CONTRACT NO. 2017-3003

G.W.P. 3042-11-00

FOUNDATION INVESTIGATION REPORT

UNNAMED TRIBUTARY CULVERT
HWY 23, STATION 21+870.06
(WALLACE TOWNSHIP)

(SITE No. 25-344/C)

CONTRACT 4
STRUCTURE REPLACEMENTS
AND REHABILITATIONS

Ministry Of Transportation

Ontario

April 2017

FOUNDATION INVESTIGATION REPORT

Culvert Replacement
Site No. 25-344/C, Highway 23
Contract 4 Structure Replacements and Rehabilitation
GWP 3042-11-00
Ministry of Transportation, West Region

Submitted to:
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REPORT

Report Number: 12-1132-0163-4000-R03
Geocres No.: 40P15-47
Distribution:

8 Copies - Stantec Consulting Ltd.
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Golder Associates

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detailed design work for GWP 3042-11-00. The project involves the detailed design of the replacement and rehabilitation of several structures along multiple highways in southern Ontario. This report addresses the proposed replacement of the culvert at Site 25-344/C on Highway 23, at about Station 21+870, in Perth County, Geographic Township of Wallace, Ontario.

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed culvert replacement by drilling boreholes and carrying out in situ and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal, in Golder Associates' proposal P2-1132-0163 dated February 25, 2013, and in Change Order 12-1132-0163-4000-C03 dated September 13, 2016. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.

2.0 SITE DESCRIPTION

The subject culvert is situated at about Station 21+870 across Highway 23, approximately 1 kilometre southwest of the intersection of Perth Road 178/Wellington County Road 4, in the Township of Wallace, Perth County, Ontario. The Town of Palmerston is approximately 3 kilometres northeast of the site. The replacement culvert will be constructed in approximately the same location as the existing culvert. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 23 is currently a two lane, undivided highway with gravel shoulders. It is generally oriented northeast-southwest in the vicinity of the site. An unnamed watercourse flows in the culvert from west to east beneath Highway 23. The existing culvert has an unknown date of construction and is 28 metres (m) long, including extensions of approximately 8.1 m on either side that were constructed circa 1959. The existing culvert is a concrete, non-rigid frame, open footing (NRFO) structure with extensions of the same nature.

Existing Dimensions (m)	Obvert Elevation (m)		Construction
	Lt[1]	Rt[1]	
3.05 x 1.80 x 28.00	388.62	388.63	Concrete NRFO

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of the watercourse and the embankments along Highway 23 near the culvert are grass covered. Broken concrete slabs have been placed at the inlet of the culvert and sand bags and broken concrete slabs have been placed at the outlet. The watercourse flows through fields on both sides of Highway 23. Selected site photographs are provided in Appendix B.

2.1 Site Geology

The project area is located within the Teeswater Drumlin Field within the northwestern limb of the Horseshoe Moraine system. This area is characterized as a drumlin field that is not bound by any well-developed terminal moraine, and also intermingled with well-draining gravel terraces, kames, moraines and poor-draining swampy land. The area consists predominately of soil with a loamy texture that is moderately compact and pale brown to yellow-brown in colour, in addition to shallow surface deposits of silty, stone-free material.[1] The overburden in the area of the site generally consists of gravel, gravelly sand, fine sand, stony sandy silt and silt.[2]

The geological mapping indicates that the underlying bedrock consists of cream and tan dolomite of the Bass Islands Formation of Upper Silurian age.[3] The bedrock surface at the site is at about elevation 365 m with the overburden thickness being about 25 m. [4]

3.0 INVESTIGATION PROCEDURES

The geotechnical field investigation was carried out on September 19 and 21, 2016, during which time three boreholes were drilled at the approximate locations shown on the Plan, Drawing 1.

The boreholes were drilled using a track-mounted Dietrich D50T drill rig supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 m using 50 millimetre (mm) outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

The recorded SPT N-values are noted on the Record of Borehole sheets. The results of the SPT testing, as presented on the Record of Borehole sheets, Drawing 1 and in Section 4.0 of this report, are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders, are known to be present in the glacial tills as discussed in the text of this report.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a piezometer was installed in borehole BH-302 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by an experienced member of our staff who located the boreholes in the field, obtained utility locates, monitored the drilling, sampling and in-situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

[1] Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p.

[2] Cowan, W.R, et al. 1977: Quaternary Geology: Palmerston, Southern Ontario; Ministry of Natural Resources; Ontario Geological Survey, Map 2382, NTS 40P/15, Scale 1:50,000.

[3] Sanford B.V., 1969: Geology Toronto-Windsor Area, Ontario; Ontario Geological Survey of Canada Map 1263A, Scale 1:250,000.

[4] Davies, L.L., McClymont, W.R., and Karrow, P.F., 1962: Bedrock Topography of the Palmerston Area, Ontario Geological Survey, Ontario Department of Mines Bedrock Topography Series Palmerston Sheet, Prelim. Map No. P.166., Scale 1:50,000.

The as-drilled borehole locations and ground surface elevations at the borehole locations are shown on the Record of Borehole sheets and on Drawing 1. Table 1, below, summarizes the coordinates, ground surface elevations, and depths of the boreholes.

Table 1: Geospatial and borehole exploration summary.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BH-301	4 854 725	193 820	389.79	9.60
BH-302	4 854 739	193 815	389.94	9.60
BH-303	4 854 735	193 835	387.98	8.08

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in-situ and laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered embankment fill materials and buried topsoil overlying layers of silt, sand and gravel, silty clay and clayey silt with clayey silt till at depth in BH-303.

The locations and elevations of the boreholes and the interpreted stratigraphic profile are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Soil Conditions

The boreholes encountered topsoil and/or fill materials at the ground surface. A 300 mm thick layer of silty topsoil was encountered at the ground surface in BH-303. Fill materials, consisting of layers of sand and gravel, silty sand and sandy silt, were encountered at the ground surface in BH-301 and BH-302 and beneath the surficial topsoil in BH-303. The fill materials were about 2.1 m thick in BH-301 and BH-302 and about 0.6 m thick in BH-303. The fill had N values, as determined in the standard penetration testing, of 5 to 14 blows per 0.3 m. Buried topsoil layers 0.2 to 0.8 m thick were encountered beneath the fill materials at depths of 2.1 to 2.9 m or between elevation 386.9 and 387.8 m. The topsoil in BH-301 had an SPT-N value of 4 blows per 0.3 m and a water content of about 46 per cent. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

Layers of compact to dense silt were encountered beneath the buried topsoil between about elevation 387.6 and 386.9 m. The silt layers were about 0.7 to 1.3 m thick at the borehole locations. The silt had N values of 16 to 19 blows per 0.3 m for tests fully completed in the silt and water contents of about 17 to 18 per cent. Grain size distribution curves for samples of the silt recovered from the standard penetration testing are provided on Figure A-1.

Compact to dense sand and gravel was encountered beneath the silt in all of the boreholes. The sand and gravel was encountered between about elevation 386.1 and 386.3 m. The sand and gravel layers were 0.4 to 1.5 m thick. The sand and gravel had N values of 20 to 46 blows per 0.3 m. A sample of the sand and gravel from BH-302 had a water content of about 9 per cent. A grain size distribution curve for a sample of the sand and gravel is provided on Figure A-2. Although not explicitly encountered during the field work, cobbles and boulders should be expected in the sand and gravel.

Clayey silt was encountered in BH-301 and BH-303 beneath the sand and gravel. The clayey silt was encountered at about elevation 384.6 and 385.9 m in BH-301 and BH-303, respectively, and was about 0.8 and 2.3 m thick. The stiff to very stiff clayey silt had N values of 12 to 18 blows per 0.3 m. A sample of the clayey silt from BH-303 had a water content of about 18 per cent and plastic and liquid limits of about 18 and 33 per cent, respectively. The results of the Atterberg limits testing are shown on Figure A-6. A grain size distribution curve for a sample of the clayey silt is shown on Figure A-3.

Beneath the clayey silt in BH-301 and BH-303 and beneath the sand and gravel in BH-302, silty clay was encountered between about elevation 383.6 and 384.8 m. BH-301 and BH-302 were terminated in the silty clay after exploring it for about 3.7 to 4.4 m. In BH-303, the silty clay was about 2.6 m thick. The stiff to very stiff silty clay had N values of 10 to 22 blows per 0.3 m with water contents ranging from about 31 to 34 per cent. Samples of the silty clay had average plastic and liquid limits of about 23 and 51 per cent, respectively, based on three Atterberg limits determinations indicating silty clay of intermediate to high plasticity. The results of the Atterberg limits testing are shown on Figure A-6. In situ vane testing attempted in BH-303 indicated undrained shear strengths in excess of 144 kilopascals. Grain size distribution curves for samples of the silty clay are shown on Figure A-4.

A layer of clayey silt till was encountered in BH-303 at approximately elevation 381.0 m. BH-303 was terminated in the clayey silt till after exploring it for about 1.1 metres. The clayey silt till had an N value of 25 blows per 0.3 m and a water content of about 17 per cent. Atterberg limits testing carried out on a sample of the clayey silt till indicated plastic and liquid limits of about 15 and 26 per cent, respectively. The results of the Atterberg limits testing are shown on Figure A-6. A grain size distribution curve for a sample of the clayey silt till is provided on Figure A-5. Cobbles and boulders should be expected in the till.

4.3 Groundwater Conditions

Groundwater conditions were observed during drilling, and a piezometer was installed in BH-302 on completion of drilling. The installation details are provided on the corresponding Record of Borehole sheet. Groundwater was encountered during drilling in BH-301 and BH-302 on September 19, 2016, and in BH-303 on September 21, 2016. A summary of the encountered and measured groundwater levels is provided in the table below.

Table 2: Encountered and measured groundwater levels.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level Elevation (m)	
			September 21, 2016	October 25, 2016
BH-301	389.79	386.9	-	-
BH-302	389.94	386.7	386.74	386.76
BH-303	387.98	386.5	-	-

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the observed groundwater levels, the change in soil colour from brown to grey and the surrounding topography, the groundwater level is inferred to typically be at about elevation 387.0 m. The groundwater levels should be expected to fluctuate seasonally and be higher during periods of sustained precipitation or during spring snow melt conditions.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by London Soil Test Limited, an Ontario Ministry of Environment and Climate Change licensed well contractor. The field operations were supervised by Mr. Daniel Hyland, E.I.T. under the direction of the Field Investigation Manager, Mr. Brett Thorner, P.Eng. The laboratory testing was carried out at Golder's London laboratory under the direction of Mr. Michael Arthur. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Ms. Cara Kennedy, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. Michael E. Beadle, P.Eng., an Associate with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

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LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to “A” size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index Relative Density	**N Blows/300 mm or Blows/ft**
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils
Consistency

	c_u, s_u	
	kPa	**psf**
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-301

METRIC

PROJECT 12-1132-0163

W.P. 3042-11-00 LOCATION N 4854724.5 , E 193819.9 ORIGINATED BY DH

DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY ZJB

DATUM GEODETIC DATE September 19, 2016 CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
389.79	GROUND SURFACE							
0.00 / 389.45 / 0.34	FILL, sand and crushed gravel, trace silt, Brown							
388.57 / 1.22	FILL, sand and gravel, some silt, with cobbles, Compact, Brown	1	SS	11		389		
387.66 / 2.13	FILL, silty sand, some gravel, with topsoil, Loose, Brown	2	SS	5		388		
386.89 / 2.90	TOPSOIL, silty, Loose, Black	3	SS	4		387	46	
386.13 / 3.66	SILT, some sand, trace to some clay, trace gravel, Compact, Brown	4	SS	18	▽			1 12 79 8
384.61 / 5.18	SAND AND GRAVEL, some silt, Compact to dense, Brown	5	SS	33		386		
		6	SS	20		385		
383.85 / 5.94	CLAYEY SILT, some sand, some gravel, Very stiff, Grey	7	SS	17		384		
380.19 / 9.60	SILTY CLAY, trace sand, with silt seams, Stiff to very stiff, Grey	8	SS	14		383		
		9	SS	11		382	47	0 1 27 72
						381		
		10	SS	22				
	END OF BOREHOLE							

Groundwater encountered at about elev. 386.9m during drilling on September 19, 2016.

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L
UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-302

METRIC

PROJECT 12-1132-0163

W.P. 3042-11-00 LOCATION N 4854738.8 , E 193815.3 ORIGINATED BY DH

DIST ___ HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY ZJB

DATUM GEODETIC DATE September 19, 2016 CHECKED BY ___

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
389.94	GROUND SURFACE						
0.00	FILL, sand and crushed gravel, trace silt				Granular Bentonite		
389.60 / 0.34	Brown						
	FILL, sand and gravel, some silt, with cobbles, Compact, Brown	1	SS	14			
388.57 / 1.37	FILL, sandy silt, some clay, some gravel, with topsoil, Compact, Brown	2	SS	10			
387.81 / 2.13	TOPSOIL, silty						
2.35	Black						
	SILT, some sand, trace clay, trace gravel, Compact, Brown	3	SS	19	Filter Sand		
		4	SS	16	Piezometer	o	0 13 79 6
386.28 / 3.66	SAND AND GRAVEL, some silt, trace clay, Compact to dense, Brown	5	SS	26	Granular Bentonite		
		6	SS	46		o	39 45 12 4
384.76 / 5.18	SILTY CLAY, trace sand, trace gravel, Stiff to very stiff, Grey	7	SS	19			
		8	SS	10		wP-w-wL (62)	0 2 16 82
		9	SS	10			
		10	SS	18	Caved Material		
380.34 / 9.60	END OF BOREHOLE						

Elevation scale: 389, 388, 387, 386, 385, 384, 383, 382, 381

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

Groundwater encountered at about elev. 386.7m during drilling on September 19, 2016.

Water level measured in piezometer at elev. 386.74m on September 21, 2016.

Water level measured in piezometer at elev. 386.76m on October 25, 2016.

+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

LDN_MTO_06 1211320163-4000.GPJ LDN_MTO.GDT 20/12/16

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-303

METRIC

PROJECT	12-1132-0163		
W.P.	3042-11-00	LOCATION	N 4854734.8 , E 193835.4
DIST		HWY	23
BOREHOLE TYPE	POWER AUGER, HOLLOW STEM		
DATUM	GEODETIC	DATE	September 21, 2016
ORIGINATED BY	DH	COMPILED BY	ZJB
CHECKED BY			

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
387.98	GROUND SURFACE
0.00	TOPSOIL, silty Brown
387.64 0.34	FILL, silty sand, some gravel, some topsoil Brown
387.22 0.76	FILL, sandy silt, some clay, some topsoil Grey
0.91	TOPSOIL, silty Compact Black
1.07	SILT, some sand, trace clay, trace gravel Compact to dense Brown and grey
386.21 1.77	SAND AND GRAVEL, some silt Dense Brown
385.85 2.13	CLAYEY SILT, some sand, trace gravel Stiff to very stiff Grey
383.56 4.42	SILTY CLAY, trace sand Stiff to very stiff Grey
380.97 7.01	CLAYEY SILT TILL, trace to some sand Very stiff Grey
379.90 8.08	END OF BOREHOLE Groundwater encountered at about elev. 386.5m during drilling on September 21, 2016.

SAMPLES

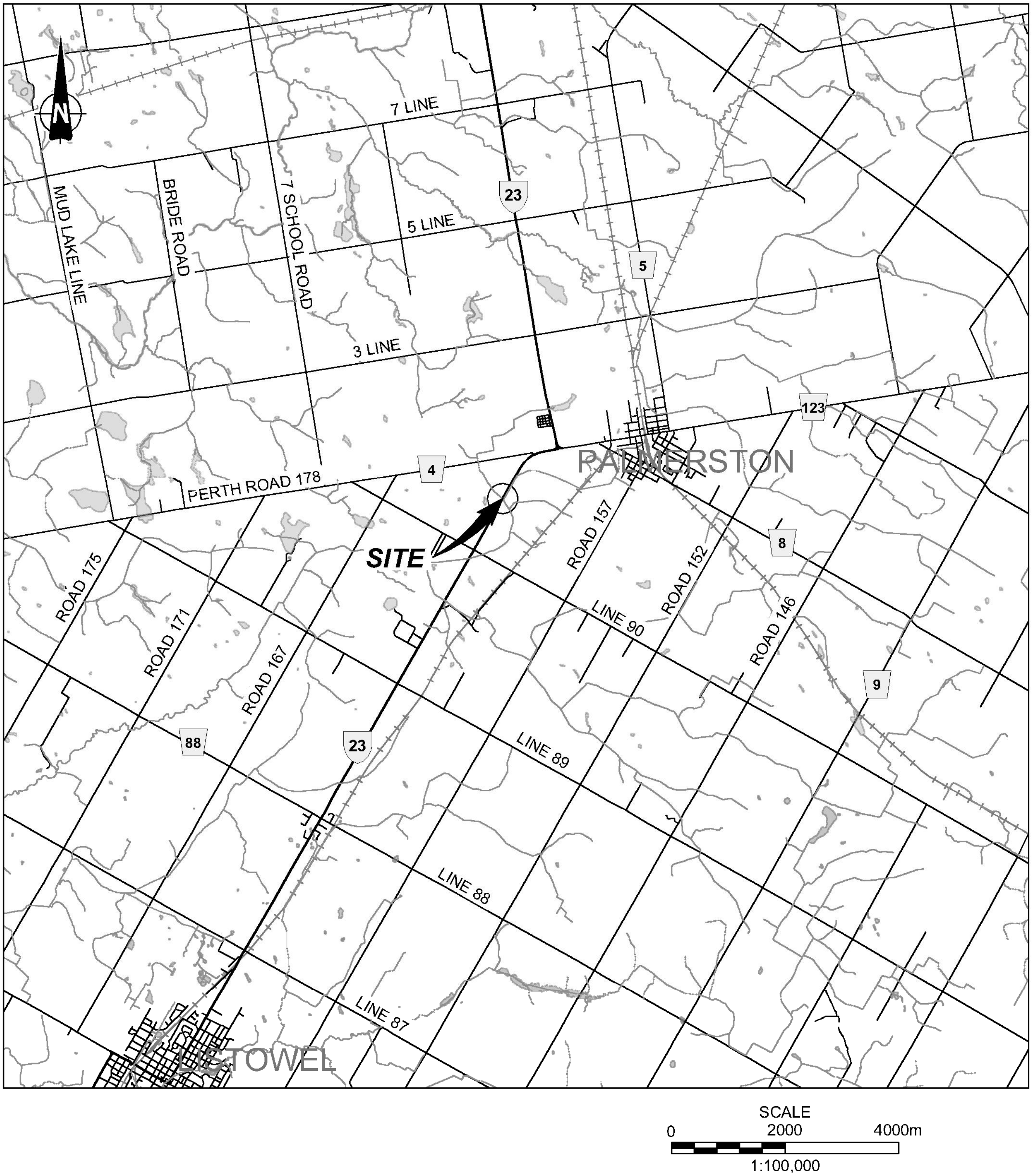
NUMBER	TYPE	"N" VALUES	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	10				
2	SS	32				
3	SS	17	1	14	37	48
4	SS	18				
5	SS	12				
6	SS	11	0	5	31	64
7	SS	11				
8	SS	25	0	6	59	35

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (387, 386, 385, 384, 383, 382, 381, 380); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Shear strength values plotted: >143.6, >143.6, >143.6, >143.6

Water content plot annotation: 43

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE



REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE

KEY PLAN

Golder Associates

PROJECT No.		12-1132-0163	FILE No.	1211320163-4000-F03001
			SCALE AS SHOWN	REV. 0
CADD	ZJB/LMK	Jan. 12/17		
CHECK			**FIGURE 1**	

Drawing file: 1211320163-4000-F03001.dwg   Jan 12, 2017 - 9:09am

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

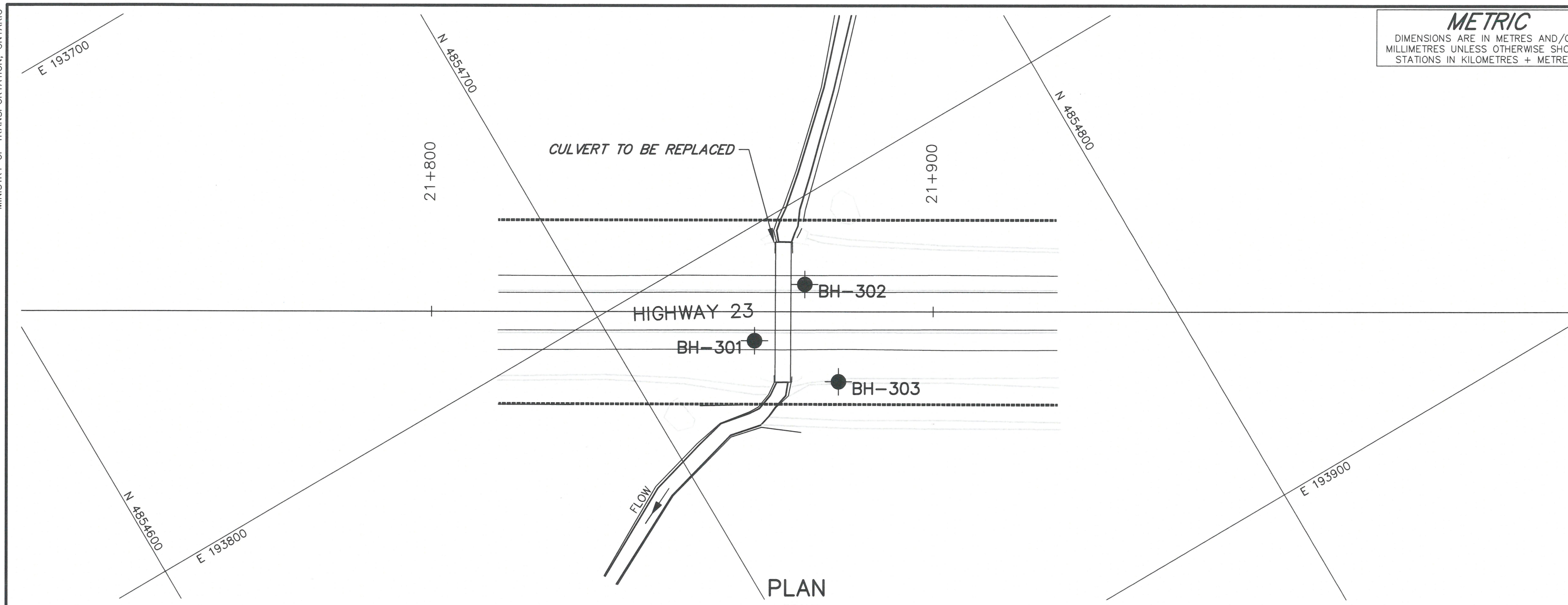
CONT No.
WP No. 3042-11-00

SHEET

UNNAMED TRIBUTARY CULVERT REPLACEMENT

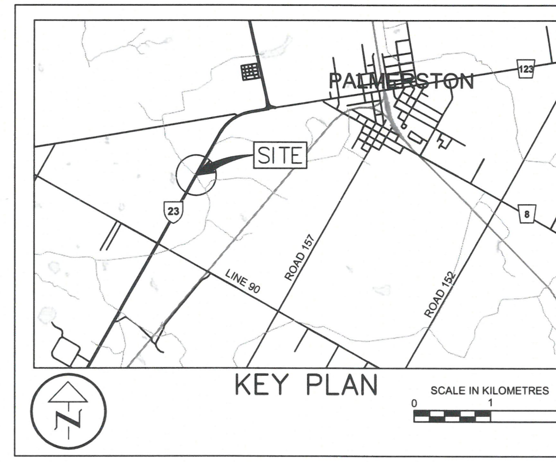
HIGHWAY 23 SITE No. 25-344/C
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



PLAN

SCALE 10 0 10 m



KEY PLAN

LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL encountered during drilling
- WL measured on October 25, 2016

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
BH-301	389.79	4 854 724.5	193 819.9
BH-302	389.94	4 854 738.8	193 815.3
BH-303	387.98	4 854 734.8	193 835.4

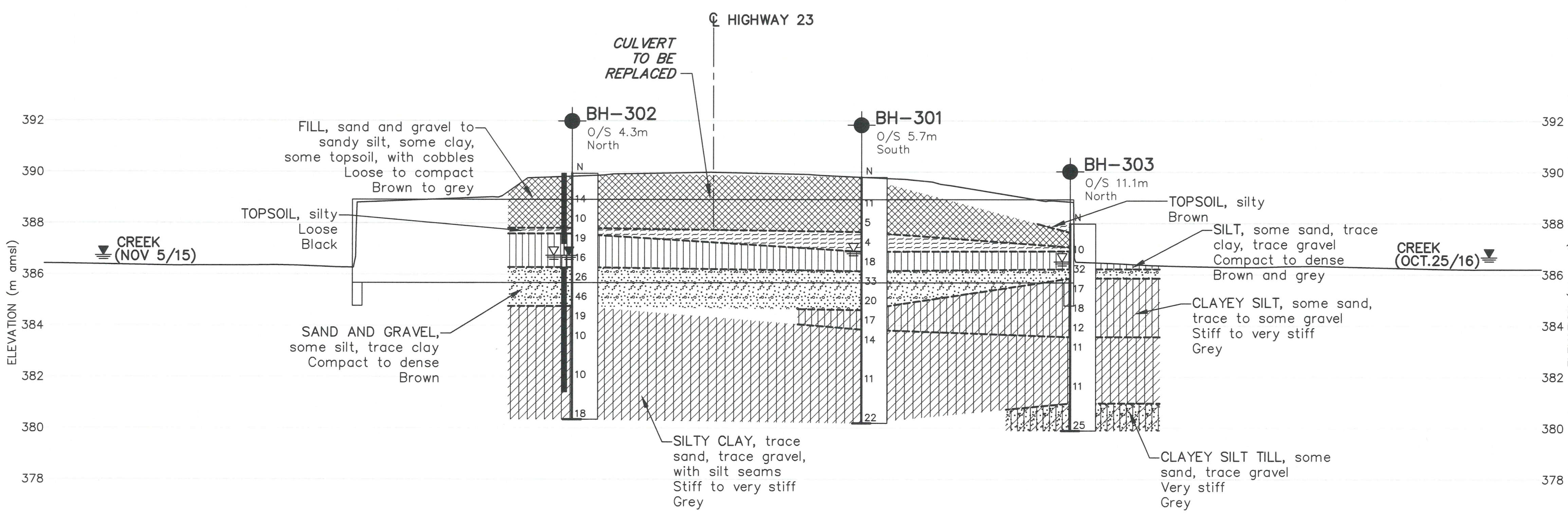
NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REFERENCE

Base plans provided in digital format by Stantec.



PROFILE ALONG ℄ OF CULVERT

HORIZONTAL SCALE 2 0 2 m
VERTICAL SCALE 2 0 2 m

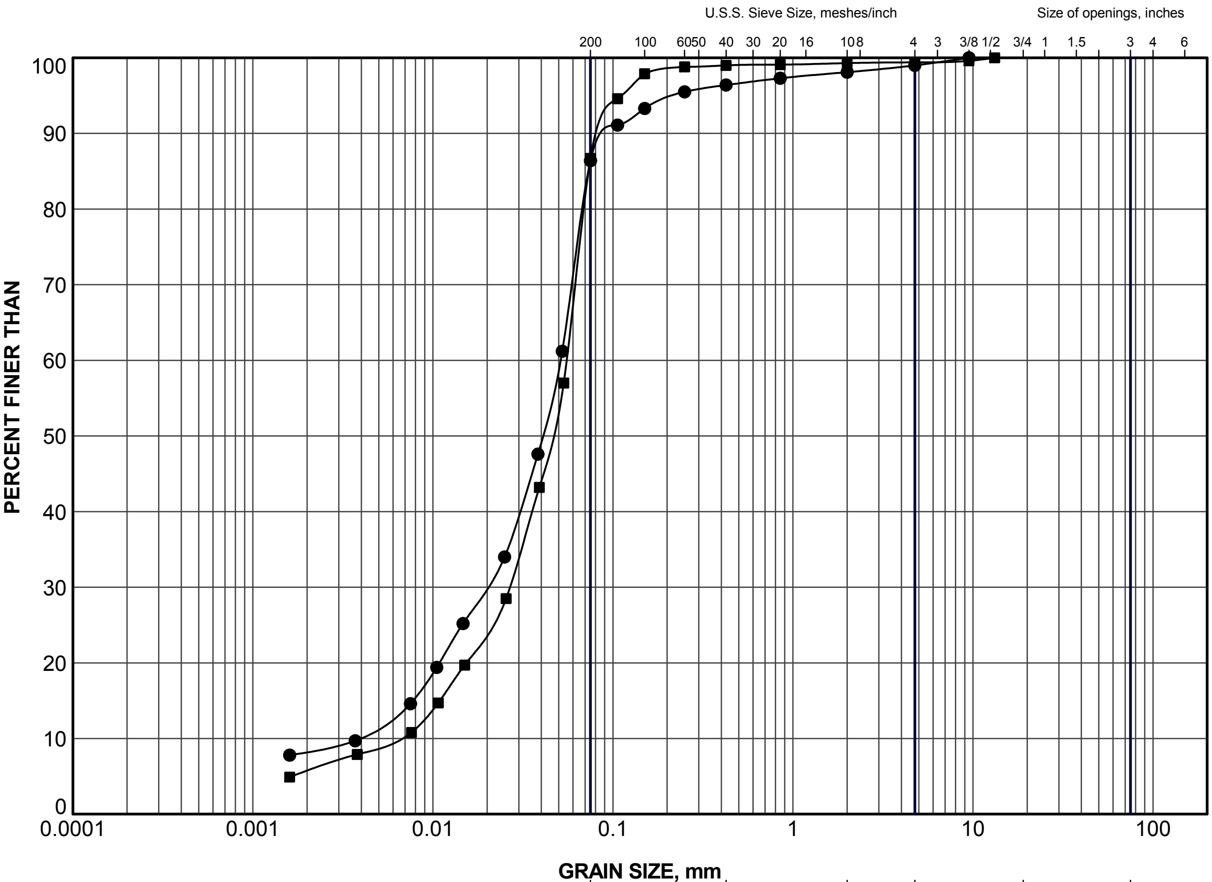
LICENSED PROFESSIONAL ENGINEER D. J. PROUT PROVINCE OF ONTARIO Apr 3/17
REGISTERED PROFESSIONAL ENGINEER F.J. HEFFERNAN PROVINCE OF ONTARIO Apr 3/17

NO.	DATE	BY	REVISION

Geocres No. 40P15-47			
HWY. 23		PROJECT NO. 12-1132-0163	DIST.
SUBM'D. BT	CHKD. DH	DATE: Mar. 22/17	SITE: 25-344/C
DRAWN: LMK	CHKD. DUP	APPD. FJH	DWG. 1

APPENDIX A

Laboratory Test Data



CLAY AND SILT	SAND SIZE			GRAVEL SIZE		Cobble Size
	fine	medium	coarse	fine	coarse	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-301	4	386.5
■	BH-302	4	386.7

PROJECT

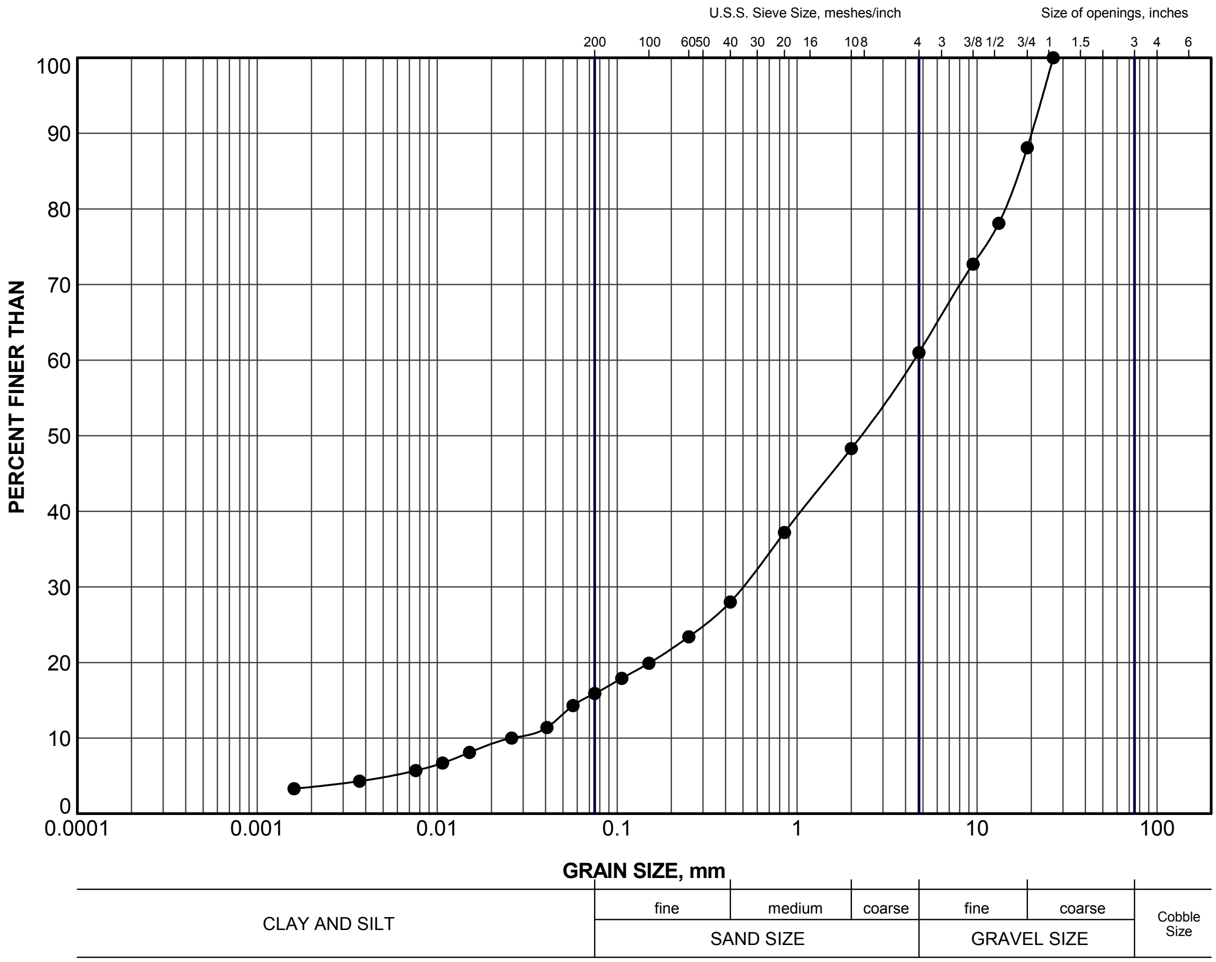
CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE

GRAIN SIZE DISTRIBUTION
SILT

Golder Associates	PROJECT No.		12-1132-0163	FILE No.1211320163-4000-F030A1		
				SCALE	N/A	REV.
	DRAWN	ZJB	Oct 26/16	FIGURE A-1		
	CHECK					

LDN_MTO_GSD GLDR_LDN.GDT 14/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-302	6	385.1

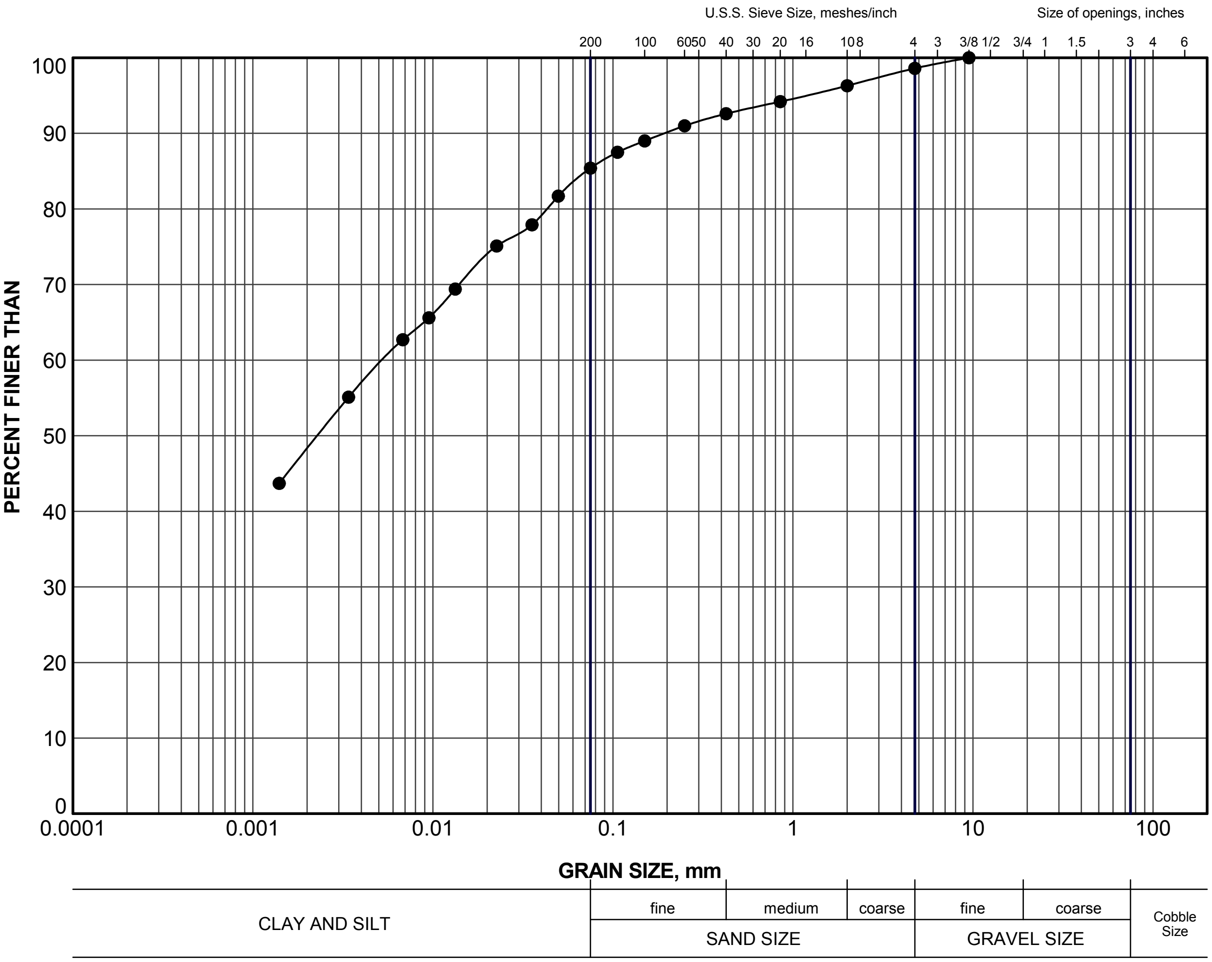
PROJECT
CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
SAND AND GRAVEL

Golder Associates

PROJECT No.	12-1132-0163	FILE No.	1211320163-4000-F030A2
		SCALE N/A	REV.
DRAWN ZJB	Oct 26/16		
CHECK		**FIGURE A-2**	

LDN_MTO_GSD GLDR_LDN.GDT 14/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-303	3	385.5

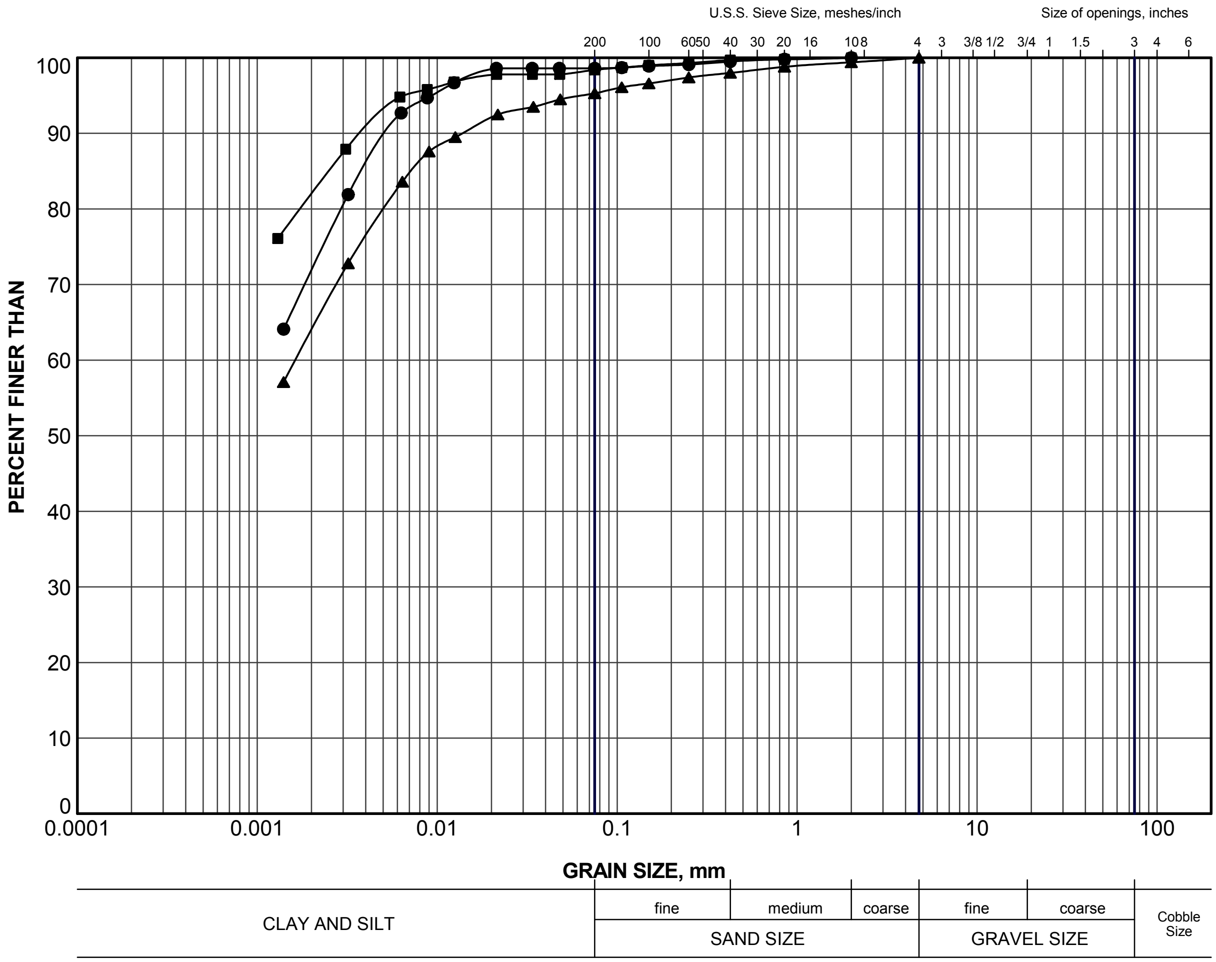
PROJECT
CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
CLAYEY SILT

Golder Associates

PROJECT No.	12-1132-0163	FILE No. 1211320163-4000-F030A3	
		SCALE N/A	REV.
DRAWN	ZJB	Oct 26/16	**FIGURE A-3**
CHECK			

LDN_MTO_GSD GLDR_LDN.GDT 17/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-301	9	381.9
■	BH-302	8	383.6
▲	BH-303	6	383.2

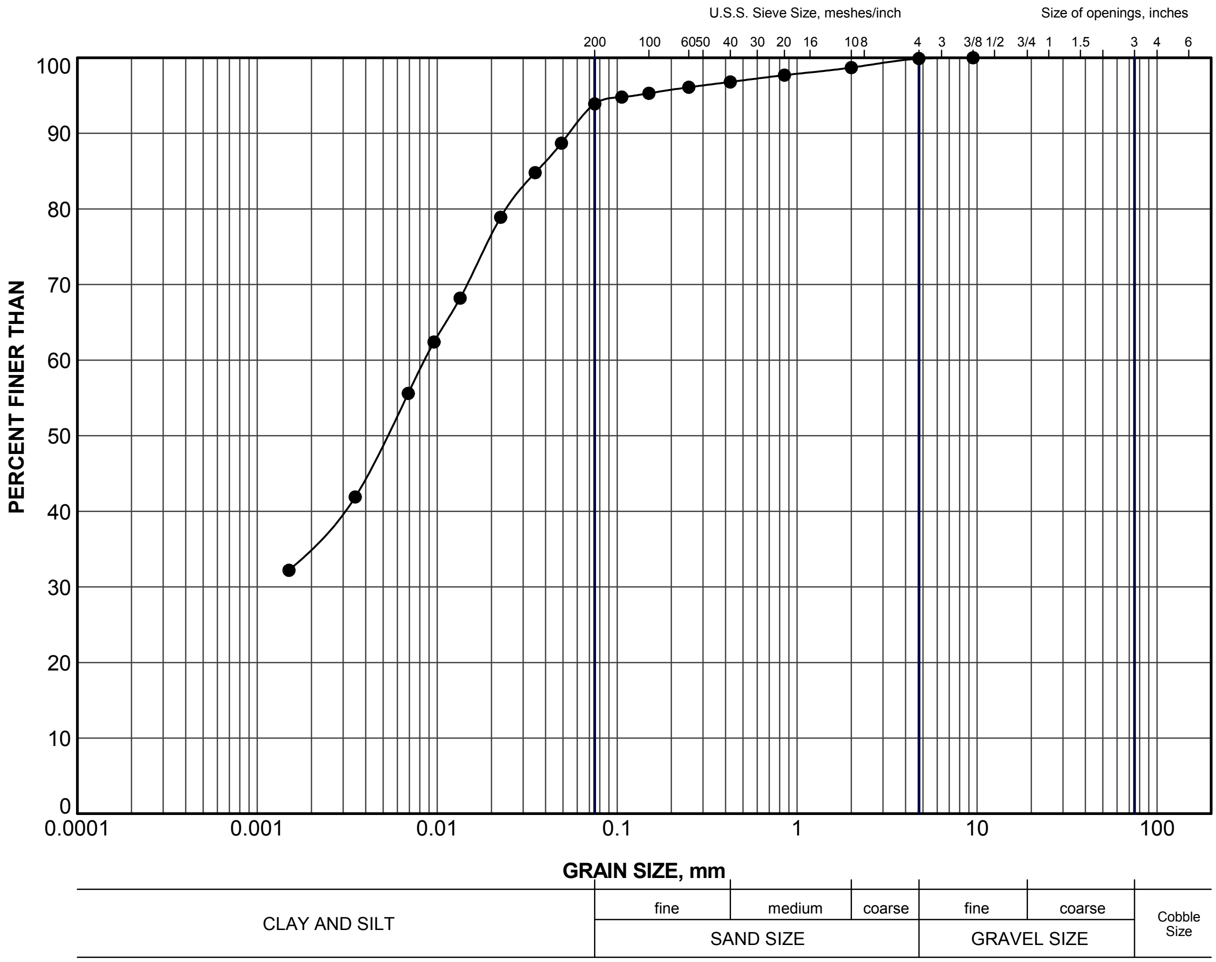
PROJECT
CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
SILTY CLAY

Golder Associates

PROJECT No.	12-1132-0163		FILE No. 1211320163-4000-F030A4	
			SCALE N/A	REV.
DRAWN	ZJB	Dec 19/16	**FIGURE A-4**	
CHECK				

LDN_MTO_GSD GLDR_LDN.GDT 19/12/16



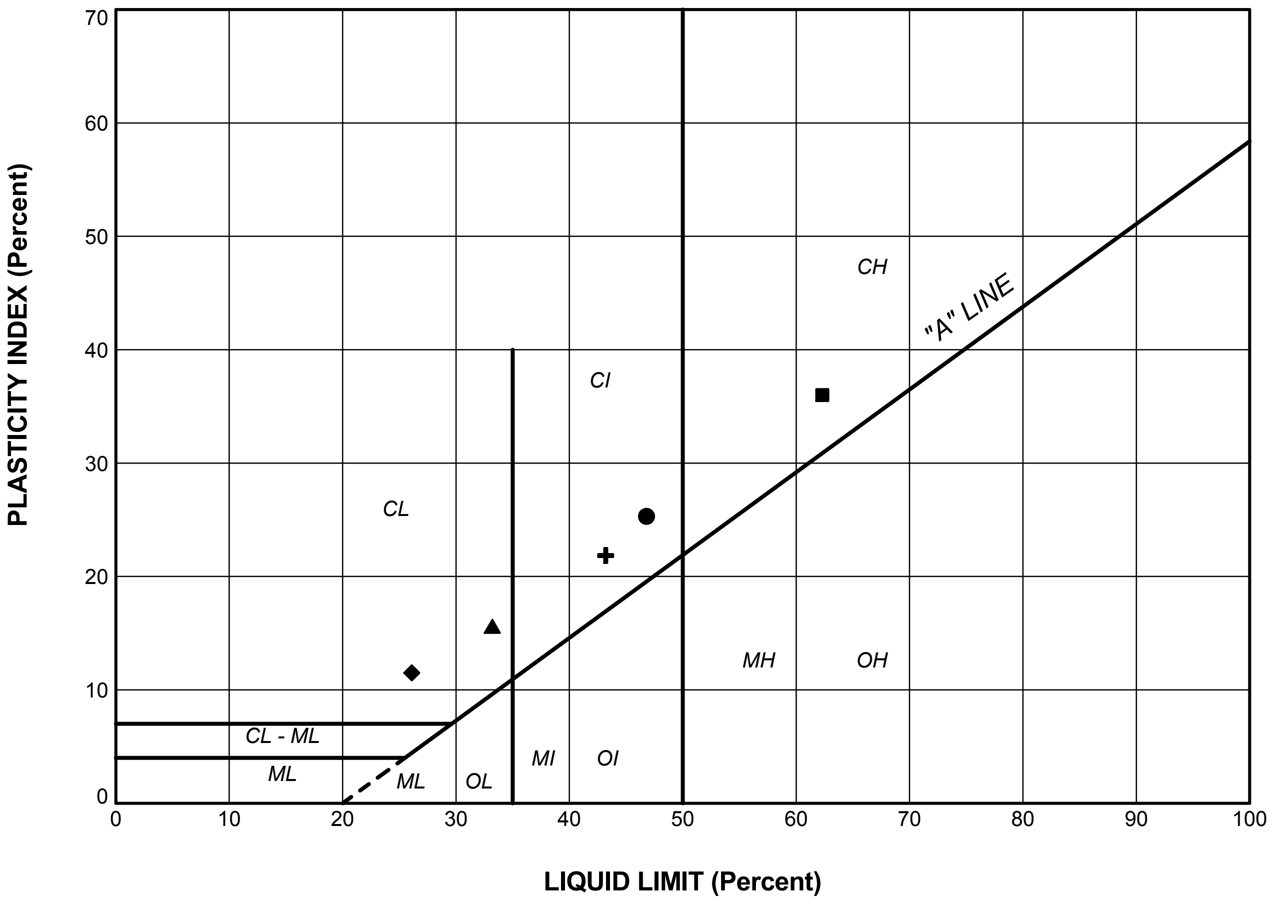
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-303	8	380.1

PROJECT	CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00
TITLE	**GRAIN SIZE DISTRIBUTION** **CLAYEY SILT TILL**

Golder Associates

PROJECT No.	12-1132-0163	FILE No.	1211320163-4000-F030A5
		SCALE N/A	REV.
DRAWN ZJB	Oct 26/16	**FIGURE A-5**	
CHECK			



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
SILTY CLAY					
●	BH-301	9	46.8	21.5	25.3
■	BH-302	8	62.3	26.3	36.0
✚	BH-303	6	43.2	21.4	21.9
CLAYEY SILT					
▲	BH-303	3	33.2	17.6	15.6
CLAYEY SILT TILL					
◆	BH-303	8	26.1	14.6	11.5

PROJECT
CULVERT REPLACEMENT, SITE 25-344/C
HIGHWAY 23
GWP 3042-11-00

TITLE
PLASTICITY CHART

Golder Associates

PROJECT No.	12-1132-0163	FILE No.1211320163-4000-F030A6	
		SCALE N/A	REV.
DRAWN	ZJB	Oct 26/16	**FIGURE A-6**
CHECK			

LDN_MTO_PI GLDR_LDN.GDT 17/10/16

APPENDIX B

Site Photographs

Photograph 1: West elevation (inlet) of Culvert Site 25-344/C (February 2, 2016).

Photograph 2: East elevation (outlet) of Culvert Site 25-344/C (February 2, 2016).

Photograph 3: Looking northeast from Highway 23, east ditch toward Culvert Site 25-344/C (February 2, 2016).

Photograph 4: Looking southwest from Highway 23, west ditch toward Culvert Site 25-344/C (February 2, 2016).

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