FOUNDATION DESIGN REPORT
LOW TO MEDIUM EMBANKMENTS
HIGHWAY 11/17 RED ROCK TO NIPIGON
FROM 4.8 KM WEST OF HWY 628 TO 1.5 KM WEST OF HWY 585
G.W.P. 647-89-00

Geocres Number: 52A-182

VOLUME 1 / 2

Report to

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ENGINEERING DISCUSSION AND RECOMMENDATIONS

1 INTRODUCTION

This report presents interpretation of the geotechnical data provided in the Foundation Investigation Report[1] and presents foundation design recommendations for low to medium embankments required for the proposed four-laning of Highway 11/17, between Red Rock and Nipigon, Ontario.

The overall project consists of the widening of Highway 11/17 from a two-lane undivided highway to a four-lane divided highway. The current section to be widened extends from 4.8 km west of Highway 628 to 1.5 km west of Highway 585 in the Township of Thunder Bay District, Ontario.

Nine areas of embankments along Highway 11/17 are addressed in this report. A summary of each section, including: location, length of section, maximum fill height and generalized stratigraphy, is presented in Table 1 provided in Appendix B through J. For each section the factual data, including borehole logs, laboratory testing results and stratigraphy drawings, have been presented in the Foundation Investigation Report[1].

The project information used for the preparation of this report was provided by MMM Group Limited (MMM) which included plans and profile drawings of the proposed Highway 11/17 alignment as of June 2013. The discussion and recommendations presented in this report are based on the information provided by MMM and the factual data obtained during the course of the investigation.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to MMM under the Ministry of Transportation Ontario (MTO) Agreement Number 6009-E-0019.

2 ENGINEERING ANALYSIS METHODOLOGY

2.1 General

The subsurface conditions were investigated to assess the stability of the proposed embankment foundations, potential settlement issues under the embankment as well as anticipated construction concerns. Analyses carried out were based on soil profiles and soil

[1] Foundation Investigation Report, Low to Medium Embankments, Highway 11/17 Red Rock to Nipigon, From 4.8 km West of Highway 628 to 1.5 km West of Highway 585, GWP 647-89-00, GEOCRES 52A-180

design parameters, selected for critical and unfavorable foundation soil conditions. Geotechnical factors to be addressed for design of embankments on this project include:

- The thickness, extent and engineering properties of the foundation soils, with consideration to the extent and thickness of peat, topsoil, organic deposits compressible and/or excessively soft/loose soils.
- The depth of bedrock or refusal material.
- Embankment material type (rock fill, granular fill or earth fill).
- Embankment geometry including height, side slope angle and requirements for stabilizing berms.
- Construction and post-construction settlement of embankments.
- Construction procedures.

For the purpose of preparing geotechnical design recommendations, a number of assumptions have been made that are consistent with MTO's standard highway design practices:

- Peat, topsoil, organic deposits and other deleterious material will be stripped prior to constructing embankments (OPSS.PROV 206).
- Where new fill is placed against an existing embankment slope or on a sloping ground surface steeper than 3H:1V, the existing fill slope will be benched (OPSD 208.010).
- The embankments will be constructed using rock fill (sources of earth fill are not expected to be available or suitable for reuse on this project). Granular fill may be used for low embankments (< 1.5 m high) and surcharge construction (if applicable).
- Embankments will be constructed as outlined in Section 3.2 with side slopes not steeper than:
  - 1.25H:1V for rock fill
  - 2H:1V for granular fill, and
  - 1.5H:1V for temporary surcharge
- A transition treatment will be provided between adjoining rock fill and granular fill embankment materials (OPSD 205.040).
- Stabilizing berms (if applicable) will be constructed using rock fill. No further material or stockpiling will be allowed above the berm and embankment design grades without further analysis.
- A transition will be provided between rock cuts and granular fills (OPSD 205.030) and rock cuts and rock fills (OPSD 205.020), where applicable
- Permanent drainage and erosion protection will be provided for all earth cuts and granular embankments slopes.

2.2 Stability Analysis

Stability analyses were carried out for embankments not founded on bedrock under both static and seismic loading conditions. Based on consideration of the risk involved and past experience with highway embankment design/monitoring, the following factors of safety are considered appropriate:

Foundation Soil Type	Minimum Recommended Factor of Safety		
	Short Term	Long Term	Seismic
Cohesionless	1.3	1.3	>1.0
Cohesive	1.3	1.5	>1.0

Stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 7) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses.

The results of stability analysis are summarized in Table A2 and the input parameters are summarized in Table A4 of Appendix A. The soil model used in the stability analyses, including soil stratigraphy, engineering properties, groundwater conditions, and embankment geometry for selected analysis are shown in their respective Appendix.

2.3 Settlement Analysis

2.3.1 Foundation Settlement

Settlement analyses for embankments not founded on bedrock were carried out to assess the immediate (elastic) settlement, magnitude and rate of primary consolidation settlement of fine grained foundation soils occurring during construction and post-construction (long-term) settlements of the foundation soils under the self-weight of the imposed new embankment materials.

In accordance with MTO's document "Embankment Settlement Criteria for Design" (March 2, 2010), one of the criteria adopted for embankment design is to limit the post-construction settlement to the maximum permissible settlement of 100 mm or less, within 20 years following paving, with a differential settlement allowance of 200:1.

Immediate settlements due to compression of the embankment foundation soils have been estimated based on elastic theory as described in CBHDC Commentary Section C6.6.

Settlement analyses were carried out utilizing the commercially available settlement program Settle^{3D} (Version 2) developed by Rocscience Inc. with the option of Terzaghi's one-dimensional consolidation theory and three dimensional Boussinesq stress computation.

The engineering parameters used in the analyses were determined by laboratory oedometer tests conducted during the current study and soil index correlations developed during current and past projects.

The results of the settlement analysis of the foundation soils are provided in Table A3 of Appendix A. The estimated magnitudes and rates of settlement are considered approximate and may vary along and across the highway alignment subject to the thickness of compressible layers at a particular location, variations in the consolidation characteristics of the cohesive deposits with depth and location, layer boundary conditions, variations in the relative density of cohesionless soils, the presence of organics or silt/sand/clay partings within the various strata, the depth to bedrock, the height of embankment, and degree of compaction achieved in the fill.

Assessment of the predicted differential and long-term settlements for culvert foundations is provided in a separate report[2] and are not addressed herein.

2.3.2 Embankment Compression

An assessment of the short and long-term compression of fill materials under self-weight was also completed. Settlement of the road grade on rock fill, due to particle re-orientation and degradation of the interparticle contacts, is expected to continue at a decreasing rate for many years. In accordance with the MTO document "Post-Construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity" (April 12, 2010), the magnitude of this settlement in compacted rock fill is expected to range from 0.5 to 1.0% of the embankment height within 1 year of embankment construction (90% in the first 6 months), and a further 0.1% of the embankment height after the 1 year period. For dumped rock fill (placed under the water level), these settlement values would be approximately doubled. The estimated settlement of granular fill embankments due to compression of the compacted fill is 0.5% of the embankment height and is expected to occur after fill placement.

The estimated settlements due to embankment compression at the maximum height of embankment in each section are included in Table A3 and the input parameters are summarized in Table A4 of Appendix A. Embankment and platform width must be overbuilt to allow for the anticipated foundation settlement and embankment compression.

2.4 Seismic Considerations

The stability analysis was checked assuming a horizontal peak ground acceleration (PGA) of 0.011g, where g is the acceleration due to gravity. The PGA has been obtained from the CHBDC. The PGA value corresponds to a 10% probability of exceedance in 50 years.

2.5 Design Alternatives

Where standard embankment construction was not feasible, supplementary analyses were carried out to assess design alternatives. An iterative approach was applied for embankment design to produce a practical and cost-effective solution achieving acceptable factors of safety against slope instability and limiting post-construction settlement to meet MTO's guidelines

[2] Foundation Design Report, Culverts, Supplementary Embankments and Cut Slopes, Highway 11/17 Red Rock to Nipigon, From 4.8 km West of Highway 628 to 1.5 km West of Highway 585, GWP 647-89-00, GEOCRES 52A-184

Design alternatives considered during analysis of the embankments typically included the following:

- Full and/or partial sub-excavation of soft cohesive foundation soils in addition to stripping of the peat, topsoil and organic deposits to improve foundation stability and reduce settlement.
- Provision of stabilizing berms to improve global stability.
- Ground improvement techniques such as providing a waiting period to allow for foundation preloading and surcharging.
- Construction techniques such as wick drain installation to accelerate settlement or staged construction to maintain stability.
- Reduction in embankment loading such as the use of lightweight fill.

The analyses carried out for this project have indicated that, in addition to stripping peat, topsoil and organic deposits, a combination of the foundation treatment measures listed above may be required at several sites to address stability and/or settlement issues.

2.6 Frost Protection

The design depth of frost penetration at this project 2.3 m. Accordingly a minimum of 2.3 m of earth cover must be provided to serve as frost protection (where required).

3 EMBANKMENT DESIGN AND CONSTRUCTION

3.1 Site Specific Discussion and Recommended Treatment

Results of the stability and settlement analyses carried out at selected critical locations are summarized in Table A2 and A3, respectively, in Appendix A. The soil properties used for engineering analysis for each section are summarized in Table A4 of Appendix A.

Discussions regarding the design alternatives for each specific embankment section are provided below. To mitigate the effects of the settlement for new embankments, it is recommended that in a number of cases, there should be an allowance for waiting period(s) between embankment stages and in advance of pavement construction. Medium to high fills, fills crossing swamps and multi-stage embankment construction should be scheduled to commence as early as practical (i.e. at the beginning of the contract period) to allow for the required waiting period(s).

3.1.1 Highway 11/17 EBL and WBL, Sta. 12+050 to 12+100

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise silt to sandy silt underlain by soft to firm silty clay followed by silt to clayey silt. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 10.4 to 15.1 m below the original ground surface.

For the proposed maximum embankment height of 5.6 m above the existing ground surface constructed as outlined in Section 2.1 and 3.2, an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure B1 and B2).

Settlement analysis to reduce post construction settlement for two design options are presented:

- Single stage embankment construction with no surcharge, allowing for an anticipated 5 and 3 month waiting period for the EBL (Figure B4) and WBL, respectively, between completion of fill placement and paving
- Single stage EBL embankment construction with a 1 m surcharge, allowing for a 3 month waiting period between completion of fill placement and paving (Figure B3)

For both design options, the estimated foundation settlement during construction, post-construction foundation settlement and embankment fill compression are summarized in Table A3.

Based on the analysis results, for an embankment constructed directly over the inorganic foundation soils, a 5 and 3 month waiting period is recommended for the EBL and WBL, respectively, between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to occur. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and the magnitude and time-rate of settlement.

It is also feasible to construct the EBL embankment directly over the inorganic foundation soils with a 1.0 m surcharge to reduce the waiting time to 3 months between completions of fill placement and surcharge removal. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and the magnitude and time-rate of settlement.

Embankment construction should be scheduled to commence as early as practical (i.e. at the beginning of the contract period) to allow for the required waiting period. The embankment in this section must be overbuilt to accommodate the predicted settlement. The rate of fill placement and the actual time for waiting prior to paving will be governed by results from the instrumentation monitoring program and may be longer than provided herein. Further recommendations and a suggested NSSP for geotechnical instrumentation monitoring have been prepared in Appendix J.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional fill and excess soil management.

3.1.2 Highway 11/17 EBL and WBL, Sta. 12+170 to 12+270

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise soft to stiff silty clay with an interlayer of firm to stiff clayey silt to silt. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 5.8 to 12.5 m below the original ground surface.

For the proposed maximum embankment height of 5.6 m above the existing ground surface constructed as outlined in Section 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure C1 and C2).

Settlement analysis to reduce post construction settlement for two design options are presented:

- Single stage embankment construction with no surcharge, allowing for an anticipated 10 and 3 month waiting period for the EBL and WBL, respectively, between completion of fill placement and paving (Figure C4 and C5)
- Single stage EBL embankment construction with a 1 m surcharge, allowing for a 6 month waiting period between completion of fill placement and paving. However, this option will require a stabilizing berm (Figure C3) to maintain embankment stability.

For both design options, the estimated foundation settlement during construction, post-construction foundation settlement and embankment fill compression are summarized in Table A3.

Based on the analysis results, for an embankment construction directly over the non organic foundation soils, a 10 and 3 months waiting period is recommended for the EBL and WBL, respectively, between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to occur. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and the magnitude and time-rate of settlement.

It is also feasible to construct the EBL embankment directly over the inorganic foundation soils with a 1.0 m surcharge to reduce the waiting time to 6 months between completion of fill placement and surcharge removal, provided that stabilizing berms are constructed prior to placing surcharge. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and the magnitude and time-rate of settlement.

Embankment construction should be scheduled to commence as early as practical (i.e. at the beginning of the contract period) to allow for the required waiting period. The embankment in this section must be overbuilt to accommodate the predicted settlement. The rate of fill placement and the actual time for waiting prior to paving will be governed by results from the instrumentation monitoring program and may be longer than provided herein. Further recommendations and a suggested NSSP for geotechnical instrumentation monitoring have been prepared in Appendix J.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional rock fill and excess soil management.

3.1.3 Highway 11/17 EBL, Sta. 12+420 to 12+540

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the EBL embankment foundation will essentially comprise sandy to clayey silt underlain by soft to stiff silty clay with trace sand which was further underlain by gravelly sand to sand and gravel. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 9.9 to 14.9 m below the original ground surface.

For the proposed maximum EBL embankment height of 3.2 m above the existing ground surface constructed as outlined in Section 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure D1 and D2).

The estimated foundation settlement during construction, post-construction foundation settlement (Figure D3) and embankment fill compression are summarized in Table A3. Based on the analysis results, for the EBL embankment construction directly over the inorganic foundation soils, a 2 months waiting period is recommended between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to occur. The embankment in this section must be overbuilt to accommodate the predicted settlement. Due to the magnitude and duration of the predicted settlement, geotechnical instrumentation monitoring is not considered a requirement for this site.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional rock fill and excess soil management.

3.1.4 Highway 11/17 EBL, Sta. 12+650 to 13+100 and Highway 11/17 WBL, Sta. 12+900 to 13+100

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise surficial layers silt and sand, underlain by a soft to stiff silty clay deposit and a lower sand to sand and gravel deposit. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 2.8 to 29.2 m below the original ground surface.

For the proposed maximum embankment height of 4.1 m above the existing ground surface constructed as outlined in Section 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure E1 and E2).

The estimated foundation settlement during construction, post-construction foundation settlement (Figure E3 and E4) and embankment fill compression are summarized in Table A3. Based on the analysis results, for an embankment constructed directly over the inorganic foundation soils, a 5 month waiting period is recommended between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to occur. The embankment in this section must be overbuilt to accommodate the predicted settlement. Due to the magnitude and duration of the predicted settlement, geotechnical instrumentation monitoring is not considered a requirement for this site.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional rock fill and excess soil management.

3.1.5 Highway 11/17 EBL and WBL, Sta. 13+300 to 13+450 (Itzcaulde Creek)

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise existing fill overlying a thick layer of soft

to stiff silty clay, underlain by deposits of silt and sand, and bedrock. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 13.7 to 20.2 m below the original ground surface.

To minimize the potential for disturbance of the existing lanes, the excavation adjacent to the existing embankment should not extend below a line inclined at 1H:1V from the toe of the existing embankment slope. Furthermore, the excavation should be limited to peat, topsoil and organic deposits and the excavation and backfilling must be carried out in section no longer than 15 m, unless roadway protection is provided.

For the proposed maximum embankment height of approximately 6.7 m above the existing ground surface under the future eastbound lane, the resulting factors of safety against slope instability was less than the minimum acceptable value of 1.3, indicating that standard embankment construction is not feasible at this location.

Staged embankment construction with a waiting period between stages in conjunction with wick drains installation, construction of stabilizing berms and placement of surcharge was found to be feasible to maintain embankment stability. To meet MTO's requirement for post-construction settlement adjacent to a non-settling structure, as outlined in "Embankment Settlement Criteria for Design" (March 2, 2010), placement of surcharge with a waiting time and incorporating EPS backfill following the waiting period are also required to limit post construction (long-term) settlement to 25 mm adjacent to the Itzcaulde Creek culvert structure.

For the maximum embankment height of 6.7 m with 1.0 m of surcharge the construction approach, excluding traffic staging requirements for the proposed four-laning procedure, will require a total of two stages of construction with a 6 month waiting period following each stage and would be as follows:

- remove peat, topsoil and organic deposits
- construct portion of sheet pile culvert carrying Itzcaulde Creek (as discussed in a separate report, see note below) under new embankment footprint
- install drainage blanket on top of the native clay to 1.0 m above the original ground surface or 1 m above the surface water level, whichever is higher, and 1 m past the lateral extent of the wick drain layout
- install wick drains in a 1.5 m centre-to-centre triangular spacing
- install geotechnical monitoring instrumentation and record baseline readings
- Stage 1 Construction
    - simultaneously construct stabilizing berm (12.5 m wide, 2.5 m high) and embankment with rock fill and granular fill (within the limits of EPS) to a maximum embankment height of 6.5 m (maximum elevation of the design pavement elevation) above existing ground surface
    - provide a 6 month waiting period following placement of fill for dissipation of excess pore pressures and increase in strength of the foundation clay
- Stage 2 Construction
    - place additional rock fill or granular fill to bring the embankment up to Stage 1 design elevation to compensate for the settlement that has occurred

  - place an additional 1.0 m of granular fill (surcharge) above Stage 1 elevation
  - provide a 6 month waiting period following placement of fill for dissipation of excess pore pressures and increase in strength of the foundation clay
- Stage 3 Construction (required in approach embankments to the culvert)
  - after the final waiting period, remove the surcharge and then subexcavate backfill adjacent to the sheet pile walls to place 2.5 m thickness of EPS and pavement structure. Extend the full 2.5 m thickness of EPS in both directions away from the culvert walls for a distance of 5.0 m, then reduced EPS thickness at a taper of 5H:1V beyond this point
- construct pavement structure

Embankment fill within the limits of the culvert and EPS must comprise granular material (not rock fill) to enable sub-excavation adjacent to the culvert and EPS placement after the surcharge period. The final EPS arrangement must have a minimum of 1.0 m granular cover. To enhance drainage of the backfill surrounding the EPS, a perforated subdrain should be installed adjacent to the culvert below the base of the EPS. Additional details for the sheet pile culvert design and EPS backfill within the approach embankments to the culvert are discussed in a separate report[3].

For an embankment constructed as outlined above and in Sections 2.1 and 3.2 the computed short term factors of safety are greater than 1.3 (Figures F1 and F2), at the completion of fill placement for both stages in the proposed construction sequence. The long term factor of safety is also computed to be greater than 1.5 (Figure F3).

The estimated foundation settlement during construction, post-construction foundation settlement (Figure F4) and embankment fill compression for an embankment construction method as outlined above are summarized in Table A3. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after each stage of embankment construction and the magnitude and time rate of settlement.

Embankment construction should be scheduled to commence as early as practical (i.e. at the beginning of the contract period) to allow for the required waiting periods. Delaying of surcharge placement is required to maintain stability of the embankment foundation during construction. The embankment in this section must be overbuilt to accommodate the large predicted settlement. The rate of fill placement and actual time for waiting prior to surcharge removal will be governed by results from the instrumentation monitoring program and may be longer than provided herein. Further recommendations and a suggested NSSP for geotechnical instrumentation monitoring have been prepared in Appendix K.

3.1.6 Highway 11/17 EBL, Sta. 16+250 to 16+460

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the EBL embankment foundation will essentially comprise soft to firm silty clay underlain by sand to

[3] Foundation Investigation and Design Report, Itzcaulde Creek Culvert, Highway 11/17 Red Rock to Nipigon, From 4.8 km West of Highway 628 to 1.5 km West of Highway 585, GWP 647-89-00, Site No. 48C-352, GEOCRES No. 48C-179

sand and gravel. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 4.6 to 13.3 m below the original ground surface.

For the proposed maximum EBL embankment height of 3.7 m above the existing ground surface constructed as outlined in Section 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure G1 and G2).

The estimated foundation settlement during construction, post-construction foundation settlement (Figure G3) and embankment fill compression are summarized in Table A3. Based on the analysis results, for the EBL embankment constructed directly over the inorganic foundation soils, a 4 month waiting period is recommended between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to occur. The embankment in this section must be overbuilt to accommodate the predicted settlement. Due to the magnitude and duration of the predicted settlement, geotechnical instrumentation monitoring is not considered a requirement for this site.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional rock fill and excess soil management.

3.1.7 Highway 11/17 EBL and WBL, Sta. 16+830 to 16+940

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise soft to stiff silty clay underlain by sand. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 7.8 to 14.9 m below the original ground surface.

For the proposed maximum embankment height of 4.1 m above the existing ground surface constructed as outlined in Sections 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.3 for short-term (undrained) conditions and 1.5 for long-term (drained) conditions (Figure H1 and H2).

Settlement analysis to reduce post construction settlement for two design options are presented:

- Single stage embankment construction with no surcharge, allowing for an anticipated 12 month waiting period between completion of fill placement and paving (Figure H4)
- Single stage embankment construction with a 1 m, allowing for a 6 month waiting period between completion of fill placement and paving. However, this option will require a stabilizing berm (Figure H3) to maintain embankment stability.

For both design options, the estimated foundation settlement during construction, post-construction foundation settlement and embankment fill compression are summarized in Table A3.

Based on the analysis results, for an embankment constructed directly over the inorganic foundation soils, a 12 month waiting period is recommended between completion of fill placement and paving to allow a portion of the time dependent foundation settlement to

occur. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and the magnitude and time-rate of settlement.

It is also feasible to construct the embankment directly over the inorganic foundations soils with a 1.0 m surcharge to reduce the waiting time to 6 months between completion of fill placement and surcharge removal, provided that stabilizing berms are constructed prior to placing surcharge. Geotechnical instrumentation monitoring will be required at this site to confirm the waiting period after fill placement and magnitude and time-rate of settlement.

Embankment construction should be scheduled to commence as early as practical (i.e. at the beginning of the contract period) to allow for the required waiting period. The embankment in this section must be overbuilt to accommodate the predicted settlement. The rate of fill placement and the actual time for waiting prior to paving will be governed by results from the instrumentation monitoring program and may be longer than provided herein. Further recommendations and a suggested NSSP for geotechnical instrumentation monitoring have been prepared in Appendix J.

It is not considered cost effective to excavate and remove the clay due to the depths of excavation required to remove the clay, the associated construction costs of additional rock fill and excess soil management.

3.1.8 Highway 11/17 EBL and WBL, Sta. 18+450 to 18+500

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise firm to stiff clayey silt underlain by sand. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 9.2 to 12.9 m below the original ground surface.

Due to the thickness of peat present at this site, the lateral extent of the peat excavation should extend beyond the footprint of the embankments at an inclination of 1H:1V or flatter from the intersection of the original ground and design embankment toe to the base of the peat layer.

For the proposed maximum embankment height of 2.3 m above the existing ground surface constructed as outlined in Sections 2.1 and 3.2 an acceptable factor of safety against slope instability was computed at greater than 1.5 for short term and long-term conditions (Figure I1).

The estimated foundation settlement during construction, post-construction foundation settlement and embankment fill compression are summarized in Table A3. Based on the analysis results, an embankment constructed directly over the inorganic foundation soils, a 3 month waiting period is recommended between completion of fill placement and paving to allow foundation settlement to occur is considered feasible. The embankment in this section must be overbuilt to accommodate the predicted settlement. Due to the magnitude and duration of the predicted settlement, geotechnical instrumentation monitoring is not considered a requirement for this site.

3.1.9 Highway 11/17 EBL and WBL, Sta. 19+850 to 19+900

After removal of peat, topsoil and organic deposits as outlined in Section 3.2 the embankment foundation will essentially comprise sand with an interlayer of silt. Auger or DCPT refusal on inferred bedrock was encountered at depths ranging from 2.2 to 5.6 m below the original ground surface.

For the proposed maximum embankment height of 4.3 m above the existing ground surface, no short term or long term global stability issues are anticipated provided proper construction methods are used as outlined in Sections 2.1 and 3.2.

The estimated foundation settlement during construction, post-construction foundation settlement and embankment fill compression are summarized in Table A3 and are less than MTO's guideline of 100 mm. Based on the analysis results, an embankment constructed directly over the inorganic foundation soils can be constructed without a waiting period between completion of fill placement of paving. The embankment in this section must be overbuilt to accommodate the predicted settlement. Due to the magnitude and duration of the predicted settlement, geotechnical instrumentation monitoring is not considered a requirement for this site.

3.2 Subexcavation of Peat, Topsoil and Organic Deposits

It is standard procedure on MTO projects to sub-excavate all peat deposits not exceeding 6 m in depth from within the footprint of the embankment, and backfill the resulting excavation with rock or granular fill. Since the depth of peat soils within the investigated areas in this report are less than 6.0 m, it is recommended that all peat soils be sub-excavated from within the proposed footprint of all embankments and any associated stabilization berms. All topsoil and organic deposits should also be stripped from under the proposed footprint of the embankment and berms (where applicable).

The anticipated and/or recommended depth of peat, topsoil and organic deposits to be removed along the proposed alignments is also summarized in Table A1 in Appendix A and are based on the thickness noted at the borehole locations. Subexcavation depths may vary at location between and away from the boreholes. The subexcavated foundation area should be backfilled with rock or granular material as described later in this report.

Removal of peat, topsoil and organic deposits may be carried out below the surface water and groundwater levels. Construction operations should include measures such as temporary dewatering and drainage/lowering of ponded water wherever practical (for example, where excavation depths are small), and provision of equipment suitable for excavation below the water level where dewatering is not practical. The surface water depths and depths to groundwater at the time of construction will vary depending upon seasonal fluctuations, rainfall patterns and swamp outlet conditions that may be impacted by beaver dams. Placement of rock fill is recommended where standing water is encountered and wick drain installation is not required.

In the stability and settlement analyses, it has been assumed that the peat, topsoil and organic deposits have been removed and replaced with rock or granular material as appropriate.

3.3 Subgrade Preparation and Embankment Construction Restriction

It should be noted that where fine-grained silt and clay soils are exposed following clearing, grubbing and stripping activities under the proposed embankment and stabilization berms (where required), these native soils are soft and moisture sensitive and may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain good trafficability of the subgrade for construction equipment. The contractor must be advised of this issue in the tender documents so that he may adjust his operations to suit the difficult subgrade conditions.

A number of embankment construction restrictions are noted in the Operational Constraints (General) – Construction Staging which will be included in the tender documents. These include construction of temporary haul roads, not allowing storing or stockpiling material and/or equipment on the stabilization berms or the main embankment. Operational Constraints (Foundation) – Surcharge and Waiting Periods are included in Appendix.

3.4 Wick Drains and Granular Drainage Blanket

Wick drain installation is required at one site (Section 3.1.5) to increase the rate of foundation settlement during construction and reduce the post construction (long-term) foundation settlement. The lateral extents of wick drain installation and anticipated tip elevation, based on interpretation of available borehole data, are shown on the Wick Drain Plan drawing included in Appendix J. The wick drain tip elevation should extend at least 0.5 m into the cohesionless silt and sand below the compressible clay or to refusal if encountered immediately below the clay. It should be noted that the tip elevations between and beyond borehole locations were estimated by interpolation and extrapolation of the data, respectively. Therefore the actual tip elevations may vary during wick drain installation.

Pre-augering and/or suitable equipment should be used to facilitate wick drain installation if obstructions are encountered during installation. Care must be exercised to avoid construction equipment travelling over and damaging wick drains.

Wick drains must not be installed in frozen ground due to the potential of the drains freezing within the frost depth and the resultant impeded drainage until the soils thaw. If no or insufficient fill cover (less than 2.0 m of soil or less than 4.0 m of rock fill) is placed over the wicks before the onset of freezing, placement of embankment fill on frozen soils and frozen wicks will delay dissipation of excess pore pressure in the foundation soils which may significantly delay the construction schedule.

The granular drainage blanket through which the wicks will be installed should be placed to 1.0 m above the original ground surface or 1 m above the surface water level, whichever is higher, and 1 m past the lateral extent of the wick drain layout. The granular drainage blanket shall be Granular B Type II or Type III, according to OPSS 1010 except that:

- 100% shall pass 37.5 mm sieve, and
- No more than 5% shall pass the 0.075 mm sieve

Non-Standard Specifications (NSSP) for wick drain and granular drainage blanket have been included in Appendix J.

3.5 Accuracy of Settlement Calculations and Geotechnical Instrumentation and Monitoring Program

The settlement predictions in this report have been carried out based on a comprehensive field and laboratory program and on assumptions based on our experience with other embankments founded on compressible soils. Notwithstanding the care taken in predicting the embankment performance, the settlement values observed in the field could vary significantly from the predictions. This is due to the high degree of variability of the soil properties along the embankment alignment. The presence of locally sensitive deposits adds uncertainty to the prediction of the performance of the embankments proposed in this project. Therefore the results of the settlement analysis should be used to compare design alternative and to assess the most likely performance of the embankments.

Geotechnical instrumentation and monitoring, to control construction of embankments, is recommended at three sites. The geotechnical instrumentation will consist of a combination of slope inclinometers, vibrating wire piezometers, settlement rods and settlement pins. The instrumentation locations, types of instrumentation, installation details and monitoring frequency are provided in Appendix J.

The results of the geotechnical instrumentation monitoring program will control the rate of the embankment construction and consequently the construction schedule. Although not anticipated, there is a risk that the pore pressure dissipation in the foundation clay will be slower than anticipated. If this situation occurs, the embankment construction may have to be slowed down which may impact the overall construction schedule. It is considered important that the construction contract includes clauses that allow for a flexible construction schedule to allow for delays associated with dissipation of excess pore pressures in the foundation soils slower than anticipated. In addition, a detailed and regular analysis of the results of the geotechnical instrumentation monitoring program during construction is considered critical to:

- Reduce the potential of an embankment failure
- Reduce the risk of a premature removal of the surcharge
- Reduce the risk of installing the permanent culverts too early

During construction, the Contract Administrator should employ experienced high complexity geotechnical staff to implement the geotechnical instrumentation monitoring program and to observe foundation performance related to construction activities.

3.6 Embankment Construction

Embankment construction should be carried out in accordance with OPSS.PROV 206. Rock size should be controlled in accordance with OPSS.PROV 206. Embankment fill may consist of granular materials and Select Subgrade Material (SSM) in compliance with OPSS.PROV 1010. Granular fill embankment slopes must be provided with erosion protection in accordance with OPSS 804.

Rock fill placed above the water table should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging.

Rock fill must be compacted as per OPSS.PROV 206. Rock fill used to backfill subexcavated areas below the water table may be placed by end dumping. Granular fill must not be used to backfill excavations below the water table.

At the pavement subgrade level or where granular fill is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS 501.

Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, the existing earth or fill slope must be benched in accordance with OPSD 208.010.

Construction of new embankments over compressible soils should be carried out in accordance with OPSS 209 "Construction Specification for Embankments Over Swamps and Compressible Soils", April 2009, with specific reference to OPSD 203.010 "Embankments Over Swamp, New Construction".

4 SUMMARY OF SITE SPECIFIC RECOMMENDATIONS

A summary of the primary recommendations for each specific area of embankment is presented on Table 1 provided in Appendix B through J. The summary is based on the discussions presented above, and these discussions should be referenced for further detail.

The anticipated and/or recommended depth of subexcavation of peat, topsoil and organic deposits at all sites is summarized in Table A1, Appendix A.

5 SEISMIC CONSIDERATIONS

Provided construction of embankments is carried out in accordance with the site-specific recommendations provided above. the minimum factor of safety, as outlined in Section 8.2, will be maintained for seismic loading conditions.

Based on the subsurface conditions encountered at the drilled locations, the potential for liquefaction of the foundation soils during a seismic event is considered to be low in accordance with CHBDC Section C4.6. Some local liquefaction and resulting toe failure may occur during a seismic event, but this is expected to be readily repaired.

6 CONSTRUCTION CONCERNS

During construction, qualified geotechnical staff should be retained to observe activities related to embankment construction and advise the Contract Administrator on construction concerns or issues related to embankment slope stability or settlement.

Potential construction concerns include, but are not necessarily limited to:

- The thickness and presence of organic deposits were investigated at the borehole locations only. Organic deposits may extend to greater depths or be encountered at other locations between boreholes.

- Geotechnical confirmation is required that all peat, topsoil and organic deposits within the proposed embankment footprint are stripped and replaced with approved backfill.
- Trafficability of construction equipment may be difficult in areas of organic deposits or excessively soft, loose/unstable and/or saturated subgrade. Disturbance of the subgrade by construction traffic must be minimized and the Contractor may have to adjust his operations in soft subgrade areas. Provisions of adequate site drainage is critical to maintain stable subgrade.
- Bedrock elevations may vary between and beyond the borehole locations. The limits of sub-excavation and wick drain installation (where required) may require modification during construction based on the conditions encountered in the field.
- Pre-augering and/or suitable equipment should be used to facilitate wick drain installation if obstructions are encountered during installation. If no or insufficient fill cover (less than 2.0 m of soil or less than 4.0 m of rock fill) is placed over the wicks before the onset of freezing, placement of embankment fill on frozen wicks will delay dissipation of excess pore pressure in the foundation soils which may significantly delay construction schedule.
- Although not anticipated, there is a risk that the pore pressure dissipation and settlement will be slower than anticipated. If this situation occurs, the embankment construction may have to be slowed down which may impact the overall construction schedule. It is considered important that the construction contract includes clauses that allow for a flexible construction schedule to allow for delays associated with dissipation of excess pore pressures in the foundation soils slower than anticipated.
- In areas with culvert construction, care must be exercised during excavation to avoid disturbing the founding subgrade. When the excavation reaches the required elevation, the subgrade should be inspected and approved by qualified geotechnical personnel employed by the Contractor.
- Where new embankments are constructed directly adjacent to existing embankments, settlement of the existing embankment may occur. Maintenance measures such as placement of asphalt overlay may be required to compensate the settlement.

7 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Jason Lee, P.Eng and Stephen Peters, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Tables

- Table A1-1 to A1-3 Summary of Peat and Organic Soil Thickness
- Table A2 Summary of Slope Stability Analysis
- Table A3-1 to A3-2 Summary of Settlement Analysis
- Table A4 Summary of Modeling Parameters

Table A1-1
Summary of Peat and Organic Soil Thickness

Appendix	Borehole / DCPT (*) / BH+DCPT (**)	Description	Depth of Investigation (m)	Depth of Peat, Topsoil and Organics Deposit (m)
B	Highway 11/17 EBL and WBL, Sta. 12+050 to 12+100			
	12+050 29R	Right toe of EBL	14.3	0.1 to 1.2
	12+060 CL*	DCPT, Right toe of WBL	10.4	
	12+080.9 17.8R	CL of EBL	13.7	
	12+090 29R*	DCPT, Right toe of EBL	15.1	
	12+090 CL*	DCPT, Right toe of WBL	12.8	
	12+056.5 27.5L	Left toe of WBL	13.4	0.1 to 0.9
	12+080 19L	CL of WBL	11.3	
	12+090 29L*	DCPT, Left toe of WBL	11.6	
C	Highway 11/17 EBL and WBL, Sta. 12+170 to 12+270			
	12+170 29R*	DCPT, Right toe of EBL	12.3	0.1 to 1.2
	12+170 CL*	DCPT, Left toe of EBL	10.4	
	12+180 19R	CL of EBL	10.1	
	12+210 29R*	DCPT, Right toe of EBL	12.5	
	12+210 CL*	DCPT, Right toe of WBL	12.5	
	12+230 19R	CL of EBL	9.1	
	12+250 29R*	DCPT, Right toe of EBL	8.8	
	12+265 CL	Right toe of WBL	10.7	
	12+190 29L*	DCPT, Left toe of WBL	5.9	0.2
	12+200 19L	CL of WBL	8.5	
	12+243 30.7L	Left toe of WBL	5.8	
	12+250 19L	CL of WBL	7.0	
	12+265 29L*	DCPT, Left toe of WBL	10.1	
D	Highway 11/17 EBL, Sta. 12+420 to 12+540			
	12+430 19R	CL of EBL	14.9	0.1 to 0.9
	12+455 28R	Right toe of EBL	14.3	
	12+455 CL*	DCPT, Left toe of EBL	14.9	
	12+480 19R	CL of EBL	14.3	
	12+505 28R*	DCPT, Right toe of EBL	12.2	
	12+505 CL	Left toe of EBL	11.6	
	12+520 19R	CL of EBL	9.9	
E	Highway 11/17 EBL and WBL, Sta. 12+650 to 13+100			
	12+750 19R	CL of EBL	4.3	0.1 to 1.7
	12+750 CL*	DCPT, Left toe of EBL	2.8	
	12+776 27R*	DCPT, Right toe of EBL	5.6	
	12+800 19R	CL of EBL	9.5	
	12+826 28R	Right toe of EBL	16.5	
	12+826 CL*	DCPT, Left toe of EBL	24.7	
	12+850 19R	CL of EBL	29.2	
	12+876 28R*	DCPT, Right toe of EBL	17.6	
	12+876 CL	Left toe of EBL	24.8	
	12+900 19R	CL of EBL	12.9	
	12+926 28R	Right toe of EBL	15.1	
	12+926 CL*	DCPT, Left toe of EBL	15.6	
	12+950 19R	CL of EBL	14.7	

Table A1-2
Summary of Peat and Organic Soil Thickness

Appendix	Borehole / DCPT (*) / BH+DCPT (**)	Description	Depth of Investigation (m)	Depth of Peat, Topsoil and Organics Deposit (m)
E	Highway 11/17 EBL and WBL, Sta. 12+650 to 13+100			
	12+976 28R*	DCPT, Right toe of EBL	12.7	0.1 to 1.7
	12+976 1R	Left toe of EBL	13.2	
	13+000 19R	CL of EBL	9.6	
	13+026 05R*	DCPT, Right toe of WBL	9.9	
	13+026 28R	Right toe of EBL	9.0	
	13+049 18R	CL of EBL	9.9	
	13+076 06R	Right toe of WBL	8.5	
	13+076 27R*	DCPT, Right toe of EBL	7.5	
	13+100 4.9R	CL of EBL	10.6	
	12+776 CL	Left toe of EBL	5.6	
	12+899 19L	CL of WBL	14.9	0.0 to 0.1
	12+926 29L	Left toe of WBL	14.9	
	12+950 19L	CL of WBL	14.0	
	12+976 29L*	DCPT, Left toe of WBL	13.8	
	13+000 19L	CL of WBL	10.4	
	13+026 29L	Left toe of WBL	14.1	
	13+050 19L	CL of WBL	13.0	
	13+077 28L*	DCPT, Left toe of WBL	15.2	
	13+100 19L*	DCPT, CL of WBL	13.0	
F	Highway 11/17 EBL and WBL, Sta. 13+300 to 13+450			
	13+300 19R	CL of EBL	14.3	0.0 to 0.3
	13+325 30R*	DCPT, Right toe of EBL	14.9	
	13+340 19R	CL of EBL	13.7	
	13+342 07R	Left toe of EBL	13.3	
	13+375 30R	Right toe of EBL	13.7	
	13+380 07R	Left toe of EBL	13.3	
	13+405.9 23.5R	CL of EBL	14.8	
	13+425 30R*	DCPT, Right toe of EBL	14.9	
	13+300 19L	CL of WBL	13.7	0.0 to 0.3
	13+318 01L	Right toe of WBL	13.3	
	13+321 17.4L	CL of WBL	14.1	
	13+324 27L*	DCPT, Left toe of WBL	15.2	
	13+350 19L	CL of WBL	14.3	
	13+368.4 24.6L	Left toe of WBL	14.3	
	13+379.1 11.2L*	DCPT, Right toe of WBL	15.2	
	13+400 19L	CL of WBL	14.8	
	13+425 30L*	DCPT, Left toe of WBL	19.8	
	13+424.6 5.7L	Right toe of WBL	20.2	
	SB-04	CL of WBL	17.2	0.0 to 0.1
	SB-03	Right toe of EBL	18.4	
	SB-01	CL of WBL	17.4	
	SB-02	Left toe of WBL	17.8	

Table A1-3
Summary of Peat and Organic Soil Thickness

Appendix	Borehole / DCPT (*) / BH+DCPT (**)	Description	Depth of Investigation (m)	Depth of Peat, Topsoil and Organics Deposit (m)
G	Highway 11/17 EBL and WBL, Sta. 16+250 to 16+460			
	16+260 19R	CL of EBL	7.8	0.2 to 1.6
	16+300 29R*	DCPT, Right toe of EBL	4.6	
	16+302 1R	Left toe of EBL	9.2	
	16+335.2 21.2R	CL of EBL	6.8	
	16+370 29R	Right toe of EBL	6.9	
	16+370 CL*	DCPT, Left toe of EBL	7.4	
	16+405 19R	CL of EBL	7.5	
	16+435 CL	Left toe of EBL	7.4	
	16+460 19L	CL of WBL	13.3	0.2
	16+460 29L*	DCPT, Left toe of WBL	10.0	
H	Highway 11/17 EBL and WBL, Sta. 16+830 to 16+940			
	16+850 19R	CL of EBL	12.4	0.2 to 0.3
	16+875 29R	Right toe of EBL	11.7	
	16+875 CL*	DCPT, Left toe of EBL	14.9	
	16+902.2 16.7R	CL of EBL	8.2	
	16+850 29L*	DCPT, Left toe of WBL	7.8	0.2
	16+863.3 23.9L	CL of WBL	10.2	
	16+896.5 28.2L	Left toe of WBL	11.2	
	16+910 19L	CL of WBL	8.0	
I	Highway 11/17 EBL and WBL, Sta. 18+450 to 18+500			
	18+463.5 14R*	DCPT, Right toe of EBL	9.7	3.0
	18+464.4 12.4R	CL of EBL	10.5	
	18+475 CL*	DCPT, Right toe of WBL	12.9	
	18+475 19L	CL of WBL	9.2	3.1
	18+475 29L*	DCPT, Left toe of WBL	11.1	
J	Highway 11/17 WBL, Sta. 19+850 to 19+900			
	19+875 19R	CL of EBL	4.7	0.0 to 0.2
	19+875 29R*	DCPT, Right toe of EBL	2.2	
	19+885 19R	CL of EBL	3.0	
	19+874.3 8.3L*	DCPT, Right toe of WBL	3.0	0.2
	19+875 19L	CL of WBL	5.6	

Table A2
Summary of Slope Stability Analyses

Appendix	Station	Embankment Height/Cut Depth (m)	Condition	Computed Factor of Safety	Figure
B	12+050 to 12+100	5.6	Short-term (undrained analysis)	1.65	B1
			Long-term (drained analysis)	1.45	B2
			Short-term (undrained analysis) with 1 m surcharge	1.40	B3
C	12+170 to 12+270	5.6	Short-term (undrained analysis)	1.41	C1
			Long-term (drained analysis)	1.51	C2
			Short-term (undrained analysis) with 1 m surcharge	1.31	C3
D	12+420 to 12+540	3.2	Short-term (undrained analysis)	1.96	D1
			Long-term (drained analysis)	2.03	D2
E	12+650 to 13+100	4.1	Short-term (undrained analysis)	1.32	E1
			Long-term (drained analysis)	1.46	E2
F	13+300 to 13+450	6.7	Short-term (undrained analysis), Stage 1	1.48	F1
			Short-term (undrained analysis), Stage 2	1.32	F2
			Long-term (drained analysis)	2.09	F3
G	16+250 to 16+460	3.7	Short-term (undrained analysis)	2.53	G1
			Long-term (drained analysis)	2.10	G2
H	16+830 to 16+940	4.1	Short-term (undrained analysis)	1.31	H1
			Long-term (drained analysis)	1.60	H2
			Short-term (undrained analysis) with 1 m surcharge	1.46	H3
I	18+450 to 18+500	2.3	Long-term (drained analysis)	1.90	I1

Table A3-1
Summary of Settlement Analyses

Note: (*) occurring within 1 year following placement, (**) occurring within 20 years following paving

Location		Design Option	Minimum Waiting Time (months)	Estimated Settlement (mm)				
				Foundation Settlement		Rock Fill Compression		Total Post Constr. Settl.(**)
				Settl. During Constr.	Post Constr. Settl.	Short Term(*) Compr.	Long Term Compr.	
12+050 to 12+100	12+070	Construction with no surcharge	EBL: 5	135	50	45	10	90
			WBL: 3	40	65	20	5	90
		Construction with 1 m surcharge	EBL: 3	145	40	45	10	85
12+170 to 12+270	12+190	Construction with no surcharge	EBL: 10	80	65	25	5	90
			WBL: 3	45	35	15	5	55
	12+240	Construction with no surcharge	EBL: 10	95	50	45	10	70
			WBL: 3	55	65	25	5	90
		Construction with 1 m surcharge, (*requires stabilizing berm*)	EBL: 6	85	60	45	10	95
12+420 to 12+540	12+490	Construction with no surcharge	EBL: 2	15	60	20	5	85
			WBL: (***)	-	-	-	-	-
12+650 to 13+100	12+850	Construction with no surcharge	EBL: 5	40	65	20	5	90
			WBL: (***)	-	-	-	-	-
	12+930		EBL: 5	15	55	20	5	80
			WBL: 5	25	30	15	5	50
13+300 to 13+450	13+340	Construction of Stage 1 (top of pavement elevation)	EBL: 6	375	-	50	5	-
		Construction of Stage 2 (1 m surcharge)	EBL: 6	45	20			25

Table A3-2
Summary of Settlement Analyses

Note: (*) occurring within 1 year following placement, (**) occurring within 20 years following paving

Location		Design Option	Minimum Waiting Time (months)	Estimated Settlement (mm)				
				Foundation Settlement		Rock Fill Compression		Total Post Constr. Settl.(**)
				Settl. During Constr.	Post Constr. Settl.	Short Term(*) Compr.	Long Term Compr.	
13+300 to 13+450	13+380	Construction of Stage 1 (top of pavement elevation)	EBL: 6	325	-	50	10	-
		Construction of Stage 2 (1 m surcharge)	EBL: 6	145	65			75
16+250 to 16+460	16+400	Construction with no surcharge	EBL: 4	55	70	20	5	90
			WBL: (***)	-	-	-	-	-
16+830 to 16+940	16+850	Construction with no surcharge	EBL: 12	90	80	20	5	85
			WBL: 12					
		Construction with 1 m surcharge, (*requires stabilizing berm*)	EBL: 6	120	70	20	5	85
			WBL: 6					
18+450 to 18+500	18+470	Construction with no surcharge	EBL: 3	50	10	10	5	25
			WBL: 3					
19+850 to 19+900	19+870	Construction with no surcharge	EBL: 0	35	~0	25	5	30
			WBL: 0					

Table A4
Summary of Modeling Parameters

Location	Soil Layer	Thickness	Unit Weight	Undrained Shear Strength	Drained Shear Strength		Young's Modulus	Primary Compression Ratio				Secondary Compression Ratio		Over-Consolidation Ratio		Coefficient of Consolidation (m^2/yr)			
			γ	c_u (τ/σ ratio)	c'	ϕ'	E	$Cc/(1+e_0)$		$Cr/(1+e_0)$		$C\alpha/(1+e_0)$		(OCR)		c_v (vertical)		c_h (horizontal)	
		(m)	(kN/m^3)	(kPa)	(kPa)	(^{o})	(MPa)	Top	Bot.	Top	Bot.	Top	Bot.	Top	Bot.	Top	Bot.	Top	Bot.
Hwy 11/17, EBL Sta. 12+070	Topsoil/Peat	1.2	14.0	---	---	30	---	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay	3.1	18.0	35	7	23	---	0.170	0.170	0.012	0.012	0.005	0.005	5.0	3.0	2	2	5	5
	Silt (Top)	6.5	19.0	---	---	28	15	---	---	---	---	---	---	---	---	---	---	---	---
	Silt (Bot.)	2.9	19.0	---	---	28	50	---	---	---	---	---	---	---	---	---	---	---	---
Hwy 11/17, EBL Sta. 12+190	Topsoil/Peat	0.2	14	N/A	N/A	N/A	---	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	3.8	18	N/A	N/A	N/A	---	0.12	0.14	0.01	0.01	0.004	0.004	6	3	2	2	5	5
	Silt	2.1	19	N/A	N/A	N/A	15	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Bot.)	3	18	N/A	N/A	N/A	---	0.08	0.14	0.01	0.01	0.002	0.004	3	3	2	2	5	5
Hwy 11/17, EBL Sta. 12+240	Topsoil/Peat	0.2	14.0	---	---	32	---	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	3.8	18.0	30	7	23	---	0.120	0.140	0.008	0.010	0.004	0.004	6.0	3.0	2	2	5	5
	Silt	2.1	19.0	---	7	23	15	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Bot.)	3.0	18.0	30	7	23	---	0.080	0.140	0.006	0.010	0.002	0.004	3.0	3.0	2	2	5	5
Hwy 11/17, EBL Sta. 12+490	Silt	1.1	19.0	---	---	30	15	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	3.0	18.0	25	7	23	---	0.120	0.180	0.008	0.013	0.004	0.005	5.0	2.5	2	2	5	5
	Silty Clay (Bot.)	9.0	18.0	25	7	23	---	0.180	0.230	0.013	0.016	0.005	0.007	2.5	1.5	2	2	5	5
Hwy 11/17, EBL Sta. 12+850	Topsoil/Peat	0.8	14.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Sandy Silt	2.2	19.0	---	---	29	10	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	7.0	18.0	20	7	23	---	0.110	0.200	0.008	0.014	0.003	0.006	3.5	1.8	2	2	5	5
	Silty Clay (Bot.)	18.0	18.0	20	7	23	---	0.200	0.200	0.014	0.014	0.006	0.006	1.8	1.1	2	2	5	5
Hwy 11/17, EBL Sta. 12+930	Topsoil/Peat	0.5	14.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Sandy Silt	1.0	19.0	---	---	29	10	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	3.5	18.0	20	7	23	---	0.110	0.160	0.008	0.011	0.003	0.005	5.0	2.5	2	2	5	5
	Silty Clay (Bot.)	7.4	18.0	20	7	23	---	0.160	0.200	0.011	0.014	0.005	0.006	2.5	1.5	2	2	5	5
Hwy 11/17, EBL Sta. 13+340	Silty Clay (1)	1.0	18.5	30	7	23	---	0.100	0.140	0.007	0.010	0.003	0.004	9.0	7.0	2	2	5	5
	Silty Clay (2)	2.0	18.0	30	7	23	---	0.140	0.180	0.010	0.018	0.004	0.005	7.0	4.0	2	2	5	5
	Silty Clay (3)	3.0	17.5	23	7	23	---	0.180	0.200	0.018	0.020	0.005	0.006	4.0	2.0	2	2	5	5
	Silty Clay (4)	3.0	17.5	23	7	23	---	0.200	0.230	0.020	0.023	0.006	0.007	2.0	1.4	2	2	5	5
	Silty Clay (5)	5.0	17.0	23	7	23	---	0.230	0.230	0.023	0.023	0.007	0.007	1.4	1.2	2	2	5	5
	Sand	0.1	19.0	---	---	30	7	---	---	---	---	---	---	---	---	---	---	---	---
Hwy 11/17, EBL Sta. 16+400	Topsoil/Peat	0.2	13.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	1.8	18.0	30	7	23	---	0.130	0.130	0.009	0.009	0.004	0.004	13.0	5.0	2	2	5	5
	Silty Clay (Mid.)	2.0	18.0	30	7	23	---	0.130	0.300	0.009	0.030	0.004	0.009	5.0	3.0	2	2	5	5
	Silty Clay (Bot.)	2.4	18.0	30	7	23	---	0.300	0.300	0.030	0.030	0.009	0.009	3.0	2.5	2	2	5	5
	Sand	1.1	20.0	---	---	30	40	---	---	---	---	---	---	---	---	---	---	---	---
Hwy 11/17, EBL Sta. 16+850	Topsoil/Peat	0.3	13.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Silty Clay (Top)	4.5	18.0	30	7	23	---	0.152	0.152	0.011	0.011	0.005	0.005	8.0	3.0	2	2	5	5
	Silty Clay (Mid.)	3.5	18.0	20	7	23	---	0.300	0.242	0.030	0.024	0.009	0.007	3.0	1.5	2	2	5	5
	Silty Clay (Bot.)	1.8	18.0	20	7	23	---	0.242	0.092	0.024	0.006	0.007	0.003	1.5	2.5	2	2	5	5
	Sand	2.3	20.0	---	---	30	40	---	---	---	---	---	---	---	---	---	---	---	---

Appendix B

Highway 11/17 EBL and WBL

Sta. 12+050 to 12+100

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table B1
Recommendation Summary Table

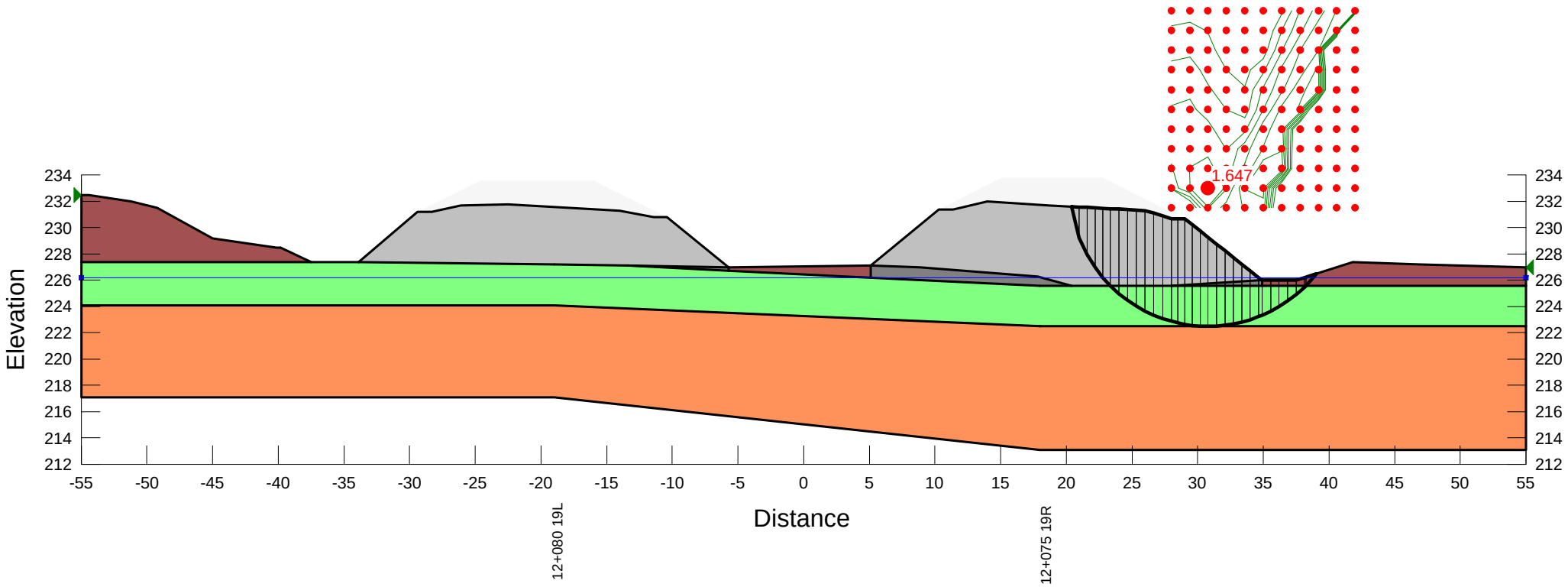
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment[3,4,5]										Treatment[3,4,5]						Rockfill Comp.[10]				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.[1]	Depth to base of Peat/ Org./ Clay[1]	Approx. Elev. of Existing Ground[2]	Elev. of Design Grade[2] (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.[7,8]	Wick Drain Spacing (c-c)[9]	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.[1]	Depth to base of Peat/ Org./ Clay[1]	Approx. Elev. of Existing Ground[2]	Elev. of Design Grade[2] (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.[7,8]	Wick Drain Spacing (c-c)[9]	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr.[6]	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
		12+050	0.1	6.1	229.7	231.4 (1.7)	0	-	-	-	-	3	0.1	6.1	229.1	231.7 (2.6)	0 1	-	-	-	-	5 3					
		12+070	0.9	4.3	227.8	231.8 (4.0)	0	-	-	-	-	3	1.2	4.3	226.1	231.7 (5.6)	0 1	-	-	-	-	5 3	45	10	150	90	240
		12+090	N/M	5.6	229.8	231.4 (1.6)	0	-	-	-	-	3	N/M	4.5	226.7	231.2 (4.5)	0 1	-	-	-	-	5 3					
12+050	12+100	All	-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 3 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving.										-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 5 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving Option 2 -Fill Placement Stage 1: Construct embankment with surcharge. Wait 3 months -Post Construction: After wait period, remove excess surcharge to design road grade elevation and complete paving														

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+070 (12+050 to 12+100)
Name: 1.ST.T
Description: Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 7/13/2013, 8:39:04 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (new)	22 kN/m³	0 kPa	42 °	1
ORGANICS (replacement)	19 kN/m³	0 kPa	30 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (TSA)	18 kN/m³	35 kPa	0 °	1
SILT	19 kN/m³	0 kPa	28 °	1



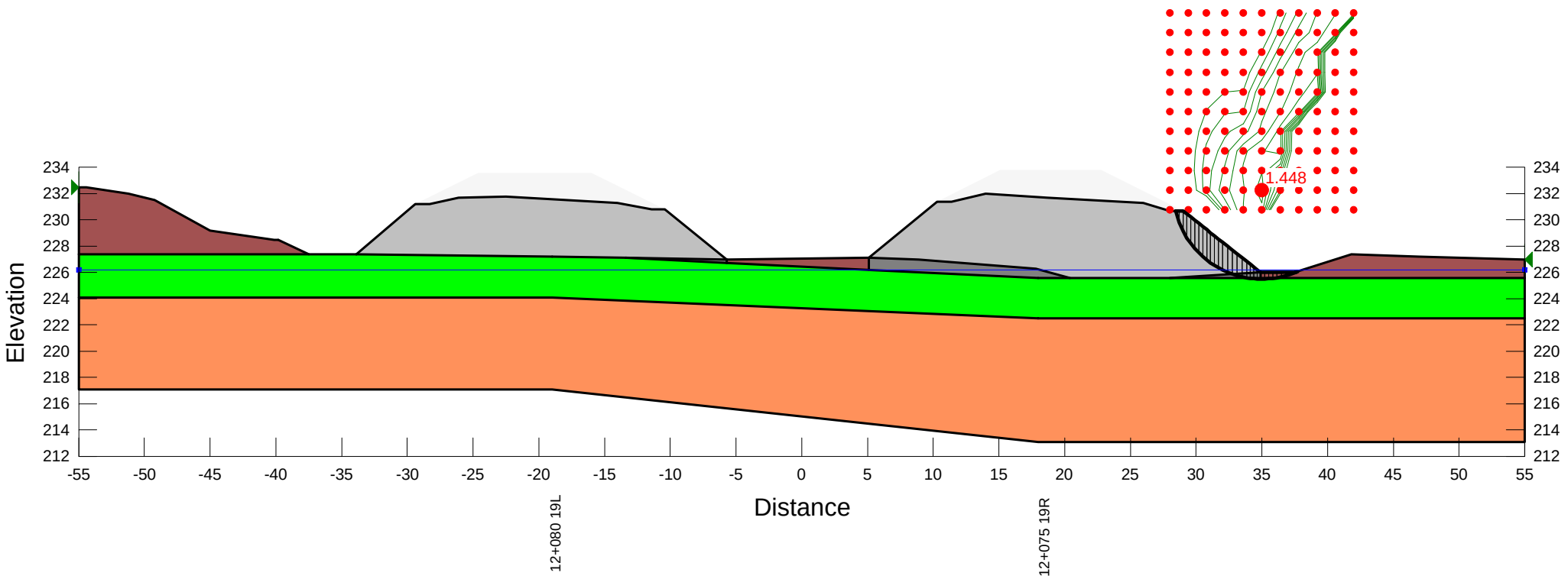
Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\12+050 to 12+100\Stabilty\12+070_001.gsz

Figure B1

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+070 (12+050 to 12+100)
Name: 1.LT.E
Description: Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 7/11/2013, 11:53:48 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (new)	22 kN/m³	0 kPa	42 °	1
ORGANICS (replacement)	19 kN/m³	0 kPa	30 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (ESA)	18 kN/m³	7 kPa	23 °	1
SILT	19 kN/m³	0 kPa	28 °	1



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\12+050 to 12+100\Stabilty\12+070_001.gsz

Figure B2

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+070 (12+050 to 12+100)
Name: 1.ST.T.s1
Description: Surcharged Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 7/14/2013, 12:03:53 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (new)	22 kN/m³	0 kPa	42 °	1
ORGANICS (replacement)	19 kN/m³	0 kPa	30 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (TSA)	18 kN/m³	35 kPa	0 °	1
SILT	19 kN/m³	0 kPa	28 °	1
SURCHARGE	21 kN/m³	0 kPa	32 °	1

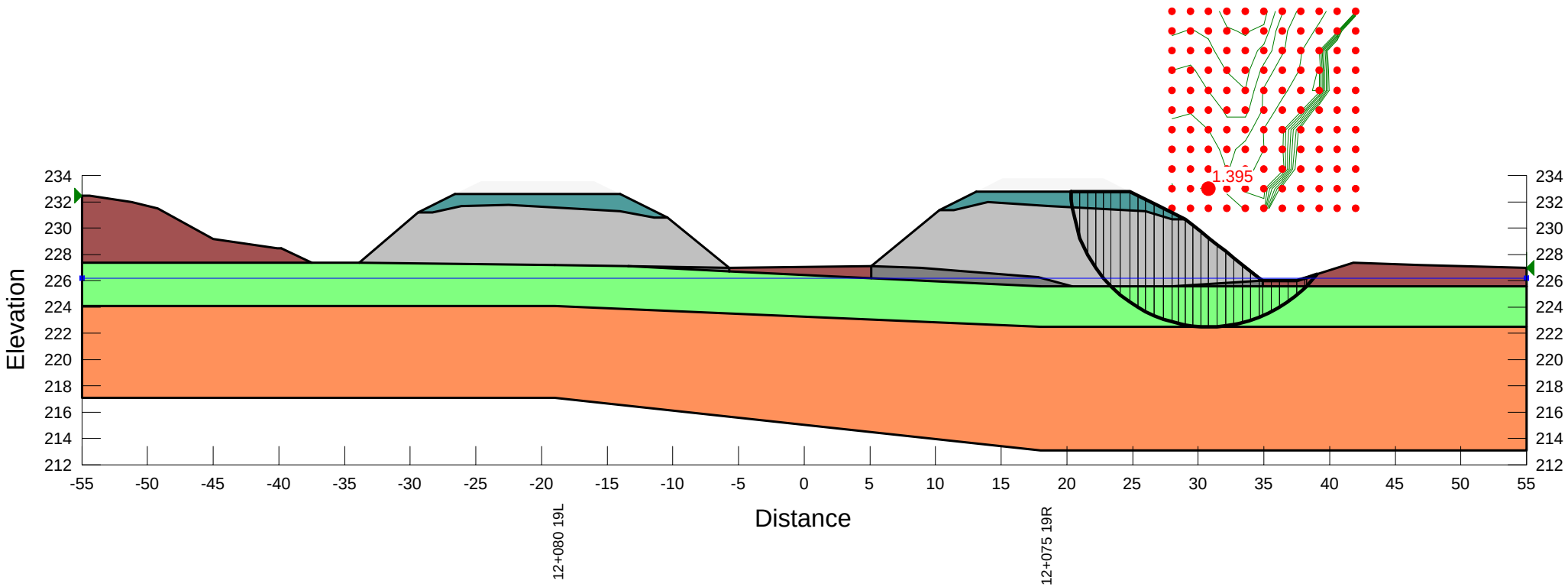


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Figure B3

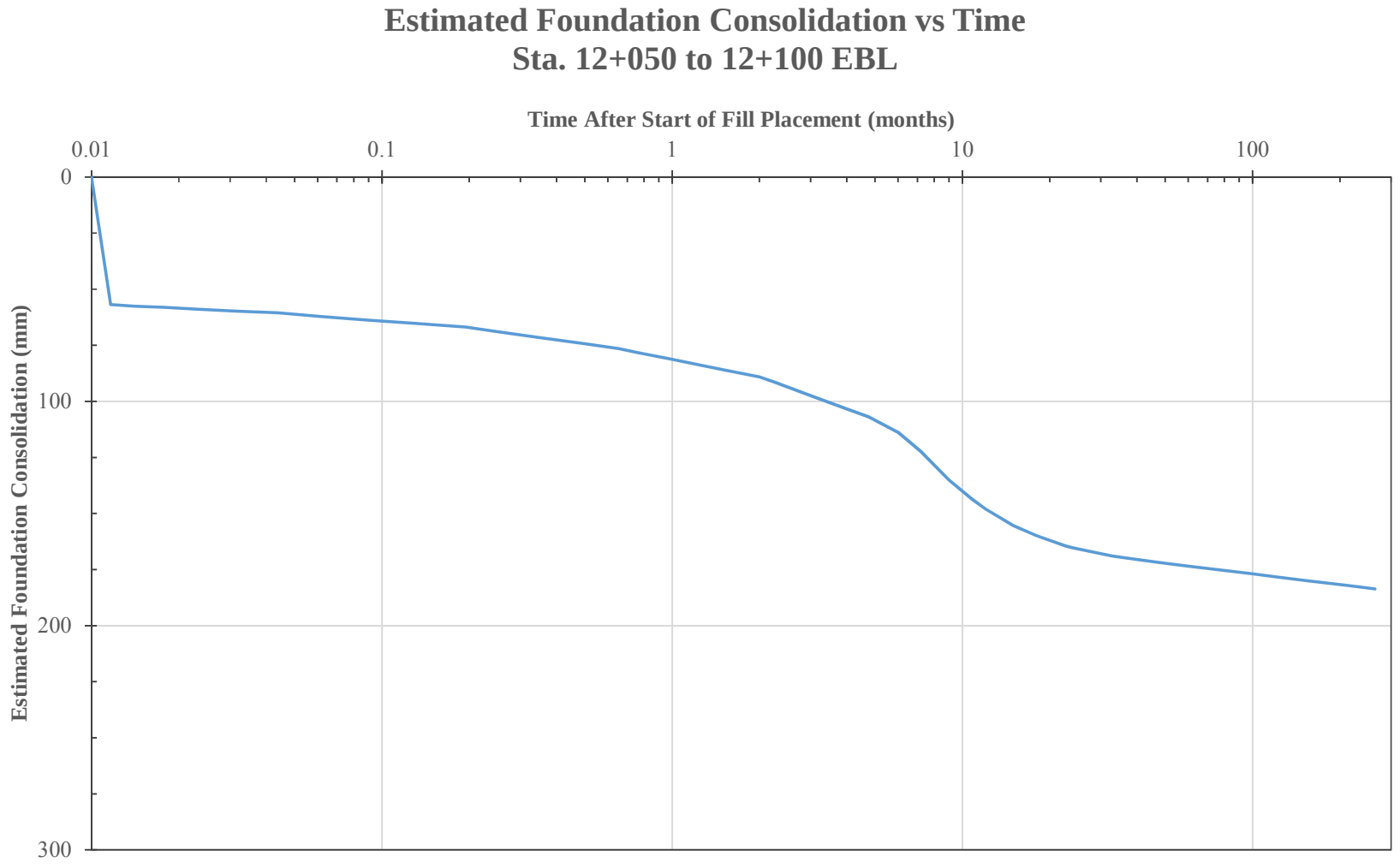


Figure B4

THURBER

Highway 11/17 - Red Rock to Nipigon

EBL and WBL - Sta. 12+050 to 12+100

Summary of Subsurface Conditions (Cohesive Soils)

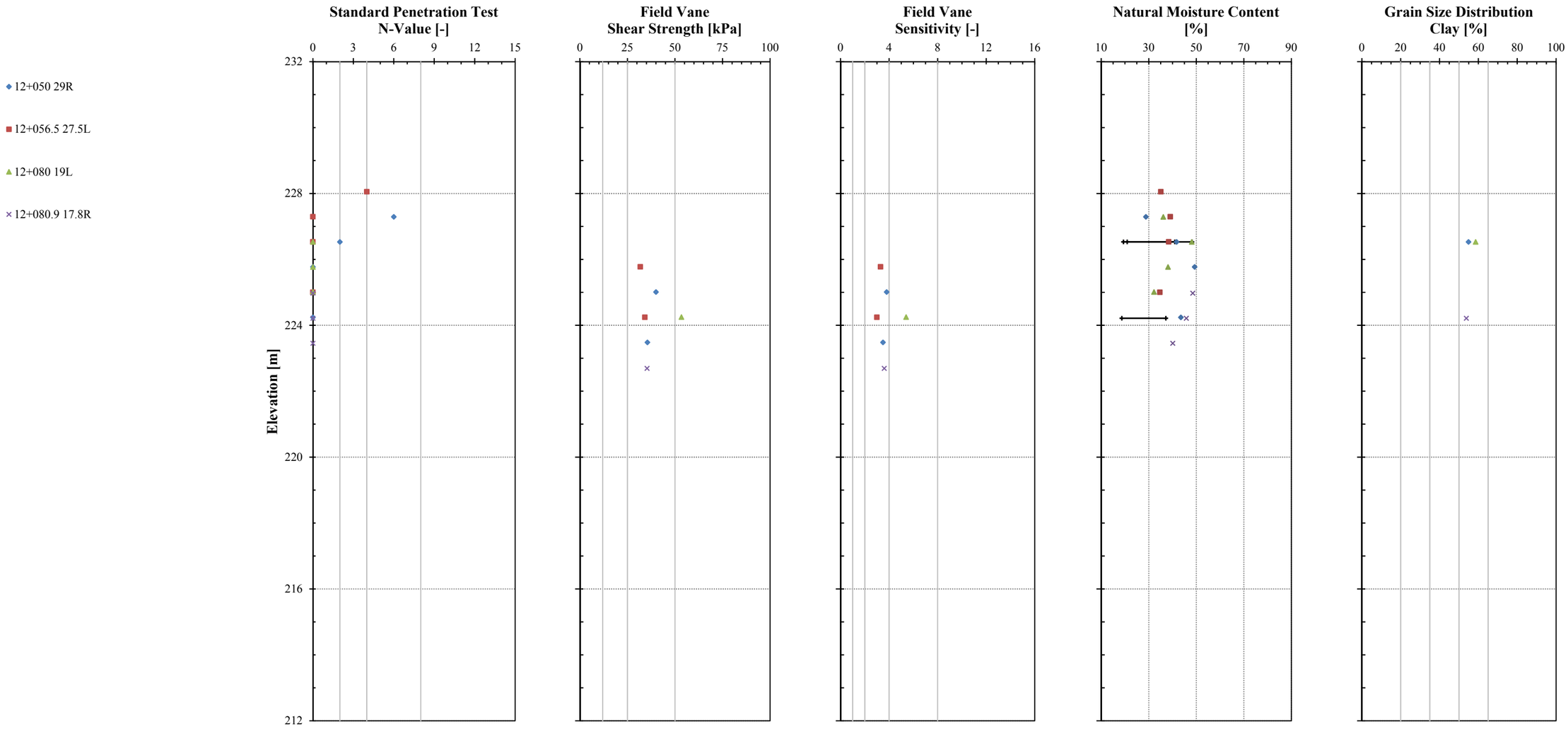


Figure B5

THURBER

Appendix C

Highway 11/17 EBL and WBL

Sta. 12+170 to 12+270

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table C1
Recommendation Summary Table

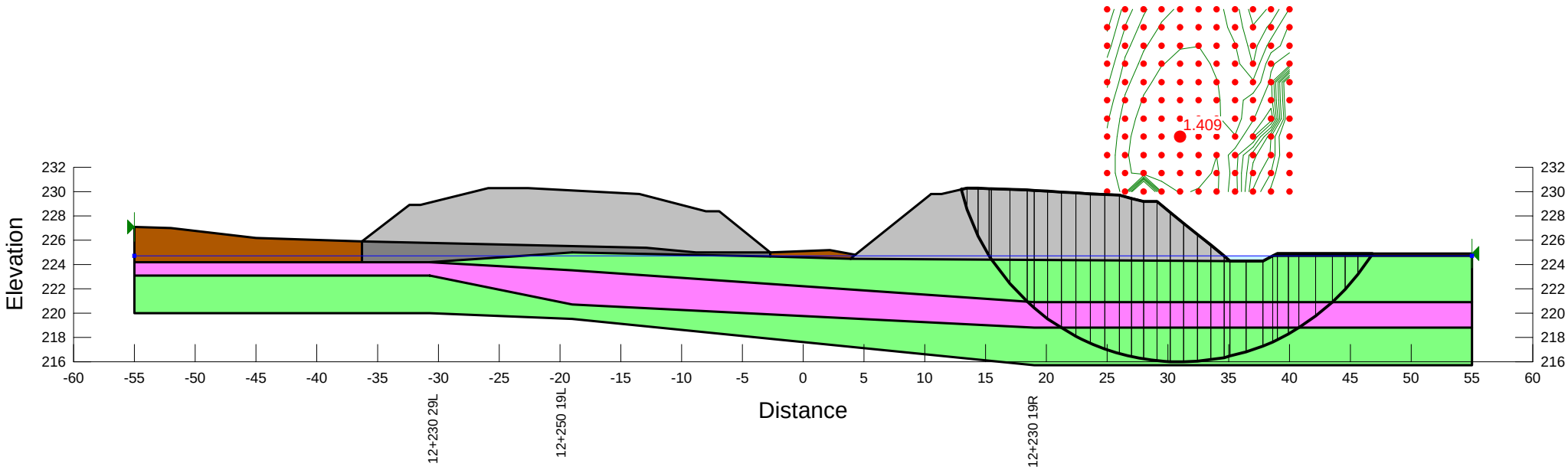
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
12+170	12+270	12+170	N/M	9.0	229.8	230.9 (1.1)	0	-	-	-	-	3	1.2	10.1	228.2	230.6 (2.4)	0 1	-	-	-	-	10 6					
		12+190	0.2	5.8	227.6	230.6 (3.0)	0	-	-	-	-	3	1.2	10.1	226.1	230.7 (4.6)	0 1	-	-	-	-	10 6					
		12+210	0.2	5.8	229.7	230.6 (0.9)	0	-	-	-	-	3	0.2	9.1	228.2	230.5 (2.3)	0 1	-	-	-	-	10 6					
		12+240	1.4 to 1.7	5.8 to 7.0	225.5	230.3 (4.8)	0	-	-	-	-	3	0.2	9.1	224.7	230.3 (5.6)	0 1	- 10	- 226.2 (1.5)	-	-	10 6	45	10	140	70	210
		12+270	0.1	10.7	229.7	230.0 (0.3)	0	-	-	-	-	3	0.1	10.7	227.6	229.8 (2.2)	0 1	-	-	-	-	10 6					
		All	-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 3 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving										-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 10 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving Option 2 -Fill Placement Stage 1: Simultaneously construct berm (to dimensions shown), embankment and surcharge. Wait 6 months. -Post Construction: After wait period, remove excess surcharge to design road grade elevation and complete paving Berm extents: -12+225 to 12+255 (taper berm outside these stations)														

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+240 (12+170 to 12+270)
Name: 1.ST.T
Description: Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 7/10/2013, 1:17:13 PM

FILL (New)	22 kN/m³	0 kPa	42 °	1
ORGANICS (Replacement)	20 kN/m³	0 kPa	32 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (TSA)	18 kN/m³	30 kPa	0 °	1
Clayey SILT (TSA)	18 kN/m³	30 kPa	0 °	1

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\12+170 to 12+270\Stability\12+240_001.gsz

Figure C1

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+240 (12+170 to 12+270)
Name: 1.LT.E
Description: Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 7/10/2013, 12:56:48 PM

FILL (New)	22 kN/m³	0 kPa	42 °	1
ORGANICS (Replacement)	20 kN/m³	0 kPa	32 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (ESA)	18 kN/m³	7 kPa	23 °	1
Clayey SILT (ESA)	18 kN/m³	7 kPa	23 °	1

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

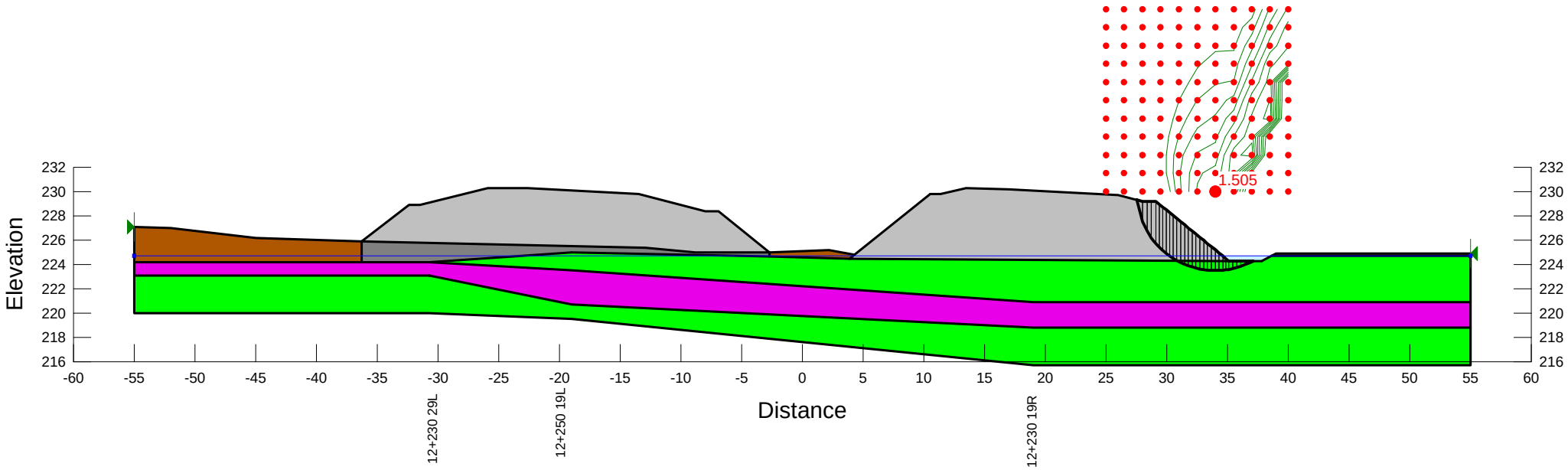


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Figure C2

Title: Highway 11/17, Nipigon, Ontario
Comments: STA: 12+240 (12+170 to 12+270)
Name: 1.ST.T.s1.b
Description: Surcharged Embankment Stability
Last Edited By: Stephen Peters
Last Solved Date: 11/27/2013, 1:29:35 PM

SURCHARGE	21 kN/m³	0 kPa	32 °	1
FILL (New)	22 kN/m³	0 kPa	42 °	1
ORGANICS (Replacement)	20 kN/m³	0 kPa	32 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
Silty CLAY (TSA)	18 kN/m³	30 kPa	0 °	1
Clayey SILT (TSA)	18 kN/m³	30 kPa	0 °	1

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

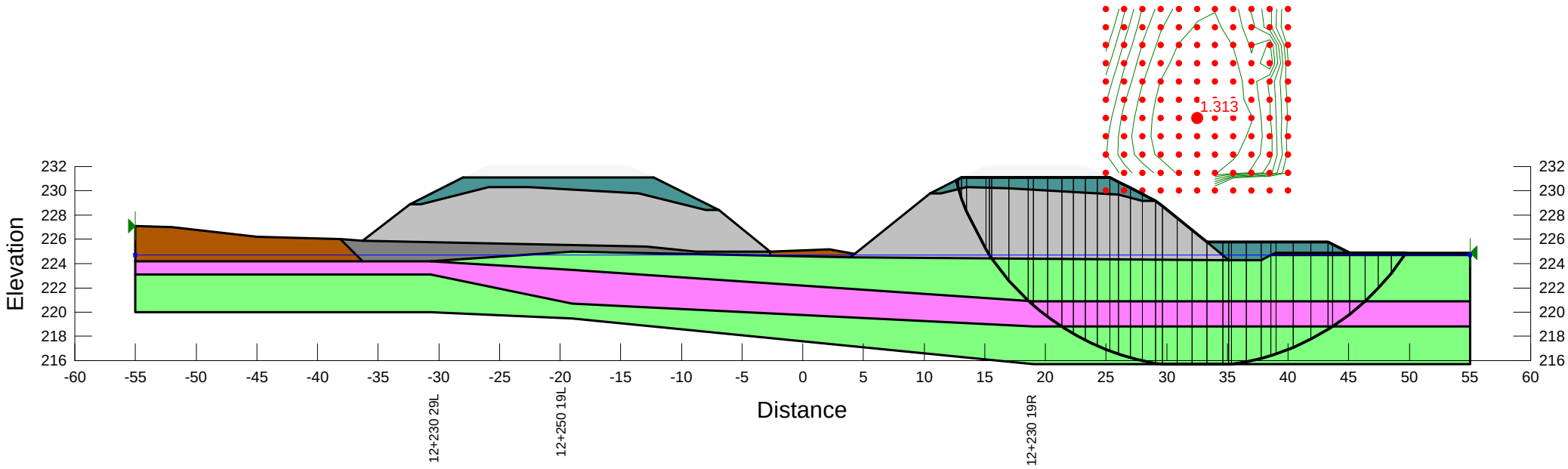

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Figure C3

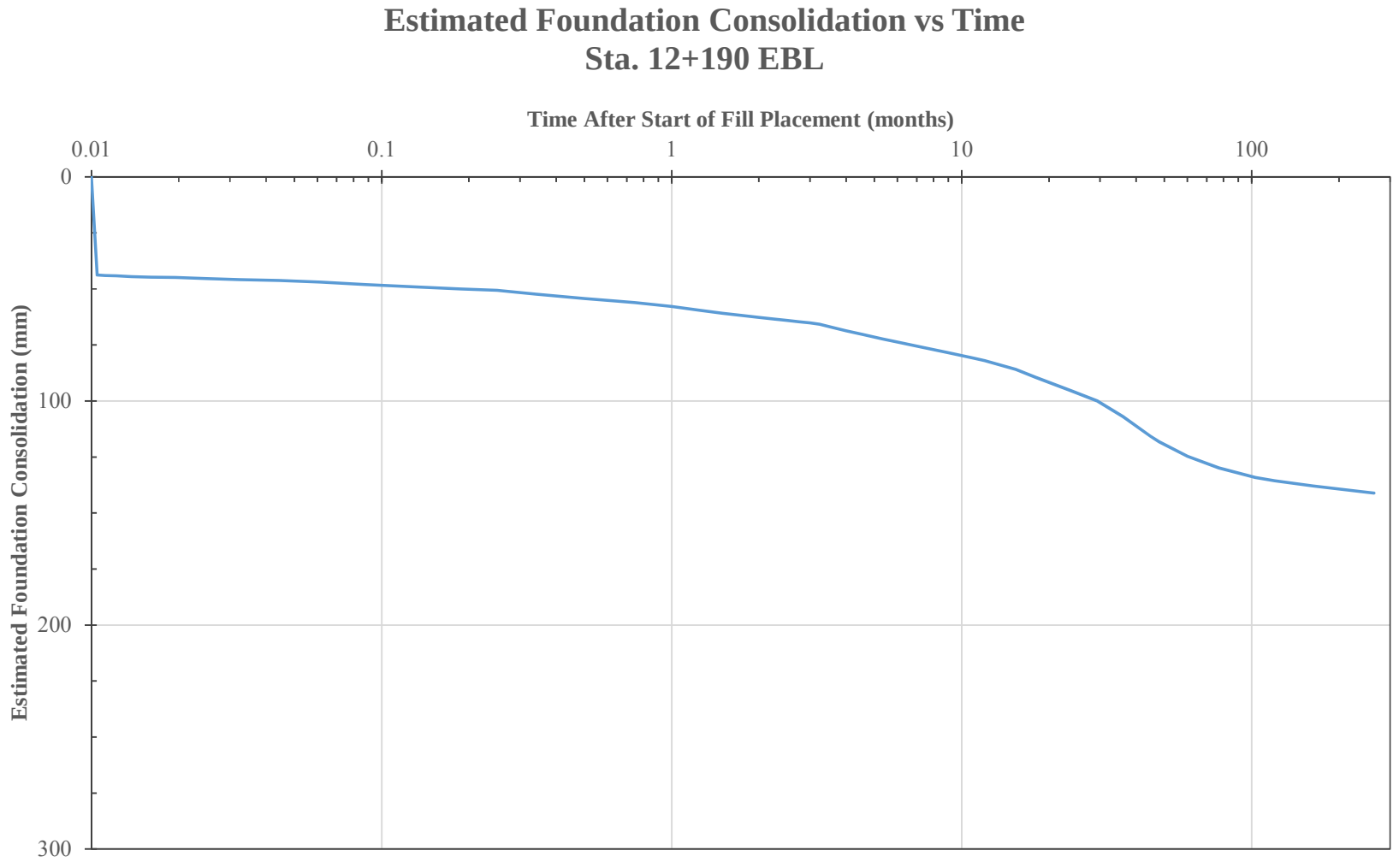


Figure C4

THURBER

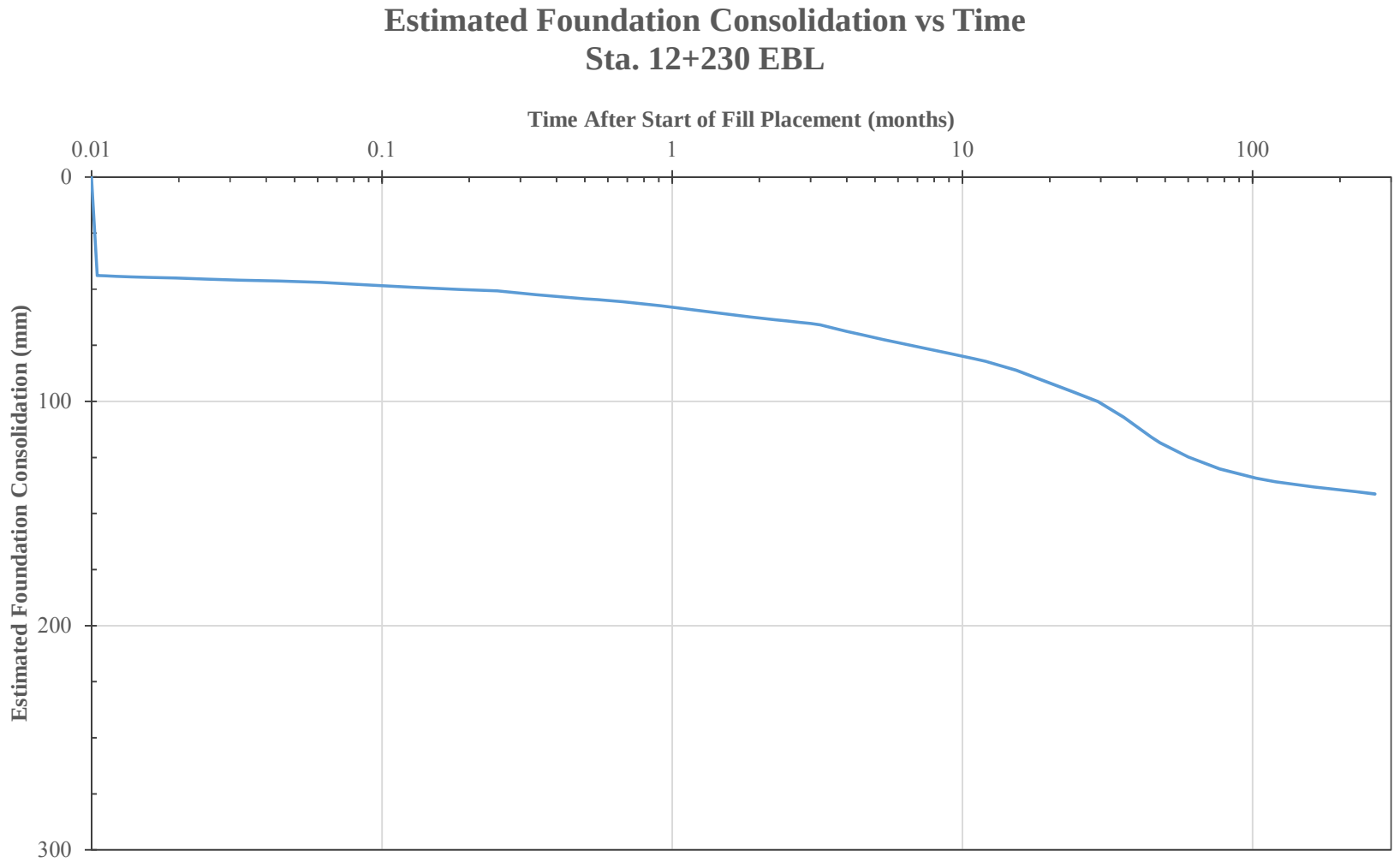


Figure C5

THURBER

Highway 11/17 - Red Rock to Nipigon

EBL and WBL - Sta. 12+170 to 12+270

Summary of Subsurface Conditions (Cohesive Soils)

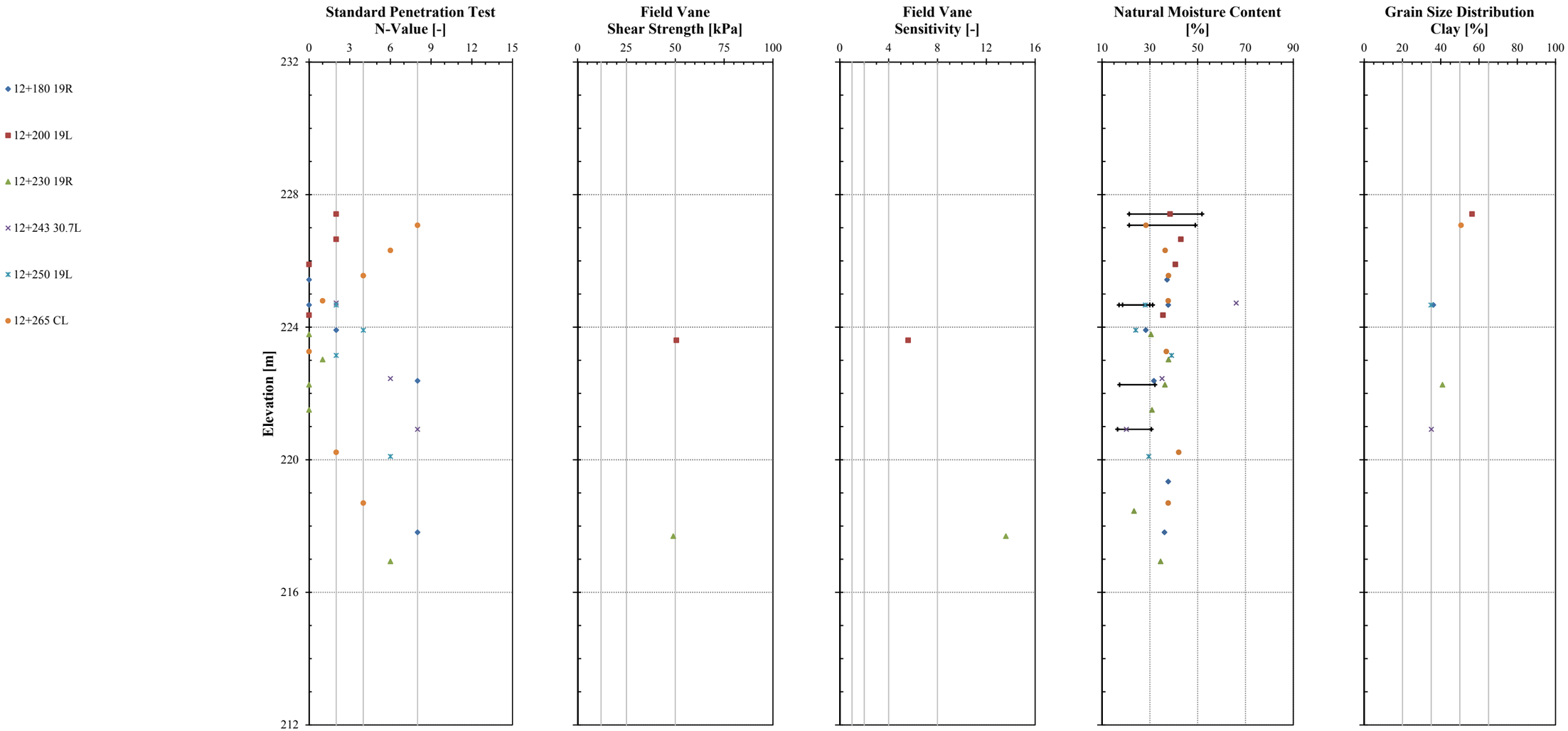


Figure C6

THURBER

Appendix D

Highway 11/17 EBL

Sta. 12+420 to 12+540

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table D1
Recommendation Summary Table

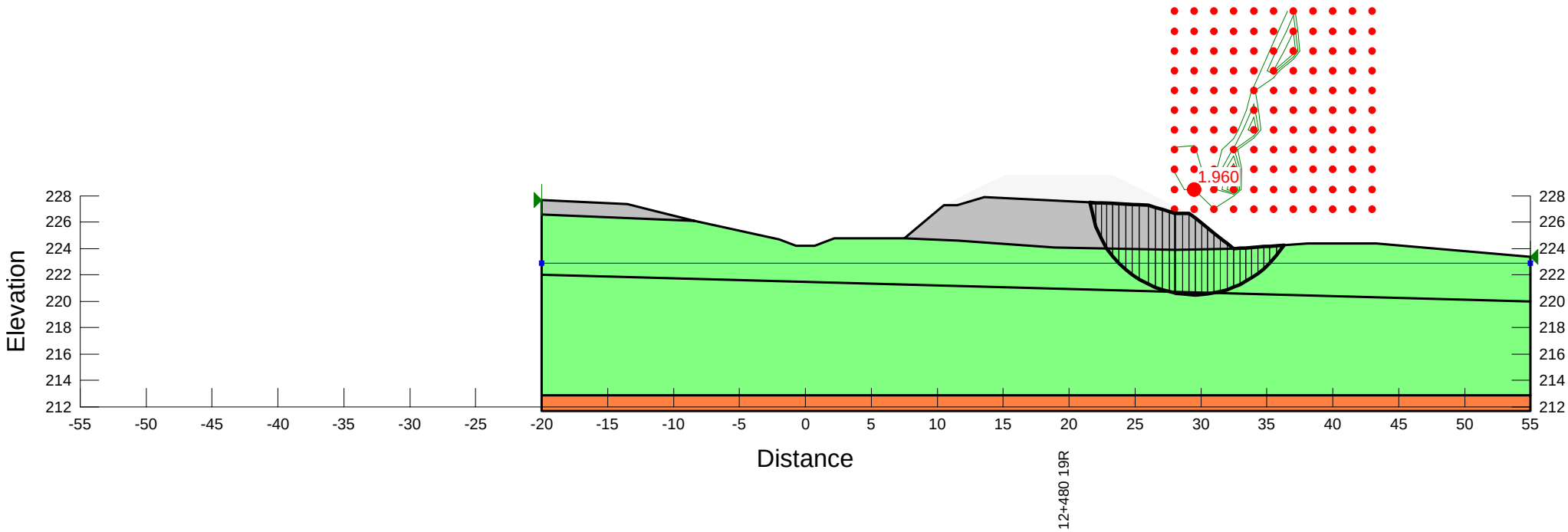
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
12+420	12+540	12+440			N/A	N/A							0.1 to 0.2	14.3 to 14.9	225.2	228.0 (2.8)	0	-	-	-	-	2					
		12+490			N/A	N/A							0.1 to 0.9	10.4 to 13.1	224.2	227.4 (3.2)	0	-	-	-	-	2	20	5	15	85	100
		12+540			N/A	N/A							0.8	8.0	224.0	227.0 (3.0)	0	-	-	-	-	2					
		All	Not part of Thurber's scope										-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 2 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving														

Title: Highway 11/17, Nipigon, Ontario
Name: 1.ST.T
Description: Embankment Stability
Comments: STA: 12+490 (12+420 to 12+540)
Last Edited By: Stephen Peters
Last Solved Date: 7/14/2013, 12:28:12 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1	
Silty CLAY 1 (TSA)	18 kN/m³	25 kPa	0 °	1	
SAND	20 kN/m³	0 kPa	30 °	1	
Silty CLAY 2 (TSA)	18 kN/m³	25 kPa	2 kPa/m	40 kPa	1



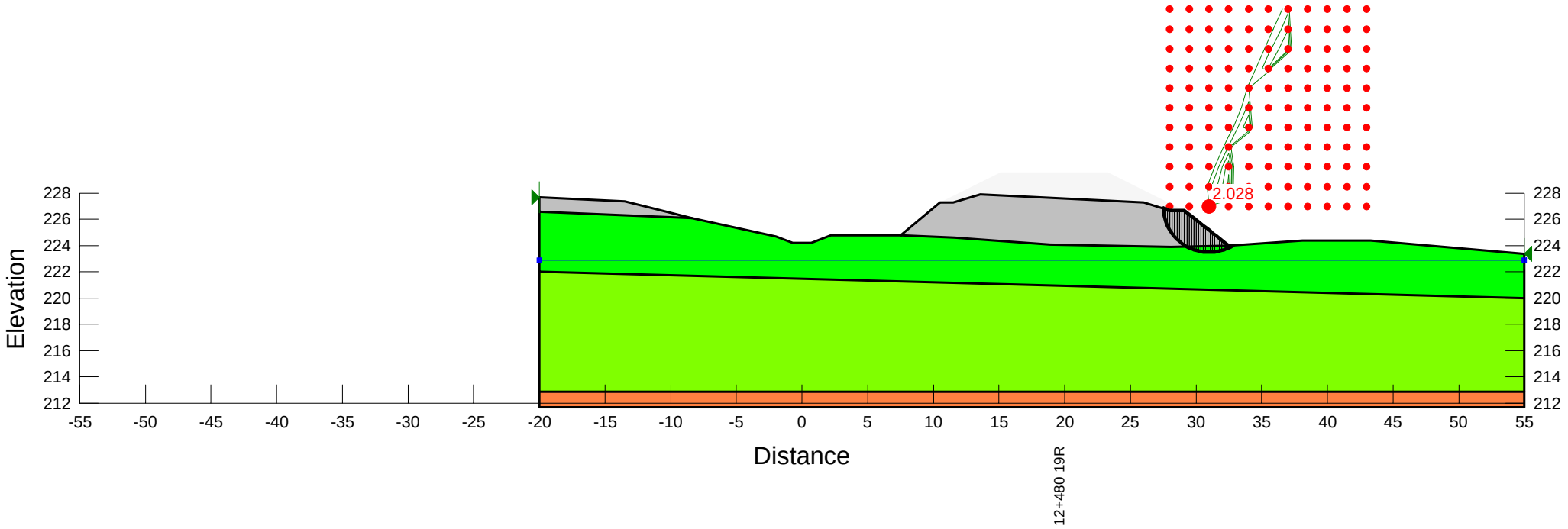
Directory: H:\19\1351\237 Hwy 11-17 Nipigon\Analysis\Embankments\12+420 to 12+540\Stability\12+490_001.gsz

Figure D1

Title: Highway 11/17, Nipigon, Ontario
Name: 1.LT.E
Description: Embankment Stability
Comments: STA: 12+490 (12+420 to 12+540)
Last Edited By: Stephen Peters
Last Solved Date: 7/13/2013, 8:57:25 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1
Silty CLAY 1 (ESA)	18 kN/m³	7 kPa	23 °	1
SAND	20 kN/m³	0 kPa	30 °	1
Silty CLAY 2 (ESA)	18 kN/m³	7 kPa	23 °	1



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\12+420 to 12+540\Stability\12+490_001.gsz

Figure D2

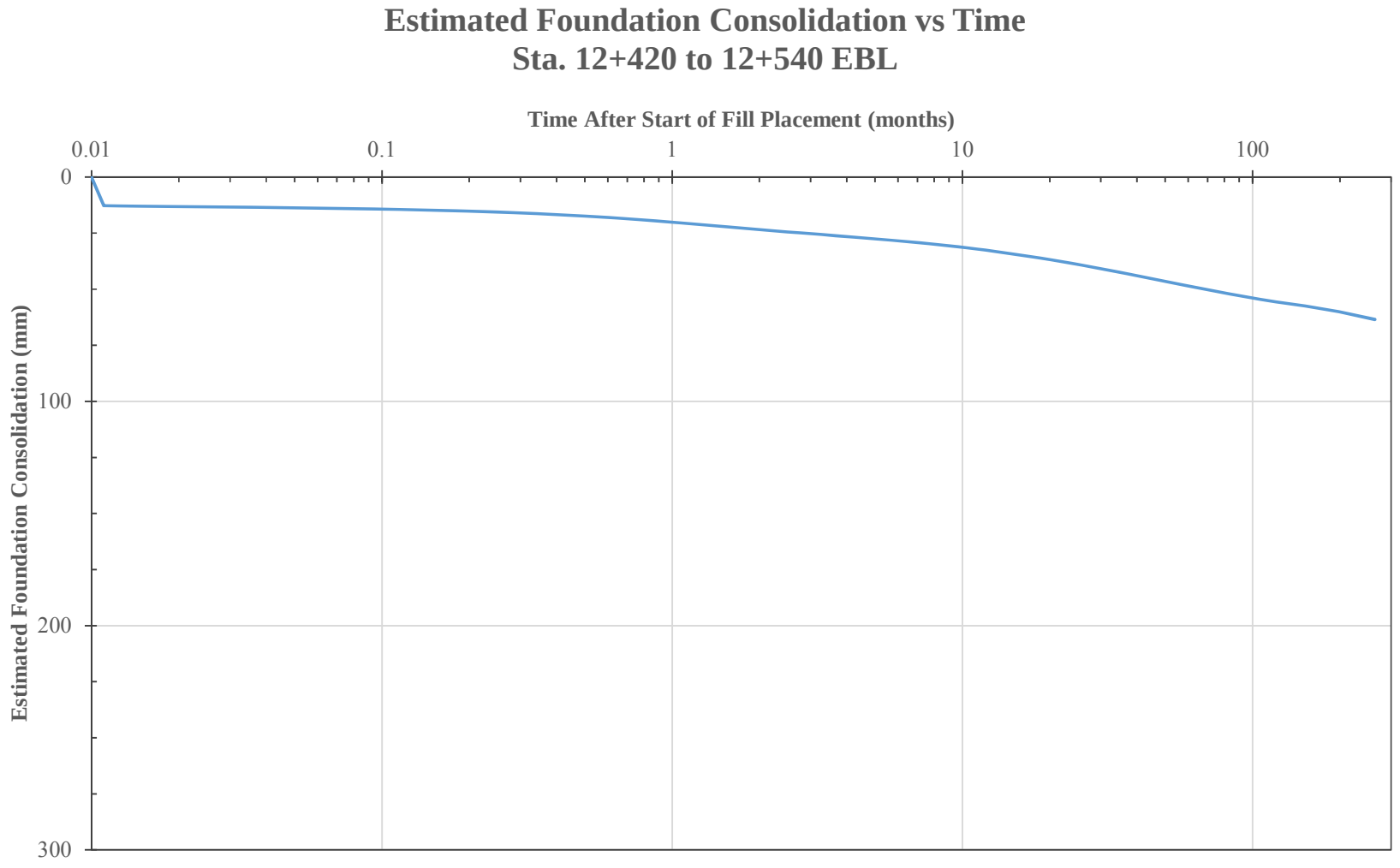

Estimated Foundation Consolidation vs Time
Sta. 12+420 to 12+540 EBL
Time After Start of Fill Placement (months)
0.01
0.1
1
10
100
0
100
200
300
Estimated Foundation Consolidation (mm)

Figure D3

Highway 11/17 - Red Rock to Nipigon

EBL - Sta. 12+420 to 12+540

Summary of Subsurface Conditions (Cohesive Soils)

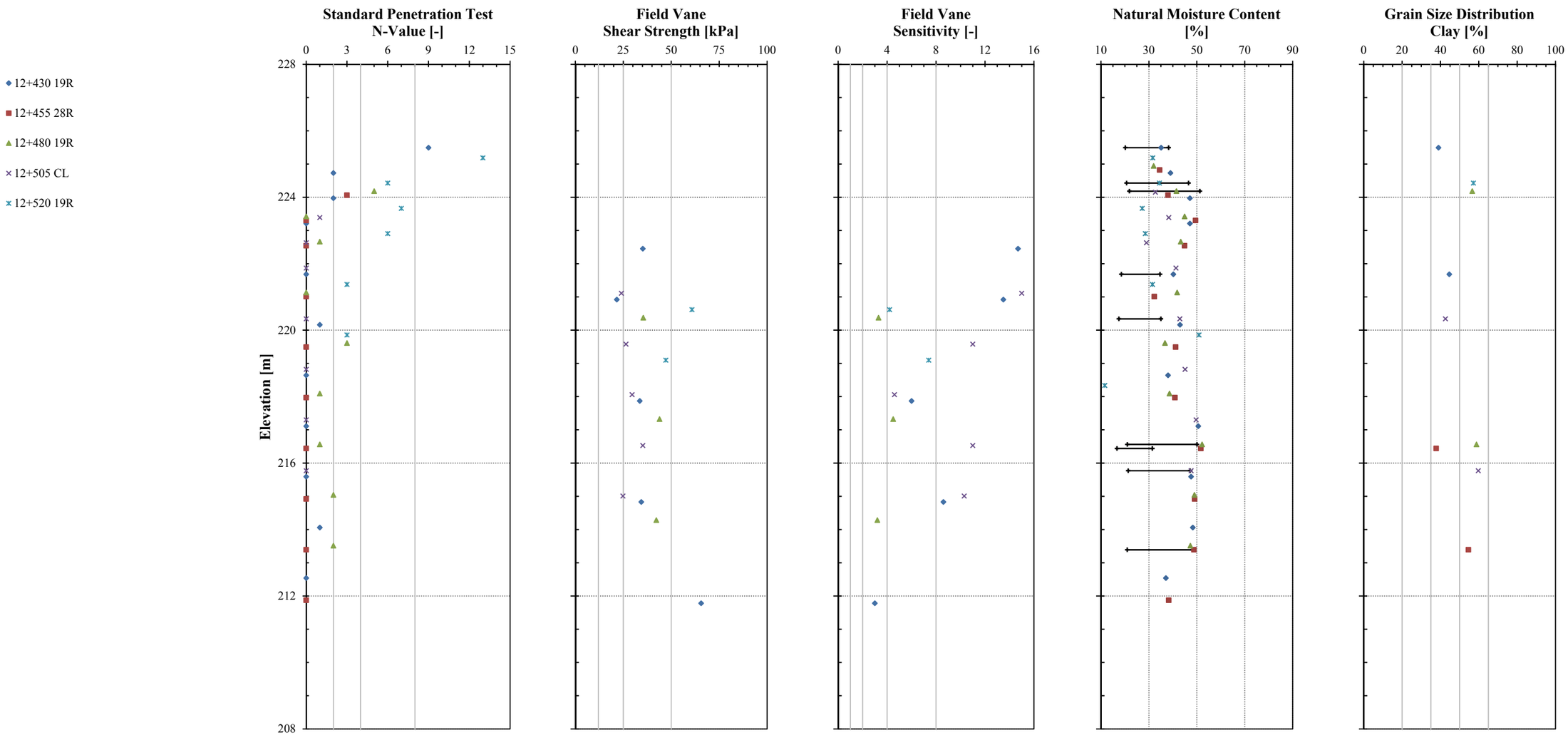


Figure D4

THURBER

Appendix E

Highway 11/17 EBL and WBL

Sta. 12+650 to 13+100

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

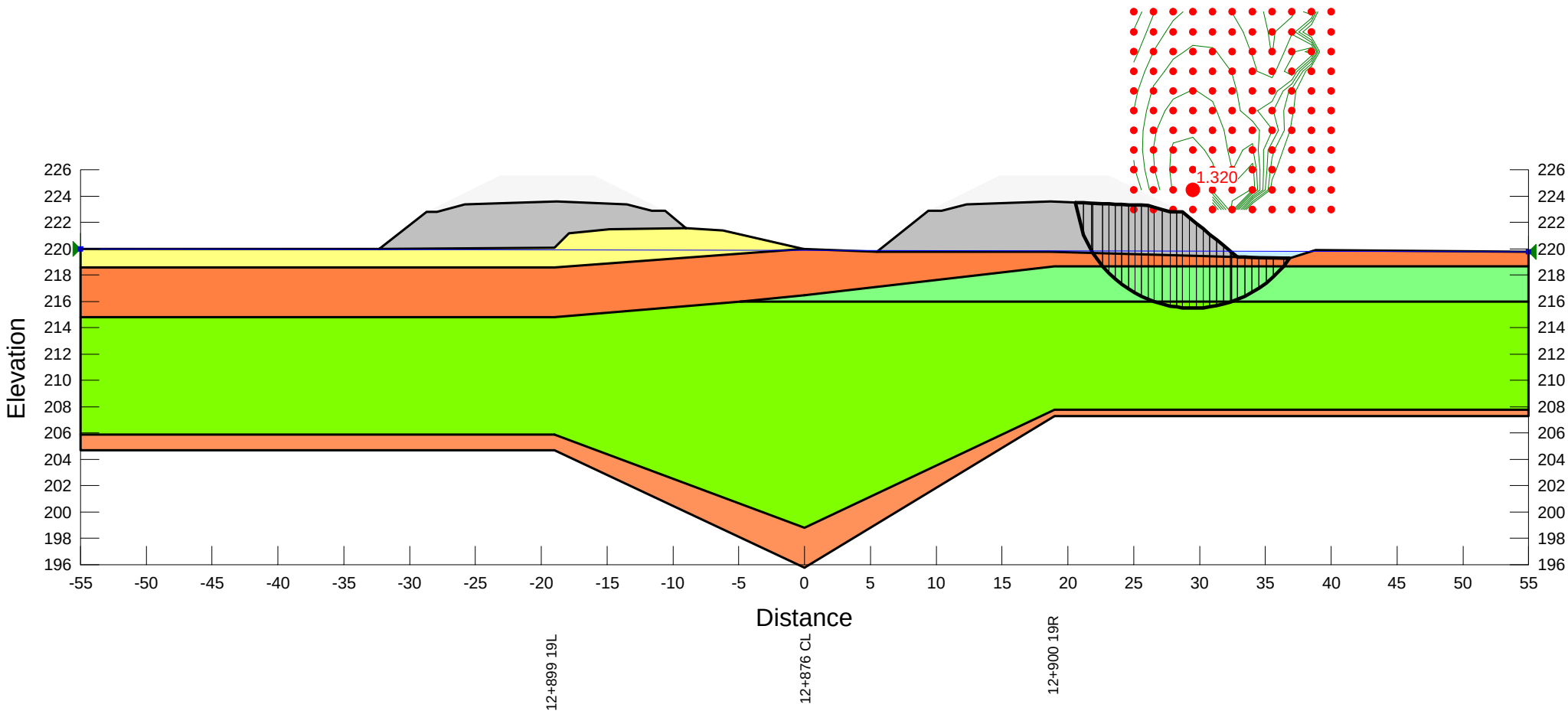
Table E1
Recommendation Summary Table

Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
12+650	13+100	12+750			N/A	N/A							0.5 to 2.3	3.5 to 5.6	220.9	225.0 (4.1)	0	-	-	-	-	5					
		12+800			N/A	N/A							0.5 to 0.8	5.6 to 16.5	220.5	224.5 (4.0)	0	-	-	-	-	5					
		12+850			N/A	N/A							0.1 to 0.8	16.5 to 26.8	220.3	224.0 (3.7)	0	-	-	-	-	5	20	5	40	90	130
		12+930	0.1	13.7 to 14.9	220.5	223.1 (2.6)	0	-	-	-	-	5	0.5 to 0.6	12.4 to 13.6	219.8	223.1 (3.3)	0	-	-	-	-	5	20	5	15	80	95
		13+100	0.1 to 0.2	8.5 to 12.2	219.8	221.5 (1.7)	0	-	-	-	-	5	0.1 to 0.2	8.5 to 12.2	219.1	221.3 (2.2)	0	-	-	-	-	5					
		All	-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 5 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving (12+650 to 12+900: Not part of Thurber's scope)											-Pre Construction: Remove organics/peat. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 5 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving															

Title: Highway 11/17, Nipigon, Ontario
Name: 1.ST.T
Description: Embankment Stability
Comments: STA: 12+890 (12+650 to 13+100)
Last Edited By: Stephen Peters
Last Solved Date: 7/12/2013, 12:01:26 PM
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1	
SAND	20 kN/m³	0 kPa	30 °	1	
SILT	19 kN/m³	0 kPa	29 °	1	
Silty CLAY 1 (TSA)	18 kN/m³	20 kPa	0 °	1	
Silty CLAY 2 (TSA)	18 kN/m³	20 kPa	1.5 kPa/m	50 kPa	1
SAND and GRAVEL	20 kN/m³	0 kPa	30 °	1	



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\12+650 to 13+100\Stability\12+890_001.gsz

Figure E1

Title: Highway 11/17, Nipigon, Ontario
Name: 1.LT.E
Description: Embankment Stability
Comments: STA: 12+890 (12+650 to 13+100)
Last Edited By: Stephen Peters
Last Solved Date: 2013-07-14, 12:33:30 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1
SAND	20 kN/m³	0 kPa	30 °	1
SILT	19 kN/m³	0 kPa	29 °	1
Silty CLAY 1 (ESA)	18 kN/m³	7 kPa	23 °	1
Silty CLAY 2 (ESA)	18 kN/m³	7 kPa	23 °	1
SAND and GRAVEL	20 kN/m³	0 kPa	30 °	1

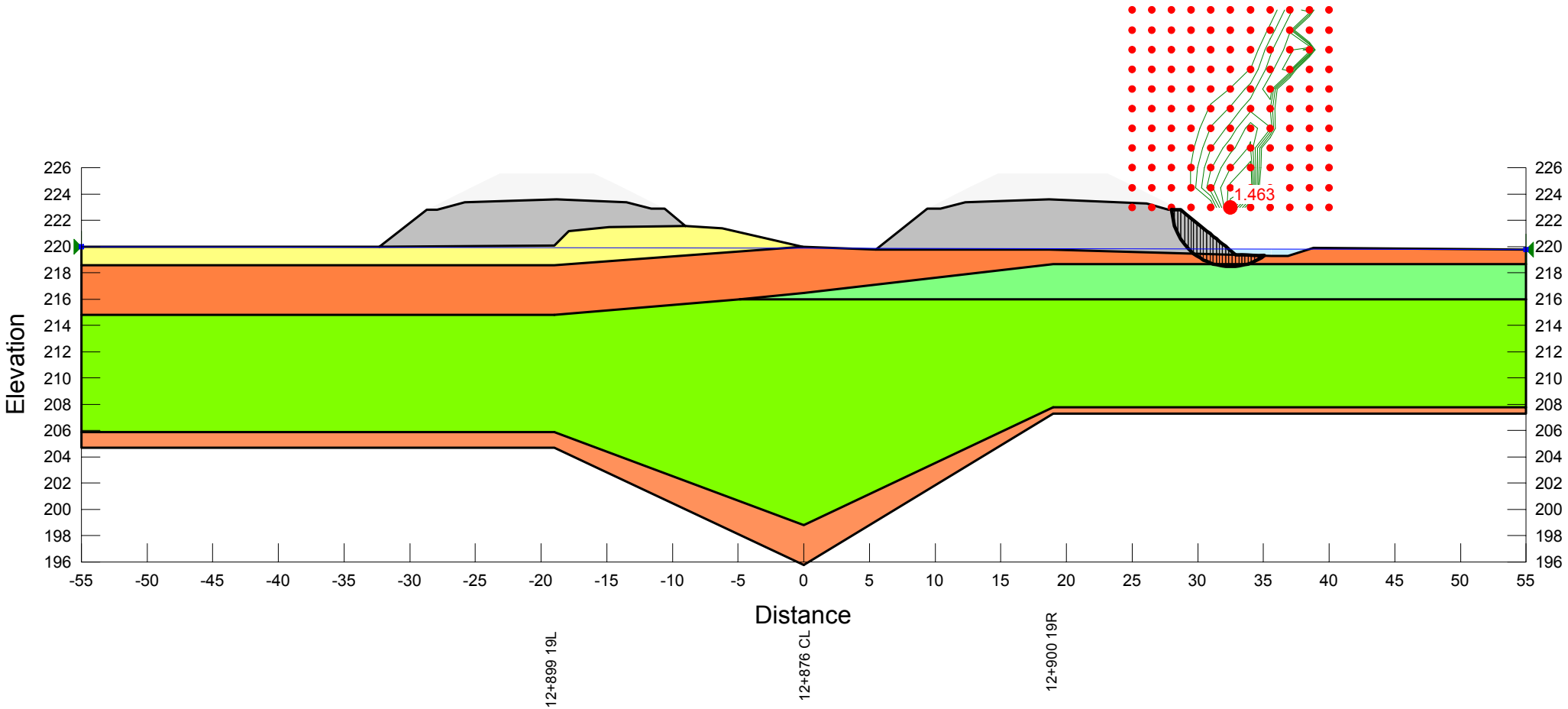


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Figure E2

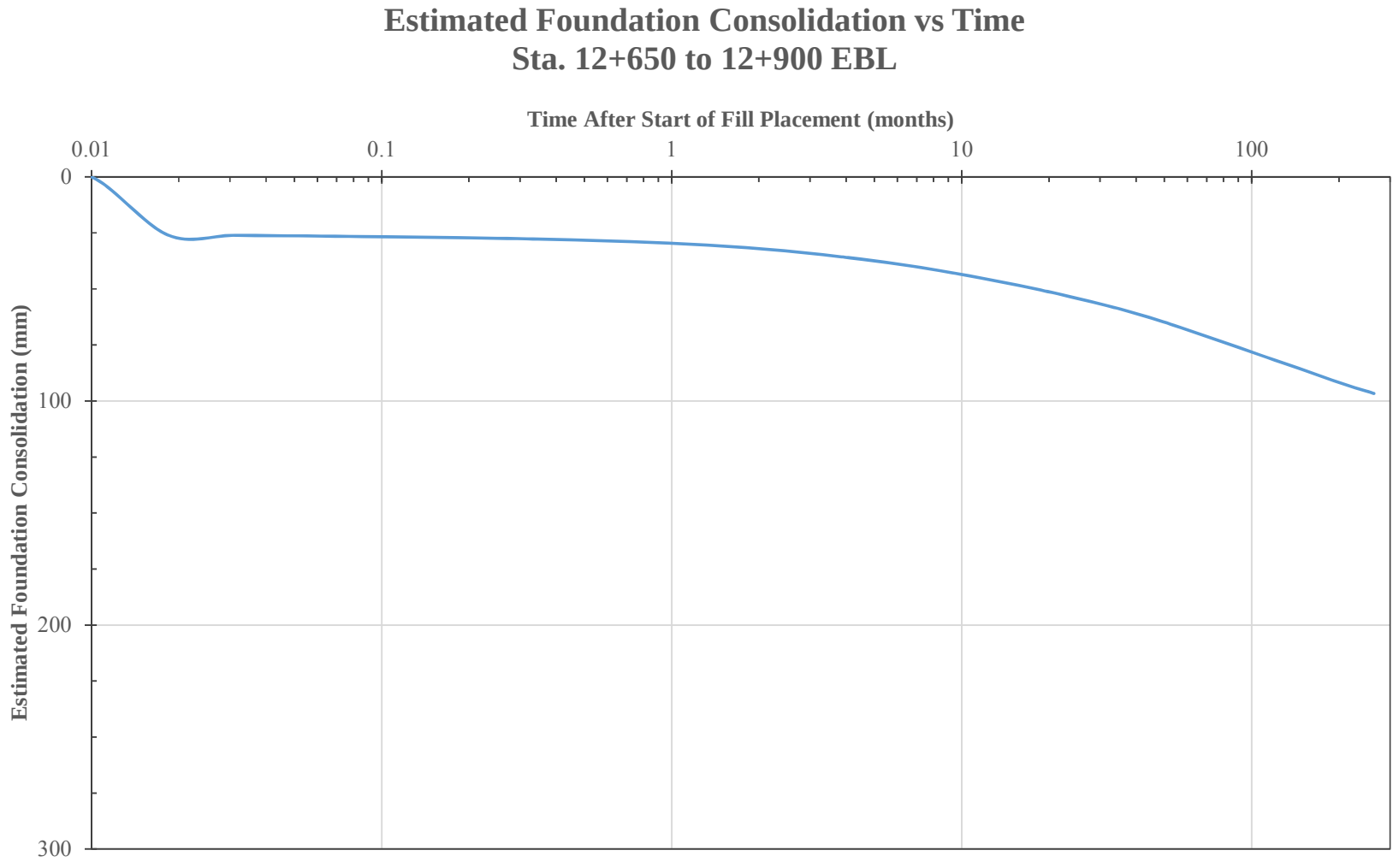


Figure E3

THURBER

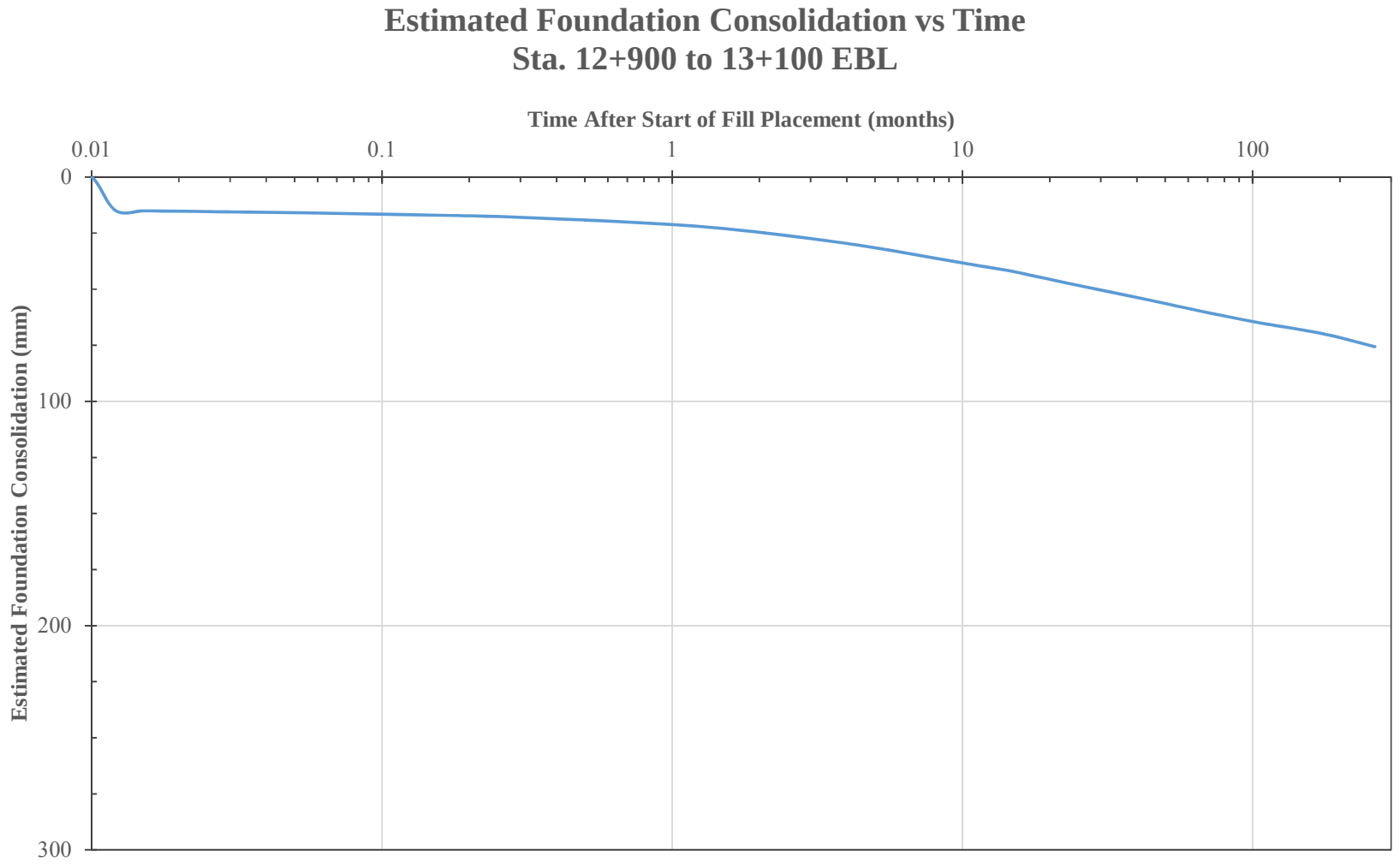

Estimated Foundation Consolidation vs Time
Sta. 12+900 to 13+100 EBL
Time After Start of Fill Placement (months)
0.01
0.1
1
10
100
0
100
200
300
Estimated Foundation Consolidation (mm)

Figure E4

Highway 11/17 - Red Rock to Nipigon

EBL - Sta. 12+650 to 13+100 and WBL - Sta. 12+900 to 13+100

Summary of Subsurface Conditions (Cohesive Soils)

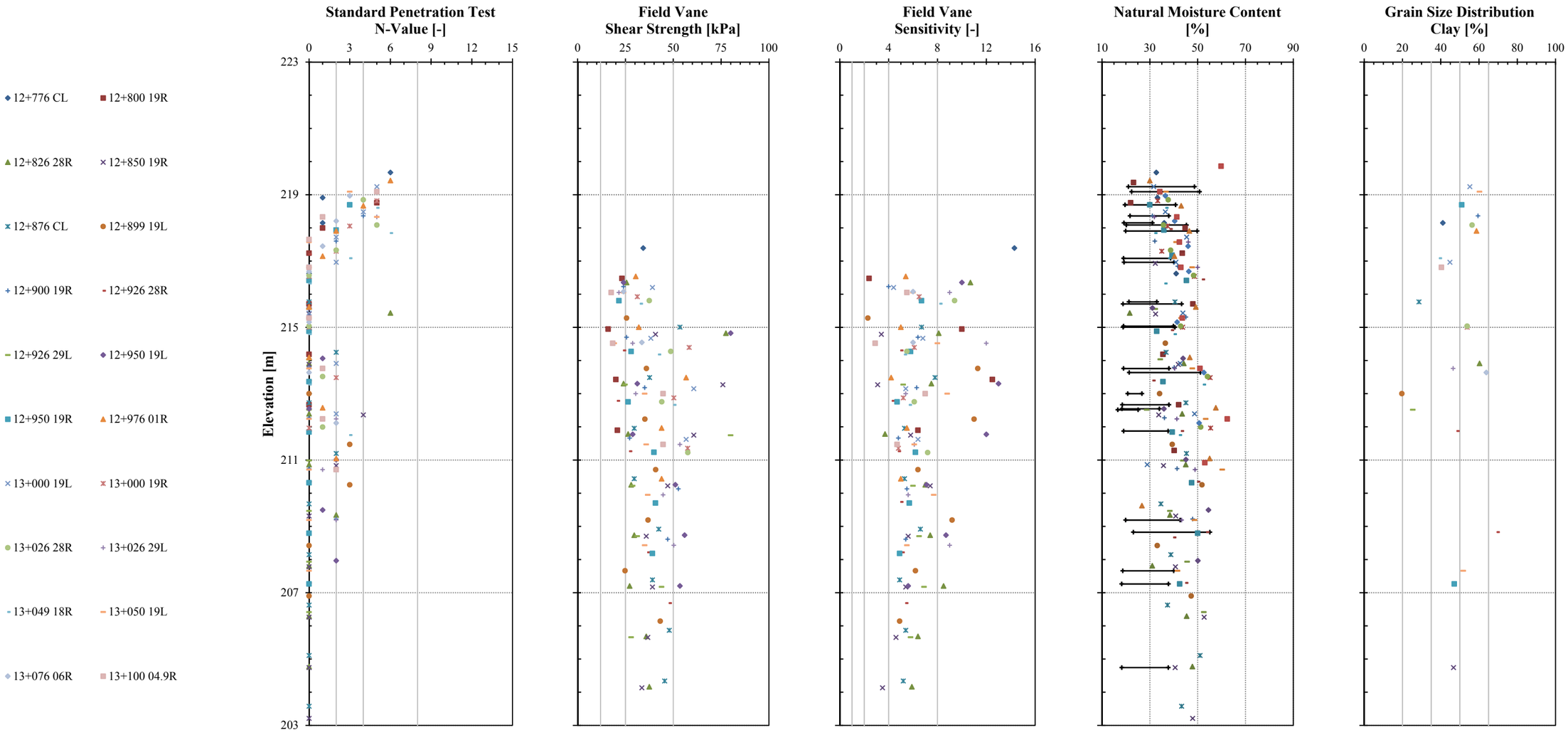


Figure E5

THURBER

Appendix F

Highway 11/17 EBL and WBL

Sta. 13+300 to 13+450

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table F1
Recommendation Summary Table

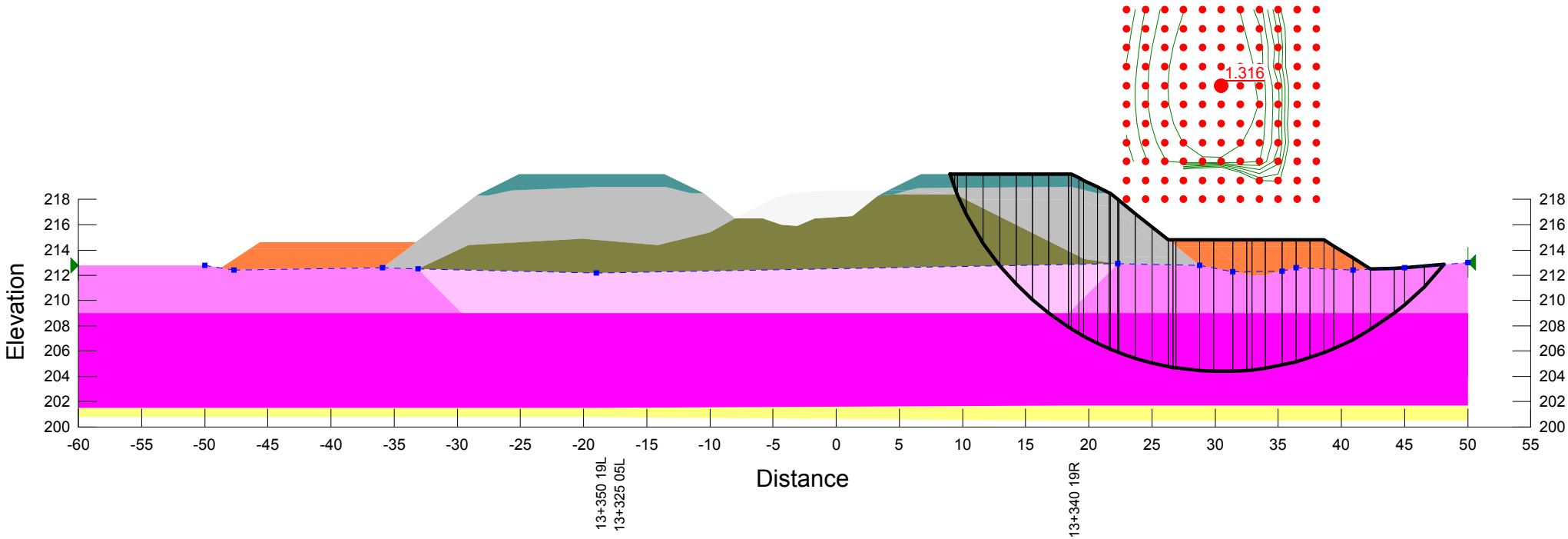
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
13+300	13+450	13+310	0.2	12.5 to 13.4	215.7	219.4 (3.7)	1	12.5	215.0 (2.5)	-	1.5	Stage 1: 6 Stage 2: 6 (12 total)	0.1	13.6	216.0	219.3 (3.3)	1	12.5	218.0 (2.5)	-	1.5	Stage 1: 6 Stage 2: 6 (12 total)					
		13+340	N/A	12.5 to 14.2	214.3	219.1 (4.8)	1	12.5	215.0 (2.5)	-	1.5		0.1 to 0.8	12.5 to 12.6	213.5	219.1 (5.6)	1	12.5	216.0 (2.5)	-	1.5		50	10	470	25	495
		13+370	N/A	13.4 to 13.8	213.9	218.9 (5.0)	1	12.5	216.0 (2.5)	-	1.5		N/A	13.7	212.2	218.9 (6.7)	1	12.5	214.5 (2.5)	-	1.5						
		13+400	N/A	14.8 to 15.7	215.6	218.6 (3.0)	1	-	-	-	1.5		0.2	14.8	214.7	218.6 (3.9)	1	-	-	-	1.5						
		13+430	N/A	15.7 to 17.5	217.2	218.3 (1.1)	-	-	-	-	-	1	N/A	15.0 to 15.7	218.2	218.3 (0.1)	-	-	-	-	-	1					
		All	-Pre Construction: - Install sheet piles for culvert (Itzcaulde Creek). - Remove organics/peat and replace with drainage blanket to 1.0 m above water level for wick drain installation. - Install wick drains (refer to wick drain drawing) - Install monitoring instrumentation. Record monitoring instrumentation baseline readings. -Fill Placement Stage 1: Simultaneously construct berm (to dimensions shown) and embankments to the design road grade. Wait 6 months. -Fill Placement Stage 2: Reconstruct embankment to Stage 1 elevation (replace grade due to settlement) + 1.0m surcharge. Wait 6 months. -Post Construction: - After wait period, remove excess surcharge and excavate to 3.5m below the design road grade elevation. - Backfill with 2.5m of EPS (to dimensions shown) and 1.0m of road base cover (refer to EPS drawing) - Complete paving. Estimated settlement: -Stage 1: 400 mm -Stage 2: 70 mm																								
			Berm extents (taper berm outside these stations): 13+300 to 13+390										13+300 to 13+390														

Title: Highway 11/17, Nipigon, Ontario
Name: 1.ST.U.s1.b
Description: Embankment Stability
Comments: STA: 13+350 (13+300 to 13+450)
Last Edited By: Stephen Peters
Last Solved Date: 2013-07-30, 10:42:28 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

SURCHARGE	21 kN/m³	0 kPa	32 °	1	Yes	
FILL (New)	22 kN/m³	0 kPa	42 °	1	Yes	
FILL (Existing)	21 kN/m³	0 kPa	32 °	1	No	
SAND/SILT	20 kN/m³	0 kPa	30 °	1	No	
Silty CLAY 1 (USA)	18 kN/m³	0.22	30	1	0.15	No
Silty CLAY 2 (USA)	18 kN/m³	0.22	23	1	0.15	No
Berm	21 kN/m³	0 kPa	32 °	1	No	
Silty CLAY 1 (USA*)	18 kN/m³	0.22	50	1	0.15	No



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\13+300 to 13+450\Stability\13+350_003.gsz

Figure F1

Title: Highway 11/17, Nipigon, Ontario
Name: 1.ST.U
Description: Embankment Stability
Comments: STA: 13+350 (13+300 to 13+450)
Last Edited By: Stephen Peters
Last Solved Date: 2014-07-22, 8:50:12 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1	Yes	
FILL (Existing)	21 kN/m³	0 kPa	32 °	1	No	
SAND/SILT	20 kN/m³	0 kPa	30 °	1	No	
Silty CLAY 1 (USA)	18 kN/m³	0.22	30	1	0.15	No
Silty CLAY 2 (USA)	18 kN/m³	0.22	23	1	0.15	No
Berm	21 kN/m³	0 kPa	32 °	1	No	
Silty CLAY 1 (USA*)	18 kN/m³	0.22	50	1	0.15	No

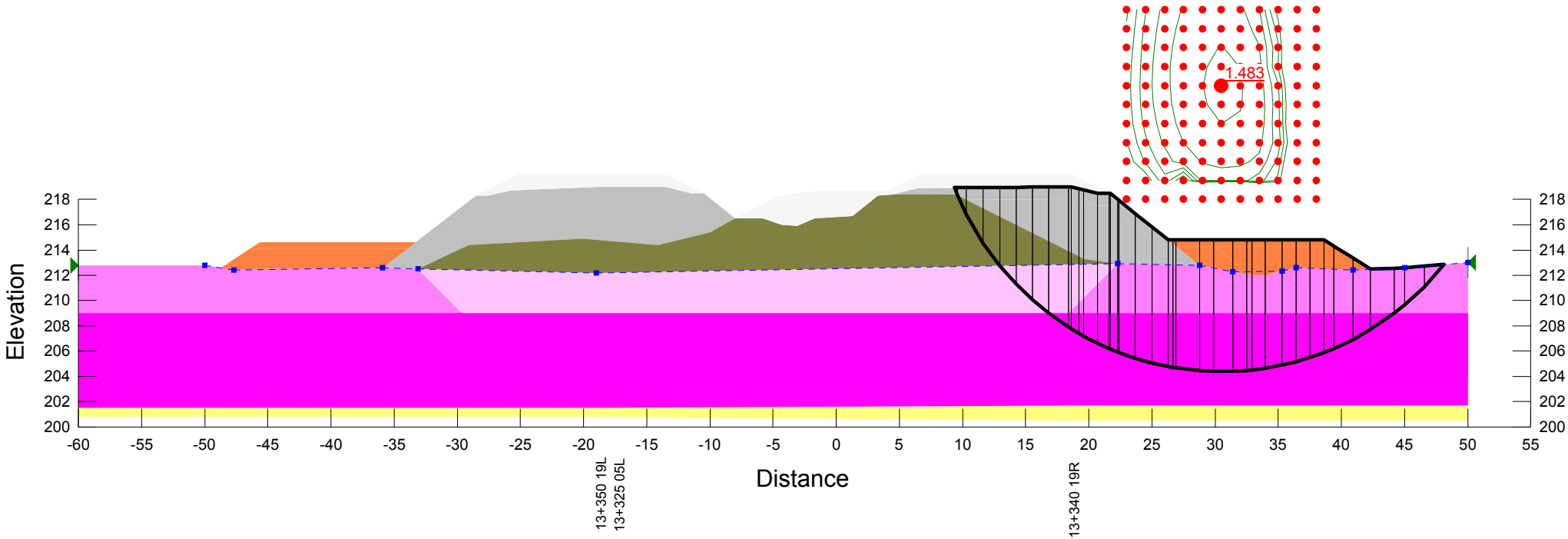


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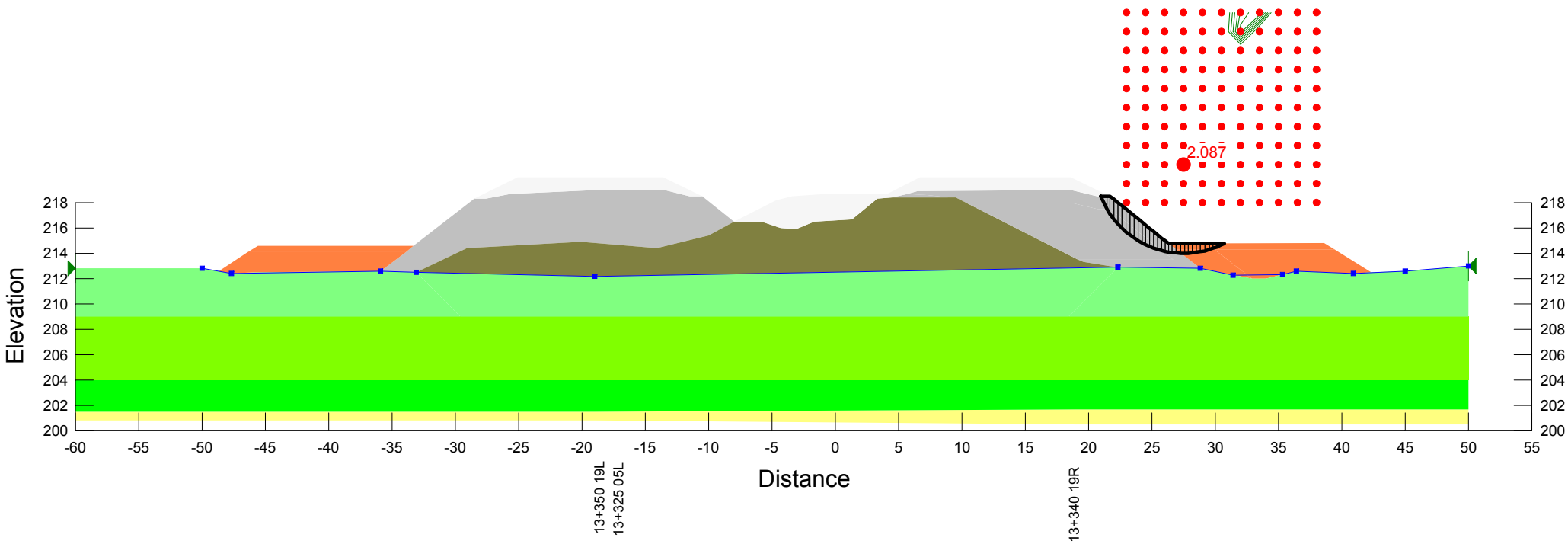
Figure F2

Title: Highway 11/17, Nipigon, Ontario
Name: 1.LT.E.b
Description: Embankment Stability
Comments: STA: 13+350 (13+300 to 13+450)
Last Edited By: Stephen Peters
Last Solved Date: 2014-07-22, 8:59:25 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1
FILL (Existing)	21 kN/m³	0 kPa	32 °	1
Silty CLAY 1 (ESA)	18 kN/m³	7 kPa	23 °	1
Silty CLAY 2 (ESA)	18 kN/m³	7 kPa	23 °	1
Silty CLAY 3 (ESA)	18 kN/m³	7 kPa	23 °	1
SAND/SILT	20 kN/m³	0 kPa	30 °	1
Berm	21 kN/m³	0 kPa	32 °	1



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\13+300 to 13+450\Stability\13+350_003.gsz

Figure F3

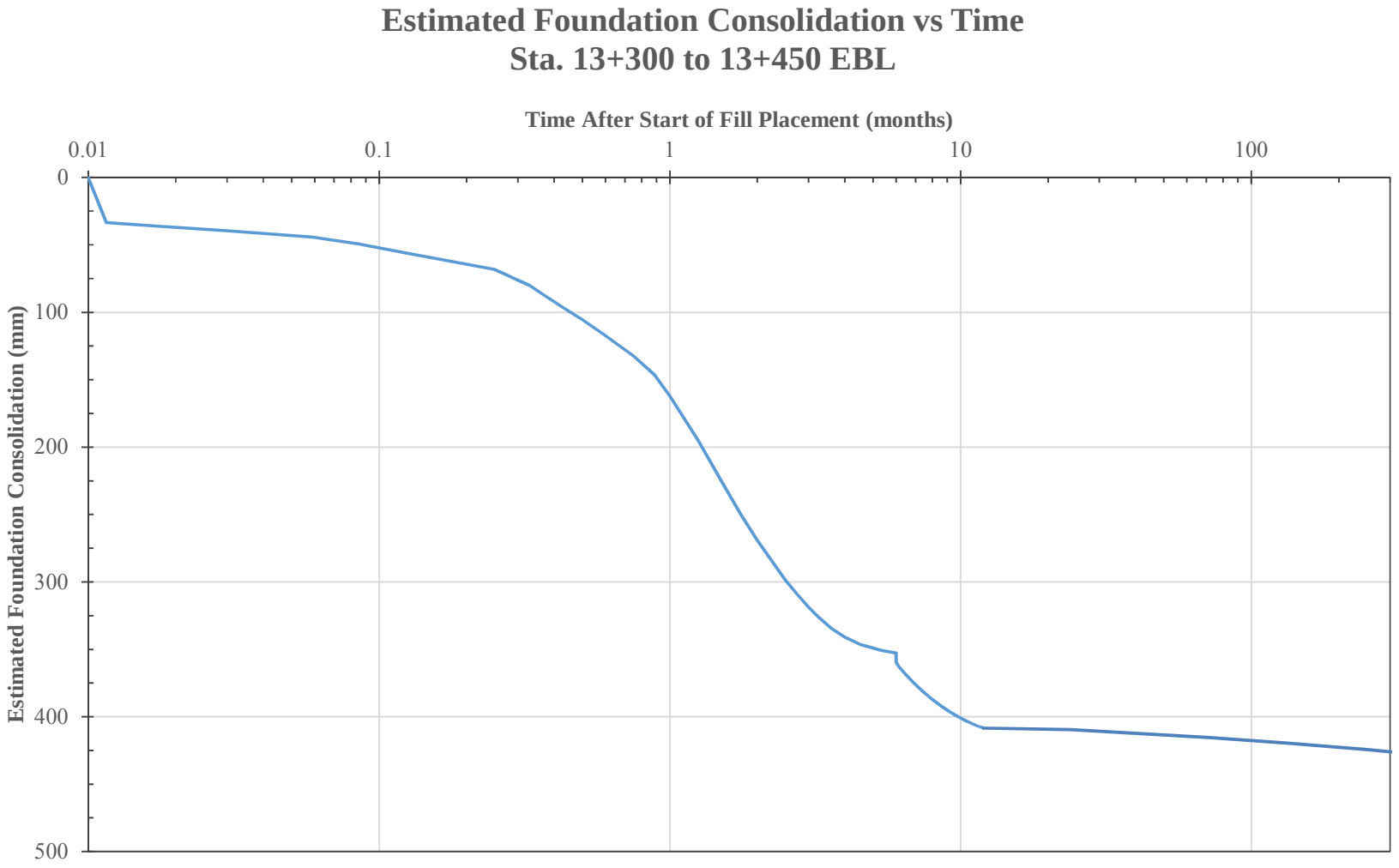


Figure F4

THURBER

Highway 11/17 - Red Rock to Nipigon

EBL and WBL - Sta. 13+300 to 13+450

Summary of Subsurface Conditions (Cohesive Soils)

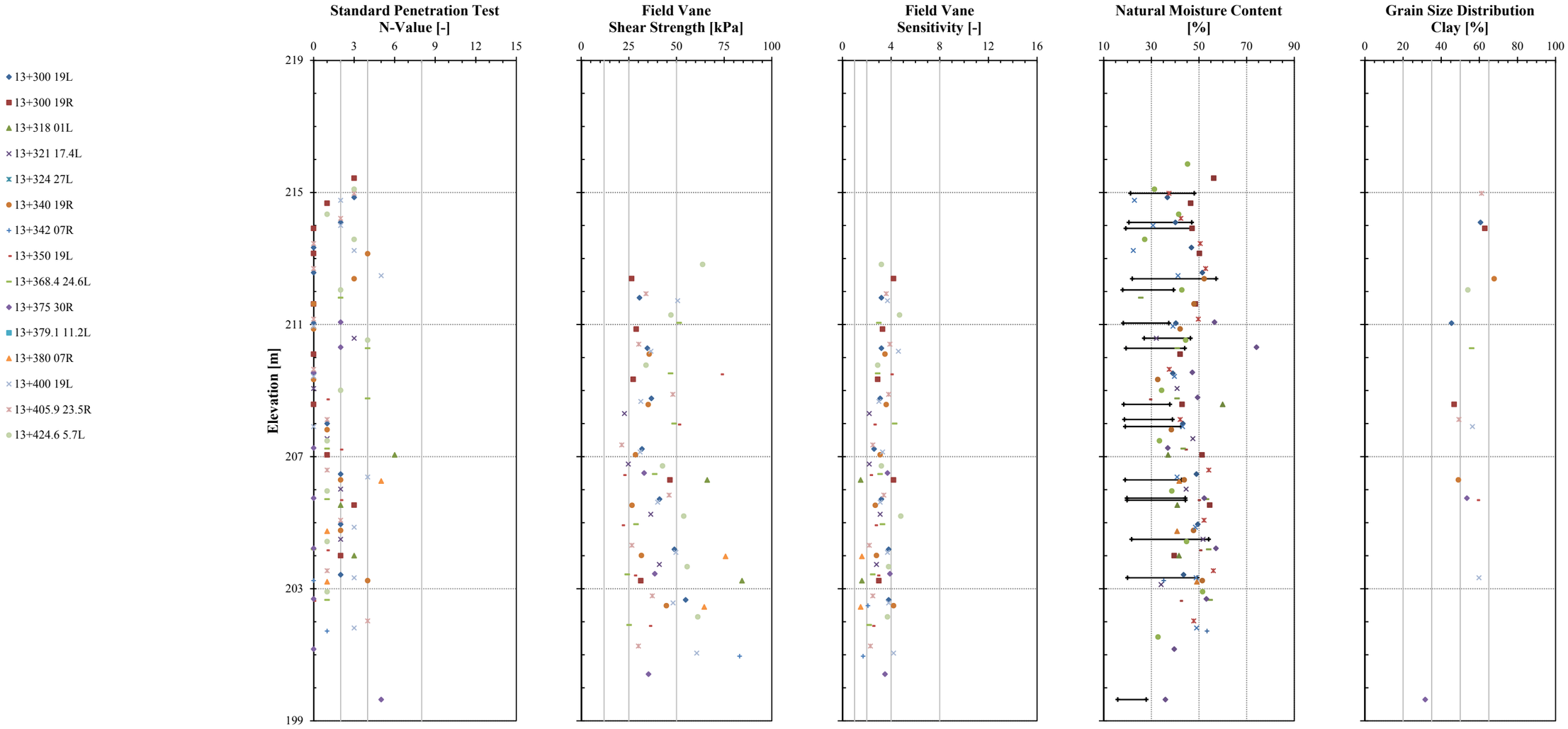


Figure F5

THURBER

Appendix G

Highway 11/17 EBL and WBL

Sta. 16+250 to 16+460

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table G1
Recommendation Summary Table

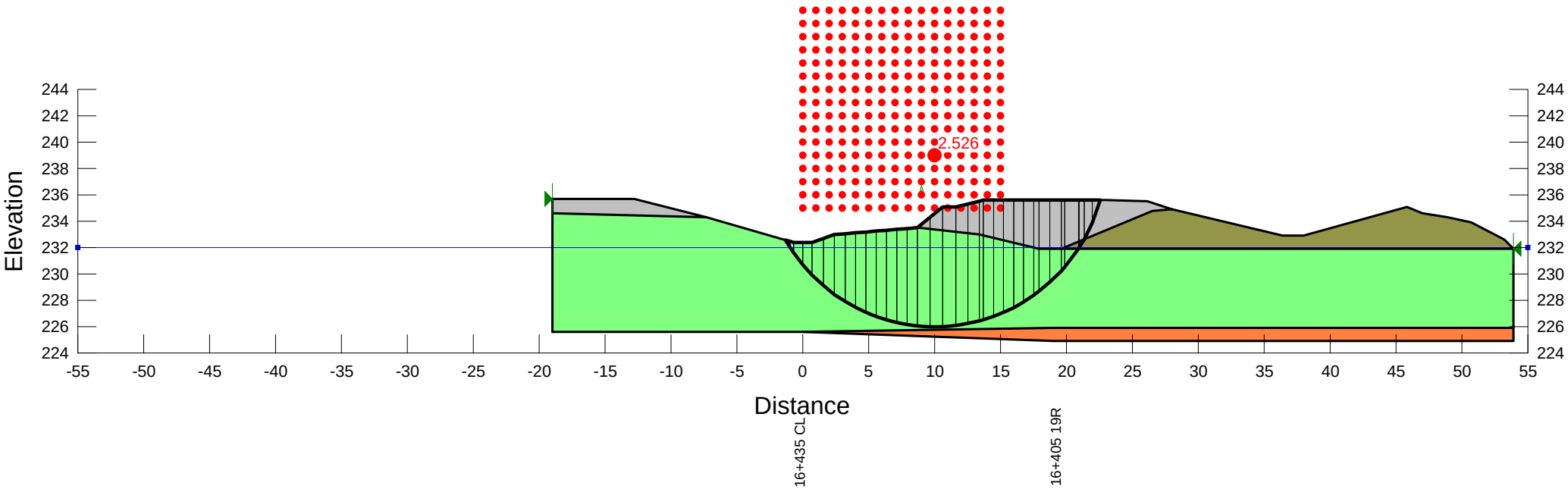
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
16+250	16+460	16+250			N/A	N/A							0.4 to 0.7	7.8 to 9.2	231.0	233.5 (2.5)	-	-	-	-	-	4					
		16+330			N/A	N/A							0.4 to 1.6	6.1 to 9.2	232.9	234.3 (1.4)	-	-	-	-	-	4					
		16+400			N/A	N/A							0.1 to 0.8	6.1 to 6.4	231.8	235.5 (3.7)	-	-	-	-	-	4	20	5	60	90	150
		All	Not part of Thurber's scope										-Pre Construction: Remove organics/peat in narrow sections to not adversely affect the stability of the existing roadway along the EBL alignment. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 4 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving															

Title: Highway 11/17, Nipigon, Ontario
Name: 2.ST.T
Description: Embankment Stability
Comments: STA: 16+410 (16+250 to 16+450)
Last Edited By: Stephen Peters
Last Solved Date: 7/11/2013, 10:46:03 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1
Silty CLAY (TSA)	18 kN/m³	30 kPa	0 °	1
SAND	20 kN/m³	0 kPa	30 °	1
FILL (Existing ?)	21 kN/m³	0 kPa	32 °	1



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\16+250 to 16+450\Stability\16+410_001.gsz

Figure G1

Title: Highway 11/17, Nipigon, Ontario
Name: 2.ST.E
Description: Embankment Stability
Comments: STA: 16+410 (16+250 to 16+450)
Last Edited By: Stephen Peters
Last Solved Date: 7/11/2013, 10:45:56 AM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1	Yes	
Silty CLAY (ESA)	18 kN/m³	7 kPa	23 °	1	0.9	No
SAND	20 kN/m³	0 kPa	30 °	1	No	
FILL (Existing ?)	21 kN/m³	0 kPa	32 °	1	No	

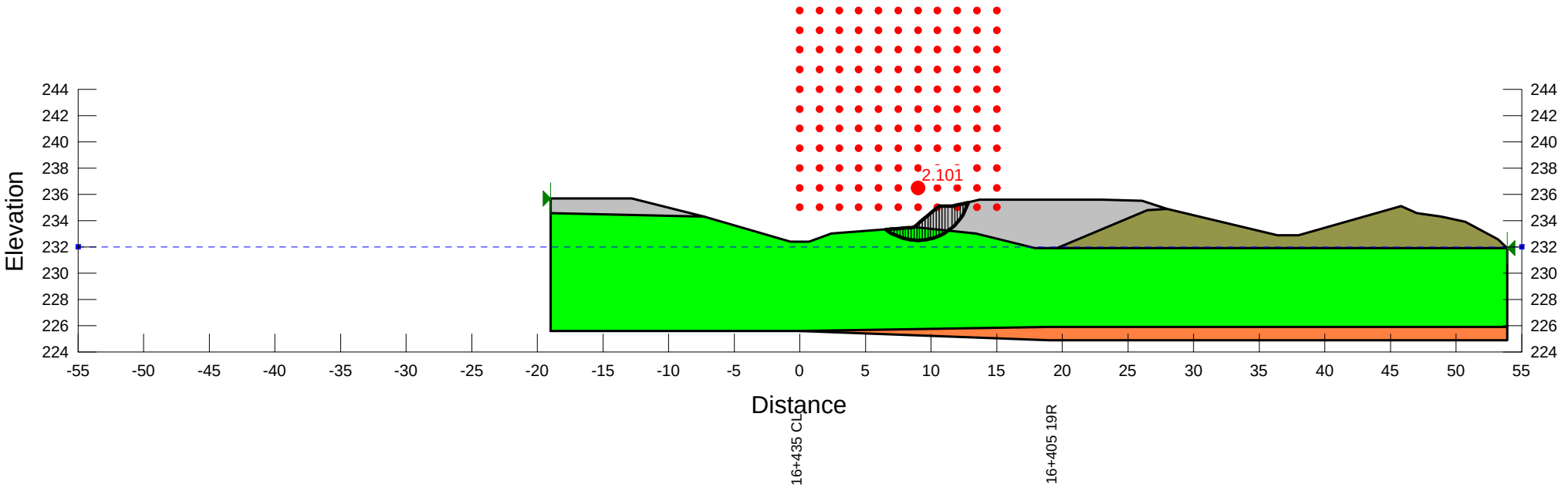


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Figure G2

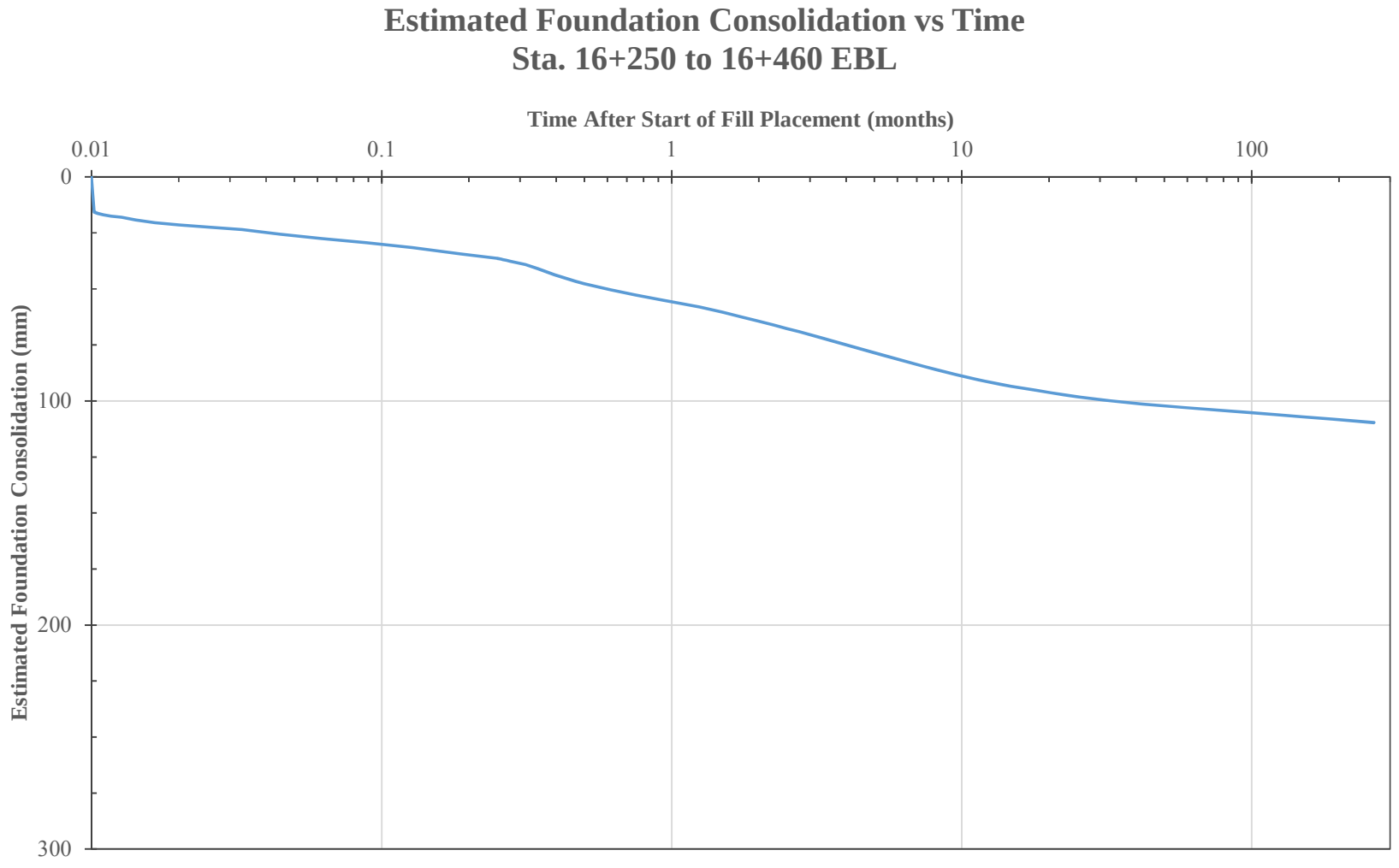

Estimated Foundation Consolidation vs Time
Sta. 16+250 to 16+460 EBL
Time After Start of Fill Placement (months)
0.01
0.1
1
10
100
0
100
200
300
Estimated Foundation Consolidation (mm)

Figure G3

Highway 11/17 - Red Rock to Nipigon

EBL - Sta. 16+625 to 16+460

Summary of Subsurface Conditions (Cohesive Soils)

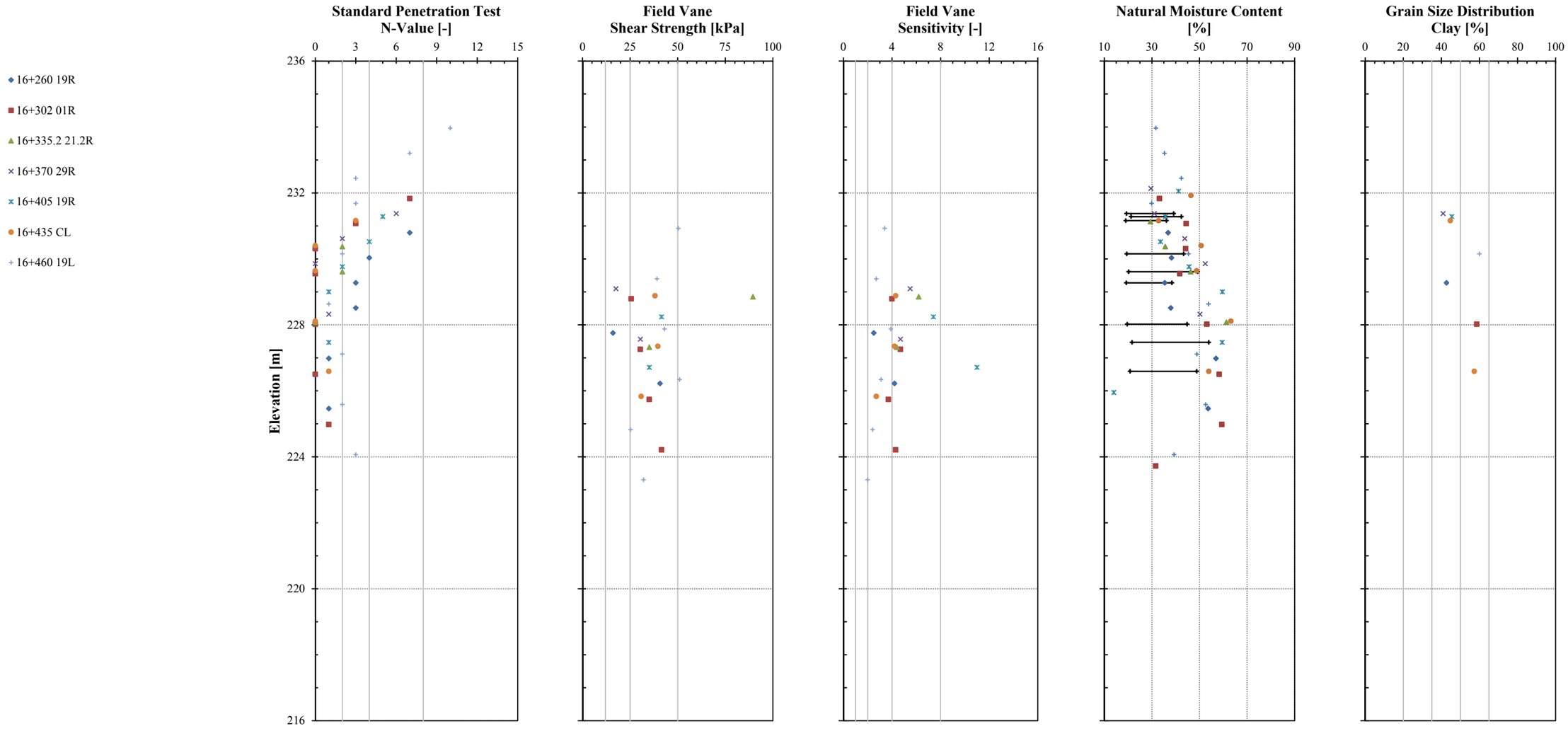


Figure G4

Appendix H

Highway 11/17 EBL and WBL

Sta. 16+830 to 16+940

Recommendations Summary Table
Selected Slope Stability Analysis Figures
Selected Settlement Analysis Figures
Summary of Subsurface Conditions

Table H1
Recommendation Summary Table

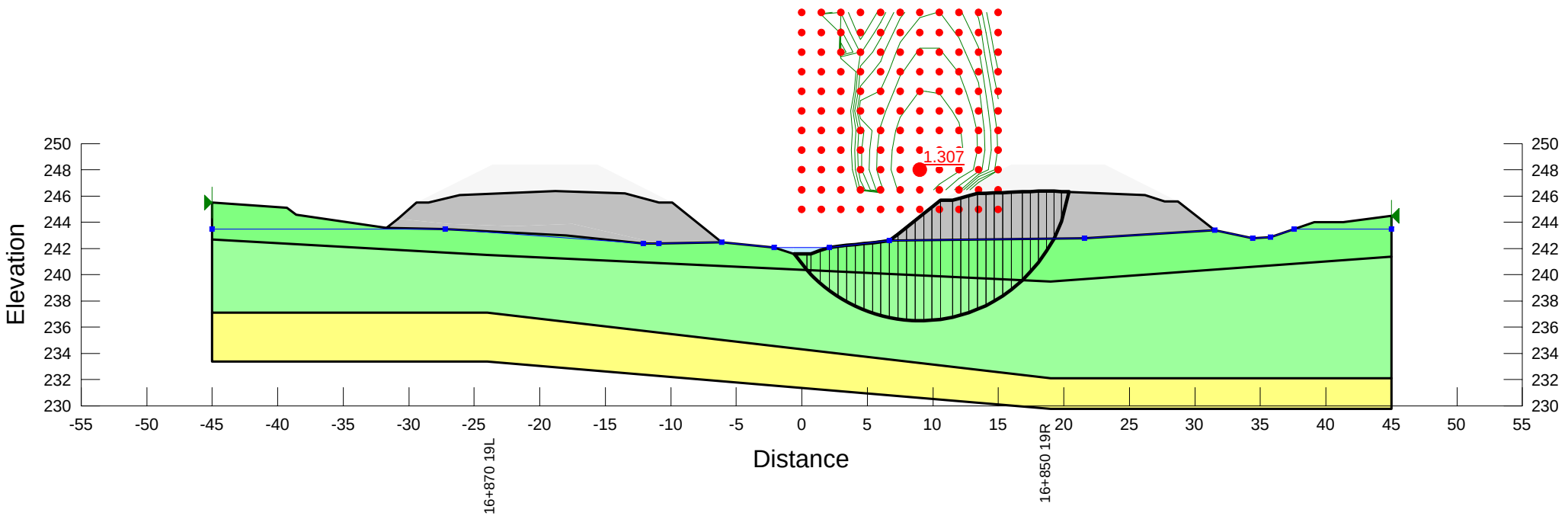
Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
		16+850	0.2 to 0.8	4.3 to 6.6	244.2	246.1 (1.9)	0 1	-	-	-	-	12 6	0.2 to 0.3	10.1 to 10.3	242.0	246.1 (4.1)	0 1	- 8.0	- 243.5 (1.5)	-	-	12 6	20	5	130	85	215
		16+900	0.2	6.6 to 8.8	243.6	247.3 (3.7)	0 1	- 8	- 245.1 (1.5)	-	-	12 6	0.2	8.2 to 10.3	245.0	247.2 (2.2)	-	-	-	-	-	12 6					
16+830	16+940	All	-Pre Construction: Remove organics/peat (artesian conditions present) Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 12 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving. Option 2 -Fill Placement Stage 1: Simultaneously construct berm (to dimensions shown), embankment and surcharge. Wait 6 months. -Post Construction: After wait period, remove excess surcharge to design road grade elevation and complete paving. Berm extents: -16+860 to 16+910 (taper berm outside these stations)											-Pre Construction: Remove organics/peat (artesian conditions present) Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 12 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving. Option 2 -Fill Placement Stage 1: Simultaneously construct berm (to dimensions shown), embankments and surcharge. Wait 6 months. -Post Construction: After wait period, remove excess surcharge to design road grade elevation and complete paving. Berm extents: -16+830 to 16+890 (taper berm outside these stations)													

Title: Highway 11/17, Nipigon, Ontario
Name: 2.ST.T
Description: Embankment Stability
Comments: STA: 16+860 (16+830 to 16+940)
Last Edited By: Stephen Peters
Last Solved Date: 7/11/2013, 1:51:00 PM

FILL (New)	22 kN/m³	0 kPa	42 °	1
Silty CLAY_1 (TSA)	18 kN/m³	30 kPa	0 °	1
Silty CLAY_2 (TSA)	18 kN/m³	20 kPa	0 °	1
SAND	20 kN/m³	0 kPa	30 °	1

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0



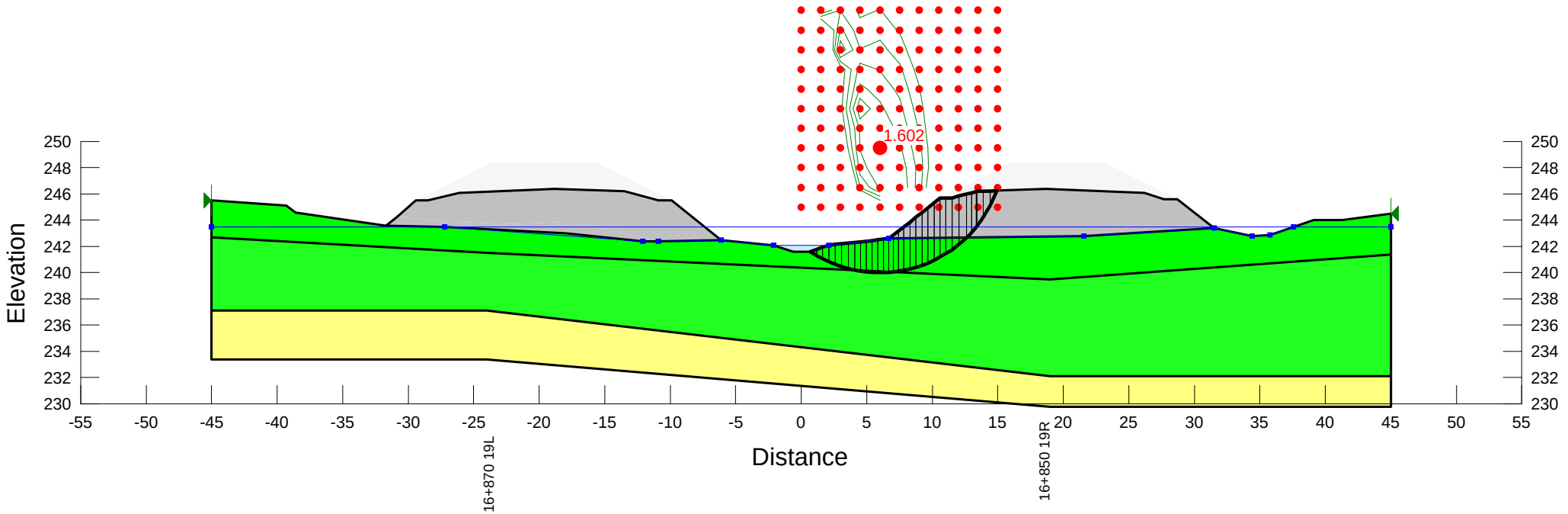
Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\16+830 to 16+940\Stability\16+860_001.gsz

Figure H1

Title: Highway 11/17, Nipigon, Ontario
Name: 2.LT.E
Description: Embankment Stability
Comments: STA: 16+860 (16+830 to 16+940)
Last Edited By: Stephen Peters
Last Solved Date: 7/11/2013, 2:04:19 PM

FILL (New)	22 kN/m³	0 kPa	42 °	1
Silty CLAY_1 (ESA)	18 kN/m³	7 kPa	23 °	1
Silty CLAY_2 (ESA)	18 kN/m³	7 kPa	23 °	1
SAND	20 kN/m³	0 kPa	30 °	2

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0



Directory: H:\19\1351\237 Hwy 11-17 Nipigon Low Fills\Analysis\16+830 to 16+940\Stability\16+860_001.gsz

Figure H2

Title: Highway 11/17, Nipigon, Ontario
Name: 2.ST.T.s1
Description: Surcharged Embankment Stability
Comments: STA: 16+860 (16+830 to 16+940)
Last Edited By: Stephen Peters
Last Solved Date: 11/27/2013, 1:11:08 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

SURCHARGE	21 kN/m³	0 kPa	32 °	1
FILL (New)	22 kN/m³	0 kPa	42 °	1
Silty CLAY_1 (TSA)	18 kN/m³	30 kPa	0 °	1
Silty CLAY_2 (TSA)	18 kN/m³	20 kPa	0 °	1
SAND	20 kN/m³	0 kPa	30 °	2

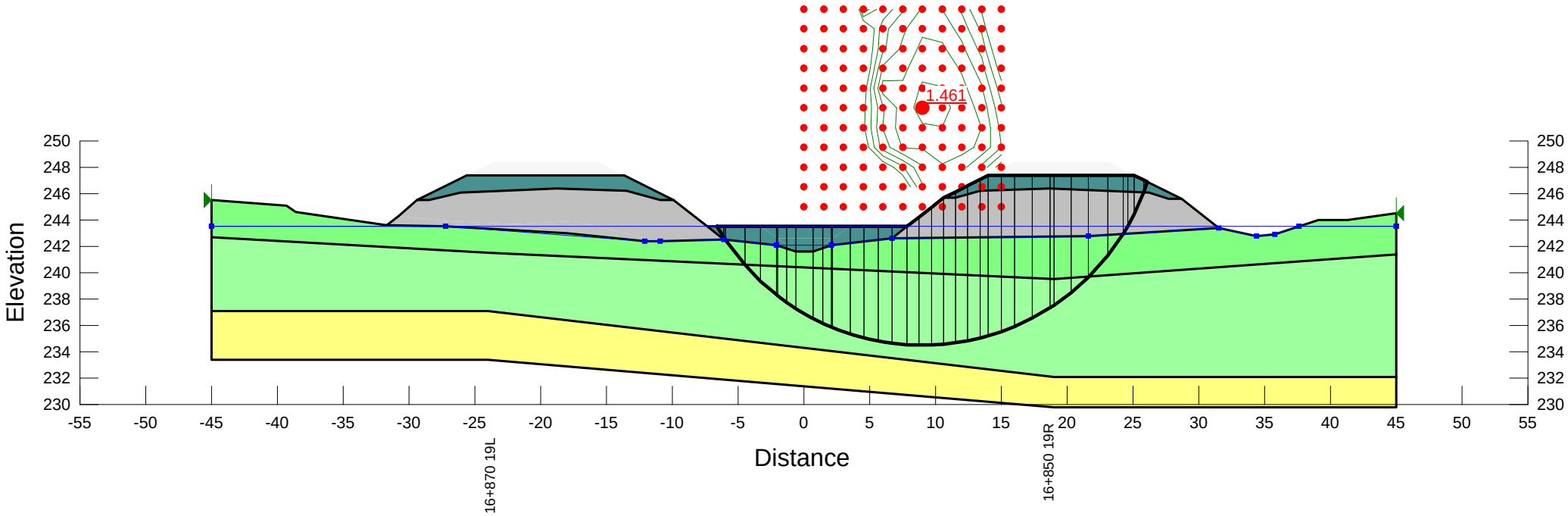


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Figure H3

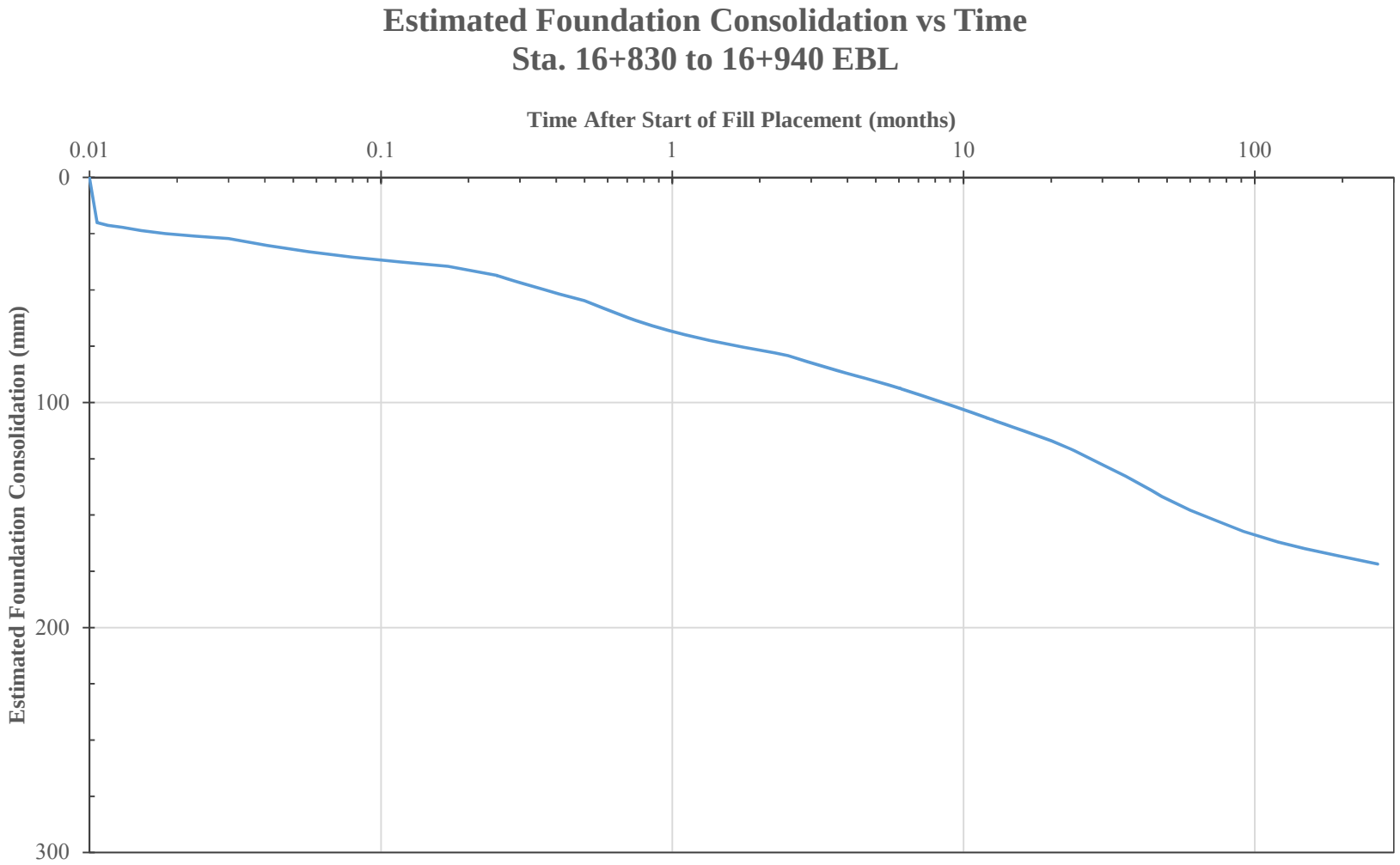

Figure H4

THURBER

Highway 11/17 - Red Rock to Nipigon

EBL and WBL - Sta. 16+830 to 16+940

Summary of Subsurface Conditions (Cohesive Soils)

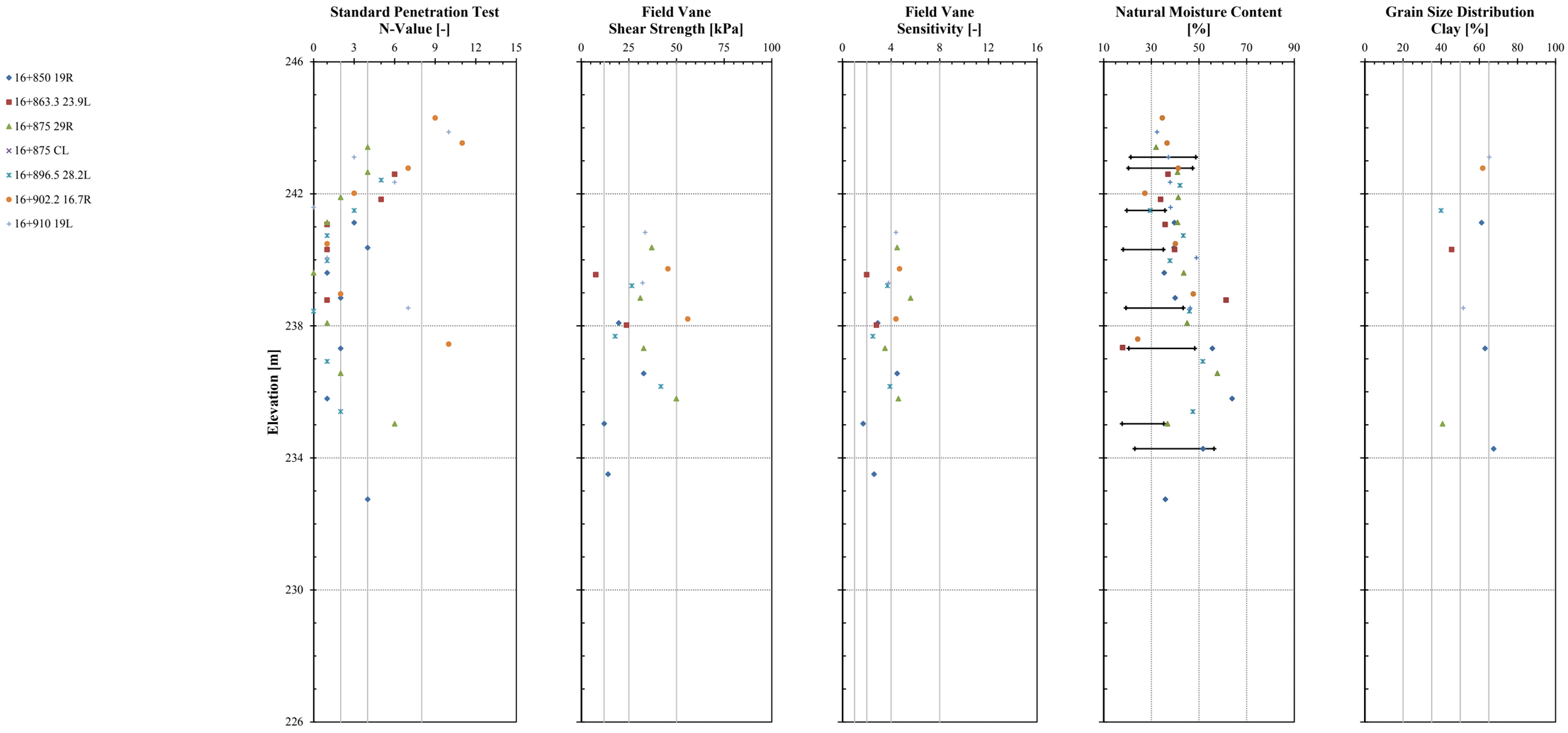

Figure H5

Appendix I

Highway 11/17 EBL and WBL

Sta. 18+450 to 18+500

Recommendations Summary Table

Selected Slope Stability Analysis Figures

Table I1
Recommendation Summary Table

Notes:
(01) Subsurface stratigraphy summary obtained from Borehole, DCPT and CPTu investigations. Ranges of values represent boreholes in vicinity of Stationing shown. Stratigraphy will vary between and beyond investigated locations.
(02) Based on AutoCAD profiles and cross sections received from MMM on June 18, 2013. Elevations are obtained within the width of roadway platform.
(03) Treatment for both sides of embankment slope, median treatment to correspond with the adjacent embankment treatment
(04) Minimum Target Factors of Safety of 1.3 (short term) and 1.5 (long term), were used during foundation stability analyses
(05) Embankments analyzed with rockfill at 1.25H:1V side slopes. Mid-height benching should be included in alignment with MTO's guidelines.
(06) Overbuild to compensate for foundation settlement occurring during wait period. An allowance should be included for loss of rockfill into soft subgrades.
(07) Reinforcement strength is Long Term Design Strength (LTDS), applicable reduction factors and suitable factor of safety should be applied. Example reinforcement: 2 layers of Tencate Mirafi 22XT (or equivalent) can provide 300 kN/m LTDS.
(08) Geosynthetic should be placed at the base of the main embankments and extend the width of embankment (not required under the berm) and requires granular material (300 mm in thicknesss) above and below each layer of geosynthetic.
(09) Wick drains installed in a triangular pattern and through a granular drainage blanket. The top of the granular drainage blanket should be at least 1.0 m above the water level. Wick drains installed below all fill placement areas (i.e. from toe of EBL berm to toe of WBL berm)
(10) Estimated rockfill compression based on MTO guidelines
(*) N/M = not measured

Stations			WBL (Left of Median)										EBL (Right of Median)										Settlement (refer to Table A3)				
							Treatment(3,4,5)										Treatment(3,4,5)						Rockfill Comp.(10)				
								Berm										Berm									
From	To	Station	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	Thickn. of Peat/ Org.(1)	Depth to base of Peat/ Org./ Clay(1)	Approx. Elev. of Existing Ground(2)	Elev. of Design Grade(2) (Height)	Height of Surcharge	Width	Elev. (Height)	Geosyn.(7,8)	Wick Drain Spacing (c-c)(9)	Wait Time Between Fill Stages and Prior to Paving	0 - 1yr.	> 1yr.	Settle. During Constr. (6)	Post Constr. Settle.	Total Est. Settl.
[-]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[kN/m]	[m]	[mon.]	[mm]	[mm]	[mm]	[mm]	[mm]
18+450	18+500	18+470	3.1	7.9	266.6	268.9 (2.3)	0	-	-	-	-	3	3.0	8.7	267.2	269.0 (1.8)	0	-	-	-	-	3	10	5	50	25	75
		All	-Pre Construction: Remove organics/peat in narrow section to not adversely affect the stability of the existing roadway along the EBL alignment. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 3 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving.											-Pre Construction: Remove organics/peat in narrow section to not adversely affect the stability of the existing roadway along the EBL alignment. Option 1 -Fill Placement Stage 1: Construct embankment with overbuild. Wait 3 months. -Post Construction: After wait period, remove excess overbuild to design road grade elevation and complete paving.															

Title: Highway 11/17, Nipigon, Ontario
Name: 4.LT.E
Description: Embankment Stability
Comments: STA: 18+470 (18+450 to 18+500)
Last Edited By: Stephen Peters
Last Solved Date: 7/12/2013, 2:00:58 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

FILL (New)	22 kN/m³	0 kPa	42 °	1
FILL (Existing ?)	21 kN/m³	0 kPa	32 °	1
ORGANICS (Replacement)	21 kN/m³	0 kPa	32 °	1
ORGANICS	14 kN/m³	0 kPa	10 °	1
SILT	20 kN/m³	0 kPa	29 °	1

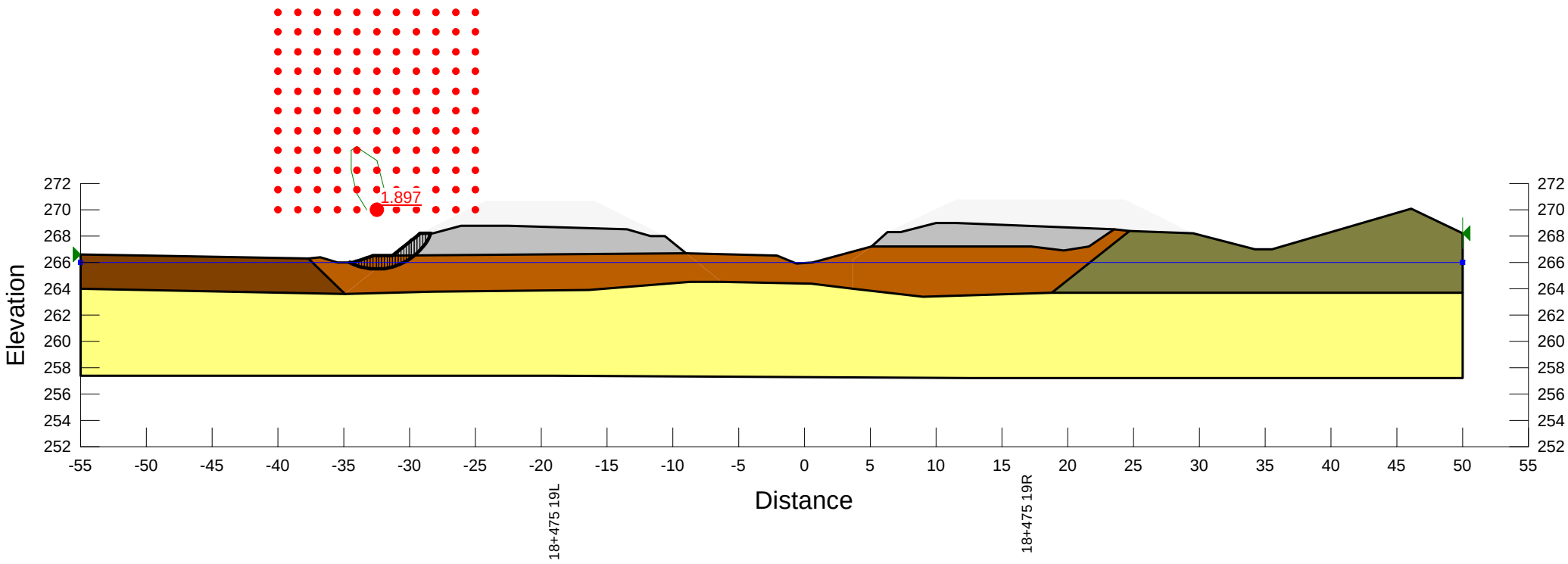

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Figure I1