

GEOCREST No. 30M4-77DIST. 4 REGION                     W.P. No. 7-91-00CONT. No.                     W. O. No.                     STR. SITE No.                     HWY. No. 6 NewLOCATION Culvert Crossing  
S of Hwy 403No of PAGES -                     

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.                     REMARKS:



Ministry  
of  
Transportation

FILE

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## **FOUNDATION DESIGN SECTION**

**foundation  
investigation and  
design report**

**ENGINEERING MATERIALS OFFICE**  
**FOUNDATION DESIGN SECTION**

WP	7-91-00	REGION	Central
HWY	6N	STR SITE	-

Proposed Culvert and Culvert Extensions  
Hwy. 6N - Highway 403 to Highway 53

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GEOCRES 30M4-77

DATE APR 25 1995

# FOUNDATION INVESTIGATION REPORT

For

Proposed Culvert and Culvert Extensions

Hwy 6N - Highway 403 to Highway 53

W.P. 7-91-00

W.P. 7-91-00, Hwy 6N, Central Region

## INTRODUCTION

This report summarizes the results of a Foundation investigation at the above mentioned site. The investigation was carried out at the request of Central Region Structural Section.

## SITE DESCRIPTION

The site is located between Hwy 403 and Hwy 53 in the Regional municipality of Hamilton-Wentworth in the Township of Ancaster where a new Hwy 6N will be constructed to join Hwy 403 and Hwy 53. Land use in the area is undeveloped. There is a sand and gravel pit at the site which appears to be abandoned. In some areas the site is heavily covered with trees.

The topography across the site is quite undulating particularly near Hwy 403 in the vicinity of the pit, with an overall slope towards the northwest.

The site lies within the physiographic region known as Norfolk Sand Plain. The sands and silts of this region were deposited as a delta in glacial lakes Whittlesy and Warren. A great discharge of meltwater from the Grand River area entered the lakes between the ice front and the moraines to the northwest, building the delta from west to east as the glacier withdrew (The Physiography of Southern Ontario, Third Edition by L.J. Chapman and D.F. Putnam, 1984).

## INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out in two stages. In the first stage three boreholes (BH 1 through BH 3) were drilled on October 6, 1994. Later more culverts and culvert extensions were added to the project and an additional six boreholes (BH 4 through BH 9) were drilled between December 6 and 9, 1994. The boreholes were advanced to depths ranging from 8.1 to 9.6m below ground surface. Borehole No. 1 was redrilled to install a piezometer to monitor accurate ground water level. A piezometer was also installed in BH 5 to monitor the groundwater level over a long period of time.

### Silt

Underlying the clayey silt deposit this non cohesive deposit was encountered only in boreholes BH 2 and 3. The top elevation of this deposit ranged from 238.3m to 239.7m. The deposit was 0.7m to 4.1m thick. The Standard penetration N-values within this layer ranged from 4 to 18 blows which suggests that the material is very loose to compact.

### Silty Sand to Sand

This non cohesive material was encountered in all boreholes as the major soil deposit at the site. At some locations this deposit was overlain by clayey silt and silt layers (BH 2,3,7,8 and 9) and at some locations it was encountered right below the ground surface (BH 1,4,5 and 6). The top elevation of this layer ranged from 234.2m to 242.7m. The boreholes were advanced to depths ranging from 2.6m to 9.6m within this deposit. The full thickness of this deposit was not explored. The Standard Penetration N-values within this deposit ranged from 1 to 40 blows. However, average N-values above elevation 236m was 6 blows and below elevation 236 was about 15 blows. This suggested that in general, the deposit is very loose to dense but on average loose to compact.

### Groundwater Conditions

Groundwater was encountered in all boreholes. Groundwater elevation ranged from 234.3m (BH 4) to 239.4 (BH 9). The groundwater depth below ground level ranged from 0.6m (BH 9) to 6.5m (BH 4). The groundwater is subject to seasonal fluctuation.

## DISCUSSION AND RECOMMENDATIONS

### General

It is proposed to construct two 135m and 58.5m long concrete box culverts, a 73m long twin concrete pipe culvert under Highway 6N between Highway 403 and Hwy 53 in Ancaster. An existing 23.1m long CSP culvert under Hwy 53 is also proposed to be extended at both ends in order to widen Hwy 53.

The 135m long box culvert will be constructed under Ramps E-E,W; E,W-E and future ramps E-S, S-W and S-E. The culvert will be 4m wide and 2m high. The invert elevations at the east and west ends of the culvert will be 239.5m and 237.5m respectively. The height of the embankment will be about 10.5m. The side slopes of the embankment will be 2H:1V.

The other 58.5m long box culvert will be constructed under Ramp W-S. The culvert will be 4m wide and 2m high. The invert elevations at the east and west ends of the culvert will be 236.8m and 236.6m respectively. There is an existing pond at the west end of the proposed culvert. Water level in the pond is at 237.9m. The height of the embankment above the culvert obvert will be about 9m.

The twin concrete pipe culverts under Ramp W-S near Hwy 403 will be 1.8m in diameter and 73m long. The invert elevation will be 235.7m and 235.5 m at the southeast and northwest ends respectively. The flow will be in the northwest direction.

The existing culvert under Hwy 53 where Hwy 6N will connect to Hwy 53 is a 2.6m diameter CSP culvert. The existing culvert is about 23m long. The proposed extension to this culvert will be 5m on the north side and 5.5m on the south side. The culvert invert elevation will be 238.3m. The fill height over the culvert extension for the Hwy 53 widening will be less than 1m.

### Structural Foundations

At some locations the culvert will be constructed below water table. Dewatering at the site is not feasible (see the dewatering section). It is recommended that a precast type culvert should be installed instead of a cast in place type culvert.

The soil at the proposed culvert invert elevation is a competent native soil. The culverts can be founded on spread footing on granular bedding (see 'Bedding' section for details) constructed on silty sand to sand deposit.

The depth of retaining walls should be determined based on frost depth and scour depth whichever is greater. Frost depth at the site is 1.2m. The retaining wall can be constructed on spread footing constructed on a 600 mm granular material in the same manner as the culvert bedding.

The following values can be utilized for the design of proposed culvert extension and the retaining wall foundations for the purposes of the O.H.B.D.C.

Bearing Capacity at U.L.S. = 300 kPa

Bearing Capacity at S.L.S. = 50 kPa

The U.L.S. value given is for a  $\phi = 28^\circ$ , The value of U.L.S. is subject to increase when the value of  $\phi$  increases with the surcharge load. U.L.S. is not a concern in design. The value of S.L.S. i.e. 50 kPa is for a 25mm settlement. For a design pressure of 200 kPa, settlement in the order of 100mm is anticipated. If the retaining wall is designed for 100 kPa, the settlement will be in the order of 50mm. Settlement at the twin culvert will be about 75mm and at the culvert extension under Hwy 53, the settlement will be about 25mm.

### Lateral Pressure

The following properties are recommended for the calculation of lateral pressure:

Granular 'A'	$\gamma = 22.8 \text{ kN/m}^3$ , $\phi = 35^\circ$ , $K_o = 0.43$ , $K_a = 0.27$
Granular 'B'	$\gamma = 21.2 \text{ kN/m}^3$ , $\phi = 30^\circ$ , $K_o = 0.50$ , $K_a = 0.33$
Native Soil (Sand)	$\gamma = 21.0 \text{ kN/m}^3$ , $\phi = 30^\circ$ , $K_o = 0.50$ , $K_a = 0.33$

If the structure is to be designed as a rigid frame then the coefficient of earth pressure at rest ( $K_o$ ) should be used. For structural elements rigidly connected to the concrete box culvert, at rest condition ( $K_o$ ) should be used to calculate the lateral pressure.

Active condition ( $K_a$ ) will govern for the calculation of pressure against retaining wall, if any.

### Lateral Resistance for Retaining Walls

Sliding resistance between the base of retaining wall footings and underlying material should be calculated assuming an angle of internal friction of  $\phi = 26^\circ$ . Lateral resistance design will not be required for the culverts.

### Stability and Settlement

No deep seated stability problems are anticipated for the proposed height of permanent embankment. The permanent embankment side slope should be at 2H:1V. For surface stability a 2m wide berm should be incorporated in the design so that no uninterrupted slope is higher than 6m. Under the concrete box culverts settlement up to 100mm should be anticipated. The settlement would be instantaneous and would take place during construction of the embankment. For the large concrete box culvert, it is recommended that the fill for the future ramps should also be placed at the same time when the new ramps are constructed to minimize the differential settlement.

Settlement under the twin pipe culvert will be in the order of 75mm and under the culvert extension under Hwy 53 negligible.

## CONSTRUCTION CONSIDERATION

### Temporary Diversion

A temporary diversion of the water course would be required to facilitate the construction of the 1.8m  $\phi$  twin pipe culvert and possibly the culvert extension of 2.6m  $\phi$  CSP culvert under Hwy 53. During our site visits the culvert under Hwy 53 was dry.



### Dewatering

At one concrete box culvert location the water table was recorded above the proposed invert elevation. Due to seasonal fluctuation, the water table at other concrete box culvert may also rise thus making the excavation below water table difficult. If the culverts are to be a cast in place type, then dewatering will be required. Due to non-cohesive type of soil massive dewatering will be required to lower the water table which will be very expensive. It is recommended that the construction should take place without dewatering. The method of construction is outlined in the 'Bedding' sections.

### Excavation

Excavation up to 6m deep will be required for the construction of the culverts. Temporary excavation can be stable at 1.5H:1V above water table and 2H:1V below water table.

### Bedding

Normally bedding for box culvert over a competent subgrade is not required. However, due to weak subgrade and high water table bedding under concrete box culvert will be required. The bedding should consist of 0.6m thick crushed stone. Excavation and subsequent backfilling operation will be carried out below water table. Where water table is above proposed invert elevation, backfilling will be carried out using 19 mm crushed stone bringing it up to a level at least 0.5m above the groundwater level. The bedding material should be properly compacted. The compacted granular material above the invert elevation should be then excavated to bring the grade to the invert level.

For the 1.8m  $\phi$  twin concrete pipe culvert, bedding should be designed as per OPSD - 802.03 class B with a modified bedding thickness of 300mm Granular 'A' or 19mm crushed stone.

For the 2.6m  $\phi$  CSP culvert extension the bedding should be designed as per OPSD - 802.02 Type 5 with a bedding thickness of 300 mm granular A or 19mm crushed stone.

### Weeping Holes

To relieve excess hydrostatic pressure behind the wall, weeping holes should be provided at 6m centre to centre.

### Construction Joints

The construction joint will be required between the precast concrete segments. The construction joints should be able to accommodate differential settlement of up to 50 mm and provide proper seal.

### Backfilling

For the two concrete box culverts, above the bedding level backfilling to the culverts should consist of suitable compacted material in accordance with MTO Standard. For fill below groundwater level and within frost depth Granular A or B should be used. The backfilling will be as per OPSD - 803.06.

For the 1.8m  $\phi$  twin pipe culvert the backfilling should be as per OPSD - 803.03 Case 1 (frost line above top of pipe).

For the 2.6m  $\phi$  CSP culvert extension under Hwy 53, above the bedding level, the cover material should consist of granular material as detailed in OPSD 803.03 Case 2 (frost line between bottom of bedding and top of pipe). The granular material should be compacted in accordance with MTO standards. For fill below groundwater elevations or below roadway within frost line, it is recommended that Granular 'A' or 'B' should be used. Backfill operations should be carried out simultaneously on both sides of the culverts as per MTO standard.

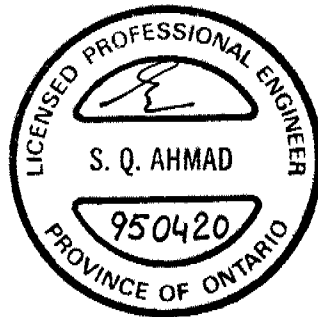
### Erosion Protection

If cutoff walls are not incorporated in the design, clay seal will be required at the inlet to prevent any piping action in the embankments. A seal of cohesive material (CI-CH clay) with a minimum thickness of 0.6m should be constructed at the culvert inlet. The seal should extend a minimum of 2m on each side of the culvert inlet and from the high water level down the embankment to the creek bed. The material for the clay seal should be as per OPSS 1205. If suitable clay is not available then the clay mixture should be prepared as per OPSS 1205.05.03.

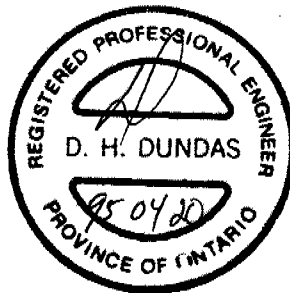
The erosion protection at the inlet and outlet may consists of a 0.6m thick rock blanket consisting of 300 mm size rock. It should extend from the high water level to the toe of the slope and at least 2m along the creek bed. I transverse direction, the erosion protection should extend a minimum of 5m on each side of the culvert.

### Miscellaneous

The fieldwork for this project was carried out under the supervision of Sameh Asaad, a trainee Engineer and Ken Ahmad, Foundation Engineer, using equipment owned and operated by K & S Drilling. The report was prepared by K. Ahmad, Foundation Engineer, reviewed and approved by D. Dundas, Senior Foundation Engineer.



K.S.Q. Ahmad, P. Eng.  
Foundation Engineer



D.H. Dundas, P. Eng.  
Senior Foundation Engineer

# RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 785 156.0; E 266 647.0 ORIGINATED BY SA  
DIST 4 HWY 6N BOREHOLE TYPE Hollow Stem Auger COMPILED BY KA  
DATUM Geodetic DATE 1994 12 06 CHECKED BY DD

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80	100	W <sub>p</sub>	W		
240.8	Ground Surface															
0.0	Silty Sand to Sandy Silt Brown, Dry to Wet V. Loose to V. Dense		1	SS	8											
			2	SS	7											
			3	SS	4											
			4	SS	72											
			5	SS	35											
			6	SS	27											
			7	SS	35											
			8	SS	40											
			9	SS	13											
			10	SS	12											
231.2																
9.6	End of Borehole															

# RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 784 818.0; E 266 750.0 ORIGINATED BY SA  
DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
DATUM Geodetic DATE 1994 12 07 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
240.0	Ground Surface																
0.0	Silty Sand to Sandy Silt Trace of Gravel Grey, Wet Loose to compact		1	SS	4												
			2	SS	7												
			3	SS	5												
			4	SS	31												
			5	SS	9												
			6	SS	10												
			7	SS	8												
			8	SS	9												
			9	SS	15												
			10	SS	16												
230.4																	
9.6	End of Borehole																

# RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 785 181.0; E 266 417.5 ORIGINATED BY SA  
DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
DATUM Geodetic DATE 1994 12 08 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
237.7	Ground Surface																
0.0	Silty Clay With Some Sand Brown, Moist Soft		1	SS	3		237										
			2	SS	2		236										
235.6			3	SS	2		235										
2.1	Silty Sand to Sandy Silt Brown to Grey Moist to Wet V. Loose to Compact		4	SS	1		234										
			5	SS	11		233										
			6	SS	7		232										
			7	SS	8		231										
			8	SS	8		230										
			9	SS	6		229										
			10	SS	5												
228.1																	
9.6	End of Borehole																

# RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords: N 4 785 219.0; E 266 350.0 ORIGINATED BY SA  
 DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
 DATUM Geodetic DATE 1994 12 08 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40						60	80
236.2	Ground Surface															
0.0	Clayey Silt With Some Sand Brown, Moist Soft		1	SS	3											
235.0			2	SS	3											
1.2			3	SS	6											
			4	SS	3											
			5	SS	8											
	Silty Sand to Sandy Silt Brown to Grey Moist to Wet V. Loose to Compact		6	SS	19											
			7	SS	13											
			8	SS	7											
			9	SS	6											
			10	SS	13											
226.6																
9.6	End of Borehole															

# RECORD OF BOREHOLE No 9

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 784 787.0; E 266 780.0 ORIGINATED BY SA  
 DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
 DATUM Geodetic DATE 1994 12 09 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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 20 40 60 80 100					WATER CONTENT (%) 10 20 30				
240.0	Ground Surface																
0.0	Clayey Silt With Sand, Organics Brown, Wet Soft		1	SS	4		239										
238.8			2	SS	8		238										
1.2			3	SS	7		237										
			4	SS	26		236										
			5	SS	33		235										
			6	SS	26		234										
			7	SS	7		233										
			8	SS	17		232										
231.9			9	SS	11												
8.1	End of Borehole																



## 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 (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

SS SPLIT SPOON	TP THINWALL PISTON
WS WASH SAMPLE	OS OSTERBERG SAMPLE
ST SLOTTED TUBE SAMPLE	RC ROCK CORE
BS BLOCK SAMPLE	PH TW ADVANCED HYDRAULICALLY
CS CHUNK SAMPLE	PM TW ADVANCED MANUALLY
TW THINWALL OPEN	FS FOIL SAMPLE

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_r$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	kn/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	kn/m <sup>3</sup>	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	kn/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	m <sup>3</sup> /s	RATE OF DISCHARGE
$\gamma_d$	kn/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	kn/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m <sup>3</sup>	SEEPAGE FORCE
$\gamma'$	kn/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL						

## **APPENDIX**

# RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 785 194.0, E 266 691.0 ORIGINATED BY BB  
DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
DATUM Geodetic DATE 1994 10 06 CHECKED BY DD

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20						40	60	80	100
242.7	Ground Surface																
0.0			1	SS	9												
			2	SS	7												
			3	SS	4												
			4	SS	18												
			5	SS	22												
			6	SS	16												
			7	SS	13												
233.1																	
9.6	End of Borehole																
	<p>Note: Original Borehole was drilled to depth 8.1 m on 1994 10 06 The Borehole was redrilled on 1994 12 08 to depth 9.6 m to install a piezometer.</p>																
	<p>1995 01 30 * GROUND WATER CONDITIONS</p> <table border="1"> <tr> <th>PIEZO. NO.</th> <th>GROUND WATER ELEVATION (Metres)</th> </tr> <tr> <td>1</td> <td>237.42</td> </tr> </table>	PIEZO. NO.	GROUND WATER ELEVATION (Metres)	1	237.42												
PIEZO. NO.	GROUND WATER ELEVATION (Metres)																
1	237.42																

# RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 785 229.0; E 266 754.0 ORIGINATED BY BB  
 DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
 DATUM Geodetic DATE 1994 10 06 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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 80 100					
241.0	Ground Surface													
0.0	Clayey Silt to Silt Some Sand, Tr. Organics Brown, Moist, Firm		1	SS	8		240							
239.7														
1.3	Silt, Trace Sand, Trace Clay Brown, wet, Loose		2	SS	8									0 0 92 8
239.0														
2.0			3	SS	6		239							
			4	SS	2		238							
			5	SS	2		237							0 78 18 4
			6	SS	4		236							
	Silty Sand to Sand Trace Clay, Brown Very Loose to Compact		7	SS	20		235							
							234							
			8	SS	10		233							
231.7			9	SS	24		232							
9.3	End of Borehole													

# RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 7-91-00 LOCATION Co-ords.: N 4 785 255.0; E 266 801.0 ORIGINATED BY BB  
 DIST 4 HWY 6N BOREHOLE TYPE Solid Stem Auger COMPILED BY KA  
 DATUM Geodetic DATE 1994 10 06 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
239.7	Ground Surface																
0.0	Clayey Silt Some Sand, Tr. Organics Moist, Firm		1	SS	7												
238.3																	
1.4			2	SS	4												
			3	SS	16												
	Silt Some Sand, Trace Clay Brown to Grey Very Loose to Compact		4	SS	18												
			5	SS	14												
			6	SS	15												
234.2																	
5.5			7	SS	24												
	Silty Sand to Sand Trace Clay, Grey Very Loose to Compact																
231.6			8	SS	4												
8.1	End of Borehole																

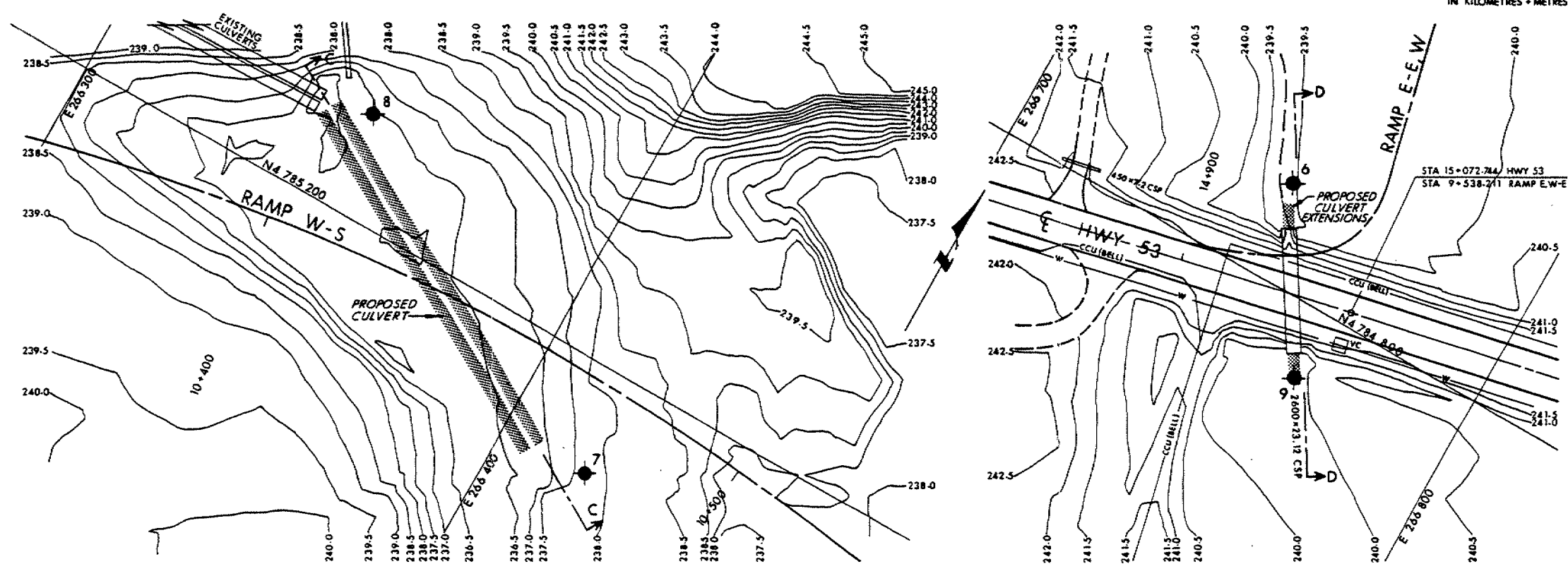
**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.

CONT No  
WP No 7-91-00

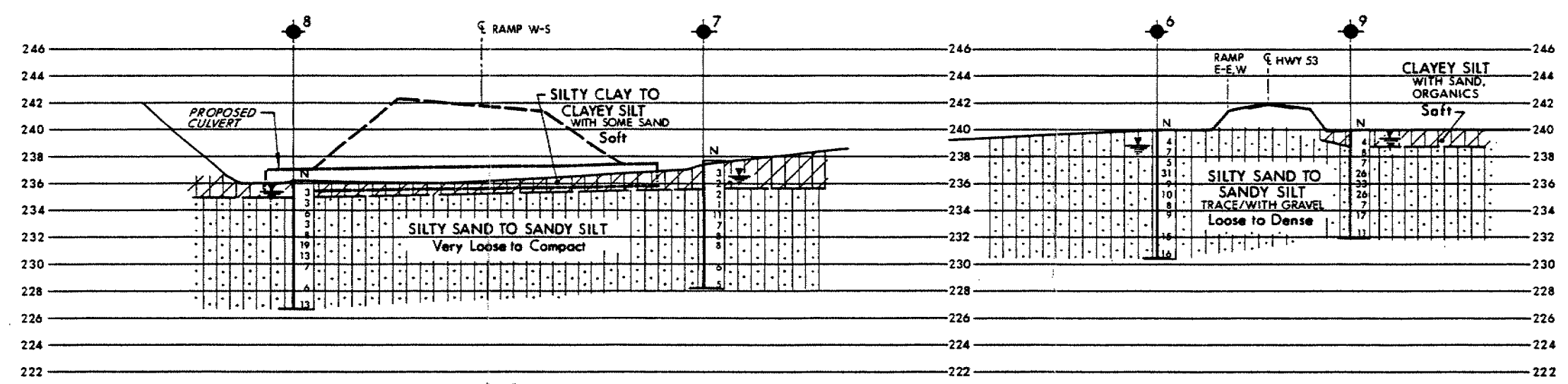


CULVERTS & CULVERT EXTENSIONS  
HWY 6N - Hwy 403 to Hwy 53  
BORE HOLE LOCATIONS & SOIL STRATA

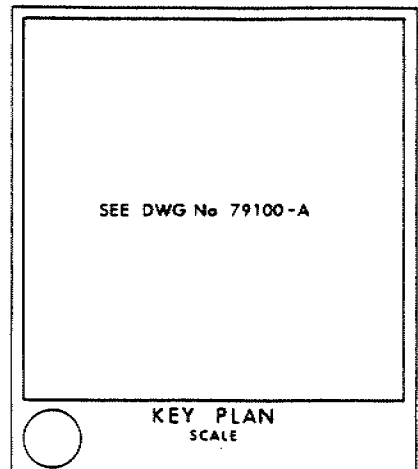
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PLANS  
SCALE  
10m 0 10m



SECTIONS  
SCALE  
10m 0 10m Hor  
4m 0 4m Vert



- LEGEND**
- Bore Hole
  - ⊕ Dynamic Cone Penetration Test (Cone)
  - ⊙ Bore Hole & 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 1994 12

No	ELEVATION	CO-ORDINATES NORTH	EAST
6	240.0	4784 818.0	266 750.0
7	237.7	4785 181.0	266 417.5
8	236.2	4785 219.0	266 350.0
9	240.0	4784 787.0	266 768.0

**=NOTE=**  
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically included in accordance with the conditions of Section GC 2.01 of OPS Gen Cond.



REF No MM Dillon HWY 6N NEW CONST PLAN/ GRAD 6. DWG/ Nov 5, 1995  
" " " " / 53- GRADE 1. DWG/ Nov 14, 1995

REV	DATE	BY	DESCRIPTION
1			

Geocres No 30M4-77

HWY No 6N	DIST 4
SUBMID K.A. CHECKED 7	DATE 1995 02 28
DRAWN D.T. CHECKED 4	APPROVED
	DWG 79100-8

**METRIC**

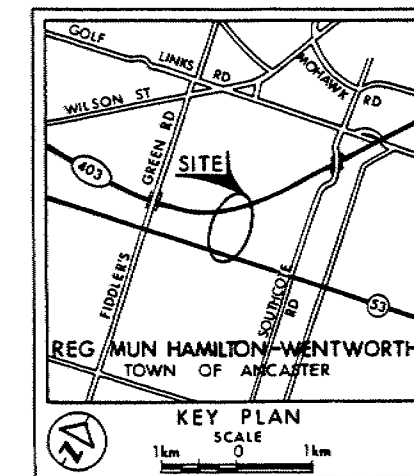
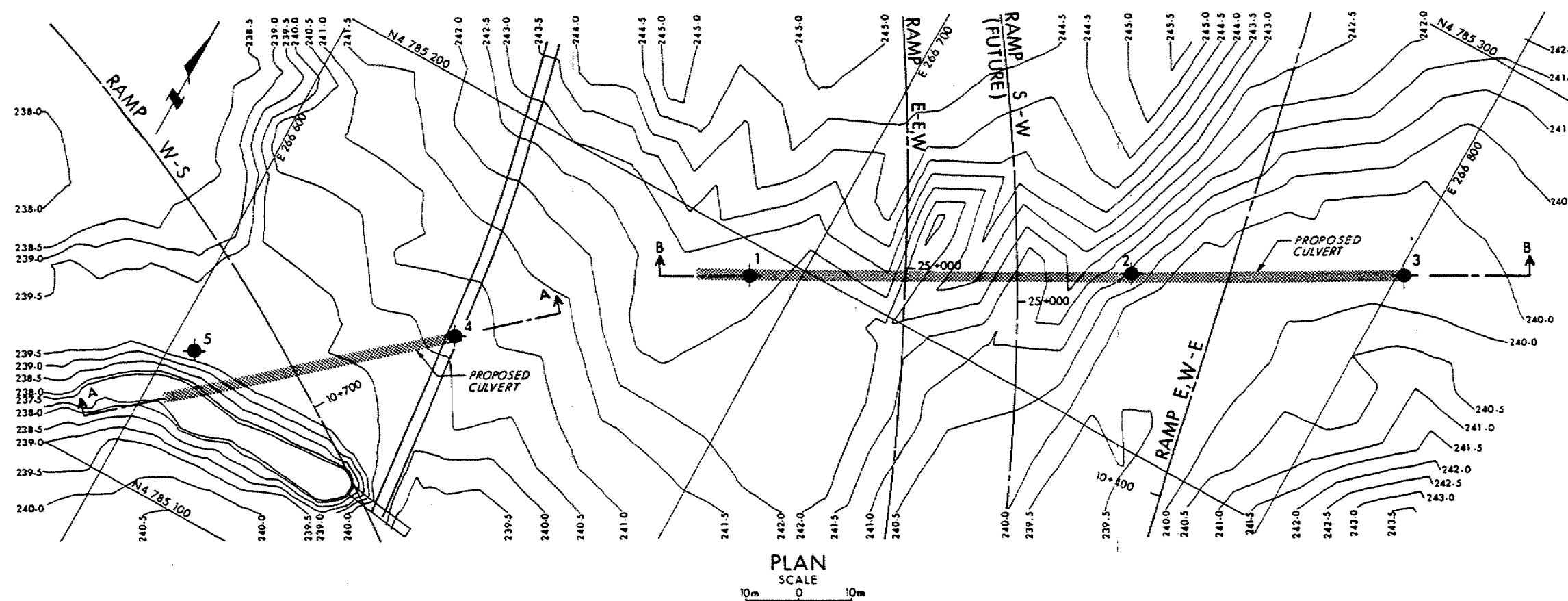
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.

CONT No  
WP No 7-91-00

CULVERTS & CULVERT EXTENSIONS  
HWY 6N -Hwy 403 to Hwy 53  
BORE HOLE LOCATIONS & SOIL STRATA



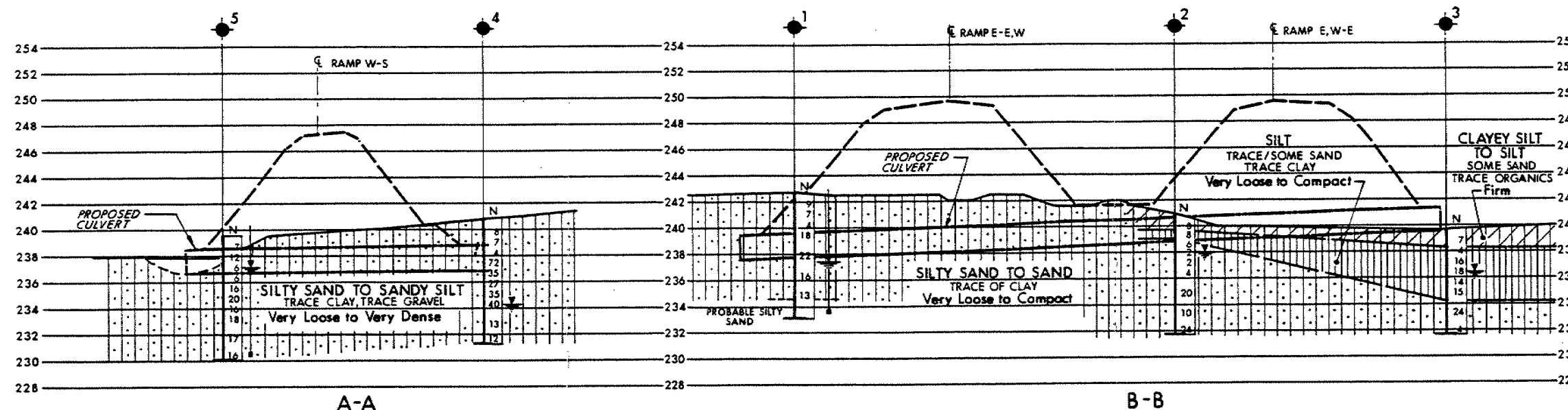
SHEET



**LEGEND**

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & 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 1994 10 and 1994 12
- W.L. in Piezometer
- Piezometer

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	242.7	4 785 194.0	266 691.0
2	241.0	4 785 230.0	266 755.0
3	239.7	4 785 255.0	266 801.0
4	240.8	4 785 156.0	266 647.0
5	239.6	4 785 129.0	266 604.5



**SECTIONS**

SCALE  
5m 0 5m Hor  
4m 0 4m Ver

**NOTE**

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen Cond



REF No MM Dillon, HWY 6N ENG PLAN / 6NEPLAN.DWG/Nov 7, 1994  
/ WSEPLAN.DWG/Nov 8, 1994

REV	DATE	BY	DESCRIPTION
1			

Geocres No 30M4-77

HWY No 6N	DIST 4
SUBAPP KA CHECKED 1995 02 28	SITE
DRAWN DT CHECKED 1995	DWG 79100-A

Due to embankment loadings, settlement under the twin pipe culvert will be in the order of 75mm and under the culvert extensions under Hwy 53 settlement will be negligible.

## CONSTRUCTION CONSIDERATIONS

### Temporary Water Course Diversion

A temporary diversion of the water course would be required to facilitate the construction of the 1.8m  $\phi$  twin pipe culvert and possibly the culvert extensions of the 2.6m  $\phi$  CSP culvert under Hwy 53. During our site visit (early December 1994), the culvert under Hwy 53 was dry.

### Dewatering

Based on the previous investigation at the site and visual examination, the water table at the site is generally above invert elevation of the box culverts. If the culverts are to be cast in place, then dewatering will be required. Due to non-cohesive type of soil, it is anticipated that extensive dewatering will be required to lower the water table which will be very expensive. It is recommended that consideration should be given to constructing without dewatering. The method of construction is outlined in the 'Bedding' section. However, the responsibility for the performance of the dewatering method and the method of construction is the responsibility of the contractor. The Contractor should be advised through NSSP of the dewatering concerns and required to submit a proposal for review. The proposal should be signed and sealed by an engineer registered with PEO and submitted to the contract administrator a minimum of 10 days prior to construction of excavations.

### Excavation

Excavation up to 6m deep will be required for the construction of the culverts. Temporary excavations will be stable at 1.5H:1V above water table and 2H:1V below water table.



### Bedding

Normally bedding for box culvert over a competent subgrade is not required. However, due to the weak subgrade and the high water table, bedding under the concrete box culvert will be required. The bedding should consist of 0.6m thick crushed stone. Excavation and subsequent backfilling operation should be without dewatering. Backfilling will be carried out using 19 mm crushed stone bringing it up to a level at least 0.5m above the groundwater level. Above the water table, the bedding material should be properly compacted. If the invert level is below the groundwater level, the compacted granular material above the invert elevation should be subexcavated without dewatering.

For the 1.8m  $\phi$  twin concrete pipe culvert, bedding should be designed as per OPSD - 802.03 class B with a modified bedding thickness of 300mm Granular 'A' or 19mm crushed stone. The same dewatering considerations apply.

For the 2.6m  $\phi$  CSP culvert extensions, the bedding should be designed as per OPSD - 802.01 Type 3 with a bedding thickness of 300 mm granular A or 19mm crushed stone. The same dewatering considerations apply.

*for pipe arch bedding OPSD-802.02 Type 5 OK. R6.01.95.*

### Weeping Holes

To relieve excess hydrostatic pressure behind the wall, weeping holes should be provided at 6m centre to centre.

### Construction Joints

The construction joint will be required between the precast concrete segments. The construction joints should be able to accommodate differential settlement of up to 50 mm and provide proper seal.

### Backfilling

For the two concrete box culverts, above the bedding level backfilling to the culverts should consist of suitable compacted material in accordance with MTO Standard. For fill below groundwater level and within frost depth Granular A or B should be used. The backfilling will be as per OPSD - 803.06.

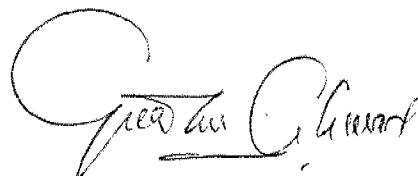
For the 1.8m  $\phi$  twin pipe culvert the backfilling should be as per OPSD - 803.03 Case 1 (frost line above top of pipe).

For the 2.6m  $\phi$  CSP culvert extension under Hwy 53, above the bedding level, the cover material should consist of granular material as detailed in OPSD 803.03 Case 2 (frost line between bottom of bedding and top of pipe). The granular material should be compacted in accordance with MTO standards. For fill below groundwater elevations or below roadway within frost line, it is recommended that Granular 'A' or 'B' should be used. Backfill operations should be carried out simultaneously on both sides of the culverts as per MTO standard.

### Erosion Protection

If cutoff walls are not incorporated in the design, clay seal will be required at the inlet to prevent any piping action in the embankments. A seal of cohesive material (CI-CH clay) with a minimum thickness of 0.6m should be constructed at the culvert inlet. The seal should extend a minimum of 2m on each side of the culvert inlet and from the high water level down the embankment to the creek bed. The material for the clay seal should be as per OPSS 1205. If suitable clay is not available then the clay mixture should be prepared as per OPSS 1205.05.03.

The erosion protection at the inlet and outlet may consist of a 0.6m thick rock blanket consisting of 300 mm size rock. It should extend from the high water level to the toe of the slope and at least 2m along the creek bed. In transverse direction, the erosion protection should extend a minimum of 5m on each side of the culvert.



K.S.Q. Ahmad, P. Eng.  
Foundation Engineer

For

D.H. Dundas, P. Eng.  
Senior Foundation Engineer

Distribution:  
P. Chackeris, Planning and Design