GRAND RIVER
AND
PROP. HWY. No 403

M.P. 159-60 DIST. 2 W.J. 63-F-14

Department of Transportation and Communications
~~DEPARTMENT OF HIGHWAYS ONTARIO~~

MEMORANDUM

TO: Mr. A. P. Watt, (2)
Regional Bridge Planning Eng.,
Southwestern Region,
London, Ontario.

ATTENTION:

FROM: Foundations Office,
Design Services Branch,
Central Bldg., Downsview.

DATE: December 3, 1971.

OUR FILE REF.

IN REPLY TO

SUBJECT:

40 P1-57
GEOCRES No.

FOUNDATION INVESTIGATION REPORT
For
Proposed Grand River Bridge 2.6 mi W of Hwy. 2
C.A.H. #403, Line 'K'
Near Brantford, Ontario.
W.O. 71-11112 - W.P. 159-60-00

Enclosed please find the complete foundation investigation report for the above-mentioned project. The report has been prepared for us by H. Q. Golder & Associates Ltd.

We believe you will find the factual information contained in the report and the recommendations relating to the design and constructions of the proposed structure and approaches, sufficient for your purposes. We would like to advise you, however, that in regards to pile capacity and caisson capacity, we feel that the Consultant has been too conservative. We would recommend that the maximum allowable load for H piles (i.e. 95 tons for 12 BP 74), and a design pressure of 50 t.s.f. for caissons installed in bedrock be used rather than the 75 tons, and 25 t.s.f. that the Consultant has recommended.

If any queries arise in regard to this report, please contact this Office.

A. G. Stermac,
PRINCIPAL FOUNDATION ENGINEER.

AGS/ao
Encl.
cc: Messrs. D. W. Farren 3541
B. R. Davis 3516
A. Rutka 3266
W. A. Zonnenberg
C ROBERTSON ~~L. E. Walker~~ X called for return of copy 6/12/71
B. J. Giroux 3401
J. R. Roy
G. A. Wrong 3255
B. A. Singh
Foundations Files
Documents

DEPARTMENT OF TRANSPORTATION

AND COMMUNICATIONS

SUBSURFACE INVESTIGATION

PROPOSED GRAND RIVER BRIDGE, HWY. 403

NEAR BRANTFORD, ONTARIO

W.O.71-11112, W.P. 159-60-00

CONT 75-132

Golder Associates

Golder Associates

CONSULTING GEOTECHNICAL ENGINEERS

H. Q. GOLDER
V. MILLIGAN
J. L. SEYCHUK
C. O. BRAWNER
D. L. TOWNSEND
F. J. HEFFERNAN
B. E. W. DOWSE
J. B. DAVIS

REPORT TO
DEPARTMENT OF TRANSPORTATION
AND COMMUNICATIONS
ON
SUBSURFACE INVESTIGATION
PROPOSED GRAND RIVER BRIDGE
HWY. 403, LINE 'K', DISTRICT NO. 4 (HAMILTON)
W.O.71-11112, W.P. 159-60-00
NEAR BRANTFORD, ONTARIO

Distribution:

14 copies - Department of Transportation and Communications, Downsview, Ontario.

2 copies - H. Q. Golder & Associates Ltd., Mississauga, Ontario.

December, 1971

71122

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ABSTRACT

The results of a subsurface investigation carried out at the proposed river crossing for line 'K' of controlled access Highway No. 403 near Brantford, Ontario are presented. The investigation has indicated that:

a) along the west river bank there is a shallow cover of recent river flood plain deposits and glacial till overlying the bedrock of the Salina Formation, and

b) within the river channel, the bedrock surface has been eroded to about 3 ft. below the bedrock surface on the adjacent banks, and has been covered by a deposit of sand, gravel, cobbles and boulders, and

c) along the east river bank there is an extensive, deep deposit of interbedded, stratified glacial till, which is about 70 ft. thick at the location of the proposed abutment.

The bedrock of the Salina Formation consists of interbedded greyish-green shale and vuggy dolomite with inclusions and precipitates of gypsum. The bedrock is fractured throughout and highly permeable to water.

It is recommended that either spread footings or caissons drilled into bedrock be used for the pier foundations. In either case, it will probably be necessary to construct the foundations in the wet using tremie concrete.

INTRODUCTION

H. Q. Golder & Associates Ltd., have been retained by the Department of Transportation and Communications to carry out a subsurface investigation at the site of the proposed river crossing for Line 'K' of controlled access Highway No. 403 across the Grand River near Brantford, Ontario. It is understood that at the present time consideration is being given to the choice of either a four or five span twin bridge structure at the site.

The purpose of the investigation was to provide sufficient geotechnical information so that the foundation requirements for either bridge alternative could be considered in conjunction with the overall estimated costs, and to provide additional geotechnical recommendations, as may be necessary, for the cut slopes which will be considered along the eastern approaches to the proposed structure.

This report presents the results of our subsurface investigation, and includes our geotechnical recommendations with regard to the foundation requirements.

SITE AND GEOLOGY

The site is located in Lot 16, Conc. II of the Township of Brantford, Brant County. At this location, the Grand River is about 350 ft. wide and flows southerly in a channel which is generally 3 ft. deep or less, (as observed at the time of this investigation) near elev. 690. The western bank of the river is generally flat within the vicinity of the proposed bridge structure (about elev. 700) or about 8 to 10 ft. above the present river level. The river terrace on the west bank is approximately one quarter of a mile wide. On the eastern bank, the land surface

rises sharply at about a 2 (horizontal) to 1 (vertical) overall slope to a high terrace or plateau which is about 135 ft. above river level (i.e. about elev. 825). The centreline for the proposed Hwy. 403 follows the line of a previously excavated gulley which was constructed to drain a relatively shallow pond about 800 ft. to the east of the crest of the bank.

Available geological information indicates that the principal soil deposits were laid down while the Grand River served as a major glacial spillway, and that some of the surficial deposits were also formed as glacial beaches. The soils along the east bank are unevenly sorted, stratified and cross-bedded sands and gravels. The geological information suggests that the typical boulder size is about 12 in. However, boulders up to 4 ft. in diameter have been excavated from the adjacent gravel pit to the east, and occasional large boulders are present on the surface of the slopes upstream of the site. The water table on the east side is reportedly about 40 to 50 ft. below the ground surface.

The drainage gulley at the crest of the east slope is about 20 to 25 ft. deep, with side slopes of about 2 (horizontal) to 1 (vertical) . The material from the drainage gulley has been bulldozed down the slope so that some oversteepening and surficial slump movements have occurred. In addition, some surface erosion has exposed the soil, and cut relatively steep channels down stream from the gulley.

Approximately 160 ft. south of centreline Sta. 458+00, groundwater under slight artesian pressure was observed to be seeping out of the slope at about elev. 754. The zone of softening

due to the seepage is about 30 ft. in diameter, and extends up the slope to about elev. 760.

Published geological mapping indicates that the bedrock consists of interbedded grey and green, irregularly bedded, soft, calcareous and argillaceous shale of the Salina Formation. This formation also contains layers of hard dolomite, and small quantities of anhydrite and gypsum are present within the grey shale beds. The general dip of the rock surface is from west to east, and the bedrock surface is reportedly about elev. 725 or lower along the east bank of the Grand River.

Detailed subsurface investigations have been previously carried out by the Foundation Section of the Department of Highways, Ontario along proposed line 'H' for Hwy. 403, approximately 250 to 300 ft. south of the present site (W.J. 63-F-14B--W.P. 159-60, May 1965). This investigation indicated that the bedrock surface was at about elev. 685 in the vicinity of the west bank, and within the river, rising to about elev. 720 on the east bank. The surface was generally level below the west bank, with minor variations in rock surface of about 5 ft., possibly due to earlier erosion of some of the softer layers of the shale.

PROCEDURE

The field work for this investigation was carried out between Oct. 28 and Nov. 26, 1971 using three diamond drillrigs supplied and operated by F. E. Johnston Drilling Co. Ltd. During this period of time, a series of 27 boreholes were put down at the proposed alternative pier and abutment locations for the east and westbound lanes, as well as along the centreline of the route at the piers and abutments. In addition one borehole was put down on

the centreline near the crest of the slope to the east of the proposed east abutment. With the exception of B.H. 28 (at the crest of the east slope), each borehole was taken down to the top of the bedrock. Because of the numerous large boulders which were observed at random locations along the river, and the fractured nature of the bedrock, the boreholes were carried down in a majority of cases into the bedrock for a depth of five ft. or until sound bedrock was observed.

A detailed log of each borehole is given on the Record of Borehole Sheets following the text of this report. The location of the borings is shown on Fig. 1 and Fig. 2, along with typical cross-sections giving the inferred stratigraphy. Longitudinal sections through the boreholes on the eastbound and westbound lanes are given on Fig. 3.

The samples obtained during the investigation were brought to our laboratory for detailed examination and testing. The results of the laboratory tests are shown on the Record of Borehole Sheets, and on Figs. 4 to 7 inclusive.

Following completion of selected boreholes, standpipes or piezometers were installed to determine the groundwater regime. The observations in the standpipes and piezometers, as well as the water levels in the open holes upon the completion of drilling, are given on the Record of Borehole Sheets.

The ground elevation and location of the boreholes were given to us by the Department of Transportation and Communications, and elevations are referred to Geodetic Datum.

SUBSURFACE CONDITIONS

The site may be divided into three general areas, and, for convenience, summarized subsurface conditions within each of these areas are discussed separately.

East Bank of Grand River

East of Sta. 459+00, the subsoil consists of a complex series of glacial till deposits which presumably were put down during late Pleistocene times. At the location of the proposed east abutment (Section A-A, Sta. 457+35), these till deposits may be roughly divided into three zones. The upper zone consists of compact to very dense sandy silt till containing gravel, cobbles and boulders, and which extends for a depth of about 30 ft. to between elev. 738 and elev. 722. This upper till, in turn, overlies a very stiff to hard silty clay 'till' with some sand and gravel which is between 10 and 20 ft. thick. Samples of the 'till' indicated stratification or layering indicating that portions of this deposit were probably laid down during short interstadial times. However, the layering was not evident in all samples. Underlying the silty clay till is a complex lower sandy silt till which contains layers of sand and gravel, and which overlies the bedrock.

With the exception of the upper surface, the complete till sequence is in a very dense state. Although no large cobbles or boulders were cored within the till deposits, it must be presumed, based upon the surficial exposures on exposed slopes, that such cobbles and boulders will exist within the till.

At the proposed abutment location, the bedrock is at about elev. 697, while closer to the river, the bedrock surface is

about elev. 693 (Section B-B), and about elev. 688 (Section C-C). The difference in bedrock elevation at the above proposed pier locations is probably due to river erosion of the shale bedrock during earlier river stages.

The bedrock consists of horizontally bedded, fractured, laminated greyish-green shale and vuggy dolomite (Salina Formation). The fractures tend to be vertical or steeply inclined, and gypsum inclusions are noted within the dolomite. In some cases, gypsum precipitates have been formed within apparently old fractures, and in one case a breccia-like sand conglomerate was noted within a shale layer. The rock quality of the core and the percentage core recovery were low, and it must be presumed that fractures and/or small cavities are relatively numerous.

Piezometers within the bedrock and above the river level were dry. The upper piezometer installed in B.H. 28 indicates that the piezometric surface is about elev. 777, about 25 ft. below the bottom of the gulley, and about 50 ft. below the crest of the bank. This piezometric surface is slightly above the zone of seepage which exists to the south of the proposed alignment at about elev. 760.

River Channel Section

Between about Sta. 459+00 and Sta. 462+40, the subsoil consists of a very shallow cover (about 6 ft. thick) of compact to dense silty sand and gravel with cobbles and boulders.

The average bedrock elevation is about elev. 683, but there are variations of plus or minus 3 ft. approximately, at specific borehole locations. The upper surface of the bedrock

consists of a dolomite layer which extends down to about elev. 678, and which overlies interbedded greyish-green shale and vuggy dolomite with gypsum inclusions. Occasional shale or dolomite boulders were noted in the overlying river deposits and it is probable that river erosion has occurred along fractures in the upper bedrock surface. Clayey material is present in the deeper portions of the bedrock, and this probably represents mudstone layers which have been reported at other locations within the Salina Formation. The core recovery from the bedrock samples was low, although samples of the core were sound. The low recovery is probably due to an appreciable number of fractures within the bedrock.

West Bank of Grand River

From about Sta. 426+40 westerly, the subsoil is composed of a thin cover of recent floodplain deposits which typically consist of compact to loose brown silty sand with some organic matter and shells. This deposit is about 5 ft. thick and represents recent material deposited from various flood stages and earlier channels of the Grand River. At the western end of the site near the proposed west abutment, the river deposits overly a hard brown clayey silt to silty clay till which contains some cobbles and boulders. The till layer is about 6 ft. thick at the location of the proposed west abutment.

At the two proposed pier locations (Sections G-G and H-H), the bedrock surface is about elev. 685.5, while at the location of the proposed west abutment (Section I-I), the bedrock surface is about elev. 690. The upper surface of the bedrock consists of grey shale and overlies interbedded shale and dolomite with gypsum cavities. The bedrock surface under the west bank

of the river is higher than that exposed in the river channel, and suggests that the present river channel has been the main channel of the Grand River for an appreciable period.

Piezometers and standpipes installed within the bedrock indicate that the piezometric surface is at river level.

DISCUSSION AND RECOMMENDATIONS

It is understood that it is proposed to construct a multi-span twin bridge structure to carry controlled access Highway 403 across the Grand River at this site. The total length of the structure will be in the order of 720 ft. The west abutment will be located at about Sta. 464+50, with the grade of the pavement at about elev. 754, or some 55 ft. above the present ground surface. The east abutment is proposed to be at about Sta. 457+20, with the roadway grade at about elev. 767, or some 5 to 15 ft. above the existing ground surface. Between the abutments, the bridge structure will be on a 2 per cent grade. At this time, it is understood that the choice of a four or five span bridge has not yet been made.

For convenience, the various geotechnical aspects of the proposed project with regard to the foundations are discussed under separate headings.

West Abutment

At this location, there is about 9 to 10 ft. of topsoil and dense sand and gravel. The abutment should be constructed within the approach fill, and should be supported on steel H-piles driven to bedrock. The steel piles should be equipped with a

reinforced driving tip to ensure proper penetration of the pile through the cobbles and boulders at the bottom of the natural deposits. Considering a heavy section, driven to practical refusal on the bedrock, a maximum capacity of 75 tons per pile should be used for design purposes.

Since the west approach embankment fill will be in the order of 55 ft. high, it will be necessary to remove all loose surficial soil prior to placing the embankment. Standard slopes of 2 (horizontal) to 1 (vertical) may be used, but particular attention should be given to the provision of surface treatment to prevent erosion, and for protection of the lower part of the fill from high water conditions.

Pier Locations

Since the choice between a four and five span bridge has not yet been made, the recommendations which are given below are of a general nature. Cross sections at each of the proposed pier locations are given on Fig. 1 and Fig. 2, and the founding elevation at each proposed pier will vary in accordance with the specific conditions. Two possible foundation types should be considered; a) spread footings, and b) drilled-in caissons.

Spread Footings Within the river channel there is about 6 ft. of sand, gravel, cobbles and boulders overlying the bedrock surface, while along the west river bank, there is about 10 ft. of recent sand and gravel river deposits overlying the bedrock. It is recommended that;

a) for those footings within the west river bank, the footings should be founded on top of the sound bedrock, in which

case an allowable bearing pressure of 10 tons per sq. ft. should be used for design purposes. The upper approximately 2 ft. of the bedrock has been weathered and fractured, and should be removed by blasting if necessary, prior to placing the concrete. Provision should be made for mass concrete to replace any inferior rock.

b) for those footings within the river channel, the footings should be founded at a depth not less than 5 ft. below the top of the bedrock in order to minimize the potential for scour. An allowable bearing pressure of 10 tons per sq. ft. may be used for design. The bedrock within the river channel tends to be more fractured due to the continued erosion and provision must be made for the use of mass concrete to replace any inferior rock at and below founding level.

c) in all cases, a detailed inspection of the bedrock surface must be made prior to the placement of any concrete.

d) provision should be made in the contract documents for the construction of the footings in the wet, if found necessary, by the use of tremie concrete.

It should be noted that the piezometers which were installed on the west river bank reflected the river level, and that the bedrock surface below the river bank is about 5 to 6 ft. below the river level. The overlying sands and gravel, as well as the fractured bedrock, will be pervious. Control of the groundwater will be difficult due to upward flow through the fractures. For footings within the river section, it will be additionally difficult to construct a dry foundation since the overburden soil is more pervious than on the river bank, and the fracturing within the bedrock has been more developed due to stream erosion. On

the east river bank (Sections B-B and C-C), the water in the boreholes reflected river level.

Because of the shallow river flow, it will be possible to construct earth cofferdams to control water inflow above the bedrock, but sealing of the bedrock will be difficult.

Drilled-in Caissons The same overburden and piezometric conditions as noted above are applicable to drilled-in caissons. However, because of the restricted area of excavation which may be exposed at each time, the total quantity of inflow will be less than that for a larger spread footing. It is recommended that:

a) the caissons should be drilled to a depth of at least 3 diameters into the sound bedrock, i.e. for a 3 ft. diameter caisson, the bedrock should be drilled to a depth in the order of 9 ft.

b) for design purposes, an allowable end bearing pressure of 25 tons per sq. ft. may be used.

c) provision for the placement of tremie concrete should be made in the contract documents, and a positive hydrostatic head should be maintained within the caisson at all times during the placement of the concrete.

The presence of gypsum inclusions and/or precipitates was noted in all boreholes which penetrated the bedrock. Tests carried out on our behalf for the sulphate content of the groundwater indicated the following results:

B.H. 10	550 ppm.
B.H. 15	1000 ppm.

These samples, taken from boreholes in the river channel section, may have had some dilution from the river water during the drilling. It is recommended that sulphate resistant cement be used for all concrete in the footings or caissons.

East Abutment

At this location, the abutment will be located in a short shallow fill section (approximately 5 ft. of fill near B.H. 1, and 15 ft. of fill at B.H. 3). To the east of the abutment, the proposed grade changes into a cut section which will be about 50 ft. deep at the crest of the present river bank (i.e. near Sta. 456+50).

The upper portion of the subsoil is loose at the location of the proposed abutment, and becomes compact to dense about 10 ft. below the ground surface. It is recommended that the abutment be founded on steel H-piles driven to practical refusal in the underlying dense till strata. In view of the anticipated hard driving conditions, it is recommended that all piles be equipped with standard reinforcing tips. A design load of 75 tons per pile may be used for 12 BP @ 74 steel H-piles driven to practical refusal.

The present east bank has local slopes steeper than 2 (horizontal) to 1 (vertical), while the exposed, untreated slopes in the drainage gulley are standing at 2 (horizontal) to 1 (vertical). It is anticipated that there will be no overall stability problems with the cut and fill sections in the vicinity of the abutments provided that standard procedures are followed utilizing 2 (horizontal) to 1 (vertical) slopes for all sections. However, the following points should be considered in the design details:

a) At B.H. 28, an upper piezometric surface is present at about elev. 777, which is above the proposed grade line in the cut section. Granular drainage blankets should be provided within the cut section to prevent surface erosion, and to minimize erosion and damage to longitudinal ditches.

b) At B.H. 28, a lower piezometric surface is present at about elev. 728, and seepage is presently occurring on the east bank about elev. 754. It is probable that the upper piezometric surface at B.H. 28 is associated with the observed seepage on the slope. Continued uncontrolled seepage through the fill adjacent to the east abutment would lead to surface instability, and it is recommended that a coarse drainage blanket be extended up the final slopes for groundwater control. It will also be necessary to provide surface protection against run-off water from the longitudinal ditches, and scour protection on the lower portion of the fill.

c) Prior to , or during, the construction of the east approach cut, additional piezometers should be installed to the east of the east abutment so that the extent and continuity of the upper piezometric surface can be defined.

d) Drainage control and granular backfill must be provided adjacent to the east abutments to control possible seepage flow in this vicinity.

D. L. Townsend, P. Eng.

J. L. Seychuk, P. Eng.

DLT:jb
71122

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	*N, 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	c_u, *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

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

NOTES:

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

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

LIST OF SYMBOLS

I. GENERAL

$\pi = 3.1416$

e = base of natural logarithms 2.7183

$\log_e a$ or $\ln a$, natural logarithm of a

$\log_{10} a$ or $\log a$, logarithm of a to base 10

t	time
g	acceleration due to gravity
V	volume
W	weight
M	moment
F	factor of safety

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) *Unit weight*

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

(b) *Consistency*

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

(c) *Permeability*

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

(d) *Consolidation (one-dimensional)*

m_v	coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$
C_c	compression index $= -\Delta e/\Delta \log_{10} \sigma'$
c_v	coefficient of consolidation
T_v	time factor $= c_v t/d^2$ (d, drainage path)
U	degree of consolidation

(e) *Shear strength*

τ_f	shear strength	
c'	effective cohesion intercept	in terms of effective stress $\tau_f = c' + \sigma' \tan \phi'$
ϕ'	effective angle of shearing resistance, or friction	
c_u	apparent cohesion*	in terms of total stress $\tau_f = c_u + \sigma \tan \phi_u$
ϕ_u	apparent angle of shearing resistance, or friction	
μ	coefficient of friction	
S_t	sensitivity	

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

Form G.A. - O - 1

Project No. 71122

RECORD OF BOREHOLE 1

LOCATION See Figure 1 BORING DATE OCT. 28 TO NOV. 9, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.	ELEVATION SCALE
	765.7	GROUND SURFACE					770
WASH BORING; H CASING		COMPACT TO VERY DENSE REDDISH BROWN SANDY SILT TO SILTY SAND TRACE TO SOME GRAVEL & CLAY (SANDY SILT TILL)		1	2" D.O.	19	
				2	"	27	
				3	"	8	760
				4	"	6	
				5	"	30	
				6	"	119	750
				7	"	105	
	737.7			8	"	121	740
WASH BORING; NX CASING	28.0	VERY STIFF TO HARD THINLY LAYERED BROWN AND GREY SILTY CLAY TILL		9	"	61	
				10	"	119	730
				11	"	80	
	718.7			12	"	42	720
	47.0	VERY DENSE SANDY SILT SOME GRAVEL AND TRACE CLAY INCREASING GRAVEL CONTENT WITH DEPTH (SILTY SAND TILL)		13	"	125	
				14	"	144	710
				15	BXL RC	-	
				16	2" D.O.	6" / 8"	700
				17	BXL RC	-	
				18	2" D.O.	15" / 5"	
	695.7			19	BXL RC	-	
BX CASING	70.0			20	"	-	
				21	"	-	
ROTARY DRILLING; BXL CORE		HORIZONTALLY BEDDED GREENISH GREY SHALE AND VUGGY DOLOMITE WITH GYPSUM INCLUSIONS AND PRECIPITATES (BEDROCK - SALINA FORMATION)		22	"	-	690
				23	"	-	
				24	"	-	
				25	"	-	680
AX	676.2			26	AXT RC	-	
	89.5	END OF HOLE					

SHALE TO EL. 688.7 THEN DOLOMITE WITH LARGE VOIDS @ EL. 686 TO 682 THEN SHALE & GYPSUM.

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. 20 40 60 80

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM. V. - ⊕ U. - ○

COEFFICIENT OF PERMEABILITY, K., CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT Wp W Wl 10 20 30 40

PERCENT CORE RECOVERY	ESTIMATED PERCENT DRILL WATER RETURN
17	100
18	100
75	
80	100
75	
80	
62	
25	0
100	
60	

15 ◆ 5 Percent axial strain at failure (0 / 10)

ADDITIONAL LAB. TESTING: MH; MH; H; MH

PIEZOMETER OR STANDPIPE INSTALLATION

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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Form G.A. - - -

Project No. - - 7122 - - - - - -

RECORD OF BOREHOLE 2

LOCATION See Figure 1 BORING DATE NOV. 10 - 16, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.
	757.1 / 0.0	GROUND SURFACE				
WASH BORING NX CASING		COMPACT BROWN SANDY SILT WITH THIN LAYERS OF SILT AND FINE SAND SOME GRAVEL (SANDY SILT TILL)		1	2" D.O.	19
				2	"	22
				3	"	19
	736.6 / 20.5					
		COMPACT TO DENSE SILTY SAND SOME GRAVEL (SILTY SAND TILL)		4	"	18
				5	"	43
	728.1 / 29.0					
ROTARY DRILLING BX CASING		HARD REDDISH - BROWN TO BROWN SILT, SOME SAND, GRAVEL AND CLAY (SILTY CLAY TILL)		6	"	65
				7	"	16/9"
	713.6 / 43.5			8	BXL RC	-
		HARD REDDISH BROWN SILTY CLAY SOME SAND (TILL)		9	"	-
	708.8 / 48.3					
		VERY DENSE BROWN SILTY SAND, SOME COBBLES & BOULDERS THROUGHOUT (SILTY SAND TILL)		10	2" D.O.	120/8"
				11	BXL RC	-
	697.1 / 60.0					
BXL CORE		SOUND GREEN-GREY SHALE (BEDROCK - SALINA FORMATION)		12	"	-
				13	"	-
	690.8 / 66.3	END OF HOLE				

ZONES OF BRECCIA-LIKE CONGLOMERATE IN OLD VOIDS.

ELEVATION SCALE: 760, 750, 740, 730, 720, 710, 700, 690, 680

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM. V. - ● U. - O

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 | 1x10 | 1x10 | 1x10)

WATER CONTENT, PERCENT (10, 20, 30, 40) — W_P, W, W_L

ADDITIONAL LAB. TESTING: MH, MH

PERCENT CORE RECOVERY: 100, 5, 100, 96

EST. % DRILL WATER RETURN: 100, 10, 20, 0

0 / 15 ◆ 5 / 10 Percent axial strain at failure

PIEZOMETER OR STANDPIPE INSTALLATION

G.S.✓

SURFACE SEAL

GRANULAR BACKFILL

BENTONITE SEAL

PIEZOMETER

PEA GRAVEL

BENTONITE SEAL

GRANULAR BACKFILL

PIEZOMETER DRY TO ELEV. 701.1 NOV. 29, 1971

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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Project No. 71122

RECORD OF BOREHOLE 3

LOCATION See Figure 1 BORING DATE NOV. 18, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/FT.
	752.8	GROUND SURFACE				
WASH BORING; NX CASING	0.0	COMPACT TO DENSE SILTY SAND TO SANDY SILT SOME GRAVEL, COBBLES AND BOULDERS (SANDY SILT TILL)		1	2" D.O.	20
				2	"	41
				3	"	40
				4	"	50/4"
				5	"	100/6"
	722.8					
ROTARY DRILLING; NX CASING; AX CASING; AXT CORE	30.0	HARD RED-BROWN CLAYEY SILT, TRACE TO SOME SAND, GRAVEL & COBBLES (CLAYEY SILT TILL)		6	"	104
	713.8			7	"	170
	39.0	VERY DENSE BROWN SILTY FINE SAND (SILTY SAND TILL)		8	"	127
	702.8			9	"	181
	50.0	VERY DENSE BROWN SAND & GRAVEL (TILL)		10	"	138
	698.3			11	AXT RC	—
	54.5	WEATHERED GREEN SHALE WITH DOLOMITE BANDS (BEDROCK - SALINA FORMATION)		12	"	—
	690.3			13	"	—
	62.5	END OF HOLE				

ELEVATION SCALE: 760, 750, 740, 730, 720, 710, 700, 690, 680

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM. V. - ● U. - O

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10, 1x10, 1x10, 1x10)

WATER CONTENT, PERCENT (Wp, W, WL)

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

G.S.

BENTONITE SEAL

GRANULAR FILL

PIEZOMETER

BENTONITE SEAL

PIEZOMETER DRY TO ELEV. 696.8 NOV. 29, 1971.

r 30

21 100

39

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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FORM G.A. - D - 1

Project No. 7022

RECORD OF BOREHOLES 4 & 5

LOCATION See Figure 1 BORING DATE NOV. 4, 5, 8 & 9, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BOREHOLE 4

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.
	703.9	GROUND SURFACE				
ROTARY WASH / BX CASING	0.0	STIFF TO VERY STIFF REDDISH GREY BROWN **CLAYEY SILT (TILL)**		1	22" D.O.	8
				2	"	32
	695.7			3	"	18
ROTARY CORE	8.2	GREENISH GREY **SHALE** WITH DOLOMITE & GYPSUM LAYERS **(BEDROCK - S.F.)**		4	BXL RC	1
				5	"	4
	689.1					
	14.8	END OF HOLE				

DOLOMITE TO EL. 693.4 THEN SHALE WITH CLAY INCLUSIONS @ EL. 681

ELEVATION SCALE: 710, 700, 690, 680

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM. V. - ⊕ U. - ○

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10)

WATER CONTENT, PERCENT (Wp W WL; 10 20 30 40)

4

20

100 100

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

G.S.

BACKFILL

GRAVEL FILTER

STANDPIPE

W.L. IN STANDPIPE AT ELEV. 691.9 ON NOV. 5, 1971

STANDPIPE DESTROYED NOV. 29, 1971.

BOREHOLE 5

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.
	704.2	GROUND SURFACE				
DRY / EX CASING	0.0	**CLAYEY SILT** WITH		1	2" D.O.	6
	701.2	COBBLES & BOULDERS		2	"	7
	3.0	FIRM TO HARD BROWN **SANDY CLAYEY SILT**, SOME GRAVEL **(TILL)**		3	"	49
	693.2			4	BX RC	–
	11.0			5	D.O.	5"
ROTARY EXT CORE		**WEATHERED** GREEN **SHALE** & **FRACTURED** VUGGY **DOLOMITE (BEDROCK - SALINA FORMATION)**		6	BXT RC	–
				7	"	–
	682.5					
	21.7	END OF HOLE				

SHALE TO EL. 687 OVER HIGHLY FRACTURED DOLOMITE AND SHALE

ELEVATION SCALE: 710, 700, 690, 680, 670

65 100

74 100

42 0

0

MH

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

W.L. IN OPEN HOLE AT ELEV. 696.2, NOV. 8/71

15 (0, 10) 5 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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FORM G.A. - O - 1

Project No. 71122

RECORD OF BOREHOLES 6 & 7

LOCATION See Figure 1 BORING DATE NOV. 3 - 11, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
		6				
	700.7	GROUND SURFACE			2"	
DRY	0.0	VERY STIFF TO HARD BROWN **CLAYEY SILT**, SOME SAND		1	D.O.	28
	695.7			2	"	48
	5.0	COMPACT **SANDY GRAVEL**, SOME SILT		3	"	22
	691.7			4	BXL RC	11
	9.0	**WEATHERED** AND **FRACTURED** GREEN **SHALE** AND VUGGY **DOLOMITE** WITH GYPSUM INCLUSIONS **(BEDROCK-SALINA FORMATION)** BECOMING **SOUND** BELOW ELEV. 681		5	"	11
				6	"	11
				7	"	11
				8	"	11
	677.7			9	"	11
	23.0	END OF HOLE				
		7				
	690.5	GROUND SURFACE			2"	
	0.0	**SAND AND GRAVEL**		1	D.O.	45
	1.2	**WEATHERED** GREENISH GREY **SHALE** AND **DOLOMITE**, BECOMING **SOUND** BELOW ELEV. 679 BUT WITH GYPSUM INCLUSIONS **(BEDROCK-SALINA FORMATION)**		2	BXL RC	–
				3	"	–
				4	"	–
				5	"	–
				6	"	–
				7	"	–
	673.9					
	16.6	END OF HOLE				

BORING METHOD: ROTARY DRILLING — BX CASING — BXL CORE

INTERBEDDED SHALE AND DOLOMITE TO EL. 679.

ELEVATION SCALE: 710, 700, 690, 680, 670

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V.- + Q.-● REM.V.- ⊕ U.-○

Elev.	Shear strength	Percent core recovery	Estimated percent drill water return
690	50		
	45		
	40	100	
	30		
	60		
680	92	0	
690	47		
	61	10	
	16		
680	90		
	100		
	98	100	

COEFFICIENT OF PERMEABILITY, K., CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT Wp W WL (10 20 30 40)

ADDITIONAL LAB. TESTING: MH

PIEZOMETER OR STANDPIPE INSTALLATION

W.L. IN OPEN HOLE AT ELEV. 691·7, NOV. 9, 1971

W.L. AT GROUND SURFACE NOV. 4, 1971

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

0 / 15 ◆ 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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Form G.A. - D - 1

Project No. 71122

RECORD OF BOREHOLES 8 & 9

LOCATION See Figure 1 BORING DATE NOV. 1-3 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BOREHOLE 8

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80) / SHEAR STRENGTH Cu., LB./SQ.FT. (NAT. V.-+ REM.V.-⊕ Q.-● U.-○)	COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10) / WATER CONTENT, PERCENT (Wp W WL)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	693.6	GROUND SURFACE					700				
WASH / BX CASING	0.0	DENSE FINE TO MEDIUM SAND WITH GRAVEL & BOULDERS		1	2" D.O.	14					
	688.5			2	"	88/6"	690				
	5.1			3	"	75/6"					
ROTARY BX CORE		WEATHERED GREY SHALE WITH LIGHT GREY DOLOMITE WITH GYPSUM INCLUSIONS (BEDROCK SALINA FORMATION)		4	BXL RC	-		15 / 50			W.L. IN OPEN HOLE AT ELEV. 690.6 NOV. 3, 1971
				5	"	-		39 / 5			
				6	"	-	680	70			
				7	"	-		30 / 0			
	673.9										
	19.7	END OF HOLE									
		VUGGY DOLOMITE LAYER BETWEEN EL. 684 & EL. 680					670				

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

BOREHOLE 9

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.	ELEVATION SCALE	PERCENT CORE RECOVERY / EST. % DRILL WATER RETURN	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	693.3	GROUND SURFACE					700			
WASH / BX CASING	0.0	DENSE BROWN SAND, SOME GRAVEL TRACE SILT		1	2" D.O.	8				
	688.1			2	"	43	690			
	5.2			3	"	33/6"				
ROTARY DRILLING BX CORE		WEATHERED SHALE BECOMING SOUND SHALE BELOW ELEV. 681 WITH DOLOMITE LAYERS CONTAINING INCLUSIONS AND PRECIPITATES OF GYPSUM (BEDROCK - SALINA FORMATION)		4	BXL RC	-		20 / 100		W.L. IN OPEN HOLE AT ELEV. 691.7 NOV. 5, 1971
				5	"	-		95 / 100		
				6	"	-		57 / 25		
				7	"	-		23 / 25		
				8	"	-	680	62 / 0		
				9	"	-		100 / 0		
				10	"	-		68 / 0		
				11	"	-		100 / 100		
				12	"	-	670	100 / 100		
	664.2									
	29.1	END OF HOLE								
		DOLOMITE TO EL. 684, THEN SHALE TO EL. 677 OVERLYING THIN INTERBEDDED SHALE AND DOLOMITE.					660			

Percent axial strain at failure (0, 5, 10, 15)

VERTICAL SCALE
1 IN. TO 10 FT.

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Project No. 7122

RECORD OF BOREHOLES 10 & 11

LOCATION See Figure 1 & 2 BORING DATE NOV. 11, 12 & 24, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.	ELEVATION SCALE
	690.8 / 0.0	RIVER LEVEL WATER					
ROTARY DRILLING BX CASING BXL CORE	689.3 / 1.0	SANDY GRAVEL COBBLES & BOULDERS		1	2" D.O.	30	690
	687.3 / 3.5	SAND & GRAVEL TILL		2	"	53	
	685.8 / 5.0	SOUND GREY DOLOMITE WITH LAYERS OF SHALE & GYPSUM INCLUSIONS (BEDROCK - SALINA FORMATION)		3	BXL RC	1	
				4	"	1	680
				5	"	1	
	670.9 / 19.9	END OF HOLE					670
		DOLOMITE TOE EL. 681 GYPSUM INCLUSIONS BEGIN AT EL. 676.					
	690.8 / 0.0	RIVER LEVEL WATER					700
ROTARY BX CASING BXL CORE	690.8 / 0.8	COMPACT TO VERY DENSE SILTY SAND AND GRAVEL WITH COBBLES & BOULDERS		1	2" D.O.	24	690
				2	BXL RC	-	
				3	"	-	
	681.8 / 9.0			4	2" D.O.	75	
	680.1 / 10.7	DOLOMITE BEDROCK		5	BXL RC	-	680
		END OF HOLE					
							670

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. -● REM. V. - ⊕ U. -○

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10)

WATER CONTENT, PERCENT (Wp W WL)

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

10

39 70

37 50

48 50

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

11

27 100

12 0

27 100

50

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

0 / 15 ◆ 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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Form G.A. - D - I

Project No. 71122

RECORD OF BOREHOLES 12 & 13

LOCATION See Figure 1 & 2 BORING DATE NOV. 9, 10, 11 & 22, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

Column headings: BORING METHOD | SOIL PROFILE (ELEV'N. DEPTH, DESCRIPTION, STRAT. PLOT) | SAMPLES (NUMBER, TYPE, BLOWS/FT.) | ELEVATION SCALE | DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. 20 40 60 80; SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O | COEFFICIENT OF PERMEABILITY, K., CM./SEC. 1x10 1x10 1x10 1x10; WATER CONTENT, PERCENT Wp W WL | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

12

Boring Method	Elev'n. / Depth	Description	Sample No.	Type	Blows/Ft.	% Core Recovery	% Drill Water Return
	690.8	RIVER LEVEL					
	0.0	WATER					
ROTARY DRILLING, BX CASING	1.0	COMPACT TO VERY DENSE SANDY GRAVEL WITH COBBLES AND BOULDERS	1	2" D.O.	56		
			2	"	24		
	682.8		3	BXL R.C.	—	75	100
			4	"	—	50	50
ROTARY DRILLING, BXL CORE	8.0	FRACTURED GREY VUGGY DOLOMITE BECOMING SOUND BELOW ELEV. 680 WITH GYPSUM INCLUSIONS (BEDROCK - SALINA FORMATION)	5	"	—	69	20
			6	"	—	39	0
	672.1		7	"	—	27	
	18.7	END OF HOLE					

Elevation scale: 690, 680, 670

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY.

13

Boring Method	Elev'n. / Depth	Description	Sample No.	Type	Blows/Ft.	% Core Recovery	% Drill Water Return
	690.8	RIVER LEVEL					
	0.0	WATER					
ROTARY DRILLING, BX CASING	1.8	COMPACT BROWN SANDY GRAVEL WITH COBBLES AND SMALL BOULDERS	1	2" D.O.	21		
	683.3		2	BXL RC	—	20	10 to 20
ROTARY DRILLING, BXL CORE	7.5	FRACTURED TO FAIRLY SOUND GREY DOLOMITE WITH SEAMS OR LAYERS OF SHALE, OCC. SEAMS CLAYEY SILT (BEDROCK, SALINA FORMATION)	3	"	—	75	
			4	"	—	31	
	674.5		5	"	—	54	
	16.3	END OF HOLE					

Elevation scale: 700, 690, 680, 670, 660

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

0, 5, 10, 15 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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FORM G.A. - D - 1

Project No. 1122

RECORD OF BOREHOLES 14 & 15

LOCATION See Figure 2 BORING DATE NOV. 18 & 24, 25, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
	690.8	RIVER LEVEL				
	0.0	WATER				
ROTARY DRILLING / BX CASING	1.3	DENSE TO VERY DENSE BROWN **SILTY SAND AND GRAVEL** WITH COBBLES		1	2" D.O.	35
				2	"	54/3"
	682.1			3	"	65
	680.6			4	BXL RC	–
	10.2	END OF HOLE				
		FAIRLY SOUND GREY SHALE & DOLOMITE (BEDROCK - SALINA FORMATION)				

ELEVATION SCALE: 700, 690, 680, 670

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM. V. - ● U. - ○

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10)

WATER CONTENT, PERCENT (Wp W WL)

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

14

30 75

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

15

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
	690.5	RIVER LEVEL				
	0.0	WATER				
ROTARY DRILLING / NX CASING	1.2	COMPACT TO DENSE **SANDY GRAVEL** WITH COBBLES & BOULDERS		1	2" D.O.	18
				2	"	41
	681.5					
BX CA. / BXL CORE	9.0	**WEATHERED** GREEN **SHALE** AND VUGGY **DOLOMITE** BECOMING **SOUND** BELOW ELEV 676 **(BEDROCK - SALINA FORMATION)**		3	"	46
				4	BXL RC	–
				5	"	–
	665.5			6	"	–
	25.0	END OF HOLE				

80 27 100 50

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

0 / 15 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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FORM G.A. 3-1

Project No. 7122

RECORD OF BOREHOLES 16 & 17

LOCATION See Figure 2 BORING DATE NOV. 12, 15 & 25, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/FT.	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80) / SHEAR STRENGTH Cu., LB./SQ.FT. (NAT. V.- + Q.-● REM.V.- ⊕ U.-○)	COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10) / WATER CONTENT, PERCENT (Wp W WL)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
ROTARY DRILLING; BX CASING; BXL CORE								16			
	690.8	RIVER LEVEL									
	5.0	WATER									
	1.0	VERY DENSE **SANDY GRAVEL** WITH COBBLES AND BOULDERS		1	D.O. 2"	58	690				
				2	BXL RC	1		67 100			
	684.3			3	"	1					
	6.5	**WEATHERED** INTERBEDDED **SHALE** AND **DOLOMITE** WITH CLAY SEAMS **(BEDROCK-SALINA FORMATION)**		4	"	1	680	22 50			
				5	"	1		25 20			
	674.9			6	"	1		50 20			
	15.9	END OF HOLE						ESTIMATED PERCENT DRILL WATER RETURN			
		SOUND SHALE BELOW EL. 678					670	PERCENT CORE RECOVERY			
								17			
							700				
ROTARY; BX CASING	693.8	RIVER LEVEL									
	9.8	WATER									
	1.0	DENSE TO VERY DENSE BROWN **SAND & GRAVEL** SOME SILT & COBBLES		1	D.O. 2"	41	690				
				2	"	90					
	683.6			3	BXL RC	—		50 75			
	681.6						680				
	9.2	END OF HOLE						ESTIMATED PERCENT DRILL WATER RETURN			
		FAIRLY SOUND DOLOMITE & SHALE (BEDROCK-SALINA FORMATION)						PERCENT CORE RECOVERY			
							670				

Percent axial strain at failure (0, 5, 10, 15)

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

DRAWN

CHECKED

Project No. 7122

RECORD OF BOREHOLES 18 & 19

LOCATION See Figure 2 BORING DATE NOV. 11, 12, & 15, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80) / SHEAR STRENGTH Cu., LB./SQ.FT. (NAT. V.- + Q.-● REM.V.- ⊕ U.-○)	COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10) / WATER CONTENT, PERCENT (Wp W Wl; 10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
								18			
	690.5	RIVER LEVEL									
	0.0	WATER					690				
ROTARY DRILLING EXL CORE / EX CA. / NX CA.	1.3	DENSE SANDY GRAVEL		1	2" D.O.	45					
	685.5			2	BXL RC	1		50			
	5.0	COARSE GRAVEL COBBLES & BOULDERS		3	"	1		17	100		
	679.5						680				
	11.0	FRACTURED GREY VUGGY DOLOMITE AND GREY GREEN SHALE WITH CLAY SEAMS (BEDROCK-SALINA FORMATION)		4	"	1		33			
				5	"	1		42	20		
				6	"	1		40			
				7	"	1		92	0		
	668.2			8	"	1	670	60			
	22.3	END OF HOLE									
		CAVITIES IN DOLOMITE MORE NUMEROUS ABOVE EL. 676, CLAY SEAMS INCREASE BELOW EL. 671.						ESTIMATED PERCENT DRILL WATER RETURN; PERCENT CORE RECOVERY			
							660				
								19			
							700				
	696.5	GROUND SURFACE									G.S.
WASH BORING & ROTARY DRILL NX CASING / ROTARY DRILLING BX CA. / BXL CORE	0.0	COMPACT TO DENSE SILTY SAND SOME GRAVEL		1	2" D.O.	4					
	691.5			2	"	19					
	5.0	COMPACT TO DENSE SANDY GRAVEL		3	"	24	690			MH	CAVED MATERIAL
				4	"	30					
	684.5			5	"	138					BENTONITE SEAL
	12.0	HIGHLY WEATHERED INTERBEDDED GREY SHALE AND DOLOMITE WITH NUMEROUS GYPSUM INCLUSIONS (BEDROCK-SALINA FORMATION)		6	BXL RC	—		25	50-0		
				7	"	—	680	61	0-10		GRANULAR FILL
				8	"	—		31			
				9	"	—	670	41	0		PIEZOMETER
				10	"	—		13			
	664.8										
	31.7	END OF HOLE									
		SHALE TO EL. 682 OVERLYING SHALY DOLOMITE, WITH CLAY SEAMS AT EL. 671.						ESTIMATED PERCENT DRILL WATER RETURN; PERCENT CORE RECOVERY.			W.L. IN PIEZOMETER AT ELEV. 691.0 NOV. 29, 1971.
							660				

0 / 15 ◆ 5 / 10 Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

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Form G.A. - D - 1

Project No. 71122

RECORD OF BOREHOLES 20 & 21

LOCATION See Figure 2 BORING DATE NOV. 19 & 24, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

20

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
	695.7	GROUND SURFACE				
DRY BORING UNCASED	0.0	SILTY SAND (TOPSOIL)		1	2" D.O.	4
	2.0	COMPACT SILTY SAND				
	4.0	COMPACT TO DENSE SANDY GRAVEL		2	"	22
	685.4			3	"	59
	11.0	END OF HOLE HIGHLY WEATHERED SHALE BEDROCK				

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V.- + Q.-● REM.V.- ⊕ U.-○

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. 20 40 60 80

COEFFICIENT OF PERMEABILITY, K., CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT Wp W WL

ELEVATION SCALE: 700, 690, 680

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: W.L. IN OPEN HOLE AT ELEV. 690.5 NOV. 24, 1971

21

BORING METHOD		ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
		697.3	GROUND SURFACE				
WASH BORING	NX CASING	0.0	SILTY SAND (TOPSOIL)		1	2" D.O.	3
		2.0	COMPACT TO LOOSE BROWN SILTY SAND		2	"	12
		689.3			3	"	4
		8.0	DENSE BROWN SILTY SAND AND GRAVEL		4	"	81
		686.3					
ROTARY	BXL CORE	11.0	WEATHERED AND FRACTURED INTERBEDDED SHALE & DOLOMITE (BEDROCK - SALINA FORMATION)		5	BXL RC	-
					6	"	-
		676.8			7	"	-
		20.5	END OF HOLE				

5	20	50
75	20	
-		

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

15 ◆ 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

DRAWN

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Form G.A. - D - 1

Project No. 71122

RECORD OF BOREHOLES 22 & 23

LOCATION See Figure 2 BORING DATE NOV. 16 & 24, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80) / SHEAR STRENGTH Cu., LB./SQ.FT. (NAT. V.- + REM.V.- ⊕ Q.-● U.-○)	COEFFICIENT OF PERMEABILITY, K, CM./SEC. (1x10 1x10 1x10 1x10) / WATER CONTENT, PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		22									
	697.3	GROUND SURFACE					700				G.S.
DRY BX CASING / ROTARY DRILLING BXL CORE	0.0 / 692.3	COMPACT BROWN **SILTY SAND**		1	2" D.O.	5					GRANULAR FILL
	5.0 / 689.3	FIRM BROWN **CLAYEY SILT**		2	"	23					
	8.0 / 685.3	COMPACT **SANDY GRAVEL**, COBBLES		3	"	11					
				4	"	25	690				
				5	"	100/6"					
	12.0	**WEATHERED** AND **FRACTURED** INTER-BEDDED GREY **SHALE** AND VUGGY **DOLOMITE** (**BEDROCK-SALINA FORMATION**)		6	BXL RC	-		29 10			
				7	"	-	680	62			
				8	"	-		50 50			
	672.4 / 24.9	END OF HOLE									PIEZOMETER
		DOLOMITE TO EL. 679 WITH CAVITIES BEGINNING AT EL. 682, CLAY INCLUSIONS BELOW EL. 679					670	ESTIMATED PERCENT DRILL WATER RETURN; PERCENT CORE RECOVERY			W.L. IN PIEZOMETER AT ELEV. 691.1 NOV. 29, 1971
		23									
	698.4	GROUND SURFACE					700				
WASH BORING / NX CASING	0.0 / 695.4	SILTY SAND (**TOPSOIL**)		1	2" D.O.	5					
	3.0	LOOSE BROWN **SILTY SAND**, TRACE OF ORGANIC MATTER		2	"	10					
	686.4			3	"	9	690				W.L. IN OPEN HOLE AT ELEV. 690.9 NOV. 25, 1971
	684.9	**SHALE BEDROCK** (WEATHERED)		4	"	139					
	12.5	END OF HOLE					680				

15 ◆ 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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Form G.A. - D - I

Project No. 71122

RECORD OF BOREHOLES 24 & 25

LOCATION See Figure 2 | BORING DATE NOV. 17 & 26, 1971 | DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. | PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

Column headings: BORING METHOD; SOIL PROFILE (ELEV'N./DEPTH, DESCRIPTION, STRAT. PLOT); SAMPLES (NUMBER, TYPE, BLOWS/FT.); ELEVATION SCALE; DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80); SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O; COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10, 1x10, 1x10, 1x10); WATER CONTENT, PERCENT (W_p, W, W_L); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

24

Boring Method	Elev'n. / Depth	Description	Sample No.	Type	Blows/Ft.	Percent Core Recovery	Estimated Percent Drill Water Return
	701.2	GROUND SURFACE					
ROTARY DRILLING, NX CASING	0.0	TOPSOIL	1	2" D.O.	9		
	1.0	COMPACT TO VERY LOOSE BROWN SANDY SILT TO SILTY FINE SAND TRACE OF CLAY AND SHELLS	2	"	26		
			3	"	7		
	689.2		4	"	3		
ROTARY DRILLING, EX CA.	12.0	VERY DENSE BROWN SAND AND GRAVEL, SOME SILT	5	"	67		
			6	"	55		
	684.2		7	"	96		
ROTARY DRILLING, BXL CORE	17.0	WEATHERED AND FRACTURED SHALE AND DOLOMITE (BEDROCK-SALINA FORMATION)	8	BXL RC	—	10	100
			9	"	—	25	0
	677.1		10	"	—	100	
	24.1	END OF HOLE					

Elevation scale: 700, 690, 680

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

25

Boring Method	Elev'n. / Depth	Description	Sample No.	Type	Blows/Ft.	Percent Core Recovery	Estimated Percent Drill Water Return
	698.7	GROUND SURFACE					
DRY BORING, BX CASING	0.0	BLACK SILTY SAND (TOPSOIL)	1	2" D.O.	11		
	694.2		2	"	20		
	4.5	LOOSE BROWN SILTY SAND, TRACE GRAVEL	3	"	4		
	689.7						
ROTARY DRILLING, BXL CORE	9.0	WEATHERED AND FRACTURED INTER-BEDDED SHALE AND VUGGY DOLOMITE (BEDROCK-SALINA FORMATION)	4	"	100		
			5	BXL RC	—	52	
			6	"	—	50	50
	677.2		7	"	—	42	
	21.5	END OF HOLE					

SMALL CAVITIES IN DOLOMITE BELOW EL. 681.

Elevation scale: 700, 690, 680, 670

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

W.L. IN OPEN HOLE AT ELEV. 691.8 NOV. 18, 1971

0 / 15 ✦ 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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CHECKED [signature]

FORM G.A. - D - 1

Project No. 7122

RECORD OF BOREHOLES 26 & 27

LOCATION See Figure 2 . BORING DATE NOV. 25, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FT.
		26				
	691.3	GROUND SURFACE				
DRY BORING — NX CASING	0.0 / 695.8	SILTY SAND (TOPSOIL)		1	2" D.O.	5
	3.5	HARD BROWN CLAYEY SILT, TRACE OF SAND AND GRAVEL		2	"	49
	689.4	(CLAYEY SILT TILL)				
DRY BORING — UNCASED	9.9	WEATHERED SHALE BEDROCK		3	"	88
	685.8			4	"	50
	13.5	END OF HOLE				
		27				
	700.7	GROUND SURFACE				
ROTARY — EX CASING	0.0	SILTY SAND (TOPSOIL)		1	2" D.O.	7
	2.0	DENSE SAND AND GRAVEL, SOME COBBLES & BOULDERS, TRACE SILT		2	"	104
	690.4					
ROTARY — BXL RC	10.3	FAIRLY SOUND GREEN SHALE AND DOLOMITE BEDROCK		3	BXL RC	—
	686.4					
	14.3	END OF HOLE				

ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80)	COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10 1x10 1x10 1x10)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
700	SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. -● REM.V. - ⊕ U. -○	WATER CONTENT, PERCENT W_P W W_L		
690				W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 25, 1971
680				
710				
700				
690	77 50			
680	ESTIMATED PERCENT DRILL WATER RETURN — PERCENT CORE RECOVERY			W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 26, 1971

0 / 15 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

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CHECKED

Form G.A. [redacted] 1

Project No. 1122

RECORD OF BOREHOLE 28

LOCATION See Figure 1 BORING DATE NOV. 19 - 26, 1971 DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN. PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/FT.
	802.0	GROUND SURFACE				
ROTARY DRILLING, NX CASING, BX CASING, BXL CORE	0.0	DENSE TO VERY DENSE **SAND** TO **SILTY SAND**, SOME GRAVEL, COBBLES AND BOULDERS		1	2" D.O.	7
				2	"	27
	791.5			3	"	88
	10.5		4		"	132/9"
				5	"	175
		HARD RED-BROWN TO GREY-BROWN **CLAYEY SILT**, TRACE TO SOME SAND, GRAVEL AND OCCASIONAL COBBLES **(TILL)**		6	"	160
				7	"	160
				8	"	137
			9		"	145/6"
				10	"	180
	747.0			11	"	195
	55.0	VERY DENSE BROWN SILTY SAND, SOME GRAVEL & COBBLES **(SANDY TILL)**	12		"	100/6"
	735.0					
	67.0		13		"	120/4"
		HARD BROWN CLAYEY SILT TO SILTY CLAY, SOME GRAVEL, TRACE OF SAND **(SILTY TILL)**		14	BXL CORE	-
				15	"	-
				16	"	-
	717.0			17	"	-
	85.0	END OF HOLE				

ELEVATION SCALE: 810, 800, 790, 780, 770, 760, 750, 740, 730, 720

DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80)

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ● REM.V. - ● U. - O

COEFFICIENT OF PERMEABILITY, K., CM./SEC. (1x10, 1x10, 1x10, 1x10)

WATER CONTENT, PERCENT (Wp, W, Ws)

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

G.S.

BENTONITE SEAL

GRAVEL FILTER

PIEZOMETER 'B'

BENTONITE SEAL

GRAVEL FILTER

PIEZOMETER 'A'

87
33 100
42
0

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

15 ◆ 5 Percent axial strain at failure (0, 10)

W.L. IN PIEZOMETER 'A' AT ELEV. 728.2 AND PIEZOMETER 'B' AT ELEV. 777.5 NOV. 29, 1971.

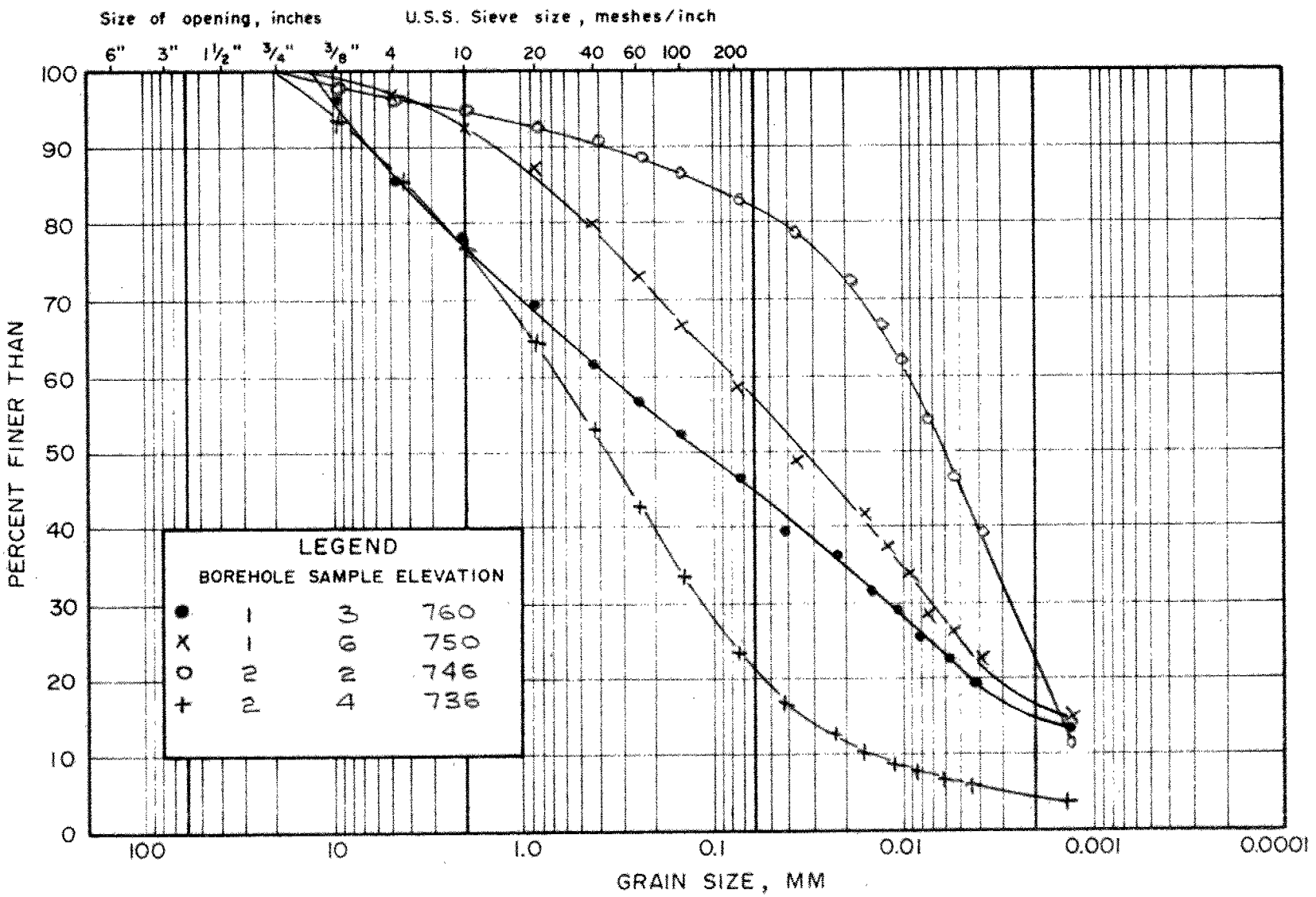
VERTICAL SCALE 1 IN. TO 10 FT.

Golder Associates

DRAWN

CHECKED

M.I.T. GRAIN SIZE SCALE



GRAIN SIZE DISTRIBUTION
UPPER SANDY SILT TILL

FIGURE 4

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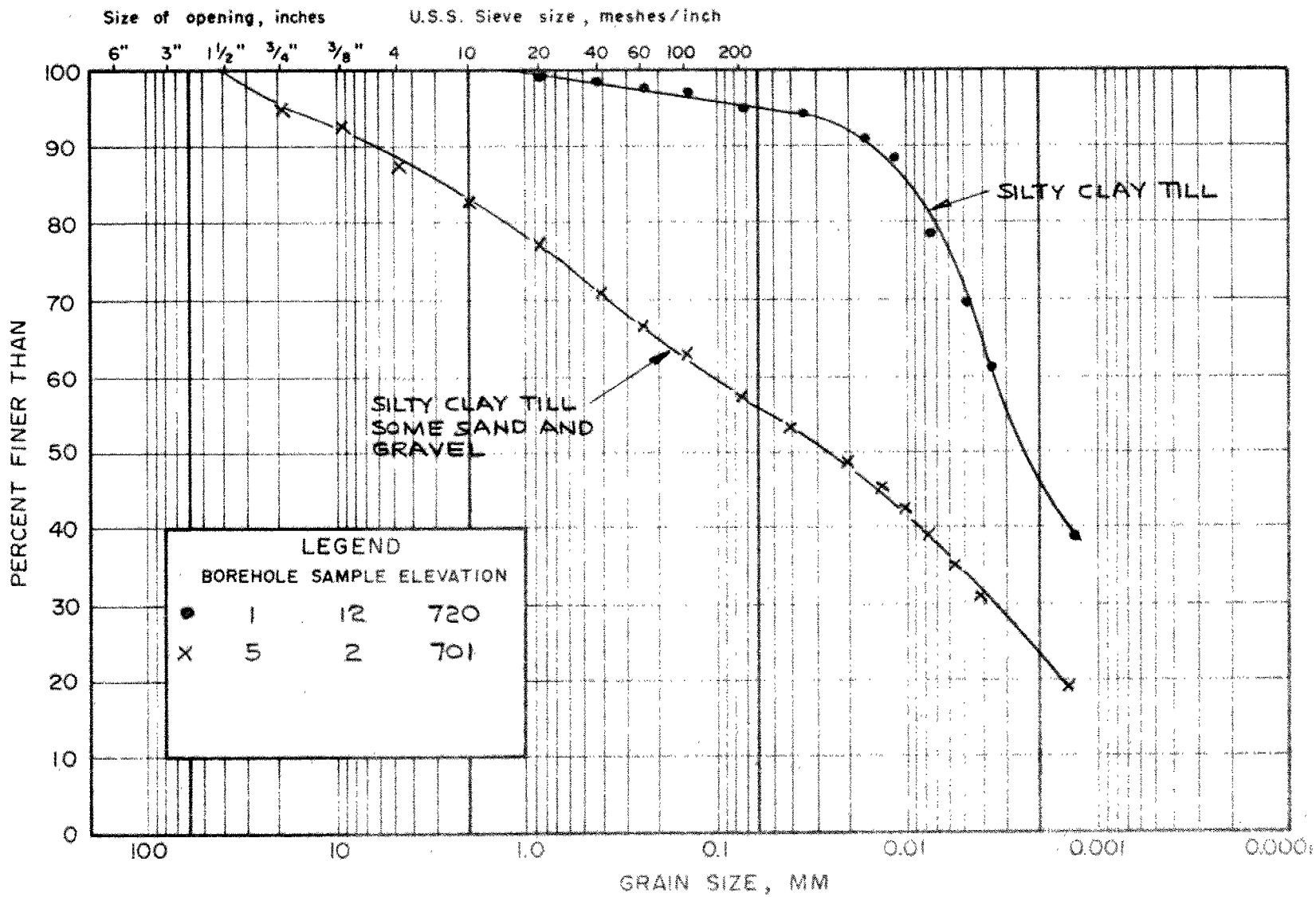
M.I.T. GRAIN SIZE SCALE



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GRAIN SIZE DISTRIBUTION
SILTY CLAY TILL

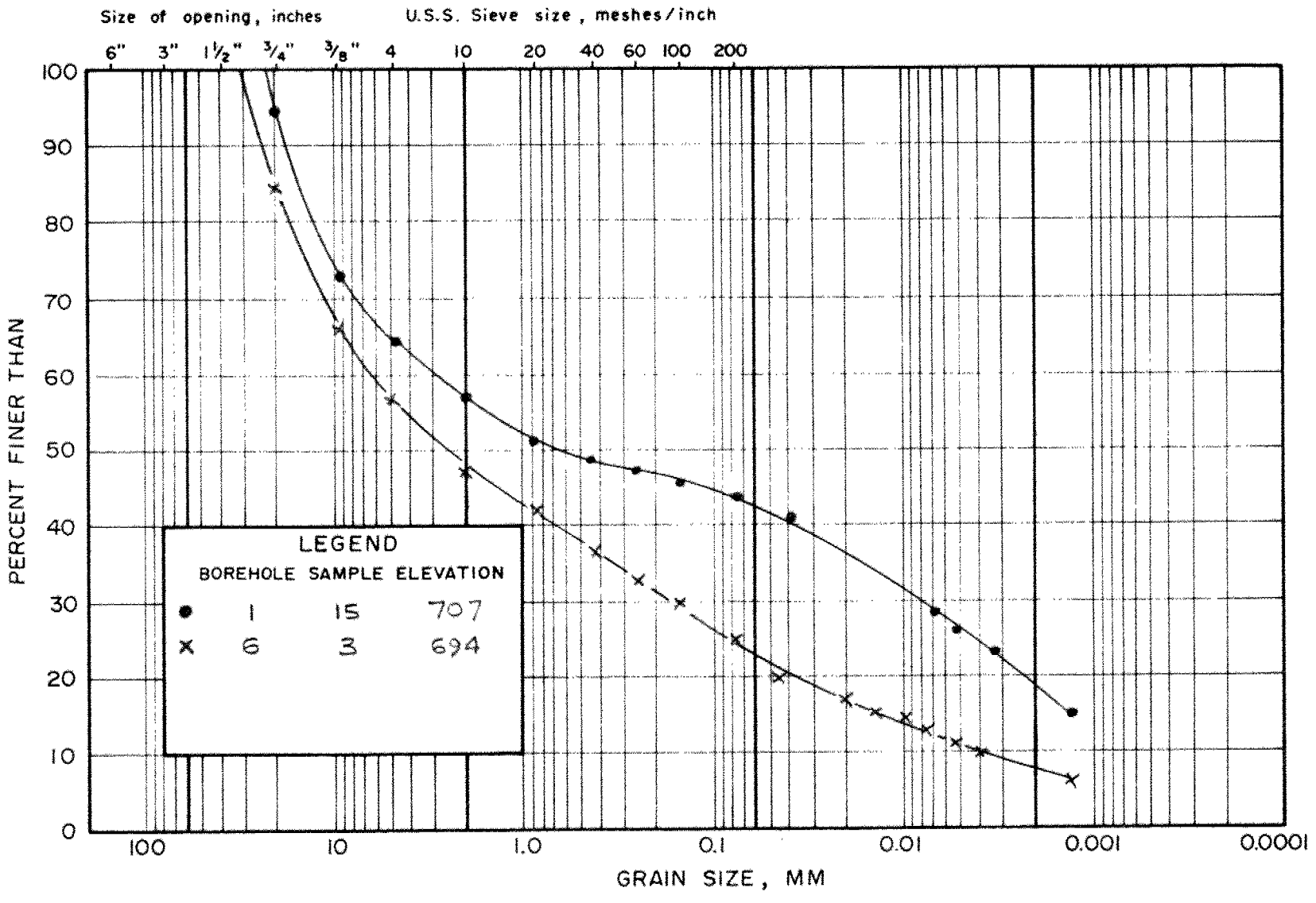
FIGURE 5

Form G.A.-D.-6

PROJECT 7122

Golder Associates

M.I.T. GRAIN SIZE SCALE

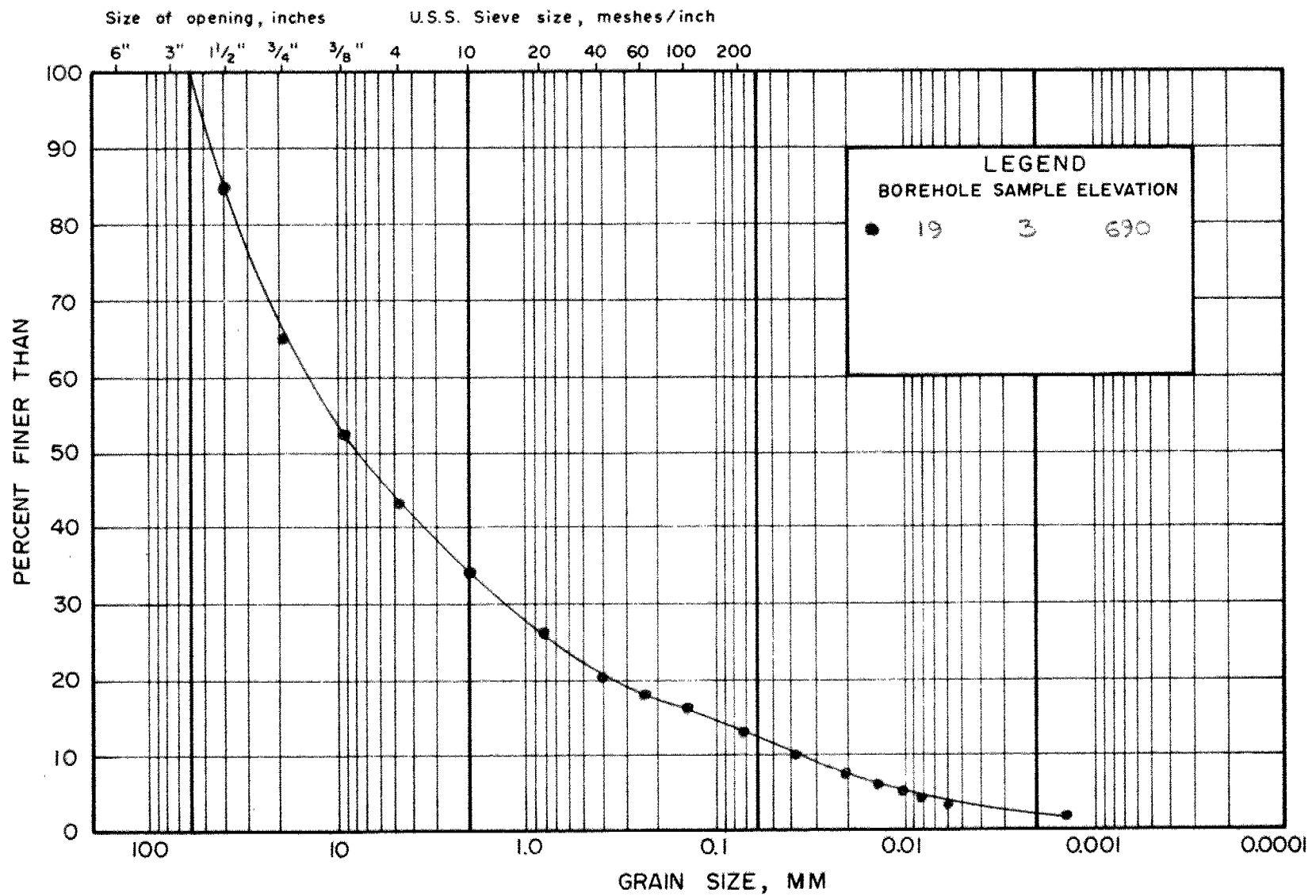


COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

GRAIN SIZE DISTRIBUTION
LOWER SANDY SILT TILL

FIGURE 6

M.I.T. GRAIN SIZE SCALE



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

GRAIN SIZE DISTRIBUTION
SANDY GRAVEL

FIGURE 7

Golder Associates

BA 1604

DEPARTMENT OF HIGHWAYS ONTARIO

MEMORANDUM

TO: Mr. A. M. Toye,
Bridge Engineer,
Bridge Division.

Attention: Mr. C. McCombie.

FROM: Mr. A. G. Stermac,
Principal Foundation Engr.,
Foundation Section,
Materials & Research Division.

DATE: February 27, 1963

OUR FILE REF.

IN REPLY TO

SUBJECT: D.H.O. PRELIMINARY FOUNDATION INVESTIGATION REPORT -
Proposed Grand River Crossing, Hwy. #403, Paris, Ont.,
W.J. 63-F-14 -- District #2 -- W.P. 159-60.
2.6 mi W. of Hwy. 2

As requested, attached we are forwarding to you, the results of our foundation investigation carried out at the above site on four separate lines, in order to establish the most favourable crossing location.

This report contains, under separate headings, a description of the existing subsoil conditions found at each of the four lines, as well as borelogs and Dwg. No. 63-F-14A.

We believe the information contained therein, will serve your immediate needs; however, if there are any queries in connection with this project, please do not hesitate to contact our Office.

A. G. Stermac,
PRINCIPAL FOUNDATION ENGINEER

AGS/MdeF
Attach.

cc: Messrs. A. M. Toye (2)
H. A. Tregaskes
H. D. McMillan
A. Gater
W. L. Fraser
J. Roy
A. Watt
W. Kinnear - Functional Planning Engr.,
London Region.

Foundations Office
Gen. Files.

PRELIMINARY FOUNDATION INVESTIGATION

For

Proposed Grand River Crossing,
Hwy. #403, Paris, Ont., District #2.
W.J. 63-F-14 -- W.P. 159-60.

A memorandum, dated January 31, 1963, was received from the Bridge Location Section, requesting a preliminary subsoil investigation at the site, on four separate lines, in order to establish the most favourable crossing location.

The field investigation consisted of 8 sampled boreholes, two on each line, and on opposite banks of the river. Samples were recovered by means of a 2-inch split-spoon sampler, driven into the soil with an energy of 350 foot-pounds per blow. Rock samples were obtained using 5-foot long AXT and BXL core barrels.

The locations and elevations of all boreholes are shown on the attached Drawing No. 63-F-14A, and were established by a D.H.O. survey crew prior to the drilling operations. All elevations are of geodetic origin.

The subsoil conditions, as plotted on the Drawing No. 63-F-14A and on the attached borehole logs, were found to be as follows:

Brown Line:

On the west side of the river, a very dense brown sand and gravel with boulders was found to a depth of 13.0 feet below ground level, or to elevation 682.0. Underlying this granular

cont'd. /2 ...

Brown Line: (cont'd.) ...

overburden, a weathered green shale with boulders extends to 21.5 feet, or elevation 673 ± where an interbedded bedrock of irregular shale and limestone bands was found, alternately grey and green in color.

On the east side of the river, no overburden was found above the weathered green shale at elevation 692.0, save for a foot of ice and loose sand. The weathered zone extended to elevation 686.0 where, again, interbedded shale and limestone bands, alternately green and grey, were found.

In general, the bedrock consists of softer and relatively harder bands, with some of the softer portion washing and grinding up while coring, as indicated by a poor recovery of only 40% - 60%.

Original Line:

In borehole #4, on the west bank of the river, a compact to very dense deposit of sand and gravel with numerous boulders was found from ground level, elevation 692.5, to elevation 674.5, some 18 feet below the ground. Traces of weathered green shale were also encountered in places. Below this overburden, a grey limestone - dolomite bedrock, was encountered.

In borehole #3, located on the east side, weathered green shale with grey limestone boulders, was found from ground level, elevation 692.0, to elevation 684.5 where grey limestone-dolomite was again encountered.

cont'd. /3 ...

Red and Blue Line:

Similar subsoil conditions as on the previous lines were encountered on this line. On the west side, a compact, brown sand and gravel was found from ground level, between elevations 690.0 and 684.5, from where weathered green shale, completely decomposed in places, extended to elevation 672.5.

The above strata were underlain by dolomite - limestone bedrock with gypsum seams. The bedrock was sound, but fissured, and was grey to white in color.

On the east side, the weathered green shale starts at ground level and extends from elevation 690.0 to 676.0, where the dolomite - limestone bedrock was encountered.

Black Line:

This was the most southerly line investigated, and the subsoil conditions were found to be considerably different from the other lines.

On both sides of the river, sand, gravel and boulders comprised the overburden between elevations 687.0 and 663.0. Dolomite - limestone bedrock, with gypsum seams was found at elevation 663.0, in both cases, and 100% recovery was achieved in a 5-foot, BXL core barrel.

No shale stratum was encountered on this line, save for traces of weathered green shale in borehole #7 on the east side of the river. In borehole #8, on the west side, numerous boulders consisting of shale, limestone, dolomite, conglomerate and occasional

cont'd. /4 ...

Black Line: (cont'd.) ...

igneous fragments were found in the overburden. At elevation 673.0, some 17 feet below the ice level, and 14 feet below ground level, artesian water was found, rising to 8 feet above the ice, or to elevation 698.0.

Summary:

Sound shaley - limestone and dolomitic - limestone was found on all lines investigated. Varying depth of sand, gravel and boulders, or a badly weathered shale, or both, comprises the overburden.

In general, sound bedrock was found at elevations 685 ± and 674 ± and the east and west banks of the river, respectively, on the Brown and Originally proposed lines.

On the Red and Blue lines, sound bedrock was encountered at elevations 676 ± and 672 ± , on the east and west sides, respectively.

Bedrock on the Black line, was found at elevation 663 ± . The depth of overburden was the greatest on this line, and artesian water was encountered on the west side.

From the above, it is evident that the bedrock is generally deeper on the west side of the river and dips in a southerly direction. Depth to bedrock, from ice level varies from 8 to 27 feet at boreholes #1 and #8, respectively.

Further investigation will be required for the proposed structure once the most suitable crossing is chosen.

cont'd. /5 ...

Miscellaneous:

The field work, carried out during the period of January 31, 1963 to February 14, 1963, together with the preparation of this report, was performed by Mr. G. Mierzynski under the general supervision of Mr. K. Selby of the Foundation Section. Equipment was owned and operated by the Johnston Drilling Co. of Ottawa.

February 1963

APPENDIX I.

61-4331

OFFICE REPORT ON SOIL EXPLORATION

BA 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 63-F-14 LOCATION Brown Line - West Side ORIGINATED BY G.M.

W.P. 159-60 BORING DATE Jan. 31 & Feb. 1, 1963. COMPILED BY G.M.

DATUM D.H.O. BOREHOLE TYPE Washboring - BX & NX Casing. CHECKED BY H.S.

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE: BLOWS / FOOT (20 40 60 80 100) / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w / WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
694.8 / 0.0	Groundlevel									W.L. in Borehole ▽ 692.8 / 2.0
	Sand, gravel and boulders - Very dense Brown		1	SS	51	690				
			2	SS	52					
681.8 / 13.0	Weathered green shale and boulders.	TOPSOIL	3	SS	51	680	Hammer Bounding			
			4	RC	-					
673.3 / 21.5	Interbedded shale and limestone bands. - green and grey.		5	RC	- AXT Core Barrel	670				30% Recovery
667.8 / 27.0	End of borehole.					660				

FORM 08-ML-1 REV. 951 OFFICE REPORT — SOIL EXPLORATION

61-4091

BA 1604

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO 2

FOUNDATION SECTION

JOB 62-Y-12 LOCATION Brow: Line - East Side N.B. D.M.

W.P. 2114-66 RECEIVED DATE Feb. 14, 1962. PLOTTED CWK

DATUM D.H.C. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.G.

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
694.0	Ice Level									1.0' of Ice
0.0										
693.0										
1.0	Sand									
692.0										
2.0	Weathered green shale & boulders.	HHOHO				690				
			1	GS	-					
			2	SS	118					
686.2			3	RC	-					
7.8	Interbedded shale and limestone bands. -Green and grey.		4	RC	-					60% Recovery
			AXT Core			680				
			5	RC	-					40% Recovery
			AXT Core							
676.7										
17.3	End of borehole.					670				

FORM OB-ML REV. 961
61-4391

OFFICE REPORT — SOIL EXPLORATION

BH 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 63-F-14 LOCATION Original Line - east side ORIGINATED BY G.M.
W.P. 159-60 BORING DATE Feb. 5, 1963. COMPILED BY G.M.
DATUM D.H.O. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.S.

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
694.0 / 0.0	Ice Level									1.0' of Ice
693.0 / 1.0	Sand									
692.0 / 2.0	Weathered green shale with limestone boulders.	OVERBURDEN	1	GS	-	690				
			2	SS	74for6"					
			3	RC	-					35% Recovery
				BXL Core						
684.5 / 9.5	Limestone-dolomite - fissured - grey		4	RC	-					
				BXL Core		680				100% Recovery
680.5 / 13.5	End of borehole.									
						670				

BA 1604

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 63-F-14 LOCATION Original Line - West Side ORIGINATED BY G.M.
W P 159-60 BORING DATE Feb. 6 & 7, 1963. COMPILED BY G.M.
DATUM D.H.O. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.S.

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
694.5 / 0.0	Ice Level									
693.5 / 1.0	▽ Water Level									1.0' of Ice
692.5 / 2.0	Groundlevel									
	Sand, gravel and boulders with traces of weathered green shale.					690				
			1	SS	28					
			2	RC	7'					
			BXL Core			680				40% Recovery
			3	RC	-					
674.5			BXL Core							30% Recovery
20.0	Limestone-dolomite - fissured - grey		4	RC	-					
670.5			BXL Core			670				100% Recovery
24.0	End of borehole.									

FORM 08 - ML - 12[illegible] REV. 1961

51-4391

OFFICE REPORT - SOIL EXPLORATION

BA 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

JOB 63-F-14 LOCATION Red & Blue Line - East Side ORIGINATED BY G.M.

W.P 159-60 BORING DATE Feb. 7 & 8, 1963. COMPILED BY G.M.

DATUM D.H.O. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.S.

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P C F	REMARKS
693.5	Ice Level									2.0' of Ice
0.0										
691.5	▽ Water Level									
2.0										
690.0	Groundlevel					690				
3.5	Weathered green shale and limestone boulders.		1	RC	-					
			2	SS	134					
			3	RC AXT Core	-					
			4	RC BXL Core	4'	680				
675.9			5	SS	>100					
17.6	Dolomite-limestone with gypsum seams - fissured - grey & white		6	RC BXL Core	-					100% Recovery
670.5						670				
23.0	End of borehole.									

OFFICE REPORT ON SOIL EXPLORATION

BA 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 63-F-14 LOCATION Red & Blue Line - West Side ORIGINATED BY G.M.

W.P. 159-60 BORING DATE Feb. 11, 1963. COMPILED BY G.M.

DATUM D.H.C. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.S.

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
693.5 / 0.0	Ice Level									
692.5 / 1.0	▽									1.0' of Ice
690.0	Groundlevel					690				
3.5	Sand and gravel Compact - brown		1	SS	20					
684.5 / 9.0	Weathered green shale - completely decomposed in places.		2	SS	123					
			3	RC	-	680				
			4	SS	14					
672.5			5	SS	42 for 6"					
21.0	Dolomite-limestone with gypsum seams - fissured - grey & white		6	RC	- BXL Core	670				100% Recovery
667.0						660				
26.5	End of borehole.									

BA 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

JOB 63-F-14 LOCATION Black Line - EastSide ORIGINATED BY G.M.
W.P. 159-60 BORING DATE Feb. 12, 1963. COMPILED BY G.M.
DATUM D.H.C. BOREHOLE TYPE Washboring - BX Casing. CHECKED BY H.S.

ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
690.8	Ice Level									1.5' of Ice
689.3 1.5	▽ Waterlevel					690				
687.8 3.0	Groundlevel									
	Sand, gravel and boulders Compact - brown & grey.		1	SS	14					
			2	SS	30	680				
	Traces of weathered green shale in places.		3	SS	16					
			4	SS	24	670				
			5	WS	-					
663.8			6	SS	88					
27.0	Dolomite-limestone with gypsum seams - fissured - grey & white.		7	RC	-	660				100% Recovery
658.3			BXL Core							
32.5	End of borehole.									

BA 1604

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 8

FOUNDATION SECTION

JOB 63-F-14 LOCATION Black Line - West Side ORIGINATED BY G.M.
W.P. 159-60 BORING DATE Feb. 13 & 14, 1963. COMPILED BY G.M.
DATUM D.H.O. BOREHOLE TYPE Washboring - BX Casing CHECKED BY H.S.

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
690.0 / 0.0	Ice Level					690				3'-0 of Ice
687.0 / 3.0	▽ Groundlevel									
	Sand, gravel and boulders - Brown and grey.		1	SS	30					
			2	RC	-					50% Recovery
				BXL Core		680				
	Boulders consist of shale, limestone, dolomite, conglomerate and occasional igneous fragments.		3	RC	-					▽ 673.0 / 17.0
				BXL Core		670				Artesian water to 81'.0 above ice
663.0 / 27.0	Dolomite-limestone with gypsum seams -fissured -grey & white.					660				100% Recovery
658.0 / 32.0	End of borehole.									

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

CONSISTENCY	'N' BLOWS / FT.	c LB. / SQ. FT.	DENSENESS	'N' BLOWS / FT.
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

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	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_P	PLASTIC LIMIT
I_P	PLASTICITY INDEX
s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
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
m_v	COEFFICIENT OF VOLUME CHANGE $= \frac{-\Delta e}{(1+e)\Delta \sigma'}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX $= \frac{\Delta e}{\Delta \log_{10} \sigma'}$
T_v	TIME FACTOR $= \frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF EFFECTIVE STRESS $\tau_f = c' + \sigma' \tan \phi'$
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF TOTAL STRESS $\tau_f = c_u + \sigma \tan \phi$
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

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

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ε	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNGS MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_o	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

DEPARTMENT OF HIGHWAYS ONTARIO

MEMORANDUM

BA 2086

To: Mr. A. M. Toye,
Bridge Engineer,
Bridge Division.

Attention: Mr. S. McCombie

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

Date: May 20, 1965

Our File Ref.

In reply to

Subject:

FOUNDATION INVESTIGATION REPORT
For
Grand River and Hwy. #403, Line 'H',
Co. of Brant, Twp. of Brantford, 2.6 mi W of Hwy. 2
Lot 16, Con. II, District #2 (London)

W.J. 63-F-14B -- W.P. 159-60

Attached, we are forwarding to you, our detailed foundation investigation report on the subsoil conditions existing at the above structure site.

We believe that you will find the factual data and recommendations contained therein, adequate for your design requirements. Should further information be required, please do not hesitate to contact our Office.

K. Y. Lo,
SUPERVISING FOUNDATION ENGINEER

KYL/MdeF
Attach.
cc: Messrs. A. M. Toye (2)
H. A. Tregaskes
H. D. McMillan
A. Gater
H. C. Dernier
J. Roy
A. Watt

Foundations Office
Gen. Files

TABLE OF CONTENTS

FOUNDATION INVESTIGATION REPORT

For

Grand River and Hwy. #403, Line 'H',
Co. of Brant, Twp. of Brantford,
Lot 16, Con. II, District #2 (London).
W.J. 63-F-14B -- W.P. 159-60

1. INTRODUCTION:

A preliminary foundation investigation was carried out during January 1963, at the site of the proposed Grand River and Hwy. #403 crossing near Paris, Ontario. Four possible lines were under consideration at the time and the subsoil conditions existing at each line were subsequently reported in Foundation Report No. W.J. 63-F-14.

Following this investigation, it was decided by the Bridge Office that the most suitable line, taking into account foundation and other considerations, would be the line referred to as the 'Brown Line', which is now designated Line 'H'. The Foundation Section were then requested to carry out a complete investigation to determine in detail, the subsoil conditions existing at this location.

The present report contains the results of the complete field investigation for the 'Brown Line', together with recommendations pertaining to the foundations for the proposed new structure to be built at this location.

cont'd. /2 ...

2. DESCRIPTION OF SITE:

2.1) Topography:

The site is located in Lot 16, Con. II, Brantford Twp. in the County of Brant. At this location the Grand River flows in a north to south direction being some 300 feet wide and one to two feet deep under normal conditions. During flood conditions, however, levels ten feet above normal have been recorded.

On the west side the nature of the terrain may be described as rolling with a general slope downwards to the river. On the east side, an embankment some 120 feet high, rises at an approximate angle of 25° immediately from the river's edge. The face of the embankment is intersected by numerous gulleys and waterways and the whole area is covered with thick bush.

2.2) Geology:

A description of the site geology has been made by Mr. B. K. Glassford, Materials and Testing Geologist, after examination by him of all the rock core samples and a visit to the bridge site on April 5, 1963. This description is as follows:

"The bedrock encountered in the drilling for this job belongs to the top of the Salina formation of the Silurian (age) system. Part of this section may be seen in the river bed of Paris and at several places upstream above that town. This rock may be described as follows:

cont'd. /3 ...

2. DESCRIPTION OF SITE: (cont'd.) ...

"The top of the Salina formation consists of grey and greenish, thin and irregular bedded, soft calcareous and argillaceous shale which weathers conchoidally. Interbedded with the shale are thin beds of brown and grey, hard dense dolomite. Some of the beds show traces of gypsum and white anhydrite. The brown beds consist of fine grained to dense dolomite with some bituminous streaks present whereas the grey beds may be described as a dolomitic shale or an argillo-calcareous mud rock."

"The rock at this location is, therefore, more or less calcareous with true shale being in the grey greenish zones of the soft argillaceous rock. This type of rock appears to weather badly on exposure, and as shown in the drill core recovery breaks up and disintegrates rapidly under abrasion".

3. FIELD WORK:

A total of nineteen boreholes was carried out during the course of this investigation. Boring was achieved by means of a conventional diamond drill adapted for soil sampling purposes. Soil samples were obtained by means of 2-inch O.D. split-spoon samplers driven into the soil by a 140-lb. hammer having a free fall of 30 inches. Rock core samples were recovered in BXL type core barrels.

The entire investigation was completed just prior to the spring thaw, thus enabling the borings in the river to be carried out from the ice.

cont'd. /4 ...

3. FIELD WORK: (cont'd.) ...

The locations and elevations of all boreholes were established in the field by London Region Engineering Surveys Section. These are shown on the accompanying Drawing 63-F-14B, which is included in the Appendix of this report.

4. SOIL TYPES AND SOIL CONDITIONS:

Subsoil at the site consists of deposits of river alluvium and glacial till overlying shale and dolomite bedrock.

West of approximate Station 459+50, the overburden consists wholly of alluvial deposits of sand, silt, gravel and boulders directly overlying the bedrock, and ranging in depth from zero to 25 feet. These deposits have a relative density which varies from loose to very dense, but are generally in a compact state.

East of Station 459+50, the subsoil consists of a dense to very dense deposit of glacial till of a predominantly granular nature with a maximum depth in excess of 60 feet. This material is mainly a silty sand with some gravel and occasional boulders with 'N' values ranging from 27 to more than 100 blows per foot.

*Bedrock encountered in the drilling for this bridge site belongs to the top of the Salina formation of the Silurian (age) system.

The drill holes in rock encountered the same types of formations in all holes; all closely related as to elevations, classifications, thickness and descriptions. The exception to this was hole no. 10, which did not correlate with the other holes with

*Description by B. K. Glassford, Geologist.

cont'd. /5 ...

4. SOIL TYPES AND SOIL CONDITIONS: (cont'd.) ...

with respect to elevations of specific formations. Reasons for this might possibly be folding or faulting in the bedding strata in this immediate vicinity. The first rock type in the holes shows a weak interbedded shale, shaley dolomite and dolomite horizon. This appears to be irregularly bedded, thin layered, soft argillaceous greenish-grey coloured shale and shaley dolomite. Some of the dolomite interbedded stratum are quite hard, but thin bedded. Drilling has broken up the strata so that recovery of core has been limited, broken and missing sections, thus making the section disjointed. Small nodules of gypsum are present. Some of the shale and shaley dolomite beds resemble a calcareous mud stone. The type of rock in this section weathers badly and would probably have a poor bearing capacity. Below this horizon as described above, approximately at or near the 680.0 elevation mark, the rock type is a hard dolomite, pitted in texture, buff to light grey colouring and appears to have a homogeneous structure and thick bedding. This rock type has good physical properties and should have excellent bearing capacities.

Ground water level in all borings located on the west bank of the river was observed, to range from el. 693.0 to el. 698.0 and on the east bank, the corresponding range was el. 710.0 to el. 744.0.

cont'd. /6 ...

5. DISCUSSION AND RECOMMENDATIONS:

5.1) General:

It is proposed to construct a multi-span twin structure to carry C.A.H. #403 over the Grand River at this site. The total length of the new bridge will be in the order of 700 feet and the height about 70 feet above river water level. The west approach to the structure will involve the construction of a 60-foot high embankment and the east approach will be formed within a cut some 50 - 55 feet in depth. For reference purposes, the proposed piers of the structure are designated, from west to east, as Pier #1 - Pier #4, and for convenience, the various aspects of the proposed project are discussed below under appropriate headings.

5.2) West Abutment (Section F - F):

At this location about 15 feet of loose to compact silty sand and sandy silt overlies bedrock. The abutment should be constructed within the approach fill and should be supported on steel H-piles driven to bedrock. Design loads are dependent on the pile section and may be as high as 75 ton/pile in the case of 12 BP at 74 H-piles.

5.3) Piers:

Up to 15 feet of loose to compact sand, gravel and boulders overlies bedrock which consists of weathered shale and dolomite underlain by hard dolomite. It is recommended that the proposed footings be founded within the hard dolomite stratum in which case, an allowable bearing pressure of 10 t.s.f. may be assumed for design purposes. The recommended footing base elevations

cont'd. /7 ...

5. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

5.3) Piers: (cont'd.) ...

are as follows:

Pier #1	(Section E - E)	--	El. 678.0
Pier #2	(Section D - D)	--	El. 670.0
Pier #3	(Section C - C)	--	El. 679.0
Pier #4	(Section B - B)	--	El. 677.0

Although the surface rock has been described as 'weathered', it will be necessary to use blasting techniques in order to excavate down to the recommended foundation levels. Local conditions may show some variation from the general picture and provision should be made in the contract for mass concrete to replace any inferior rock material which is encountered below the recommended levels.

It will be necessary to dewater the excavations in order to place concrete in the 'dry'. In consideration of any dewatering scheme, it should be borne in mind that the overburden is highly permeable and that the rock, itself, is likely to contain water-bearing fissures.

5.4) East Abutment (Section A - A):

At this location, the south end of the abutment will be located in a fill section and the north end in a cut section. Subsoil consists of up to 60 feet of compact to very dense glacial till overlying bedrock. It is recommended that the abutment be perched within the partial cut - fill section and be founded on steel H-piles driven either to bedrock or to practical refusal in the very dense till stratum. For estimation purposes, it can be assumed that the final tip elevations of the piles will range

cont'd. /8 ...

5. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

5.4) East Abutment (Section A - A): (cont'd.) ...

from el. 700.0 on the south end of the abutment to el. 725.0 on the north end. In view of the hard driving conditions, it is recommended that 12 BP at 74 steel H-piles be adopted and be fitted with standard reinforced tips. Driving should be carried out by means of a Delmag D 22 hammer or equivalent, and in the event that some piles do not reach bedrock, driving should be continued for at least 4 feet with the condition that the penetration resistance is in excess of 200 blows/foot. The capacity of the pile should be checked finally by means of the Hiley Formula according to D.H.O. Standards DD 1218 and DD 1219, utilizing a safety factor of 3.0. A design load of 75 tons per pile is recommended if the above conditions are complied with.

5.5) Structure Approaches:

No stability problems are anticipated with regard to the proposed cut and fill sections in the immediate vicinity of the abutments provided standard D.H.O. procedures are followed, utilizing 2:1 side slopes for both types of section. It will be necessary to provide surface protection against run-off water and scour protection up to high water level.

5.6) Ground Water:

Attention is drawn to the fact that ground water in the vicinity of the proposed structure might possibly have a high sulphate content due to the gypsum and anhydrite minerals present in the sedimentary rocks underlying the area. This might influence

cont'd. /9 ...

5. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

5.6) Ground Water: (cont'd.) ...

the type of concrete and cement to be used to avoid sulphate reaction on the footings.

6. SUMMARY:

A foundation investigation at the site of the proposed C.A.H. #403 and Grand River crossing near Paris, Ontario, is reported. Within the river bed and on the west bank of the river, subsoil consists of shallow (zero to 25 ft.) alluvial deposits of silt, sand, gravel and boulders, overlying shale and dolomite bedrock. On the east bank of the river, subsoil consists of up to 60 feet of dense to very dense granular type glacial till overlying shale and dolomite bedrock.

It is recommended that the pier footings be founded within the hard dolomite bedrock with an allowable pressure of 10 t.s.f. Dewatering may present some construction problems due to the permeability of the overburden and the possibility of water-bearing fissures in the bedrock.

For the abutments, piled foundations are recommended, utilizing 12 BP at 74 steel H-piles driven to bedrock or to practical refusal in the till stratum. In this case, a design load of 75 tons/pile is recommended. Further details are given in Section 5 above.

No stability problems are anticipated for the proposed cuts and fills in the immediate vicinity of the abutments. Protection against scour and run-off water will be necessary.

cont'd. /10 ...

7. MISCELLANEOUS:

The field work for this project was carried out during the period January 31 to April 12, 1963, under the supervision of Mr. G. Mierzynski, Project Foundation Engineer, and Mr. B. Kliem of this Section.

Equipment used was owned and operated by Johnston Drilling Co. Ltd.

This report was prepared by Mr. K. Selby, Senior Foundation Engineer, with the assistance of Mr. A. K. Barsvary, Project Foundation Engineer.

May 1965

APPENDIX I.

OFFICE REPORT ON SOIL EXPLORATION

BA 2036

DEPARTMENT OF HIGHWAYS ONTARIO

MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

HWY. 63-F-14 LOCATION Sta. 463+29, 20' Rt. ORIGINATED BY P.P.

W.P. 159-60 BORING DATE Jan. 31 to Feb. 1, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - NX & BX Casings. CHECKED BY

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT / SHEAR STRENGTH P.S.F	LIQUID LIMIT W_L / PLASTIC LIMIT W_P / WATER CONTENT w (w_P w w_L) / WATER CONTENT % 10 20 30	UNIT DENSITY P.C.F	REMARKS
694.8 0.0	Groundlevel									
	Sand, gravel and boulders. Very dense Brown.		1	SS	51	690				
			2	SS	52					
681.8 13.0	Weathered green shale and boulders.		3	SS	51	680				Gr: 30 Sa: 33% Si&Cl 37
676.8 18.0	Weathered shale and dolomite bands. Green and grey.		4	RC	-					
			5	RC	-	670				
667.8 27.0	End of borehole.									

BA 2086

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 63-F-14
W P 159-60
DATUM Geodetic

LOCATION Sta. 459+58, 39' Rt.
BORING DATE Feb. 4, 1963.
BOREHOLE TYPE Washbore - NX & BX Casings.

ORIGINATED BY P.P.
COMPILED BY
CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
694.0 / 0.0	Icelevel									
693.0										
692.0	Sand									
	Weathered, green shale and boulders.		2	SS	108	690				
680.2 / 7.8			3	RC	-					
	Weathered shale and dolomite Green and grey.		4	RC	-					
			5	RC	-	680				
676.6 / 17.4	End of borehole.					670				

OFFICE REPORT ON SOIL EXPLORATION

BA 2016

DEPARTMENT OF HIGHWAYS ONTARIO

HIGHWAY ENGINEERING DIVISION

RECORD OF BOREHOLE NO. 9

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 1 - South Corner. Sta. 459+81, 68' Lt. ORIGINATED BY P.P.

W. P. 159-60 BORING DATE Mar. 7, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — w_P w w_L — WATER CONTENT %	BULK DENSITY γ P.C.F	REMARKS
691.5	Groundlevel									
0.0										
690.0	Sand and gravel					690				
1.5			1	RC	-					
	Weathered shale and dolomite.									
	Green and grey		3	RC	-					
						680				
677.2										
14.3	Dolomite									
675.7	Hard									
						670				
15.8	End of borehole.									

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF PUBLIC WORKS ONTARIO

MATERIALS & TESTING DIVISION

BA 2086

RECORD OF BOREHOLE NO. 10

FOUNDATION SECTION

JOB 63-F-13 LOCATION Pier No. 1 - North Corner, Sta. 459+36, 67' Rt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 8, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F	REMARKS
694.0	Groundlevel									
0.0	Sand, gravel and Boulders. Grey and brown.									WL 694.0
690.0						690				
4.0	Weathered shale and dolomite fissured. Green and grey Soft		1	SS	80					
			2	RC	-					
684.0			3	RC	-					
10.0	Dolomite Hard		-	RC	-					
80.0						680				
14.0	Dolomite with gypsum nodules and seams.		-	RC	-					
			-	RC	-					
70.6										

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 11

FOUNDATION SECTION

JOB 63-F-14
W P 159-60
DATUM Geodetic

LOCATION Pier No. 2 - North Side Sta. 460+76 63' Rt.
BORING DATE Mar. 11, 1963.
BOREHOLE TYPE Washbore - BX Casing.

ORIGINATED BY P.P.
COMPILED BY
CHECKED BY

ELEV. / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_p — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS
691.5	Waterlevel									
0.0						690				
689.0	Groundlevel									
2.5	Sand, gravel and boulders.									
685.0	Brown		1	SS	69			H		
6.5	Weathered shale & dolomite (Fissured, broken)									
682.0	Grey									
9.5	Dolomite. Hard. Seams of shale.		2	RC	-	680				
678.5										
13.0	Dolomite with gypsum nodules.									
677.0										
14.5	End of borehole.					670				

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 12

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier #2 - South Side Sta. 461+23, 72' Lt. ORIGINATED BY P.P.

W.P. 159-60 BORING DATE Mar. 11, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT / SHEAR STRENGTH P.S.F.	LIQUID LIMIT — wL / PLASTIC LIMIT — wP / WATER CONTENT — w / WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
691.5	Waterlevel								
0.0					690				
688.5	Groundlevel								
3.0	Sand and gravel. Brown.								
685.0		1	SS	115					
6.5	Weathered shale and dolomite. Green and grey.								
680.0		2	RC	-	680				
11.5	Weathered shale and dolomite bands. - Green and grey First 1.5'								
75.0									
16.5	End of borehole.								
					670				

BA 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 13

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 2 - ℄ Sta. 460+98 5' Lt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 12, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
691.5	Waterlevel									
0.0						690				
688.5	Groundlevel									
3.0	Sand, gravel and boulders. Brown.		1	SS	93					
684.0										
7.5	Weathered shale and dolomite. Soft.									
682.0										
9.5	Dolomite. Hard		2	RC	-	680				
676.9	Buff grey.									
14.6	End of borehole.					670				

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

RECORD OF BOREHOLE NO. 14

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 3 - South (Rt.) Side. Sta 462+59 77' Lt. ORIGINATED BY P.P.

W.P. 159-60 BORING DATE Mar. 13, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV. DEPTH	SOIL AND ROCK DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
691.5	Waterlevel									
0.0						690				
689.0	Groundlevel									
2.5	Sand, gravel and boulders. Brown.		1	SS	28					
682.5										
9.0	Weathered shale and dolomite..		2	RC	-	680				
677.5										
14.0	Weathered shale and dolomite bands. Honeycombed & fissured. Weathered seams at 14' & 15'									
673.5						670				
18.0	End of borehole.									

DEPARTMENT OF PUBLIC WORKS ONTARIO
MATERIALS & TESTING DIVISION

BA 2086

RECORD OF BOREHOLE NO 15

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 3 - North (Lt.) Side Sta. 462+14 54' Rt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 14, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F	LIQUID LIMIT w_L — PLASTIC LIMIT w_p — WATER CONTENT w — WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
691.5	Waterlevel									
0.0						690				
688.5	Groundlevel									
3.0	Sand, gravel and boulders. Brown. Very dense.		1	SS	20					
						680				
677.5										
14.0	Pitted dolomite		2	RC	4"					
673.5										
18.0	Weathered shale and dolomite. Soft.									
669.5						670				
22.0	Dolomite. Hard.									
665.0										
26.5	End of borehole.									
						660				

FORM 03 ML 2 REVISED — OFFICE REPORT ON SOIL EXPLORATION

BA 2058

DEPARTMENT OF HIGHWAYS, ONTARIO

MATERIALS INVESTIGATION DIVISION

RECORD OF BOREHOLE NO. 16

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier #3 - ℄ Sta. 462+37 9' Lt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 15, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX Casing. CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT W_L — PLASTIC LIMIT W_P — WATER CONTENT W — WATER CONTENT %	PULK DENSITY P.C.F.	REMARKS
691.5	Waterlevel									
0.0						690				
688.5	Groundlevel									
3.0	Sand, gravel and boulders. Brown.		1	RC	-					
681.5										
10.0	Shale & Dolomite					680				
679.5	Soft weathered									
12.0	End of borehole.					670				

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

DEPARTMENT OF [illegible] ONTARIO
SOILS ENGINEERING SECTION

RECORD OF BOREHOLE NO. 17

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 4 - South (Rt.) Side Sta. 463+99 81' Lt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 18, 1964. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - NX & BX Casings. CHECKED BY

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 10 20 30 40 50 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — w_P w w_L WATER CONTENT %	UNIT DRY WEIGHT P.C.F.	REMARKS
696.0	Groundlevel									
0.0	Sand, gravel and boulders. Very loose to very dense. Brown.		1	SS	2	690				WL-G.L.
685.0			2	SS	82		Refusal			
11.0	Weathered shale and dolomite. Soft.									
678.5			3	RC	-	680				
17.5	Dolomite. Hard. Buff grey.									
677.0	End of borehole.									
19.5										

DEPARTMENT OF HIGHWAYS ONTARIO

MATERIALS & TESTING DIVISION

BA 208

RECORD OF BOREHOLE NO. 18

FOUNDATION SECTION

JOB 63-F-14 LOCATION Pier No. 4 - ℄ Sta. 463+76 14' Lt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 19, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - NX & BX Casings. CHECKED BY

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w / WATER CONTENT %	BULK DENSITY P C F	REMARKS
695.5	Groundlevel									
0.0	Sand, gravel and boulders. Compact to very dense. Brown.		1	SS	21	690				WL-G.L.
			2	SS	89		Refusal			
681.5										
14.0	Weathered shale. Fissured, broken green.		3	RC	-	680				
677.5										
676.5	Dolomite. Hard									
19.0	End of borehole.									

BA 2086

DEPARTMENT OF HIGHWAYS, ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 19

FOUNDATION SECTION

JOB 63-F-14 LOCATION West Abutment - North (Lt.) Side Sta. 464+95 50' Rt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 19, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX & NX Casings CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
699.0	Groundlevel									
0.0	Sandy silt. Organic topsoil. Dark brown. Loose.		1	SS	5					WL=693.0
691.0										
8.0	Sand with occasional gravel. Loose		2	SS	7	690				
685.0										
14.0	Weathered shale and dolomite. fissured and broken. Green and grey.		3	SS	92/9"		Refusal			
			4	RC	-	680				
675.0										
24.0	End of borehole.									

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

DEPARTMENT OF PUBLIC WORKS

MATERIALS TESTING DIVISION

RECORD OF BOREHOLE NO. 20

JOB 63-2-14 LOCATION West Abutment - South Side Sta. 465+40 85' Lt. ORIGINATED BY P.P.

W P 159-60 BORING DATE Mar. 20, 1963. COMPILED BY

DATUM Geodetic BOREHOLE TYPE Washbore - BX & NX Casings. CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 10 20 30	UNIT DENSITY γ P.C.F.	REMARKS
699.0	Groundlevel									
0.0	Sandy silt to silty sand. Organic, with decayed vegetable matter. Dark brown and grey. Loose to compact.		1	SS	3	690				
			2	SS	29					
687.0				SS	13					
12.0	Weathered shale. Soft. Grey.									
680.0						680				
19.0	Pitted dolomite. Hard. Buff grey.		4	RC	-					
677.0										
22.0	End of borehole.									

BA 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 21

FOUNDATION SECTION

JOB 63-F-14 LOCATION Sta. 465+17 17' Lt. ORIGINATED BY G.M.
W.P. 159-60 BORING DATE Mar. 20, 1963. COMPILED BY A.B.
DATUM G.S.C. BOREHOLE TYPE Dynamic Cone CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w / WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
699.0 0.0	Groundlevel					690 680	End of Penetration @15' Hammer bouncing			

OFFICE REPORT ON SOIL EXPLORATION

BA 2086

DEPARTMENT OF HIGHWAYS – ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 22

FOUNDATION SECTION

JOB 63-F-14 LOCATION Sta. 458+18 4' Rt. ORIGINATED BY G.M.

W.P. 159-60 BORING DATE Mar. 26 & 27, 1963. COMPILED BY A.B.

DATUM G.S.C. BOREHOLE TYPE Washboring, BX Casing. CHECKED BY

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	REMARKS
764.0	Groundlevel					
0.0	Silty sand with gravel and occasional boulders Also seams of sand and sandy silt. (Till) Dense to very dense. Brown and grey colored.					
		1	SS	35	760	
		2	SS	38		
		3	SS	50		
		4	SS	23	750	Non plastic
		5	SS	50		
		6	SS	71		WL 20'
		7	SS	38/4"	740	
		8	SS	93		
		9	SS	104	730	
722.0	@41.9' Bedrock					
42.0	End of borehole.				720	

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.

LIQUID LIMIT — w_L; PLASTIC LIMIT — w_P; WATER CONTENT — w

WATER CONTENT % 10 20 30

BULK DENSITY P.C.F.

BA 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 23

FOUNDATION SECTION

JOB 63-F-14 LOCATION Sta. 457+95 72' Rt. ORIGINATED BY G.M.
W P 159-60 BORING DATE Mar. 28 to Apr. 2, 1963. COMPILED BY A.B.
DATUM G.S.C. BOREHOLE TYPE Washboring, NX Casing CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
784.0 / 0.0	Groundlevel									
	Sand, gravel and occasional boulders with silty clay and silty sand. (Till) Compact to very dense.		1	SS	26	780				
			2	SS	29	770				
			3	SS	41					
			3A	SS	30					
			3B	SS	35	760				
	Brown and grey coloured.		4	SS	76					
						750				
			5	SS	81					
						740				WL - 44'
			6	SS	140					
			7	SS	104					
						730				
			8	CS						
726.5 / 57.5	End of borehole		9	SS	96/6"					

B1 2086

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 24

FOUNDATION SECTION

JOB 63-F-14 LOCATION Sta. 458+40 63' Lt. ORIGINATED BY G.M.
W P 159-60 BORING DATE April 3, 1963. COMPILED BY A.B.
DATUM G.S.C. BOREHOLE TYPE Washboring, BX Casing. CHECKED BY

ELEV. / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P C F	REMARKS
736.0	Groundlevel									
0.0	Sand and gravel Top 4' organic. Brown. Compact.		1	SS	27	730				
	Sand, silt and clay mixture with occasional gravel (Till)		2	SS	43					
			3	SS	73					
	Dense to very dense.		4	SS	85	720				
	Grey.		5	SS	118					
			6	SS	65	710		Non Plastic		WL = 26'
703.0			7	SS	100					
33.0	End of borehole.					700				

BA 2086

DEPARTMENT OF [illegible] - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 25

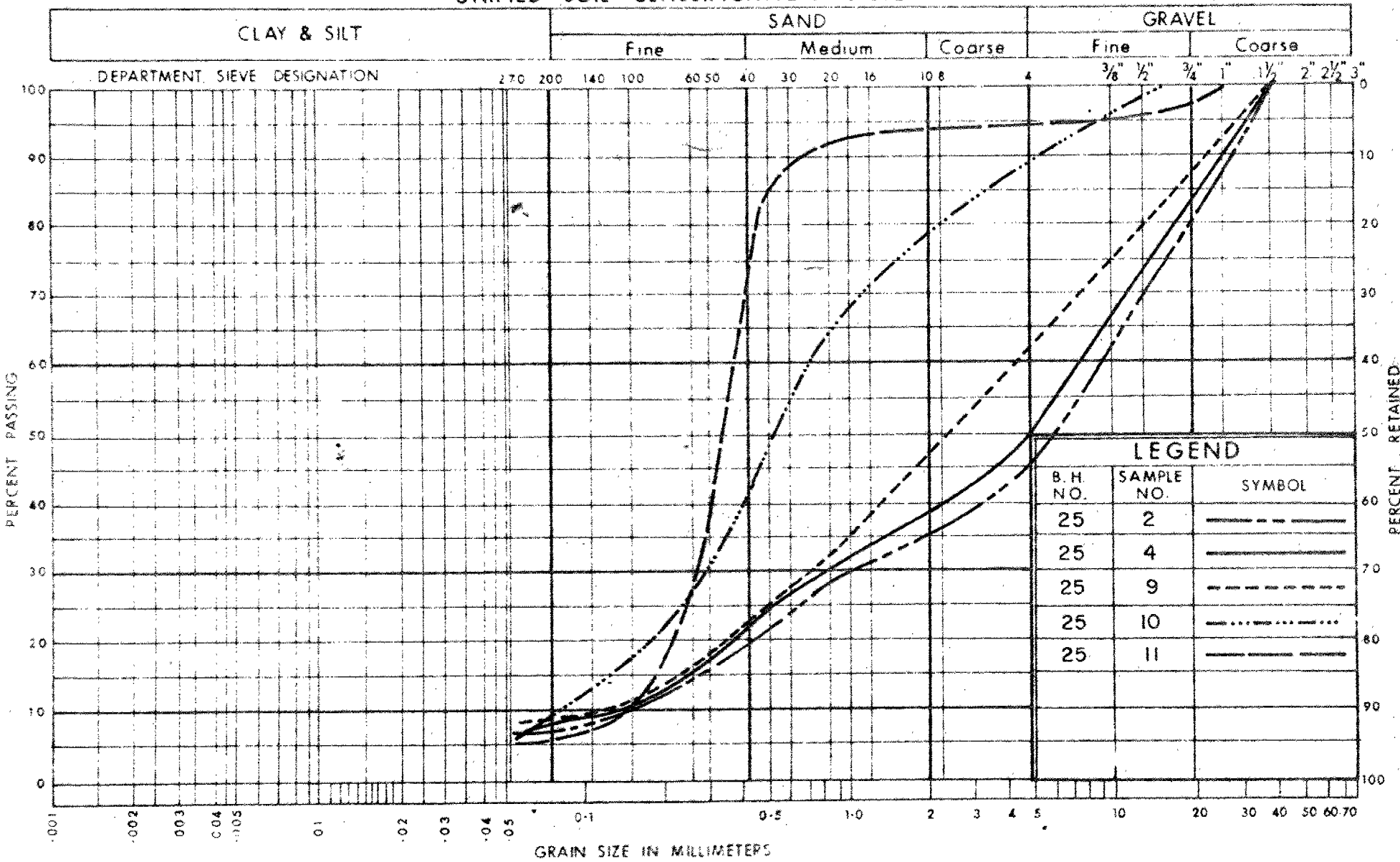
FOUNDATION SECTION

Job 63-F-14 LOCATION Sta. 457+17 81' Rt. ORIGINATED BY G.M.
W.P. 159-60 BORING DATE April 8-11, 1963. COMPILED BY A.B.
DATUM No BOREHOLE TYPE Washboring, NX Casing. CHECKED BY

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — SHEAR STRENGTH P.S.F.	LIQUID LIMIT w_L — PLASTIC LIMIT w_P — WATER CONTENT w — WATER CONTENT % 10 20 30	BULK DENSITY P.C.F.	REMARKS
	Groundlevel									
0.0	Sand and gravel with occasional boulders. Compact to very dense. Brown grey.		1	SS	69					
			2	SS	62					
			3	SS	35					
			4	SS	104					
			5	SS	105					
			6	SS	76					
			7	SS	105					
			8	SS	63					WL @ 40'
			9	SS	98					
			10	SS	90					
			11	SS	51					
65.0	Silty sand with gravel and some clay. Till. Very dense.		12	SS	100/3"					
			13	SS	60/3"					
71.5	End of borehole.									

REV. APR. 1965

UNIFIED SOIL CLASSIFICATION SYSTEM

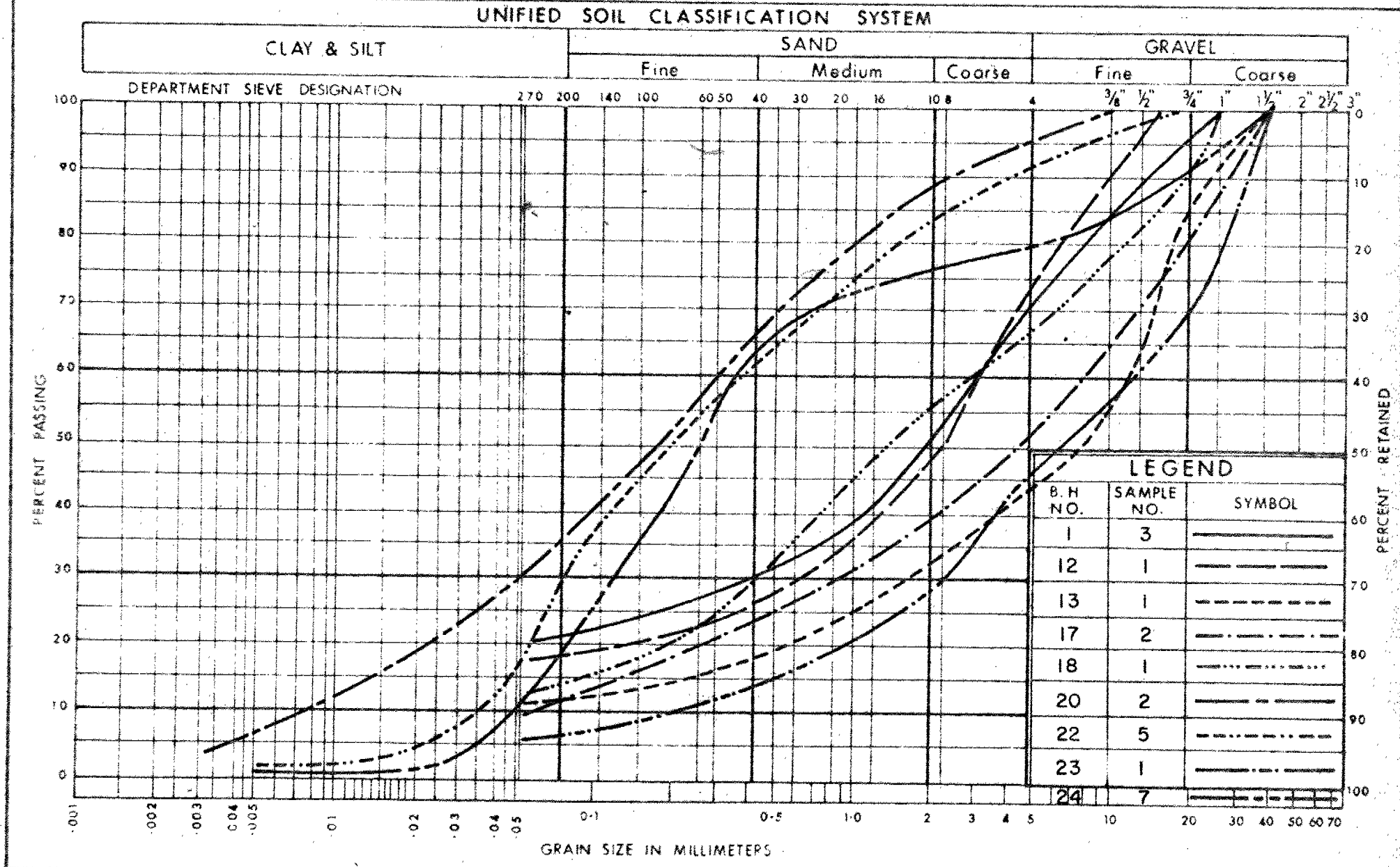


DEPARTMENT OF HIGHWAYS
MATERIALS and TESTING DIVISION
ONTARIO

GRAIN SIZE DISTRIBUTION

W.P No. 159-60
JOB No. 63-F-14
GRAND RIVER & HWY. 403

REV APR 1965



DEPARTMENT OF HIGHWAYS
MATERIALS and TESTING DIVISION
ONTARIO

GRAIN SIZE DISTRIBUTION

W.P No. 159 - 60
JOB No. 63 - F - 14
GRAND RIVER & HWY. 403

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

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	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_P	PLASTIC LIMIT
I_P	PLASTICITY INDEX
s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
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
m_v	COEFFICIENT OF VOLUME CHANGE $= \frac{-\Delta e}{(1+e)\Delta \sigma'}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX $= \frac{\Delta e}{\Delta \log_{10} \sigma'}$
T_v	TIME FACTOR $= \frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF EFFECTIVE STRESS $\tau_f = c' + \sigma' \tan \phi'$
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF TOTAL STRESS $\tau_f = c_u + \sigma \tan \phi$
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

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

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ε	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNGS MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_o	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

CONSISTENCY	'N' BLOWS / FT.	c LB. / SQ. FT.	DENSENESS	'N' BLOWS / FT.
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

35MM
DRAWING