

Foundation Investigation and Design Report

Culvert #48 Highway 101

Station 20+326 Township of Foleyet

GWP 5383-11-00

Geocres No.: 42B-10

SUBMITTED TO:

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Part A - FOUNDATION INVESTIGATION REPORT

1 Introduction

TBT Engineering Limited (TBTE) has been retained by Hatch Mott MacDonald (HMM) to provide foundation investigation and design services for the proposed culvert replacements on Highway 101 at four separate locations. These sites are a part of the Highway 101 Resurfacing, from 0.3 km west of Young Street in Foleyet, easterly for 20.9 km, to 0.7 km east of Horwood Lake Road. The foundation investigations were conducted to provide subsurface data for the proposed culvert replacements.

This report addresses the conditions for Culvert #48 located at Sta. 20+326 in the Township of Muskego. The remaining foundation sites (Culvert 17, Culvert 21 and Culvert 34) are addressed under separate covers.

This investigation consisted of two midpoint boreholes drilled adjacent to the existing culvert, two boreholes drilled for roadway protection, two boreholes drilled at the culvert openings, laboratory testing and geotechnical analysis of the data. This report (Part A) describes the subsurface conditions encountered during the investigation. The boreholes are labeled from 100 to 105.

The foundation section has assigned GEOCRES No. 42B-10 to this site.

2 Site Description

The foundation investigations were carried out to investigate subsurface conditions for Culvert #48 located at Sta. 20+326 along Hwy 101 in the Township of Muskego, in the county of New Liskeard Area. The culvert located at this site is an 800 mm centreline CSP which is in poor condition. The culvert services an unnamed water course.

The culvert site is located in a rural area of moderate terrain relief. The area is generally tree covered and bedrock outcrops are common.

The road embankment at this location is approximately 3.5 m high with side slopes of approximately 2 horizontal to 1 vertical on both the right and left side. To the left side of Hwy 101 at the culvert location there is a low lying swamp area draining through the culvert to the right side of the highway. There is a bedrock outcrop westerly on the right side of the highway. The water level in the water course at the culvert inlet was measured approximately 150 mm above the invert, (approx. elevation of 335.0) on July 16, 2013.



Site Photo 1 . Looking Westerly from Culvert

2.1 Surficial Geology

Available surficial geology mapping (OGS NOEGTS Map 5102 . Foleyet) indicates the site is located in a terrain unit comprised of bedrock knob with a subordinate landform of sand and boulder till ground moraine. The surrounding terrain is of moderate local relief which is rolling to undulating.

3 Investigation Procedures

A geotechnical site investigation was undertaken from August 9 to the 21, 2013. The borehole locations are illustrated on the Borehole Location and Soil Strata Drawings found in Appendix D.

The borehole locations were identified in the field by TBTE personnel and service clearances were completed prior to mobilizing the drill rig to site. The boreholes were advanced using an all terrain mounted drill rig equipped with hollow stem augers and a cat head used to carry out Standard Penetration Testing (SPT). Where auger drilling methods proved unsatisfactory, casing was advanced using wash boring techniques. Soil samples were obtained from the auger flights and using a split spoon sampler as a part of the Standard Penetration Testing . Refusal material was sampled using diamond coring techniques.

Surveys were completed by HMM and were based on North American Datum 1983, MTM CSRS Zone 12. HMM has indicated control was established from existing published Horizontal Control Monuments and a Geodetic Benchmark using the Canadian Geodetic Vertical Datum 1928. The following horizontal control points and vertical control points were utilized throughout this project (as provided by HMM):

- HCM #00820020065, #00820020066, #00820020067, #00820020068, #00820020071, #00820020072 and #00820020073
- VCM (GBM) #00819728231 Elev. 329.411, #00819728232 Elev. 328.108, #00819728233 Elev. 343.051, #00819728235 Elev. 345.516, #00819728236 Elev. 349.557 and #00819728239 Elev. 336.635

All boreholes were backfilled with a bentonite mixture following drilling. Temporary standpipes have been removed and decommissioned.

4 Laboratory Testing

Samples which were obtained during the field investigation were subjected to routine laboratory testing. The routine testing included moisture content, Atterberg limits and grain size analysis (where appropriate). The results of this testing are shown on the Borehole Logs (Appendix A) and on the laboratory data reports (Appendix B).

5 Sub-Surface Conditions

Details of the subsurface conditions are provided on the borehole and core logs (Appendix A) and on the Soil Strata Drawing (Appendix D).

The subsurface soils at this site typically consist of fills through the embankment which overlie sand over bedrock. Clay was encountered within one borehole. Numerous cobbles and boulders were present within the fill materials, and occasional cobbles and boulders within the sand. All boreholes extended to practical refusal (100+ blows/0.3 m) and refusal material was drilled and/or sampled using diamond casing/coring techniques.

5.1 Asphalt

Asphalt was encountered at the embankment surface at Boreholes 100, 101, 102, and 103. The asphalt's thickness ranges from 45 to 55 mm.

5.2 Organic Matter

Organic matter was encountered at the ground surface of Borehole 104. The material has a thickness of 0.3 m. Based on a single sample the natural moisture content of this material is 107 %.

5.3 Fill - Sand

Sand fill was encountered beneath the asphalt at Boreholes 100, 101, 102, and 103. The sand fill was encountered at elevation 337.8 to 338.8 and varied in thicknesses from 0.6 to 1.4 m. Four samples were selected for grain size distribution testing. The fill ranges from silty sand with trace gravel to gravelly sand with some silt. The test results indicate a grain size distribution of 7 to 26 % gravel, 60 to 76 % sand, and 10 to 22 % silt/clay sized particles. The sand is compact to dense as indicated by N_{60} values ranging from 11 to 40 blows/0.3 m.

5.4 Fill – Sand and Gravel with Cobbles and Occasional Boulders

Inferred sand and gravel with numerous cobbles and occasional boulders was encountered beneath the sand fill at Boreholes 100, 101, 102, and 103. Boulders were identified in Borehole 103. Auger refusal was met at the interface between the two fill materials and the boreholes were advanced using wash boring techniques. Recovery of sample material from SPT testing proved difficult due to the presence of numerous cobbles and boulders and the matrix material was determined through observations of the wash water. The coarse fill was encountered at elevation 336.4 to 337.5 and varied in thicknesses from 1.9 to 2.6 m. The material is very dense as indicated by N_{60} values of 100+ blows/0.3 m, which were mainly noted to be on cobbles/boulders. At Boreholes 100 and 103 at depths of 1.7 and 1.3 m respectively, N_{60} values of 5 and 4 blows/0.3 m respectively, were recorded, indicating the sand and gravel matrix material is loose.

5.5 Sand

Gravelly sand with trace silt to silty sand was encountered beneath the fill at Boreholes 100, 101, 102, 103, beneath the organic matter at Borehole 104 and at ground surface at Borehole 105. The sand was encountered at elevation 333.8 to 336.0 and varied in thicknesses from 1.0 to 4.2 m. Five samples were selected for grain size distribution testing. The test results indicate a grain size distribution of 0 to 29 % gravel, 58 to 80 % sand, and 9 to 32 % silt/clay sized particles. Occasional cobbles were noted within this stratum. The sand is typically very loose to compact as indicated by N_{60} values ranging from 1 to 12 blows/0.3 m. At Borehole 101 at a depth of 4.0 m, an N_{60} value of 43 blows/0.3 m was recorded.

5.6 Clay

Silty clay with sand was encountered beneath the sand at Borehole 100. The silty clay was encountered at an elevation of 333.1 with a thickness of 1.0 m. Based on a single Atterberg Limit test, the silty clay has a natural moisture content approaching the plastic limit. The clay is stiff as indicated by an N_{60} value of 12 blows/0.3 m.

5.7 Bedrock

Bedrock was encountered at all borehole locations. The following table indicates the recorded bedrock elevation and depth at each borehole. Bedrock was encountered underlying the silty clay at Borehole 100 and beneath the sand at all remaining boreholes. Bedrock was sampled using diamond coring techniques. The bedrock is

medium grained biotite granite. Detailed core logs and photos of the rock cores are provided in Appendix A.

Table 5.1: Bedrock

Borehole Number	Bedrock Depth (m)	Bedrock Elevation
100	6.2	332.1
101	5.0	332.8
102	4.6	333.5
103	5.4	333.4
104	4.5	330.9
105	3.5	332.5

The rock quality designation (RQD) is an indirect measure of the number of fractures and the amount of jointing in the rock mass. The RQD is expressed as a percentage of the ratio of summed core lengths (greater than 100 mm) to the total length cored. The RQD index is used to provide a classification for the rock quality according to the following limits.

Table 5.2: RQD/ Rock Quality Correlation

RQD %	ROCK QUALITY
0 . 25	Very Poor
25 . 50	Poor
50 . 75	Fair
75 . 90	Good
90 . 100	Excellent

The RQD as presented on the borehole and core logs varies from 47 to 100 %. The majority of RQDs were measured to be 71 to 100 % and can be described as fair to excellent, with one sample with an RQD of 47 % indicating poor quality at Borehole 104.

In order to classify the bedrock with respect to strength, point load tests were conducted on selected core samples. The test results are tabulated below.

Table 5.3: Estimated Uniaxial Compressive Strength

Borehole Number	Depth (m)	Elevation	*Estimated Uniaxial Compressive Strength (MPa)
100	6.50	331.8	591
	8.30	330.0	271
	9.10	329.2	411
101	5.70	332.1	214
	7.00	330.8	240
	7.40	330.4	192
102	5.30	332.8	209
	6.50	331.6	220
	7.70	330.4	286
103	5.80	333.0	240
	7.30	331.5	251
	9.70	329.1	207
104	4.50	330.9	276
	5.60	329.8	269
	7.30	328.1	296
105	3.50	332.5	207
	5.70	330.3	251
	6.60	329.4	253

* Estimated based on published correlations.

Based on the range in estimated uniaxial compressive strength, the intact bedrock is classified as very strong to extremely strong.

5.8 Ground Water

The ground water levels were observed upon completion of drilling from August 9 to 21, 2013 at and are provided below. Ground water levels will vary from season to season and from the effects of heavy precipitation events. The water level in the culvert was at elevation 335.0 on July 16, 2013.

Table 5.4: Ground Water Level

Borehole	Depth below Ground Surface (m)	Elevation
100	3.0	335.3
101	2.8	335.0
103	3.0	335.8
105	0.6	334.9

6 Miscellaneous

Laboratory testing was carried out at the TBT Engineering Limited laboratory in Thunder Bay. The drill equipment for this investigation was operated by TBT Engineering. The field operations were supervised by Alan Finke and Peter Pilgrim. Laboratory testing was supervised by T. Fummerton C.E.T. This report was prepared by Steven Seller, P.Eng, and reviewed by W. Hurley, P.Eng (TBTE designated principal contact identified for MTO Foundation Engineering projects).

Part B - FOUNDATION DESIGN RECOMMENDATIONS

7 Introduction

TBT Engineering Limited (TBTE) has been retained by Hatch Mott MacDonald (HMM) to provide foundation investigation and design services for the proposed culvert replacements on Highway 101. There are four culvert sites along Highway 101, which require investigation for the Highway 101 Resurfacing, from 0.3 km west of Young Street in Foleyet, easterly for 20.9 km, to 0.7 km east of Horwood Lake Road. This report addresses the conditions at Culvert 48 located at Sta. 20+326 in the Township of Muskego. The final design of the proposed culverts could include the use of closed bottom culverts and/or open footing culverts. However it is understood that the preferred culvert replacement structure is a closed bottom corrugated steel pipe.

The foundation investigation as described in Part A, were carried out to investigate subsurface conditions at this site. The investigation at Culvert #48 consisted of six boreholes; BH 100, 101, 102, 103, 104 and 105.

The subsurface soils at this site typically consist of fills which overlie sand over bedrock. Numerous cobbles and boulders were present in the fill and native sand.

The purpose of this section of the report (Part B) is to provide foundation design recommendations for various foundation options. These are based on the conditions encountered at the borehole locations and TBTE's interpretation of the subsurface conditions at the sites.

8 Structure Foundations

The culvert located at this site is an 800 mm centreline CSP which is in poor condition. The culvert services an unnamed water course.

The culvert site is located in a rural area of moderate terrain relief. The area is generally tree covered and bedrock outcrops are common.

The road embankment at this location is approximately 3.5 m high with side slopes of approximately 2 horizontal to 1 vertical on both the right and left side. To the left side of Hwy 101 at the culvert location there is a low lying swamp area draining through the culvert to the right side of the highway. There is a bedrock outcrop westerly on the right side of the highway. The water level in the water course at the culvert inlet was measured approximately 150 mm above the invert, (approx. elevation of 335.0) on July 16, 2013.

8.1 Initial Foundation Option Considerations

Multiple foundation systems have been considered for the proposed culvert replacement. The foundation systems considered are presented in the following table:

Table 8.1: Foundation Options

Option		Advantages	Disadvantages	Comments
Closed Bottom Culvert	Timber, steel or concrete culvert with appropriate bedding. Similar to existing culvert.	<ul style="list-style-type: none"> - Least costly option - Least excavation required 	<ul style="list-style-type: none"> - Requires removal of existing culvert and any associated channel bedding material - Requires construction within the creek 	Recommended.
Open Footing Culvert	Footings on Native Sand	<ul style="list-style-type: none"> - Longer spans may be considered to minimize construction within the existing channel. - Existing culvert can be left in place. - Least excavation required of footing options. - Less costly than footings on rock fill. - No rock fill required. 	<ul style="list-style-type: none"> - Excavation below water is required. - Low geotechnical resistance and reactions. - Potential disturbance of subgrade during construction. - Mitigation of frost effects requires extensive fill cover. 	Not Recommended.
	Footing on Rock Fill	<ul style="list-style-type: none"> - Longer spans may be considered to minimize construction within the existing channel. - Highest geotechnical capacities for footings. - Allows for construction of shallow footings. - Less costly than piled options. - Rock fill cover and pad below footing can be considered to reduce / limit frost effects. 	<ul style="list-style-type: none"> - Excavation below water is required. - Additional cost for rock fill - Rock fill cannot be compacted below water - Potential disturbance of subgrade during construction. 	Not Recommended.
	Driven Piles	<ul style="list-style-type: none"> - Typically high geotechnical capacity is achieved. - Excavation below water level may be reduced or eliminated. - Longer spans may be considered to minimize construction within the existing channel. 	<ul style="list-style-type: none"> - Driven piles are expected to encounter shallow refusal. - Short piles are more likely to wander/walk+during driving. - Additional costs for cranes. - Additional property required for laydown areas for materials. 	Not Recommended.
	Drilled Piles	<ul style="list-style-type: none"> - Typically high geotechnical capacity is achieved. - Excavation below water level may be reduced or eliminated. 	<ul style="list-style-type: none"> - Additional costs for speciality contractor. 	Not Recommended.
Sheet Pile Structure	Sheet piles with structural slab.	<ul style="list-style-type: none"> - Limited excavation required. - Can be constructed outside of channel footprint. - Construction within the existing channel can be minimized. 	<ul style="list-style-type: none"> - Driven/Vibrated piles are expected to encounter shallow refusal. - Additional costs for cranes. - Additional property required for laydown areas for materials. - Anticipated inadequate penetration and toe resistance. 	Not Recommended.

Design parameters for the recommended foundation system are presented below. It is understood that there will be no horizontal or vertical realignment at the culvert location and the anticipated replacement structure is a closed bottom corrugated steel pipe.

Unless noted otherwise, foundation design parameters are given for static, vertically and concentrically loaded foundations in compression.

8.2 Closed Bottom Culverts

Closed bottom culverts can be placed on compacted granular material either in an earth excavation, or natural embankment. The culvert shall be placed on appropriate bedding fill material and backfilled in accordance with the appropriate OPSD 800 series drawings. Any organic materials encountered at the culvert location shall be removed as indicated in OPSD 203.040.

The soil through the embankment and the native sand can be preliminarily classified as Type 3 soils, as defined by the Occupational Health and Safety Act and Regulations for Construction Projects. The soil types should be reassessed as excavations proceed and adjustments to construction methodologies should be taken as required.

9 Culvert Camber

The provision of culvert camber is not anticipated as the final vertical alignment of the highway will not be increased, and therefore settlements of the embankment will be negligible.

10 Culvert Replacement - Staging

10.1 Staging – General

The replacement of the culvert must be completed utilizing a staged construction methodology. In order to provide a single trafficable lane (during construction) and expose sufficient length of existing culvert the existing roadway must be temporarily widened. The placement of the temporary widening can induce up to a maximum of 25 mm of settlement, which may not be fully realized during construction operations. Any

organics encountered beneath the widening shall be removed both along the existing slope and along the native ground.

The staging is understood to incorporate three stages:

- Stage 1 . Temporary trafficable lane on the right side.
- Stage 2 . Temporary trafficable lane on the left side.
- Stage 3 . Final roadway configuration.

10.2 Staging - Geotechnical Model

Stability modeling was carried out using Slope/W software and limit equilibrium analysis using the Morgenstern-Price method.

The soil properties established for the embankment and foundation soils are presented in Table 10.1. The estimated strength properties of the native soils have been based on published correlations with index tests.

Stability analyses have been completed to investigate potential configurations for the proposed embankments (based on provided drawings) during construction for the proposed culvert replacement. The design was based on providing a minimum calculated factor of safety (FoS) of 1.3 during construction (staging embankments), a (FoS) of 1.3 for final configuration. A uniformly distributed traffic load of 20 kPa over the traversable lane(s) was applied in both cases.

Table 10.1: Stability Analyses Soil Properties

Soil	Effective Shear Strength Properties		Unit Weight, (kN/m ³)
	Effective Angle of Internal Friction, ϕ (degrees)	Effective Cohesion Intercept, C (kPa)	
Granular B Type I	35	0	20
Compacted Sand Fill	32	0	20
Inferred Sand and Gravel Fill	30	0	20
Native Sand	29	0	20
Clay	28	0	18

Granular B Type 2 and/or rock fill was not considered for this project due to a lack of availability.

10.3 Stability Analysis Results and Recommendations

Slope stability modeling was completed based on the staging drawings provided by HMM. The culvert will be replaced in two stages, with traffic maintained over alternate sections. This may require a significant longitudinal section of temporary road construction. The final roadway embankment will then be restored at its current location (Stage 3).

Various slope configurations were analyzed to determine sections which would meet the design stability requirements. The results of the stability analyses for suitable sections have been included in Appendix C and are summarized below.

Table 10.2 – Stability Analysis Results

Stage	Seismic Load	Minimum FoS	Target Fos	Comment
1	No	1.3	1.3	-
2	No	1.3	1.3	-
3	No	1.3	1.3	Constructed from Compact Sand/Gravel
3	No	1.5	1.3	Constructed from Compact Granular B Type 1

The following recommendations have been derived from the analysis:

- Slopes through existing embankment fills shall be constructed at 2(H):1(V) or flatter.
- Temporary slopes constructed of compacted reworked embankment fill (sand fill to sandy gravel fill) shall be constructed at 2(H):1(V) or flatter (FoS 1.3).
- Permanent slopes constructed of compacted reworked embankment fill (sand fill to sandy gravel fill) shall be constructed at 2(H):1(V) or flatter (FoS 1.3).
- Permanent slopes constructed of compacted Granular B Type 1 shall be constructed at 2(H):1(V) or flatter (FoS 1.5).
- Culvert extensions will be required to accommodate the temporary trafficable lanes, both left and right.

11 Temporary Roadway Protection

Staging configurations may require shallow roadway protection. The presence of numerous cobbles and occasional boulders within the embankment fill and native sand, and the shallow bedrock may limit the use of conventional sheet piling. Extensive bracing would be required to provide lateral support. Pre-excavation may be required due to the presence of cobbles and boulders within the fill.

Gravity wall designs may be considered where space is available.

Vertical roadway protection may utilize soldier pile and lagging systems. The soldier piles may need to be installed in pre-drilled holes through the cobbles and boulders. The wall system should be designed to provide support in both directions (i.e. as each side of the embankment is constructed).

Lateral support of the system may be attained using anchors into the soils behind the wall system. The anchor system would have to be designed to provide support from beyond the active zone behind the wall system. There may be insufficient soil section available in all sections of the embankment for conventional embedded soil supported anchors. Methods using deadmen, rakers or other form of support may be needed.

These systems may be designed using the methods provided in the CHDBC. Lateral loads should include active or at-rest pressures as appropriate for soil and traffic loadings and the compaction surcharge as described in Section 12. Active loads are appropriate for yielding conditions while at-rest pressures should be used for non-yielding cases.

12 Backfill and Bedding Material

The existing site materials may not be suitable for use as structural backfill or bedding. Testing and sorting of the existing embankment materials will be required to ensure that they are acceptable and do not contain frost susceptible soils. Granular ~~MA~~ Type I or Granular ~~MA~~ may be specified as structural backfill in specific zones. Placement of backfill material around the culvert should be completed in accordance with the manufacturer's recommendations. A compaction surcharge should be added in

accordance with the CHDBC. The culvert must also be designed to resist hydrostatic pressures where applicable.

Lateral earth pressure coefficients (unfactored) for potential granular backfill at level ground conditions have been provided in Table 12.1.

Table 12.1: Lateral Earth Pressure Coefficients (Unfactored)

Material	$\Phi' \text{ (}^\circ\text{)}$	Bulk Unit Weight of Soil, (kN/m ³)	Lateral Earth Pressure Coefficients (K)		
			Active Ka	At Rest Ko	Passive Kp
Granular A	35	20 - 22	0.27	0.43	3.7
Granular B Type I	35	20 - 22	0.27	0.43	3.7
Inferred Sand and Gravel Fill	30	19 - 21	0.33	0.50	3.0

No factor of safety or resistance factor has been included in the above coefficients.

A compaction surcharge should be accounted for in accordance with the Canadian Highway Bridge Design Code (CHBDC) Section 6.9.3 when calculating lateral pressures.

13 Seismic Considerations

The following seismic parameters have been based on Section 4.4 of the Canadian Highway Bridge Design Code (CHBDC) and Figure A3.1.6, and the data provided in Table A3.1.1 based on Timmins, Ontario:

- Peak Horizontal Acceleration of 0.04 to 0.08
- Zonal Acceleration Ratio of 0.05
- Zonal Velocity Ratio of 0.05
- Velocity Related Seismic Zone of 0
- Acceleration Related Seismic Zone of 1

Based on the subsurface soil stratigraphy at this site the site has been determined to be Soil Profile Type 1. Therefore, according to Table 4.4 of the Canadian Highway Bridge Design Code, a Site Coefficient S_a (ground motion amplification factor) of 1 should be used in seismic design.

Retaining structures (if any) should be designed using earth pressure coefficients that incorporate the effects of earthquake loading. The seismic component of the earth pressure distribution is additional to the static earth pressure distribution. The seismic distribution may be taken as an inverted triangle with the maximum pressure at the top of the wall/structure and the minimum pressure at the toe. These earth pressure coefficients should be determined as per the Canadian Highway Bridge Design Code Section 4.6.4.

The foundation soils at the site are assessed as not being prone to liquefaction.

14 Dewatering, Excavations and Channel Diversion

Excavations should be excavated and sloped in accordance with the requirements of the Occupational Health and Safety Act. The soils below the ground water level are coarse grained and permeable. Flows in to open excavations below the ground water level will be rapid. Potential obstructions such as the numerous cobbles and occasional boulders within the native soils and embankment materials, should be noted as described in the nonstandard provision provided in Appendix E.

Channel diversion is not anticipated to be required during construction. Improvements or revisions to the channel may be required following removal of the existing culvert. It is anticipated the excavations will be completed using conventional construction with dam and pump methods to allow culvert construction in the dry. Foundation implications are expected to be minimal, providing the new culvert spans the full channel width.

15 Scour Protection

Where appropriate, foundation elements should be provided with sufficient scour protection in the event of elevated river levels. Scour protection should be designed taking into account hydrologic and hydraulic concerns and in accordance with Section 1.10.5 of the Canadian Highway Bridge Design Code.

16 Estimated Frost Depth and Frost Protection

Based on the Ontario Provincial Standard Drawing 3090.1 Foundation Frost Depth for Northern Ontario+the estimated frost depth penetration within the expected embankment fill is 2.4 m. The embankment soils anticipated within the frost depth are considered to

be of low frost susceptibility (MTO Pavement Design and Rehabilitation Manual). Frost treatments should conform to OPSD 803.031.

17 Potential Construction Issues

No major construction difficulties are foreseen at this site. Issues which may require consideration include:

- Control of surface water during construction. Permanent positive drainage will be ensured during the design phase.
- Control of groundwater during excavation below the creek/groundwater level.
- Excavation through existing fill material may be difficult due to the presence of numerous cobbles and boulders. The contractor should have adequate equipment on site.
- Impacts of temporary trafficable lanes on existing utilities and property.

18 Limitations

Conclusions and recommendations presented in this report are based on the information determined at the borehole locations. Subsurface and groundwater conditions between and beyond these locations may differ from those encountered. Conditions may become apparent during construction that were not detected and could not be anticipated at the time of the site investigation.

The comments given in this report on potential construction problems and possible methods of construction are intended only for the guidance of the designer.

Groundwater levels indicated are based on the information described within the report. The presence of all conditions that could affect the type and scope of dewatering procedures which may be considered cannot readily be determined from boreholes. These include local and seasonal fluctuations of the groundwater level, changes in soil conditions between test locations, thin and/or discontinuous layers of highly permeable soils, etc.

The information contained within this report in no way reflects any environmental aspect of the site or soil.

19 Closure

We trust the above addresses your project requirements at this time. Should you have any questions or comments, please do not hesitate the contact us at your convenience.

Yours truly,

For TBT ENGINEERING



Steven Seller, P.Eng.
Project Engineer



Wayne Hurley, P.Eng.
Senior Engineer
Principal Contact for MTO Foundations

APPENDIX A

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 \bar{N} .

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c		COMPRESSION INDEX
C_s		SWELLING INDEX
C_a		RATE OF SECONDARY CONSOLIDATION
C_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v		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'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
C_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i		SENSITIVITY = $\frac{C_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_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		DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_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
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u		UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_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 = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L		LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i		HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C		CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

TBT Engineering Consulting Group			RECORD OF Borehole No 100			1 OF 1 METRIC	
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48	
TWP Muskego HWY 101			LOCATION MTM 12 N5341962.109, E208910.306			TBTE JOB# 13-121	
DATE 2013 August 9			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic	
						ORIGINATED BY A.F.	
						COMPILED BY T.B.	
						CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	DYNAMIC CONE PENETRATION RESISTANCE PLOT	
						<div style="display: flex; justify-content: space-between;"> <div> <p>20 40 60 80 100</p> <p>SHEAR STRENGTH kPa</p> <p>○ UNCONFINED ✕ FIELD VANE</p> <p>■ SPT (N) ★ LAB VANE</p> <p>20 40 60 80 100</p> </div> <div> <p>20 40 60</p> <p>WATER CONTENT (%)</p> <p>W_p W W_L</p> </div> </div>	
338.7	ASPHALT - 45 mm		1	AS			
338.6	FILL - SAND - some silt, trace gravel, brown						
337.7	FILL - SAND & GRAVEL - numerous cobbles, loose to very dense (inferred)		2	SS	100+		
1.0							
			3	SS	5		
335.7	SAND - some silt, brown, very loose to loose		4	SS	3		
3.0							
			5	SS	4		
			6	SS	9		
333.5	CLAY - Silty, some sand, trace gravel, stiff		7	SS	12		
5.2							
332.5	BEDROCK - Biotite Granite: Medium grained, weakly foliated/lineated, white		8	SS	100+		
6.2							
			1	RC			
			2	RC			
329.3	End of Borehole @ 9.4 m.		3	RC			
9.4							

✕³, ★³: Numbers refer to Sensitivity
NP Non Plastic
○ 3% STRAIN AT FAILURE

ONL_MOT_BH_MTM 13-121 CULVERT 48.GPJ ONL_MOT_GDT 15/3/13

TBT Engineering Consulting Group			RECORD OF Borehole No 101			1 OF 1		METRIC	
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48		ORIGINATED BY A.F.	
TWP Muskego HWY 101			LOCATION MTM 12 N5341945.036, E208928.283			TBTE JOB# 13-121		COMPILED BY T.B.	
DATE 2013 August 9			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic		CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	DYNAMIC CONE PENETRATION RESISTANCE PLOT		SHEAR STRENGTH kPa	
						20 40 60 80 100 ○ UNCONFINED ✕ FIELD VANE ■ SPT (N) ★ LAB VANE		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)	
337.8 337.4	ASPHALT - 55 mm FILL - SAND - some silt, trace gravel, brown, dense		1	AS					
	2		SS	40					
336.4 1.4	FILL - SAND & GRAVEL - numerous cobbles, very dense (inferred)		3	SS	100+				
			4	SS	100+				
333.8 4.0	SAND - Gravelly, trace silt, grey, dense		5	SS	43				
332.8 5.0	BEDROCK - Biotite Granite: Medium grained, weakly foliated/lineated, white		6	SS	100+				
			1	RC					
			2	RC					
			3	RC					
329.5 8.3	End of Borehole @ 8.3 m.								

ONL_MOT_BH_MTM 13-121 CULVERT 48.GPJ ONL_MOT_GDT 15/3/13

TBT Engineering Consulting Group			RECORD OF Borehole No 102			1 OF 1		METRIC	
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48		ORIGINATED BY A.F.	
TWP Muskego HWY 101			LOCATION MTM 12 N5341951.001, E208912.543			TBTE JOB# 13-121		COMPILED BY T.B.	
DATE 2013 August 9			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic		CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	DYNAMIC CONE PENETRATION RESISTANCE PLOT		SHEAR STRENGTH kPa	
						20 40 60 80 100 ○ UNCONFINED ✕ FIELD VANE ■ SPT (N) ★ LAB VANE		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)	
						20 40 60 80 100 20 40 60		20 40 60	
338.3	ASPHALT - 50 mm								
338.0	FILL - SAND - trace gravel, trace silt, brown		1	AS					
337.7	FILL - SAND & GRAVEL - numerous cobbles (inferred)								
0.6									
335.8	SAND - Silty, trace gravel, brown, loose to compact		2	SS	7				
2.5									
333.7	BEDROCK - Biotite Granite: Medium grained, weakly foliated/lineated, white		3	SS	12				
4.6									
333.7			1	RC					
332			2	RC					
331									
330.5	End of Borehole @ 7.8 m.								
7.8									

Auger Refusal @ 0.6 m. Advanced with B Casing.

2 77 (21)

RC # 1
REC = 100%
RQD = 92%

RC # 2
REC = 81%
RQD = 81%

TBT Engineering Consulting Group			RECORD OF Borehole No 103			1 OF 1 METRIC						
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48						
TWP Muskego HWY 101			LOCATION MTM 12 N5341967.979, E208894.559			TBTE JOB# 13-121						
DATE 2013 August 20			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic						
						CHECKED BY S.S.						
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					
339.4	ASPHALT - 45 mm											
338.8	FILL - SAND - Gravelly, trace silt, brown, compact		1	AS								Water level @ 3.0 m on completion.
338.1			2	SS	11							26 64 (10)
338.1	FILL - SAND & GRAVEL - numerous cobbles & boulders, loose to very dense (inferred)		3	SS	4							18 60 (22)
1.3			4	SS	100+							Auger Refusal @ 1.2 m. Advanced B Casing.
			5	SS	100+							
	- boulder											
335.6	SAND - some gravel, some silt, occasional cobbles, brown, loose		6	SS	7							
3.8												
334.0	BEDROCK - Biotite Granite: Medium grained, spaced/weak biotite foliation, light to dark in colour		1	RC								RC # 1 REC = 100% RQD = 86%
5.4	----- - light to dark in colour with zones of pink/red		2	RC								RC # 2 REC = 100% RQD = 100%
	----- - light to dark in colour with zones of pink/red that intensify closer to a coarse grained (pegmatitic) zone		3	RC								RC # 3 REC = 71% RQD = 71%
329.2	End of Borehole @ 10.2 m.											
10.2												

x³, ★³: Numbers refer to Sensitivity
 NP Non Plastic
 ○ 3% STRAIN AT FAILURE

ONL_MOT_BH_MTM 13-121 CULVERT 48.GPJ ONL_MOT_GDT 15/3/13

TBT Engineering Consulting Group			RECORD OF Borehole No 104			1 OF 1		METRIC	
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48		ORIGINATED BY P.P.	
TWP Muskego HWY 101			LOCATION MTM 12 N5341944.958, E208905.722			TBTE JOB# 13-121		COMPILED BY T.B.	
DATE 2013 August 14			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic		CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	DYNAMIC CONE PENETRATION RESISTANCE PLOT		SHEAR STRENGTH kPa	
335.4	ORGANIC MATTER - 300 mm		1	AS					
0.0									
335.1	SAND & GRAVEL - numerous cobbles & boulders		2	SS	100+				
0.3									
	- cobbles								
	- boulders								
330.9	BEDROCK - Biotite Granite: Medium grained, weakly foliated/lineated, white		1	RC					
4.5									
			2	RC					
327.8	End of Borehole @ 7.6 m.								
7.6									

TBT Engineering Consulting Group			RECORD OF Borehole No 105			1 OF 1		METRIC	
W.P. 5383-11-00			PROJECT Culvert Investigation			SITE NO. Culvert #48		ORIGINATED BY P.P.	
TWP Muskego HWY 101			LOCATION MTM 12 N5341967.148, E208923.154			TBTE JOB# 13-121		COMPILED BY T.B.	
DATE 2013 August 21			BOREHOLE TYPE Hollow Stem Auger/B Casing			DATUM Geodetic		CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L
335.5 0.0	SAND - trace silt to Silty, some gravel, occasional cobbles, compact, brown		1	AS			335		
	----- - grey		2	SS	10		334		
	----- - trace organics, brown		3	SS	10		333		
332.0 3.5	BEDROCK - Biotite Granite: Medium grained, spaced/weak biotite foliation, light to dark in colour with pink/red zones		1	RC			332		
			2	RC			331		
							330		
328.8 6.7	End of Borehole @ 6.7 m.						329		

ROCK CORE LOG

Project #: 13-121

Client: Hatch Mott Macdonald

Site: Highway 101

Page 1 of 1

Borehole# 100

Lab# 13-0627

Logger: PB & SS

Date: August 19th, 2013

Strength (MPa)

VH = Very High = >200
H = High = 50-200
M = Medium = 15-50
L = Low = 4-15
VL = Very Low = 1-4

Weathering

U = Unweathered (No signs)
S = Slightly (Oxidized)
M = Moderately (Discoloured)
H = Highly (Friable)
C = Completely (Soil-like)

Discontinuity type

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

Orientation

F = Flat (0-20°)
D = Dipping (20-50°)
V = Near Vertical (>50°)

Spacing

VW = Very wide = >3m
W = Wide = 1-3m
M = Moderate = 0.3-1m
C = Close = 5-30cm
VC = Very close = <5cm

Roughness

RU = Rough undulating
RP = Rough planar
SU = Smooth undulating
SP = Smooth planar
LU = Slickensided undulating
LP = Slickensided planar

Aperture

O = Open
C = Closed
F = Filled

Filling

T = Tight, hard
O = Oxidized
SA = Slightly altered, clay free
S = Sandy, Clay free
SI = Sandy, silty, minor clay
NC = Non-softening clay
SC = Swelling, softening clay
N = No filling

OCCASIONAL FEATURES

DISCONTINUITIES

OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

WEATHERING

STRENGTH

GENERAL DESCRIPTION
(Rock type(s), %, colour, texture, etc.)

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Biotite Granite: Medium grained, weakly foliated/lineated, white

87.3%

100.0%

1/1

From
6.2
To
7.3

From
6.2
To
7.3

Biotite Granite: Medium grained, weakly foliated/lineated, white

71.1%

89.6%

1/2

From
7.3
To
8.9

From
7.3
To
8.9

Biotite Granite: Medium grained, weakly foliated/lineated, white

92.7%

92.7%

1/3

From
8.9
To
9.4

From
8.9
To
9.4

7.99-8.24, 8.76-8.84, zones of granitic veining with banded morphology, a finer grained spaced biotite foliation, and interior zones of darker, finer grained quartzofeldspathic material.

ROCK CORE LOG

Project #: 13-121

Client: Hatch Mott Macdonald

Site: Highway 101

Page 1 of 1

Borehole# 101

Lab# 13-0628

Logger: Patrick Belshaw

Date: August 19th, 2013

Strength (MPa)

VH = Very High = >200
H = High = 50-200
M = Medium = 15-50
L = Low = 4-15
VL = Very Low = 1-4

Weathering

U = Unweathered (No signs)
S = Slightly (Oxidized)
M = Moderately (Discoloured)
H = Highly (Friable)
C = Completely (Soil-like)

Discontinuity type

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

Orientation

F = Flat (0-20°)
D = Dipping (20-50°)
V = Near Vertical (>50°)

Spacing

VW = Very wide = >3m
W = Wide = 1-3m
M = Moderate = 0.3-1m
C = Close = 5-30cm
VC = Very close = <5cm

Roughness

RU = Rough undulating
RP = Rough planar
SU = Smooth undulating
SP = Smooth planar
LU = Slickensided undulating
LP = Slickensided planar

Aperture

O = Open
C = Closed
F = Filled

Filling

T = Tight, hard
O = Oxidized
SA = Slightly altered, clay free
S = Sandy, Clay free
SI = Sandy, silty, minor clay
INC = Non-softening clay
SC = Swelling, softening clay
N = No filling

OCCASIONAL FEATURES

DISCONTINUITIES

OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

WEATHERING

STRENGTH

GENERAL DESCRIPTION
(Rock type(s), %, colour, texture, etc.)

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Biotite Granite: Medium grained, weakly foliated/lineated, white

95.9%

95.9%

1/1

From
5.0
To
5.7

From
5.0
To
5.7

Biotite Granite: Medium grained, weakly foliated/lineated, white

93.1%

93.1%

1/2

From
5.7
To
7.2

From
5.7
To
7.2

Biotite Granite: Medium grained, weakly foliated/lineated, white

100.0%

100.0%

1/3

From
7.2
To
8.3

From
7.2
To
8.3

ROCK CORE LOG

Project #: 13-121

Client: Hatch Mott Macdonald

Site: Highway 101

Page 1 of 1

Borehole# 102

Lab# 13-0629

Logger: Patrick Belshaw

Date: August 19th, 2013

Strength (MPa)

VH = Very High = >200
H = High = 50-200
M = Medium = 15-50
L = Low = 4-15
VL = Very Low = 1-4

Weathering

U = Unweathered (No signs)
S = Slightly (Oxidized)
M = Moderately (Discoloured)
H = Highly (Friable)
C = Completely (Soil-like)

Discontinuity type

B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

Orientation

F = Flat (0-20°)
D = Dipping (20-50°)
V = Near Vertical (>50°)

Spacing

VW = Very wide = >3m
W = Wide = 1-3m
M = Moderate = 0.3-1m
C = Close = <5cm
VC = Very close = <5cm

Roughness

RU = Rough undulating
RP = Rough planar
SU = Smooth undulating
SP = Smooth planar
LU = Slickensided undulating
LP = Slickensided planar

Aperture

O = Open
C = Closed
F = Filled

Filling

T = Tight, hard
O = Oxidized
SA = Slightly altered, clay free
S = Sandy, Clay free
SI = Sandy, silty, minor clay
NC = Non-softening clay
SC = Swelling, softening clay
N = No filling

OCCASIONAL FEATURES

DISCONTINUITIES

OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

WEATHERING

STRENGTH

GENERAL DESCRIPTION
(Rock type(s), %, colour, texture, etc.)

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Biotite Granite: Medium grained, weakly foliated/lineated, white

92.4%

100.0%

1/1

From
4.6
To
6.3

From
4.6
To
6.3

Biotite Granite: Medium grained, weakly foliated/lineated, white

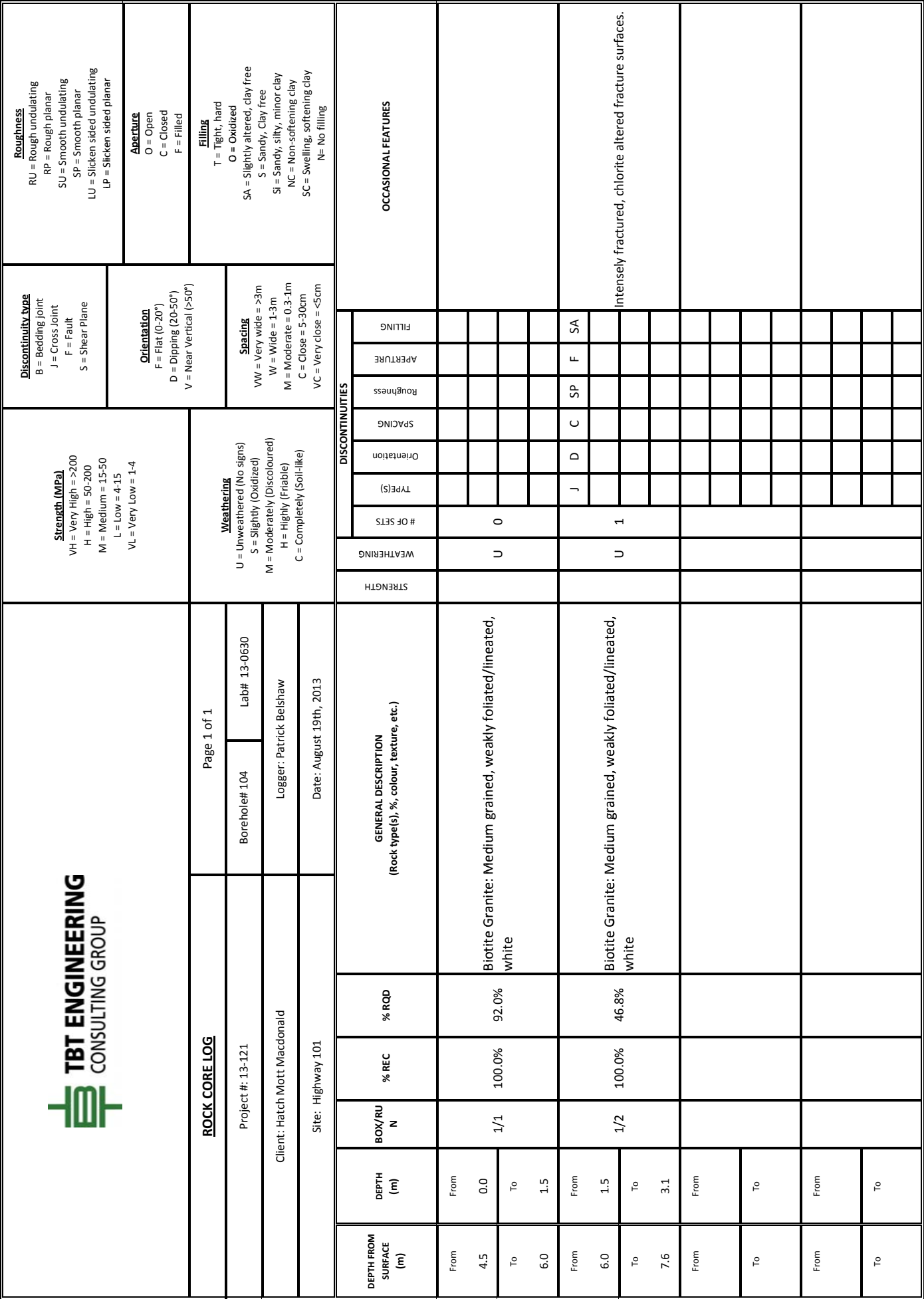
81.3%

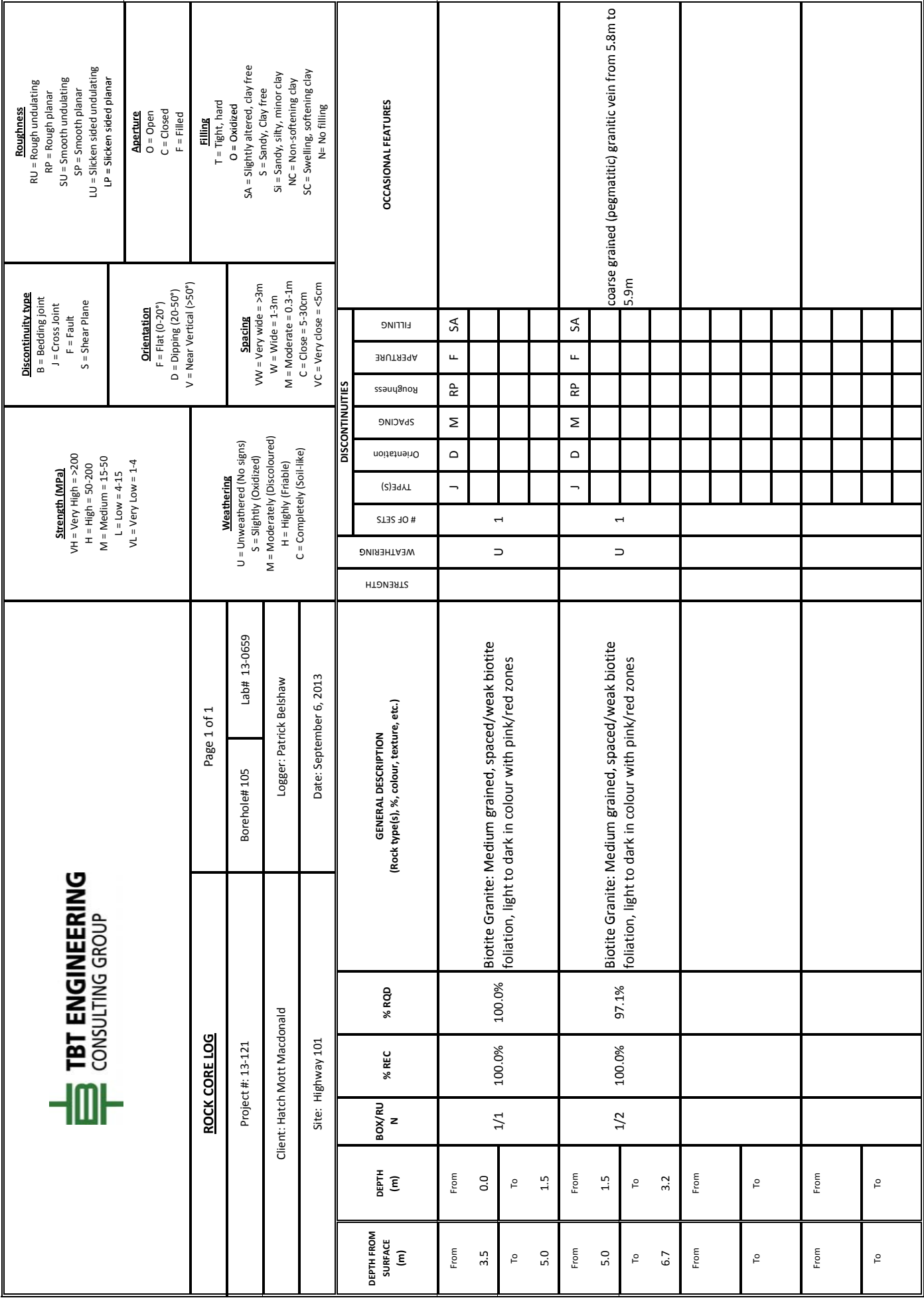
81.3%

1/2

From
6.3
To
7.8

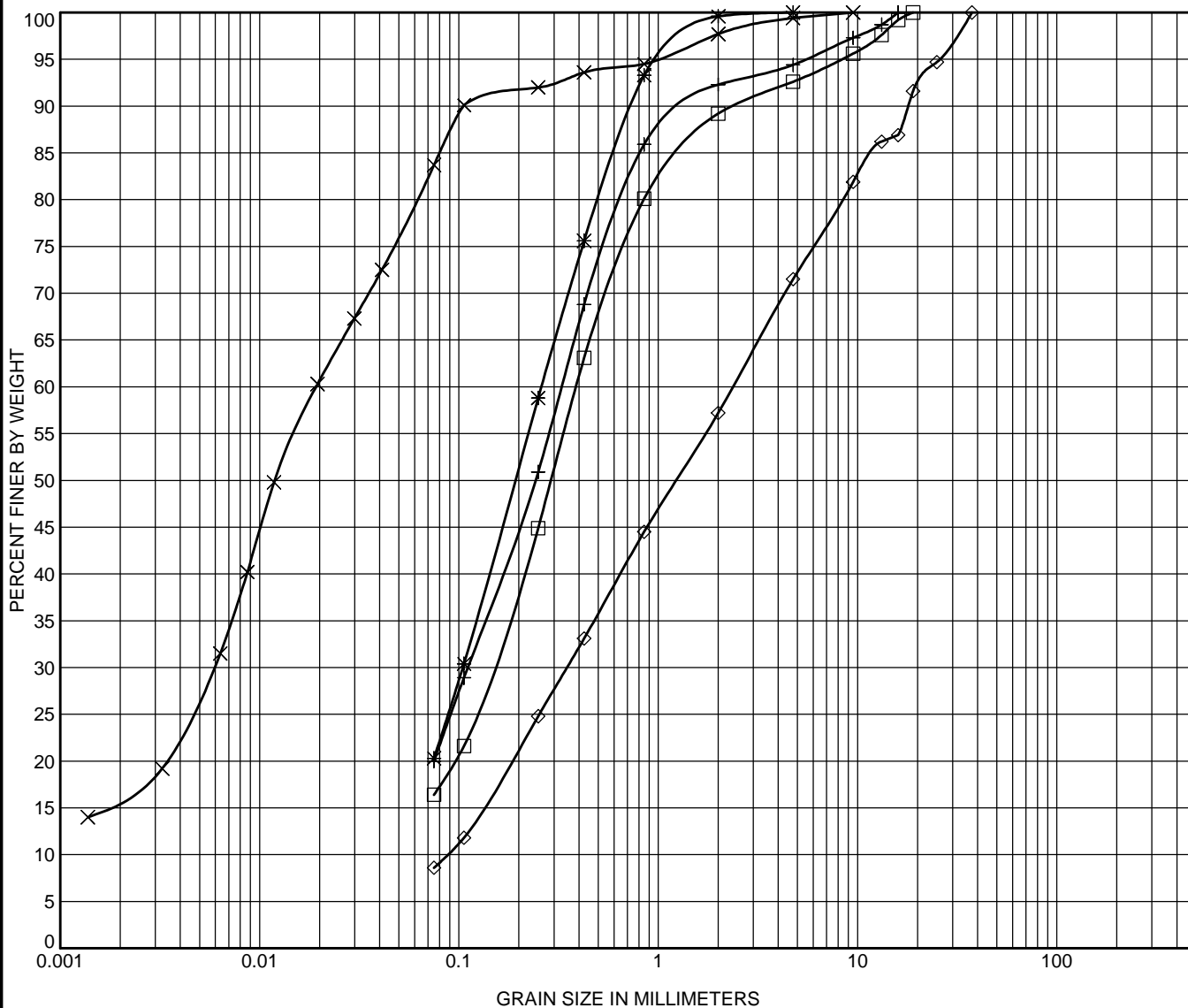
From
6.3
To
7.8





APPENDIX B

Laboratory Test Data



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:
SILT & SAND & GRAVEL

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 100	0.40	19	0.388	0.144		7.4	76.2	16.4	
* 100	3.80	4.75	0.26	0.105		0.0	79.7	20.3	
x 100	5.30	9.5	0.019	0.006		0.6	15.7	83.7	
+ 101	0.75	16	0.327	0.111		5.6	74.4	20.0	
◇ 101	4.00	37.5	2.369	0.349	0.087	28.5	62.9	8.6	



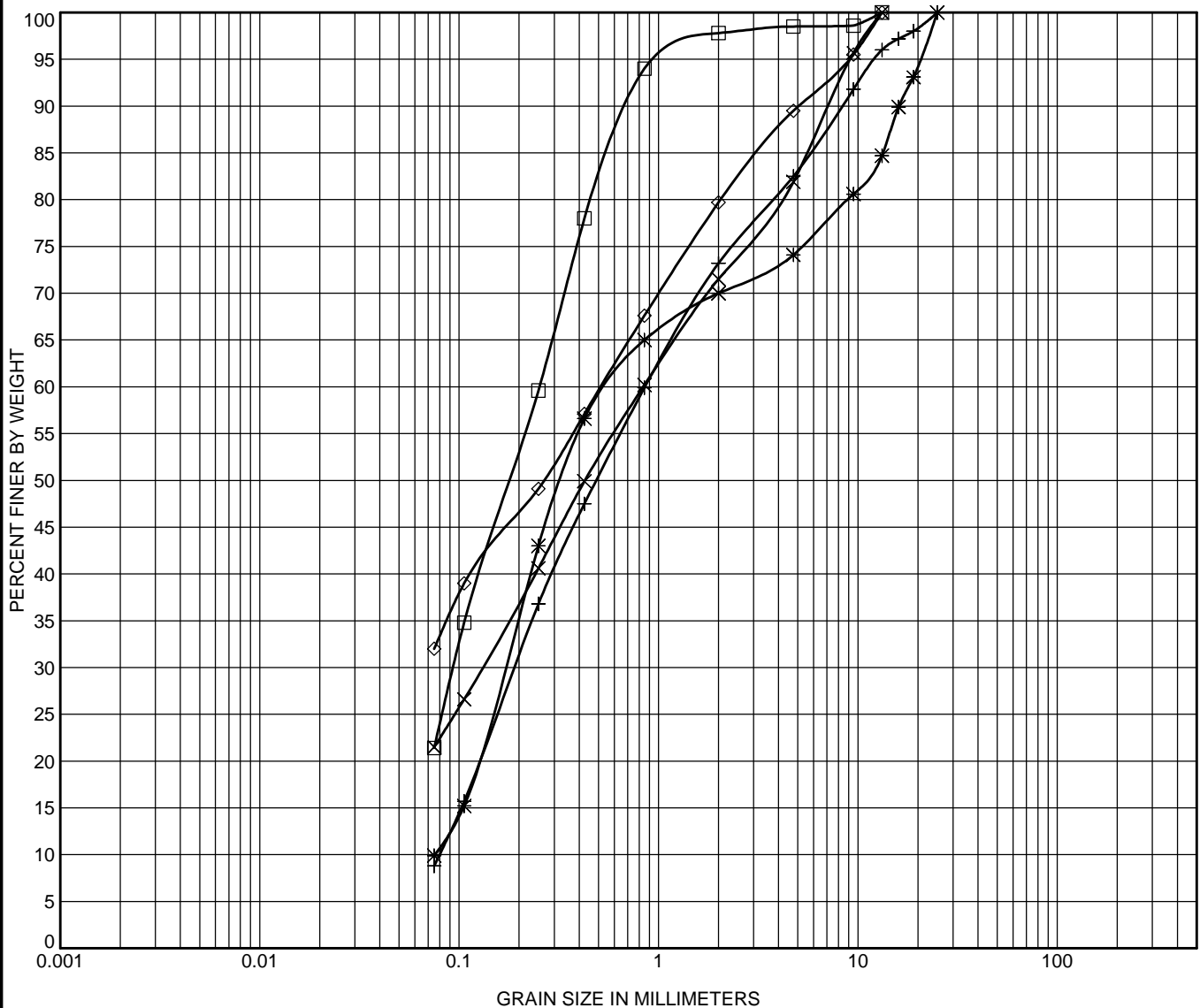
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Web: www.tbte.ca

GRAIN SIZE DISTRIBUTION

Project: Culvert Investigation

W P: 5383-11-00

DIST: Muskego HWY: 101



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:
SILT & SAND & GRAVEL

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 102	3.00	13.2	0.253	0.094		1.5	77.1	21.4	
* 103	0.75	25	0.563	0.167	0.075	25.9	64.2	9.9	
x 103	1.30	13.2	0.839	0.131		18.1	60.4	21.5	
+ 105	0.30	25	0.855	0.19	0.08	17.5	73.7	8.8	
◇ 105	1.50	13.2	0.515			10.5	57.5	32.0	



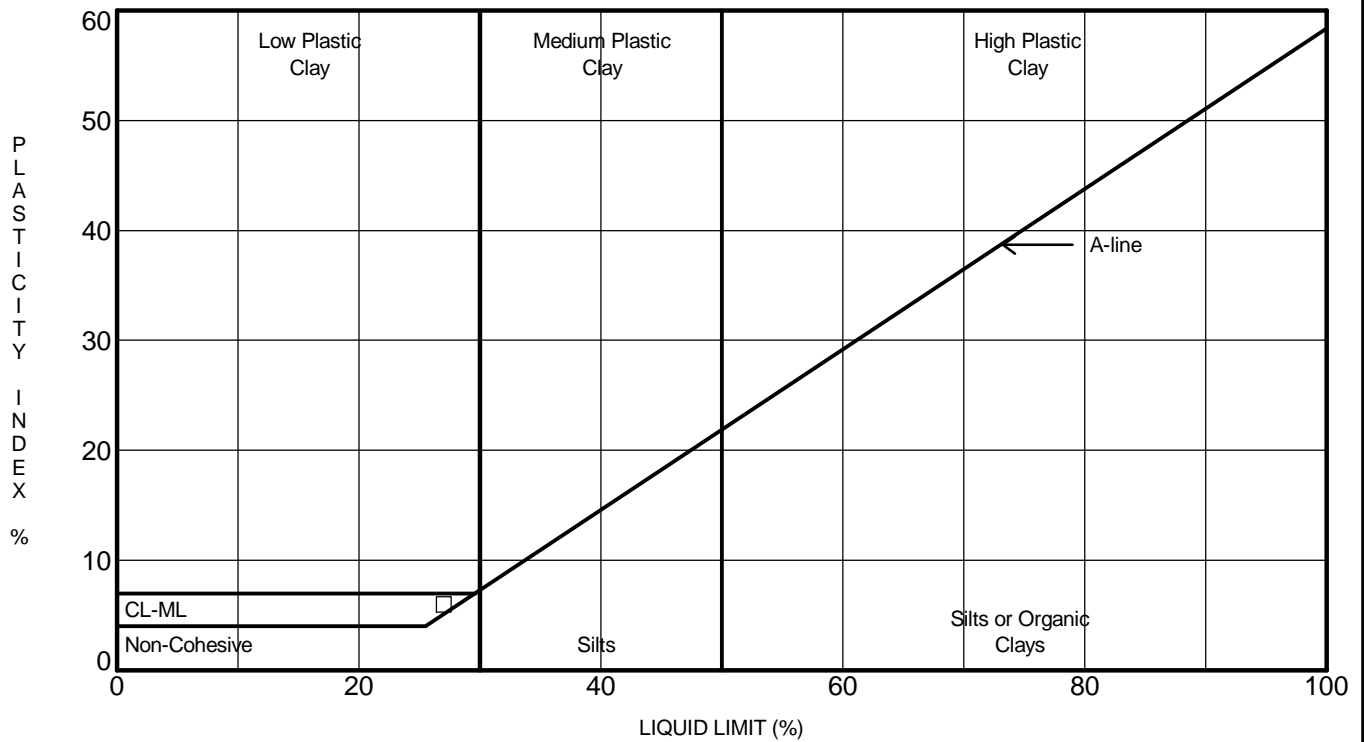
TBT Engineering Ltd.
1918 Yonge Street
Thunder Bay, Ontario P7E 6T9
PH: 807-624-5160
FX: 807-624-5161
Email: tbte@tbte.ca
Web: www.tbte.ca

GRAIN SIZE DISTRIBUTION

Project: Culvert Investigation

W P: 5383-11-00

DIST: Muskego HWY: 101



Remarks:
NON-PLASTIC - SAND & SILT

Borehole No.	Sample No.	Depth (m)	LL%	PL%	PI%	M/C%
<input type="checkbox"/> 100		5.30	27	21	6	22



TBT Engineering Ltd.
1918 Yonge Street
Thunder Bay, Ontario P7E 6T9
Telephone: 807-624-5160
Fax: 807-624-5161

ATTERBERG LIMIT RESULTS

W P: 5383-11-00

District: Muskego

Highway: 101

APPENDIX C

Staging Stability Models

Culvert #48 - Widening Stage 1

Name: Sand Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 32 °

Name: Sand & Gravel Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 30 °
Piezometric Line: 1

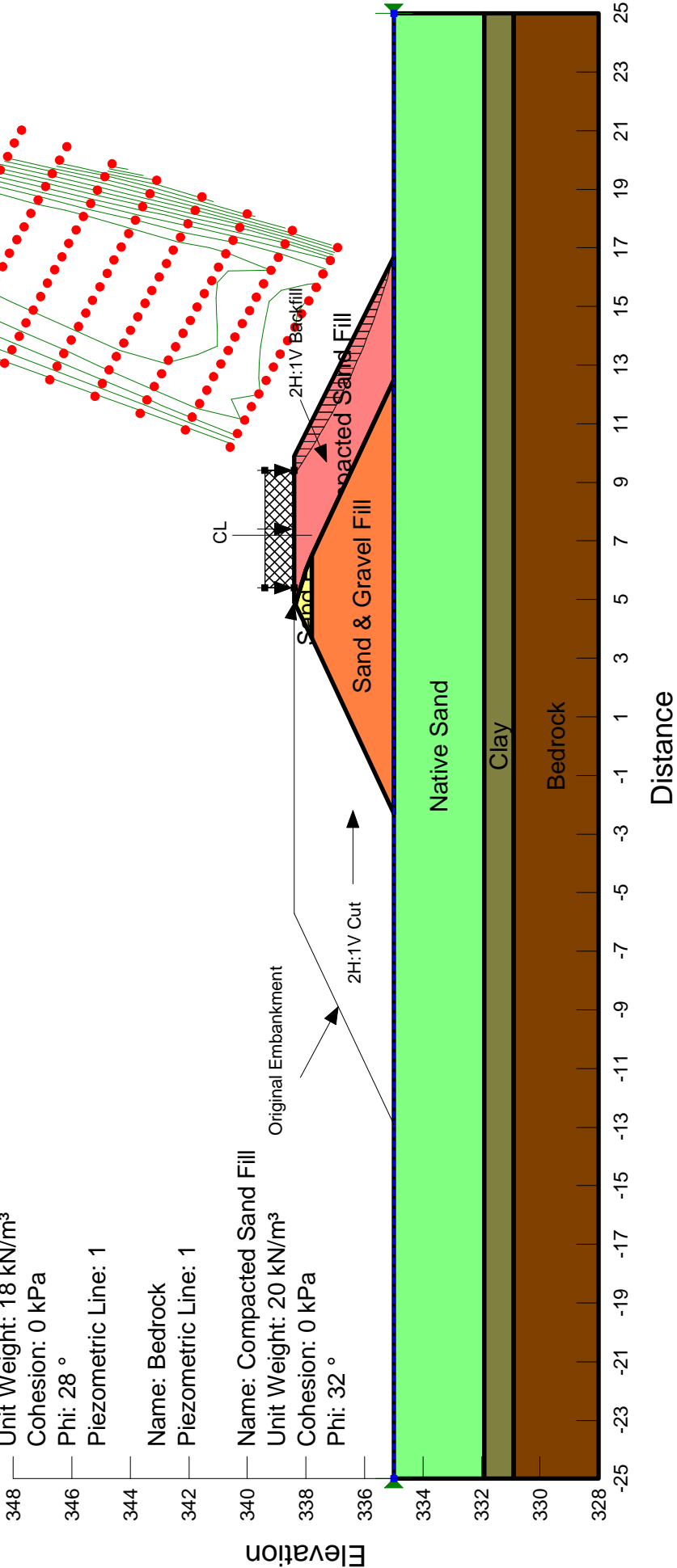
Name: Native Sand
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 29 °
Piezometric Line: 1

Name: Clay
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Piezometric Line: 1

Name: Bedrock
Piezometric Line: 1

Name: Compacted Sand Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 32 °

File Name: Culvert #48 Cut and Widening NS DN L2R Stage 1.gsz
Kind: SLOPE/W
Method: Morgenstern-Price
PWP Conditions Source: Piezometric Line
Surcharge (Unit Weight): 20 kN/m³
FOS: 1.3



Culvert #48 - Widening Stage 1

- Name: Sand Fill

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Phi: 32 °
- Name: Sand & Gravel Fill

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Phi: 30 °

Piezometric Line: 1
- Name: Native Sand

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Phi: 29 °

Piezometric Line: 1
- Name: Clay

Unit Weight: 18 kN/m³

Cohesion: 0 kPa

Phi: 28 °

Piezometric Line: 1
- Name: Bedrock

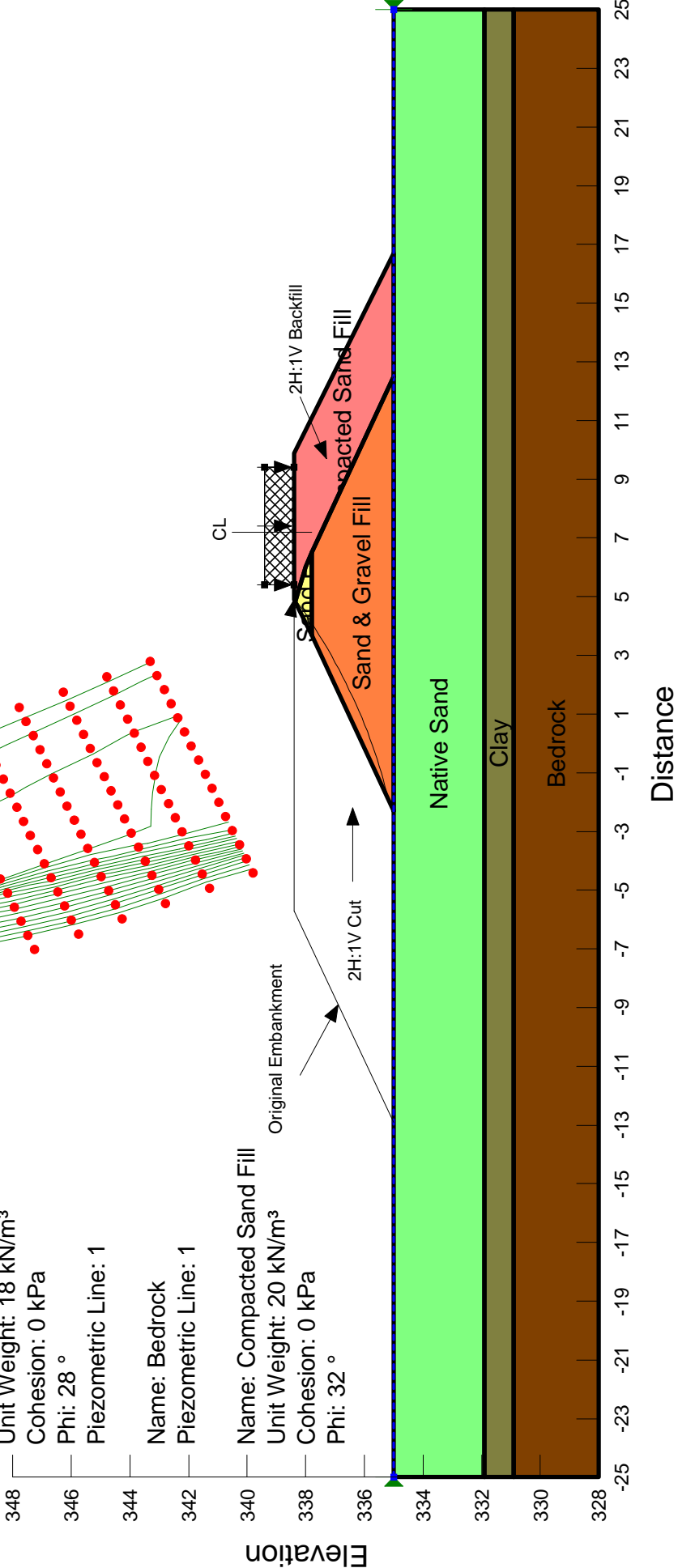
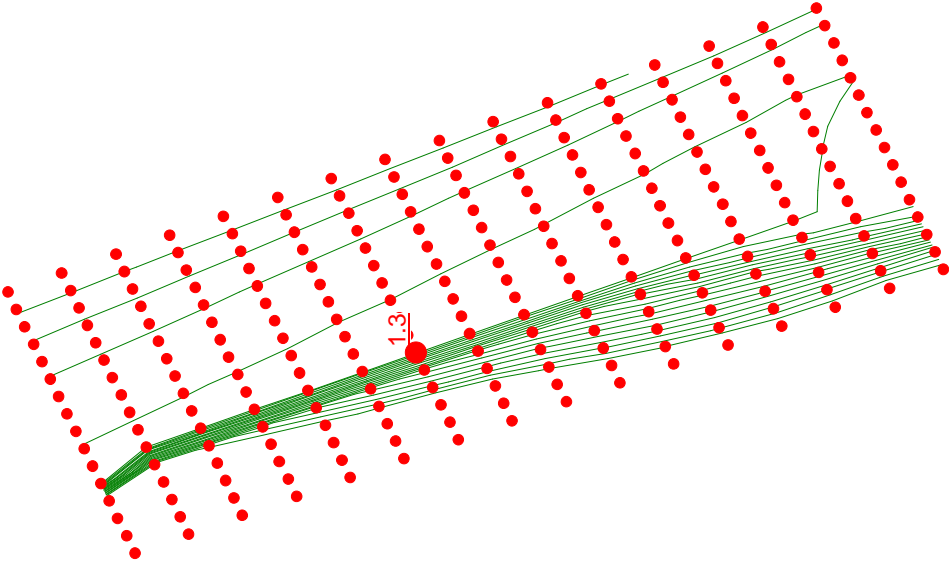
Piezometric Line: 1
- Name: Compacted Sand Fill

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Phi: 32 °

File Name: Culvert #48 Cut and Widen NS DN R2L Stage 1.gsz
Kind: SLOPE/W
Method: Morgenstern-Price
PWP Conditions Source: Piezometric Line
Surcharge (Unit Weight): 20 kN/m³
FOS: 1.3



Culvert #48 - Stage 2 Widening Slope 2(H):1(V)

File Name: Culvert #48 Cut and Widen NS DN L2R Stage 2.gsz
Kind: SLOPE/W
Method: Morgenstern-Price
PWP Conditions Source: Piezometric Line
Surcharge (Unit Weight): 20 kN/m³
FOS: 1.3

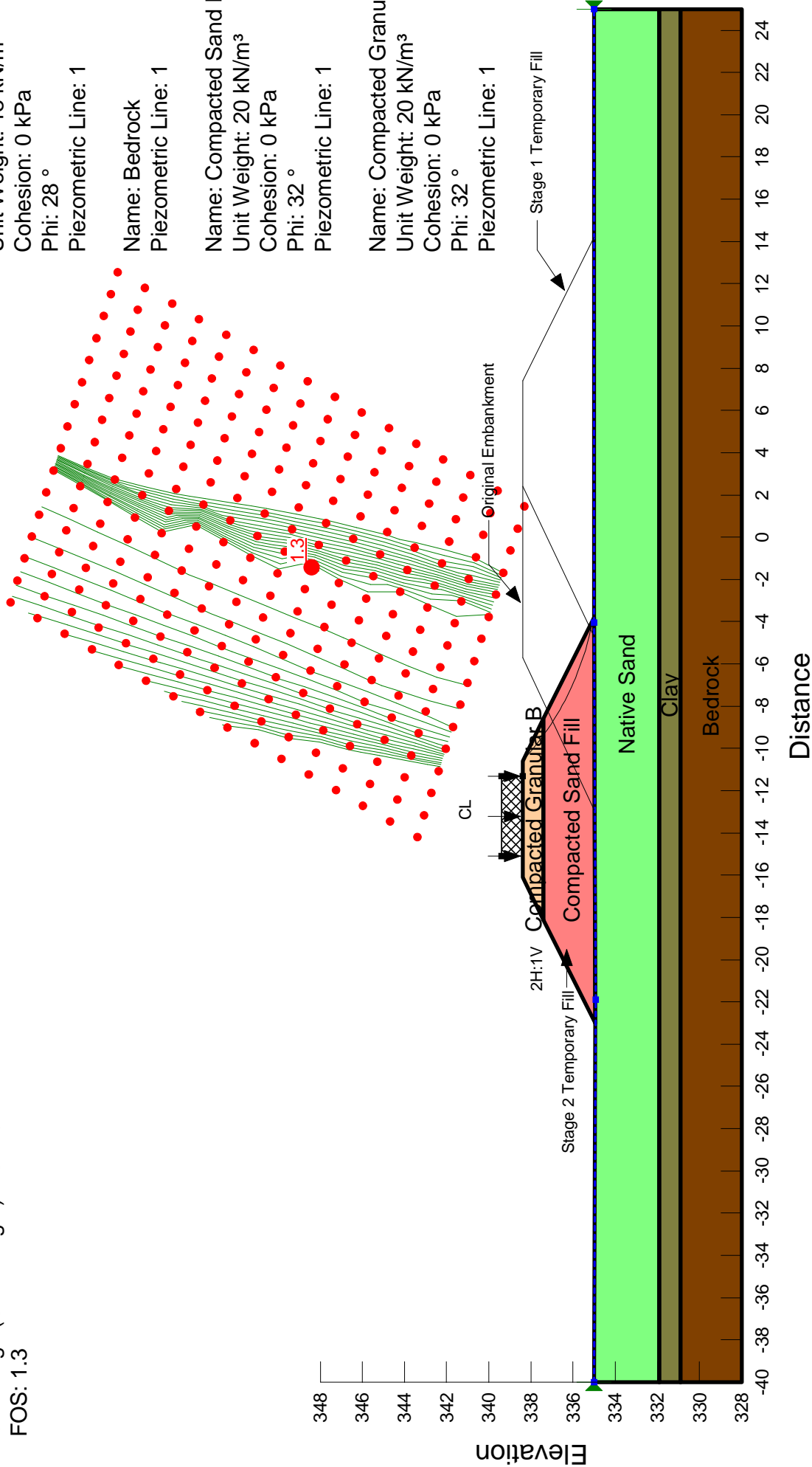
- Name: Native Sand
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 29 °
Piezometric Line: 1

Name: Clay
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Piezometric Line: 1

Name: Bedrock
Piezometric Line: 1

Name: Compacted Sand Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 32 °
Piezometric Line: 1

Name: Compacted Granular B
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 32 °
Piezometric Line: 1



Culvert #48 - Widening Stage 3

Name: Native Sand
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 29 °
Piezometric Line: 1

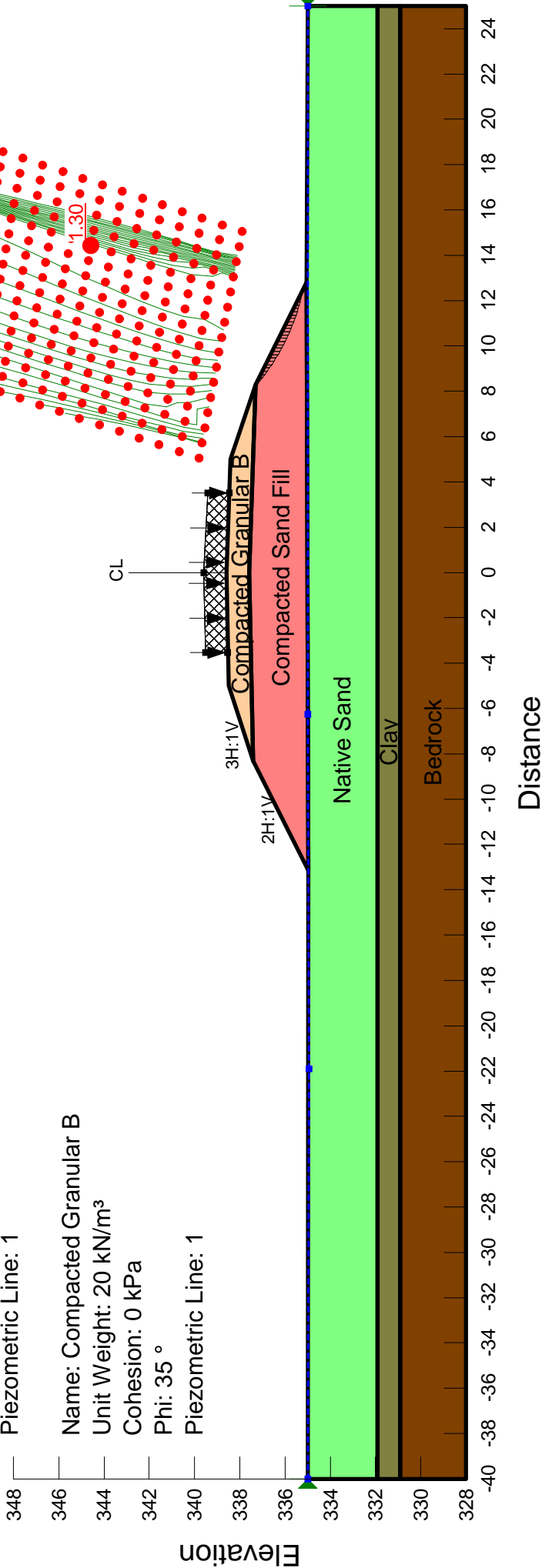
Name: Clay
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Piezometric Line: 1

Name: Bedrock
Piezometric Line: 1

Name: Compacted Sand Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 32 °
Piezometric Line: 1

Name: Compacted Granular B
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Piezometric Line: 1

File Name: Culvert #48 Cut and Widen NS DN L2R Stage 3.gsz
Kind: SLOPE/W
Method: Morgenstern-Price
PWP Conditions Source: Piezometric Line
Surcharge (Unit Weight): 20 kN/m³
FOS: 1.30



Culvert #48 - Widening Stage 3

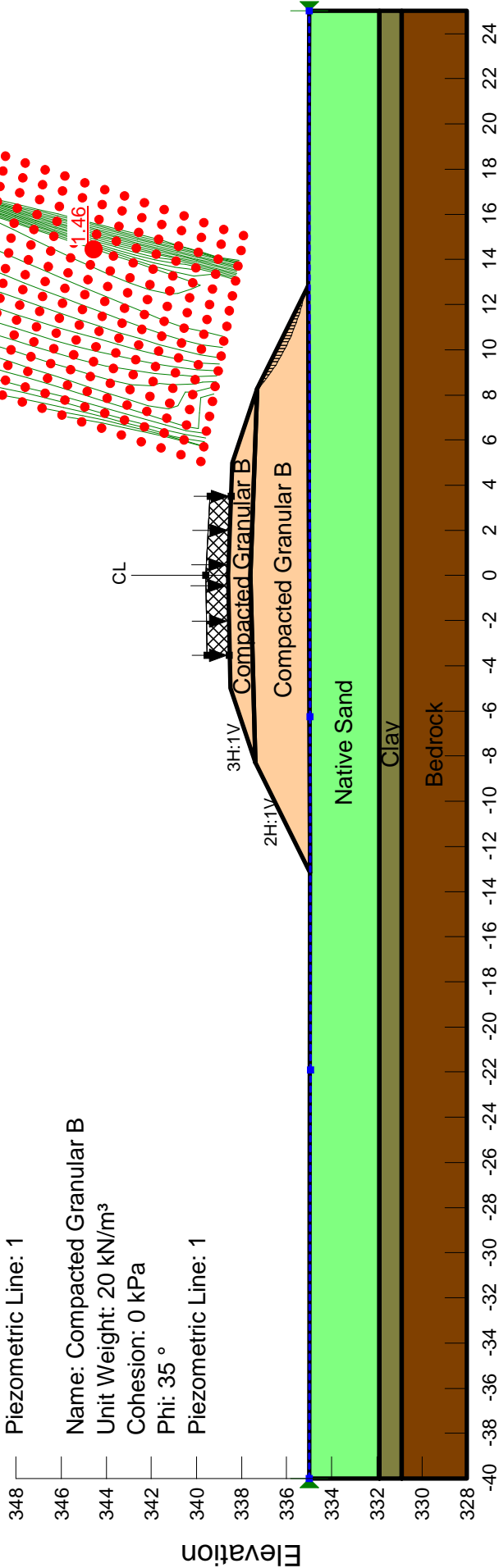
File Name: Culvert #48 Cut and Widen NS DN L2R Stage 3 Gran B.gsz
Kind: SLOPE/W
Method: Morgenstern-Price
PWP Conditions Source: Piezometric Line
Surcharge (Unit Weight): 20 kN/m³
FOS: 1.46

Name: Native Sand
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 29 °
Piezometric Line: 1

Name: Clay
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Piezometric Line: 1

Name: Bedrock
Piezometric Line: 1

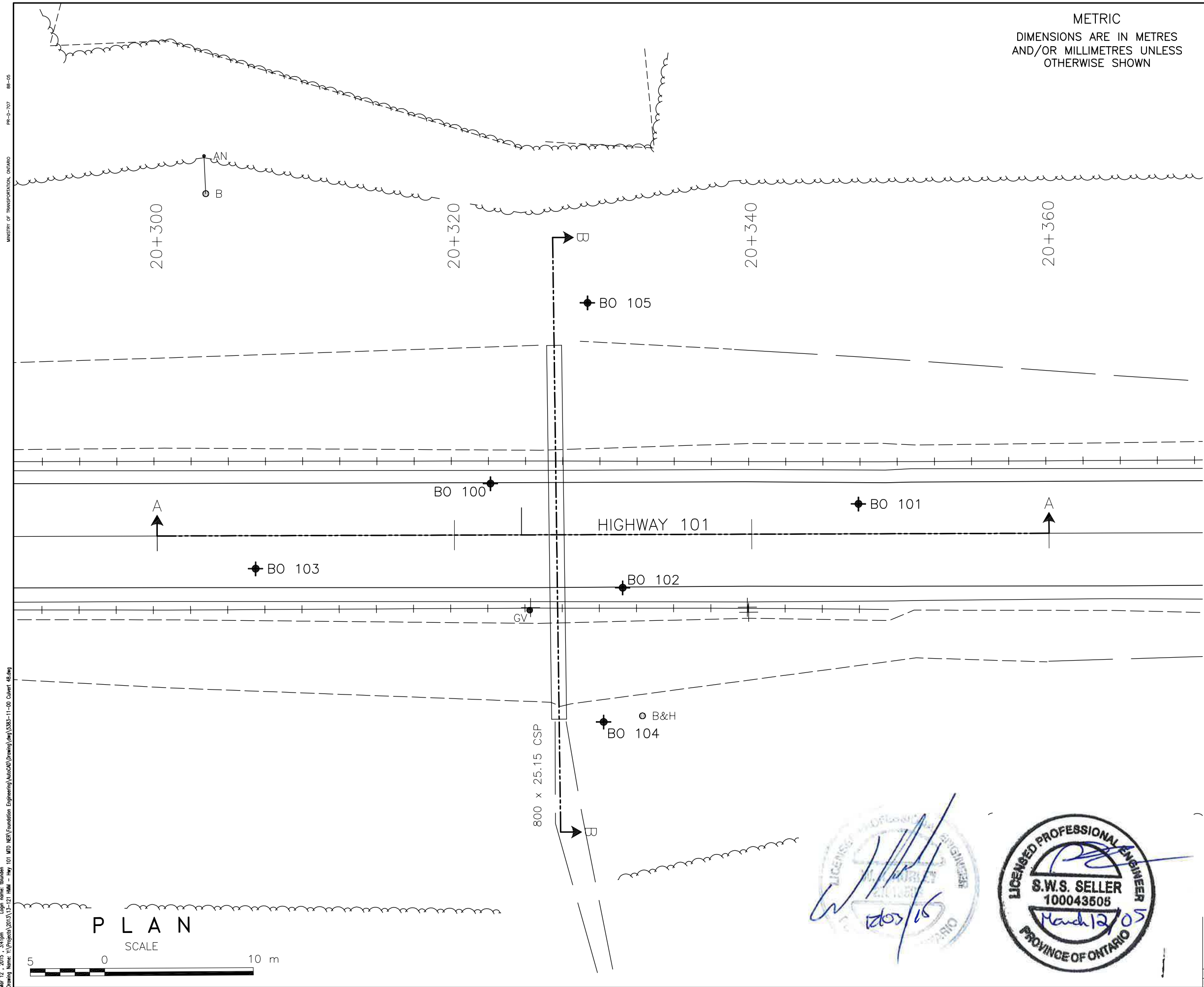
Name: Compacted Granular B
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Piezometric Line: 1



Distance

APPENDIX D

Borehole Locations and Soil Strata Drawing




METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN


GEOCREs No. 42B-10

CONT No. .


GWP No. 5383-11-00



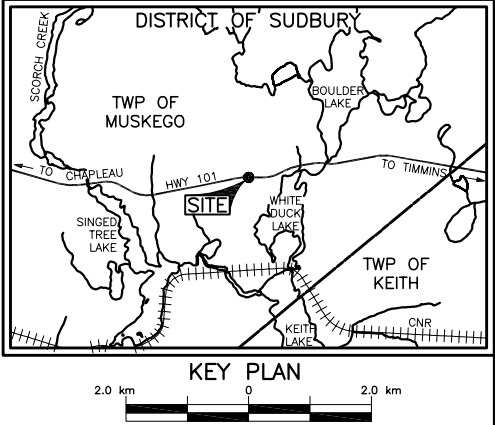
SHEET .



Ontario



TBT ENGINEERING
CONSULTING GROUP



LEGEND				
◆	Borehole			
'N'	Std Pen Test (Blows/0.3m)			
▼	Water Level			
EOH	End of Hole			
AR	Auger Refusal			

No	ELEVATION	CO-ORDINATES (MTM)	
		NORTH	EAST
100	338.7	12 5 341 962	208 910
101	337.8	12 5 341 945	208 928
102	338.3	12 5 341 951	208 913
103	339.4	12 5 341 968	208 895
104	335.4	12 5 341 945	208 906
105	335.5	12 5 341 967	208 923

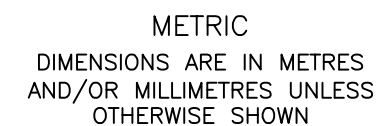
—NOTE—
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.



REVISIONS		DESIGN		CHK		WH		CODE		LOAD.		DATE	
13/12/10	WH	ISSUED IN DRAFT										2013/12/23	
												DWG	1

Mar 12, 2015 3:54 pm
Drawing Name: \\projects\2013\13-121 HMM - Hwy 101 MTD MERV\Foundation Engineering\AutoCAD\Drawings\42B-11-00 Culvert 48.dwg
Login name: iblandan
PR-D-707 88-05 MINISTRY OF TRANSPORTATION, ONTARIO

SHEET



LEGEND

- | AR | | Auger Refusal | |
|-----|-----------|--------------------|---------|
| No | ELEVATION | CO-ORDINATES (MTM) | |
| | | NORTH | EAST |
| 100 | 338.3 | 12 5 341 962 | 208 910 |
| 101 | 337.8 | 12 5 341 945 | 208 928 |
| 102 | 338.1 | 12 5 341 951 | 208 913 |
| 103 | 338.8 | 12 5 341 968 | 208 895 |
| 104 | 335.4 | 12 5 341 945 | 208 906 |
| 105 | 336.0 | 12 5 341 967 | 208 923 |

—NOTE—

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

REVISIONS							
	13/12/10	WH	ISSUED IN DRAFT				
					DESCRIPTION		
DESIGN	SS	CHK	WH	CODE	LOAD.	DATE	2013/12/23
DRAWN	IB	CHK	WH	SUF		DWG.	2

APPENDIX E

Non Standard Special Provisions

NOTICE TO CONTRACTOR – Presence of Coarse Aggregates in Existing Embankment

Special Provision

The contractor is advised that cobbles and boulders as well as zones of loose granular materials were encountered in the embankment fills and sub-grade during the foundation and geotechnical investigations at various borehole locations.