

**FOUNDATION INVESTIGATION AND DESIGN REPORT
FOR
REGIONAL ROAD 58 UNDERPASS
W.P. 72-00-00, SITE 33-175
HIGHWAY 401
TOWNSHIP OF NORTH DUMFRIES
REGIONAL MUNICIPALITY OF WATERLOO, ONTARIO**

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FOUNDATION INVESTIGATION REPORT

for
Regional Road 58 Underpass
W.P. 72-00-00, Site 33-175
Highway 401
Township of North Dumfries
Regional Municipality of Waterloo, Ontario

INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed replacement of the existing underpass at Regional Road 58 and Highway 401 in the Township of North Dumfries, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation (MTO).

Highway 401 passes under Regional Road 58 at approximate Station 11+622, Highway 401 chainage, in the Township of North Dumfries (ref. Bridge Site Plan E-188/401-01 'Proposed Crossing at the King's Highway 401 and Regional Road 58' prepared by the Surveys and Plans section of the MTO's Southwestern Engineering office in March 2003). The proposed underpass structure will be about 13 m wide and have span lengths of 43.4 m each.

The report pertains to the proposed underpass structure and approaches within about 20 m of the abutments.

SITE DESCRIPTION

The site is situated at the intersection of the existing Highway 401 and Regional Road 58. The structure to be replaced carries Regional Road 58 traffic over Highway 401 (Station 10+000, Regional Road 58 chainage). At the location of the underpass, Regional Road 58 runs roughly in the north-south direction. The existing approach fill embankments are about 8 m high.

The site is located in the Township of North Dumfries in the Regional Municipality of Waterloo (Southwestern Ontario), some 15 km east of the Drumbo Road (County Road 29) interchange along Highway 401. The surrounding area is primarily rural in nature, with active agricultural operations or vacant lands adjacent to Highway 401.

The study area is part of the Waterloo Hills (Waterloo Moraine) physiographic region. The surface is composed of sandy hills and moraines with sandy outwash soils occupying the hollows, the topography gently sloping to the southwest. In general, the surficial geology in the region is fairly uniform with predominant sand and silt deposits. Bedrock consists of dolostone of the Salina Formation and is expected to exist at a depth of about 35 m.

INVESTIGATION PROCEDURES

The field work for this study was carried out during the period of May 26 to June 11, 2003 and comprised eight boreholes advanced to depths of 12.7 to 30.9 m, as summarized in the following table, at the locations indicated on Drawing 1 (Appendix B):

Location	Borehole No.	Depth (m)
North Approach	175-1	18.9
North Abutment, East Side	175-2	17.4
North Abutment, West Side	175-3	30.6
Central Pier, East Side	175-4	12.7
Central Pier, West Side	175-5	24.7
South Abutment, East Side	175-6	30.9
South Abutment, West Side	175-7	18.7
South Approach	175-8	18.7

The locations of and ground surface elevations at the boreholes were established in the field by Peto MacCallum Ltd. The following benchmark shown on the drawing referred to above was used for vertical reference:

HCM 00919690077: RIB with DISC on west side of
Regional Road 58 south of
Highway 401
Elevation 307.956 (geodetic)

The boreholes were advanced using continuous flight hollow stem augers, powered by truck-mounted CME-75 drill rigs, supplied and operated by specialist drilling contractors, working under the full-time supervision of members of our engineering staff.

Representative samples of the soil were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Dynamic cone penetration tests were also carried out to supplement the strength data. Pocket penetrometer testing was performed to assess the shear strength of the cohesive soils.

The groundwater conditions in the boreholes were closely monitored in the course of the field work. Upon completion of drilling, four piezometers each consisting of a 19 mm diameter PVC pipe slotted over the bottom 600 mm were installed in boreholes 175-1, 175-2, 175-7 and 175-8 to monitor groundwater conditions. The annular space around the pipe was backfilled as illustrated on the respective borehole logs. The water level in the piezometers was measured immediately following installation and on July 2, 2003. Upon completion of drilling, the remaining boreholes were backfilled in accordance with the MTO procedures.

All of the recovered samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determinations. Atterberg limits testing and grain size distribution analyses were carried out on selected samples, their results being presented in Figures 1 to 4 (Appendix A) and on the Record of Borehole sheets (Appendix B).

SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard and dynamic cone penetration as well as pocket penetrometer test results, groundwater observations and moisture content determinations. The results of Atterberg limits testing and grain size distribution analyses conducted on the samples submitted for laboratory testing are also shown on the borehole logs.

The borehole locations and stratigraphic profile along the alignment of the structure prepared from the borehole data are presented on Drawing 1 (Appendix B).

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised a surficial pavement structure and sand fill over native deposits of clayey silt and silt underlain by sand. The road embankments at this location are about 8 m high. The strata encountered are summarized below.

Pavement Structure

A surficial pavement structure was present in all boreholes except boreholes 175-4 and 175-5 put down in the median of Highway 401 at the centre pier of the existing underpass. The pavement structure consisted of about 130 mm of asphaltic concrete over 360 to 430 mm of granular material.

Fill

Surficially at the centre pier (boreholes 175-4, 175-5) and directly beneath the pavement structure at other locations was fill. Predominantly composed of sand and gravel in the boreholes at the centre pier and of sand in the remaining boreholes, the fill was respectively loose to dense (SPT-'N' of 6 to 33) and very loose to very dense (SPT-'N' of 4 to 83/230mm). The thickness of this unit varied between 2.2 to 2.9 m (boreholes 175-4, 175-5) and 7.4 to 8.6 m. The moisture content of the fill ranged from 3 to 22%, typically from 5 to 9%.

It is noted that cobbles/boulders were identified within or below the fill in the boreholes advanced at the south abutment and approach.

Clayey Silt/Silty Clay

Discontinuous layers of cohesive clayey silt (partially till in boreholes 175-5 and 175-8) were encountered at depths of 2.2 to 3.7 m (elevation 298.3 to 299.8) in boreholes 175-4, 175-5 and 8.7 to 10.1 m (elevation 297.9 to 299.6) in the remaining boreholes. The clayey silt underlay silt in borehole 175-1, sandy silt topsoil in borehole 175-2, silty clay in borehole 175-4, sand in borehole 175-8 and the fill in the remaining boreholes. Having a thickness of separate layers of 0.4 to 4.7 m, the clayey silt was interlayered with silt in boreholes 175-5 and 175-7.

This deposit was soft to very stiff in consistency, typically firm to stiff, and had a moisture content of 20 to 27%, locally 9%. Pocket penetrometer tests conducted on three samples of the unit retrieved from boreholes 175-4 and 175-5 indicated an undrained shear strength in a range of 35 to 135 kPa.

The results of Atterberg limits testing and grain size distribution analysis are shown in Figures 1 and 2 respectively (Appendix A). The clayey silt has liquid and plastic limits of 21 to 27 and 14 to 18 respectively, thus giving the plasticity index of 7 to 9.

An 800 mm thick layer of cohesive silty clay was identified between the fill and clayey silt at 2.9 m depth (elevation 299.1) in borehole 175-4. The consistency of the silty clay was very stiff as confirmed by a pocket penetrometer test (an unconfined compressive strength of 275 kPa).

The clayey silt was penetrated at depths of 4.5 to 5.6 m (elevation 296.4 to 297.5) in the boreholes at the centre pier and 10.2 to 17.7 m (elevation 290.6 to 298.1) in the remaining boreholes.

Silt

Underlying the fill in borehole 175-1 and clayey silt in other boreholes was non-plastic silt. This unit was encountered at depths of 3.6 to 5.6 m (elevation 296.4 to 298.4) in boreholes 175-4, 175-5 and 8.6 to 12.5 m (elevation 295.5 to 299.4) in the remaining boreholes. The thickness of separate layers of the silt varied between 0.5 and 16.9 m. The unit was very loose to compact, locally dense (SPT-'N' up to 41), and had a moisture content of 17 to 28%. The silt was penetrated at depths of 20.1 to 27.1 m (elevation 281.2 to 282.1) in boreholes 175-3, 175-5 and 175-6. The remaining boreholes were terminated in the unit at depths of 12.7 to 18.9 m (elevation 289.1 to 290.8).

The results of grain size distribution analyses conducted on selected samples of the silt are presented in Figure 3.

Sand

Overlain by the silt in boreholes 175-3, 175-5 and 175-6 was cohesionless very dense sand of various granulometric composition. In addition, a 600 mm thick layer of loose sand was revealed at a depth of 8.6 m (elevation 299.4) in borehole 175-8. The deposit was not penetrated upon termination of the deep boreholes at depths of 24.7 to 30.9 m (elevation 277.3 to 277.7).

The results of grain size distribution analyses conducted on two samples of the sand are presented in Figure 4.

Groundwater

Groundwater was observed in all the boreholes during or upon completion of drilling. In the process of augering, water was detected at 3.7 m depth (elevation 298.3) in the boreholes at the centre pier and at depths of 8.5 to 14.6 m (elevation 293.7 to 299.8) in the remaining boreholes. Immediately after drilling, groundwater was measured in boreholes 175-1, 175-2, 175-7 and 175-8 to be at depths of 12.3 to 14.6 m (elevation 293.4 to 296.0) and in boreholes 175-4 and 175-5 at respective depths of 9.8 and 7.6 m (elevation 292.2 and 294.4).

Piezometers were installed in boreholes 175-1, 175-2, 175-7 and 175-8 upon completion of drilling. The subsequent readings taken on July 2, 2003 showed water levels to be at the following depths/elevations:

Borehole 175-1		Borehole 175-2		Borehole 175-7		Borehole 175-8	
Depth (m)	Elevation	Depth (m)	Elevation	Depth (m)	Elevation	Depth (m)	Elevation
11.2	296.8	11.5	296.7	12.3	296.0	12.1	295.9

Based on these measured water levels and visual examination of the samples retrieved during drilling, the stabilized groundwater level at this site is expected to be near elevation 296.8.

Groundwater levels may fluctuate subject to seasonal variations and precipitation patterns.

CLOSURE

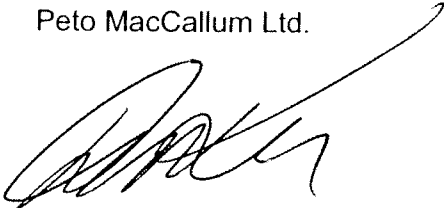
The field work was carried out under the supervision of Mr. F. Portela and Mr. R. Agahzadeh and direction of Mr. G.O. Degil, Ph.D, Senior Project Supervisor. The equipment was supplied by Geo-Environmental Drilling Inc. and Elite Drilling.

The report was prepared by Mr. G.O. Degil, Ph.D., Senior Project Supervisor. It was reviewed by Mr. D.W. Kerr, M. Eng., P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, M.Eng., P.Eng., President, carried out an independent review of the report.

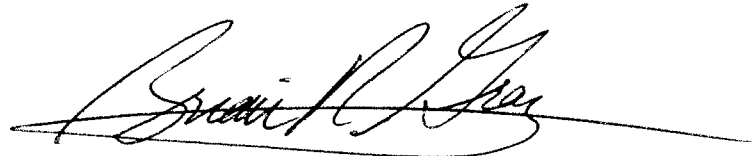


Yours very truly

Peto MacCallum Ltd.



Dennis W. Kerr, M.Eng., P.Eng.
Chief Foundation Engineer

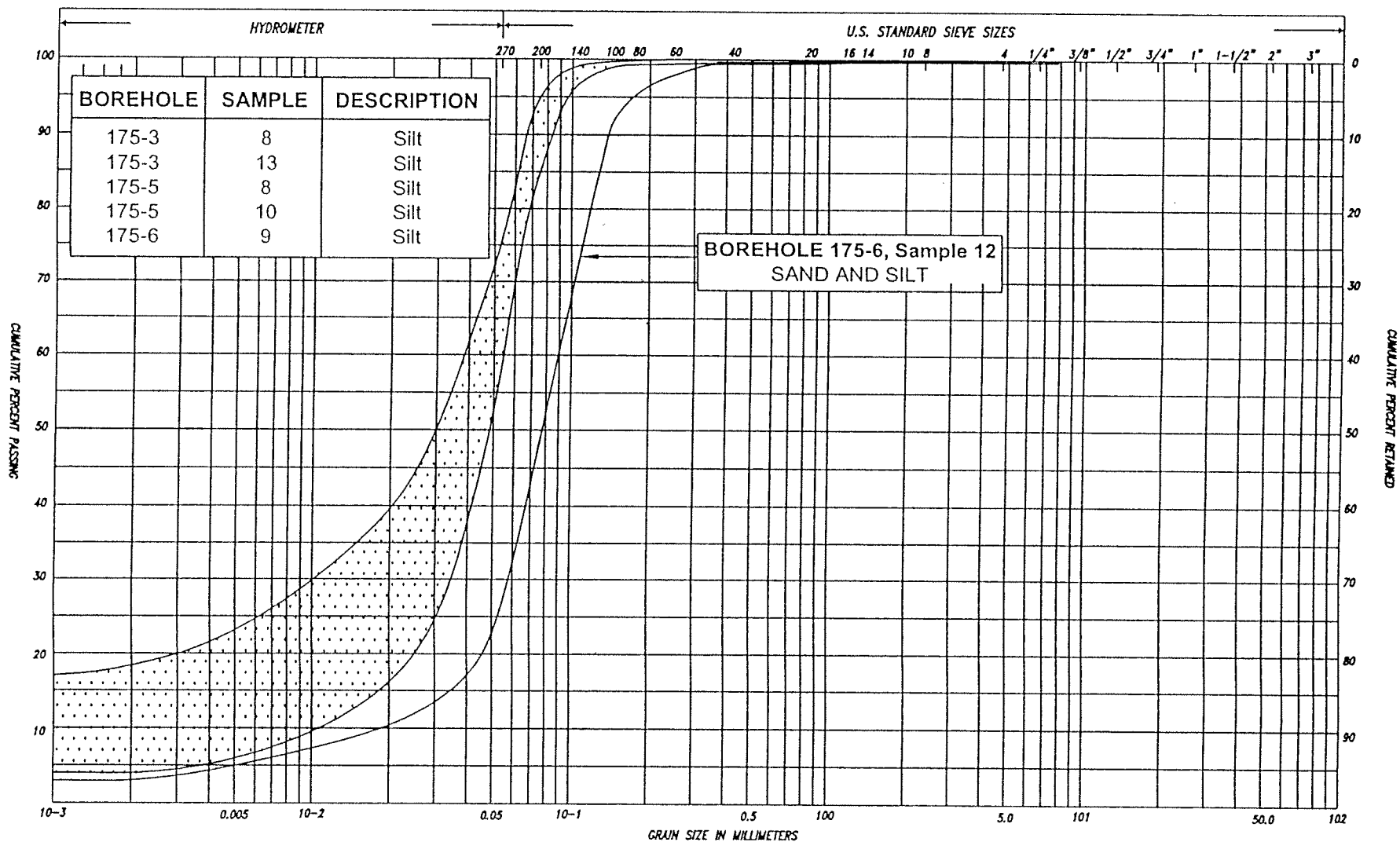


Brian R. Gray, M.Eng., P.Eng.
President

GD:lad

APPENDIX A

FIGURE 1 – PLASTICITY CHART
FIGURES 2 TO 4 – GRAIN SIZE DISTRIBUTION CHARTS



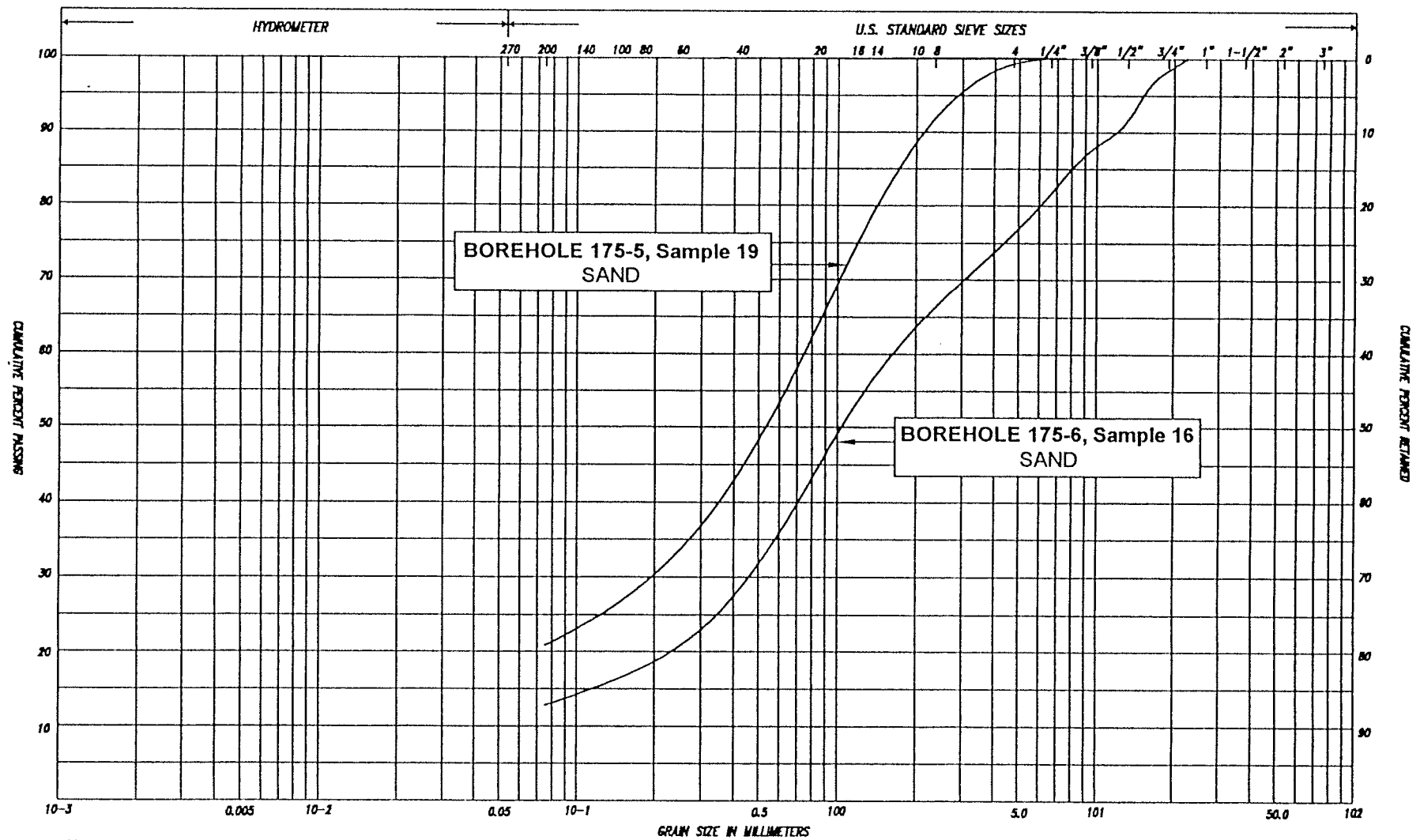
SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL				COB- BLES	UNIFIED	
						SAND									M.I.T.	
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.
		SILT						SAND								
CLAY		SILT			V. FINE		FINE		MED.		COARSE		GRAVEL			U.S. BUREAU
							SAND									



Ministry of
Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SILT, trace to some sand and clay
SAND AND SILT, trace clay

FIG No. 3
HIGHWAY 401
W.P. No. 72-00-00



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

APPENDIX B

RECORD OF BOREHOLE SHEETS
DRAWINGS 1 AND 2

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 31mm 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 (31mm O.D. 60° CONE ANGLE) DRIVEN BY 473 J IMPACT ENERGY ON 1" 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.

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 (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	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_f	kPa	REMOULDED SHEAR STRENGTH
S_f	1	SENSITIVITY = $\frac{c_u}{\tau_f}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	KN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	KN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	KN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	KN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	KN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	KN/m^2	SEEPAGE FORCE
γ'	KN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 175-1

1 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 502 N; 225 799 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 30, 2003 CHECKED BY M.R.A.

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 Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
308.0								20 40 60 80 100						
0.0	Pavement structure: 130mm of asphaltic concrete over 400mm of granular material							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
307.5								20 40 60 80 100						
0.5	Sand, trace gravel													
	Very dense Brown (Fill)													
			1	SS	55									
			2	SS	63									
			3	SS	50/15cm									
			4	SS	50/15cm									
	trace silt													
	Compact		5	SS	17									
299.4														
8.6	Silt, trace sand and clay, with clayey silt seams													
	Compact Brown Moist to grey		6	SS	15									
297.9														
10.1	Clayey silt, trace sand, with silt lenses													
	Firm Grey Moist		7	SS	6									
	fine sandy silt lenses													
	Soft Wet		8	SS	2									
	Stiff		9	SS	8									
293.2														
14.8	Cont'd													

RECORD OF BOREHOLE No 175-1

2 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 502 N; 225 799 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 30, 2003 CHECKED BY M.R.A.

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 Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE									
308.0							20	40	60	80	100						
	Silt, some fine sand																
	Loose to Grey compact		10	SS	9												
							292										
			11	SS	10												
							291										
							290										
289.1			12	SS	12												
18.9	End of borehole																
	<div><div><div></div><div></div><div></div><div></div></div><div>Water level measured after drilling</div><div>Water level observed during drilling</div><div>Piezometer Readings:</div><div>Date Depth(m)</div><div>May 30/03 14.6</div><div>July 02/03 11.2</div><div>Borehole Backfill</div><div>Legend:</div><div><div><div></div><div></div><div></div><div></div></div><div>Native backfill</div><div><div></div><div></div><div></div><div></div></div><div>Bentonite seal</div><div><div></div><div></div><div></div><div></div></div><div>Filter sand</div><div><div></div><div></div><div></div><div></div></div><div>Screen</div></div></div>																

RECORD OF BOREHOLE No 175-2

1 of 2 METRIC





W.P. 72-00-00 LOCATION Co-ords. 4 797 493 N; 225 808 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 30, 2003 CHECKED BY M.R.A.

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 Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								20	40	60							80	100
308.2																		
0.0	Pavement structure: 130mm of asphaltic concrete over 430mm of granular material						308											
307.6																		
0.6	Sand, trace silt and gravel																	
	Dense Brown (Fill)		1	SS	41		307											
							306											
			2	SS	34		305											
							304											
	Very dense		3	SS	50/15cp		303											
							302											
			4	SS	50/15cp		301											
	Compact						300											
300.2			5	SS	12		299											
8.0	Sandy silt topsoil																	
299.5	Compact Dark Moist brown																	
8.7	Clayey silt, trace sand, with fine sandy silt lenses		6	SS	12		298											
	Stiff Brown Moist						297											
	Grey						296											
297.3			7	SS	11		295											
10.9	Silt, some fine sand						294											
	Compact Grey Wet to loose		8	SS	9													
	clayey silt seams																	
			9	SS	11													
	Saturated																	
	Cont'd																	

RECORD OF BOREHOLE No 175-2

2 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 493 N; 225 808 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 30, 2003 CHECKED BY M.R.A.

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	20					
308.2	Silt, some fine sand Compact Grey Wet to loose		10	SS	8								
290.8			10	SS	7								
17.4	End of borehole												
<p>▽ Water level observed during drilling</p> <p>▼ Water level measured after drilling</p> <p>Piezometer Readings:</p> <p>Date Depth(m)</p> <p>May 30/03 14.0</p> <p>July 02/03 11.5</p> <p>Borehole Backfill Legend:</p> <p> Native backfill</p> <p> Bentonite seal</p> <p> Filter sand</p> <p> Screen</p>													

RECORD OF BOREHOLE No 175-3

1 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 485 N; 225 803 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 29, 2003 CHECKED BY M.R.A.

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		20 40 60 80 100	20 40 60 80 100					
308.3													
0.0	Pavement structure: 130mm of asphaltic concrete over 430mm of granular material					308							
307.7													
0.6	Sand, trace gravel Dense to Brown very dense (Fill)		1	AS	-	307							
			2	AS	-	306							
			3	AS	-	305							
			4	SS	50/8cm	304							
	trace silt and organics Very loose		5	SS	4	303							
299.6						302							
8.7	Clayey silt, trace sand, with fine sandy silt lenses and partings Firm Brown Wet		6	SS	7	299							0 2 78 20
	trace gravel Grey Moist		7	SS	7	298							
296.6						297							
11.7	Silt, some sand, trace to some clay Very Grey Saturated loose		8	SS	2	296							0 12 73 15
	clayey silt seams		9	SS	2	295							
						294							

Cont'd

RECORD OF BOREHOLE No 175-3

2 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 485 N; 225 803 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 29, 2003 CHECKED BY M.R.A.

[illegible]

RECORD OF BOREHOLE No 175-3

3 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 485 N; 225 803 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 29, 2003 CHECKED BY M.R.A.

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			20	40	60	80	100					
308.3																	
277.7			16	SS	507	10cm	278										
30.9	End of borehole																
	▽ Water level observed during drilling																

RECORD OF BOREHOLE No 175-4

1 of 1 METRIC

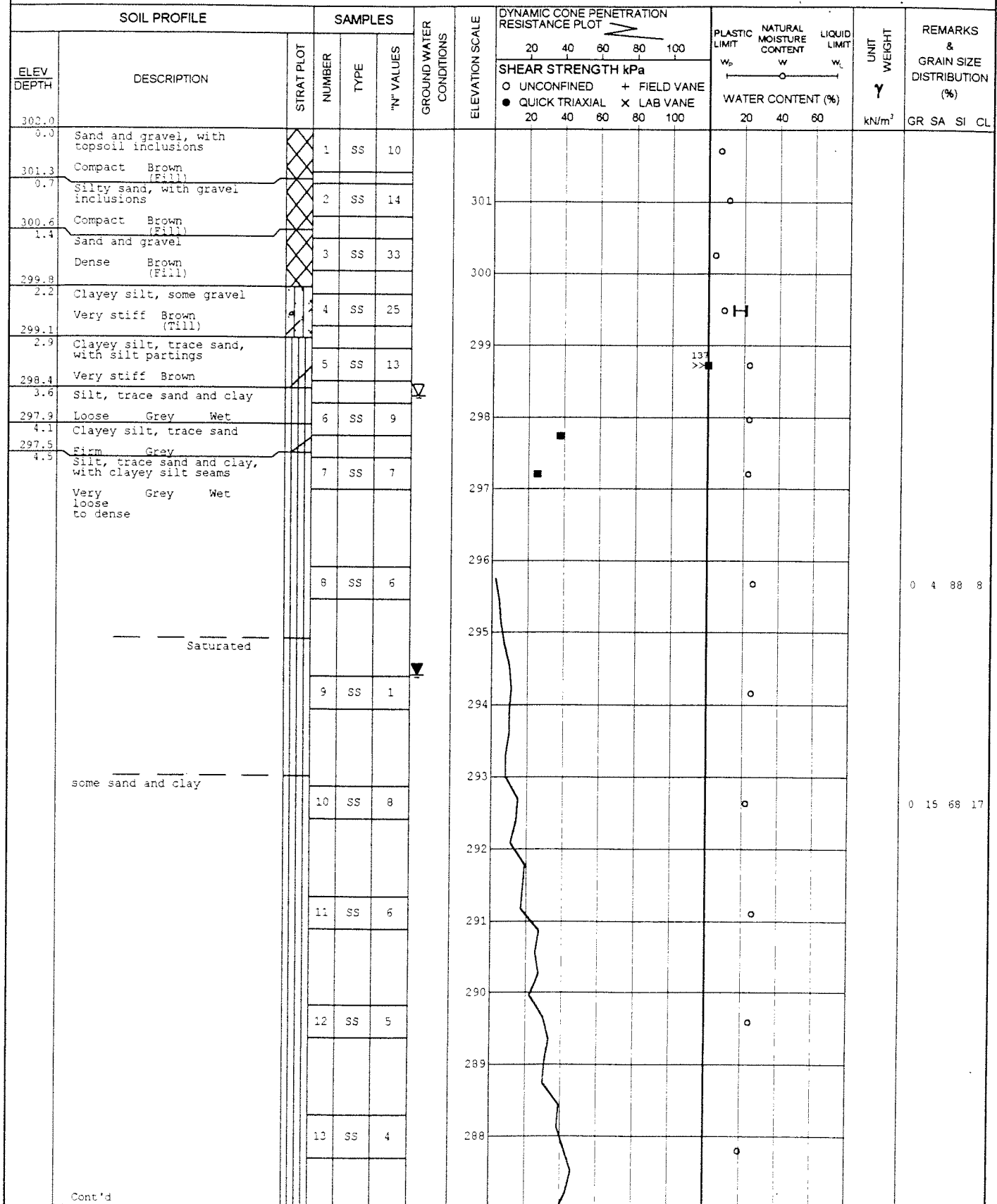
W.P. 72-00-00 LOCATION Co-ords. 4 797 450 N; 225 826 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 27, 2003 CHECKED BY M.R.A.

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			20 40 60 80 100	20 40 60 80 100					
302.0														
0.0	Sand and gravel, with topsoil and organic inclusions		1	SS	18									
	Compact Brown to loose (Fill)		2	SS	30		301							
			3	SS	7		300							
			4	SS	6									
299.1														
2.9	Silty clay, trace sand Very stiff Brown		5	SS	15		299							
298.3														
3.7	Clayey silt, trace sand, with silt partings and lenses Stiff Grey Wet		6	SS	10		298							
			7	SS	11		297							
296.4														
5.6	Silt, trace sand and clay Loose Grey Wet		8	SS	8		296							
							295							
			9	SS	10		294							
	silty clay seams Compact						293							
			10	SS	13		292							
	Saturated						291							
			11	SS	11		290							
	Wet													
289.3			12	SS	18									
12.7	End of borehole													
	■ Penetrometer test													
	▽ Water level observed during drilling													
	▼ Water level measured after drilling													

RECORD OF BOREHOLE No 175-5

1 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 432 N; 225 811 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 26, 2003 CHECKED BY M.R.A.



RECORD OF BOREHOLE No 175-5

2 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 432 N; 225 811 E ORIGINATED BY E.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 26, 2003 CHECKED BY M.R.A.

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	20 40 60 80 100					
302.0	Silt, some sand and clay Very loose to dense Grey Saturated		14	SS	WR*								
286													
285			15	SS	WR*								
284													
283			16	SS	1								
282													
281													
280													
279			17	SS	100/10cm								
278													
277.3			18	SS	70/8cm								
274.7			19	SS	50/15cm								
24.7	End of borehole												
	■ Penetrometer test ▽ Water level observed during drilling ▽ Water level measured after drilling * Penetration under weight of rods only												

RECORD OF BOREHOLE No 175-6

1 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 401 N; 225 833 E ORIGINATED BY F.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers & Wash Boring COMPILED BY G.D.
DATUM Geodetic DATE May 28, 2003 CHECKED BY M.R.A.

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			20 40 60 80 100	20 40 60 80 100					
308.3														
0.0	Pavement structure: 130mm of asphaltic concrete over 360mm of granular material						308							
0.5	Sand, trace gravel Very dense Brown (Fill)													
			1	AS	--									
			2	SS	61									
			3	AS	--									
	trace silt		4	SS	50/15cm									
301.3														
7.0	Sand and gravel, trace silt Very dense Brown (Fill)		5	SS	71									
300.1														
8.2	Cobbles and boulders													
299.5														
8.8	Clayey silt, trace sand, with silt partings and lenses Very stiff Brown Moist		6	SS	17									
298.1														
10.2	Silt, trace sand and clay, with clayey silt seams Loose Grey Wet		7	SS	7									
	fine sandy silt lenses		8	SS	6									
	some clay		9	SS	5									
293.3	Cont'd													

RECORD OF BOREHOLE No 175-6

2 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 401 N; 225 833 E ORIGINATED BY E.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers & Wash Boring COMPILED BY G.D.
DATUM Geodetic DATE May 28, 2003 CHECKED BY M.R.A.

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
308.3							20	40	60	80	100	20	40	60			
15.0	Silt, some clay, trace sand																
			10	SS	6												
	clayey silt seams																
	Saturated																
			11	SS	8												
	sand lenses																
	Compact Wet																
			12	SS	21												
		</															

RECORD OF BOREHOLE No 175-6

3 of 3 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 401 N; 225 833 E ORIGINATED BY E.P.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers & Wash Boring COMPILED BY G.D.
DATUM Geodetic DATE May 28, 2003 CHECKED BY M.R.A.

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			20	40	60	80	100					
308.3																
	Sand, with gravel, trace silt and clay, occ. cobbles															
277.4	Very dense Grey Wet															
30.9	End of borehole		16	SS	97/28cm											24 63 (13)
	▽ Water level observed during drilling															

RECORD OF BOREHOLE No 175-7

1 of 2 METRIC





W.P. 72-00-00 LOCATION Co-ords. 4 797 393 N; 225 828 E ORIGINATED BY R.A.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE June 11, 2003 CHECKED BY M.R.A.

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
308.3							20 40 60 80 100	○ UNCONFINED + FIELD VANE						
0.0	Pavement structure: 190mm of asphaltic concrete over 350mm of granular material	•••						● QUICK TRIAXIAL x LAB VANE						
307.8														
0.5	Gravelly sand, some silt, with numerous cobbles													
	Brown Moist (Fill)													
306.2														
2.1	Sand, trace to some gravel, trace silt, with occ. cobbles													
	Dense to Brown Moist very dense (Fill)		1	SS	44									

RECORD OF BOREHOLE No 175-7

2 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 393 N; 225 928 E ORIGINATED BY R.A.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE June 11, 2003 CHECKED BY M.R.A.

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			20	40					
308.3	Clayey silt, trace to some fine sand Firm Grey Wet		7	SS	5									
			8	SS	7									
290.6	Silt, some fine sand Loose Grey Saturated													
17.7														
289.6			9	SS	5									
18.7	End of borehole													
<p>▽ Water level observed during drilling</p> <p>▼ Water level measured after drilling</p> <p>Piezometer Readings: Date Depth(m) June 11/03 12.3 July 02/03 12.3</p> <p>Borehole Backfill Legend:</p> <p> Native backfill</p> <p> Bentonite seal</p> <p> Filter sand</p> <p> Screen</p>														

RECORD OF BOREHOLE No 175-8

1 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 381 N; 225 837 E ORIGINATED BY F.P./R.A.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 27, 2003 CHECKED BY M.R.A.

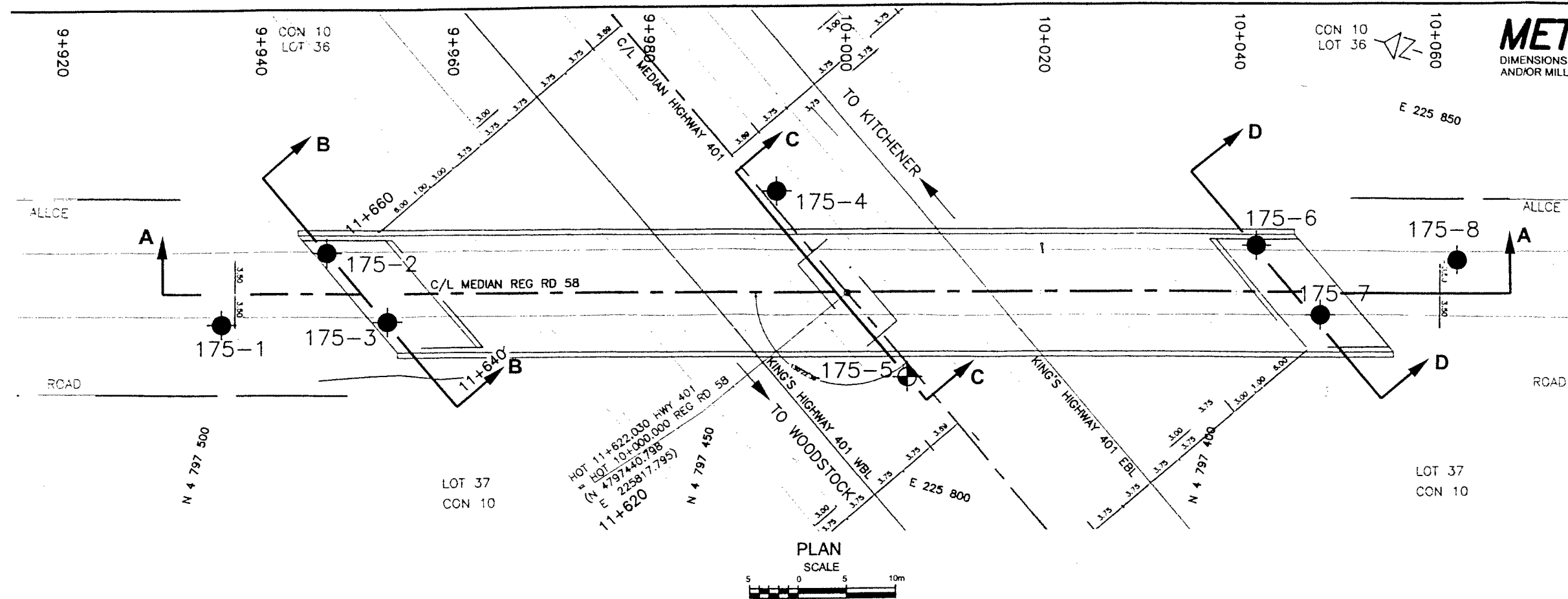
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE									
308.0							20	40	60	80	100	20	40	60	kn/m ³	GR SA SI CL	
0.0	Pavement structure: 130mm of asphaltic concrete over 380mm of granular material																
307.5																	
0.5	Sand and gravel, with silty sand inclusions																
	Very dense Brown (Fill)		1	SS	61												
306.4																	
1.6	Sand, with gravel inclusions		2	SS	50/15cm												
	Very dense Brown (Fill)		3	SS	50/15cm												
			4	SS	66												
	silty sand inclusions		5	SS	83/23cm												
			6	SS	65												
	cobbles/boulders																
300.4																	
7.6	Sand and gravel, with silty sand inclusions		7	SS	50/15cm												
	Very dense Brown (Fill)																
299.4																	
8.6	Sand, trace silt																
298.8	Loose Brown Moist to wet																
9.2	Clayey silt, trace sand and gravel		8	SS	20												
	Very stiff Brown (Fill)																
297.9																	
10.1	Clayey silt																
	Firm Grey Wet		9	SS	5												
295.5			10	SS	8												
12.5	Silt, some fine sand, trace clay																
	Loose to Grey Saturated compact																
			11	SS	6												
	Cont'd																

RECORD OF BOREHOLE No 175-8

2 of 2 METRIC

W.P. 72-00-00 LOCATION Co-ords. 4 797 381 N; 225 837 E ORIGINATED BY E.P./R.A.
DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE May 27, 2003 CHECKED BY M.R.A.

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													
308.3	Silt, some fine sand, trace clay Loose to Grey Saturated compact		12	SS	18													
			13	SS	9													
289.3			14	SS	12													
18.7	End of borehole																	
	<div style="display: flex; align-items: center;"> <div style="width: 10px; height: 10px; border: 1px solid black; margin-right: 5px;"></div> <div>Water level observed during drilling</div> </div> <div style="display: flex; align-items: center;"> <div style="width: 10px; height: 10px; border: 1px solid black; margin-right: 5px;"></div> <div>Water level measured after drilling</div> </div> <p><u>Piezometer Readings:</u></p> <table border="0"> <tr> <td>Date</td> <td>Depth (m)</td> </tr> <tr> <td>June 11/03</td> <td>14.0</td> </tr> <tr> <td>July 02/03</td> <td>12.1</td> </tr> </table> <p><u>Borehole Backfill Legend:</u></p> <div style="display: flex; flex-direction: column; gap: 5px;"> <div style="display: flex; align-items: center;"> <div style="width: 15px; height: 10px; border: 1px solid black; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px);"></div> <div>Native backfill</div> </div> <div style="display: flex; align-items: center;"> <div style="width: 15px; height: 10px; border: 1px solid black; background: repeating-linear-gradient(-45deg, transparent, transparent 2px, black 2px, black 4px);"></div> <div>Bentonite seal</div> </div> <div style="display: flex; align-items: center;"> <div style="width: 15px; height: 10px; border: 1px solid black; background: repeating-linear-gradient(0deg, transparent, transparent 2px, black 2px, black 4px);"></div> <div>Filter sand</div> </div> <div style="display: flex; align-items: center;"> <div style="width: 15px; height: 10px; border: 1px solid black; background: repeating-linear-gradient(90deg, transparent, transparent 2px, black 2px, black 4px);"></div> <div>Screen</div> </div> </div>	Date	Depth (m)	June 11/03	14.0	July 02/03	12.1											
Date	Depth (m)																	
June 11/03	14.0																	
July 02/03	12.1																	



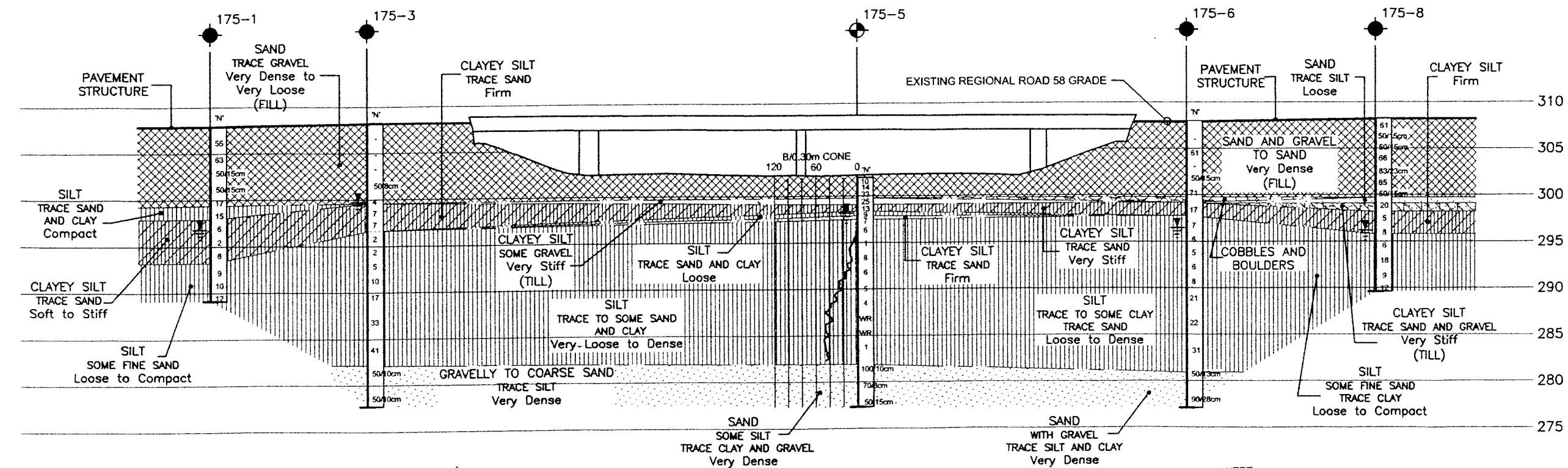
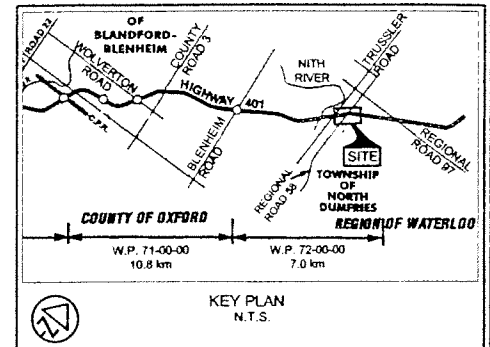
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES

CONT No
WP No 72-00-00

HIGHWAY 401
Regional Road 58 Underpass
BOREHOLE LOCATIONS & SOIL STRATA



Peto MacCallum Ltd.
CONSULTING ENGINEERS



CENTRE LINE PROFILE SECTION A-A

TO DRAWING 2 FOR SECTIONS B-B, C-C AND D-D.

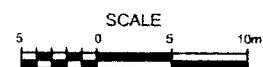
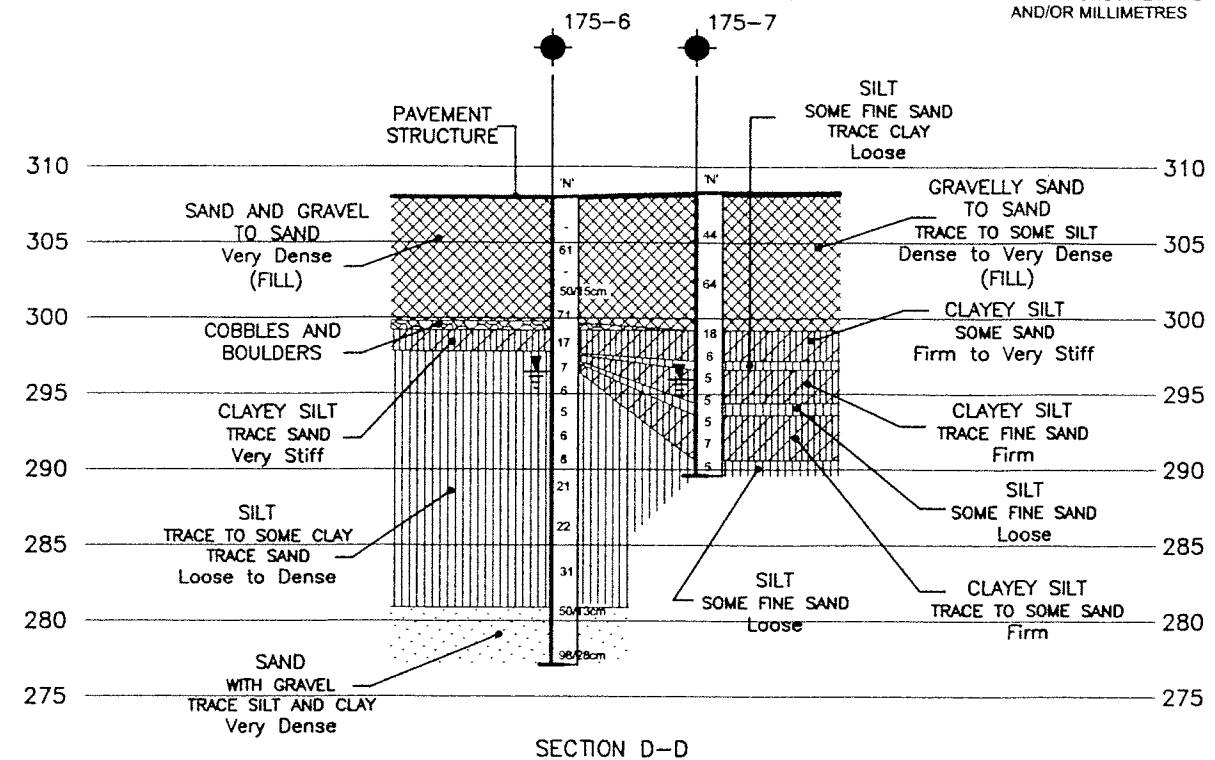
LEGEND			
	Borehole		
	Dynamic Cone Penetration Test (Cone)		
	Borehole & Cone		
	Auger Probe		
N	Blows/0.3m (Std. Pen Test, 475 J / blow)		
CONE	Blows/0.3m (60°Cone, 475 J / blow)		
	W.L. at time of investigation May - July 2003		
	Head		
	ARTESIAN WATER Encountered		
BH No	ELEVATION	NORTHING	EASTING
175-1	308.0	4 797 502	225 799
175-2	308.2	4 797 493	225 808
175-3	308.3	4 797 485	225 803
175-4	302.0	4 797 450	225 826
175-5	302.0	4 797 432	225 811
175-6	308.3	4 797 401	225 833
175-7	308.3	4 797 393	225 828
175-8	308.0	4 797 381	225 837

- NOTE -
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

NOTE:
SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLE, RECORD OF PENETRATION TEST AND AUGER PROBE LOGS FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.

Geocres No.	40PB-130
HWY No	401
SUBNO	GD
CHECKED	GD
DATE	
APPROVED	DWK
DATE	
SITE	33-175
DWG	1



Peto MacCallum Ltd.
CONSULTING ENGINEERS

OF
BLANDFORD-BLENHEIM
WOLVERTON ROAD
COUNTY ROAD 3
HIGHWAY 401
NITH RIVER
TRUSSARD ROAD
REGIONAL ROAD 10
REGIONAL ROAD 7
TOWNSHIP OF NORTH DUMFRIES
SITE
REGION OF WATERLOO
COUNTY OF OXFORD
W.P. 71-00-00
10.8 km
W.P. 72-00-00
7.0 km
KEY PLAN
N.T.S.

[illegible]

- NOTE -

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			

Geocore No. 40P8-130

JAWY No	401					DIST
SUBMIT	GD	CHECKED	GO	DATE		SITE 33-175
DRAWN	TK	CHECKED	MRA	APPROVED	DWKK	DWG 2

**FOUNDATION DESIGN REPORT
FOR
REGIONAL ROAD 58 UNDERPASS
W.P. 72-00-00, SITE 33-175
HIGHWAY 401
TOWNSHIP OF NORTH DUMFRIES
REGIONAL MUNICIPALITY OF WATERLOO, ONTARIO**

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TABLE OF CONTENTS

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Spread Footings	5
ABUTMENT WALLS	6
APPROACH EMBANKMENTS	8
EXCAVATION AND GROUNDWATER CONTROL	9
CLOSURE	12

APPENDICES:

TABLE I	-	GRADATION SPECIFICATION FOR SAND FILL IN PRE-AUGERED HOLES AT INTEGRAL ABUTMENTS
FIGURE 1	-	LATERAL EARTH PRESSURE DISTRIBUTION: SINGLY-BRACED CUTS IN COHESIVE SOILS
FIGURE 2	-	LATERAL EARTH PRESSURE DISTRIBUTION: MULTI-BRACED CUTS IN COHESIVE SOILS
FIGURE 3	-	GENERAL RECOMMENDATIONS REGARDING UNDERPINNING OF FOUNDATIONS/UTILITIES LOCATED CLOSE TO EXCAVATION

FOUNDATION DESIGN REPORT
for
Regional Road 58 Underpass
W.P. 72-00-00, Site 33-175
Highway 401
Township of North Dumfries
Regional Municipality of Waterloo, Ontario

INTRODUCTION

This report provides preliminary geotechnical comments and recommendations regarding design and construction of foundations, abutments, a centre pier and approach embankments for the proposed underpass at Regional Road 58 and Highway 401 located in the Township of North Dumfries, Regional Municipality of Waterloo, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation (MTO).

Replacement of the existing four span underpass with a new two span reinforced concrete structure is contemplated. The proposed underpass structure will be about 13 m wide with span lengths of 43.4 m (ref. Bridge Site Plan E-188/401-01 'Proposed Crossing at the King's Highway 401 and Regional Road 58 prepared by the Surveys and Plans Section of the MTO's Southwestern Regional Engineering office, dated March 2003).

Highway 401 passes under Regional Road 58 at approximate Station 11+622, Highway 401 chainage (station 10+000, Regional Road 58 chainage). The design road grade of Regional Road 58 at the underpass location is at approximate elevation 310.3, about 2 m higher than the existing grade, and elevation 302.3 on Highway 401 (shown on the drawing referred to above). The approach embankments to the underpass will be about 8 m high. Information concerning the type of foundation that supports the existing structure is not shown on the drawing.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised a surficial pavement structure and sand fill over native deposits of clayey silt and silt underlain by

sand. It is noteworthy that cobbles/boulders were identified in the sand and within the fill in the boreholes put down at the south abutment and approach.

FOUNDATIONS

Driven Piles

Use of steel H-piles is the recommended method to support the foundation loads of this structure. Use of integral abutments supported on H-piles is considered to be feasible.

The piles should be driven into the very dense sand anticipated near elevation 281 to 282, some 20 m below the Highway 401 road grade. Recommended values for geotechnical resistance at ULS and SLS for an HP 310 x 110 pile are:

		<u>HP 310 x 110</u>
Factored Geotechnical Resistance at ULS	=	1650 kN
Geotechnical Resistance at SLS	=	1150 kN

The resistance at SLS allows for 25 mm of compression of the founding medium.

A reduction factor has been applied to the geotechnical resistance values since the piles will set in very dense sand and negative skin friction may develop on the piles due to placement of fill on the existing approach embankments to raise the grade by 2 m.

Provided low displacement H-piles are employed and driven to refusal to mobilise end-bearing resistance, a reduction in the recommended resistance to account for group effects is not required.

The HP 310 x 110 section is recommended to minimize the potential for damage when driving through the cobbles/boulders identified in the boreholes drilled at the site.

The soil adjacent to the upper portion of the piles is expected to comprise well-compacted approach fill over firm to stiff clayey silt and loose to compact silt. To accommodate movement of the integral abutment, two concentric CSPs that extend 3 m below the bottom of the abutment should be placed around the pile to create an annular space. The inner CSP should be filled with sand meeting the gradation requirements of Granular B Type I. Alternatively, a single CSP filled with loose uniform sand meeting the requirements shown in Table I may be used. Refer to MTO Report SO-96-01 for further details.

Since the piles will be at least 20 m long and cobbles/boulders were identified during drilling, it is considered, based on our extensive experience with pile driving under similar conditions, that a hammer that **transfers** at least 40 kJ of energy to the pile should be employed to drive piles. The **rated energy** of the hammer should therefore be 50 to 55 kJ, depending on the type of equipment employed. The pile resistance should be confirmed during installation by dynamic analysis or the Hiley formula, assuming an ultimate resistance of 3700 kN for HP 310x110 piles.

Provision should be made for re-striking of the piles to compensate for potential soil relaxation. Re-striking may be discontinued if the pile resistance is found to be unaffected (no decrease with time) by soil relaxation.

Driving shoes such as the Titus 'H' Bearing Pile Point or equivalent should be provided to minimize the potential for damage when driving through material containing cobbles/boulders and setting into the very dense sand. The H-piles should be driven to refusal anticipated at approximate elevation 281.

The piles should be installed and monitored in accordance with the requirements of Special Provision 903S01 (February 2001). This should involve confirmation of the founding elevation, alignment, plumbness, uniformity of set and quality of splices, and should be done on a full time basis by experienced geotechnical personnel.

Pile caps should be provided with at least 1.2 m of earth cover or equivalent thermal insulation as protection against frost action. A 25 mm thick layer of polystyrene insulation is thermally equivalent to 600 mm of soil cover.

Resistance to lateral loads may be provided in part by mobilization of passive resistance along the pile below the annular space. The lateral resistance recommended is as follows:

		<u>HP 310 x 110</u>
Factored Lateral Resistance at ULS	=	125 kN
Lateral Resistance at SLS	=	40 kN

If greater resistance is required, batter piles could be installed.

The coefficient of horizontal subgrade reaction, k_s , for granular backfill, the native clayey silt and the underlying silt should be computed using the following equation to evaluate the point of contraflexure:

- embankment fill above the clayey silt surface, elevation ± 299.5

$$k_s = n_h z/b$$

where z = depth (m)

b = pile width (m)

$$\begin{aligned} n_h &= 14,000 \text{ kN/m}^3 \text{ for Granular "A" backfill} \\ &= 10,000 \text{ kN/m}^3 \text{ for compact to dense silt/sand} \end{aligned}$$

- native clayey silt below the granular fill between elevation 296.5 to 299.5

$$k_s = \frac{67c_u}{b}$$

$$\begin{aligned} c_u &= \text{undrained shear strength of the clayey silt} \\ &= 50 \text{ kPa} \end{aligned}$$

b = pile width (m)

- silt below elevation 296.5

$$k_s = n_h z/b$$

$$n_h = 3,500 \text{ kN/m}^3$$

Spread Footings

It is considered that spread footings founded on the native undisturbed soil or a pad of structural fill is not a feasible means of supporting the foundation loads due to the low bearing resistances of the clayey silt and underlying silt as well as the potential for significant total and differential settlement of the foundation units. Based on the engineering properties of the subgrade soils, the geotechnical resistance at ULS and SLS of a 2.5 m wide strip footing founded near elevation 299 is considered to be 250 and 100 kPa respectively. Cognizant of the

increased foundation load on the only centre pier that is proposed to replace the existing three piers, the above values are considered insufficient to provide the necessary support to the structure.

ABUTMENT WALLS

The abutment walls should be designed to resist the unbalanced horizontal earth pressure imposed by the backfill adjacent to the wall as well as the compaction pressure imposed during placement of the backfill. The lateral earth pressure, p , may be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC), CAN/CSA-S6-00, March 2001, or employing the following equation, assuming a triangular pressure distribution:

$$p = K (\gamma h + q) + C_p$$

where

K = lateral earth pressure coefficient

γ = unit weight of free-draining granular material (kN/m^3)

h = depth below final grade (m)

q = surcharge load (kPa) if present

C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)

Free-draining granular material should be used as backfill behind the wall. The following parameters are recommended for design:

	<u>Granular "A"</u>	<u>Granular "B"</u>
Angle of Internal Friction, degrees	35	32
Unit weight, kN/m^3	22.8	21.2
Coefficient of Active Earth Pressure K_a	0.27	0.31
Coefficient of Earth Pressure At Rest K_o	0.43	0.47
Coefficient of Passive Earth Pressure K_p	3.69	3.25

Refer to Report SO-96-01 for procedures to determine the earth pressure coefficient to be employed during design of integral abutments. The coefficient of earth pressure at rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures.

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost-free outlet.

A retained soil system (RSS) founded on the native clayey silt below the fill could also be employed. The parameters to be employed for design of the RSS will be dependent upon the type of backfill employed to construct the RSS:

	<u>Granular "A"</u>	<u>Granular "B"</u>	<u>Clayey Silt</u>
Friction Angle, degrees	35	32	0
Cohesion, kPa	0	0	50
Unit weight, kN/m ³	22.8	21.2	19.0

The recommended geotechnical resistance for an RSS wall constructed on the firm to stiff (north abutment) and stiff to very stiff (south abutment) clayey silt near elevation 300 is:

Factored Geotechnical Resistance at ULS = 250 kPa

Geotechnical Resistance at SLS = 100 kPa

The RSS supplier should be responsible for specifying the type of backfill material employed, taking into consideration the engineering properties of the proprietary product, the design life of the structure, the pullout resistance required, drainage requirements and the predicted settlements noted in the section titled "Approach Embankments".

The supplier of the RSS should also be responsible for design of the structure (backfill, reinforcement, internal and external stability) and provide drawings to show pertinent information such as location, length, height, elevations, performance level, appearance etc.

APPROACH EMBANKMENTS

The approach embankment will be raised by 2 m and be a total of 8 m high. It is anticipated that earth fill or granular material will be employed to raise the grade to the design level. Placement of the fill on the existing embankment and/or native clayey silt is considered to be feasible.

Any topsoil and other deleterious material within the plan area of the fill should be stripped prior to placement of the embankment fill.

Backfilling adjacent to the structure should be carried out in conformance with Ontario Provincial Standards specifications for granular backfill (OPSD 3501.00).

The embankments should be constructed in accordance with OPSD 200.020, 202.01, 208.01 and OPSS 206 dated December 1993 amended by Special Provision (Draft dated June 20, 2001). The side slopes of the embankment should be inclined no steeper than 2 horizontal to 1 vertical. For erosion control and slope maintenance purposes, a 2 m wide mid-height berm should be provided so that no uninterrupted slope is greater than 8 m high.

It is considered that the approach embankments constructed in accordance with these recommendations will be stable. Settlement of the embankment fill due to consolidation of the underlying native soil is computed to be in the order of 10 to 20 mm and be completed within three months following placement of the fill.

Some settlement of the embankment fill surface, both during and following completion of construction, due to “consolidation” of the fill is also likely to occur. The magnitude of total settlement is estimated to be about 0.25% of the fill height with 50% occurring during construction (based on 12 month construction period) and the remainder within one year following completion of construction.

EXCAVATION AND GROUNDWATER CONTROL

It is expected that the abutment foundations will be located within the existing approach embankments.

Excavation for construction of the anticipated piled foundations is expected to extend partially through the existing embankment fill and/or up to 2 m into the native clayey silt. Consequently, the maximum depth of excavation is expected to be 2 to 5 m.

The soil at the site is classified as Type 3 soil according to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Therefore, temporary cut slopes over the full depth of the excavation should be inclined at 45° to the horizontal. The need to excavate flatter sideslopes if excessively soft/wet materials or concentrated seepage zones are encountered locally should not be overlooked.

Shoring will be required to support the walls of the excavation and adjacent traffic lanes during construction. The magnitude and distribution of the lateral earth pressures acting on a braced excavation wall is dependent upon the support system used, the number of supports, the allowable movements and the construction sequence. The recommended design earth pressure distribution for singly and multi-braced walls, for the conditions that exist at the site, are presented in Figures 1 and 2 respectively. Recommendations concerning design and construction of the braced excavation support systems are provided in the figures.

A soldier pile and lagging system may be considered. Provided the spacing between soldier piles is at least five pile diameters, the unfactored lateral passive resistance developed on the face of the soldier pile below the base of the excavation may be taken as the passive earth pressure developed over an equivalent wall area of width three times the pile diameter and depth of six times the pile diameter. A passive earth pressure coefficient K_p of 3.0 is recommended for this computation.

Additional lateral resistance could be provided by installing tiebacks anchored in the firm to stiff clayey silt and/or the underlying loose to compact silt. It must be noted, however, that the groundwater level is expected to be near elevation 296.8 and the silt deposit exists below the clayey silt unit. It may be difficult to install anchors in the cohesionless silt below the water table.

The unfactored pull-out resistance (R) of anchors grouted in cohesionless material can be estimated using the following equation:

• Silt:

$$R = K_f \sigma'_z L_s A_s$$

where K_f = anchorage coefficient
= 0.3 for loose to compact silt

σ'_z = effective vertical stress at midpoint of anchor
= $\gamma' z$

γ' = effective unit weight of overburden soil
= 20.0 kN/m³ above groundwater level
(elevation 296.8 for design purposes)
= 10.2 kN/ m³ below groundwater level

z = depth to midpoint of anchor (m)

L_s = fixed length of anchor (m)

A_s = unit surface area of the
fixed length of anchor (m²/m)

- Clayey silt:

$$R = \alpha A_s L_s \tau_u$$

where α = reduction factor related to the undrained shear strength
= 0.6

A_s = effective unit surface area of the anchor in the clayey silt (m^2/m)

L_s = effective embedment length of the anchor in the clayey silt (m)

τ_u = average undrained shear strength of the clayey silt
over the anchor length
= 50 kPa

A resistance factor of 0.4 should be applied to the computed anchor capacity to determine the ULS resistance.

The ground surface adjacent to the excavation is expected to experience some inward movement and vertical settlement. The magnitude of movements adjacent to a braced cut can be limited by selection of an appropriate lateral earth pressure coefficient (see Figures 1 and 2) provided good quality workmanship and construction practice is employed. The anticipated magnitude of movements is as follows:

Movement (% of Excavation Depth)

Lateral Movement	
Braced Excavation	0.2
Anchored Wall	0.1
Vertical Movement	0.05

Construction procedures should be specifically suited to limit any consequent settlement of the pavement subgrade behind the excavation face.

Foundations of heavily loaded/settlement sensitive structures and/or utilities, if located within close proximity to the excavation, may require underpinning to preserve the integrity of these structures. Further comments and general recommendations in this regard are provided in Figure 3.

Based on groundwater levels measured during the field investigation, it is anticipated that the stabilized groundwater level at this site will be below the excavation base, near elevation 296.8. However, wet silt layers were identified locally above this level. Groundwater seepage or surface water inadvertently entering the foundation excavation is expected to be readily handled using conventional sump pumping techniques. Some sloughing and seepage from localized silt zones should be anticipated.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

CLOSURE

The report was prepared by Mr. G.O. Degil, Ph.D., Senior Project Supervisor. It was reviewed by Mr. D.W. Kerr, M.Eng., P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, M.Eng., P.Eng., designated MTO contact, carried out an independent review of the report.



Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "D. W. Kerr", written over a horizontal line.

Dennis W. Kerr, M.Eng., P.Eng.
Chief Foundation Engineer



A handwritten signature in black ink, appearing to read "Brian R. Gray", written over a horizontal line.

Brian R. Gray, M.Eng., P.Eng.
Designated MTO Contact

GD:lad

TABLE I

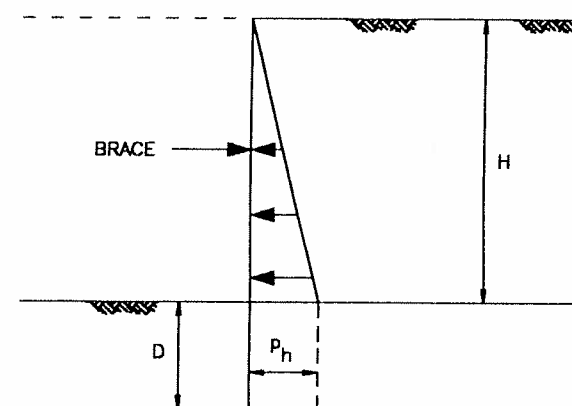
**Gradation Specification for Sand Fill in
Pre-Augered Holes at Integral Abutments**

MTO Sieve Designation		Percentage Passing by Mass
2 mm	#10	100
600 µm	#30	80 – 100
425 µm	#40	40 – 80
250 µm	#60	5 – 25
150 µm	#100	0 – 6

From MTO Report S0-96-01, Revision 1 – July, 1996.

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
2. Stability of base of excavation must be confirmed when bracing system design, excavation geometry and surcharge loads are established.
3. Earth pressure diagram is applicable to maximum depth of cut of 12m (40 ft.).
4. Structural components of bracing system should be confirmed adequate for each level of excavation.
5. If sheeting will not permit drainage, bracing system must be designed to resist water pressure.
6. Surcharge loads such as street/construction traffic, supported utilities, adjacent foundations, temporary stockpiles and other loads carried by bracing system are not included in earth pressure diagram.
7. Temporary surcharge loading should not be closer to the face of the excavation than half the depth of excavation unless accounted for in bracing design.
8. If settlement sensitive structures are located near the excavation, special measures should be undertaken to control settlements. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction.
9. Earth pressure diagram is applicable for relatively short construction periods. If excavation is to be open for long periods, monitoring of deformation is essential, the earth pressure diagram must be reviewed, and remedial works may be required.
10. Earth pressure diagram does not account for extended periods of exposure of the excavation to freezing temperatures.
11. Bracing system should be regularly examined for signs of distress.
12. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
13. This sheet should be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

EARTH PRESSURE DIAGRAM

$$p_h = \text{design lateral earth pressure} \\ = K\gamma H$$

K = lateral earth pressure coefficient

γ = unit weight of soil

H = depth of excavation

D = depth of embedment of soldier piles (if used).

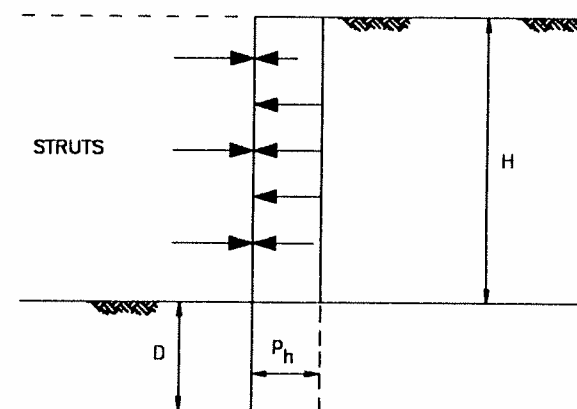
RECOMMENDED DESIGN PARAMETERS

$$\gamma = 20.4 \text{ kN/m}^3$$

$K = 0.35$ (movement of retained soil acceptable)
 0.50 (movement of adjacent structures/facilities unacceptable)

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
2. Stability of base of excavation must be confirmed when bracing system design, excavation geometry and surcharge loads are established.
3. Earth pressure diagram is applicable to maximum depth of cut of 12m (40 ft.).
4. Structural components of bracing system should be confirmed adequate for each level of excavation.
5. If sheeting will not permit drainage, bracing system must be designed to resist water pressure.
6. Surcharge loads such as street/construction traffic, supported utilities, adjacent foundations, temporary stockpiles and other loads carried by bracing system are not included in earth pressure diagram.
7. Temporary surcharge loading should not be closer to the face of the excavation than half the depth of excavation unless accounted for in bracing design.
8. If settlement sensitive structures are located near the excavation, special measures should be undertaken to control settlements. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction.
9. Earth pressure diagram is applicable for relatively short construction periods. If excavation is to be open for long periods, monitoring of deformation is essential, the earth pressure diagram must be reviewed, and remedial works may be required.
10. Earth pressure diagram does not account for extended periods of exposure of the excavation to freezing temperatures.
11. Bracing system should be regularly examined for signs of distress.
12. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
13. This sheet should be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

EARTH PRESSURE DIAGRAM

$$P_h = \text{design lateral earth pressure} \\ = 0.65K\gamma H$$

K = lateral earth pressure coefficient

γ = unit weight of soil

H = depth of excavation

D = depth of embedment of soldier piles (if used).

RECOMMENDED DESIGN PARAMETERS

$$\gamma = 20.0 \text{ kN/m}^3$$

$K = 0.35$ (movement of retained soil acceptable)
 0.50 (movement of adjacent structures/facilities unacceptable)

NOTES

1. The need to underpin existing footings/utilities is dependent upon soil type, proximity of the existing facility to the face of the excavation, loads imposed on the foundation and permissible movements.

ZONE A:

Foundations of relatively heavy and/or settlement sensitive structures/utilities located in Zone A generally require underpinning.

ZONE B:

Foundations of structures located within Zone B generally do not require underpinning. Consideration should be given to underpinning of settlement sensitive utilities or heavy foundation units located in this zone.

ZONE C:

Utilities and foundations located within Zone C do not normally require underpinning.

Underpinning of foundations located in Zones A and B should extend at least into Zone C.

2. As an alternative to underpinning, it may be possible to control movement of existing utilities and foundations by supporting the face of the excavation with bracing/tiebacks or a rigid (caisson) wall. Horizontal and vertical earth pressures imposed on the excavation wall by non-underpinned foundations must be considered in the design of the support system.
3. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction to monitor any movement which may occur.
4. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
5. This sheet is to be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

