

H. Q. GOLDER & ASSOCIATES LTD.

CONSULTING CIVIL ENGINEERS

H. Q. GOLDER
V. MILLIGAN
L. G. SODERMAN
J. L. SEYCHUK

2444 BLOOR STREET WEST
TORONTO 9, ONTARIO
763-4103
767-9201

September 28, 1966.

Department of Highways,
Materials and Testing Division,
Highway 401 and Keele Street,
DOWNSVIEW, Ontario.

Attention: Mr. A.G. Stermac, P.Eng.
Principal Foundation Engineer.

RE: PRELIMINARY SUBSURFACE INVESTIGATION
PROPOSED QUEEN ELIZABETH WAY RECONSTRUCTION
NIAGARA FALLS TO FORT ERIE, ONTARIO.

Dear Sirs:

Twelve copies of our report on the above project, with a Cronaflex copy of Figure 1, Sheets 1 and 2, were sent to you today by messenger.

You will note that in our report the location of borehole 14, put down at the proposed Gilmore Road interchange, is given as station 219+90; 22 feet right of the Queen Elizabeth Way east bound lane centerline. The survey information supplied to us located this boring at station 219+90; 47 feet right of the Queen Elizabeth Way east bound lane. The offset was checked in the field and corrected by an engineer from our staff.

We trust that our report contains sufficient information for your feasibility study requirements. If you have any questions regarding this report, please call us.

Yours truly,
H.Q. GOLDER & ASSOCIATES LTD.



J.L. Seychuk, P. Eng.

JLS:tp

Hwy. 401 & Keele St.,
 Downsview, Ontario.

August 2, 1966

Materials and Testing Division

M. G. Calder and Associates Ltd.,
 2644 Bloor Street West,
 Toronto, Ontario.

Attention: Mr. J. L. Szychuk

- Re: Letter of Authority - Foundation Investigations -
1. Bigger Road (Lyons Creek) - W.P. 158-64-2
 2. Deer Road (No W.P.)
 3. Bonhart Road (No W.P.)
 4. Gordon Road - W.P. 159-64
 5. Baker Road (No W.P.)
 6. Townline Rd. & Black Creek Rd. - W.P. 167-64
 7. Slidemount Road - W.P. 165-64
 8. Gilmore Road - W.P. 164-64
 9. Thompson Road - W.P. 162-64
 10. Concession Road - W.P. 161-64
 11. North St./Central Ave. Port Erie - W.P. 160-64
- District No. 4 (Hamilton) --

Dear Sir:

This is to authorize you to carry out the preliminary foundation investigation at the above mentioned sites. The investigation at each site should be carried out only to the extent to well define the problems that can be expected and will have to be resolved. As discussed with your representative, Mr. J. L. Szychuk, on July 28, 1966, two boreholes at each location should be sufficient. However, if in your opinion, a much better understanding of the problem can be achieved by putting down an additional hole, you should proceed and do it.

We are advised that apparently the most critical sites are the ones listed under (1), (5), (6), (10), and (11), and we would therefore appreciate it if these would be done first. Best priority should be given to the jobs which have W.P. numbers assigned.

You are requested to prepare one report for all the structures, but the report should be a compilation of separate reports for each

cont'd. /2 ...

August 2, 1966

of these structures. A separate drawing is to be prepared for each structure. This will make it possible, if the necessity arises, to take out the report for any of the structures, together with its drawing, and treat it separately.

We have already emphasized the urgency of this job, and it was agreed that the field work will be started on August 2, 1966. If it is at all possible, we would appreciate it if you could organize two crews to carry out the field work simultaneously, thus speeding up the assignment considerably.

In accordance with our terms of reference, you are to have a qualified soils engineer in charge of the field work at all times. Any deviation from this arrangement has to meet our prior approval.

Twelve (12) copies of the report will be required for our distribution. Previous requirements as to preliminary borehole information and laboratory testing progress should be followed.

Since the drawings accompanying the foundation report, showing the location of borings, the inferred subsoil conditions, etc., are to become contract drawings, you are requested to prepare them in accordance with the D.E.O. Standards. To enable you to do this, we are supplying you with a sample drawing with all the necessary explanations, together with linen sheets for your drawings. You are also requested to provide us with Cronaflex copies of the drawings.

Charges for the work performed will be in accordance with your Schedule of Rates, dated October 1, 1965, and invoice to be addressed to the attention of the undersigned.

We are attaching the following Purchase Order J 30822, covering the purchase of any new material required for this work, in order that you may use this as a basis for exemption from the Federal Tax for such purchases. The Exemption Certificate is printed thereon.

AGG/RS&P
Attach.

Yours very truly,

A. Sternik

for A. Rutka,

MATERIALS & TESTING ENGINEER

cc: Messrs. S. McCombie
C. E. Hunter
H. Greenland
W. S. Melinyskyn
T. J. Kovich
Mrs. I. Steinberg
H. Konings
A. Crowley
H. Skymanski (2)
Foundations Office
Gen. Files (2)

w.p. 153-64-2

Mr. S. S. Davis,
Bridge Engineer,
Bridge Division.

Foundation Section,
Materials & Testing Div.,
Room 107, Lab. Bldg.

Attention: Mr. S. McCoskie

September 28, 1966

SEP 28 1966

PRELIMINARY SUBSURFACE INVESTIGATION ---
By E. Q. Golder and Associates Limited
Proposed Queen Elizabeth Way Reconstruction,
Niagara Falls to Fort Erie, County of Welland, Ont.
District No. 4 (Hamilton)

Attached, please find the above mentioned report prepared and submitted by the consultant, E. Q. Golder and Associates Ltd.

We have reviewed the report and believe that it contains all the necessary information for the feasibility study of this portion of the reconstruction of the Queen Elizabeth Way.

The investigation has disclosed that at certain crossings no problems exist, while at some others, certain design measures will have to be incorporated in order to deal with the less favourable subsoil conditions. However, on the overall, it can be stated that no major problems are to be expected regarding the foundations of structures and construction of fills and cuts at the various crossings.

Rough estimates of bearing capacity and settlement values are given which can be used as a guide in deciding on the type of foundations to be used. However, as it is stated in the report, these values should be used as a guide only. Additional borings, testing and calculations, will have to be carried out on a number of crossings in order to define the subsoil conditions more precisely, and to provide more accurate figures of allowable bearing capacities and predicted settlements.

cont'd. /s ...

Mr. B. B. Davis,
Bridge Engineer -
Attn: Mr. E. McCombie

September 28, 1966

We are of the opinion that the information contained in this report will be adequate for this stage of the design work. However, should you require any interpretation or additional information, please don't hesitate to contact this Office.

MSB/SieP
Attach.

A. G. Starace
A. G. Starace,
PRINCIPAL FOUNDATION ENGINEER

cc: Messrs. B. B. Davis (2)
E. A. Traganos
D. W. Farron
C. K. Hunter (2)
E. Greenland
H. S. Kellingshyn
T. J. Kovach
A. Watt

Foundations Office
Gen. Files ✓

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CONSULTING CIVIL ENGINEERS

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2444 BLOOR STREET WEST
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763-4103
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W.P.158-64-2 to W.P.162-64

W.P.164-64, W.P.165-64 & W.P.167-64

REPORT

TO

DEPARTMENT OF HIGHWAYS, ONTARIO

ON

PRELIMINARY SUBSURFACE INVESTIGATION

PROPOSED QUEEN ELIZABETH WAY RECONSTRUCTION

NIAGARA FALLS TO FORT ERIE

COUNTY OF WELLAND

ONTARIO

Distribution:

- 12 copies - Department of Highways, Ontario,
Toronto, Ontario.
- 2 copies - H. Q. Golder & Associates Ltd.,
Toronto, Ontario.

September, 1966.

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ABSTRACT

The results of a preliminary soil investigation to determine the general subsurface conditions at the sites of seven proposed interchanges and five proposed flyovers to be constructed along a 14.7 mile section of the Queen Elizabeth Way extending from the City of Niagara Falls to the Town of Fort Erie, Ontario, are reported. General foundation design information to assist in a feasibility study of the proposed structures and their associated roadway approach embankments or cut sections are also presented. The soil conditions and specific recommendations for each of the twelve structure locations are detailed in Appendices I to XII following this report.

It was found that the area under investigation is generally underlain by some 10 to 60 feet of firm to stiff silty clay which has been desiccated to a very stiff to hard condition in the upper 20 feet. The silty clay stratum is underlain in all but the eastern portion of the route by dense till. The silty clay or till is in turn underlain by bedrock, the upper surface of which varies along the route from a depth of 10 to greater than 100 feet. The groundwater level at the sites is within the silty clay stratum and varies between a depth of about 3 and 20 feet.

No overall stability problems are anticipated for the proposed roadway approach embankments or cut sections constructed with side slopes of 2 horizontal to 1 vertical. Settlement of embankments some 20 to 25 feet high is estimated to be as much as 6 inches at sites where the silty clay stratum extends down to a depth of 60 feet.

The proposed structures may be founded on spread footings placed in the upper desiccated crust of the silty clay stratum as outlined in the main body of this report. Allowable bearing pressures and estimated settlements at each site are discussed in the appendices. As an alternative the abutments, and if necessary the piers, may be founded on H-piles driven to refusal in the competent till stratum or bedrock. Pile loads of up to 75 tons/pile may be used.

INTRODUCTION

H. Q. Golder & Associates Ltd. have been retained by the Department of Highways, Ontario to carry out preliminary subsurface investigations for seven proposed interchanges and five proposed flyovers along the Queen Elizabeth Way between the City of Niagara Falls and the Peace Bridge over the Niagara River in Fort Erie, Ontario. The purpose of the investigations was to determine the general subsurface conditions at each site and to provide preliminary foundation information for a feasibility study of constructing the proposed structures.

This report presents the general subsurface conditions and engineering recommendations established by the overall investigation. The soil conditions and specific recommendations for each site are detailed in the appendices following this report.

PROCEDURE

The field work for the overall investigation was carried out between August 3 and 30, 1966. During this period a total of 24 boreholes, 22 of which had adjacent dynamic penetration tests, were put down at the 12 structure locations. Two borings were carried out at each structure location to provide general coverage of each site. The borings were taken down to depths ranging between

about 10 and 100 feet using two Penndrill mobile power auger units supplied and operated by the F.E. Johnston Drilling Co. Ltd., Toronto, Ontario. Besides conventional power auger boring methods the borings were advanced using both wash boring and diamond core drilling techniques where non-cohesive soil, boulders or bedrock was encountered. A standpipe or piezometer was installed in 21 boreholes for groundwater level observation purposes. The field work was supervised throughout by members of our engineering staff.

The general locations of the boreholes put down during the investigations are shown on Figure 1, Sheets 1 and 2, General Site Plan, located in a pocket following the Records of Boreholes. The detailed locations of the borings put down at each separate bridge site are shown on the individual site drawings, Figures 8 to 19, which are included in the appendices following Figure 7. A detailed log for each boring is given on the Records of Boreholes following the text of this report. A section of the inferred subsurface stratigraphy along the existing Queen Elizabeth Way from Niagara Falls to Fort Erie is shown on Figure 1, Sheets 1 and 2. Soil stratigraphy sections across the site of each of the proposed structures are presented on Figures 8 to 19.

The samples obtained during the investigations were brought to our laboratory for detailed examination and testing. The

results of the laboratory testing are shown on the Records of Boreholes and on Figures 2 to 6, inclusive.

The elevations given in this report are referred to Geodetic datum and were determined from bench marks previously established at each of the proposed structure locations. The borehole elevations and locations were supplied to us by the Department of Highways, Ontario.

SITE AND GEOLOGY

The seven interchanges and five flyovers proposed are located along a 14.7 mile section of the Queen Elizabeth Way extending from the Welland River in the City of Niagara Falls to the Peace Bridge over the Niagara River in Fort Erie, Ontario. Along this distance the Queen Elizabeth Way passes through the Townships of Willoughby to the west and Bertie to the east, the township line being some 200 feet west of Black Creek. The proposed structures crossing the Queen Elizabeth Way are to be constructed at the following sites:

- 1) W.P.158-64-2:- Bigger Road Underpass - located some 525 feet west of the existing Lyons Creek Road crossing.
- 2) - Beck Road Flyover - located at the existing Beck Road crossing.
- 3) - Bossert Road Flyover - located at the existing Bossert Road crossing.

- 4) W.P.159-64:- Sodom Road Underpass - located at the existing Sodom Road crossing.
- 5) - Baker Road Flyover - located at the existing Baker Road crossing.
- 6) W.P.167-64:- Black Creek Road Underpass - located some 1,000 feet west of the existing Black Creek Road crossing.
- Townline Road Flyover - located at the existing Townline Road crossing.
- 7) W.P.165-64:- Ridgemount Road Flyover - located at the existing Ridgemount Road crossing.
- 8) - Sunset Drive Flyover - located at the existing Sunset Drive crossing.
- 9) W.P.164-64:- Gilmore Road Underpass - located at, or some 200 feet east of the existing Gilmore Road crossing (Alternate Sites).
- 10) W.P.162-64:- Thompson Road Overpass - located at the existing Thompson Road crossing.
- 11) W.P.161-64:- Concession Road Overpass - located at the existing Concession Road crossing.
- 12) W.P.160-64:- North Street Underpass - located some 400 feet east of the existing Central Avenue crossing.

Outside the existing Queen Elizabeth Highway at each of the above proposed structure locations, the ground surface is generally fairly flat and grass covered to lightly wooded. With the exception of North Street where the Queen Elizabeth Way is located in about a 15 foot deep cut, the highway grade is at about the surrounding ground surface elevation. The highway itself consists of 4 paved lanes with medium strip and associated gravel shoulders. Along each side of the highway there is a drainage ditch which varies from

about 40 feet wide and 10 feet deep to about 10 feet wide and 3 feet deep. The grade of the existing cross-roads is at about the surrounding ground elevation. The roads themselves vary from single lane tracks to paved two-lane secondary highways.

All of the proposed structure sites are located within the Physiographic Region known as the Haldimand Clay Plain. Based on available geological information it is known that the overburden in this region consists of lacustrine clay deposited in glacial Lake Warren formed during the retreat of the last continental glacier. Underlying the lacustrine clay, which may reach a depth of 50 feet or greater, there is a basal till deposited during the last period of glaciation.

Within the Township of Willoughby and extending to about the New York Central - Canadian National Railway overhead in the Township of Bertie, the overburden is underlain at a depth of from about 20 to greater than 80 feet by calcareous shale, argillaceous dolomite and gypsum of the Salina Formation. East of the overhead the bedrock rises steeply to a depth of about 10 feet along a subterranean ridge comprised of argillaceous dolomite of the Bertie-Akron series. East of about Pettit Road the bedrock changes to grey cherty limestone of the Onondaga Formation and drops to a depth of about 30 to 40 feet at the Niagara River.

SUBSURFACE CONDITIONS

The detailed stratigraphy encountered in each boring is given on the Records of Boreholes. A section of the stratigraphy along the existing Queen Elizabeth Way has been interpolated from this data and is presented on Figure 1, Sheets 1 and 2. Following is a summarized account of the inferred subsurface conditions along the overall section under consideration.

Below a shallow discontinuous clayey topsoil layer, the borings at the structure locations generally encountered an extensive clay stratum which varies in thickness from about 63 feet in the vicinity of Lyons Creek in the western third of the route to less than 10 feet near Gilmore and Pettit Roads in the centre of the route. This stratum consists generally of grey silty clay with a trace to some sand and a trace of gravel. The upper 10 to 25 feet of the stratum has been weathered red-brown and in this upper desiccated crust the clay frequently has a layered or laminated structure. Occasional lenses or layers of silt (as in borehole 2) are present within the lower portion of the clay stratum. Two typical grading curves for samples of the silty clay are shown on Figure 2.

Based on 28 Atterberg limit determinations the liquid limit of the clay varies between about 30 and 60 and the corresponding plasticity index is between 10 and 25. The natural water content is

generally between 20 and 40 percent and varies from below the plastic limit to a liquidity index of about 0.5. The results of the Atterberg limit tests are summarized on Figure 6. This figure indicates that there is a trend for a decrease in the plasticity index with depth and that the in situ water content increases slightly with depth. The Atterberg limit test results have also been plotted on a Plasticity Chart which is presented on Figure 5. This figure indicates that the material is a glacial clay of generally medium plasticity.

The results of unit weight determinations, which have been plotted against depth on Figure 6, indicate that the total unit weight of the clay varies between 110 and 145 lb/cu.ft. but is generally between 120 and 130 lb/cu.ft.

The undrained shear strength of the clay was determined by in situ vane testing in the field and by undrained triaxial compression tests on relatively undisturbed samples in the laboratory. The results of these tests are plotted on the Records of Boreholes and summarized on Figure 6. The shear strength profile gives a remarkably uniform pattern with depth along the 15 miles of investigation. The test results indicate that the undrained shear strength of the clay is greater than 2,000 lb/sq.ft. in about the upper 10 feet of the stratum and decreases with depth to an average minimum

value of about 1,000 lb/sq.ft. at some 35 feet below ground surface. Below 35 feet the undrained shear strength increases to a value greater than 1,300 lb/sq.ft. at a 60 foot depth. Based on these strength results together with the standard penetration test results, also summarized on Figure 6, the consistency of the clay is very stiff to hard in the upper desiccated crust and is generally firm to stiff below about a 10 to 25 foot depth.

Remoulded field vane tests gave values ranging between about 250 and 900 lb/sq.ft. Based on these results the clay has an average sensitivity, which is defined as the ratio of undisturbed strength to remoulded strength, of about 2.

Underlying the silty clay stratum in localized areas (Gilmore Road and Bigger Road sites) the borings encountered some 5 to 20 feet of red-brown silty sand containing a trace to some clay and, at Gilmore Road, some thin clayey silt layers. A typical grain size distribution curve for the sand is presented on Figure 3. Based on the results of standard penetration tests, which gave "N" values ranging between 9 and greater than 100 blows/foot, and resistance to casing and augering advance, the silty sand deposits are considered to be in a dense to very dense state of packing. The low "N" values are probably due to unavoidable "piping" at the bottom of the borings.

The extensive silty clay stratum and local silty sand deposits are underlain at most of the proposed structure locations by glacial till. The till, which was not encountered at the two eastern-most sites (Concession Road and North Street) increases in thickness from about one foot in the central portion of the route to about 15 feet or greater at the western end of the route. The till consists generally of red-brown to grey silty sand and gravel with a trace to some clay but varies to a clayey silt with sand and some gravel. Occasional cobbles were encountered by the borings put down in the western portion of the route. Typical grain size distribution curves for samples of the till, obtained using 1½ inch I.D. sampling equipment, are presented on Figure 4.

Based on the results of standard penetration tests, which gave "N" values generally greater than 100 blows/foot, the sandy till is generally in a very dense state of packing and the consistency of the clayey portion is generally hard. The upper 2 to 3 feet of the till, however, is occasionally compact to dense.

The silty clay and till strata are underlain by bedrock which was proved in 8 of the borings by core drilling in AXT size. The auger holes were taken to refusal on what is considered to be bedrock in 13 borings and bedrock was not encountered in 3 borings. At one site (Bigger Road) bedrock was not encountered within about a

100 foot depth in either of the two borings put down.

From the borings put down bedrock is greater than 100 feet below ground surface in the extreme western portion of the route, but rises to between about a 10 to 30 foot depth in the central and eastern portions of the route.

West of about the Willoughby-Bertie township line the bedrock at the cored locations consists of fairly sound to sound grey dolomite with some vertical and horizontal fractures. Numerous thin layers and inclusions of gypsum were encountered at the Black Creek Road site. East of the township line the borings encountered fairly sound to sound grey dolomitic limestone which grades to limestone at the eastern end of the Queen Elizabeth Way. The limestone bedrock contains some vertical and horizontal fractures and occasional gypsum inclusions. Along the entire route the upper one to three feet of rock is frequently weathered and, in many cases, auger penetration of up to about one foot or so was possible.

In about the central portion of the route at the proposed Townline Flyover, a recent deposit of soft to firm silty clay underlies the Black Creek floodplain followed by a loose silty sand overlying bedrock. The silty sand deposit is probably a reworked till as indicated by the grading curve on Figure 3. The presence of these deposits indicates that at some time in the past Black Creek

eroded the extensive clay stratum covering the general area down to at least well into the underlying till deposit.

With the exception of boreholes 13, 14 and 24, a piezometer or standpipe was installed in each of the borings following their completion. Periodic readings were taken in these installations during the course of the field work and two weeks after completion of the work. The installation details together with the latest readings obtained on September 12, 1966 are shown on the Records of Boreholes and on Figures 1 and 8 to 19, inclusive.

The readings indicate that the natural groundwater level across the site is within the silty clay stratum and varies from about 3 to 19 feet below ground surface. In general however the groundwater level was found to be some 6 to 10 feet below the surface. At the majority of the sites and particularly in the double installation in borehole 1 a difference in water level of up to 10 feet was observed in adjacent installations. This difference may be due to underdrainage of the clay through the till or fractured bedrock resulting in a decrease in the piezometric level in the clay with depth. With the limited number of installations at each site (generally two) this phenomenon has however not been definitely established.

DISCUSSION

It is understood that the proposed Queen Elizabeth Way reconstruction between Niagara Falls and Fort Erie, Ontario is to include the construction of seven interchanges with underpass or overpass structures and five flyovers. The details of the proposed structures, such as the number of spans and whether they are to be continuous or simply supported, are not known. The height of the proposed roadway approach embankments to underpass and flyover structures is expected to be some 20 to 25 feet. At the two interchanges where overpass structures are to be employed (Concession Road and Thompson Road) the depth of the proposed cut sections is some 15 to 20 feet.

Approach Embankments

There should be no overall stability problem for roadway approach embankments of the order of 20 to 25 feet high, provided the embankments are constructed using 2 horizontal to 1 vertical end and side slopes and that suitable fill properly compacted in place is used. Any topsoil or surficial organic deposits, such as the Black Creek floodplain deposit encountered at Townline Road should be removed beneath the full width of the proposed embankment. Further, to prevent surficial instability due to erosion gullying resulting from surface water run-off, the slopes should be sodded or

seeded and mulched.

The total consolidation settlement of a 22 foot high embankment, constructed on a 60 foot thick silty clay deposit having the undrained shear strength profile shown on Figure 6, is estimated to be about 4 to 6 inches. Anticipated settlements of approach embankments some 20 feet high will vary from this value of about 4 to 6 inches at the western end of the site (Bigger and Beck Roads) to negligible values where the clay overburden is shallow and desiccated throughout as at Gilmore Road and Sunset Drive. The anticipated settlement of approach embankments at the individual sites is discussed in the appendices following this report.

Cut Sections

It is understood that it is proposed to employ overpass structures and associated cut sections at the Concession and Thompson Road interchanges. The proposed cut sections will extend down to a depth of about 15 to 20 feet below existing ground surface and will therefore generally be within the very stiff or upper crust portion of the silty clay stratum. For preliminary design purposes the cut sections should be designed using side slopes of 2 horizontal to 1 vertical to ensure long term overall stability in the overconsolidated (by desiccation) clay. The side slopes should be sodded or

seeded and mulched to prevent surficial instability due to surface water erosion.

Foundations

The significant stratum for foundation design purposes is the extensive hard, becoming firm to stiff with depth, silty clay deposit which underlies most of the proposed structure locations. The clay deposit varies in thickness from about 10 to 60 feet along the route and above a depth of about 20 feet is generally very stiff to hard. In general the undrained shear strength of the clay varies with depth as shown on Figure 6. Because of the extensive nature of the clay deposit, consideration has been given to founding the proposed structures along the route on spread footings placed within the clay.

Due to the decrease in shear strength of the clay, the allowable bearing pressure for spread footings depends on both the footing size and founding elevation. In order to take advantage of the very stiff to hard upper crust the footings should be founded as high as possible in the clay stratum. For adequate frost protection, however, a minimum of 4 feet of earth cover should be provided above the underside of all footings.

The general shear strength profile taken for design of

footings founded in the clay stratum is shown on Figure 7. The allowable bearing pressure for spread footings, based on the shear stress criterion without taking into consideration settlement, is given on Figure 7. A factor of safety of 3 has been applied to the ultimate bearing capacity values in the computation of the allowable bearing pressures shown on this figure. For conventional highway structures spread footings of the order of 5 to 10 feet wide are anticipated. Based on Figure 7, an allowable bearing pressure of about 2.5 tons/sq.ft. may be used for a 10 foot wide footing founded above a 5 foot depth. The allowable bearing pressure decreases to about 1.5 tons/sq.ft. at a depth of 15 feet. It should be noted that Figure 7 is presented to serve as a guide in preliminary foundation design along the route and should not be used for final design purposes.

Based on the engineering properties obtained, the past pre-consolidation pressure for the clay at depth is considered to be up to 1 ton/sq.ft. Since the pressures induced at depth (below the crust) by footings carrying the allowable loadings are generally less than the past preconsolidation pressure, consolidation settlement should not be excessive. The total settlement of footings loaded to the allowable bearing pressure, based on the shear strength criterion as given on Figure 7, has been estimated using a theoretical stress distribution in the clay and an assumed rebound compression

index of 0.05.

The results obtained, which are presented on Figure 7, indicate that the total consolidation settlement of spread footings of the size anticipated and founded above a 15 foot depth will be of the order of 1 to 1.5 inches, provided care is taken during construction to prevent softening of the subsoil at and below foundation elevation.

A total settlement of about 1 inch is considered to be within tolerable limits for bridge piers. However, at sites where the clay deposit is thick, abutments founded on spread footings located within the roadway approach embankments will experience settlement of the order of that discussed for the embankments, that is some 4 to 6 inches. This would give rise to a differential settlement of several inches between bridge piers and abutments. This is probably beyond tolerable limits for structures of the type envisioned. Consideration should therefore be given to founding the abutments on piles, particularly for continuous structures, at sites where the thick deposit of firm to stiff clay was encountered.

For abutments founded on steel H-pile sections driven to practical refusal on bedrock or within the very dense till, a load of up to 75 tons/pile may be used. Settlement of abutments resting on piles should be negligible.

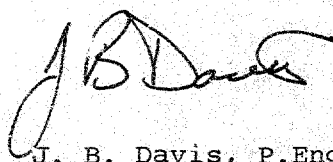
The use of piles at the abutment locations will however give rise to differential settlements of about 1 inch between the abutments and piers placed on spread footings. To eliminate differential settlement the piers could also be pile supported.

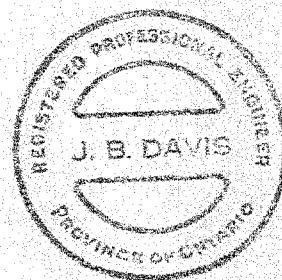
Consideration has also been given to constructing the embankments and allowing the majority of the settlement to occur prior to construction of the structures which could then be founded on spread footings. However, based on experience in the general area, it is considered that a period of about 2 years would be required for sufficient consolidation settlement to take place.

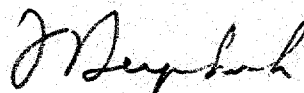
The above discussion for spread footing design (as illustrated on Figure 7) pertains primarily to areas along the western portion of the route where the clay is thick. Where the clay is less than about 20 feet in thickness it is generally desiccated throughout. In this case the allowable bearing pressure for spread footings is not appreciably effected by footing size and founding elevation as the strength of the clay is relatively constant with depth. Allowable bearing pressures for footings at each individual site are given in the Appendices.

Construction Procedures

In general no construction difficulties are anticipated at the proposed structure sites as the overburden at foundation grade consists of relatively impervious silty clay. Where excavations are taken down below the groundwater level seepage into the excavation should be minor. This seepage, together with any surface water collecting in the excavations, can be readily controlled by pumping from sumps. At Townline Road and possibly Gilmore Road, however, excavation below the groundwater level in non-cohesive soils may be required. Therefore some form of groundwater control other than sumps may be necessary.


J. B. Davis, P.Eng.





J. L. Seychuk, P.Eng.

JBD:JLS:hdg
66099
September 27, 1966.

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

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

WH	sampler advanced by static weight—weight, hammer
PH	sampler advanced by pressure—pressure, hydraulic
PM	sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

Consistency	<i>c_u</i> , lb./sq. ft.
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 *Q* or *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	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_s	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_s	sensitivity

$\left. \begin{array}{l} \text{in terms of effective stress} \\ \tau_f = c' + \sigma' \tan \phi' \end{array} \right\}$

$\left. \begin{array}{l} \text{in terms of total stress} \\ \tau_f = c_u + \sigma \tan \phi_u \end{array} \right\}$

*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.

RECORD OF BOREHOLE 1

LOCATION

See Figure 1

BORING DATE AUG. 5-13, 1965

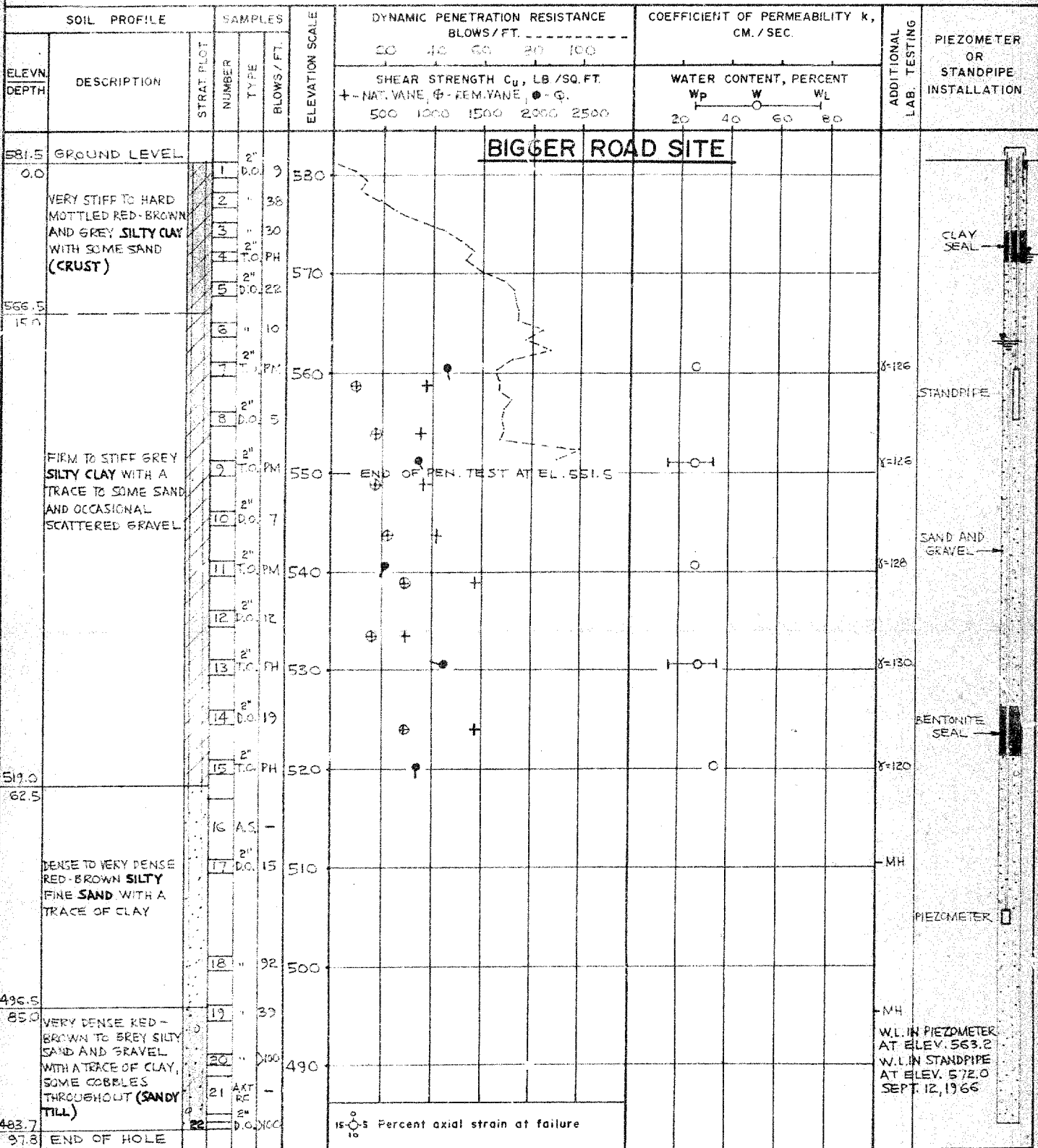
DATUM GEODETTIC

BOREHOLE TYPE POWER AUGER BORING

BOREHOLE DIAMETER 4.5" BX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



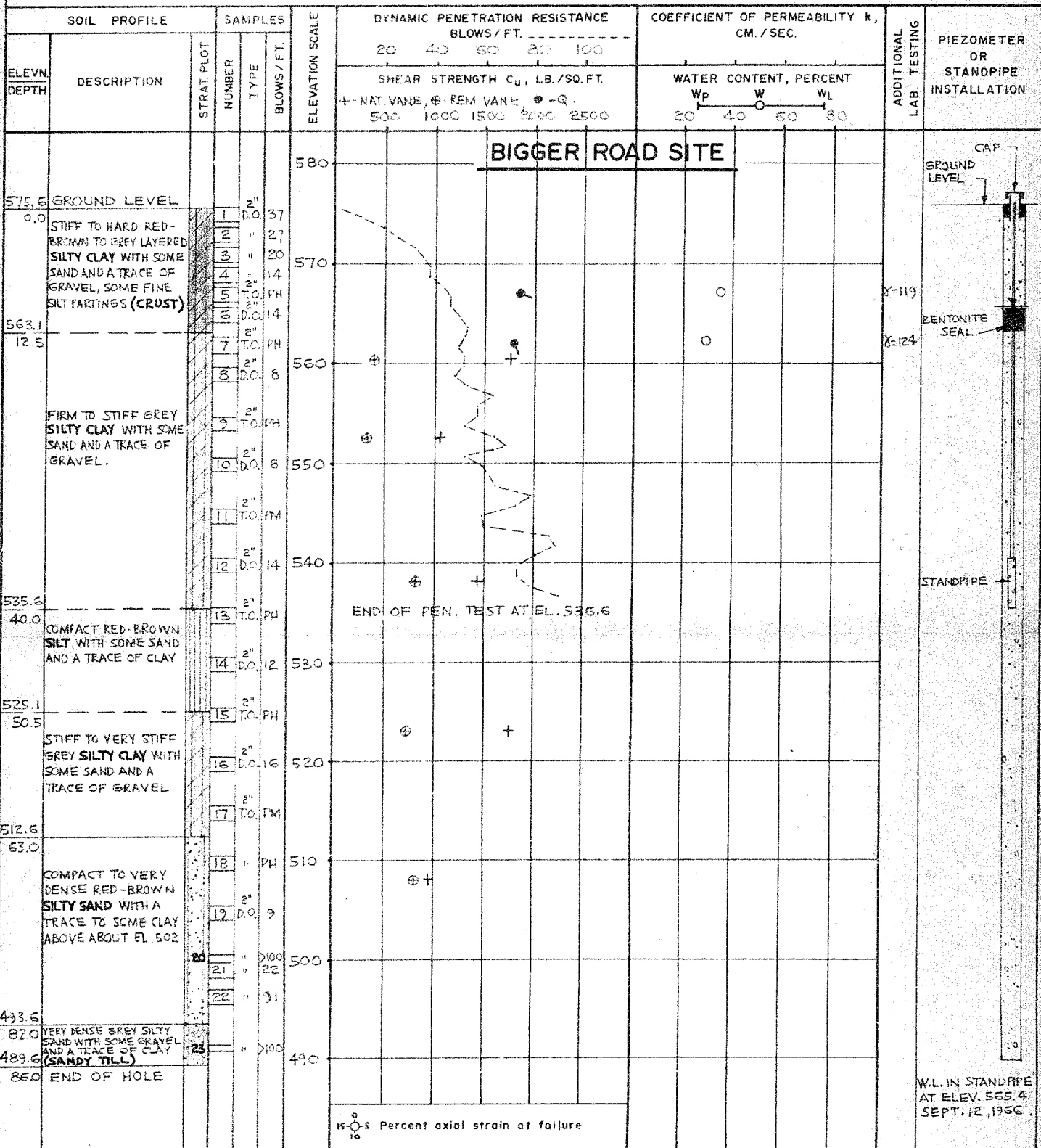
VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN
CHECKED

RECORD OF BOREHOLE 2

LOCATION See Figure 1 BORING DATE AUG. 3-8, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5" BX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



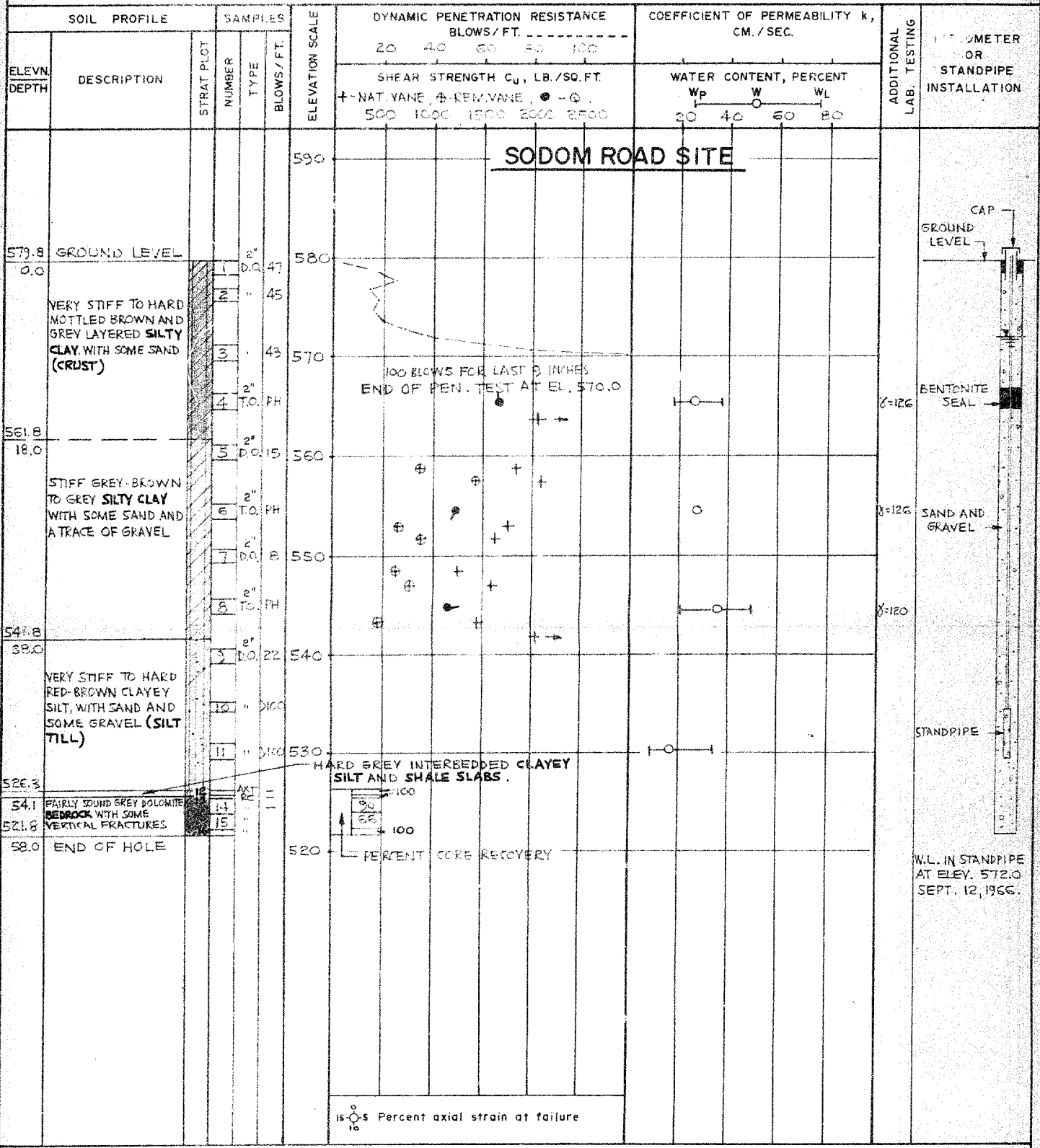
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

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

RECORD OF BOREHOLE 3

LOCATION See Figure 1 BORING DATE AUG. 15-17, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5" BX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

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

RECORD OF BOREHOLE 4

LOCATION See Figure 1

BORING DATE AUG. 17, 1966

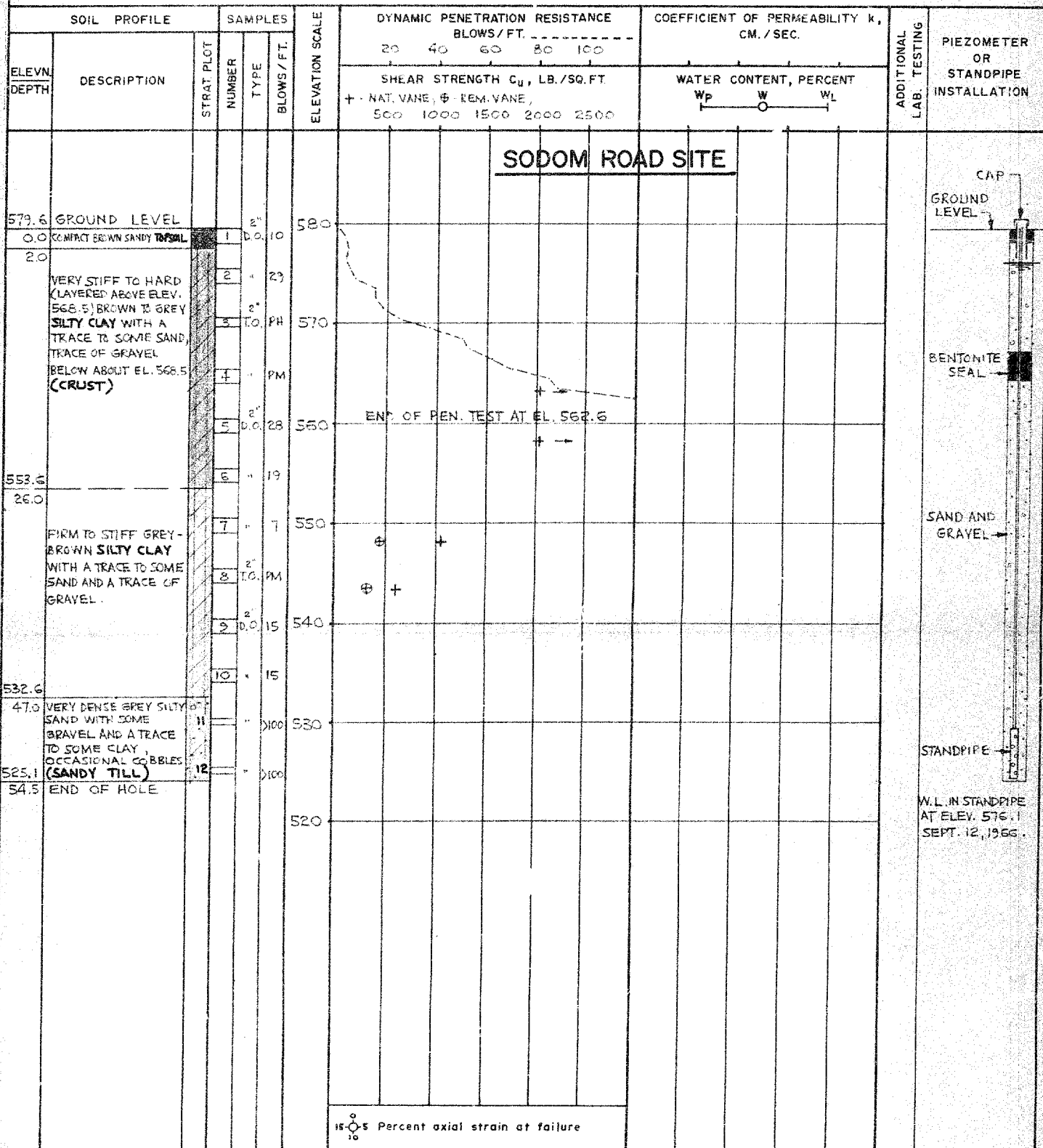
DATUM GEODETIC

BOREHOLE TYPE POWER AUGER BORING

BOREHOLE DIAMETER 4.5 "

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES

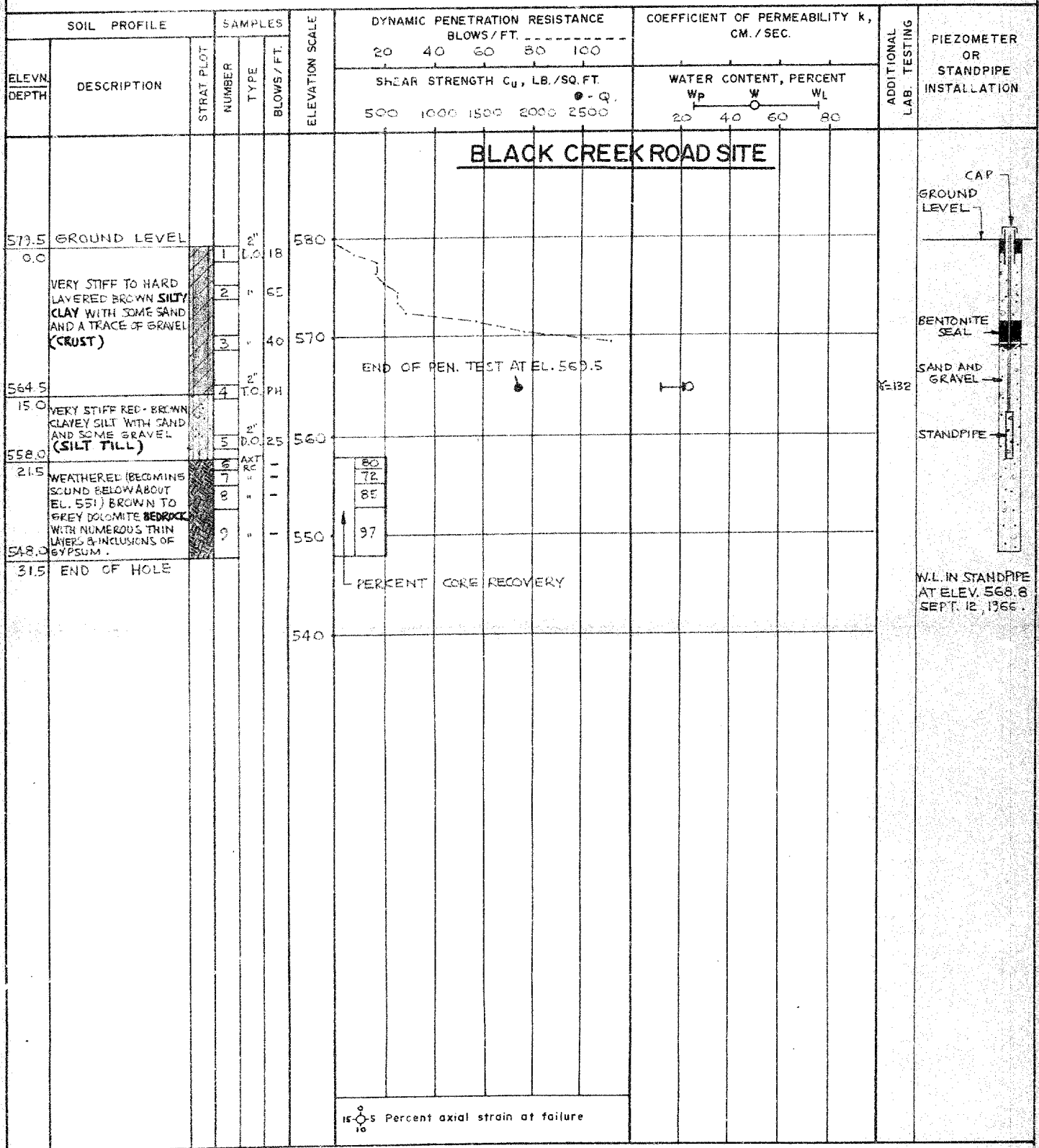
VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *me*
CHECKED *me*

RECORD OF BOREHOLE 5

LOCATION See Figure 1 BORING DATE AUG. 17-18, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5", BX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



15-0-5 Percent axial strain at failure

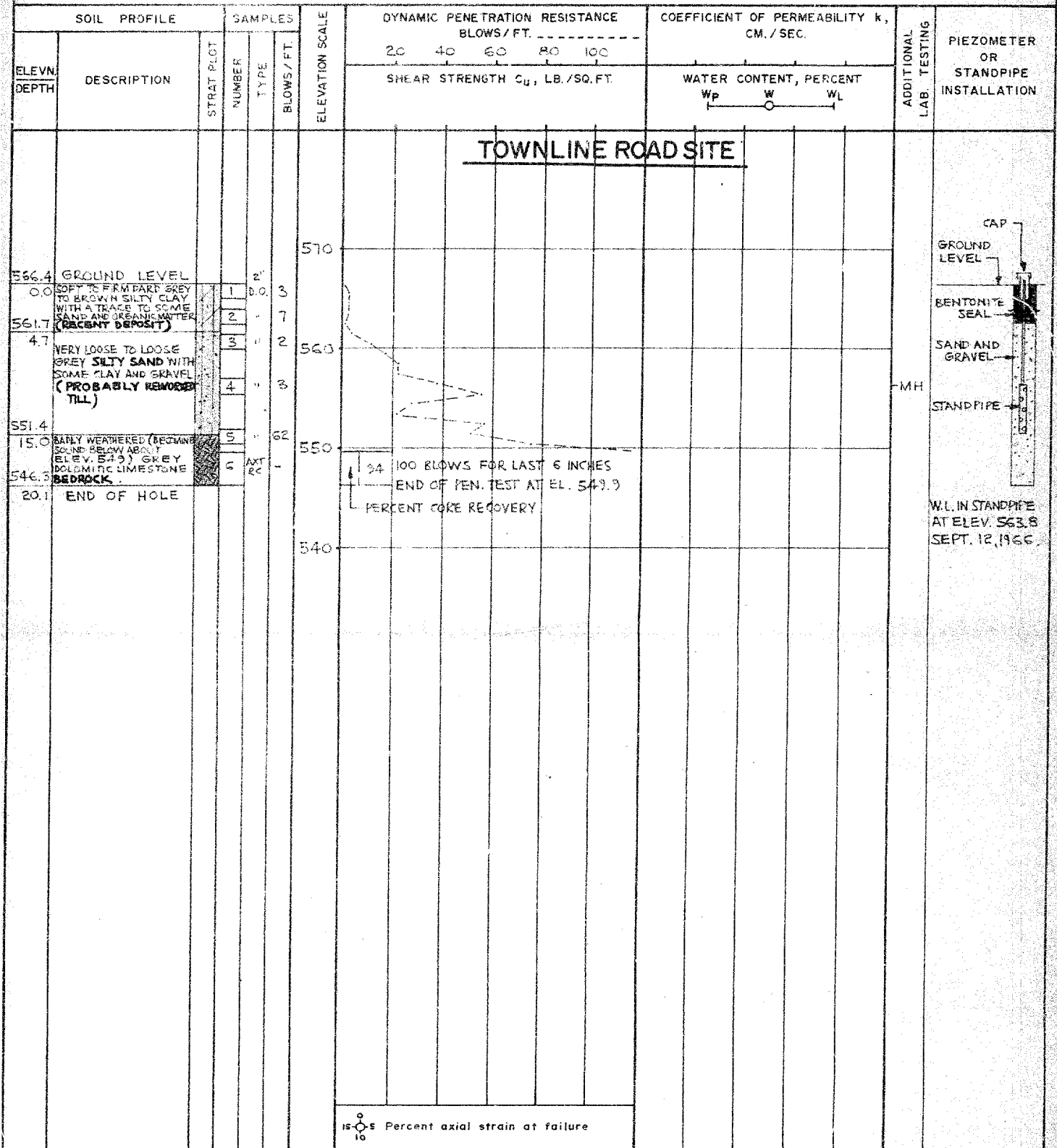
VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN *Th W*
CHECKED *ED*

RECORD OF BOREHOLE G

LOCATION See Figure 1 BORING DATE AUG. 18, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER ALICEA BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



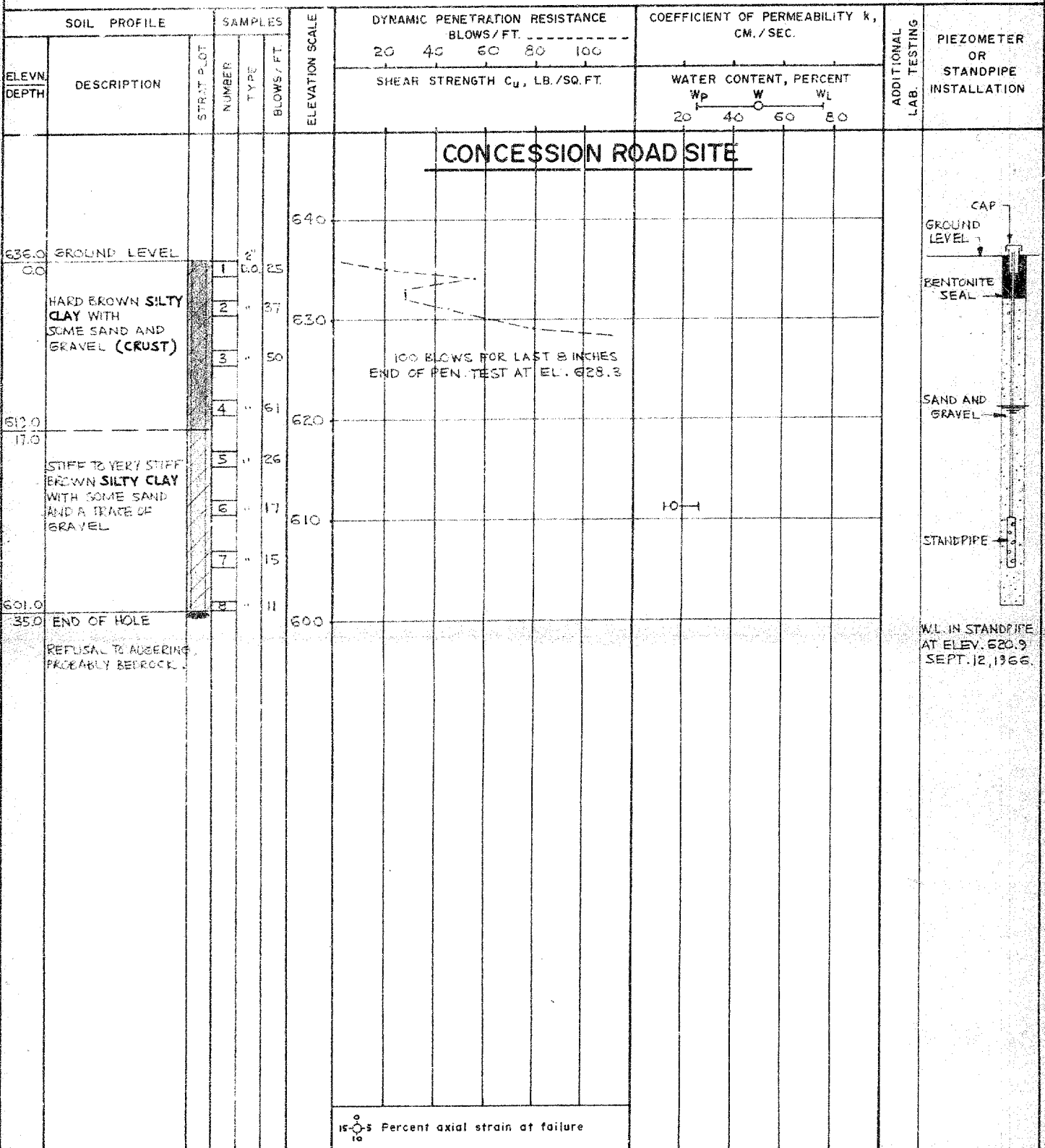
VERTICAL SCALE
 1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *Th W*
 CHECKED *J. D.*

RECORD OF BOREHOLE 7

LOCATION See Figure 1 BORING DATE AUG. 19, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



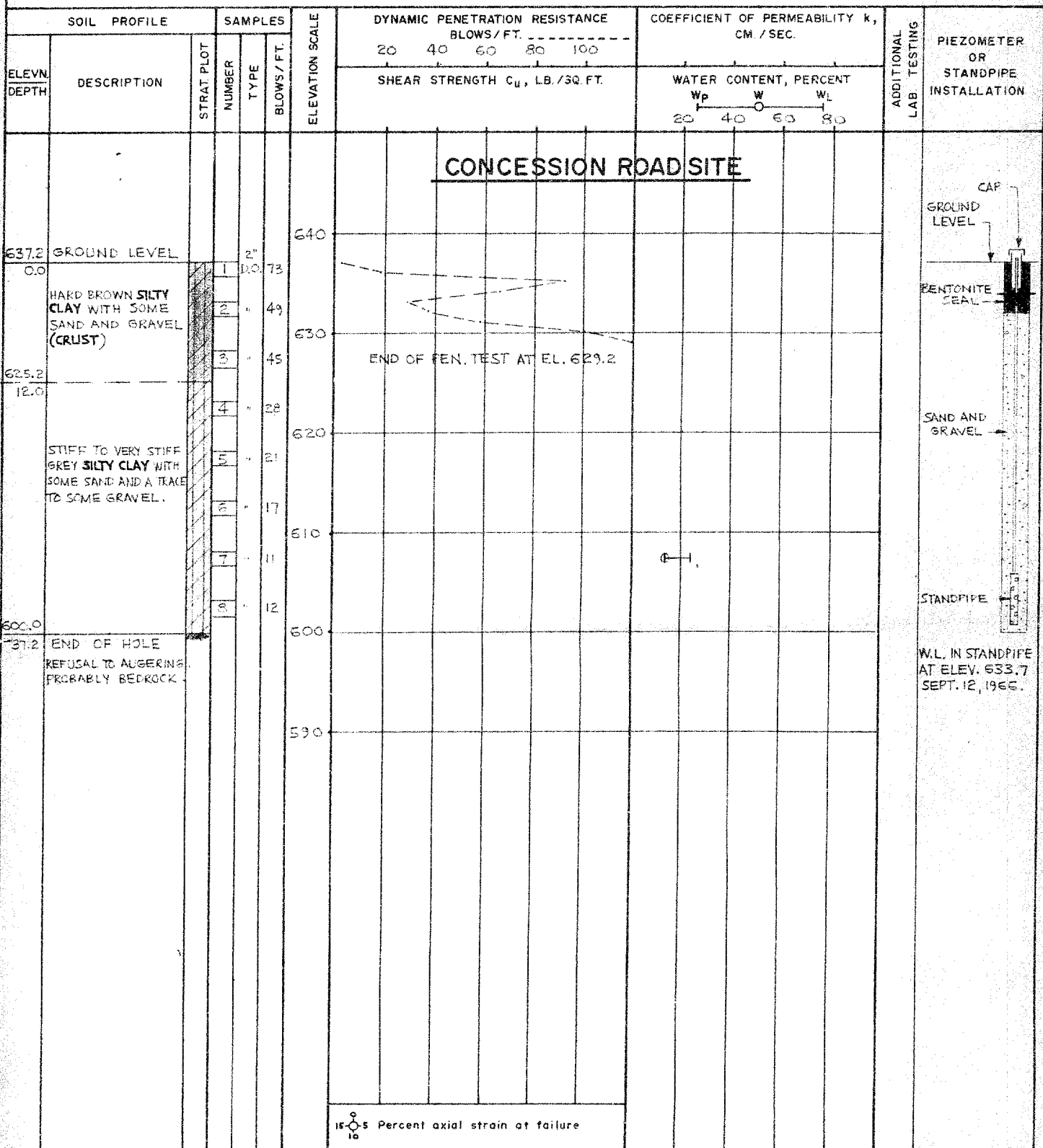
VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN
CHECKED

RECORD OF BOREHOLE 8

LOCATION See Figure 1 BORING DATE AUG. 23, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



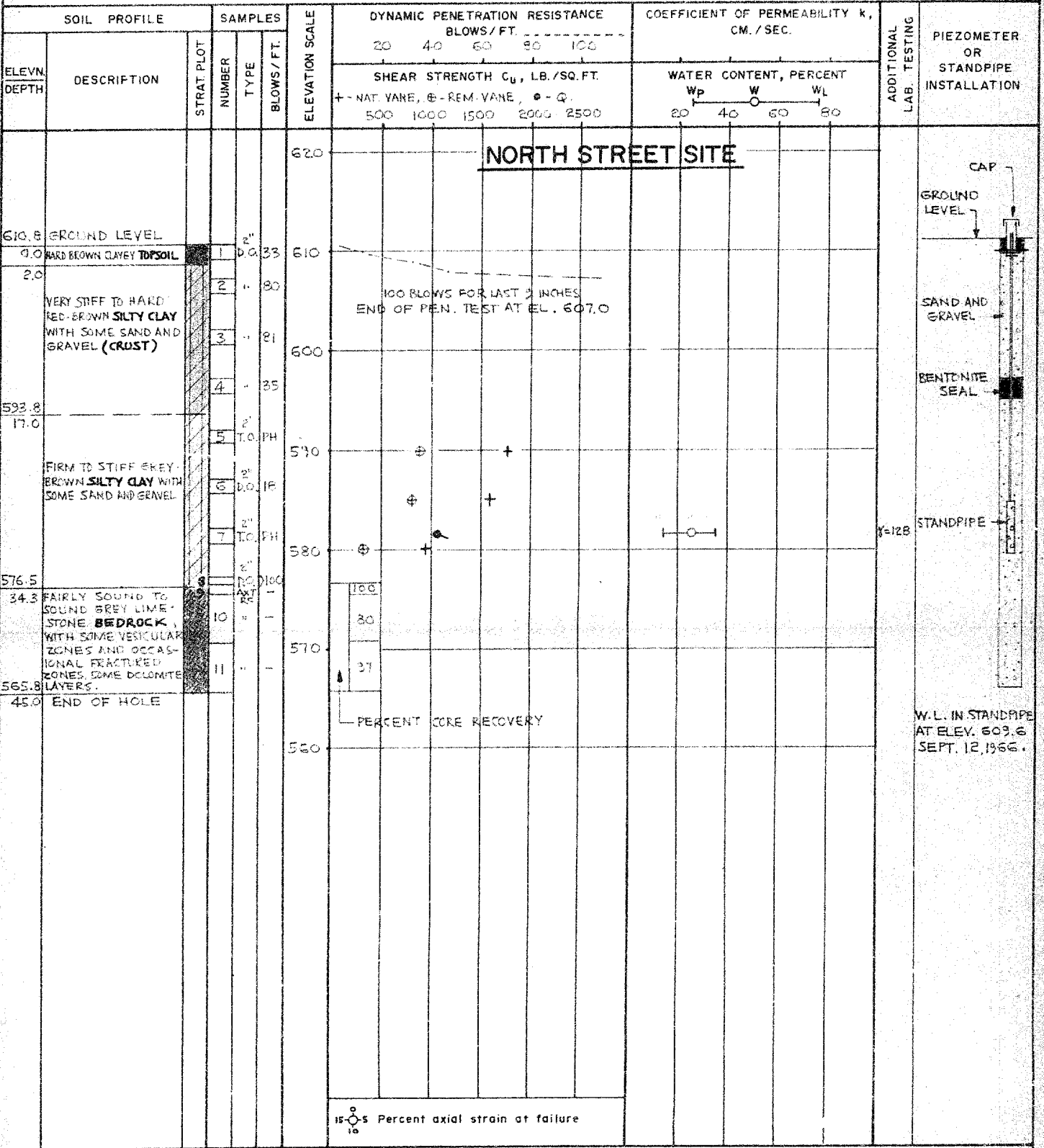
VERTICAL SCALE
 1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN *M.W.*
 CHECKED *JED*

RECORD OF BOREHOLE 9 "L"

LOCATION See Figure 1 BORING DATE AUG. 11-12, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5" EX CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
 1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN *MLW*
 CHECKED *JSD*

RECORD OF BOREHOLE IO 47

LOCATION See Figure 1

BORING DATE AUG. 13-15, 1966

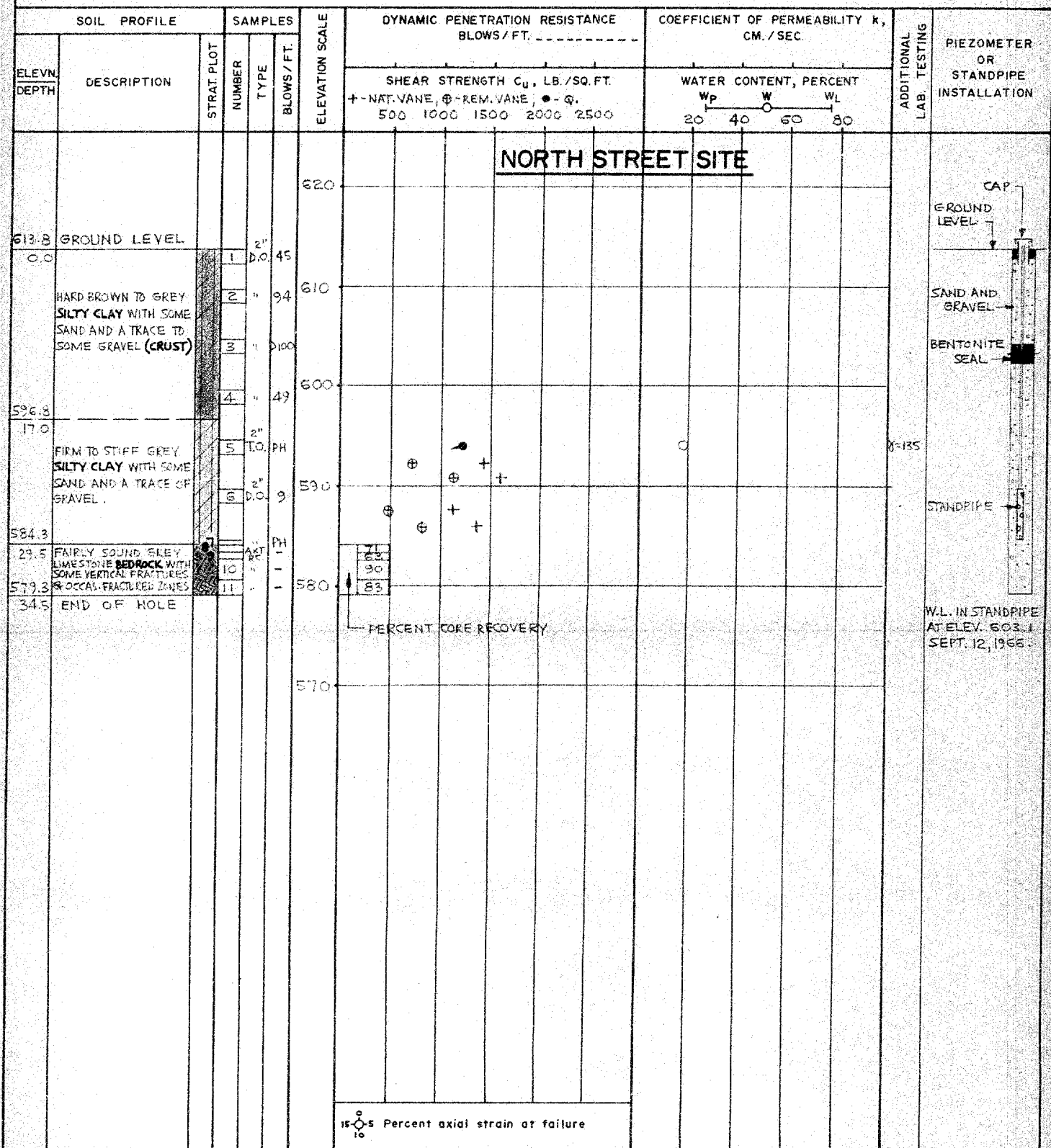
DATUM GEODETIC

BOREHOLE TYPE POWER AUGER BORING

BOREHOLE DIAMETER 4.5", 8X CASING

SAMPLER HAMMER WEIGHT 40 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



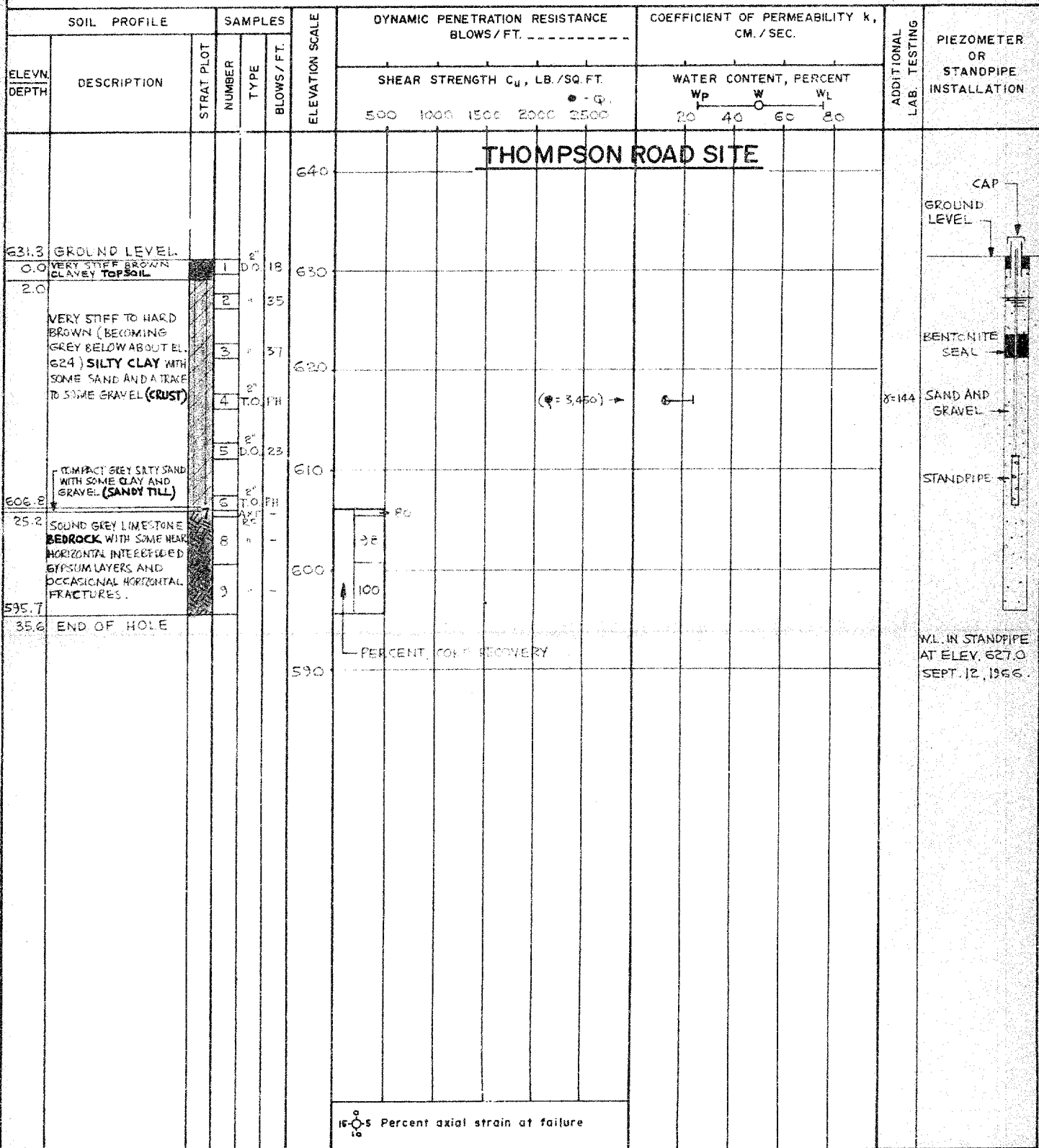
VERTICAL SCALE
1 INCH TO 10' - 0"

COLDER & ASSOCIATES

DRAWN M. W.
CHECKED 135

RECORD OF BOREHOLE II

LOCATION See Figure 1 BORING DATE AUG. 18-19, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5", 8X CASING
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



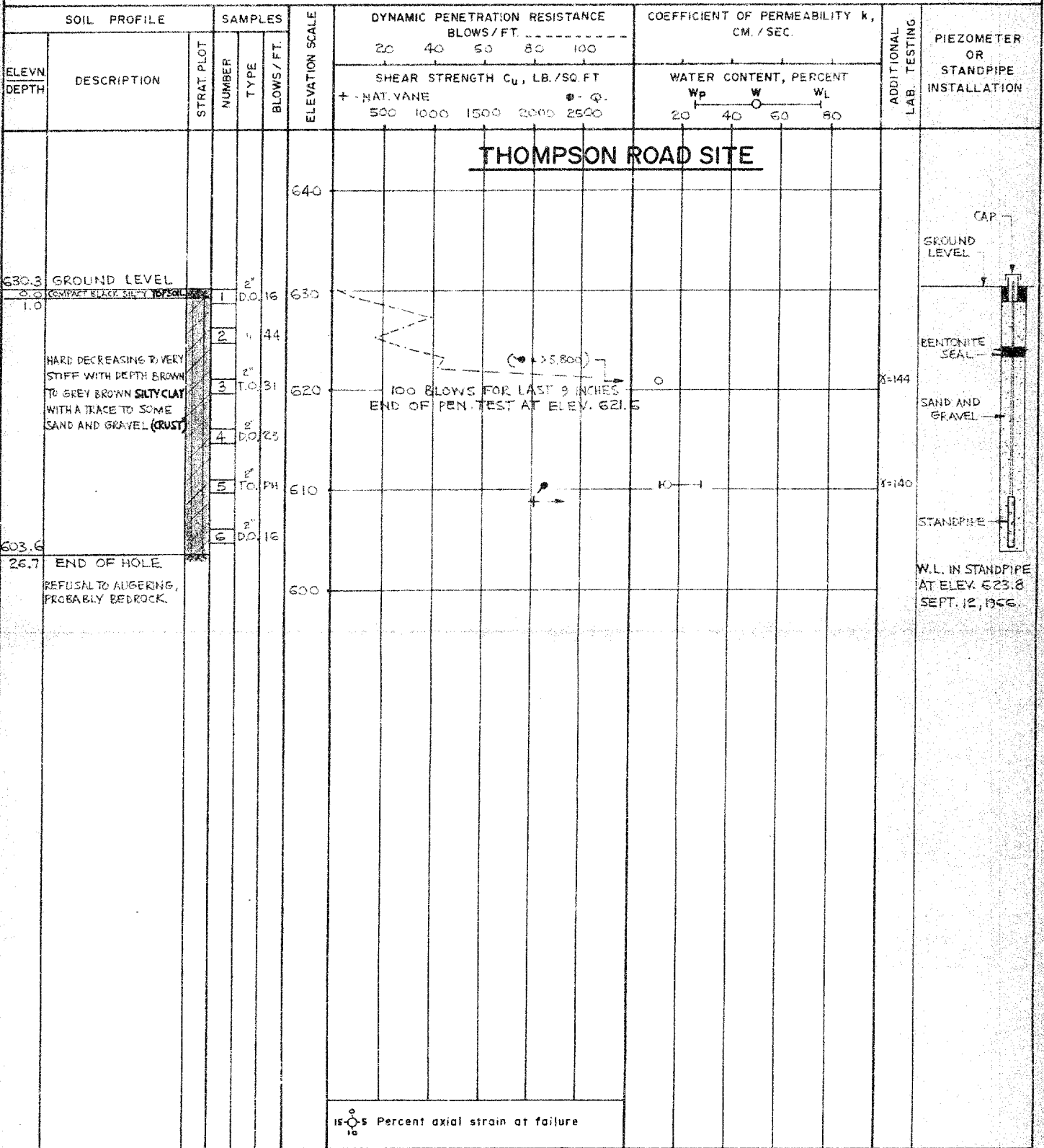
VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

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

RECORD OF BOREHOLE 12

LOCATION See Figure 1 BORING DATE AUG. 19 & 22, 1966. DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
 1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

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

RECORD OF BOREHOLES 13, 14

LOCATION

See Figure 1

BORING DATE

AUG. 22, 1966

DATUM

GEODETIC

BOREHOLE TYPE

POWER AUGER BORING

BOREHOLE DIAMETER

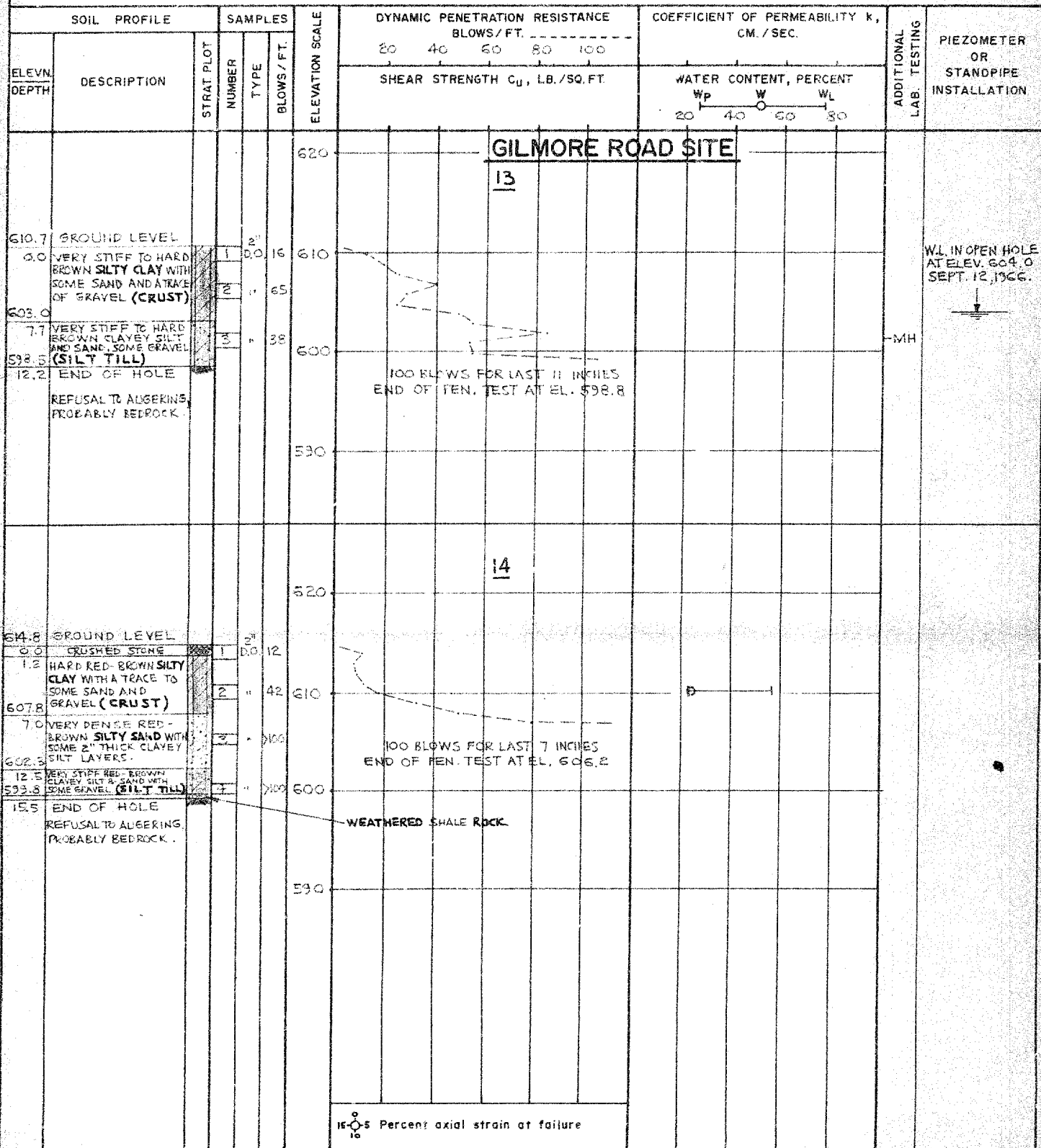
4.5"

SAMPLER HAMMER WEIGHT 140 LB.

DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB.

DROP 30 INCHES



15-10-5 Percent axial strain at failure

VERTICAL SCALE

1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN

CHECKED

RECORD OF BOREHOLE 15

LOCATION See Figure 1

BORING DATE AUG. 23, 1966

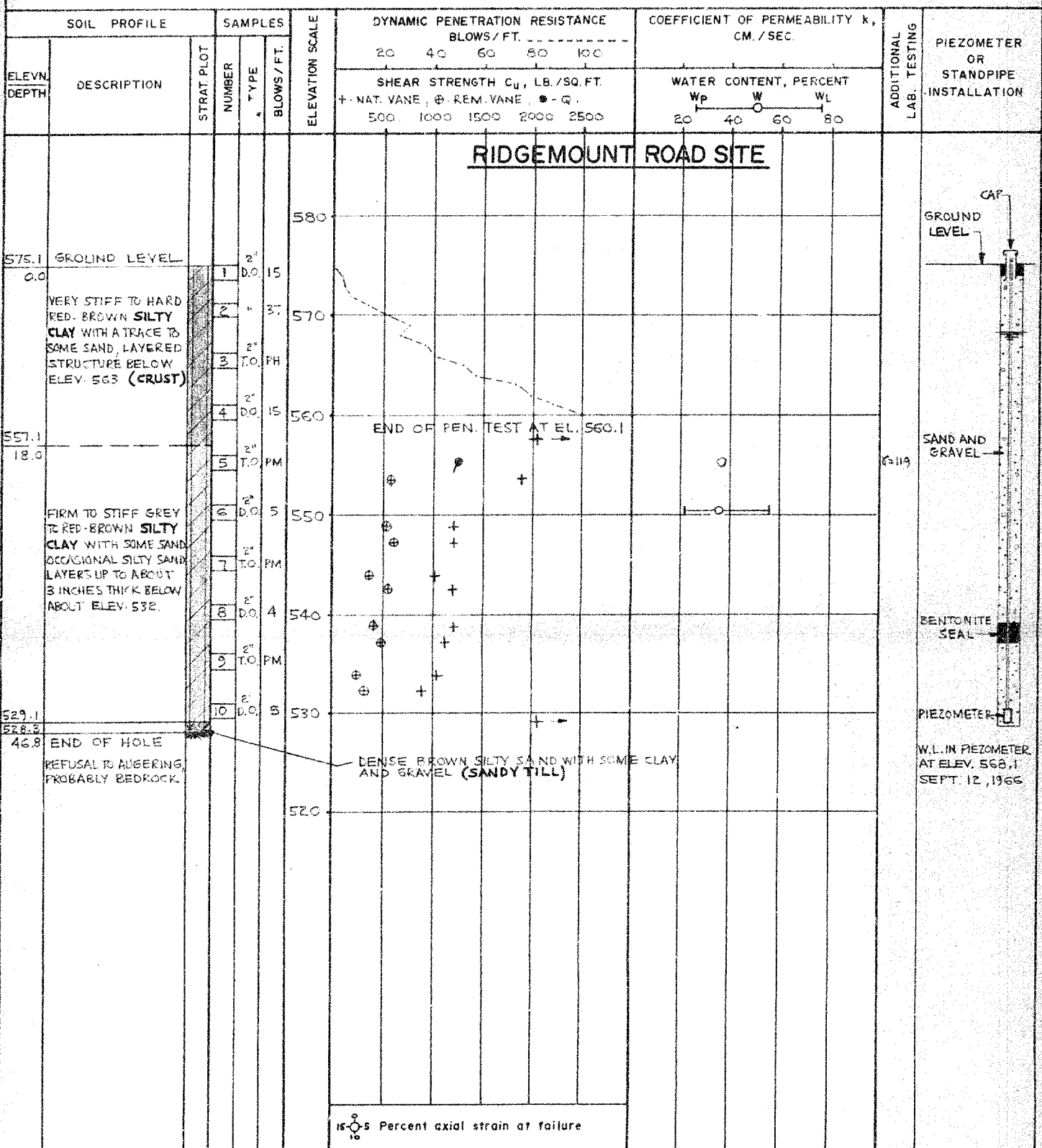
DATUM GEODETIC

BOREHOLE TYPE POWER AUGER BORING

BOREHOLE DIAMETER 4.5"

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



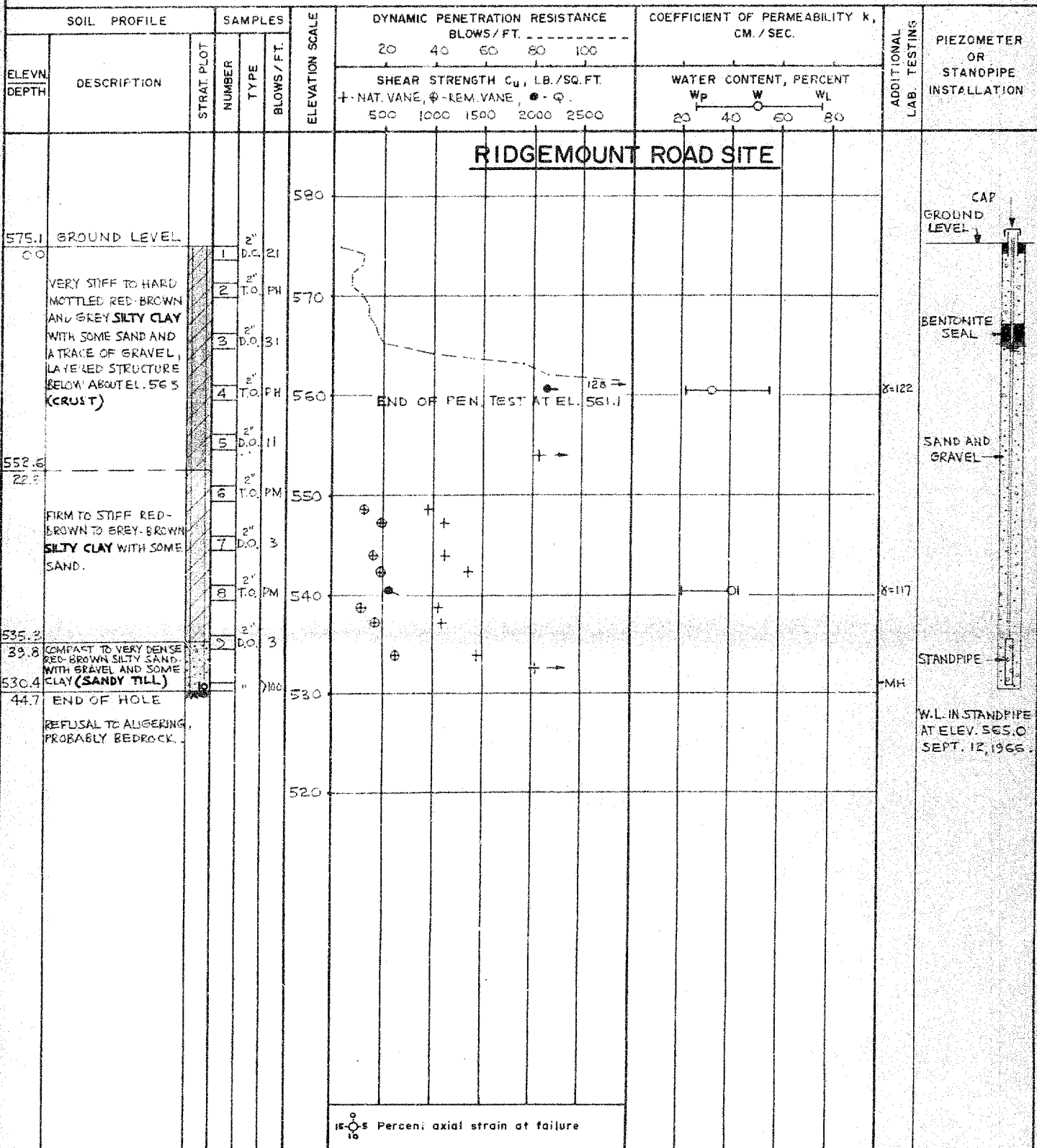
VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN MW
CHECKED BD

RECORD OF BOREHOLE 16

LOCATION See Figure 1 BORING DATE AUG. 23-24, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



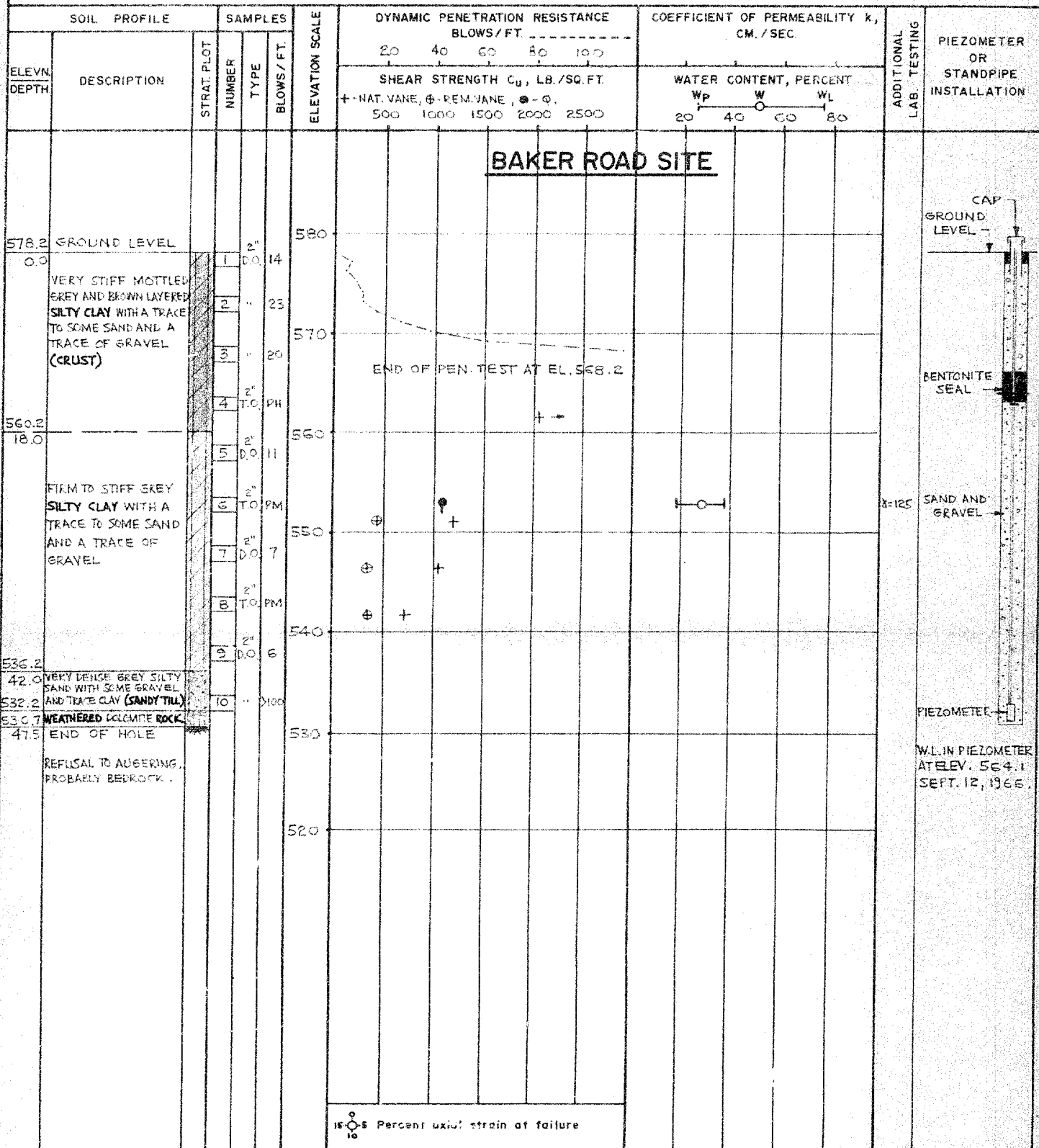
VERTICAL SCALE
1 INCH TO 10' - 0"

COLDER & ASSOCIATES

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

RECORD OF BOREHOLE 17

LOCATION See Figure 1 BORING DATE AUG. 24-25, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN *JLB*
CHECKED *JLB*

RECORD OF BOREHOLE 19

LOCATION

See Figure

BORING DATE

AUG. 24-25, 1966

DATUM

GEODETIC

BOREHOLE TYPE

POWER AUGER BORING

BOREHOLE DIAMETER

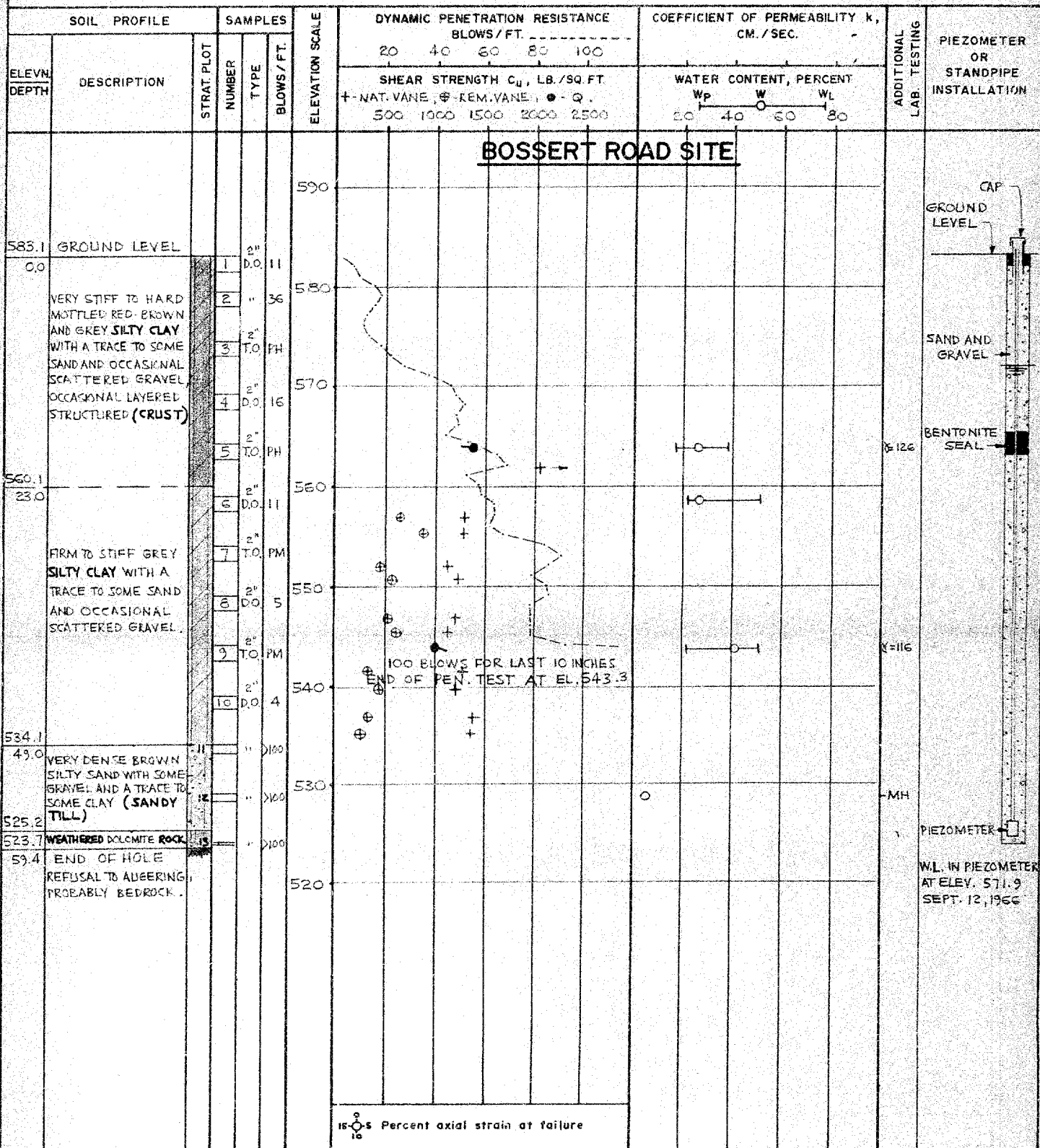
4.5"

SAMPLER HAMMER WEIGHT 140 LB.

DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB.

DROP 30 INCHES

VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN *mm*
CHECKED *ED*

RECORD OF BOREHOLE 20

LOCATION

See Figure 1

BORING DATE

AUG. 25, 1966

DATUM

GEODETIC

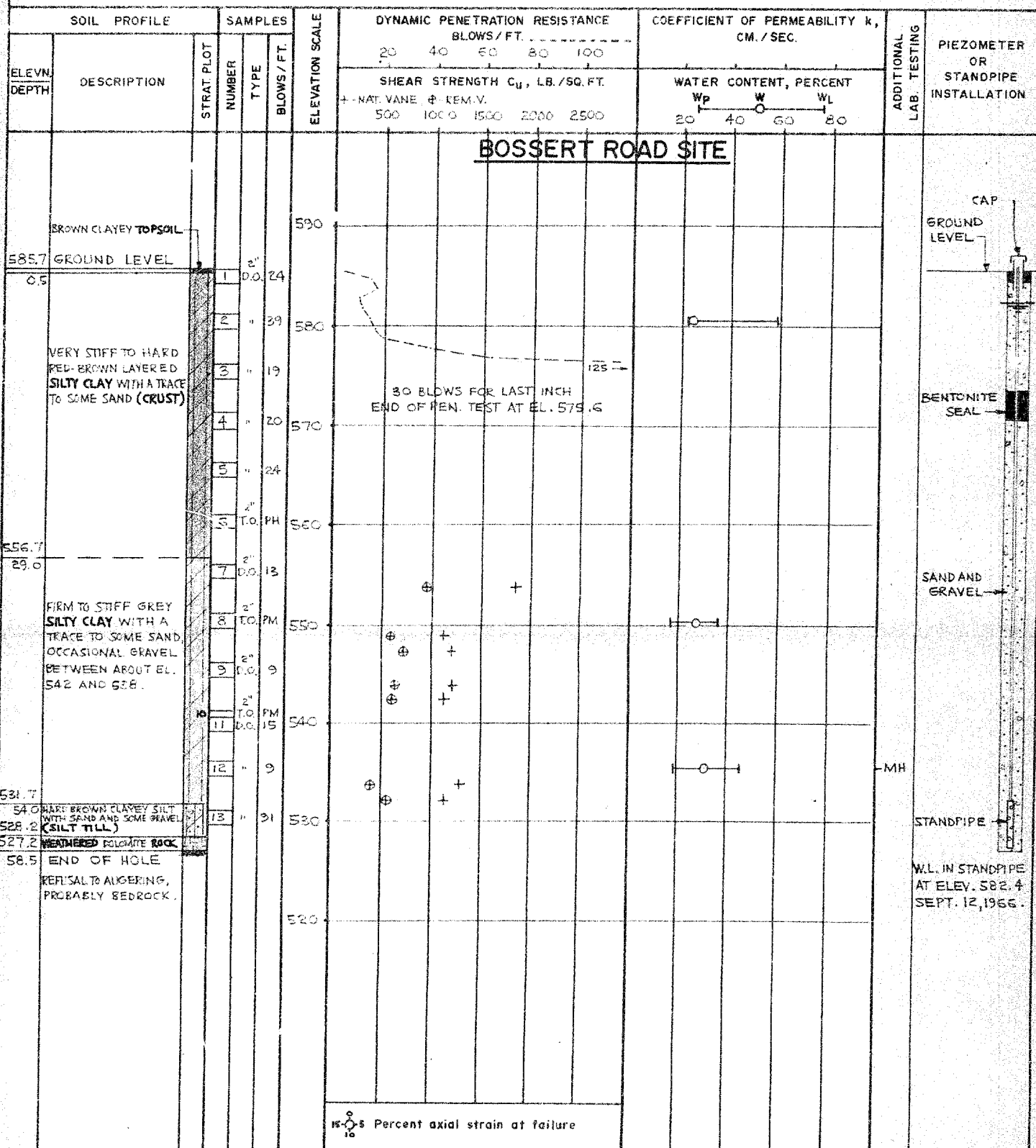
BOREHOLE TYPE

POWER AUGER BORING

BOREHOLE DIAMETER 4.5"

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN mw
CHECKED ABD

RECORD OF BOREHOLE 21

LOCATION

See Figure 1

BORING DATE

AUG 25-29, 1966

DATUM

GEODETIC

BOREHOLE TYPE

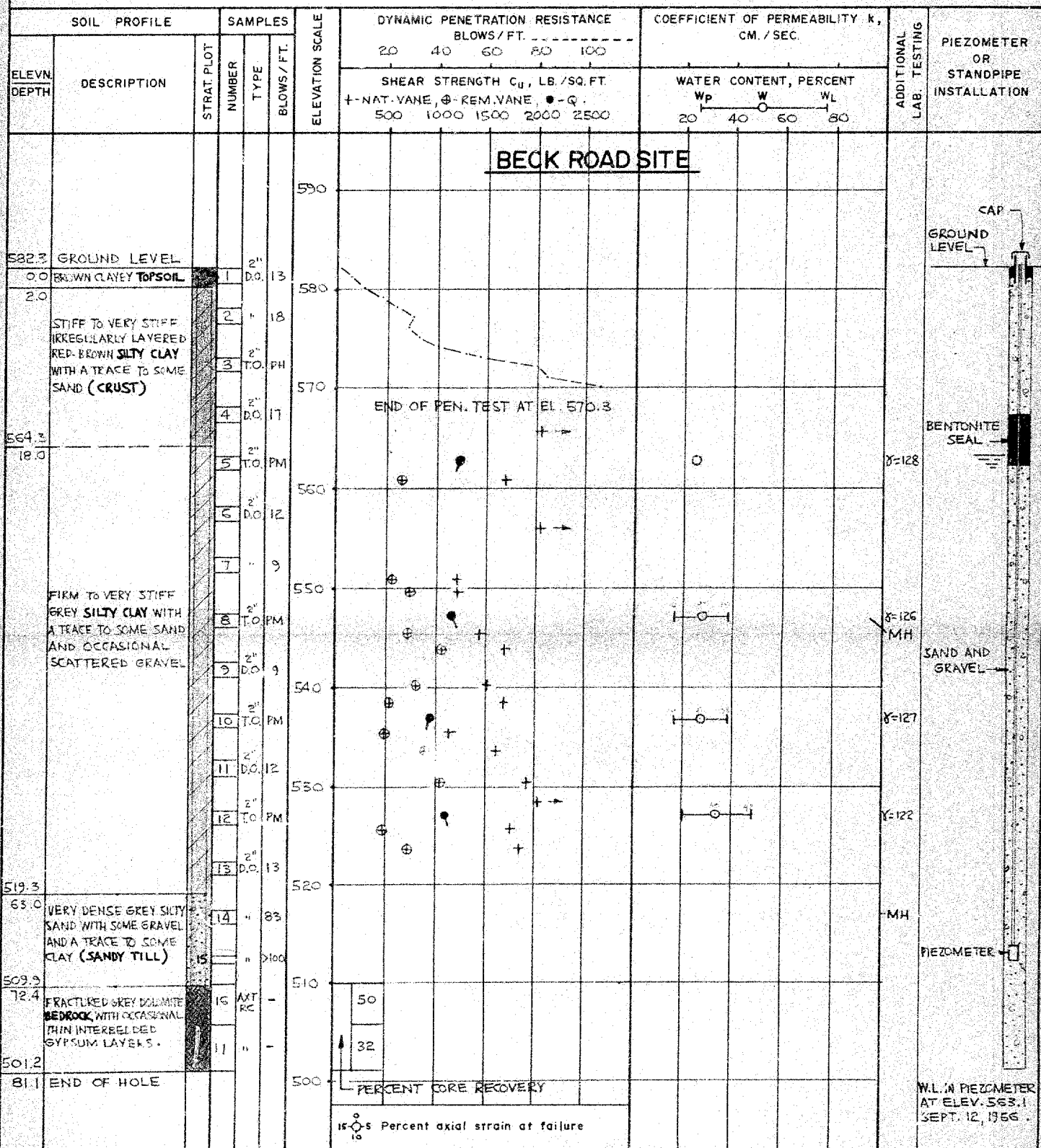
POWER AUGER BORING

BOREHOLE DIAMETER

4.5" EX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES

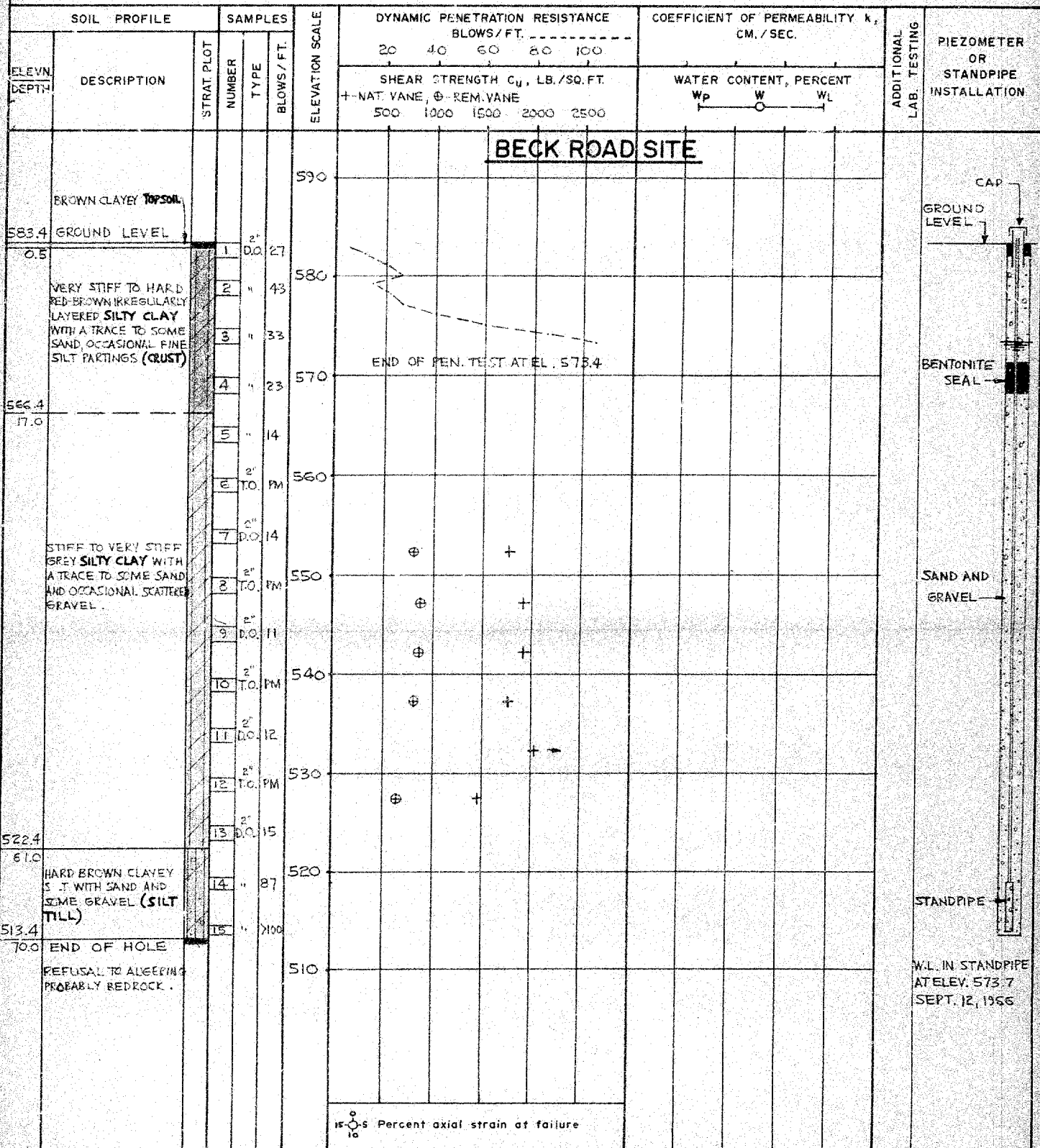


COLDER & ASSOCIATES

DRAWN *msd*
CHECKED *gbl*

RECORD OF BOREHOLE 22

LOCATION See Figure 1 BORING DATE AUG. 29, 1966 DATUM GEODETIC
 BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"
 SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES



VERTICAL SCALE
1 INCH TO 10'-0"

GOLDER & ASSOCIATES

DRAWN *ALD*
CHECKED *ARD*

RECORD OF BOREHOLES 23, 24.

LOCATION See Figure 1

BORING DATE AUG. 23, 1966

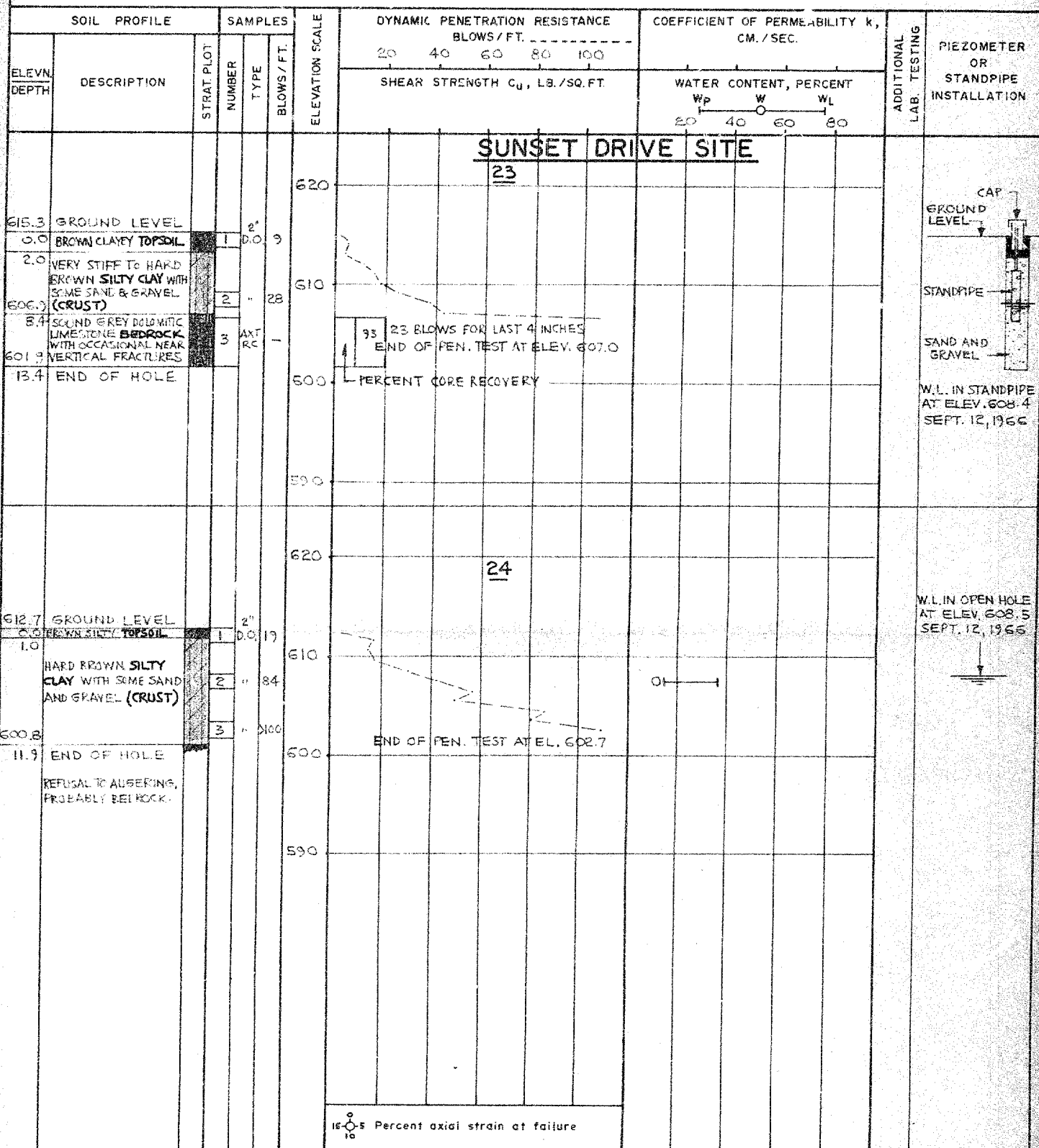
DATUM GEODETIC

BOREHOLE TYPE POWER AUGER BORING

BOREHOLE DIAMETER 4.5", BX CASING

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES

PEN. TEST HAMMER WEIGHT 140 LB. DROP 30 INCHES

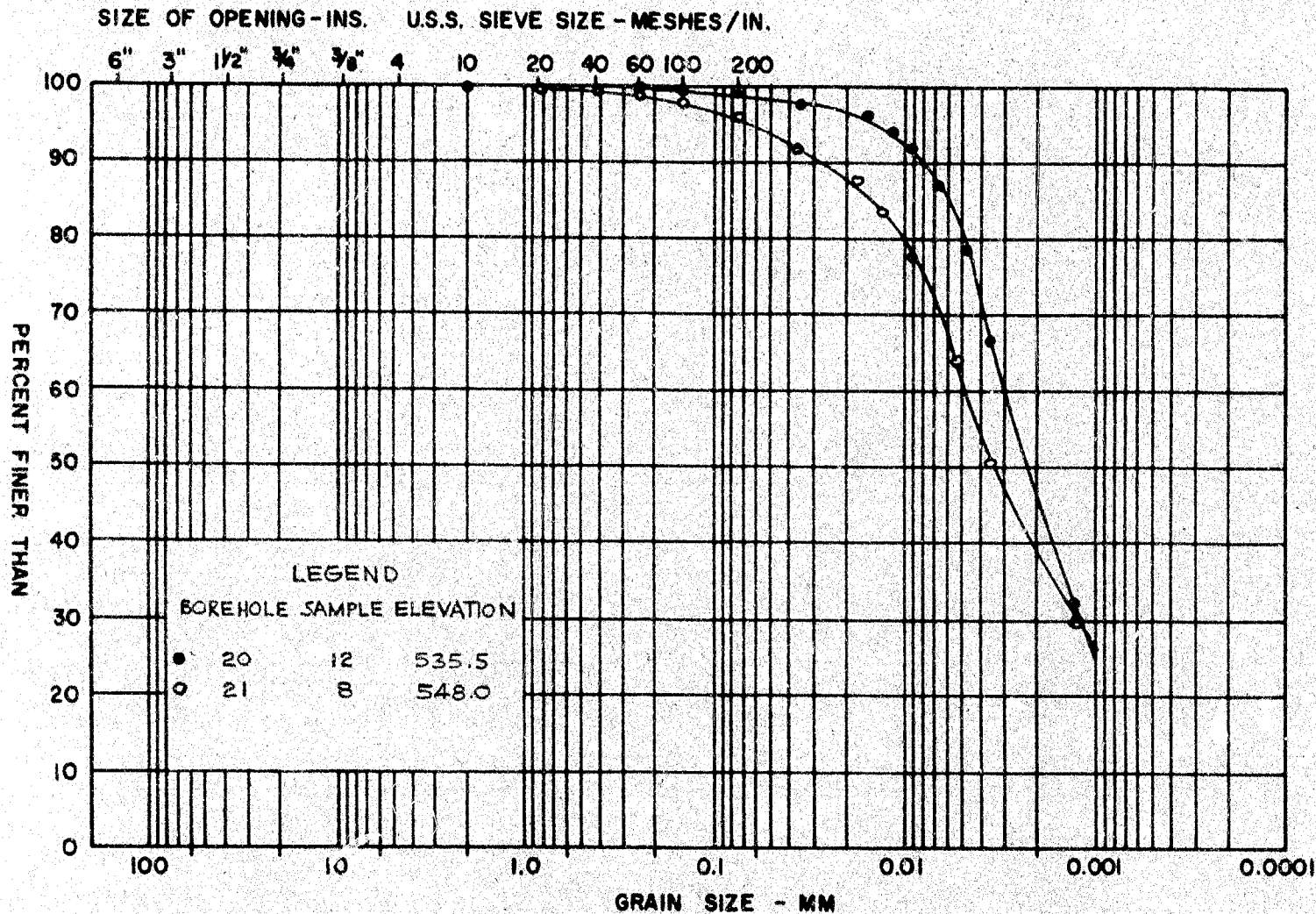


VERTICAL SCALE
1 INCH TO 10' - 0"

GOLDER & ASSOCIATES

DRAWN mw
CHECKED BD

M.I.T. GRAIN SIZE SCALE



GOLDER & ASSOCIATES

GRAIN SIZE DISTRIBUTION
SILTY CLAY STRATUM

FIGURE 2

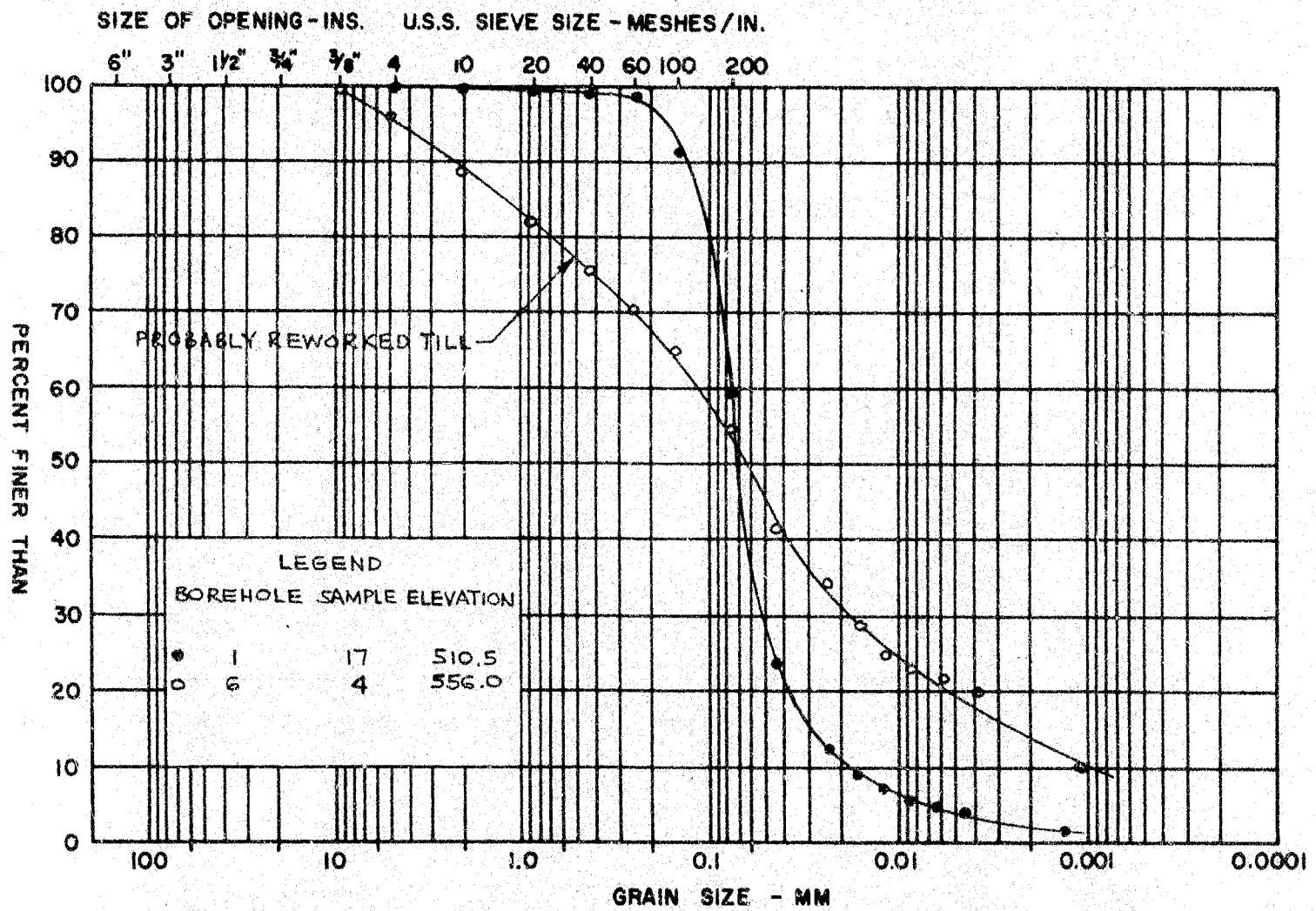
COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE		CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED		

M.I.T. GRAIN SIZE SCALE

GRAIN SIZE DISTRIBUTION
SILTY SAND

FIGURE 3

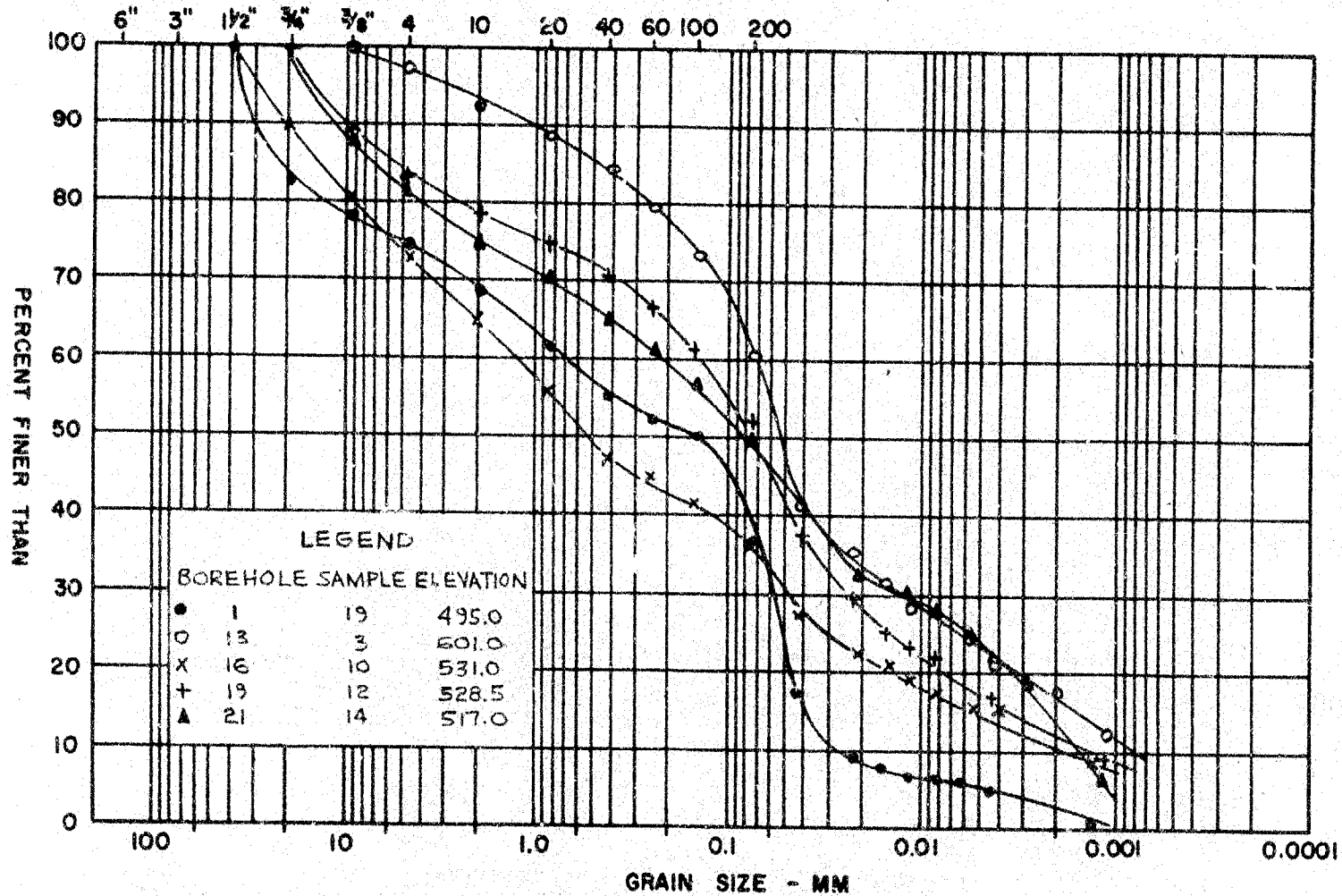
GOLDER & ASSOCIATES



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

M.I.T. GRAIN SIZE SCALE

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



GOLDER & ASSOCIATES

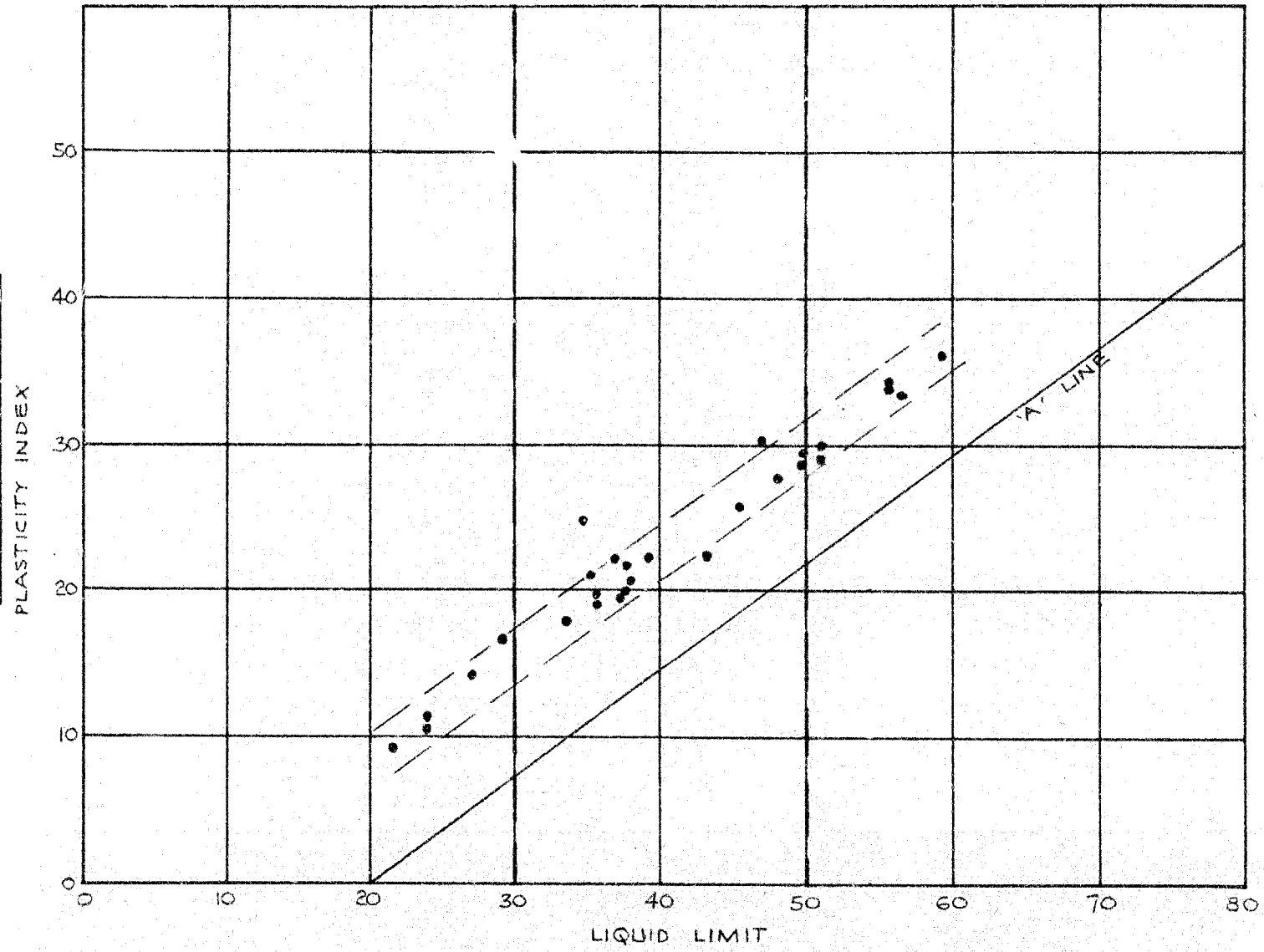
GRAIN SIZE DISTRIBUTION
(TILL)

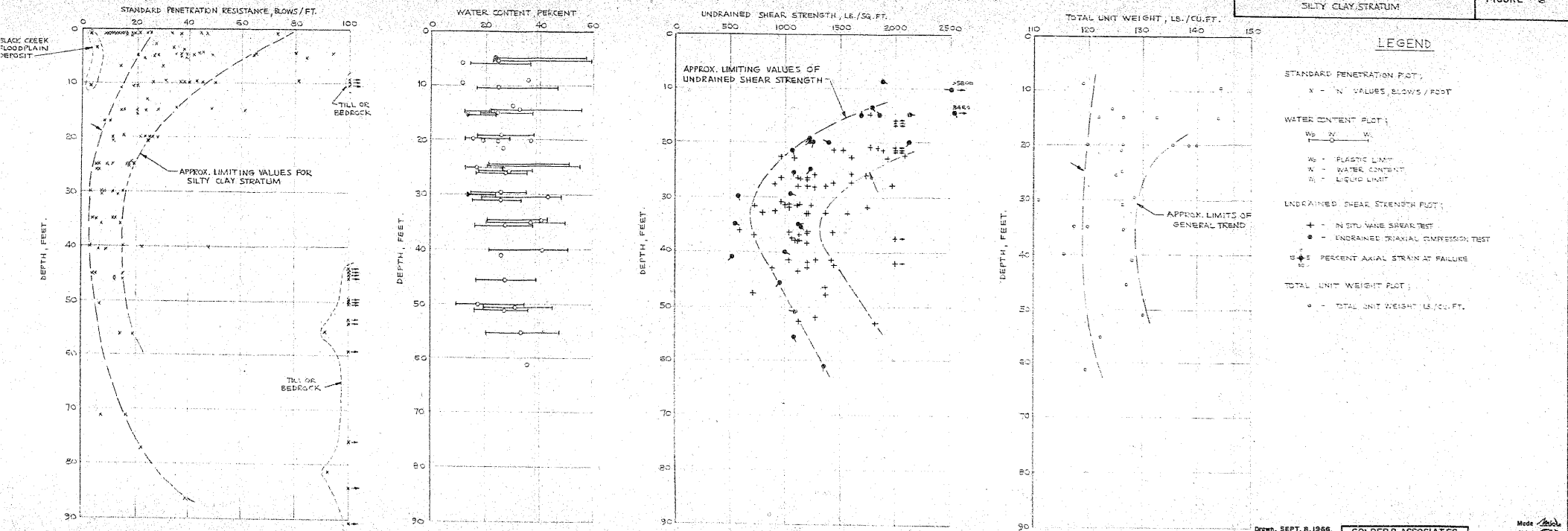
FIGURE 4

PLASTICITY CHART
SILTY CLAY STRATUM

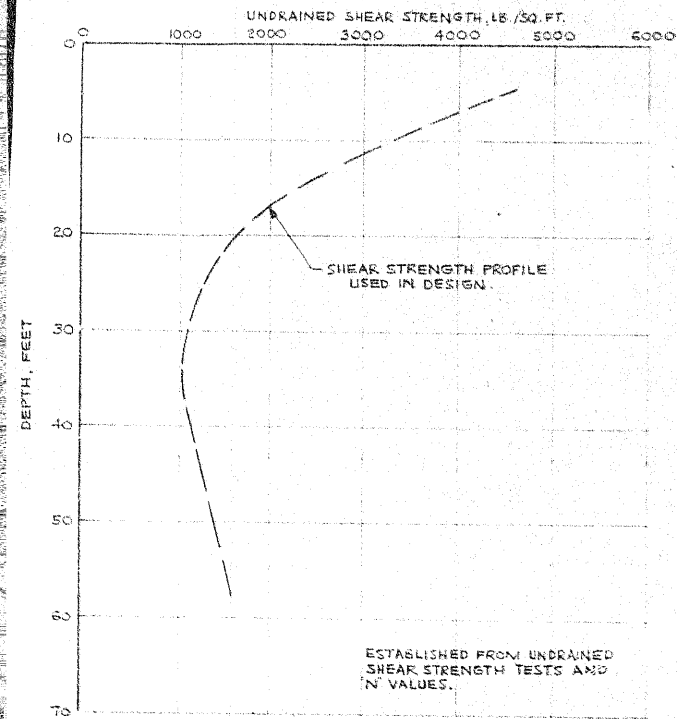
FIGURE 5

GOLDER & ASSOCIATES

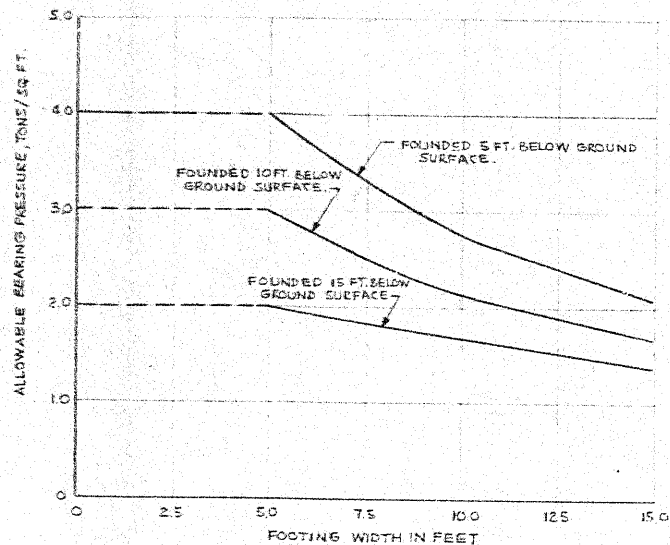




UNDRAINED SHEAR STRENGTH PROFILE USED FOR DESIGN



VARIATION OF ALLOWABLE BEARING PRESSURE WITH FOOTING WIDTH AND FOUNDING DEPTH

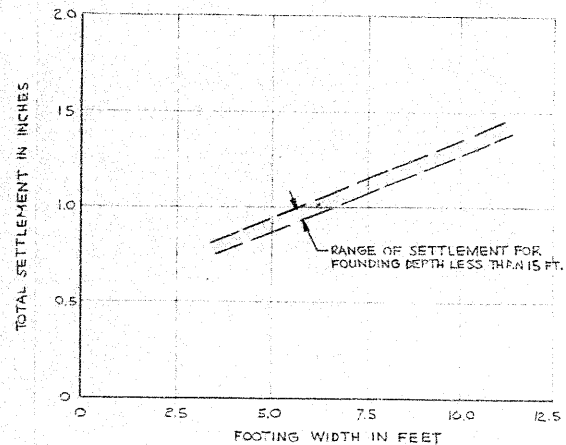


NOTE: ALLOWABLE BEARING PRESSURES GIVEN ABOVE ARE 1/3 OF ULTIMATE BEARING CAPACITY (i.e. F.S. = 3.0)

ALLOWABLE BEARING PRESSURES AND ESTIMATED SETTLEMENTS BASED ON GENERAL ENGINEERING PROPERTIES OF SILTY CLAY STRATUM.

FIGURE 7

ESTIMATED SETTLEMENT OF FOOTINGS FOUNDED ABOVE 15 FT. DEPTH (EXCLUDING SURCHARGE LOADING SUCH AS APPROACH EMBANKMENTS)



APPENDIX ISITE NO. 1 - BIGGER ROAD -- W.P. 158-64-2

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed underpass structure and interchange which is to carry a future extension of Bigger Road over the Queen Elizabeth Way is located some 750 feet west of the west branch of Lyons Creek in the Township of Willoughby, County of Welland, Ontario. The field work for the investigation at this structure location was carried out between August 3 and 14, 1966. During this period two borings (numbered 1 and 2), with accompanying dynamic penetration tests, were put down to depths of about 98 and 86 feet using a mobile power auger equipped to carry out both wash boring and diamond core drilling operations.

The locations of the borings together with a section of the inferred subsurface stratigraphy across the site are shown on Figure 8, following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by some 63 feet of silty clay extending down to about elevations 512 and 519. The stratum consists generally of a homogeneous grey silty clay with a trace to some sand and a trace of gravel, but above about elevation 565 the clay frequently has a layered structure and has been weathered and desiccated to a red-brown colour. The clay is of medium plasticity with a liquid limit of about 35 and a plasticity index of about 20. The in situ water content increases from about 25 to 35 percent with depth. Based on the results of in situ field vane tests, undrained triaxial compression tests and standard penetration tests, the clay is stiff to hard in the upper desiccated zone and firm to stiff below about elevation 565. A plot of undrained shear strength versus elevation is presented on Figure 8.

In borehole 2, a 10 foot thick inclusion of compact red-brown silt containing some sand and a trace of clay was encountered within the clay between about elevations 535 and 525.

The silty clay stratum is underlain by some 20 feet of compact to very dense red-brown silty sand containing a trace of clay. The sand is in turn underlain at about elevation 493 to 497 by a deposit of sandy till which was not completely penetrated by either

boring. The till consists of very dense red-brown silty sand and gravel with a trace of clay. Some cobbles were encountered throughout the till deposit necessitating the use of diamond drilling techniques.

The groundwater level across the site was established in each borehole by readings taken in piezometers. The groundwater level was found to be within the silty clay stratum at an average elevation of about 565.

DISCUSSION

As shown on the plan given on Figure 8, it is proposed to construct an interchange with an underpass structure to carry Bigger Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available but it is understood that roadway approach embankments up to 25 feet high are proposed.

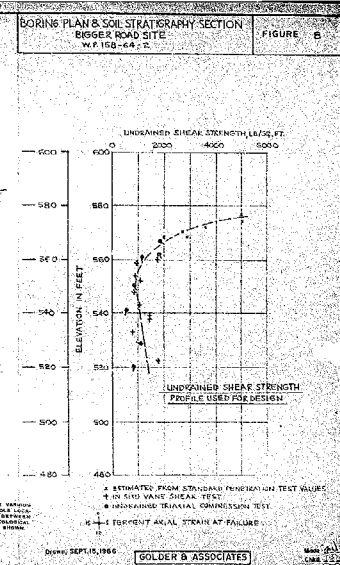
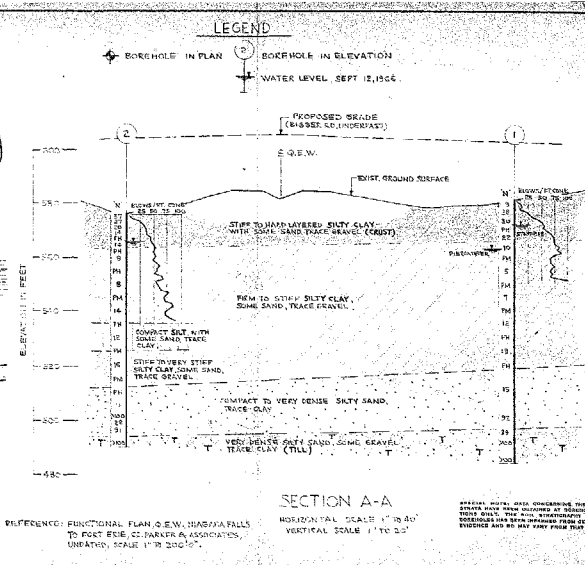
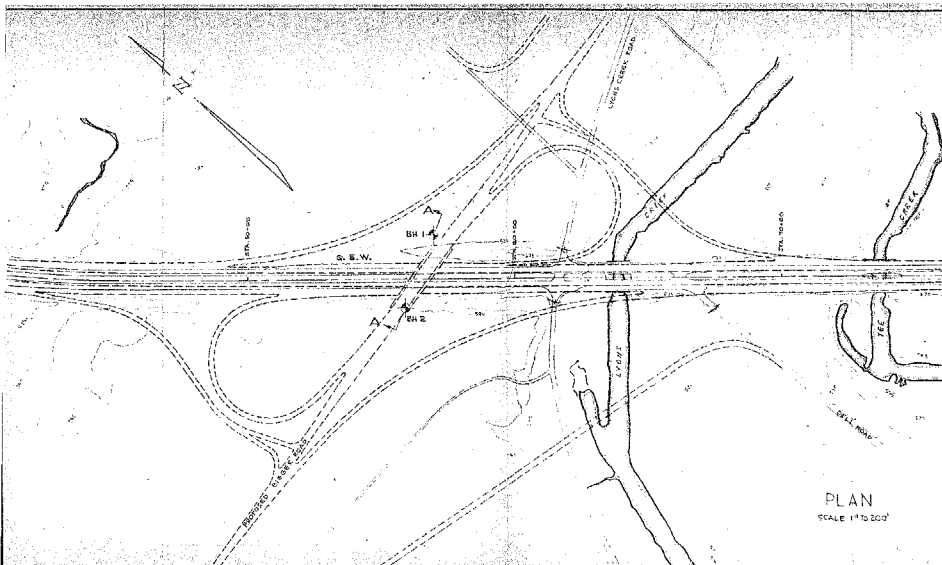
The significant stratum at this site is the firm to stiff silty clay deposit of which the upper 10 to 15 feet have been weathered to a stiff to hard crust. There should be no overall stability problem for 25 foot high roadway embankments placed on the clay, provided side and end slopes of not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed

of properly compacted fill material. All topsoil should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 4 to 6 inches.

Spread footings may be considered for support of the structure, especially at pier locations. Since the undrained shear strength of the clay decreases with depth the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take advantage of the very stiff upper crust footings should be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design an allowable bearing pressure some 10 to 15 percent less than that given on Figure 7 of the main report may be used. This is because the undrained shear strength at this site is lower than that taken for general design along the route. As an example a five foot wide footing founded at elevation 571 (a depth of about 10 feet) should be designed for an allowable bearing pressure of about 2.5 tons/sq.ft. Settlement of pier footings imposing the above loading is estimated to be of the order of 1 to 1.5 inches.

The use of spread footings throughout could result in differential settlements of up to several inches between piers and

abutments. To minimize or eliminate differential settlement consideration should be given to founding the abutments and, if a continuous structure is to be employed at this site, also the piers on piles. For 12 inch steel H-piles driven to refusal in the very dense till an allowable load of up to 70 tons/pile may be used for preliminary design.



APPENDIX IISITE NO. 2 - BECK ROAD - NO W.P. 442-65

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed flyover to carry the existing Beck Road over the Queen Elizabeth Way is located in the Township of Willoughby, County of Welland, Ontario. The field work for the subsurface investigation at this structure location was carried out between August 25 and 29, 1966. During this period two borings (numbered 21 and 22), with accompanying dynamic penetration tests were put down to depths of about 80 and 70 feet using a mobile power auger equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface conditions across the site are presented on Figure 9 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by up to 2 feet of brown clayey topsoil followed by some 60 feet of silty clay

extending down to about elevation 520. The clay stratum consists generally of homogeneous grey silty clay containing a trace to some sand and occasional scattered gravel. Above about elevation 565 the clay has an irregularly layered structure and has been weathered and desiccated to a red-brown colour. The clay is of medium plasticity with a liquid limit of about 40 and a plasticity index of about 22. The in situ water content increases from about 25 percent to 35 percent with depth. Based on the results of in situ field vane tests, undrained triaxial compression tests and standard penetration tests, the consistency of the clay is stiff to hard in the upper desiccated zone and firm to very stiff below about elevation 565. A plot of undrained shear strength versus elevation is presented on Figure 9.

The clay is underlain by some 10 feet of till which in borehole 21 consists of very dense grey silty sand with some gravel and a trace to some clay and is a hard brown clayey silt with sand and some gravel in borehole 22.

Underlying the till at elevations 510 and 513 in boreholes 21 and 22, respectively, fractured grey dolomite bedrock was encountered. Bedrock was proved by core drilling for about 10 feet in borehole 21 and was inferred from auger refusal in borehole 22.

The groundwater level across the site was found to be within the silty clay stratum between about elevations 563 and 573, on September 12, 1966.

DISCUSSION

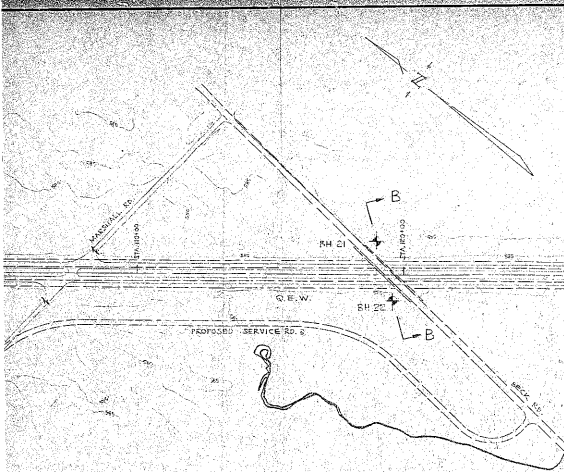
As shown on the plan given on Figure 9, it is proposed to construct a flyover to carry Beck Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available but it is understood that roadway approach embankments up to 25 feet high will be required.

The significant stratum at this site is the firm to very stiff silty clay deposit of which the upper 18 feet have been weathered to a stiff to hard crust. There should be no overall stability problem for 25 foot high roadway embankments placed on the clay, provided side and end slopes of not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. All topsoil should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 4 to 5 inches.

Spread footings may be considered for the support of the structure, especially at pier locations. Since the undrained shear

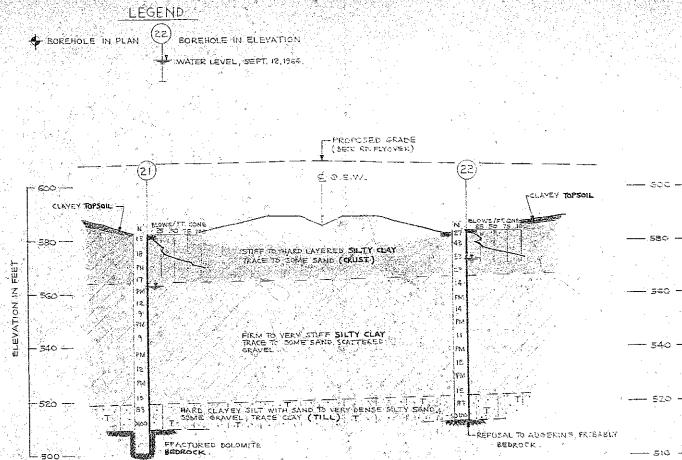
strength of the clay decreases with depth, the allowable bearing pressure for spread footings is dependent on footing width and founding elevation. To take advantage of the very stiff upper crust, footings should be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design, the allowable bearing pressures given on Figure 7 in the main report may be used. As an example, a five foot wide footing founded at about elevation 578 (a depth of about 5 feet) may be designed for an allowable bearing pressure of up to 4 tons per sq.ft. Settlement of pier footings imposing the above loading is estimated to be of the order of 1 to 1.5 inches.

The use of spread footings throughout could result in differential settlements of up to several inches between piers and abutments. To minimize differential settlement consideration should be given to founding the abutments and, if a continuous structure is to be employed at this site, also the piers on piles. For 12 inch steel H-piles driven to refusal in the very dense till or on bedrock, an allowable load of up to 70 tons per pile may be used for preliminary design.



PLAN
SCALE 1" TO 200'

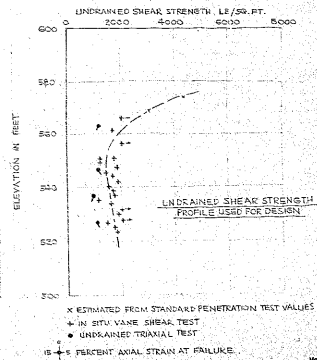
REFERENCE: FUNCTIONAL PLAN, Q.E.W. NIAGARA FALLS
TO FORT BRIS, C. J. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 250'-0"



SECTION B-B
HORIZONTAL SCALE: 1" TO 40'-0"
VERTICAL SCALE: 1" TO 20'-0"

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

BOREHOLE PLAN & SOIL STRATIGRAPHY
BECK ROAD SITE
NO. W. P. NUMBER
FIGURE 3



Drawn, SEPT. 20, 1966

GOLDER & ASSOCIATES

Mod
Chad
Appa

APPENDIX IIISITE NO. 3 - BOSSERT ROAD - NO W.P. 443-65

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed flyover to carry the existing Bossert Road over the Queen Elizabeth Way is located in the Township of Willoughby, County of Welland, Ontario. The field work for the subsurface investigation at this structure location was carried out on August 24 and 25, 1966. Two borings (numbered 19 and 20), with accompanying dynamic penetration tests, were put down to a depth of about 60 feet using a mobile power auger.

The location of the borings together with a section of the inferred subsurface conditions across the site are presented on Figure 10 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by some 50 feet of silty clay extending down to about elevation 533. The

clay stratum consists generally of homogeneous grey silty clay with a trace to some sand and a trace to gravel, but above about elevation 560 the clay frequently has a layered structure and has been weathered and desiccated to a red-brown colour. The clay is of medium to high plasticity with a liquid limit of between about 35 and 60 and a corresponding plasticity index of between 20 and 30. The in situ water content increases from about 25 percent in the desiccated crust to about 40 percent at depth. Based on the results of in situ field vane tests, undrained triaxial compression tests and standard penetration tests, the clay has a very stiff to hard consistency in the upper desiccated crust and is firm to stiff below about elevation 560. An undrained shear strength profile for the clay is presented on Figure 10.

The clay is underlain by some 3 to 10 feet of till which in borehole 19 consists of very dense brown silty sand with some gravel and a trace of clay and is a hard brown clayey silt with sand and some gravel in borehole 20.

At about elevation 525 to 528, the till is underlain by what is considered to be weathered bedrock. Auger refusal on what is probably sound bedrock was met at about elevations 524 and 527 in boreholes 19 and 20, respectively.

The groundwater level across the site was found to be within the desiccated crust of the silty clay stratum between about elevations 572 and 582, on September 12, 1966.

DISCUSSION

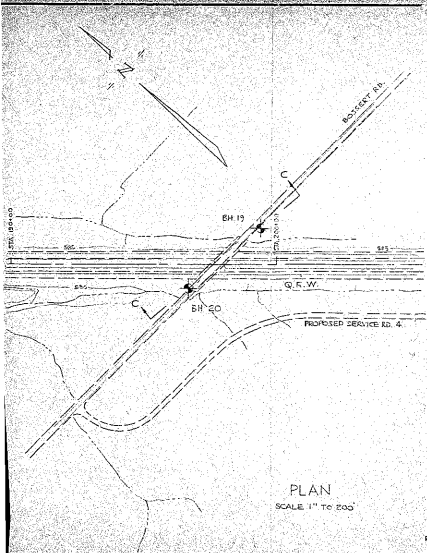
As shown on the plan given in Figure 10, it is proposed to construct a flyover to carry Bossert Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 22 feet high will be required.

The significant stratum at this site is the firm to stiff silty clay deposit, of which the upper 20 to 30 feet have been weathered to a very stiff to hard crust. There should be no overall stability problem for 22 foot high roadway embankments placed on the clay, provided side and end slopes not steeper than 2 horizontal to 1 vertical are used and the embankment is constructed of properly compacted fill material. Any topsoil deposits should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 3 to 5 inches.

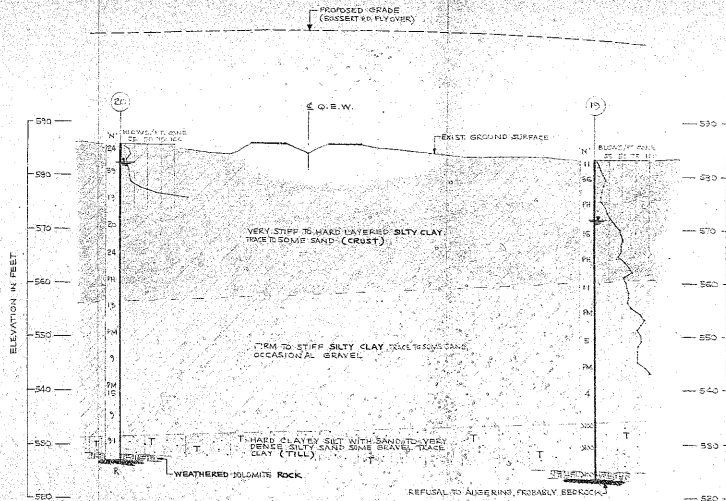
Spread footings may be considered for the support of the structure, especially at pier locations. Since the undrained shear

strength of the clay decreases with depth, the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take advantage of the very stiff upper crust, footings should be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design, the allowable bearing pressure given on Figure 7 of the main report may be used. As an example, a footing 5 feet wide founded at elevation 584 (a depth of about 5 feet) may be designed for an allowable bearing pressure of up to 4 tons/sq.ft. Settlement of pier footings imposing the above loading is estimated to be about 1 inch.

The use of spread footings throughout could result in differential settlements of several inches between piers and abutments. To minimize or eliminate differential settlement, consideration should be given to founding the abutments and, if a continuous structure is to be employed at this site, also the piers on piles. For 12 inch steel H-piles driven to refusal in the very dense till or on bedrock an allowable load of up to 75 tons per pile may be used for preliminary design.



REFERENCE: FUNCTIONAL PLAN, Q.E.W. NIAGARA FALLS
TO FORT ERIE, C.C. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 200' - 0"



SPECIAL NOTE: DATA CONCERNING THE VARIOUS
STRATA HAVE BEEN OBTAINED BY BORING LOCAL
TRENCHES ONLY. THE SOIL STRATIGRAPHY BETWEEN
BORINGHOLE HAS BEEN INFERRED FROM GEOLOGICAL
EVIDENCE AND SO MAY VARY FROM THAT SHOWN.

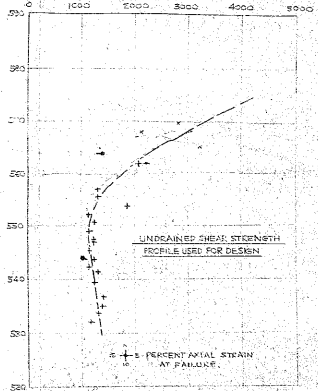
BORING PLAN & SOIL STRATIGRAPHY SECTION
BOSSERT ROAD SITE
NO. W.P. NUMBER

FIGURE 10

LEGEND

- BOREHOLE IN PLAN
- BOREHOLE IN ELEVATION
- ± WATER LEVEL, SEPT. 12, 1966

UNDRAINED SHEAR STRENGTH, LB/SQ. FT.



x ESTIMATED FROM STANDARD PENETRATION TEST VALUES
+ IN SITU VANE SHEAR TEST
• UNDRAINED TRIAXIAL TEST
DRAWN, SEPT. 19, 1966

GOLDER & ASSOCIATES

Made by
CHS
App'd

APPENDIX IVSITE NO. 4 - SODOM ROAD - W.P. 159-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed underpass structure which is to carry the existing Sodom Road over the Queen Elizabeth Way is located in the Township of Willoughby, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out between August 15 and 17, 1966. During this period two borings (numbered 3 and 4), with accompanying dynamic penetration tests, were put down to depths of about 52 and 54 feet using two mobile power augers, one of which was equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 11 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

Underlying some 2 feet of compact brown sandy topsoil on

the north side of the Queen Elizabeth Way and directly beneath ground surface on the south side, the borings encountered a silty clay stratum some 38 to 47 feet thick. The stratum consists generally of homogeneous grey silty clay with a trace to some sand and a trace of gravel, but above a depth of about 22 feet the clay generally has a layered structure and has been weathered and desiccated to a red-brown colour. The clay is of medium plasticity with a liquid limit of about 40 to 50 and a plasticity index of about 20 to 30. The in situ water content increases from about 25 percent to 35 percent with depth. Based on the results of in situ field vane tests, undrained triaxial compression tests and standard penetration tests, the clay is very stiff to hard in the upper desiccated zone and firm to stiff below about elevation 560. A plot of undrained shear strength versus elevation is presented on Figure 11.

The silty clay stratum is underlain by up to about 16 feet of till which was not completely penetrated by borehole 4. The till varies across the site from red-brown clayey silt with sand and some gravel to silty sand with some gravel and a trace to some clay. Occasional cobbles were encountered in the sandy portion of the till. Standard penetration tests carried out in the till indicate that the clayey portion is generally hard and the sandy portion very dense. The upper 3 to 4 feet of the clayey portion of the till, however, has

been softened to a very stiff consistency.

Underlying the till in borehole 3 is fairly sound grey dolomite bedrock containing some vertical fractures. The bedrock was proved for about 4 feet by core drilling in AXT size.

The groundwater across the site was established in each borehole by readings taken in standpipes. On September 12, 1966 the groundwater level was found to be within the upper crust of the silty clay stratum at about elevation 572 to 576.

DISCUSSION

As shown on the plan given on Figure 11, it is proposed to construct an interchange with an underpass structure to carry Sodom Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 25 feet high will be required.

The significant stratum at this site is the stiff silty clay deposit, of which the upper 20 to 25 feet have been weathered to a very stiff to hard crust. There should be no overall stability problem for 25 foot high roadway embankments placed on the clay, provided side and end slopes not steeper than 2 horizontal to 1 vertical

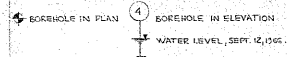
are used and the embankments are constructed of properly compacted fill material. All topsoil should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 3 to 4 inches.

Spread footings may be considered for support of the underpass structure, especially at pier locations. Since the undrained shear strength of the clay decreases with depth the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take advantage of the very stiff upper crust, footings should be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design the allowable bearing pressures given on Figure 7 of the main report may be used. As an example, a five foot wide footing founded at about elevation 575 (a depth of about 5 feet) could be designed for an allowable bearing pressure of up to 4 tons/sq.ft. Settlement of pier footings imposing the above loading is estimated to be about 1 inch.

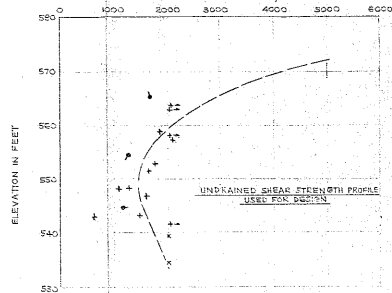
At this site the use of spread footings throughout could result in differential settlements of up to several inches between piers and abutments. To minimize or eliminate differential settlement consideration should be given to founding the abutments, and if

a continuous structure is to be employed, also the piers on piles. For 12 inch steel H-piles driven to refusal in the very dense till or on bedrock, an allowable load of up to 75 tons/pile may be used for preliminary design.

LEGEND



UNDRAINED SHEAR STRENGTH, LB./SQ. FT.

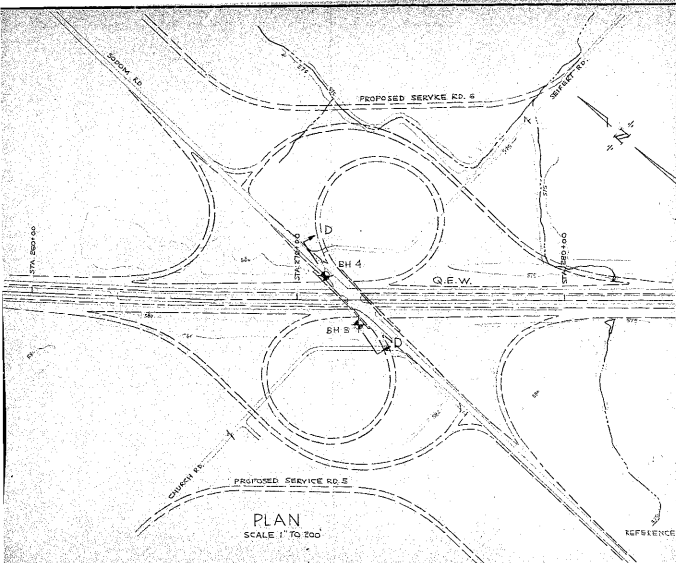


- x ESTIMATED FROM STANDARD PENETRATION TEST VALUES
- + IN SITU VANE SHEAR TEST
- UNDRAINED TRIAXIAL COMPRESSION TEST
- 1% PERCENT AXIAL STRAIN AT FAILURE

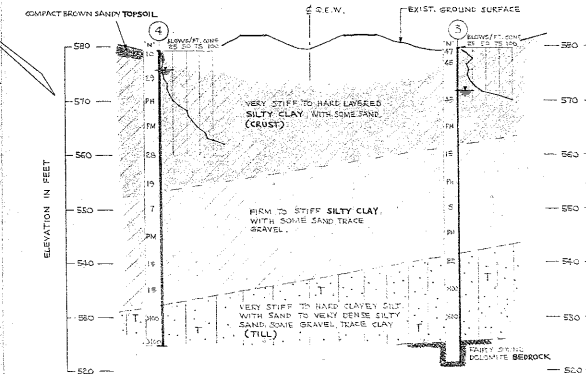
Drawn, SEPT. 19, 1966.

GOLDER & ASSOCIATES

Made by
Chd.
Appd.



PLAN
SCALE 1" TO 200'



SECTION D-D
HORIZONTAL SCALE 1" TO 40'-0"
VERTICAL SCALE 1" TO 10'-0"

REFERENCE: FUNCTIONAL PLAN Q.E.W. NIAGARA FALLS TO PORT ERIC, C.C. PARKER & ASSOCIATES, INC., 1964, SCALE 1" TO 200'-0"

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

APPENDIX V

SITE NO. 5 - BAKER ROAD - NO W.P. 445-65

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed flyover to carry the existing Baker Road over the Queen Elizabeth Way is located in the Township of Willoughby, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out on August 24 and 25, 1966. Two borings (numbered 17 and 18), with accompanying dynamic penetration tests, were put down to a depth of about 45 feet using a mobile power auger.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 12 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by as much as 42 feet of silty clay extending down to between about eleva-

tions 536 and 540. The stratum consists generally of grey silty clay with a trace of some sand and gravel, but above about elevation 560 the clay has a layered structure and has been weathered and desiccated to a mottled red-brown and grey colour. The clay is of medium plasticity with a liquid limit of between about 40 and 50 and a corresponding plasticity index of between 20 and 30. The in situ water content increases from about 25 percent in the desiccated crust to about 45 percent near the bottom of the stratum. Based on the results of in situ field vane tests, undrained triaxial compression tests and standard penetration tests, the consistency of the clay is very stiff to hard in the upper desiccated zone but decreases to firm to stiff below about elevation 555. A plot of undrained shear strength versus elevation is presented on Figure 12.

The clay is underlain in boreholes 17 and 18, respectively, by 4 and 7 feet of till. The till varies from very dense grey silty sand with some gravel and a trace of clay in borehole 17 to hard brown clayey silt with sand, some gravel and occasional cobbles in borehole 18.

The till is underlain at about elevation 533 by weathered dolomite rock which was penetrated for up to 1.5 feet by the augers. Refusal to augering on what is probably sound dolomite bedrock was met at about elevation 531 to 532.

Readings taken in the standpipe installations on September 12 1966 indicate that the groundwater level across the site is within the desiccated crust of the silty clay at about elevation 564 to 569.

DISCUSSION

As shown on the plan given on Figure 12, it is proposed to construct a flyover to carry Baker Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 22 feet high will be required.

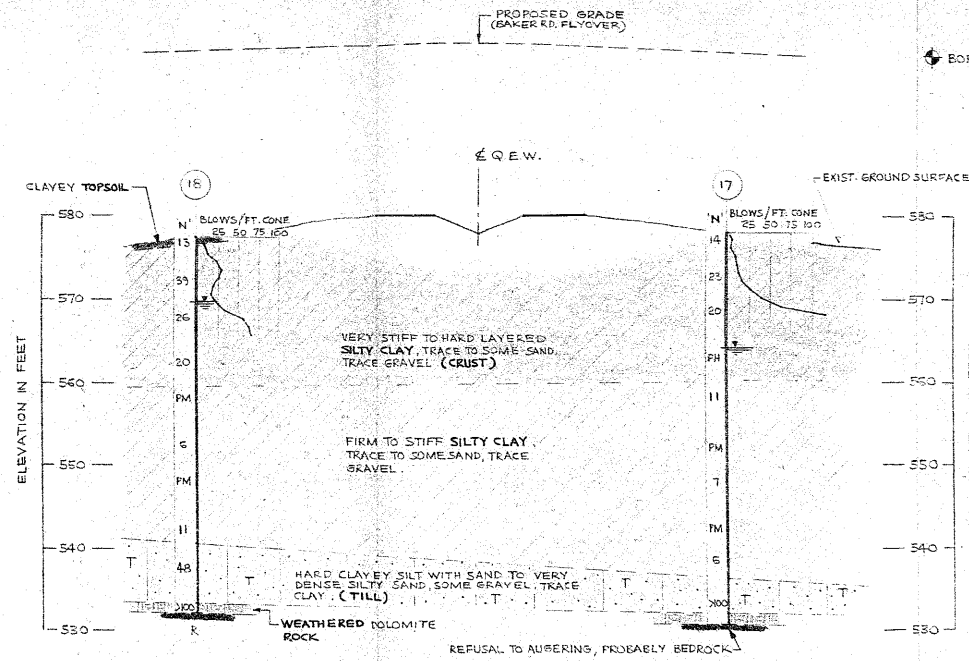
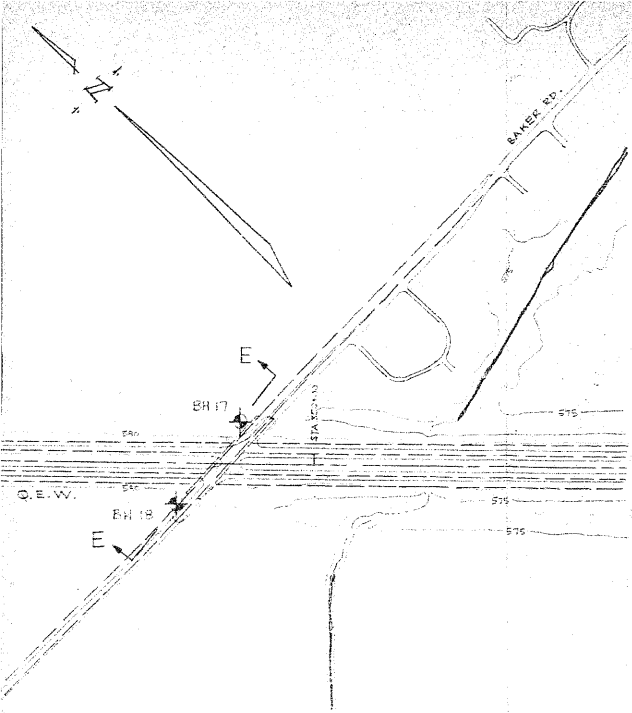
The significant stratum at this site is the firm to stiff silty clay deposit, of which the upper 18 feet have been weathered to a very stiff to hard crust. There should be no overall stability problem for 22 foot high roadway embankments placed on the clay, provided side and end slopes not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. All surficial deposits such as topsoil should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 4 to 5 inches.

Spread footings may be considered for the support of the

flyover structure, especially at pier locations. Since the undrained shear strength of the clay decreases with depth, the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take advantage of the very stiff upper crust, footings should be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design allowable bearing pressures similar to those given on Figure 7 of the main report may be used. However, the allowable bearing pressure for footings of the order of 10 feet wide or any footings founded more than about 5 feet below ground surface should be reduced by about 15 percent from the values given on Figure 7. This is because the undrained shear strength with depth at this site is lower than that taken for general design along the route. As an example, a 10 foot wide footing founded at elevation 573 (a depth of about 5 feet) should be designed for an allowable bearing pressure of not greater than about $2\frac{1}{4}$ tons/sq.ft. Settlement of pier footings imposing the above loading is estimated to be of the order of 1 to 1.5 inches.

At this site the use of spread footings throughout could result in differential settlements up to several inches between piers and abutments. To minimize or eliminate differential settlement consideration should be given to founding the abutments and, if a contin-

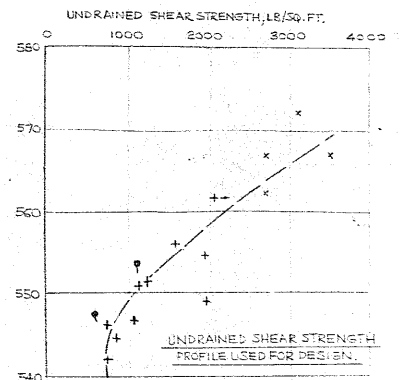
uous structure is to be employed at this site, also the piers on piles. For 12 inch steel H-piles driven to refusal in the till or bedrock, an allowable load of up to 75 tons/pile may be used for preliminary design.



REFERENCE: FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS
 TO FORT ERIG, C.C. PARKER & ASSOCIATES,
 UNDATED, SCALE 1" TO 200'-0".

LEGEND

- BOREHOLE IN PLAN
- BOREHOLE IN ELEVATION
- WATER LEVEL, SEPT. 12, 1966



- x ESTIMATED FROM STANDARD PENETRATION TEST VALUES.
- + IN SITU VANE SHEAR TEST
- UNDRAINED TRIAXIAL TEST

15-5 PERCENT AXIAL STRAIN AT FAILURE
 10

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

Drawn, SEPT. 20, 1966

GOLDER & ASSOCIATES

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

APPENDIX VISITE NO. 6 - TOWNLINE ROAD AND BLACK CREEK ROAD - W.P. 167-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed underpass structure which is to carry the realigned Black Creek Road over the Queen Elizabeth Way is located some 1,000 feet west of the existing Black Creek Road at-grade crossing in the Township of Willoughby, County of Welland, Ontario. The proposed Townline Road flyover is located some 2,350 feet east of the proposed Black Creek Road interchange in the Township of Bertie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out on August 17 and 18, 1966. During this period two boreholes (numbered 5 and 6), with accompanying dynamic penetration tests, were put down to depths of about 20 and 30 feet using two mobile power augers equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface conditions along the Queen Elizabeth Way are presented on Figure 13 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

At the borehole 5 location, put down at the proposed Black Creek Road interchange, the site is underlain by about 15 feet of desiccated brown silty clay with some sand and a trace of gravel. The silty clay has a layered structure and the consistency of the clay is very stiff to hard.

The silty clay is underlain by some 6 feet of very stiff till consisting of red-brown clayey silt with sand and some gravel. The till is followed at about elevation 558 by sound grey dolomite bedrock, the upper portion of which has been weathered.

The proposed Townline Road flyover is to be located within the Black Creek floodplain. Borehole 6 put down at this site indicates that the floodplain is underlain by some 5 feet of recently deposited soft to firm dark grey to brown silty clay with a trace to some sand and organic matter. This surficial floodplain deposit is followed by about 10 feet of very loose to loose grey silty sand with some clay and gravel. The silty sand has a till-like appearance and is probably a till which has been reworked by stream action.

The reworked till is underlain at about elevation 551 by sound grey dolomitic limestone bedrock which has been weathered in the upper 2 to 3 feet.

At the proposed Black Creek Road interchange the groundwater level (on September 12, 1966) was within the desiccated clay at about elevation 569 or some 11 feet below ground surface. Near Black Creek (Townline Road Flyover) the groundwater level was found to be at about elevation 564 which corresponds to the water level in the creek.

DISCUSSION

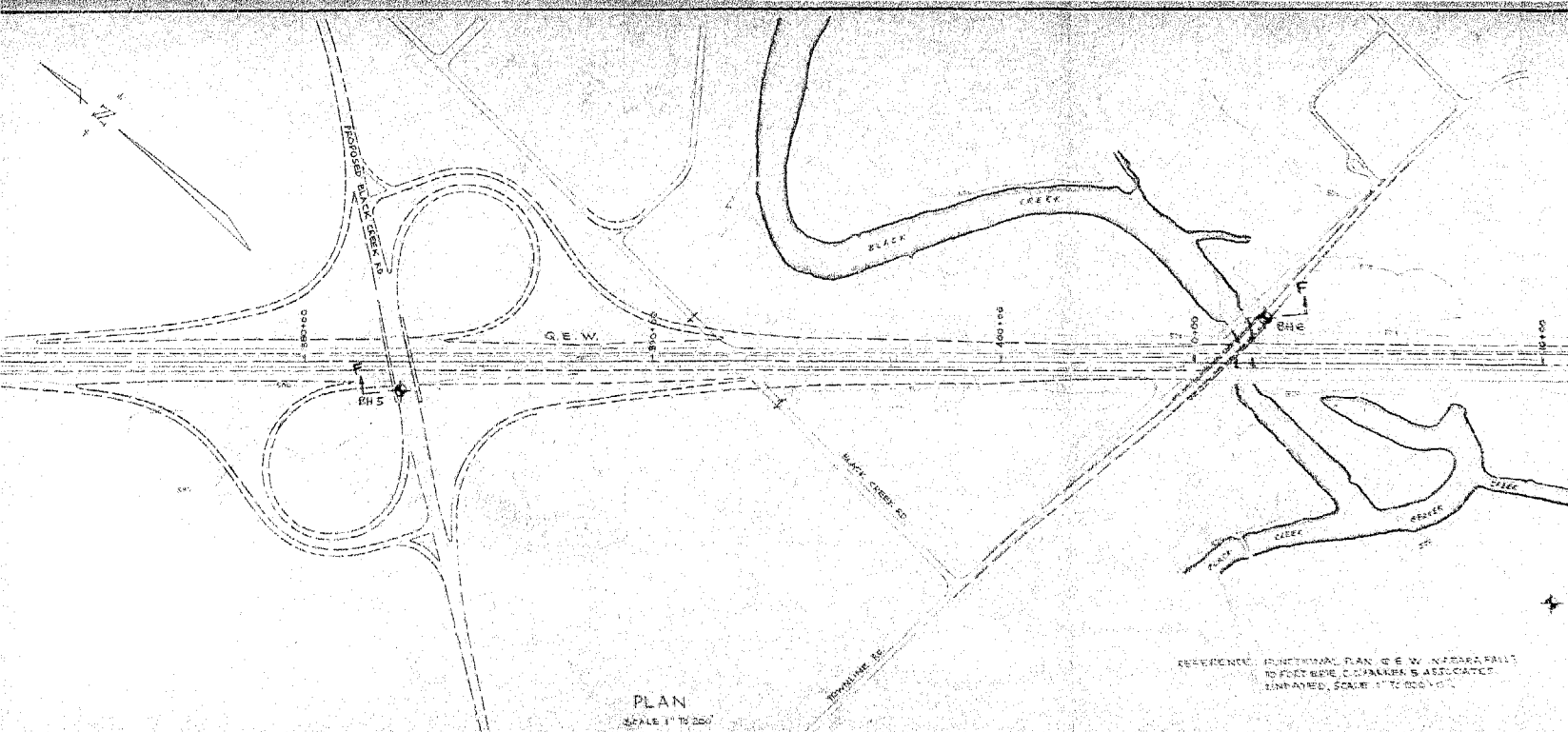
As shown on the plan given on Figure 13, it is proposed to construct an interchange with an underpass structure to carry Black Creek Road over the Queen Elizabeth Way and a flyover to carry Townline Road over the Queen Elizabeth Way and Black Creek. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 22 feet high at Black Creek Road and up to 30 feet high at Townline Road will be required.

The significant stratum for foundation design purposes at the Black Creek Road site is the very stiff to hard desiccated silty clay deposit and at the Townline Road site the significant strata are the loose reworked till and the bedrock. There should be no overall stability problem for roadway embankments of the height envisaged at either site, provided end and side slopes of not steeper

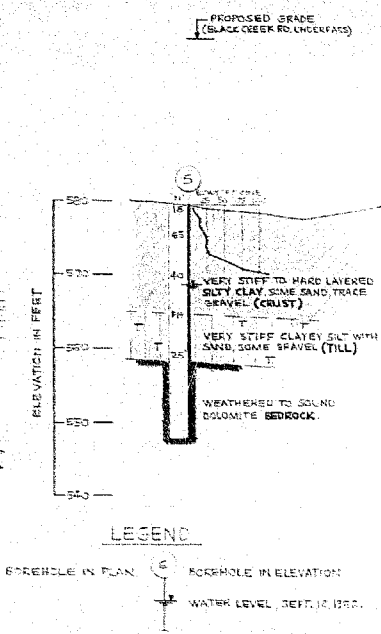
than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. Further, any topsoil deposits and all of the soft clayey Black Creek floodplain deposit must be removed beneath the full embankment width. Settlement due to consolidation of the subsoil under the full embankment loading is estimated to be less than 1 inch at the Black Creek Road site and about 1 to 2 inches at the Townline Road site.

At the Black Creek Road site the underpass structure may be founded on spread footings placed in the hard silty clay deposit using for preliminary design purposes an allowable bearing pressure of up to 4 tons/sq.ft. Because the till underlying the clay is relatively softer, the footings should be founded as high as possible in the clay consistent with frost protection requirements of 4 feet of earth cover. Should it be necessary to take the footings down below about elevation 570, the allowable bearing pressure should be reduced to 3 tons/sq.ft. Settlement of footings imposing the above loading should be less than about 1 inch or of the order estimated for the roadway approach embankments. Stub abutments may be founded within the roadway approach embankments using a bearing pressure of 2 tons/sq.ft., provided the roadway fill is adequately compacted under engineering supervision.

Due to the loose state of compaction of the overburden at Townline Road, the structure should be founded on the bedrock using either spread footings or piles. For spread footings founded on the weathered upper portion of the bedrock an allowable bearing pressure of 10 tons/sq.ft. may be used for preliminary foundation design. The use of spread footings will require excavation in non-cohesive soil below the groundwater level, thus necessitating some method of groundwater control such as a sheet pile cofferdam around the footing excavations or dewatering by means of a properly installed vacuum well point system. To avoid costly groundwater control operations, consideration should be given to founding the Townline Road flyover structure on piles and bearing on bedrock. For example, 12 inch steel H-piles driven to refusal in the bedrock may be designed using an allowable load of up to 75 tons/pile. Settlement of the flyover structure founded on bedrock as discussed above will be negligible.



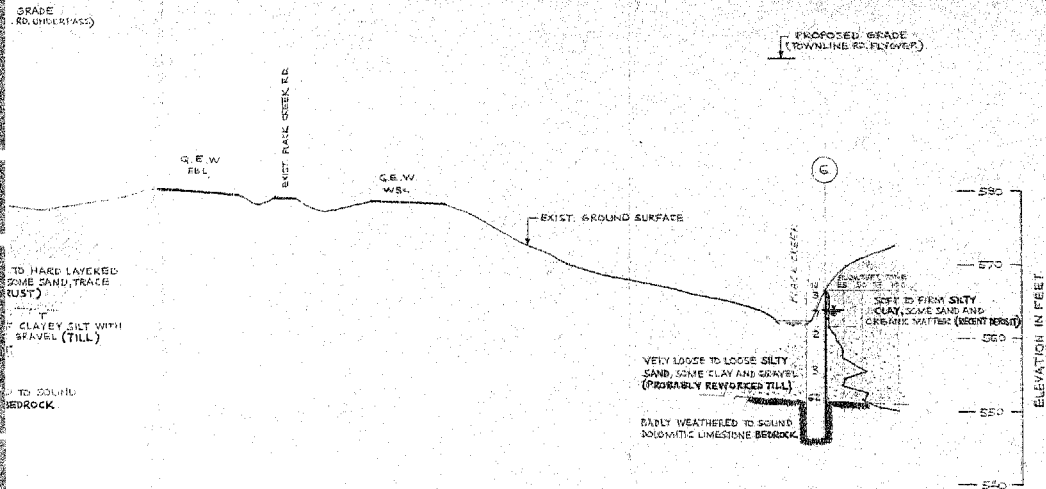
PLAN
SCALE 1" TO 200'



REFERENCE: FUNCTIONAL PLAN OF D.E.W. NEAR FALLS
TO FOOT BRIDGE, CHAMBERS IS ASSOCIATED
ENGINEER, SCALE 1" TO 200' 0"

BORING PLAN & SOIL STRATIGRAPHY SECTION
 TOWNLINE & BLACK CREEK RDS. SITE
 W.P. 167-64

FIGURE 15



SECTION F-F

HORIZONTAL SCALE: 1" TO 200'
 VERTICAL SCALE: 1" TO 10'

SPECIAL NOTE: DATA CONCERNING THE VARIOUS STRATA HAVE BEEN OBTAINED AT SPORADIC LOCAL TONES ONLY. THE SOIL STRATIGRAPHY BETWEEN BOREHOLE HAS BEEN INFERRRED FROM GEOLOGICAL EVIDENCE AND DO NOT VARY FROM THAT SHOWN.

DRAWN, SEPT. 16, 1966.

GOLDER & ASSOCIATES

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

APPENDIX VIISITE NO. 7 - RIDGEMOUNT ROAD - W.P. 165-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed flyover to carry the existing Ridgemount Road over the Queen Elizabeth Way is located in the Township of Bertie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out on August 23 and 24, 1966. Two borings (numbered 15 and 16), with accompanying dynamic penetration tests, were put down to a depth of about 45 feet using a mobile power auger.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 14 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by as much as 46 feet of silty clay extending down to between about elevations 529 and 535. This stratum consists generally of homogeneous

grey silty clay with some sand and, below about elevation 532, occasional silty sand layers. Above a depth of about 20 feet the clay has been weathered and desiccated to a red-brown colour and occasionally has a layered structure. The silty clay is of medium to high plasticity with a liquid limit of between about 45 and 55 and a plasticity index of about 22 to 34. The in situ water content varies from about 30 percent in the upper desiccated zone to about 40 percent in the lower portion of the stratum. Based on the results of in situ field vane test, undrained triaxial compression tests and standard penetration tests, the consistency of the clay in the desiccated crust is very stiff to hard and in the lower portion of the deposit, below about elevation 555, it is firm to stiff. An undrained shear strength profile for the silty clay is presented on Figure 14.

The silty clay is underlain by up to about 5 feet of compact to very dense sandy till consisting of red brown silty sand with some clay and gravel.

Refusal to augering on what is probably sound to fairly sound bedrock was met at about elevation 530 in both borings.

Following completion of each boring a standpipe or piezometer was installed for groundwater level observation. On September 12, 1966 the groundwater level was found to be within the silty clay stratum at about elevation 565 to 568.

DISCUSSION

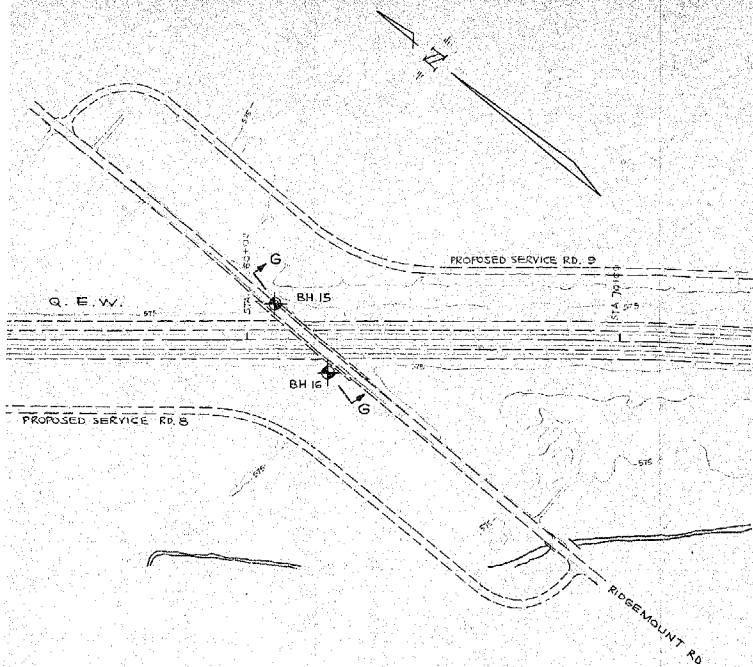
As shown on the plan given on Figure 14, it is proposed to construct a flyover to carry Ridgemount Road over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 22 feet high will be required.

The significant stratum at this site is the firm to stiff silty clay deposit, of which the upper 20 feet have been weathered to a very stiff to hard crust. There should be no overall stability problem for 22 foot high roadway embankments, provided side and end slopes of not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. Any topsoil deposits should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be of the order of 3 to 5 inches.

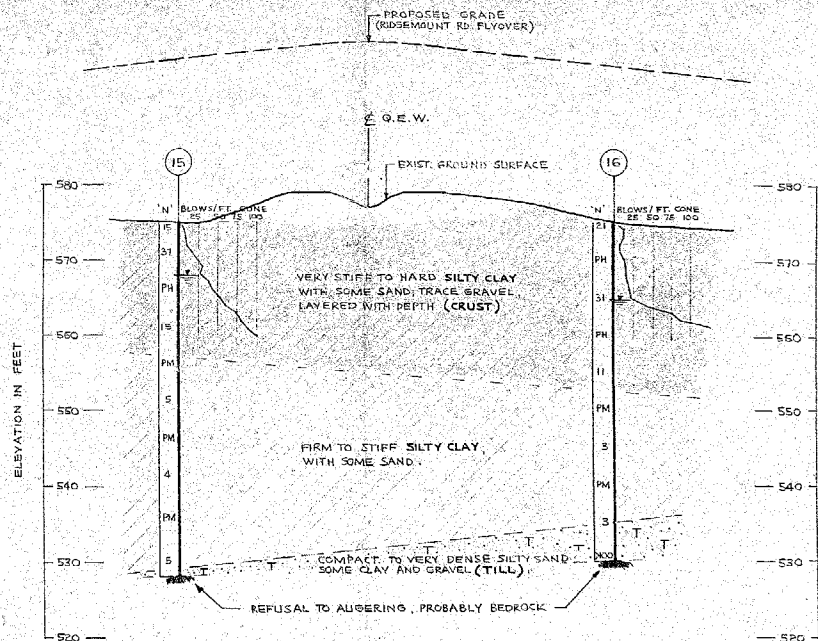
Spread footings may be considered for support of the structure, especially at pier locations. Since the undrained shear strength of the clay decreases with depth the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take advantage of the very stiff upper crust, footings should be founded as high as possible in the clay consistent with

frost protection requirements of 4 feet of earth cover. For preliminary footing design the allowable bearing pressures given on Figure 7 of the main report may be used. As an example, a five foot wide footing founded at elevation 570 (a depth of about 5 feet) may be designed for an allowable bearing pressure of up to 4 tons/sq.ft. Settlement of pier footings imposing the above loading is estimated to be of the order of 1 inch.

At this site the use of spread footings throughout could result in differential settlements of up to several inches between piers and abutments. To minimize or eliminate differential settlement consideration should be given to founding the abutments and, if a continuous structure is to be employed at this site, also the piers on piles. For 12 inch steel H-piles driven to refusal on bedrock, an allowable load of up to 75 tons/pile may be used for preliminary design.



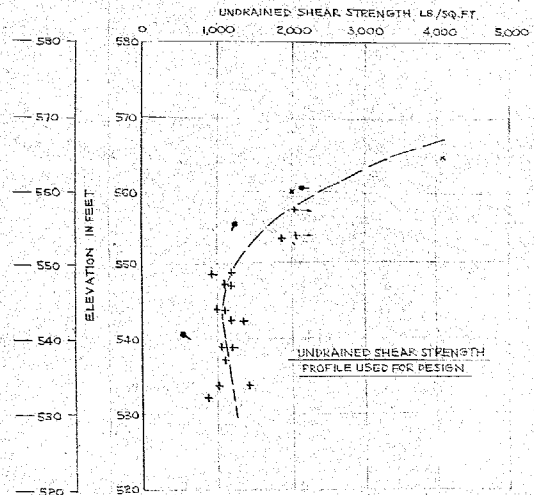
REFERENCE: FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS
TO FORT ERIE, C. C. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 200'-0".



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

LEGEND

- BOREHOLE IN PLAN
- BOREHOLE IN ELEVATION
- WATER LEVEL, SEPT. 12, 1966



- * ESTIMATED FROM STANDARD PENETRATION TEST VALUES
- + IN-SITU VANE SHEAR TEST
- UNDRAINED TRIAXIAL COMPRESSION TEST

PERCENT AXIAL STRAIN AT FAILURE

Drawn, SEPT. 15, 1966.

GOLDER & ASSOCIATES

Made by
Chkd. by
Appd. by

APPENDIX VIIISITE NO. 8 - SUNSET DRIVE - NO W.P. 44 7-65

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed flyover to carry the existing Sunset Drive over the Queen Elizabeth Way is located in the Township of Bertie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out on August 23, 1966. Two borings (numbered 23 and 24), with accompanying dynamic penetration tests, were put down to a depth of about 12 feet using a mobile power auger equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 15 following the text of this appendix. Logs for each boring are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by 1 to 2 feet of brown silty topsoil. Underlying the topsoil the borings encountered about 6 and 10 feet of desiccated brown silty clay

containing some sand and gravel. Based on standard penetration test results the consistency of the clay is very stiff to hard and generally hard.

The silty clay is underlain at a depth of some 8 to 12 feet by sound grey dolomitic limestone bedrock which was proved by core drilling for a depth of 5 feet in borehole 23 and was inferred from auger refusal in borehole 24.

Groundwater level observations made on September 12, 1966 indicate that the groundwater level is within the silty clay stratum at about elevation 608.

DISCUSSION

As shown on the plan given on Figure 15, it is proposed to construct a flyover to carry Sunset Drive over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 23 feet high will be required.

The significant stratum at the site is the very stiff to hard desiccated silty clay deposit. There should be no overall stability problem for 23 foot high roadway embankments placed on the clay, provided side and end slopes not steeper than 2 horizontal to

1 vertical are used and the embankments are constructed of properly compacted fill material. All topsoil deposits should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading should be negligible.

Spread footings may be considered for support of the fly-over structure. For footings founded in the silty clay stratum an allowable bearing pressure of up to 4 tons/sq.ft. may be used for preliminary design. As footings must be placed at a depth of at least 4 feet below final ground surface for adequate frost protection purposes, consideration should be given to taking the footings down to bedrock (8 to 12 feet below ground surface) using an allowable bearing pressure of at least 10 tons/sq.ft. Settlement of footings founded in either the hard silty clay or on bedrock should be negligible.

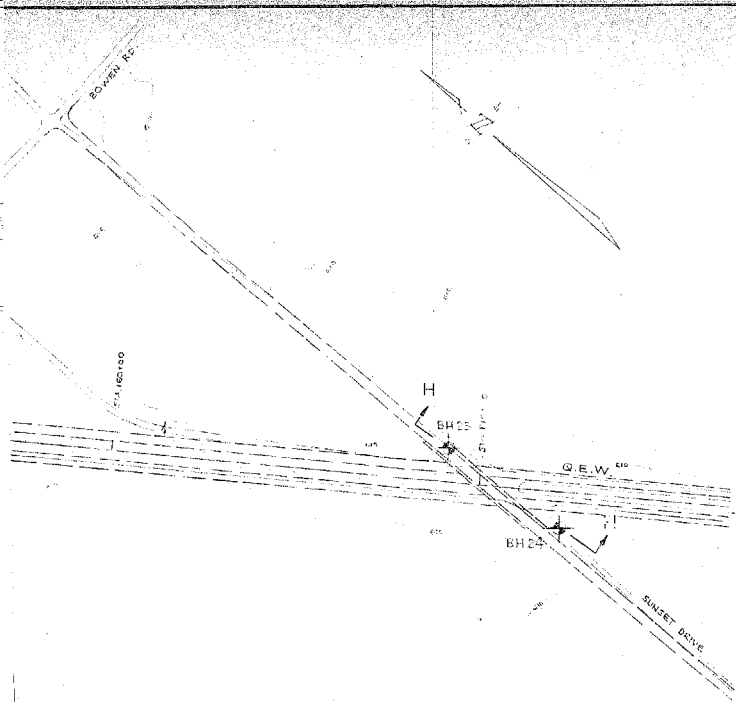
LEGEND

BOREHOLE IN PLAN

2.4

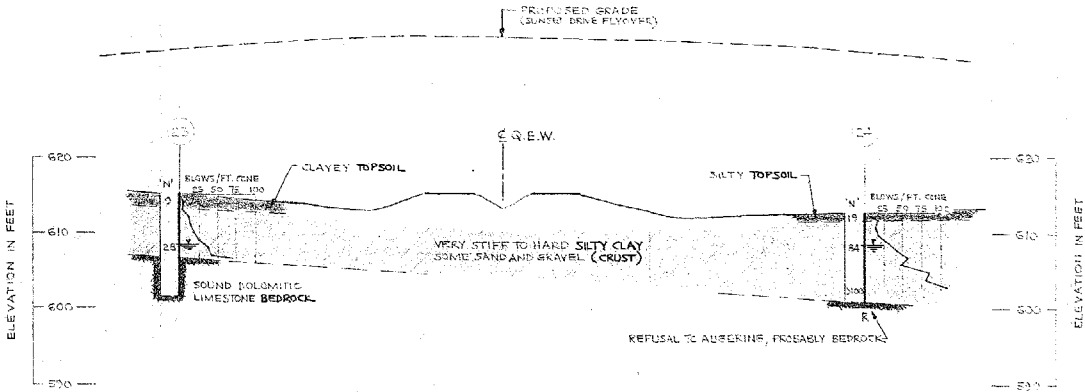
BOREHOLE IN ELEVATION

WATER LEVEL, SEPT. 12, 1966



PLAN
SCALE 1" TO 200'

REFERENCE: FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS
TO FORT ERIE, C.C. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 200'-0"



SECTION H-H

HORIZONTAL SCALE 1" TO 40'-0"
VERTICAL SCALE 1" TO 10'-0"

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

Drawn, SEPT. 21, 1966.

GOLDER & ASSOCIATES

Mod. *GA*
Chk. *GA*
Appd. *GA*

APPENDIX IXSITE NO. 9 - GILMORE ROAD - W.P. 164-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed underpass structure to carry the existing Gilmore Road over the Queen Elizabeth Way is located in the Township of Bertie, County of Welland, Ontario. An alternative underpass structure to carry the realigned Pettit Road over the Queen Elizabeth Way at a location some 200 feet east of Gilmore Road has also been proposed. The field work for the subsurface investigation at this site was carried out on August 22, 1966. Two borings (numbered 13 and 14), with accompanying dynamic penetration tests, were put down to a depth of about 15 feet using a mobile power auger.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 16 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain by about 7 feet of hard desiccated

red-brown silty clay containing a trace to some sand and gravel. Underlying the silty clay in borehole 14 there is a deposit of very dense red-brown silty sand some 5 feet thick. The silty sand contains some layers of clayey silt up to about 2 inches thick.

The silty sand in borehole 14 and the silty clay in borehole 13 are underlain by about 4 feet of very stiff to hard till consisting of red-brown clayey silt with sand and some gravel. Refusal to augering on what is probably bedrock was met at depths of 12 and 15 feet or at about elevation 599.

The groundwater level established in borehole 13 on September 12, 1966 was at a depth of about 7 feet or at elevation 604.

DISCUSSION

As shown on the plan given on Figure 16, it is proposed to construct an interchange with underpass structure to carry either Gilmore Road or, as an alternative, the realigned Pettit Road over the Queen Elizabeth Way. As the project is in feasibility study stage no structural details are available, but it is understood that roadway approach embankments up to 25 feet high will be required.

The significant stratum at this site is the very stiff to hard desiccated silty clay deposit. There should be no overall

stability problem for roadway embankments placed on the clay, provided side and end slopes of not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. Any topsoil deposits should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be negligible.

Spread footings could be considered for support of the underpass structure. For footings founded in the hard silty clay an allowable bearing pressure of up to 4 tons/sq.ft. may be used for preliminary design. To provide adequate frost protection the footings should be placed at least 4 feet below final ground elevation. Should the footings be taken down into the very dense silty sand or very stiff till underlying the clay an allowable bearing pressure of up to 4 tons/sq.ft. may also be used. However, excavation below the groundwater level in cohesionless soil (such as the silty sand deposit) will require some method of groundwater control. This control may be achieved either by construction of a sheet pile cofferdam around each footing excavation or by a general dewatering scheme such as properly installed vacuum well points.

Settlement of spread footings imposing the above loading should be less than about $\frac{1}{2}$ inch.

APPENDIX XSITE NO. 10 - THOMPSON ROAD - W.P. 162-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed overpass structure to carry the Queen Elizabeth Way at about existing grade over Thompson Road is located in the Township of Bertie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out between August 18 and 22, 1966. During this period two borings (numbered 11 and 12), one of which had an accompanying dynamic penetration test, were put down to depths of about 35 and 27 feet using a mobile power auger equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface stratigraphy across the site are presented on Figure 17 following the text of this appendix. Logs for each boring and the results of laboratory testing are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by some

1 to 2 feet of dark clayey to silty topsoil. Underlying the topsoil the borings encountered about 25 feet of brown to grey desiccated silty clay containing some sand and a trace to some gravel. The clay is of low plasticity with a liquid limit of about 25 to 30 and a plasticity index of about 14. The in situ water content is about 10 to 15 percent and is fairly constant with depth. Based on the results of undrained triaxial compression tests and standard penetration tests, the clay is hard above about elevation 620 but decreases to very stiff with depth.

Underlying the silty clay in borehole 11 a thin veneer of compact till, less than 1 foot thick, was encountered. The till consists of grey silty sand with some clay and gravel.

The till in borehole 11 and the silty clay in borehole 12 are underlain at about elevation 603 to 606 by sound grey limestone bedrock. The bedrock was proved in borehole 11 by core drilling in AXT size for about 10 feet and was inferred from refusal to augering in borehole 12.

Following completion of each boring a standpipe was installed for groundwater level observation. On September 12, 1966 the groundwater level was found to be within the silty clay stratum at about elevation 624 to 627.

DISCUSSION

As shown on the plan given on Figure 17, it is proposed to construct an interchange with an overpass structure to carry Thompson Road under the Queen Elizabeth Way and an underpass structure to carry one ramp of the interchange over the Queen Elizabeth Way. Two alternative locations for the underpass structure are proposed. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments to the underpass structure up to 20 feet high will be required and roadway cut sections for the overpass structure are to be some 20 feet deep.

The significant stratum at the site is the hard, decreasing to very stiff with depth, desiccated silty clay deposit which overlies bedrock. There should be no overall stability problem for roadway embankment or cut sections of the heights proposed, provided side and, where applicable, end slopes no steeper than 2 horizontal to 1 vertical are used. The embankments should be constructed of properly compacted fill material and all topsoil deposits should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be less than 1 inch.

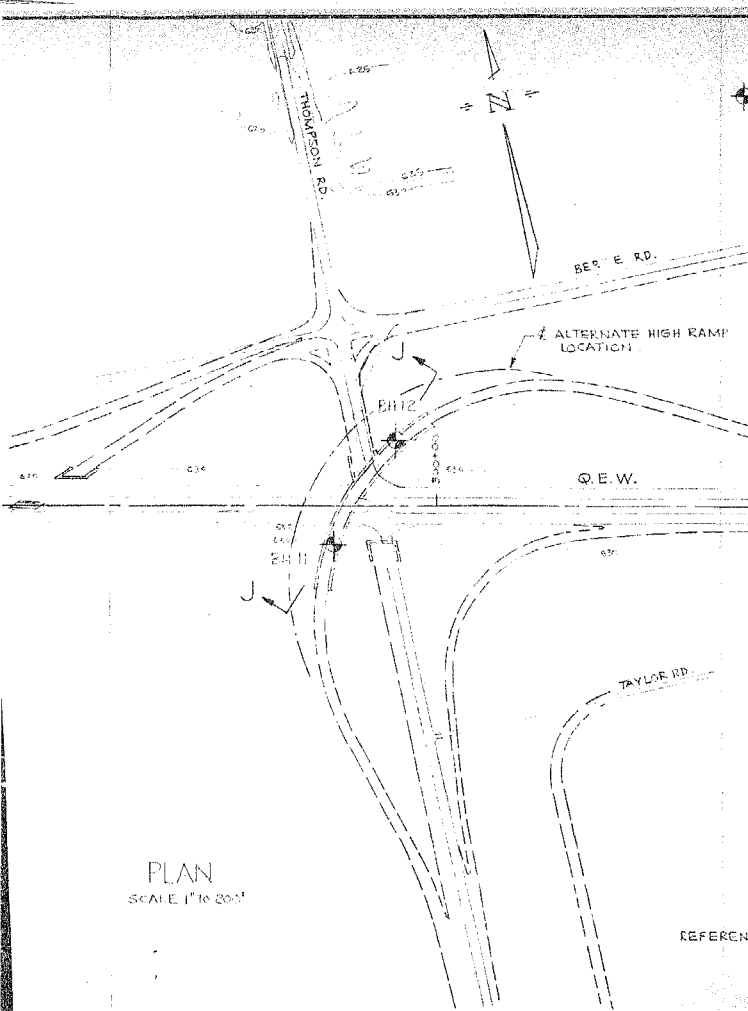
Strip or spread footings may be considered for support of both the overpass and underpass structures. For preliminary design purposes the underpass structure associated with the proposed ramp may be founded on spread footings using an allowable bearing pressure of up to 4 tons/sq.ft. Due to the decrease in the undrained shear strength of the clay with depth, the allowable bearing pressure for strip footings supporting the overpass structure at elevation 610 or below should be reduced to 2 tons/sq.ft. For both structures the footings should be placed such that a minimum of 4 feet of earth cover is provided for frost protection purposes. Settlement of footings imposing the above bearing pressures is estimated to be less than about 1 inch.

As an alternative it may be more economical to found the overpass structure on strip footings taken down into the bedrock, the upper surface of which is at about elevation 605 or some 8 feet below the proposed grade of Thompson Road. For this condition the footings may be designed using an allowable bearing pressure of at least 10 tons/sq.ft. and the settlement should be negligible.

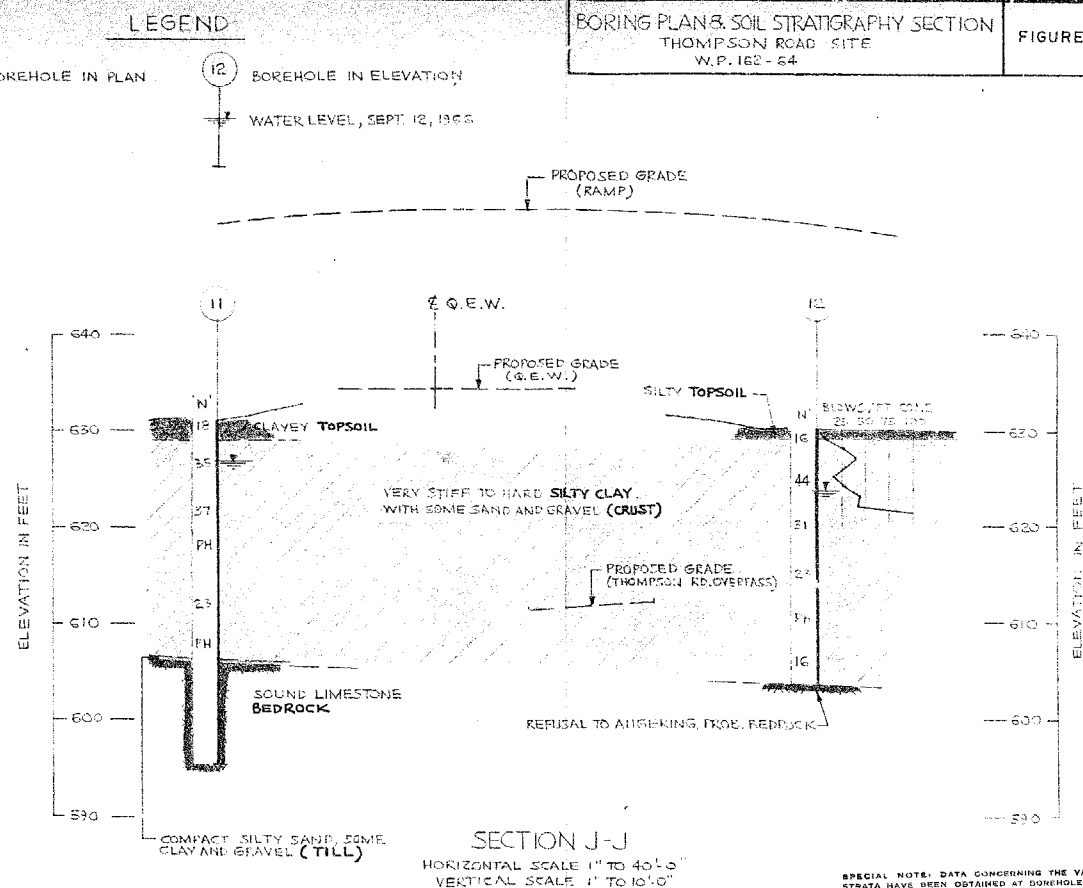
In addition to carrying the Queen Elizabeth Way over Thompson Road, the walls of the overpass are to act as an earth retaining structure. Therefore free-draining and non-frost-susceptible granular backfill material should be provided for at least 4 feet

horizontally behind the walls. Provision for positive drainage from this material should be made to ensure that no hydrostatic or ice pressures build up behind the walls. With full effective drainage and assuming the overpass to be a rigid structure, it is recommended that a coefficient of earth pressure at rest, $K_0 = 0.5$ and a total unit weight, $\gamma = 130$ lb/cu.ft. be used for the compacted granular fill in the design of the walls.

In the computation of sliding resistance between a rough concrete footing and the undisturbed silty clay subsoil a cohesion value of about 1,500 lb/sq.ft., which is a limiting value, may be used in design. If the footings are taken to bedrock a coefficient of friction of 0.60 may be used.



REFERENCE: FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS
TO FORT ERIE, C.C. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 300'-0"



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

Drawn, SEPT. 20, 1966.

GOLDER & ASSOCIATES

Mode
Chkd.
Appd.

APPENDIX XISITE NO. 11 - CONCESSION ROAD - W.P. 161-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed overpass structure to carry the Queen Elizabeth Way at about existing grade over Concession Road is located in the Township of Bertie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out on August 19 and 23, 1966. During this period two borings (numbered 7 and 8), with accompanying dynamic penetration tests, were put down to a depth of about 35 feet using a mobile power auger.

The locations of the two borings together with a section of the inferred subsurface conditions across the site are presented on Figure 18 following the text of this appendix. Logs for each of the borings are given in the main body of the report.

SUBSURFACE CONDITIONS

The site is underlain at the borehole locations by some 35 feet of brown to grey silty clay, the upper 12 to 17 feet of which are weathered and desiccated. The silty clay deposit contains

some sand and a trace to some gravel. The clay is of low plasticity with a liquid limit of about 25 and a plasticity index of about 12. The in situ water content of the clay is about 13 to 17 percent. Based on standard penetration test results, the consistency of the upper desiccated portion of the clay is hard decreasing to stiff below about elevation 620.

Refusal to augering on what is probably dolomite or limestone bedrock was met immediately beneath the silty clay stratum at about elevation 600.

Following completion of each boring a standpipe was installed for groundwater level observation. On September 12, 1966 the groundwater level at the borehole locations was found to be at elevations 621 and 634 or some 3 and 15 feet below ground surface.

DISCUSSION

As shown on the plan given on Figure 18, it is proposed to construct an interchange with an overpass structure to carry Concession Road under the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that a cut some 20 feet deep will be required beneath the Queen Elizabeth Way.

The significant stratum at this site is the stiff to very stiff silty clay deposit, of which the upper 12 to 17 feet have been weathered to a hard crust. There should be no overall stability problem for 20 foot deep cut sections made primarily of the desiccated upper crust of the clay, provided side slopes of not steeper than 2 horizontal to 1 vertical are used.

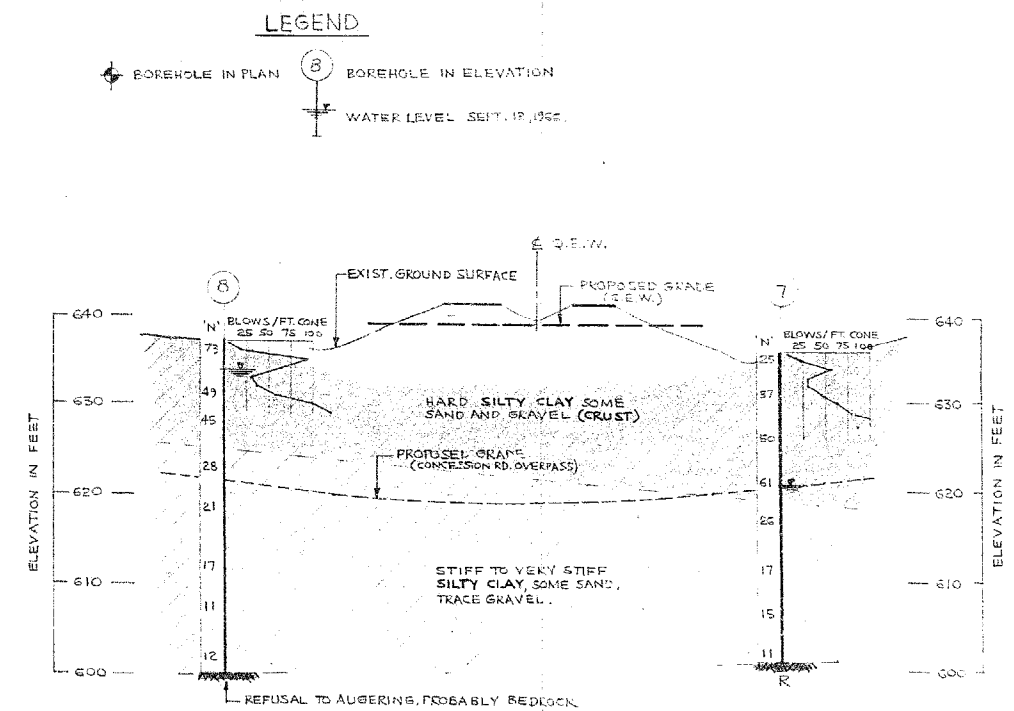
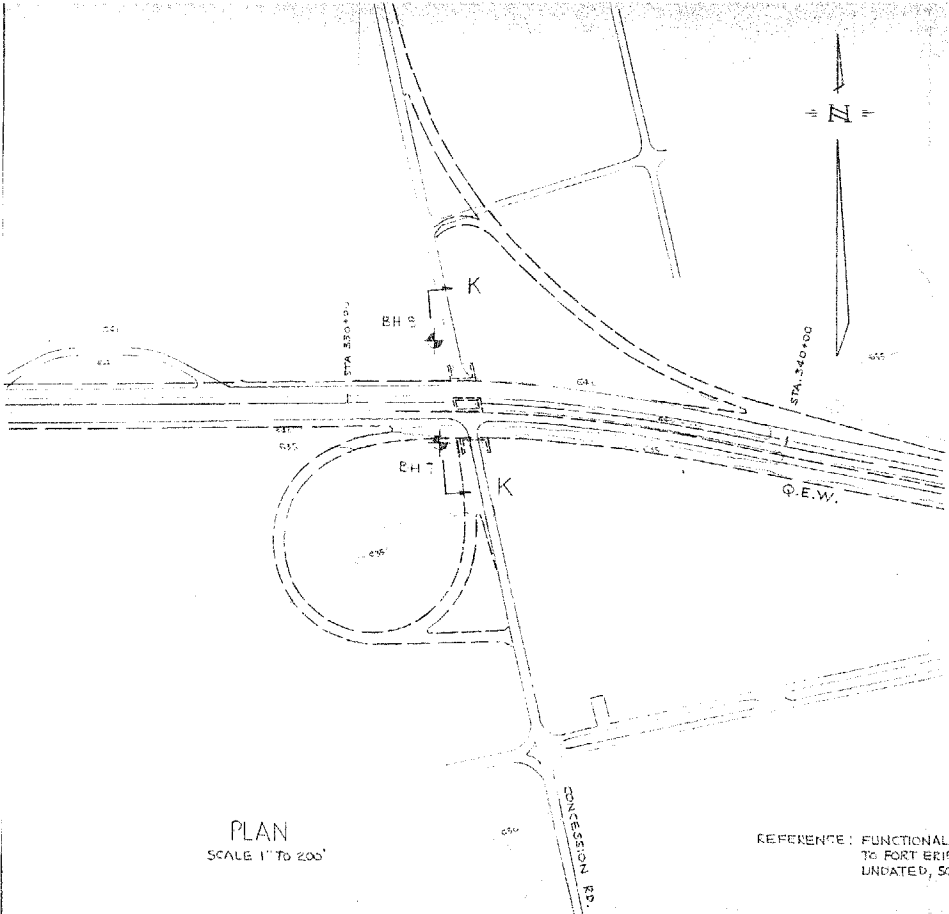
Strip footings placed in the stiff to very stiff lower portion of the silty clay may be considered for the support of the overpass structure. For preliminary footing design an allowable bearing pressure of $1\frac{1}{2}$ tons/sq.ft. may be used. Settlement of footings designed for a bearing pressure of $1\frac{1}{2}$ tons/sq.ft. is estimated to be about 1 inch. For frost protection purposes the footings should be placed at least 4 feet below the final grade beneath the overpass.

As an alternative the structure may be founded on piles driven down to bedrock. For 12 inch steel H-piles driven to refusal on the bedrock an allowable load of up to 75 tons/pile may be used. To provide greater rigidity pipe piles filled with concrete could also be considered.

In addition to carrying the Queen Elizabeth Way over Concession Road, the walls of the overpass are to act as earth

retaining structures. Therefore free-draining and non-frost-susceptible granular backfill material should be provided for at least 4 feet horizontally behind the walls. Provision for positive drainage from this material should be made to ensure that no hydrostatic or ice pressures build up behind the walls. With full effective drainage and assuming the overpass to be a rigid structure, it is recommended that a coefficient of earth pressure at rest, $K_0 = 0.5$ and a total unit weight, $\gamma = 130$ lb/cu.ft. be used for the compacted granular fill in the design of the walls.

In the computation of sliding resistance between a rough concrete footing and the undisturbed silty clay subsoil a cohesion value of about 1,500 lb/sq.ft., which is a limiting value, may be used in design.



REFERENCE: FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS
TO FORT ERIE, C.C. PARKER & ASSOCIATES,
UNDATED, SCALE 1" TO 200'-0".

SPECIAL NOTE: DATA CONCERNING THE VARIOUS
STRATA HAVE BEEN OBTAINED AT BOREHOLE LOCA-
TIONS ONLY. THE SOIL STRATIGRAPHY BETWEEN
BOREHOLES HAS BEEN INFERRED FROM GEOLOGICAL
EVIDENCE AND SO MAY VARY FROM THAT SHOWN.

Drawn, SEPT. 1966.

GOLDER & ASSOCIATES

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

APPENDIX XIISITE NO. 12 - NORTH STREET - W.P. 160-64

This appendix covers the preliminary subsurface investigation carried out at the above site which is located within the area of the proposed general reconstruction of the Queen Elizabeth Way between Niagara Falls and Fort Erie, Ontario.

The site of the proposed underpass structure which is to carry the future extension of North Street over the Queen Elizabeth Way is located in the Town of Fort Erie, County of Welland, Ontario. The field work for the subsurface investigation at this site was carried out between August 11 and 15, 1966. During this period two borings (numbered 9 and 10), one of which had an accompanying dynamic penetration test, were put down to depths of about 45 and 35 feet using a mobile power auger equipped for diamond core drilling operations.

The locations of the two borings together with a section of the inferred subsurface conditions across the site are shown on Figure 19 following the text of this appendix. Logs for each of the borings are given in the main body of the report.

SUBSURFACE CONDITIONS

Underlying some 2 feet of hard brown clayey topsoil on

the north side of the Queen Elizabeth Way and beneath ground surface on the south side, the borings encountered about 30 feet of grey brown to grey silty clay containing some sand and a trace to some gravel. The upper 17 feet of the stratum have been weathered and desiccated to a brown colour. The clay is of medium plasticity and based on one test result has a liquid limit of 35 and a plasticity index of 21. The in situ water content is about 20 to 25 percent. Based on in situ field vane testing, undrained triaxial compression tests and standard penetration tests, the upper desiccated portion of the clay is very stiff to hard and below about elevation 595 the consistency of the clay decreases to firm to stiff.

The clay is underlain at between elevations 576 and 584 by fairly sound to sound grey limestone bedrock which was proved by core drilling in AXT size for up to about 10 feet in the borings.

Following completion of each boring a standpipe was installed for groundwater level observation. On September 12, 1966 the installation in borehole 10 indicated the groundwater level to be at about elevation 603 or some 11 feet below ground surface. The water level in borehole 9 was found to be about 1 foot below ground surface but it is felt that this installation is not operating properly and that the high water level is wash water within the borehole.

DISCUSSION

As shown on the plan given on Figure 19, it is proposed to construct an interchange with an overpass structure to carry the proposed North Street or Central Avenue extension over the Queen Elizabeth Way. As the project is in the feasibility study stage no structural details are available, but it is understood that roadway approach embankments some 7 to 12 feet high are to be constructed on top of the existing Queen Elizabeth roadway cut slopes.

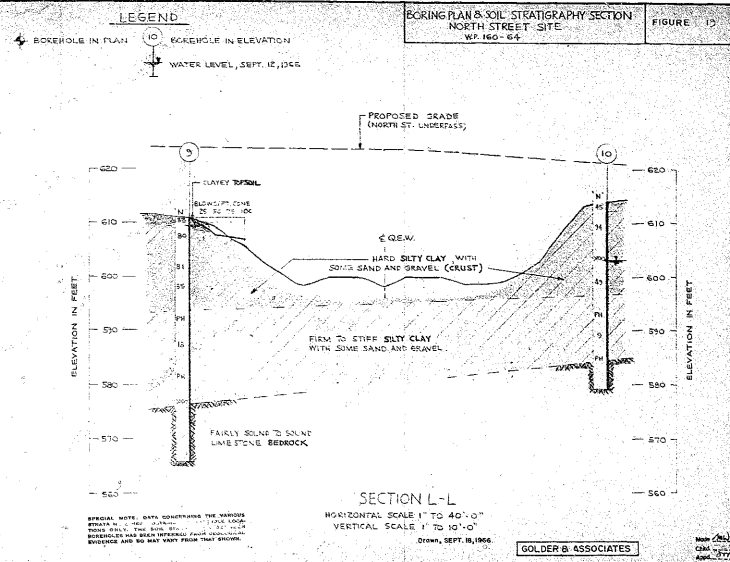
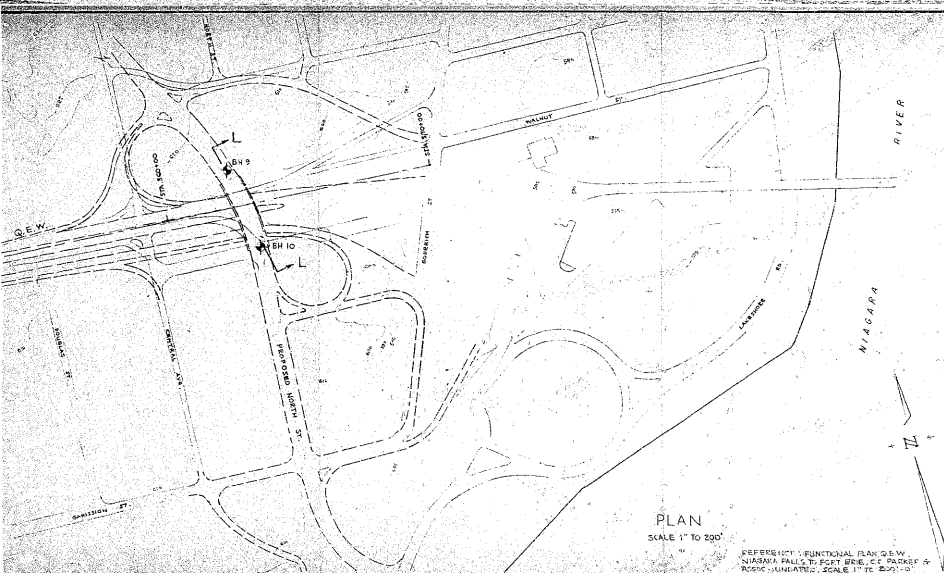
The significant stratum at this site is the firm to stiff silty clay deposit, of which the upper 17 feet have been weathered to a hard crust. There should be no overall stability problem for roadway approach embankments of the height required, provided side and end slopes not steeper than 2 horizontal to 1 vertical are used and the embankments are constructed of properly compacted fill material. All topsoil should be removed beneath the full width of the embankments. Consolidation settlement under the full embankment loading is estimated to be less than 1 inch.

Spread footings may be considered for support of the proposed overpass structure. Since the undrained shear strength of the clay decreases with depth the allowable bearing pressure for spread footings varies with footing width and founding elevation. To take

advantage of the hard upper crust footings should, where possible, be founded as high as possible in the clay consistent with frost protection requirements of at least 4 feet of earth cover. For preliminary footing design the allowable bearing pressures given on Figure 7 of the main report may be used if the ground surface across the entire site is taken to be at about elevation 613. This assumption would result in a founding depth of about 20 feet (below elevation 613) for spread footings placed at least 4 feet below the bottom of the existing Queen Elizabeth Way cut section. For 5 foot wide footings placed at about elevation 593 an allowable bearing pressure of up to about 1.5 tons/sq.ft. may be used. For 10 foot wide footings this value should be reduced to about 1 ton/sq.ft. Settlement of spread footings imposing the above loading is estimated to be about 1 inch.

Since the roadway approach embankments are to be less than 12 feet in height above the hard desiccated crust of the clay, consideration can be given to placing the abutments in the fill. For stub abutments resting on spread footings an allowable bearing pressure of 2 tons/sq.ft. may be used, provided that the roadway embankments are properly compacted during placing. Settlement of the stub abutments under this loading is estimated to be of the same order as for the piers discussed above.

Because of the relatively low bearing capacity available at depth in the clay, it may be more economical to found the piers on piles. For 12 inch steel H-piles driven to refusal on bedrock an allowable loading of up to 75 tons/pile may be used for preliminary design. Founding of the proposed piers on end bearing piles and the proposed abutments on spread footings within the roadway approach fill could result in a differential settlement of as much as 1 inch between the piers and abutments. If differential settlements of this order cannot be tolerated it would be necessary to place the stub abutments on piles driven to bedrock.



66-F-222-C

WP*158-64-2 WP*165-64

WP*159-64 WP*167-64

WP*160-64 WP*442-65

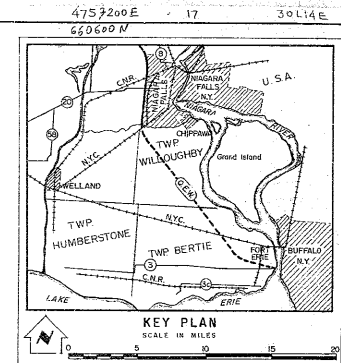
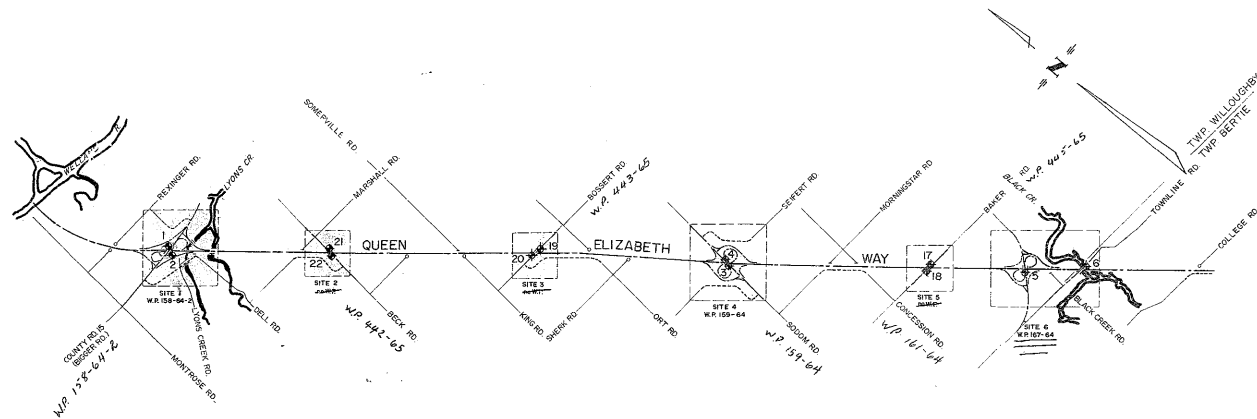
WP*161-64 WP*443-65

WP*162-64 WP*445-65

WP*164-64 WP*447-65

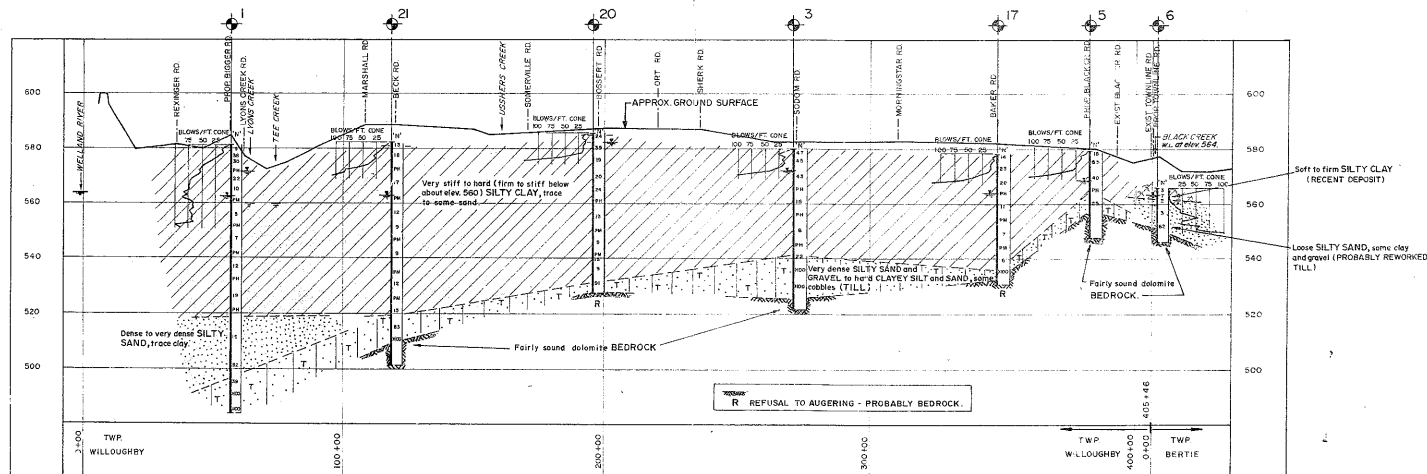
Q. E. W.

NIAGARA FALLS
TO FORT ERIE



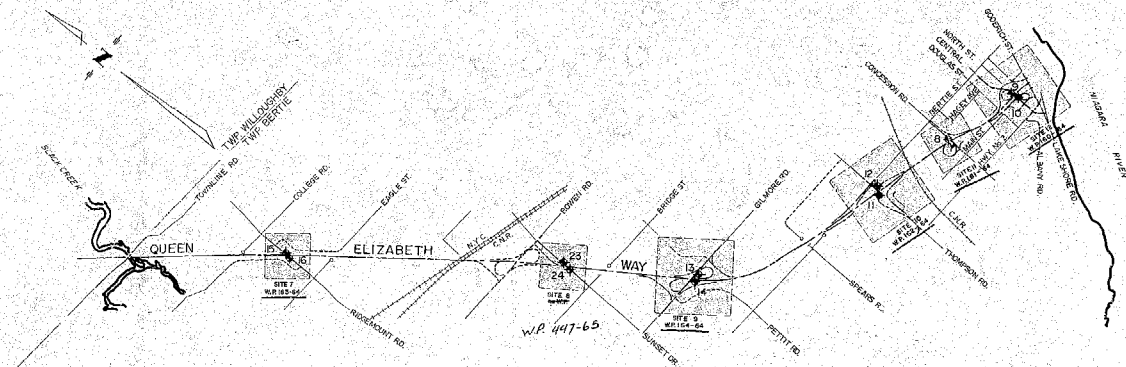
NO.	ELEVATION	STATION	OFFSET	
1	581.5	57+105	132' L. E.B.L.	TWP WILLOUGHBY
2	575.6	56+00	127' E.B.L.	
3	579.8	272+25	72' R. E.B.L.	
4	579.6	271+23	64' L. E.B.L.	
5	579.3	282+75	59' R. E.B.L.	TWP BERTIE
6	566.4	2+00	103' L. W.B.L.	
7	578.2	349+12	71' L. W.B.L.	
18	577.4	346+50	73' R. E.B.L.	
19	583.1	199+40	110' L. W.B.L.	TWP WILLOUGHBY
20	595.7	196+00	62' R. E.B.L.	
21	582.3	119+00	97' L. W.B.L.	
28	583.4	119+55	74' R. E.B.L.	

REVISIONS		
DATE	BY	DESCRIPTION

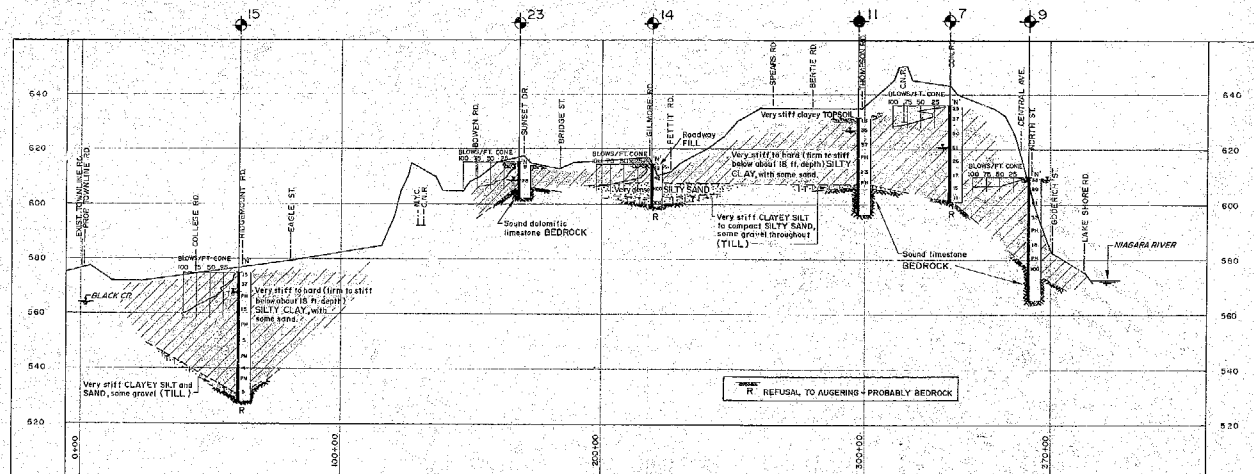


REF PLAN - KEY MAP, Q.E.W., NIAGARA FALLS TO FORT
ERIE, C.C. PARKER & ASSOCIATES, JULY 12, 1966.
SCALE 1"=25,000

REF PROFILE - FUNCTIONAL PLAN, Q.E.W., NIAGARA FALLS TO
FORT ERIE, C.C. PARKER & ASSOCIATES, UNDATED
SCALE 1"=200'-0"



PLAN
SCALE 1:25,000



SECTION
HORIZONTAL SCALE 1:25,000

FOR KEY PLAN, SEE
DRAWING 1 - SHEET 1.



KEY PLAN
SCALE IN MILES

LEGEND

- Bare Hole
- ⊕ Cone Penetration Hole
- ⊕ Bare & Cone Penetration Hole
- ⊕ Water Levels established at time of field investigation (Sept 12, 1966)

NO.	ELEVATION	STATION	OFFSET
7	636.0	532+10	61' RT. E.B.L.
8	637.2	532+00	60' LT. W.B.L.
9	610.8	562+50	52' LT. W.B.L.
10	613.8	563+25	50' RT. E.B.L.
11	631.5	577+02	57' RT. E.B.L.
12	630.3	589+10	50' LT. W.B.L.
13	610.7	524+20	50' LT. W.B.L.
14	614.9	519+90	22' RT. E.B.L.
15	575.1	60+79	60' LT. W.B.L.
16	575.1	62+20	64' RT. E.B.L.
23	615.3	109+12	62' LT. W.B.L.
24	612.7	172+30	70' LT. W.B.L.

NOTE

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

REGIONS	DATE	BY	DESCRIPTION

H.Q. GOLDER & ASSOCIATES LTD.

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION - FOUNDATION SECTION

QUEEN ELIZABETH WAY
NIAGARA FALLS TO FORT ERIE

KING'S HIGHWAY NO. QUEEN ELIZABETH WAY DIST. NO. 4
CO. OF. WELLS
TWP. OF. BERTIE LOT CON.

PLAN & SOIL STRATIGRAPHY

SUBMIT J.D.	CHECKED 7/8	W.P. NO.	1	DRAWING NO.
DRAWN BY W.W.	CHECKED 7/8	JOB NO.		1 SHEET 2
DATE: SEPT. 13, 1966		SITE NO.		BRIDGE DRAWING NO.
APPROVED		CONT. NO.		

REF. PLAN - KEY MAP, Q.E.W. NIAGARA FALLS TO FORT ERIE, C.C. PARKER & ASSOCIATES, JULY 12, 1966
SCALE 1:25,000
REF. PROFILE - FUNCTIONAL PLAN, Q.E.W. NIAGARA FALLS TO FORT ERIE, C.C. PARKER & ASSOCIATES, UNDATED
SCALE 1:25,000

PRINT RECORD	NO.	FOR	DATE