

G.I.-30 SEPT. 1976

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GEOCRES No. 41K-38

W.P. No. 918-59

CONT. No. _____

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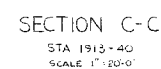
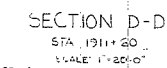
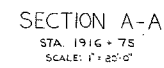
HWY. No. 17 DIST. 18

LOCATION STA. 1909+00 TO STA.
1918+00

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. 2

REMARKS: _____

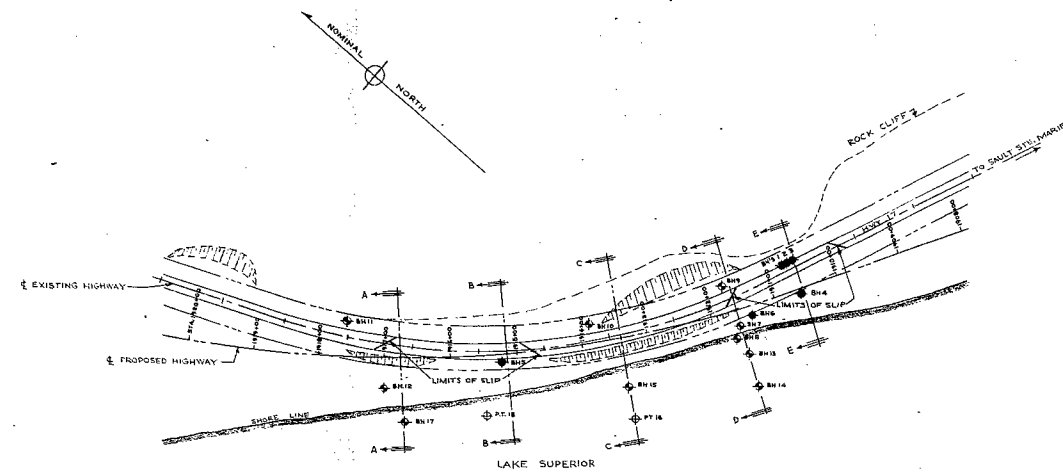


SAND AND GRAVEL AND GRANULAR FILL	$\gamma = 130 \text{ LBS./CU.FT.}$ $\gamma' = 67 \text{ LBS./CU.FT.}$ $\phi = 30^\circ$ $c = 0$
VARVED CLAY	$\gamma = 105 \text{ LBS./CU.FT.}$ $\gamma' = 47 \text{ LBS./CU.FT.}$ $\phi' = 20^\circ$ $c = 0$

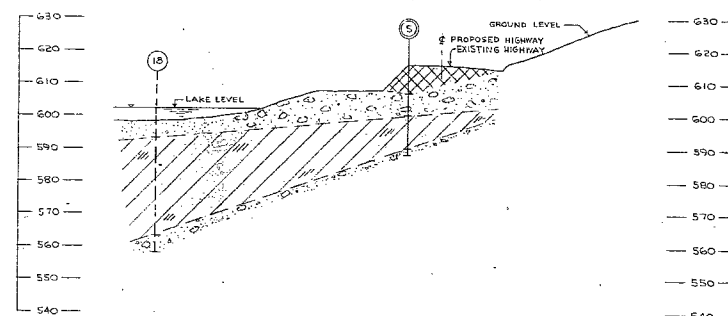
- ◆ BOREHOLE IN PLAN (BY GEOCON LTD)
- ✦ PENETRATION TEST IN PLAN (BY GEOCON LTD)
- ◆ BOREHOLE IN PLAN (BY D.H.O.)
- BOREHOLE IN ELEVATION (BY GEOCON LTD)
- PENETRATION TEST IN ELEVATION (BY GEOCON LTD)
- BOREHOLE IN ELEVATION (BY D.H.O.)

41 K-38
GEOCRE No.

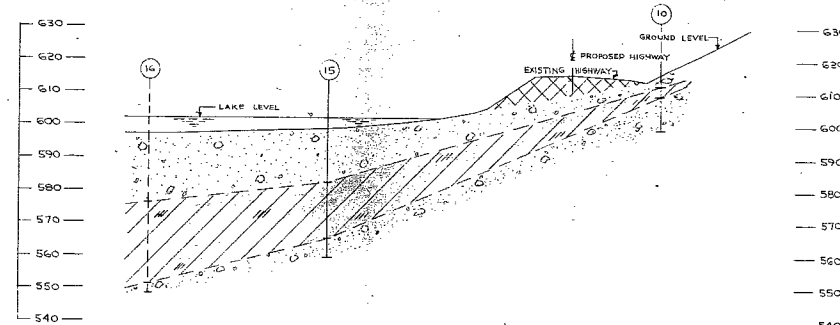
REVISIONS		REVISIONS		REFERENCE		REFERENCE	
MARK	DATE	DESCRIPTION	MARK	DATE	DESCRIPTION	DWG. NO.	DESCRIPTION
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						DEPARTMENT OF HIGHWAYS ONTARIO TORONTO ONTARIO PROPOSED HIGHWAY 17 SAULT STE. MARIE ONTARIO RECOMMENDED BERM SECTIONS	
						DATE OCT 21, 1960 SCALE 1"=20'-0" MADE 25-MAY-61 CHKD. F.H. APPR. 177 No. 57120-2	



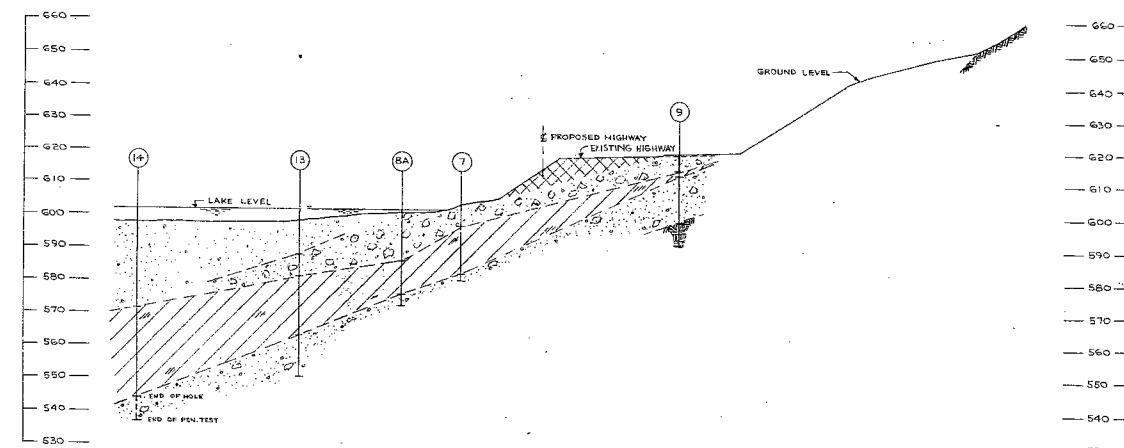
PLAN
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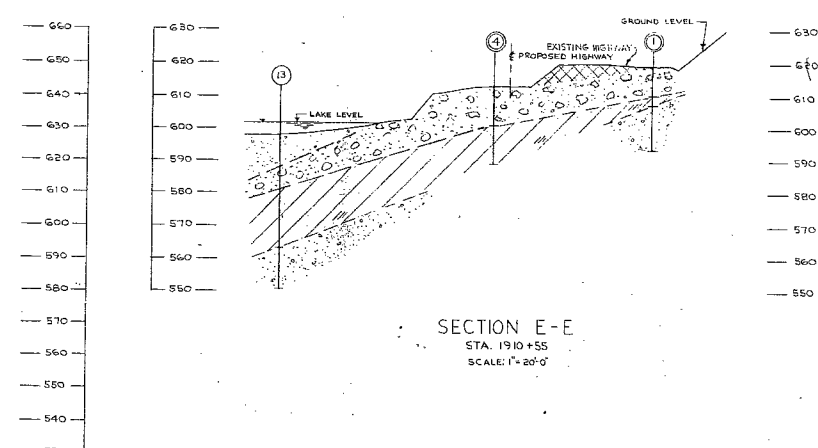
SECTION B-B
STA. 1915+15
SCALE: 1"=20'-0"



SECTION C-C
STA. 1913+40
SCALE: 1"=20'-0"



SECTION D-D
STA. 1911+60
SCALE: 1"=20'-0"



SECTION E-E
STA. 1910+55
SCALE: 1"=20'-0"



KEY PLAN
SCALE: 1"=5/8 MILES

STRATIGRAPHY

- GRAVEL FILL
- PEAT
- COMPACT BROWN COARSE SAND AND GRAVEL, WITH ABUNDANT BOULDERS
- LOOSE TO COMPACT GREY GRAVELLY FINE TO MEDIUM SAND
- SOFT TO STIFF REDDISH GREY VARVED CLAY
- COMPACT TO VERY DENSE GREY SILTY TO SAND GRAVEL WITH ABUNDANT BOULDERS
- RED GRANITE BEDROCK

LEGEND

- BOREHOLE IN PLAN (7) IN ELEVATION (BY GEOCON LTD)
- PEN. TEST IN PLAN (18) IN ELEVATION (BY GEOCON LTD)
- BOREHOLE IN PLAN (1) IN ELEVATION (BY D.H.O.)

SPECIAL NOTE: DATA CONCERNING THE VARIOUS STRATA HAVE BEEN OBTAINED AT BOREHOLE LOCATIONS ONLY. THE SOIL STRATIGRAPHY BETWEEN BOREHOLES HAS BEEN INFERRED FROM GEOLOGICAL, EXISTING AND SO NEW VARY FROM THAT SHOWN.

41K-38
GEOCONS No.

REVISIONS		REVISIONS		REFERENCE		REFERENCE	
MARK	DATE	DESCRIPTION	MARK	DATE	DESCRIPTION	MARK	DATE

DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO
EXISTING AND PROPOSED HIGHWAY 17
SAULT STE. MARIE
BORING PLAN AND SOIL STRATIGRAPHY

GEOCON LTD
DATE: SEPT. 7, 1960 SCALE: AS SHOWN
J.A. F.H. J.P.
No. S 7120-1

41K-38
GEOCRES No.

Mr. A. M. Toye,

November 18, 1960.

Bridge Engineer.

FOUNDATION INVESTIGATION REPORT

Materials & Research Section.

by: Geocon, Limited.

Attention: Mr. S. McCombie.

Re: Existing and Proposed Highway 17,
Sta. 1909+00 to Sta. 1918+00,
Sault Ste. Marie, Ont., Dist. 18
W.P. 918-59.

We have reviewed the above mentioned report and have found the results of the investigation well presented. The recommendations are conclusive and, we believe, adequate for your future work.

Prior to the submitting of this report, the possibility of relocating the highway was discussed with the Location Section and at that time, it was agreed that such an alternative was feasible. In view of the many difficulties and uncertainties connected with the safe construction of the highway at the proposed location, it is strongly recommended that the highway be relocated in accordance with the proposal contained in the report. If this recommendation is adopted, the suggested additional subsoil investigation should be carried out, also.

Should there be further questions with respect to this problem that you would like to discuss, please feel free to call on our Office.

AGS/MdeF
Attach.

cc: Messrs. A. M. Toye (2) ✓
H. A. Tregaskes
D. G. Ramsay
G. K. Hunter
D. P. Collins
E. R. Saint
A. Watt

L. G. Soderman,
PRINCIPAL FOUNDATIONS ENGR.
Per:

L. G. Soderman
(A. G. Stermac,
FOUNDATIONS OFFICE ENGR.)

Foundations Office
Gen. Files.

To be Plotted on 41K

BA 1151

GEOCON LTD

HEAD OFFICE

180 VALLÉE ST., MONTREAL 18, QUEBEC

TELEPHONE UN. 6-7632

Rexdale, Ontario,
October 31st, 1960.

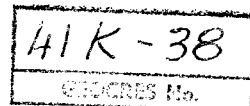
DISTRICT OFFICES

14 HAAS ROAD
REXDALE, TORONTO, ONT.
TEL. CH. 4-8641

1425 WEST PENDER ST.
VANCOUVER 5, B.C.
TEL. MU. 1-8926

Department of Highways, Ontario,
Downsview, Ontario.

Attention: Mr. L. G. Soderman, P. Eng.,
Principal Foundation Engineer.



Re: Soil Conditions and Engineering Study,
Existing and Proposed Highway 17,
W.P. 918-59,
Sault Ste. Marie, Ontario.

Dear Sirs:

This letter accompanies our detailed report covering the investigation carried out for the above site.

We find that the site is covered by two gravel strata separated by a stratum of varved clay whose thickness increases towards the lake. All the strata slope towards the lake and the lower boundary of the varved clay dips at about 20 degrees to the horizontal. Artesian pressures up to about 20 feet above lake level were observed in the boreholes.

The existing slope failures were analyzed using both circular arc and composite surface methods. The use of composite surface analysis is not mathematically rigorous but it is felt that it more closely approximates the geometry of the failure than the circular arc analysis.

As discussed in the report, the proposed roadway will necessitate the use of a large berm and multi-stage construction. Because of the time and control requirements involved, the construction of the berm does not seem practical. It is therefore recommended that the roadway be relocated towards the north and that it be founded on the dense lower gravel stratum or on bedrock.

We believe that this report gives all the information for safe and economical embankment design. If we can be of any further service, however, please do not hesitate to call us.

Yours very truly,

GEOCON LTD

V. Milligan per SLS.

V. Milligan, P. Eng.,
Assistant Chief Engineer.

VM/dw
S7120

S7120
REPORT
TO
DEPARTMENT OF HIGHWAYS, ONTARIO
ON
SOIL CONDITIONS AND ENGINEERING STUDY
EXISTING AND PROPOSED HIGHWAY 17
W.P. 918-59
SAULT STE. MARIE ONTARIO

Distribution:

- 10 copies - Department of Highways, Ontario,
Downsview, Ontario.
- 2 copies - Geocon Ltd,
Rexdale, Ontario.

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INTRODUCTION

Geocon Ltd has been retained by the Department of Highways, Ontario by letter dated August 19th, 1960, to investigate and report on the soil conditions between Stations 1909+00 and 1920+00 on Highway 17 adjacent to the shore of Lake Superior between Havilland Bay and Chippewa Falls.

The object of the investigation was to determine and interpret the soil and water conditions at the site as they affect the stability of the existing roadway and to make recommendations concerning the stability of embankments in a proposed re-alignment of this section of Highway 17.

A description of the procedure, site and geology, and detailed accounts of the soil and water conditions are given in Appendix I of this report. The results of the in-situ and laboratory testing are shown on the Office Reports on Soil Exploration in Appendix I and on the Figures in Appendix II. A drawing showing the borehole locations, together with the inferred soil stratigraphy, is located in the pocket at the rear of the report.

SUMMARIZED SOIL CONDITIONS

The embankment fill consists of sandy gravel, the thickness of which ranges across the roadway from about 3 feet on the north side to 8 feet on the south side. All of the naturally occurring soil strata below the roadway slope towards the lake. Underlying the embankment fill is a stratum of compact sandy gravel with a thickness of from 5 to 15 feet. Below the lake bottom, the sandy gravel grades into a fine to medium sand with a maximum thickness of 26 feet as encountered in the boreholes. A stratum of soft to firm varved clay underlies the sandy gravel or sand stratum. The varved clay stratum is wedge-shaped in section with the thickness decreasing up the slope. The maximum thick-

ness of varved clay encountered in one of the offshore boreholes was 28 feet. The lower boundary of the clay is inclined at about 20 degrees to the horizontal. A stratum of silty to sandy gravel with boulders underlies the clay. On penetrating this stratum, artesian effects were observed and water rose to a maximum elevation of 622 in boreholes. This stratum was not penetrated by all the boreholes, but it is believed that its average thickness is about 15 feet.

SLOPE STABILITY

It is understood that at least two slope failures took place between Stations 1909+00 and 1920+00 on Highway 17 during the period May-June, 1960. This section had been constructed approximately 15 years ago and the failure took place without any modification to the existing grade.

It is further understood that it is proposed to relocate the highway towards the lake and to increase the grade. This is outlined on Drawing S7120-2 which shows both the existing and proposed section of roadway embankment.

Analyses of Existing Slope Failures

In view of the fact that the existing embankment failed some 15 years following construction without modification to the slope, it is considered that the artesian effects observed in the lower gravel stratum and the steep slope of the clay were the major factors causing instability of the embankment.

Effective stress analyses were carried out on a typical section from each failure area. The results of analyses carried out on the slopes at Station 1910+55 and Station 1916+75 are shown on Drawing S7120-3 in Appendix III. The failure surfaces investigated

were drawn to fit as closely as possible the geometry of failure as observed in the field. Both circular arc and composite surface analyses were employed. The piezometric water level was considered to be at elevation 625 throughout. The form of a typical composite surface analysis is shown on Drawing S7120-5 in Appendix IV.

The design values used in the stability analyses are shown on Drawing S7120-3 in Appendix III. Using these values the factors of safety obtained are reasonably close to 1.0. It should be noted in these analyses that c' in the varved clay deposit has been considered to be zero while the average value obtained in the laboratory was 200 pounds per square foot.

Because the liquidity index of the light layer of the deposit is generally higher than the dark layer, and therefore has a more unstable structure, it is considered that the assumption c' equal to zero is valid. From the mode of failure, it is probable that the existing failures largely took place through the silty interface between the varved clay and gravel strata.

Long Term Stability

Computations show that the long term stability of the revised roadway section will be critical and that berms will be required.

The artesian pressure at the site could possibly be relieved by the use of bleeder wells or a gravel filled cut-off trench at the top of the existing slope. However, due to the possibility of silting up, these wells could not be relied on for more than a limited period. Therefore, in long term stability calculations, it is necessary to consider full artesian pressure acting at the base of the varved clay deposit. The design values adopted are those which were used in the

analyses of the existing failures, that is, c' equal to zero and ϕ' equal to 20 degrees. Drawing S7120-2 in the pocket at the rear of the report shows the berm sections required for the proposed embankment and the calculated factor of safety of each overall section. The criterion used for design of the proposed roadway embankment and berm was a minimum factor of safety of 1.3. However, it has been necessary in these analyses to assume the soil conditions beyond the area covered by the offshore boreholes. Furthermore, the analyses of the stability of the end of the berm depends entirely on the validity of the extrapolated soil conditions and any stability analysis on the end of the berms could serve only as a guide until soil conditions in this area have been defined.

In the construction of the berm, granular material should be used throughout. However, to protect against erosion by wave action the outer edge of the berm should be constructed of rock fill for a thickness of at least 10 feet.

Short Term Stability

During construction of the roadway and the necessary berms, pore pressures will be set up in the varved clay stratum due to the increased effective overburden pressure. If we assume that the ratio of increase in pore pressure, Δu , to the increase in effective major principal stress, $\Delta \sigma_1$, is about 1 then any addition of load or increase in effective overburden pressure will set up a pore pressure exactly equivalent to the load. This implies that the parameter, \bar{B} , is equal to 1 which is a reasonable assumption for normally or lightly over-consolidated varved deposits. This pore pressure would dissipate with time, but in the short term, the addition of a berm would add little to the frictional resistance through the varved clay deposit. Basically, in these effective stress analyses the addition of a berm

improves the factor of safety mainly by counter-balancing part of the overturning moments produced by the roadway embankment. Therefore, if construction of the roadway and berm fills does not take place at a rate slow enough to allow sufficient pore pressure dissipation the short term stability could be much more critical than long term.

It could prove grossly uneconomical to design a very large berm or succession of berms just to satisfy the short term or 'end of construction' case stability and consequently consideration was given to multi-stage construction.

Multi-Stage Construction

The object of employing multi-stage construction is to allow sufficient time for the dissipation of a large part of the excess pore pressures. The changes in pore pressure which take place are discussed below and are shown diagrammatically on Drawing S7120-4 in Appendix IV.

Before any construction takes place, it is recommended that the artesian pressure should be reduced and if possible eliminated. This could be accomplished by two alternative methods. Firstly, bleeder wells could be installed in the offshore area. These wells should penetrate into the lower gravel stratum and should be spaced about 25 feet apart in a line running parallel to the roadway and out beyond the edge of the proposed berms. Secondly, the artesian pressure could be relieved by constructing a cut-off trench on the north side of the road which would penetrate the varved clay stratum. This trench should be backfilled with granular material.

However, because of the impermeable nature of the clay, there will be a considerable time lag before the pore pressure due to artesian pressure dissipates at the center of the stratum. The pore pressure distribution in the clay stratum when 50 percent of the artesian pore pressure

has dissipated at the center of the stratum is shown by the line U_d on Drawing S7120-4. The time involved for this change from U_a , which represents the pore pressure distribution in the varved clay due to artesian effects, to U_d depends on the thickness of the stratum as well as the permeability of the clay, but it should be of the order of 6 months to 1 year.

After the pore pressures have dissipated to that shown by the line U_d , construction of the berm shown on Drawing S7120-2, can begin. The loading imposed by the berm will set up pore pressure in the underlying clay stratum and assuming $\bar{B} = 1$, the magnitude of the pore pressures will approach the effective weight of the berm for the case of rapid construction. This increase, added to the U_d distribution, results in the U_{db} pore pressure distribution. That part of the pore pressure which is in excess of that produced by water at lake level, shown by line U_1 , is made up of the residual pore pressure induced by artesian effects and the pore pressure due to berm loading.

Before construction of the roadway is begun, it is recommended that sufficient time should be allowed for much of the excess pressure shown by U_{db} to dissipate. The berms have been designed for long term stability using a pore pressure distribution as shown by line U_a . Once the pore pressures fall from U_{db} to a value equal to or less than U_a , it would be safe to construct the roadway. The pore pressure distribution U_{d1b1} which is the distribution when 50 percent of the excess pore pressure has dissipated at the center of the stratum, fulfills this criterion. The time necessary between the construction of the berms and the construction of the roadway above berm level is estimated to be of the order of 6 months to 1 year. However, in this case as well as in the case of the drop in pore pressure after relief of the artesian head, it would be necessary to install piezometers in the clay stratum to determine the time requirements for adequate pore pressure dissipation.

It may be seen that the problem of constructing the roadway embankment as presently proposed is most complex. Strict control of construction in the field would be required and it is possible that the time limits estimated for the successive stages could be grossly exceeded. In view of these points, it is considered that the most practical solution is to revise the proposed alignment. This is discussed below.

HIGHWAY RELOCATION

The advantages of relocation in this area in a direction away from the lake are firstly a better alignment of the highway. Secondly, the clay which decreases in thickness in this direction could readily be excavated and the roadway safely constructed on the dense lower gravel stratum or partially on the gravel stratum and bedrock. The excavation of the clay would greatly increase the stability of the roadway, thus eliminating the necessity for berm and multi-stage construction. However, to facilitate excavation of the clay it may be necessary to minimize artesian effects in the lower gravel stratum during construction. It is considered that the artesian pressure can be partially relieved by a deep trench adjacent to the excavation.

It is understood that at least one lane of the existing Highway 17 would be kept open for traffic. Starting the excavation from about the centre of the existing roadway, the amount of relocation necessary would vary from about 70 feet northwards from the proposed centreline at Station 1916+75 to about 90 feet northwards at Station 1910+55. However, there are no borings near the rock wall and the depth of the clay stratum cannot be predicted accurately.

In order to define the depth of clay that has to be removed and the volume of rock cut that will be required, it will be imperative to put short exploratory boreholes between Stations 1909+00 and 1920+00 along the boundaries of the revised roadway alignment. Only after this is done can detailed measures be defined for the relocation.

CONCLUSIONS AND RECOMMENDATIONS

1. The critical stratum at the site is a soft to stiff varved clay which is wedge-shaped. The clay stratum increases in thickness and slopes steeply downwards in the direction of the lake. The varved clay is overlain and underlain by sand and gravel deposits.

2. The highest artesian water level measured at the time of the investigation was 622. A value of 625 has been used for stability analyses.

3. Stability analyses show that a berm is necessary to ensure an adequate factor of safety for long term stability.

4. Stability analyses show that it is necessary to employ multi-stage construction in order that these berms designed for long term stability will be adequate for short term stability.

5. It is considered that if multi-stage construction is used, piezometers should be installed to measure the pore pressure changes.

6. The alternative to multi-stage construction is to employ a series of lateral berms of decreasing height.

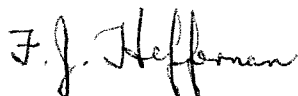
7. Consideration should be given to relocating the highway northwards where after excavation of the clay stratum, it could be founded on the dense lower gravel stratum. It is recommended that this measure be adopted.

PERSONNEL

9.

The field work was carried out under the technical supervision of Mr. R. M. Quigley and Mr. R. Gibson. This report was written by Mr. R. M. Quigley and Mr. F. Heffernan, checked by Mr. J. L. Seychuk and reviewed by Mr. V. Milligan.

FJH/dw
S7120



F. J. Heffernan,
Senior Soils Engineer.

APPENDIX I

Procedure
Soil Conditions
Water Conditions
Office Reports on Soil Exploration

GEOCON

PROCEDURE

The field work was carried out between July 29th and August 25th, 1960, and included all borings and penetration tests from 9 to 18 inclusive. Borings 1 to 8A inclusive were put down prior to July 29th, before Geocon Ltd was retained to do the whole investigation. The first six of these nine borings were supervised by Department of Highways, Ontario personnel. Borings 7, 8 and 8A were supervised by Geocon Ltd for Department of Highways, Ontario, on a consulting basis.

Boreholes and penetration tests 9 to 18 were put down using a skid-mounted machine drillrig. Holes 13 to 18 inclusive, were put down from a raft assembled at the site.

Disturbed samples of the granular soils were taken with 2 inch sampling equipment for soil identification and density determinations. Undisturbed 2 inch and/or 3 inch Shelby tube samples were taken in the varved clay stratum in most borings. In situ vane shear strength determinations of the clay were taken in several of the offshore borings.

The locations of the borings and the inferred soil stratigraphy are shown on S7120-1 located in the pocket at the rear of this report. Detailed logs of the borings are given on the Office Reports on Soil Exploration in this Appendix.

The laboratory testing was carried out in the Toronto Soil Mechanics Laboratory of Geocon Ltd. The samples taken by Department of Highways personnel during the first part of the investigation were also tested by Geocon Ltd. The test results are given on the Office Reports and on the Figures in Appendix II. The samples remaining after testing will be stored until March 1st, 1961, at which time you will be notified regarding their disposal.

Elevations are Geodetic and referred to a bench mark located in the root of a triple maple tree, 69 feet right of station 1910+95. The elevation of this bench mark was taken as 624.70 in accordance with D.H.O. reference map No. W.P.918-59.

SOIL CONDITIONS

The principal soil strata encountered by the borings are as follows:

Topsoil

Approximately six inches of sandy topsoil, derived from underlying sand and gravel was encountered in borings 4 and 9. Six to eight inches of clayey organic topsoil was encountered in borings 10 and 11. Topsoil was absent from all other borings except number 12 in which peat occurred at surface.

Peat

About 5.5 feet of peat was encountered at surface in boring 12. The peat is largely fibrous but contains numerous tree stumps and large tree roots. The lateral extent of the peat was not determined, in accordance with instructions from D.H.O. Materials and Research Engineer, who decided this could be done more cheaply during construction.

Fill

The fill in the existing highway embankment was encountered in borings 1, 2, 3 and 5 put down on the shoulder of the road. The fill consists of brown sandy gravel with boulders, identical to the underlying gravel layer. The embankment is wedge-shaped, the fill averaging about 8 feet in thickness along the left shoulder

Fill (continued)

and 2 or 3 feet along the right shoulder.

The fill is estimated to be compact in relative density. For computations purposes, the wet unit weight and the angle of internal friction were taken as 130 pounds per cubic foot and 30 degrees, respectively.

Compact Upper Gravel Layer

A stratum of very coarse sandy gravel containing abundant rounded and angular boulders underlies the topsoil or the embankment fill over most of the site. On land, the layer was absent only in boreholes 10 and 11 and at these locations it may have been excavated for drainage purposes. In boring 12, the stratum underlies the peat layer. The layer slopes down from the high rock hill thickening somewhat towards the lake. Offshore it slopes beneath more recent fine to medium sands and eventually pinches out so that it was not encountered in borehole 14. Northward, up the hill from the highway, the layer thickens and probably merges with the lower gravel layer. The stratum varied from 5 to 15.5 feet in thickness in the boreholes in which it was encountered.

The location, shape and composition of the layer suggests that it consists of talus material which has been somewhat reworked by water action. The pebbles and boulders consist chiefly of granite with diorite. The sand, distributed throughout the stratum, is generally medium to coarse grained and very angular.

Compact Upper Gravel Layer (continued)

Standard penetration resistance or "N" values varying from 20 to 32 and averaging 23 blows per foot were obtained in the sandier portions of the stratum. Generally the cobbles and large pebbles were so closely spaced that representative values were difficult to obtain. The average "N" values of 23 which is considered to be representative indicates that the stratum is compact in relative density.

For computation purposes, the following properties were taken for the stratum.

Wet unit weight	130 pounds per cubic foot
Saturated unit weight	135 " " " "
Submerged unit weight	73 " " " "
Angle of Internal Friction	30 degrees

Loose to Compact Grey Fine to Medium Sand

A stratum of very angular, grey, gravelly, fine to medium sand occurs at lake bottom in most of the offshore boreholes. It is bouldery in the upper one or two feet near shore, and grades into the upper gravel stratum approximately along the shoreline. The layer is wedge-shaped, thickening from zero to over 26 feet offshore in borehole 14. In holes 14 through 18 inclusive, this stratum overlies the varved clay. In borehole 13, it is separated from the varved clay by about 6 feet of the upper gravel stratum.

Standard penetration resistance or "N" values varying from 5 to 27 and averaging 12 blows per foot were obtained in the stratum. On the basis of these values and the dynamic penetration tests, the stratum is considered to be loose to compact in relative density.

Loose to Compact Grey Fine to Medium Sand (continued)

For computations purposes the layer was assumed to have a saturated unit weight of 130 pounds per cubic foot and an angle of internal friction of 30 degrees.

Soft to Stiff Reddish-Grey Varved Clay

A stratum of varved clay was encountered directly beneath the upper gravel stratum in all holes except 10, 11, 14, 15, 16, 17 and 18. In borings 10 and 11, the varved clay occurs at surface beneath 6 to 8 inches of topsoil. In the other holes the gravel stratum is absent and the clay underlies the more recent gravelly fine to medium sand stratum.

The stratum of varved clay slopes down the hillside at an angle averaging about 20 degrees. It is wedge shaped, increasing in thickness from about 1.5 feet, a few feet north of the right shoulder of the road, to a maximum of about 28 feet, 100 feet offshore in borehole 14.

The individual varves show a great deal of variation. The clay layers are reddish brown and the silt layers are light grey. Where they are well developed, the clay layers vary from 1/4 to 3/4 inches in thickness and the silt layers vary from 1/8 to 1/4 inches. Several of the Shelby tubes were oriented in order to determine the bedding of the varves. It was found that as a general rule the individual varves slope down towards the lake at an angle of approximately 20 degrees.

Where the stratum was thinnest up near the right shoulder of the road, the varves were poorly developed but the clay was distinctly laminated.

Soft to Stiff Reddish-Grey Varved Clay (continued)

Beneath the toe of the slope at water's edge, the clay showed evidence of previous sliding. The top of the clay dropped suddenly downwards between boreholes 7 and 8A and the clay samples showed slip planes along which silt had been smeared. In these slide areas the varves seemed to be randomly oriented. Large lumps of varved clay were noticed beneath the boulders at irregular intervals along the shoreline. These lumps apparently represent old slumps which occurred before or during deposition of the upper gravel stratum. In the western part of the site the clay comes very close to surface along the shoreline as shown by borehole 17 and penetration test 18.

Extensive laboratory testing was conducted on samples of the varved clay. Undrained triaxial compression tests were performed on samples from every borehole to obtain a strength versus depth relationship. In situ vane shear strength determinations were run in the field. The results of the strength tests are given on the Office Reports on Soil Exploration and on the Figures in Appendix II.

The 18 unconsolidated undrained compressive strengths obtained on samples of the clay varied from 0.32 to 5.3 tons per square foot. Two high values of 1.4 and 5.2 tons per square foot obtained on very silty material from boring 4 are considered to be non-representative and are excluded. An adjusted average value of 0.71 tons per square foot was thus obtained. The stratum is, therefore, soft to stiff and generally firm in consistency.

Typical stress strain curves for the clay are given on Figure 1 in Appendix II. In-situ vane shear strengths were obtained in many of the borings. The results of vane tests in borehole 17 are plotted versus depth on Figure 2 and this is considered to be typical. This

Soft to Stiff Reddish-Grey Varved Clay (continued)

figure shows that generally there is definite increase in strength with depth. However, this figure and the borehole logs also show that in any one borehole, the strength versus depth relationship may differ from this or even be the reverse as is the case in borehole 14. In borehole 8A, the strength increases with depth then falls off greatly at the bottom of the stratum. This trend is also shown in borehole 7 by the unconsolidated undrained triaxial tests shown on the Office Report for this hole.

Five consolidated undrained triaxial tests with pore pressure measurements were run on samples of the varved clay. All samples were selected so that the layers sloped at about 20 degrees in the test specimen. All samples failed through the clay layers. The resulting effective stress circles are plotted on Figure 7. The average effective stress shear strength parameters selected are as follows:

cohesion intercept	$C' = 200$ psf
angle of shearing resistance	$\phi' = 20$ degrees

Based on experience, it is known that for a plasticity index of 55, ϕ_d should be in the vicinity of 21 degrees. This checks well with the measured ϕ' . The plasticity index of 55 was the highest obtained in the stratum.

Two consolidation tests were performed on the clay. The consolidation curves are given on Figures 5 and 6. Both of these curves show that the clay is overconsolidated; one to 2.9 tsf and the other to 4.3 tsf. The two compression index values are 1.05 and 1.37. The shape of the curves indicate that the clay is sensitive. The sensitivity is estimated to be about 6 to 8.

Soft to Stiff Reddish-Grey Varved Clay (continued)

Wet unit weights obtained on samples of the clay varied from 100 to 122 pounds per cubic foot. A weighted average of 105 pounds per cubic foot is considered representative of the stratum. The natural moisture contents varied from 25 to 66 percent. An average moisture content of 46 percent is considered representative.

Atterberg limits conducted on typical clay gave average liquid and plastic limits of 78 and 28 respectively. Three unrepresentative silty samples gave average liquid and plastic limits of 31 and 23 respectively. A plasticity index of 51 is considered representative of the stratum. The highest plasticity index obtained was 55.

Limits were also run in the individual clay and clayey silt laminae of sample 7, borehole 12. The natural moisture content, liquid limit and plastic limits for the clay laminae were 67, 80, and 29 respectively. In the silt laminae they were 39, 40 and 21 respectively.

Dense Lower Gravel Stratum

A stratum of silty to sandy gravel with boulders underlies the varved clay stratum in all boreholes. This stratum is very similar to the upper gravel stratum and probably joins with it up the slope where the clay pinches out. The borings penetrated the stratum for distances varying from 1 to 15 feet with only borehole 9 passing through it. In borehole 9, the thickness was approximately 14 feet.

Dense Lower Gravel Stratum (continued)

The composition of this stratum is very similar to the upper gravel layer except that it contains more fine sand and grey silt with occasional clayey zones. In a few of the disturbed samples the material was identified as till and in others as poorly sorted sandy gravel. In borehole 12, a 3 foot thick layer of dense grey silty fine sand formed the upper part of this stratum. It is considered that the stratum consists of a heterogeneous mixture of talus, fluvial sand and gravel, and glacial till.

Artesian water was encountered in this stratum in all borings which penetrated it. Very pronounced differences in the rate of artesian flow water were found to be due to permeability differences rather than water pressure difference.

Standard penetration resistance or "N" values obtained in the stratum varied from 21 to greater than 100 blows per foot indicating that the material is compact to very dense. An adjusted average value of 47 blows per foot indicates that the stratum is generally dense.

For computation purposes the stratum was assumed to have a saturated unit weight of 135 pounds per cubic foot and an angle of internal friction of 35 degrees.

Granite Bedrock

In borehole 9, seven feet of very hard red granite drill core was obtained. This material is identical to granite outcrops 100 feet away and is considered to be bedrock. It is possible, however, in view of 10 to 20 foot diameter boulders seen up the slope, that this is a large boulder.

WATER CONDITIONS

X.

The elevation of Lake Superior at the time of the investigation was 602. However, artesian pressure was invariably encountered on penetrating the varved clay stratum and the head was observed to range from 6 feet at borehole 15 to 20 feet at borehole 20. These differences in head are believed to be due to permeability variations within the lower gravel stratum. The artesian pressure in the spring will probably be higher than that observed during the investigation and a piezometric water level of 625 was used for stability calculations.

EXPLANATION OF THE FORM "OFFICE REPORT ON SOIL EXPLORATION"

The object of this form is to enable a comprehensive study of the soil to be made by combining on one sheet all of the information obtained from the boring. An explanation of the various columns of the report follows.

ELEVATION AND DEPTH

This column gives the elevation and depth of boundaries between the various soil strata. The elevation is referred to the datum shown in the general heading.

WATER CONDITIONS

In this column the water level in the casing at the time of boring or the water table in the ground, determined by a series of observations in a piezometer or standpipe, is indicated to scale by a horizontal line with the symbol W.L. or W.T. above the line. A notation of any complicated groundwater conditions will be made in this column.

DESCRIPTION

A description of the soil, using standard terminology, is contained in this column. The consistency of cohesive soils and the relative density of non-cohesive soils are described by the following terms:

<u>Consistency</u>	<u>U-Strength Tons/sq. ft.</u>	<u>Relative Density</u>	<u>Standard Penetration Resistance, Blows/ft.</u>
Very soft	0.03 to 0.25	Very loose	0 to 4
Soft	0.25 to 0.5	Loose	4 to 10
Firm	0.5 to 1.0	Compact	10 to 30
Stiff	1.0 to 2.0	Dense	30 to 50
Very stiff	2.0 to 4.0	Very dense	over 50
Hard	over 4.0		

STRATIGRAPHIC PLOT

The stratigraphic plot follows the standard symbols of the National Research Council, Canada.

ELEVATION SCALE

The information in all columns is plotted to a true elevation scale which is shown in this column.

GRAPHS

The main body of the report forms a graph which is used to plot to correct elevation the important soil properties which are obtained through field and laboratory tests. The scales and symbols for the plotting are shown at the head of the column.

OTHER TESTS

In this column are shown, by symbol, the other field or laboratory tests which have been performed on the soil and for which the results have not been plotted on the above graph.

SAMPLES

The first three columns describe the condition, type and number of each sample obtained from the boring. The location and extent of each sample is plotted to scale.

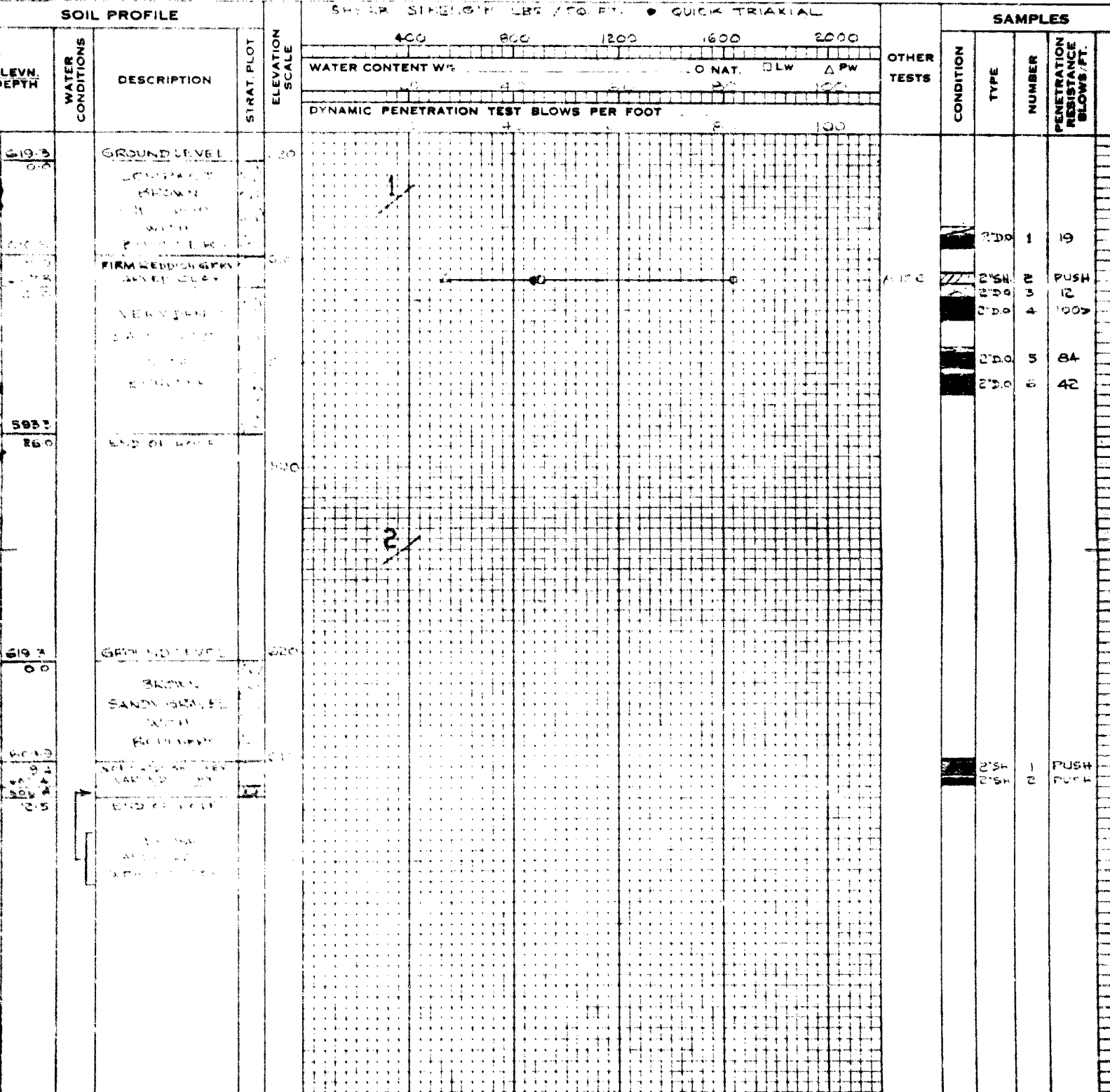
In the last column is shown the penetration resistance in blows of 4200 inch-pounds required to drive one foot of the sampler into the ground. When a 2 inch Drive Sampler is used the result obtained is termed the "Standard Penetration Resistance".

GEOCON

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT NO. 100-100 BORING NO. 1 #2 DATUM 100' 0" 0" CASING 84
 BORING DATE 10/1/60 REPORT DATE 10/1/60 COMPILED BY F. H. CHECKED BY F. H.
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS. ENERGY)


SAMPLE CONDITION		SAMPLE TYPES			ABBREVIATIONS	
	DISTURBED	AS AUGER SAMPLE	FS FOIL SAMPLE	V IN-SITU VANE TEST	γ WET UNIT WEIGHT	
	FAIR	ST SLOTTED TUBE	SO SLEEVE-OPEN	M MECHANICAL ANALYSIS	K PERMEABILITY	
	GOOD	WS WASHED SAMPLE	SF SLEEVE-FOOT VALVE	U UNCONFINED COMPRESSION	C CONSOLIDATION	
	LOST	DO DRIVE-OPEN	TO THIN WALLED OPEN	QC TRIAXIAL CONSOLIDATED QUICK	WL WATER LEVEL IN CASING	
		DF DRIVE-FOOT VALVE	RC ROCK CORE	Q TRIAXIAL QUICK	WT WATER TABLE IN SOIL	
		CS CHUNK SAMPLE		S TRIAXIAL SLOW		



GEOCON

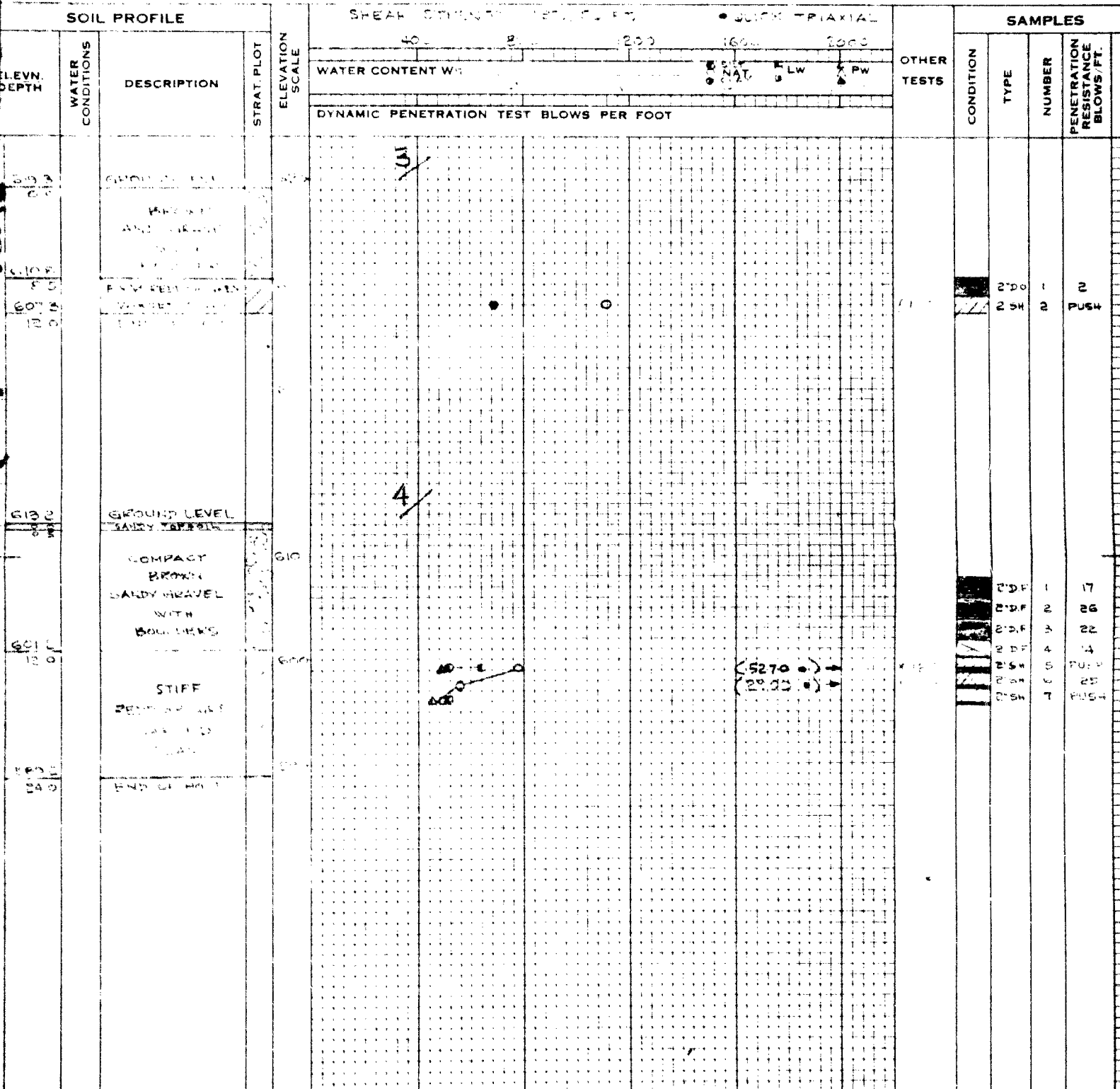
OFFICE REPORT ON SOIL EXPLORATION

CONTRACT NO. 100 BORING # 344 DATUM 1000.00 CASING 2X
 BORING DATE JULY 8, 1964 REPORT DATE JULY 15, 1964 COMPILED BY J. H. W. CHECKED BY J. H. W.
 SAMPLER HAMMER WT 140 LBS DROP 20 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS ENERGY)

SAMPLE CONDITION
 DISTURBED
 FAIR
 GOOD
 LOST

SAMPLE TYPES
 AS AUGER SAMPLE FS FOIL SAMPLE
 ST SLOTTED TUBE SO SLEEVE OPEN
 WS WASHED SAMPLE SI SLEEVE FOOT VALVE
 DO DRIVE OPEN TO THIN WALLED OPEN
 DF DRIVE-FOOT VALVE RC ROCK CORE
 CS CHUNK SAMPLE

ABBREVIATIONS
 V IN-SITU VANE TEST
 M MECHANICAL ANALYSIS
 U UNCONFINED COMPRESSION
 OC TRIAXIAL CONSOLIDATED QUICK
 Q TRIAXIAL QUICK
 S TRIAXIAL SLOW
 W WET UNIT WEIGHT
 K PERMEABILITY
 C CONSOLIDATION
 WL WATER LEVEL IN CASING
 WT WATER TABLE IN SOIL



OFFICE REPORT ON SOIL EXPLORATION

CONTRACT	52-100-1	BORING #	52-100-1	DATUM	FOOTING	CASING	52-100-1
BORING DATE	5-1-50	REPORT DATE	5-1-50	COMPILED BY	AS	CHECKED BY	5-1-50
SAMPLER HAMMER WT	40	LBS	DROP	30	INCHES	(PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS. ENERGY)	

SAMPLE CONDITION

<input type="checkbox"/>	DISTURBED
<input type="checkbox"/>	FAIR
<input type="checkbox"/>	GOOD
<input checked="" type="checkbox"/>	LOST

SAMPLE TYPES

AS	AUGER SAMPLE	FS	FOIL SAMPLE
ST	SLOTTED TUBE	SO	SLEEVE OPEN
WS	WASHED SAMPL	SF	SLEEVE FOOT VALVE
DO	DRIVE OPEN	TO	THIN WALLED OPEN
DF	DRIVE FOOT VALVE	RC	ROCK CORE
CS	CRUNK SAMPLE		

ABBREVIATIONS

V	IN-SITU VANE TEST	γ	WET UNIT WEIGHT
M	MECHANICAL ANALYSIS	K	PERMEABILITY
U	UNCONFINED COMPRESSION	C	CONSOLIDATION
QC	TRIAxIAL CONSOLIDATED QUICK		
Q	TRIAxIAL QUICK	WL	WATER LEVEL IN CASIN
S	TRIAxIAL SLOW	WT	WATER TABLE IN SOIL

SOIL PROFILE

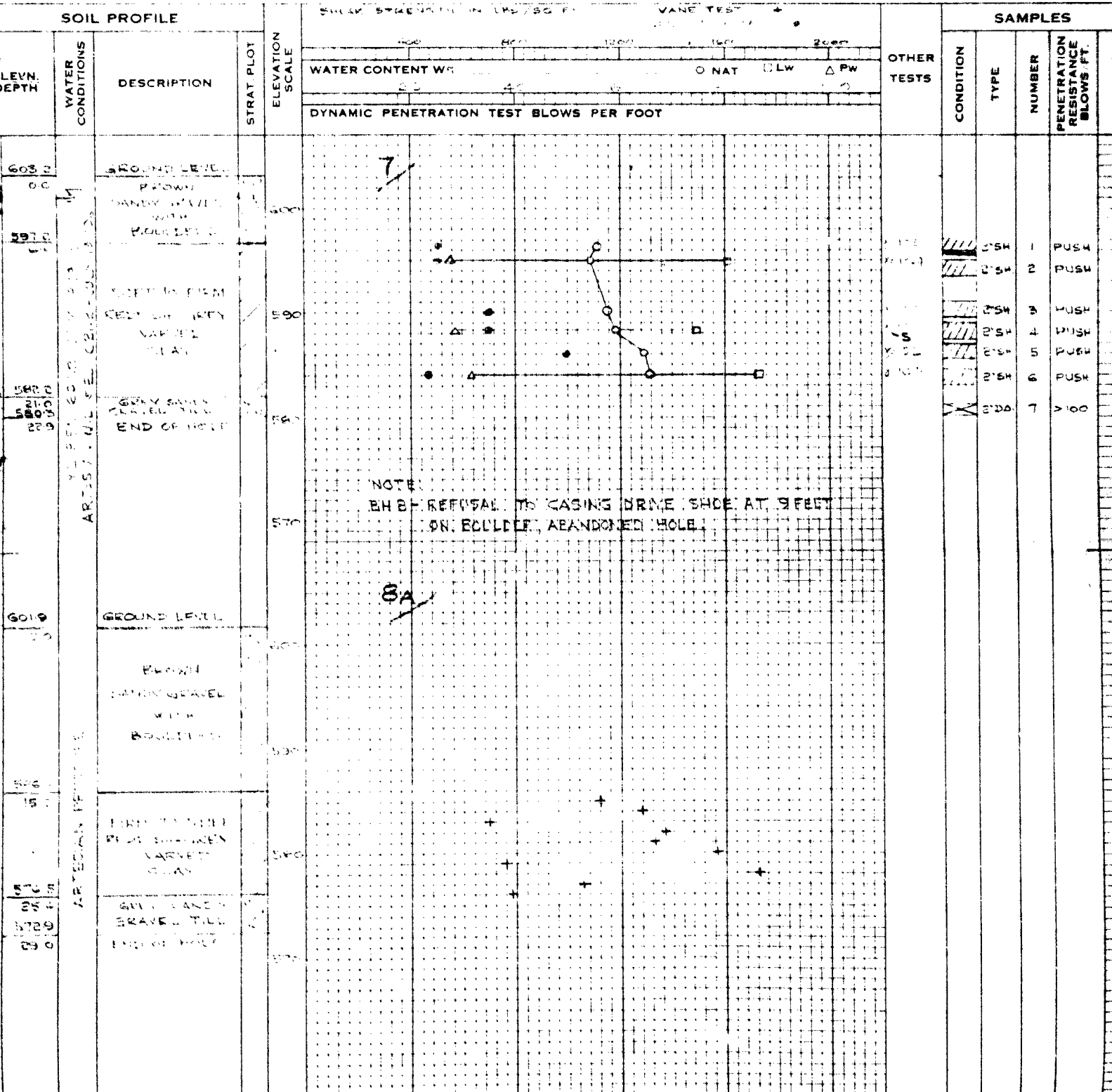
SOIL PROFILE									OTHER TESTS				SAMPLES			
ELEVATION DEPTH	WATER CONDITIONS	DESCRIPTION	STRAT. PLOT	ELEVATION SCALE	WATER CONTENT W _t				OTHER TESTS	CONDITION	TYPE	NUMBER	PENETRATION RESISTANCE BLOWS/FT.			
					O	NAT.	LW	Δ PW								
					DYNAMIC PENETRATION TEST BLOWS PER FOOT											
0.0		GROUND LEVEL			5											
0.5		CLAY														
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GEOCON

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT NO. 1000 BORING # 100A DATUM 1000 CASSING 3X
 BORING DATE 10/10/60 REPORT DATE 10/10/60 COMPILED BY 100A CHECKED BY 100A
 SAMPLER HAMMER WT 40 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS. ENERGY)

SAMPLE CONDITION		SAMPLE TYPES			ABBREVIATIONS	
	DISTURBED	AS AUGER SAMPLE	FS FOIL SAMPLE	V IN-SITU VANE TEST	γ WET UNIT WEIGHT	
	FAIR	ST SLOTTED TUBE	SO SLEEVE OPEN	M MECHANICAL ANALYSIS	K PERMEABILITY	
	GOOD	WS WASHED SAMPLE	SF SLEEVE FOOT VALVE	U UNCONFINED COMPRESSION	C CONSOLIDATION	
	LOST	DO DRIVE OPEN	TO THIN WALLED OPEN	QU TRIAXIAL CONSOLIDATED QUICK	WL WATER LEVEL IN CASING	
		DF DRIVE FOOT VALVE	RC ROCK CORE	Q TRIAXIAL QUICK	WT WATER TABLE IN SOIL	
		CS CHUCK SAMPLE		S TRIAXIAL SLOW		



OFFICE REPORT ON SOIL EXPLORATION

SAMPLE CONDITION

SAMPLE TYPES

ABBREVIATIONS

	DISTURBED
	FAIR
	GOOD
	LOST

AS AUGER SAMPLE
ST SLOTTED TUBE
WS WASHED SAMPLE
DO DRIVE OPEN
DF DRIVE FOOT VALVE
CS CHUNK SAMPLE

F.S. FOIL SAMPLE
S.O. SLEEVE-OPEN
S.F. SLEEVE-FOOT VALVE
T.O. THIN WALLED OPEN
R.C. ROCK CORE

V . IN SITU VANE TEST
M . MECHANICAL ANALYSIS
U . UNCONFINED COMPRESSION
QC . TRIAXIAL CONSOLIDATED QUICK
Q . TRIAXIAL QUICK
S . TRIAXIAL SLOW

7. WET UNIT WEIGHT
 K. PERMEABILITY
 C. CONSOLIDATION

WL - WATER LEVEL IN CASING
WT - WATER TABLE IN SOIL

SOIL PROFILE				SHEAR STRENGTH LBS./SQ. FT. • QUICK TRIAXIAL					OTHER TESTS	SAMPLES				
EVL. DEPTH	WATER CONDITIONS	DESCRIPTION	STRAT. PLT	ELEVATION SCALE	400 800 1200 1600 2000									
					WATER CONTENT W% NAT. LW Δ Pw									
					DYNAMIC PENETRATION TEST BLOWS PER FOOT									
610-1 0-1		GROUND LEVEL		570	9/									
614.2 4.2		LOOSE TO COMPACT BROWN GRAYLY SAND WITH BOUNDINGS		610	BROWN SANDY TO SOIL									
598.7 15.5		FIRM REDDISH-BROWN VARNISHED CLAY												
594.7 21.0		COMPACT GREY & BROWN GRAVELLY SAND WITH BOUNDINGS												
590.7 26.0		SOUND RED GRANITE BEDROCK OR LARGE BOULDER												
580.7 28.0		END OF HOLE												
612.3 0.3		GROUND LEVEL		610	10/									
609.3 3.0		SLATE BEDROCK TO 610.0 SOFT REDDISH GREY CLAY												
594.0 13.4		VERY DENSE GREY & BROWN GRAVELLY SAND		600										
		END OF HOLE												

OFFICE REPORT ON SOIL EXPLORATION

SAMPLE CONDITION

SAMPLE TYPES

ABBREVIATIONS

	DISTURBED
	FAIR
	GOOD
	LOST

A.S. AUGER SAMPLE
S.T. SLOTTED TUBE
W.S. WASHED SAMPLE
D.O. DRIVE-OPEN
D.F. DRIVE-FOOT VALVE
C.S. CHUNK SAMPLE

F.S. - FOIL SAMPLE
S.O. - SLEEVE-OPEN
S.F. - SLEEVE-FOOT VALVE
T.O. - THIN WALLED OPEN
R.C. - ROCK CORE

V - IN-SITU VANE TEST
M - MECHANICAL ANALYSIS
U - UNCONFINED COMPRESSION
QC - TRIAXIAL CONSOLIDATED QUICK
Q - TRIAXIAL QUICK
S - TRIAXIAL SLOW

- 7. WET UNIT WEIGHT
- 8. PERMEABILITY
- 9. CONSOLIDATION

WL - WATER LEVEL IN CASING
WT - WATER TABLE IN SOIL

SOIL PROFILE				SPECK STRENGTH LOG				WIDIC TRIAXIAL				SAMPLES			
ELEV. DEPTH	WATER CONDITIONS	DESCRIPTION	STRAT. PLOT	ELEVATION SCALE	WATER CONTENT W _c	SHRINKAGE S _w	LIQUID LIMIT LL	PLASTIC LIMIT PL	NAT. CLW	ΔPW	OTHER TESTS	CONDITION	TYPE	NUMBER	PENETRATION RESISTANCE BLOWS FT.
DYNAMIC PENETRATION TEST BLOWS PER FOOT															
605.7 0.0	ARTESIAN W.L. 570.7 - AUG. 12, 1960	GRASSY LAKE			12/										
602.2 5.5		BLACK TO BROWN MUD & MUD													
599.7 10.0		BOULDERS WITH LITTLE SAND													
582.7 23.0		SOFT TO FIRM REDDISH-GREY VARIED CLAY													
579.7 26.0		DENSE GREY SILTY FINE SAND													
570.7 35.0		DENSE TO VERY DENSE GREY SANDY GRAVEL WITH BOULDERS													
END OF HOLE															
601.9 0.0	ARTESIAN W.L. 570.7 - AUG. 12, 1960	LAKE LEVEL			13/										
598.4 3.5		WATER													
587.9 14.0		LOOSE TO COMPACT GREY GRAVELLY FINE TO MEDIUM SAND													
581.4 20.5		COMPACT GREY GRAVELLY COARSE SAND WITH BOULDERS													
563.4 38.5		SOFT TO FIRM REDDISH-GREY VARIED CLAY													
550.9 51.0		COMPACT TO DENSE SANDY GRAVEL WITH BOULDERS													
END OF HOLE															

GEOCON

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT S 7120 BORING # 14 DATUM GEODETIC CASING NX 4 BX
 BORING DATE AUG 6 1960 REPORT DATE AUGUST 30 60 COMPILED BY AT. CHECKED BY
 SAMPLER HAMMER WT. 140 LBS. DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS. ENERGY)

SAMPLE CONDITION

☐ DISTURBED
☐ FAIR
☐ GOOD
☐ LOST

SAMPLE TYPES

A.S. - AUGER SAMPLE
 S.T. - SLOTTED TUBE
 W.S. - WASHED SAMPLE
 D.O. - DRIVE-OPEN
 D.F. - DRIVE-FOOT VALVE
 C.S. - CHUNK SAMPLE
 F.S. - FOIL SAMPLE
 S.O. - SLEEVE-OPEN
 S.F. - SLEEVE-FOOT VALVE
 T.O. - THIN WALLED OPEN
 R.C. - ROCK CORE

ABBREVIATIONS

V - IN-SITU VANE TEST
 M - MECHANICAL ANALYSIS
 U - UNCONFINED COMPRESSION
 QC - TRIAXIAL CONSOLIDATED QUICK
 Q - TRIAXIAL QUICK
 S - TRIAXIAL SLOW
 γ - WET UNIT WEIGHT
 K - PERMEABILITY
 C - CONSOLIDATION
 WL - WATER LEVEL IN CASING
 WT - WATER TABLE IN SOIL

SOIL PROFILE

SHEAR STRENGTH IN LBS./SQ. FT.

VANE TEST +

400 600 1200 1600 2000

WATER CONTENT W% O NAT. PLW Δ Pw

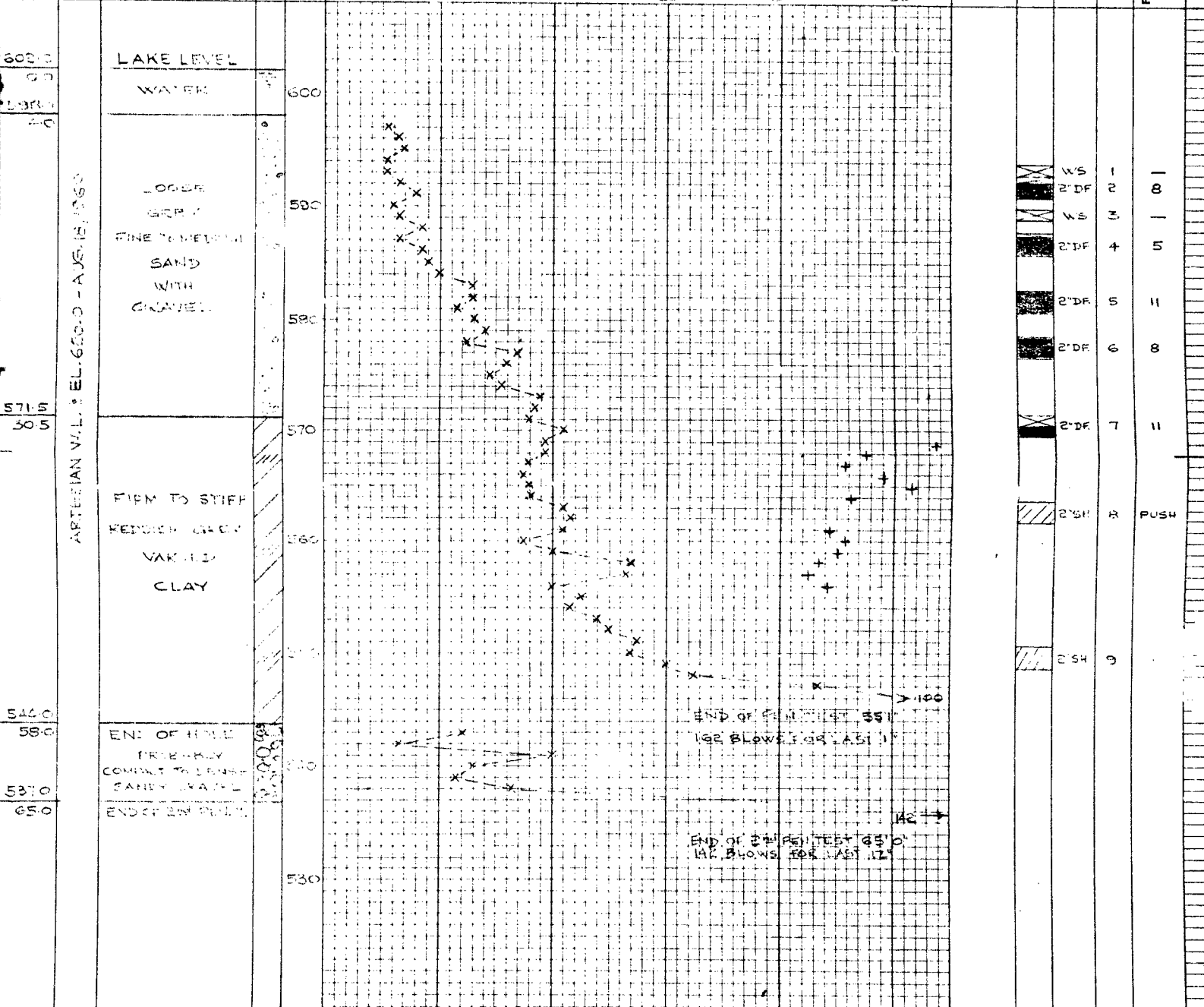
DYNAMIC PENETRATION TEST BLOWS PER FOOT X X X

20 40 60 80 100

OTHER TESTS

SAMPLES

CONDITION TYPE NUMBER PENETRATION RESISTANCE BLOWS/FT.



GEOCON

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT 57120 BORING # 15 & PEN TEST 15 DATUM GLOUCESTER CASING INK & BK
 BORING DATE AUG 22 60 REPORT DATE AUG 23 60 COMPILED BY AT CHECKED BY J. L.
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS ENERGY)

SAMPLE CONDITION



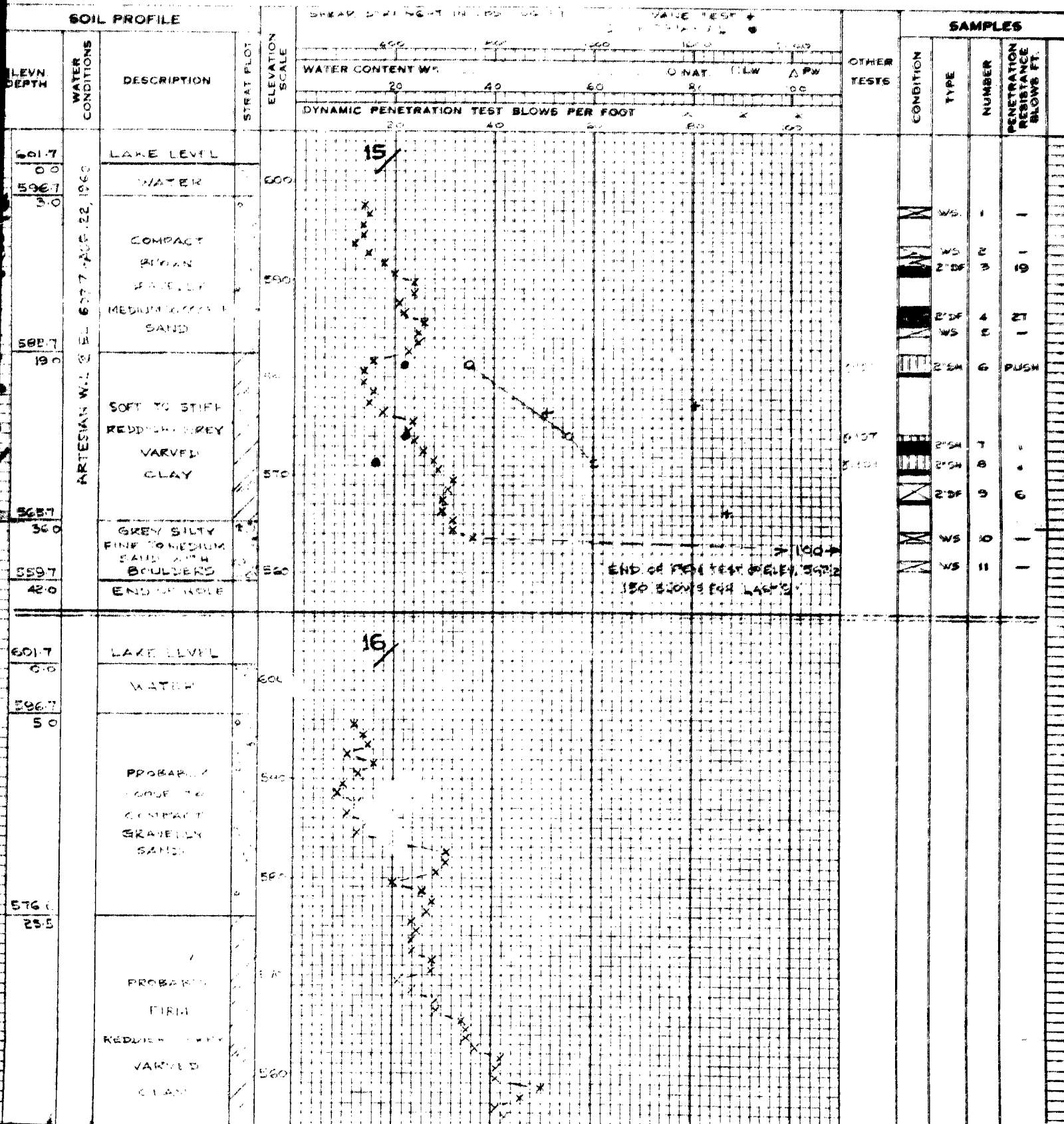
A.S. AUGER SAMPLE
 S.T. SLOTTED TUBE
 W.S. WASHED SAMPLE
 D.O. DRIVE OPEN
 D.F. DRIVE FOOT VALVE
 C.S. CHUNK SAMPLE

SAMPLE TYPES

S.S. FOIL SAMPLE
 S.O. SLEEVE OPEN
 S.F. SLEEVE FOOT VALVE
 T.O. THIN WALLED OPEN
 R.C. ROCK CORE

ABBREVIATIONS

V - IN-SITU VANE TEST
 M - MECHANICAL ANALYSIS
 U - UNCONFINED COMPRESSION
 Q.C. TRIAXIAL CONSOLIDATED QUICK
 Q - TRIAXIAL QUICK
 S - TRIAXIAL SLOW
 W - WET UNIT WEIGHT
 K - PERMEABILITY
 C - CONSOLIDATION
 WL - WATER LEVEL IN CASING
 WT - WATER TABLE IN SOIL



SAMPLE CONDITION



AS AUGER SAMPLE
ST SLOTTED TUBE
WS WASHED SAMPLE
DO DRIVE OPEN
DF DRIVE FOOT VALVE
CS CHUNK SAMPLE

SAMPLE TYPES

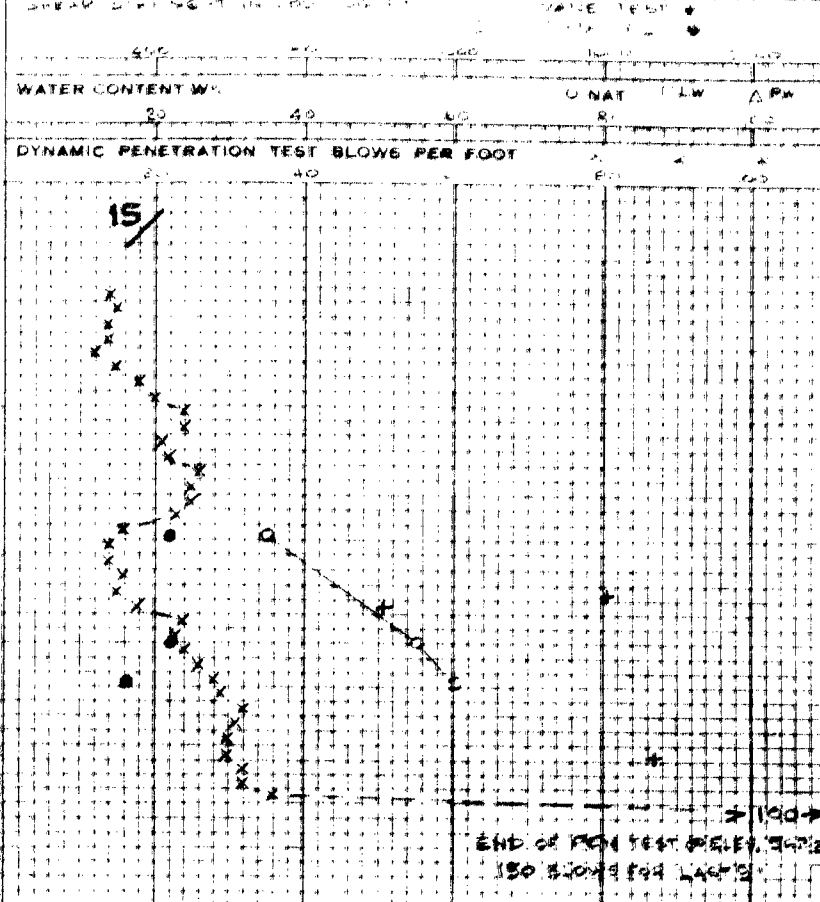
FS FOIL SAMPLE
SO SLEEVE OPEN
SF SLEEVE FOOT VALVE
TO THIN WALLED OPEN
RC ROCK CORE

ABBREVIATIONS

V - IN SITU VANE TEST
M - MECHANICAL ANALYSIS
U - UNCONFINED COMPRESSION
QU - TRIAXIAL CONSOLIDATED QUICK
Q - TRIAXIAL QUICK
S - TRIAXIAL SLOW
γ - UNIT WEIGHT
K - PERMEABILITY
C - CONSOLIDATION
WL - WATER LEVEL IN CASING
WY - WATER TABLE IN SOIL

SOIL PROFILE

LEVN DEPTH	WATER CONDITIONS	DESCRIPTION	STRAT PLOT	ELEVATION SCALE
501.7 0.0	ARTESIAN W.L. @ 500.7 AND 502.190	LAKE LEVEL		
506.7 5.0		WATER		600
		COMPACT BROWN FINELY MEDIAN GRAIN SAND		550
508.7 19.0		SOFT TO STIFF REDDISH GREY VARVED CLAY		500
508.7 36.0		GREY SILTY FINE TO MEDIUM SAND WITH BOULDERS		550
509.7 42.0		END OF HOLE		550



SAMPLES			
CONDITION	TYPE	NUMBER	PENETRATION RESISTANCE BLOWS FT.
WS	1	1	
WS	2	1	
2DF	3	19	
2DF	4	27	
WS	5	1	
2DF	6	PUSH	
WS	7	1	
2DF	8	1	
2DF	9	6	
WS	10	1	
WS	11	1	

501.7 0.0	ARTESIAN W.L. @ 500.7 AND 502.190	LAKE LEVEL		
506.7 5.0		WATER		600
		PROBABLY LOOSE TO COMPACT GRAVELLY SAND		550
576.1 28.5		PROBABLY FIRM REDDISH GREY VARVED CLAY		500
551.1 50.5		PROBABLY DENSE SANDY GRAVEL WITH BOULDER		550
548.0 53.4		END OF PEN. T.		550



SAMPLES			
CONDITION	TYPE	NUMBER	PENETRATION RESISTANCE BLOWS FT.
WS	1	1	
WS	2	1	
2DF	3	19	
2DF	4	27	
WS	5	1	
2DF	6	PUSH	
WS	7	1	
2DF	8	1	
2DF	9	6	
WS	10	1	
WS	11	1	

OFFICE REPORT ON SOIL EXPLORATION

ELEV. DEPTH	WATER CONDITIONS	DESCRIPTION	STRAT. PLOT	ELEVATION SCALE	WATER CONTENT W%			DYNAMIC PENETRATION TEST BLOWS PER FOOT			OTHER TESTS	CONDITION	TYPE	NUMBER	PENETRATION RESISTANCE BLOWS/FT.
					NAT	LW	PL	20	40	60					
601.6 599.9 598.0 596.1	ARTESIAN W.L. @ EL. 601.7 - AUG 27, 96	LAKE LEVEL		600											
592.1 590.2 588.3		WATER		590											
		BROWN FINE TO MEDIUM SAND		580											
		SOFT TO STIFF REDDISH-GRAY VARNED CLAY		570											
558.1 498.1 553.9 47.9		GREEN SANDY GRAVEL WITH BOULDERS END OF HOLE		550											
601.4 597.4 593.4 590		LAKE LEVEL		600											
		WATER		590											
		PROBABLY LOOSE MEDIUM SAND		580											
		PROBABLY SOFT TO STIFF REDDISH-GRAY VARNED CLAY		570											

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT S 7120 BORING # 17 & PEN. TEST 18 DATUM GEODETIC CASING NX # BX
 BORING DATE AUG 22 - 27, 60 REPORT DATE AUGUST 31, 60 COMPILED BY A T CHECKED BY F.H.
 SAMPLER HAMMER WT. 140 LBS. DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS. ENERGY)

SAMPLE CONDITION



A.S. - AUGER SAMPLE
 S.T. - SLOTTED TUBE
 W.S. - WASHED SAMPLE
 D.O. - DRIVE-OPEN
 D.F. - DRIVE-FOOT VALVE
 C.S. - CHUNK SAMPLE

SAMPLE TYPES

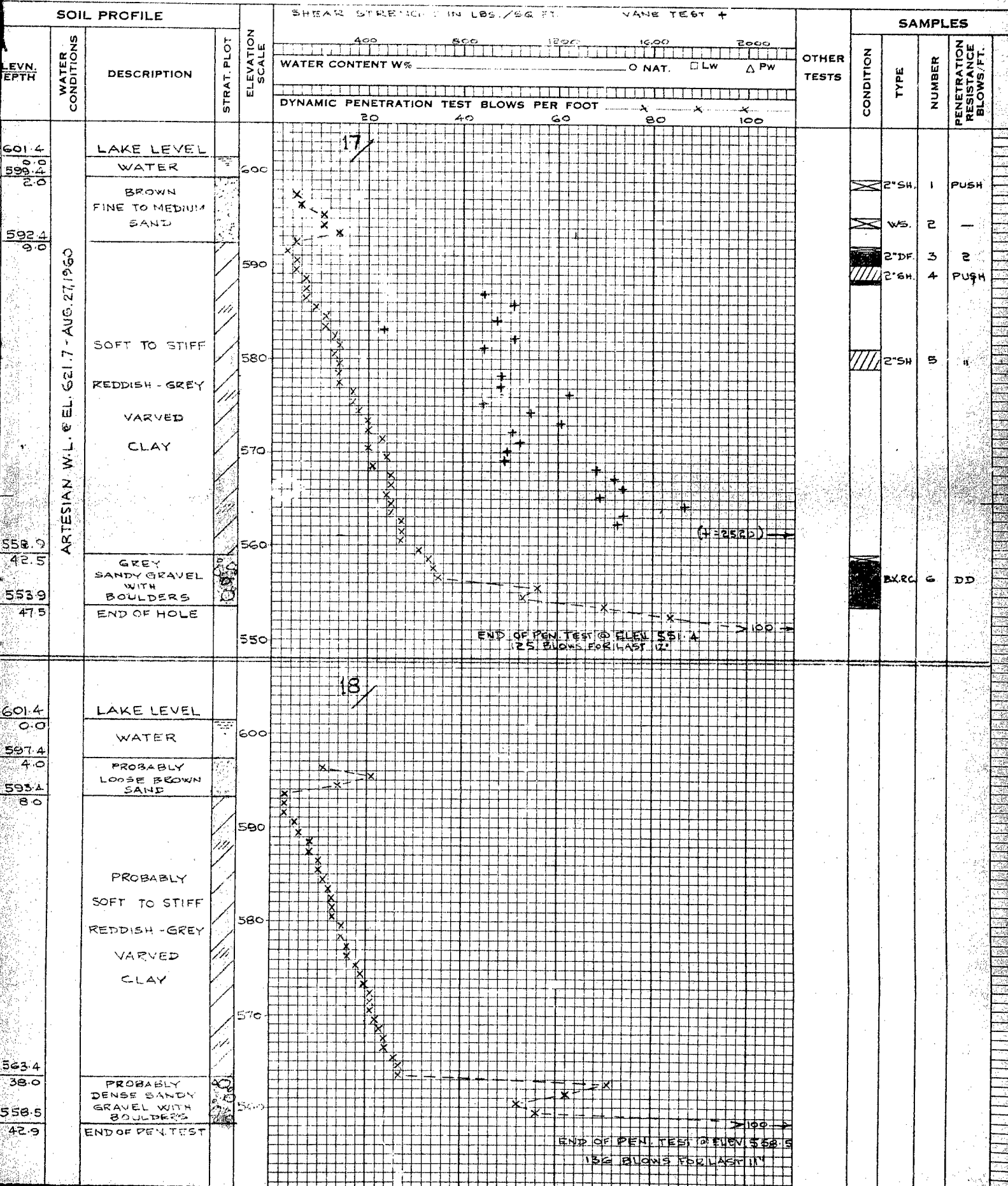
F.S. - FOIL SAMPLE
 S.O. - SLEEVE OPEN
 S.F. - SLEEVE-FOOT VALVE
 T.O. - THIN WALLED OPEN
 R.C. - ROCK CORE

ABBREVIATIONS

V - IN-SITU VANE TEST
 M - MECHANICAL ANALYSIS
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 K - PERMEABILITY
 C - CONSOLIDATION

WL - WATER LEVEL IN CASING
 WT - WATER TABLE IN SOIL



APPENDIX II

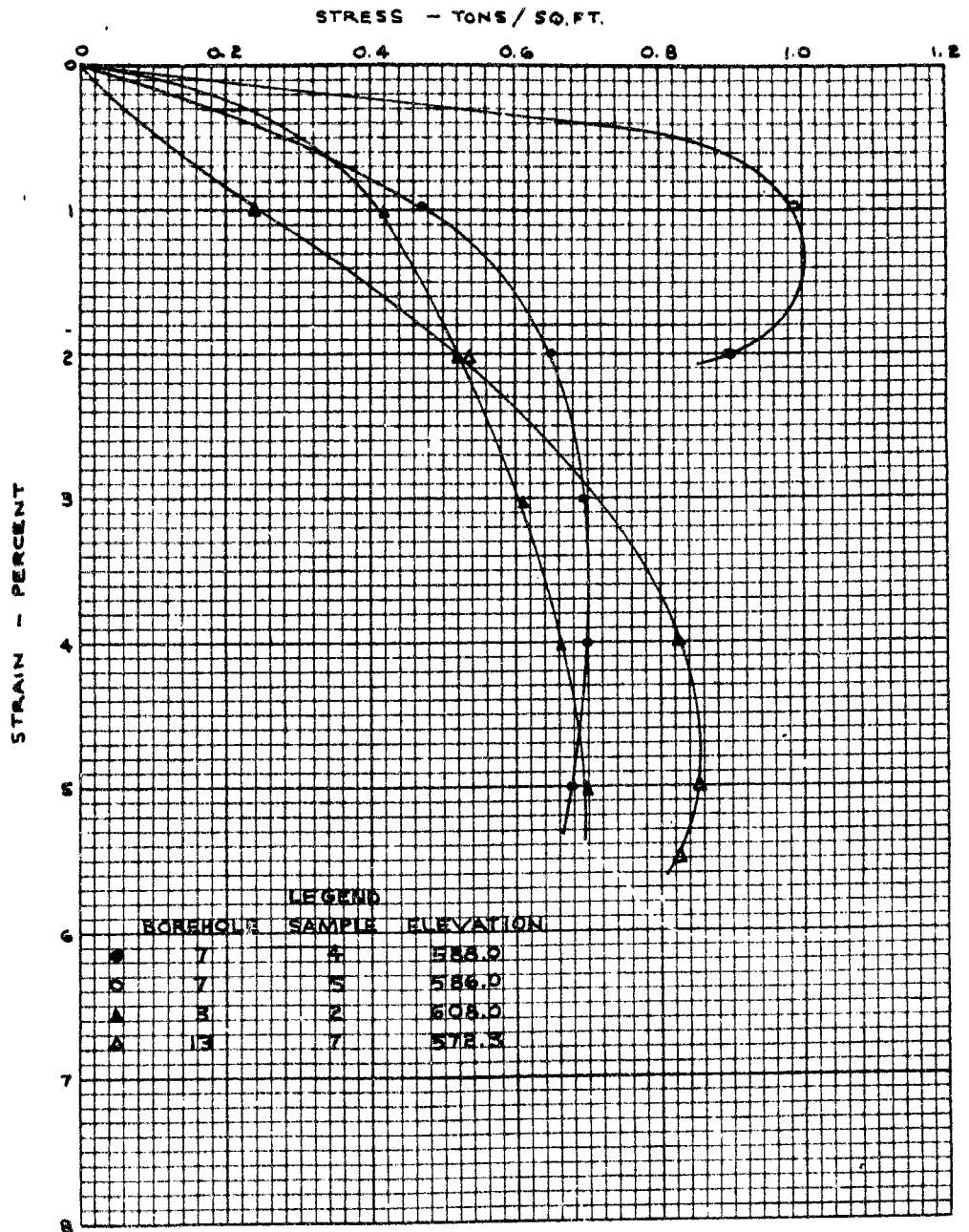
FIGURES - LABORATORY TESTING

GEOCON

QUICK TRIAXIAL TESTS

REPRESENTATIVE STRESS STRAIN CURVES

APPENDIX II
FIGURE I
PROJECT 57120



GEOCON

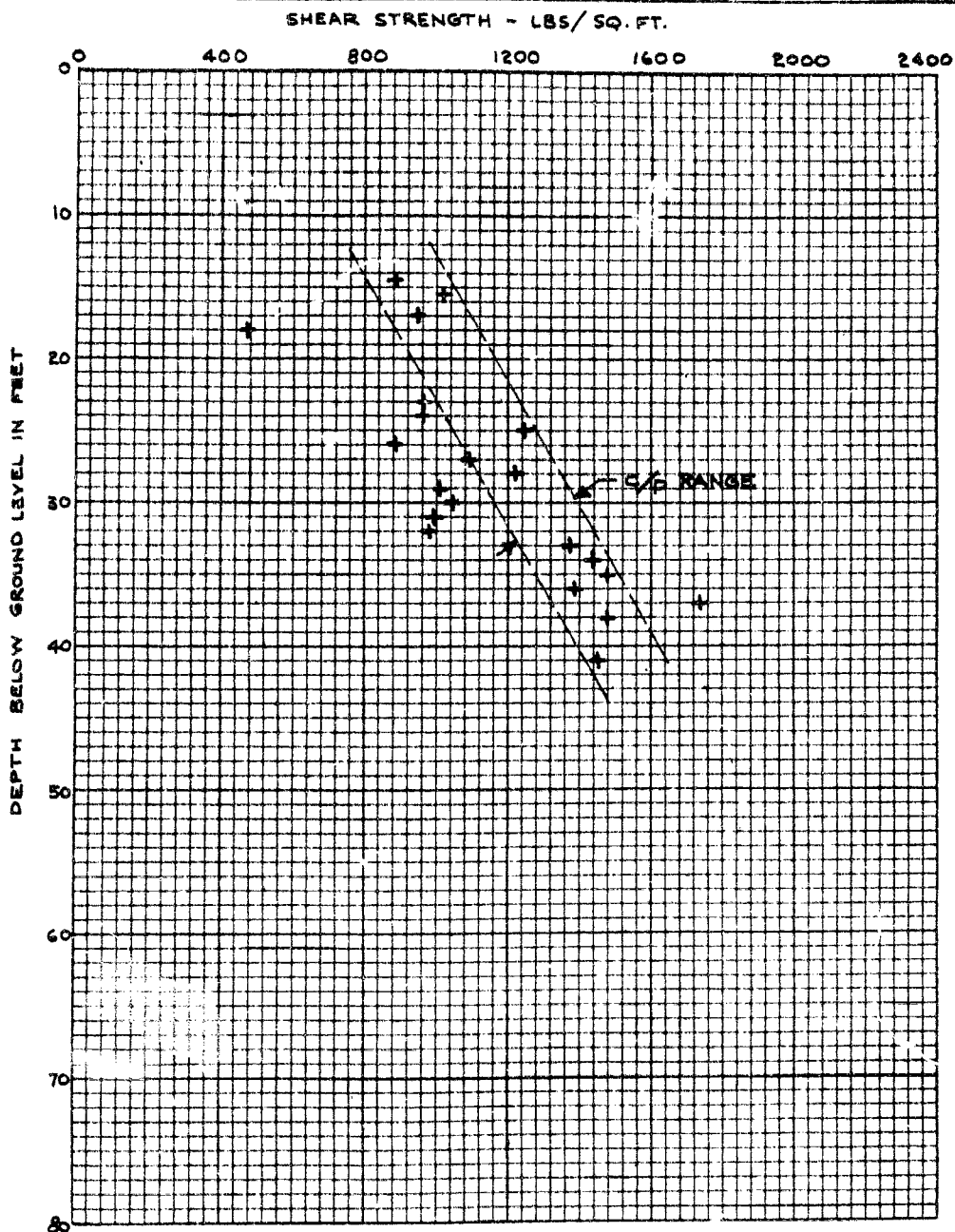
SHEAR STRENGTH VS DEPTH

TYPICAL VANE TEST RESULTS

APPENDIX II

FIGURE 2

PROJECT 57120

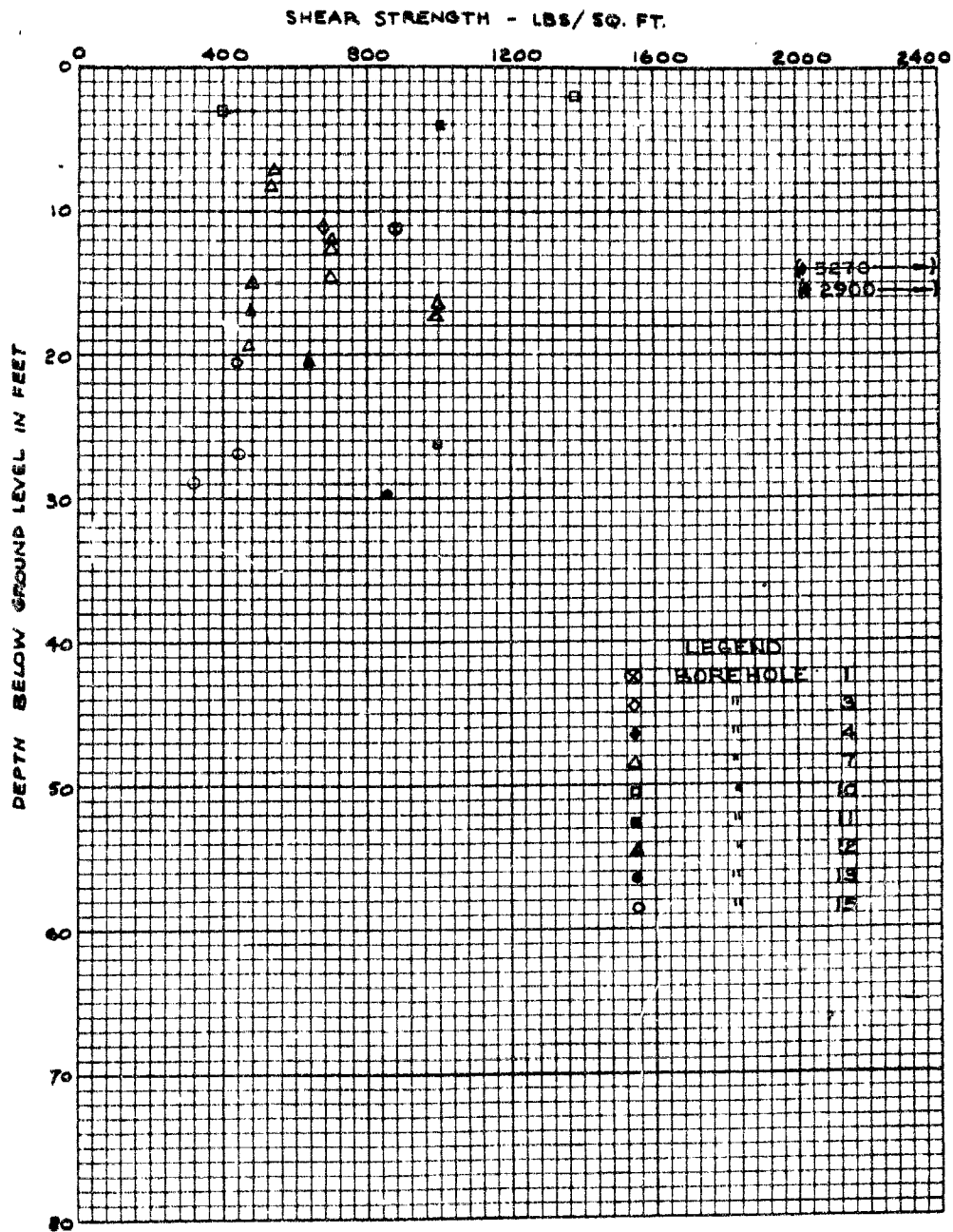


GEOCON

SHEAR STRENGTH VS DEPTH

QUICK TRIAXIAL TESTS

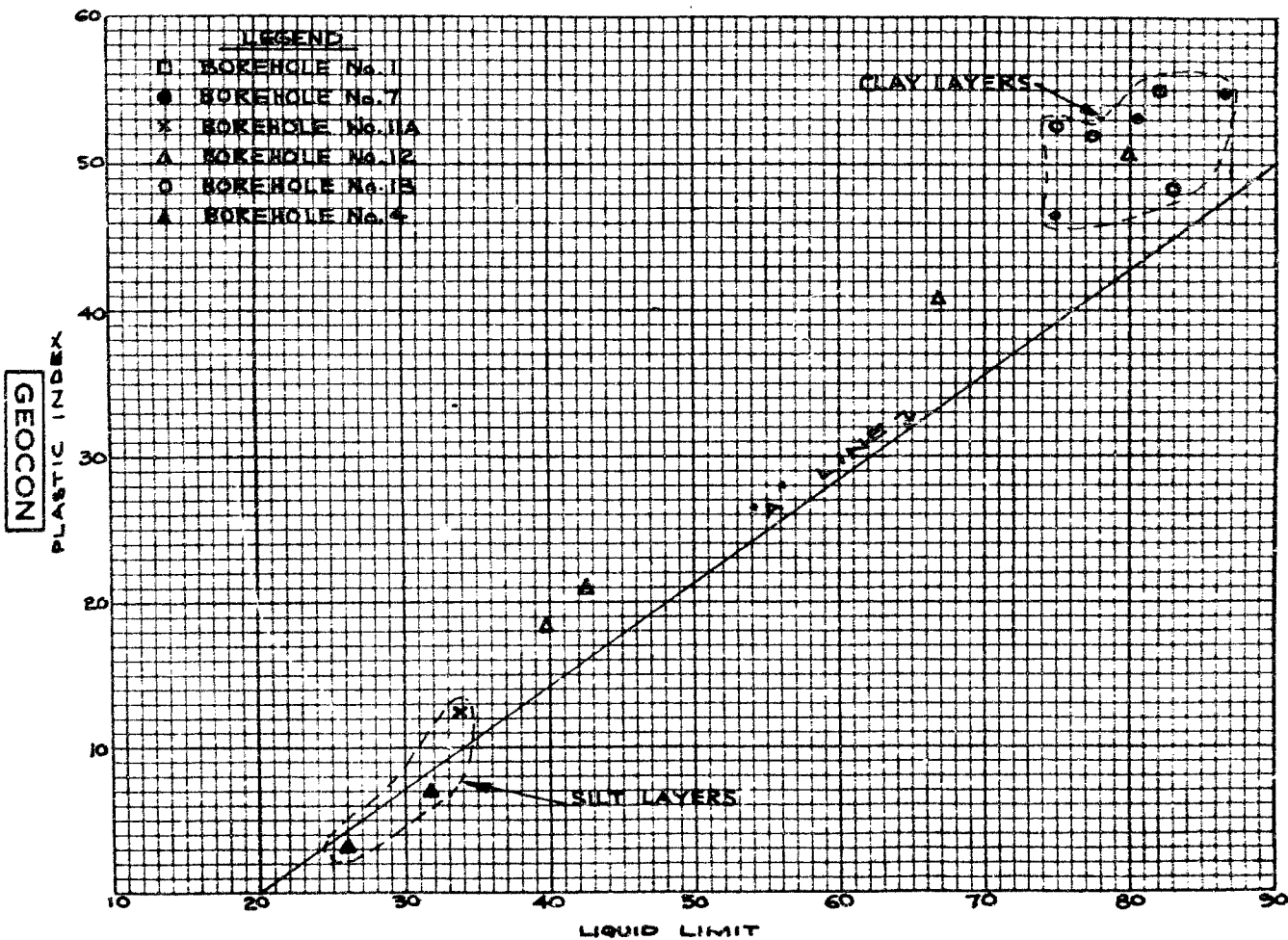
APPENDIX II
FIGURE 3
PROJECT 57120



GEOCON

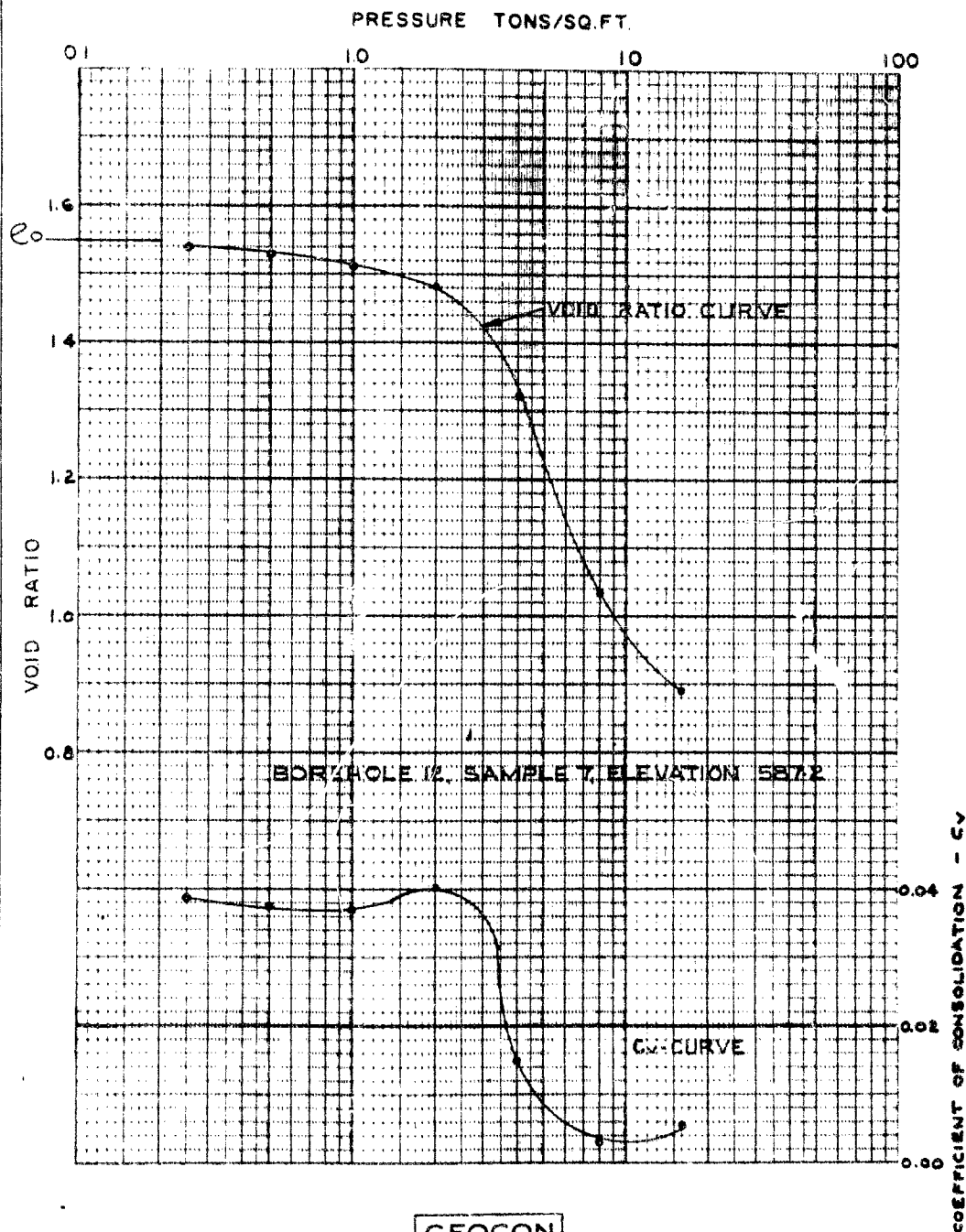
PLASTICITY CHART

APPENDIX II
FIGURE 4
PROJECT S7120



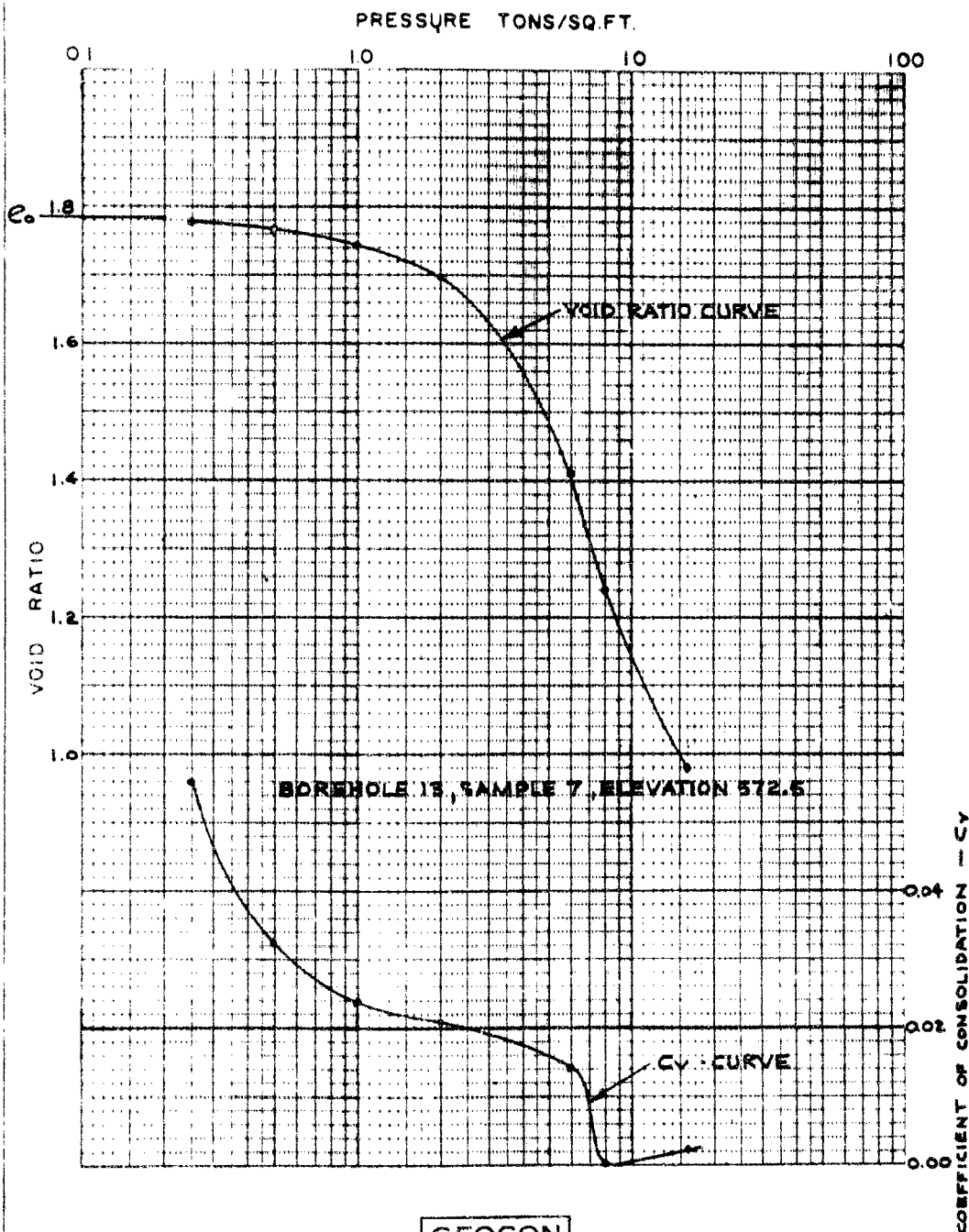
VOID RATIO-PRESSURE CURVES CONSOLIDATION TEST

APPENDIX II
FIGURE 5
PROJECT S7120



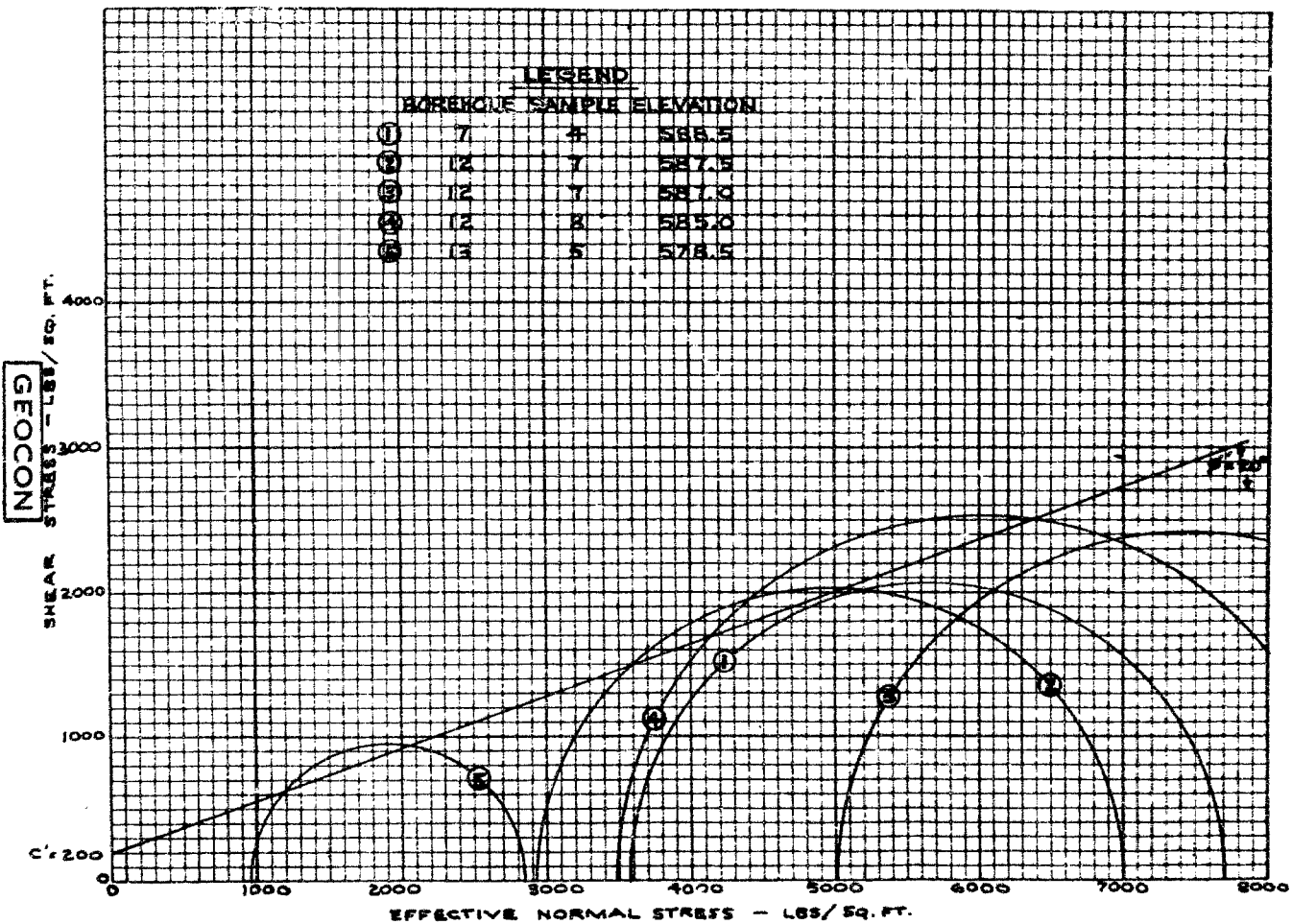
VOID RATIO-PRESSURE CURVES CONSOLIDATION TEST

APPENDIX II
FIGURE 6
PROJECT 57120



CONSOLIDATED UNDRAINED TRIAXIAL TESTS
WITH PORE PRESSURE MEASUREMENTS
MOHR'S CIRCLES

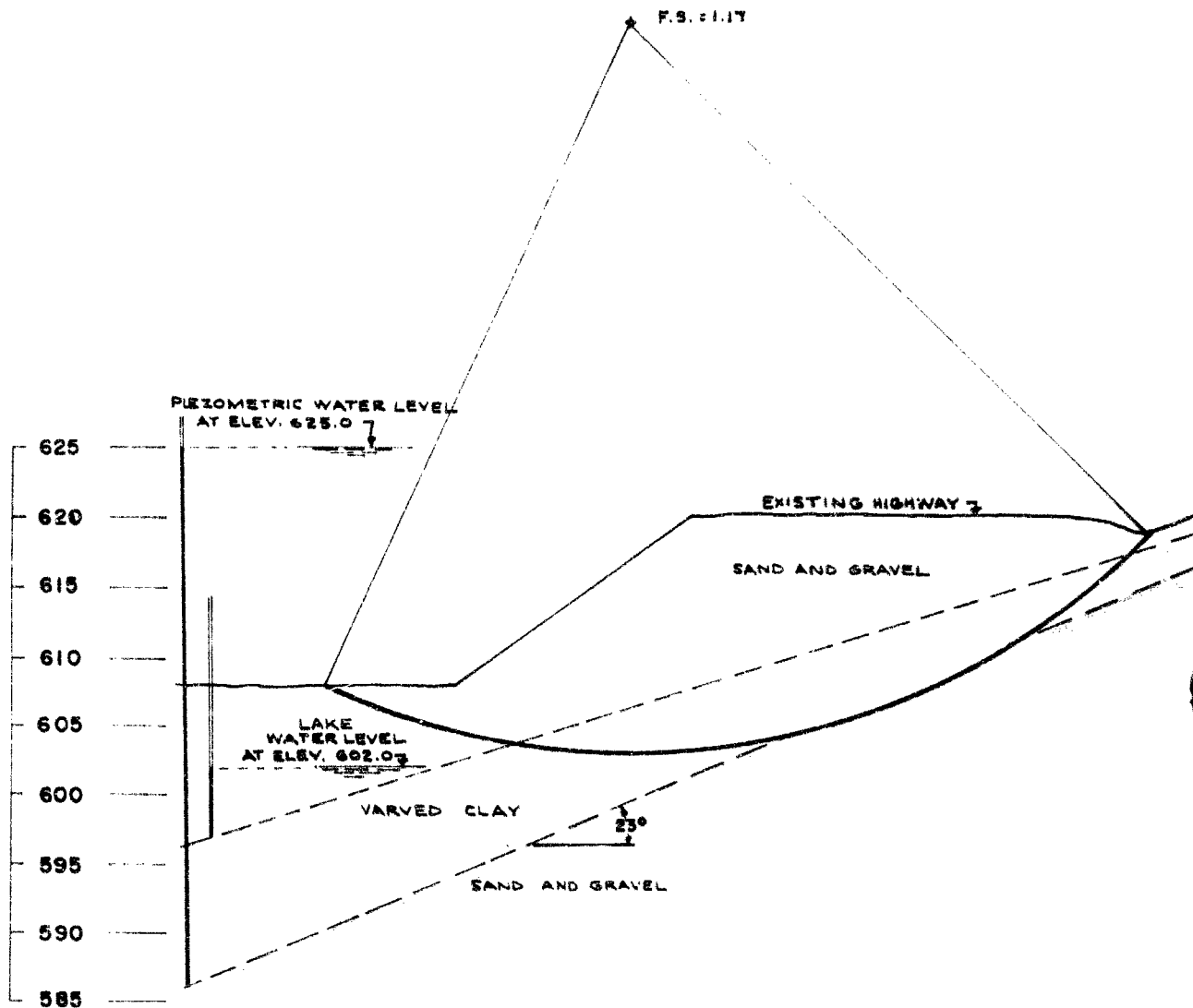
APPENDIX II
FIGURE 7
PROJECT 57120



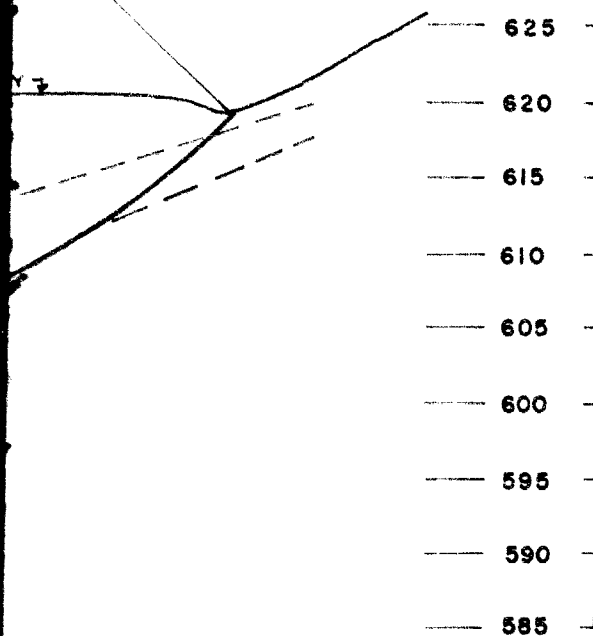
APPENDIX III

DRAWING S7120-3 ANALYSES OF RECENT FAILURES

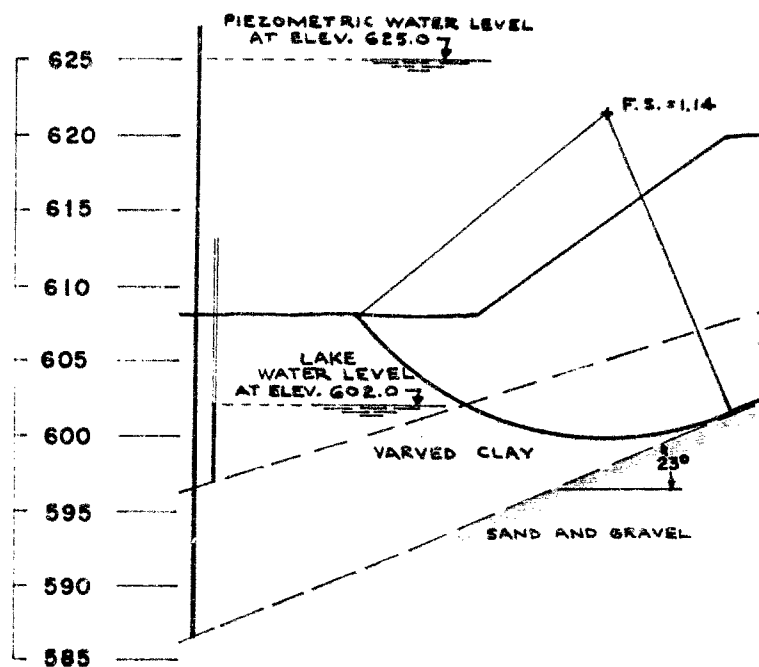
GEOCON



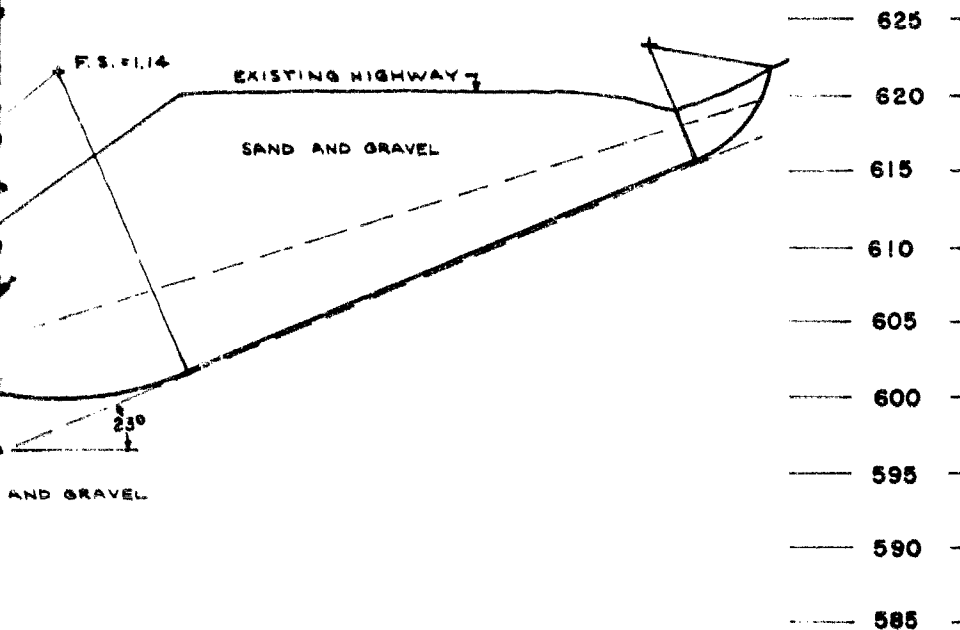
SECTION AT STATION 1916+75
CIRCULAR ARC ANALYSIS



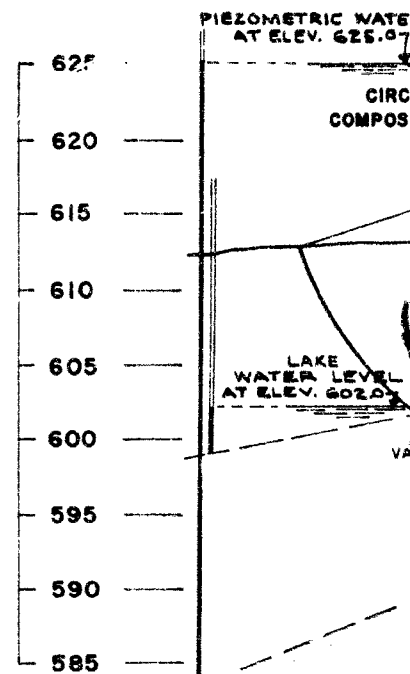
6+75



SECTION AT STA
COMPOSITE SURF



N AT STATION 1916+75
MPOSITE SURFACE ANALYSIS

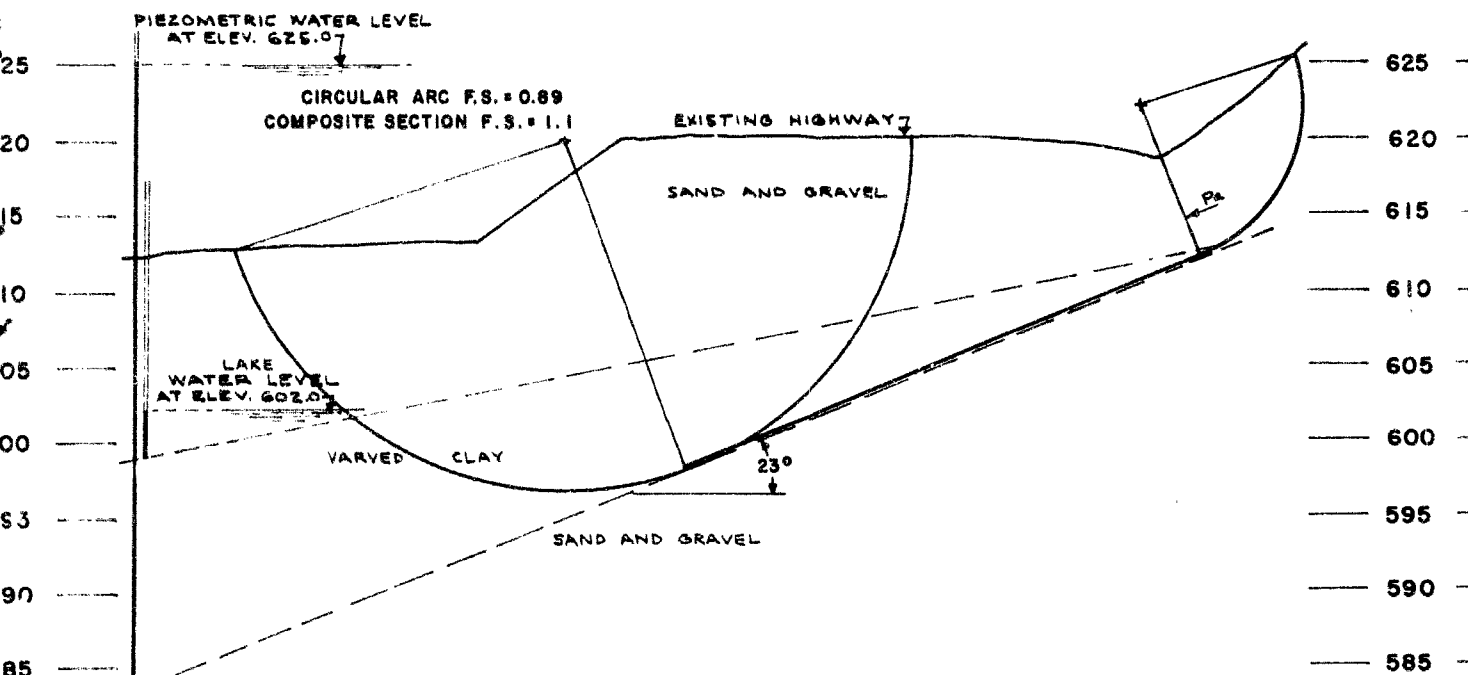


SE
CIRC

DESIGN VALUES

GRANULAR MATERIAL - - - - - $\gamma = 130 \text{ LBS/CU. FT.}$
 $\gamma' = 67 \text{ LBS/CU. FT.}$
 $C = 0$
 $\phi = 30^\circ$

VARVED CLAY ----- $\gamma = 105$ LBS./CU. FT.
 $\gamma' = 47$ LBS./CU. FT.
 $c' = 0$
 $\phi' = 20^\circ$



SECTION AT STATION 1910+55

CIRCULAR ARC AND COMPOSITE SURFACE ANALYSIS

DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO ONTARIO
PROPOSED AND EXISTING HIGHWAY 17
SAULT STE. MARIE ONTARIO
ANALYSES OF RECENT FAILURES

GEOC
DATE OCT. 21, 1978
MADE CHKD APP
M.W. F.H. 878

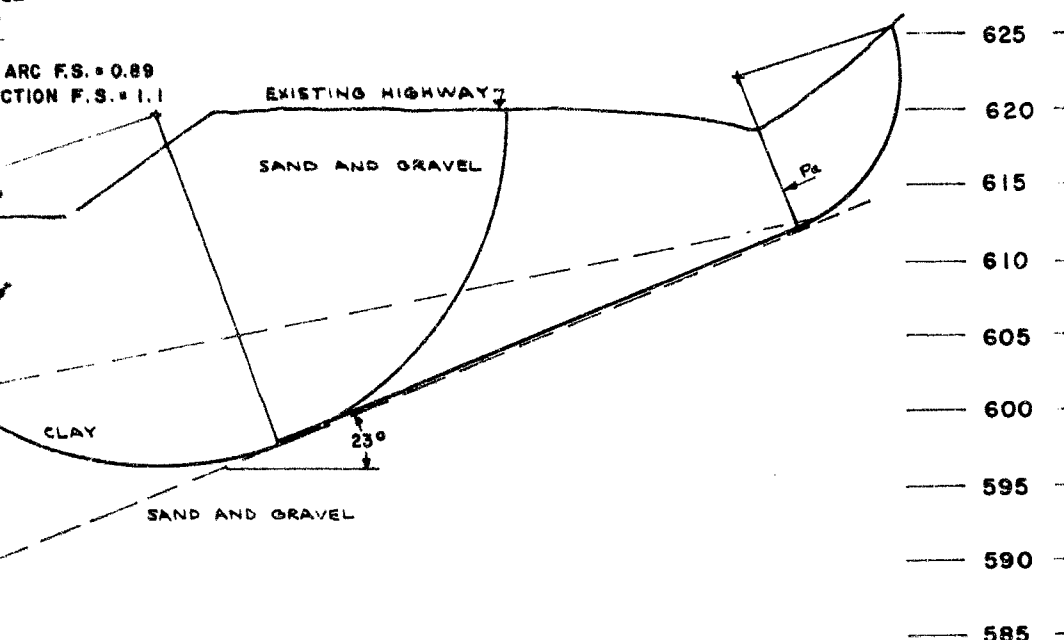
DESIGN VALUES

GRANULAR MATERIAL ----- $\gamma = 130$ LBS./CU. FT.
 $\gamma' = 67$ LBS./CU. FT.
 $c = 0$
 $\phi = 30^\circ$

VARVED CLAY ----- $\gamma = 105$ LBS./CU. FT.
 $\gamma' = 47$ LBS./CU. FT.
 $c' = 0$
 $\phi' = 20^\circ$

EL

ARC F.S. = 0.89
 CTION F.S. = 1.1



ION AT STATION 1910+55
 R ARC AND COMPOSITE SURFACE ANALYSIS

41K-38
 GEORES No.

DEPARTMENT OF HIGHWAYS, ONTARIO
 TORONTO
 PROPOSED AND EXISTING HIGHWAY 17
 SAULT STE. MARIE
 ONTARIO
 ANALYSES OF RECENT FAILURES

GEOCON LTD

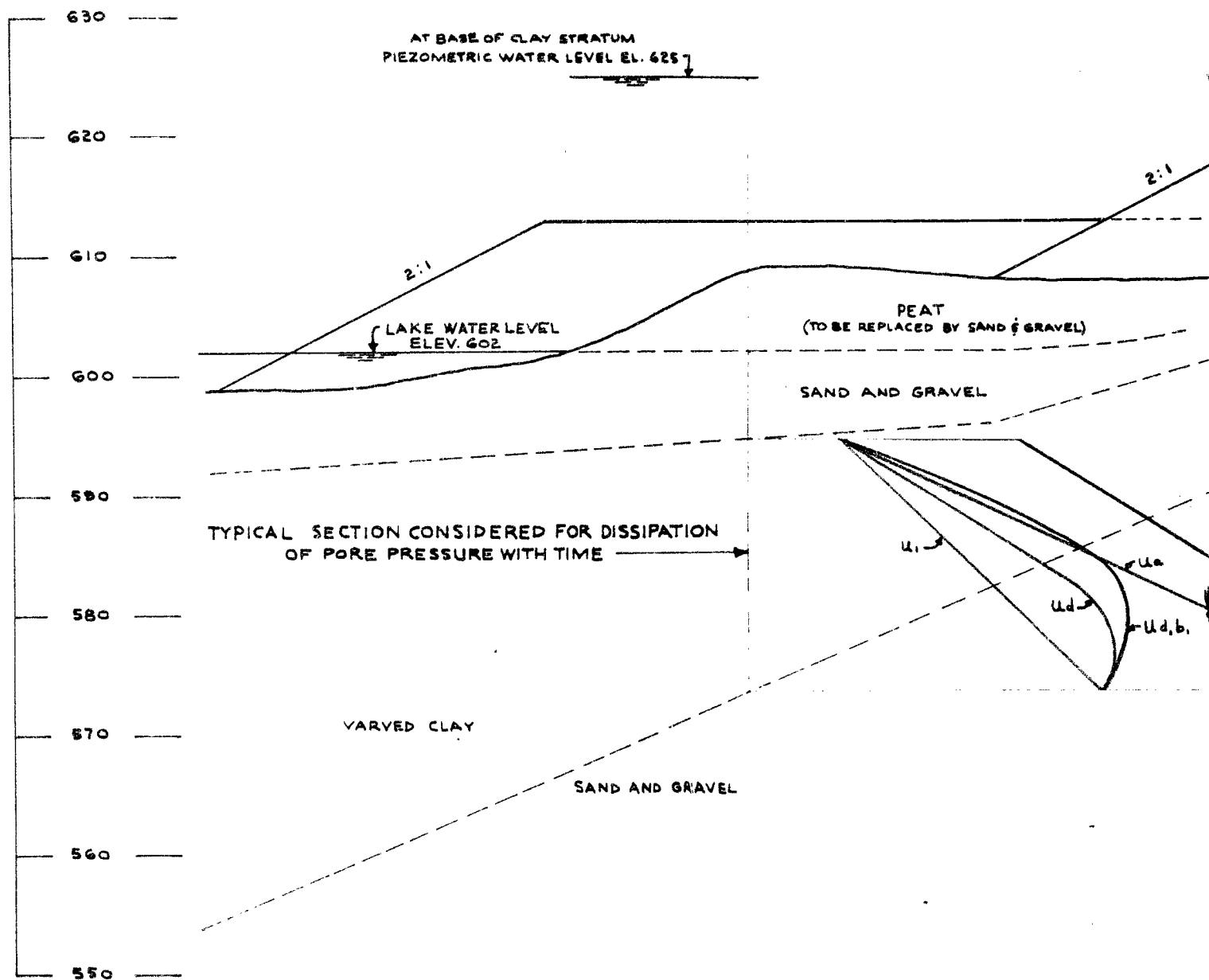
DATE OCT. 21, 1960 SCALE 1" = 10'-0"

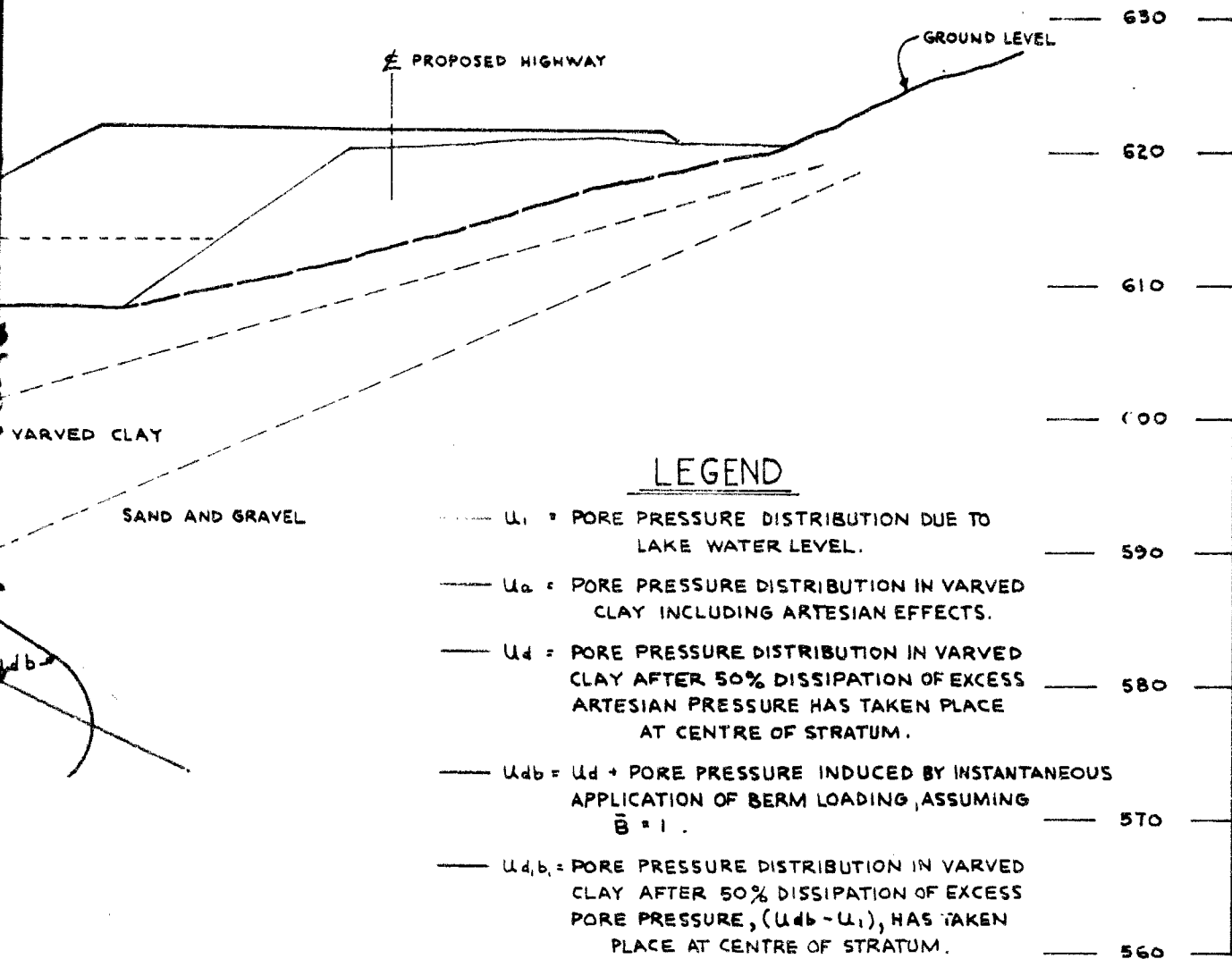
MADE CHKD APP'D
 M.W. F.H. 7/8 No. S 7120-3

APPENDIX IV

Drawing S7120-4 Schematic Section Showing Pore
Pressure Distribution for Clay
Stratum during Construction

Drawing S7120-5 Form of Effective Composite
Surface Analysis





41K-38

GEOCRE No.

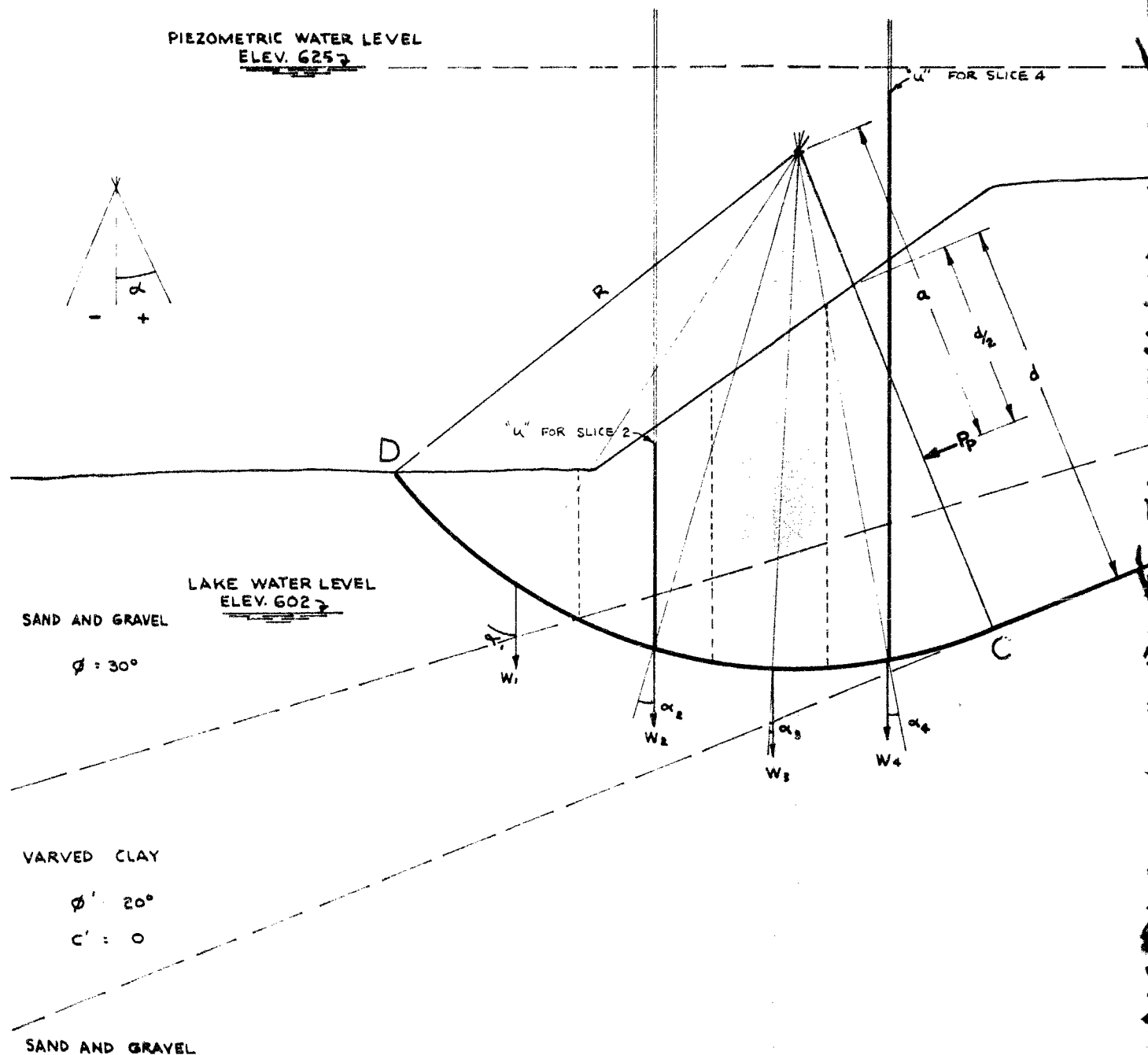
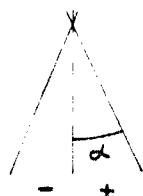
DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO ONTARIO
PROPOSED AND EXISTING HIGHWAY 17
SAULT STE. MARIE ONTARIO
SCHEMATIC SECTION SHOWING PORE PRESSURE DISTRIBUTION IN CLAY STRATUM DURING CONSTRUCTION

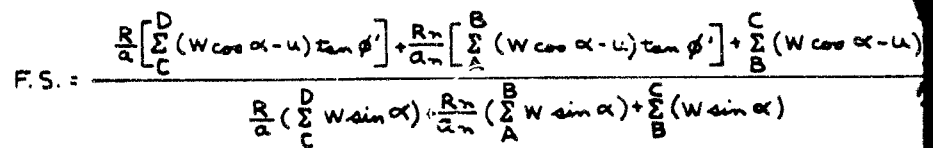
GEOCON LTD

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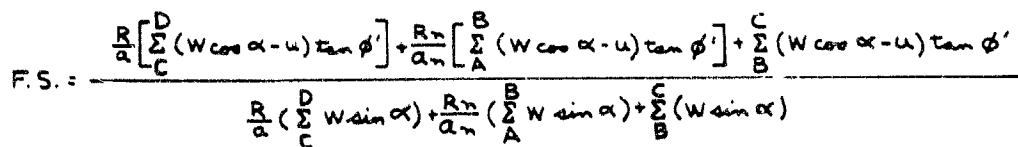
MADE CHKD APPD
M.W. E.H. JY8 No. S 7120-4

PIEZOMETRIC WATER LEVEL
ELEV. 625.3





DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO ONTARIO
PROPOSED AND EXISTING HIGHWAY 1
SAULT STE. MARIE ONTARIO
FORM OF EFFECTIVE COMPOSITE SURFACE ANALYSIS



GEOCRES No.

DEPARTMENT OF HIGHWAYS, ONTARIO
TORONTO ONTARIO

PROPOSED AND EXISTING HIGHWAY 17
SAULT STE. MARIE ONTARIO

FORM OF EFFECTIVE COMPOSITE SURFACE ANALYSIS

GEOCON LTD

DATE NOV. 1, 1960 SCALE 1" = 5'-0"

MADE	CHKD	APPD
M.W.	F.H.	<i>MS</i>

No. S7120-5