

# Foundation Investigation and Design Report

## Culvert #34 Highway 101

Station 16+932 Township of Muskego

GWP 5383-11-00

Geocres No.: 42B-8

### SUBMITTED TO:

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### SUBMISSION DATE:

February 12, 2015



**TBT ENGINEERING**  
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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 #34 located at Sta. 16+932 in the Township of Muskego. The remaining foundation sites (Culvert 17, Culvert 21 and Culvert 48) are addressed under separate covers.

This investigation consisted of two midpoint boreholes drilled adjacent to the existing culvert and 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 200 to 203.

The MTO Foundation section has assigned GEOCRES No. 42B-8 to this site.

## 2 Site Description

The foundation investigations were completed to investigate subsurface conditions for Culvert #34 located at Sta. 16+932 along Hwy 101 in the Township of Muskego.

Highway 101 runs in an east-west direction at this location. The culvert located at this site is composed of an 800 mm centreline CSP which is to be replaced with an 800 mm pipe culvert. 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 with bedrock outcrops.

The road embankment at this location is approximately 4.0 m high on the right side and 4.5 m on the left side with side slopes of approximately 2 horizontal to 1 vertical on both sides. A low lying swamp area was encountered at both sides of the embankment of the existing culvert openings along Highway 101.

**Photo 2.1 – Looking Southerly 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 22 to 24, 2013 for Boreholes 200 – 202 and November 26, 2013 for Borehole 203. Access to Borehole 203 required the use of swamp mats to traverse the wet soft ground. The borehole locations are illustrated on the Borehole Location and Soil Strata Drawing 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 750 CME drill rig equipped with hollow stem augers and an automatic hammer used to conduct Standard Penetration Testing (SPT). Where auger drilling methods proved unsatisfactory, casing was advanced using wash boring techniques. Due to poor ground conditions swamp mats were used to gain access to drill the borehole at the culvert outlet (Borehole 203). 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 logs (Appendix A) and on the Soil Strata Drawing (Appendix D).

The subsurface soils through the embankment at this site typically consist of embankment fills which overlie native sand over bedrock. Silts and organic matter were encountered within the boreholes at the culvert openings. Occasional cobbles were present within the fill materials and sand layer. 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 embankment surface at Boreholes 201 and 202, which were drilled through the shoulder of the highway. The asphalt's thickness ranged from 45 to 50 mm.

### **5.2 Fill – Sand to Sand and Gravel**

Sand to sand and gravel fill with occasional to numerous cobbles was encountered beneath the asphalt at Borehole 201 and 202. The fill was encountered at elevation 344.4 with a thickness ranging from 4.6 to 5.6 m. A layer of sand fill was also encountered below the surficial root mat in Borehole 203. The sand fill was encountered at elevation 340.5 in Borehole 203 with a thickness of 0.8 m. Grain size analysis conducted on selected samples of the fill material indicate the layer consist of 6 - 39% gravel , 49 - 74% sand and 9 - 41% silt/clay size particles. The material is typically compact to dense as indicated by "N" values of 18 to 42 blows/0.3 m, with one "N" value

of 4 blows/0.3 m within Borehole 201. A single blow count of >100 blows per 0.3 m was measured in Borehole 200, indicative of a cobble or boulder.

### **5.3 Organic Matter**

Organic matter was encountered at Borehole 202 and 203, at the ground surface (elevation 340) of Borehole 203 and elevation 339.8 at Borehole 202. The thickness of the organic matter ranged from 0.2 to 0.9 m. Based on a single sample the natural moisture content of this material is 87 %.

### **5.4 Silt**

Silt was encountered beneath organic matter at Borehole 203. The silt layer was encountered at elevation 339.4 with a thickness of 0.9 m. Grain size distribution analyses conducted on a selected sample indicate the material consists of 0% gravel, 4% sand, and 96% silt/clay sized particles. Atterberg limit tests conducted on the selected sample indicates the material is non plastic. The silt is compact as indicated by "N" value of 17 blows/0.3 m.

### **5.5 Sand**

Sand with occasional cobbles was encountered at all borehole locations. The sand was encountered at elevations ranging from 338.5 to 340.6 and varied in thickness from 2.7 to 6.7 m. Five samples were selected for grain size distribution testing. The sand ranges from some silt to silty with trace to some gravel. The test results indicate a grain size distribution of 1 to 19 % gravel, 49 to 72 % sand, and 15 to 33 % silt/clay sized particles. The sand is very loose to compact as indicated by "N" values ranging from 1 to 28 blows/0.3 m. The presence of cobbles encountered within the sand resulted in "N" occasional values of 100+blows/0.3m.

### **5.6 Gravel**

A gravel layer with occasional cobbles was encountered below the sand in Borehole 200. The gravel layer was encountered at elevation 337.9 with a thickness of 1.2m. Grain size distribution analyses conducted on a selected sample indicate the material consists of 64 % gravel, 30 % sand, and 5 % silt/clay sized particles. The gravel is very compact indicated by "N" value 20 blow/0.3m.

## 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 sand in Boreholes 201,202 and 203 and beneath the gravel at Borehole 200. Bedrock was sampled using diamond coring techniques. The bedrock encountered is medium grained biotite granite in Borehole 202 and paragneiss in Borehole 200,201 and 203. 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
200	3.9	336.7
201	11.9	332.5
202	11.9	332.5
203	9.9	334.0

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 45 to 100 %. The majority of RQDs were measured to be 69 to 100 % and can be described as fair to excellent, with one sample with an RQD of 45 % indicating poor quality at Borehole 201.



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)
200	5.20	331.5	220
	5.60	331.1	255
	6.90	329.8	269
201	12.60	319.9	304
	13.80	318.7	271
	14.90	317.6	268
202	12.00	320.5	158
	12.80	319.7	143
	13.70	318.8	175

\* 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 observed upon completion of drilling on August 22, 2013 are provided below. Ground water levels will vary from season to season and from the effects of heavy precipitation events.

**Table 5.4: Ground Water Level**

Borehole	Depth below Ground Surface (m)	Elevation
200	0.7	339.8
203	0.3	340.4

## 6 Miscellaneous

Laboratory testing was conducted 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).

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## **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 34 located at Sta. 16+932 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 investigations as described in Part A, was completed out to investigate subsurface conditions at this site. The investigation at Culvert #34 consisted of four boreholes; BH 200, 201, 202, and 203.

The subsurface soils at this site typically consist of embankment fills and organic matter which overlie native sand, over bedrock. Gravel with numerous cobbles was 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.

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## **8 Structure Foundations**

The culvert located at this site is composed of an 800 mm centreline CSP which is to be replaced with an 800 mm pipe culvert. 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 with bedrock outcrops.

The road embankment at this location is approximately 4.0 m high on the right side and 4.5 m on the left side with side slopes of approximately 2 horizontal to 1 vertical on both sides. A low lying swamp area was encountered at both sides of the embankment of the existing culvert openings along Highway 101.

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

Design parameters for the above 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. Design recommendations are provided for this culvert configuration.

## **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 widened.

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 completed 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 embankment configurations 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) and a (FoS) of 1.3 for final (Stage 3) configuration. A uniformly distributed traffic load of 20 kPa over the traversable lane(s) was applied in all cases.

**Table 10.1: Stability Analyses Soil Properties**

Soil	Effective Shear Strength Properties		Unit Weight, $\gamma$ (kN/m <sup>3</sup> )
	Effective Angle of Internal Friction, $\phi'$ (degrees)	Effective Cohesion Intercept, $C'$ (kPa)	
Granular B Type I	35	0	20
Compact Sand/Gravel Fill	33	0	20
Existing Sand/Gravel Fill	32	0	20
Native Sand	30	0	20
Organic Material	29	0	12

Granular B Type 2 and/or rock fill were 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 preliminary 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	1.4	1.3	-
3	No	1.3	1.3	Constructed from Compact Sand and Gravel
3	No	1.4	1.3	Constructed from Compact Granular B Type 1

The following recommendations have been derived from the analysis:

- All organic matter beneath the embankment should be removed where encountered.
- 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 1.4).
- Culvert extensions will be required to accommodate the removal of organic matter beneath the embankment.

The stability analyses have been presented in Appendix C.

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## **11 Temporary Roadway Protection**

Staging configurations may require shallow roadway protection. The shallow bedrock limits 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 potentially boulders within the fill.

Gravity wall designs may be considered where space is available.

Vertical roadway protection may be completed using soldier pile and lagging systems. The soldier piles could be installed in drilled holes in the bedrock to provide toe support. 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 involve 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 11. 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 "B" Type I, or Granular "A" 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.

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

**Table 12.1: Lateral Earth Pressure Coefficients**

Lateral Earth Pressure Coefficients (K)					
Compacted Granular Backfill	Phi' (°)	Bulk Unit Weight of Soil, $\gamma$ (kN/m <sup>3</sup> )	Active Ka	At Rest Ko	Passive Kp
Granular A	35	20 – 22	0.27	0.43	3.7
Granular B	35	20 – 22	0.27	0.43	3.7
Sand/Gravel Fill	33	20 – 22	0.29	0.46	3.4

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 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 g
- 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” (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. Potential obstructions such as the numerous cobbles within the native soils and embankment materials, should be noted as described in the nonstandard provision provided in Appendix E. Flows in to open excavations below the ground water level can be rapid.

Channel diversion is not anticipated to be required during construction. It is anticipated the excavations will be completed using conventional construction with dam and pump methods to allow culvert construction in the dry. Improvements/revisions to the channel may be required following removal of the existing culvert. 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

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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. The contractor should have adequate equipment on site.



## **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 to contact us at your convenience.

Yours truly,

For TBT ENGINEERING



Steven Seller, P.Eng.  
Senior 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		MECHANICAL PROPERTIES OF SOIL	
S S SPLIT SPOON	T P THINWALL PISTON	$m_v$	$\text{kPa}^{-1}$ COEFFICIENT OF VOLUME CHANGE
W S WASH SAMPLE	O S OSTERBERG SAMPLE	$C_c$	1 COMPRESSION INDEX
S T SLOTTED TUBE SAMPLE	R C ROCK CORE	$C_s$	1 SWELLING INDEX
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY	$C_a$	1 RATE OF SECONDARY CONSOLIDATION
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY	$C_v$	$\text{m}^2/\text{s}$ COEFFICIENT OF CONSOLIDATION
T W THINWALL OPEN	F S FOIL SAMPLE	H	m DRAINAGE PATH
<b>STRESS AND STRAIN</b>		$T_v$	1 TIME FACTOR
		U	% DEGREE OF CONSOLIDATION
$u_w$	kPa PORE WATER PRESSURE	$\sigma'_{vo}$	kPa EFFECTIVE OVERBURDEN PRESSURE
$r_u$	1 PORE PRESSURE RATIO	$\sigma'_p$	kPa PRECONSOLIDATION PRESSURE
$\sigma$	kPa TOTAL NORMAL STRESS	$\tau_f$	kPa SHEAR STRENGTH
$\sigma'$	kPa EFFECTIVE NORMAL STRESS	$c'$	kPa EFFECTIVE COHESION INTERCEPT
$\tau$	kPa SHEAR STRESS	$\phi'$	-° EFFECTIVE ANGLE OF INTERNAL FRICTION
$\sigma_1, \sigma_2, \sigma_3$	kPa PRINCIPAL STRESSES	$C_u$	kPa APPARENT COHESION INTERCEPT
$\epsilon$	% LINEAR STRAIN	$\phi_u$	-° APPARENT ANGLE OF INTERNAL FRICTION
$\epsilon_1, \epsilon_2, \epsilon_3$	% PRINCIPAL STRAINS	$\tau_R$	kPa RESIDUAL SHEAR STRENGTH
E	kPa MODULUS OF LINEAR DEFORMATION	$\tau_r$	kPa REMOULDED SHEAR STRENGTH
G	kPa MODULUS OF SHEAR DEFORMATION	$S_t$	1 SENSITIVITY = $\frac{C_u}{\tau_r}$
$\mu$	1 COEFFICIENT OF FRICTION		
<b>PHYSICAL PROPERTIES OF SOIL</b>			
$\rho_s$	$\text{kg}/\text{m}^3$ DENSITY OF SOLID PARTICLES	e	1, % VOID RATIO
$\gamma_s$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF SOLID PARTICLES	n	1, % POROSITY
$\rho_w$	$\text{kg}/\text{m}^3$ DENSITY OF WATER	w	1, % WATER CONTENT
$\gamma_w$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF WATER	$S_r$	% DEGREE OF SATURATION
$\rho$	$\text{kg}/\text{m}^3$ DENSITY OF SOIL	$w_L$	% LIQUID LIMIT
$\gamma$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF SOIL	$w_p$	% PLASTIC LIMIT
$\rho_d$	$\text{kg}/\text{m}^3$ DENSITY OF DRY SOIL	$w_s$	% SHRINKAGE LIMIT
$\gamma_d$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF DRY SOIL	$I_p$	% PLASTICITY INDEX = $w_L - w_p$
$\rho_{sat}$	$\text{kg}/\text{m}^3$ DENSITY OF SATURATED SOIL	$I_L$	1 LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
$\gamma_{sat}$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF SATURATED SOIL	$I_C$	1 CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
$\rho'$	$\text{kg}/\text{m}^3$ DENSITY OF SUBMERGED SOIL	$e_{max}$	1, % VOID RATIO IN LOOSEST STATE
$\gamma'$	$\text{kN}/\text{m}^3$ UNIT WEIGHT OF SUBMERGED SOIL	$e_{min}$	1, % VOID RATIO IN DENSEST STATE
		$I_D$	1 DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
		D	mm GRAIN DIAMETER
		$D_n$	mm n PERCENT - DIAMETER
		$C_u$	1 UNIFORMITY COEFFICIENT
		h	m HYDRAULIC HEAD OR POTENTIAL
		q	$\text{m}^3/\text{s}$ RATE OF DISCHARGE
		v	m/s DISCHARGE VELOCITY
		i	1 HYDRAULIC GRADIENT
		k	m/s HYDRAULIC CONDUCTIVITY
		j	$\text{kN}/\text{m}^2$ SEEPAGE FORCE

TBT Engineering Consulting Group		<b>RECORD OF Borehole No 200</b>				1 OF 1		<b>METRIC</b>				
W.P. <b>5383-11-00</b>		PROJECT <b>Culvert Investigation</b>		SITE NO. <b>Culvert #34</b>		ORIGINATED BY <b>C.H.</b>						
TWP <b>Muskego</b> HWY <b>101</b>		LOCATION <b>MTM 12 N5344078.417, E206388.076</b>		TBTE JOB# <b>13-121</b>		COMPILED BY <b>T.B.</b>						
DATE <b>2013 August 22</b>		BOREHOLE TYPE <b>Hollow Stem Auger/B Casing/Core</b>		DATUM <b>Geodetic</b>		CHECKED BY <b>S.S.</b>						
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	'N' VALUES					
340.6	SAND - some gravel, some silt, brown, compact to very dense		1	AS								17 68 (15) Water level @ 0.7 m on Septmber 06, 2013.  Auger Refusal. Advanced with B Casing.
0.0												
337.9	GRAVEL - Sandy, trace silt, numerous cobbles, brown, compact		2	SS	16							64 30 (5) Temporary Standpipe installed to 2.9 m.  RC # 1 REC = 100% RQD = 85%
2.7												
336.7	BEDROCK - Paragneiss: Medium grained, light to dark colour		3	SS	100+							RC # 2 REC = 100% RQD = 93%
3.9												
			4	SS	20							
			5	SS	100+							
			1	RC								
			2	RC								
333.4	End of Borehole @ 7.2 m.											
7.2												

x<sup>3</sup>, ★<sup>3</sup>: Numbers refer to  
 NP Non Plastic  
 ○ 3% STRAIN AT FAILURE

ONL\_MOT\_BH\_MTM 13-121 CULVERT 34.GPJ ONL\_MOT\_GDT 15/2/11

TBT Engineering Consulting Group			<b>RECORD OF Borehole No 201</b>			1 OF 1		<b>METRIC</b>				
W.P. <b>5383-11-00</b>			PROJECT <b>Culvert Investigation</b>			SITE NO. <b>Culvert #34</b>		ORIGINATED BY <b>C.H.</b>				
TWP <b>Muskego</b> HWY <b>101</b>			LOCATION <b>MTM 12 N5344077.912, E206373.416</b>			TBTE JOB# <b>13-121</b>		COMPILED BY <b>T.B.</b>				
DATE <b>2013 August 23</b>			BOREHOLE TYPE <b>Hollow Stem Auger</b>			DATUM <b>Geodetic</b>		CHECKED BY <b>S.S.</b>				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
344.4	ASPHALT - 45 mm		1	AS			344					
340.0	FILL - SAND - some silt, trace gravel, brown, compact to dense		2	SS	31		343					7 74 (18)
			3	SS	27		342					Advance Casing @ 1.5 m.
	----- - SAND & GRAVEL - occasional to numerous cobbles, grey, very loose to compact		4	SS	4		341					
			5	SS	21		340					
339.2	SAND - Silty, trace gravel, occasional cobbles, grey, compact		6	SS	22		339					
5.2			7	SS	18		338					1 72 (28)
			8	SS	17		337					
			9	SS	28		336					
332.5	BEDROCK - Paragneiss: Medium grained, light to dark colour		10	SS	100+		335					
11.9			1	RC			334					RC # 1 REC = 95% RQD = 45%
			2	RC			333					RC # 2 REC = 100% RQD = 86%
329.3	End of Borehole @ 15.1 m.						332					
15.1							331					
							330					

x<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity  
 NP Non Plastic  
 ○ 3% STRAIN AT FAILURE



TBT Engineering Consulting Group			RECORD OF Borehole No 202			1 OF 1			METRIC												
W.P. <b>5383-11-00</b>			PROJECT <b>Culvert Investigation</b>			SITE NO. <b>Culvert #34</b>			ORIGINATED BY <b>C.H.</b>												
TWP <b>Muskego</b> HWY <b>101</b>			LOCATION <b>MTM 12 N5344068.454, E206373.193</b>			TBTE JOB# <b>13-121</b>			COMPILED BY <b>T.B.</b>												
DATE <b>2013 August 24</b>			BOREHOLE TYPE <b>Hollow Stem Auger/B Casing/Core</b>			DATUM <b>Geodetic</b>			CHECKED BY <b>S.S.</b>												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE														
344.4	ASPHALT - 50 mm						344														
340.9	FILL - SAND & GRAVEL - trace silt, brown to grey		1	AS																	39 52 (9)
	- SAND & SILT to Silty - trace to some gravel, occasional cobbles, compact to dense		2	SS	42																Water level @ 4.3 m on completion.
			3	SS	30																14 50 (35)
			4	SS	20																
			5	SS	23																11 65 (24)
			6	SS	18																
339.8	PEAT - numerous cobbles, brown		7	SS	15																6 53 (41)
338.7	SAND - Silty, some to trace gravel, occasional cobbles, grey, loose to compact		8	SS	12																19 49 (33)
			9	SS	16																
			10	SS	10																
			11	SS	8																6 65 (29)
332.9	SAND - Gravelly, some silt, occasional cobbles, grey, compact		12	SS	27																27 55 (18)
332.5	BEDROCK - Biotite Granite: Medium grained, light to dark in colour with pink/red zones		1	RC																	RC # 1 REC = 99% RQD = 91%
329.5			2	RC																	RC # 2 REC = 95% RQD = 69%
14.9	End of Borehole @ 14.9 m.																				

x<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity  
 NP Non Plastic  
 ○ 3% STRAIN AT FAILURE

ONL\_MOT\_BH\_MTM 13-121 CULVERT 34.GPJ ONL\_MOT\_GDT 15/2/11

## RECORD OF Borehole No 203

1 OF 1

METRIC

W.P. <b>5383-11-00</b>	PROJECT <b>Culvert Investigation</b>	SITE NO. <b>Culvert #34</b>	ORIGINATED BY <b>C.H.</b>
TWP <b>Muskego</b> HWY <b>101</b>	LOCATION <b>MTM 12 N5344071, E206357</b>	TBTE JOB# <b>13-121</b>	COMPILED BY <b>T.B.</b>
DATE <b>2013 November 26</b>	BOREHOLE TYPE <b>Hollow Stem Auger/Core</b>	DATUM <b>Geodetic</b>	CHECKED BY <b>S.S.</b>

ON MOT\_BH\_MTM 13-121 CULVERT 34.GPJ ON MOT.GDT 15/2/11

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

**ROCK CORE LOG**

Project #: 13-121

Borehole# 203

Lab# 13-1205

Client: Hatch Mott Macdonald

Logger: Terry Dupuis

Site: Culvert # 34 - Highway 101

Date: December 1, 2013

Page 1 of 1

**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  
R = 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-swelling clay  
SC = Swelling, softening clay  
N = No filling

**OCCASIONAL FEATURES**

**DISCONTINUITIES**

TYPE(S)

# OF SETS

WEATHERING

STRENGTH

Orientation

SPACING

Roughness

APERTURE

FILLING

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

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Paragneiss: Medium grained, strong compositional foliation, light to dark colour

91.4%

100.0%

1/1

From  
0.0  
To  
2.4

From  
6.7  
To  
9.1

Paragneiss: Medium grained, strong compositional foliation, light to dark colour

100.0%

100.0%

1/2

From  
2.4  
To  
3.2

From  
9.1  
To  
9.9

From

From

To

To

From

From

To

To

**ROCK CORE LOG**

Project #: 13-121

Borehole# 202

Lab# 13-0892

Client: Hatch Mott Macdonald

Logger: Terry Dupuis

Site: Culvert # 34 - Highway 101

Date: October 23, 2013

Page 1 of 1

**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**

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D = Dipping (20-50°)  
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**Spacing**

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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**

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N = No filling

**OCCASIONAL FEATURES**

**DISCONTINUITIES**

**TYPE(S)**

**# OF SETS**

**WEATHERING**

**STRENGTH**

**Orientation**

**SPACING**

**Roughness**

**APERTURE**

**FILLING**

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

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Biotite Granite: Medium grained, biotite foliation, light to dark in colour with pink/red zones

90.7%

98.7%

1/1

From  
0.0  
To  
1.5

From  
11.9  
To  
13.4

Biotite Granite: Medium grained, biotite foliation, light to dark in colour with pink/red zones

68.7%

94.7%

1/2

From  
1.5  
To  
3.0

From  
13.4  
To  
14.9

<div><div>TBT ENGINEERING CONSULTING GROUP</div><div><div>ROCK CORE LOG</div><div><div>Page 1 of 1</div><div><div>Borehole# 201</div><div>Lab# 13-0661</div></div><div><div>Client: Hatch Mott Macdonald</div><div>Logger: Patrick Belshaw</div></div><div><div>Site: Culvert # 34 - Highway 101</div><div>Date: September 6, 2013</div></div></div></div></div>										<div><div><div>Strength (MPa)</div><div>VH = Very High = &gt;200 H = High = 50-200 M = Medium = 15-50 L = Low = 4-15 VL = Very Low = 1-4</div></div><div><div>Discontinuity type</div><div>B = Bedding Joint J = Cross Joint F = Fault S = Shear Plane</div></div><div><div>Roughness</div><div>RU = Rough undulating RP = Rough planar SU = Smooth undulating SP = Smooth planar LU = Slickensided undulating LP = Slickensided planar</div></div></div>			<div><div><div>Weathering</div><div>U = Unweathered (No signs) S = Slightly (Oxidized) M = Moderately (Discoloured) H = Highly (Friable) C = Completely 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--	--	--	--	--	--	--	--	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	---	--	--	--	--	--

**ROCK CORE LOG**

Project #: 13-121

Borehole# 200

Page 1 of 1

Lab# 13-0660

Client: Hatch Mott Macdonald

Logger: Patrick Belshaw

Site: Culvert # 34 - Highway 101

Date: September 6, 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  
R = 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

**STRENGTH**

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

% RQD

% REC

BOX/RUN

DEPTH (m)

DEPTH FROM SURFACE (m)

Paragneiss: Medium grained, strong compositional foliation, light to dark colour

84.9%

100.0%

1/1

From  
0.0  
To  
1.7

From  
3.9  
To  
5.6

Paragneiss: Medium grained, moderate compositional foliation, light to dark colour

93.3%

100.0%

1/2

From  
1.7  
To  
3.3

From  
5.6  
To  
7.2

**DISCONTINUITIES**

WEATHERING

# OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

U

1

J

D

W

RP

O

O

U

1

J

F

M

RP

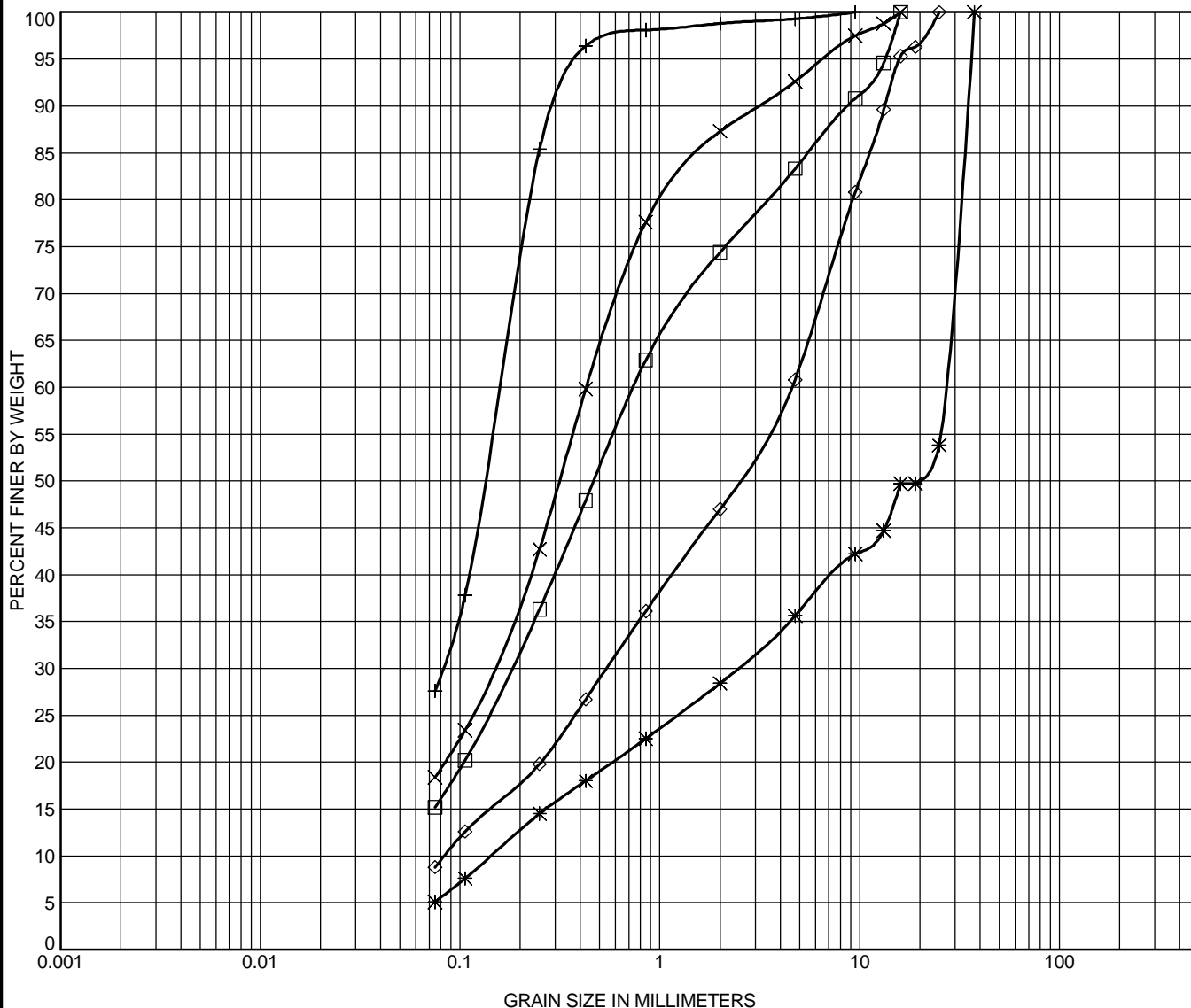
O

O



## **APPENDIX B**

### **Laboratory Test Data**



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:  
TILL - SILTS & SANDS & GRAVELS

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 200	0.75	16	0.743	0.179		16.7	68.1	15.2	
* 200	3.00	37.5	26.398	2.424	0.143	64.4	30.5	5.1	
X 201	0.75	16	0.428	0.142		7.4	74.2	18.4	
+ 201	7.40	9.5	0.158	0.081		0.7	71.7	27.6	
◇ 202	0.40	25	4.518	0.542	0.084	39.2	52.0	8.8	



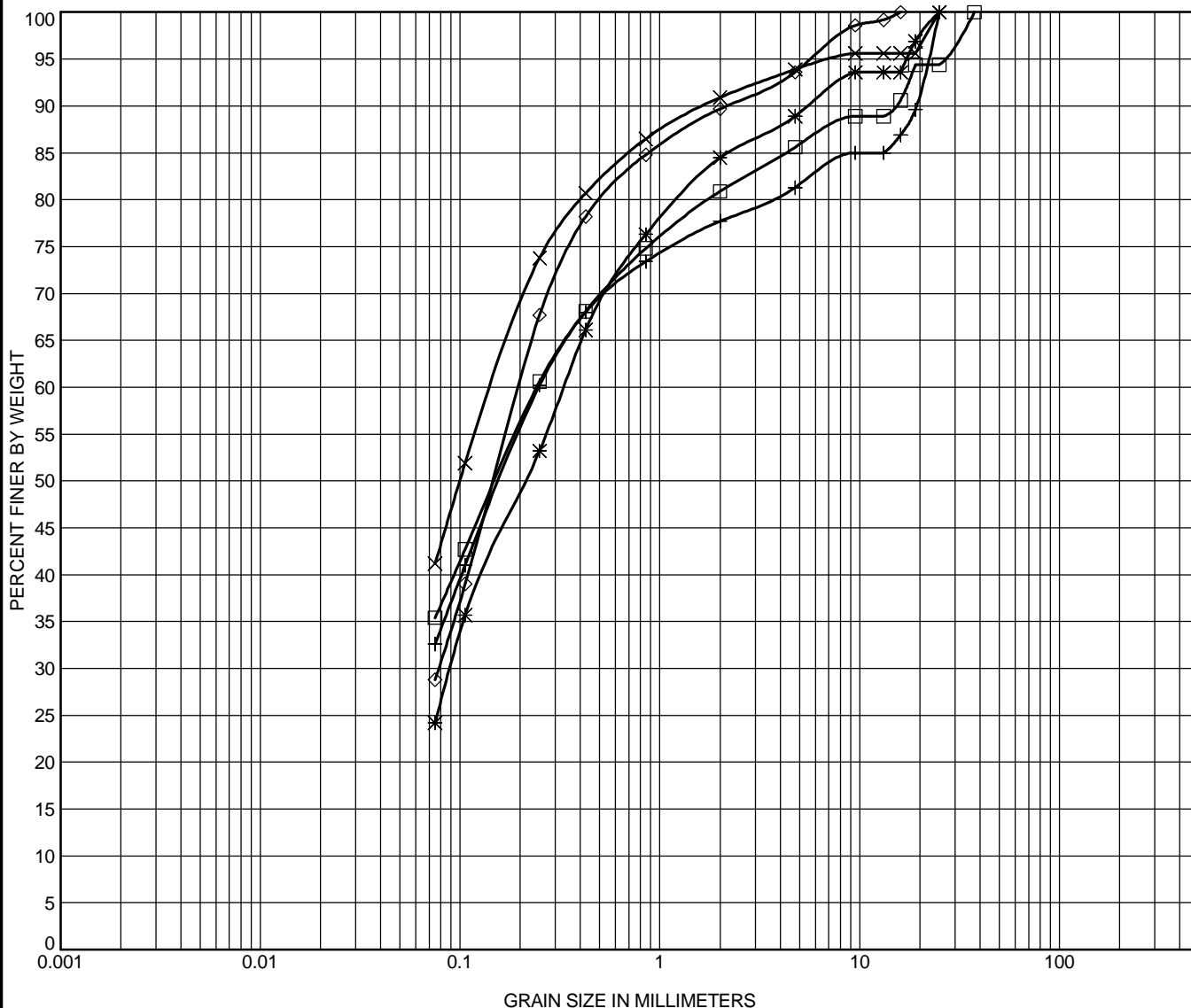
TBT Engineering Ltd.  
1918 Yonge Street  
Thunder Bay, Ontario P7E 6T9  
PH: 807-624-5160  
FX: 807-624-5161  
Email: tbte@tbte.ca  
Web: www.tbte.ca

## GRAIN SIZE DISTRIBUTION

Project: Culvert Investigation

W P: 5383-11-00

DIST: Muskego HWY: 101



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:  
TILL - SILTS & SANDS & GRAVELS

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 202	1.50	37.5	0.243			14.4	50.2	35.4	
* 202	3.00	25	0.331	0.089		11.1	64.7	24.2	
× 202	4.50	25	0.146			6.1	52.7	41.2	
+ 202	6.00	25	0.248			18.7	48.7	32.6	
◇ 202	10.50	16	0.199	0.078		6.4	64.8	28.8	



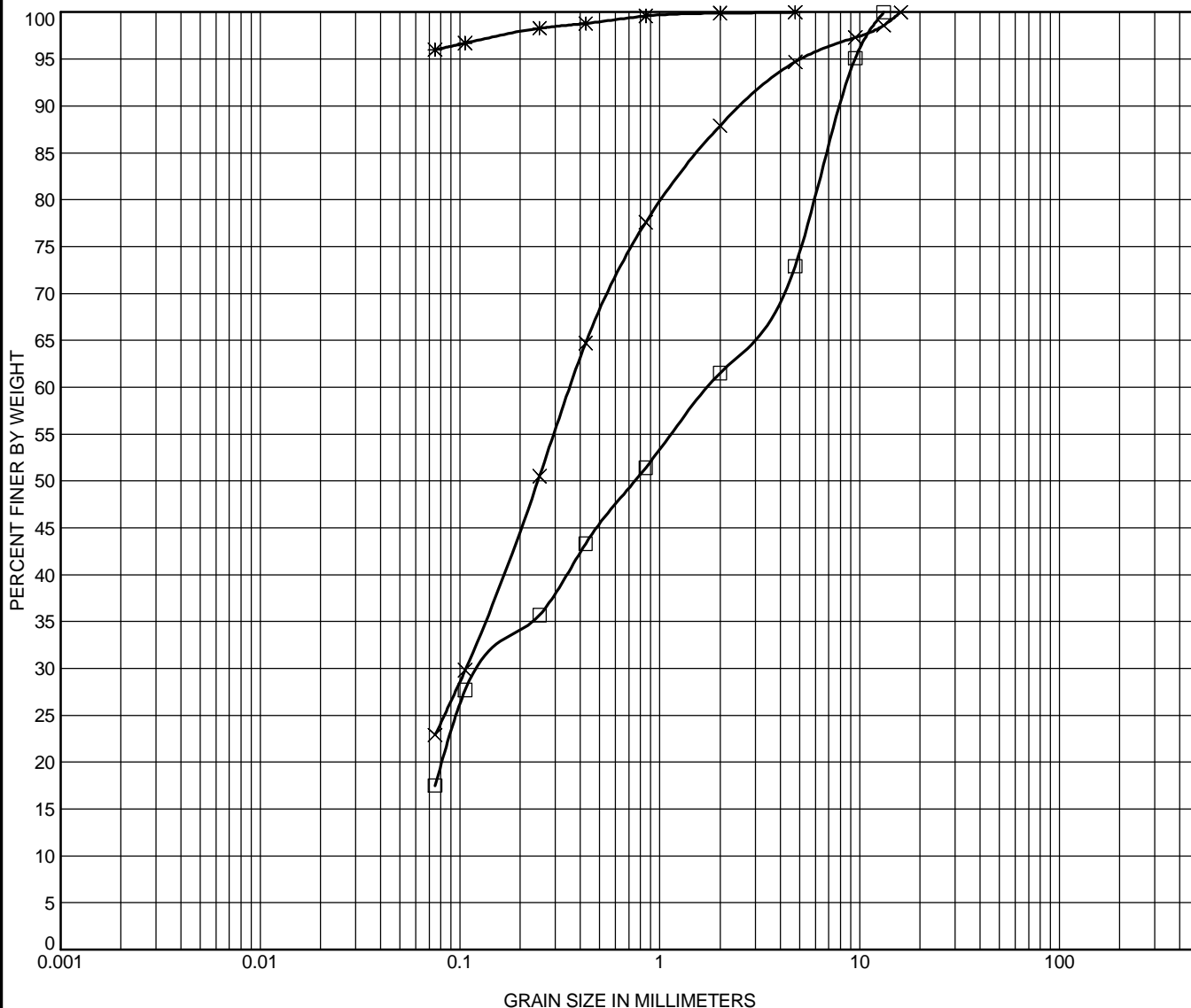
TBT Engineering Ltd.  
1918 Yonge Street  
Thunder Bay, Ontario P7E 6T9  
PH: 807-624-5160  
FX: 807-624-5161  
Email: tbte@tbte.ca  
Web: www.tbte.ca

## GRAIN SIZE DISTRIBUTION

Project: Culvert Investigation

W P: 5383-11-00

DIST: Muskego HWY: 101



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:  
TILL - SILTS & SANDS & GRAVELS

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
□ 202	12.00	13.2	1.761	0.136		27.1	55.4	17.5	
* 203	1.50	4.75				0.0	4.0	96.0	
X 203	3.00	16	0.357	0.107		5.3	71.8	22.9	



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

## GRAIN SIZE DISTRIBUTION

Project: Culvert Investigation

W P: 5383-11-00

DIST: Muskego HWY: 101

## **APPENDIX C**

### **Staging Stability Models**

# Culvert #34 - Stage 1 - Peat Excavation

Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.4

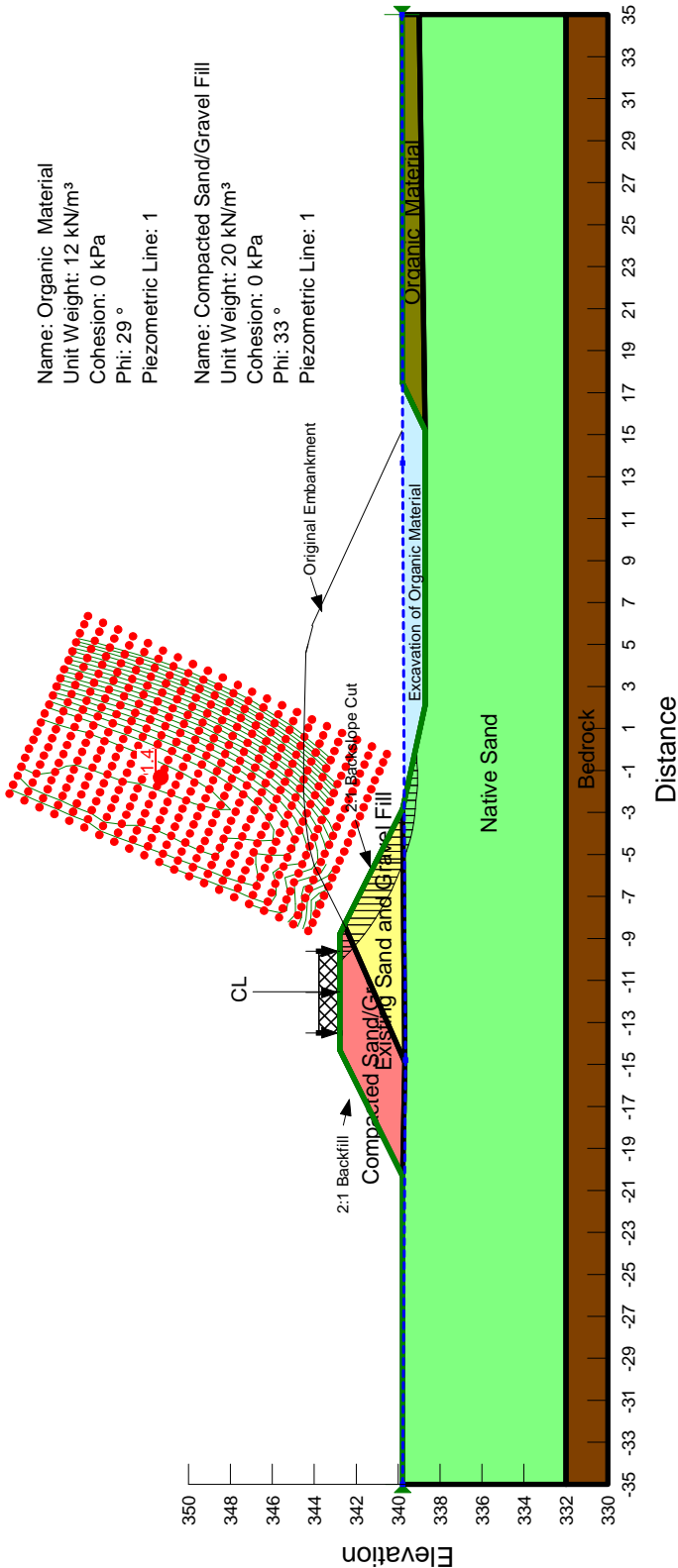
Name: Existing Sand and Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 32 °  
Piezometric Line: 1

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

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1



# Culvert #34 - Stage 1 - Peat Excavation

Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.3

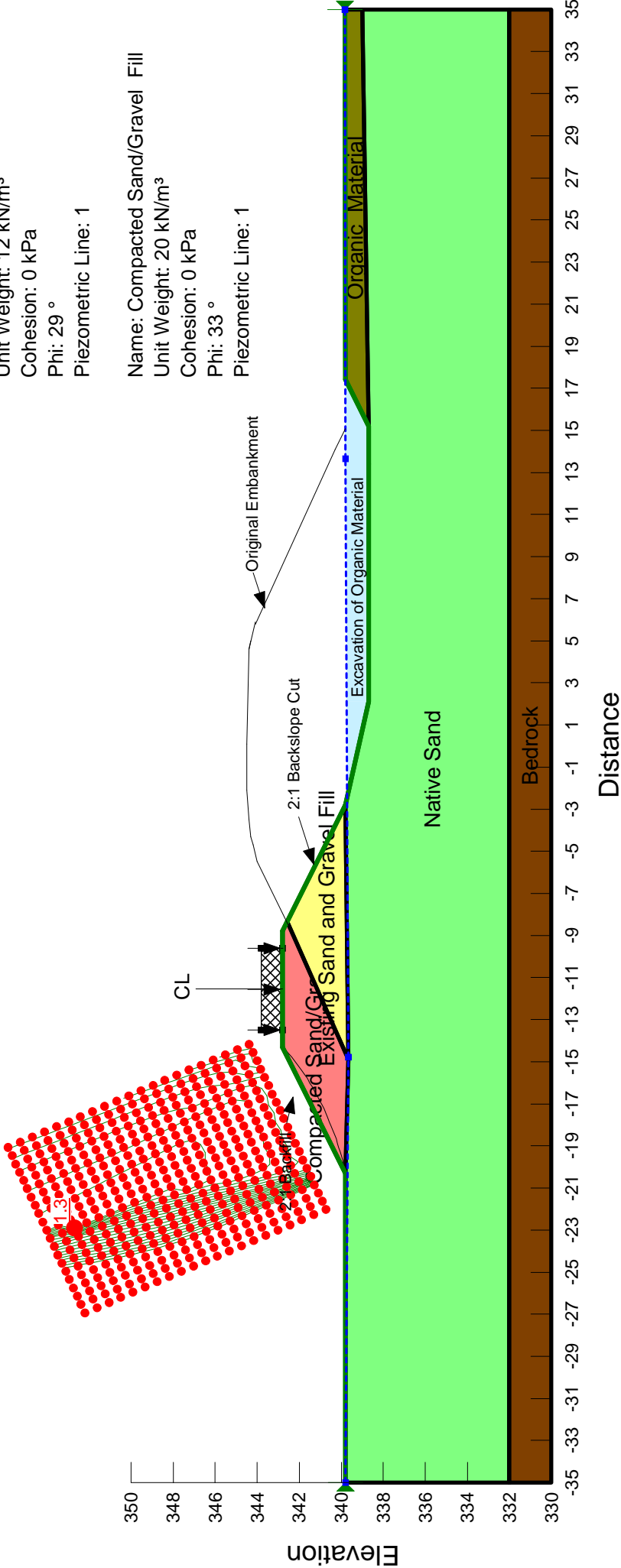
Name: Existing Sand and Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 32 °  
Piezometric Line: 1

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

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1



# Culvert #34 - Stage 2 - Widening Slope 2(H): 1(V)

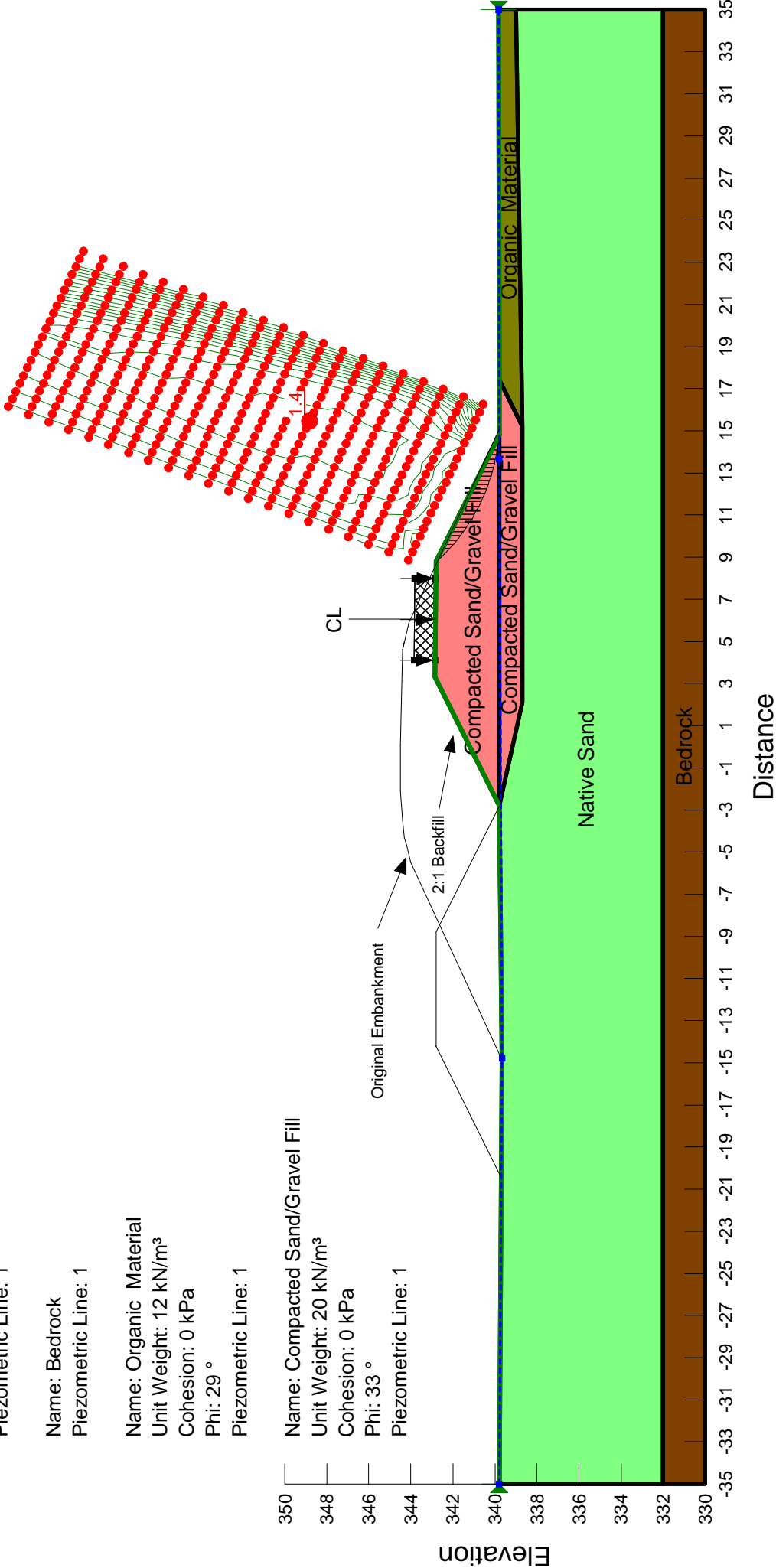
Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.4

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

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1





# Culvert #34 - Stage 2 - Widening Slope 2(H): 1(V)

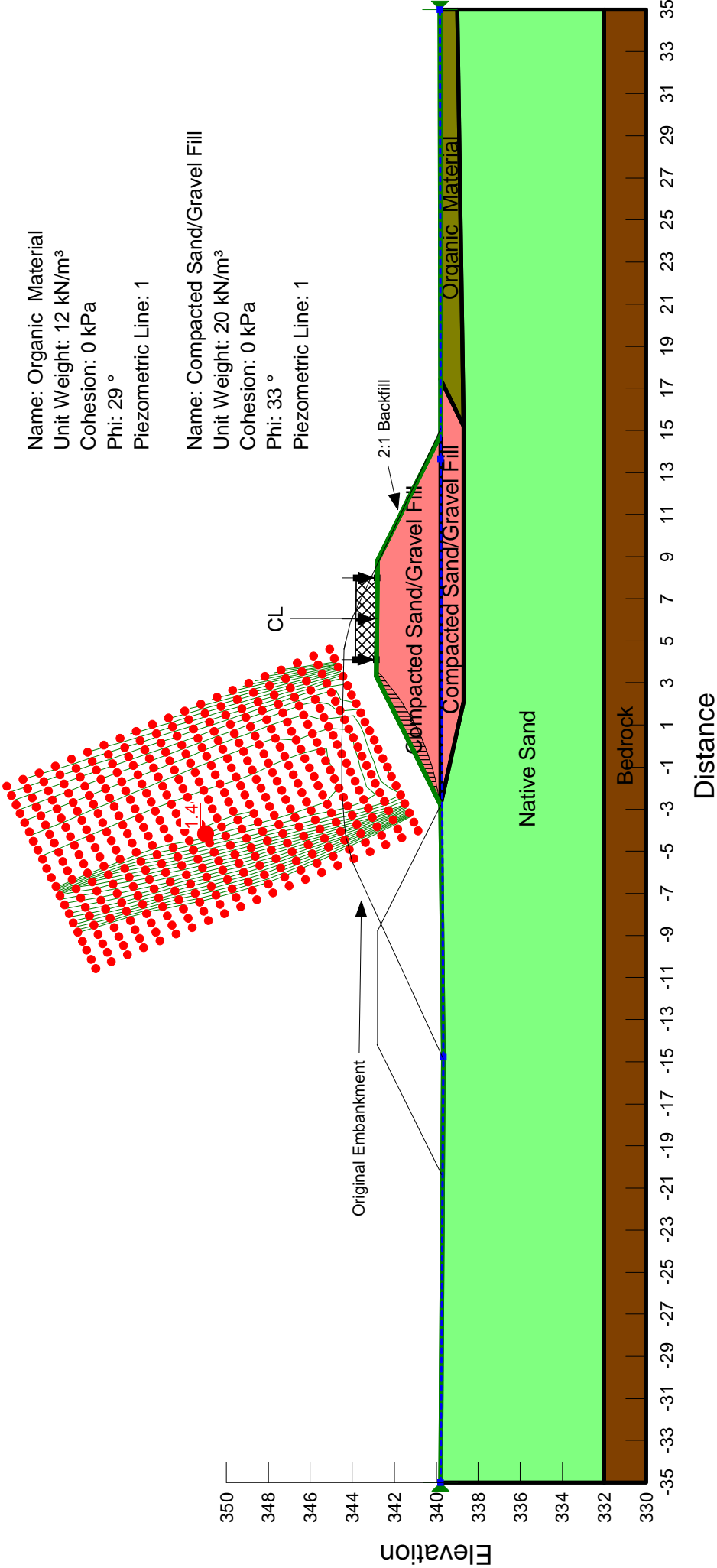
Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.4

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

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1



# Culvert #34 - Stage 3 Widening Slope 2(H):1(V)

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

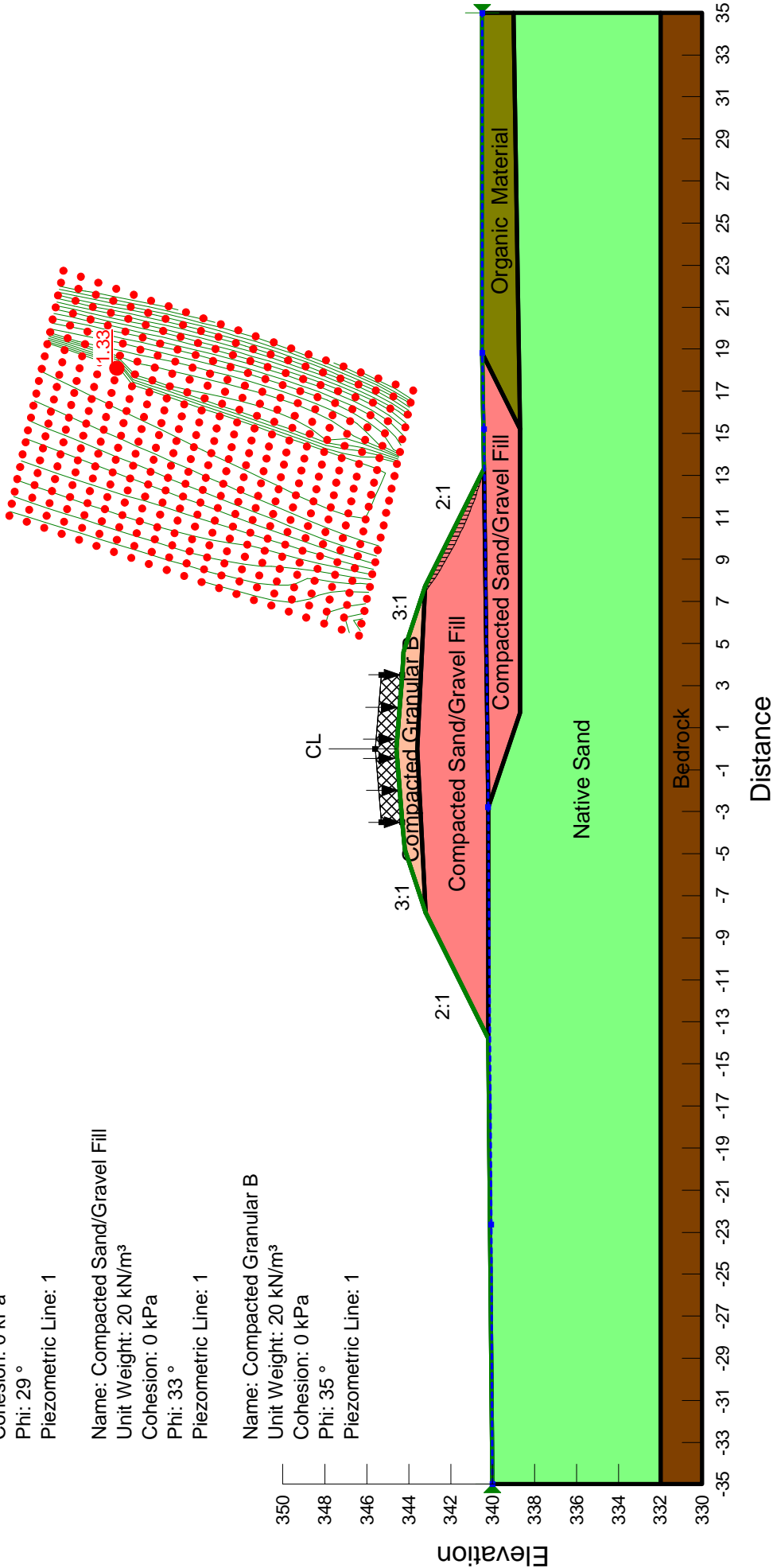
Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.33

Name: Bedrock  
Piezometric Line: 1

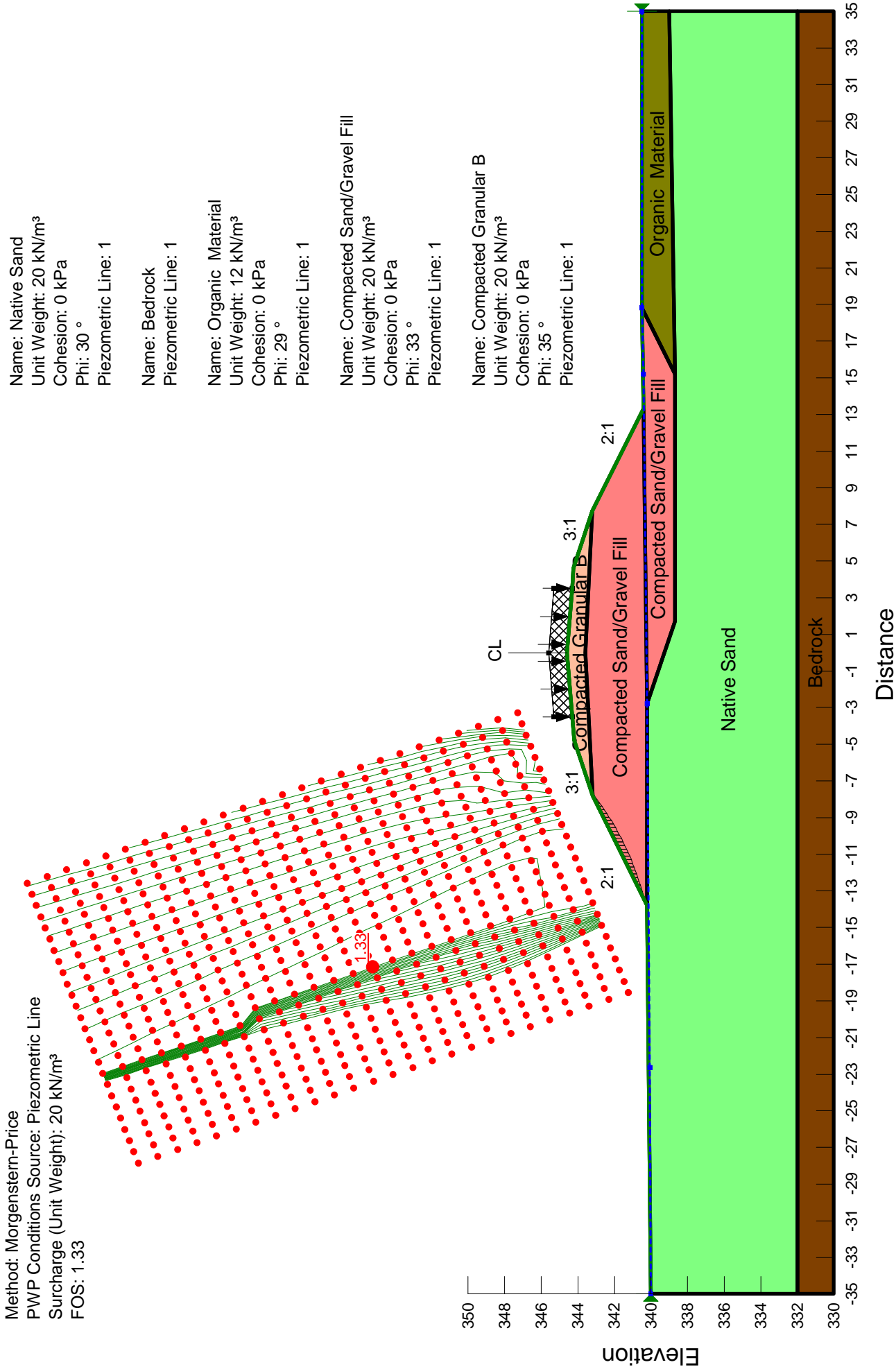
Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1

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



# Culvert #34 - Stage 3 Widening Slope 2(H):1(V)



# Culvert #34 - Stage 3 Widening Slope 2(H):1(V)

Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.42

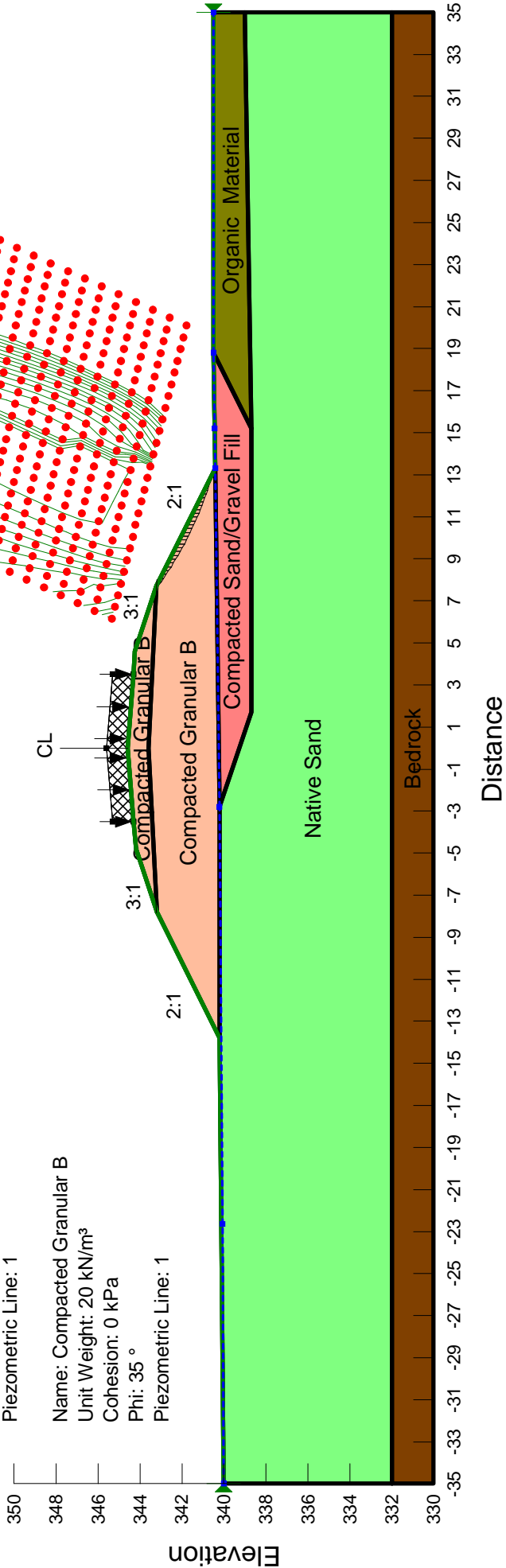
Name: Native Sand  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 30 °  
Piezometric Line: 1

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1

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



# Culvert #34 - Stage 3 Widening Slope 2(H):1(V)

Method: Morgenstern-Price  
PWP Conditions Source: Piezometric Line  
Surcharge (Unit Weight): 20 kN/m³  
FOS: 1.43

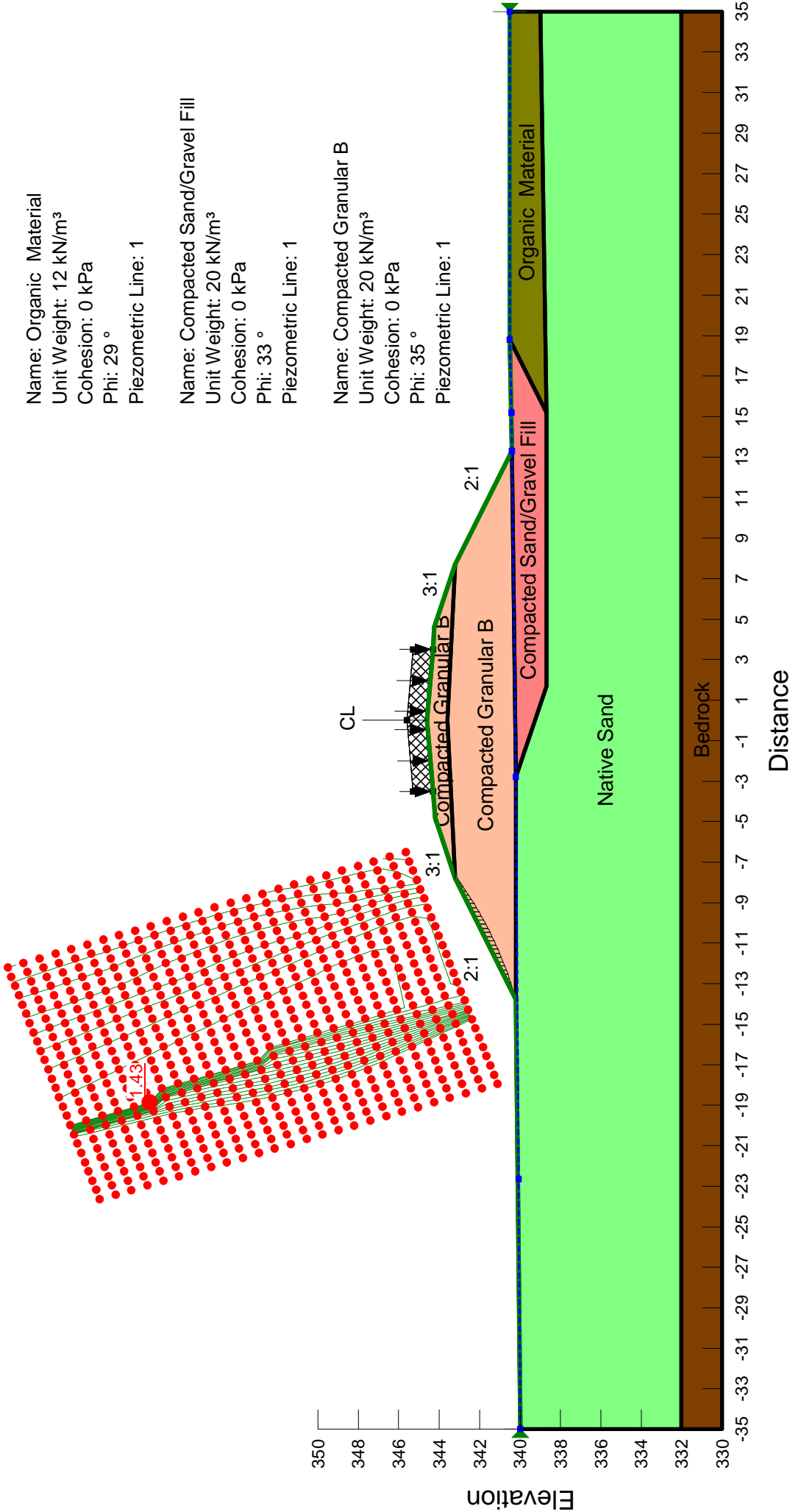
Name: Native Sand  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 30 °  
Piezometric Line: 1

Name: Bedrock  
Piezometric Line: 1

Name: Organic Material  
Unit Weight: 12 kN/m³  
Cohesion: 0 kPa  
Phi: 29 °  
Piezometric Line: 1

Name: Compacted Sand/Gravel Fill  
Unit Weight: 20 kN/m³  
Cohesion: 0 kPa  
Phi: 33 °  
Piezometric Line: 1

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



## **APPENDIX D**

### **Borehole Locations and Soil Strata Drawing**


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

GEOCRES No. 42B-8  
CONT No. 2007-xx  
GWP No. 5383-11-00

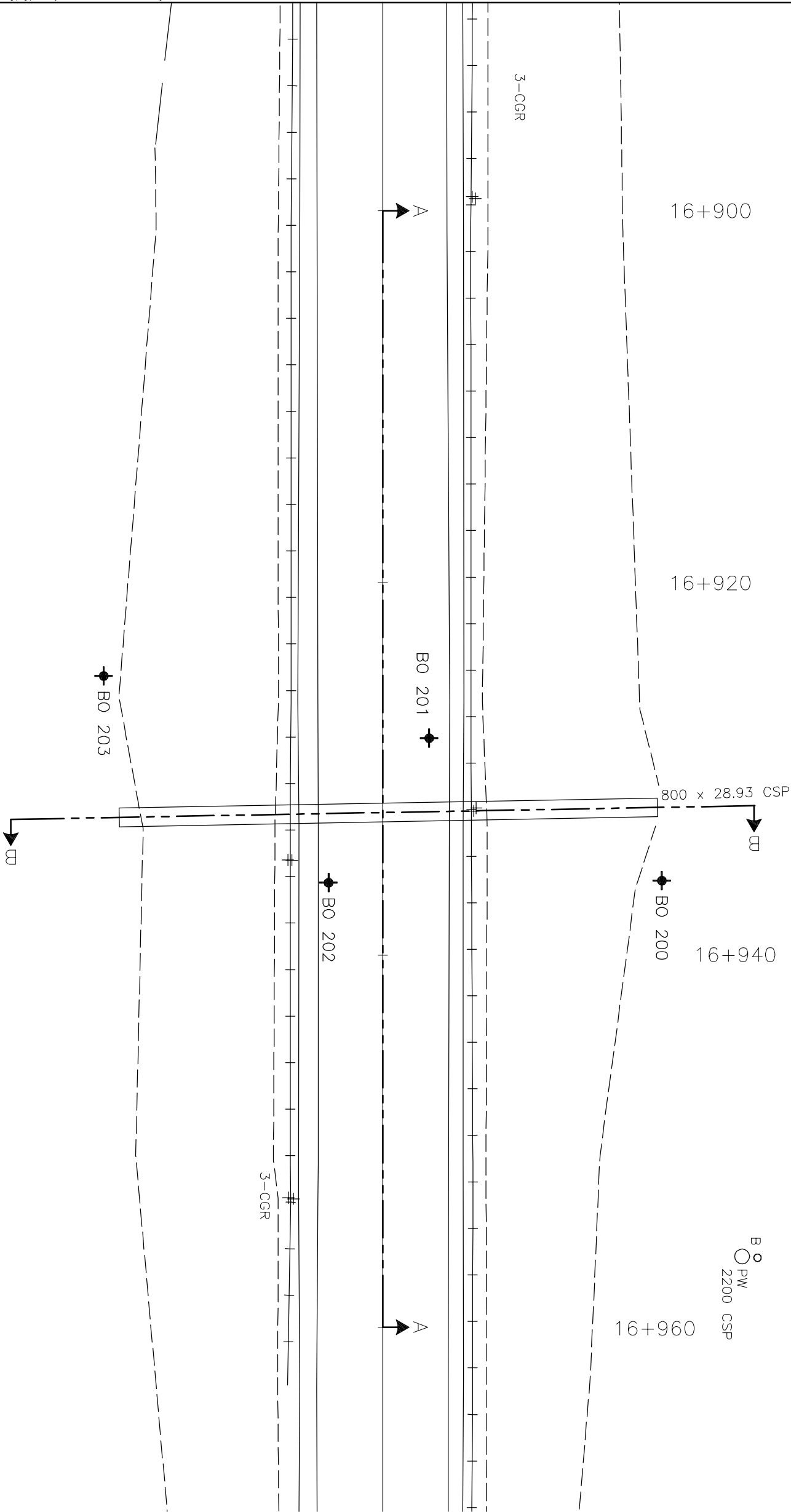
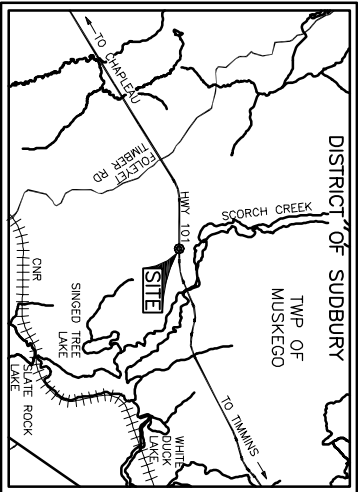


CULVERT 34  
AT HWY 101  
CULVERT INVESTIGATION  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET  
37

  
Ministry of Transportation  
Northwestern Region  
Structural Section

  
TBT ENGINEERING  
CONSULTING GROUP



LEGEND

Borehole			
No	ELEVATION	CO-ORDINATES (NMTM)	
		NORTH	EAST
200	325.3	12 5 344 078	206 388
201	328.5	12 5 344 078	206 373
202	328.3	12 5 344 068	206 373
203	342.6	12 5 344 071	206 357

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

REVISIONS

DESIGN	SS CHK	WH CODE	XXXX-XX	LOAD XX-XX-MXDATE	2013/12/23
DRAWN	TB CHK	WH SITE	N/A	DWG	1

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

GEOCRES No. 42B-8

CONT No. 2007-xx

GWP No. 5383-11-00



CULVERT 34  
AT HWY 101

CULVERT INVESTIGATION

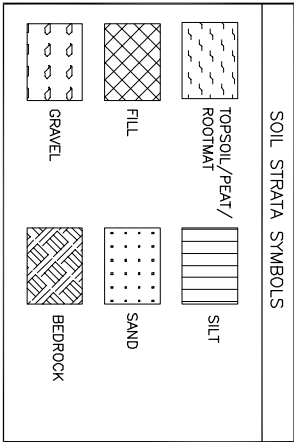
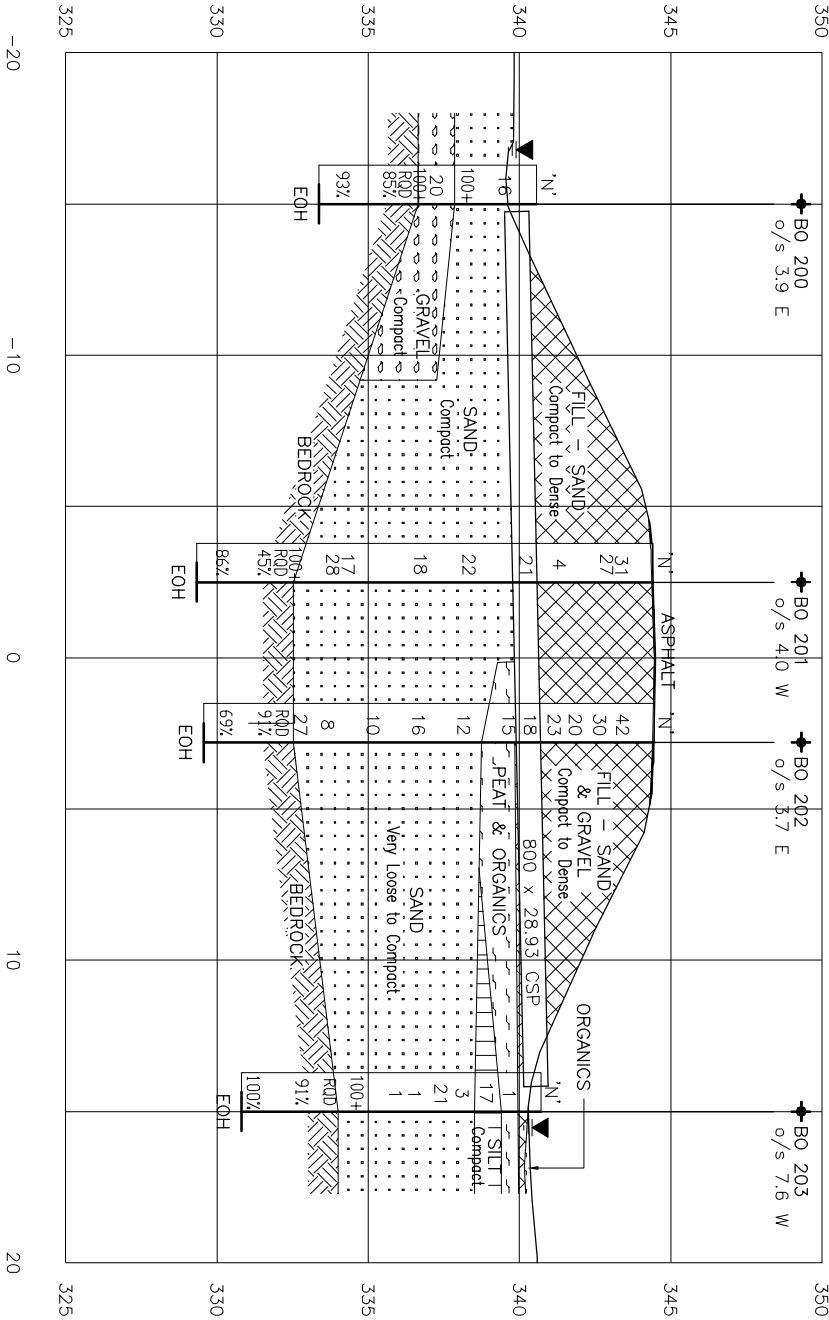
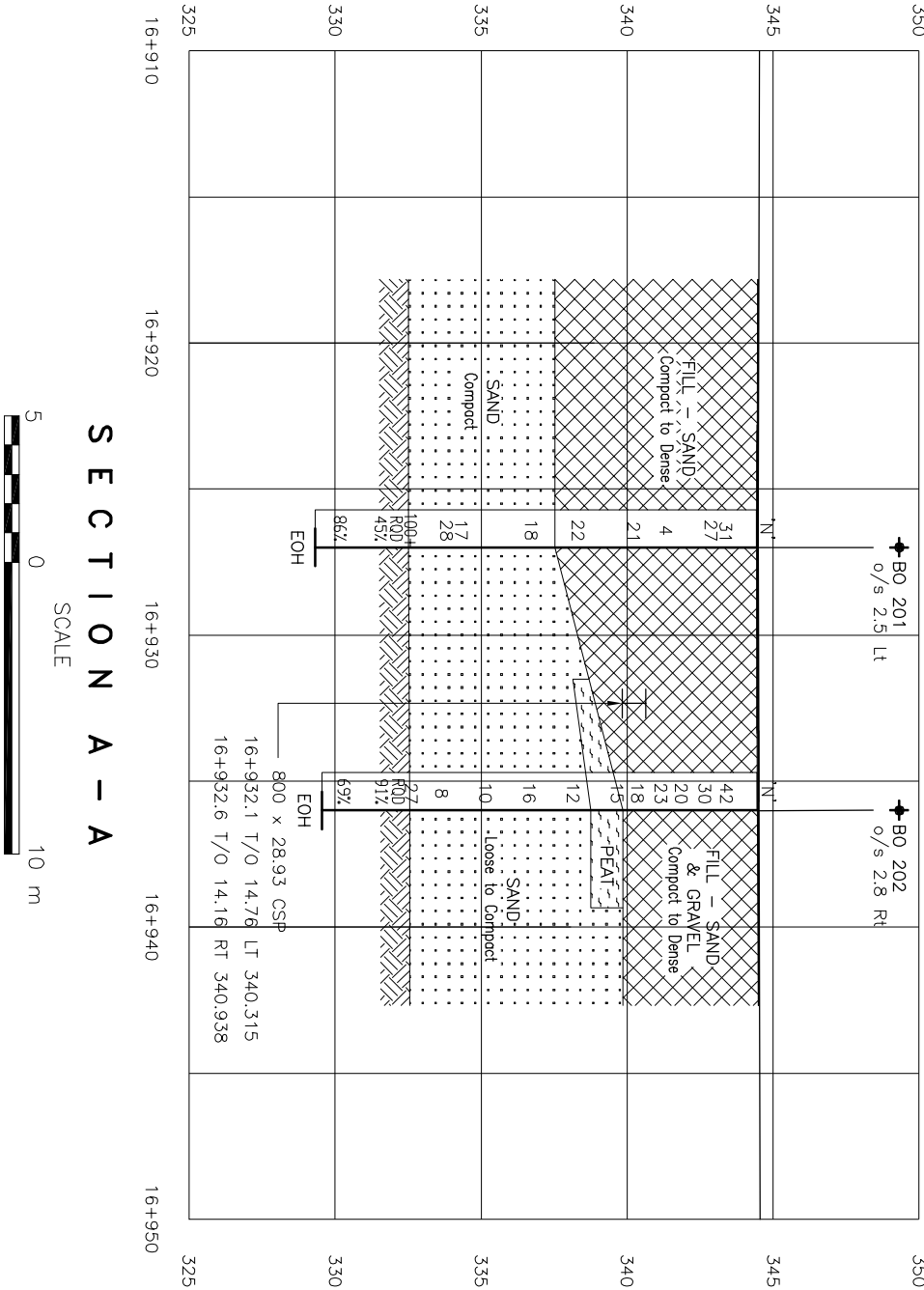
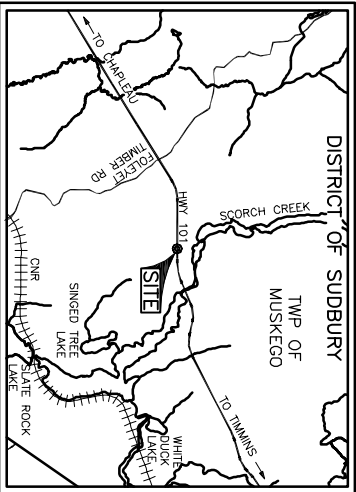
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET  
38

Ministry of Transportation  
Northwestern Region  
Structural Section



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LEGEND			
+	Borehole		
N'	Std Pen Test (Blows/0.3m)		
W	Water Level		
EDH	End of Hole		
No	ELEVATION	CD-COORDINATES (MTR)	
200	325.3	12 5 344 078	206 388
201	328.5	12 5 344 078	206 373
202	328.3	12 5 344 068	206 373
203	342.6	12 5 344 071	206 357

**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	
DESIGN	SS	CHK	WH
DRAWN	TB	CHK	WH
		SITE	N/A
		DWG	2



## **APPENDIX E**

### **Non Standard Special Provisions**

**NOTICE TO CONTRACTOR – Presence of Coarse Aggregates in Existing Embankment**

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Special Provision

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**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.**