



**FOUNDATION INVESTIGATION AND DESIGN REPORT
for
SHELLSWELL CREEK (WILLOW CREEK) CULVERT REPLACEMENT
SITE NO. 30-504C, HIGHWAY 11
TOWNSHIP OF ORO-MEDONTE
SIMCOE COUNTY, ONTARIO
G.W.P. 2115-10-00**

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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PML Ref.: 12KF069A-C3A
Index No.: 138FIR and 139FDR
GEOCRES No.: 31D-592
February 11, 2015



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Explanation of Terms Used in Report

Record of Borehole Sheets

Figure C-GS-1 – Grain Size Distribution Envelope for Sand with Silt Fill

Figure C-GS-2 – Grain Size Distribution Envelope for Silty Sand to Sand with Silt Till

Figure C-PC-1 – Plasticity Chart for Sand with Silt Fill

Figure C-PC-2 – Plasticity Chart for Silty Sand to Sand with Silt Till

Drawing SC-1 – Borehole Locations and Soil Strata

Appendix FIR-A – Site Photographs

FOUNDATION INVESTIGATION REPORT

for

Shellswell Creek Culvert (Willow Creek) Replacement
Site No. 30-504C, Highway 11
Township of Oro-Medonte
Simcoe County, Ontario
GWP 2115-10-00

1. INTRODUCTION

This report summarizes the results of the foundation investigation required for the 100% Detail Design of the proposed Shellswell Creek (Willow Creek) culvert replacement. The study was carried out by Peto MacCallum Ltd. (PML) for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The existing culvert is located on Highway 11 at Station 19+494 in the Township of Oro-Medonte, Simcoe County.

The purpose of this report is to incorporate the additional investigation with the results of the preliminary investigation carried out in January 2013 and to summarize the subsurface stratigraphy encountered at the proposed replacement culvert site.

2. SITE DESCRIPTION AND GEOLOGY

The Shellswell Creek culvert is located approximately 550 m southwest of the existing at-grade crossing of Highway 11 Southbound Lanes (SBL) and 7th Line N. The site is about 14 km southwest of the City of Orillia in the Geographic Township of Oro-Medonte, Simcoe County. Site photographs are included in Appendix FIR-A.

General land use in the vicinity of the culvert site includes commercial activities to the north and farmland with isolated farm houses to the north and south. Locally, the existing Highway 11 is a four lane highway. The local topography of the site is generally flat. The existing Highway 11 embankment is approximately 5 to 6 m high at the proposed culvert location. Shellswell Creek flows approximately in a northwest to southeast direction at the proposed culvert location. The ground cover includes grasses and bushes near the creek area and stands of trees elsewhere.



The soil cover at the project site is derived from sandy till plain deposits which overlie Paleozoic (Middle Ordovician) age Simcoe Group, Bobcaygeon Formation (limestone) bedrock. The bedrock is estimated at about 115 m at the proposed culvert location based on Ministry of Northern Development and Mines Map P3212, Bedrock Topography, Barrie Area, 1993.

3. INVESTIGATION PROCEDURES

The additional subsurface investigation required for the 100% Detail Design was completed on November 11, 12, and 13, 2014. Two boreholes (C-3 and C-4) were both drilled to 12.4 m. The preliminary subsurface investigation was carried out on January 11 and 21, 2013 and included two boreholes (C-1 and C-2) that were drilled to 8.1 and 6.2 m respectively. A total of four boreholes completed are shown on Drawing SC-1, appended. Although the results of the combined investigations are considered representative due to the uniform soil cover in the four drilled boreholes, allowances should be made for local variations in subsurface stratigraphy.

The locations of the boreholes were selected by PML allowing for drill rig accessibility and buried utilities. The ground surface elevations for borehole C-1 and C-2 were established by exp Geomatics. The locations and elevations of boreholes C-3 and C-4 were established in the field during drilling and were verified against the General Arrangement Drawings received from AECOM on December 10, 2014. All elevations in this report are expressed in meters.

All four boreholes were advanced using continuous flight solid stem augers through the soil cover. Boreholes C-1 and C-2 were completed with a track-mounted CME-55 drill rig while boreholes C-3 and C-4 were drilled using a D-90 truck-mounted drill rig. All equipment was supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor.

Soil samples were recovered from the boreholes at regular 0.75 and 1.5 m intervals of depth using the standard penetration test method. Standard penetration tests were conducted to assess the strength characteristics of the substrata. Soils were identified in accordance with the MTO soil classification manual procedures.



The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, where encountered, by measuring the groundwater level in the open holes.

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

The recovered soil samples were returned to the PML laboratory in Toronto for detailed visual examination, laboratory testing and classification. The laboratory testing program for the preliminary foundation investigation included the following tests:

- Natural moisture content determinations (13)
- Atterberg Limits (2)
- Grain size distribution analyses (6)

In addition to the preliminary investigation, the 100% Detail Design subsurface investigation included the following laboratory tests:

- Natural moisture content determinations (18)
- Atterberg Limits (3)
- Grain size distribution analyses (7)

The laboratory grain size distribution envelopes for the combined investigation for the fill materials and native soils are presented in Figure C-GS-1 and Figure C-GS-2 respectively. The Atterberg Limits results for the fill materials and native soils are presented in Figure C-PC-1 and Figure C-PC-2 respectively. All of the test results are summarized on the Record of Borehole sheets.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration test results and groundwater observations. The results of laboratory grain size distributions, Atterberg Limits and moisture content determinations are also shown on the Record of Borehole sheets.



The borehole locations and stratigraphic profile are shown on Drawing SC-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the soil boundaries are assumed and may vary.

The previous two boreholes (C-1 and C-2) completed for the preliminary foundation investigation and design report will be incorporated into the following discussion in addition to the two boreholes (C-3 and C-4) recently completed for the 100% Detail Design.

The subsurface stratigraphy revealed in the boreholes on the highway generally comprised of pavement fill underlain by thick sandy fill layers underlain by cohesionless deposits of sand with silt till. Similarly, off road, the subsurface stratigraphy revealed in the boreholes generally comprised of topsoil and organic material underlain by sandy fill layers and the native silty sand to sand with silt till. Cobbles were encountered within the silty sand to sand with silt till deposit. Groundwater was observed in all four boreholes.

4.1 Fill

Boreholes C-3 and C-4 were drilled on the existing shoulders of Highway 11. A 0.4 and 0.6 m thick pavement structure, including 75 and 100 mm thick asphalt and a 325 and 500 mm granular base course was encountered in borehole C-3 and C-4 respectively.

Underlying the pavement, sand with silt fill was encountered in borehole C-3 and C-4 extending to 7.3 and 7.0 m (elevation 276.0 and 276.4) respectively. The sand with silt fill included trace to some gravel and trace to some clay. The fill material possesses a similar grading as the native silty sand to sand with silt till found within the study area. N values typically ranged from 10 to 30 blows indicating compact density. A low N value of 4 reflected the presence of topsoil and wood debris in the fill. Similarly, random high N values of 55 and 75 per 18 cm penetration indicated the presence of cobbles.

The results of the grain size distribution analyses for the sand with silt fill samples are included in Figure C-GS-1. The Atterberg plasticity chart for the fill material is presented in Figure C-PC-1. The liquid and plastic limits of the sand with silt fill sample were 14 and 13, respectively, with the



corresponding plasticity index 1 for soil sample 8 of borehole C-3. Within the sandy fill of boreholes C-3 and C-4, the moisture content determinations ranged from 4 to 15%.

Boreholes C-1 and C-2 were completed off road near the proposed culvert ends. A 1.1 m thick sandy fill layer was encountered below a 300 mm thick topsoil layer in boreholes C-1 and C-2 extending to elevation 276.4 and 275.9 respectively. N values varied from 3 to 9 indicating very loose to loose compactness. The moisture content determinations ranged from 13 to 19%.

4.2 Topsoil

A 0.3 m thick topsoil layer was encountered surficially in boreholes C-1 and C-2. Topsoil inclusions were encountered in boreholes C-3 and C-4 throughout the sand with silt fill layer underlying the pavement fill. Within borehole C-3, topsoil layers and wood debris were encountered from 5.5 to 7.3 m (elevation 277.8 to 276.0). The topsoil layers and wood debris overlie the native sand with silt till.

It is noted that the wood pieces found in these boreholes suggest that old shoring systems for previous culvert extensions may be present near the existing culvert.

4.3 Silty Sand to Sand with Silt Till

A cohesionless silty sand to sand with silt till deposit was encountered in all four boreholes. The till material was encountered below the topsoil and sandy fill layer at 1.4 m (elevation 276.4 and 275.9) in boreholes C-1 and C-2. Boreholes C-3 and C-4 encountered the sand with silt till at 7.3 and 7.0 m (elevation 276.0 and 276.4) respectively. All four of the boreholes were terminated in the silty sand to sand with silt till at 8.1, 6.2, 12.4 and 12.4 m (elevations 269.7, 271.1, 270.9 and 271.0) in boreholes C-1, C-2, C-3 and C-4 respectively. Cobbles were encountered within the silty sand to sand with silt till deposit below 5.2 m (elevation 272.6) in borehole C-1, below 2.9 m (elevation 274.4) in borehole C-2 and below 9.2 m (elevation 274.2) in borehole C-4. Wet sand seams were also noted during drilling. N values ranged from 16 to 105 blows per 15 cm penetration indicating compact to very dense compactness.



The results of grain size distribution analyses for the silty sand to sand with silt till samples are included in Figure C-GS-2. Due to insufficient soil recovery, soil samples 3 and 4 of borehole C-2 were combined for Atterberg Limit testing and grain size distribution analysis. The Atterberg plasticity chart for the till material is presented in Figure C-PC-2. The liquid and plastic limits of the silty sand to sand with silt till sample were 14 and 12, respectively, with the corresponding plasticity index value of 2 for soil sample 3 of borehole C-1. The result of Atterberg Limit test was “non plastic” for the combined soil samples of borehole C-2. The liquid and plastic limits of the sand with silt till sample were 13 and 12, respectively, with the corresponding plasticity index value of 1 for soil sample 11 of borehole C-3. Similarly, the liquid and plastic limits of the sand with silt till sample were 14 and 12, respectively, with the corresponding plasticity index value of 2 for soil sample 13 of borehole C-4. The moisture content determinations for the till material typically ranged from 6 to 10%.

4.4 Groundwater

The water level at the culvert was at approximate elevation 276.6 during the survey of the culvert by exp Geomatics. The elevation was received in an email dated December 17, 2013.

Groundwater was encountered in all four boreholes. During drilling, groundwater was observed at 5.6, 1.5, 5.5 and 7.0 m (elevations 272.2, 275.8, 277.8 and 276.4) in boreholes C-1, C-2, C-3 and C-4, respectively. Upon completion of drilling, groundwater was measured at 4.9, 1.0, 4.9 and 6.4 m (elevations 272.9, 276.3, 278.4 and 277.0) in boreholes C-1, C-2, C-3 and C-4, respectively. The high groundwater level in borehole C-3 (elevation 278.4) is likely due to local perched water condition, since groundwater level at the site is governed by the water level in Shellswell Creek in view of the relatively pervious soil stratigraphy. The groundwater level is subject to seasonal fluctuations and rainfall patterns.



5. CLOSURE

Mr. F. Portela carried out the field investigation for boreholes C-1 and C-2 under the supervision of Mr. B. Rao, P. Eng. Mr. A. Lo carried out the field investigation for boreholes C-3 and C-4 for this study under the supervision of Mr. K. Daly, BEng, EIT and Mr. C. M. P. Nascimento, P. Eng., Project Manager. Walker Drilling Ltd. supplied the drill rig for the entire subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This Foundation Investigation Report was prepared by Mr. K. Daly, BEng, EIT and reviewed by Mr. B. R. Gray, MEng, P. Eng., Principal Consultant. Mr. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Kyle R. Daly, BEng, EIT
Project Supervisor, Geotechnical Services



Brian R. Gray, MEng, P. Eng.
Principal Consultant



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

KD/CN/BRG:kd-mi-nk-jk

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No. C-1

1 of 1

METRIC

G.W.P.	2115-10-00	LOCATION	Coords: 4 926 250.5 N; 301 662.4 E	ORIGINATED BY	F.P.
DIST	Central	HWY	11	BOREHOLE TYPE	Continuous Flight Solid Stem Augers
DATUM	Geodetic	DATE	January 11, 2013	COMPILED BY	B.R.
				CHECKED BY	N.R.

[illegible]

RECORD OF BOREHOLE No. C-2

1 of 1

METRIC

G.W.P. 2115-10-00 **LOCATION** Coords: 4 926 196.1 N; 301 671.0 E **ORIGINATED BY** F.P.
DIST Central **HWY** 11 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** B.R.
DATUM Geodetic **DATE** January 21, 2013 **CHECKED BY** N.R.

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												
277.3	Ground Surface						20	40	60	80	100									
0.0	Topsoil		1	SS	7															
277.0																				
0.3	Sand, topsoil inclusions																			
	Loose Brown Moist to grey		2	SS	4															
	(FILL)																			
275.9																				
1.4	Sand with silt some clay, some gravel		3	SS	51															
	Dense to Grey Moist very dense		4	SS	45															
	wet sand seams																			
	cobbles		5	SS	50/3cm															
	(TILL)		6	SS	100/15cm															
			7	SS	105/15cm															
271.1			8	SS	104/15cm															
6.2	End of borehole																			
	Samples 5 to 8: Sampler bouncing																			
										</										

RECORD OF BOREHOLE No. C-3

1 of 1

METRIC

G.W.P. 2115-10-00 **LOCATION** Coords: 4 926 236.0 N ; 301 666.5 E **ORIGINATED BY** A.L.
DIST Central **HWY** 11 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** November 12 and 13, 2014 **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) 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										
283.3	Ground Surface						20	40	60	80	100									
0.0	75mm asphalt over sand and gravel																			
282.9	(PAVEMENT FILL)																			
0.4	Sand, with silt some to trace gravel trace to some clay topsoil inclusions		1	SS	19															
	Compact Brown Moist to loose		2	SS	16							○								
			3	SS	14							○				13 59 21 7				
			4	SS	19							○								
			5	SS	24							○								
			6	SS	14							○				7 52 29 12				
			7	SS	15							○								
	wood debris topsoil layers		8	SS	4							○				9 52 29 10				
	Compact Grey Wet (FILL)		9	SS	18															
276.0			10	SS	15								○							
7.3	Sand, with silt some gravel, trace clay		11	SS	98								○			19 44 29 8				
	Very dense Grey Moist (TILL)		12	SS	50/8cm															
			13	SS	50/10cm															
270.9			14	SS	50/5cm															
12.4	End of borehole																			
* 2014 11 12 & 13 ▽ Water level observed during drilling ▼ Water level measured after drilling																				

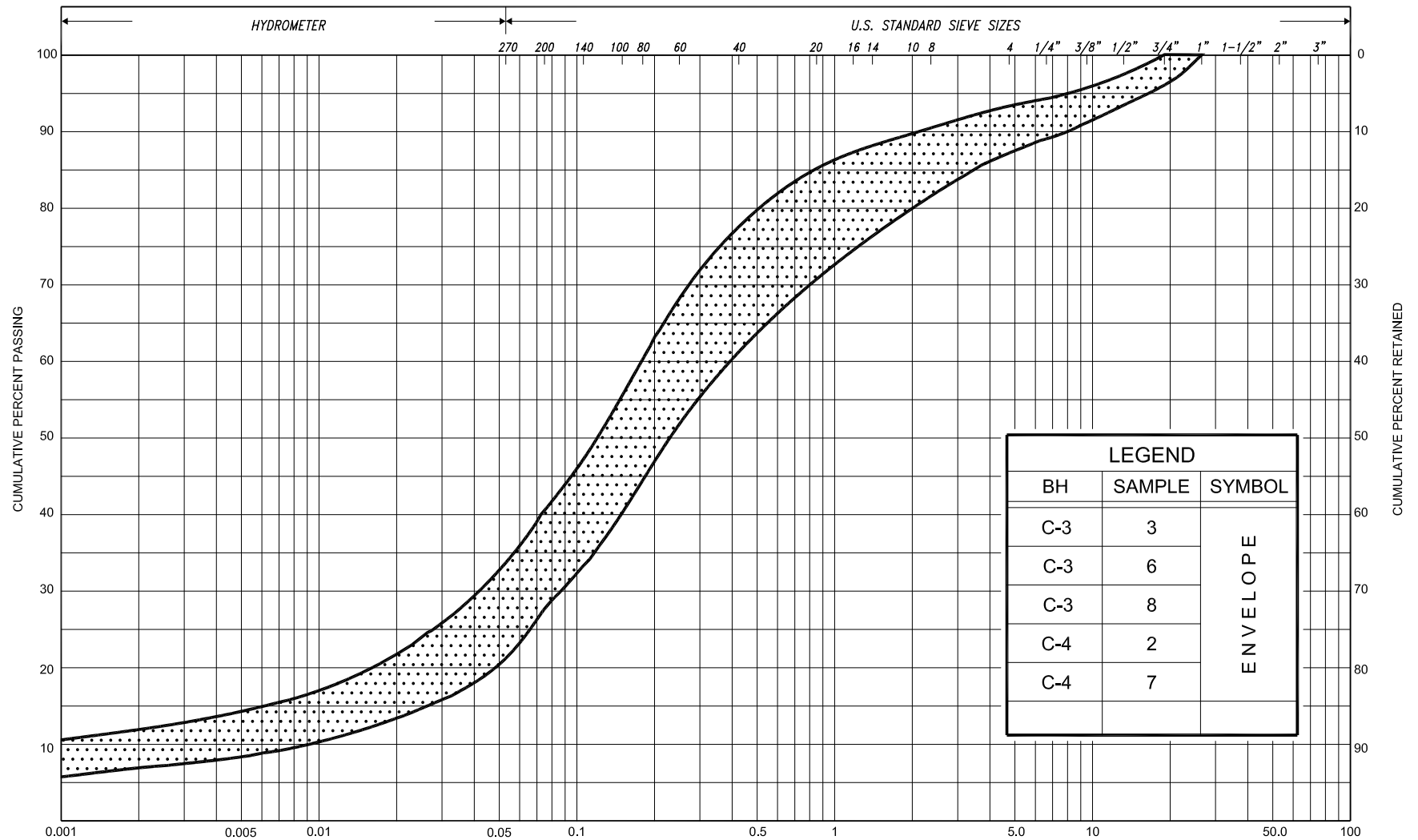
RECORD OF BOREHOLE No. C-4

1 of 1

METRIC

G.W.P. 2115-10-00 **LOCATION** Coords: 4 926 212.8 N ; 301 666.8 E **ORIGINATED BY** A.L.
DIST Central **HWY** 11 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** November 11 and 12, 2014 **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa										WATER CONTENT (%)		
							○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
283.4	Ground Surface						20	40	60	80	100								
0.0	100mm asphalt over sand and gravel																		
282.8	(PAVEMENT FILL)		1	SS	22														
0.6	Sand, with silt some gravel trace to some clay cobbles topsoil inclusions		2	SS	25							○				12 56 24 8			
	Compact to Brown Moist very dense to grey		3	SS	13							○							
	(FILL)		4	SS	10							○							
			5	SS	55							○							
			6	SS	17							○							
			7	SS	30							○				12 52 25 11			
			8	SS	17														
			9	SS	75/18cm							○							
276.4			10	SS	50/15cm														
7.0	Sand, with silt some clay, trace gravel Very dense Grey Moist		11	SS	75							○							
	cobbles, wet seams		12	SS	50/13cm														
	(TILL)		13	SS	81/25cm							○H				9 49 30 12			
271.0			14	SS	50/10cm														
12.4	End of borehole																		
	* 2014 11 11 & 12 ▽ Water level observed during drilling ▼ Water level measured after drilling NOTE: Initially, the borehole was drilled 3.5m northeast of this location. Refusal was encountered due to probable boulders.																		



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



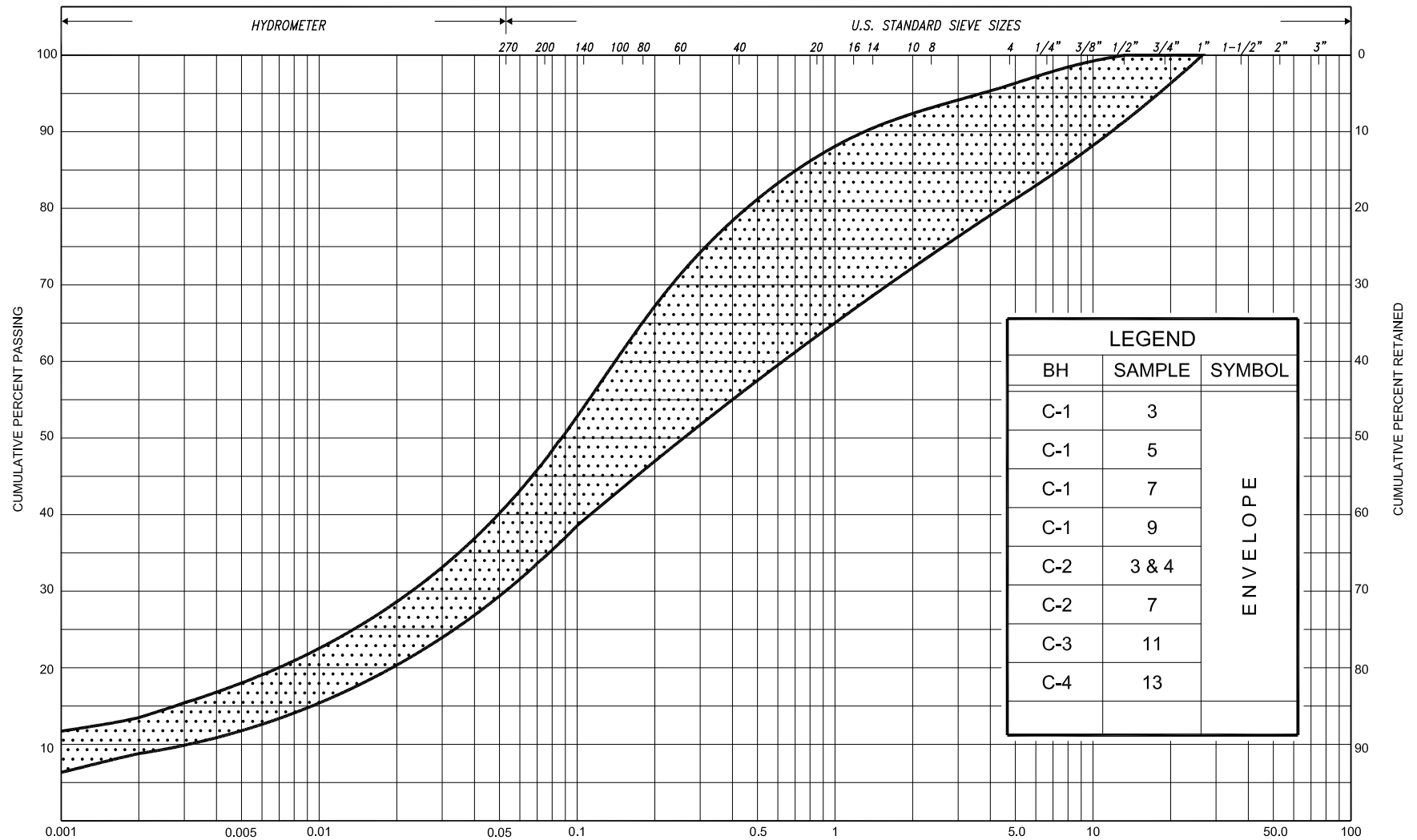
GRAIN SIZE DISTRIBUTION

SAND, with silt, some clay, some gravel
(FILL)

FIG No. C-GS-1

HWY: 11

G.W.P. No. 2115-10-00



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



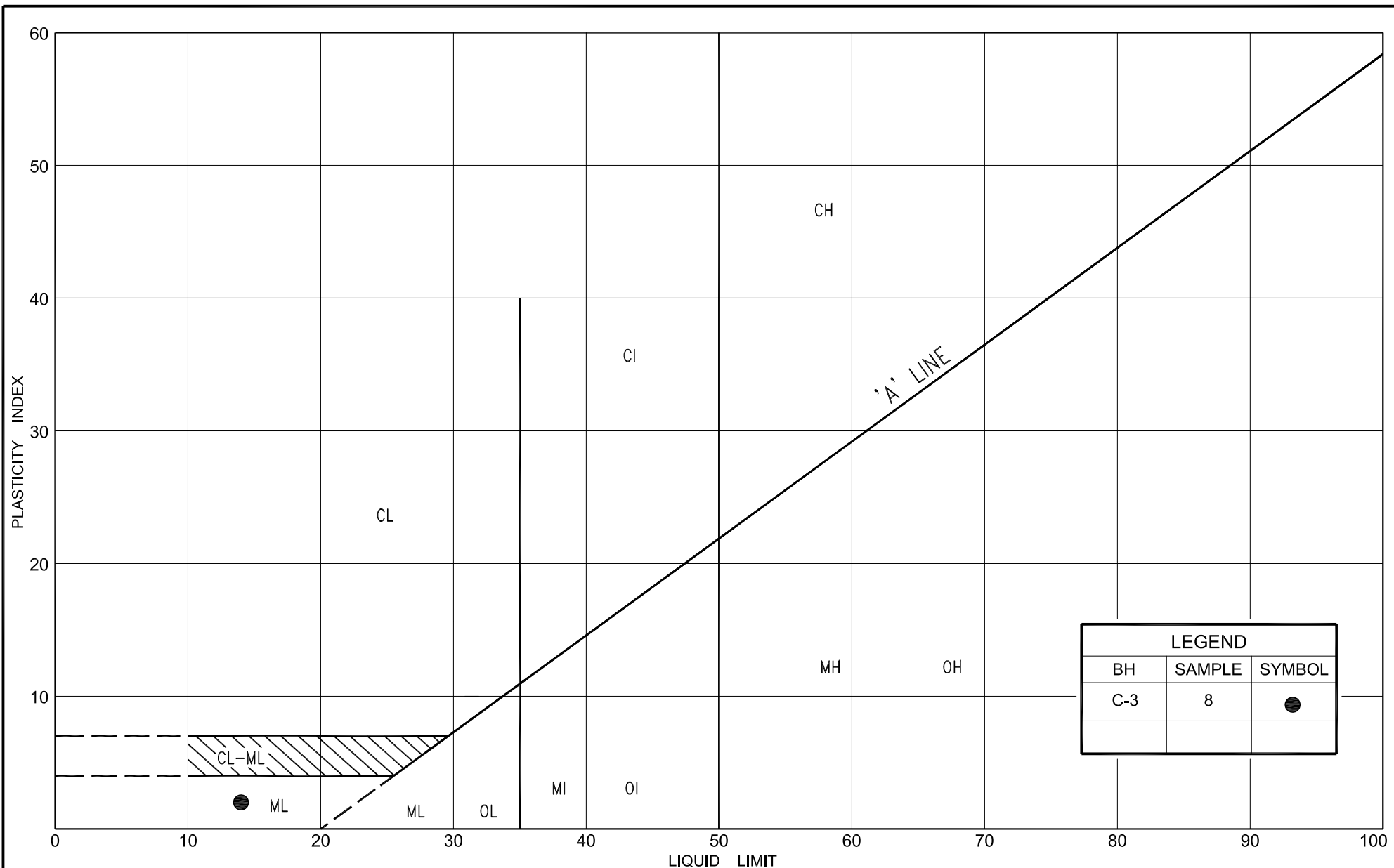
GRAIN SIZE DISTRIBUTION

SILTY SAND to SAND with silt, some clay, trace to some gravel
(TILL)

FIG No. C-GS-2

HWY: 11

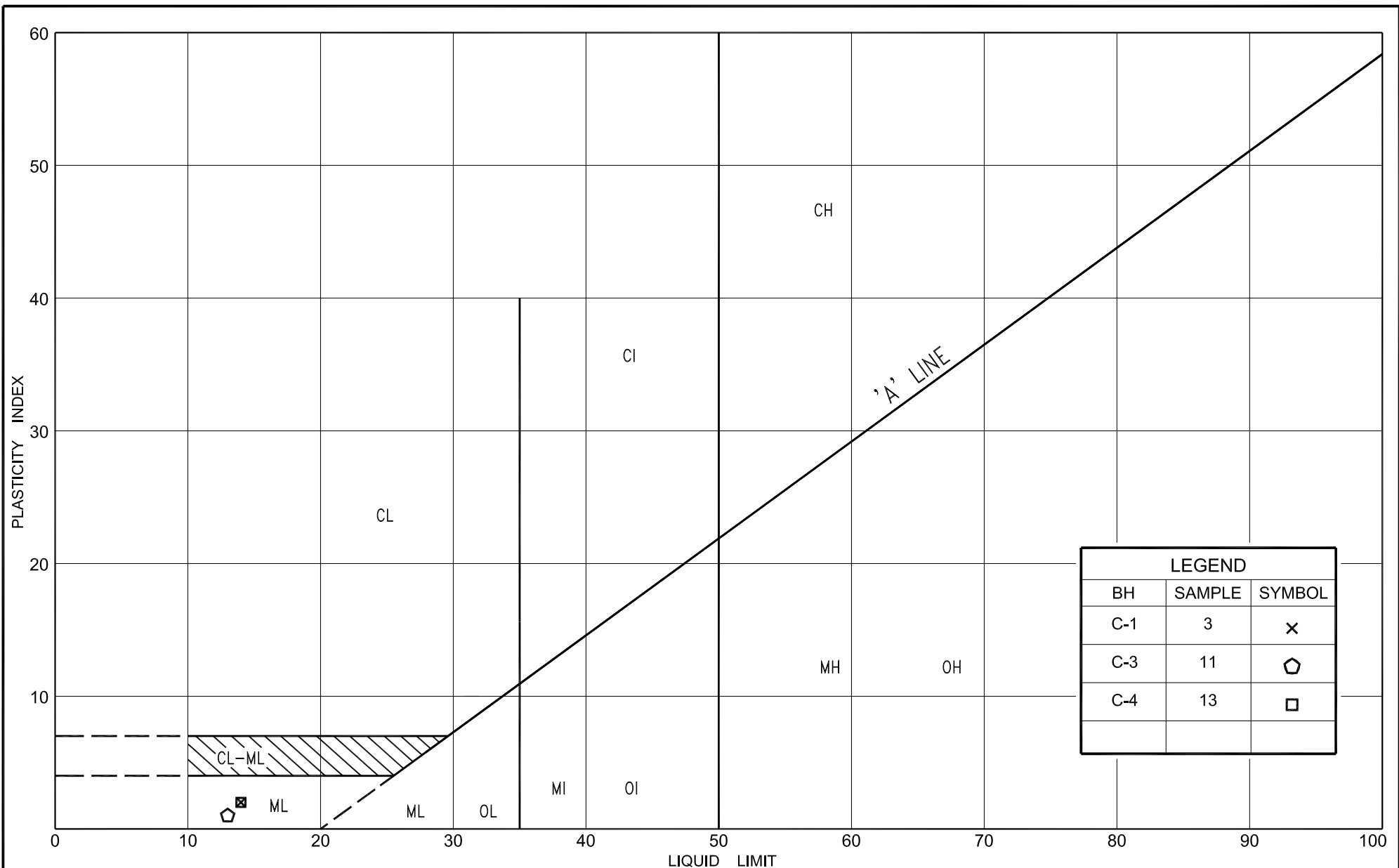
G.W.P. No. 2115-10-00



PLASTICITY CHART

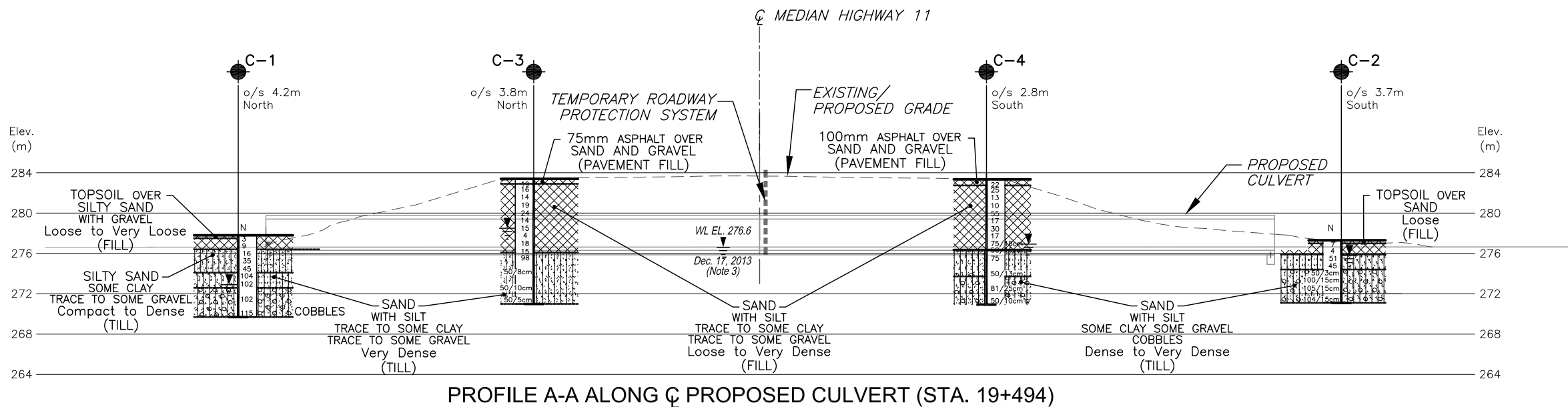
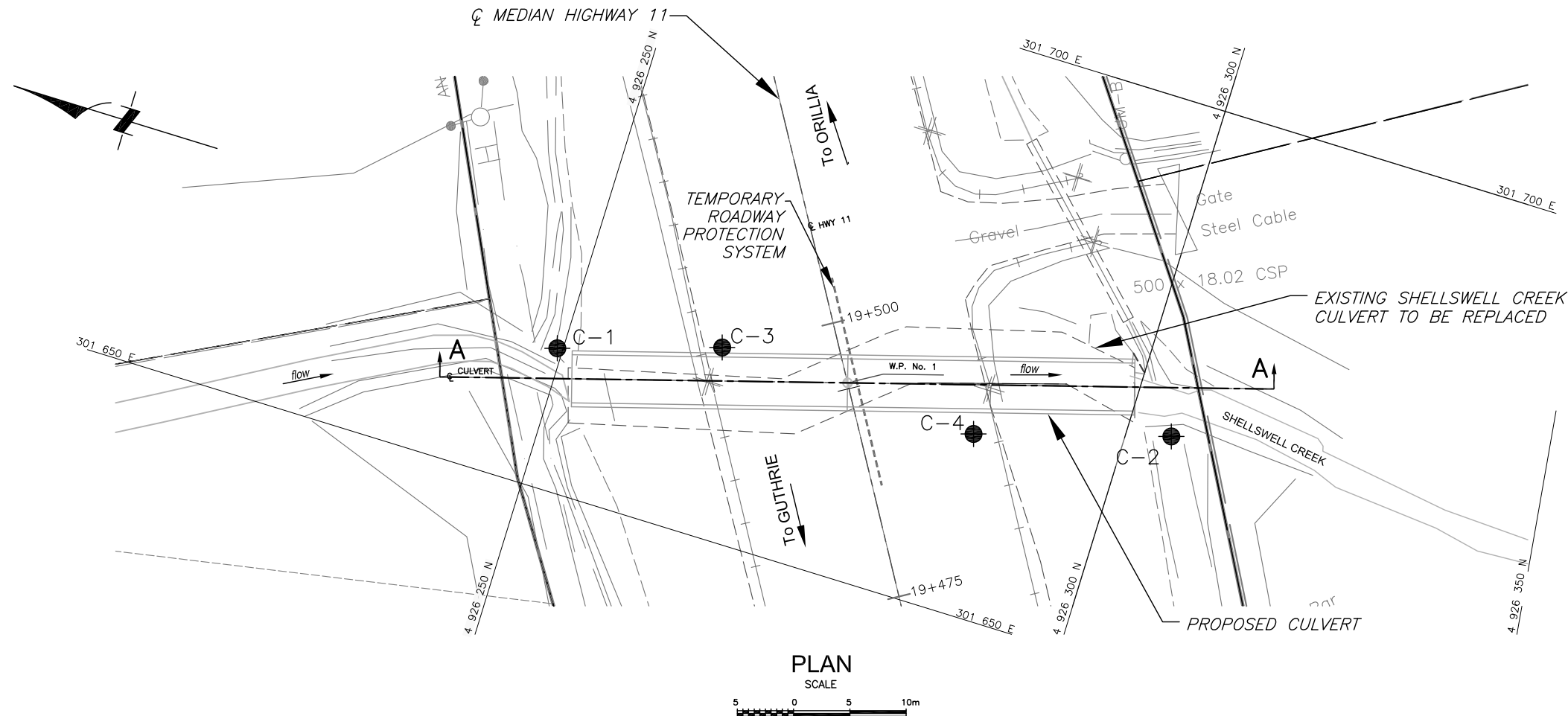
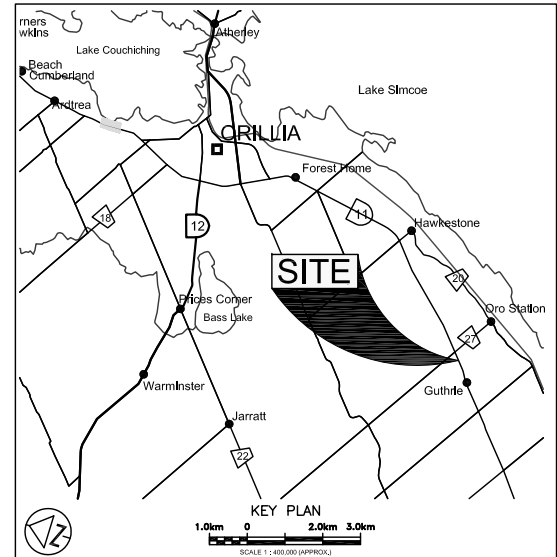
SAND, with silt, some clay, some gravel (ML)
(FILL)

FIG No.	C-PC-1
HWY:	11
W.P. No.	2115-10-00



PLASTICITY CHART
 SILTY SAND to SAND, with silt, some clay, trace to some gravel (ML)
 (TILL)

FIG No.	C-PC-2
HWY:	11
W.P. No.	2115-10-00



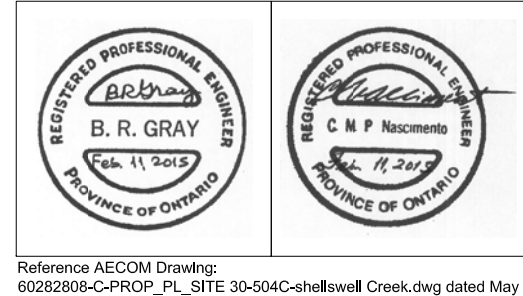
LEGEND			
	Borehole		
	Borehole and Cone		
	Auger Probe		
N	Blows/0.3m (Std. Pen Test, 475 J/blow)		
CONE	Blows/0.3m (60 Cone, 475 J/blow)		
	WL at time of investigation Jan. 2013 and Nov. 2014		
*	Water level not established		
	Head		
	ARTESIAN WATER Encountered		
	PIEZOMETER		
BH No	ELEVATION	NORTHINGS	EASTINGS
C-1	277.8	4 926 250.5	301 662.4
C-2	277.3	4 926 196.1	301 671.0
C-3	283.3	4 926 236.0	301 666.5
C-4	283.4	4 926 212.8	301 666.8

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. 31D-592			
HWY No	11	DATE	FEB. 11, 2015
SUBM'D	NA	CHECKED	KD
DRAWN	NA	CHECKED	BRG
APPROVED	CN	DATE	FEB. 11, 2015
DWG	SC-1	SITE	30-504C

- NOTES:
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
 - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION, ONLY REPLACEMENT ON SAME ALIGNMENT IS ILLUSTRATED.
 - WATER LEVEL IN CULVERT WAS PROVIDED BY THE SURVEYOR VIA EMAIL DATED DECEMBER 17, 2013.
 - DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



Reference AECOM Drawing:
60282808-C-PROP_PL_SITE 30-504C-shellswell Creek.dwg dated May 2014



APPENDIX FIR-A

Site Photographs



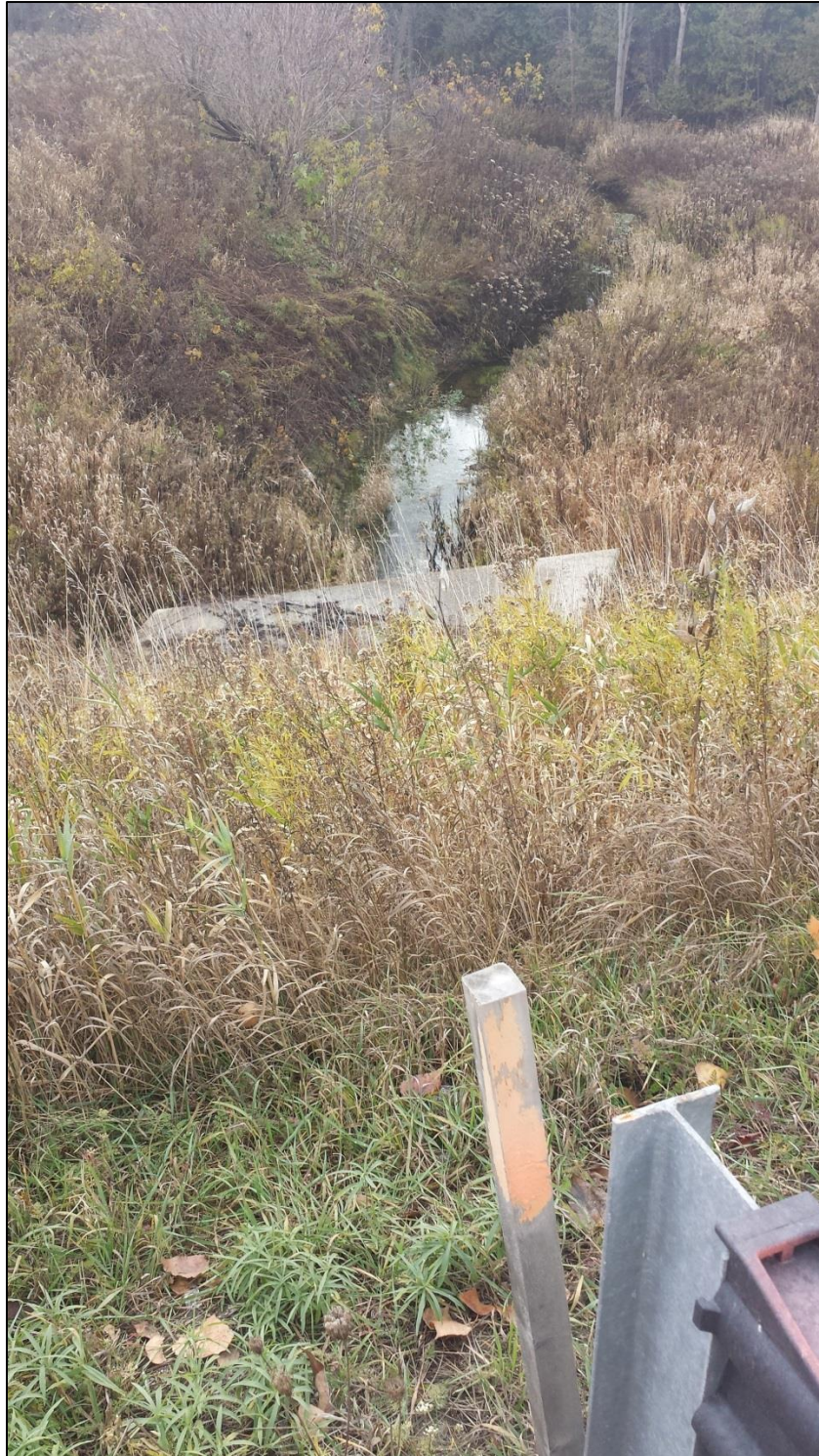
Photograph 1: Taken from the SBL shoulder, facing north at borehole C-3 (October 30, 2014)



Photograph 2: Taken from the top of the SBL embankment, facing south. (October 30, 2014)



Photograph 3: Taken from the toe of the SBL embankment, facing south. (October 30, 2014)



Photograph 4: Taken from the top of the NBL embankment to Shellswell Creek existing culvert outlet, facing east. (October 30, 2014)



Photograph 5: Taken from the toe of the NBL embankment, looking at the Shellswell Creek culvert outlet, facing west. (October 30, 2014)



**FOUNDATION DESIGN REPORT
for
SHELLSWELL CREEK (WILLOW CREEK) CULVERT REPLACEMENT
SITE NO. 30-504C, HIGHWAY 11
TOWNSHIP OF ORO-MEDONTE
SIMCOE COUNTY, ONTARIO
G.W.P. 2115-10-00**

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

Distribution:

- 1 cc: AECOM for distribution to MTO, Project Manager
+ 1 digital copy (PDF)
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February 11, 2015



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Table 1 – List of Standard Specifications Referenced in Report

Appendix FDR-A – Preliminary Staged Construction Drawings by AECOM

Appendix FDR-B – Recommended Non Standard Special Provisions

FOUNDATION DESIGN REPORT

for

Shellswell Creek Culvert (Willow Creek) Replacement
Site No. 30-504C, Highway 11
Township of Oro-Medonte
Simcoe County, Ontario
GWP 2115-10-00

1. INTRODUCTION

The proposed replacement of the Shellswell Creek (Willow Creek) culvert is planned as a part of rehabilitation of Highway 11. This report was prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

This foundation design report for Detailed Design purposes provides foundation engineering comments and recommendations for the design and construction of the proposed replacement of the Shellswell Creek culvert and a temporary roadway protection system which will be required for the staged construction.

A list of the standard specifications referenced in this report is compiled in Table 1. All elevations in this report are expressed in meters.

1.1 Background

The proposed Shellswell Creek culvert will replace the existing culvert at Station 19+494 in the Township of Oro-Medonte, Simcoe County. The length and span of the existing and replacement culverts are approximately the same, at 50.3 and 4.9 m, respectively and the new culvert is to be constructed at the same invert levels. It is proposed that the new culvert be a precast concrete box culvert. Alternatively, a cast-in-place concrete culvert may be considered. The temporary roadway protection will be located along the centerline of the Highway 11 platform.

In summary, the subsurface stratigraphy at the proposed culvert inlet and outlet generally consisted of a 1.4 m thick topsoil and sandy fill unit underlain by cohesionless compact to very dense deposit of silty sand to sand with silt till. The boreholes completed on the Highway 11 platform included 7.3 and 7.0 m thick pavement and sand with silt fill underlain by cohesionless very dense sand with silt till. Cobbles were encountered within the till deposit. Wood pieces found in these boreholes suggest that old shoring systems for previous culvert extensions may be present and an allowance should be carried for their removal during construction. The measured



groundwater level varied from 1.0 to 6.4 m (elevations 272.9 to 278.4) upon completion of the boreholes. The high water level at elevation 278.4 in Borehole C-3 likely reflects the presence of perched water within the embankment fill, since the groundwater level at the site is governed by the water level in Shellswell Creek in view of the typical relatively pervious soil stratigraphy. The water level of Shellswell Creek at the time of surveying by exp Geomatics was at elevation 276.6. The elevation data was received in an email dated December 17, 2013 and may vary from this level at the time of construction.

1.2 Discussion

From a foundation perspective, the construction of the proposed replacement culvert by the cut and cover method is feasible at the existing culvert location or on a new alignment, subject to the following comments. Trenchless or tunneling methods were not considered at this site in view of the shallow cover over the culvert and the required 4.9 m span for the replacement culverts.

It is understood that a precast concrete box culvert will replace the existing Shellswell Creek culvert. However, a cast-in-place concrete culvert may also be considered for construction. The replacement culvert may be constructed on the existing or new alignment as selected by the Contractor. A discussion of the advantages and disadvantages of the two culvert options is included in Section 7 of this report.

It is considered that a precast culvert can typically tolerate a maximum of 100 mm of differential settlement and a cast-in-place culvert can typically tolerate a maximum of 25 mm of differential settlement.

Because the underlying native soils are in a very dense compactness condition and have been loaded with the existing Highway 11 embankment for a substantial period of time, negligible total and differential settlements are anticipated from the underlying deposits after the new culvert is installed.

The construction of the replacement culvert should consider groundwater control measures for construction under wet or dry conditions. Site specific groundwater control measures are required because of the pervious subgrade soils and possible high water levels at the site during construction due to seasonal creek water level fluctuations.



AECOM has proposed three options to replace the existing culvert as described in further detail in the following Section 2 of this report. The Offline and Online Culvert Replacement (Base Options) reduces the traffic to one lane each direction and the Online Culvert Replacement (Widening Option) maintains two traffic lanes each direction by widening the highway embankment.

For the purpose of widening the embankment under NBL and SBL, it is anticipated that approximately 6.0 to 6.5 m of suitable fill will be placed over the original ground level at the toes of the Highway 11 embankment. To minimize transverse settlements of the pavement surface, approximately 1.4 m of existing loose surficial fill materials should be excavated below the widened platform footprint.

The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the Contractor. It is noted that no responsibility or liability is assumed by the consultants or the MTO for alerting the Contractor to all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the Contractor.

The foundation frost penetration depth at the site is 1.6 m according to OPSD 3090.101.

2. CONSTRUCTION CONSIDERATIONS

2.1 Culvert Replacement Options

AECOM has prepared three culvert replacement options and are as follows:

(A) Offline Base Option

- Culvert replacement on new alignment
- Creek realignment outside MTO right-of-way (ROW)
- Temporary Roadway Protection System required
- Traffic reduced to one lane each way

(B) Online Base Option

- Culvert replacement on the existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protect System required
- Traffic reduced to one lane in each direction



(C) Widening Option

- Culvert replacement on existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protection System required
- Two lanes of traffic each way will be maintained during the construction stages by temporarily or permanently widening the NBL and SBL

2.2 Staged Construction

Staged construction will be required to remove the existing culvert and to install the new Shellswell Creek culvert while maintaining traffic on the Highway 11. AECOM provided the preliminary staged construction drawings for the Online Base Option that is included in Appendix FDR-A. Three construction stages are identified for the Offline Base Option and two construction stages are identified for the Online Base Option and the Widening Option.

For the Offline Base Option the stages are as follows:

- Stage 1: Construction of the proposed culvert under NBL
- Stage 2: Construction of the proposed culvert under SBL
- Stage 3: Realignment of the creek

For the Online Base Option the stages are as follows:

- Stage 1: Construction of the proposed culvert under NBL
- Stage 2: Construction of the proposed culvert under SBL

For the Widening Option the stages are as follows:

- Stage 1: Widening of the existing SBL and construction of the new culvert under NBL
- Stage 2: Widening of the existing NBL and construction of the new culvert under SBL



It is anticipated that a suitable roadway protection system following OPSS.PROV 539 will be necessary to support the walls of excavation and adjacent traffic lanes during staged construction for either option. Further details are included in Section 2.4 of this report.

2.3 Embankment Widening

If Widening Option is adopted for the replacement of the culvert, widening of the embankment will be required to facilitate two lanes for each traffic direction. The embankment widening should follow the OPSD 203.030. It is recommended that 1.4 m of existing topsoil and very loose to loose fill materials be excavated down to native compact to very dense sandy till soils along the widening and at the inlet and outlet locations and be replaced with suitable fill for the widening of the Highway 11 embankment. An approximate maximum 6.5 to 7.0 m fill height would be required to widen the highway embankment from the sub-excavated subgrade level.

Embankment fill should be placed and compacted in accordance with OPSS.PROV 206 and OPSS.PROV 501. New embankment fill against existing embankment slopes or on a sloping ground surface should be benched into the existing slope in accordance with OPSD 208.010.

Granular fill, earth fill or rockfill (if locally available) can be utilized to widen the highway embankment. Estimates of rock fill settlement (if used on the project) should be consistent with the MTO "Post Construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity", dated September 14, 2010.

The magnitude of the fill surface settlement by self-compression that would occur during and after construction of the embankment depends on the type of fill material placed and the height of placed. However, the estimated magnitude of maximum settlement of the compacted fill during construction where placed above the groundwater table ranges from 55 to 140 mm (typically 0.75 to 2% of the maximum 7.0 m embankment height) and should not influence the design.

Assuming the use of conventional cohesionless earth fill, such as sandy silt or silty sands similar to the fill type in the existing embankment and/ or granular fills, such as OPSS Granular A or B Type I or II, it is estimated that the post construction settlement of the new embankment constructed as recommended in this report will be less than 10 to 30 mm. About 5 to 20 mm of this post construction settlement is expected to take place immediately after completion of construction and the remaining settlement is anticipated to occur over a period of 3 months after



construction. These potential settlements will adequately satisfy the MTO guidelines for transverse differential settlements as outlined in the MTO "Embankment Settlement Criteria Guidelines" dated March 2, 2010.

It is noted that the settlements of the native compact to very dense silty sand glacial till subgrade soils are estimated to be in the order of 5 to 15 mm under the maximum 7.0 m height of embankment widening.

To minimize differential settlement between the existing and widened embankment areas due to self settlement of the fill, the use of granular fill or cohesionless earth fill is preferred since the majority of their settlements will occur during construction. Coarse Granular fill such as Granular B Type II will also be required to fill over wet subgrade areas, in particular those adjacent to the outlet and inlet of the culvert.

Further geotechnical analyses may need to be carried out by the Contractor to assess the specific construction requirement of the new embankment fills, including appropriate settlement monitoring instrumentation.

The detail design level evaluation of the allowable settlement using the fill materials selected by the Contractor should be carried out to be in accordance with the MTO "Embankment Settlement Criteria Guidelines" dated March 2, 2010.

2.4 Roadway Protection System

To maintain traffic adjacent to the construction area, a roadway protection system will be required during staging for the new Shellswell Creek culvert installation.

A roadway protection system should be designed according to OPSS.PROV 539. It is recommended that a minimum performance level 2 be implemented to prevent excessive lateral movement of the adjacent existing embankment during construction. The Contractor should be responsible for the selection, detailed design and performance of the roadway protection scheme.

The OPSS.PROV 539 calls for monitoring of the roadway protection system by the Contractor to check the horizontal and vertical displacements of the roadway surface during construction. A maximum of 12 mm of settlement should be allowed on the travelled Highway 11 section adjacent to the excavations.



Alternative roadway protection schemes such as sheet piling or anchored soldier piles and lagging should be considered. Typically, sheet piling can be used to reduce loss of native soils below the water table. Soldier piles and lagging are generally considered suitable for applications above groundwater table in cohesive materials but can be used for cohesionless fill materials provided that adequate care to prevent loss of ground from behind the shoring is implemented by the Contractor.

The following table presents an overview assessment of the advantages and disadvantages, including relative costs and risk/consequences of the roadway protection system alternatives from the foundation perspectives at the Shellswell Creek culvert site.

ALTERNATIVES	ADVANTAGES	DISADVANTAGES
Sheet piles	<ul style="list-style-type: none">• Sheet piles will be interlocked therefore loss of native soils will be negligible• Suitable for high water table conditions• Suitable to drive for varying bedrock profile, if required• Low risk of soil loss	<ul style="list-style-type: none">• Higher cost• May require soil anchors/rakers for lateral support• Larger construction equipment is required than for soldier piles
Soldier piles and lagging	<ul style="list-style-type: none">• Lower cost• Smaller construction equipment is required than for sheet piles	<ul style="list-style-type: none">• Requires care to avoid excessive settlement that may occur due to loss of cohesionless soils• Unsuitable with high water table• High risk of soil loss

Based on the above table, sheet piles are considered to be adequate due to the presence of cohesionless fill materials with a high water table and consequently, high risk of soil loss leading to excessive movement. This site condition implies that the roadway protection should not consist of a soldier piles and lagging at this site, unless care is taken during and after installation to avoid loss of soil between and behind the lagging boards.



2.5 Excavation

The open cut excavation method is anticipated to replace the existing Shellswell Creek culvert.

Excavation to the anticipated subgrade level of the new Shellswell Creek culvert is expected to extend through the embankment fill, topsoil (near culvert ends) and sandy fill soils into the native deposit of cohesionless compact to very dense silty sand to sand with silt till. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment. All excavations should be conducted in accordance with OPSS 902. Cobbles and boulders may be encountered in the native till soil during excavation and should be removed from the subgrade for the new culvert.

It is also considered that wood pieces found in the boreholes drilled through the embankment suggest that old shoring systems for previous culvert extensions may be present and may cause difficulties during construction. It is recommended that a contingency allowance be carried in the contract for the removal of old shoring systems during construction, if required.

For the culvert replacement on new alignment (Off Line Base Option) the first stage of the excavation should include the fill above and then beside the existing culvert to avoid sliding or instability concerns. The Contractor should design the level of the fill excavation as temporary works. It is recommended that the excavation of the fill should be carried out on both sides of the culvert at the same time to avoid instability. For the Offline Base Option, the bottom section of the existing culvert may be left in place and backfilled with suitable material. Since the new culvert will be installed at the same invert level, the backfill material should be placed and compacted as recommended in Section 4 of this report.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, typically the in-situ compact to loose soils are considered as Type 3 soils necessitating temporary cut slopes to be inclined no steeper than 1H:1V. Very loose soils are considered Type 4 soils necessitating temporary cut slopes to be inclined no steeper than 3H:1V. Below the water table, cut slopes should be shaped at 3H:1V or flatter. Where composite soil types exist, the excavation slopes should be cut to the requirements of the soil type with the highest number that is present in the slope according to OHSA.

All construction work should be carried out in accordance with the Occupational Health and Safety Act and with local/MTO regulations.



2.6 Groundwater Control

The extent of groundwater control will depend on the depth of excavation below the ground water level at the time of construction and on the Contractor's construction techniques. Groundwater control refers to both surface water management during and after construction and to dewatering during construction. This aspect is the responsibility of the Contractor as temporary works, but consideration could be given to either constructing in the dry, which would require dewatering or constructing underwater, which would not require full groundwater control.

Reference is made to OPSS 517 and 518 which pertain to construction dewatering.

It will be likely necessary to implement measures to control seasonal ponded or surface water flow at the culvert location. Conventional procedures such as dam and pump and/or diversion of the any overland flow streams should be sufficient at the measured water levels during the investigation, when the water level in the creek was at approximately elevation 276.6. Nevertheless, it should be considered that groundwater levels are subject to seasonal fluctuations and precipitation patterns and where the groundwater table is well above the proposed subgrade level at the time of construction, cofferdams may be required for the installation of the culvert. The Contractor is responsible for the selection, detailed design and performance of the cofferdams.

It is also recommended that the work be carried out during the usually dry months of June to September 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.

It should be considered that a permit to take water (PTTW) is required by the Ministry of the Environment for water taking over 50,000 litres per day. From a geotechnical standpoint the requirement for a PTTW will depend on the water tightness of the Contractor's selected roadway protection system and use of cofferdams. The PTTW requirement will also depend on the groundwater levels at the time of construction since these are subject to seasonal fluctuations and precipitation patterns. A PTTW may also be required to address other project facets, such as those of Hydrology engineering.



3. FOUNDATIONS

The following recommendations apply to both precast box concrete and cast-in-place concrete culvert options, except for the sliding resistance in Section 3.2.3 where different parameters are tabulated for the two options.

3.1 Geotechnical Bearing Resistances

It is assumed that the invert levels of the proposed box culvert will be specified to match the existing culvert invert levels. The invert levels of the existing culvert are measured at approximately elevation 276.4 at the inlet and elevation 276.3 at the outlet. The subgrade level for a concrete box culvert is interpreted to be about 0.5 m below the invert levels at elevations 275.9 and 275.8 allowing for the thickness of concrete base of the culvert and for the recommended total 300 mm thickness of the bedding and leveling courses.

It is estimated that about 1.9 and 1.5 m of excavation will be required to achieve the anticipated culvert subgrade levels at the inlet and outlet locations (boreholes C-1 and C-2), respectively. The level of the excavation for sandy fill or native till removal may vary under the Highway 11 to achieve the anticipated subgrade level.

The Granular A or Granular B Type II bedding materials and the underlying cohesionless compact to very dense sand with silt till soils that are in the zone of influence below the design subgrade level are considered capable of adequately supporting the stress imposed by the replacement concrete box culvert. Because the underlying soils are in a compact to very dense condition and in particular have been loaded with the existing Highway 11 embankment for a substantial period of time, the estimated relatively small 5 to 15 mm settlements anticipated from the underlying native deposits after the new culvert is installed may be neglected. It is also considered that cambering will not be required at the replacement culvert location.



The recommended factored geotechnical bearing resistances at ultimate limit states (ULS) and the geotechnical reaction at serviceability limit states (SLS) for the proposed concrete box culvert constructed on the native cohesionless soils below the granular bedding layer are as follows:

CULVERT SECTION	SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Entire Length	Granular A or Granular B Type II Bedding over Cohesionless Silty Sand to Sand Till	450	300

The geotechnical reaction at SLS normally allows for a 25 mm compression of the founding medium. In addition, the cohesionless soil settlements under the proposed culvert discussed previously in this section should be considered. A foundation embedment depth of 1.4 to 1.5 m and groundwater at about 0.3 to 0.4 m above the culvert invert levels were assumed for computation of the geotechnical reaction.

3.2 General Comments

3.2.1 Subgrade Preparation

Preparation of the subgrade for construction of the culvert should be performed and monitored in accordance with OPSS 902. All cobbles and boulders if encountered should be removed from the subgrade level. A site review should be conducted by qualified geotechnical personnel during preparation of the subgrade and compaction of the granular fill.

For the box culvert, it is recommended to provide a minimum 500 mm of combined granular and levelling course with minimum 300 mm thick granular bedding below the culvert. The bedding material should comprise Granular A or Granular B Type II and be compacted in conformance with OPSS.PROV 501 (Method A). Granular materials should conform to OPSS.PROV 1010.

The geometry of the subgrade preparation, cover backfill and frost taper treatment for the box culvert should be carried out in accordance with MTOD 803.021, OPSS 422 and MTO SP 422S01.



3.2.2 Modulus of Subgrade Reaction

The estimated values of the modulus of subgrade reaction for box culvert constructed on the local undisturbed subgrade native soils or compacted materials are as follows.

SOIL TYPE	MODULUS OF SUBGRADE REACTION, MN/m ³
Undisturbed Silty Sand to Sand with Silt Till	15
Compacted Granular A or Granular B Type II	45

3.2.3 Sliding Resistance

The following parameters should be used to compute sliding resistance of precast box culvert and cast-in-place headwall and wingwall foundations. The friction angles have been reduced by a factor of 0.67 for precast box culvert foundations to account for the smooth concrete base.

SOIL TYPE	FOUNDATION FRICTION ANGLE (Degrees)		COHESION (kPa)	UNIT WEIGHT (kN/m ³)
	CAST-IN-PLACE	PRECAST		
Granular A or Granular B Type II	35	23	0	22.8
Silty Sand to Sand with Silt Till	33	21	0	21.0

The structural designer should use a factor of 0.8 for the above values of friction angle and cohesion when performing the sliding resistance check.

3.2.4 Seismic Site Coefficient

The seismic site coefficient for the conditions at the Shellswell Creek culvert site is 1.0 -Type I soil profile as per clause 4.4.6 of the CHBDC.

4. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 3121.150, OPSS 422, MTOD 803.021 and SP 422S01. The requirement for frost taper is provided in the Pavement Design Report. Granular materials should conform to OPSS.PROV 1010.



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) should be restricted to minimize the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to MTO OPSS.PROV 501 and OPSS 902 for additional comments.

The proposed culvert 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 exerted 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) or employing the following equation assuming a triangular pressure distribution.

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

where p = lateral earth pressure (kPa)
 K = lateral earth pressure coefficient
 γ = unit weight of backfill material above design water level (kN/m³)
 γ' = unit weight of submerged backfill material below design water level (kN/m³)
 $\quad = \gamma - \gamma_w$
 γ_w = unit weight of water
 $\quad = 9.8 \text{ kN/m}^3$
 h_1 = depth below final grade (m), above design water level
 h_2 = depth below design water level (m)
 q = any surcharge load (kPa)
 C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)
where ϕ = angle of internal friction of retained soil (35° for Granular A or B Type II)
 δ = angle of friction between soil and wall (23.5° for Granular A or B Type II)

The seismic site coefficient for the conditions at this site was provided in Section 2.2.4.

The following parameters are recommended for design:

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	EXCAVATED MATERIAL (*)
Angle of Internal Friction, degrees	35	33
Unit Weight, kN/m ³	22.8	21.0
Coefficient of Active Earth Pressure (K_a)	0.27	0.29
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.45
Coefficient of Passive Earth Pressure (K_p)	3.69	3.45

(*) Assumes that backfill materials are locally excavated or imported inorganic cohesionless soils.



The design should consider both the maximum water level in the creek and the stabilized groundwater level condition. The maximum creek water level will be dictated by flood flow conditions and should be defined by the project hydrological engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls.

5. HEADWALLS AND WINGWALLS

The previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilized for the design of the foundations for headwalls and wingwalls, if required. The wall founding levels should match those of the respective culverts where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established 1.6 m of earth cover for adequate foundation frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided previously in Section 3 for precast and cast-in-place concrete foundations.

A weeping tile system and/or weep holes should be installed to minimize the build-up of hydrostatic pressure behind the headwalls and wingwalls. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 μm according to OPSS 1860) placed to prevent migration of fines into the system. The outlet drainage pipes should be placed on a positive grade.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls etc.) are considered to be appropriate. The backfill should consist of OPSS Granular A or Granular B Type II. The cut-off walls should extend laterally to protect the granular backfill material and to a depth at least equal to the fluctuation of the water level at the culvert location to prevent flow below the culvert that could erode the granular base/bedding material. The requirements of CHBDC clauses 1.9.5.6 and 1.9.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511, OPSS.PROV 1004 and OPSD 810.010 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert foundation. The actual design requirements concerning the length and width of aprons



at the inlet/outlet of the culvert as well as the rock size, apron thickness, height of erosion protection on the embankment slope and type of material (clay seals at the inlet, drainage and/or filter blankets at the outlet) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by the project hydrologist. A non-woven Class II geotextile with an FOS of 75-150 m according to OPSS 1860 should be placed below the rip-rap to minimize the potential for erosion of fine particles from below the treatment.

Any newly constructed embankment slopes and retained soils behind the headwalls and wingwalls should be covered with topsoil or suitable excess earth material and seeded in accordance with OPSS 802 and OPSS.PROV 804, 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. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor.

SOIL TYPE	K FACTOR
Sand	0.2
Silt	0.3

7. DISCUSSION OF FOUNDATION ALTERNATIVES

The following table summarizes the advantages, disadvantages and inferred risks/consequences of two foundation alternatives for installation of the culverts:

PRECAST CONCRETE BOX CULVERT		CAST-IN-PLACE BOX CULVERT	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
Shorter culvert construction schedule than cast-in-place concrete culvert construction	Precast concrete provides lower sliding resistance than cast-in-place concrete	Cast-in-place concrete provides higher sliding resistance than precast concrete	Longer culvert construction schedule than precast concrete culvert construction

From the foundation perspective, either box culvert alternative (precast or cast-in-place concrete) is feasible.



The precast concrete option constructed at the design invert levels is considered to be less costly than the cast-in-place concrete alternative since construction of the culvert will be expedited without the forming and setting time needed for cast-in-place concrete construction. It is expected, however, that the construction of headwalls, if required, will offset some of the cost advantages of the box culvert construction.

It is noted that the selection of the culvert type also depends on other considerations such as substrate material and commercially available (off the shelf) precast culvert sizes. These facets are to be evaluated by the Contractor.

8. PREFERRED OPTION

From the foundation point of view, both options, described in section 2.1, are feasible to replace the existing culvert. The following table presents the advantages and disadvantages for the three options.

OPTION	ADVANTAGES	DISADVANTAGES
Offline Base Option	<ul style="list-style-type: none"> Existing culvert will remain in place during construction Do not need to divert creek water flow during construction 	<ul style="list-style-type: none"> Three construction stages Creek realignment falls outside MTO ROW after construction Traffic reduced to one lane each way Increase of culvert length Requires roadway protection system
Online Base Option	<ul style="list-style-type: none"> Two construction stages Construction within MTO ROW Creek realignment not needed No embankment widening is required 	<ul style="list-style-type: none"> Traffic reduced to one lane each way Requires Roadway Protection System
Widening Option	<ul style="list-style-type: none"> Two construction stages Construction within MTO ROW Maintain two lanes for each traffic direction during construction Creek realignment not needed Shorter culvert required 	<ul style="list-style-type: none"> Widening of NBL and SBL required to maintain two lanes for each traffic direction during construction Requires roadway protection system



From the foundation standpoint, the Online Base Option is preferred because of the better control of the groundwater and no embankment widening is required with this option. For selecting one the three options, cost and schedule should also be taken into consideration.

9. CLOSURE

This Foundation Design Report was prepared by Mr. K. Daly BEng, EIT, and reviewed by Mr. B. R. Gray, MEng, P.Eng., Principal Consultant. Mr. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Kyle R. Daly, BEng, EIT
Project Supervisor, Geotechnical Services



Brian R. Gray, MEng, P. Eng.
Principal Consultant



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

KD/CN/BRG:kd-mi-jk



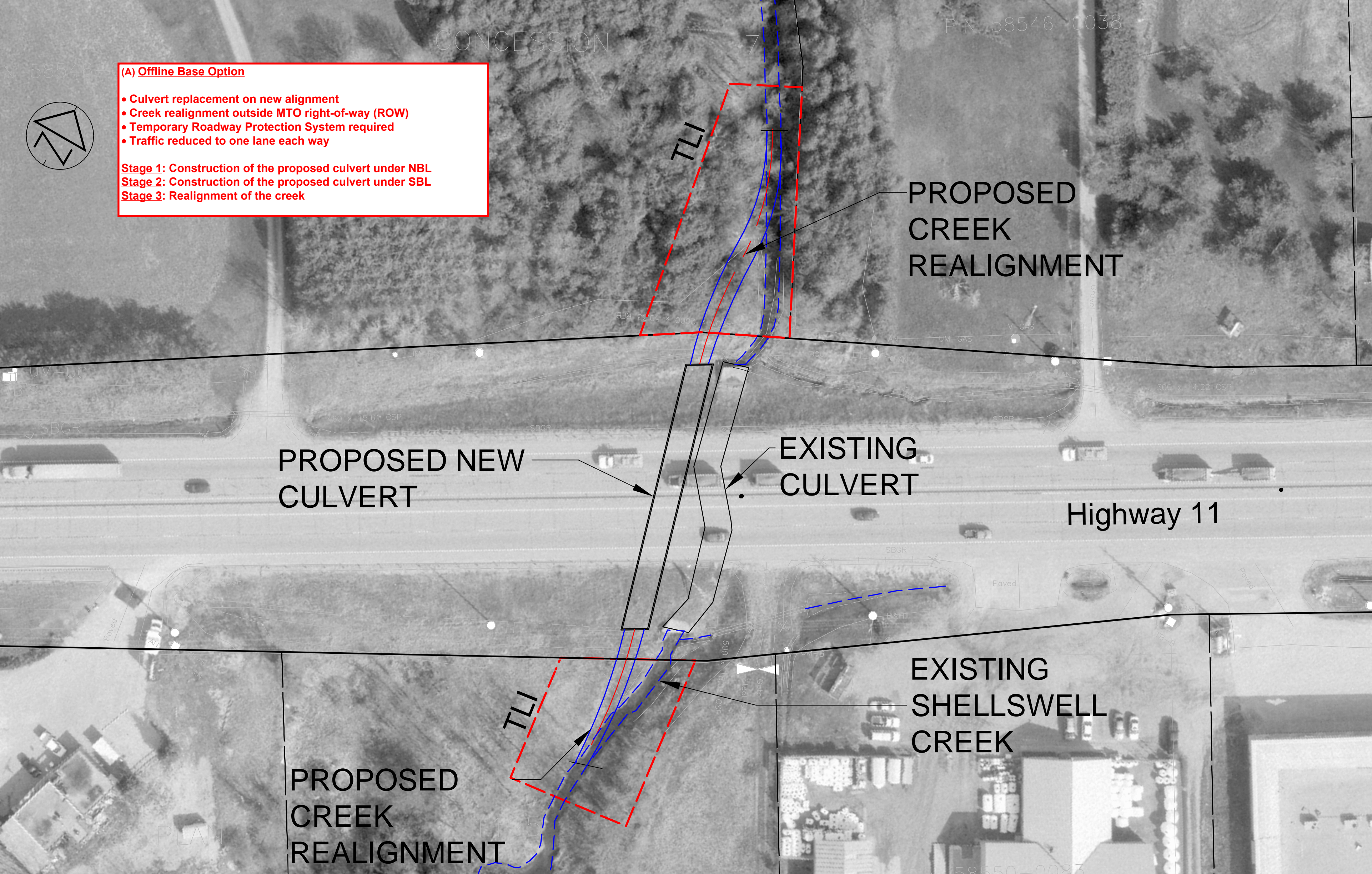
TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS.PROV 206	Construction Specification for Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water From Dewatering Operations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling of Structures
OPSS. PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1860	Material Specification for Geotextiles
SP 422S01	Construction Specification for Precast Concrete Box Culvert
OPSD 203.030	Embankments Over Swamp
OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depth for Southern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements - Walls Retaining
MTOD 803.021	Bedding and Backfill for Precast Concrete Box Culverts



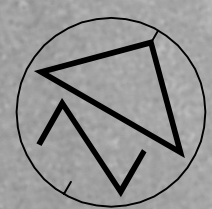
APPENDIX FDR-A

Preliminary Staged Construction Drawings by AECOM



PIN 58546-0038

N 58546



- (A) Offline Base Option**
- Culvert replacement on new alignment
 - Creek realignment outside MTO right-of-way (ROW)
 - Temporary Roadway Protection System required
 - Traffic reduced to one lane each way
- Stage 1:** Construction of the proposed culvert under NBL
Stage 2: Construction of the proposed culvert under SBL
Stage 3: Realignment of the creek

PROPOSED
CREEK
REALIGNMENT

PROPOSED NEW
CULVERT

EXISTING
CULVERT

Highway 11

EXISTING
SHELLSWELL
CREEK

PROPOSED
CREEK
REALIGNMENT

PLAN

PIN 58550-0083

(B) Online Base Option

- Culvert replacement on the existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protect System required
- Traffic reduced to one lane in each direction

Stage 1: Construction of the proposed culvert under NBL

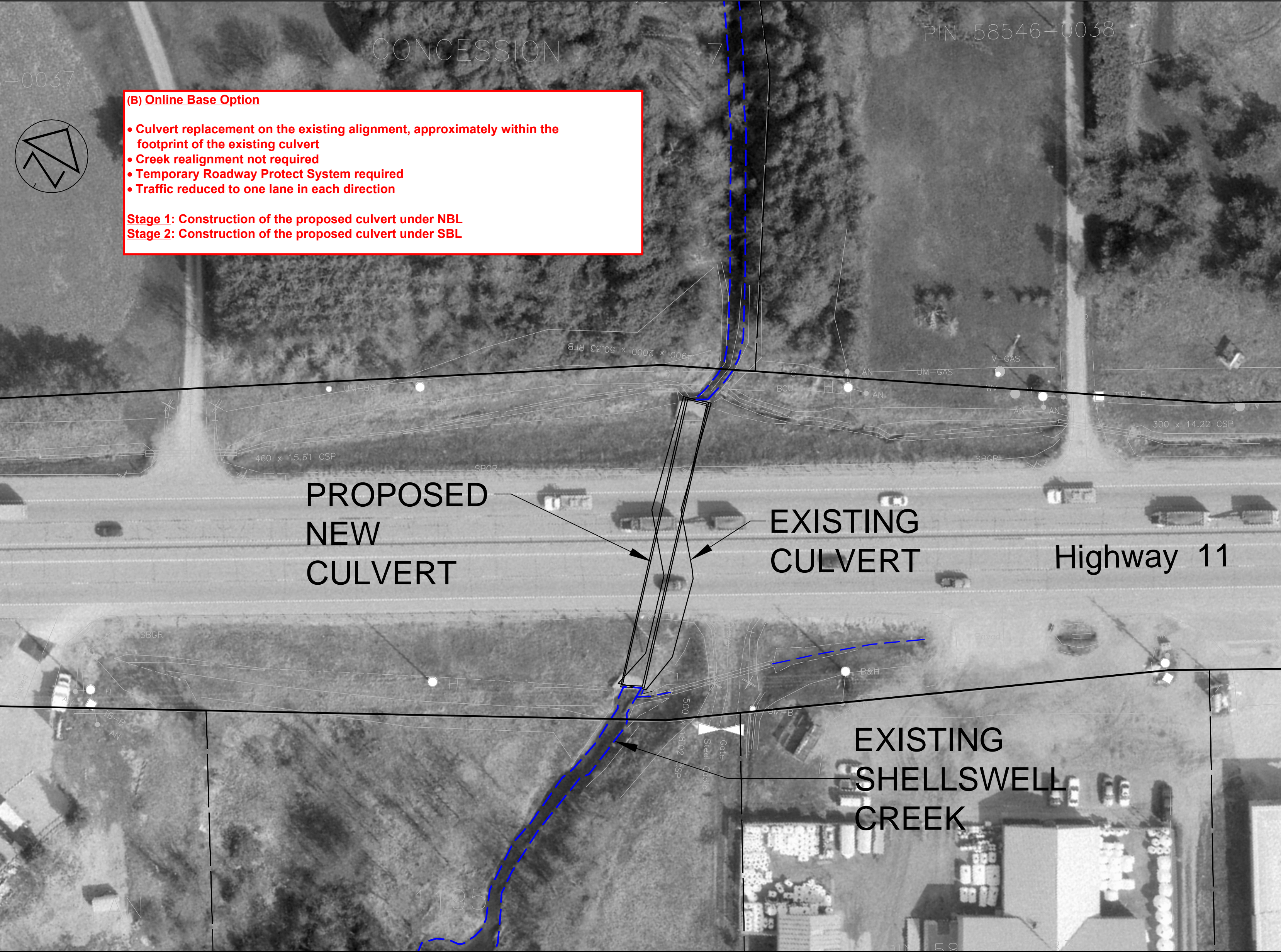
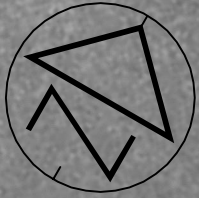
Stage 2: Construction of the proposed culvert under SBL

**PROPOSED
NEW
CULVERT**

**EXISTING
CULVERT**

Highway 11

**EXISTING
SHELLSWELL
CREEK**



CONCESSION

PIN 58546-0038

-0037

(C) Widening Option

- Culvert replacement on existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protection System required
- Two lanes of traffic each way will be maintained during the construction stages by temporarily or permanently widening the NBL and SBL

Stage 1: Widening of the existing SBL and construction of the new culvert under NBL
Stage 2: Widening of the existing NBL and construction of the new culvert under SBL

WIDENING OF SBL NOT SHOWN

PROPOSED NEW CULVERT

EXISTING CULVERT

Highway 11

WIDENING OF NBL NOT SHOWN

EXISTING SHELLSWELL CREEK

1195

PIN 58

PIN 58546-0038

CONCESSION

7

0037

(C) Widening Option

- Culvert replacement on existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protection System required
- Two lanes of traffic each way will be maintained during the construction stages by temporarily or permanently widening the NBL and SBL

Stage 1: Widening of the existing SBL and construction of the new culvert under NBL
Stage 2: Widening of the existing NBL and construction of the new culvert under SBL

WIDENING OF SBL NOT SHOWN

PROPOSED NEW CULVERT

EXISTING CULVERT

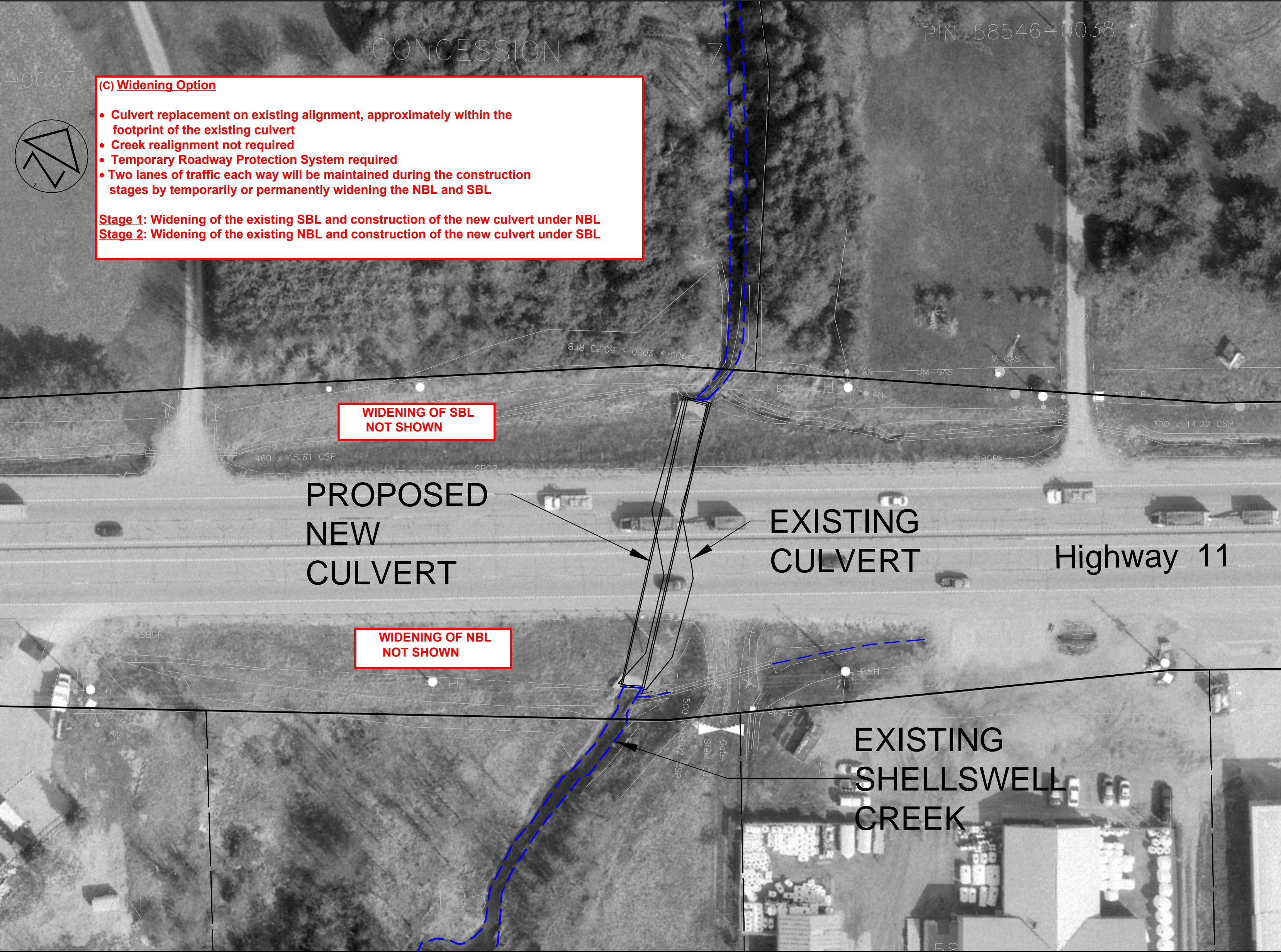
Highway 11

WIDENING OF NBL NOT SHOWN

EXISTING SHELLSWELL CREEK

1195

58



(C) Widening Option

- Culvert replacement on existing alignment, approximately within the footprint of the existing culvert
- Creek realignment not required
- Temporary Roadway Protection System required
- Two lanes of traffic each way will be maintained during the construction stages by temporarily or permanently widening the NBL and SBL

Stage 1: Widening of the existing SBL and construction of the new culvert under NBL

Stage 2: Widening of the existing NBL and construction of the new culvert under SBL

- Stage 1: Widening of the existing SBL and construction of the new culvert under NBL**
Stage 2: Widening of the existing NBL and construction of the new culvert under SBL

Stage 1: Widening of the existing SBL and construction of the new culvert under NBL
Stage 2: Widening of the existing NBL and construction of the new culvert under SBL

**WIDENING OF SBL
NOT SHOWN**

PROPOSED NEW CULVERT

EXISTING
CULVERT

Highway 11

**WIDENING OF NBL
NOT SHOWN**



EXISTING
- SHELLSWELL
CREEK

METRIC

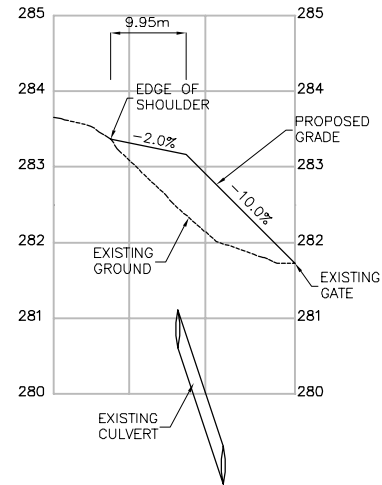
PLATE No
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WP 2053-14-00



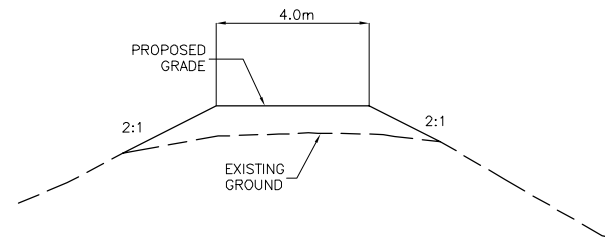
CONSTRUCTION STAGING
STAGE 1
STA 19+325 TO STA 19+700

SHEET
STG-2

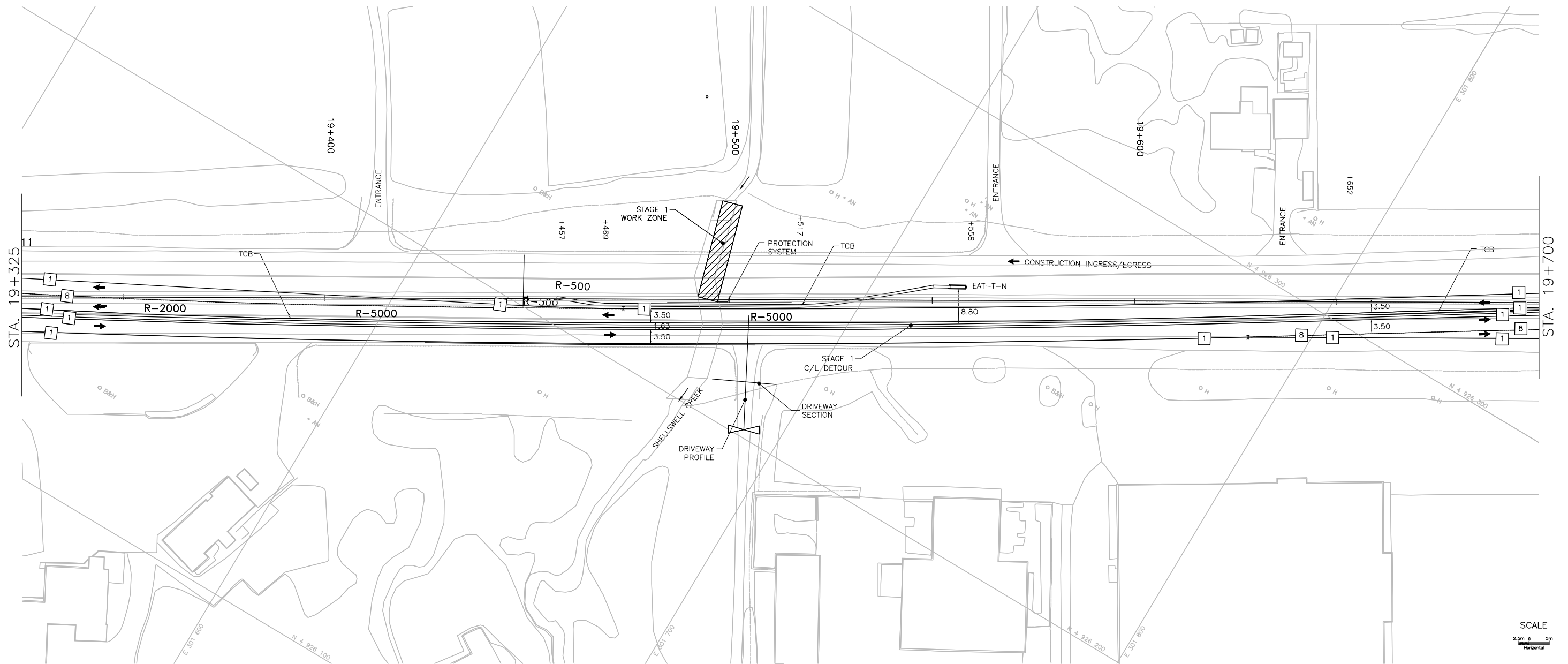
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DRIVEWAY PROFILE



DRIVEWAY SECTION



SCALE
2.5m 5m
Horizontal

METRIC

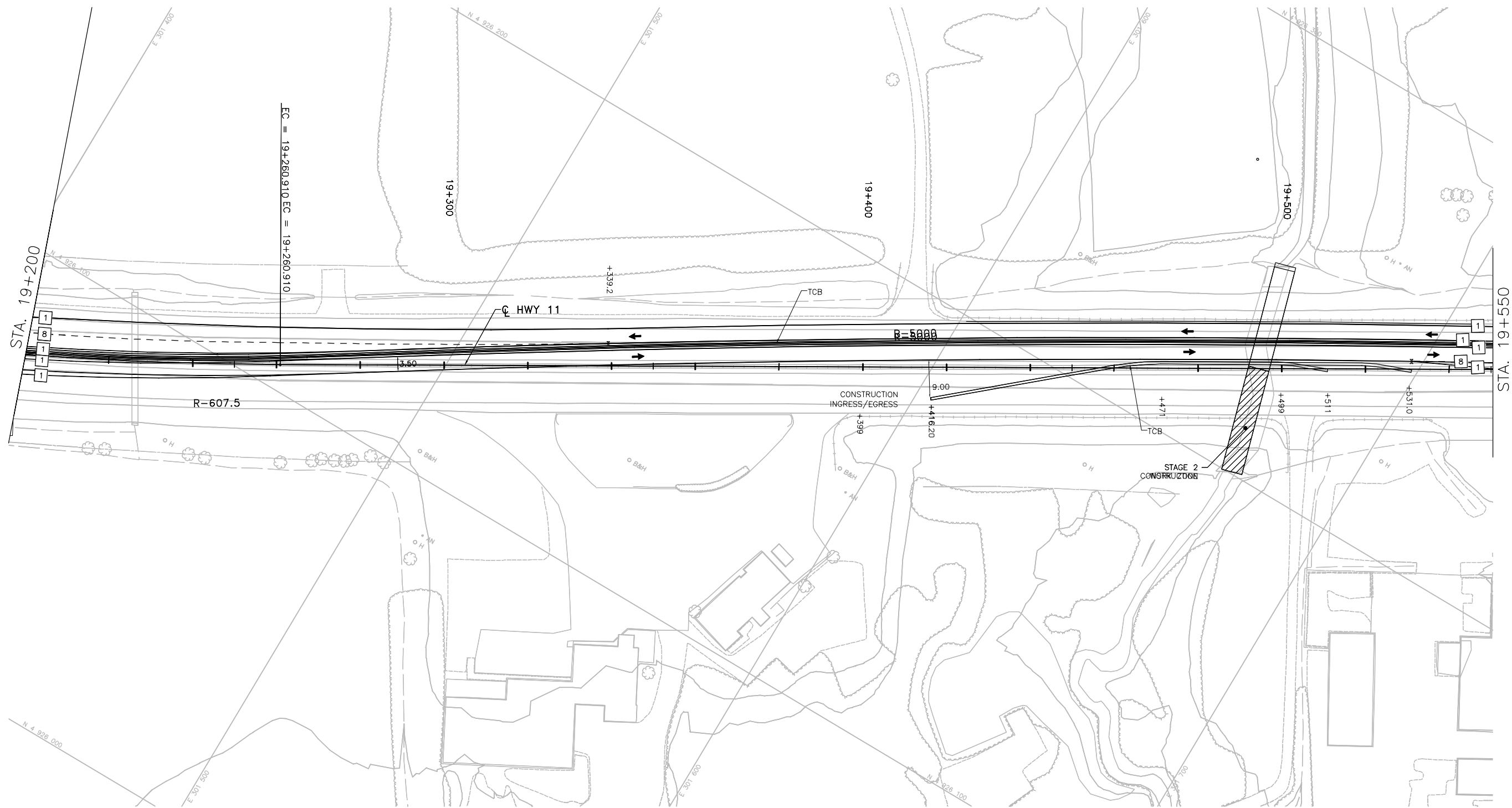
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WP 2053-14-00

CONSTRUCTION STAGING
STAGE 2
STA 19+200 TO STA 19+550

AECOM



SHEET
STG-5



SCALE
2.5m 0 5m
Horizontal



APPENDIX FDR-B

Recommended Non Standard Special Provisions



NSSP – Presence of Cobbles and Boulders in the Ground (Addition to OPSS 539 and OPSS 902)

The Contractor shall be advised that cobbles and boulders are present within the ground and that the Contractor shall use appropriate methods for the preparation of subgrade and the installation of sheet piles and H-piles to address this ground condition.

NSSP – Possible Presence of Old Shoring System in the Ground (Addition to OPSS 539)

The Contractor shall be advised that an old shoring system may be present adjacent to the existing culvert based on wood debris found in the fill. A Contingency Allowance is to be carried in the tenders.