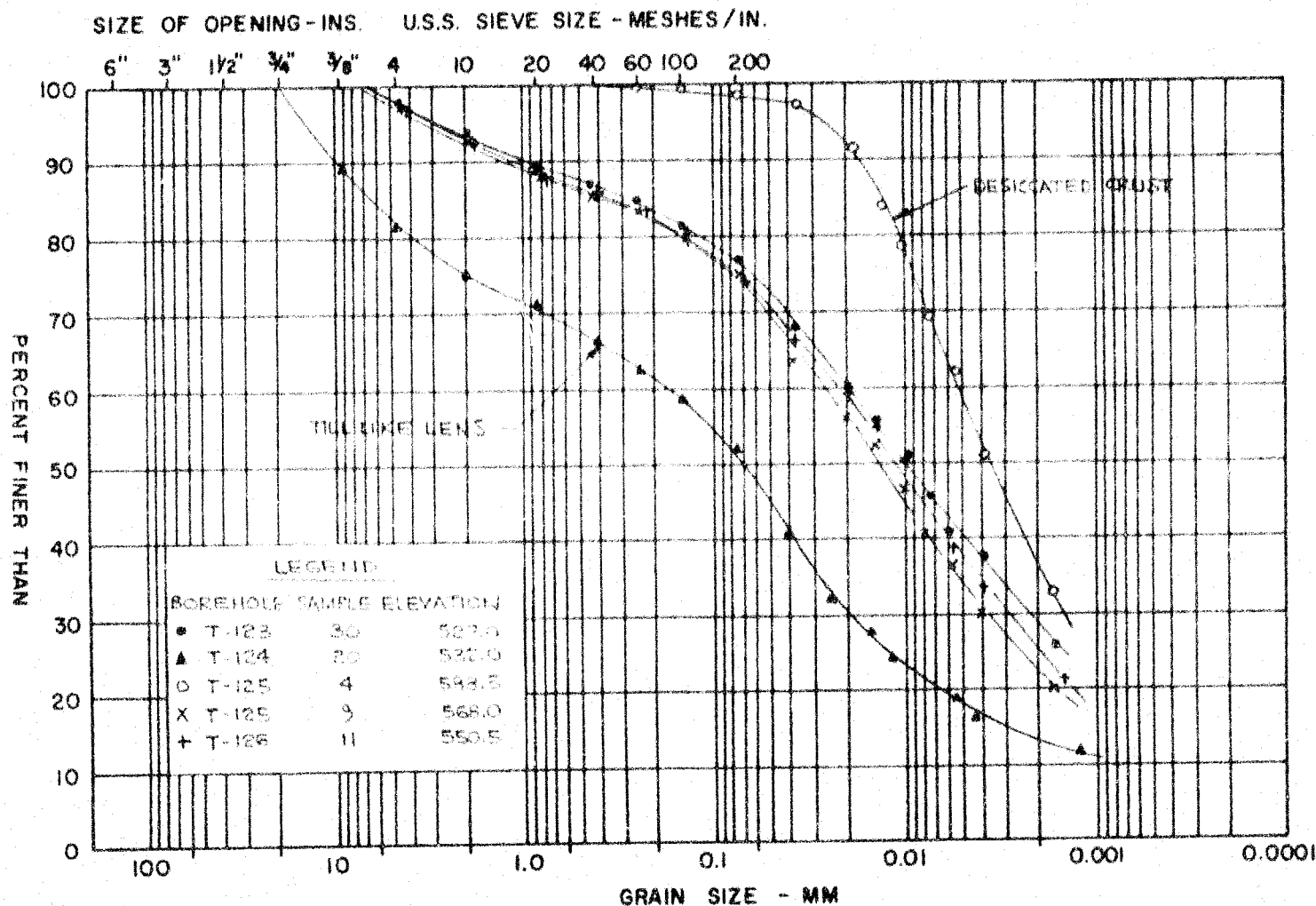
GRAIN SIZE DISTRIBUTION
CLAYEY SILT STRATUM

FIGURE 1-26

GOLDER & ASSOCIATES

M.I.T. GRAIN SIZE SCALE

GRAIN SIZE DISTRIBUTION
CLAYEY SILT STRATUM



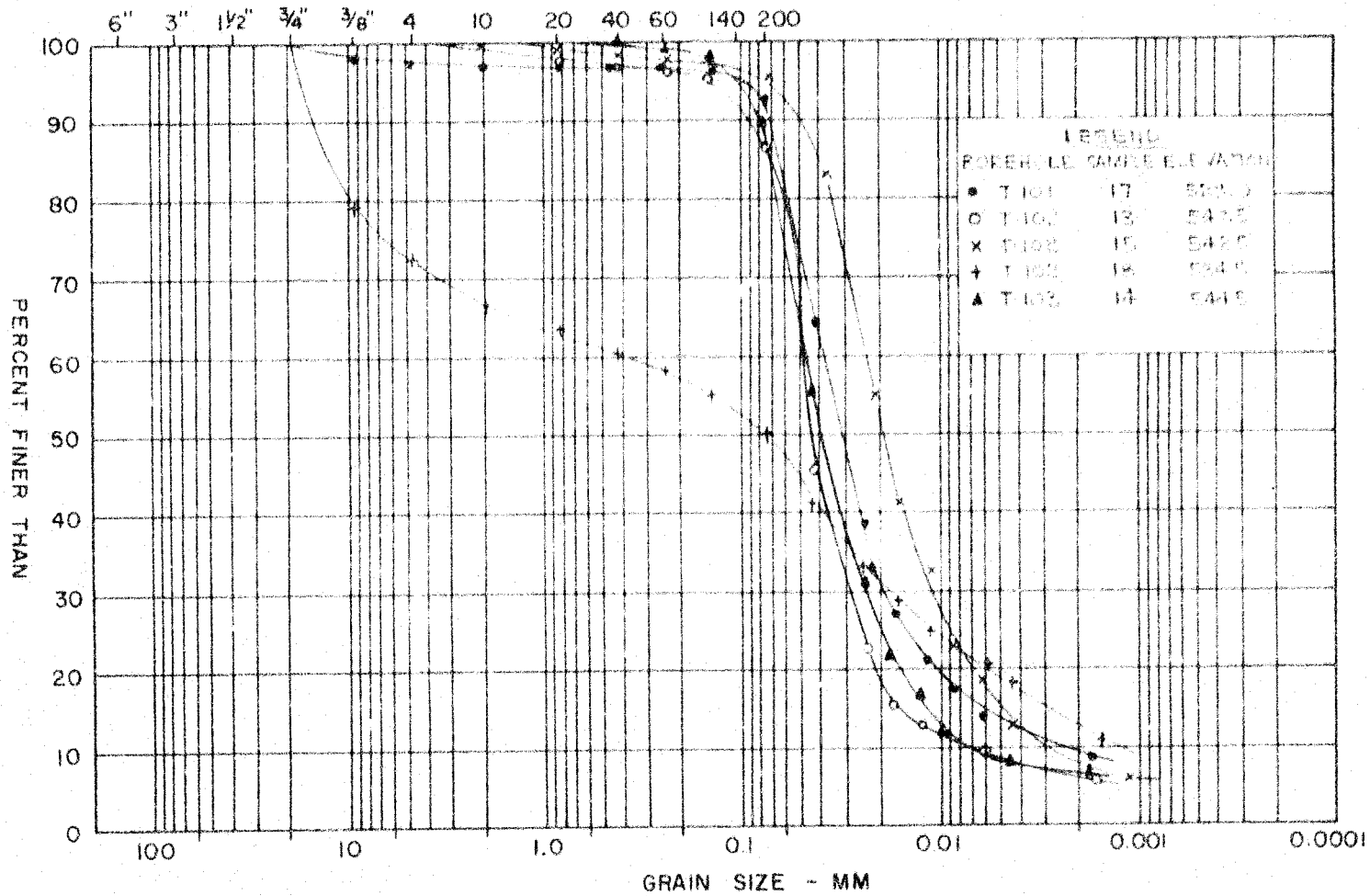
GOLDER & ASSOCIATES

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

FIGURE 1-27

M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES/IN.



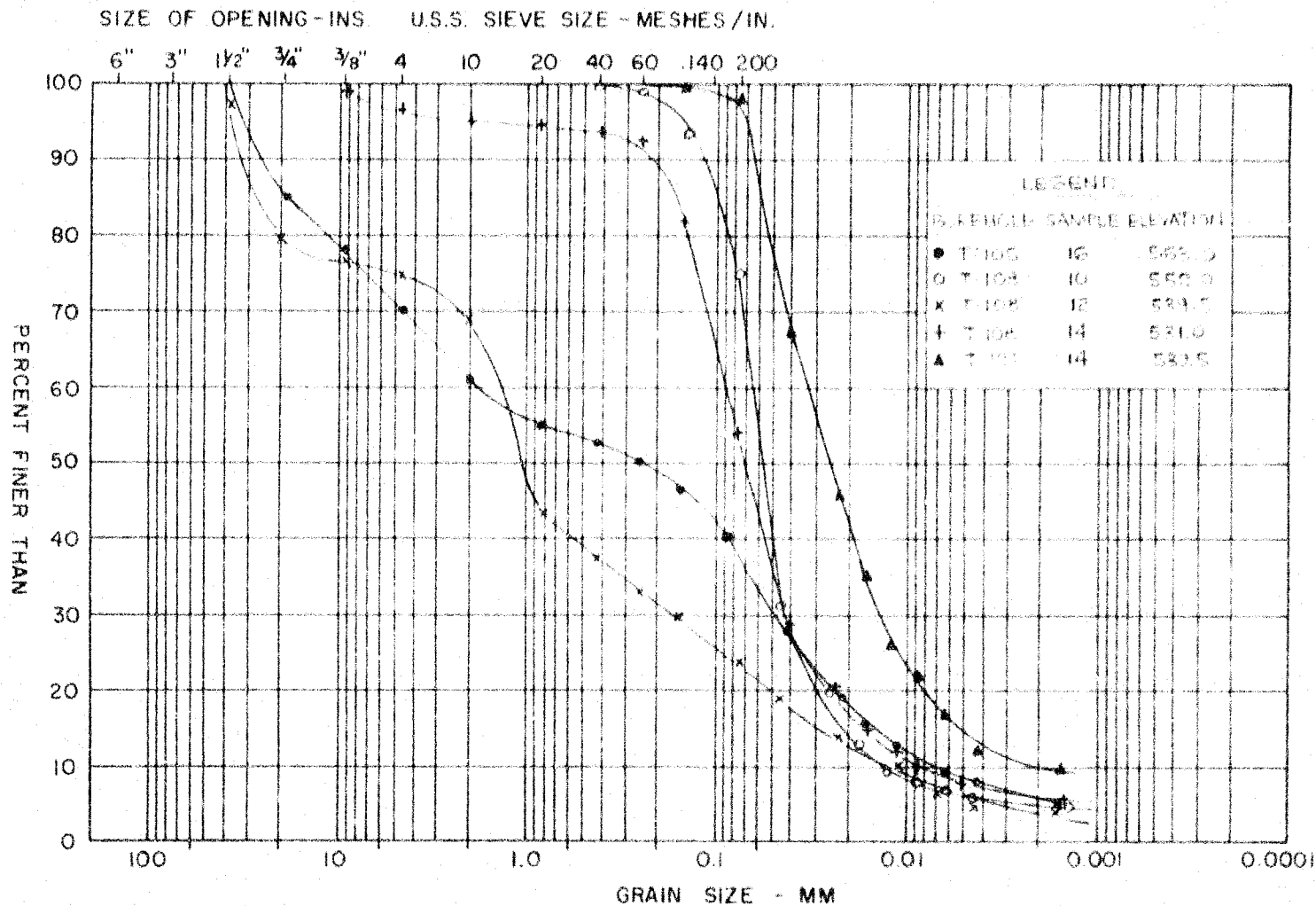
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION
POKERHOLE SAMPLE ELEVATION

FIGURE 1-28

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

M.I.T. GRAIN SIZE SCALE



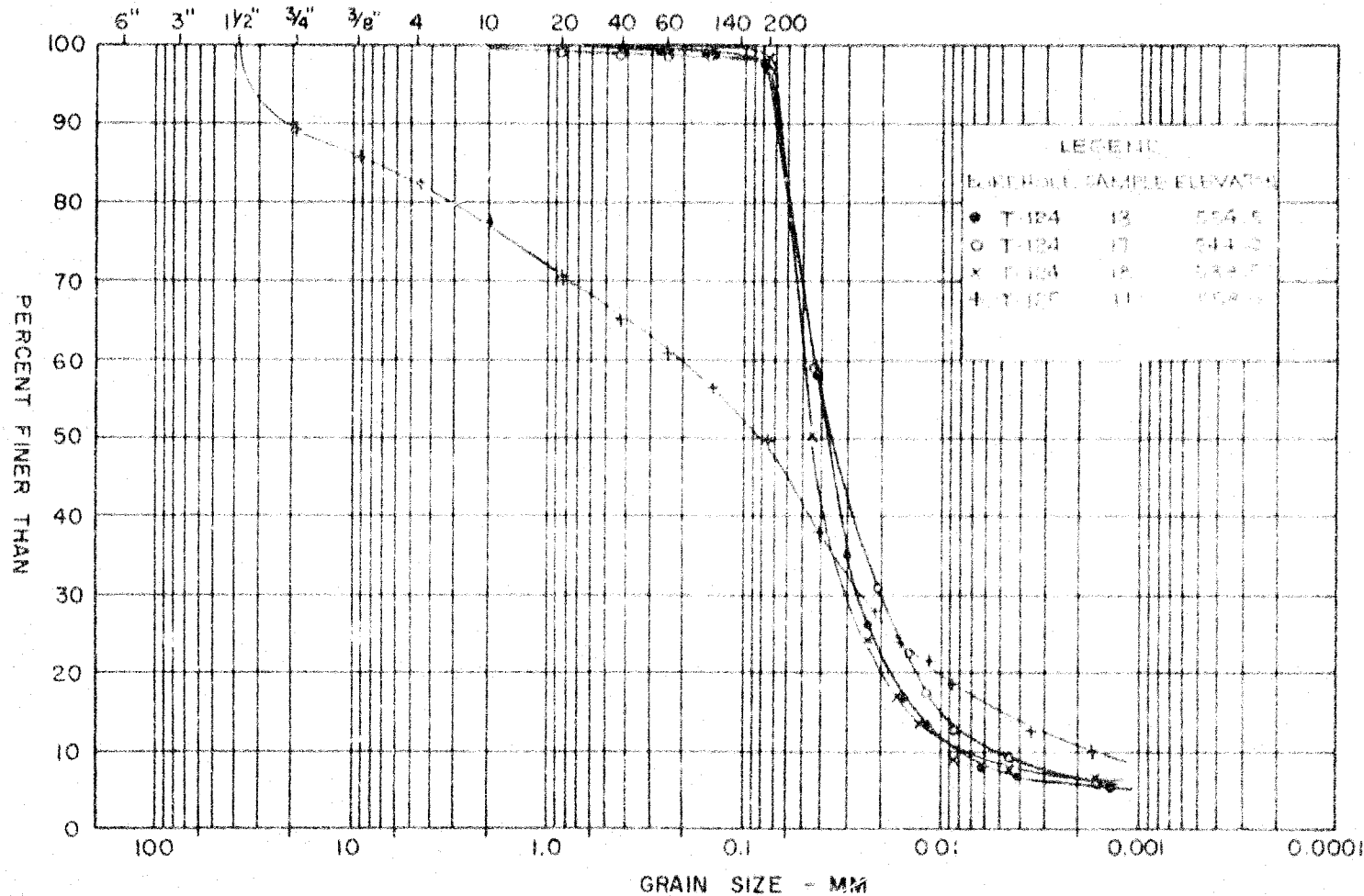
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-29

M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES/IN.

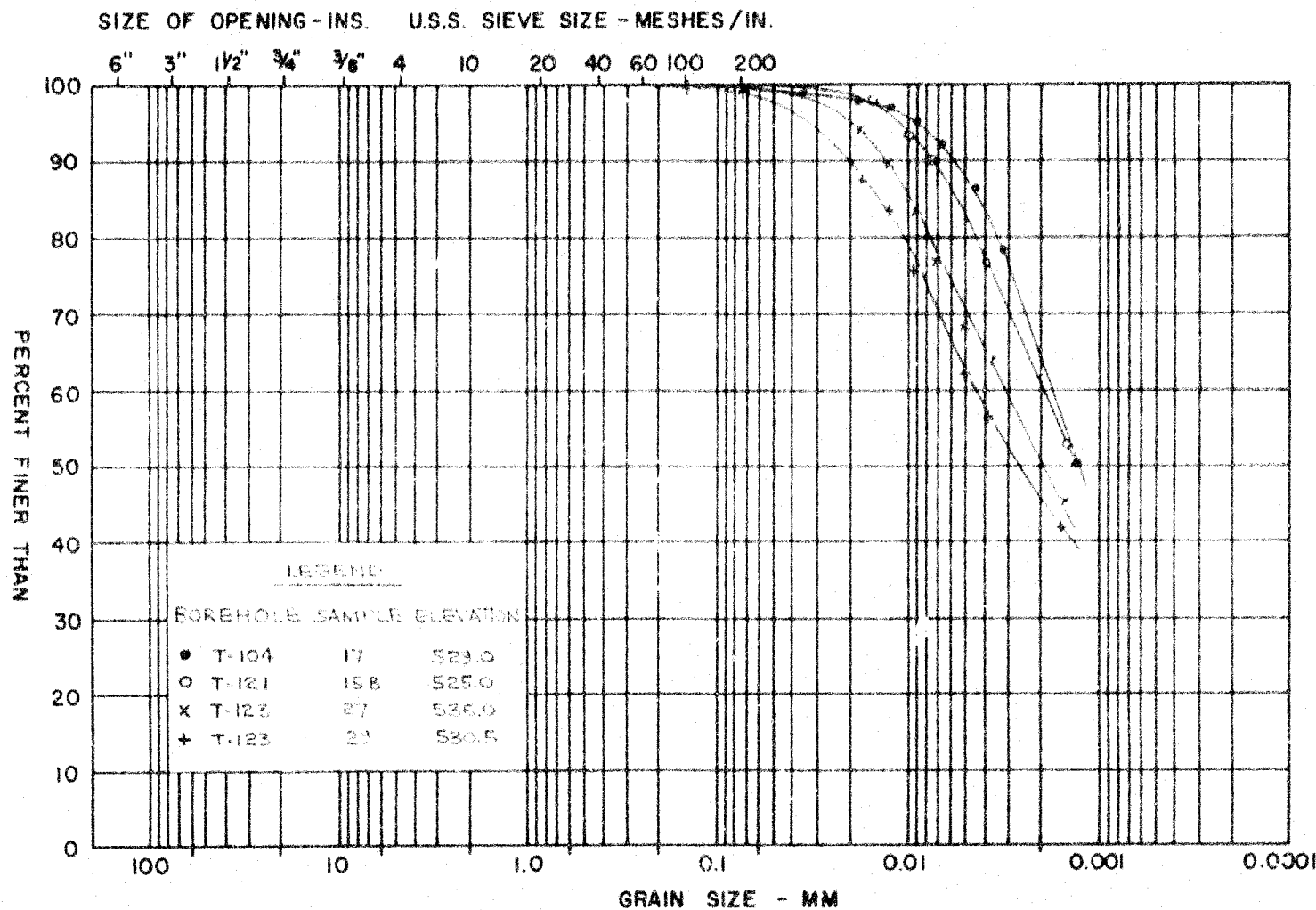


GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-20

M.I.T. GRAIN SIZE SCALE

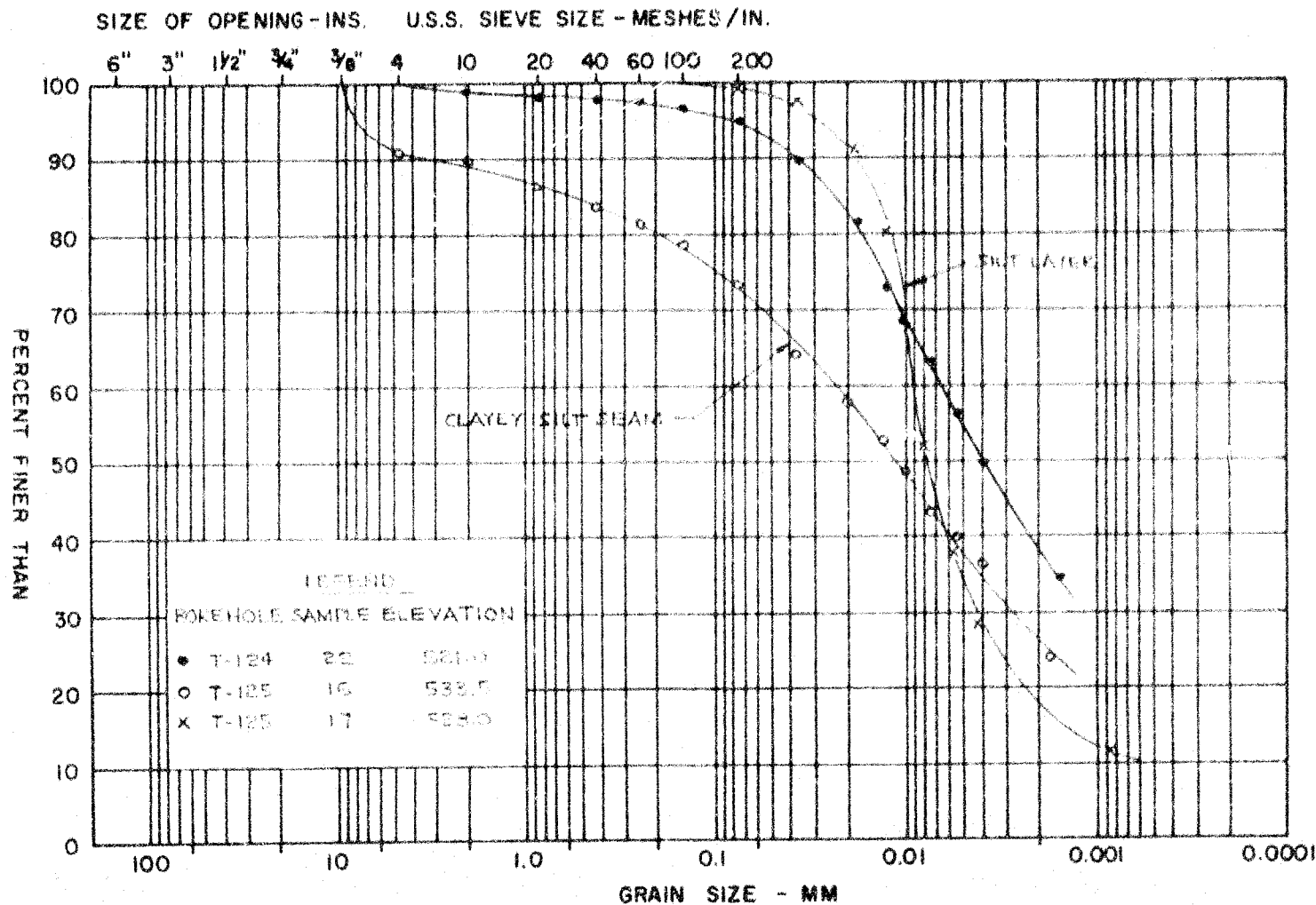


GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-21

M.I.T. GRAIN SIZE SCALE



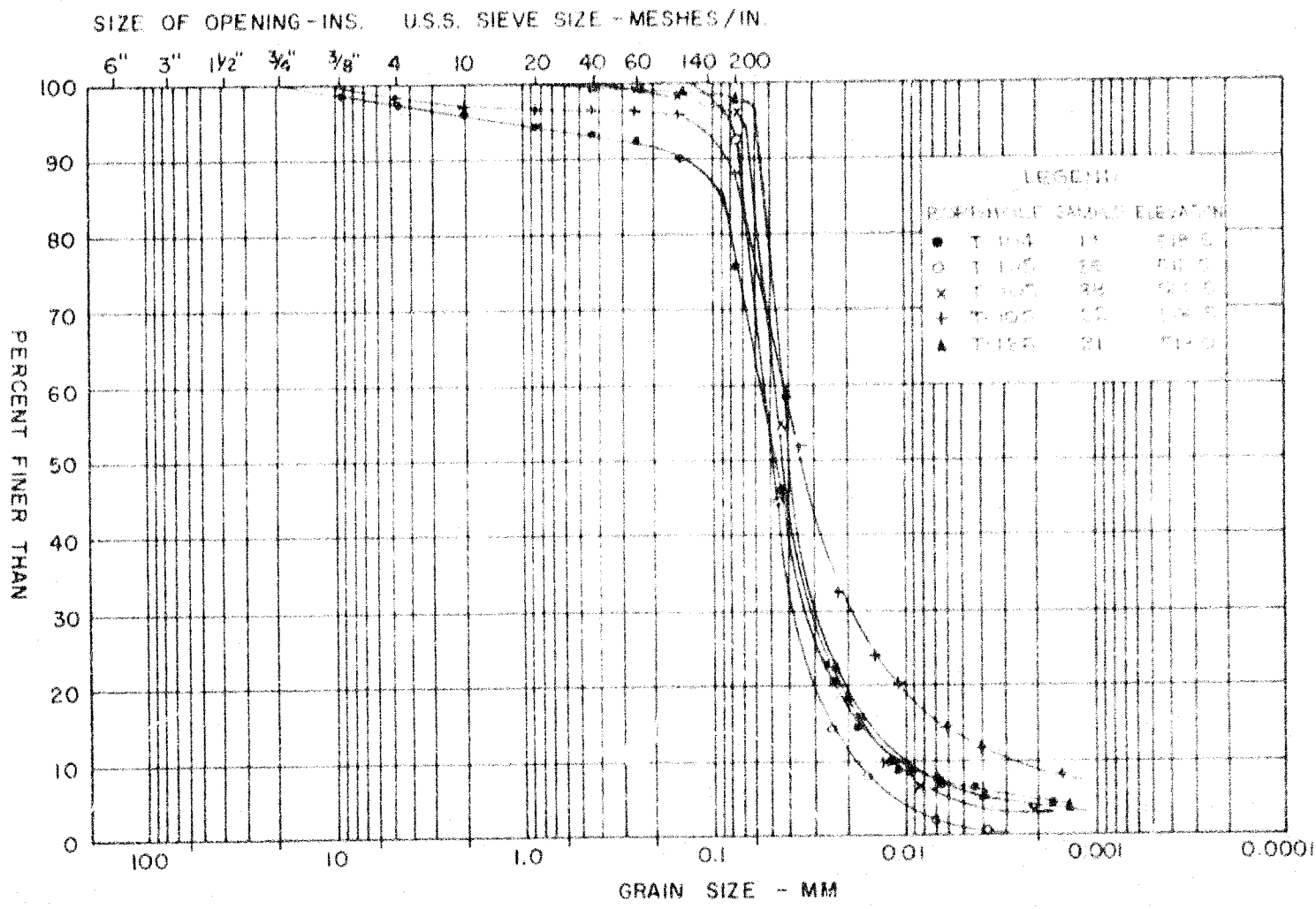
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-32

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

M.I.T. GRAIN SIZE SCALE



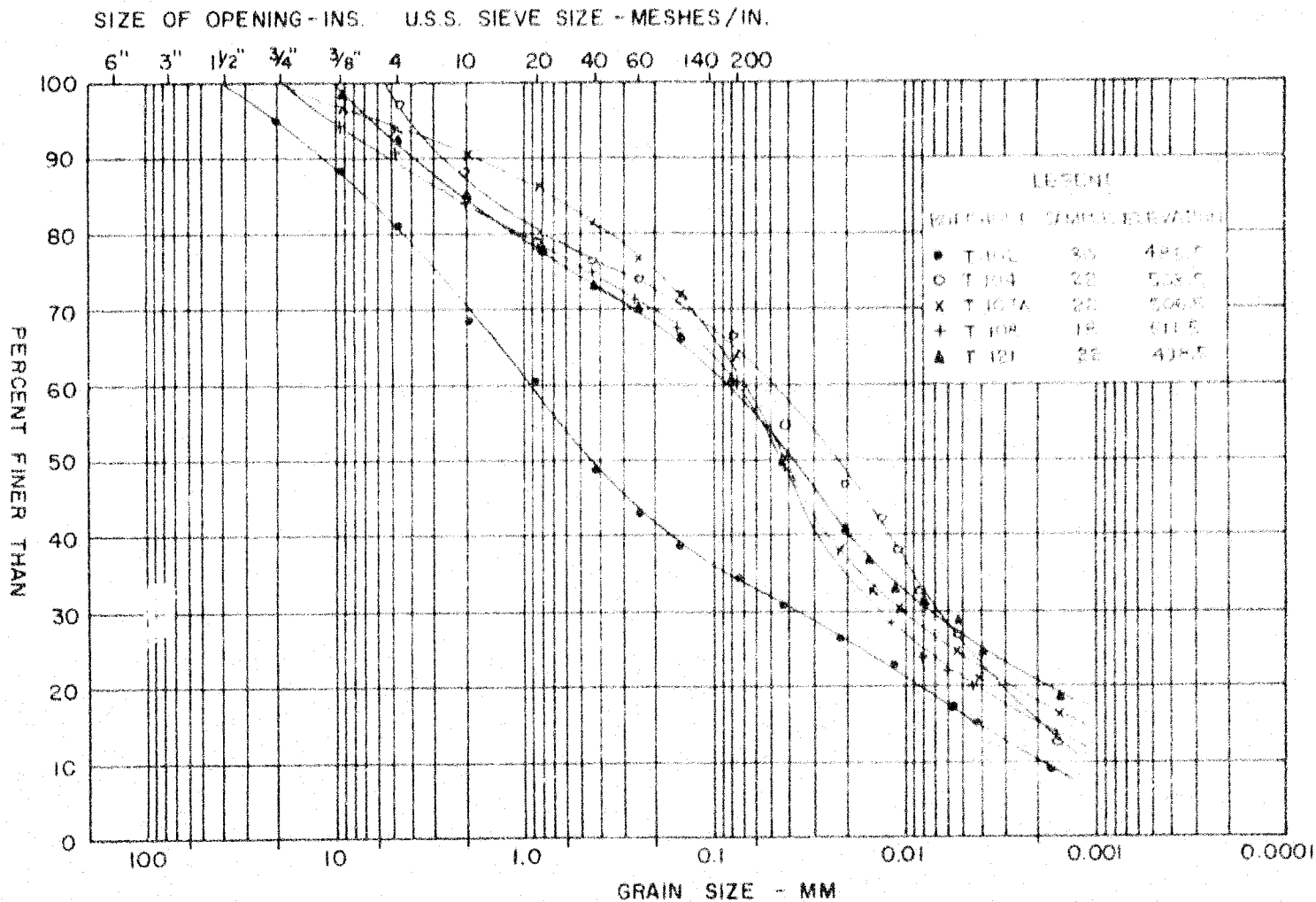
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-23

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

M.I.T. GRAIN SIZE SCALE

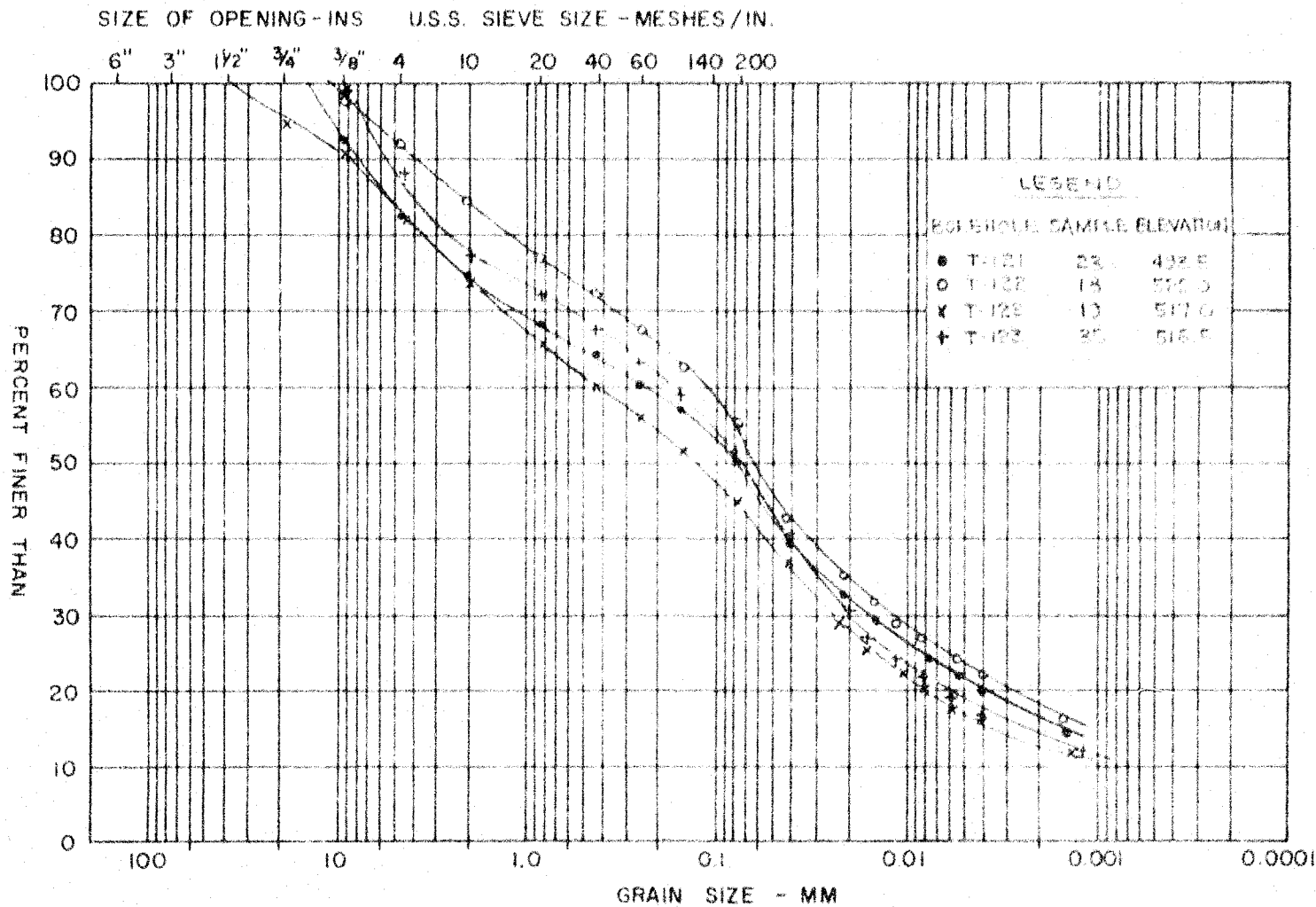


GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-54

M.I.T. GRAIN SIZE SCALE



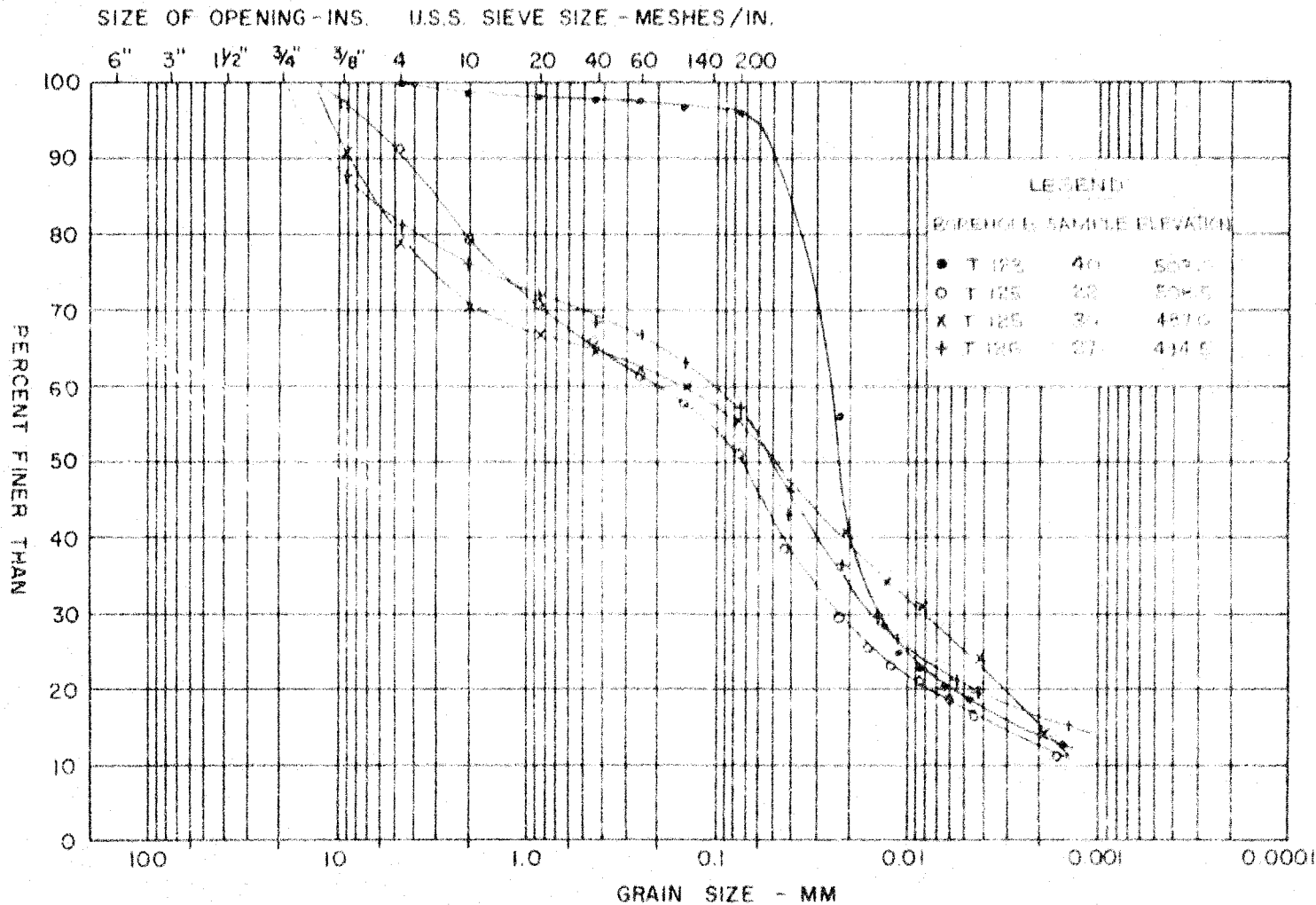
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION
TILL STATION (EST. 100100)

FIGURE 1-35

COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE	
	GRAVEL SIZE			SAND SIZE			FINE GRAINED			

M.I.T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

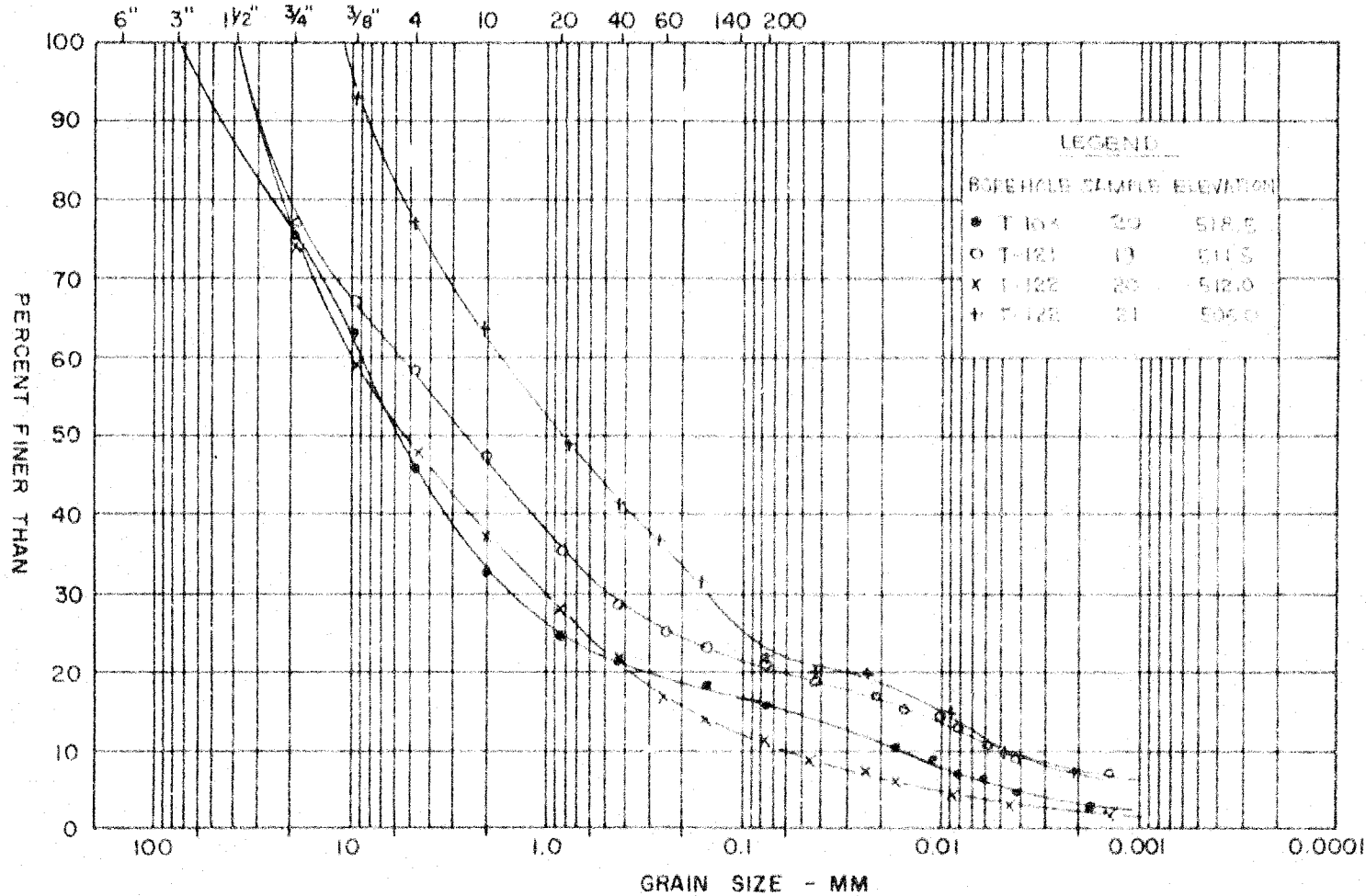
GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION

FIGURE 1-26

M.I.T. GRAIN SIZE SCALE

SIZE OF OPENING - INS. U.S.S. SIEVE SIZE - MESHES/IN.

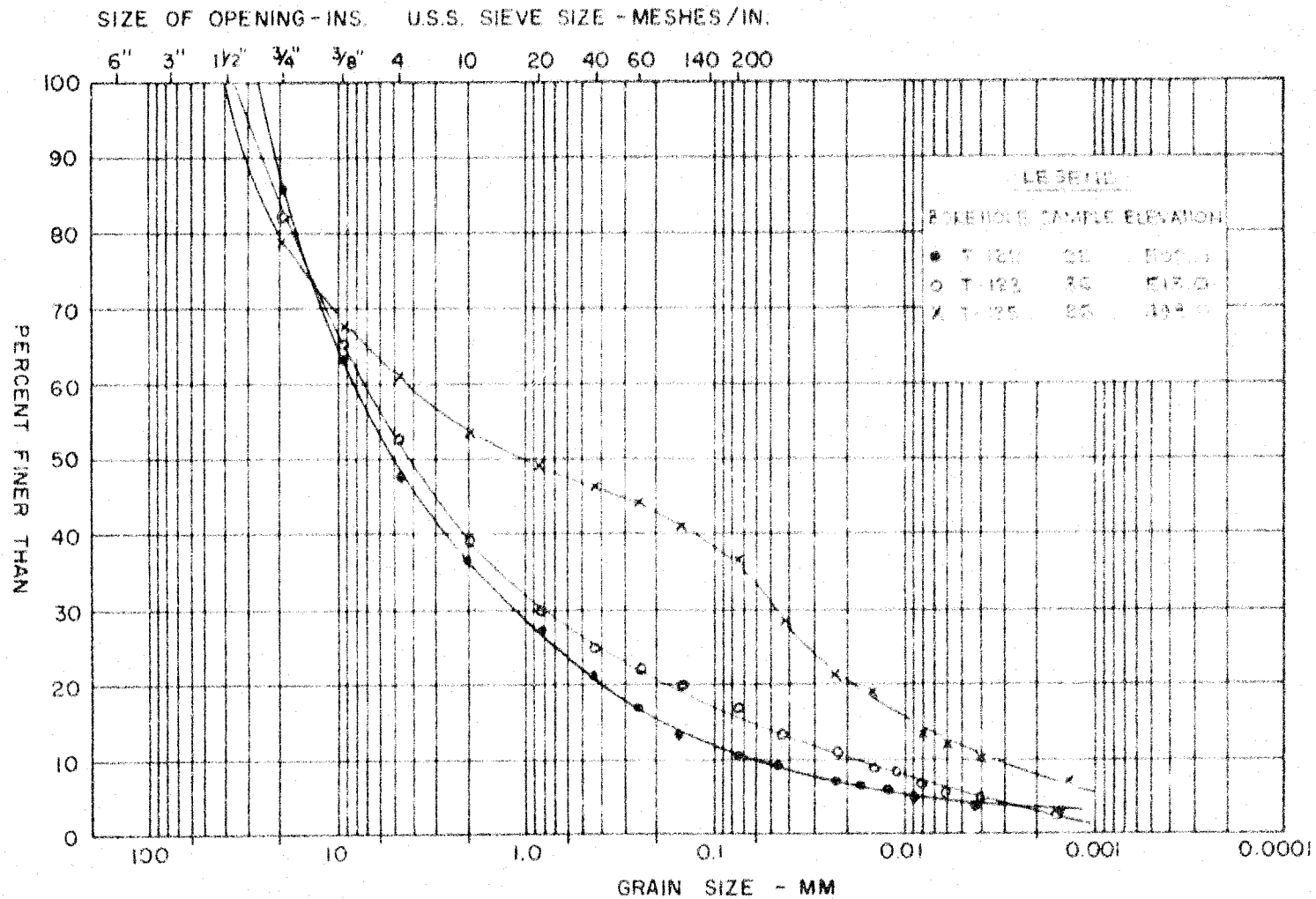


GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION
TILL STATION (GRAVELLY FILLION)

FIGURE 1-27

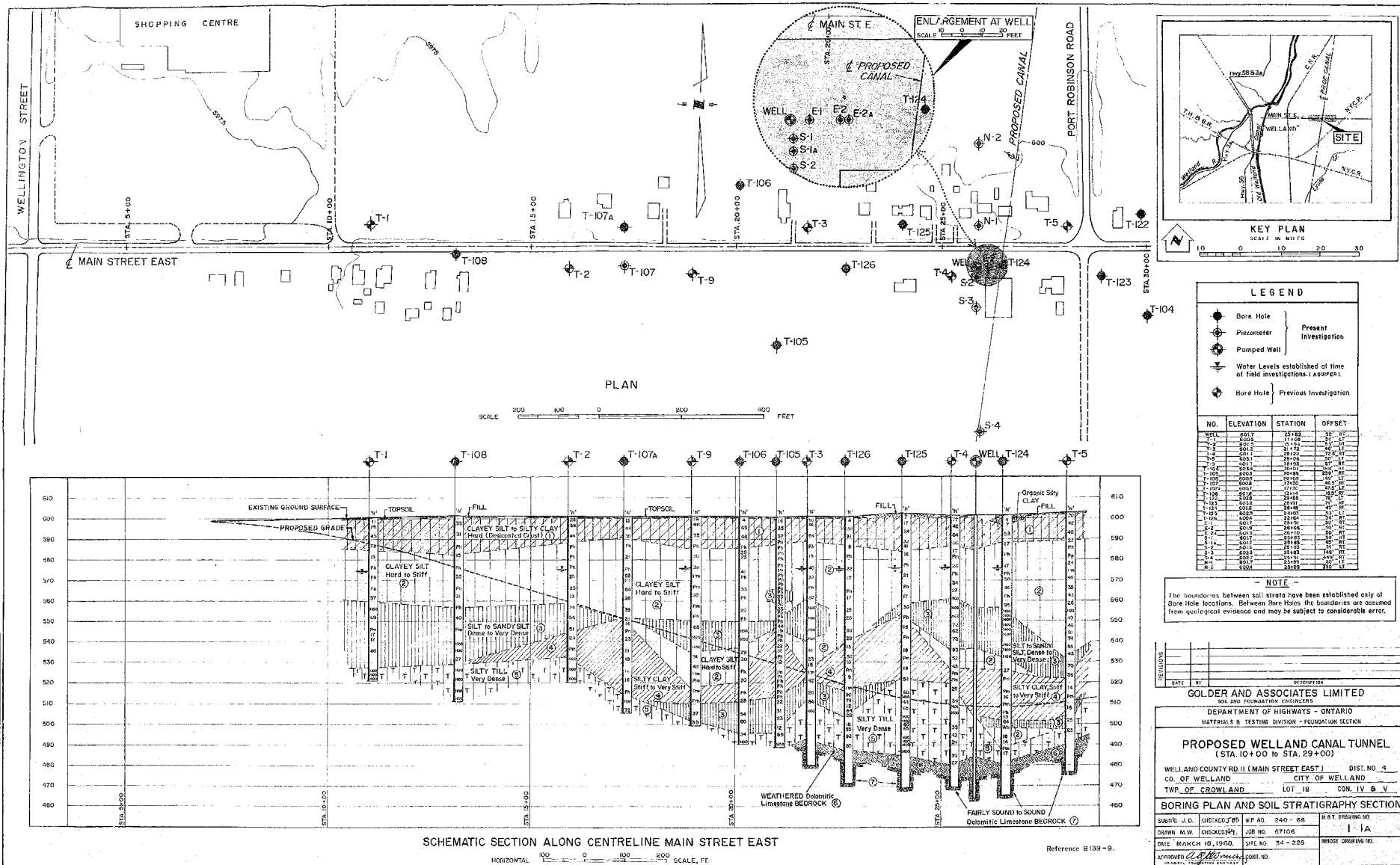
M.I.T. GRAIN SIZE SCALE



GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION
PILEHOLE SAMPLE ELEVATION

FIGURE 1-36



NO.	ELEVATION	STATION	OFFSET
501-1	501.7	15183	51
501-2	500.4	15183	51
501-3	501.5	15183	51
501-4	501.2	15183	51
501-5	501.1	15183	51
501-6	501.1	15183	51
501-7	501.1	15183	51
501-8	501.1	15183	51
501-9	501.1	15183	51
501-10	500.3	15183	51
501-11	500.3	15183	51
501-12	500.3	15183	51
501-13	500.3	15183	51
501-14	500.3	15183	51
501-15	500.3	15183	51
501-16	500.3	15183	51
501-17	500.3	15183	51
501-18	500.3	15183	51
501-19	500.3	15183	51
501-20	500.3	15183	51
501-21	500.3	15183	51
501-22	500.3	15183	51
501-23	500.3	15183	51
501-24	500.3	15183	51
501-25	500.3	15183	51
501-26	500.3	15183	51
501-27	500.3	15183	51
501-28	500.3	15183	51
501-29	500.3	15183	51
501-30	500.3	15183	51
501-31	500.3	15183	51
501-32	500.3	15183	51
501-33	500.3	15183	51
501-34	500.3	15183	51
501-35	500.3	15183	51
501-36	500.3	15183	51
501-37	500.3	15183	51
501-38	500.3	15183	51
501-39	500.3	15183	51
501-40	500.3	15183	51
501-41	500.3	15183	51
501-42	500.3	15183	51
501-43	500.3	15183	51
501-44	500.3	15183	51
501-45	500.3	15183	51
501-46	500.3	15183	51
501-47	500.3	15183	51
501-48	500.3	15183	51
501-49	500.3	15183	51
501-50	500.3	15183	51
501-51	500.3	15183	51
501-52	500.3	15183	51
501-53	500.3	15183	51
501-54	500.3	15183	51
501-55	500.3	15183	51
501-56	500.3	15183	51
501-57	500.3	15183	51
501-58	500.3	15183	51
501-59	500.3	15183	51
501-60	500.3	15183	51
501-61	500.3	15183	51
501-62	500.3	15183	51
501-63	500.3	15183	51
501-64	500.3	15183	51
501-65	500.3	15183	51
501-66	500.3	15183	51
501-67	500.3	15183	51
501-68	500.3	15183	51
501-69	500.3	15183	51
501-70	500.3	15183	51
501-71	500.3	15183	51
501-72	500.3	15183	51
501-73	500.3	15183	51
501-74	500.3	15183	51
501-75	500.3	15183	51
501-76	500.3	15183	51
501-77	500.3	15183	51
501-78	500.3	15183	51
501-79	500.3	15183	51
501-80	500.3	15183	51
501-81	500.3	15183	51
501-82	500.3	15183	51
501-83	500.3	15183	51
501-84	500.3	15183	51
501-85	500.3	15183	51
501-86	500.3	15183	51
501-87	500.3	15183	51
501-88	500.3	15183	51
501-89	500.3	15183	51
501-90	500.3	15183	51
501-91	500.3	15183	51
501-92	500.3	15183	51
501-			

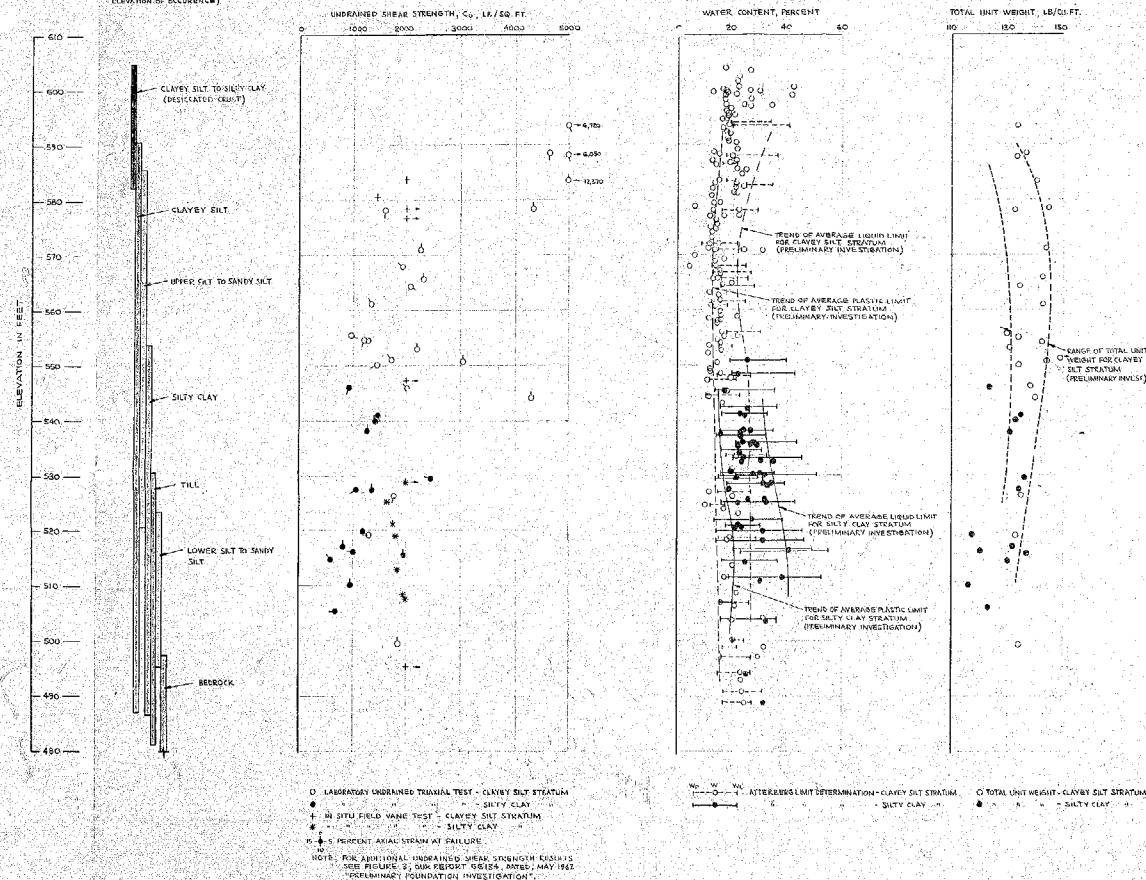
NOTE

The boundaries between soil strata have been established only of Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.

DATE	BY	DESCRIPTION
<p align="center">GOLDER AND ASSOCIATES LIMITED SOL AND FOUNDATION ENGINEERS</p> <p align="center">DEPARTMENT OF HIGHWAYS - ONTARIO MATERIALS & TESTING DIVISION - FOUNDATION SECTION</p> <p align="center">PROPOSED WELLAND CANAL TUNNEL (STA. 10+00 TO STA. 29+00)</p> <p>WELLAND COUNTY RD 11 (MAIN STREET EAST) DIST. NO. 4 CO. OF WELLAND CITY OF WELLAND TWP. OF CROWLAND LOT 18 CON. IV & V</p> <p align="center">BORING PLAN AND SOIL STRATIGRAPHY SECTION</p>		
SUBMIT J.D.	CHECKED J.D.	HP NO. 240 - 88
DESIGN M.W.	CHECKED M.W.	JOB NO. 67106
DATE MARCH 16, 1968	SPEC. NO.	34 - 225
APPROVED <i>C.B. Brown</i>	CONST. NO.	
		TEST. LOGGING NO. 1 - 1A
		PROCEED DRAWING NO.

SIMPLIFIED SOIL STRATIGRAPHY (INDICATING APPROXIMATE AND PRELIMINARY ELEVATION OF OCCURRENCE)

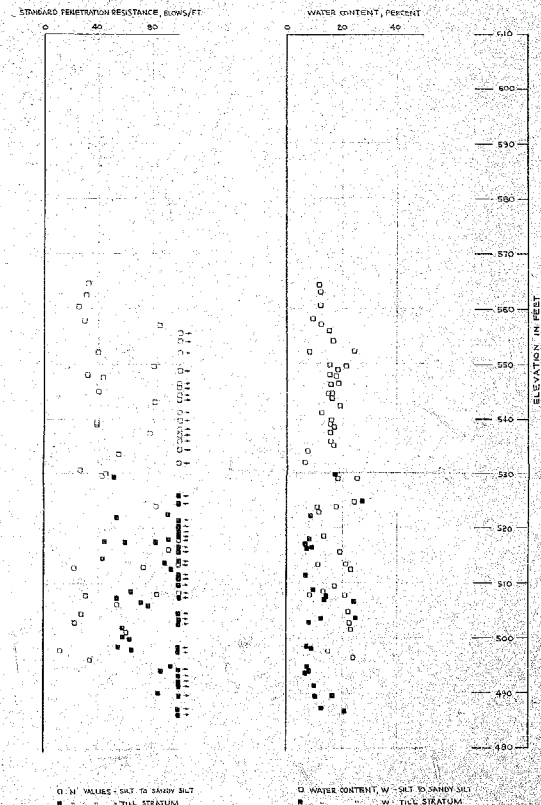
CLAYEY SILT AND SILTY CLAY STRATA



SUMMARY OF ENGINEERING PROPERTIES (OVERBURDEN DEPOSITS)

FIGURE 1-5

SILT AND TILL STRATA



Drawn: APRIL 6, 1968

GOLDER & ASSOCIATES

Scale: 1" = 10' Vert. 1" = 100' Horiz.