CONTRACT NO. 2017-3003

G.W.P. 3042-11-00

FOUNDATION INVESTIGATION REPORT

HWY 9, HODGINS DRAIN CULVERT

(SITE No. 2-463/C)

CONTRACT 4
STRUCTURE REPLACEMENTS
AND REHABILITATIONS

Ministry Of Transportation

Ontario

April 2017

FOUNDATION INVESTIGATION REPORT

Culvert Replacement, Hodgins Drain Culvert
Site No. 2-463/C, Highway 9
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-R07
Geocres No.: 41A-241
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 Hodgins Drain Culvert at Site 2-463/C on Highway 9, at about Station 19+405 in Bruce County, Geographic Township of Kincardine.

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 the Change Order 12-1132-0163-4000-C03 revised 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 19+405 Highway 9, approximately 850 metres (m) northwest of Bervie, Ontario, in the Township of Kincardine, Bruce County, Ontario. 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 9 is a two-lane, undivided highway with paved shoulders and a post and cable fence guardrail system. The highway is generally oriented northwest-southeast in the vicinity of the subject site. The Hodgins Drain watercourse flows in the culvert from north to south beneath Highway 9. The existing culvert has an overall length of 27.3 m, including extensions. The dates of construction for both the original portion and the extensions are unknown. The original structure consists of concrete non-rigid frame open footing (NRFO) construction and the extensions consist of open footing concrete rigid frame (RFO) construction.

Existing Dimensions (m)	Obvert Elevation (m)		Construction
	Lt[1]	Rt[1]	
4.27 x 1.83 x 27.3	258.28	258.13	Concrete NRFO/RFO

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

The banks of the watercourse and the embankments along Highway 9 near the culvert are grass-covered, with young trees and shrubs on the north embankment and isolated young trees on the south embankment. Rip-rap lines the streambed on the north side of the culvert at the inlet. The watercourse flows through fields on both sides of Highway 9. Selected site photographs are provided in Appendix B.

2.1 Site Geology

The project area is located within the physiographic region of Huron Slope, which is generally a clay plain modified by a narrow strip of land which was modified by twin beaches of glacial Lake Warren, which flank the moraine.[1] The overburden in the area of the site generally consists of modern alluvium of silt, sand and gravel.[2]

The geological mapping indicates that the underlying bedrock consists of limestone, dolostone, and shale, which is part of the Detroit River Group, Onondaga formation of the Middle Devonian epoch.[3] The bedrock surface at the site is at about elevation 238 m, [4] with the overburden thickness being about 24 m. [5]

3.0 INVESTIGATION PROCEDURES

The geotechnical field investigation was carried out on October 5 and 25, 2016, during which time four boreholes were drilled at the approximate locations shown on Drawing 1.

Boreholes labeled BH-701 and BH-702 were drilled using a track-mounted Diedrich D50T drilling rig supplied and operated by a specialist drilling subcontractor. Samples of the overburden were typically obtained at depth intervals of 0.75 or 1.5 m using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes labeled BH-703 and BH-704 were drilled by a member of our engineering staff using manual drilling equipment; the soil profile at these locations was observed as the hole was advanced; selected grab samples of the overburden were obtained from the auger for further classification at Golder's laboratory.

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 retrieved to about 40 millimetres (mm). Therefore, particles or objects that may exist within the overburden 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 till.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a piezometer was installed in BH-701 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 positioned 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 uniquely-labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests consisting

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

[2] Cowan, W.R,, and Pinch, J.J. 1986. Quaternary Geology of the Walkerton-Kincardine Area. Southern Ontario; Ontario Geological Survey, Map P.2956, Geological Series-Preliminary Map, scale 1:50,000. Geology 1975-1979.

[3] Ontario Geological Survey, 1991. Bedrock geology of Ontario, southern sheet. Ontario Geological Survey, Map 2544, scale 1:1 000 000.

[4] Davies, L.L., McClymont, W.R., and Karrow, P.F., 1962: Bedrock Topography Series Kincardine – Walkerton Sheet, Ontario Department of Mines, Prelim. Map No. P.165, Scale 1:50,000.

[5] Kelly, R.I. and Carter, T.R., 1993. Drift thickness, Kincardine area, southerd Ontario; Ontario Geological Survey, Preliminary Map, P.3203, Scale 1:50,000.

of water content determinations, grain size distribution analyses and Atterberg limits were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

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-701	4 888 744	383 871	262.0	11.1
BH-702	4 888 750	383 845	261.5	12.7
BH-703	4 888 765	383 353	257.0*	1.3
BH-704	4 888 736	383 847	257.1*	1.2

* Borehole elevations have been inferred based on profile ground surface elevations provided

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed 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, represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

BH-701 and BH-702 were drilled in the roadway shoulder and traffic lane and generally encountered the pavement structure, granular fill, sandy silt, clayey silt till, silt, and clayey silt. In the hand auger borings, located adjacent to the culvert inlet and outlet, topsoil, sandy silt, silt, clayey silt, and silty sand were observed.

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

Asphaltic concrete was encountered at the surface of BH-701 and BH-702. The asphaltic concrete was about 60 mm thick in BH-701 and 250 mm thick in BH-702.

Sand and crushed gravel fill, interpreted to be granular base, extends to depths of about 230 to 710 mm below pavement surface at BH-701 and BH-702, respectively. Sand and gravel fill, interpreted to be granular subbase, underlies the road base material in BH-701 and extends to 760 mm below ground surface.

Clayey silt fill was encountered below the inferred pavement structure in BH-701 and BH-702. The clayey silt fill extends to a depth of 2.9 m below ground surface. This fill is generally considered to be firm to very stiff, based on SPT N values, as determined in the standard penetration testing, ranging between 5 and 16 blows per 0.3 m. The clayey silt fill had a water content of about 13 per cent. The results of a grain size distribution analysis are provided on Figure A-1 in Appendix A.

The clayey silt fill is underlain by sandy silt fill, with topsoil and organics. Based on SPT N values that ranged between 3 and 7 blows per 0.3 m, the sandy silt fill is very loose to loose. This fill was encountered to depths of 3.7 m and 4.4 m in BH-701 and BH-702, respectively.

BH-703 and BH-704 encountered sandy topsoil to depths of about 150 mm and 250 mm, respectively. No testing to determine organic content or other nutrients was carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

The above-noted fill and topsoil are underlain by native soil consisting of silt, sandy silt, clayey silt till, and/or clayey silt. Silt was encountered below the topsoil at BH-704 and below the clayey silt till in BH-702 at elevations 256.8 and 256.3 m, respectively. The silt was 0.3 and 0.8 m in BH-704 and in BH-702, respectively. Based on a SPT N value of 14 blows per 0.3 m, the silt is considered to be compact. Sandy silt was encountered in BH-703 and BH-704 from elevation 256.9 and 256.5 m, respectively and was 0.9 to 1.1 m thick.

A layer of clayey silt and sand about 0.8 m thick, was encountered beneath the fill in BH-701. This stratum was firm with a SPT N value of 7 blows per 0.3 m and a water content of about 28 per cent. Results of one grain size distribution analysis are provided on Figure A-2 in Appendix A.

Clayey silt till was encountered below the sandy silt in BH-701 at about elevation 257.6 m and the sandy silt fill in BH-702 at about elevation 257.1 m. The clayey silt till was stiff to hard based on SPT N values ranging from 13 and 40 blows per 0.3 m. The clayey silt till had water contents of 17 and 21 per cent. The results of grain size distribution analyses carried out on two samples of the clayey silt till are provided on Figure A-3 in Appendix A. Although, not specifically encountered in this investigation, cobbles and boulders should be anticipated in the clayey silt till deposits.

All of the boreholes were terminated in a deposit of clayey silt. The clayey silt was encountered between elevations 255.5 and 256.2 m and was explored for 0.2 to 6.7 m. The clayey silt had water contents of about 23 and 25 per cent and SPT N values of 9 to 22 blows per 0.3 m, indicating a stiff to very stiff consistency. The results of grain size distribution analyses carried out on two samples of the clayey silt are provided on Figure A-4 in Appendix A.

A 0.1 m thick seam of grey silty sand was encountered in BH-703 below the sandy silt at elevation 256.0 m. The silty sand had a water content of about 23 per cent. The results of a grain size distribution analysis of a sample of the silty sand are presented on Figure A-5.

Results from Atterberg limits tests carried out on the clayey silt fill, clayey silt till, and clayey silt are provided on Figure A-6 in Appendix A. All tests indicate clayey soils of low plasticity.

4.3 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling, and a groundwater observation piezometer was installed in BH-701. The installation details are provided on the corresponding Record of Borehole sheet following the text of this report. Groundwater was encountered during drilling in BH-702 and BH-703 at depths of 5.4 and 1.0 m or at approximate elevation 256.1 and 256.0 m, respectively. The water level was measured in the piezometer installed in BH-701 at depths of 1.9 to 4.2 m or approximate elevaitons 257.84 to 260.17 m between October 4, 2016 and January 6, 2017. 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) October 4, 2016	Measured Groundwater Level Elevation (m) October 25, 2016	Measured Groundwater Level Elevation (m) January 6, 2017
BH-701	262.05	dry	257.84	258.87	260.17
BH-702	261.47	256.1	-	-	-
BH-703	257.04*	256.0	-	-	-
BH-704	257.08*	dry	-	-	-

* Borehole elevation inferred based on profiled ground surface elevations provided

The above 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 256.5 m. Given the presence of a clayey silt till overlain by granular soils, perched water conditions are possible at this site. In addition, the groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions. The elevated groundwater levels measured in BH-701 suggest a perched groundwater table in the sandy silt or fill.

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. William Hanson, E.I.T. and Mr. Jordan Kiss, 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. Terry Nicholas, P.Eng, who is a senior consultant 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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CK/DUP/TN/FJH/cr

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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
$\sigma_1, \sigma_2, \sigma_3$	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 $= \sigma'_p / \sigma'_{vo}$

(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**	c_u, s_u **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-701

METRIC

PROJECT 12-1132-0163
W.P. 3042-11-00
LOCATION N 4888744.2 , E 383871.0
ORIGINATED BY WH
DIST HWY 9
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY ZJB/LMK
DATUM GEODETIC
DATE October 5, 2016
CHECKED BY

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%) Wp / W / WL	UNIT WEIGHT kN/m³	GR	SA	SI	CL
262.05	PAVEMENT SURFACE					262						
0.06	ASPHALT											
0.23	FILL, sand and crushed gravel Brown											
261.29 0.76	FILL, sand and gravel, some silt, with cobbles Brown	1	SS	5	Granular Bentonite	261						
	FILL, clayey silt, some sand, trace gravel, with topsoil layers Firm to stiff Brown and grey	2	SS	7		260						
		3	SS	9								
259.15 2.90	FILL, sandy silt, with topsoil and organics Very loose Grey	4	SS	3		259						
258.39 3.66	CLAYEY SILT AND SAND Firm Brown	5	SS	7		258	plotted		0	40	37	23
257.63 4.42	CLAYEY SILT TILL, trace gravel, with cobbles, with sand seams at about elev. 256.0m Stiff to hard Brown	6	SS	13	Cuttings	257						
		7	SS	40		256						
		8	SS	14	Filter Sand		plotted		0	0	66	34
254.96 7.09	CLAYEY SILT, trace sand, with silt seams Stiff to very stiff Grey				Piezometer	255						
		9	SS	16		254						
		10	SS	12	Cuttings	253	plotted		0	1	57	42
		11	SS	12		252						
250.92 11.13	END OF BOREHOLE					251						

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 / NATURAL MOISTURE CONTENT / LIQUID LIMIT — WATER CONTENT (%) 10 20 30
REMARKS & GRAIN SIZE DISTRIBUTION (%)

Borehole dry during drilling on October 4, 2016

Water level measured in piezometer at elev. 257.84m on October 4, 2016.

Water level measured in piezometer at elev. 258.87m on October 25, 2016.

Water level measured in piezometer at elev. 260.17m on January 6, 2017.

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-702

METRIC

PROJECT 12-1132-0163

W.P. 3042-11-00

LOCATION N 4888750.1 , E 383844.7

ORIGINATED BY WH

DIST HWY 9

BOREHOLE TYPE POWER AUGER, HOLLOW STEM

COMPILED BY ZJB/LMK

DATUM GEODETIC

DATE October 5, 2016

CHECKED BY

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%) wP – w – wL	GR	SA	SI	CL
261.47	PAVEMENT SURFACE									
0.00	ASPHALT									
0.25	FILL, sand and crushed gravel Brown									
260.76 0.71	FILL, clayey silt, some sand, trace gravel, with topsoil layers Stiff to very stiff Brown and grey	1	SS	13						
		2	SS	16						
		3	SS	15		plotted	0	23	51	26
258.57 2.90	FILL, sandy silt, trace clay, with topsoil layers Firm Brown and grey	4	SS	7						
		5	SS	5						
257.05 4.42	CLAYEY SILT TILL, some sand, trace gravel Stiff Brown	6	SS	14		plotted	1	12	54	33
256.29 5.18	SILT, some sand, with clayey silt pockets Compact Brown	7	SS	14	▽ (elev. 256.1)					
255.53 5.94	CLAYEY SILT, trace sand, with silt seams Stiff to very stiff Brown to grey at about elev. 254.4m	8	SS	12						
		9	SS	9						
		10	SS	17						
		11	SS	15		plotted	0	0	68	32
		12	SS	22						
248.82 12.65	END OF BOREHOLE Groundwater encountered at about elev. 256.1m during drilling on October 4, 2016.									

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; ELEVATION SCALE (261 to 249); 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 wP, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wL, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-703

METRIC

PROJECT 12-1132-0163
W.P. 3042-11-00
LOCATION N 4888765.0 , E 383852.8
ORIGINATED BY JK
DIST HWY 9
BOREHOLE TYPE
COMPILED BY ZJB/LMK
DATUM GEODETIC
DATE October 25, 2016
CHECKED BY

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER (SAMPLES)	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
257.04	GROUND SURFACE													
0.00 / 0.15	TOPSOIL, sandy, with organics Brown SANDY SILT, trace clay, trace gravel Brown to grey at about elev. 257.0m						257							
255.97 / 1.17 / 1.32	SILTY SAND, trace clay Grey CLAYEY SILT, trace sand, trace gravel Grey		1 2	AS AS		▽	256		○ (about 23)		0	21	71	8
	END OF BOREHOLE													

Plot scales: Dynamic cone penetration 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. REMARKS & GRAIN SIZE DISTRIBUTION (%).

Groundwater encountered at about elev. 256.0m during drilling on October 25, 2016.

Borehole elevation has been inferred based on profile ground surface elevations provided.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-704

METRIC

PROJECT 12-1132-0163

W.P. 3042-11-00

LOCATION N 4888735.9 , E 383847.2

ORIGINATED BY JK

DIST ___ HWY 9

BOREHOLE TYPE ___

COMPILED BY ZJB/LMK

DATUM GEODETIC

DATE October 25, 2016

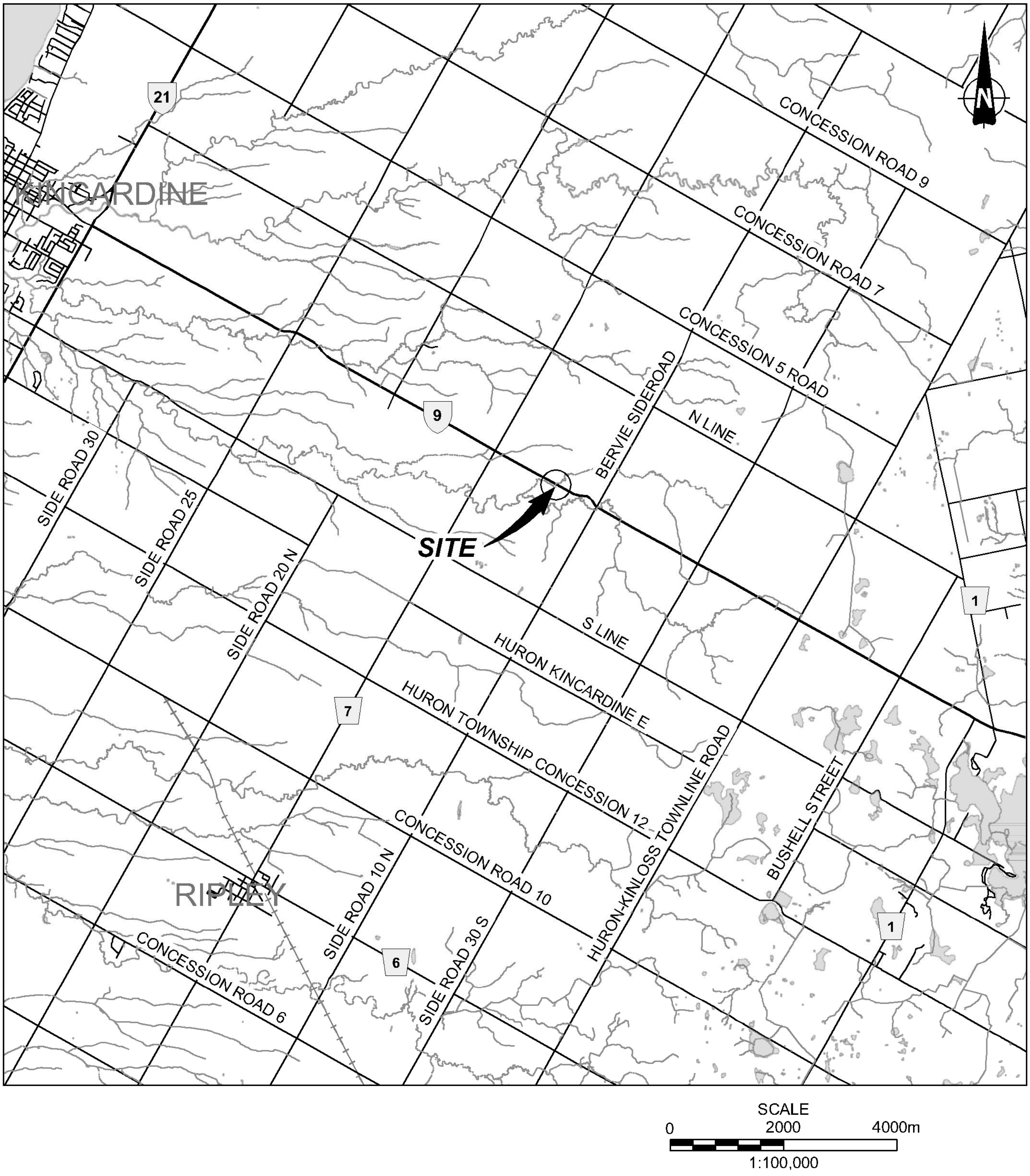
CHECKED BY ___

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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
257.08	GROUND SURFACE										
0.00	TOPSOIL, sandy Brown						257				
0.25	SILT, some sand, some clay Brown										
0.51 / 256.17	SANDY SILT, some gravel, trace clay, with sand layers Brown										
0.91 / 255.84	CLAYEY SILT, trace sand, some gravel Grey		1	AS			256				
1.24	END OF BOREHOLE										

Borehole dry during drilling on October 25, 2016

Borehole elevation has been inferred based on profile ground surface elevations provided.

$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ 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
HODGINS DRAIN CULVER REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE

KEY PLAN

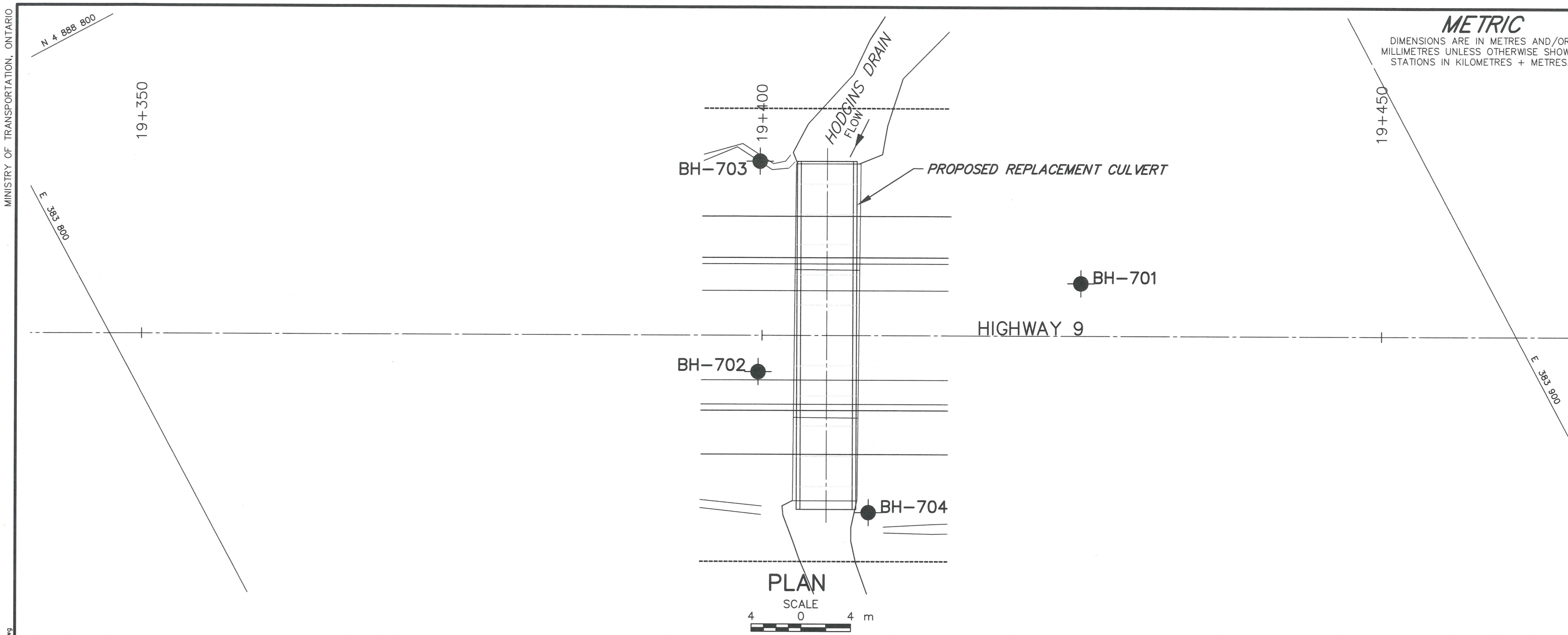
Golder Associates

PROJECT No.	12-1132-0163	FILE No.	1211320163-4000-F07001
		SCALE AS SHOWN	REV. 0
CADD	ZJB/LMK	Jan. 12/17	
CHECK			FIGURE 1

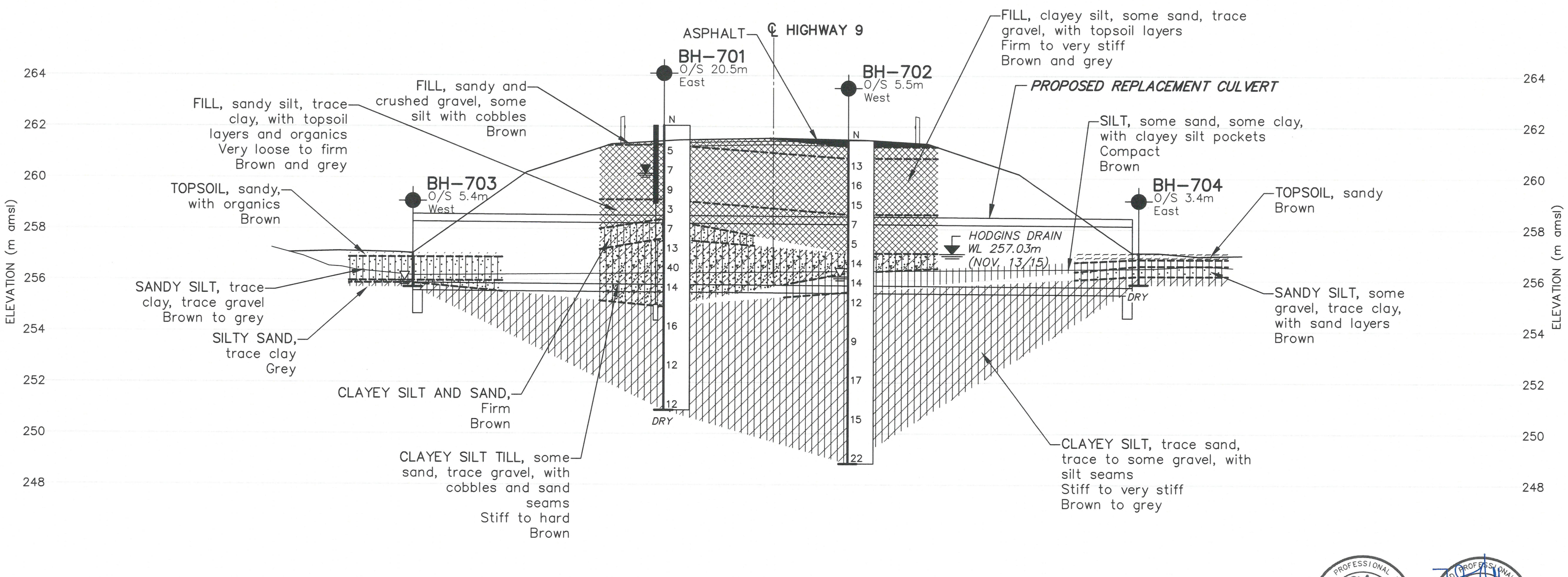
Drawing file: 1211320163-4000-F07001.dwg Jan 12, 2017 - 9:14am

MINISTRY OF TRANSPORTATION, ONTARIO

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



PLAN
SCALE 4 0 4 m



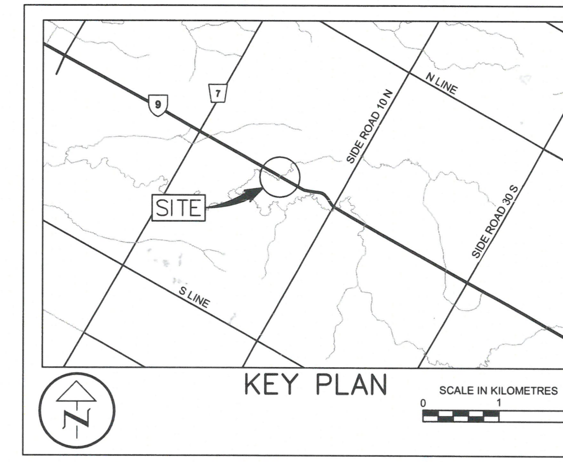
PROFILE ALONG ℄ OF CULVERT
HORIZONTAL SCALE 2 0 2 m VERTICAL SCALE 2 0 2 m

CONT No.
WP No. 3042-11-00

SHEET

HODGINS DRAIN CULVERT REPLACEMENT
HIGHWAY 9 SITE No. 2-463/C
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



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 measured on January 6, 2017
- WL encountered during drilling
- DRY — Borehole dry during drilling

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11) NORTHING	EASTING
BH-701	262.05	4 888 744.2	383 871.0
BH-702	261.47	4 888 750.1	383 844.7
BH-703	257.04*	4 888 765.0	383 852.8
BH-704	257.08*	4 888 735.9	383 847.2

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.

* Borehole elevations have been inferred based on profile ground surface elevations provided.

REFERENCE

Base plans provided in digital format by Stantec.

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

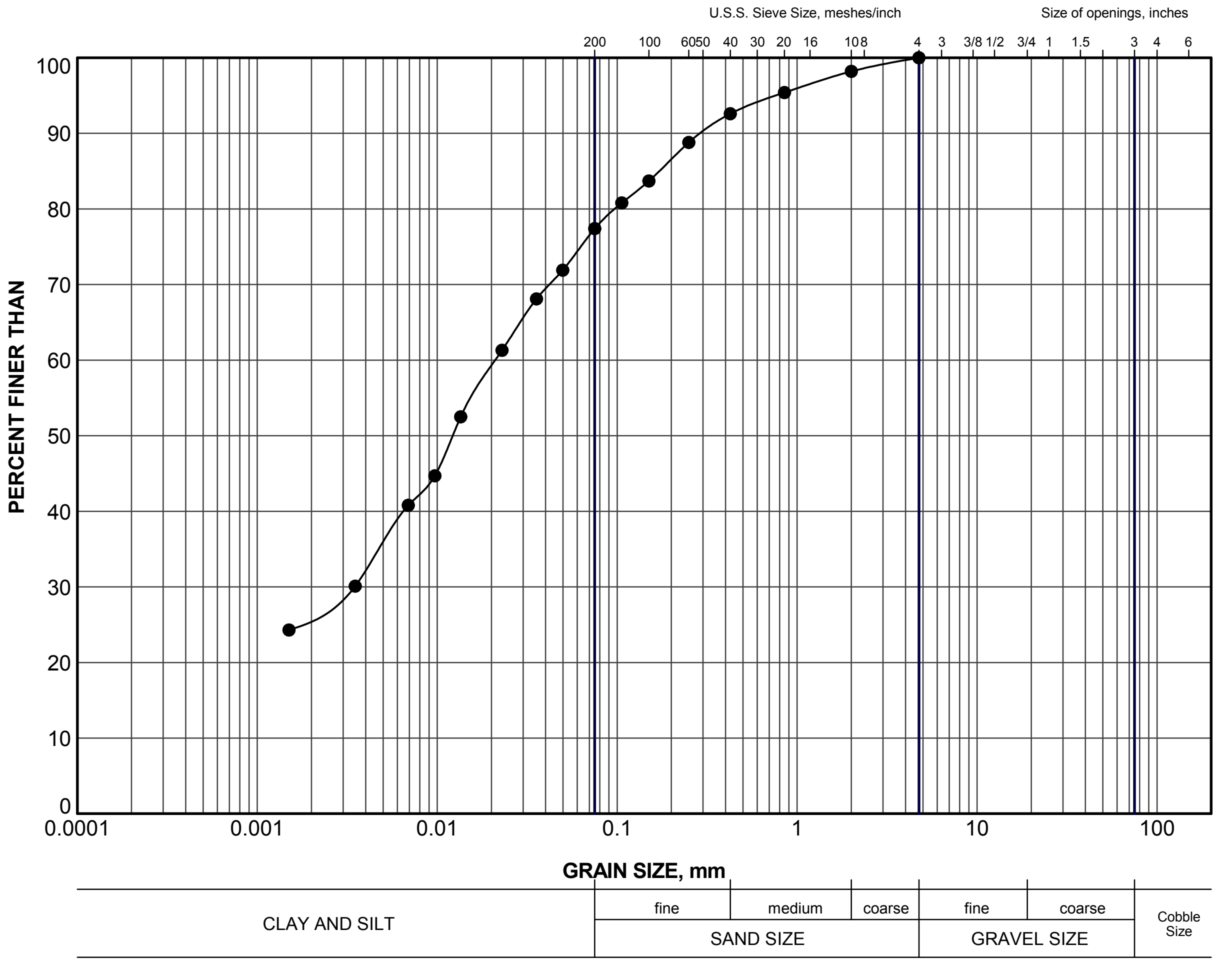
NO.	DATE	BY	REVISION

Geocres No. 41A-241			
HWY. 9		PROJECT NO. 12-1132-0163	DIST.
SUBM'D. DH	CHKD. DH	DATE: Feb. 16/17	SITE: 2-463/C
DRAWN: LMK	CHKD. DUP	APPD. FJH	DWG. 1

PLOT DATE: March 31, 2017
FILENAME: \\golder.gds\gal\London\active\2012\1132 – Geo\1132-0100\12-1132-0163 STANTEC-FDNS-MEGA CULVERTS-3011-E-0041\Drafting\AutoCAD files\1211320163-4000-D07001.dwg

APPENDIX A

Laboratory Test Data



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-702	3	259.0

PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE

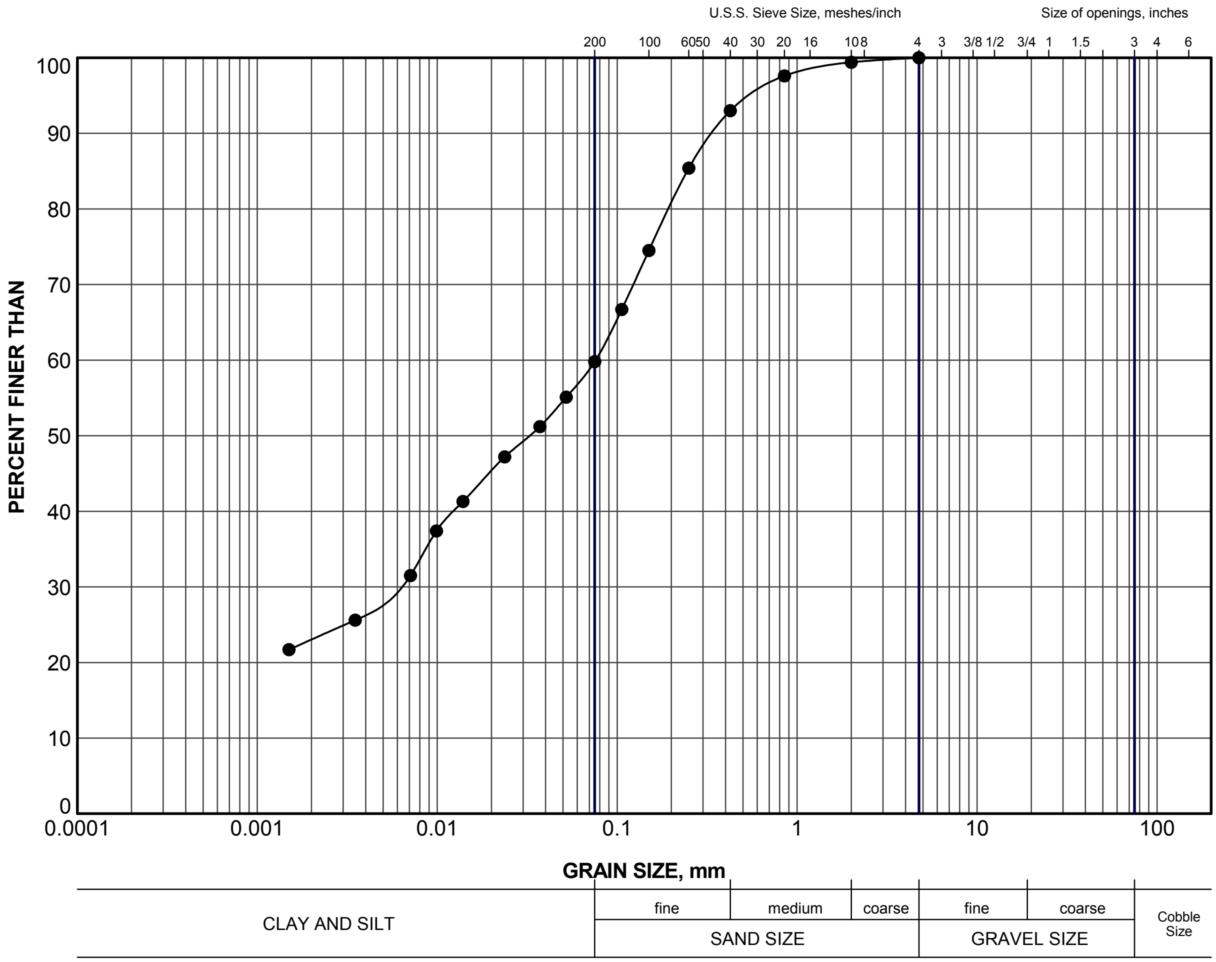
GRAIN SIZE DISTRIBUTION
FILL

Golder Associates

PROJECT No.	12-1132-0163	FILE No.	1211320163-4000-F070A1
DRAWN	ZJB Nov 4/16	SCALE N/A	REV.
CHECK			

FIGURE A-1

LDN_MTO_GSD GLDR_LDN.GDT 24/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-701	5	258.0

PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE

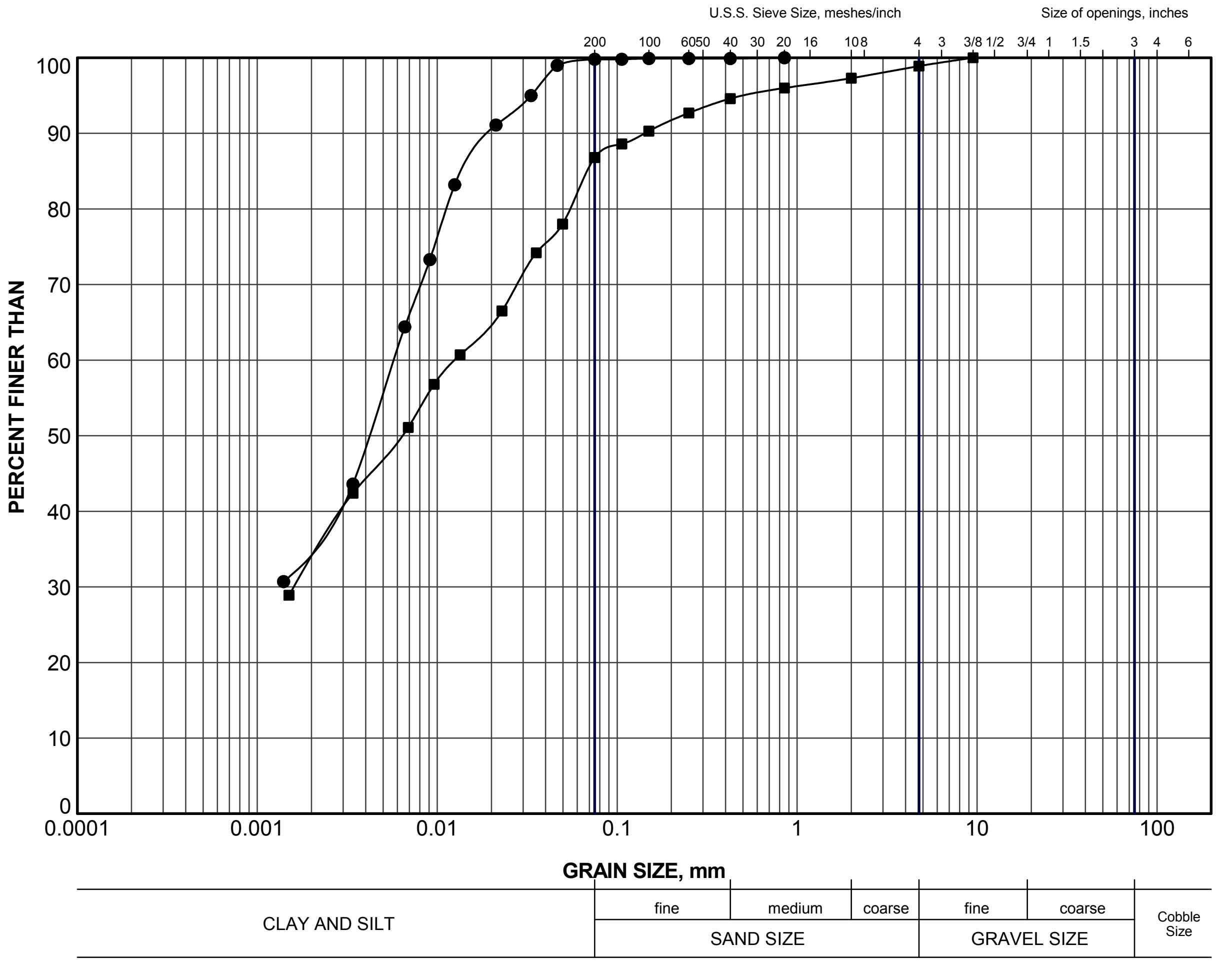
GRAIN SIZE DISTRIBUTION

CLAYEY SILT AND SAND

Golder Associates

PROJECT No.	12-1132-0163	FILE No. 1211320163-4000-F070A2	
		SCALE N/A	REV.
DRAWN	ZJB/LMK	Feb 15/17	FIGURE A-2
CHECK			

LDN_MTO_GSD GLDR_LDN.GDT 24/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-701	8	255.8
■	BH-702	6	256.7

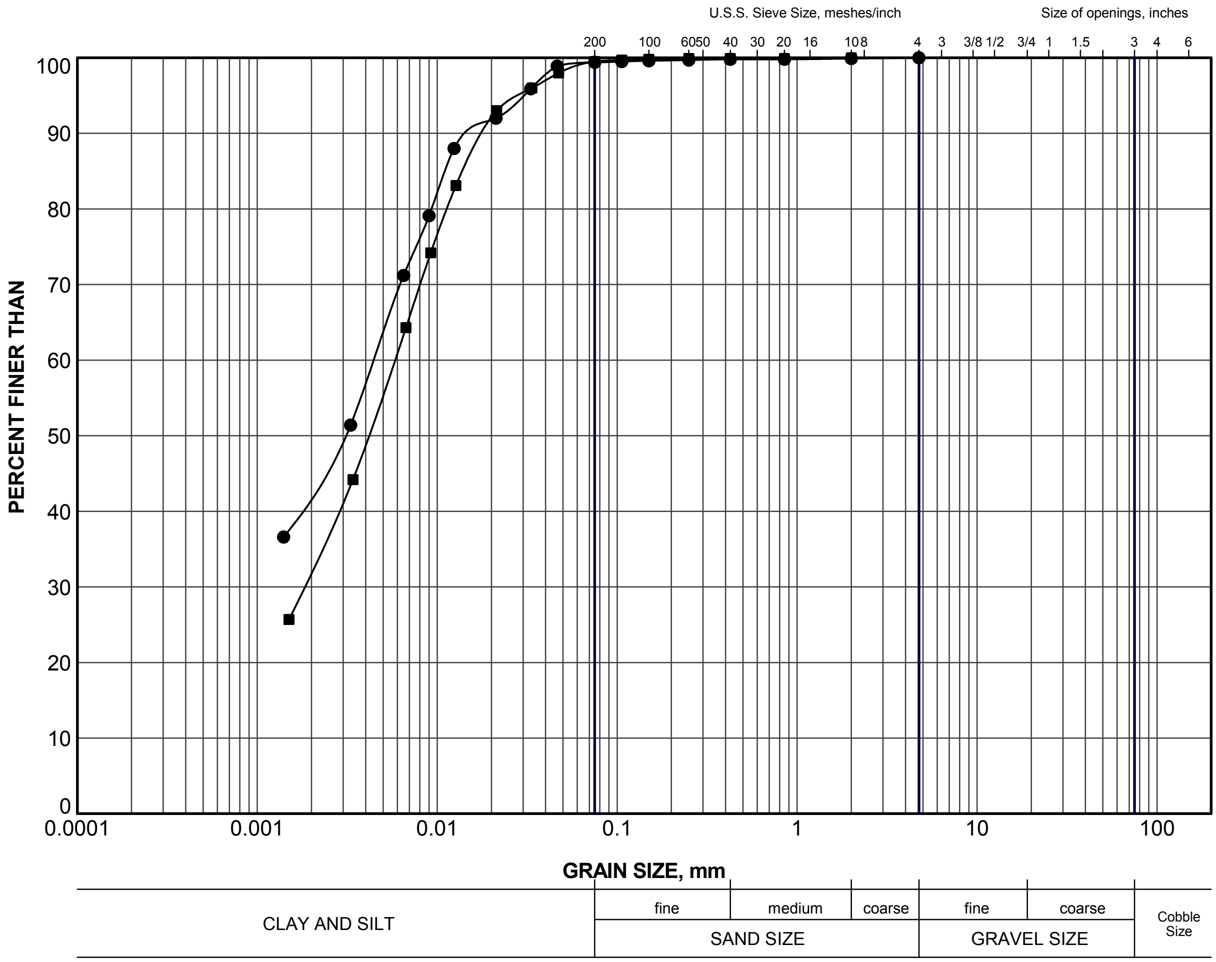
PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TILL

Golder Associates

PROJECT No.	12-1132-0163		FILE No. 1211320163-4000-F070A3	
			SCALE N/A	REV.
DRAWN	ZJB	Dec 21/16	**FIGURE A-3**	
CHECK				

LDN_MTO_GSD GLDR_LDN.GDT 24/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-701	10	252.7
■	BH-702	11	250.6

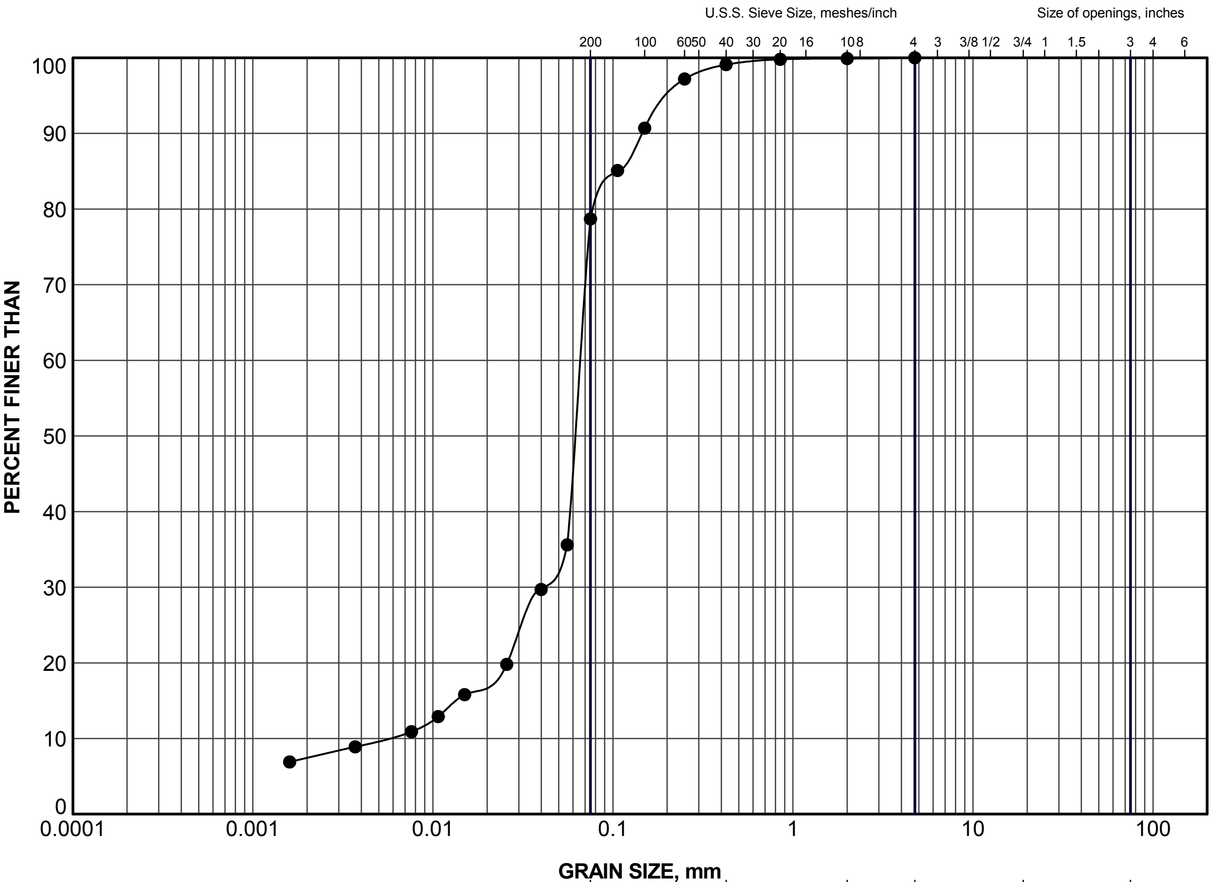
PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
CLAYEY SILT

Golder Associates

PROJECT No.	12-1132-0163	FILE No. 1211320163-4000-F070A4	
		SCALE N/A	REV.
DRAWN	ZJB	Nov 4/16	FIGURE A-4
CHECK			

LDN_MTO_GSD GLDR_LDN.GDT 24/10/16



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	BH-703	1	1.1

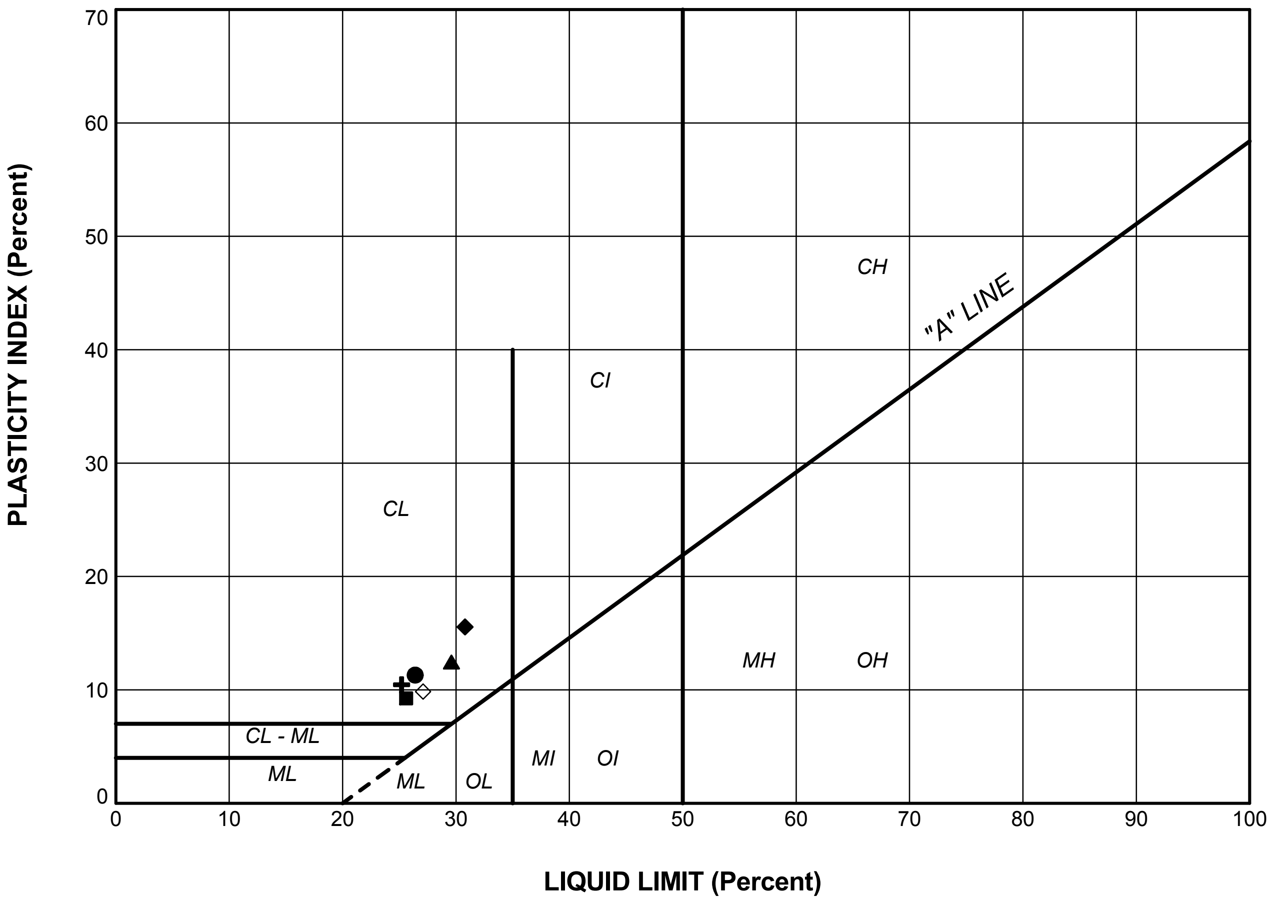
PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE
GRAIN SIZE DISTRIBUTION
SILTY SAND

Golder Associates

PROJECT No.	12-1132-0163	FILE No. 1211320163-4000-F070A5
		SCALE N/A REV.
DRAWN ZJB	Nov 4/16	FIGURE A-5
CHECK		

LDN_MTO_GSD GLDR_LDN.GDT 04/11/16



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
FILL					
✚	BH-702	3	25.2	14.8	10.5
CLAYEY SILT AND SAND					
●	BH-701	5	26.4	15.1	11.3
CLAYEY SILT TILL					
■	BH-701	8	25.6	16.4	9.3
◆	BH-702	6	30.8	15.3	15.6
CLAYEY SILT					
▲	BH-701	10	29.6	17.2	12.5
◇	BH-702	11	27.1	17.3	9.9

PROJECT
HODGINS DRAIN CULVERT REPLACEMENT, SITE NO. 2-463/C
HIGHWAY 9
GWP 3042-11-00

TITLE
PLASTICITY CHART

Golder Associates

PROJECT No.		12-1132-0163	FILE No.1211320163-4000-F070A6
			SCALE N/A REV.
DRAWN	ZJB/LMK	Feb 15/17	FIGURE A-6
CHECK			

LDN_MTO_PI GLDR_LDN.GDT 24/10/16

APPENDIX B

Site Photographs

Photograph 1: North elevation (inlet) of Culvert Site 2-463/C.

Photograph 2: South elevation (outlet) of Culvert Site 2-463/C.

Photograph 3: Looking northwest along Highway 9, north ditch toward inlet of Culvert Site 2-463/C.

Photograph 4: Looking southeast along Highway 9, south ditch toward outlet of Culvert Site 2-463/C.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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