



**FOUNDATION INVESTIGATION REPORT
for
NORTHEAST CORNER RETAINING WALL
FREDERICK STREET UNDERPASS
SITE NO. 33-234
G.W.P. 3110-09-00
CITY OF KITCHENER, ONTARIO**

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(GEOCRES No. 40P8-48)

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FOUNDATION INVESTIGATION REPORT
for
Northeast Corner Retaining Wall
Frederick Street Underpass, Site No. 33-234
GWP 3110-09-00
City of Kitchener, Ontario

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the northeast concrete retaining wall of the Frederick Street Underpass on Highway 7 / 85 (Kitchener-Waterloo Expressway) in the City of Kitchener. Peto MacCallum Ltd. (PML) carried out the investigation to determine the probable causes of the wall movement for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The retaining wall has experienced progressive movement (tilting) towards the highway. The purpose of this report was to summarize the subsurface stratigraphy encountered in the foundation investigation. A previous foundation investigation dated July 1966 for the Frederick Street Underpass was obtained from the MTO library GEOCREs No.40P8-48. A copy of the previous Report with the borehole logs and Foundation Drawing is enclosed in Appendix A for reference.

The inspection of the condition of the retaining wall above and below grade including the foundation and the associated appurtenances is considered a structural facet and was not in the scope of this investigation.

2. SITE DESCRIPTION AND GEOLOGY

The retaining wall is located on the northeast corner of the Frederick Street underpass and along the east side of the Highway 7 speed change lane (to Victoria Street). The wall is approximately 5.4 m high above grade at the bridge abutment and tapers down northerly to approximately 1.8 m height. Further description of the retaining wall are presented in Section 5 of this report.

Photographs of the site and retaining wall taken on July 20 and October 8, 2011 are presented in Appendix B.



Land use in the vicinity of the site includes the existing Highway 7 / 85 transportation corridor including the Frederick Street underpass amidst residential and commercial areas. The local topography of the site is generally flat at Highway 7 / 85. The terrain rises away from the highway and a series of retaining walls exists north and south of the Frederick Street underpass abutments. The ground in front of the retaining wall area includes a paved shoulder and sidewalk. Grasses and bushes cover the ground behind the wall (Photographs 1 to 4). The grade behind the retaining wall slopes up about 2.0 m to the east at an approximate angle of 18°.

Based on the existing construction records and report referenced above, the underpass was constructed by excavating approximately 4.7 m below the previously existing ground level and constructing the Frederick Street structure at its original road grade level.

A double catch basin exists in front of the sidewalk about 14 m north of the south end of the retaining wall, indicating the presence of a storm sewer under the roadway (Photograph 2).

The site is located within in the physiographic region known as the Waterloo Hills that is characterised by sandy hills, sandy till ridges, kames and kames moraines with outwash sandy soils occupying the intervening hollows. The principal surficial soil in the area is fine sand at the hilly regions to more uniform sandy and gravelly materials at the alluvial terraces of the Grand River spillway. Typically, the surficial soils overlay clayey soils/ clay tills.

3. INVESTIGATION PROCEDURES

The condition of the existing retaining wall was surveyed on October 8, 2011 and the results are presented in Section 5 of this report. The subsurface investigation was carried out during the period of April 8 to July 20, 2011. A total of four boreholes (RW-1 to RW-4) were advanced to depths ranging from 6.4 to 9.8 m at the locations shown on Drawing RW-1, appended.

The borehole locations had to be moved away from the retaining wall to clear existing buried utilities. The boreholes located on the Highway 7 / 85 speed change lane were advanced on April 8, 2011 using continuous flight hollow stem augers powered by a truck-mounted CME 55 drill rig. Behind



the retaining wall, the boreholes were drilled in July 2011 with a portable drill rig (Dynamic Ram Sounder). The drill rigs were supplied and operated by specialist drilling contractors, working under the full-time supervision of a PML field supervisor.

Soil samples were recovered from the boreholes drilled on the highway at regular 0.75 and 1.5 m intervals of depth using the standard penetration test method. Continuous sampling was undertaken from the boreholes drilled behind the retaining wall using the standard penetration test. One dynamic cone penetration test was also conducted to assess the strength characteristics of the substrata. Because the shear strength of the clayey soils was too high for using field vane testing, penetrometer tests were carried out on cohesive split spoon soil samples to evaluate their shear strength. Soils were identified in accordance with the MTO soil classification manual procedures.

The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and where encountered by measuring the groundwater level in the open holes. A total of two 19 and 30 mm diameter PVC standpipe piezometers were installed in boreholes RW-1 and RW-3 for subsequent groundwater level monitoring.

The boreholes were backfilled with a bentonite/cement mixture where required in accordance with the MTO guideline and MOE Reg. 903 for borehole abandonment.

The locations of the test holes were laid out by PML as allowed by access and underground utilities and were surveyed by MMM Group Ltd. All elevations in this report are provided in metres.

The recovered soil samples were returned to our laboratory in Toronto for detailed visual examination, laboratory testing and tactile examination to confirm field classification. The laboratory testing program included the following tests:

- Natural moisture content determinations (32)
- Grain size distribution analyses (19)
- Atterberg limits tests (4)



The laboratory grain size distribution charts are presented in Figures RW-GS-1 to RW-GS-7. The Atterberg plasticity test results are shown on the Figures RW-PC-1 and RW-PC-2.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole Sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration test results, penetrometer shear strength values, groundwater observations, details of piezometer installations and piezometric level readings. The results of laboratory particle size distributions and Atterberg limits and moisture content determinations are also shown on the Record of Borehole Sheets.

4.1 Fill

A 1.4 m thick fill unit was encountered in boreholes RW-1 and RW-2 drilled on the existing Highway 7 speed change lane in front of the retaining wall. The unit extended to 1.4 m depth (elevation 318.3). The fill layer includes asphalt over granular base and subbase materials including sand and crushed gravel. N values were 3 and 11 indicating very loose to compact relative density. The moisture content results were 15 and 16%.

In addition, a 2.3 m thick fill (backfill material for retaining wall) was present in boreholes RW-3 and RW-4 drilled behind the retaining wall. The unit extended to 2.3 m (elevation 320.0 and 321.2). The fill unit behind the retaining wall is heterogeneous and includes cohesionless silty sand / silt / gravelly sand and cohesive clayey silt. N values ranged from 14 to 27 indicating compact relative density or very stiff consistency.

The results of grain size distribution analysis for fill samples from boreholes RW-3 and RW-4 are included in Figures RW-GS-1 to RW-GS-5. The plasticity chart is presented in Figure RW-PC-1. The fill samples from boreholes RW-3 and RW-4 include 4 to 29% clay, 11 to 54% silt, 20 to 68% sand and 3 to 23% gravel sized materials. Eight grain size analyses were carried out on the fill samples obtained behind the retaining wall. The fines content (total of the silt and clay components) of these samples was in excess of 17% and in 7 of 8 samples ranged from 38 to 71%. The liquid and



plastic limits obtained on a clayey silt fill sample were 22 and 12, respectively with a corresponding plasticity index value of 10. The moisture content determinations varied from 5 to 11%.

4.2 Sand

A cohesionless native sand deposit was encountered below the fill at 2.3 m (elevation 320.0 and 321.2) in boreholes RW-3 and RW-4 drilled behind the wall. The deposit was 2.1 and 3.6 m thick extending to 4.4 and 5.9 m (elevation 317.6 and 317.9). It is noted that the sand deposit contains gravelly to with gravel in borehole RW-4 below elevation 319.7. N values ranged from 9 to 21, typically 13 and 14. The relative density of the sand deposit was compact with local loose layers.

The results of grain size distribution analysis for sand samples are included in Figure RW-GS-6. The moisture content determinations varied from 3 to 20%.

4.3 Silty Clay

A cohesive silty clay stratum was encountered below the fill at 1.4 m (elevation 318.3) in boreholes RW-1 and RW-2 and below the sand at 4.4 and 5.9 m (elevation 317.9 and 317.6) in boreholes RW-3 and RW-4. The stratum was at least 1.1 to 8.4 m thick extending to the borehole termination depths of 6.4 to 9.8 m (elevation 309.9 to 316.5). The boreholes were terminated within the silty clay stratum at 6.4 to 9.8 m (elevation 309.9 to 316.5).

It is noted that cobbles were encountered below elevation 317.0 in boreholes RW-3 and RW-4. N values ranged from 9 to 67 and 50 to 70 for 13 and 15 cm sampler penetration. Pocket penetrometer test results were 175 and 225 kPa. The stratum was very stiff to hard consistency.

The results of grain size distribution analysis for silty clay samples are included in Figure RW-GS-7. The plasticity chart is presented in Figure RW-PC-2. The liquid limits and plastic limits varied from 35 to 45 and 17 to 23, respectively with plasticity index values of 18 and 22. The moisture content determinations varied from 9 to 25%.



4.4 Groundwater

Groundwater was encountered in all of the boreholes. During augering, groundwater was observed at 3.0 and 4.2 m (elevation 319.3) in boreholes RW-3 and RW-4. Upon completion of drilling, groundwater was measured at 7.3 m (elevation 312.4) in borehole RW-2. Cave-in was observed in boreholes RW-1, RW-2 and RW-4 at 5.0 to 8.7 m (elevation 311.0 to 318.5).

A piezometer was installed in each of boreholes RW-1 and RW-3 for subsequent groundwater level monitoring. The piezometric water level readings are tabulated below:

BOREHOLE NO.	GROUND SURFACE ELEVATION	BOREHOLE DEPTH (m)	WATER LEVEL READING IN PIEZOMETER	
			DEPTH (m)	ELEVATION
RW-1	319.7	9.8	2.9 (Apr. 8, 2011)	316.8
RW-3	322.3	6.4	Dry (July 19, 2011)	-
			3.3 (Sept. 23, 2011)	319.0
			3.3 (Oct. 8, 2011)	319.0

The readings taken in the piezometer on April 8, 2011 immediately after installation, showed the water level to be at 2.9 m (elevation 316.8) in borehole RW-1. The flush mounted casing located on the highway pavement was damaged and could not be removed for further piezometer readings. Groundwater was not encountered in the borehole RW-3 piezometer on July 19, 2011. The readings taken in the piezometer RW-3 on September 23 and October 8, 2011 (65 and 81 days after installation) showed the water level to be stabilized at 3.3 m (elevation 319.0). It is noted that the groundwater levels are subject to seasonal fluctuations and precipitation patterns.

5. RETAINING WALL CONDITION SURVEY

Construction of the Frederick Street underpass and associated retaining walls was carried out under the MTO contract No. 68-62 in 1968. The MTO Foundation Investigation and Design Report prepared for the underpass construction has the GEOCREC No. 40P8-48. These original



documents indicate that the previously existing ground was cut under the Frederick Street bridge approximately 4.7 m to allow the Highway 7 / 85 to pass underneath. The earth slopes resulting from the excavations were supported by cast-in-place concrete retaining walls extending to north and south from the bridge abutments.

The subject retaining wall is located at the northeast corner of the Frederick Street underpass. The retaining wall supports the cut slope for Highway 7 / 85 speed change lane and abutment slope. The wall is a cast-in place concrete cantilever wall comprising a total of four panels with 9.1 m (30 ft) each panel. The total length of the retaining wall along Highway 7 / 85 speed change lane is about 36.6 m (120 ft). The retaining wall is about 5.4 m (17 ft 9 in) high at the south end decreasing northerly to 1.8 m (5 ft 10 in) at the north end.

The construction drawings called for the retaining wall to be constructed with a vertical front face and a slightly tapered back face. A review of the inspection report for Frederick Street Underpass, prepared by the Proctor & Redfern Group, dated November 1982 indicated that in 14 years the top of the wall had moved ± 125 mm towards the highway from its original position at the time of construction in 1968. From 1982 to 2011 (29 years), the top of the wall moved an additional ± 105 mm, for an approximate total of ± 230 mm towards the highway from its original position.

The rate of movement was calculated based on the above data to be approximately ± 9 mm/year from its construction to 1982. From 1968 to 2011 the rate of movement was about ± 5 mm/year. The rate of movement is summarized in the following table.

Measurement Years	Top of Wall Total Movement at Abutment		Elapsed Time Since 1968 (Years)	Rate of Movement	
	(mm)	(degrees)		(mm/Year)	(degrees/Year)
1982	125	1.3	14	9	0.09
2011	230	2.4	43	5	0.06

Photographs of the site and retaining wall taken on July 20 and October 8, 2011 are presented in Appendix B.



On October 8, 2011, the measurements of the top of the wall deflection from the vertical were obtained at four locations using a measuring tape and a plumb bob as illustrated in Photographs 6, 8, 9 and 10. The measurements are summarized in the following table.

Location of Section from Bridge Abutment	Retaining Wall Height above Sidewalk (m)	Overhang to Sidewalk Level (Note 1) (mm)	Rotation Angle (degrees)	Remarks
At abutment	4.4	165 (Note 2)	2.4	Measuring tape used
7 m north	4.0	152	2.1	Plumb bob and measuring tape used
14 m north	3.6	114	1.8	Plumb bob and measuring tape used
20 m north	3.1	41	0.8	Plumb bob and measuring tape used

Notes: (1) Overhang is the approximate distance that the top of the retaining wall is currently over the edge of the sidewalk at the retaining wall face.

(2) At this location, measurements were taken to the face of the bridge abutment. Top of wall – 230 mm (9 in.); 1.8 m above sidewalk – 127 mm (5 in.); 0.3 m above sidewalk – 64 mm (2.5 in.).

The measurements indicate a gradual increment of the leaning of the retaining wall toward the highway that becomes more pronounced southerly from 0.8° to 2.4° as the height of the retaining wall increases.

It is understood from MRC that further to the CCTV camera survey of the storm sewer in December 2011, the pipe is in acceptable condition and that sand was not found inside the pipe indicating that a breach has not occurred in the past.

6. MISCELLANEOUS

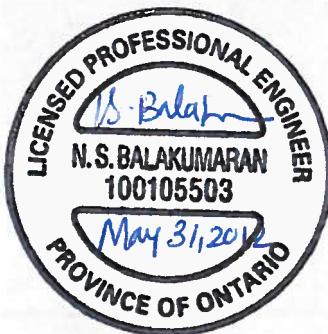
Messrs. F. Portela, A. Lo, R. Blair carried out the field investigation for this study under the supervision of Mrs. N.S. Balakumaran, P. Eng. and Mr. C. M. P. Nascimento, P. Eng., Project Manager. London Soils and Sonic Drilling. supplied the drill rigs for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.



This report was prepared by Mrs. N. S. Balakumaran, P. Eng. and reviewed by Mr. C. M. P. Nascimento, P. Eng., Project Manager. Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



Nesam S. Balakumaran, P.Eng.
Project Engineer



Carlos M.P. Nascimento, P.Eng.
Project Manager



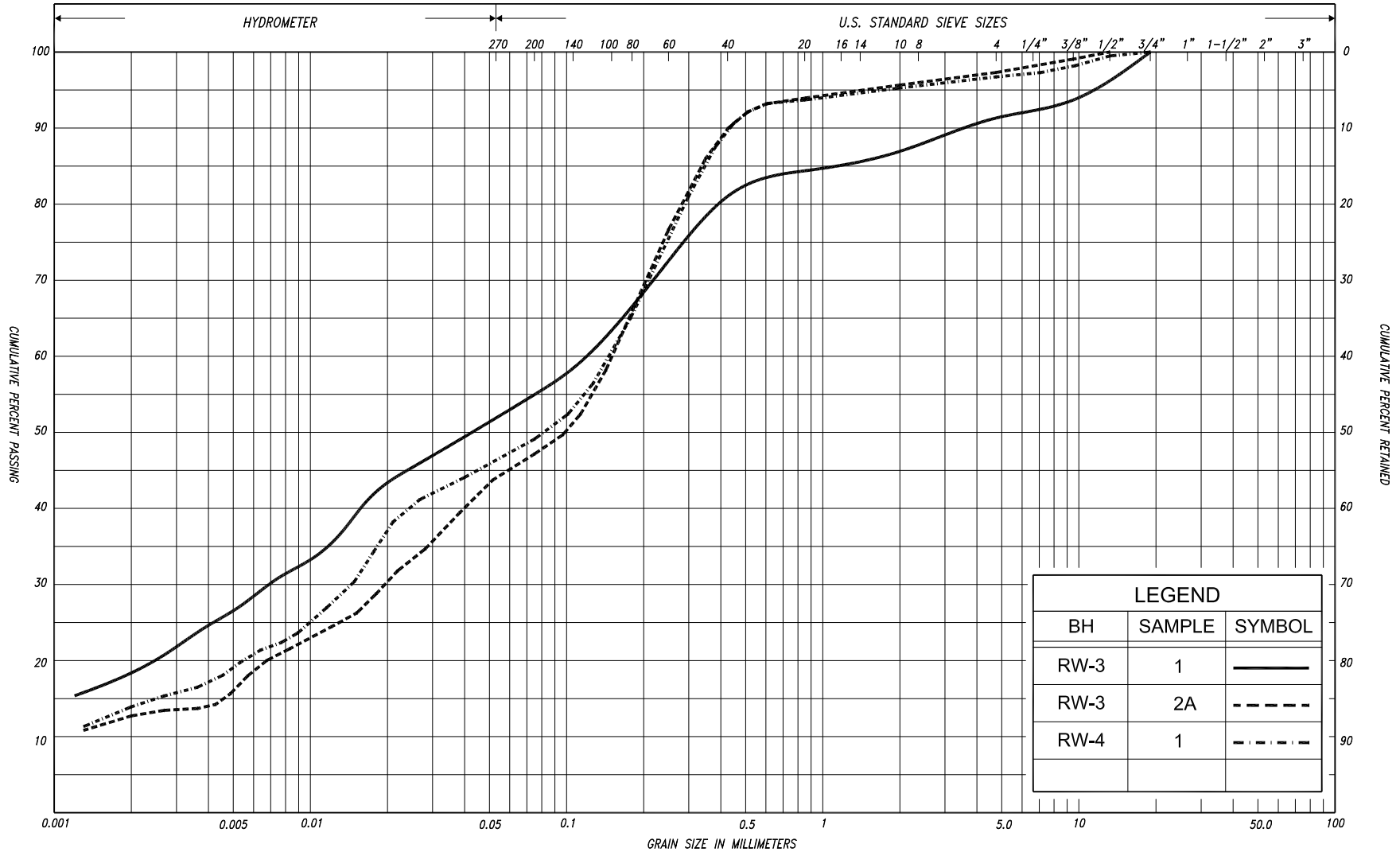
Brian R. Gray, MEng, P.Eng.
MTO Designated Principal Contact

NB/CN/BRG:nb-mi



TABLE A-1
LIST OF ATTERBERG LIMITS RESULTS

SOIL TYPE	BOREHOLE NO.	SAMPLE NO.	DEPTH / ELEVATION (m)	MOISTURE CONTENT (W %)	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)
Clayey Silt Fill	RW-3	3B	2.1 / 320.2	-	22	12	10
Silty Clay	RW-2	3	1.9 / 317.8	19	36	18	18
	RW-2	5	3.3 / 316.3	19	35	17	18
	RW-2	7	6.3 / 313.4	21	45	23	22



SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL				COBBLES	UNIFIED						
CLAY	FINE		MEDIUM		COARSE	SAND					GRAVEL				COBBLES	M.I.T.					
	SILT					FINE		MEDIUM		SAND		COARSE		GRAVEL				COBBLES	U.S. BUREAU		
CLAY			SILT			V. FINE	FINE	MED.	COARSE		SAND					GRAVEL				COBBLES	U.S. BUREAU

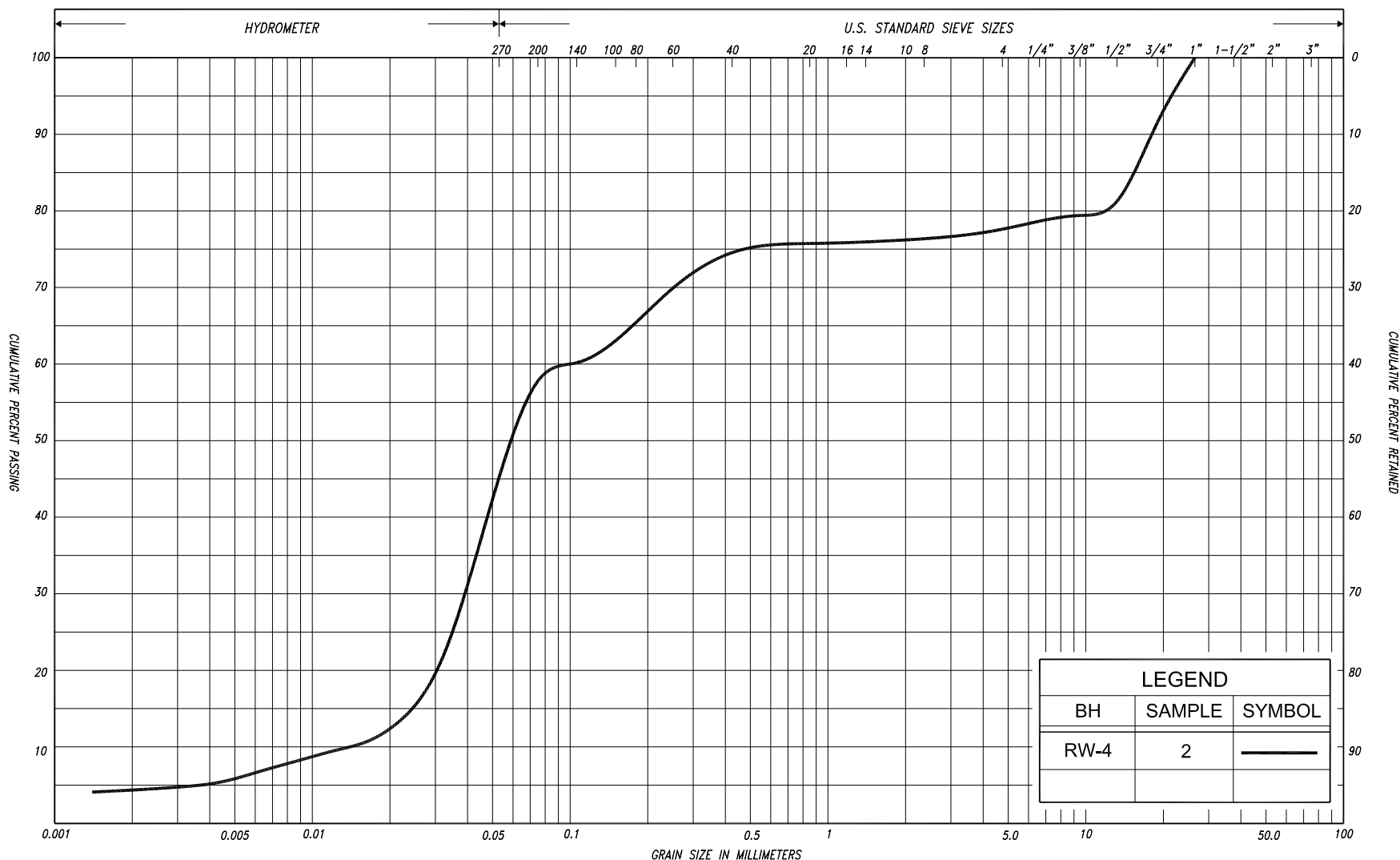
GRAIN SIZE DISTRIBUTION SILTY SAND, some clay, trace gravel (FILL)

FIG No. RW-GS-1

HWY: 7 / 85

G.W.P. No. 3110-09-00





SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED	
CLAY	FINE		MEDIUM		COARSE		SAND		GRAVEL			COBBLES	M.I.T.		
	SILT		FINE		MEDIUM		COARSE								
CLAY		SILT			V. FINE		FINE		MED.		COARSE		GRAVEL		U.S. BUREAU
					SAND										

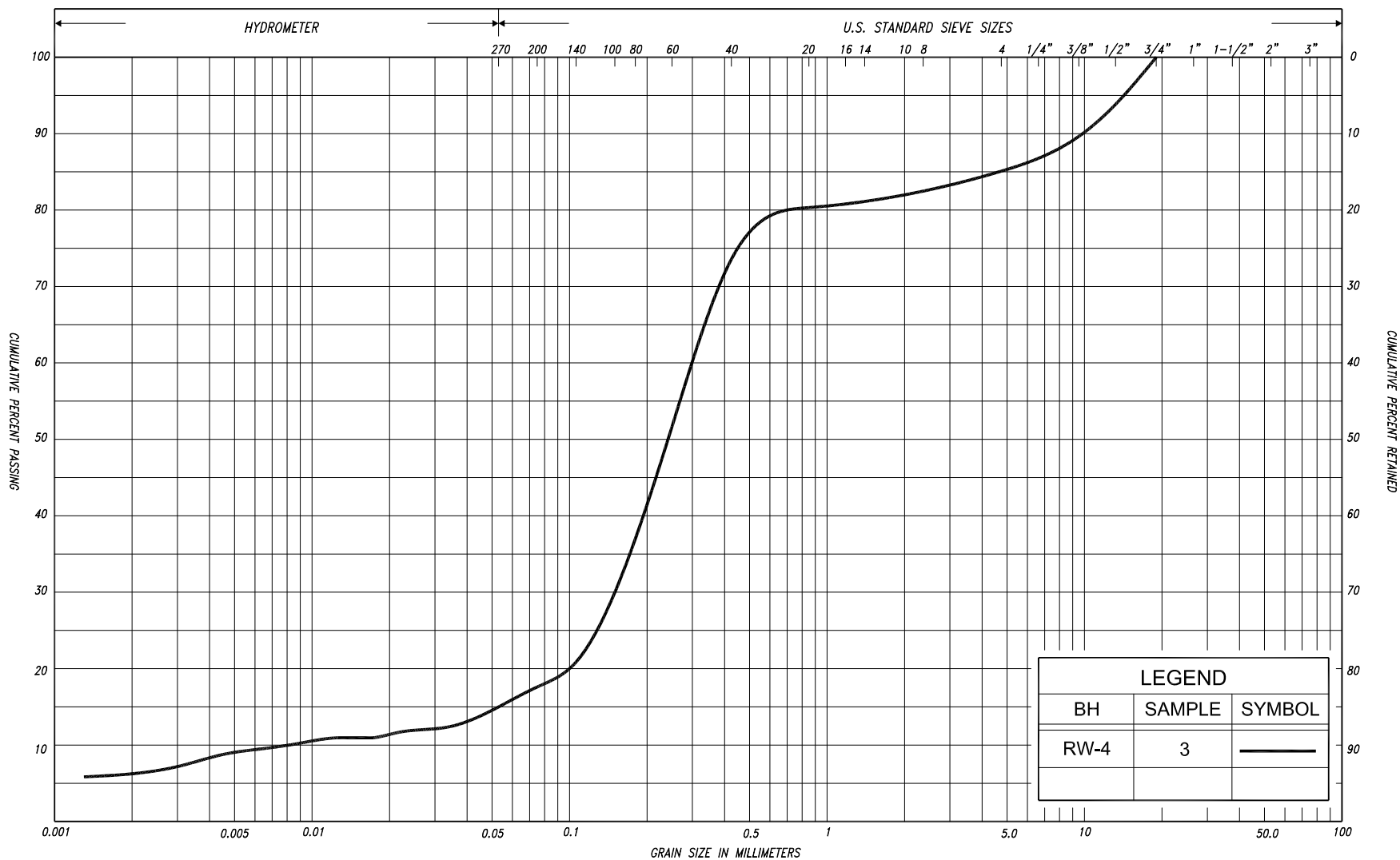


GRAIN SIZE DISTRIBUTION SILT, some sand, some gravel, trace clay (FILL)

FIG No. RW-GS-2

HWY: 7 / 85

G.W.P. No. 3110-09-00



LEGEND		
BH	SAMPLE	SYMBOL
RW-4	3	—

SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COB BLES	UNIFIED	
				SAND									
CLAY	FINE	MEDIUM		COARSE	FINE	MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.
	SILT												
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU
					SAND								

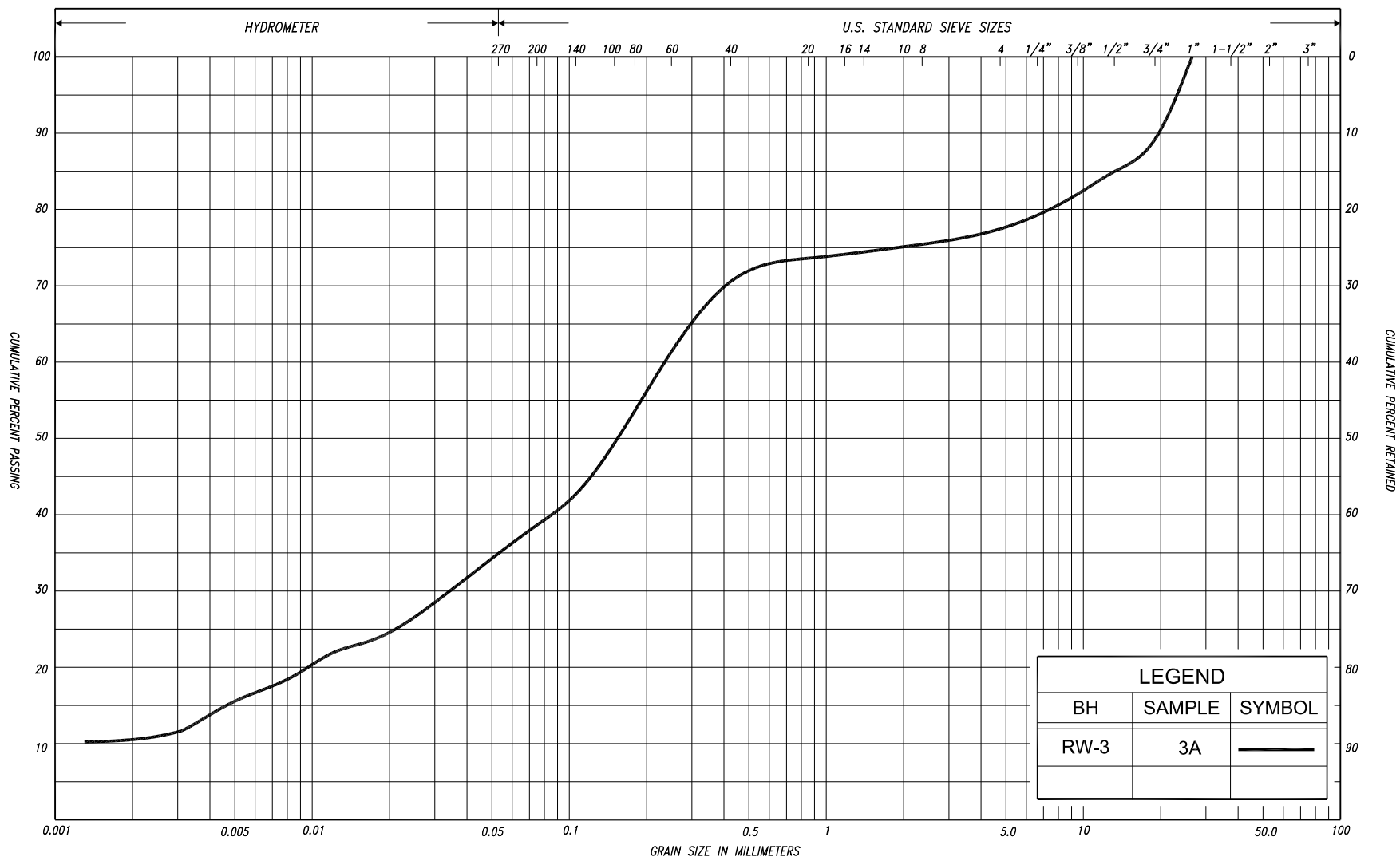


GRAIN SIZE DISTRIBUTION SAND, some silt, some gravel, trace clay (FILL)

FIG No. RW-GS-3

HWY: 7 / 85

G.W.P. No. 3110-09-00

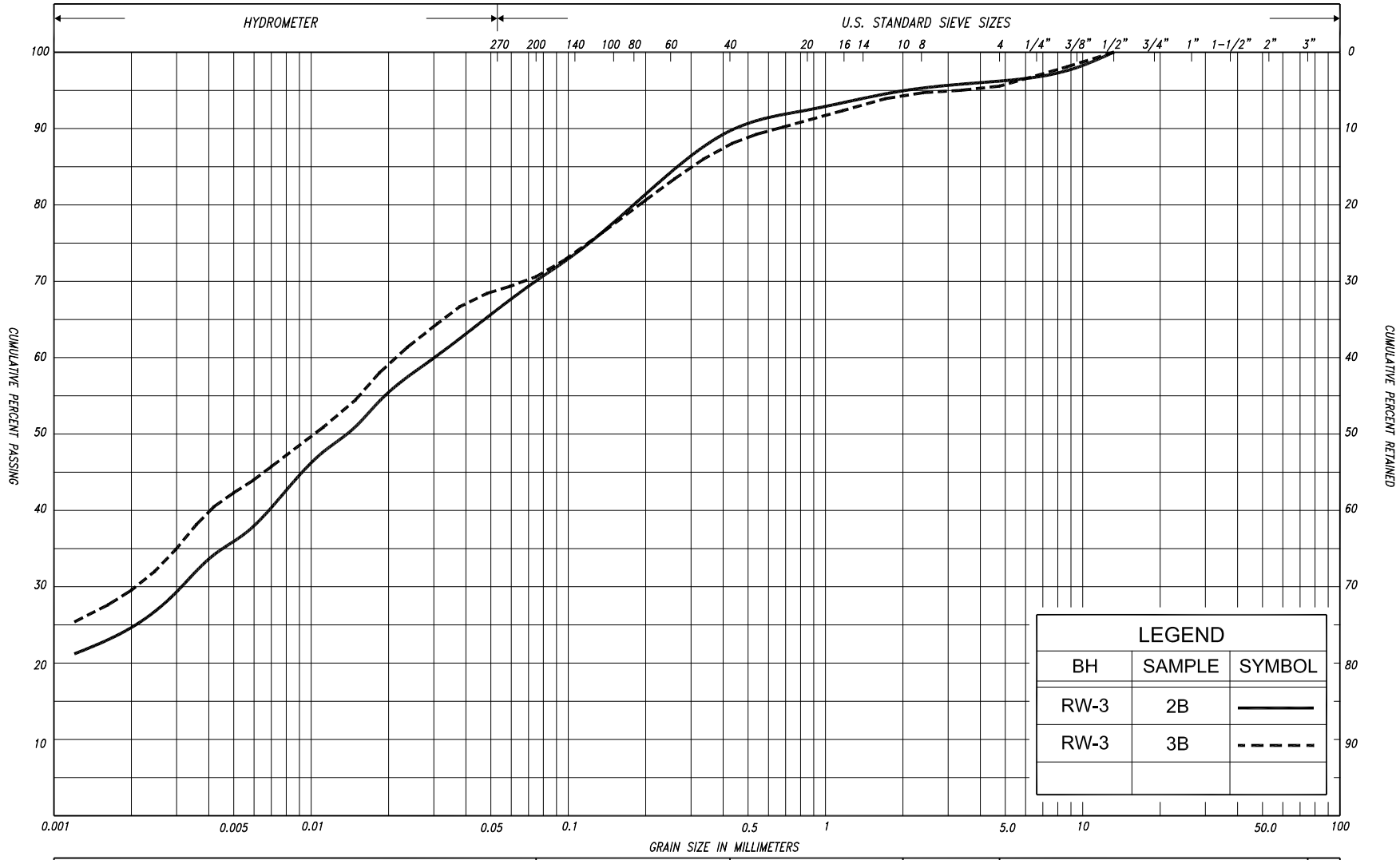


SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED			
					SAND												
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.	
	SILT							SAND									
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL						U.S. BUREAU	
					SAND												



GRAIN SIZE DISTRIBUTION GRAVELLY SAND, with silt, some clay (FILL)

FIG No. RW-GS-4
HWY: 7 / 85
G.W.P. No. 3110-09-00



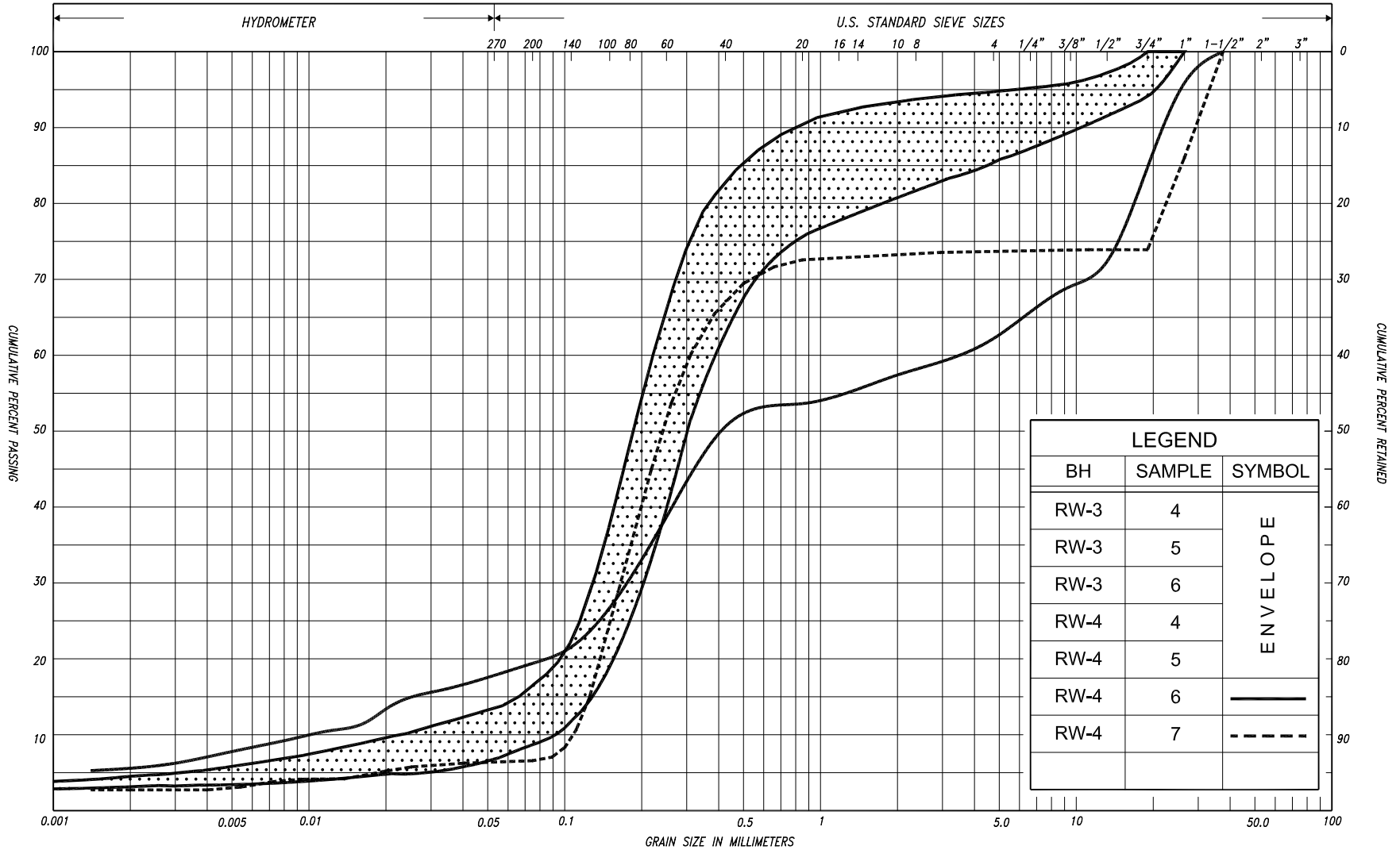
LEGEND		
BH	SAMPLE	SYMBOL
RW-3	2B	————
RW-3	3B	- - - - -

SILT & CLAY						FINE		MEDIUM		COARSE		GRAVEL				COB BLES	UNIFIED	
						SAND												
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL				COBBLES	M.I.T.
	SILT																	
CLAY			SILT			V. FINE	FINE	MED.	COARSE		GRAVEL						U.S. BUREAU	
						SAND												

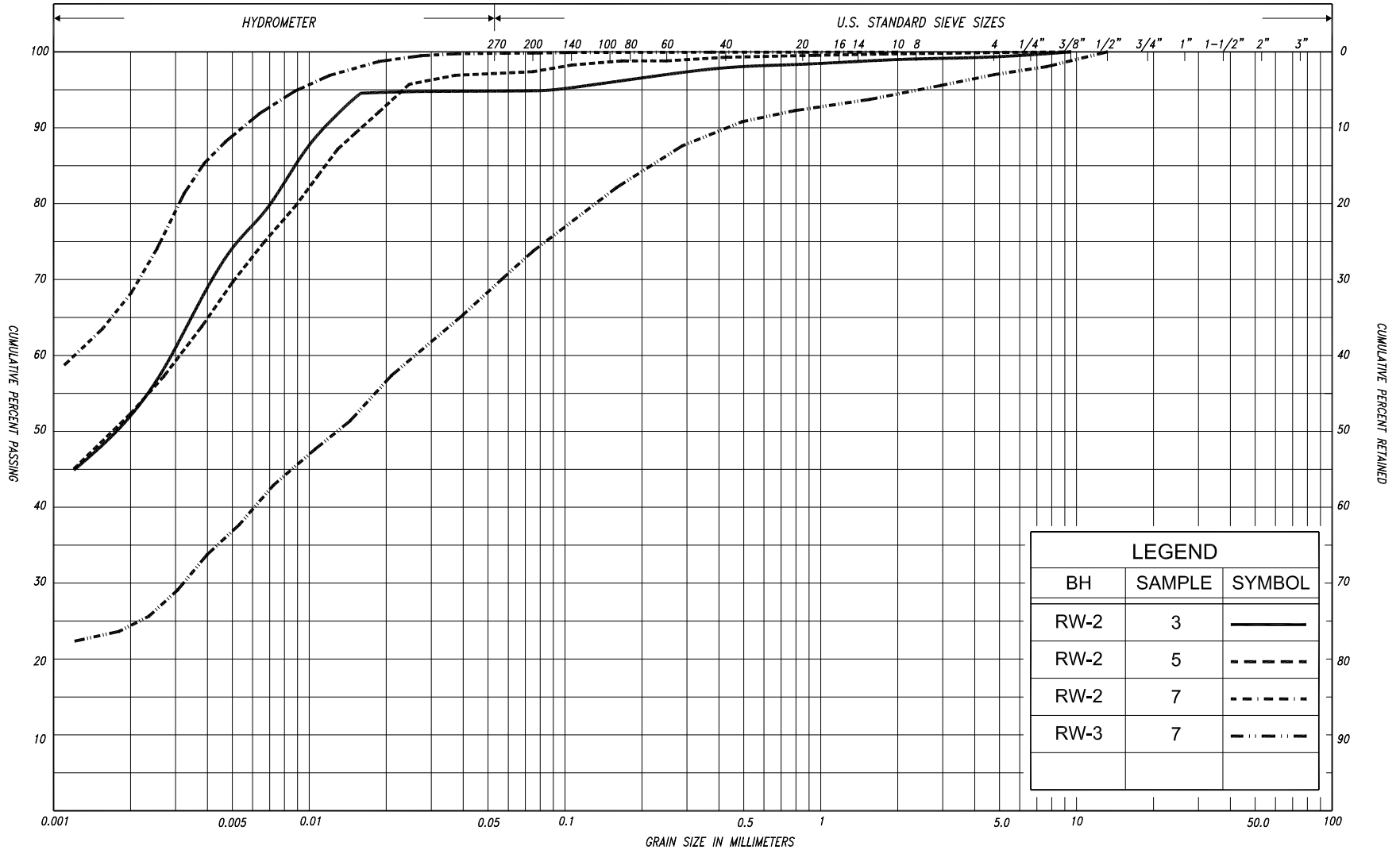


GRAIN SIZE DISTRIBUTION
CLAYEY SILT, with sand, trace gravel (CI)
(FILL)

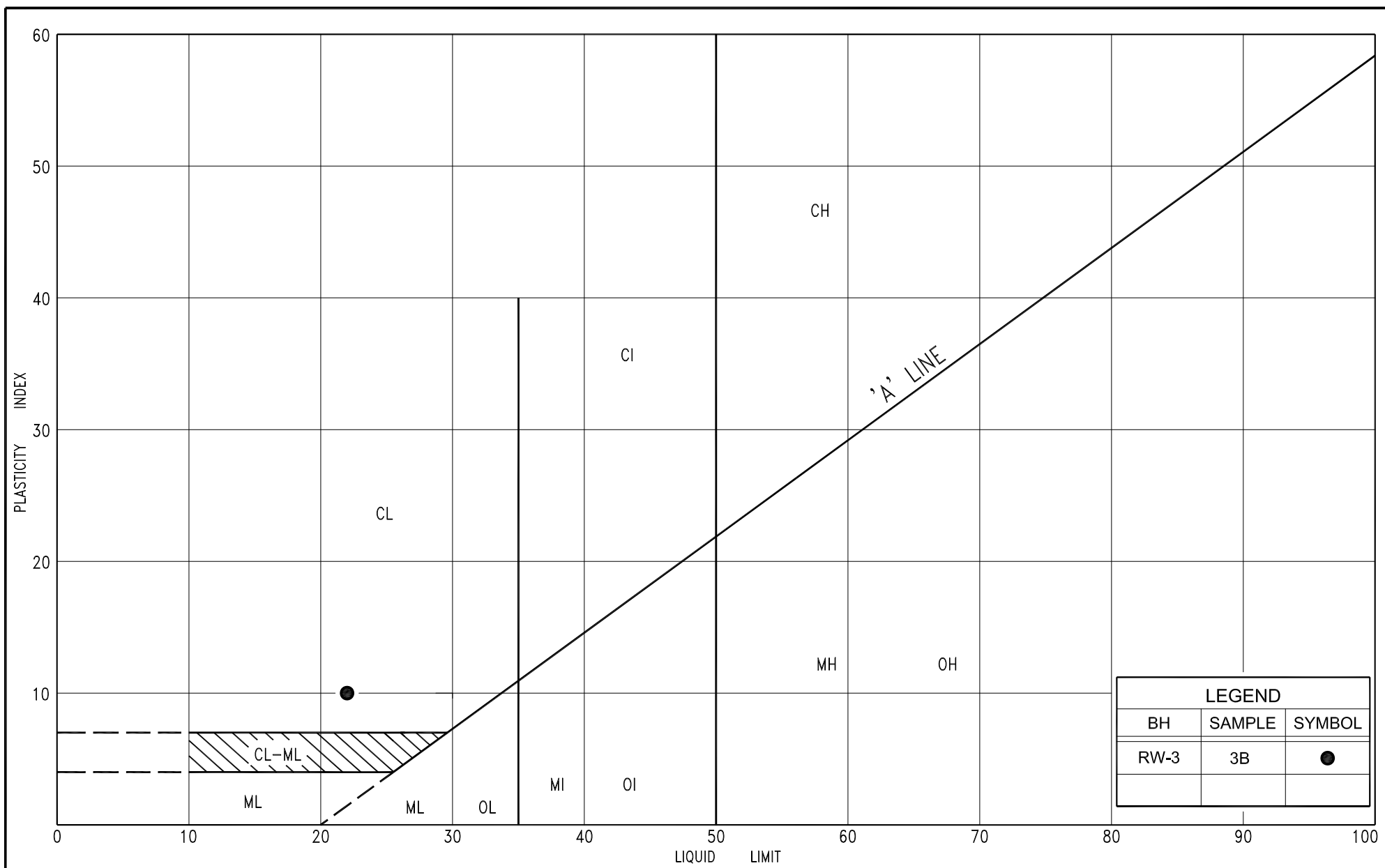
FIG No. RW-GS-5
HWY: 7 / 85
G.W.P. No. 3110-09-00



SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED			
				SAND													
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.	
	SILT																
CLAY			SILT			V. FINE		FINE		MED.		COARSE		GRAVEL			U.S. BUREAU
						SAND											



SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL			COB BLES	UNIFIED			
				SAND													
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.	
	SILT																
CLAY			SILT			V. FINE		FINE		MED.		COARSE		GRAVEL			U.S. BUREAU
						SAND											

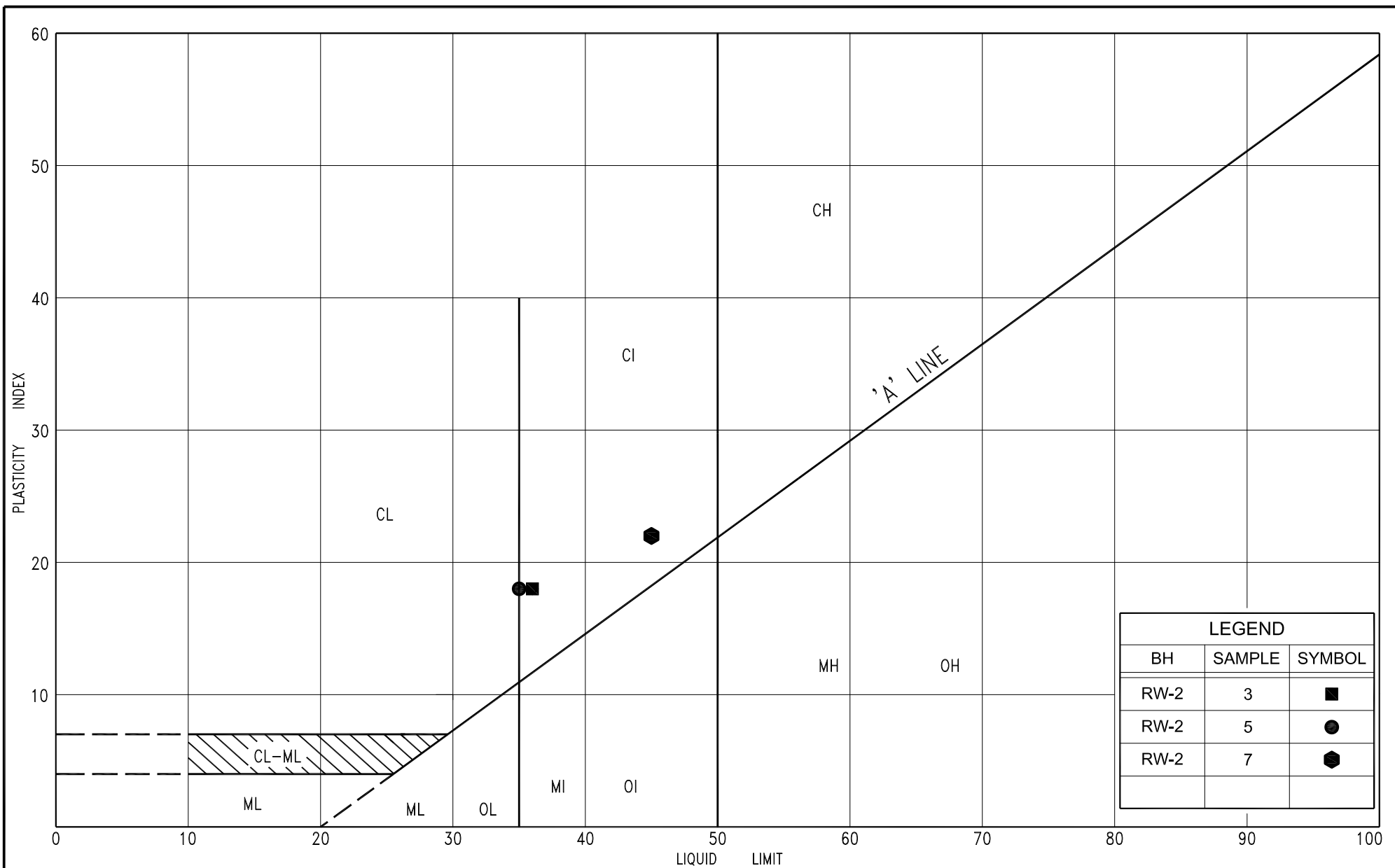


PLASTICITY CHART
 CLAYEY SILT, with sand, trace gravel (CL)
 (FILL)

FIG No. RW-PC-1

HWY: 7 / 85

G.W.P. No. 3110-09-00



EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m ³	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m ³	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m ³ /s	RATE OF DISCHARGE
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m ³	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No RW-1

1 of 1

METRIC

G.W.P. 3110-09-00 LOCATION Coords: 4 813 701.9 N; 226 222.6 E ORIGINATED BY R.B.
DIST London HWY 7/ 85 BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test COMPILED BY N.S.B.
DATUM Geodetic DATE April 08, 2011 CHECKED BY B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		SHEAR STRENGTH kPa									WATER CONTENT (%)		
319.7	Ground Surface					*	20	40	60	80	100	20	40	60				
0.0	Asphalt over sand some silt, some gravel Very loose Brown Wet (FILL)		1	AS	-													
318.3			2	SS	3													
1.4	Silty clay, trace sand Very stiff Brown Moist sand layers to 4.9m Hard to Greyish very stiff brown		3	SS	17											(**)		
			4	SS	34													
			5	SS	25													
			6	SS	28													
			7	SS	37													
			8	SS	31													
			9	SS	33													

RECORD OF BOREHOLE No RW-2

1 of 1

METRIC

G.W.P. 3110-09-00 **LOCATION** Coords: 4 813 710.4 N; 226 223.0 E **ORIGINATED BY** R.B.
DIST London **HWY** 7/ 85 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** N.S.B.
DATUM Geodetic **DATE** April 08, 2011 **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT										PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa					WATER CONTENT (%)									
							○ UNCONFINED + FIELD VANE					○ QUICK TRIAXIAL × LAB VANE									
							20	40	60	80	100	20	40	60							
319.7	Ground Surface																				
0.0	Asphalt over sand and crushed gravel, trace silt Compact Brown Moist (FILL)		1	AS	-																
			2	SS	11																
318.3																					
1.4	Silty clay, trace gravel sand layers Stiff Dark Moist brown sand layers to 3.7m Hard Greyish brown		3	SS	9												(**)				
			4	SS	31												1 4 43 52				
			5	SS	23												0 2 45 53				
			6	SS	44																
			7	SS	43												0 0 32 68				
			8	SS	35																
			9	SS	29																
309.9	End of borehole																				
9.8																					

RECORD OF BOREHOLE No RW-3

1 of 1

METRIC

G.W.P. 3110-09-00 **LOCATION** Coords: 4 813 719.3 N; 226 229.5 E **ORIGINATED BY** F.P.
DIST London **HWY** 7/ 85 **BOREHOLE TYPE** Dynamic Ram Sounder **COMPILED BY** N.S.B.
DATUM Geodetic **DATE** July 19, 2011 **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	○ QUICK TRIAXIAL	+	×	FIELD VANE						LAB VANE		
322.3	Ground Surface						20	40	60	80	100						GR SA SI CL			
0.0	Silty sand some clay, trace gravel organic inclusions		1	SS	14												8 37 37 18			
	Compact Grey Moist (FILL)		2	SS	27												3 50 34 13			
	clayey silt layers																4 26 45 25			
	gravelly sand		3	SS	20												23 39 27 11			
320.0	Compact Brown Damp clayey silt layers																4 25 42 29			
2.3	Sand trace to some gravel trace clay		4	SS	21												15 76 6 3			
	Compact Brown Moist to wet		5	SS	18												10 76 10 4			
			6	SS	14												(14*) 73 12 4			
317.9	Silty clay trace sand, trace gravel silty sand and gravelly sand layers, cobbles		7	SS	36												3 23 50 24			
4.4	Hard Grey Moist		8	SS	67															
			9	SS	70/15cm															
315.9	End of borehole																			
6.4	Sample 9: Sampler bouncing																			
	<div>* 2011 07 19</div>																			
	<div>▽ Water level observed during drilling</div>																			
	<div>(**) Base of footing -El.318.2</div>																			
	<div>Water Level Readings:</div>																			
	<div>Date Depth Elev. (m)</div>																			
	<div>July 19,'11 Dry ----</div>																			
	<div>Sept. 23,'11 3.3 319.0</div>																			
	<div>Oct. 08, '11 3.3 319.0</div>																			
	<div>Piezometer Legend:</div>																			
	<div><div><div></div><div></div><div></div></div> Bentonite seal</div>																			
	<div><div><div></div><div></div><div></div></div> Filter sand</div>																			
	<div><div><div></div><div></div><div></div></div> 30mm dia. PVC screen</div>																			
	<div><div><div></div><div></div><div></div></div> Filter bed</div>																			

RECORD OF BOREHOLE No RW-4

1 of 1

METRIC

G.W.P. 3110-09-00 **LOCATION** Coords: 4 813 705.4 N; 226 228.2 E **ORIGINATED BY** A.L.
DIST London **HWY** 7/ 85 **BOREHOLE TYPE** Dynamic Ram Sounder **COMPILED BY** N.S.B.
DATUM Geodetic **DATE** July 20, 2011 **CHECKED BY** B.R.G.

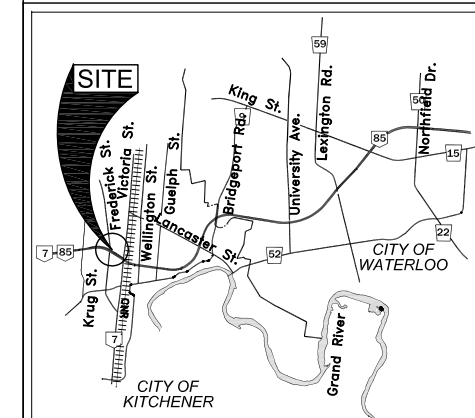
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)																										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)																									
								○ UNCONFINED + FIELD VANE																																			
								● QUICK TRIAXIAL × LAB VANE																																			
323.5	Ground Surface						20	40	60	80	100					GR	SA	SI	CL																								
0.0 2.3	Silty sand, some clay trace gravel, rootlets		1	SS	21	▽*							○			4	47	35	14																								
	Compact Brown Moist (FILL)		2	SS	21								○							22	20	54	4																				
	Silt with sand, trace gravel		3	SS	21								○											15	68	11	6																
	Compact Grey Sand, some silt some gravel, trace clay																											321.2	2.3														
	Compact Brown Clayey silt, trace sand		4	SS	20								●																			321											
	Very stiff Grey Sand trace to some gravel trace to some silt trace clay		5	SS	13								○																							320							
	Compact Brown Moist to wet		6	SS	13								○																											319			
	Gravelly to with gravel		7	SS	9								○																														
		8	SS	14							○			317.6																													
Silty clay, trace gravel cobbles		9	SS	49							●							317																									
Stiff to hard Grey Moist		10	SS	52/15cm																		316.5																					
		11	SS	50/13cm																						7.0																	
End of borehole																																											
Samples 10 and 11: Sampler bouncing																																											
* 2011 07 20																																											
▽ Water level observed during drilling																																											
(**) Base of footing -El.318.2																																											
Note: Borehole cave-in at 5.0m																																											

CONT No
GWP No 3110-09-00



FREDERICK STREET UNDERPASS
RETAINING WALL
HIGHWAY 7/85
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEY PLAN
SCALE
1 0 1 2 3km

LEGEND

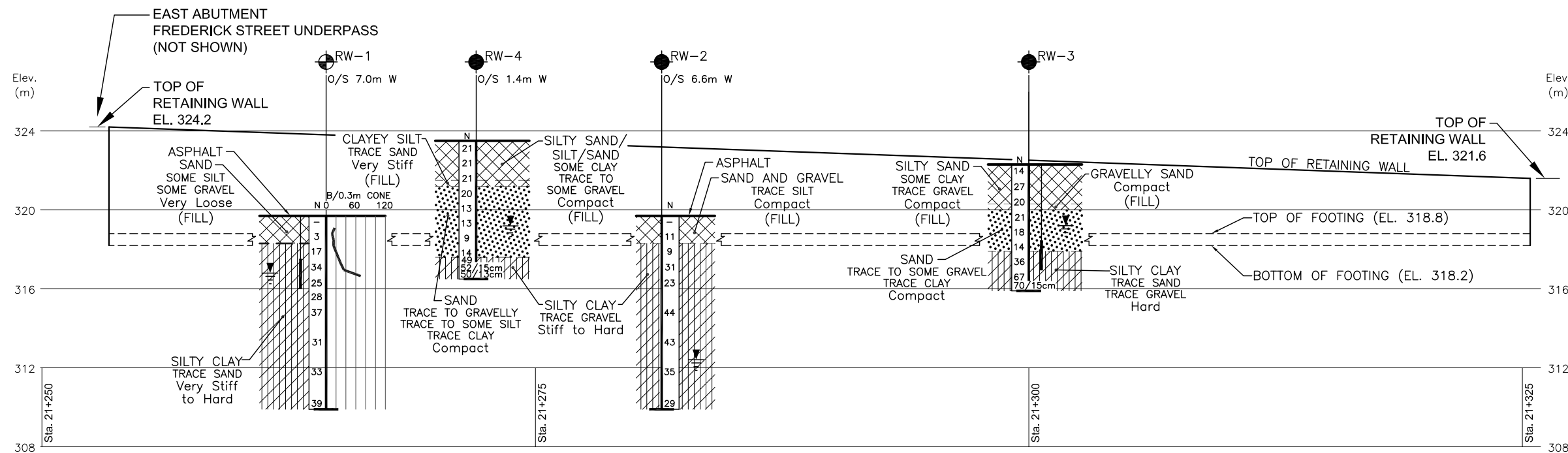
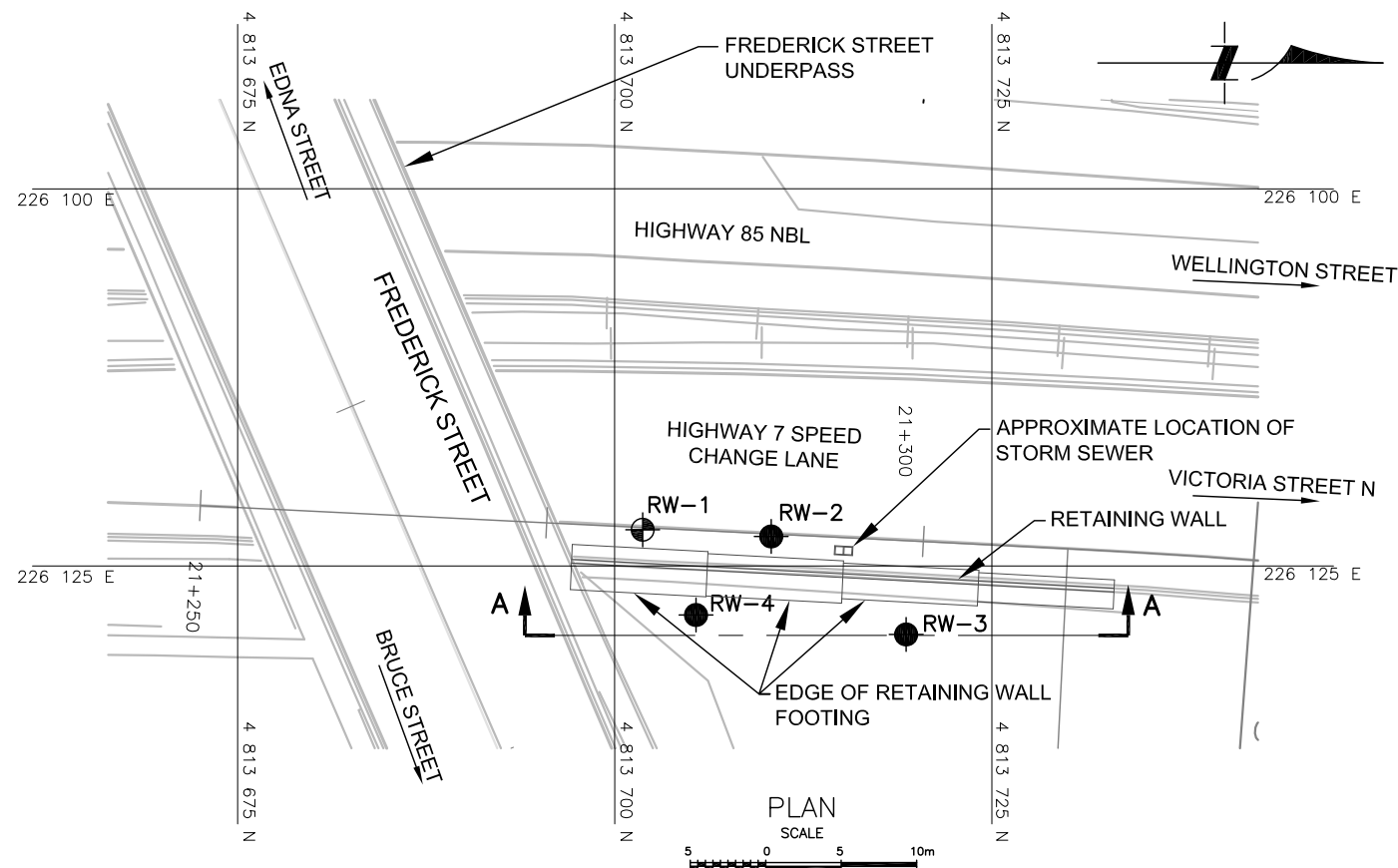
- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation April and July 2011
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
RW-1	319.7	4 813 701.9	226 222.6
RW-2	319.7	4 813 710.4	226 223.0
RW-3	322.3	4 813 719.3	226 229.5
RW-4	323.5	4 813 705.4	226 228.2

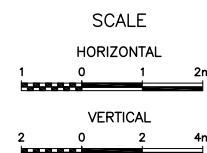
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 40P8-199			
HWY No 7 / 85			DIST London
SUBM'D NA	CHECKED NSB	DATE MAY 28, 2012	SITE
DRAWN NA	CHECKED CN	APPROVED BRG	DWG RW-1



PROFILE A - A



NOTES:

- DRAWING RW-1 SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND THE RECORD OF LOG OF BOREHOLES.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



REF MRC Drawing: 2010362_Alignment.dwg; CONTRACT
DRAWINGS - CONTRACT No. 68-62



APPENDIX A

PREVIOUS INVESTIGATION REPORT FOR
THE FREDERICK STREET UNDERPASS
DATED JULY 1966 (GEOCRES NO. 40P8-48)

66-F-53
W.P. # 634-64
KITCHENER -
WATERLOO
EXPRESSWAY
FREDERICK ST.
UNDERPASS

GEORGE
ADP8-48

FOUNDATION INVESTIGATION REPORT

For
Frederick Street Underpass
Kitchener-Waterloo Expressway
District #4 (Hamilton)
W.J. 66-F-53 -- W.P. 634-64

1. INTRODUCTION:

A request dated April 15, 1966, for a foundation investigation at the site of the proposed crossing of Frederick Street and the Kitchener-Waterloo Expressway, was received by this office from Mr. W. S. Melinyshyn, Regional Bridge Location Engineer.

A field investigation was subsequently carried out by this Section. Presented in this report are the results of this investigation, together with recommendations pertaining to the foundation design for this structure.

2. DESCRIPTION OF SITE:

The site is located 3/4 mile west of the east boundary of Kitchener City Limits on Frederick Street. The surrounding immediate area is partially built up and the topography is generally flat. The centre-line of the proposed expressway at this point passes through a proposed cut of about 17 feet deep at a grade of elevation 1052.0.

Physiographically, the site is located in the region referred to as the "Waterloo Hills." Soils in this region are mainly well drained glacio-fluvial deposits.

3. FIELD WORK AND LABORATORY TESTING:

A total of nine sampled boreholes and sixteen dynamic cone penetration tests was carried out during the course of the

cont'd. /2 ...

3. FIELD WORK AND LABORATORY TESTING: (Cont'd.) ...

field investigation using a conventional diamond drill adapted for soil sampling purposes.

Samples were obtained using a 2" O.D. split-spoon soil sampler advanced by blows of a 140-lb. hammer falling freely a distance of 30" thus imparting an impulse of 350 ft.-lbs./blow.

The locations and elevations of all boreholes were surveyed in the field by personnel from A. D. Margison and Associates, and are shown on Drawing #66-F-53A, which accompanies this report.

Samples were visually examined in the field prior to transportation to the laboratory where they were carefully visually classified. Subsequently, combinations of the following tests were carried out on selected samples:

Atterberg Limits
Moisture Contents
Grain-Size Distributions

The laboratory test results are summarized on the borelog sheets attached to the Appendix of this report.

4. SUBSOIL CONDITIONS:

4.1) General:

Subsoil at the site consists of stratified glacio-fluvial deposits, mostly of fine-grained composition. Detailed descriptions of the soil in each borehole are recorded in borehole logs appended to this report, together with the inferred stratigraphical profile of the area in question, shown on Drawing #66-F-53A.

From ground level downwards, the soil types encountered were as follows:

4.2) Topsoil:

Topsoil of loose sand with traces of organics, from three to six feet in depth, was found to overlies the site area adjacent to the existing road.

cont'd. /3 ...

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.3) Sand with traces of Silt:

The depth of this deposit ranges from about 8 to 22 feet. The material consists mostly of sand (90%) with traces of silt (10%). 'N' values obtained from Standard Penetration tests, ranged from 9 to 47 blows/ft., indicating a loose to dense relative density.

4.4) Clayey Silt:

This deposit of grey clayey silt of low plasticity was found in B.H. No's 3, 6 and 7. 'N' values obtained by Standard Penetration tests, ranged from 16 to 34 blows/ft., indicating a very stiff to hard consistency. Tests for moisture content and Atterberg limits gave the following average values: moisture content = 16%, plastic limit = 15%, liquid limit = 20%. Based on the foregoing, the shear strength of this deposit is estimated to range from 2,000 to 4,500 p.s.f.

4.5) Fine Sandy Silt to Silty Fine Sand:

This deposit has an average moisture content of 17%. Standard Penetration tests gave 'N' values ranging from 29 to 157 blows/ft., indicating a relative density of dense to very dense.

4.6) Clayey Silt with some Sand and Gravel:

This brownish-grey deposit was found in most of the boreholes with a varying thickness from 3 feet in B.H. #10 to 10 feet in B.H. #6. Mechanical analyses indicate the following average grain-size distribution: gravel 10%, sand 27%, silt 45%, clay 17%. Standard Penetration tests gave 'N' values ranging from 13 to 70 blows/ft., indicating a stiff to hard consistency. The results of Atterberg limit tests showed this soil to fall mainly in the classification of CL (clayey silt). The results of these tests are summarized as follows:

cont'd. /4 ...

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.6) Clayey Silt with some Sand and Gravel: (cont'd.) ...

	<u>Minimum</u>	<u>Maximum</u>	<u>Average</u>
Plastic Limit	10.6%	19.8%	14.5%
Liquid Limit	17.7%	49.1%	28.8%
Moisture Content	8.6%	22.4%	14.9%

The shear strength of this deposit is estimated to range from 2,000 to more than 4,000 p.s.f.

4.7) Silty Clay:

This silty clay of medium plasticity, was found in every borehole. The material consists of silty clay, brownish-grey in colour. It is similar to the clayey silt deposit described in Section 4.4, except with a higher plasticity and does not have the sand and gravel content. Average grain-size distribution indicated by mechanical analyses are: sand 1%, silt 48%, clay 51%. 'N' values obtained from Standard Penetration tests, ranged from 41 to 130 blows/ft., indicating a hard consistency. The results of Atterberg limit tests, showed that this deposit is classified as silty clay (CI) on the Plasticity Chart; the summary of the tests are as follows:

	<u>Minimum</u>	<u>Maximum</u>	<u>Average</u>
Plastic Limit	15.4%	22.2%	19.5%
Liquid Limit	32.5%	55.5%	43.7%
Moisture Content	14.5%	26.0%	20.7%

The shear strength of this deposit is estimated to be more than 4,000 p.s.f.

4.8) Silty Fine Sand to Fine Sandy Silt:

This deposit was found to underlie the silty clay deposit in every borehole, having an 'N' value of more than 99 blows/ft.,

cont'd. /5 ...

4. SUBSOIL CONDITIONS: (cont'd.) ...

4.8) Silty Fine Sand to Fine Sandy Silt: (cont'd.) ...

and an average moisture content of 13.7%. These results indicate that this material has a very dense relative density.

4.9) Silty Clay:

This brownish-grey silty clay of medium plasticity, is found below the silty fine sand to fine sandy silt described in Section 4.6, in B.H. #2 and B.H. #4 only. The index properties are: plastic limit = 17.4%, liquid limit = 36.6%, moisture content = 17.5%. The consistency of this material is hard, as indicated by 'N' values ranging from 46 to 130 blows/ft., given by Standard Penetration tests. Based on the foregoing, the shear strength of this deposit is estimated to be more than 4,000 p.s.f.

5. GROUNDWATER:

Groundwater levels at the time of field investigation were found to range from El. 1054.2 in B.H. #14 to El. 1059.4 in B.H. #2.

8. MISCELLANEOUS:

The field work for this project was carried out during the period May 26 to June 6, 1966, under the supervision of Mr. D. T. Wan, Project Foundation Engineer, who also prepared this report. Mr. K. G. Selby, Supervising Foundation Engineer, generally supervised the entire project and reviewed this report. The equipment used was owned and operated by Dominion Soil Investigation Limited.

July 1966

APPENDIX I

FOUNDATION SECTION

CHECKED BY K.G.S.

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE	LIQUID LIMIT ——— w_L	BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER	TYPE		BLOWS / FOOT	BLOWS / FOOT		
							WATER CONTENT ——— w		
							w_p ——— w_L		
							WATER CONTENT %		
1072.7	Groundlevel								
0.0									

FOUNDATION SECTION

JOB 66-F-53 LOCATION N 200.887.525, E 210.709.963 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE May 26, 1966. COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Penetration & Washboring. CHECKED BY K.G.S.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE	LQUID LIMIT ——— WL	BULK DENSITY	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / 100T	PLASTIC LIMIT ——— WP			
							20	40			60
							SHEAR STRENGTH P.S.F.	WP ——— WL			
								WATER CONTENT %			
								15	30	45	
1072.4	Groundlevel					1070					Sa 80% Si 20% G. W. L. ▽ KL ▽ 1059.4 Sa 96% Si 4% Gr 14% Sa 27% Si 44% Cl 15%
0.0	Sand (topsoil)										
1068.4	Loose		1	SS	8						
4.0	Sand occasional trace of silt. Compact.		2	SS	24						
			3	SS	20						
			4	SS	25	1060					
		5	SS	10							
		6	SS	30							
1052.4	Clayey silt with some sand and gravel Stiff to hard.	7	SS	28	1050						
20.0		8	SS	15							
		9	SS	57							
1045.4	Silty clay Hard Brownish grey.	10	SS	71							
27.0		11	SS	44	1040						
		12	SS	194							
		13	SS	88	1030						
		14	SS	100/11"							
1028.4	Fine sandy silt to silty fine sand. Very dense.	15	SS	85/74"	1020						
44.0											
1013.4	Silty clay Hard Brownish grey.	16	SS	120	1010						
59.0			17	SS	92	1000					
			18	SS	46	990					
988.9	End of borehole.	19	SS	130	980						
83.5											

FOUNDATION SECTION

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F.	LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WP — W — WL WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER	TYPE					
1069.3 0.0	Groundlevel								
1044.5 24.8	End of borehole.					100/9"			

FOUNDATION SECTION

JOB 66-F-53

LOCATION N 200.821.407. E210.811.176

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE May 31, 1966.

COMPILED BY D.W.

DATUM Genetic

BOREHOLE TYPE Dynamic Cone Penetration

CHECKED BY K.G.S. 8/2

[illegible]

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 8

FOUNDATION SECTION

JOB 66-F-53 LOCATION N 200.939.749. E 210.847.402 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE June 6, 1966. COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Dynamic Cone Penetration. CHECKED BY K.G.S.

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 SHEAR STRENGTH P.S.F.	LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W WP — WL WATER CONTENT %	BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE					
1068.1	Groundlevel								
0.0									
1047.3	End of borehole.								
20.8									

120/9"

FOUNDATION SECTION

ORIGINATED BY D.W.

COMPILED BY D.W.

CHECKED BY K.G.S.O.

8a	5%
81	95%

FOUNDATION SECTION

JOA 66-F-53

LOCATION N 200,883.088, E 210,947.710

ORIGINATED BY D.W.

W.P. 634-64

BORING DATE MAY 31, 1966.

COMPILED BY D.W.

DATUM Geodetic

BOREHOLE TYPE Penetration & Washboring

CHECKED BY K.G.S.

[illegible]

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 13

FOUNDATION SECTION

JOB 66-P-53 LOCATION N 200,914.762 E 211,000.220 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE June 2, 1966 COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Dynamic Cone Penetration CHECKED BY K.G.S.

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — WL		BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.	PLASTIC LIMIT — WP	WATER CONTENT — W		
1067.0	Groundlevel										
0.0											
					1060						
					1050						
1044.4											
22.6	End of borehole.										
					1040						

100/7"

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 14

FOUNDATION SECTION

JOB 66-P-53 LOCATION N 200.997.938, E 210.999.324 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE June 2, 1966 COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Penetration & Washboring CHECKED BY K.G.S.

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	20	40	60	80	100	WP	WL		
1067.2	Groundlevel														
0.0	Sand (Topsoil)														
1062.2	Compact	1	SS	11											
5.0		2	SS	14	1060										
	Sand with trace of silt.	3	SS	18											
		4	SS	15											
	Compact.	5	SS	15	1050										
		6	SS	17											
		7	SS	20											
		8	SS	28											
1041.2	Silty clay with trace of sand. Hard.	9	SS	130	1040										
1038.2		10	SS	100	9"										
29.0	Sand with some silt. Very dense.	11	SS	62	1030										
1026.2		12	SS	93											
41.0	Silty clay. Hard.	13	SS	47	1020										
1015.2															
52.0	Fine sandy silt. Very dense.	14	SS	109	1010										
1006.2															
61.0	Silty clay Hard														
1000.7	Brownish gray	15	SS	120	1000										
66.5	End of borehole.														

Sa 89%
Si 11%
GWL El.

1054.2

Sa 93%
Si 7%

Gr 2%
Sa 97%
Si 1%

100/11"

321.5

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 16

FOUNDATION SECTION

JOB 66-F-53 LOCATION N 201,116.543, E 210,741.917 ORIGINATED BY D.W.
W.P. 634-64 BORING DATE June 3, 1966 COMPILED BY D.W.
DATUM Geodetic BOREHOLE TYPE Penetration & Washboring CHECKED BY K.G.S.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT — WL PLASTIC LIMIT — WP		BULK DENSITY P.C.F.	REMARKS
E. EV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS / FOOT		20	40	60	80	100	WP	WL	
1065.0	Groundlevel													
0.0	Sand					1060								
	Compact		1	SS	17									
1056.0			2	SS	26									
9.0			3	SS	62	1050								
	Clayey silt to silty clay with some sand and gravel.		4	SS	111									
	Very stiff to hard		5	SS	126									
	Brownish grey.		6	SS	87	1040								
1036.0			7	SS	85									
29.0			8	SS	83									
	Silty clay		9	SS	39	1030								
	Hard													
	Brownish grey.		10	SS	105									
1024.0			11	SS	9376	1020								
41.0														
	Silty fine sand.													
	Very dense													
1008.5			12	SS	116	1010								
56.5	End of borehole.					1000								

100/8"

Gr 7%
Sa 28%
S1 46%
Cl 19%

Sa 2%
S1 41%
Cl 57%

FOUNDATION SECTION

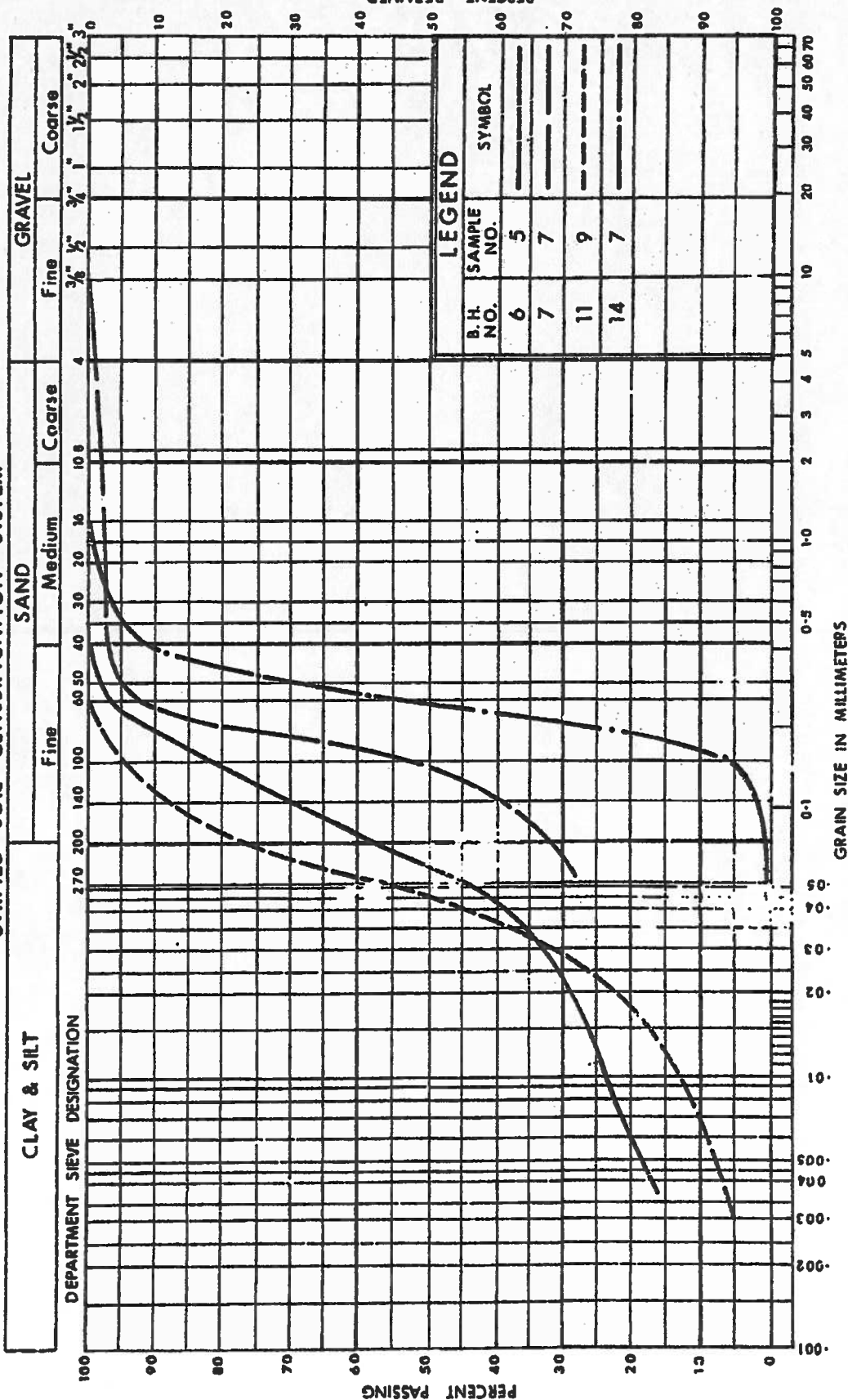
ORIGINATED BY D.W.

COMPILED BY D.W.

CHECKED BY K.G.

SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE			LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	BLOWS / FOOT	SHEAR STRENGTH P.S.F.	WATER CONTENT %	WATER CONTENT %	WATER CONTENT %		
1069.6 0.0	Groundlevel												
	Sand		1	SS	9								
	Loose to v. dense		2	SS	70		1060						
			3	SS	28								
1054.6 15.0	Clayey silt Very stiff to hard.		4	SS	14								
1049.1 20.5	Fine sandy silt, v. dense		5	SS	22		1050						
1046.6 23.0			6	SS	27								
			7	SS	53								
	Clayey silt to silty clay.		8	SS	150	7"	1040						
	Hard.		9	SS	60	10"							
	Brownish grey.		10	SS	88								
			11	SS	76		1030						
1025.1 44.5	re sandy silt. very dense		12	SS	68	6"	1020						
1013.8 55.8	End of borehole.		13	SS	50	4"	1010						

UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT OF HIGHWAYS
MATERIALS and
TESTING
DIVISION



GRAIN SIZE DISTRIBUTION

W.P. No. 634-64

JOB No. 66-F-53

ONTARIO

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:-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT.</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
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
c_a	APPARENT COHESION
ϕ_a	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_r	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 (YOUNG'S 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

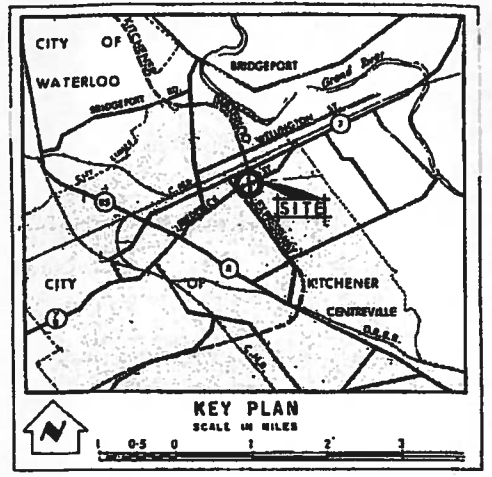
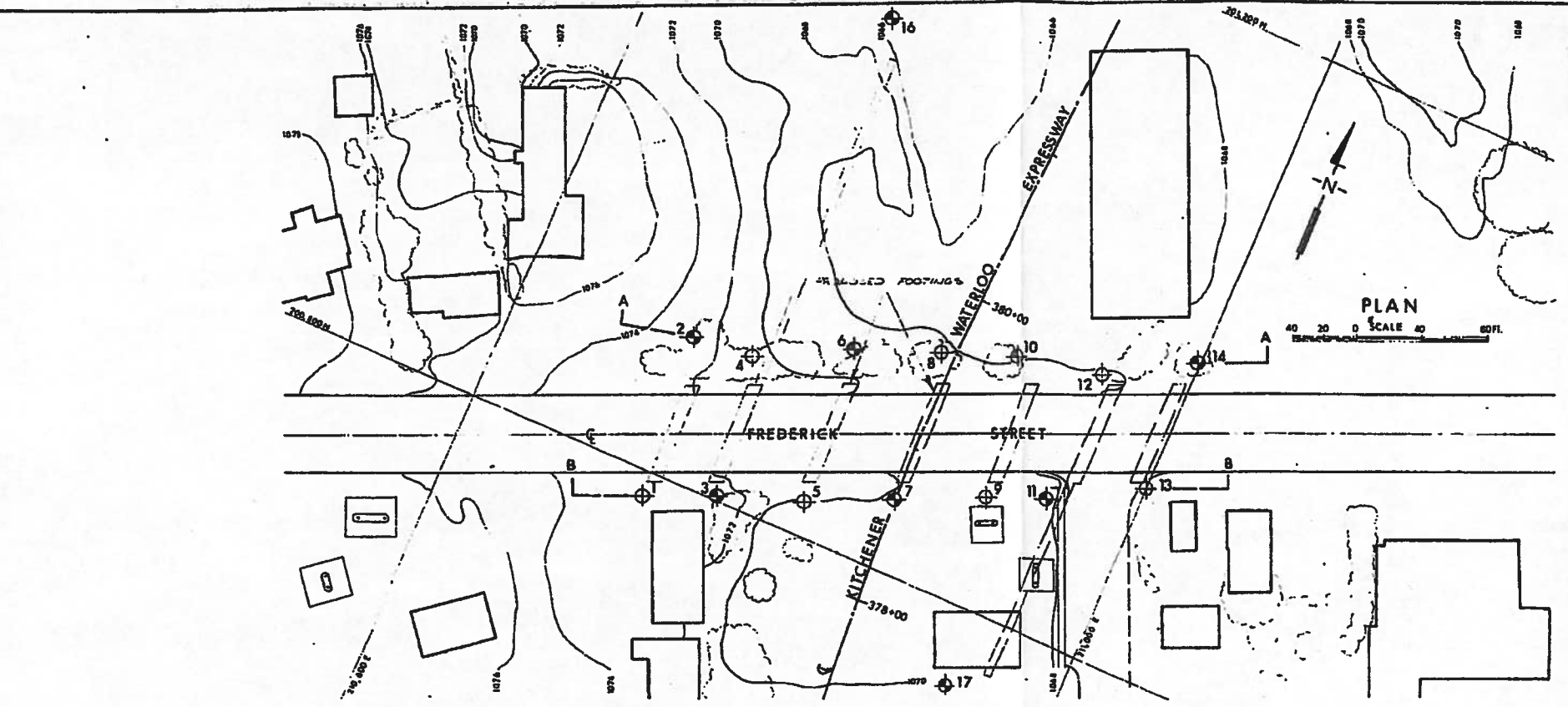
H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

A. D. Margison and Associates Limited
Consulting Professional Engineers

W.P. 634-64, Kitchener-Waterloo Expressway
Frederick Street Underpass
Project No. 2121

Bore Hole No.	Elevation	North Coordinates	East Coordinates
1	1072.73	200,786.159	210,719.093
3	1071.88	200,803.248	210,761.731
5	1069.78	200,821.407	210,811.176
7	1069.06	200,844.706	210,861.156
9	1069.03	200,873.400	210,912.942
11	1068.15	200,883.088	210,947.710
13	1066.95	200,914.762	211,000.220
17	1069.586	200,754.293	210,935.966

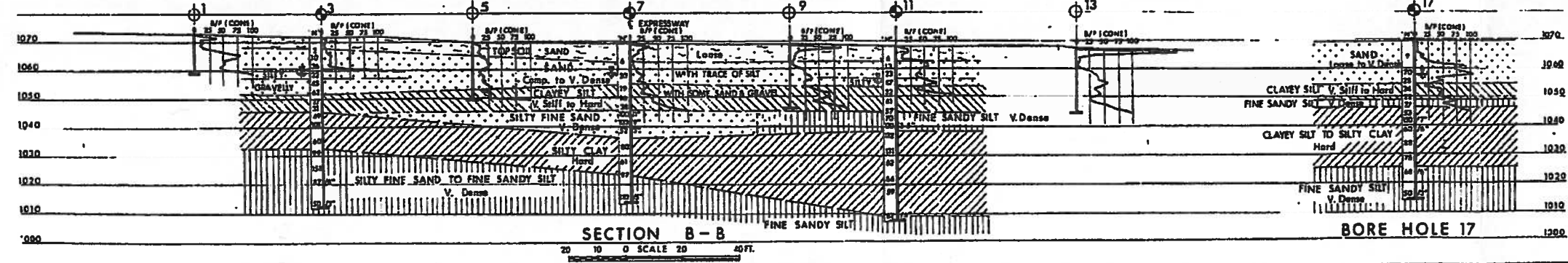
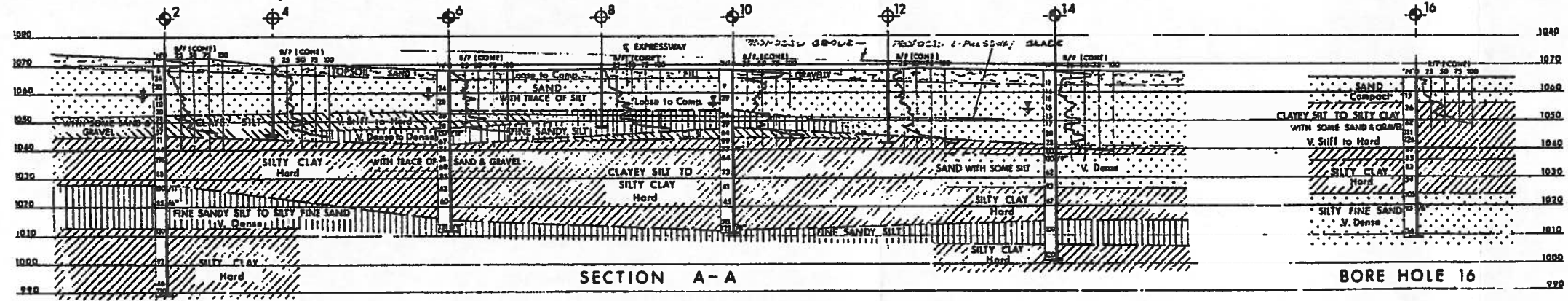
2	1072.41	200,887.529	210,709.963
4	1069.34	200,890.443	210,747.672
6	1067.89	200,919.964	210,802.832
8	1068.09	200,939.749	210,847.402
10	1067.91	200,955.200	210,895.815
12	1067.55	200,967.693	210,949.158
14	1067.23	200,997.938	210,999.324
16	1064.97	201,116.543	210,741.917



- LEGEND**
- Bore Hole
 - Comp. Penetration Hole
 - Bore & Comp. Penetration Hole
 - Water Levels established at time of field investigation MAY & JUNE 1966

NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	1072.7	200,786	210,719
2	1072.4	200,887	210,709
3	1071.9	200,803	210,761
4	1069.3	200,890	210,747
5	1069.8	200,821	210,811
6	1067.7	200,919	210,802
7	1069.1	200,844	210,861
8	1068.1	200,939	210,847
9	1069.0	200,873	210,913
10	1067.9	200,955	210,895
11	1068.2	200,883	210,947
12	1067.6	200,967	210,949
13	1067.0	200,914	211,000
14	1067.2	200,997	210,999
16	1065.0	201,116	210,741
17	1069.6	200,754	210,953

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



REVISIONS	DATE	BY	DESCRIPTION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION FOUNDATION SECTION

FREDERICK STREET

KING'S HIGHWAY NO. KITCHENER-WATERLOO EXPY, DIST. NO. 4
CO. WATERLOO CITY OF KITCHENER
TWP. _____ LOT _____ CON. _____

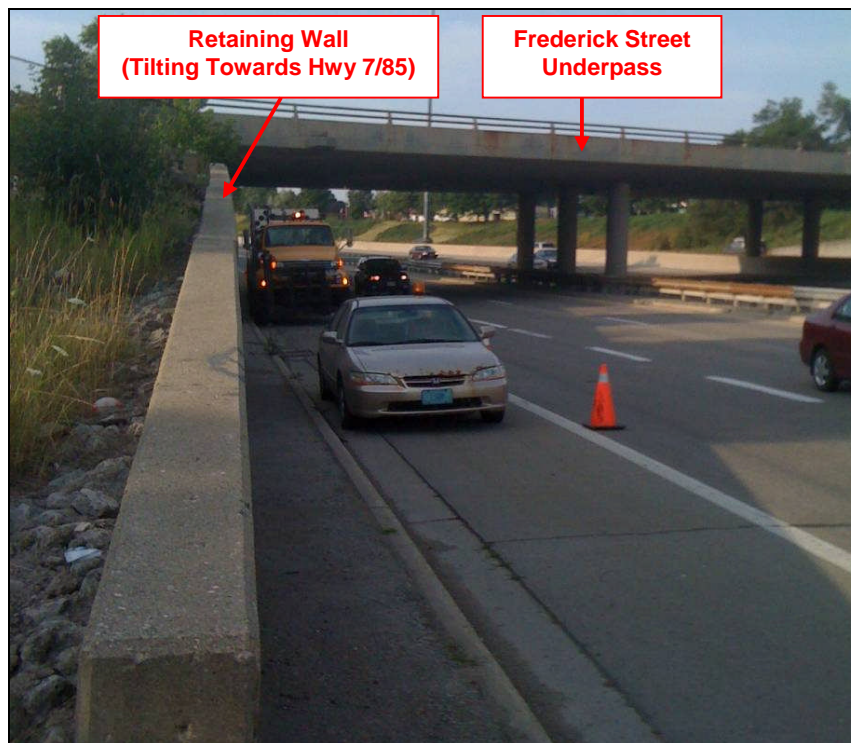
BORE HOLE LOCATIONS & SOIL STRATA

SUBMIT D.W.	CHECKED	REP. NO. 634-68	BY DRAWING NO.
DRAWN S.O.	CHECKED	JOB NO. 66-F-53	66-F-53A
DATE 10 AUG 1966	SITE NO.	BY DRAWING NO.	
APPROVED	CONT. NO.		

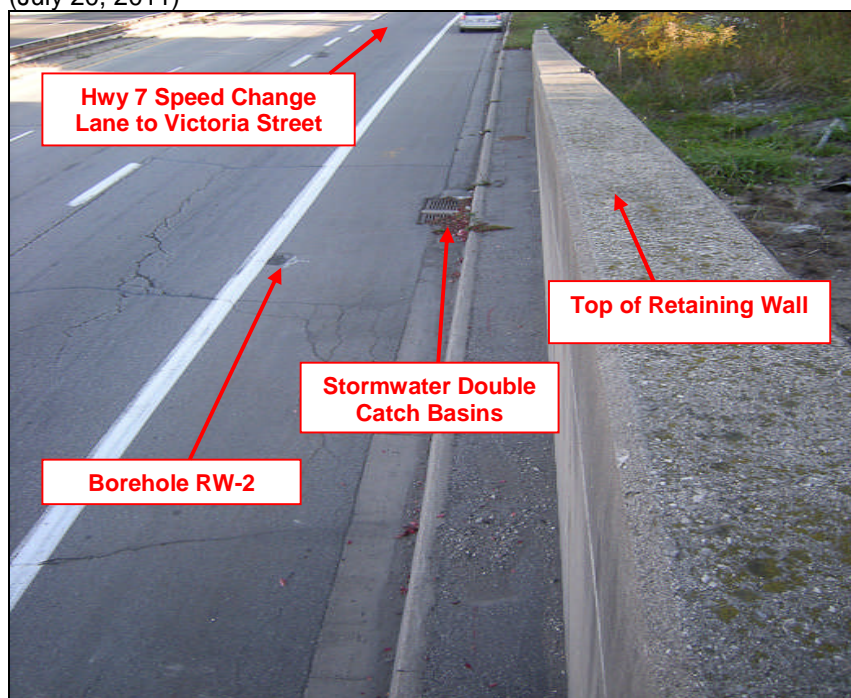


APPENDIX B

SITE PHOTOGRAPHS 1 to 10



Photograph 1: Looking south from north end of the retaining wall. (July 20, 2011)



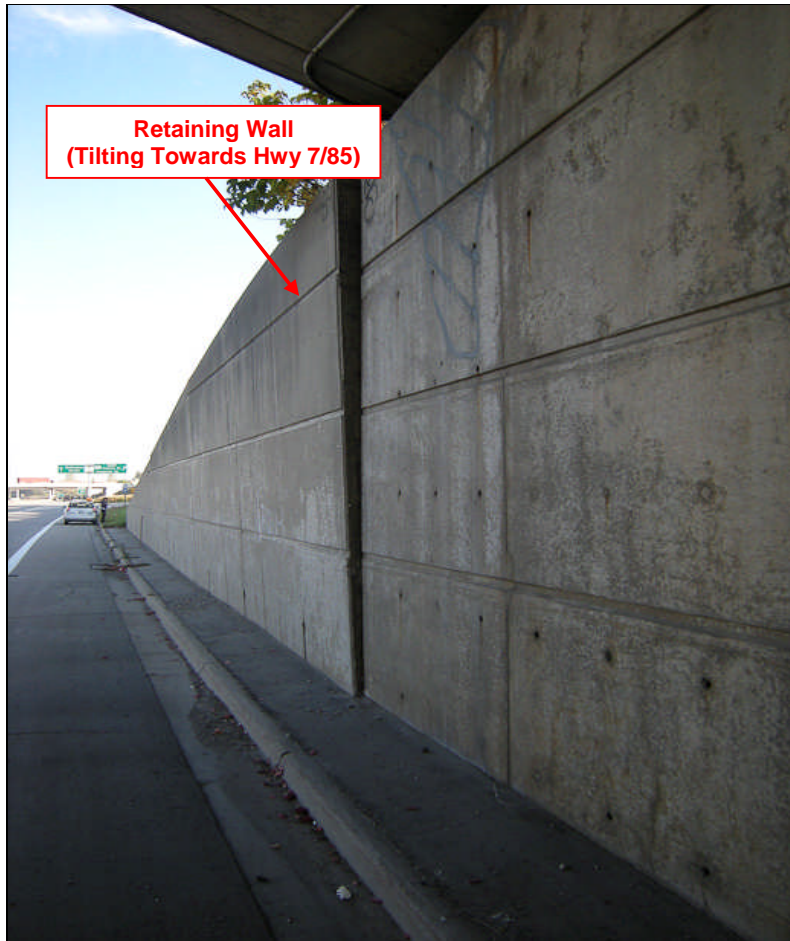
Photograph 2: Looking north from south portion of retaining wall. A double catch basin is located about 14 m north from south end of the retaining wall. (October 8, 2011)



Photograph 3: Looking north from borehole RW-4. Drill rig (Dynamic Ram Sounder) at borehole RW-4. (July 20, 2011)



Photograph 4: Looking south from approximately 3 m north of borehole RW-3. (July 20, 2011)



Photograph 5: Looking north from east shoulder under the Frederick Street underpass. (October 8, 2011)



Photograph 6: Close-up view of south end of retaining wall. Measurement to face of abutment was taken at retaining wall/abutment joint, approximately 64 mm (2.5 in.) at 0.3 m (1 ft.) above ground surface, 127 mm (5 in.) at 1.8 m (6 ft.) and 230 mm (9 in.) at top of retaining wall. (October 8, 2011)



Photograph 7: Close-up view from top of retaining wall at abutment. (October 8, 2011)



Photograph 8: Overhang measurement was taken from approximately 7 m north of south end of the retaining wall and it was approximately 152 mm (6 in.). (October 8, 2011).



Photograph 9: Overhang measurement was taken from approximately (at double catch basin) 14 m north of south end of the retaining wall and it was approximately 114 mm (4.5 in.). (October 8, 2011)



Photograph 10: Overhang measurement was taken from approximately 20 m north of the south end of the retaining wall and it was approximately 41 mm (1 5/8 in.) (October 8, 2011)