



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

CULVERT REPLACEMENTS

REHABILITATION OF HIGHWAY 10, MARKDALE TO CHATSWORTH

G.W.P. 330-88-00

OWEN SOUND, ONTARIO

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1 cc: PML Hamilton	Index No.: 008FIR and 009FDR
1 cc: PML Kitchener	Geocres No.: 40P8-139
1 cc: PML Toronto	February 28, 2005



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Figure 1 – Location Map

Photographs 1 to 4 – Culverts 1 and 2

Figures GS-1 to GS-3 – Results of Grain Size Distribution Analyses

Explanation of Terms Used in Report

Record of Borehole Sheets

Drawings 1 to 3 – Borehole Locations & Soil Strata

Peto MacCallum Ltd.

C O N S U L T I N G E N G I N E E R S

FOUNDATION INVESTIGATION REPORT

for

Culvert Replacements

Rehabilitation of Highway 10, Markdale to Chatsworth

G.W.P. 330-88-00

Owen Sound, Ontario

1. INTRODUCTION

Rehabilitation of the approximate 25 km long section of Highway 10 that extends from the Markdale north limits northerly to the junction of Highways 6 and 10 in Chatsworth near Owen Sound, Ontario is planned. This section of the highway is located in the County of Grey as shown on the attached Location Map (Figure 1). This report was prepared for McCormick Rankin Corporation on behalf of the Ministry of Transportation of Ontario.

Rehabilitation of the highway will involve replacement of two culverts where the Spey River crosses Highway 10 south of Chatsworth as well as replacement of the wing walls on the east end of the culvert located south of the abandoned CPR crossing.

For the purposes of this report, the culverts have been designated by the following numbers:

CULVERT	SITE No.	APPROXIMATE STATION	CULVERT No.
Spey River culvert located south of Grey County Road 40 WP 330-88-02	8-463-C	31+344	1
Spey River culvert located south of the south limit of Chatsworth WP 3017-03-01	8-402-C	32+754	2
Culvert located south of former CPR rail line WP not available	—	28+994	3

There is one chainage equation for Highway 10 within the project limits just north of Markdale:

$$\begin{array}{rcl} \text{Station } 34+248.401 & = & \text{Station } 10+000.000 \\ \text{Township of Artemesia} & & \text{Township of Holland} \end{array}$$



This report provides a summary of the factual information obtained during the field investigation conducted at the locations of the proposed culvert replacements.

2. SITE DESCRIPTION AND GEOLOGY

Highway 10 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy areas. Land use along the study corridor is mainly agricultural with some forested/swamp areas and residential development.

The project area lies in the physiographic region known as the Horseshoe Moraines and is characterised by a complex of till ridges and plains, kame moraines, outwash plains and spillways. The till soils present in the area tend to be loamy and contain numerous cobbles and boulders. The main soil types in the region are Pike Lake loam, Harriston loam, Osprey loam, Harkaway loam, Donnybrook loam and Muck (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984). Bedrock generally comprises sandstone, shale, dolostone and siltstone of the Guelph Formation.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out in the period of August 16 to 31, 2004 and comprised a total of 10 boreholes advanced to depths of 3.0 to 8.2 m below existing grade. The approximate locations of the boreholes put down at the culvert locations along with stratigraphic cross-sections are shown on the corresponding Borehole Locations & Soil Strata drawings for the respective culverts (Drawings 1, 2 and 3).

The borehole numbers are provided with a prefix code to reflect the specific culvert number for ease of reference.

The borehole layout was established in accordance with requirements noted in the Request for Proposal. The control line set along the Highway 10 alignment was paint marked in the field by Callon Dietz Inc. and used to reference the boreholes. Peto MacCallum Ltd. selected the borehole locations and established their elevations relative to the ground surface elevations along the centreline shown on the highway profile.



The boreholes were advanced using continuous flight solid and hollow stem augers, powered by a track-mounted CME-75 drill rig, and mechanised hand sampling equipment (portable rotary drilling). The equipment was supplied and operated by specialist drilling contractors working under the full-time supervision of a member 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. Four additional dynamic cone penetration tests were conducted in selected boreholes to confirm the relative density of cohesionless strata.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. All the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines for borehole abandonment procedures.

All of the recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing program consisting of routine moisture content determinations and 15 grain size distribution analyses was carried out on selected samples. The results of the laboratory grain size distribution analyses are presented in Figures GS-1 to GS-3.

4. SUMMARISED 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 test data, groundwater observations and moisture content determinations. The results of laboratory grain size distribution analyses conducted on selected samples are also shown on the borehole logs.

The borehole locations and stratigraphic cross-sections prepared from the borehole and dynamic cone penetration test data for the respective culverts are presented on Drawings 1 to 3. The



boundaries between soil strata have been established only at the borehole locations. Between boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations was generally consistent and typically comprised gravelly/sandy/silty fill and/or coarse fibrous peat underlain by cohesionless soils varying broadly in granulometric composition between gravel and silt. A description of the subsurface stratigraphy identified at each culvert is summarized in the following paragraphs.

4.1 Culvert 1 – Spey River (South), Station 31+344

Three boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes comprised a surficial fill or peat overlying cohesionless gravelly/sandy/silty soils. Groundwater was at depths of 0.2 to 4.5 m (elevation 289.9 to 291.1).

4.1.1 Fill

Surficial fill was present in borehole C1-2 put down at the road shoulder. The unit comprised 0.8 m of sand and gravel underlain by 1.4 m of sandy silt. The fill had a moisture content of 8 to 12% and was penetrated at 2.2 m depth (elevation 292.2).

4.1.2 Peat

A deposit of peat was present surficially in boreholes C1-1 and C1-3. The peat was 1.4 and 1.5 m thick and coarse fibrous in texture. The moisture content of this deposit ranged from 19 to 37%. The peat was penetrated at elevation 289.9 in borehole C1-1 and 289.5 in borehole C1-3.

4.1.3 Gravel/Sand and Gravel

A 1.5 m thick layer of gravel was encountered directly beneath the peat at a depth of 1.4 m (elevation 289.9) in borehole C1-1. This layer was compact (SPT-'N' values of 11 and 20) with a moisture content of 7 and 8% determined on two recovered samples. The results of a grain size distribution analysis performed on the gravel are presented in Figure GS-1.



Underlying the fill and silty/sandy soils (described below) at 7.0 m depth (elevation 287.4) in borehole C1-2 was sand and gravel. This unit was dense (SPT-'N' value of 42) and had a thickness of at least 1.2 m. The moisture content of the sand and gravel was about 8%. The borehole was terminated in this unit at a depth of 8.2 m (elevation 286.2).

4.1.4 Sand/Silty Sand

Cohesionless sand was revealed below the peat, gravel or silt (described below) at depths of 1.5 to 4.0 m (elevation 288.4 to 290.4) in all three boreholes. This stratum was loose to dense, typically compact (SPT-'N' values of 10 to 33; dynamic cone penetration resistance values of 9 to about 100) and had a confirmed thickness of 1.4 m in borehole C1-2. The moisture content of the sand varied between 8 and 16%. Augering in boreholes C1-1 and C1-3 was terminated within the stratum at respective depths of 6.7 and 3.6 m (elevation 284.6 and 287.4). The results of grain size distribution analyses performed on representative samples of the sand are presented in Figure GS-2.

The sand overlay a layer of silty sand at 5.4 m depth (elevation 289.0) in borehole C1-2. This layer was 1.6 m thick, compact (SPT-'N' value of 22) and had a moisture content of about 21%. The silty sand was penetrated at a depth of 7.0 m (elevation 287.4).

4.1.5 Silt

Non-plastic silt was encountered below the fill at 2.2 m depth (elevation 292.2) in borehole C1-2. This unit was 1.8 m thick and very loose (SPT-'N' values of 2 and 3). The moisture content of the silt ranged from 20 to 22%. The unit was penetrated at a depth of 4.0 m (elevation 290.4). The results of a grain size distribution analysis performed on the silt are presented in Figure GS-3.

4.1.6 Groundwater

Water was observed in all the boreholes in the course of the field work. Upon completion of drilling, groundwater was at depths of 0.2 to 4.5 m (elevation 289.9 to 291.1). Observed groundwater levels are subject to seasonal fluctuations and rainfall patterns. The water level in the creek at the time of the field investigation was near elevation 291.



4.2 Culvert 2 – Spey River (North), Station 32+754

Three boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes comprised a surficial fill or peat overlying gravelly soils underlain by silt and sand. Groundwater was at depths of 0.3 to 1.5 m (elevation 286.8 to 288.2).

4.2.1 Fill

Surficial fill was present in borehole C2-2 put down at the road shoulder. The unit was 3.7 m thick and predominantly consisted of sand and gravel. The fill had a moisture content of 6 to 16%, locally 53% where organics were encountered in the fill, and was penetrated at elevation 286.0.

4.2.2 Peat

A deposit of peat was present surficially in boreholes C2-1 and C2-3. The peat was 700 and 900 mm thick and coarse fibrous in texture. The moisture content of this deposit varied between 11 and 45%. The peat was penetrated at elevation 287.2 in borehole C2-1 and 286.9 in borehole C2-3.

4.2.3 Gravel to Sand and Gravel

Gravelly soils of various granulometric composition (gravel, sandy gravel, sand and gravel) were encountered below the fill or peat at depths of 0.7 to 3.7 m (elevation 286.0 to 287.2) in all three boreholes. These strata were typically compact to very dense (SPT-'N' values of 17 to 68), very loose to loose in the upper 1 m of the sandy gravel in borehole C2-3 as indicated by dynamic cone penetration resistance, and had a confirmed thickness of 3.1 m in borehole C2-1. The moisture content ranged from 6 to 12%.

The sand and gravel in borehole C2-1 was penetrated at a depth of 3.8 m (elevation 284.1); boreholes C2-2 and C2-3 were terminated in the gravel and sandy gravel strata (the former upon refusal on probable boulders/cobbles) at respective depths of 6.7 and 3.4 m (elevation 283.0 and 284.4).



The results of grain size distribution analyses performed on representative samples of the gravel, sandy gravel, sand and gravel are presented in Figure GS-1.

4.2.4 Sand

Underlying the silt layer (described below) at 5.5 m depth (elevation 282.4) in borehole C2-1 was cohesionless sand. This unit was dense (SPT-'N' value of 37) and had a thickness of at least 1.2 m. The moisture content of the sand was about 7%.

The results of a grain size distribution analysis performed on the sand are presented in Figure GS-2. The borehole was terminated within the unit at a depth of 6.7 m (elevation 281.2).

4.2.5 Silt

Non-plastic silt till was encountered directly beneath the sand and gravel at a depth of 3.8 m (elevation 284.1) in borehole C2-1. This stratum was 1.7 m thick and compact (SPT-'N' value of 26). The silt till had a moisture content of about 13% and was penetrated at 5.5 m depth (elevation 282.4). The results of a grain size distribution analysis performed on the silt till are presented in Figure GS-3.

4.2.6 Groundwater

Water was observed in all the boreholes in the course of the field work. Upon completion of drilling, groundwater was at depths of 0.3 to 1.5 m (elevation 286.8 to 288.2). Observed groundwater levels are subject to seasonal fluctuations and rainfall patterns. The water level in the creek at the time of the field investigation was at elevation 287.3.

4.3 Culvert 3 – Station 28+994

Four boreholes were drilled along the wing walls at the east end of this culvert. The subsurface stratigraphy revealed in the boreholes comprised a surficial fill and/or peat overlying cohesionless sandy/silty soils containing occasional cobbles/boulders. Groundwater was measured in three boreholes at depths of 0.3 to 2.6 m (elevation 318.8 to 319.3).



4.3.1 Fill

Surficial fill was present in boreholes C3-1 and C3-4 put down at the road shoulder. The unit comprised 0.7 and 1.4 m of sand and gravel underlain by 2.4 and 1.4 m of sandy silt. The fill had a moisture content of 8 to 13% and was penetrated in boreholes C3-1 and C3-4 at respective depths of 3.1 and 2.8 m (elevation 318.8 and 319.1).

4.3.2 Peat

A deposit of peat was present surficially in boreholes C3-2, C3-3 and directly beneath the fill in the remaining two boreholes. The peat was 200 to 600 mm thick and coarse fibrous in texture. The moisture content of this deposit varied between 12 and 20%. The peat was penetrated at depths of 0.2 to 3.5 m (elevation 318.4 to 319.1).

4.3.3 Sand

Cohesionless sand was encountered below sandy/silty soils (described below) in borehole C3-2 and below the peat in borehole C3-4 at respective depths of 1.4 and 3.4 m (elevation 317.9 and 318.5). This unit was very loose to dense (based on both standard and dynamic cone penetration test data) and had a confirmed thickness of 0.2 to 0.8 m. The moisture content of the sand was about 11%.

The results of a grain size distribution analyses performed on the sand are presented in Figure GS-2. The unit was penetrated at 4.2 m depth (elevation 317.7) in borehole C3-4; augering in borehole C3-2 was terminated within the sand at a depth of 1.6 m (elevation 317.7).

4.3.4 Sand and Silt

A layer of sand and silt was identified directly beneath the peat at depths of 0.2 and 0.6 m (elevation 319.1 and 318.7) in boreholes C3-2 and C3-3 respectively. This layer was 0.4 to 1.0 m thick and very loose (assessment made using the dynamic cone penetration test data). The sand and silt had a moisture content of 10 to 16% and was penetrated in boreholes C3-2 and C3-3 at respective depths of 1.2 and 1.0 m (elevation 318.1 and 318.3).



4.3.5 Sandy Silt

Underlying the sand and silt in boreholes C3-2, C3-3 or sand in borehole C3-4 was sandy silt (till in boreholes C3-2 and C3-4). In borehole C3-4, this stratum was compact to very dense (SPT-'N' values of 25 to over 50) and had a thickness of at least 2.1 m. In the other two boreholes, it was 0.2 to 0.3 m thick and loose to compact as indicated by dynamic cone penetration resistance. The moisture content of the sandy silt till ranged from 9 to 12%.

The stratum was penetrated in boreholes C3-2 and C3-3 at respective depths of 1.4 and 1.3 m (elevation 317.9 and 318.0); borehole C3-4 was terminated within the sandy silt till at a depth of 6.3 m (elevation 315.6).

The results of a grain size distribution analysis performed on the sandy silt till are presented in Figure GS-3.

4.3.6 Silt

Non-plastic silt till was encountered below the peat at a depth of 3.5 m (elevation 318.4) in borehole C3-1 and below the sandy silt at 1.3 m depth (elevation 318.0) in borehole C3-3. This unit was compact to dense (SPT-'N' values of 12 to 42). The moisture content of the silt till varied between 9 and 15%. Both boreholes were terminated within this unit at respective depths of 6.9 and 3.0 m (elevation 315.0 and 316.3).

The results of grain size distribution analyses performed on representative samples of the silt till are presented in Figure GS-3.

4.3.7 Groundwater

Groundwater was measured in three boreholes to be at depths of 0.3 to 2.6 m (elevation 318.8 to 319.3) upon completion of drilling. No water was detected in borehole C3-4 in the course of the field work. Observed groundwater levels are subject to seasonal fluctuations and rainfall patterns. The water level in the creek at the time of the field investigation was near elevation 319.



5. CLOSURE

The field work was carried out under the supervision of Mr. R. Mount, BEng, E.I.T., and direction of Mr. G. Idzik, BAsC, Field Supervisor. The equipment was supplied by Geo-Environmental Drilling Inc. and Sonic Soil Sampling (Ontario).

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. D.W. Kerr, MEng, P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "G. Degil", is positioned above the printed name.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



A handwritten signature in black ink, appearing to read "D. W. Kerr", is positioned above the printed name.

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

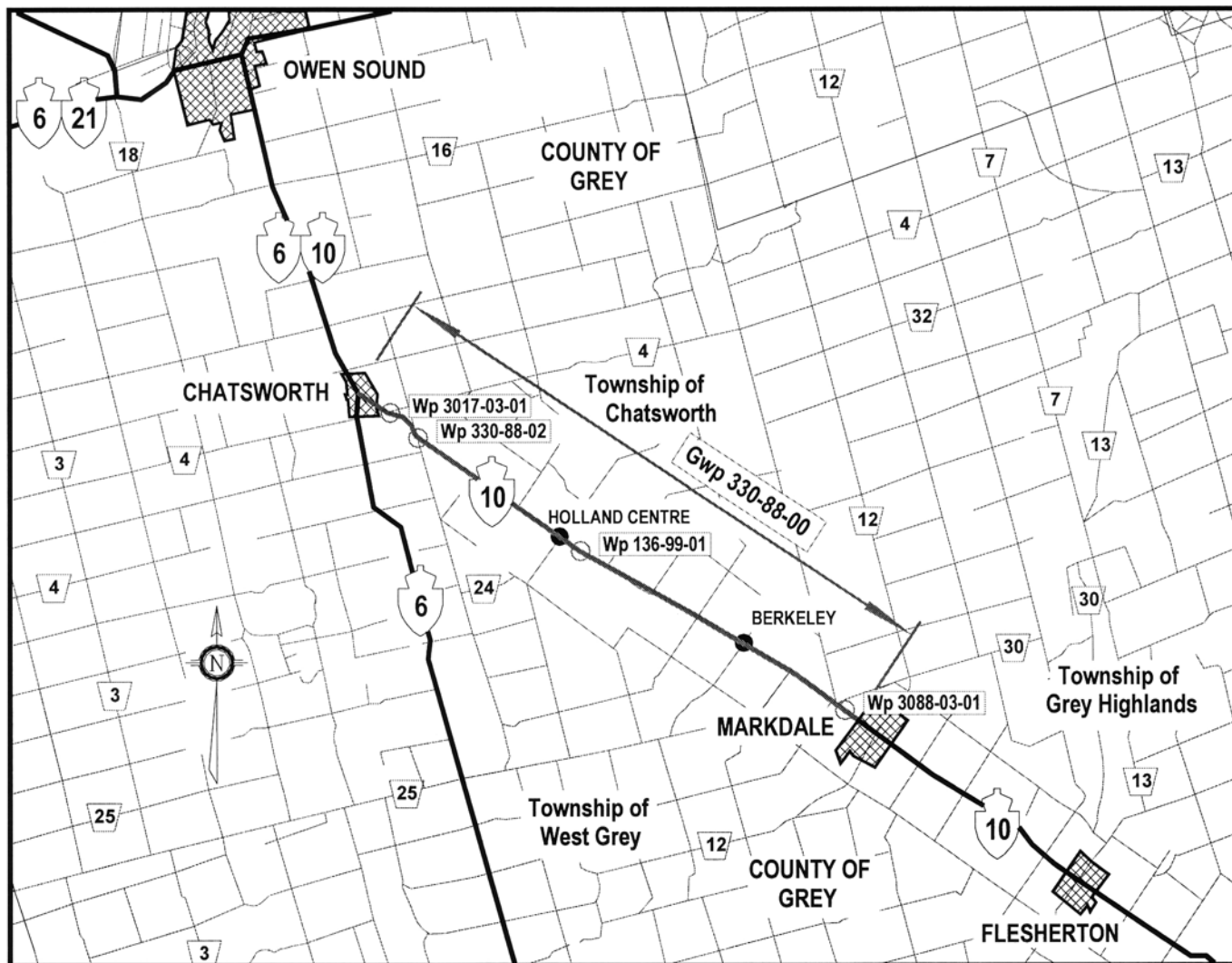


A handwritten signature in black ink, appearing to read "Brian R. Gray", is positioned above the printed name.

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



GD/DWK/BRG-gd:lr-mi





Photograph 1: North side of Culvert 1 (Sta. 31+344) looking east.



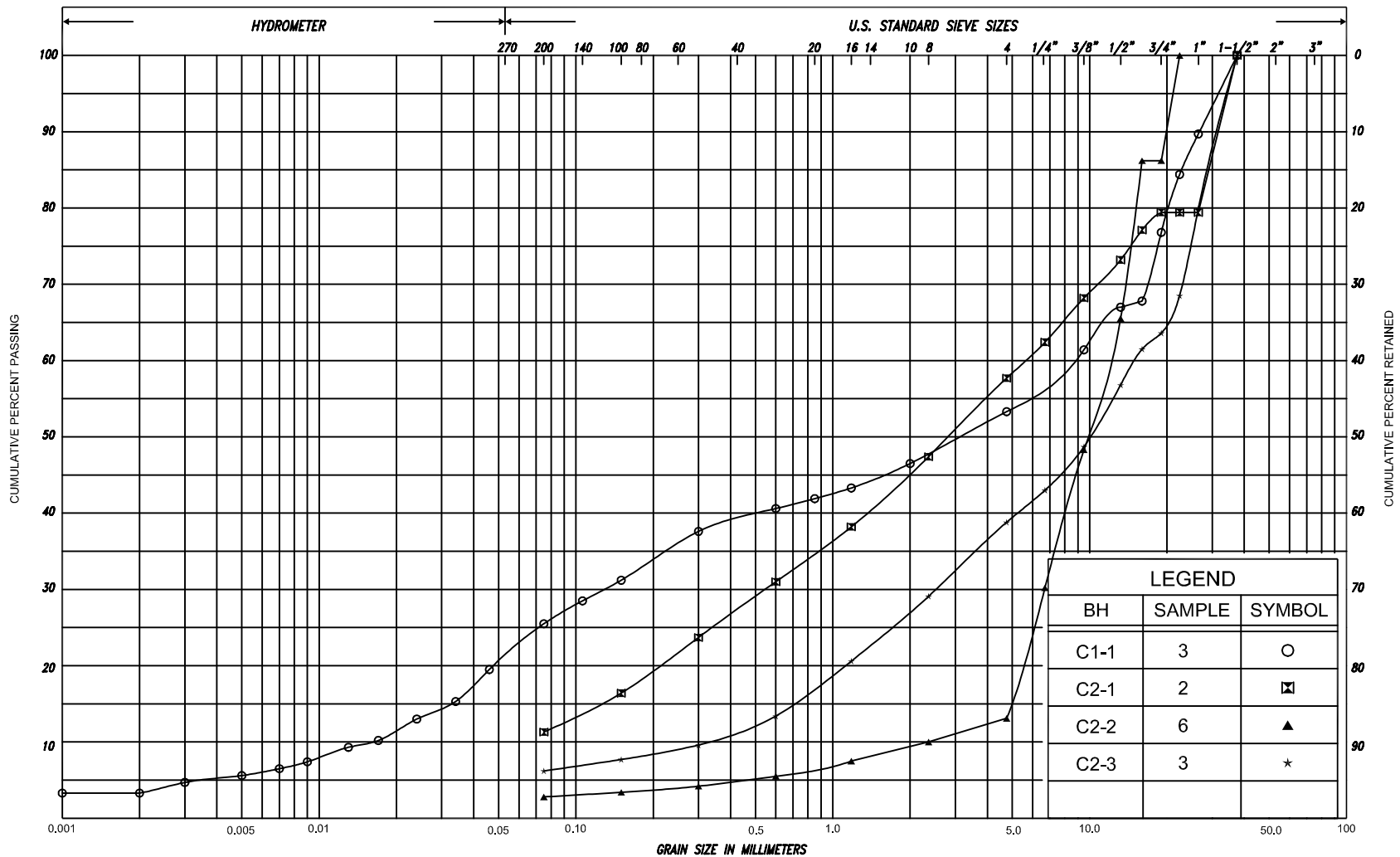
Photograph 2: South side of Culvert 1 (Sta. 31+344) looking east.



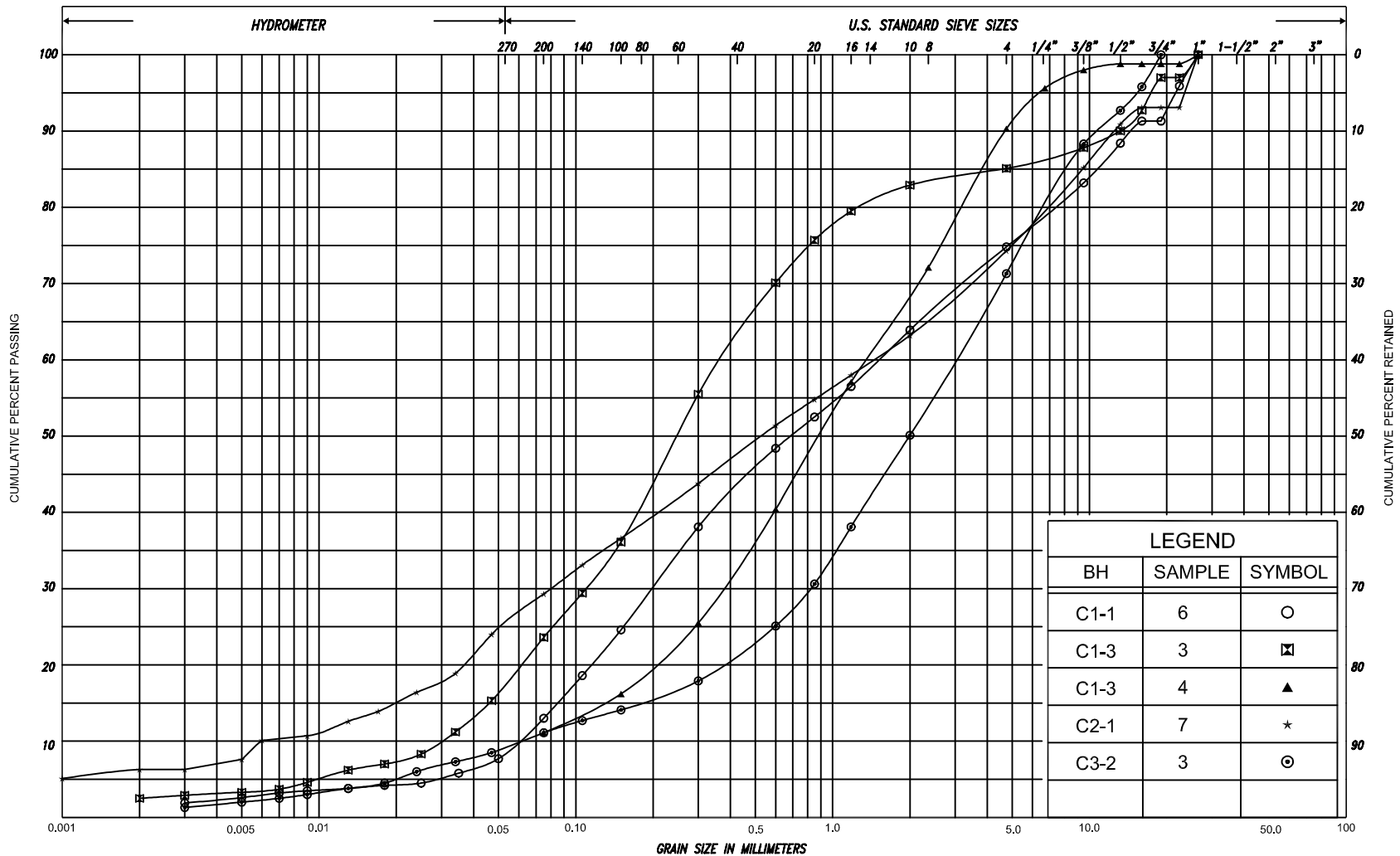
Photograph 3: South side of Culvert 2 (Sta. 32+754) looking west.



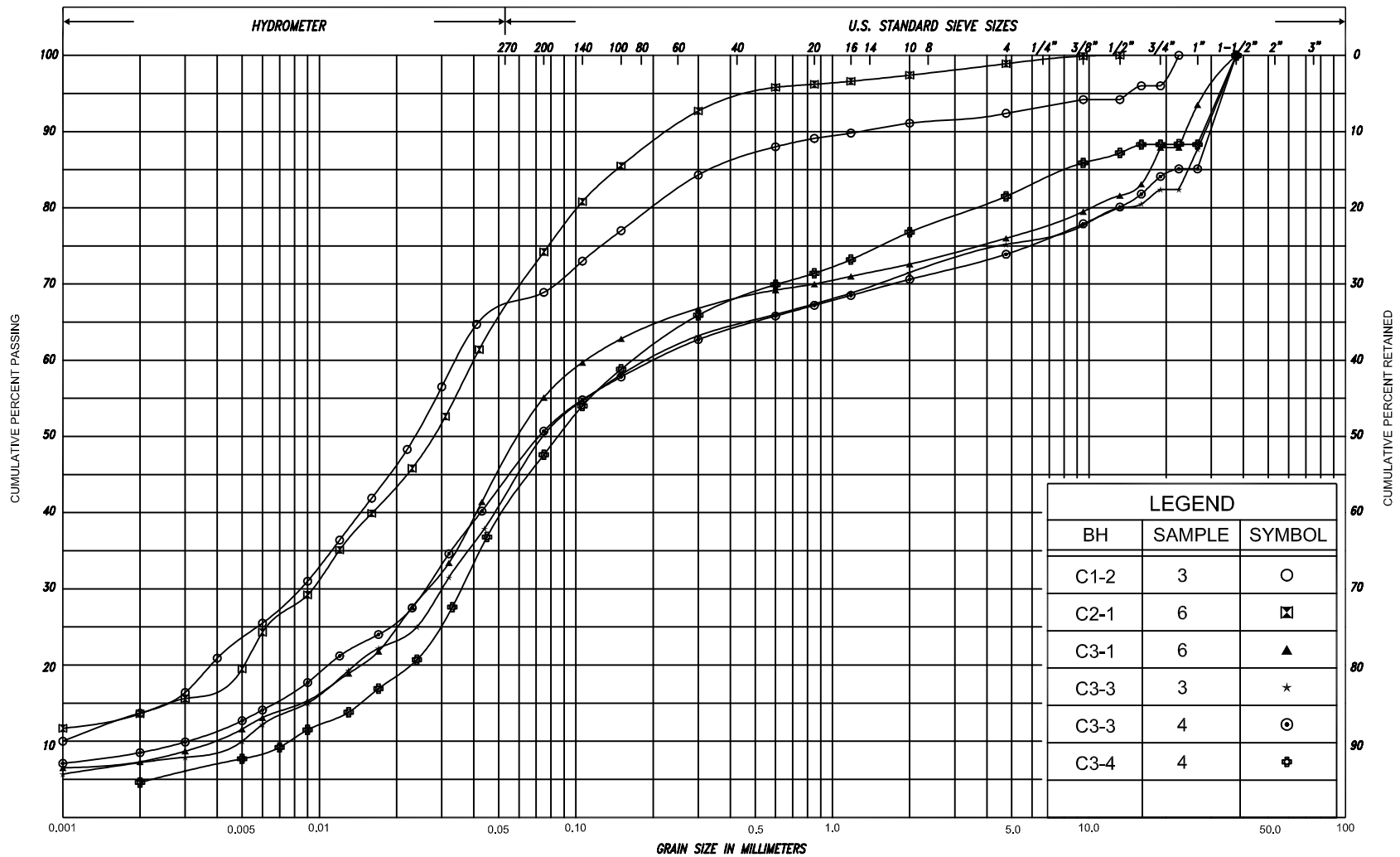
Photograph 4: North side of Culvert 2 (Sta. 32+754) looking west.



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



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

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.

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:

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

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_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

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 C1-1										1 of 1	METRIC					
W.P. 330-88-02		LOCATION		Co-ords: 4 923 518 N; 195 471 E Hwy 10, Sta. 31+340, o/s 14m Rt				ORIGINATED BY RM								
DIST 33 HWY 10		BOREHOLE TYPE		Continuous Flight Solid Stem Augers				COMPILED BY GD								
DATUM Geodetic		DATE		August 31, 2004				CHECKED BY								
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 × LAB VANE								
291.3	Ground Surface															
0.0	Peat, coarse fibrous trace sand, trace gravel Black		1	SS	WH**	↓*	291									
			2	SS	5		290									
289.9	Gravel, with sand, with silt, trace clay Compact Brown Moist	3	SS	20	289										47 27 23 3	
		4	SS	11												
288.4	Sand, with gravel, some silt Compact Brown Moist to dense	5	SS	20	288											
		6	SS	26	287										25 62 (13)	
		7	SS	33	286											
284.6	End of borehole						285									
6.7	<p>* 2004 08 31</p> <p>▼ Water level measured after drilling</p> <p>WH** Refers to penetration under weight of rods and hammer</p>															

RECORD OF BOREHOLE No C1-2

1 of 1

METRIC

W.P. 330-88-02 LOCATION Co-ords: 4 923 508 N; 195 453 E ORIGINATED BY RM
 DIST 33 HWY 10 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY GD
 DATUM Geodetic DATE August 18, 2004 CHECKED BY _____

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										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
294.4	Ground Surface							20	40	60	80	100								
0.0	Sand and gravel, trace silt					▼*	294										8 23 56 13			
	Brown Moist (FILL)																			
	Sandy silt, some gravel		1	SS	23									○						
trace gravel, trace wood					293															
	Brown/grey		2	SS	9									○						
292.2	Silt, with sand, some clay, trace gravel						292													
2.2	Very loose Dark Wet		3	SS	3										○					
	loose brown					291								○						
290.4	Sand, some silt, trace gravel					290														
	Loose Brown Wet to compact		5	SS	10										○					
289.0	Silty sand, trace gravel					289														
5.4	Compact Brown Wet					288										○				
			6	SS	22															
287.4	Sand and gravel, trace silt					287														
7.0	Dense Brown Wet															○				
286.2	End of borehole		7	SS	42															
8.2																				
			</																	

* 2004 08 18

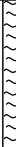



▼ Water level measured after drilling

RECORD OF BOREHOLE No C1-3

1 of 1

METRIC

W.P. 330-88-02 LOCATION Co-ords: 4 923 502 N; 195 442 E ORIGINATED BY RM
 DIST 33 HWY 10 BOREHOLE TYPE Manual Sampling + D.C.P.T. COMPILED BY GD
 DATUM Geodetic DATE August 25, 2004 CHECKED BY _____

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									
291.0	Ground Surface							20	40	60	80	100					
0.0	Peat, coarse fibrous with sand and gravel Dark brown		1	AS		▼*											
289.5			2	AS			290										
1.5	Sand, with silt some gravel, trace clay Loose Brown Wet to compact moist some silt Dense		3	AS			289										15 61 22 2
287.6			4	AS			288										10 78 (12)
287.4	End of borehole																
3.6	End of dynamic cone penetration test																
* 2004 08 25																	
▼ Water level measured after drilling																	

RECORD OF BOREHOLE No C2-1										1 of 1		METRIC					
W.P. 3017-03-01			LOCATION Co-ords: 4 924 270 N; 194 292 E Hwy 10, Sta. 32+750, o/s 11.6m Lt			ORIGINATED BY RM											
DIST 33 HWY 10			BOREHOLE TYPE Continuous Flight Solid Stem Augers			COMPILED BY GD											
DATUM Geodetic			DATE August 31, 2004			CHECKED BY											
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 × LAB VANE									
287.9	Ground Surface																
0.0	Peat, coarse fibrous		1	SS	1												
	Dark brown																
287.2																	
0.7	Sand and gravel, some silt		2	SS	17												
	Compact Brown Wet to dense																
			3	SS	20												
			4	SS	43												
			5	SS	30												
284.1																	
3.8	Silt, with sand, some clay, trace gravel																
	Compact Brown Moist to wet (TILL)		6	SS	26												
282.4																	
5.5	Sand, with gravel, with silt, trace clay																
	Dense Brown Moist		7	SS	37												
281.2																	
6.7	End of borehole																
<p>* 2004 08 31</p> <p> Water level measured after drilling</p>																	

RECORD OF BOREHOLE No C2-2										1 of 1		METRIC					
W.P. 3017-03-01			LOCATION Co-ords: 4 924 277 N; 194 294 E Hwy 10, Sta. 32+752, o/s 4.8 m Lt.			ORIGINATED BY RM											
DIST 33 HWY 10			BOREHOLE TYPE Continuous Flight Solid and Hollow Stem Augers			COMPILED BY GD											
DATUM Geodetic			DATE August 16, 2004			CHECKED BY											
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 × LAB VANE									
289.7	Ground Surface																
0.0	Sand and gravel, trace silt Brown Moist (FILL)		1	SS	11												
	Sand, some silt, trace gravel Wet with organics Grey		2	SS	3												
	Sand and gravel		3	SS	3												
286.0			4	SS	10												
3.7	Gravel, some sand, trace silt Compact Brown Wet to very dense		5	SS	17												
			6	SS	68												
283.0	End of borehole Refusal on probable boulders/cobbles																
6.7																	

RECORD OF BOREHOLE No C2-3

1 of 1

METRIC

W.P. 3017-03-01 LOCATION Co-ords: 4 924 295 N; 194 299 E
Hwy 10, Sta. 32+754, o/s 14m Rt ORIGINATED BY RM
 DIST 33 HWY 10 BOREHOLE TYPE Manual Sampling + D.C.P.T. COMPILED BY GD
 DATUM Geodetic DATE August 25, 2004 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
287.8	Ground Surface																
0.0	Peat, coarse fibrous		1	AS													
	Dark brown																
286.9	Sandy gravel, trace silt		2	AS													
0.9	Very loose to very dense		3	AS													
	Dark brown to brown		4	AS													
284.4	End of borehole																
3.4																	
	* 2004 08 25																
	Water level measured after drilling																

RECORD OF BOREHOLE No C3-1										1 of 1		METRIC					
G.W.P. 330-88-00			LOCATION			Co-ords: 4 921 832 N; 197 049 E Hwy 10, Sta. 28+984, o/s 5.5 m Rt.			ORIGINATED BY RM								
DIST 33 HWY 10			BOREHOLE TYPE			Continuous Flight Solid Stem Augers			COMPILED BY GD								
DATUM Geodetic			DATE			August 18, 2004			CHECKED BY								
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 × LAB VANE									
321.9	Ground Surface																
0.0	Sand and gravel, trace silt Brown Moist (FILL) Sandy silt, trace gravel		1	SS	24												
			2	SS	9												
			3	SS	4												
318.8	Peat, coarse fibrous		4	SS	5												
318.4	Dark brown																
3.5	Silt, with gravel, some sand, trace clay with occ. cobbles/ boulders Compact Brown Moist (TILL) to wet 200 mm layer of fine sand		5	SS	12												
	Dense		6	SS	42												24 20 49 7
315.0	End of borehole																
6.9	Refusal on probable boulders																
	* 2004 08 18 Water level measured after drilling																

RECORD OF BOREHOLE No C3-2

1 of 1

METRIC

G.W.P. 330-88-00 LOCATION Co-ords: 4 921 838 N; 197 049 E ORIGINATED BY RM
 DIST 33 HWY 10 BOREHOLE TYPE Manual Sampling + D.C.P.T. COMPILED BY GD
 DATUM Geodetic DATE August 24, 2004 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60	W _p W W _L				
319.3	Ground Surface													
0.0	Peat, coarse fibrous													
0.2	Dark brown Sand and silt, trace gravel, trace organics		1	AS										
318.1	Very Dark Wet loose brown		2	AS										
317.9	Sandy silt, some gravel													
317.4	Loose Brown Wet (TILL)		3	AS										
1.6	Sand, with gravel, trace to some silt													
	Compact Dark Wet to dense brown													
316.3	End of borehole													
3.0	End of dynamic cone penetration test													
	* 2004 08 24													
	Water level measured after drilling													

RECORD OF BOREHOLE No C3-3

1 of 1

METRIC

G.W.P. 330-88-00

LOCATION

Co-ords: 4 921 839 N; 197 046 E
Hwy 10, Sta. 28+991, o/s 9m Rt

ORIGINATED BY RM

DIST 33

HWY 10

BOREHOLE TYPE

Manual Sampling + D.C.P.T.

COMPILED BY GD

DATUM Geodetic

DATE

August 24, 2004

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
319.3	Ground Surface													
0.0	Peat, coarse fibrous with sand and gravel		1	AS		↓*	319							
318.7	Black													
0.6	Sand and silt, trace gravel, trace organics		2	AS			318							
318.3														
1.0	Very Dark Wet													
318.0	Loose brown		3	AS										25 24 44 7
1.3	Sandy silt, some gravel													
	Loose Brown Wet													
	to compact													
	Silt, with gravel, with sand, trace clay		4	AS			317							27 21 44 8
	Dense Light Moist													
	brown to wet													
316.3	(TILL)													
3.0	End of borehole													
	Refusal on probable cobbles/boulders													
	* 2004 08 24													
	Water level measured after drilling													

RECORD OF BOREHOLE No C3-4 1 of 1 METRIC																	
G.W.P. 330-88-00		LOCATION		Co-ords: 4 921 840 N; 197 040 E Hwy 10, Sta. 28+996, o/s 5.6 m Rt.				ORIGINATED BY RM									
DIST 33 HWY 10		BOREHOLE TYPE		Continuous Flight Solid Stem Augers				COMPILED BY GD									
DATUM Geodetic		DATE		August 18, 2004				CHECKED BY									
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 × LAB VANE									
321.9	Ground Surface																
0.0	Sand and gravel, trace silt Brown Moist (FILL)	X	1	SS	11												
	Sandy silt, trace gravel		2	SS	4												
319.1																	
2.8	Peat, coarse fibrous Dark brown	~	3	SS	3												
318.5																	
3.4	Sand, fine trace silt, trace gravel	•															
	Very loose Light Moist loose brown																
317.7																	
4.2	Sandy silt, some gravel, trace clay with occasional cobbles	•	4	SS	25												18 34 44 4
	Compact Light Wet to very brown dense (TILL)																
315.6			5	SS	50/ 8cm												
6.3	End of borehole Refusal on probable boulders																
	* Borehole dry on completion of drilling																

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES

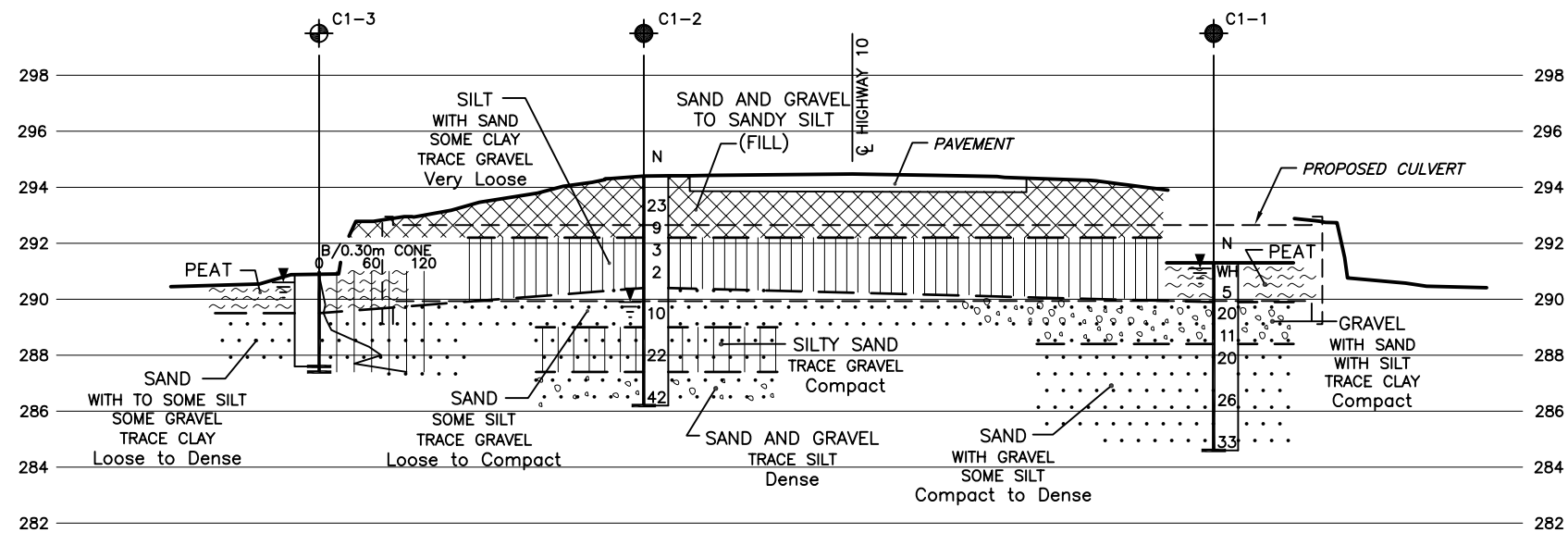
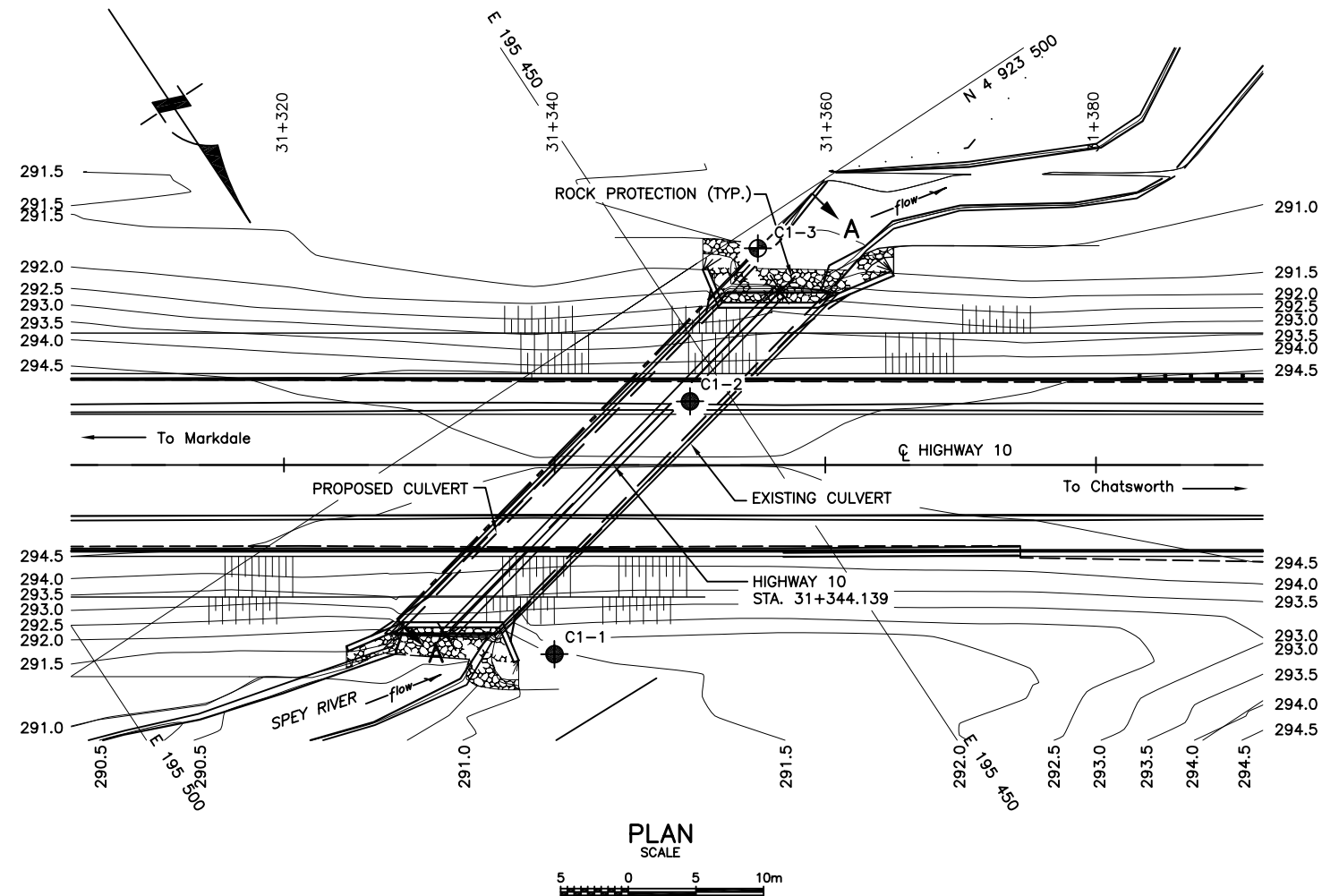
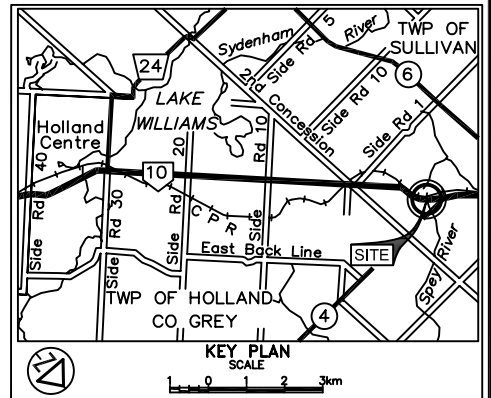
CONT No
WP No 330-88-02

HIGHWAY 10
CULVERT 1 - SPEY RIVER (SOUTH)
BOREHOLE LOCATIONS & SOIL STRATA



SHEET

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS



SECTION A-A
SCALE

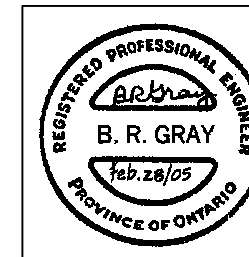
NOTE:

SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES.
REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF
SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY
TEST RESULTS.

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)		
	W L at time of investigation Aug 2004		
	Head		
	ARTESIAN WATER		
	Encountered		
	PIEZOMETER		

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C1-1	291.3	4 923 518	195 471
C1-2	294.4	4 923 508	195 453
C1-3	291.0	4 923 502	195 442

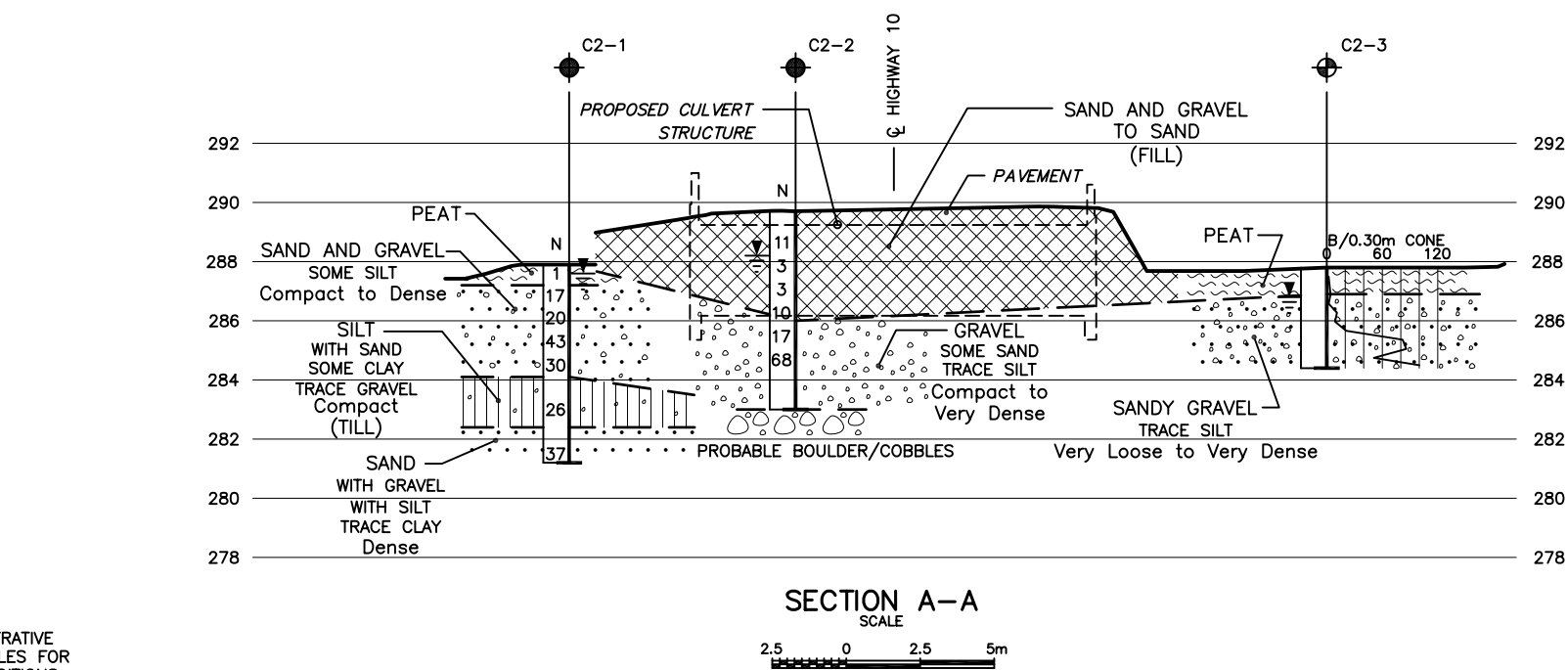
NOTE:
The boundaries between soil strata have been established
only at Borehole locations. Between Boreholes the
boundaries are assumed from geological evidence.



REVISIONS	DATE	BY	DESCRIPTION

Geocres No.			
HWY No	10	CHECKED	GD
SUBM'D	RM	DATE	FEB 28, 2005
DRAWN	MM	APPROVED	DWK
DIST	33	SITE	8-463-C
DWG	1		

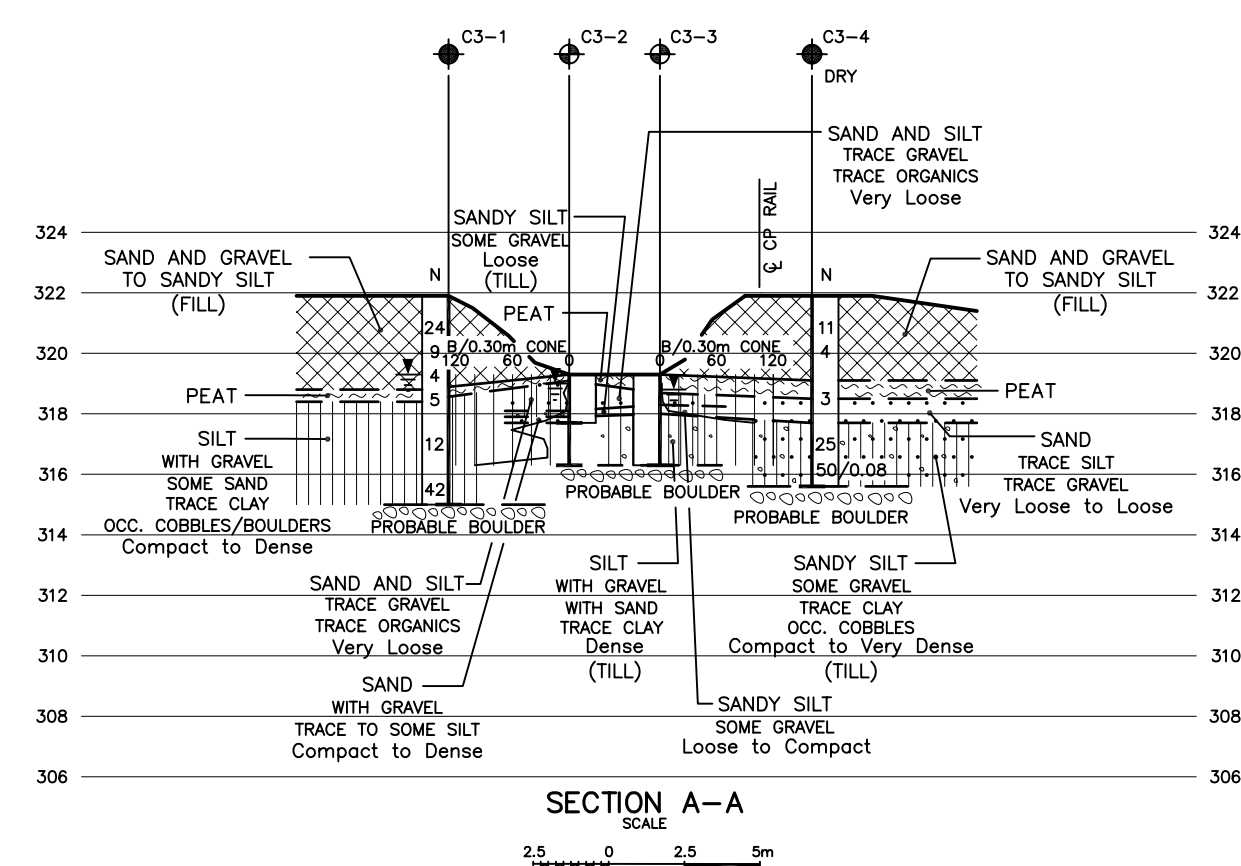
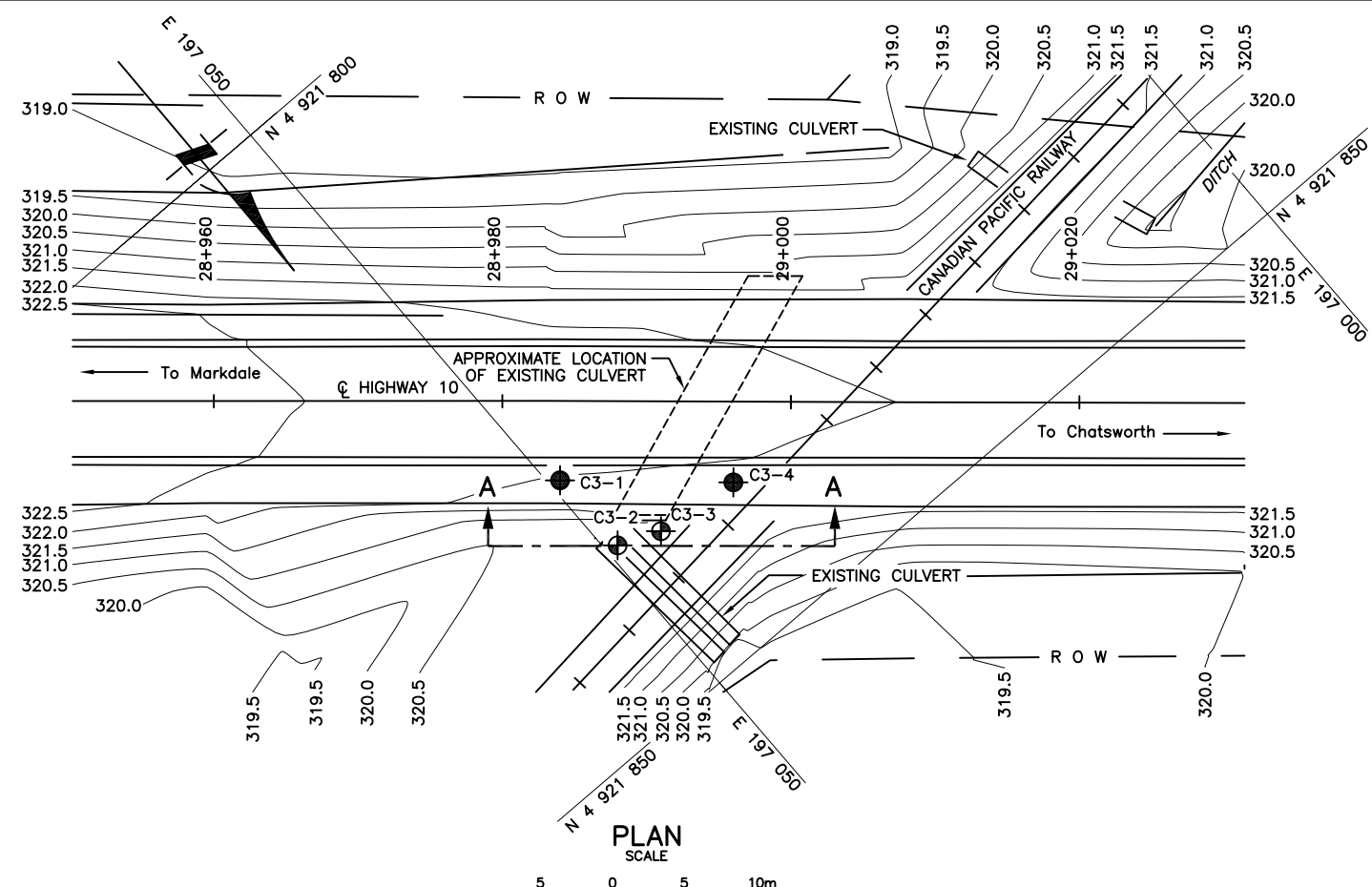
REF No E-S5706-320-01GA_Dec03_2004; December 2004



SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.


REVISIONS						
	DATE	BY	DESCRIPTION			
Geocres No.						
HWY No		10			DIST 33	
SUBM'D		RM	CHECKED	GD	DATE FEB 28, 2005	SITE 8-402-C
DRAWN		MM	CHECKED	BRG	APPROVED DWK	DWG 2

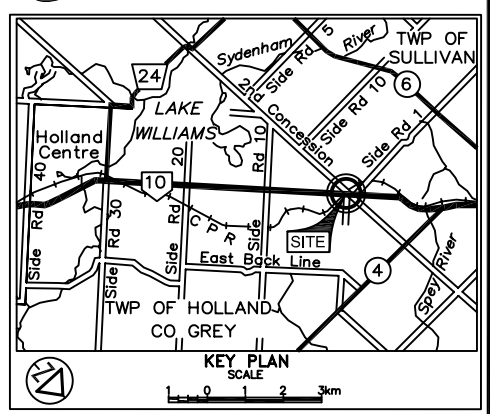
REF No E-S5706-330-01GA_Dec03_2004; December 2004










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

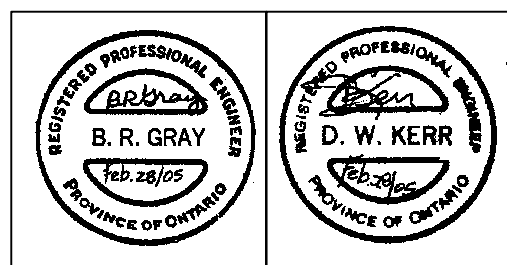
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES

CONT No GWP No 330-88-00	 SHEET
HIGHWAY 10 CULVERT 3 BOREHOLE LOCATIONS & SOIL STRATA	



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)		
	W L at time of investigation Aug 2004		
	Head		
	ARTESIAN WATER Encountered		
	PIEZOMETER		

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C3-1	321.9	4 921 832	197 049
C3-2	319.3	4 921 838	197 049
C3-3	319.3	4 921 839	197 046
C3-4	321.9	4 921 840	197 040



- 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	
Geocres No.			
HWY No	10	DIST	33
SUBM'D	RM	CHECKED	GD
DATE	FEB 28, 2005	SITE	
DRAWN	MM	CHECKED	BRG
APPROVED	DWK	DWG	3



FOUNDATION DESIGN REPORT

for

CULVERT REPLACEMENTS

REHABILITATION OF HIGHWAY 10, MARKDALE TO CHATSWORTH

G.W.P. 330-88-00

OWEN SOUND, ONTARIO

PETO MacCALLUM LTD.
16 FRANKLIN STREET SOUTH
KITCHENER, ONTARIO
N2C 1R4
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PML Ref.: 04KF049B
Index No.: 009FDR
Geocres No.: 40P8-139
February 28, 2005



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FIGURE 1 – LATERAL EARTH PRESSURE DISTRIBUTION:
SINGLY-BRACED CUTS IN COHESIONLESS SOILS

FIGURE 2 – LATERAL EARTH PRESSURE DISTRIBUTION:
MULTI-BRACED CUTS IN COHESIONLESS SOILS

FIGURE 3 – GENERAL RECOMMENDATIONS REGARDING
UNDERPINNING OF FOUNDATIONS/UTILITIES
LOCATED CLOSE TO EXCAVATION

Peto MacCallum Ltd.

C O N S U L T I N G E N G I N E E R S

FOUNDATION DESIGN REPORT

for

Culvert Replacements

Rehabilitation of Highway 10, Markdale to Chatsworth

G.W.P. 330-88-00

Owen Sound, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed replacement of two culverts and the wing walls at the east end of another culvert while rehabilitating the approximate 25 km long section of Highway 10 that extends from the Markdale north limits northerly to the junction of Highways 6 and 10 in Chatsworth near Owen Sound, Ontario. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

For the purposes of this report, the culverts have been given reference numbers 1 to 3. The location, type and proposed works at each culvert are as follows:

CULVERT No.	SITE No.	LOCATION (HIGHWAY 10 CHAINAGE)	EXISTING CULVERT TYPE	PROPOSED WORKS
1	8-463-C	Station 31+344 Spey River culvert located south of Grey County Road 40	4.9 x 1.5 m Concrete Non-Rigid Frame Open Footings	Replacement with cast-in-place 5.0 x 2.0 m reinforced concrete box culvert
2	8-402-C	Station 32+754 Spey River culvert located south of the south limit of Chatsworth	6.1 x 1.8 m Concrete Non-Rigid Frame Open Footings	Replacement with cast-in-place 6.1 x 2.1 m reinforced concrete box culvert
3	—	Station 28+994 Culvert located south of former CPR rail line	1.2 x 0.9 m Concrete Non-Rigid Frame	Replacement of wing walls at east end

This report pertains to the proposed culvert replacements and associated bedding/backfill zones.

Based on the road grade and ground surface elevations at the toe of slope at each culvert location, the embankment fill height at the locations of the culverts ranges from 2.0 to 3.5 m.

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The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations was generally consistent and typically comprised gravelly/sandy/silty fill and/or coarse fibrous peat underlain by cohesionless soils varying broadly in granulometric composition between gravel and silt. The groundwater level measured during the field investigation conducted in August 2004 was typically 1 to 2 m above the proposed subgrade level of the culvert.

2. FOUNDATIONS

2.1 Culvert 1 – Spey River (South), Station 31+344

The invert of the proposed culvert is indicated to be near elevation 290.3 (ref.: Preliminary General Arrangement drawing 'Highway 10. Spey River Culvert (South)' prepared by MRC in November 2004). The design subgrade level of the granular base is interpreted to be near elevation 289.8.

The subgrade material below this level revealed in boreholes C1-1 and C1-2 comprised compact to dense sandy/gravelly soils. The compact sand in borehole C1-3 was encountered below the inferred design invert level, at approximate elevation 289.5. The high groundwater level at the time of the field investigation was at elevation 291.1.

The embankment height at this location is about 3.5 m.

It is considered that the compact to dense sand exposed in the boreholes at and below the design subgrade is capable of supporting the stress imposed by the embankment and culvert foundation.

The peat deposit and loose to very loose soils revealed above the subgrade should be excavated prior to placement of the granular base below the culvert and replaced with engineered fill.

Fill placed under the culvert should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP 105S10. The granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.



It is noted that the depth of excavation will be about 2 m beyond the toe of the existing embankment and 5 m within the existing embankment fill.

Further, the excavation will be some 2 m below the groundwater level and extend into the existing embankment. A positive groundwater control system will be needed and bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of this report.

The culvert foundations constructed on the compact to dense sandy/gravelly soils should be designed using the following geotechnical resistance for the 5 m wide box culvert:

Factored Geotechnical Resistance at ULS = 550 kPa
Geotechnical Resistance at SLS = 175 kPa

2.2 Culvert 2 – Spey River (North), Station 32+754

The invert of the proposed culvert is indicated to be near elevation 286.5 (ref.: Preliminary General Arrangement drawing 'Highway 10. Spey River Culvert (North)' prepared by MRC in November 2004). The design subgrade level for the Granular A base is interpreted to be near elevation 286.2.

The subgrade material below this level revealed in the boreholes comprised compact to dense sandy/gravelly soils. The high groundwater level at the time of the field investigation was at elevation 288.2.

The embankment height at this location is about 2 m.

Construction of the foundations for the culvert replacement on the compact sandy/gravelly soils is considered to be feasible.

Fill placed under the culvert should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP 105S10. The granular fill zone should



extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.

It is noted that the depth of excavation will be about 2 m beyond the toe of the existing embankment and 4 m within the existing embankment fill.

Further, the excavation will be some 2 m below the groundwater level and extend into the existing embankment. A positive groundwater control system will be needed and bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of this report.

The culvert foundations should be designed using the following geotechnical resistance for the 6.1 m wide box culvert:

Factored Geotechnical Resistance at ULS	=	800 kPa
Geotechnical Resistance at SLS	=	200 kPa

2.3 Culvert 3 – Station 28+994

Replacement of the wing walls at the east end of the existing culvert is planned. The centreline profile drawings along Highway 10 (provided by MRC in May 2004) indicate that the invert of the culvert is near elevation 318.5.

Based on the borehole data, the invert level of the existing culvert and the concrete culvert base thickness, it is believed that the existing culvert is founded near elevation 318.0 on compact native silt/sand. The groundwater level was at approximate elevation 319.0 at the time of the field investigation.

The foundations of the replacement wing walls should be founded at the same level as the existing wing walls. Construction of the wing wall foundations at the east end of the culvert on the compact silt/sand following excavation of the fill, peat and very loose to loose silty/sandy soils to expose the competent material is considered to be appropriate.



Fill placed under the wing walls to accommodate any variation in the level of the native surface should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP 105S10. The granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 45° to the horizontal.

The foundations of the wing walls should be designed using the following geotechnical resistance for a 1.5 m wide footing:

Factored Geotechnical Resistance at ULS	=	350 kPa
Geotechnical Resistance at SLS	=	150 kPa

2.4 General Comments

The resistance at SLS allows for 25 mm of settlement of the founding medium. Differential settlement along the culvert length is expected to be less than 75% of this value.

Preparation of the subgrade for construction of the culverts and wing walls should be performed and monitored in accordance with SP 902S01 (December 2001). This should include site review by geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the engineered fill, if required.

Fill placed under the culvert to accommodate any variation in the level of the native surface and/or replace any peat/organic deposits extending below the design founding level should comprise granular material compacted to at least 95% of the target density in conformance with OPSS 501 and SP 105S10. The limit of the granular fill zone should extend beyond the culvert base a minimum 0.5 m and down to the subgrade at 1 horizontal to 1 vertical (1H:1V) and be established by a site specific survey.

Subgrade preparation, cover backfill and frost treatment for the culverts should be carried out in accordance with Ontario Provisional Standards – OPSD 803.010 and OPSS 422. The bedding material for a precast box culvert, if employed, should comprise at least 150 mm of Granular A.



A frost penetration depth of 1.6 m should be employed.

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with the Ontario Provincial Standard specifications and drawings (OPSD 803.010, OPSS 3504 and OPSS 422).

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) restricted to minimize the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to OPSD 808.010 for additional requirements for operation of heavy equipment near the culverts.

The culverts must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure imposed by the backfill adjacent to the culvert walls.

The lateral earth and water pressure, p (kPa), should 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:

$$p = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p$$

where p = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of free draining granular material above the design water level (kN/m³)

γ' = unit weight of submerged granular material below the design water level (kN/m³)

γ_w = unit weight of water
= 9.8 kN/m³

h_1 = depth below final grade (m), above design water level

h_2 = depth below design water level (m)

q = any surcharge load (kN/m²)

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



The following parameters are recommended for design:

PARAMETER	GRANULAR A	GRANULAR B TYPE II	EXCAVATED GRANULAR MATERIAL
Angle of Internal Friction (degrees)	35	35	30
Unit Weight (kN/m ³)	22.8	22.8	20.0
Coefficient of Active Earth Pressure (K_a)	0.27	0.27	0.33
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.43	0.50
Coefficient of Passive Earth Pressure (K_p)	3.69	3.69	3.00

The design should consider both the maximum water level in the stream and the stabilized groundwater level condition. The groundwater level measured at the respective culvert locations was noted previously. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydraulic engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls. The horizontal force imposed on the walls of the box culverts will be resisted by the base slab.

A weeping tile system and/or weep holes should be installed at the wing walls to minimize the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 μ m according to OPSS 1860) placed 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.

4. EXCAVATION AND GROUNDWATER CONTROL

The groundwater level observed in the boreholes at the time of the field investigation was 1 to 2 m above the anticipated depth of excavation. Since the sandy/gravelly soils at the site are relatively pervious, dewatering with conventional sump pumps may not be sufficient and wells or well points may be required prior to excavation to provide a stable excavation base.



Excavation to the anticipated founding level of the culverts is expected to extend some 2 m below the highest observed groundwater level through the pavement structure, fill, peat and native deposits of gravel, sand and silt. Subject to adequate groundwater control, excavation of the soil should be feasible using conventional equipment. The in situ materials are typically classified as Type 3 soils according to Occupational Health and Safety Act criteria and temporary cut slopes inclined at 1H:1V should be employed.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as draining and/or diversion of the stream should be sufficient. Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

The dewatering system should be installed by a specialist dewatering contractor. The design of the dewatering system should be left to the Contractor's discretion so that the system meets a performance specification to maintain and control the groundwater at least 0.6 m below the excavation base in order to provide a stable excavation.

It is recommended that the work be carried out during the dry summer months to minimize the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

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

It is anticipated that 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, is 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 sandy/gravelly soils. The unfactored pull-out resistance (R) of anchors grouted in cohesionless material can be estimated using the following equation:

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

where σ'_z = effective vertical stress at midpoint of fixed length of anchor (kN/m^2)

= γh_1 if total anchorage length is above the design groundwater level
 = $\gamma h_1' + \gamma' h_2$ if design groundwater level is above the anchor

γ = bulk unit weight of soil above design groundwater level
 = 20 kN/m^3

γ' = buoyant unit weight of soil below design groundwater level
 = 10.2 kN/m^3

h_1 = depth below ground surface to midpoint of anchor (m)

h_1' = depth below ground surface to design groundwater level (m)

h_2 = depth below design groundwater level to midpoint of anchor (m)

A_s = circumference of fixed length of anchor (m)

L_s = effective embedment length of anchor (m)

K_f = anchorage coefficient
 = 0.8 for compact sand/silt
 = 2.0 for compact gravel, sandy gravel, sand and gravel

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:

	<u>Movement (% of Excavation Depth)</u>
Lateral Movement	
Braced Excavation	0.20
Anchored Wall	0.10
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.

5. EMBANKMENT FILL

It is anticipated that the embankment height at the culvert locations will not exceed 4 m.

The anticipated subgrade for the embankments typically comprises compact gravel, sand or silt. Peat was encountered in the boreholes drilled beyond the toes of the existing embankment as well as below the fill in both boreholes advanced on the road shoulder at Culvert 3. The peat and other excessively loose, soft, organic or otherwise deleterious materials within the limits of the embankment fill should be subexcavated prior to placement of the fill.

The embankment side slopes should be inclined no steeper than 2H:1V. A vegetation cover or other measures should be established to control surface runoff and minimise erosion of the embankment slopes.



It is considered that the subgrade soil is capable of supporting the embankment. Settlement of the embankment material is expected to be in the order of 25 mm. The settlement is expected to occur as the fill is placed and be essentially complete within one month following placement of the fill.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series (particularly OPSD 803.030 and 803.020 for open and box culverts) to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. The cut-off walls should extend to a depth at least equal to the fluctuation of the water level at each culvert location to prevent flow below the culvert that could erode the bedding material as well as extend laterally to protect the granular material. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511 and 1004 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements (length and width of the aprons at the inlet/outlet of the culvert as well as the rock size, apron thickness and height of erosion protection on the embankment slope) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by a hydraulic engineer. A non-woven, Class II geotextile with an FOS of 75-150 μm , according to OPSS 1860, should be placed below the rip-rap to minimize the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the wing walls should be topsoiled and seeded (as per OPSS 570 and 572) as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per OPSS 571) shall be placed where it currently exists with a view to aesthetics. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
Sand/Sandy Gravel	0.1



7. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. D.W. Kerr, MEng, P.Eng., Chief Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "Grigory O. Degil".

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



A handwritten signature in black ink, appearing to read "Dennis W. Kerr".

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



A handwritten signature in black ink, appearing to read "Brian R. Gray".

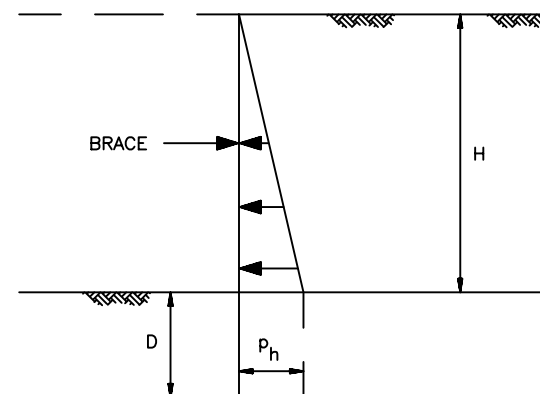
Brian R. Gray, MEng, P.Eng.
MTO Designated Contact



GD/DWK/BRG-gd:lr-mi

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. If groundwater table is well above base of excavation and/or artesian conditions exist, local lowering of the groundwater level will be necessary to prevent bottom heave/piping of the base of the excavation.
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 = 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

γ = 20.0 kN/m³

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

LATERAL EARTH PRESSURE DISTRIBUTION

SINGLY-BRACED CUTS IN COHESIONLESS SOILS

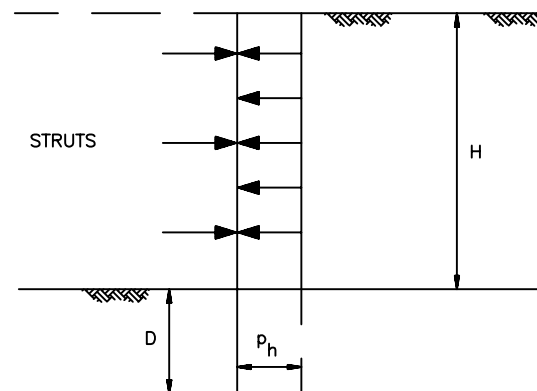


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NOTES

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. If groundwater table is well above base of excavation and/or artesian conditions exist, local lowering of the groundwater level will be necessary to prevent bottom heave/piping of the base of the excavation.
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, 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.
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EARTH PRESSURE DIAGRAM

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

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

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

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

LATERAL EARTH PRESSURE DISTRIBUTION

MULTI-BRACED CUTS IN COHESIONLESS SOILS



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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.

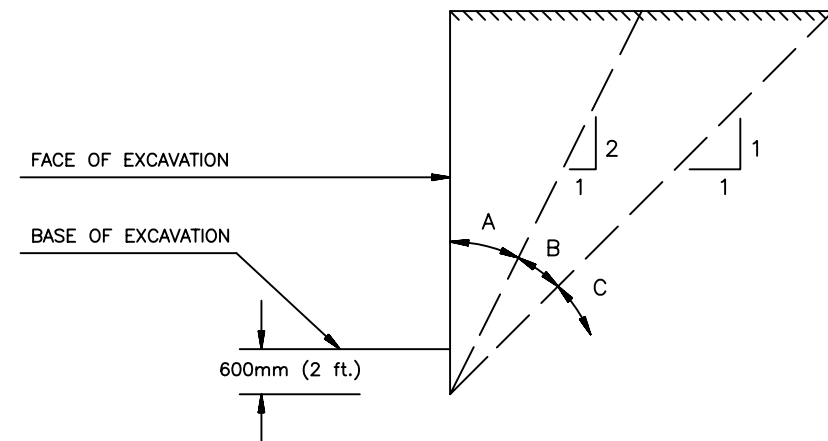
ZONE B:

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.

STANDARD DRAWING

GENERAL RECOMMENDATIONS REGARDING UNDERPINNING OF FOUNDATIONS/UTILITIES
LOCATED CLOSE TO EXCAVATION



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