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Foundation Investigation
Report

Agreement No. 5016-E-0016

GWP 411-00-00

GEOCRES No. 410-35

**Culvert Replacement, Stn. 19+829
Highway 129, Birch Township,
District of Sudbury**

Prepared For:

Ministry of Transportation

Northeast Region

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The Ministry of Transportation

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Project Name:

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Highway 129, Reaney Township, District of Sudbury

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1 Foundation Investigation Report

1.1 Introduction

This Foundation Investigation Report (FIR) presents the results of a geotechnical investigation completed by **exp** Services Inc. (**exp**) for the replacement of a centreline culvert located on Highway 129 at Station 19+829, within Birch Township, District of Sudbury, Ministry of Transportation (MTO) Northeastern Region. This work was undertaken under Agreement No. 5016-E-0016, GWP 411-00-00. The terms of reference (TOR) were presented in the MTO Request for Quotation Document dated August 22, 2016.

The purpose of the investigation is to evaluate the subsurface conditions along the proposed culvert replacement alignment in order to provide geotechnical information necessary for the design of the culvert replacement. The site specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing.

This FIR has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The centreline culvert replacement site is located on Highway 129 at Station 19+829 within Birch Township. The site is located approximately 45 km south of the South Junction of Highway 101. The location of the culvert and a cross section of the existing culvert alignment are shown on Dwg. No. 1 in Appendix A.

The existing culvert consists of a non-structural, corrugated steel pipe (CSP), approximately 1.2 m in diameter and 29.48 m long. At this site, Highway 129 is an asphalt paved, two lane, north/south roadway having approximately 1.0 m wide partially paved shoulders and cable guide rails on both sides of the roadway. The highway embankment at the investigated location is approximately 6.7 m high on the east side of the roadway and 7.7 m high on the west side of the roadway. The embankment side slopes are approximately 1.5H:1V on both sides, from the top to toe of the embankment. Photographs of the site and existing culvert are included in Appendix B.

The general site conditions were assessed on November 16, 2016. The existing waterway flows from the west to the east through the existing culvert. Immediately adjacent to the waterway on both sides of the roadway embankment, the terrain generally consists of low lying vegetation and grasses and a thick forest consisting of both deciduous and coniferous trees.

The side slopes of the highway embankment are covered with large boulder rip-rap with some grass and light vegetation near the crest of the embankment. Guardrails at the top of the embankment and trees near the embankment toe all appeared to be standing vertically, suggesting there is not likely any stability issues with the current embankment. Bedrock outcrops were not observed at the site. The surface of Highway 129 near the culvert location was in fair shape, with moderate wheel track rutting and moderate transverse, longitudinal, and map cracking.

1.2.2 Geological Setting

In accordance with Ontario Geological Survey Northern Ontario Engineering Geology Terrain Study 86, the dominant landform at the culvert site is ground moraine consisting mainly of till. Local relief is generally moderate (15 to 60 m) and the terrain is generally undulating to rolling. Overall drainage is good (dry). Within Birch Township, rock knobs generally occur within the ground moraine.



Ministry of Northern Development and Mines (MNDM) Map 2543, Bedrock Geology of Ontario East-Central Sheet indicates the bedrock at the culvert location consists of tonalite to granodiorite, foliated to gneissic, with minor supracrustal inclusions.

1.3 Investigation Procedures

1.3.1 Site Investigation and Field Testing

The field investigation was performed on January 15, 19, and May 3 to 4, 2017. The field program consisted of the advancement of three (3) sampled boreholes (BH-1 to BH-3). The boreholes were located along the existing culvert alignment to provide subsurface information for the design of the proposed new culvert. Borehole BH-1 was located within the travelled southbound lane, as close as possible to the crest of the western embankment. Boreholes BH-2 and BH-3 were advanced at accessible locations near the outlet and inlet, respectively, of the culvert. The borehole locations are shown on Dwg. No. 1 in Appendix A.

Borehole BH-1 was advanced using a truck mounted CME-55 drill rig equipped with hollow stem augers, NW casing, and standard soil sampling equipment. Due to access restrictions, Boreholes BH-2 and BH-3 were advanced with portable tripod mounted equipment with a cathead and Hilti D200 drill. The drilling equipment was operated by a specialist drilling contractor, Landcore Drilling. Each borehole was advanced to approximately 6.0 m below the culvert invert.

The borehole locations (referenced to MTM NAD83 coordinate system, Zone 13) and their ground surface elevations were surveyed by **exp** personnel following drilling using hand-held GPS equipment. The geodetic borehole and water elevations were surveyed using a Temporary Benchmark (TBM) established on the roadway centreline at Stn. 19+825. The TBM was assigned an elevation of 464.7 m based on a survey of the site provided to **exp** by the MTO. The borehole and TBM locations are shown on Dwg. No. 1 in Appendix A.

Soil samples were obtained using a 51 mm outside diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs in Appendix C. The original field (uncorrected) SPT "N" values were recorded on the borehole logs and used to provide an assessment of the in-situ compactness condition of encountered cohesionless soils.

Upon completion of the boreholes, groundwater measurements were carried out within the boreholes in accordance with MTO guidelines. The measured groundwater levels after completion were recorded on the borehole logs as shown in Appendix C. The boreholes were decommissioned using bentonite in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

The fieldwork was supervised by members of **exp**'s engineering staff who directed the drilling and sampling operations, logged borehole data in accordance with the MTO Soil Classification System, and retrieved soil samples for subsequent laboratory testing and identification.

All of the recovered soil samples were placed in labelled moisture-proof bags and returned to **exp**'s Sudbury Laboratory for additional visual, textural, olfactory examination and selective testing.

1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included determination of natural moisture content on all samples and particle size distribution for approximately 25% of the collected soil samples. All of the laboratory tests were carried out in accordance with MTO and/or ASTM Standards as appropriate.



The laboratory test results are summarized on the attached borehole logs in Appendix C. The results of the particle size analyses are presented graphically in Appendix D.

1.4 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the Record of Borehole Sheets in Appendix C. Laboratory test results are provided in Appendix D. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

A borehole location plan and stratigraphic section are provided in Appendix A. It should be noted that the stratigraphic boundaries indicated on the borehole logs and stratigraphic section are inferred from semi-continuous sampling, observations of the drilling progress, and results of the Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be interpreted as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered within the embankment (BH-1) consist of asphalt overlying fill materials, native silt, and till materials. At the toes of the embankment slopes (BH-2 and BH-3), the subsurface conditions encountered consist of a thin layer of peat overlying native sand, and till materials. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

1.4.1 Asphalt

Asphalt was encountered at the surface of Borehole BH-1 and was approximately 50 mm thick. Asphalt thicknesses may further vary beyond the borehole location.

1.4.2 Fill Materials

Fill materials were encountered below the asphalt at Borehole BH-1 and extended to approximately 7.6 m depth. Directly below the asphalt was an approximately 1.0 m thick layer of moist gravel and sand fill with cobbles and trace silt. Below the gravel and sand fill was very dense rock fill consisting of cobbles and boulders that extended to 6.9 m depth. The cobbles and boulders ranged in diameter from approximately 0.1 to 0.7 m. A wet, sandy gravel seam was encountered within the rock fill at approximately 5.3 m depth. Underlying the rock fill was an approximately 0.7 m thick layer of silty sand fill with some gravel. The silty sand fill was frozen at the time of the investigation. One SPT was performed within the silty sand fill, resulting in an uncorrected "N" value of 102 blows per 300 mm, classifying the silty sand fill as very dense in compactness condition.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests and one (1) grain size analysis. The grain size analysis was performed on the upper gravel and sand fill. The test results are as follows:

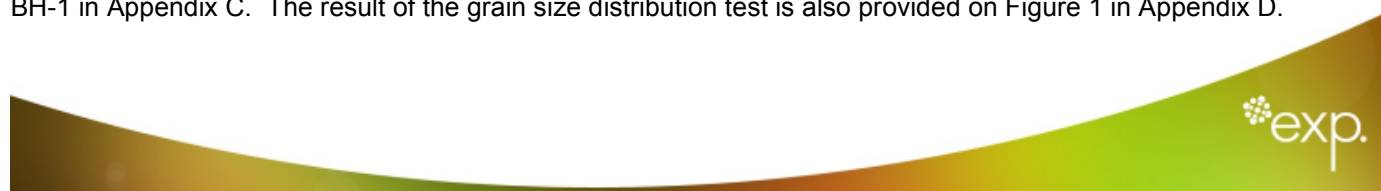
Moisture Content:

- 2 to 20 %

Grain Size Distribution:

- 52 % gravel
- 42 % sand
- 6 % fines

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheet for BH-1 in Appendix C. The result of the grain size distribution test is also provided on Figure 1 in Appendix D.



1.4.3 Peat

Peat was encountered at the surface of Boreholes BH-2 and BH-3 and was approximately 0.2 to 0.3 m thick. The peat was black in colour, and wet.

Laboratory testing performed on samples of the peat consisted of two (2) moisture content tests. The test results are as follows:

Moisture Content:

- 36 to 45 %

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

1.4.4 Silt

Underlying the fill material at Borehole BH-1 was an approximately 0.7 thick layer of native silt. The silt was grey in colour, and contained some sand and trace organics. One SPT performed within the silt resulted in an uncorrected "N" value of 7 blows per 300 mm, classifying the silt as loose in compactness condition.

Laboratory testing performed on a sample of the silt consisted of one (1) moisture content test. The test results are as follows:

Moisture Content:

- 25 %

The results of the moisture content test is provided on the Record of Borehole Sheet for BH-1 in Appendix C.

1.4.5 Sand

Underlying the peat at Borehole BH-3 was native sand that extended to approximately 4.6 m depth. The sand was grey to brown in colour, moist to wet, and contained some silt, and trace to some gravel. Uncorrected SPT "N" values within the sand ranged from 14 to 23 blows per 300 mm, classifying the sand as compact in compactness condition.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 11 to 38 %

Grain Size Distribution:

- 13 % gravel
- 68 % sand
- 19 % silt

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheet for BH-3 in Appendix C. The result of the grain size distribution test is also provided on Figure 2 in Appendix D.



1.4.6 Till

Underlying the silt at Borehole BH-1, the peat at BH-2, and the sand at BH-3 was native till that extended to the termination depth of each borehole. The till ranged in composition from sandy gravel till with trace silt; to gravelly sandy silt till; to sand and silt/silt and sand till with trace to some gravel and trace clay. The till was generally brown to grey in colour and moist to wet. Generally, uncorrected SPT "N" values within the till ranged from 14 to 110 blows per 300 mm, classifying the till as compact to very dense in compactness condition. The upper 0.3 m of the till at BH-2 was generally loose in compactness condition.

Laboratory testing performed on selected samples consisted of sixteen (16) moisture content tests and five (5) grain size analysis. The test results are as follows:

Moisture Content:

- 8 to 18 %

Grain Size Distribution:

- 1 to 66 % gravel
- 26 to 68 % sand
- 9 to 51 % silt
- 0 to 2 % clay

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 3 in Appendix D.

1.5 Groundwater and Surface Water Conditions

Groundwater was observed in Borehole BH-1 at approximately 7.3 m depth, Elev. 457.3 m. Note, however, that this water elevation is not likely accurate as water was pumped into the borehole for the washboring techniques utilized. Washboring techniques were also used at BH-2 and BH-3 with the portable equipment utilized, and as such, no groundwater measurements were made in these boreholes. As such, accurate groundwater measurements could not be obtained in the boreholes upon completion.

Note, however, that samples within Borehole BH-1 were generally frozen to wet below 6.9 m depth, Elev. 457.7 m. In addition, samples at BH-2 and BH-3 were generally wet from surface, Elev. 457.1 and 458.0 m, respectively. This could infer a groundwater level located between Elev. 457.0 and 458.0 m.

The water level within the adjacent open water was measured on June 26, 2017 and it was at approximately Elev. 457.3 at the culvert inlet and at Elev. 456.6 m at the culvert outlet. This is generally at a similar level as the wet samples encountered within the boreholes, which also further supports the inference above regarding the groundwater level.

Groundwater would be expected to reflect levels in the adjacent open water and to fluctuate seasonally. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.



2 Closure

A subsurface investigation is a limited sampling of a site. The subsurface conditions have been established only at the test hole locations noted. Should any conditions at the site be encountered that 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 perform additional investigation and analysis.

The number of test holes required to determine the localized underground conditions between test holes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual test hole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Ian MacMillan, P.Eng. It has been reviewed by Andy Schell, M.Sc.(Eng.), P.Eng., TaeChul Kim, M.E.Sc., P.Eng., and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Shane Tobias.

Yours truly,

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Appendix A – Drawings



19+800

METRIC
DIMENSIONS ARE IN METERS AND/OR
MILLIMETERS UNLESS OTHERWISE SHOWN.
STATIONS ARE IN KILOMETERS +METERS



Agreement No. 5016-E-0016
GWP 411-00-00
GEOCRES No. 410-35

CULVERT REPLACEMENT, STN. 19+829
HIGHWAY 129, BIRCH TOWNSHIP
DISTRICT OF SUDBURY
**BOREHOLE LOCATION PLAN AND SOIL
STRATA**



SHEET
1

exp. **exp Services Inc.**

KEY PLAN - NTS



LEGEND

- BOREHOLE LOCATION
- STANDARD PENETRATION TEST (BLOWS/300mm)
- TEMPORARY BENCHMARK (EL. 484.7 m)
- ESTIMATED WATER LEVEL IN BOREHOLE

BOREHOLE COORDINATES

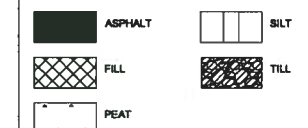
BOREHOLE NO.	APPROX. ELEV. (m)	MTM COORDINATES	
		NORTHING	EASTING
BH-1	484.6	5252554.9	364844.3
BH-2	457.1	5252558.9	364888.6
BH-3	458.0	5252545.5	364829.1

NOTES

This drawing is for subsurface information only. The proposed structure details/work are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

SOIL STRATA SYMBOLS

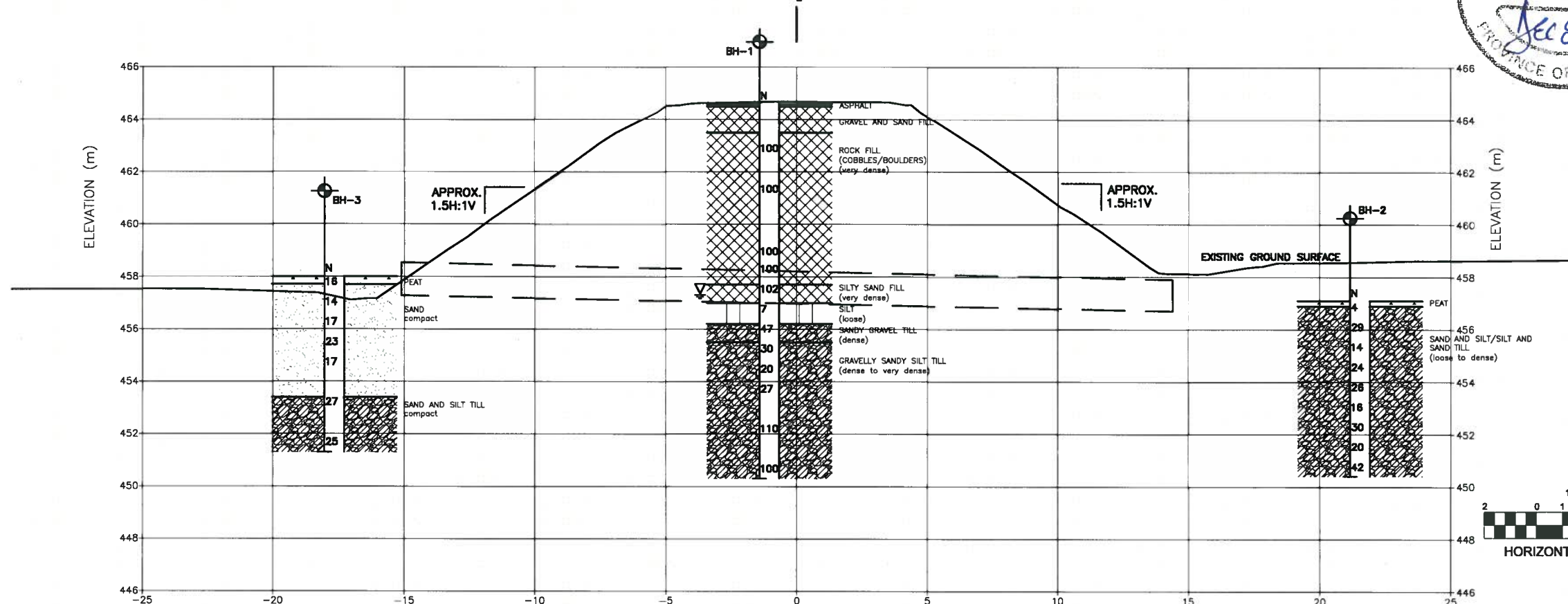


REVISIONS

DATE	BY	DESCRIPTION
2017.10.04	IM	SUBMISSION FOR MTO REVIEW
2017.11.28	IM	FINAL REPORT SUBMISSION
SCALE: AS NOTED		PROJECT NO.: SUD-00014543-AG
SUBMD: IM	CHECKED: AS	DATE: 2017.10.04
DRAWN: IM	CHECKED: SG	APPROVED: SG DWG. 1

PLAN

HIGHWAY 129



CROSS SECTION A-A AT STN. 19+825

Appendix B – Photographs





Photograph No. 1 – Highway 129 at Culvert, Stn. 19+829 (Facing North)



Photograph No. 2 – West Embankment (Facing North)



Photograph No. 3 – West Embankment at Culvert (Facing North-West)



Photograph No. 4 – Culvert Inlet (Facing West)



Photograph No. 5 – East Embankment (Facing North)



Photograph No. 6 – East Embankment at Culvert (Facing North-East)



Photograph No. 7 – Culvert Outlet (Facing East)

Appendix C – Borehole Logs



Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.

ISSMFE SOIL CLASSIFICATION											
CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		
<div><div>0.002</div><div>0.006</div><div>0.02</div><div>0.06</div><div>0.2</div><div>0.6</div><div>2.0</div><div>6.0</div><div>20</div><div>60</div><div>200</div></div>											
EQUIVALENT GRAIN DIAMETER IN MILLIMETRES											
CLAY (PLASTIC) TO				FINE		MEDIUM		CRS.		FINE COARSE	
SILT (NONPLASTIC)				SAND				GRAVEL			
UNIFIED SOIL CLASSIFICATION											

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	$5 \leq Pp \leq 10\%$
Little	$15 \leq Pp \leq 25\%$
Some	$30 \leq Pp \leq 45\%$
Mostly	$50 \leq Pp \leq 100\%$

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	$N < 5$
Loose	$5 \leq N < 10$
Compact	$10 \leq N < 30$
Dense	$30 \leq N < 50$
Very Dense	$50 \leq N$

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

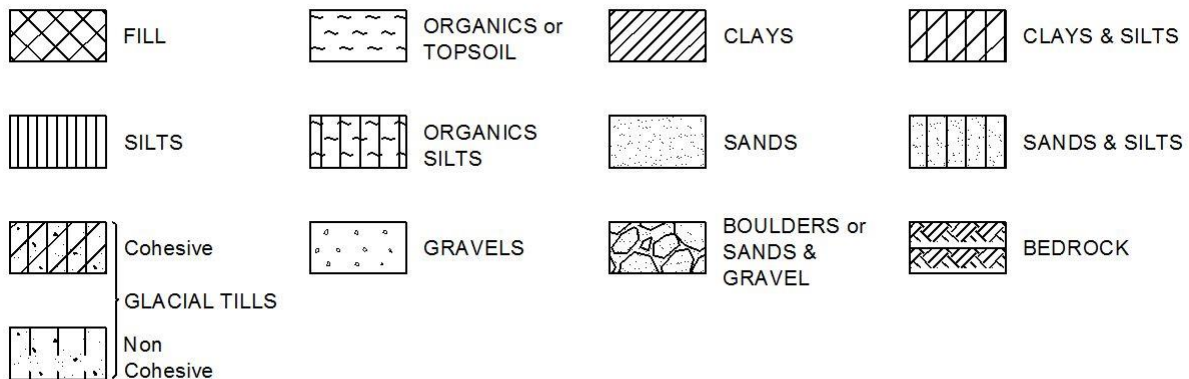
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

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
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path
T_v	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_p	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	$-\circ$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$-\circ$	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
γ_s	kN/m^3	Unit weight of solid particles
ρ_w	kg/m^3	Density of water
γ_w	kN/m^3	Unit weight of water
ρ	kg/m^3	Density of soil
γ	kN/m^3	Unit weight of soil
ρ_d	kg/m^3	Density of dry soil
γ_d	kN/m^3	Unit weight of dry soil
ρ_{sat}	kg/m^3	Density of saturated soil
γ_{sat}	kN/m^3	Unit weight of saturated soil
ρ'	kg/m^3	Density of submerged soil
γ'	kN/m^3	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_p	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_p$
I_C	%	Consistency index = $(W_L - W)/I_p$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m^3/s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m^3	Seepage force

RECORD OF BOREHOLE No BH-1

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 19+833, MTM-13, 5252554.88N, 364844.34E, Non-Structural Culvert at Stn. 19+829 ORIGINATED BY ST
DIST Sudbury HWY 129 BOREHOLE TYPE Continuous Flight HSA and Washboring with NW Casing COMPILED BY IM
DATUM Geodetic DATE 2017.05.03 - 2017.05.04 LATITUDE 47.409501 LONGITUDE -83.204344 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60						80	100
464.6	Pavement Surface																
463.6	ASPHALT (~ 50 mm thick) FILL, gravel and sand, trace silt, with cobbles, brown, moist.		1	AS											52 42 (6)		
463.6	ROCK FILL (COBBLES/BOULDERS), coring procedures utilized to penetrate cobbles/boulders. Cobbles/boulders range in size from 0.1 to 0.7 m diameter.																
463.6		2	SS	100													
		3	SS	100													
	sandy gravel seam, some silt, brown at ~ 5.3 m depth.																
		4	SS	100													
			5	SS	100												
457.8	FILL, silty sand, some gravel, brown, frozen, very dense.		6	SS	102												
457.0	SILT, some sand, trace organics, grey, wet, loose.																
457.0		7	SS	7													
456.2	TILL, sandy gravel, trace silt, brown, wet, dense.		8	SS	47										66 26 (9)		
455.5	TILL, gravelly, sandy silt, grey, wet, dense.		9	SS	30												
	compact below ~ 9.9 m depth.																
		10	SS	20											33 33 34 0		
	very dense below ~ 12.2 m depth.																
		11	SS	27													
			12	SS	110												

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

ONTARIO MTO SUD-00014543-AG - HWY. 129 - CL CULVERT 19+829.GPJ ONTARIO MTO.GDT 11/17/17

RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 19+838, MTM-13, 5252558.89N, 364866.56E, Non-Structural Culvert at Stn. 19+829 ORIGINATED BY ST
DIST Sudbury HWY 129 BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill COMPILED BY IM
DATUM Geodetic DATE 2017.01.15 - 2017.01.15 LATITUDE 47.409535 LONGITUDE -83.204049 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						
457.1	Ground Surface						20	40	60	80	100						
457.0	PEAT, black, wet.		1	SS	4												
0.2	TILL, sand and silt to silt and sand, brown, wet, loose.		2	SS	29												
	some gravel, trace clay, compact to dense below ~ 0.8 m depth.		3	SS	14											15 47 37 2	
	brown to grey below ~ 1.5 m depth.		4	SS	24												
	grey below ~ 3.1 m depth.		5	SS	26											12 37 51 1	
			6	SS	16												
			7	SS	30												
			8	SS	20												
			9	SS	42												
450.4	END OF BOREHOLE Borehole terminated at ~ 6.7 m depth.																
6.7	NOTES: 1. This drawing to be read with the subject report and project numbers as presented above. 2. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.																

RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 19+826, MTM-13, 5252545.50N, 364829.11E, Non-Structural Culvert at Stn. 19+829 ORIGINATED BY ST
DIST Sudbury HWY 129 BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill COMPILED BY IM
DATUM Geodetic DATE 2017.01.19 - 2017.01.19 LATITUDE 47.409418 LONGITUDE -83.204547 CHECKED BY IM

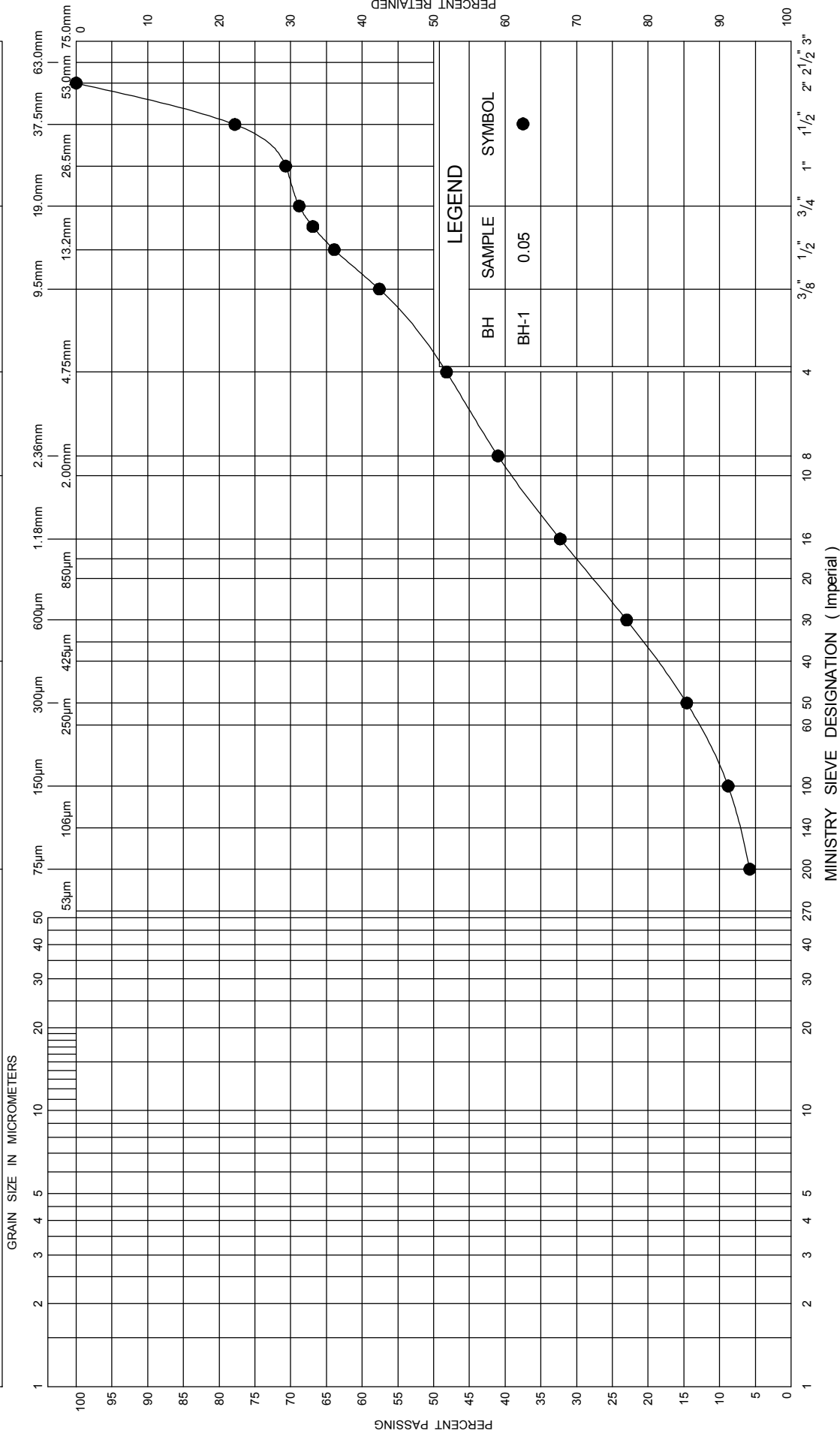
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)								
458.0	Ground Surface							20	40	60	80	100					
0.0	PEAT, black, wet.		1	SS	16												
457.7	SAND, some silt, grey, wet, compact. brown, trace to some gravel below ~ 0.8 m depth.		2	SS	14		457										
0.3			3	SS	17		456										
			4	SS	23		455										
			5	SS	17		454										
							453										
453.4	TILL, sand and silt, trace gravel, trace clay, grey, wet, compact.		6	SS	27		452										
4.6																	
			7	SS	25												
451.3	END OF BOREHOLE Borehole terminated at ~ 6.7 m depth.																
6.7	NOTES: 1. This drawing to be read with the subject report and project numbers as presented above. 2. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.																

Appendix D – Laboratory Test Results



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse

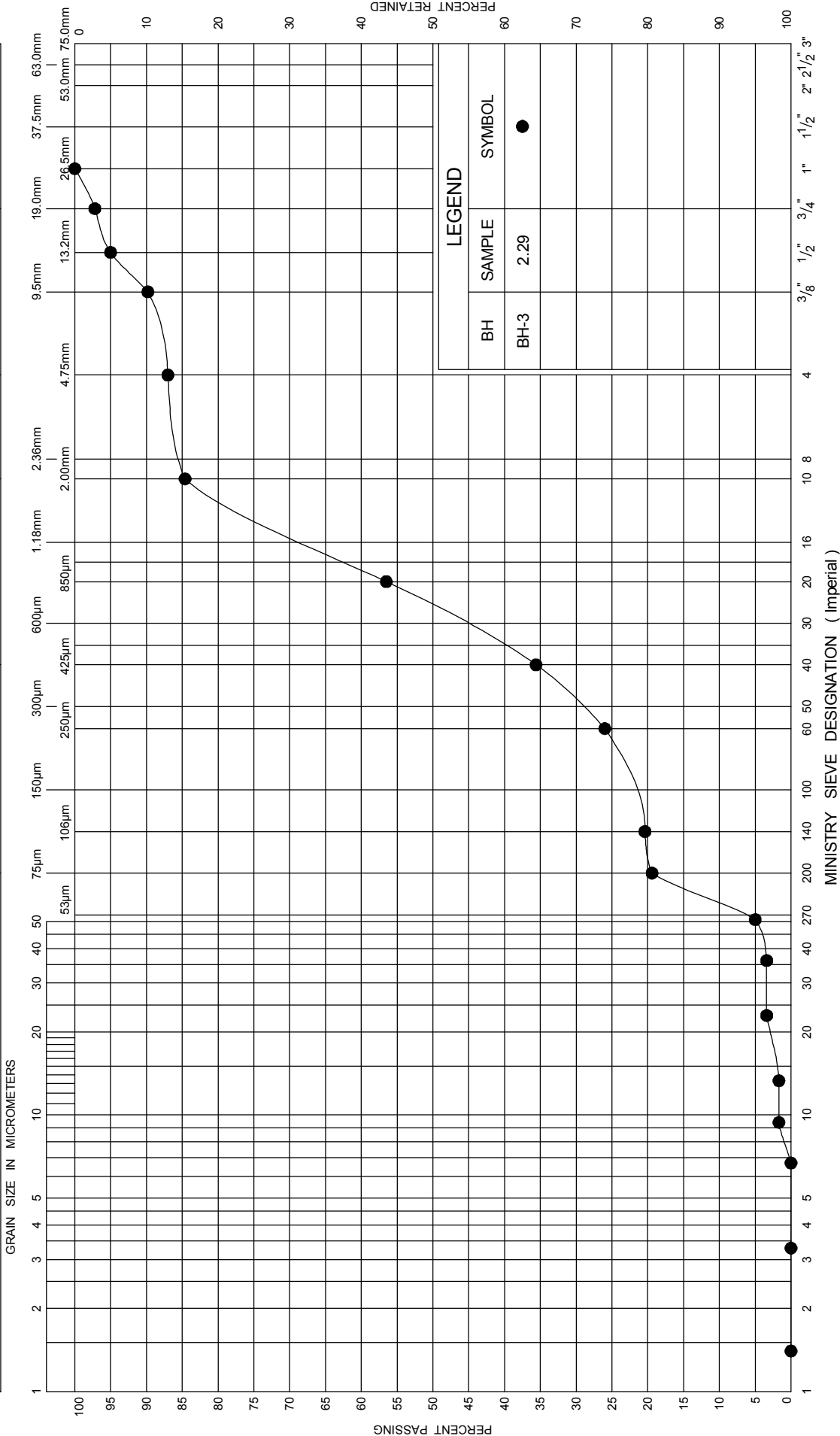


FIG No 2

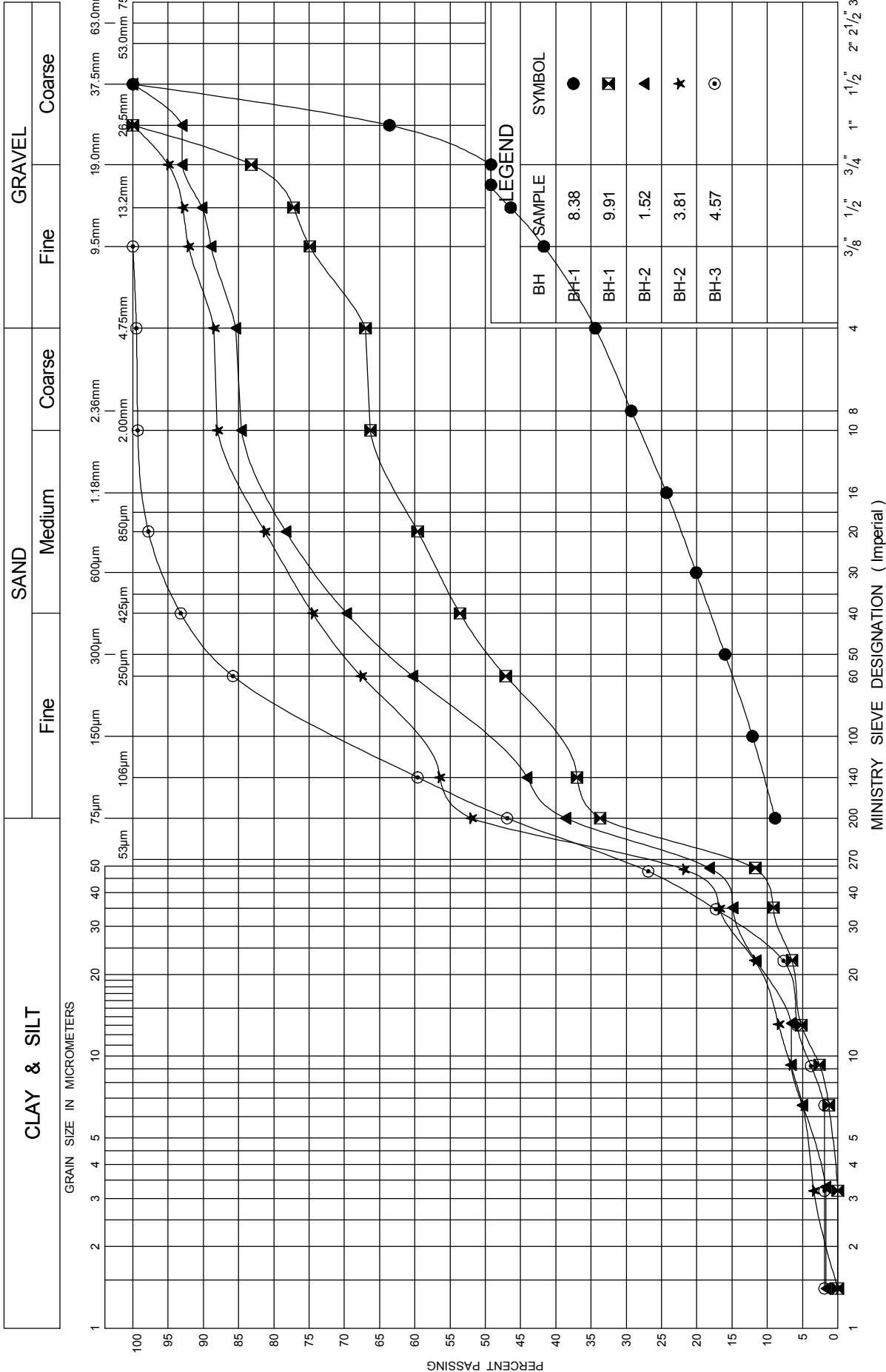
W P 411-00-00,5016-E-0016

Culvert Replacement



Sand

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

FIG No 3

W P 411-00-00,5016-E-0016

Culvert Replacement