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Golder Associates

SOIL AND FOUNDATION ENGINEERS

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REPORT

TO

GORE & STORRIE LIMITED

ON

SOIL INVESTIGATION

PROPOSED NEW WATER INTAKE

BELLEVILLE UTILITIES COMMISSION

BELLEVILLE ONTARIO.

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ABSTRACT

The results of a soil investigation to determine the subsurface conditions at the location of a proposed water intake line and intake structure in the Bay of Quinte at the western limits of Belleville, Ontario are reported and recommendations are made for foundation design and construction of the proposed pipe line and intake structure.

The bay bottom is underlain by very soft organic silt. The organic silt is of limited thickness (3 to 5 feet) within about 900 feet of the shoreline. Beyond 900 feet, the thickness of the organic silt increases, being about 25 feet thick at the proposed intake structure location. In the area of the inlet structure, the organic silt is underlain by some 10 feet of soft clayey silt. The organic silt and the clayey silt is underlain by compact to dense silty sand and gravel (till) and by limestone bedrock.

The trench for the intake pipe will be excavated into bedrock at the shoreline and into the compact to dense till to about 900 feet from the shoreline. The trench in the till will be difficult to dredge and it is considered that a dipper dredge would probably be most effective. A bedding layer of sand should be placed on this coarse till. Beyond Station 9+00, the intake pipe will be founded on the very soft organic silt. It is recommended in order to minimize underwater connections in this soft and compressible material that the pipe be assembled in long lengths on land or on barges, floated into position, and sunk into position in the dredged trench. Little sinkage is expected of the pipe below the dredged depth (5 feet below existing bay bottom).

It is recommended that the light intake structure be founded on the very soft organic silt at a depth of about 5 feet below bay bottom. The estimated design bearing pressure (40 lb/sq.ft.) is below the maximum allowable bearing pressure of 200 lb/sq.ft. Flexible joints should be provided to accomodate the differential settlement between the intake structure and the first sections of the pipe line.

INTRODUCTION

H. Q. Golder & Associates Ltd. have been retained by Gore & Storrie Limited, Consulting Engineers to the Belleville Utilities Commission, to carry out a soil investigation for a new water intake structure and 36" diameter intake line for Belleville, Ontario. The purpose of this investigation was to determine the subsoil conditions at the site and based on this information, to make recommendations for the foundation design and construction of the proposed structures.

PROCEDURE

The field work for this investigation was carried out between January 12 and January 21, 1970. Twelve boreholes were put down from the ice surface along the proposed water intake line using a drill rig supplied by the F. E. Johnston Drilling Co. Limited, Ottawa. Seven of the boreholes,located within one thousand feet from shore, were advanced some 9 to 20 ft. below the bay bottom. Bedrock was cored in three of these borings to define the bedrock surface close to shore. The five other boreholes were put down beyond 1,000 feet from shore in the deep overburden area in the vicinity of the water intake structure. At the proposed water intake structure location, bedrock was found 33 ft. below the bay bottom and was proved by core drilling in AXT size for a depth of 8 feet. The shear strength of the organic silt and clay was determined by in situ vane testing. The field work was supervised throughout by a member of our engineering staff.

A detailed log of each boring is given on the Record of Borehole sheets following the text of this report. The locations of the borings together with 1 foot contours of the bay bottom are shown on Fig. 1. A section of inferred soil stratigraphy along the proposed water intake line is shown on Fig. 2.

The soil samples obtained during the investigation were brought to our laboratory for detailed examination and testing. The results of the laboratory tests are shown on Figs. 3 to 6.

The elevations given in this report are referred to the ice level in the bay, which was given to us as 244.1, Geodetic datum, by Gore & Storrie Limited at the time of the investigation.

SITE AND GEOLOGY

The site is located in the Bay of Quinte at the western boundary of the City of Belleville, Ontario, just south of the existing Water Purification Plant. The depth of water increases in the offshore direction to approximately 15 ft. at the proposed intake structure.

From available geological information it is known that this area is underlain by thinly bedded limestone bedrock of the Trenton formation, Middle Ordovician Period. A thin layer of glacial drift, covers most of the bedrock in the Belleville area. In the area near Lake Ontario, thin lacustrine clay deposits, which were formed in glacial lakes, are present. In general, the overburden deposits are relatively thin in this area due to the erosion caused by glaciers. At the harbour bottom, however, recent lacustrine deposits of organic silt overlie the clay and glacial drift overburden.

SOIL CONDITIONS

The detailed soil stratigraphy encountered in each borehole is given on the Record of Borehole sheets and is illustrated on the stratigraphic section on Fig. 2. Following is a summarized account of the soil conditions along the proposed water intake.

Organic Silt

The harbour bottom is underlain by a deposit of dark brown to dark grey organic silt. The organic silt was found in all the boreholes and ranged in thickness from 2 feet at 700 ft. from shore to 24 feet at 1800 ft. from shore. The results of a grading analysis on a sample of the organic silt is shown on Fig. 3. The natural water content of this deposit on a dry weight basis varies from about 480 percent at the top to about 170 percent at the bottom of the stratum. The sampling tools and casings were advanced through most of this deposit under their own weight except near the bottom where the consistency increased and manual pressure was exerted on the sampling tool. In situ vane shear testing was carried out in the organic silt and the shear strength ranged from about 50 to 440 lb/sq.ft. indicating that the consistency of the deposit is very soft to soft. Remoulded vane tests were also carried out and the sensitivity ranged from 1.5 to 3. The vane test results are summarized on Fig. 7.

In borehole 10, the organic silt is underlain by approximately 2 feet of grey blue silt. A mechanical analysis carried out on a sample of the silt is shown on Fig. 4. The N value for this sample was 2 blows/ft. Underlying the grey blue silt is 3 feet of layered light grey and dark grey clay containing a trace of twigs and roots. This deposit was also found only in borehole 10. The N value in this clay was 13 blows/ft.

Clayey Silt

Underlying the organic silt in boreholes 1, 2, 7, and 8 is a stratum of grey clayey silt which ranges in thickness from 5 ft. at borehole 2 to 12 ft. at borehole 7. Grading analyses carried out on two samples of the clayey silt are shown on Fig. 5. The natural water content was found to vary between 34 and 39 percent. The sampler was advanced easily through this stratum either by the weight of the hammer or by manual pressure. The shear strength, determined by in situ vane tests, ranged from 160 to 700 lb/sq.ft. though, in general, the shear strengths were found to range between 220 and 400 lb/sq.ft. and the clayey silt is considered to be of soft consistency.

This stratum contains some sand, shells, and organic material.

Silty Sand Till

A deposit of grey silty sand and gravel with a trace of clay was encountered in most of the boreholes. This material is believed to be a glacial till. The till varied in thickness from 1 ft. to 16 ft. and was found to directly overlie the bedrock. The results of mechanical analyses on two samples of the till are given on Fig. 6. and show the well graded character of the stratum.

Standard penetration test in the till gave N values ranging from about 20 blows/ft. to greater than 100 blows/ft. Based on this information the relative density of the till is considered th be compact to very dense.

Limestone Bedrock

Limestone bedrock was proved by core drilling in borehole 1 at the proposed water intake location and in boreholes 9, 10 and 11 near the shoreline. From the core recovered the limestone bedrock is considered to be sound.

WATER CONDITIONS

At the time of the investigation, the ice level in the Bay of Quinte was at elevation 244.1. No artesian or unusual water conditions were encountered in the boreholes during drilling.

DISCUSSION

a) General

It is understood that it is planned to construct a new water intake line for the Belleville Water Purification Plant. The intake line, of 36 inch diameter, is to extend 1500 feet into the Bay of Quinte and to be located to the west of the existing 30 inch diameter line as shown in plan on Fig. 1. The existing line of steel pipe was constructed in the fall of 1923 and encountered soft bottom at and beyond about 1,000 feet from shore. It appears from construction drawings that some sinkage of the pipe occurred in the soft bottom. The intake crib was of very light construction and flexible joints were provided near the end of the pipe line and at the pipe intake connection. As presently planned, the new pipe above soft overburden could consist of either steel, polyethylene or fibre reinforced plastic. The inlet assembly will probably consist of light pipe openings founded on pads to reduce the bearing pressure, on a submerged weight basis, to about 40 lb/sq.ft.

b) Intake Line

The invert of the intake line is to be located some 12 feet below the bay bottom at the shoreline and some 5 feet below the bay bottom near the inlet (see Fig. 2.). The boreholes put down along the proposed intake line indicates that the invert will be in the limestone bedrock for about the first 100 feet leading from the terminal chamber. A silty sand and gravel (glacial till) will be at invert level from about Station 1+00 to about Station 9+00. Beyond about Station 9+00, the pipe invert will be founded on very soft organic silt which increases in thickness to about 20 feet at the intake location.

Based on the N values obtained in the glacial till which generally ranged from about 20 to 50 blows/ft., the density of this material is considered to be compact to dense. The well graded nature of the material can be seen from the grading curves on Fig. 6. In addition, the glacial till contained boulders which required diamond drilling techniques to advance the casing in boreholes 4, 11 and 12. This glacial till will be a difficult material to dredge. It is considered that a dipper dredge will be effective in excavating this glacial till material. The well graded till should stand on a relatively steep dredged slope. The overlying organic silt will require a flatter excavation slope. A sand bedding layer should be placed on the base of the trench above this coarse till. Consideration could be given to the use of concrete pipe where the glacial till is at invert level

Based on the experience of trying to sample the surface portion of the organic silt stratum in the field, it is felt that the upper few feet of this stratum exists in situ in virtually a suspended state. The water content of the surface sample in borehole 2 was measured as 480 percent based on a dry weight basis. At invert level (about 5 feet below bay bottom level), the shear strength of the organic silt has been measured by in situ vane testing as 70 lb/sq.ft. or more.

The submerged unit weight of the organic silt is estimated to be about 10 lb/cu.ft. at the bay bottom and about 15 lb/cu.ft. at a depth of 5 feet. Calculations indicate that the submerged weight for a 39 inch diameter pipe would have to be limited to about 100 lb/lineal foot in order that it may be bouyant within its own diameter on the bay bottom. However, with depth the organic silt acquires a small, but appreciable, shear strength so that bouyancy of the pipe is not the only criterion which will control sinkage of the pipe. It is estimated that a 3 ft. diameter pipe which weighs 200 lb/lineal foot will not sink below a depth where the undrained shear strength equals 70 lb/sq.ft. This depth is considered to be some 5 to 6 feet below bay bottom.

Present plans call for laying the pipe in a 5 ft. deep trench. Some minor sinkage is to be expected at this depth and there will be construction difficulties in attempting to make underwater connections of the pipe sections above this very soft organic silt. It is recommended that the intake pipe, for the area where soft organic silt underlies the invert,be joined in long sections on land or on barges, floated into place during favourable weather conditions and lowered into the pre-dredged trench.

Alternatively, if the pipe is joined in short sections in the trench within the soft organic silt, it is recommended that a sand layer at least 1 foot thick be tremied onto the trench base to minimize sinkage and to provide a working base for divers.

c) Intake Structure

It is understood that the inlet structure will probably be made up of a light pipe assembly founded on pads. The pads, founded about 5 feet below bay bottom, will distribute the load to a bearing pressure of about 40 lb/sq.ft. and will provide lateral stability.

The shear strength measured by in situ vane testing in borehole 1 was 100 lb/sq.ft. at a depth of 5 feet below bay bottom. Based on this shear strength value, the maximum allowable bearing value at this depth in design of the water inlet assembly pads is 200 lb/sq.ft. It is recommended, however, that the present design bearing pressure of 40 lb/sq.ft. be maintained to limit settlement of the inlet structure. Consideration should also be given to providing a sand pad of 1 ft. minimum thickness above the organic silt as a levelling base for the founding of the assembly pads.

It is expected that the inlet assembly structure will settle less than the adjacent pipeline and flexible joints should be provided to accomodate this differential movement.

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PROVINCE OF ONTARIO

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March, 1970.

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
- 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 $\tau_f = c_u + \sigma \tan \phi_u$)
- 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.

Project No. [illegible]

RECORD OF BOREHOLE 12

LOCATION See Figure 1 BORING DATE JAN. 22, 1970 DATUM GEODETIC

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

STA. 7+39, ON ℄

BORING METHOD	ELEV'N / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE
							245
	244.1	ICE SURFACE					
CASING	0.0	ICE					
CASING	242.6 / 1.5	WATER					240
							235
NX	232.9 / 11.2	SOFT DARK BROWN ORGANIC SILT		1	2" D.O.	29	
	230.8 / 13.3	DENSE GREY SILTY SAND AND GRAVEL (TILL) BOULDERS FROM 15.0' TO 18.0' DEPTH		2	"	>100	230
BX CASING							225
BX CASING				3	"	40	
	222.1 / 22.0	END OF HOLE					220
							215

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

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

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

WATER CONTENT, PERCENT

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

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

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.

CHECKED F.F.H.

RECORD OF BOREHOLE 11

LOCATION See Figure 1 BORING DATE JAN. 20, 1970 DATUM GEODETIC

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

STA. 3+52, ON ℄

BORING METHOD	ELEV'N. DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.	ADDITIONAL LAB. TESTING
	244.1	ICE SURFACE				
	244.1 / 0.0	ICE				
	242.6 / 1.5	WATER				
WASH BORING NX CASING	236.5 / 7.6	SOFT DARK BROWN ORGANIC SILT	1	2" O.D.	P.M.	
			2	"	10	
	233.1 / 11.0	COMPACT TO DENSE GREY SILTY SAND AND GRAVEL, TRACE CLAY (TILL)	3	"	22	M.H
BX CASING			4	"	37	
ROTARY DRILLING BX CORE	217.1 / 27.0	SOUND GREY LIMESTONE BEDROCK	5	BX RC	—	
			6	"	—	
	210.2 / 33.9	END OF HOLE				

Elevation scale: 245, 240, 235, 230, 225, 220, 215, 210, 205

Core run 5: 90 / 100; Core run 6: 100

EST. % DRILL WATER RETURN

% CORE RECOVERY

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

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

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

WATER CONTENT, PERCENT W_P W W_L

PIEZOMETER OR STANDPIPE INSTALLATION

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N. CHECKED F.T.H.

RECORD OF BOREHOLE 10

LOCATION See Figure 1 BORING DATE JAN. 19, 1970 DATUM GEODETIC

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

STA. 1+27, ON ℄

BORING METHOD	ELEV'N. / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	% CORE RECOVERY	EST. % DRILL WATER RETURN	ADDITIONAL LAB. TESTING
						245			
	244.1	ICE SURFACE							
BX CASING	0.0	ICE							
BX CASING	242.8 / 1.3	WATER							
BX CASING	241.1 / 3.0	GRANITE BOULDERS	1	BX RC	—	240			
BX CASING	238.8 / 5.3	WOOD	2	2" D.O.	>100				
ROTARY DRILLING, AX CASING	6.1	VERY SOFT DARK BROWN ORGANIC SILT, SOME WOOD, TRACE WOOD CHIPS	3	"	P.M.				
ROTARY DRILLING, AX CASING			4	2" ST.	P.M.	235			
ROTARY DRILLING, AX CASING	233.1 / 11.0	VERY LOOSE GREY BLUE SILT, SOME SAND AND GRAVEL, TRACE ORGANIC	5	2" D.O.	2				MH
ROTARY DRILLING, AX CASING	231.6 / 12.5	STIFF LAYERED LIGHT GREY AND DARK GREY CLAY, TRACE TWIGS AND ROOTS	6	"	13	230			
ROTARY DRILLING, AX CASING	228.6	COMPACT GREY SANDY SILT AND GRAVEL (TILL)	7	"	14				
ROTARY DRILLING, AXT CORE	227.7 / 16.4	SOUND GREY LIMESTONE BEDROCK	8	AXT RC	—		97	100	
ROTARY DRILLING, AXT CORE						225			
ROTARY DRILLING, AXT CORE			9	"	—		100		
	220.3 / 23.8	END OF HOLE				220			
						215			

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

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

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

WATER CONTENT, PERCENT W_p W W_l

PIEZOMETER OR STANDPIPE INSTALLATION

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

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.

CHECKED F.J.H.

RECORD OF BOREHOLE 9

LOCATION See Figure 1 BORING DATE JAN. 20, 1970 DATUM GEODETIC

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

STA. 0+73, ON ℄

Boring Method	Elev'n / Depth	Description	Number	Type	Blows/Ft.	Elevation Scale
	244.1	ICE SURFACE				245
Rotary Drilling – X Casing	0.0	ICE				
	0.9	WATER				
	240.6 / 3.5	BOULDERS				240
	239.6 / 4.5	SOFT DARK BROWN ORGANIC SILT, TRACE OF WOOD	1	2" D.O.	P.M.	235
	233.9 / 10.2	LOOSE GREY SILTY SAND AND GRAVEL (TILL) TRACE CLAY, LIMESTONE BOULDER AT 12.0'	2	"	P.M.	
Rotary Drilling – BX Core	231.6 / 12.5	FAIRLY SOUND GREY FOSSILIFEROUS LIMESTONE BEDROCK	3	BX RC	—	230
			4	"	—	
	225.2 / 18.9	END OF HOLE				225
						220

Core run 3: 100 (% core recovery), 100 (est. % drill water return)

EST. % DRILL WATER RETURN
% CORE RECOVERY

Chart headings: 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

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

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.H.
CHECKED F.T.H.

RECORD OF BOREHOLE 8

LOCATION: See Figure 1 BORING DATE: JAN. 16, 1970 DATUM: GEODETIC

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

STA. 15+77, 160' LT. ℄

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.
	244.1	ICE SURFACE			
	0.0 / 242.6	ICE			
	1.5	WATER			
NX CASING	228.7 / 15.4	~~SOFT DARK~~ BROWN ORGANIC SILT	1	2" D.O.	Wh
			2	2" T.O.	Wh
WASH BORING			3		P.M.
	204.6 / 39.5	VERY SOFT TO SOFT GREY ORGANIC CLAYEY SILT LAYERED WITH SILTY SAND			
	197.7 / 46.4	TILL			
	47.0	END OF HOLE			

Elevation scale: 245, 240, 235, 230, 225, 220, 215, 210, 205, 200, 195

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

SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + Q. - ⊖ REM.V. - ⊕ U. - O — 500 1000 1500 2000

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

WATER CONTENT, PERCENT W_p W W_L — 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Water content at elev. approx. 206: 166; H

Legend: 15 ◇ 5 (0 above, 10 below) Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.

CHECKED F.T.H.

RECORD OF BOREHOLE 7

LOCATION See Figure 1 BORING DATE JAN. 15 & 16, 1970 DATUM GEODETIC.

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

STA. 17+77, ON ℄

Boring method: WASH BORING, NX CASING

ELEV'N. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.
244.1	ICE SURFACE			
0.0 / 243.0 / 1.1	ICE			
	WATER			
228.5 / 15.6	SOFT DARK BROWN ORGANIC SILT	1	2" D.O.	Wh
		2	2" T.O.	Wh
		3	"	P.M.
204.? / 40.?	SOFT GREY SILT, SOME SAND, CLAY AND SHELLS	4	"	Wh
		5	"	P.M.
		6	2" D.O.	1
192.1 / 52.0	GREY SILTY SAND AND GRAVEL (TILL)			
190.5 / 53.6	END OF HOLE			

Column headings: BORING METHOD; SOIL PROFILE (ELEV'N./DEPTH, DESCRIPTION, STRAT. PLOT); SAMPLES (NUMBER, TYPE, BLOWS/FT.); ELEVATION SCALE (245, 240, 235, 230, 225, 220, 215, 210, 205, 200, 195, 190, 185); DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80); SHEAR STRENGTH Cu., LB./SQ.FT. (500, 1000, 1500, 2000) 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 (20, 40, 60, 80); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

Additional lab testing at approx. elev. 199.5: H

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

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.

CHECKED F.J.H.

RECORD OF BOREHOLE 6

LOCATION See Figure 1 BORING DATE JAN. 15, 1970 DATUM GEODETIC

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

STA. 15+89, 213' RT. ℄

BORING METHOD	SOIL PROFILE: ELEV'N / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/FT.
	244.1 / 0.0	ICE SURFACE			
		ICE			
	242.3 / 1.8				
		WATER			
WASH BORING NX CASING	229.1 / 15.0	SOFT DARK BROWN ORGANIC SILT	1	2" D.O.	Wh
			2	"	Wh
			3	"	P.M.
	198.1 / 46.0	GREY SILTY SAND AND GRAVEL (TILL)			
	195.6 / 48.5	END OF HOLE			

Column headings: ELEVATION SCALE (195–245); DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80); SHEAR STRENGTH Cu., LB./SQ.FT. (500, 1000, 1500, 2000) — 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

Legend: 0 / 15 ⊕ 5 / 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.
CHECKED F.J.H.

RECORD OF BOREHOLE 5

LOCATION See Figure 1 BORING DATE JAN. 15, 1970 DATUM GEODETIC

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

STA. 2+52, ON ℄

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE
	244	ICE SURFACE					245
	0.0 / 242.5	ICE					
	1.5	WATER					240
WASH BORING, NX CASING	236.9 / 7.2	SOFT DARK BROWN ORGANIC SILT, TRACE WOOD AND ROOTS		1	2"	[illegible]	235
	232.1 / 12.0	DENSE TO VERY DENSE GREY SILTY SAND AND GRAVEL, TRACE OF CLAY (TILL)		2	"	G	230
UNCASED				3	"	42	
	224.2			4	"	100	225
	19.5	END OF HOLE					220

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

5 - 10 Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.

CHECKED F.S.A.

RECORD OF BOREHOLE 4

LOCATION See Figure 1 BORING DATE JAN. 14, 1970 DATUM GEODETIC

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

STA. 4+64.5, ON ℄

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	STRAT. PLOT	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
							245				
	244.1	ICE SURFACE									
	0.0 / 242.8	ICE									
	1.3	WATER					240				
CASING	235.9 / 8.2	LOOSE DARK BROWN ORGANIC SANDY SILT		1	D.O.		235				
NX				2	"	23					
	231.8 / 12.3	COMPACT TO VERY DENSE GREY SILTY SAND AND GRAVEL (TILL) TRACE CLAY AT TRANSITION 8" LIMESTONE BOULDER AT 19.0'					230				
BX CASING				3	"	19					
				4	"	60					
UNCASED				5	BX RC	—	225				
	222.3			6	2" D.O.	66					
	21.8	END OF HOLE									
							220				

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

VERTICAL SCALE
1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.
CHECKED F.T.H.

RECORD OF BOREHOLE 3

LOCATION See Figure 1 BORING DATE JAN. 14, 1970 DATUM GEODETIC

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

STA. 9+70, ON ℄

BORING METHOD	ELEV'N. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE	SHEAR STRENGTH / DYNAMIC PENETRATION	WATER CONTENT / PERMEABILITY	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	244.1	ICE SURFACE					245				
	243.0 / 0.0	ICE									
	1.1	WATER					240				
							235				
WASH BORING, NX CASING	231.2 / 12.9						230				
		VERY SOFT DARK GREY ORGANIC SILT TRACE OF SHELLS		1	2" D.O.	P.M.					
				2	C.S.		225	⊕+ ⊕+			
	222.2			3	2" D.O.	P.M.					
	21.9	COMPACT TO DENSE GREY SILTY SAND AND GRAVEL, TRACE OF CLAY (TILL)		4	"	21	220				
				5	"	37				MH	
	217.1 / 27.0	END OF HOLE					215				

Legend: DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. 20 40 60 80; SHEAR STRENGTH Cu., LB./SQ.FT. 500 1000 1500 2000; NAT. V. - + Q. - ⊖ REM. V. - ⊕ U. - O; COEFFICIENT OF PERMEABILITY, K., CM./SEC. 1x10 1x10 1x10 1x10; WATER CONTENT, PERCENT Wp W Wl

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

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.
CHECKED F.J.H.

rm G.A. - D - 1

Project No. 71 750

RECORD OF BOREHOLE 2

LOCATION See Figure 1 BORING DATE JAN. 13 & 14, 1970 DATUM GEODETIC

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

STA. 12+27, ON ℄

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. (500, 1000, 1500, 2000) NAT. V. - + C. - ⊕ REM. V. - ⊕ U. - O	COEFFICIENT OF PERMEABILITY, K., CM./SEC. / WATER CONTENT, PERCENT (20, 40, 60, 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
							245				
	244.1	ICE SURFACE									
	243.1 / 1.0	ICE									
							240				
		WATER									
							235				
	229.8 / 14.3						230				
WASH BORING, NX CASING		VERY SOFT TO SOFT DARK BROWN TO DARK GREY ORGANIC SILT, TRACE SHELLS		1	2" D.O.	Wh			⊙ → 480		
							225	+ +			
							220				
				2	"	Wh					
							215				
								⊕ + ⊕ + ⊕ +			
	211.1 / 33.0	SOFT GREY CLAYEY SILT, TRACE SAND					210				
				3	"	Wh					
	206.1 / 38.0	VERY DENSE GREY SILT, SAND AND GRAVEL, TRACE CLAY (TILL)		4	"	>100	205				
	204.3 / 39.8	END OF HOLE									
							200				

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

VERTICAL SCALE
1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.
CHECKED F.J.H.

RECORD OF BOREHOLE 1

LOCATION See Figure 1 BORING DATE JAN. 13, 1970 DATUM GEODETIC

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

STA. 15+63, ON ℄

BORING METHOD	ELEV'N. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/FT.
	244.1 / 0.0	ICE SURFACE			
	243.1 / 1.0	ICE			
		WATER			
WASH BORING, NX CASING	228.9 / 15.2	VERY SOFT DARK GREY ORGANIC SILT, TRACE OF SHELLS	1	2" D.O.	Wh
			2	"	Wh
			3	"	Wh
			4	"	Wh
			5	"	P.M.
			6	"	P.M.
	205.1 / 39.0	SOFT GREY CLAYEY SILT TRACE OF SAND SHELLS AND ORGANIC MATERIAL	7	2" D.O.	P.M.
ROTARY DRILLING, AXT CORE	195.9 / 48.2	SOUND GREY FOSSILIFEROUS LIMESTONE BEDROCK	8	AXT RC	
			9	"	
	187.6 / 56.5	END OF HOLE			

Column headings: SOIL PROFILE; SAMPLES; ELEVATION SCALE; DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20, 40, 60, 80); SHEAR STRENGTH Cu., LB./SQ.FT. (500, 1000, 1500, 2000) 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 (20, 40, 60, 80); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

Elevation scale: 245, 240, 235, 230, 225, 220, 215, 210, 205, 200, 195, 190, 185

Core: % CORE RECOVERY 100, 100; EST. % DRILL WATER RETURN 100

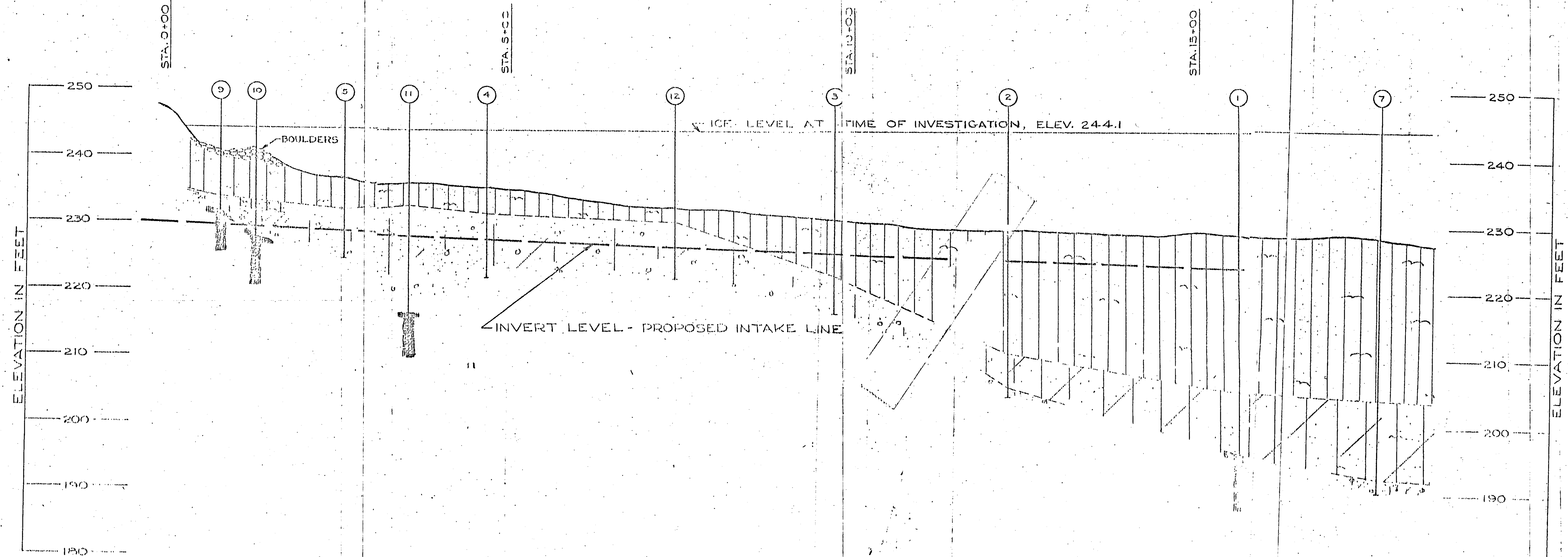
15 ◊ 5 Percent axial strain at failure (10)

VERTICAL SCALE 1 IN. TO 5 FT.

Golder Associates

DRAWN D.N.
CHECKED F.J.H.

SOIL STRATIGRAPHY SECTION | FIGURE 2



SECTION ALONG PROPOSED INTAKE

SCALE: HOR. 1" to 100'
VER. 1" to 10'

STRATIGRAPHY

- VERY SOFT TO SOFT DARK BROWN TO DARK GREY ORGANIC SILT, TRACE SHELLS
- VERY LOOSE GREY BLUE SILT, SOME SAND AND GRAVEL, TRACE ORGANIC MATERIAL
- STIFF LAYERED LIGHT GREY AND DARK GREY CLAY, TRACE OF TWIGS AND ROOTS
- SOFT GREY CLAYEY SILT, TRACE OF SAND, SHELLS AND ORGANIC MATERIAL
- LOOSE TO VERY DENSE GREY SILTY SAND AND GRAVEL, TRACE CLAY, SOME BOULDERS (TILL)
- FAIRLY SOUND TO SOUND GREY FOSSILIFEROUS LIMESTONE BEDROCK

LEGEND

- BOREHOLE IN ELEVATION

NOTE

Data concerning the various strata have been obtained at borehole locations only. The soil stratigraphy between the boreholes has been inferred from geological evidence and so may vary from that shown.
For detailed stratigraphy at each borehole location refer to the record of borehole sheets.

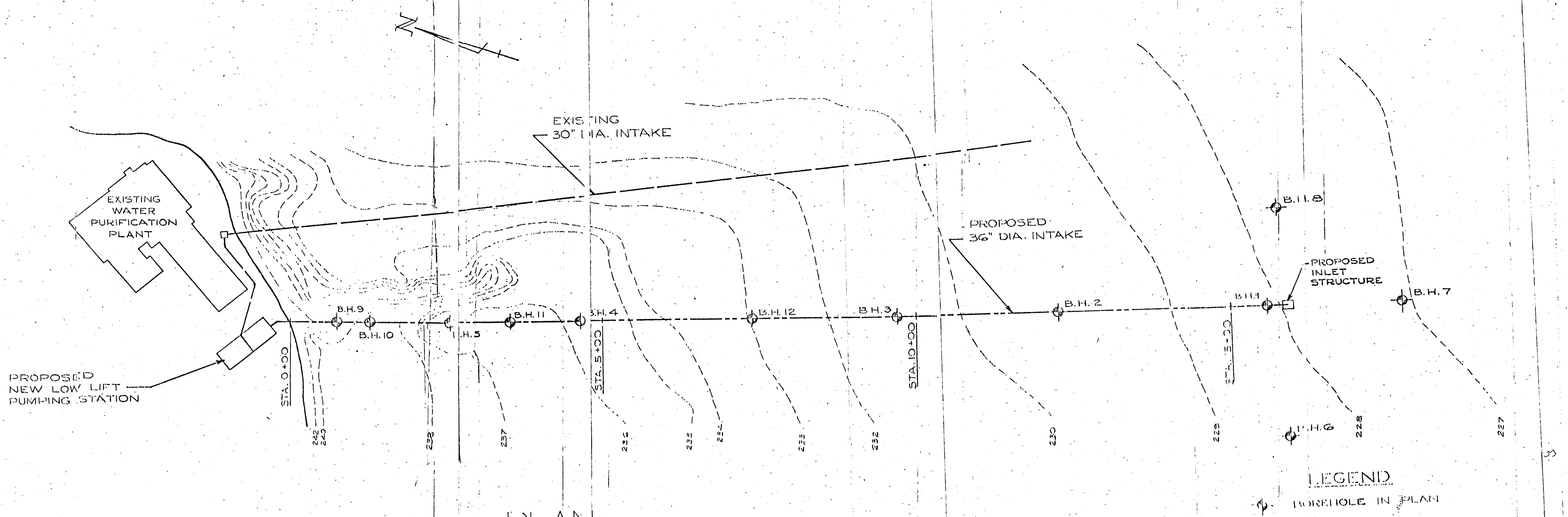
Date [illegible]

Golder Associates

Drawn
Chkd
Appd.

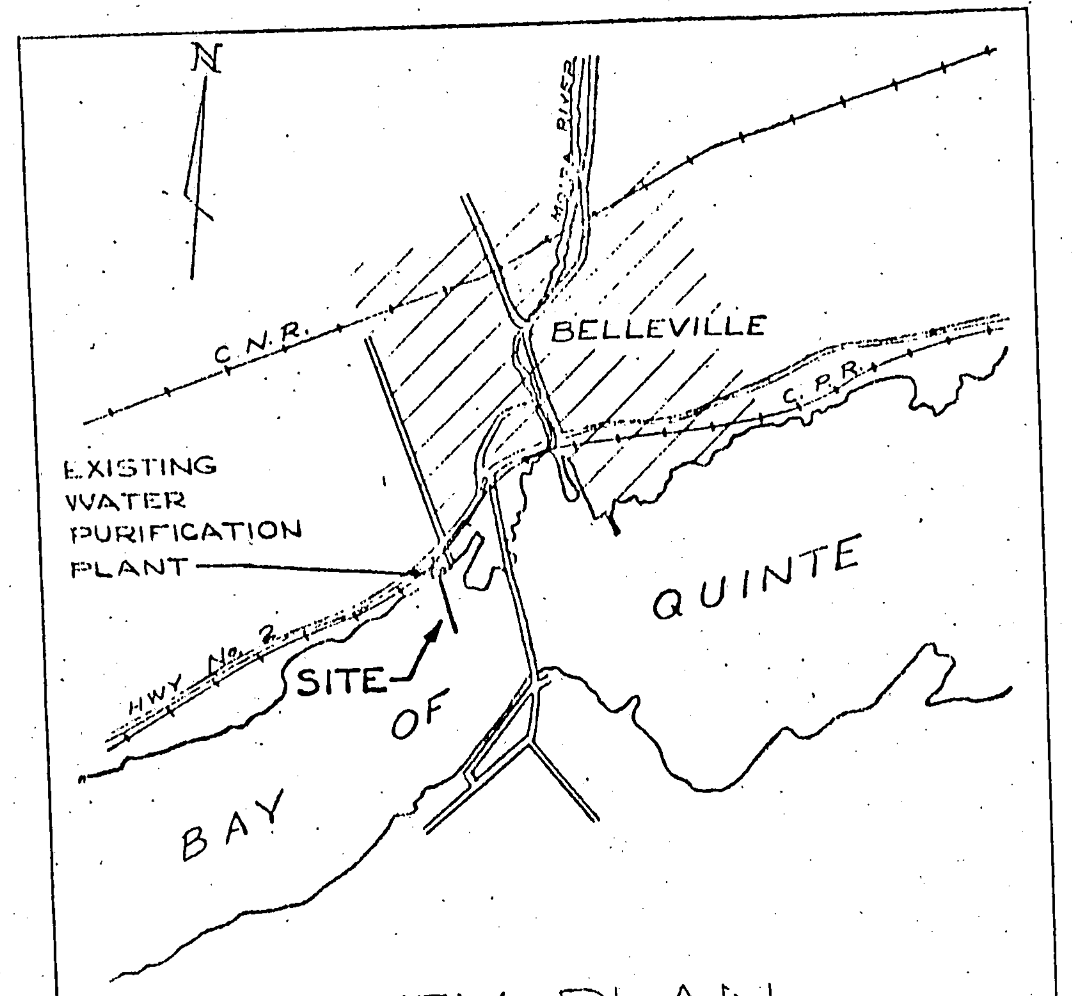
BORING PLAN

FIGURE 1



PLAN

SCALE: 1" To 100'



KEY PLAN

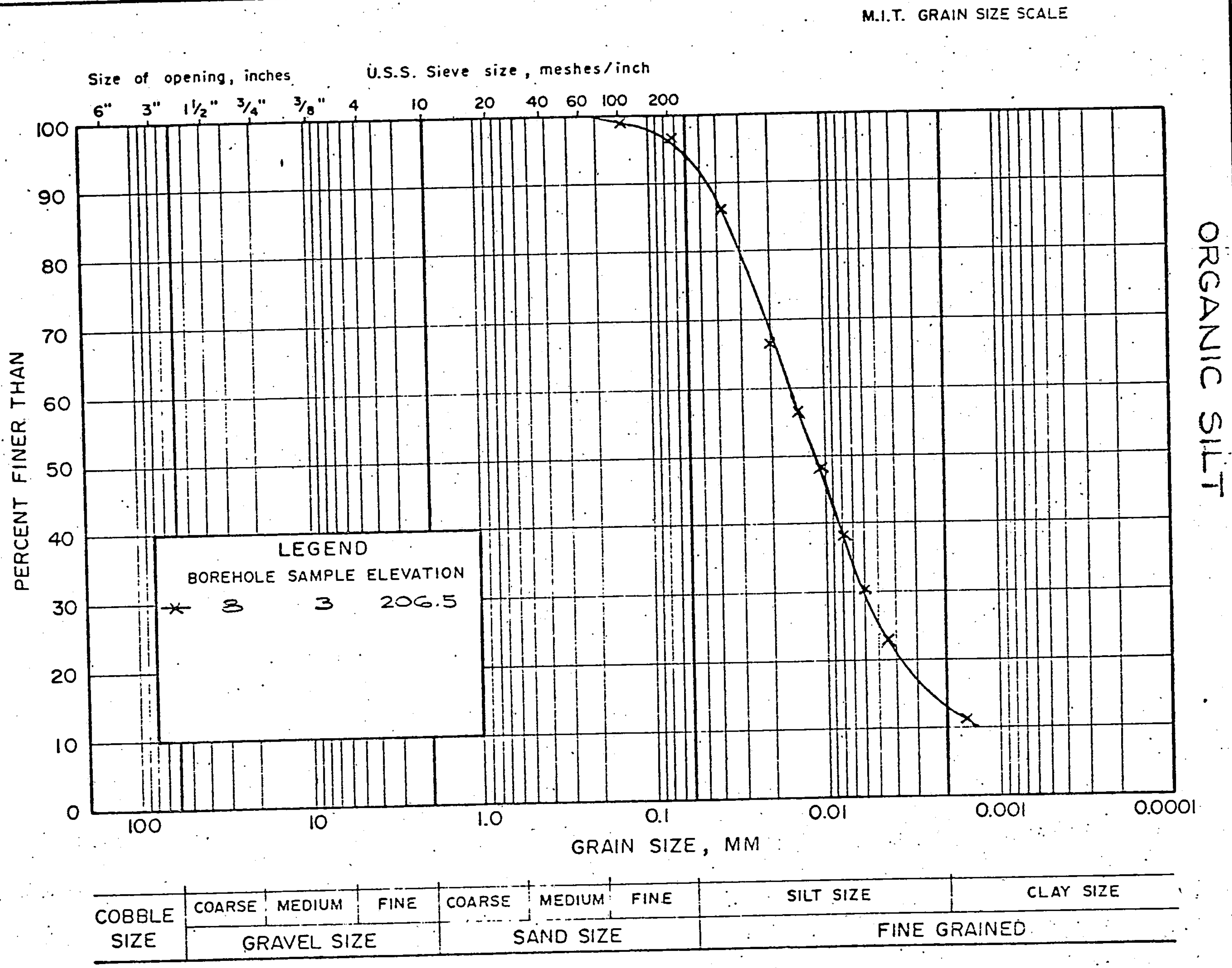
SCALE: 1" To 1 MILE

REFERENCE: GORE AND STORRIE LTD.
BELLEVILLE WATER PURIFICATION PLANT
NEW INTAKE 1970
DRAWING No. 1, FILE No. 23-D-10352
DATED DEC. 1969

Date FEB. 2, 1970

Golder Associates

Drawn D.N.
Chkd
Appd



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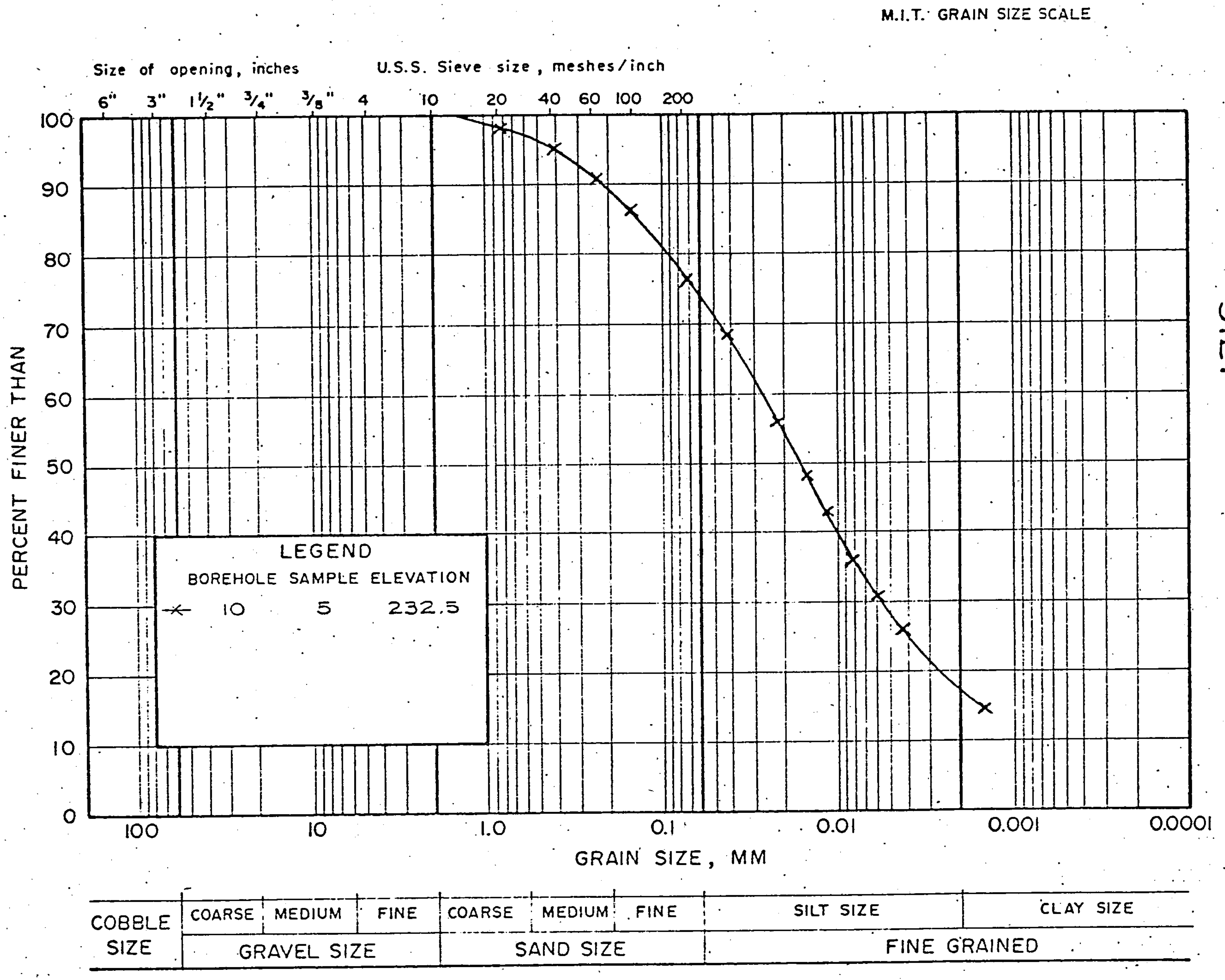
GRAIN SIZE DISTRIBUTION

FIGURE 3

PROJECT No.



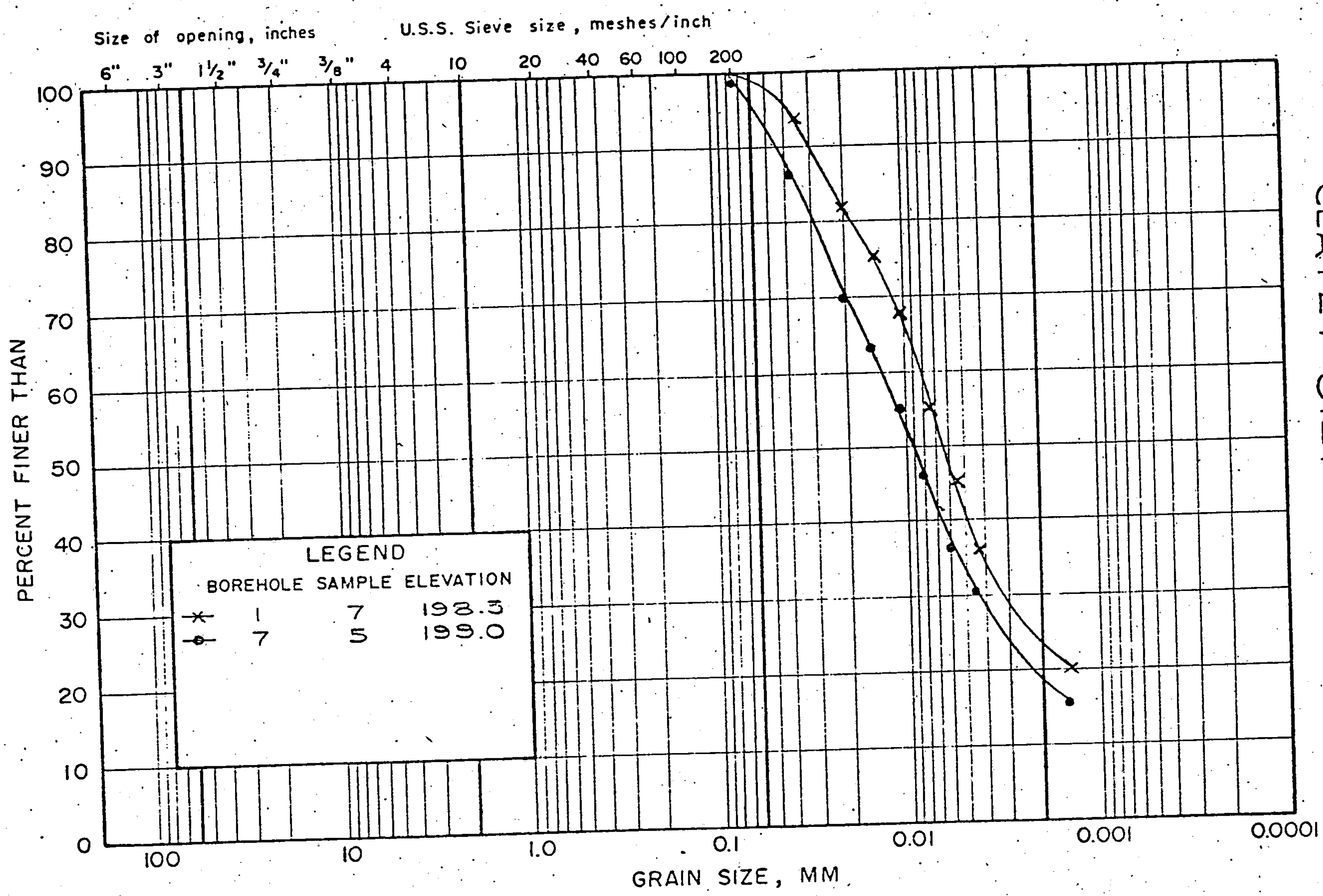
SILT

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 4

M.I.T. GRAIN SIZE SCALE



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

CLAYEY SILT

GRAIN SIZE DISTRIBUTION

FIGURE 5

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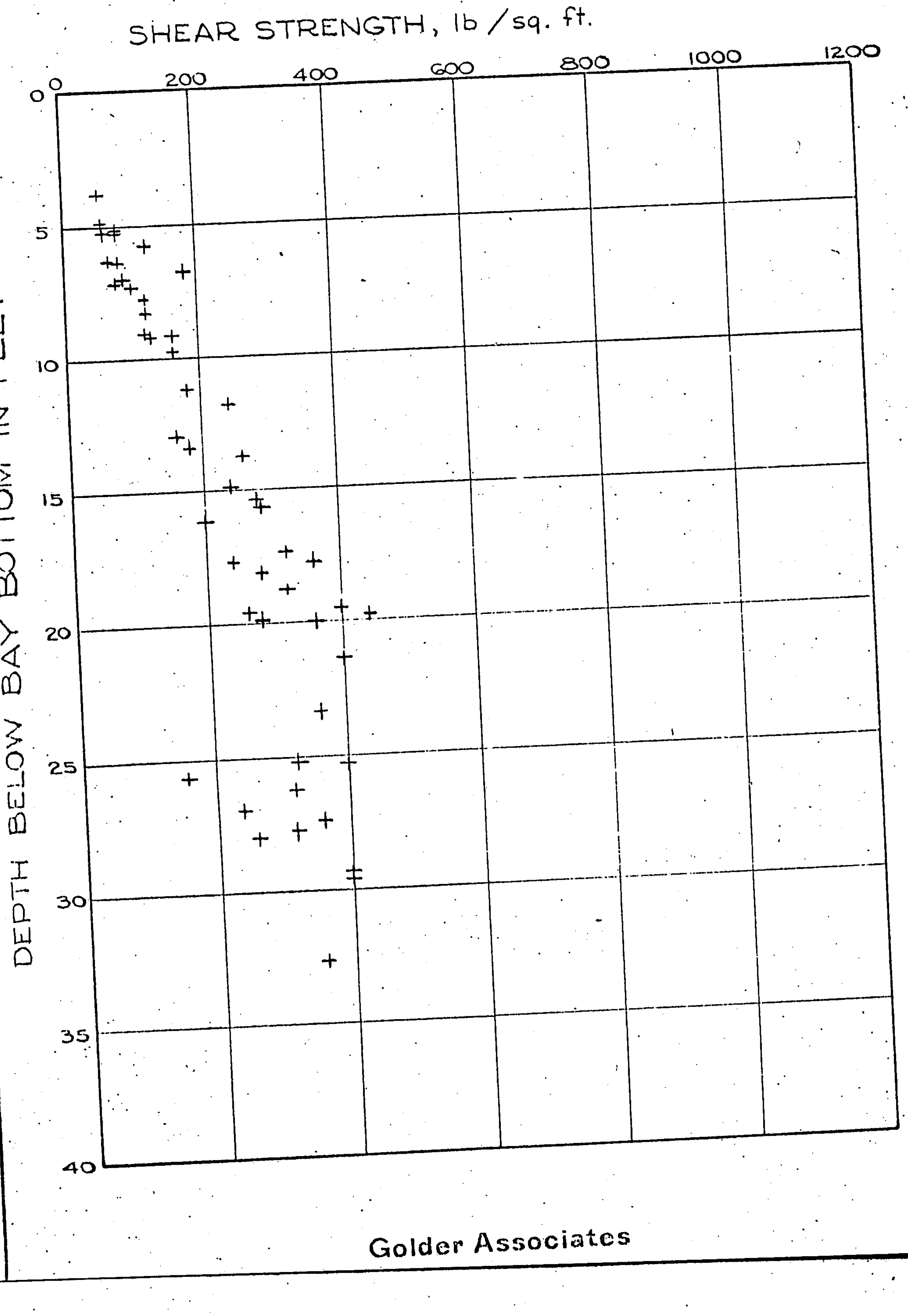
SHEAR STRENGTH PROFILE

FIGURE 7



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Form G.A-0-5