FINAL REPORT

Foundation Investigation Report
Englehart Project
HWY 11, Township of Pacaud
Culvert # 60 Extension Replacement and Slope Failure
Station 11+684
Englehart, Ontario
WO 2009-11030
MTO GEOCRES No. 31M-81

Prepared for:
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and

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Trow Associates Inc.

August 05, 2009

SD000391349a

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FOUNDATION INVESTIGATION

Foundation Investigation

1.1 Introduction

This report presents the results of a geotechnical investigation carried out by Trow Associates Inc. (Trow) at the outlet extension of Culvert # 60, located on the east side of Highway 11 at Station 11+684 within Township of Pacaud. Trow was retained by D. F Elliot on behalf of MTO to undertake this assignment. Terms of Reference and scope of work are as outlined in the Trow proposal dated June 2, 2009, pertaining to this project. Culvert # 60 consists of a 1200 diameter by 76.2 m long new liner pipe placed in a 1670 mm wide by 1830 mm high old concrete box and two new extensions, a 1200 mm diameter by 30 m long Corrugated Steel Pipe (CSP) extension at the inlet (west) side and a 1200 mm diameter by 13 m long CSP extension at the outlet (east) side. The new liner pipe and extensions were installed in the fall of 2008. However, a failure occurred in November, 2008 on the east (outlet) side which caused a failure of the end section of the CSP extension. It is Trow's understanding that the north side slope, the slope perpendicular to the culvert extension, had failed and resulted in and damage to the pipe. The end section of the failed CSP culvert was observed to have an elliptical shape with the vertical dimension being greater. The new CSP at the outlet side was installed in two 6 to 7 m sections beyond the termination of the concrete box. Subsequent examination indicated that the full section of the CSP extension (13m) was damaged and, therefore, must be replaced. Photographs of the site and damaged pipe are included in Appendix A.

The site specific geotechnical investigation consisted of test borings, borehole logging, and field and laboratory testing. Three boreholes were strategically located aiming to identify the location of its surface of rupture and extent of displaced materials (i.e. zones of depletion and accumulation). The first boring was placed in the area above the slope failure, but beyond its perimeter, to provide comparative data on the stable and unstable portions of the slope. The second boring was located near centre of the main body of the slope failure, while the third borehole was drilled in the area below the toe of the slope failure. These two boreholes were located in the area of the landslide main body and its toe to explore for the displaced material and underlying stable material.

The purposes of this subsurface investigation was to obtain sufficient geotechnical data to analyze the likely reasons for failure, including the impact of construction approaches, and to assess current geotechnical conditions and their influence on repair proposal. The results of the site specific geotechnical investigation are presented in Part 1 Foundation Investigation of this report. Part 2 Design Report includes a background of the site, back-analyses of failure and guidance regarding stability and any mitigation or control measures that would be required during repair/replacement of section(s) of the CSP extension.

1.2 Site Description and Geological Setting

1.2.1 Site Description

Culvert # 60 is located at Station 11+684 on Highway 11, approximately 17 km north of the Town of Englehart, and 4.3 km south of the junction of Highways 11 and 112, in the District of Timiskaming. The site plan is shown on Drawing No. 1 in Appendix B.

Culvert # 60 crosses the highway embankment and conveys collected surface water from the valley at the west side of the embankment. The culvert is skewed to the highway embankment, having a SW-NE direction. As mentioned above, the existing culvert consists of a 1200 diameter by 76.2 m long new liner pipe placed in a concrete box 1670 mm wide by 1830 mm high , and its obvert is at a depth of approximately 8 m below the profile grade at the centerline of Highway 11. The liner pipe culvert is extended at both, inlet and outlet, sides. The extension at the inlet (west) side is a 1220 mm diameter by 30 m long Corrugated Steel Pipe (CSP), while a 1200 mm diameter by 13 m long CSP extension is placed at the outlet (east) side. The elevations of the top of the culvert at the inlet and outlet ends are about 243.65 m and 239.28 m, respectively.

The failed section of CSP culvert is located at the outlet (east) side of Culvert # 60. The inlet of the culvert is in place and functioning properly, including manholes and catch basins. The side slopes at the inlet area are similar to, or steeper, than the east outlet side.

During the field investigation it was observed that the failed CSP culvert area had been backfilled/graded with final slopes from the highway embankment and with gentler north and south slopes to the outlet ravine. Some rock fill was apparent on the slopes, and in the outlet areas, as can be seen on the photographs in Appendix A. Sections of the slope had been filled/excavated to current conditions. Within the right of way, the site was clear of bushes and trees.

The drainage in the area generally consists of roadside ditches which drain into nearby streams. The drainage from the roadside ditch located south of the outlet CSP extension is conveyed from the ditch to the south down to the area of the culvert by a gravel/cobble lined ditch, as shown on Photographs 3 and 5 in Appendix A. A small gully partway up the south slope also drained into the area, but it was not connected to the gravel-lined downslope ditch. The roadside ditch to the north drained, unchannelized, into and through the north slope material, as shown on Photographs 4 and 6 in Appendix A.

1.2.2 Geological Setting

According to Ontario Geological Survey (OGS) Map 5021, as well as Ontario Geological Survey Map 2555 (Quaternary Geology, New Liskeard) and the Ministry of Northern Development and Mines Map 2543 (Bedrock Geology of Ontario, East-Central Sheet), the site is located in the Neoarchean Group comprised of mainly igneous origin rock.

The Englehart area is situated in a physiographic division of the Canadian Shield known as the Cobalt Plain. The overburden soils have been mapped as glaciolacustrine deposits consisting of upper massive to lower laminated, rhythmically bedded (also referred to as varved) silts and clays with occasional rock knobs.

1.3 Investigation Procedures

1.3.1 Field Program

The fieldwork for this investigation was performed between June 15, 2009 and June 22, 2009. The fieldwork consisted of drilling three (3) sampled boreholes (BH60-1, BH60-2 and BH60-3) and installing of two (2) piezometers in BH60-1 and BH60-3. The boreholes were strategically located to permit assessment of slopes. The 20.4 m deep Borehole BH60-2 was drilled at the east shoulder of the existing highway embankment in the area beyond the estimated slope failure perimeter. Borehole BH60-1 was drilled while Borehole BH60-3 was drilled near the outlet of the culvert. Boreholes BH60-1 and BH60-3 were 10.2 m and 6.7 m deep, respectively.

Boreholes BH60-1 and BH60-2 were advanced using a Bombardier mounted CME-55 drill rig, equipped with a hollow stem auger (4-1/4" HAS) and standard soil sampling equipment. They were drilled by Marathon Drilling. Due to uncertainty in slope stability and difficulties to mobilize the drill rig down the slope, Borehole BH60-3 drilled near the culvert outlet was advanced by hand drilling/sampling equipment operated by a specialist drilling contractor, Sonic Soil Sampling.

From the drilling program, soil samples were obtained using a 51 mm OD split-spoon sampler in conjunction with Standard Penetration Tests at 0.75 m intervals within the estimated zone of surface rapture (estimated Elevations between 241 m and 235 m) and 1.5 m intervals in other zones. Sampling and testing procedures were in general accordance with ASTM D1586. This consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm diameter OD split-spoon sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as SPT 'N' value of the soil and this gives an indication of the consistency or the relative density of the soil deposit. However, the manual hammer used for hand testing was 31.7 kg, one half of the standard hammer weight. As a result, the corresponding blow counts were factored by 0.5.

In addition, selected, undisturbed, 50 mm diameter "Shelby" tube samples were obtained in cohesive deposits. Field vane testing was also completed in the boreholes throughout the cohesive soils to measure the *in-situ* undrained shear strength of the soils. The field vane testing was conducted in accordance with ASTM D2573-08.

All fieldwork was supervised by a member of Trow's engineering staff who directed the drilling and sampling operations, logged the factual borehole data in accordance with the MTO Soils Classification System for foundation report, and retrieved soil samples for subsequent laboratory testing and identification. All of the recovered soil samples were placed in moisture-proof bags and returned to Trow's Brampton laboratory for additional visual, textual and olfactory examination and for selected laboratory testing.

Following completion of the boreholes, water level measurements were obtained from the boreholes in accordance with Ministry of Transportation guidelines. Standpipe piezometers were installed in Boreholes BH60-1 and BH60-3 to permit long term monitoring of groundwater levels at the site. Borehole BH60-2 was backfilled with auger cuttings and sealed with bentonite pellets.

Details of the soil strata encountered in the boreholes are included in attached logs in Appendix C, and plotted on the profile included in Drawing No. 1 in Appendix B. The locations of the boreholes were determined in the field using Garmin Global Positioning Systems (GPS) equipment. The final geodetic locations and elevations shown on Drawing No. 1, Appendix B, are established based on the site survey map provided by D. F. Elliott Consulting Engineers Ltd.

1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to detailed visual examination and classification. The laboratory testing program included moisture content determination of all samples (LS-701) and routine classification testing of approximately 25% of the selected soil samples. The routine testing included grain size distribution (LS-702) and Atterberg limits (LS-703/704). In addition, two undisturbed, "Shelby" tube cohesive samples were subjected to laboratory unconfined compression tests (ASTM D2166).

The laboratory test results are provided on the attached borehole logs in Appendix C. The results of the grain size analyses and Atterberg limits tests are presented in Appendix D.

1.4 Subsurface Conditions

The subsurface conditions encountered during the field investigation are summarized on the attached borehole logs in Appendix C. The "Explanation of Terms Used in Report" preceding the borehole logs (Appendix C) forms an integral part of and should be read in conjunction with this report.

A borehole location plan and a strata plot of the soils encountered in the boreholes are provided on Drawing No.1 in Appendix B. In general, the stratigraphy along the centerline of the slope failure between Boreholes BH60-1 and BH60-2 consisted of sand and gravel fill, silty clay fill, silty clay, clayey silt and silty sand.

A summary of the soil and groundwater conditions encountered in the boreholes is provided below.

1.4.1 Sand and Gravel Fill

In BH60-1 and BH60-2 sand and gravel fill was encountered at the ground surface. The thickness of the sand fill was 1.1 m in BH60-2 and 2.3 m in BH60-1. The composition of this layer was sand and gravel matrix with a 0.12 m thick layer of topsoil over (BH60-2). This layer was brown in colour, very moist to damp. Based on the "N" value from the Standard Penetration Tests, the compactness of the sand and gravel fill was assessed as loose to compact.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests. The test results are as follows:

Moisture Content:

- 4.5% to 12.6%

Grain Size Distribution:

- 20% gravel;
- 66% sand;
- 14% silt and clay

The results of the moisture content tests are provided on the Record of Borehole sheets in Appendix C. The results of the grain size distribution test on sand and gravel fill are provided on Figure 1 in Appendix D.

1.4.2 Silty Clay and Clayey Silt Fill

Beneath sand and gravel fill materials, there is a silty clay and clayey silt fill as indicated on Boreholes BH60-2 and BH60-1. The thickness of this fill was 6.5 m at BH60-2. At that location, the layer extended to depth up to 7.6 m, which corresponds to approximate Elevation of 238.4 m. A similar layer was encountered in BH60-1 below the gravel and sand fill at elevation of 240.0 m, but it was found to be only 0.8 m thick. The silty clay fill was encountered in BH60-3 at the ground surface. The fill predominately consists of silt and clay with a trace of gravel. The surficial material in BH60-3 contains decayed wood fragments and rootlets as well. The silty clay and clayey silt fill is grey and very moist to wet. Measured SPT "N" values varied from 1 to 5 indicating very soft to firm consistency. Field vane measurements indicated that the undrained shear strength of this silty clay fill was about 20 kPa at the elevation of around 242 m, and then it increased with depth to a maximum value of about 50 kPa at Elevation 239 m. Sensitivity, the measure of peak shear strength and remolded shear strength, ranged from 1.5 to 3, indicating the silty clay fill is low to medium sensitive.

Laboratory testing performed on selected samples consisted of moisture content tests. The test results are as follows:

Moisture Content:

- 24.8% to 32.9%

The results of the moisture content are provided on the Record of Borehole sheets in Appendix C.

1.4.3 Silty Clay

Beneath the fill materials, a stratum of silty clay was encountered as the principal native soil unit in all boreholes (BH60-1, BH60-2 and BH60-3). The silty clay was encountered at a depth of approximately 7.6 m below existing grade (approximate Elevation 238.4 m) in BH60-2. In Boreholes BH60-1 and BH60-3 the silty clay was encountered at a depth of approximately 3.1 m (approximate Elevation 239.2 m) and 1.8 m (approximate Elevation 237.0 m), respectively. In BH60-2 the layer was about 9.4 m thick extending to a depth of approximately 17 m below ground (approximate Elevation 229 m). Boreholes BH60-1 and BH60-3 were terminated in the silty clay stratum at depths of approximately 10.2 m (approximate Elevation 232.1 m) and 6.7 m (approximate Elevation 232.1 m), respectively.

Generally, the silty clay was thinly laminated with clayey silt (varved). The individual layers or laminations varied in thickness from a few millimeters to a few centimeters, but in general were about one centimeter thick. The portions of silty clay and clayey silt varied also, but in general the clay portion dominated. The silty clay is grey in colour and saturated.

SPT "N" values within the silty clay encountered in BH60-1 and BH60-2 ranged from 0 to 9 indicating very soft to stiff material. SPT "N" values measured in Borehole BH60-3 were somewhat higher (up to 13), probably due to use of hand equipment for drilling and testing, The standard penetration resistance values should not be considered an accurate assessment of the consistency of the soil given the varying composition and method of drilling.

Field vane tests and laboratory unconfined compression tests were performed to examine undrained shear strengths of silty clay. All results of the *in-situ* field vane tests measured in all boreholes and unconfined compression tests are plotted on the records of boreholes, Appendix C. In addition, the summary of the results is shown on Figure 5, attached in Appendix D. As it can be seen, the measured values of the undrained shear strength ranged from 27 kPa to 55 kPa. Even though the data scattered, it suggests that the undrained shear strength profile of native silty clay changes with depth. Undrained shear strengths of around 30 kPa were measured at Elevations between 238 m and 235 m. Subsequently the strength increased to about 45 kPa at Elevation 230 m. The undrained shear strengths of the two samples measured in the unconfined compression tests were

34.6 kPa (from BH60-2 at Elevation 236.5 m) and 30 kPa (from BH60-3 at Elevation 233.2 m). Sensitivity ranged from 1.8 to 2.75, indicating the silty clay is low to medium sensitive.

Laboratory testing performed on selected samples consisted of moisture content, grain size distribution, Atterberg Limits and unconfined compression tests. The test results are as follows:

Moisture Content:

- 25.4% to 61.3%

Grain Size Distribution:

- 0% gravel;
- 1% to 2% sand;
- 37% to 42%silt; and
- 57% to 62% clay.

Atterberg Limit:

- Liquid Limits: 34% to 53%
- Plastic Limits: 17% to 22%.

Unconfined Compression:

- Undrained Shear Strength 30 kPa and 34.6 kPa

The results of the moisture content, grain size distribution and Atterberg Limits and unconfined compression tests are provided on the Record of Borehole sheets in Appendix C. The results of the grain size distribution tests on the silty clay are provided on Figure 2 in Appendix D. The results of the Atterberg Limits tests are provided on Figure 4 in Appendix D. The results of two unconfined compression tests are shown on Figure 7, Appendix D.

1.4.4 Clayey Silt

Clayey silt was encountered underlying the silty clay in Borehole BH60-2. The clayey silt was encountered at a depth of approximately 17 m below ground, corresponding to Elevation of approximately 229 m. The layer was 1.8 m thick and extended to the depth of 18.6 m (approximate Elevation 227.4 m).

The clayey silt is grey and generally wet. Based on the "N" values obtained from the SPT, the consistency of the clayey silt was considered soft.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content:

- 26%

Grain Size Distribution:

- 0% gravel;
- 9% sand;
- 66%silt; and
- 25% clay.

The result of the moisture content test are provided on the Record of Borehole sheet in Appendix C. The results of the grain size distribution tests on the clayey silt are provided on Figure 3 in Appendix D.

1.4.5 Silty Sand

Silty sand was encountered underlying the clayey silt in Borehole BH60-2. The silty sand was encountered at a depth of approximately 18.6 m below ground, corresponding to elevation of approximately 227.4 m. Borehole BH60-2 was terminated in this layer at the depth of 20.4 m (approximate Elevation 225.6 m).

The silty sand generally contained silt and sand, trace gravel, and was generally wet. Based on the "N" values obtained from the SPT, the compactness of the silty sand was very loose to loose.

Laboratory testing performed on selected samples consisted of moisture content tests. The test results are as follows:

Moisture Content:

- 19.7% to 30%

The results of the moisture content tests are provided on the Record of Borehole sheets in Appendix C.

1.4.6 Groundwater

Information regarding the groundwater levels at the site was obtained by measuring the water levels in the open boreholes after completion of drilling and in the piezometers installed in Boreholes BH60-1 and BH60-3. The measured groundwater levels are shown on the borehole logs. The groundwater levels encountered in the boreholes are also shown in table below.

The difference in groundwater level between boreholes could be due to disturbance in the holes at the time of drilling and that the boreholes had not stabilized prior to backfilling.

Seasonal variations in the water table should be anticipated, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods.

Table 1.1. Groundwater levels recorded at Culvert # 60

Borehole Number [Top Elevation (m)]	**Date of Drilling**	**Groundwater Level** Depth Below Existing Grade (m) [Elevation (m)]			
		After Completion	06/24/2009	06/25/2009	06/27/2009
BH60-1* [242.3]	06/16/2009	dry	1.8 [240.5]	1.8 [240.5]	1.8 [240.5]
BH60-2 [246.0]	06/15/2009	7.6 [238.4]	-	-	-
BH60-3* [238.8]	06/22/2009	4.5 [234.3]	2.4 [236.4]	1.5 [237.3]	1.2 [237.6]

* - piezometer

1.5 Closure

A soil investigation is a limited sampling of a site. The information is collected at specific borehole locations and can be extrapolated to an approximate limited area around the borehole. The extent of the limited area depends on the variability of the soil and groundwater conditions as influenced by geological processes and the construction activities. Should any conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to allow reassessment of our recommendations. It may then be necessary to carry out additional field work and analyses.

This report has been prepared by S. Micic, Ph.D., P.Eng. and reviewed by S. Gonsalves, M.Eng., P.Eng. Designated MTO Foundation Contact. The field investigation was conducted by Victor Tam and Greg Qu.

Trow Associates Inc.

Silvana Micic, Ph.D, P.Eng.
Geotechnical Engineer

S.E. Gonsalves, M.Eng., P.Eng.
Principal Engineer
Designated MTO Foundation Contact

APPENDIX A

Photographs

Photograph 1: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking west. Culvert outlet and failed CSP pipe.

Photograph 2: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking north-west. Failed slope.

Photograph 3: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking south. Culvert outlet and gravel lined ditch.

Photograph 4: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking south-east. Failed slope and north roadside ditch.

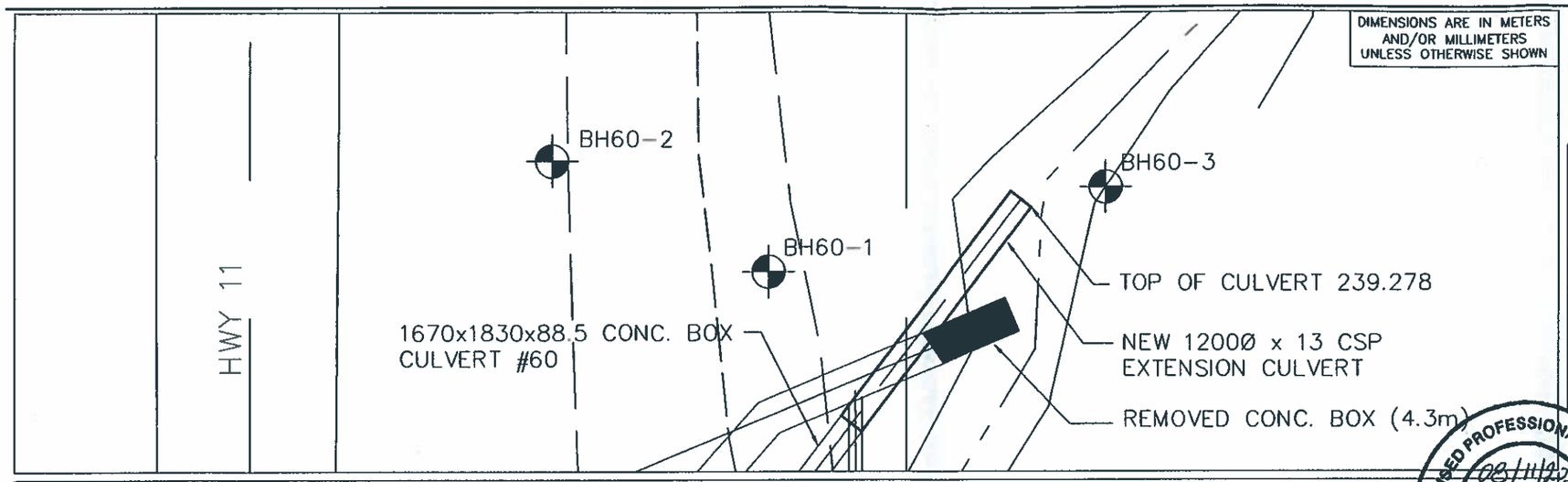
Photograph 5: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking south. Culvert outlet and gravel lined ditch.

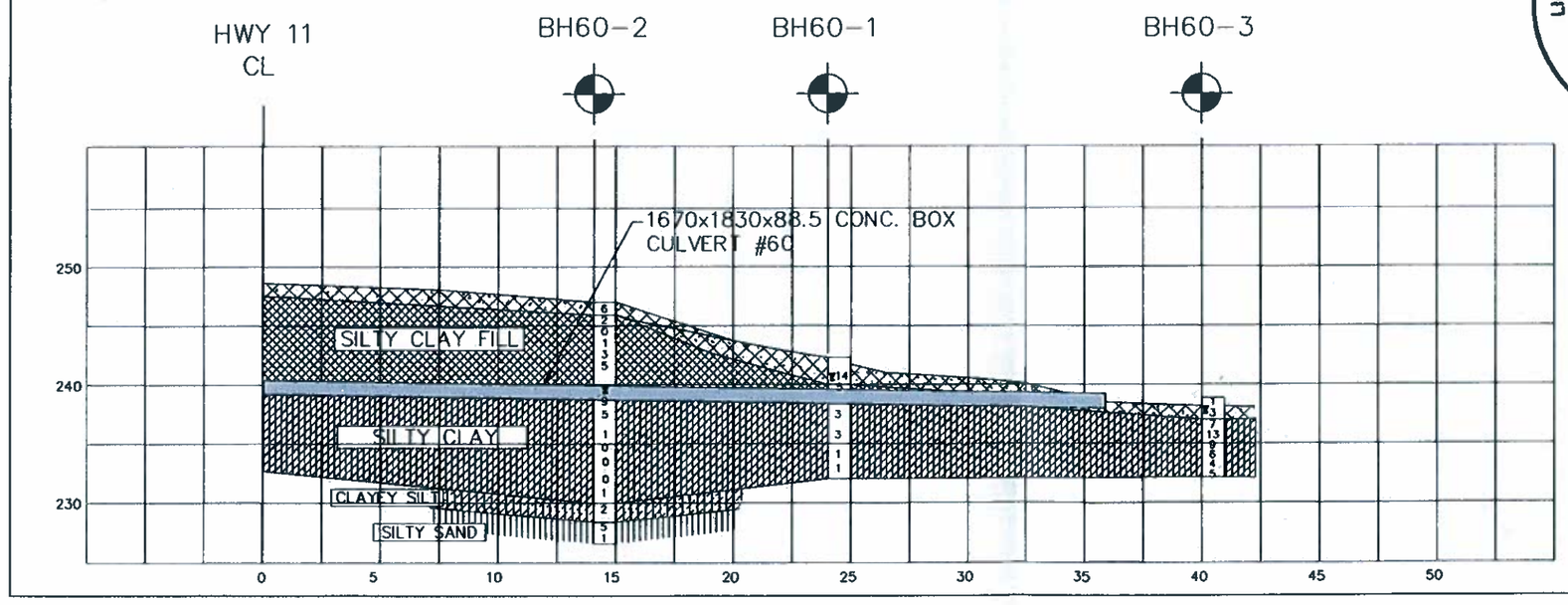
Photograph 6: Culvert # 60 at Station 11+684 (Pacaud Township).
On east side of Highway 11, looking north. Roadside ditch.

APPENDIX B

Drawing

DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN

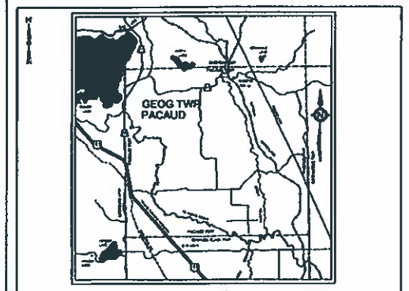




CONT	No. 2007-5192
WO	No. 2009-11030
MTO GEOCRES	No. 31M-81

HWY 11 - STATION 11+684
CULVERT # 60
EXTENSION REPLACEMENT

SHEET 1



KEY MAP
Not to Scale

LICENSED PROFESSIONAL ENGINEER
S. MICIC
100050187
PROVINCE OF ONTARIO
08/11/20

LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
08/11/2009

LEGEND

- Borehole
- Blow/0.3m
- Water Level
- CULVERT

No.	ELEV	NORTHING	EASTING
BH60-1	242.26	379988.2	5311734
BH60-2	246.03	379977.4	5311731
BH60-3	238.81	379997.4	5311747

-NOTES-

1. The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2. This drawing to be read with subject report.
3. The base plan was provided by D.F. Elliott Consulting Engineers LTD.
4. This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
5. Borehole locations are approximate.
6. Borehole elevations should not be used to design building(s), or floor slab(s), or parking lot(s) grades.

REVISIONS			
DATE	BY	DESCRIPTION	

SOIL STRATA SYMBOLS:

GRAVEL & SAND FILL OR TOP SOIL
SILTY CLAY FILL
SILTY CLAY
SILTY SAND
CLAYEY SILT

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PROJECT TITLE AND LOCATION:
Engleheart Project
Culvert #60 Extension Replacement and Slope Failure - Station 11+684
HWY 11, Township of Pacaud
Engleheart, Ontario

DRAWING TITLE:
BOREHOLE LOCATIONS AND SOIL STRATA

PROJECT NO.	SD000391349A	DWN.:	JI
SCALE:	AS NOTED	CHKD.:	SM
DATE:	JULY 2009	DWG. No.:	1

APPENDIX C

Borehole Logs

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 $\overline{N}$.

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

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

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

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINT AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
σ_1, σ_2, σ_3	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
ε_1, ε_2, ε_3	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICALL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	^{o}	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	^{o}	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
P_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	s_r	%	DEGREE OF SATURATION	D_n	mm	N PERCENT – DIAMETER
P	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
P_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = $(W_L - W_L)$	v	m/s	DISCHARGE VELOCITY
P_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(W - W_P)/ I_P$	i	1	HYDAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $(W_L - W) / 1_P$	k	m/s	HYDRAULIC CONDUCTIVITY
P'	kg/m^3	DENSITY OF SUBMERED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

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Trow Brampton, Ontario L6T 4V1

RECORD OF BOREHOLE No BH60-1

SHEET 1 OF 1 **METRIC**

PROJECT NO. SD000391349A **LOCATION** Failed Zone, Culvert #60, N379988.2 E5311734 **ORIGINATED BY** VT

DIST ON **HWY** 11 **BOREHOLE TYPE** Hollow Stem Auger,200mm **COMPILED BY** GQ

DATUM Geodetic **DATE** 06/16/2009 - **CHECKED BY** SM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
242.3										
0.0	FILL - gravel and sand; compact, brown, damp		1	AS						
			2	SS	14	▽	20	66		(14)
240.0										
2.3	FILL - clayey sand, interbedded with silty clay layers, trace gravel, brown and grey, wet		3	SS	5					
239.2										
3.1	SILTY CLAY (CI) - varved structure,trace wet clayey silt seams, grey, saturated, firm		4	SS	3					
			5	SS	3					
			6	SS	3		0	1	37	62
			7	SS	1					
			8	SS	1					
232.1										
10.2	END OF BOREHOLE									

Notes:
1. Borehole advanced by hollow-stem augers.
2. Standpipe piezometer installed to 9.14m depth; bentonite sealed between 0.0m to 0.91m depth and 6.4m to 7.3m depth.
3. This drawing is part of subject report, project number as referenced, and must only be read in conjunction with that report.
4. Interpretation assistance by Trow is required before use by others.

SPT TEST (N-Value) ●
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 PL — NATURAL WATER CONTENT w — LIQUID LIMIT LL
WATER CONTENT (%) 10 20 30

ELEVATION SCALE: 242, 241, 240, 239, 238, 237, 236, 235, 234, 233

UNIT WEIGHT γ kN/m³

+2 (239) +2.4 (237) +2 (235) +2.7 (234) +1.8 (232)

47 (238) 44.4 (236) 43.8 (235) 61.3 (233)

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

ON_MOT HWY11 ENGLEHEART 17 JULY 2009 VANEGREGMETHOD UNMODIFIED.GPJ ON_MOT.GDT 09/08/06

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Brampton, Ontario L6T 4V1

RECORD OF BOREHOLE No BH60-2

METRIC

PROJECT NO. SD000391349A **LOCATION** Embankment Crest (East),Culvert #60, N379977.4 E5311731 **ORIGINATED BY** VT

DIST ON **HWY** 11 **BOREHOLE TYPE** Hollow Stem Auger,200mm **COMPILED BY** GQ

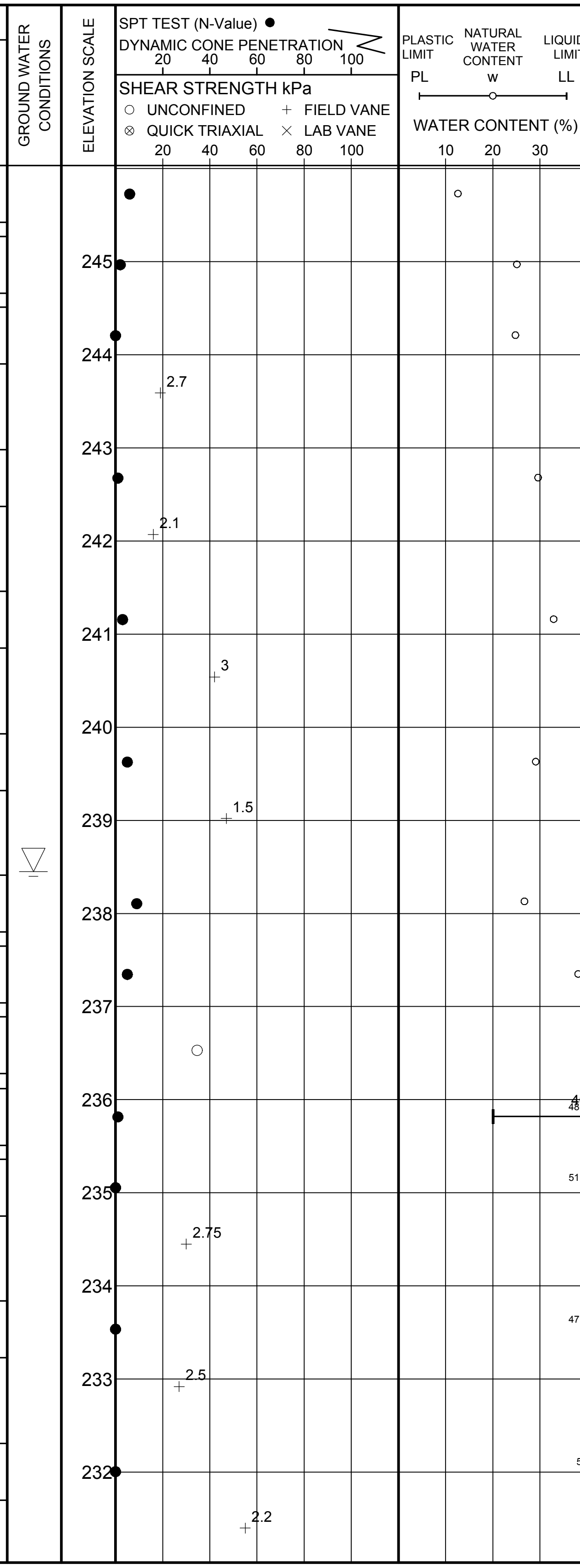
DATUM Geodetic **DATE** 06/15/2009 - 06/16/2009 **CHECKED BY** SM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
246.0 / 0.0	Topsoil ~120mm over FILL - sand and gravel, brown, very moist, loose
245.0 / 1.1	FILL - clayey silt and silty clay, some sand, trace gravel, grey, very moist, very soft to firm - trace peaty silt at ~6.2 m depth
238.4 / 7.6	SILTY CLAY (CI)- varved structure,trace wet clayey silt seams, grey, saturated, soft to stiff

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	6
2	SS	2
3	SS	0
4	SS	1
5	SS	3
6	SS	5
7	SS	9
8	SS	5
9	TW	
10	SS	1
11	SS	0
12	SS	0
13	SS	0



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	0	2	39	59

Continued Next Page

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

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RECORD OF BOREHOLE No BH60-2

SHEET 2 OF 2 **METRIC**

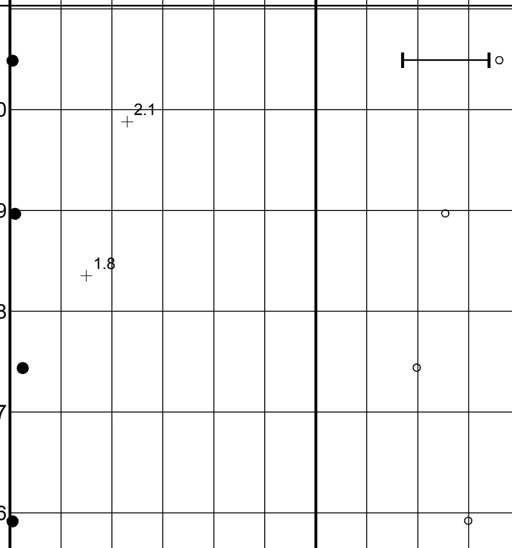
PROJECT NO. SD000391349A **LOCATION** Embankment Crest (East),Culvert #60, N379977.4 E5311731 **ORIGINATED BY** VT

DIST ON **HWY** 11 **BOREHOLE TYPE** Hollow Stem Auger,200mm **COMPILED BY** GQ

DATUM Geodetic **DATE** 06/15/2009 - 06/16/2009 **CHECKED BY** SM

ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
		14	SS	1					
					230				
229.0 17.0	CLAYEY SILT - trace sand; grey, wet, soft	15	SS	2	229	0	9	66	25
					228				
227.4 18.6	SILTY SAND - trace gravel, occasional silty clay seams, grey, wet, very loose to loose	16	SS	5					
					227				
		17	SS	1	226				
225.6 20.4	END OF BOREHOLE Notes: 1. Borehole advanced by hollow-stem augers 2. This drawing is part of subject report, project number as referenced, and must only be read in conjunction with that report. 3. Interpretation assistance by Trow is required before use by others.								

Column headings: SOIL PROFILE; STRAT PLOT; GROUND WATER CONDITIONS; SPT TEST (N-Value) ●; 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 PL, NATURAL WATER CONTENT w, LIQUID LIMIT LL, 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

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RECORD OF BOREHOLE No BH60-3 SHEET 1 OF 1 METRIC

PROJECT NO. SD000391349A **LOCATION** Embankment Toe(East), Culvert #60, N379997.4 E5311747 **ORIGINATED BY** VT

DIST ON **HWY** 11 **BOREHOLE TYPE** Hand Drilling **COMPILED BY** GQ

DATUM Geodetic **DATE** 06/22/2009 - **CHECKED BY** SM

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) ● / 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 PL / NATURAL WATER CONTENT w / LIQUID LIMIT LL / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
238.8											
0.0	Topsoil ~120mm over FILL -silty clay, trace gravel, occasional decayed wood fragments and rootlets; organic stains, brown, damp		1	SS	1		238				
			2	SS	3	▽					
237.0	-becoming grey and very moist below 1.5m		3	SS	7		237				
1.8	SILTY CLAY (CI to CH)- varved structure,trace wet clayey silt seams, grey, saturated, firm		4	SS	13		236				
			5	SS	9						
			6	SS	6		235	+ 1.9			0 1 42 57
			7	SS	4		234				
			8	TW				○			
			9	SS	5		233	+ 2			
232.1											
6.7	END OF BOREHOLE										

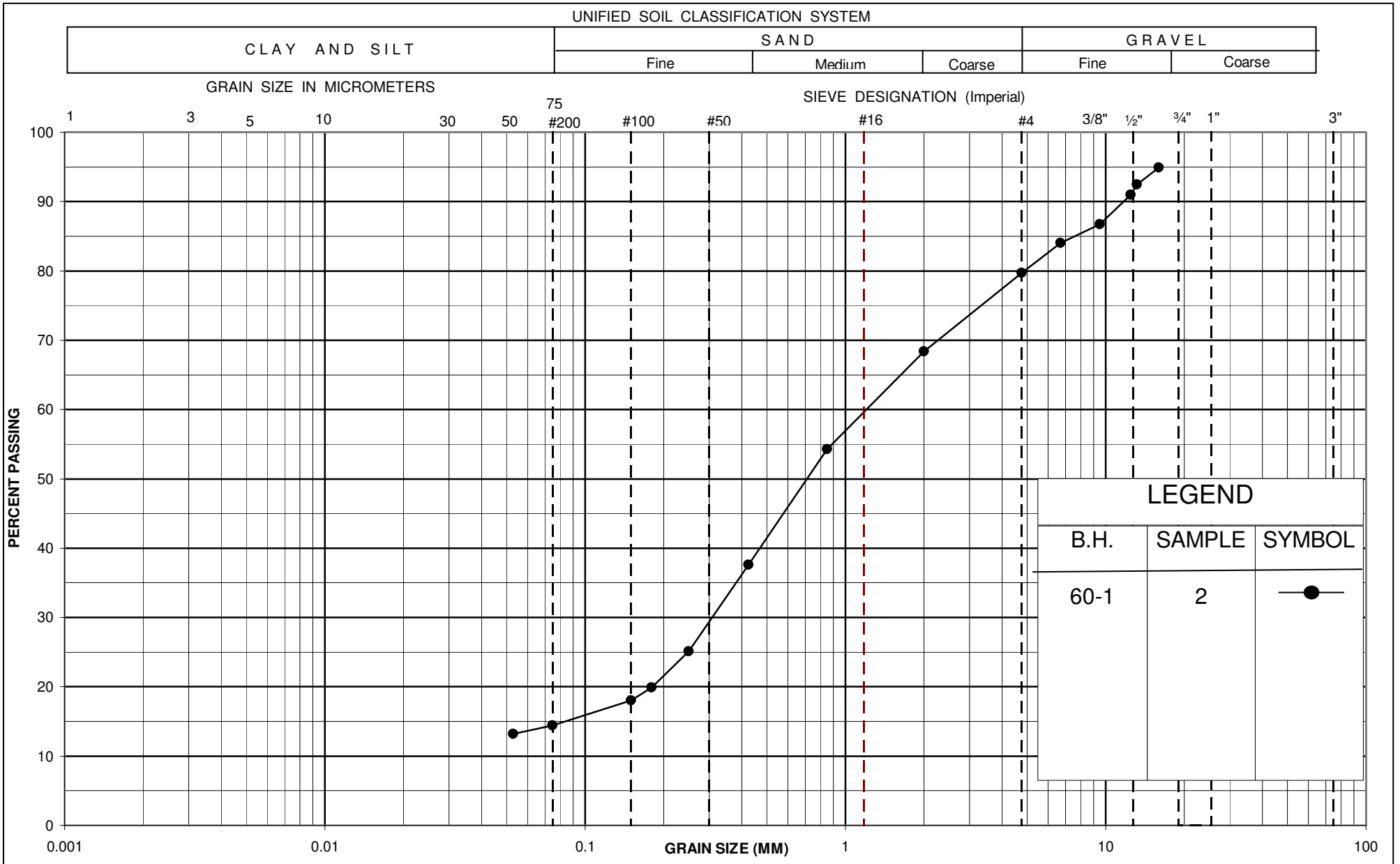
Notes:
1. Borehole advanced by hand drilling/sampling equipment.
2. Standpipe piezometer installed to 4.88m depth; bentonite sealed between 0.0m to 0.91m depth.
3. This drawing is part of subject report, project number as referenced, and must only be read in conjunction with that report.
4. Interpretation assistance by Trow is required before use by others.

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

ON_MOT HWY11 ENGLEHEART 17 JULY 2009 VANEGREGMETHOD UNMODIFIED.GPJ ON_MOT.GDT 09/08/06

APPENDIX D

Laboratory Data



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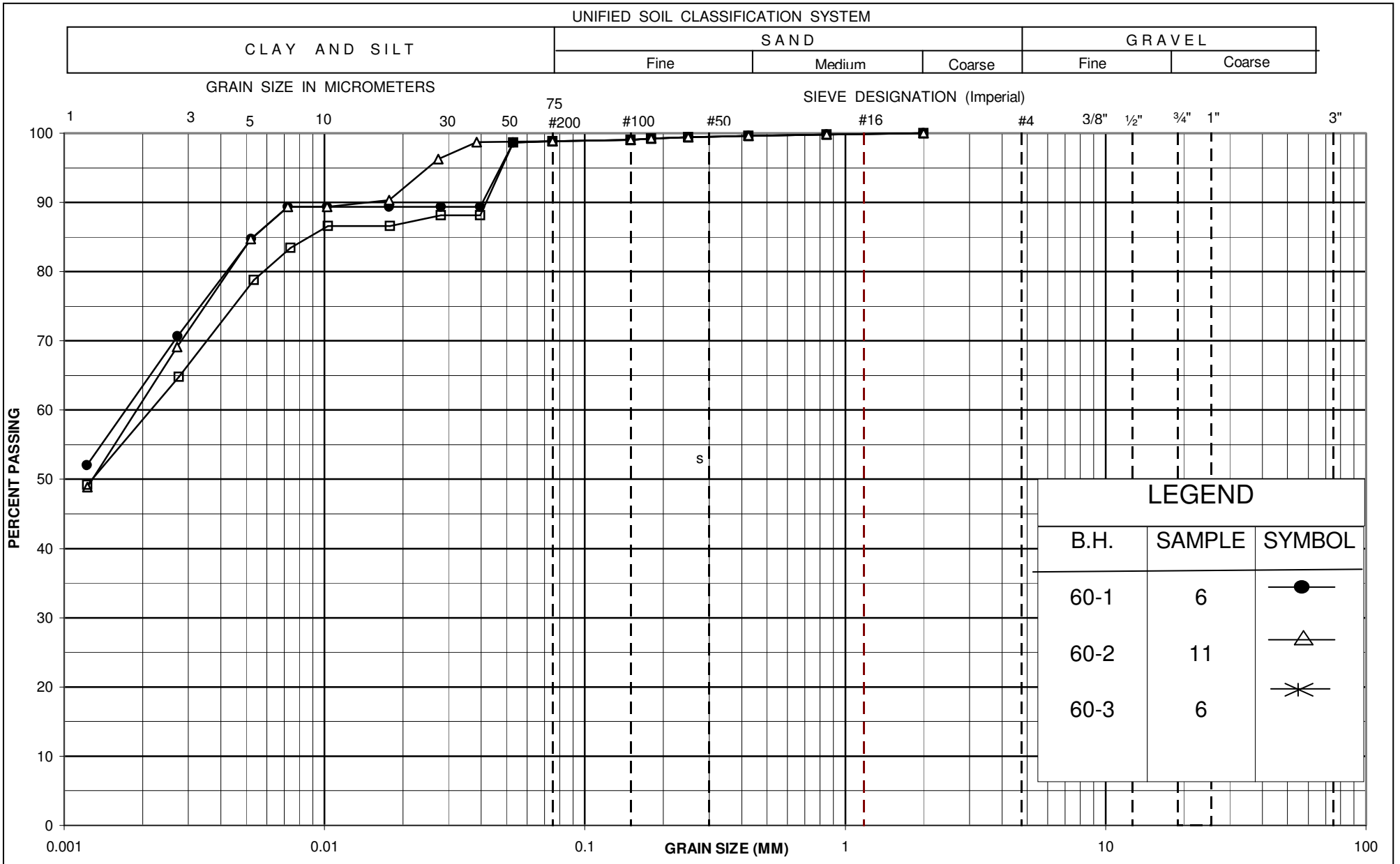
GRAIN SIZE DISTRIBUTION

Sand and Gravel Fill

FIGURE No. 1

WO: 2009-11030

Hwy 11 - Culvert # 60 Extension Replacement and Slope Failure



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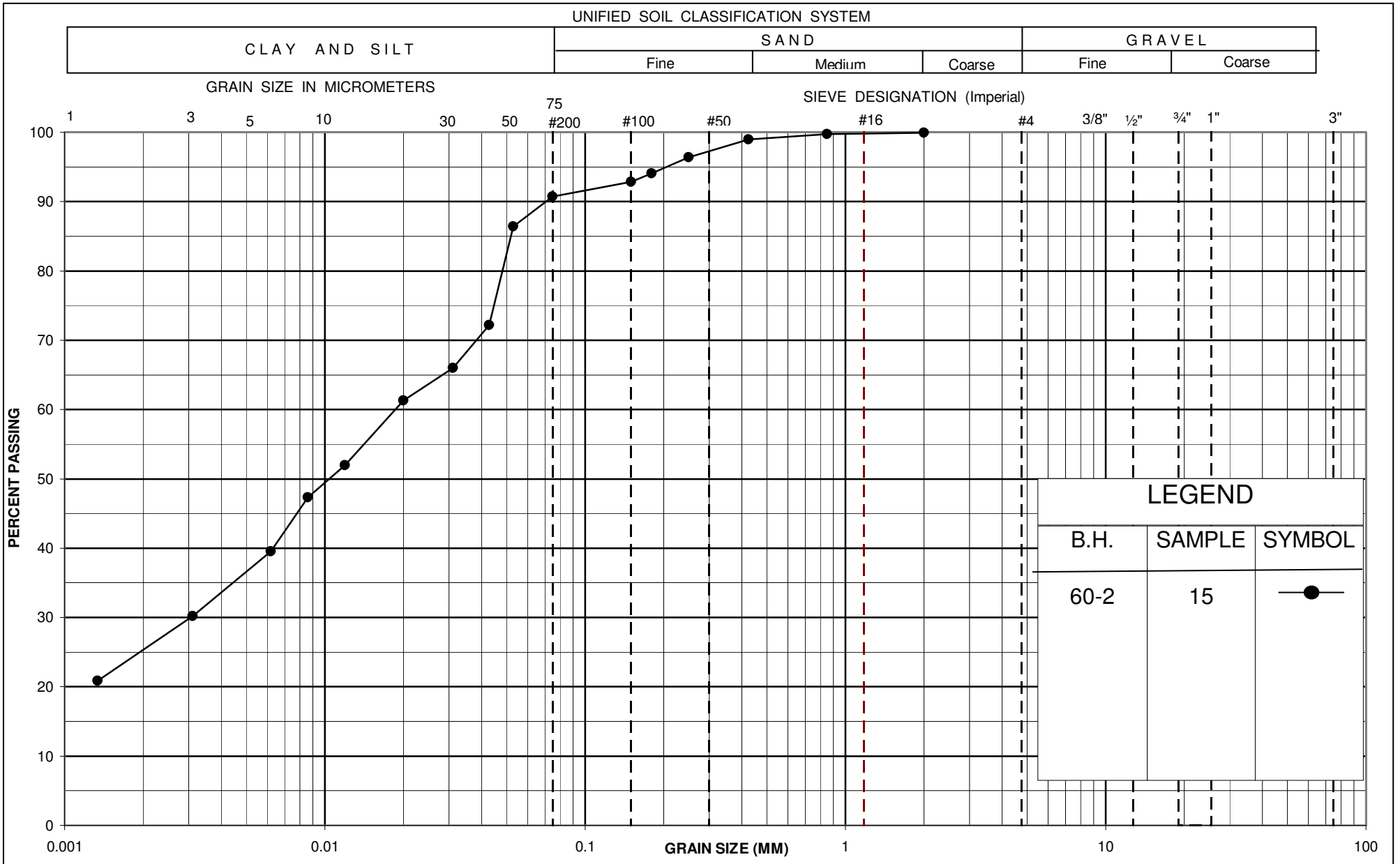
GRAIN SIZE DISTRIBUTION

SILTY CLAY

FIGURE No. 2

WO: 2009-11030

Hwy 11 - Culvert # 60 Extension Replacement and Slope Failure



Trow

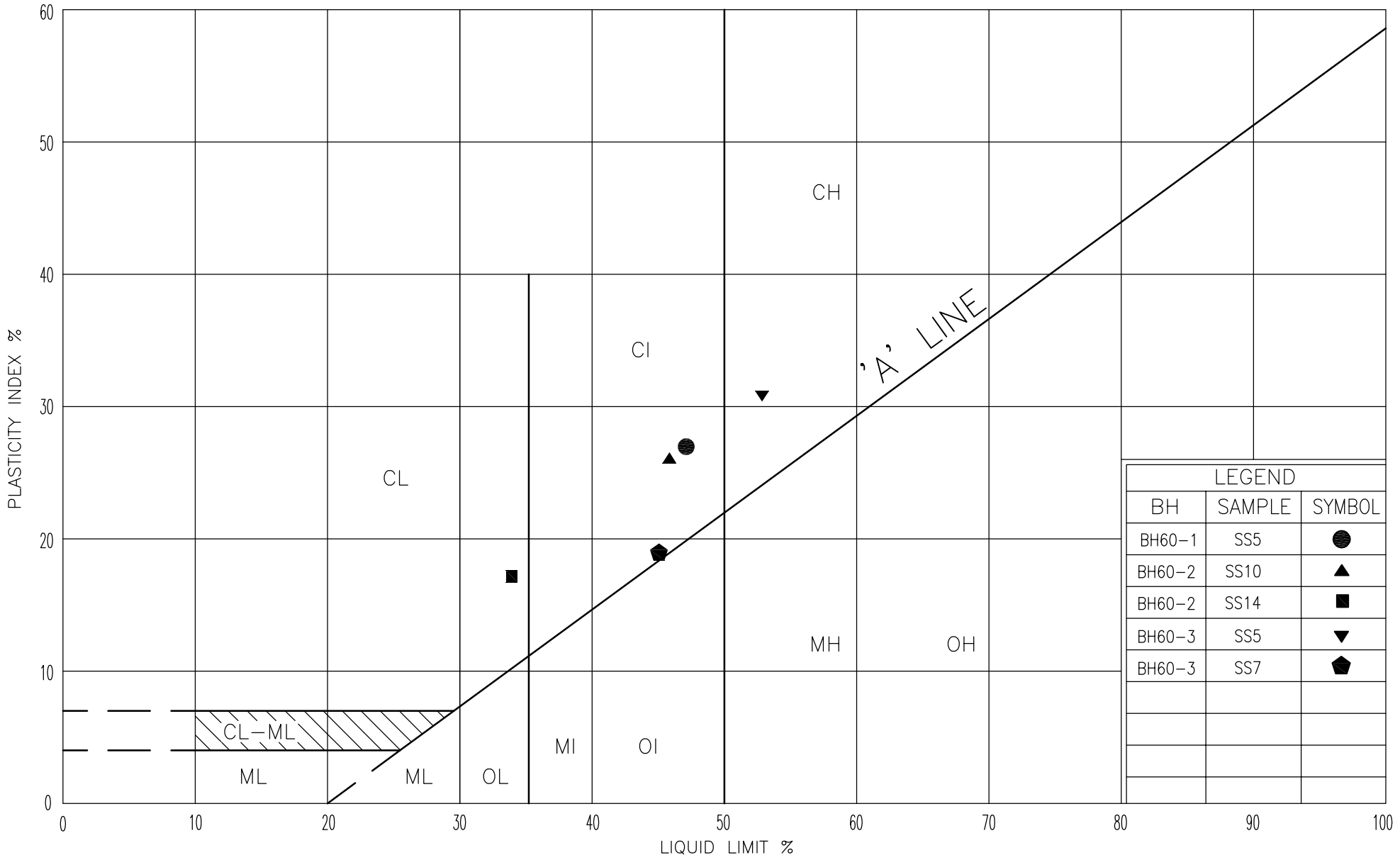
GRAIN SIZE DISTRIBUTION

CLAYEY SILT

FIGURE No. 3

WO: 2009-11030

Hwy 11 - Culvert # 60 Extension Replacement and Slope Failure



Trow

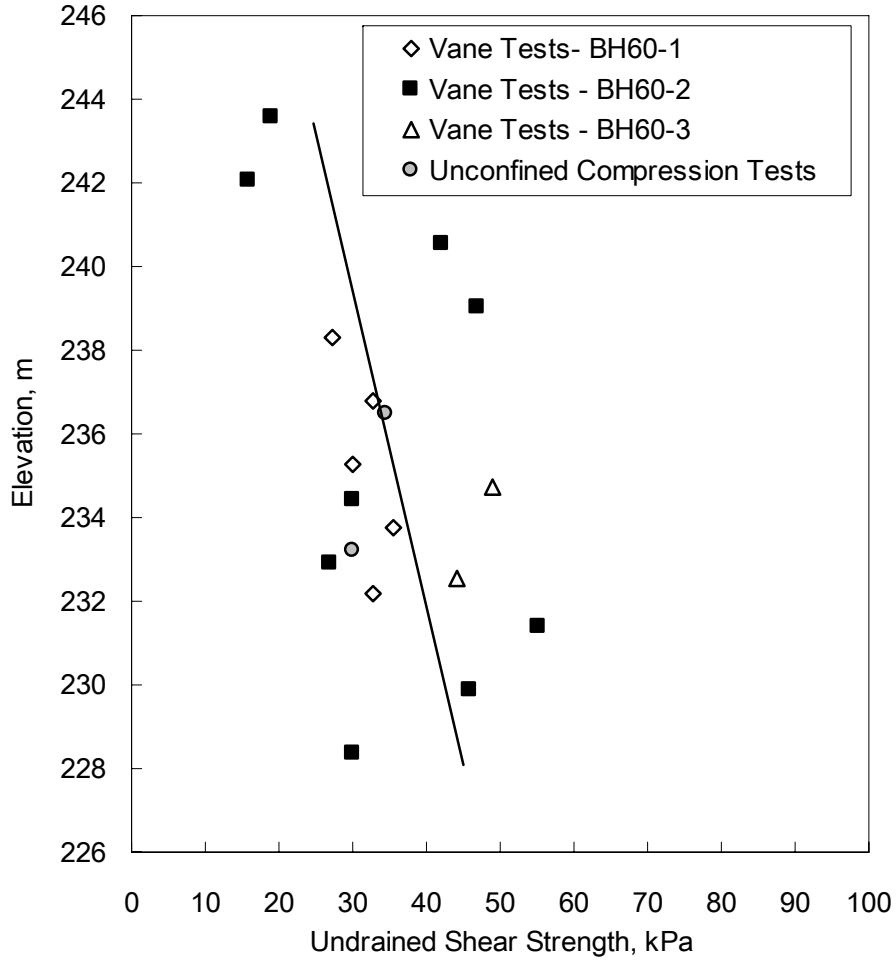
PLASTICITY CHART
SILTY CLAY, CL, CI, AND CH

FIGURE No. 4

G.W.P 2009–11030

Hwy 11 – Culvert # 60
Extension Replacement and Slope Failure

Strength Profile
Silty Clay



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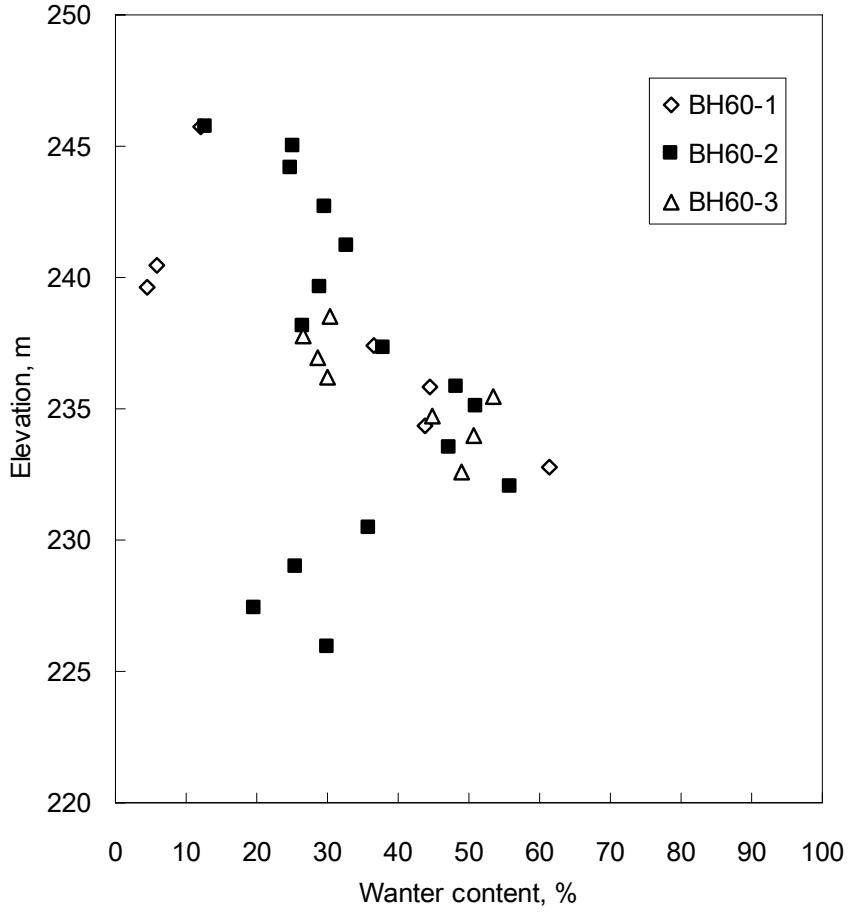
Moisture Conten Profile



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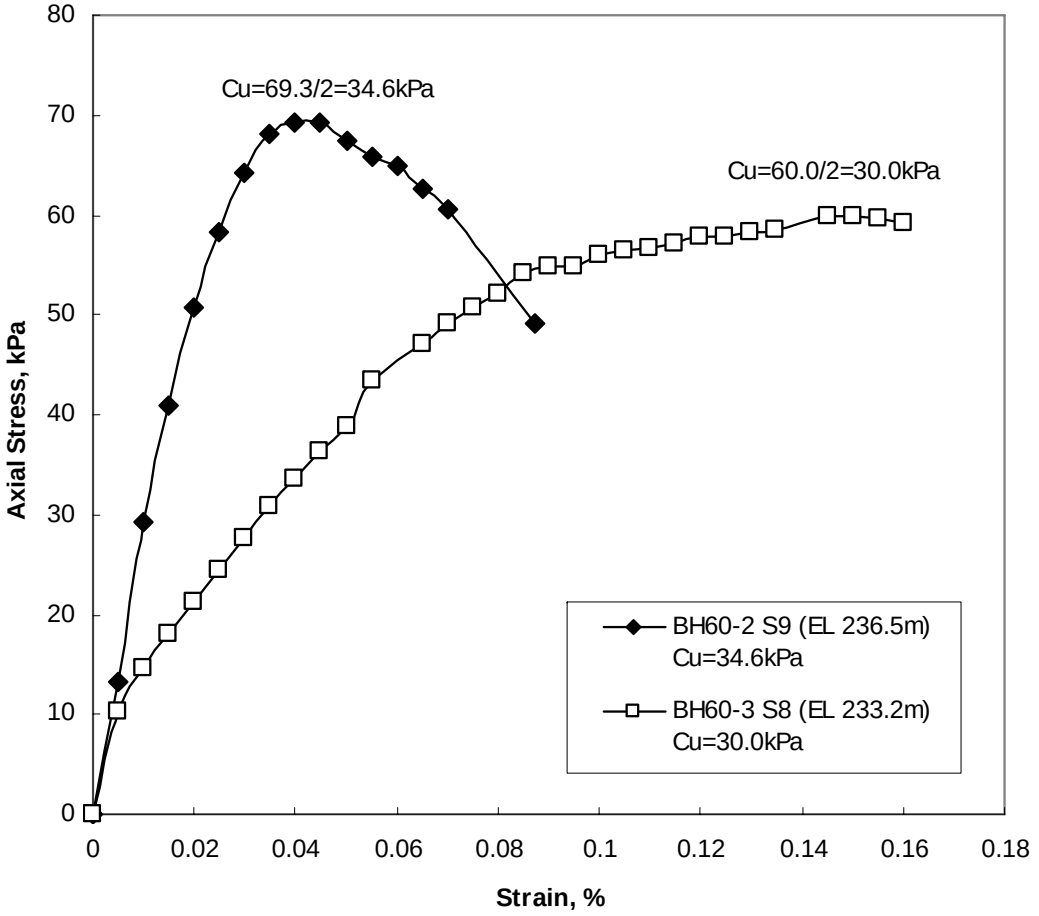
	DATE: July 2009	PROJECT: Englehart Project - HWY 11, Culvert # 60 Replacement and Slope Failure	PROJECT No. SD000391349a
	DRAWN: SM		

Unconfined Compression Test
Silty Clay



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