PHASE II
GEOTECHNICAL INVESTIGATION AND SLOPE STABILITY ANALYSIS REPORT
HIGHWAY 602, 0.2 KM SOUTH OF BONE ROAD
TOWNSHIP OF CROZIER
AGREEMENT No.: 6009-E-0007
GWP: 6093-10-00
GEOCRES NO.: 52C-23

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Prepared for:

Ministry of Transportation
Geotechnical Section
Northwestern Region
615 South James Street
Thunder Bay, Ontario
P7E 6P6

1 copy - Ministry of Transportation, Thunder Bay, ON
1 copy – DST Consulting Engineers Inc., Thunder Bay

DST CONSULTING ENGINEERS INC.
605 Hewitson Street, Thunder Bay, Ontario P7B 5V5
Phone: 1-807-623-2929 Fax: 1-807-623-1793

DST CONSULTING ENGINEERS INC.

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation (MTO), Geotechnical Section, Northwestern Region to conduct a geotechnical investigation and provide remediation options for a slope failure along Highway 602, 4.67 Km south of the East junction of Highway 11 and 602. This work was carried out under Agreement No.: 6009-E-0007 - Geotechnical Retainer - GWP 6093-10-00.

This report addresses the phase II field investigation, laboratory test program, factual report on conditions (Part 1) and remediation options for the failed slope (Part 2).

Phase I of this investigation was completed in the January 2011 and was carried out under Agreement No.: 6009-E-0007 - Geotechnical Retainer - GWP 6093-10-00, WP 6058-10-03.

Phase II provides additional geotechnical data in the area of the slope failure.

2. SITE DESCRIPTION

The site is located on highway 602, 4.67 km south of east junction of highway 11 and 602, in the Township of Crozier.

The slope failure is located at the north bound lane, along an embankment and is 200 m south of Bone Road. Cold mix patching has been used to repair the pavement drop. The height of the existing embankment is approximately 10 m and the overall slope of the embankment is at an approximate gradient of 2.3H: 1V (Figure 2.1), however the slope near the roadway is close to 1.3H: 1V. The east side of the highway at this location is moderately wooded (Figure 2.2), while the west side has been cleared for agricultural use.

It is noted that a 100 mm gas line servicing the area is present at this location on the east side of the existing alignment from the southern site limits to approximately Station 9+790 where it crosses to the west of the alignment and extends to the northern site limits.

Figure 2.1 Slope Failure (looking north)

Figure 2.2 Failed slope vegetation (looking north)

Figure 2.3 Failed slope vegetation (looking south)

Figure 2.4 Approximately 2 m exposed slope face

Figure 2.5 Cobble and boulder fill on foreslope (looking northwest)

Figure 2.6 Cobble and boulder fill on foreslope (looking west)

3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between June 6th and 14th, 2011 utilizing a CME 750 drill rig as well as portable equipment that were operated by DST personnel. A total of thirteen (13) boreholes were advanced at this site, nine (9) using hollow stem augers and four (4) using portable tripod equipment. Boreholes were advanced to depths ranging from 6.1 to 12.8 m.

The hydraulically powered boreholes were advanced using hollow stem augers. Five hydraulically powered boreholes were advanced at the edge of the southbound lane and four hydraulically powered boreholes were advanced at the edge of the northbound lane. Monitoring wells were installed in all of the boreholes advanced in the northbound lane to various depths for the purposes of determining the groundwater level.

Four boreholes were also advanced at mid slope and at the toe of the slope at the failure location by continuous sampling using portable tripod equipment equipped with a split spoon sampler.

Borehole locations and stratigraphic sections are shown on the Borehole Location Plan, (Appendix B). The numbers/locations of all boreholes and depths of boreholes were specified by MTO in consultation with DST.

The centreline of the main failure was determined to be Station 9+831 as indicated on the base drawings provided by the MTO. The ground surface elevations at the borehole locations were surveyed by DST personnel. Elevations were measured for the borehole locations at the slope failure site with respect to survey monument No. 244 that is located approximately at station 9+920, approximately 7 m east of the road centreline with an elevation of 343.24 m (Appendix B). Table 3.1 summarizes the borehole locations and depths.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, performed sampling, in-situ testing and logged the boreholes. In-situ tests included Standard Penetration Tests (SPT) and Field Vane Tests (FVT). The soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included moisture contents, sieve analyses, and Atterberg limits. A total of one hundred and twenty three (123) moisture contents, thirteen (13) particle size analyses and twenty four (24)

Atterberg limits analyses have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs (Appendix C), and Plots (Appendix D).

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH6	9+730.5	343.2	6.2	3.2 Lt
BH7	9+781	343.4	6.1	2.1 Lt
BH8	9+832	343.4	6.1	3.2 Lt
BH9	9+858	343.4	6.1	2.2 Lt
BH10	9+900	343.5	6.1	3.0 Lt
BH11	9+731	343.2	12.8	3.0 Rt
BH12	9+781	343.4	12.7	2.9 Rt
BH13	9+825	343.4	12.7	2.7 Rt
BH14	9+872	343.4	12.7	3.5 Rt
BH15	9+743	339.2	6.1	28.0 Rt
BH16	9+816	332.3	6.1	38.7 Rt
BH17	9+830	341.0	6.1	9.0 Rt
BH18	9+762.5	332.9	6.1	47.0 Rt

4. DESCRIPTION OF SUBSURFACE CONDITIONS

The subsurface conditions at the failure locations are presented based on the data obtained during field and laboratory testing.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in Boreholes 6 through 14, consists of surface treatment overlying a sand fill material that is underlain predominantly by native silty clay material, but in areas underlain by native silty sand over silty clay. The generalized stratigraphy at the toe of the embankment, based on conditions encountered in Boreholes 16 and 18, consists of a thin layer of topsoil and organics over native silty clay. The groundwater table is expected to be close or slightly above the elevation of river water level at the base of the embankment.

Various cross sectional profiles of the site can be found in Appendix B. Auger refusal was encountered in the area of the culvert crossing and is discussed in the Phase I geotechnical report. Auger refusal on cobble and boulder fill was not encountered in Phase II of the investigation but was visually identified on the embankment foreslope.

4.1 Topsoil and Organics

A topsoil layer of up to 100 mm was encountered in Boreholes 15 through 18.

4.2 Surface Treatment

Surface treatment was encountered in Boreholes 7 through 9 and 11 through 14 with a thickness of 30 to 50 mm. An asphalt layer was also encountered in Boreholes 7 and 9 with a thickness of 50 to 80 mm between depths of 0.14 and 0.22 m.

4.3 Sand Fill

Sand fill was encountered in Boreholes 6 through 14 and 17 from surface up to 0.8 m below surface. The thickness of the embankment fill layer encountered is between approximately 0.4 and 0.8 m within the road structure and approximately 0.6 m at Borehole 17. Within the sand fill occasional cobbles were noted during the drilling process. Grain size distributions of the fill material are reported in borehole logs (Enclosures 1 to 13) and plots (Enclosures 14 and 15).

Directly below the surface treatment a fill of predominant sand was encountered. Gradation analyses conducted on samples from Borehole 7, 8, 11 and 14 indicate gravel, sand, and fine contents from approximately 16 to 32%, 59 to 72% and 6 to 12% respectively. This material does not classify as Granular A meeting OPSS specifications due to material

percentages passing the 13.2 mm, 9.5 mm, 4.75 mm, 1.18 mm, 300 µm and 75 µm sieves were too high. Samples from Boreholes 11 and 14 do classify as Granular B, Type I meeting OPSS specifications, whereas, samples from Boreholes 7 and 8 do not classify as Granular B Type I meeting OPSS specifications due to the material percentage passing the 75 µm sieve was too high. The moisture content of samples was between 3 and 7%.

4.4 Cobble and Boulder Fill

Cobble and boulder fill was not encountered at the location of the advanced boreholes in Phase II of the geotechnical investigation. Cobble and boulder fill was identified in the vicinity of the existing culvert at approximately Station 9+840 in Phase I the geotechnical investigation and is further described in the report submitted under Agreement No.: 6009-E-0007 - Geotechnical Retainer - GWP 6093-10-00, WP 6058-10-03. The presence of cobble and boulder fill was visually identified on the foreslope between Stations 9+825 and 9+840 as shown in Figure 2.5 and Figure 2.6 near the outflow of the existing culvert. The thickness of the cobble and boulder fill is unknown but could extend for more than 1 m.

4.5 Sand

Loose sand was encountered in Boreholes 7 and 12 from 0.7 m below surface up to 2.1 m below surface. The thickness of the sand layer encountered is between approximately 0.7 and 1.4 m. at Boreholes 7 and 12 respectively. Gradation analyses conducted on a sample from Borehole 7 indicate gravel, sand, silt and clay contents of approximately 0%, 53%, 31% and 16% respectively. This material does not classify as Granular A or B meeting OPSS specifications due to fine material percentages being too high. The moisture content of samples was between 17 and 24%.

4.6 Clay

Firm to hard silty clay layer was found at all borehole locations at depths between ground surface and 12.8 m below ground surface. The thickness of this stratum is not defined in all boreholes as borehole terminus was reached prior to the bottom of the stratum. Atterberg limits tests carried out on samples from all boreholes indicate this clay has a low to high plasticity with liquid limits and plasticity indices from 30 to 64% and 13 to 43% respectively. Gradation analyses conducted on samples from Boreholes 8, 11, 12, 13, 14 and 17 indicate gravel, sand, silt and clay contents of from approximately 0 to 6%, 13 to 39%, 31 to 69% and 15 to 55% respectively. Moisture contents of samples range from 18 to 37%.

4.7 Groundwater

As measured by the MTO, the water level at the river had an elevation of 329.13 m. Monitoring wells were installed in Boreholes 11 through 14 and were measured to be dry June 24th, 2011, two weeks after installation. Due to the low permeable nature of the clay materials found at the site, an accurate water level reading might be difficult to obtain from a monitoring well. The groundwater table is expected to be close or slightly above to the elevation of river water level at the base of the embankment. The groundwater levels can be expected to vary with season and precipitation events.

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PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

5. PROJECT DESCRIPITION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation (MTO), Geotechnical Section, Northwestern Region to conduct a geotechnical investigation and provide remediation options for a slope failure along Highway 602, 4.67 Km south of the East junction of Highway 11 and 602. This work was carried out under Agreement No.: 6009-E-0007 - Geotechnical Retainer - GWP 6093-10-00.

Phase I of this investigation was completed in the January of 2011 and was carried out under Agreement No.: 6009-E-0007 - Geotechnical Retainer - GWP 6093-10-00, WP 6058-10-03.

This part of the report (PART 2) presents interpretation of the geotechnical data presented in the factual report and presents geotechnical design recommendations for the proposed remediation of the slope failure.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in Boreholes 6 through 14, consists of surface treatment overlying a sand fill material that is underlain predominantly by native silty clay material, but in areas underlain by native silty sand over silty clay. The generalized stratigraphy at the toe of the embankment, based on conditions encountered in Boreholes 16 and 18, consists of a thin layer of topsoil and organics over native silty clay. The groundwater table is expected to be close or slightly above to the elevation of river water level at the base of the embankment.

Options considered to remediate the failed area in the Phase I investigation included rock fill flanking berms of various configurations and sheet piling. From additional information on the failure extent obtained during Phase II of the investigation the use of sheet piling is no longer considered a feasible option.

Options to remediate the failed area considered in Phase II of the investigation include replacement with rock fill and construction of a toe berm, replacement with granular fill, replacement with granular fill reinforced with geogrid, soil nailing and replacement with

lightweight fill. Use of lightweight fill as a remedial option was dismissed as embankment settlement is not an issue and lightweight fill will only provide a reduction in the driving forces at an excessive cost therefore stability analyses for this option was not performed.

All options considered would be required in addition to the evaluation of the site hydrology and improvement of the culvert drainage. Additionally, rerouting Highway 602 may be considered as future road use could affect the limits of remediation work.

6. SOIL PARAMETERS FOR STABILITY ANALYSIS

A representative stratigraphy has been interpreted from the borehole data of Highway 602 from Station 9+730 to 9+900 and is presented in the above sections. The stratigraphy was modelled using the results of the field and laboratory analysis as well as DST's knowledge of the site.

Soil properties interpreted based on in-situ testing and laboratories are shown in Table 5.1 which was used in the modelling. Several different conditions were considered to assess the physical stability of the site. The short term stability of the slopes was checked using undrained parameters, while the long term stability was checked using drained parameters.

Table 6.1 Soil parameters used in the slope stability analysis

Material	Density (kN/m^3)	Drained Angle of Internal Friction (degrees)	Undrained Cohesion (C) kPa
Granular Fill	22	32	0
Rock Fill	19	40	0
Clay	18	26	50

7. SLOPE STABILITY ANALYSIS

The rock fill embankment with toe berm and an underlying clay slope of 2.5H:1V is the preferred rehabilitation option of the MTO. Final edits to the analyzed slope geometry were focussed on this option with other options being considered preliminary.

7.1 Existing Conditions and Cause of Failure

Potential failures of the embankment were analyzed, including deep circular failures through the underlying silty clay soils, shallow slides through the fill materials, and lateral sliding below the fill (to the east). Analyses were performed with both a low and high groundwater table to reflect seasonal variations. The analyses were carried out utilizing the software Slope/W by Geo-slope International. The outputs presented below represent the most critical condition.

Analyses for circular failures, both deep and shallow, were carried out for the critical cross-section as provided by MTO for short and long term conditions using Slope/W software. For these analyses both undrained and drained analyses were carried out. As Morgenstern & Price's method satisfies force equilibrium, overall moment equilibrium and inter slice moment equilibrium as well as providing consistent results for all groundwater conditions (Bo 2003, Bo & Choa 2004), this method was applied and factors of safety from this method have been reported here.

In each analysis two 21 kPa line loads were applied in the north bound lane to represent truck traffic.

The following table shows factors of safety of the selected cases under undrained and drained conditions for the current embankment configuration. Example slope stability analysis outputs can be found in Appendix E, Figures 1 and 2. Cross sections of the existing slope conditions are provided in Drawing 2.

Table 7.1 Slope stability at centerline of failure

Remedial Option	Groundwater Condition	Existing Embankment Slope	Factor of Safety	
			Undrained	Drained
Clay Embankment	high water	2H:1V	>1.5	1.06
Clay Embankment	low water	2H:1V	>1.5	1.10

As can be seen above, the factor of safety for the existing slope under drained conditions is close to unity under conditions of both high and low groundwater and indicates unfavourable slope stability. The failure at the site is likely occurring as the result of a gradually steepening slope due to erosion, the undermining of the road from inadequate drainage as well as reoccurring smaller slope failures. Inadequate drainage significantly increases the potential for elevating the groundwater level during the spring thaw and heavy rainfall events due to the increased retention of water at the top of the slope which further reduces the factor of safety of the slope. The current conditions at the site (localized failure in northbound lane) are likely a precursor to a larger future slope failure.

Borehole 17 identified a weak plane approximately 4.2 m below surface. This coincides with the failure surface modelled under the existing embankment conditions shown in Appendix E in which the thickness of the slip mass at BH 17 is estimated to be approximately 3 and 5 m under the existing embankment conditions with low and high water tables respectively.

7.2 Stability Analysis with Rock Fill Embankment and Toe Berm

The stability analyses were carried out with a remedial profile with rock fill material for short and long term conditions under a high groundwater in the embankment. An embankment slope of 1.5H:1V with varying widths of fill and variable heights of toe berm were evaluated to achieve stability within the embankment. Analyses were also carried out for temporary slope assuming the existing embankment will be excavated at either 2H:1V or 2.5H:1V slope from the centreline of the existing road to the existing elevation at the toe of embankment and constructed with benching as per OPSD 208.010. For this case only the undrained condition was considered as excavation will be for short temporary duration.

The following table shows factors of safety of the selected cases under undrained conditions for the temporary embankment configuration. Example slope stability analysis outputs can be found in Appendix E, Figures 3 and 4.

Table 7.2 Temporary clay embankment slope stability at centerline of failure

Remedial Option	Groundwater Condition	Temporary Embankment Slope	Factor of Safety
			Undrained
Clay Embankment	low water	2H:1V	> 1.5
Clay Embankment	low water	2.5H:1V	> 1.5

The following tables show factors of safety of the selected cases under undrained and drained conditions for the various rock fill embankment configurations. Example slope stability analysis outputs can be found in Appendix E, Figures 5 and 6. Plan view and cross sections of the proposed remedial methods are shown in Drawings 3 through 8.

Table 7.3 Rock fill embankment with 2H:1V underlying slope and 5.5 m high toe berm slope stability at centerline of failure

Remedial Option	Groundwater Condition	Proposed Embankment Slope	Minimum width of Fill at Top of Embankment, (m)	Toe Berm Bench Width, (m)	Toe Berm Width at Toe, (m)	Factor of Safety	
						Undrained	Drained
Rock Fill Embankment	high water	1.5H:1V	5.0	8.0	9.0	> 1.5	1.3

Table 7.4 Rock fill embankment with 2.5H:1V underlying slope and 5.5 m high toe berm slope stability at centerline of failure

Remedial Option	Groundwater Condition	Proposed Embankment Slope	Minimum width of Fill at Top of Embankment, (m)	Toe Berm Bench Width, (m)	Toe Berm Width at Toe, (m)	Factor of Safety	
						Undrained	Drained
Rock Fill Embankment	high water	1.5H:1V	6.0	9.5	6.5	> 1.5	1.3

Sliding failures were also analyzed, and indicate a safety factor in excess of 1.3 for all conditions utilizing the 1.5H:1V configuration.

7.3 Stability Analysis with Granular Fill Embankment

The stability analyses were carried out with a remedial profile with improved engineered fill material for short and long term conditions under a high groundwater in the embankment.

Embankment slopes of 2H:1V, 2.5H:1V and 3H:1V were evaluated to achieve stability within the embankment.

The following table shows factors of safety of the selected cases under undrained and drained conditions for the granular fill embankment configurations. Example slope stability analysis outputs can be found in Appendix E, Figures 7 through 9. Plan view and cross section of the proposed remedial method with a 3H:1V embankment slope is shown in Drawing 9.

Table 7.5 Granular embankment slope stability at centerline of failure

Remedial Option	Groundwater Condition	Proposed Embankment Slope	Minimum Width of Fill at Toe of Embankment, (m)	Factor of Safety	
				Undrained	Drained
Granular Fill Embankment	high water	2H:1V	12.0	1.2	1.3
Granular Fill Embankment	high water	2.5H:1V	10.0	1.5	1.3
Granular Fill Embankment	high water	3H:1V	11.5	> 1.5	1.4

As shown in Table 7.5, the factor of safety increases when the embankment foreslope becomes gentler as well as when the minimum thickness of the granular layer increases. Sliding failures were also analyzed, and indicate a safety factor in excess of 1.3 for all conditions utilizing the 2.5H:1V and 3H:1V configurations.

7.4 Stability Analysis with Granular Fill Embankment reinforced with Geogrid

The stability analyses were carried out with a remedial option for short and long term conditions under a high groundwater in the embankment. Embankment slopes of 2H:1V and 2.5H:1V with minimum fill width at toe of embankment of between 9.3 and 12.0 m were evaluated to achieve stability within the embankment. A geogrid maximum allowable load capacity was 34 kN/m was assumed.

The following table shows factors of safety of the selected cases under undrained and drained conditions for the granular fill embankment with geogrid reinforcing configuration. Example slope stability analysis outputs can be found in Appendix E, Figures 10 and 11. Plan view and cross sections of the proposed remedial methods are shown in Drawings 10 and 11.

Table 7.6 Granular embankment with geogrid reinforcement slope stability at centerline of failure

Remedial Option	Groundwater Condition	Proposed Embankment Slope	Minimum Width of Fill at Toe of Embankment, (m)	Factor of Safety	
				Undrained	Drained
Granular Fill Embankment with Geogrid Reinforcement	high water	2.5H:1V	9.3	1.5	1.3
Granular Fill Embankment with Geogrid Reinforcement	high water	2H:1V	12.0	1.5	1.4

As shown in Table 7.6, the factor of safety increases when the slope of the proposed embankment becomes gentler and as the minimum width of fill at the toe of embankment increases which allows for additional development length of the geogrid. Sliding failures were also analyzed, and indicate a safety factor in excess of 1.3 for conditions utilizing the 2H:1V and 2.5H:1V configurations with a minimum width of fill at the toe of embankment of 12.0 m and 9.3 m respectively.

7.5 Stability Analysis with Soil Nailing

The stability analyses were carried out with another remedial profile for short and long term conditions under a high groundwater in the embankment. An embankment slope of 2H:1V with nail spacing of 2 m by 2 m and nail lengths 9.0 m was evaluated to achieve stability within the embankment. 35M diameter steel with a shear capacity of 170 MPa for the bar as utilized for analysis.

The following table shows the factor of safety of the selected case under undrained and drained conditions for embankment with soil nail reinforcing configuration. Example slope stability analysis output can be found in Appendix E, Figure 12. Plan view and cross sections of the proposed remedial method is shown in Drawing 12.

Table 7.7 Soil nail embankment slope stability at centerline of failure

Remedial Option	Groundwater Condition	Proposed Embankment Slope	Soil Nail Spacing (m)	Soil Nail Length (m)	Factor of Safety	
					Undrained	Drained
Soil Nail	high water	2H:1V	2 x 2	9.0	> 1.5	1.3

Sliding failures were also analyzed, and indicate a safety factor in excess of 1.3 for all conditions utilizing the 2H:1V configuration with a nail length of 9 m or longer.

8. RECOMMENDATIONS

All recommended remedial options must include the evaluation of the existing site hydrology and improvement of the existing culvert drainage.

To remediate the slope failure at this location it is recommended that the limits of remediation extend from approximately Station 9+750 to Station 9+900 for all remedial options. As requested by MTO, costing analysis for the rock fill embankment with was performed with remedial limits of Station 9+780 to Station 9+880.

8.1 Rock Fill Slope with Toe Berm

Construction methodology must be in accordance with all relevant Ministry guidelines. It is assumed the existing embankment will be excavated at a 2H:1V or 2.5H:1V slope in a top down manner from the centreline of the existing road to the existing elevation at the toe of embankment and constructed with benching as per OPSD 208.010 in a top down manner as per Ministry of Transportation Ontario request.

With a 2H:1V underlying clay slope the minimum rock fill slope required to stabilize the embankment with factor of safety greater than 1.3 is 1.5H:1V with a minimum width of fill at the top of embankment of 5.0 m, minimum width of berm at the toe of 9.0 m, minimum height of berm at the toe of 5.5 m and a bench width of 8.0 m. With a 2.5H:1V underlying clay slope the minimum rock fill slope required to stabilize the embankment with factor of safety greater than 1.3 is 1.5H:1V with a minimum width of fill at the top of embankment of 6.0 m, minimum width of berm at the toe of 6.5 m, minimum height of berm at the toe of 5.5 m and a bench width of 9.5 m. All rock fill materials should meet requirements of Rip-Rap R-10 as per OPSS 1004.

A gentler rock foreslope will increase the factor of safety and reduce the potential for future distortions at the site. Placement of rock fill over the entire embankment length is required as placement of rock materials only at the top of the slope will not provide an adequate factor of safety against a failure. The anticipated required embankment height is approximately 11 m, should extend from approximately Station 9+750 to Station 9+900 and be tapered into the existing embankment at the end locations.

It is recommended that all existing organics (including all tree growth) be removed prior to the placement of granular materials on the slope. Upon completion of fill placement, topsoil should be placed to support vegetative growth and the slope should be vegetated with native saplings.

A non-woven geotextile should also be placed between the rock materials and the underlying clay layers. The geotextile will help to prevent the movement of fines, and provide additional erosion resistance. The non-woven geotextile should conform to (OPSS 1860.07.05.01 Class II) and have a filtration opening size (FOS) less than or equal to 135 µm.

8.2 Granular Fill Slope

Construction methodology must be in accordance with all relevant Ministry guidelines. As shown in Table 7.5 various slope gradients are able to stabilize the embankment with factor of safety greater than 1.3 dependent on the minimum width of fill at the toe of the embankment and underlying clay slope. With an underlying clay slope of 2H:1V the minimum widths of fill at the embankment toe required to provide factor of safeties of 1.3 are 12.0 m, 10.0 m for granular slopes of 2H:1V and 2.5H:1V respectively. A factor of safety of 1.4 was achieved with a minimum width of fill at the embankment toe of 11.5 m for a granular slope of 3H:1V.

A gentler granular foreslope will increase the factor of safety and reduce the potential for future distortions at the site. Placement of compacted granular fill over the entire embankment length is required as placement of granular materials only at the top of the slope will not provide an adequate factor of safety against a sliding failure. The anticipated required embankment height is approximately 11 m, should extend from approximately Station 9+750 to Station 9+900 and be tapered into the existing embankment at the end locations.

It is recommended that all existing organics (including all tree growth) be removed prior to the placement of granular materials on the slope. Upon completion of granular fill placement, topsoil should be place to support vegetative growth and the slope should be vegetated with native saplings.

A non-woven geotextile should also be placed between the granular materials and the underlying clay layers. The geotextile will help to prevent the movement of fines, and provide additional erosion resistance. The non-woven geotextile should conform to (OPSS 1860.07.05.01 Class II) and have a filtration opening size (FOS) less than or equal to 135 µm.

8.3 Granular Fill Slope with Geogrid Reinforcement

Construction methodology must be in accordance with all relevant Ministry guidelines. As shown in Table 7.6 the minimum slope required to stabilize the geogrid reinforced embankment with factor of safety greater of 1.4 is 2H:1V using a compacted granular fill with a minimum width of fill at the embankment toe of 12.0 m and an underlying clay slope of 2H:1V. Alternatively, a

factor of safety greater of 1.3 can also be achieved with a slope of 2.5H:1V using a compacted granular fill with a minimum width of fill at the embankment toe of 9.3 m and an underlying clay slope of 2H:1V.

A gentler granular foreslope will increase the factor of safety and reduce the potential for future distortions at the site. Placement of compacted granular fill with geogrid reinforcement over the entire embankment length is required if utilizing a 2H:1V embankment slope as placement of granular materials only at the top of the slope will not provide an adequate factor of safety against a sliding failure. When utilizing a 2.5H:1V embankment slope geogrid reinforcement is only required on the upper half of the slope. The anticipated required embankment height is approximately 11 m, should extend from approximately Station 9+750 to Station 9+900 and be tapered into the existing embankment at the end locations.

It is recommended that all existing organics (including all tree growth) be removed prior to the placement of granular materials on the slope. Upon completion of granular fill placement, topsoil should be place to support vegetative growth and the slope should be vegetated with native saplings.

A non-woven geotextile should also be placed between the granular materials and the underlying clay layers. The geotextile will help to prevent the movement of fines, and provide additional erosion resistance. The non-woven geotextile should conform to (OPSS 1860.07.05.01 Class II) and have a filtration opening size (FOS) less than or equal to 135 µm.

8.4 Soil Nailing

Construction methodology must be in accordance with all relevant Ministry guidelines. As shown in Table 7.7 the minimum slope required to stabilize the soil nail reinforced embankment with factor of safety greater than 1.3 is 2H:1V using with 9.0 m soil nails installed in a 2 m x 2 m pattern into the native clay soil. Some site grading would be required to remove large irregularities in the slope, such as at the crest or locations or significant erosion. Existing cobble and boulder fill would not require removal and soil nails would be located as close as possible.

The anticipated remediation should extend from approximately Station 9+750 to Station 9+900 and be tapered into the existing embankment at the end locations.

It is recommended that large tree growth be removed from the embankment prior to the installation of soil nails to allow for machine access but smaller vegetation be left intact. Upon completion of soil nailing the slope should be vegetated with native saplings.

8.5 General Recommendations

8.5.1 Site Drainage

As noted in the borehole logs, a layer of cobble/boulder fill is present under the roadway. DST recommends the replacement of the cobble/boulder fill with a suitable material (Granular B, Type 1 or equivalent). If it is found that the cobble/boulder fill layer extends beyond a meter in depth, then a non-woven geo-textile should be placed before backfilling is conducted to the required height.

Also as noted by the MTO, the culvert located approximately 10 m north of the failure zone has failed. All remedial options must include the evaluation of the existing site hydrology and improvement of the existing culvert drainage.

8.5.2 Rerouting of Highway 602

Consideration should be given to rerouting Highway 602 and would include the closure of Highway 602 at the failure site, but would require remediation of the failure to maintaining access for the residents of the area. The extent of the remediation required may be reduced dependent on future road use. Rerouting options may include routing traffic to Highway 611 along Bone Road and Busch Road or around the failure site along Bone Road, Ducharmes Road and Stewart Road. Improvements to the road structure and drainage along these sections may be required.

9. CLOSURE

Based on the information collected from field investigation and parameters interpreted from laboratory test results and groundwater monitoring data, the failure at the site was likely to have occurred as the result of a gradually steepening slope due to erosion as well reoccurring smaller slope failures. Additionally, the presence of a potentially high groundwater level during the spring thaw and heavy rainfall events combined with inadequate drainage further reduces the factor of safety of the slope. The current conditions at the site (localized failure in northbound lane) are likely a precursor to a larger future slope failure.

Remedial options discussed in Section 8 include construction of a rock fill embankment with a toe berm, construction of a granular embankment at a 3H:1V slope, construction of a granular embankment reinforced with geogrid at a 2.5H:1V slope and the installation of soil nails in the existing clay embankment at a 2H:1V slope. Table 9.1 summarizes the advantages and disadvantages of the considered options.

Due to the limited space at the toe of the embankment the existing embankment materials need to be trimmed and replaced with proposed fill. Stability analyses were carried out for the worst section, however, slope gradients of the embankment become gentler when moving away from the centreline of the failed embankment. In the quantity and cost estimate a reduced quantity of fill and excavation for the more stable slope was taken into consideration.

Table 9.1 Remedial options advantages and disadvantages comparison

Remedial Option	Advantages	Disadvantages
Rock Fill Embankment 1.5H:1V with Toe Berm	• certain effectiveness • ease of construction	• requires large material quantity • requires complete removal of vegetation
Granular Embankment 3H:1V	• certain effectiveness • ease of construction	• requires large material quantity • requires complete removal of vegetation
Granular Embankment with Geogrid Reinforcement 2.5H:1V	• steeper allowable slope over a strictly granular embankment • lower material requirement than strictly granular embankment	• requires complete removal of vegetation
Soil Nail Clay Embankment	• maintains existing embankment geometry • requires minimum excavation and grading • requires minimum additional granular materials • retains vegetative growth on embankment	• requires specialized contractor • drivability of soil nails should be confirmed in a test section

DST is of the opinion that the best suited remedial option allowing for rapid implementation is the installation of soil nails. This option is recommended as it combines a high degree of certainty in effectiveness with the minimum site disturbance, minimum additional material requirements and maintains the existing slope geometry. A test section should be completed such that drivability of the selected nail configuration can be confirmed.

MTO has indicated that their preferred construction option is the 1.5H:1V Rock Fill Embankment with a toe berm and an underlying clay slope of 2.5H:1V. Final edits to drawings and cross sections were limited to the preferred MTO option. A class E estimate of the cost of rehabilitating the failed slope with a rock fill embankment with a toe berm and underlying clay slope of 2.5H:1V is $340,000.00, based on remediation limits of Station 9+780 to 9+880 and material cost information provided by the MTO.

10. LIMITATIONS OF REPORT

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:

Wesley Saunders, P.Eng
Project Manager (GeoServices)

Reviewed by:

Dr. M W Bo, PhD., P. Eng, P.Geo, Int PE,
C.Geol, C. Eng, Eur Geol, Eur Eng
Senior Principal / Director (GeoServices)

APPENDIX 'A'

LIMITATIONS OF REPORT

L I M I T A T I O N S O F R E P O R T

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

APPENDIX 'B'

DRAWINGS

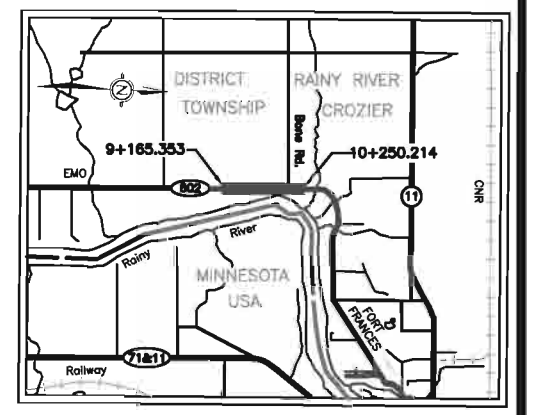
MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT	No	6009-E-0007
GWP	No	6093-10-00
GeoCres	No	52C-23

SLOPE FAILURE
(200 m South of Bone Rd.)
Highway 602 – Crozier Twp.
Geotechnical Investigation

SHEET



KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark
- Fill
- Organics
- Topsoil
- Till
- Bedrock
- Sand
- Silt
- Clay
- Sand & Gravel
- Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
BH9	343.44	5383430	270135	9+858	2.2 m LT
BH10	343.48	5383472	270134	9+900	3.0 m LT
BH11	343.21	5383304	270147	9+731	3.0 m RT
BH12	343.41	5383354	270140	9+781	2.9 m RT
BH13	343.44	5383398	270140	9+825	2.2 m RT
BH14	343.39	5383444	270140	9+872	3.5 m RT
BH15	339.23	5383318	270168	9+743	28.0 m RT
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

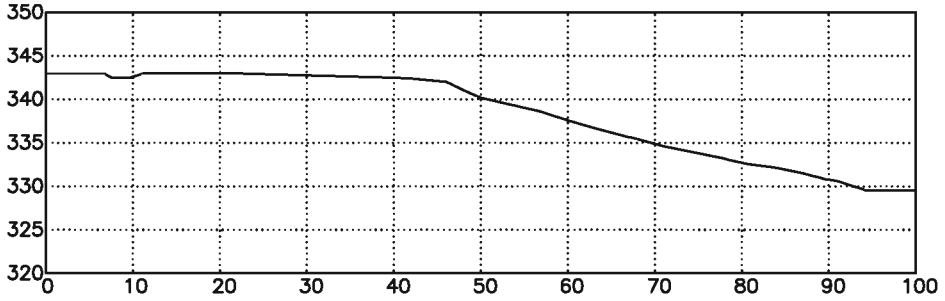
SCALE
10m 0 10 20 30 40 50m

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

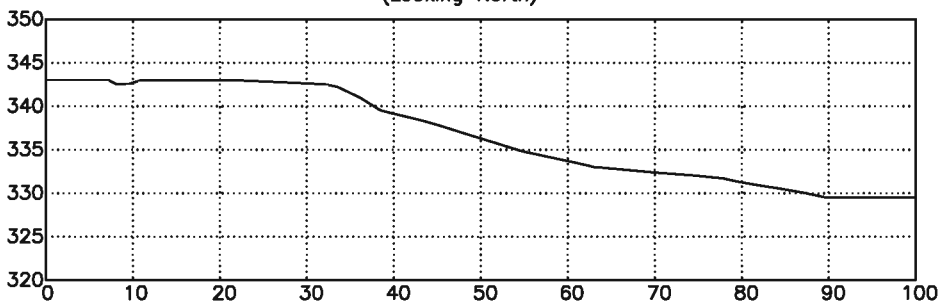
DST consulting engineers
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

DRAWING 1

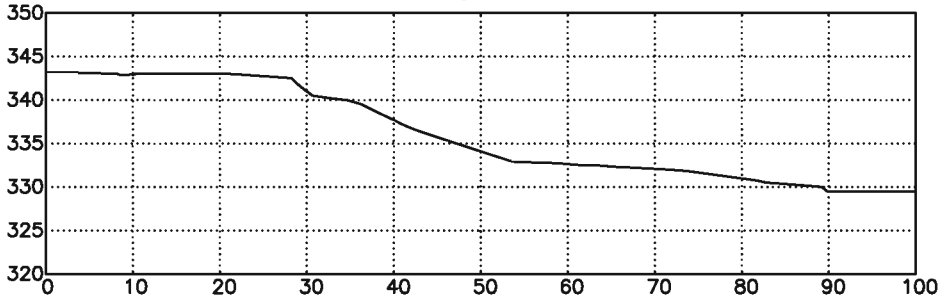
PROFILE ALONG SECTION A–A'
(Looking North)



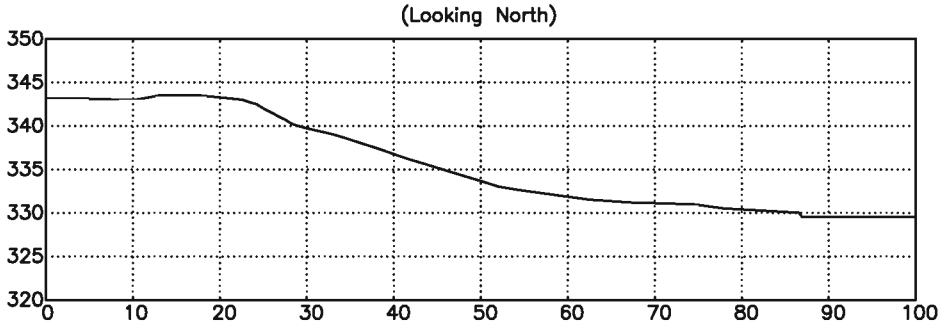
PROFILE ALONG SECTION B–B'
(Looking North)



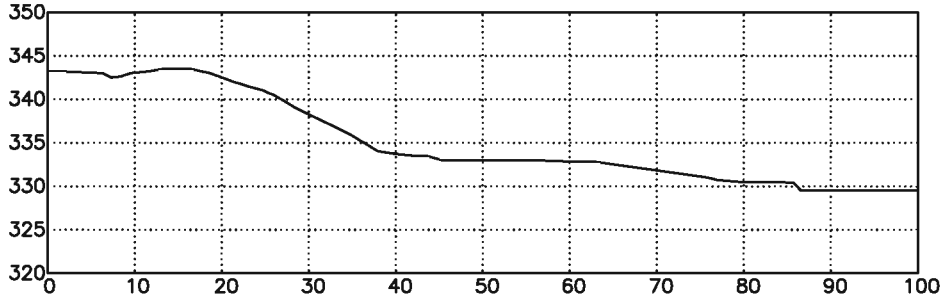
PROFILE ALONG SECTION C–C'
(Looking North)



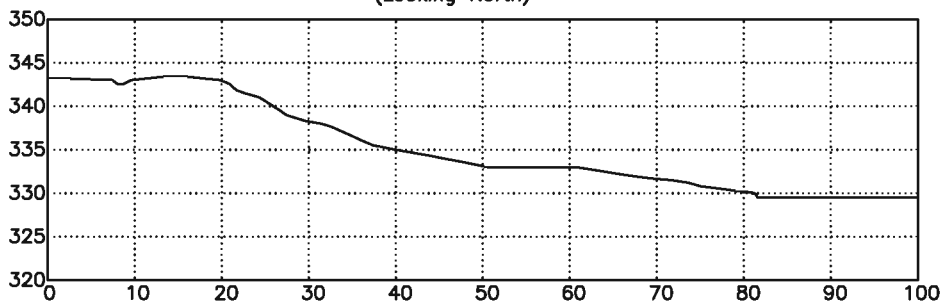
PROFILE ALONG SECTION D–D'
(Looking North)



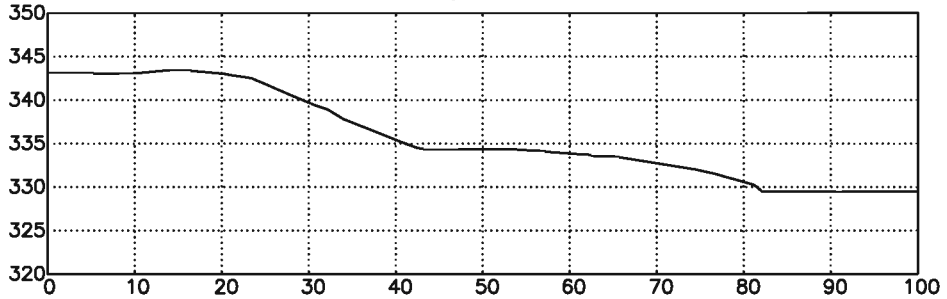
PROFILE ALONG SECTION E–E'
(Looking North)



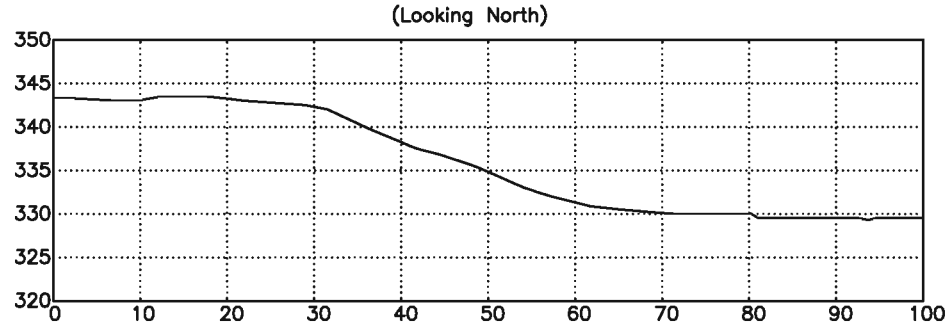
PROFILE ALONG SECTION F–F'
(Looking North)



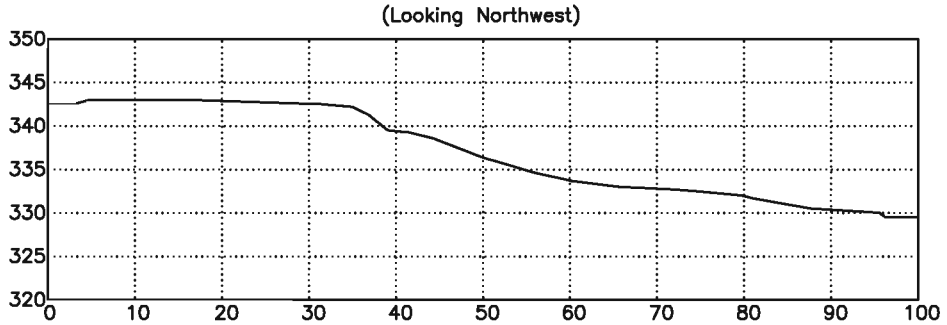
PROFILE ALONG SECTION G–G'
(Looking North)



PROFILE ALONG SECTION H–H'
(Looking North)



PROFILE ALONG SECTION I–I'
(Looking Northwest)

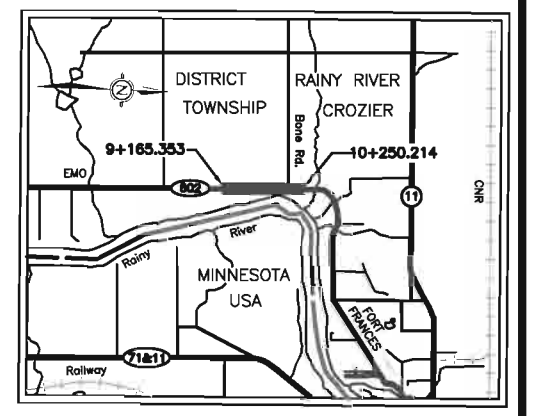


METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009–E–0007
GWP No 6093–10–00
GeoCres No 52C–23

SLOPE FAILURE
(200 m South of Bone Rd.)
Highway 602 – Crozier Twp.
Geotechnical Investigation

SHEET



KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
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- Sand & Gravel
- Boulders

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BH14	343.39	5383444	270140	9+872	3.5 m RT
BH15	339.23	5383318	270168	9+743	28.0 m RT
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
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DST consulting engineers
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605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
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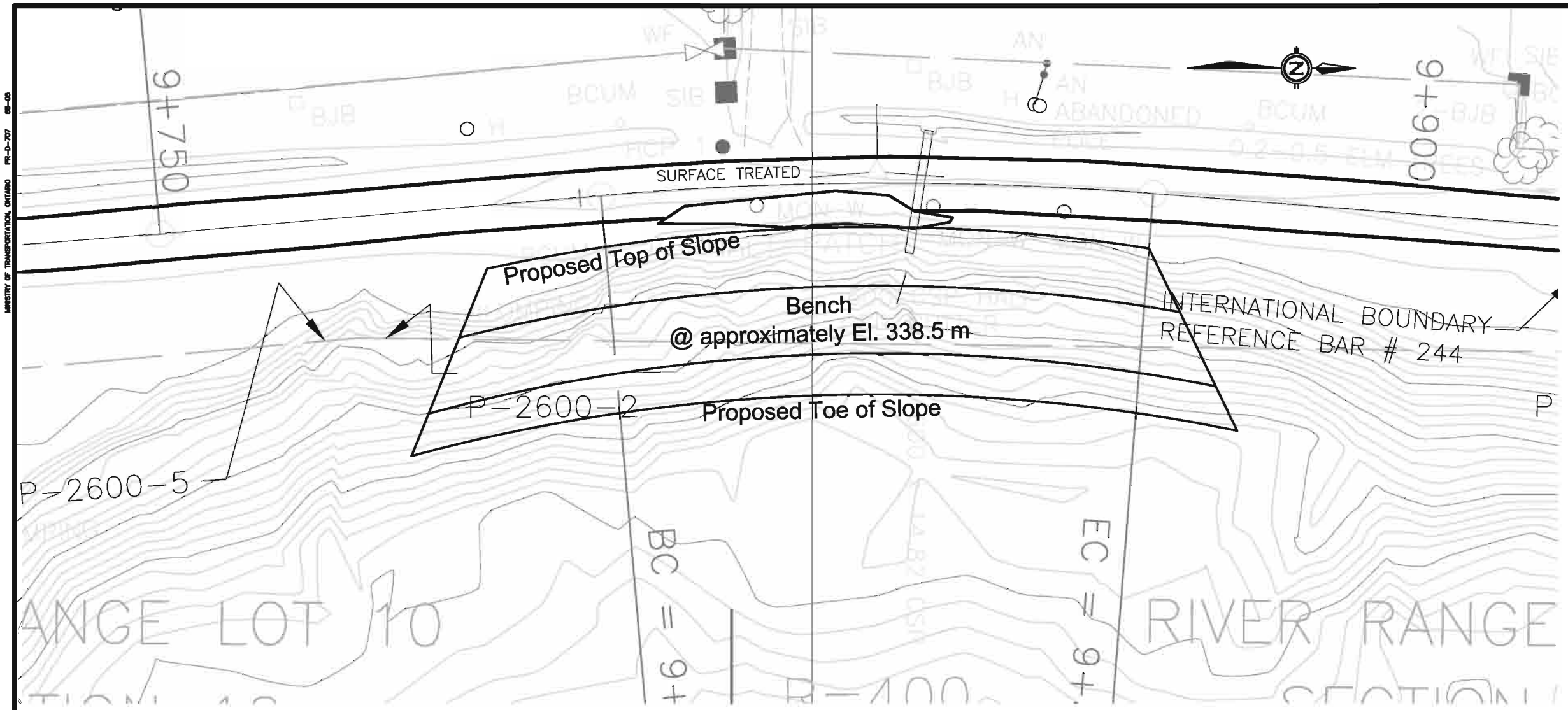
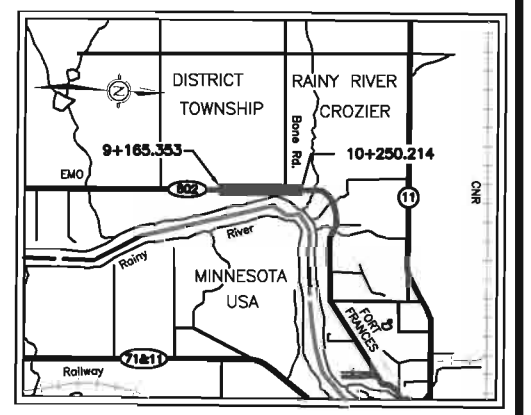
DRAWING 2

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
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- Benchmark
- Fill
- Organics
- Topsoil
- Till
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- Clay
- Sand & Gravel
- Boulders

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BH14	343.39	5383444	270140	9+872	3.5 m RT
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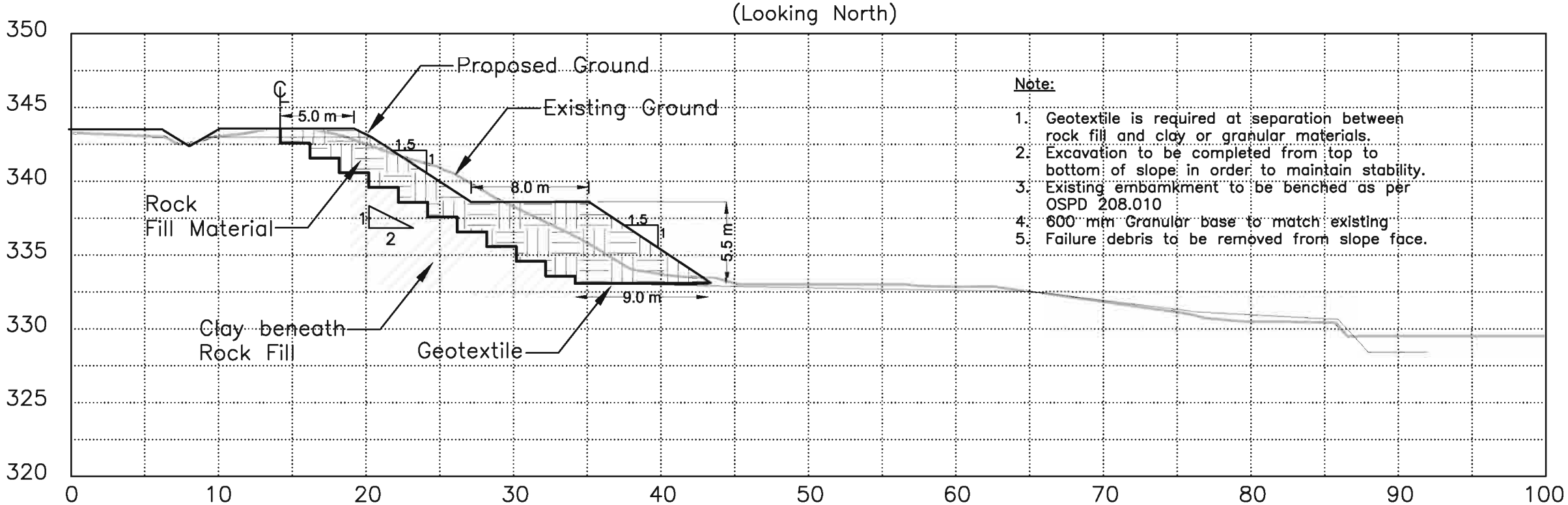
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

BENCH REINFORCEMENT OPTION (1.5H:1V)
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



Note:

1. Geotextile is required at separation between rock fill and clay or granular materials.
2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embamkment to be benched as per OSPD 208.010
4. 600 mm Granular base to match existing
5. Failure debris to be removed from slope face.

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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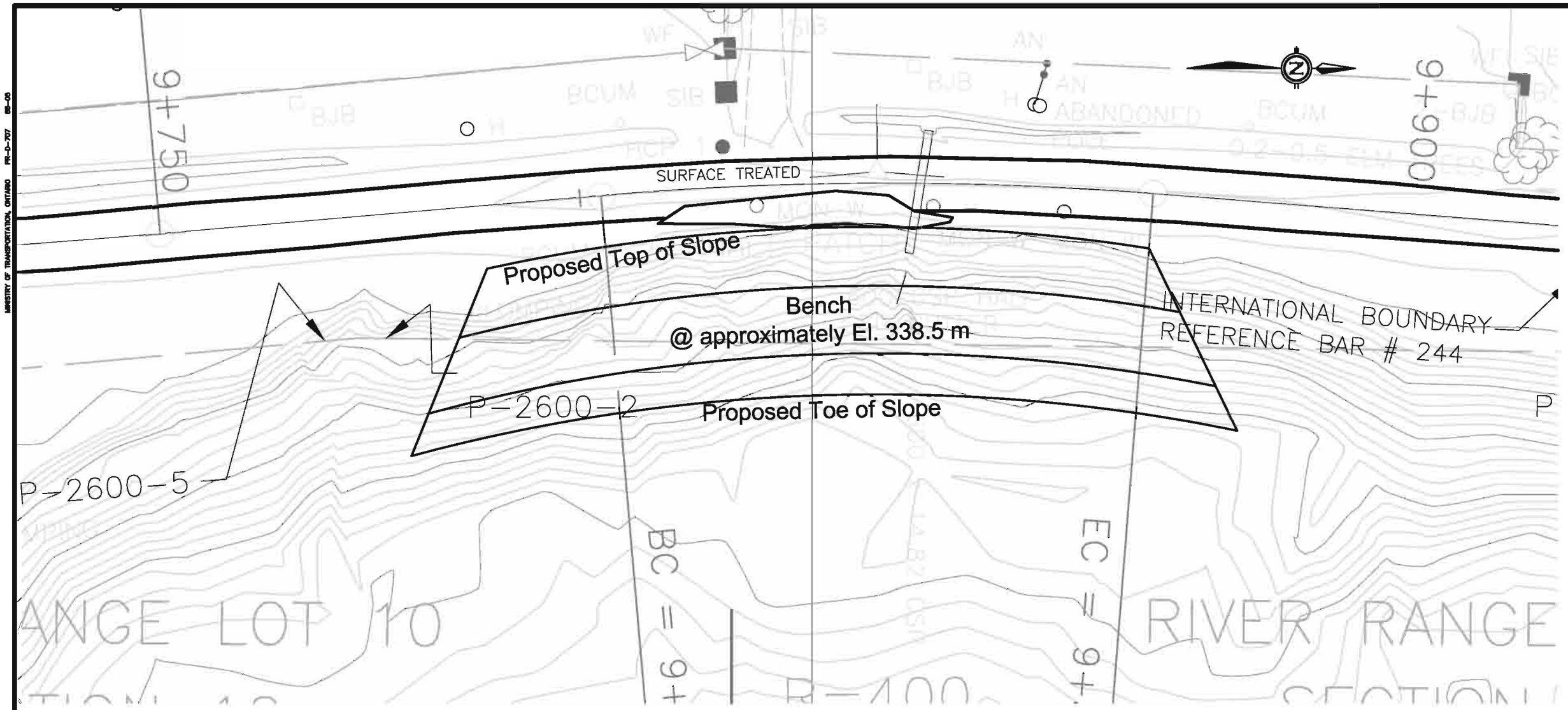
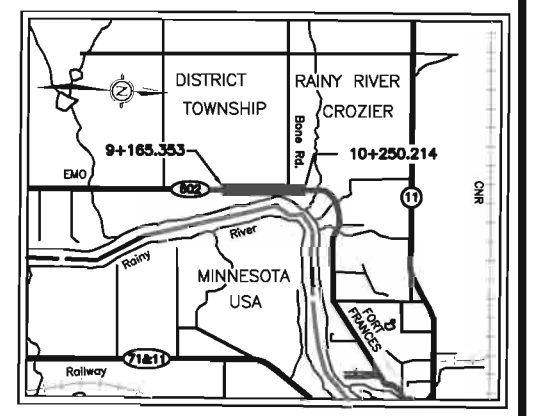
DRAWING 3

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

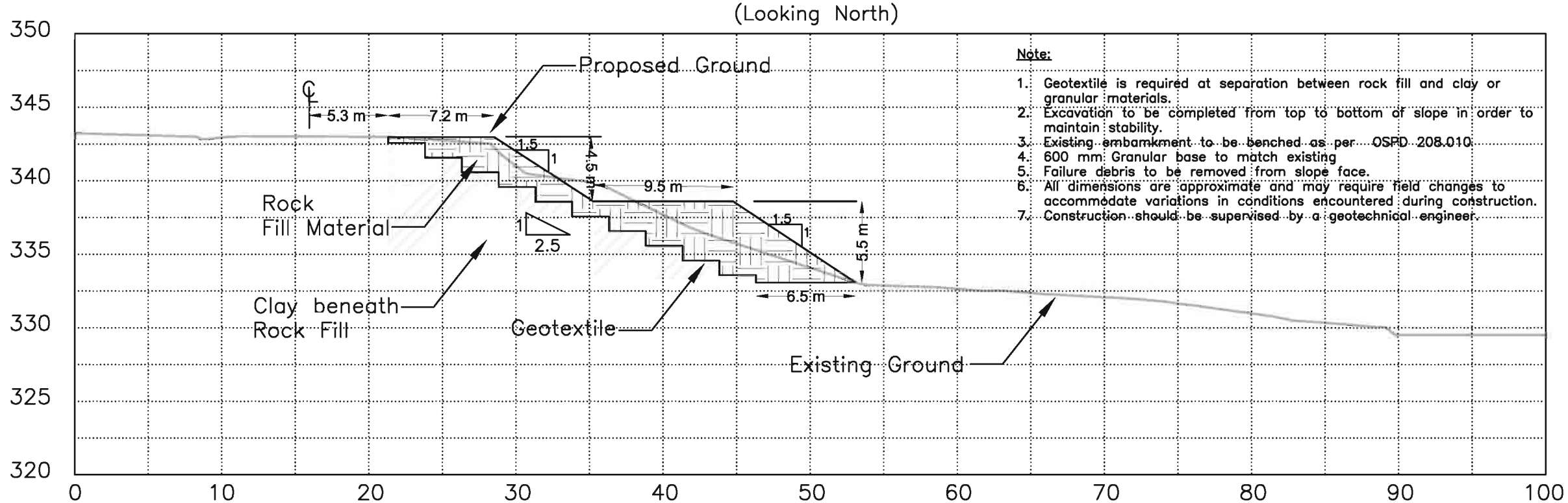
CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		N
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

BENCH REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION C–C' at Station 9+782
(Looking North)



Note:
1. Geotextile is required at separation between rock fill and clay or granular materials.
2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embankment to be benched as per OSPD 208.010.
4. 600 mm Granular base to match existing
5. Failure debris to be removed from slope face.
6. All dimensions are approximate and may require field changes to accommodate variations in conditions encountered during construction.
7. Construction should be supervised by a geotechnical engineer.

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

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COORDINATE REFERENCE: MTM NAD83 ZONE 16

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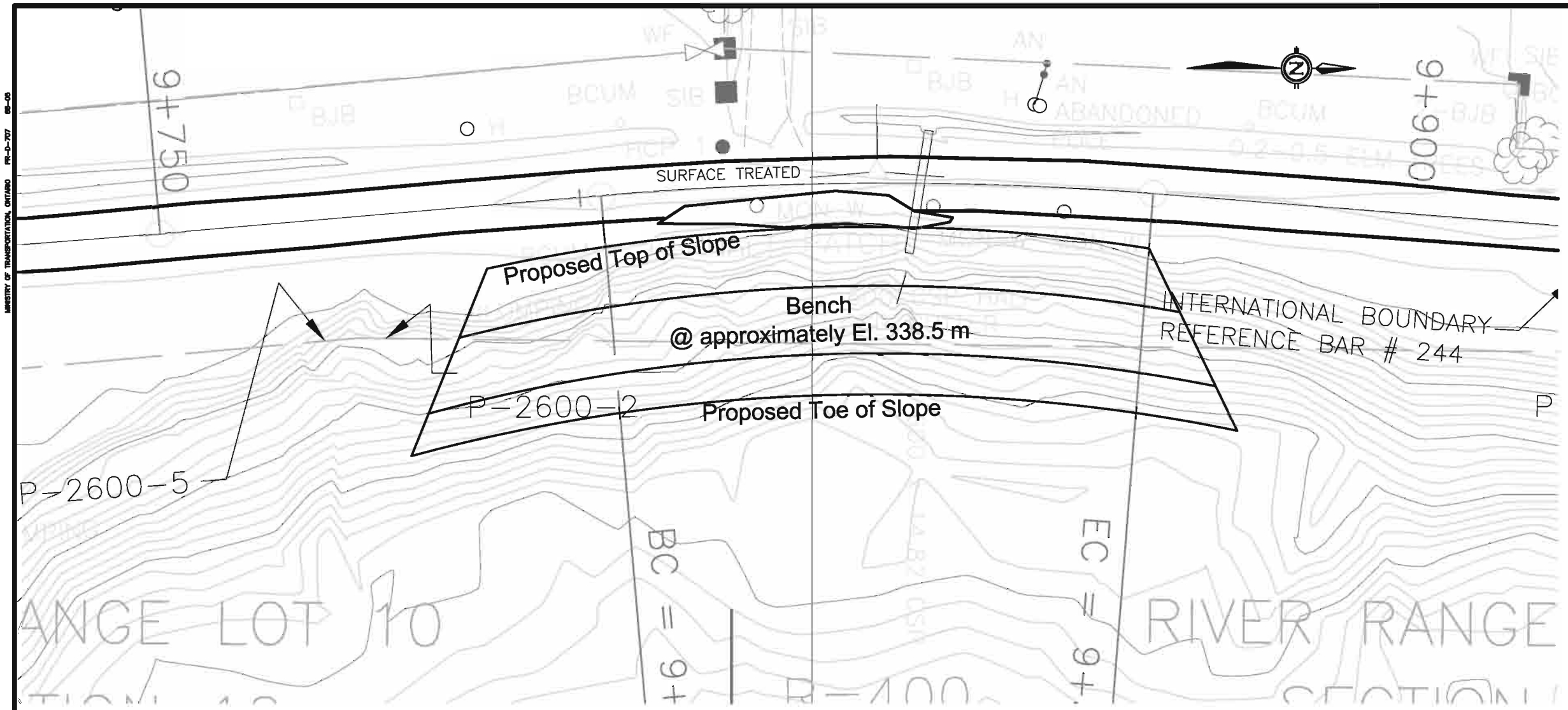
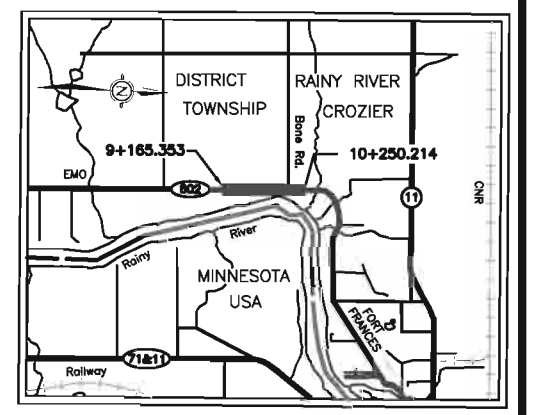
DRAWING 4

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

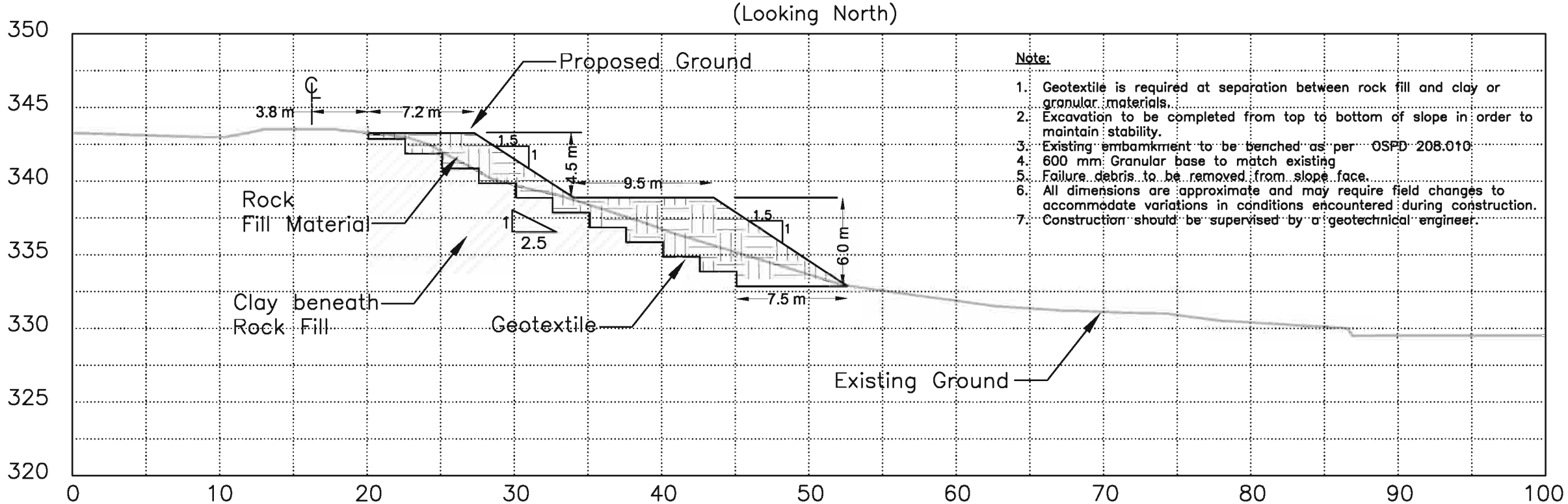
CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

BENCH REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION D–D' at Station 9+807
(Looking North)



Note:
1. Geotextile is required at separation between rock fill and clay or granular materials.
2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embamkment to be benched as per OSPD 208.010
4. 600 mm Granular base to match existing
5. Failure debris to be removed from slope face.
6. All dimensions are approximate and may require field changes to accommodate variations in conditions encountered during construction.
7. Construction should be supervised by a geotechnical engineer.

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
BH9	343.44	5383430	270135	9+858	2.2 m LT
BH10	343.48	5383472	270134	9+900	3.0 m LT
BH11	343.21	5383304	270147	9+731	3.0 m RT
BH12	343.41	5383354	270140	9+781	2.9 m RT
BH13	343.44	5383398	270140	9+825	2.2 m RT
BH14	343.39	5383444	270140	9+872	3.5 m RT
BH15	339.23	5383318	270168	9+743	28.0 m RT
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

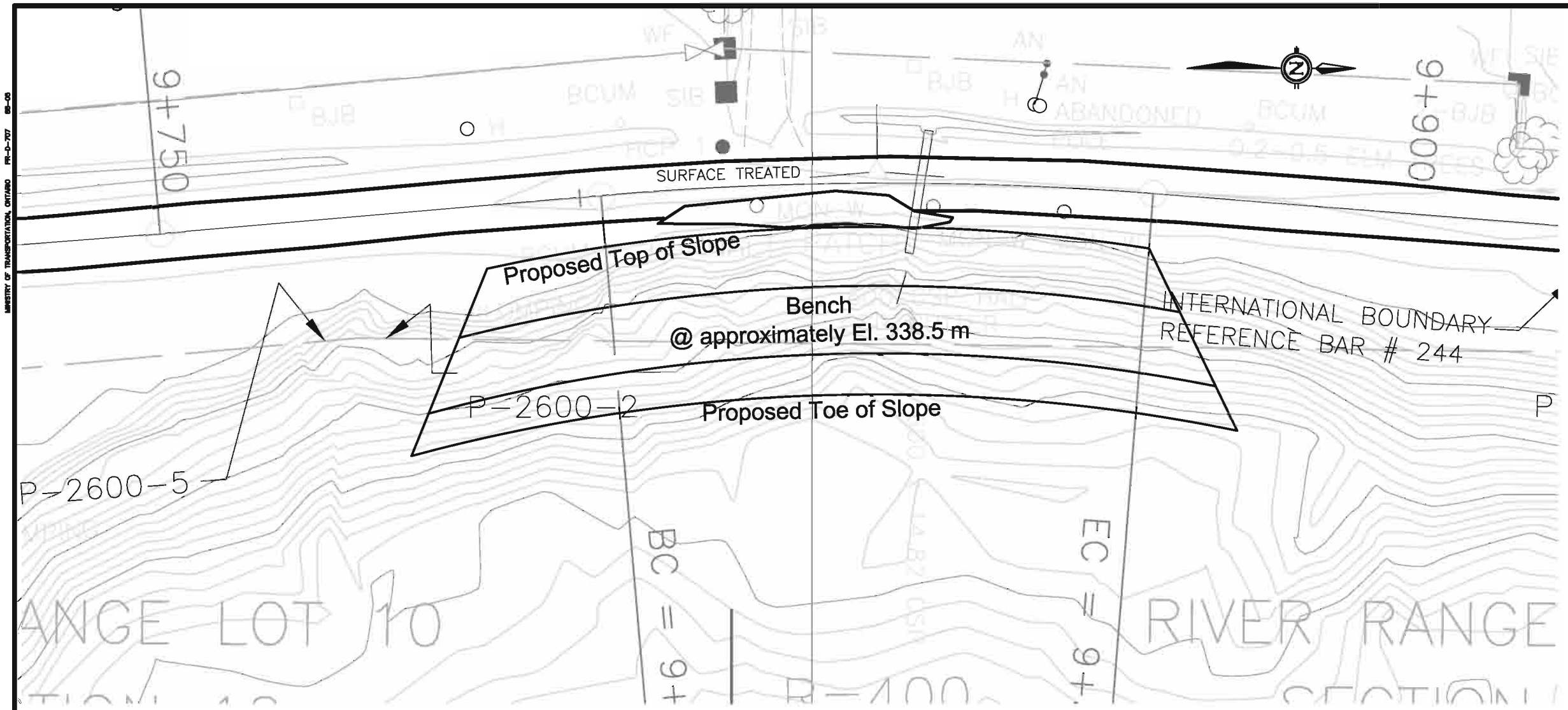
DST consulting engineers
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

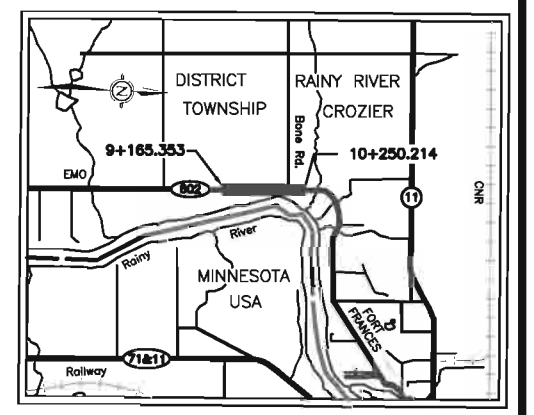
DRAWING 5

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

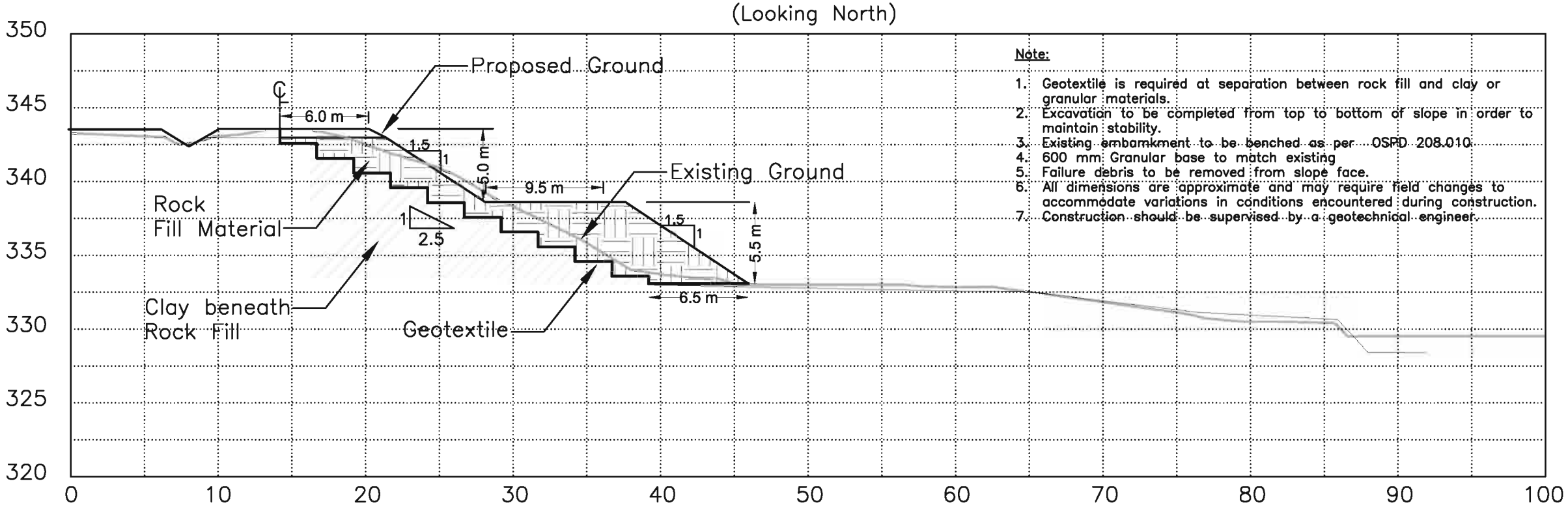
CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

BENCH REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



Note:
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2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embankment to be benched as per OSPD 208.010.
4. 600 mm Granular base to match existing
5. Failure debris to be removed from slope face.
6. All dimensions are approximate and may require field changes to accommodate variations in conditions encountered during construction.
7. Construction should be supervised by a geotechnical engineer.

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
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BH10	343.48	5383472	270134	9+900	3.0 m LT
BH11	343.21	5383304	270147	9+731	3.0 m RT
BH12	343.41	5383354	270140	9+781	2.9 m RT
BH13	343.44	5383398	270140	9+825	2.2 m RT
BH14	343.39	5383444	270140	9+872	3.5 m RT
BH15	339.23	5383318	270168	9+743	26.0 m RT
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
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Thunder Bay, ON P7B 5V5
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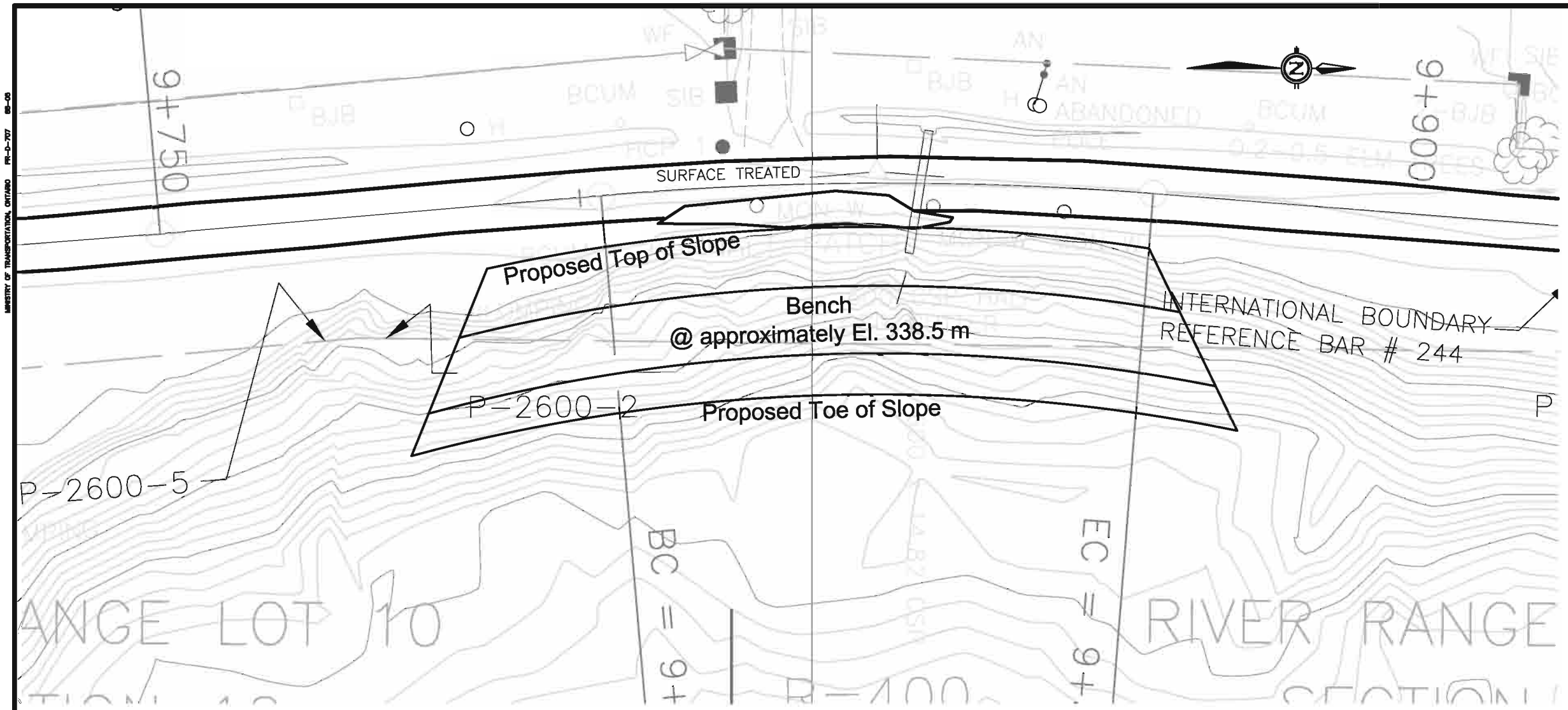
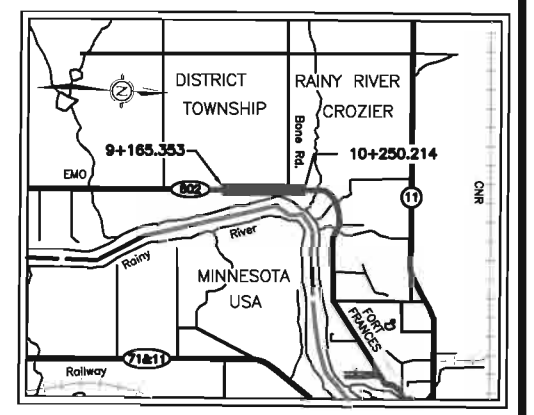
DRAWING 6

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

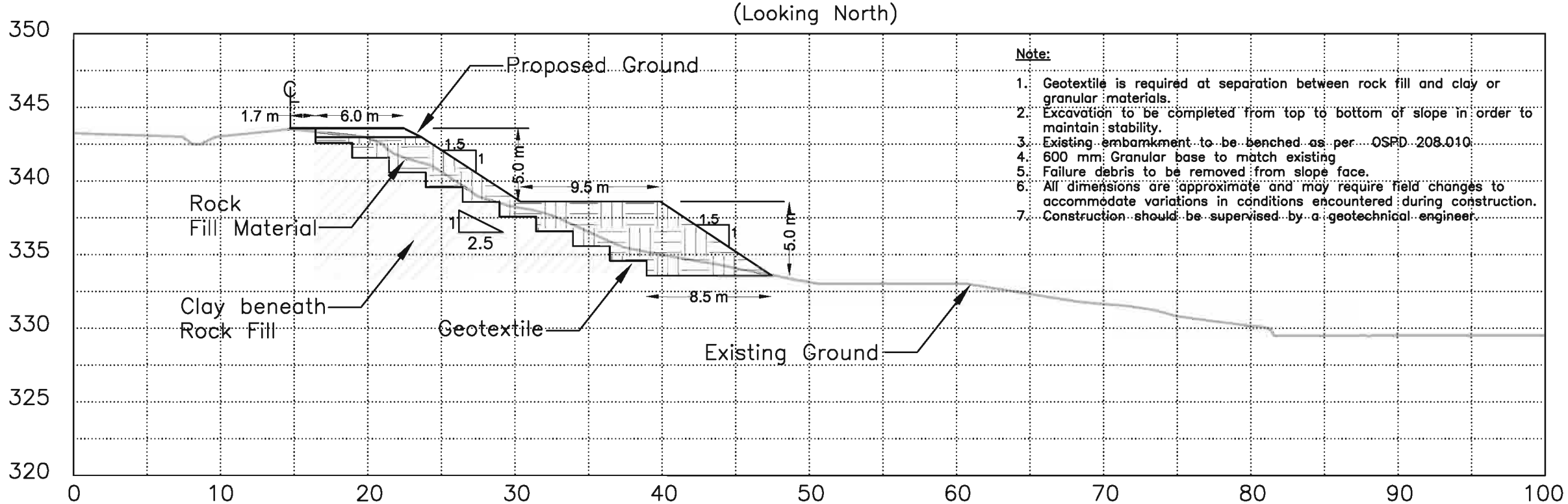
CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

BENCH REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION F–F' at Station 9+856
(Looking North)



Note:
1. Geotextile is required at separation between rock fill and clay or granular materials.
2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embamkment to be benched as per OSPD 208.010
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5. Failure debris to be removed from slope face.
6. All dimensions are approximate and may require field changes to accommodate variations in conditions encountered during construction.
7. Construction should be supervised by a geotechnical engineer.

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
BH9	343.44	5383430	270135	9+858	2.2 m LT
BH10	343.48	5383472	270134	9+900	3.0 m LT
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BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
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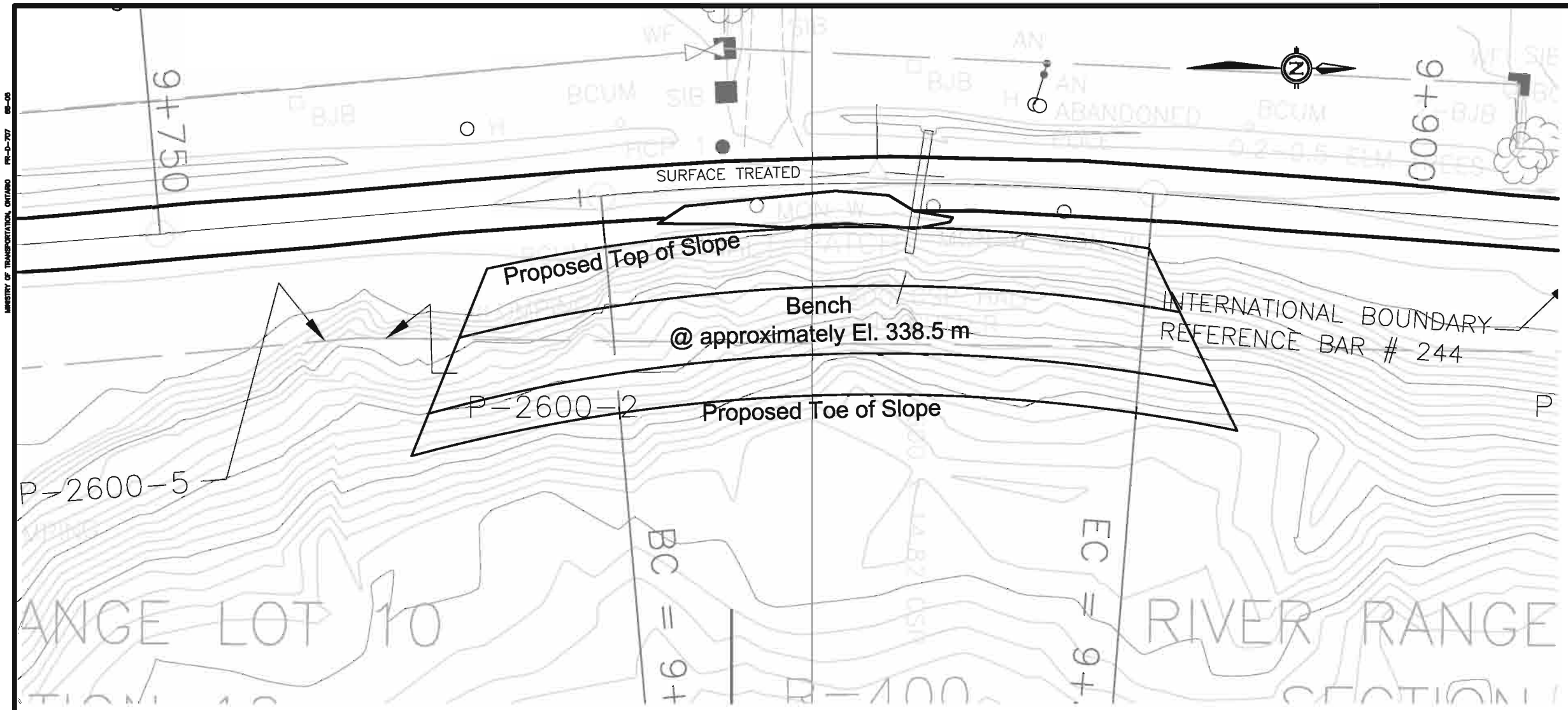
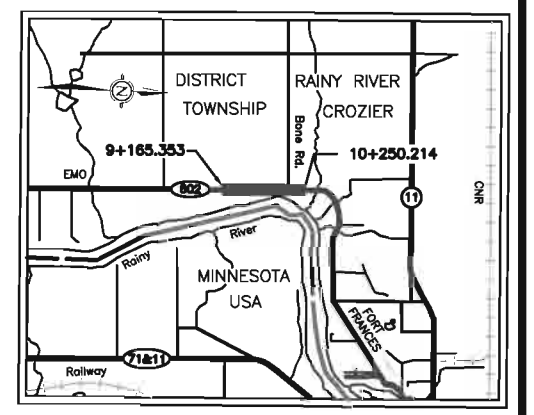
DRAWING 7

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET





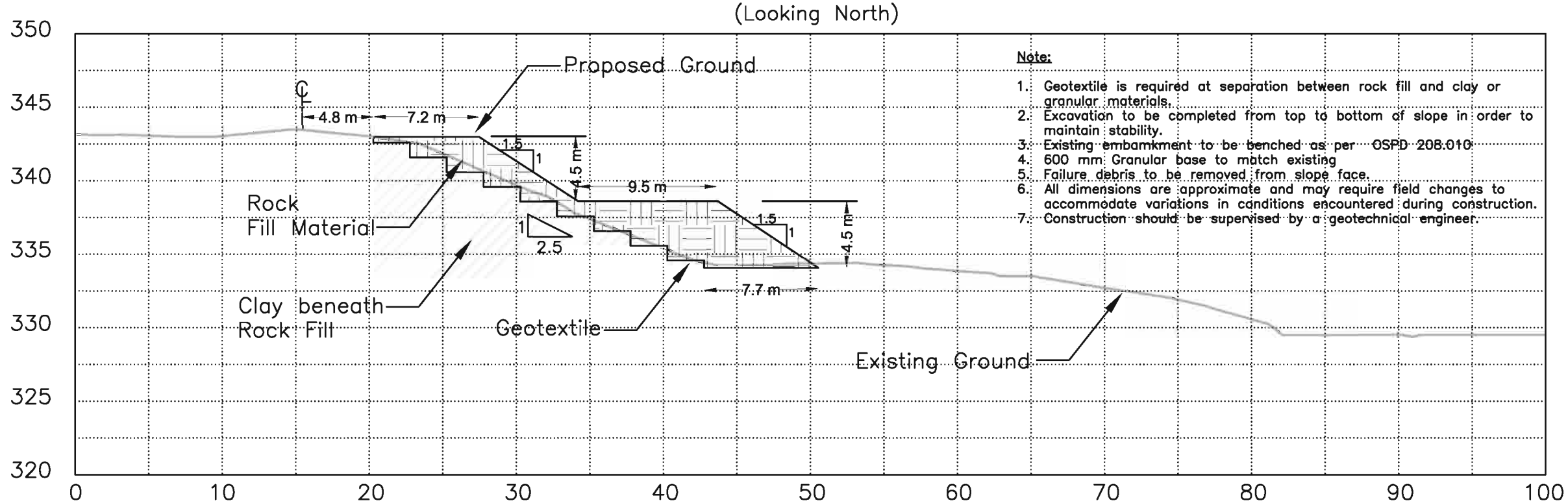
KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

BENCH REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION G–G' at Station 9+881
(Looking North)



Note:

1. Geotextile is required at separation between rock fill and clay or granular materials.
2. Excavation to be completed from top to bottom of slope in order to maintain stability.
3. Existing embankment to be benched as per OSPD 208.010
4. 600 mm Granular base to match existing
5. Failure debris to be removed from slope face.
6. All dimensions are approximate and may require field changes to accommodate variations in conditions encountered during construction.
7. Construction should be supervised by a geotechnical engineer.

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
BH9	343.44	5383430	270135	9+858	2.2 m LT
BH10	343.48	5383472	270134	9+900	3.0 m LT
BH11	343.21	5383304	270147	9+731	3.0 m RT
BH12	343.41	5383354	270140	9+781	2.9 m RT
BH13	343.44	5383398	270140	9+825	2.2 m RT
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BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
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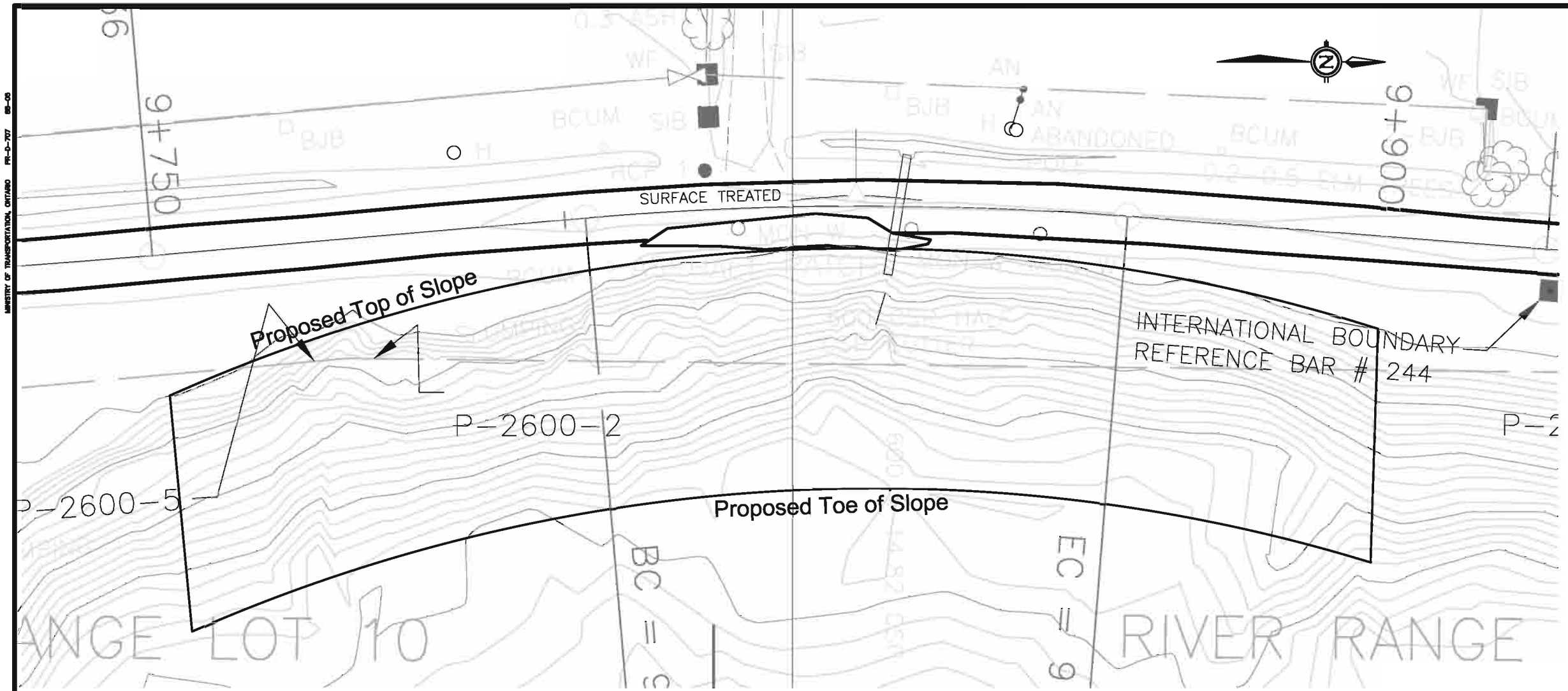
DRAWING 8

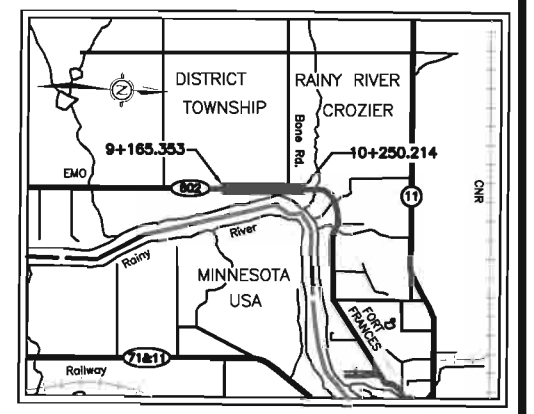
MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06



METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET



KEY PLAN

1.0 km 0 1.0 km

SCALE 1:50,000

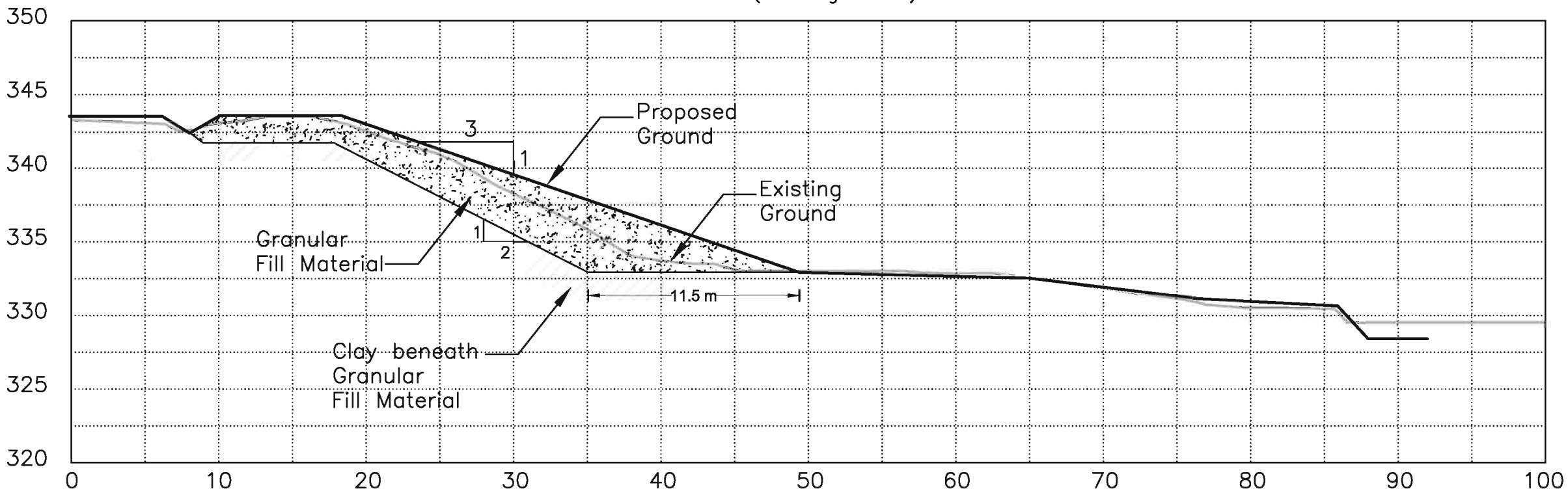
LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock

Sand, Silt, Clay, Sand & Gravel, Boulders

GRANULAR EMBANKMENT OPTION (3H:1V)
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
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BH9	343.44	5383430	270135	9+858	2.2 m LT
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BH13	343.44	5383398	270140	9+825	2.2 m RT
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BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

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DRAWING 9

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

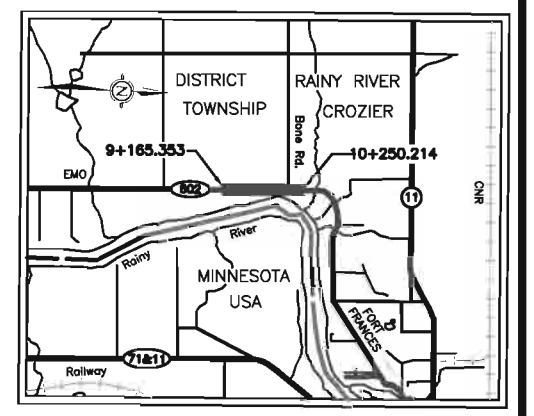
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009-E-0007
GWP No 6093-10-00
GeoCres No 52C-23

SLOPE FAILURE
(200 m South of Bone Rd.)
Highway 602 – Crozier Twp.
Geotechnical Investigation

SHEET

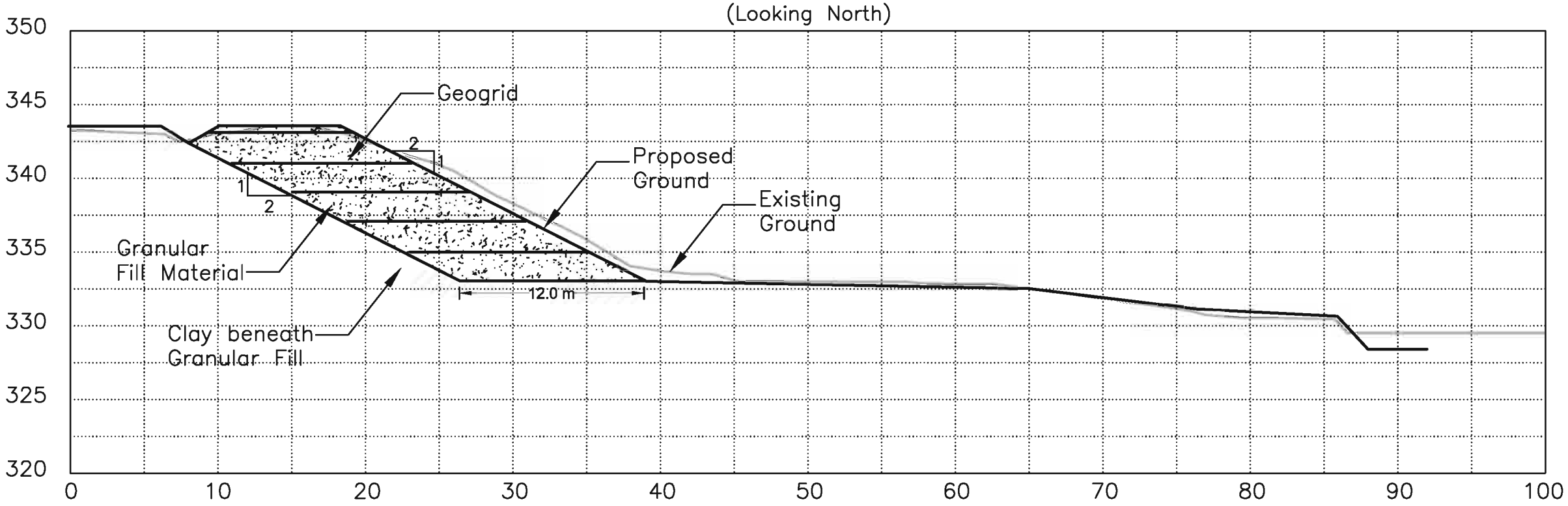


KEY PLAN

1.0 km 0 1.0 km

SCALE 1:50,000

GEOGRID REINFORCEMENT OPTION (2H:1V)
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock
Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
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BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

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DRAWING 10

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-05

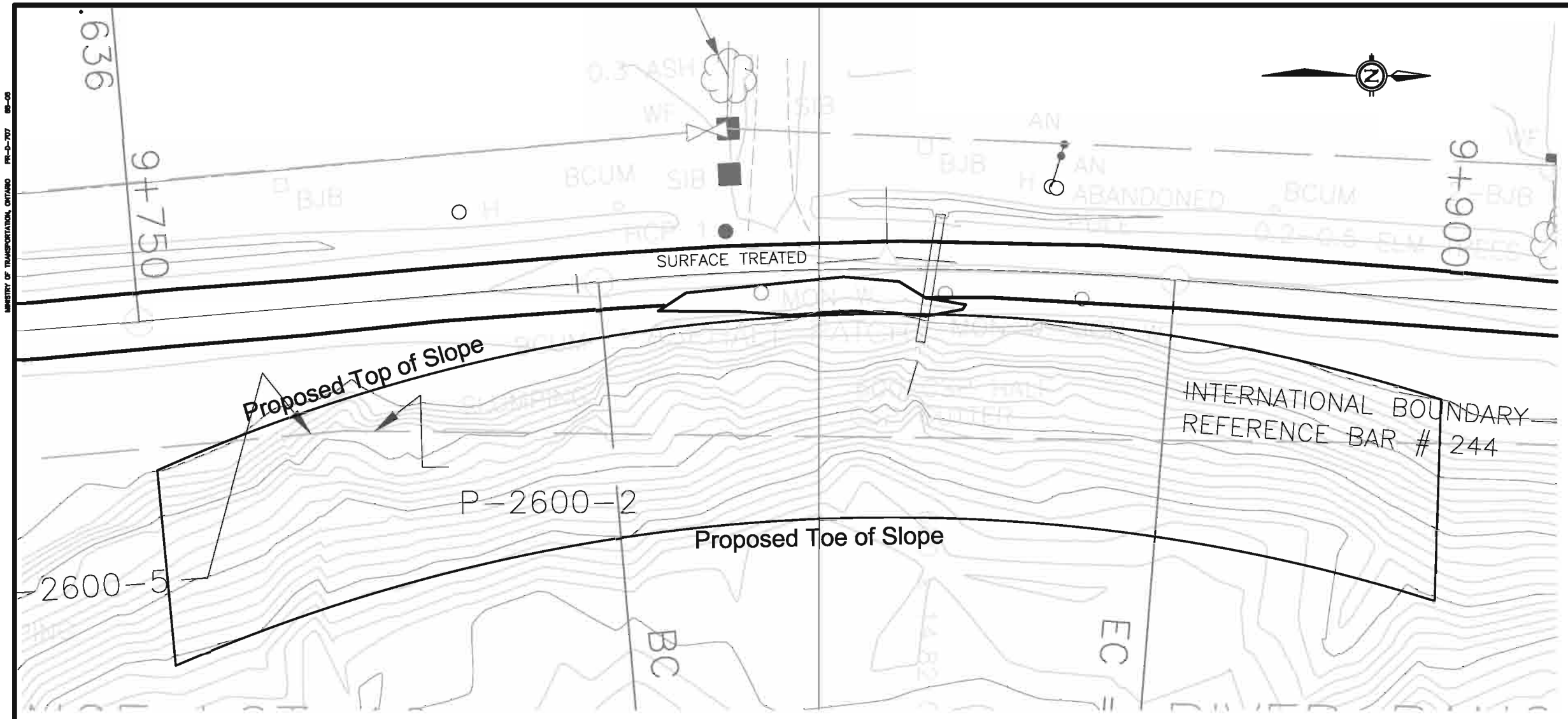
METRIC

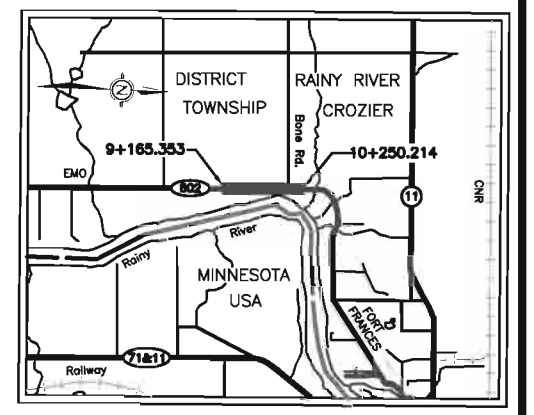
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT	No	6009-E-0007
GWP	No	6093-10-00
GeoCres	No	52C-23

SLOPE FAILURE
(200 m South of Bone Rd.)
Highway 602 – Crozier Twp.
Geotechnical Investigation

SHEET





KEY PLAN

1.0 km 0 1.0 km

SCALE 1:50,000

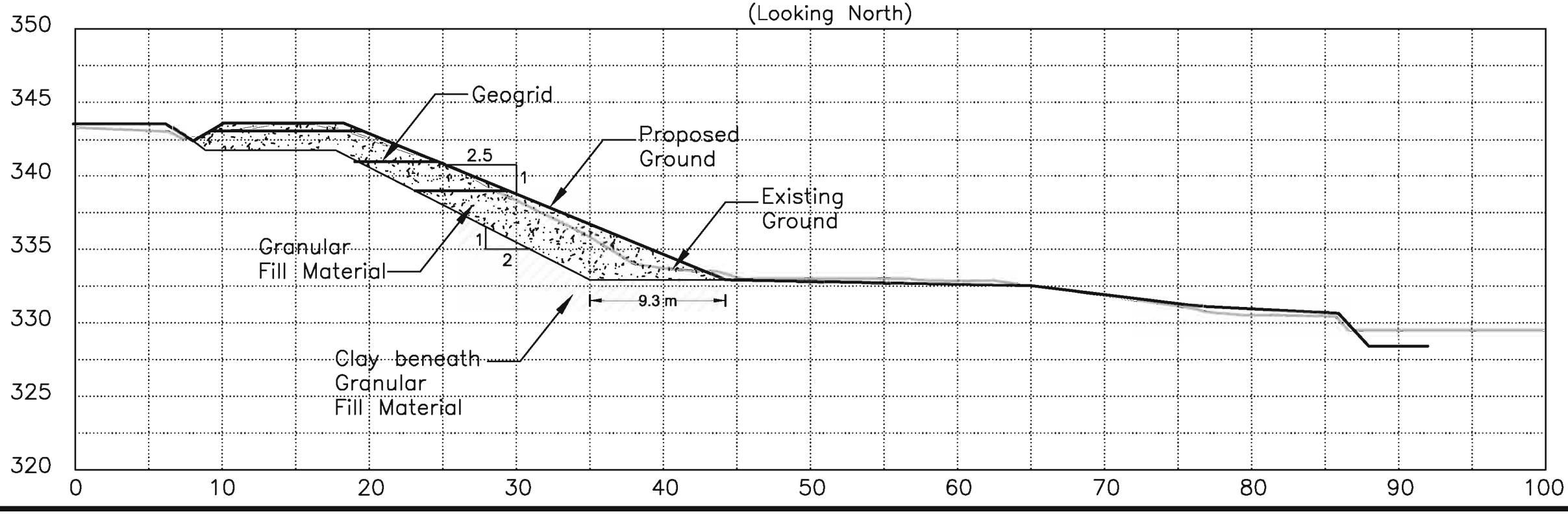
LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of Investigation.
- Benchmark

Fill, Organics, Topsoil, Till, Bedrock

Sand, Silt, Clay, Sand & Gravel, Boulders

GEOGRID REINFORCEMENT OPTION (2.5H:1V)
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



No.	Elevation	Northing	Easting	Station	Offset
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BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

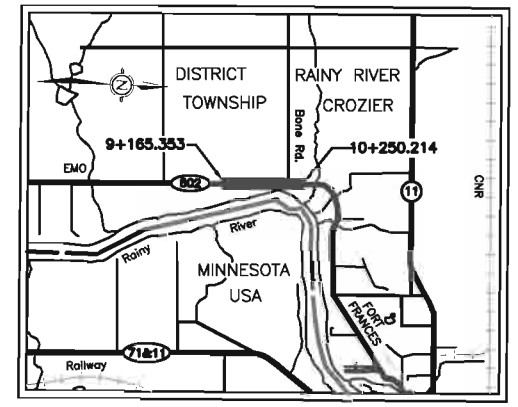
DST consulting engineers
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

DRAWING 11

MINISTRY OF TRANSPORTATION, ONTARIO FR-D-707 88-06

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS

CONT No 6009-E-0007 GWP No 6093-10-00 GeoCres No 52C-23		
SLOPE FAILURE (200 m South of Bone Rd.) Highway 602 – Crozier Twp. Geotechnical Investigation		SHEET

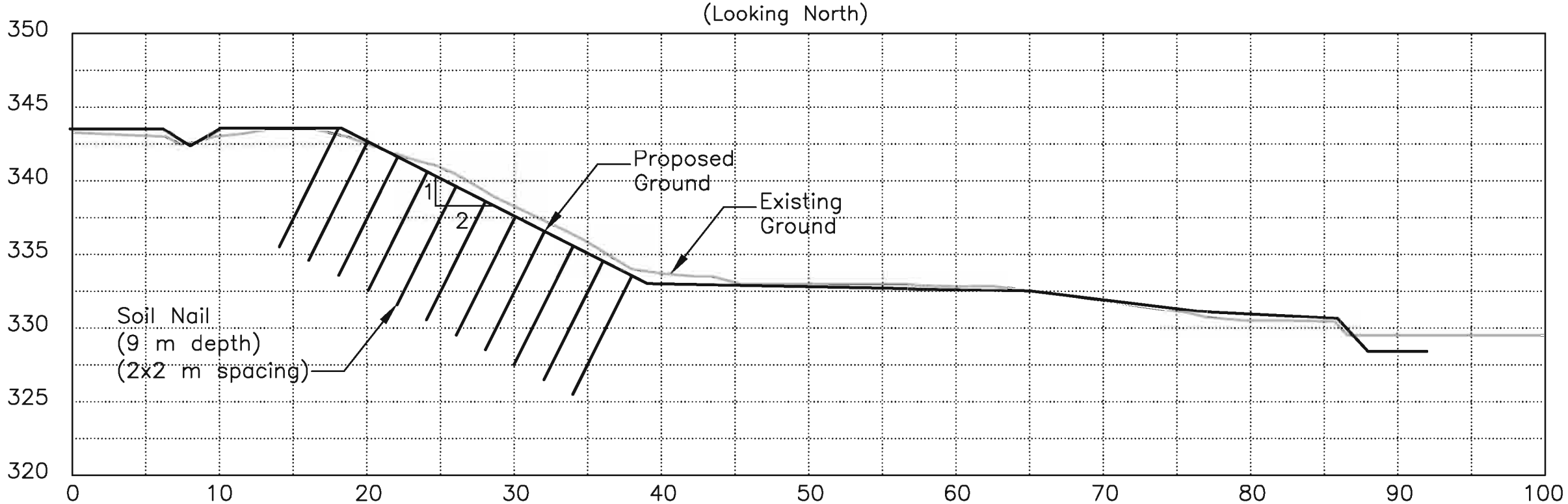


KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND

- Borehole
- Borehole with DCPT
- Dynamic Cone Penetration Test (DCPT)
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- Benchmark
- Fill
- Organics
- Topsoil
- Till
- Bedrock
- Sand
- Silt
- Clay
- Sand & Gravel
- Boulders

SOIL NAIL OPTION
PROFILE ALONG SECTION E–E' at Station 9+831
(Looking North)



No.	Elevation	Northing	Easting	Station	Offset
BH6	343.225	5383303	270142	9+730.5	3.2 m LT
BH7	343.43	5383353	270135	9+781	2.1 m LT
BH8	343.44	5383404	270132	9+832	3.2 m LT
BH9	343.44	5383430	270135	9+858	2.2 m LT
BH10	343.48	5383472	270134	9+900	3.0 m LT
BH11	343.21	5383304	270147	9+731	3.0 m RT
BH12	343.41	5383354	270140	9+781	2.9 m RT
BH13	343.44	5383398	270140	9+825	2.2 m RT
BH14	343.39	5383444	270140	9+872	3.5 m RT
BH15	339.23	5383318	270168	9+743	28.0 m RT
BH16	332.319	5383390	270173	9+816	38.7 m RT
BH17	341.01	5383402	270144	9+830	9.0 m RT
BH18	332.93	5383339	270186	9+762.5	47.0 m RT

COORDINATE REFERENCE: MTM NAD83 ZONE 16

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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Thunder Bay, ON P7B 5V5
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Email: thunderbay@dstgroup.com

DRAWING 12

APPENDIX 'C'

BOREHOLE LOGS

RECORD OF BOREHOLE No BH06

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383303 m N, 270142 m E (9+730.5, 3.2 m LT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 7.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.2											
342.8	FILL - SAND - some gravel, trace silt, brown		AS1	AS			343				Dry on completion. Open to 5.3 m
0.4	CLAY - Silty - some sand, trace gravel, brown/grey, very stiff to hard										
			SS2	SS	5		342	×2			
			SS3	SS	7						
			SS4	SS	8		341	×3			
			SS5	SS	8		340	×			
			SS6	SS	13		339	×			
			SS7	SS	13			×2			
			SS8	SS	13		338	×2			
337.0											
6.2	End of Borehole at 6.2 m										

○ UNCONFINED × FIELD VANE

□ QUICK TRIAXIAL ★ LAB VANE

$\times^3$, $\star^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 1

RECORD OF BOREHOLE No BH07

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383353 m N, 270135 m E (9+781, 2.1 m LT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 7.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) O UNCONFINED X FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.2	SURFACE TREATMENT - 50 mm		AS1	AS							
0.2	FILL - SAND - 90 mm ASPHALT - 80 mm						343				16 72 (12)
342.7											
0.7	FILL - SAND - some gravel and silt, brown										
	SAND - Silty, some clay, brown, loose		SS2	SS	5						0 53 31 16
342.0							342				Dry on completion. Open to 5.3 m
1.4	CLAY - Silty, some sand, trace gravel and organics, brown, very stiff		SS3	SS	6			X²			
			SS4	SS	10		341	X³			
			SS5	SS	10		340	X			
			SS6	SS	8		339	X²			
			SS7	SS	8			X⁴			
			SS8	SS	10		338	X³			
337.3											
6.1	End of Borehole at 6.1 m										

X³, ★³: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 2

RECORD OF BOREHOLE No BH08

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383404 m N, 270132 m E (9+832, 3.2 m LT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 8.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.0	SURFACE TREATMENT - 30 mm										
342.7	FILL - SAND - Gravelly, trace silt, brown		AS1	AS			343				30 59 (10) Dry on completion. Open to 5.3 m
0.7	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		SS2	SS	5						
			SS3	SS	4		342				0 17 69 15
			SS4	SS	9		341				
			SS5	SS	9		340				
			SS6	SS	10		339				
			SS7	SS	9			✕2			
			SS8	SS	10		338	✕2			
337.3											
6.1	End of Borehole at 6.1 m										

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

ENCLOSURE 3

RECORD OF BOREHOLE No BH09

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383430 m N, 270135 m E (9+858, 2.2 m LT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 8.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.2 / 0.2	SURFACE TREATMENT - 50 mm FILL - SAND - 95 mm ASPHALT - 50 mm		AS1	AS			343				Dry on completion. Open to 5.3 m
342.8 / 0.7	FILL - SAND - trace gravel and silt, brown CLAY - Silty, some sand, trace gravel, brown, hard		SS2	SS	9						
			SS3	SS	10		342				
			SS4	SS	12		341				
			SS5	SS	11		340				
			SS6	SS	11		339				
	- - - - - brown/grey, occasional cobbles		SS7	SS	13						
			SS8	SS	10		338				
337.3											
6.1	End of Borehole at 6.1 m										

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

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 4

RECORD OF BOREHOLE No BH10 1 OF 1 METRIC

W.P. 6009-E-0007 LOCATION 5383472 m N, 270134 m E (9+900, 3.0 m LT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 8.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.5										
	FILL - SAND - some gravel, trace silt, brown		AS1	AS						Dry on completion. Open to 5.3 m
342.8							343			
0.7	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		SS2	SS	8			✕²		
			SS3	SS	7		342	✕		
			SS4	SS	10		341	✕		
			SS5	SS	9		340	✕		
			SS6	SS	9		339	✕		
			SS7	SS	9			✕²		
			SS8	SS	9		338	✕		
337.4										
6.1	End of Borehole at 6.1 m									

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

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 5

RECORD OF BOREHOLE No BH11

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383304 m N, 270147 m E (9+731, 3.0 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 10.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, □ QUICK TRIAXIAL, × FIELD VANE, ★ LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.2								20 40 60 80 100 / 50 100 150 200 250	20 40 60		
343.0	SURFACE TREATMENT - 30 mm		AS1	AS			343				
342.8	FILL - SAND - Gravelly, trace silt, brown										31 61 (8)
0.4	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		AS2	AS	6		342				Dry on completion. Open to 12.2 m
			SS3	SS	8		341	×			
			SS4	SS	12		340	×			
			SS5	SS	9		339	×			
			SS6	SS	10		338	×			
			SS7	SS	7		337	×			
			SS8	SS	7		336	×2			
			SS9	SS	7		335	×			1 13 39 47
			SS10	SS	7		334	×2			
			SS11	SS	5		333	×2			
			SS12	SS	8		332	×2			
330.4							331				
12.8	End of Borehole at 12.8 m										

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

ENCLOSURE 6

RECORD OF BOREHOLE No BH12

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383354 m N, 270140 m E (9+781, 2.9 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 9.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE) (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.0	SURFACE TREATMENT - 30 mm										
342.8	FILL - SAND - some gravel, trace silt, brown		AS1	AS			343				Dry on completion. Open to 12.2 m
0.7	SAND - Silty, some clay, brown, loose		SS2	SS	3						
341.3			SS3	SS	10		342	$\times^2$			
2.1	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		SS4	SS	8		341	✕			0 17 32 50
			SS5	SS	8		340	✕			
			SS6	SS	8		339	$\times^2$			
			SS7	SS	6		338	✕			
			SS8	SS	7		337	$\times^2$			
			SS9	SS	7		336	$\times^2$			
			SS10	SS	7		335	✕			
			SS11	SS	9		334	✕			
330.7			SS12	SS	11		333	✕			
12.7	End of Borehole at 12.7 m						332				
							331	✕			

$\times^3$, $\star^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 7

RECORD OF BOREHOLE No BH13

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383398 m N, 270140 m E (9+825, 2.2 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 9.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.4 / 0.0	SURFACE TREATMENT - 40 mm										
	FILL - SAND - some gravel, trace silt, brown		AS1	AS			343				Dry on completion. Open to 12.2 m
342.7 / 0.8	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		AS2	AS							
	- some wood debris		SS3	SS	5		342				1 14 62 23
			SS4	SS	9		341				
			SS5	SS	7		340				
			SS6	SS	7						
			SS7	SS	10		339				1 13 31 55
			SS8	SS	9		338				
			SS9	SS	9		337				
			SS10	SS	10		336				
			SS11	SS	9		335				
			SS12	SS	11		334				
330.7							333				
12.7	End of Borehole at 12.7 m						332				
							331				

$\times^3$, $\star^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 8

RECORD OF BOREHOLE No BH14

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383444 m N, 270140 m E (9+872, 3.5 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 8.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
343.4											
343.0	SURFACE TREATMENT - 30 mm										
342.8	FILL - SAND - Gravelly, trace silt, brown		AS1	AS			343				32 61 (6)
0.6	CLAY - Silty, some sand, trace gravel, brown, very stiff to hard		SS2	SS	6						Dry on completion. Open to 12.2 m
			SS3	SS	12		342	✕²			
			SS4	SS	11		341	✕²			
			SS5	SS	8		340	✕²			
	- - - - - occasional rootlets		SS6	SS	8						
			SS7	SS	8		339	✕			
							338	✕			
			SS8	SS	8		337	✕²			
			SS9	SS	7		336	✕			
			SS10	SS	8		335	✕²			
			SS11	SS	8		334	✕			
							333				
							332				
330.7			SS12	SS	8		331				4 12 31 53
12.7	End of Borehole at 12.7 m										

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

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 9

RECORD OF BOREHOLE No BH15 1 OF 1 METRIC

W.P. 6009-E-0007 LOCATION 5383318 m N, 270168 m E (9+743, 28.0 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Probe (52 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 12.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
339.2							
339.1 / 0.1	TOPSOIL - 50 mm CLAY - Organicy, black - 50 mm						
	CLAY - Silty, some sand, trace gravel, brown/grey, firm to stiff		SS1	SS	3		339
			SS2	SS	6		
	- - - - - trace rootlets		SS3	SS	4		338
			SS4	SS	7		
	- - - - - occasional cobbles		SS5	SS	7		337
			SS6	SS	11		336
			SS7	SS	12		
			SS8	SS	14		335
			SS9	SS	10		
			SS10	SS	11		334
333.1							
6.1	End of Borehole at 6.1 m						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: 50 100 150 200 250

○ UNCONFINED ✕ FIELD VANE

□ QUICK TRIAXIAL ★ LAB VANE

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$✕^3$, $★^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 10

RECORD OF BOREHOLE No BH16

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383390 m N, 270173 m E (9+816, 38.7 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Probe (52 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 11.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
332.3										
332.2 / 0.2	ORGANICS - fibrous, black CLAY - Silty, some sand, trace gravel, brown/grey, firm to very stiff		SS1	SS	8		332			
			SS2	SS	22					
			SS3	SS	11		331			
			SS4	SS	13					
	- - - - - trace sand		SS5	SS	10		330			
			SS6	SS	17					
			SS7	SS	7		329			
	- - - - - occasional cobbles		SS8	SS	8					
			SS9	SS	13		328			
			SS10	SS	18		327			
326.2										
6.1	End of Borehole at 6.1 m									

$\times^3$, $\star^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 11

RECORD OF BOREHOLE No BH17 1 OF 1 METRIC

W.P. 6009-E-0007 LOCATION 5383402 m N, 270144 m E (9+830, 9.0 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Probe (52 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 10.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE) (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
341.0											
340.9 / 0.1	TOPSOIL - 50 mm										
340.4 / 0.6	FILL - SAND - some gravel, trace silt and organics, brown, loose to compact		SS1	SS	7						0 28 33 40
	CLAY - Silty, with sand, trace gravel, brown, firm to very stiff		SS2	SS	14		340				
			SS3	SS	23						6 39 33 23
	- - - - - trace organics		SS4	SS	13		339				
			SS5	SS	16						
			SS6	SS	13		338				
			SS7	SS	16						
			SS8	SS	6		337				
			SS9	SS	15						
			SS10	SS	20		336				
334.9							335				
6.1	End of Borehole at 6.1 m										

$\times^3$, $\star^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 12

RECORD OF BOREHOLE No BH18

1 OF 1

METRIC

W.P. 6009-E-0007 LOCATION 5383339 m N, 270186 m E (9+762.5, 47.0 m RT) ORIGINATED BY PR

DIST HWY 602 BOREHOLE TYPE Probe (52 mm ID) COMPILED BY ML

DATUM MTM Zone 16 DATE 12.6.11 CHECKED BY WS/BV

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (50 100 150 200 250) ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
332.9											
332.9 / 0.0	TOPSOIL - 50 mm										
332.8 / 0.1	CLAY - Organicy, black, very stiff		SS1	SS	5						
332.1											
0.8	CLAY - Silty, some sand, trace gravel, brown/grey, firm to stiff		SS2	SS	12		332				
			SS3	SS	6						
	- - - - - some wood		SS4	SS	7		331				
			SS5	SS	7						
	- - - - - occasional cobbles		SS6	SS	9		330				
			SS7	SS	9		329				
			SS8	SS	11						
			SS9	SS	15		328				
			SS10	SS	14						
326.8							327				
6.1	End of Borehole at 6.1 m										

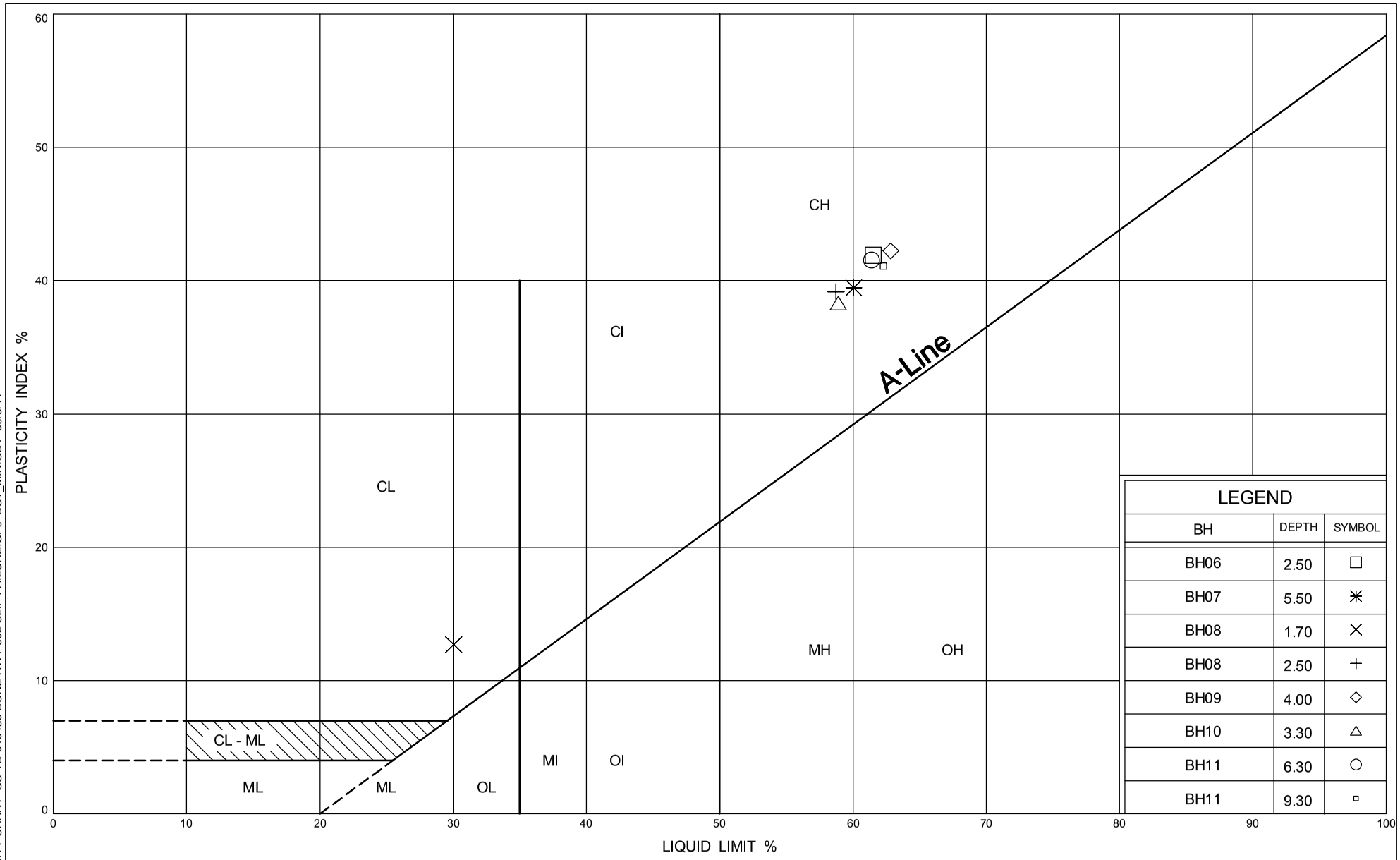
✕³, ★³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-013488 BONE HWY 602 SLIP FAILURE - WES EDIT.GPJ DST_MIN.GDT 7/7/11

ENCLOSURE 13

APPENDIX 'D'

SOILS LABORATORY DATA



ONTARIO MOT PLASTICITY CHART GS-TB-013488 BONE HWY 602 SLIP FAILURE.GPJ DST_MIN.GDT 30/6/11

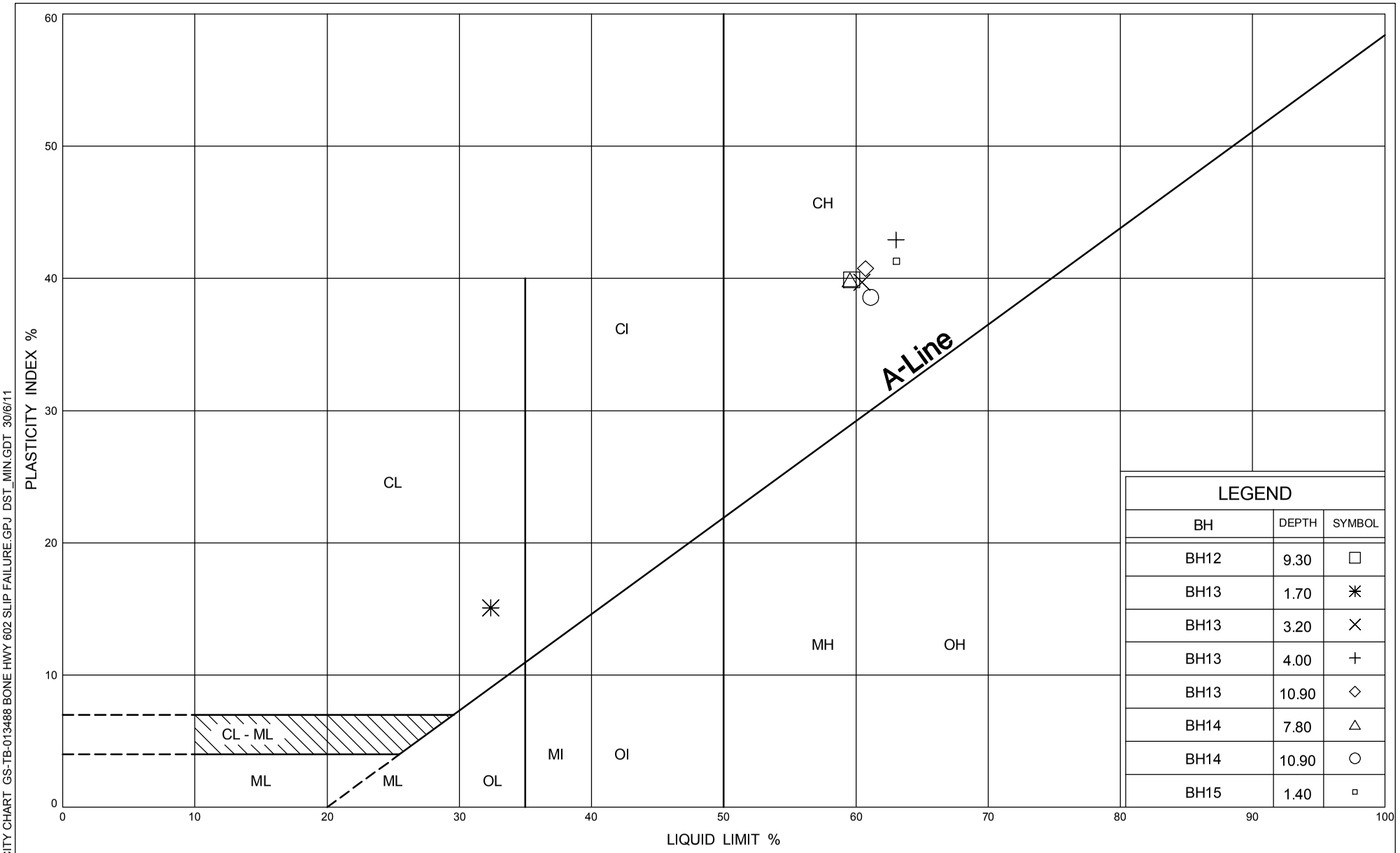
Ministry of Transportation Ontario

PLASTICITY CHART

ENCLOSURE 1

W P 6009-E-0007

HIGHWAY 602



Ministry of Transportation Ontario

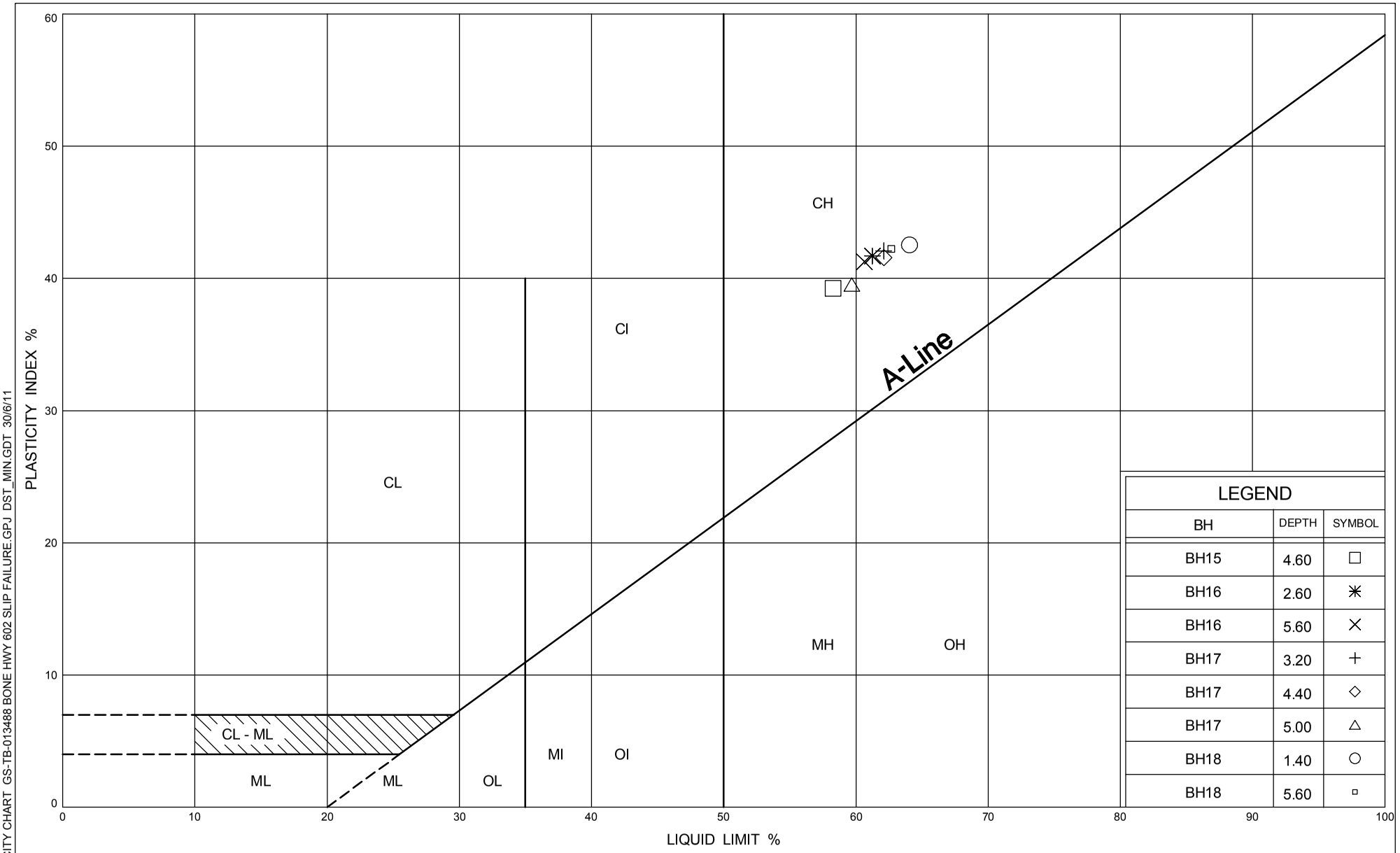
PLASTICITY CHART

ENCLOSURE 2

W P 6009-E-0007

HIGHWAY 602

ONTARIO MOT PLASTICITY CHART GS-TB-013488 BONE HWY 602 SLIP FAILURE.GPJ DST_MIN.GDT 30/6/11



ONTARIO MOT PLASTICITY CHART GS-TB-013488 BONE HWY 602 SLIP FAILURE.GPJ DST_MIN.GDT 30/6/11

Ministry of Transportation Ontario

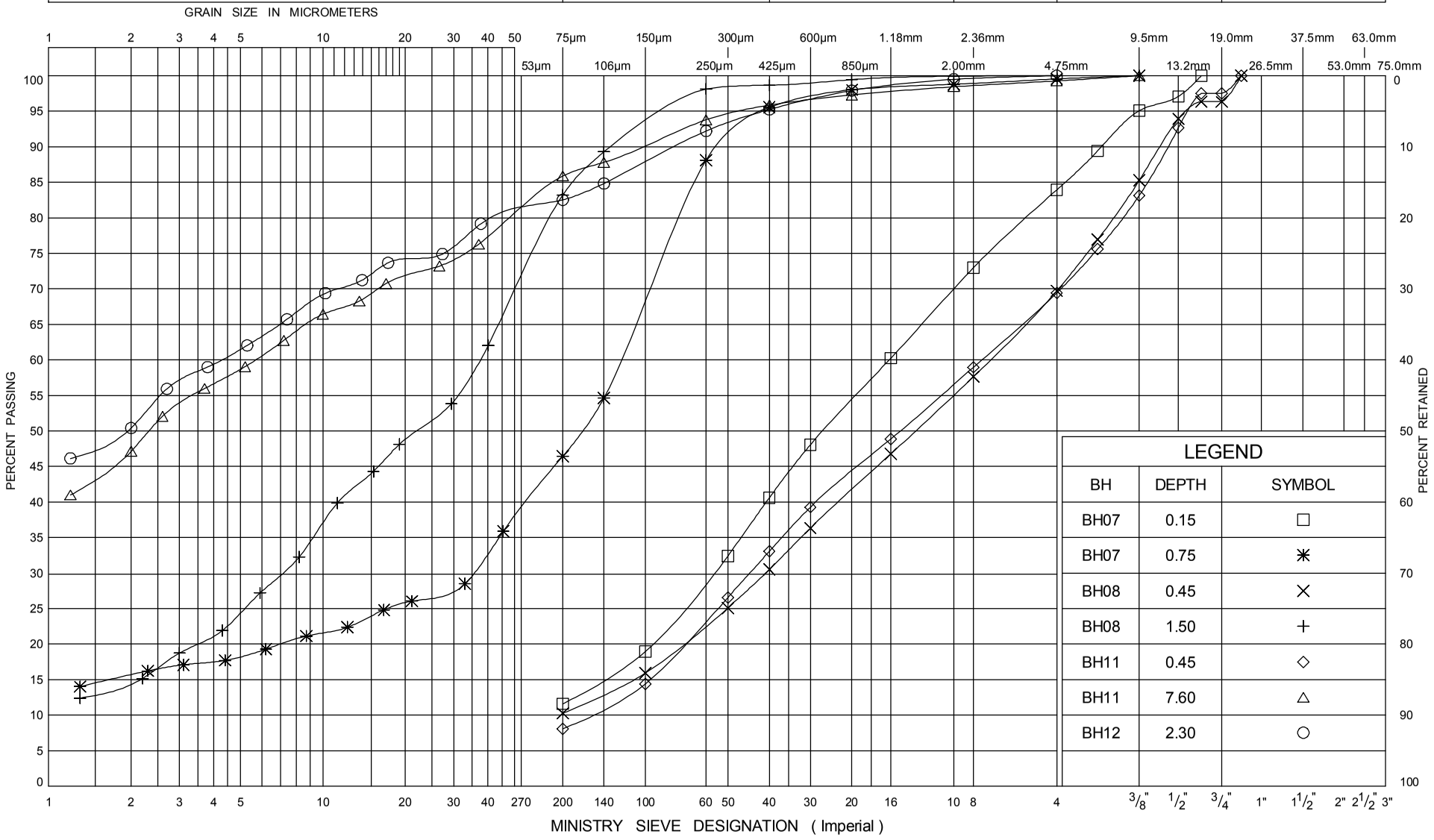
PLASTICITY CHART

ENCLOSURE 3

W P 6009-E-0007

HIGHWAY 602

UNIFIED SOIL CLASSIFICATION SYSTEM



ONTARIO MOT GRAIN SIZE GS-TB-013488 BONE HWY 602 SLIP FAILURE.GPJ DST_MIN.GDT 27/6/11

Ontario

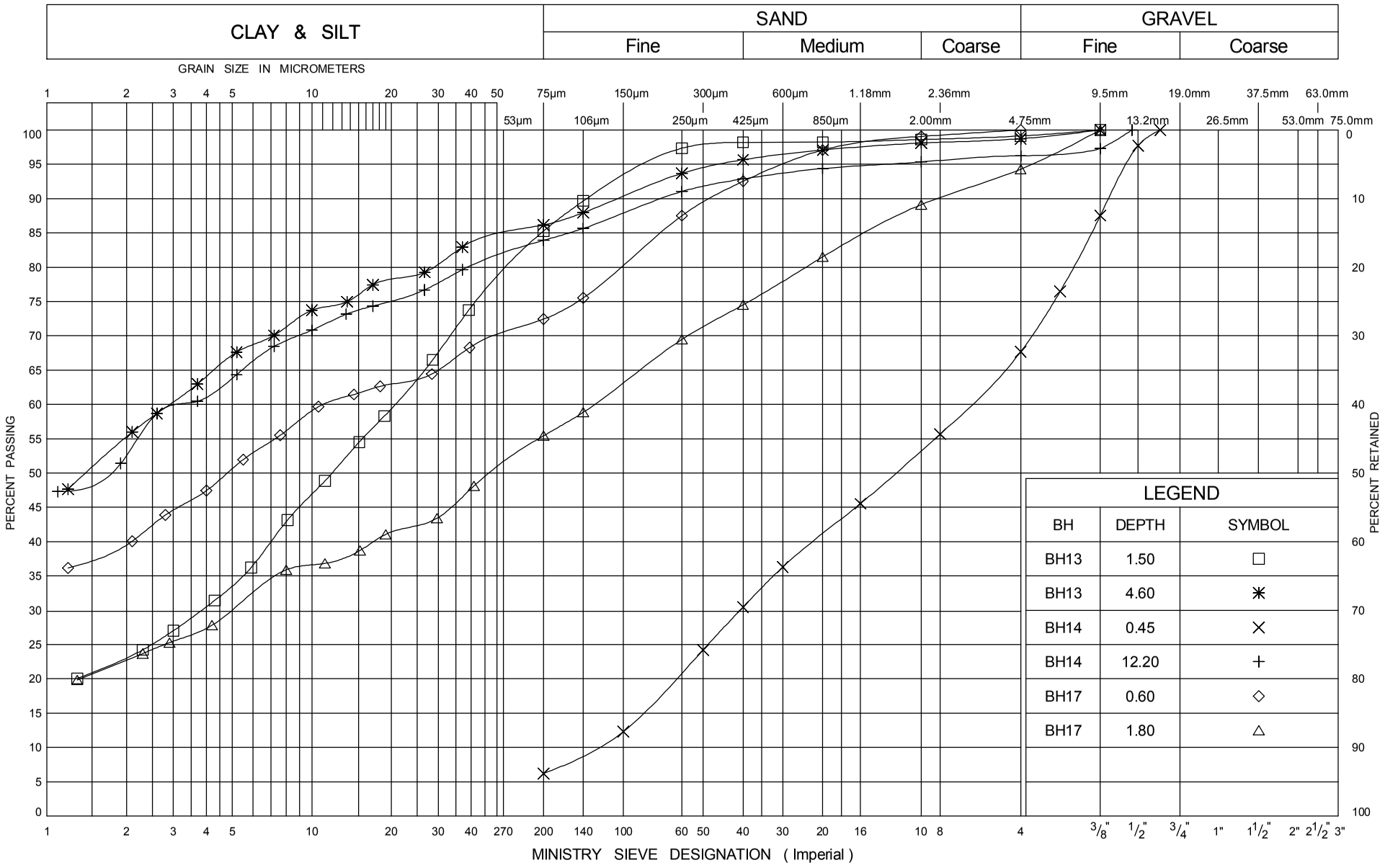
GRAIN SIZE DISTRIBUTION

ENCLOSURE 4

W P 6009-E-0007

HIGHWAY 602

UNIFIED SOIL CLASSIFICATION SYSTEM



ONTARIO MOT GRAIN SIZE GS-TB-013488 BONE HWY 602 SLIP FAILURE.GPJ DST_MIN.GDT 27/6/11

Ontario

GRAIN SIZE DISTRIBUTION

ENCLOSURE 5

W P 6009-E-0007

602

APPENDIX 'E'

SLOPE STABILITY OUTPUT

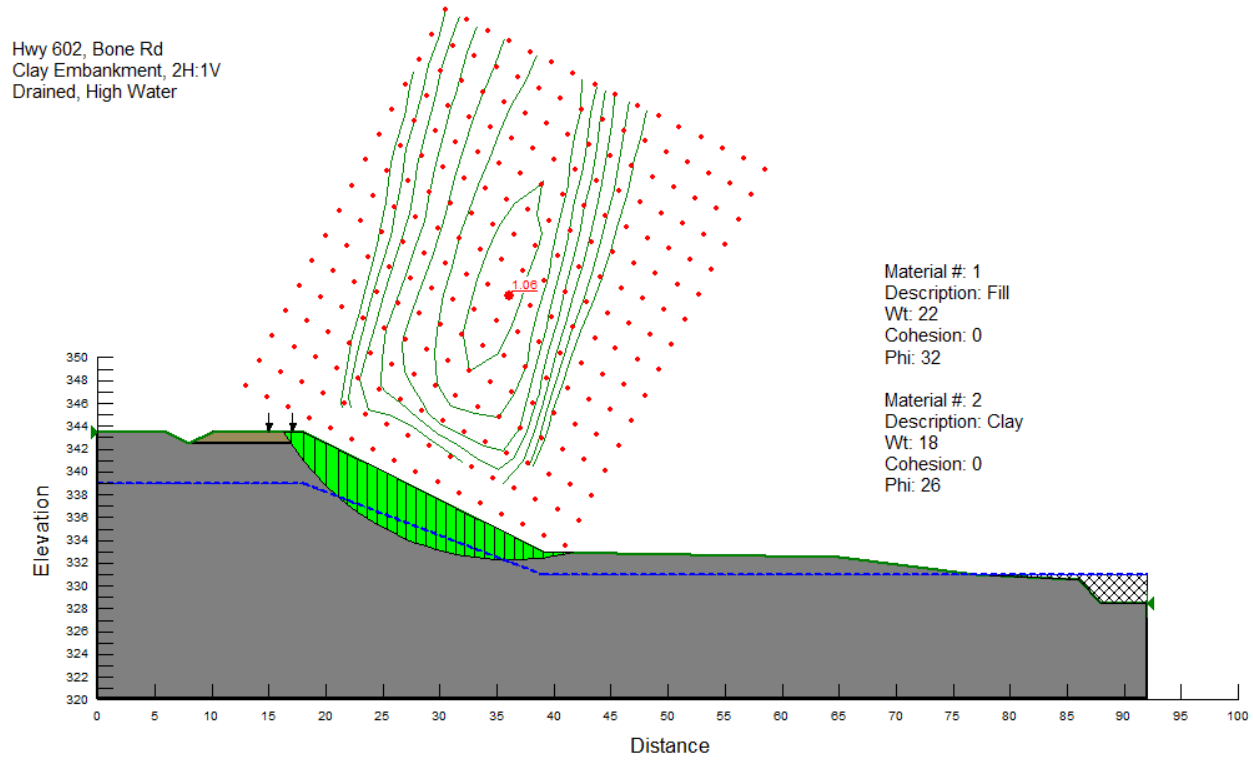


Figure 1 Clay embankment 2H:1V, drained condition with high water

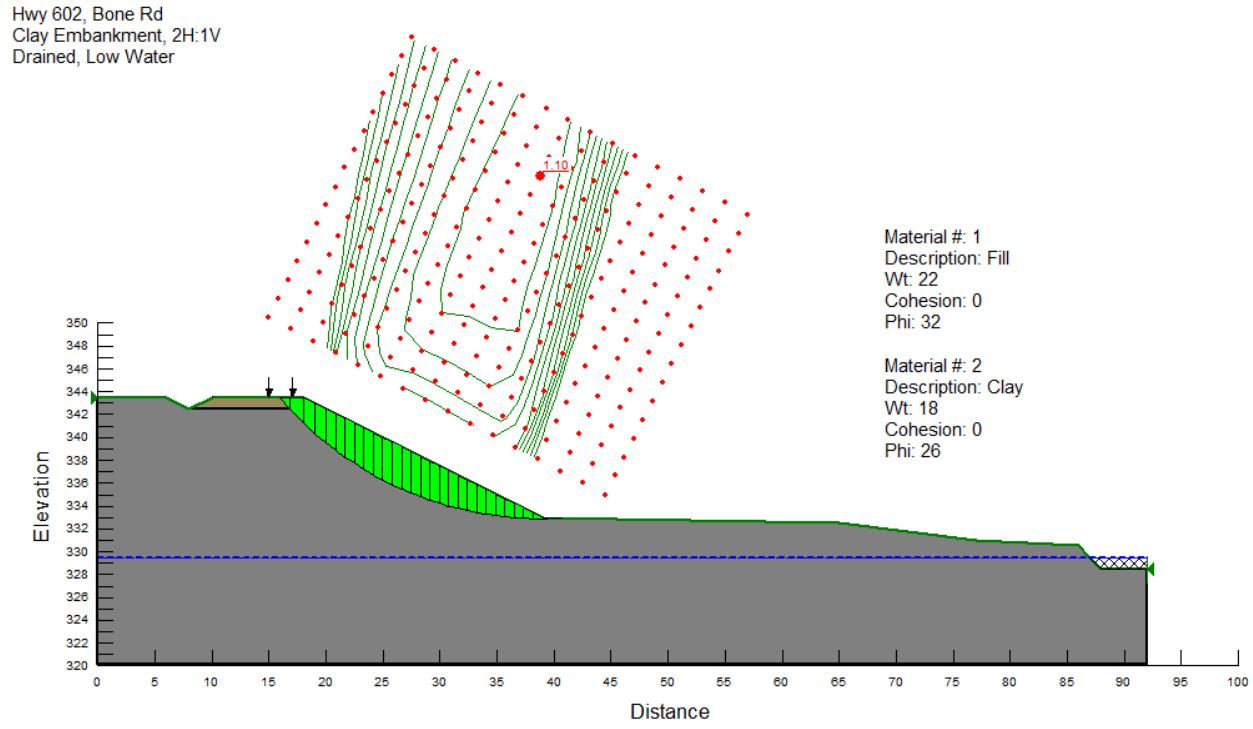


Figure 2 Clay embankment 2H:1V, drained condition with low water

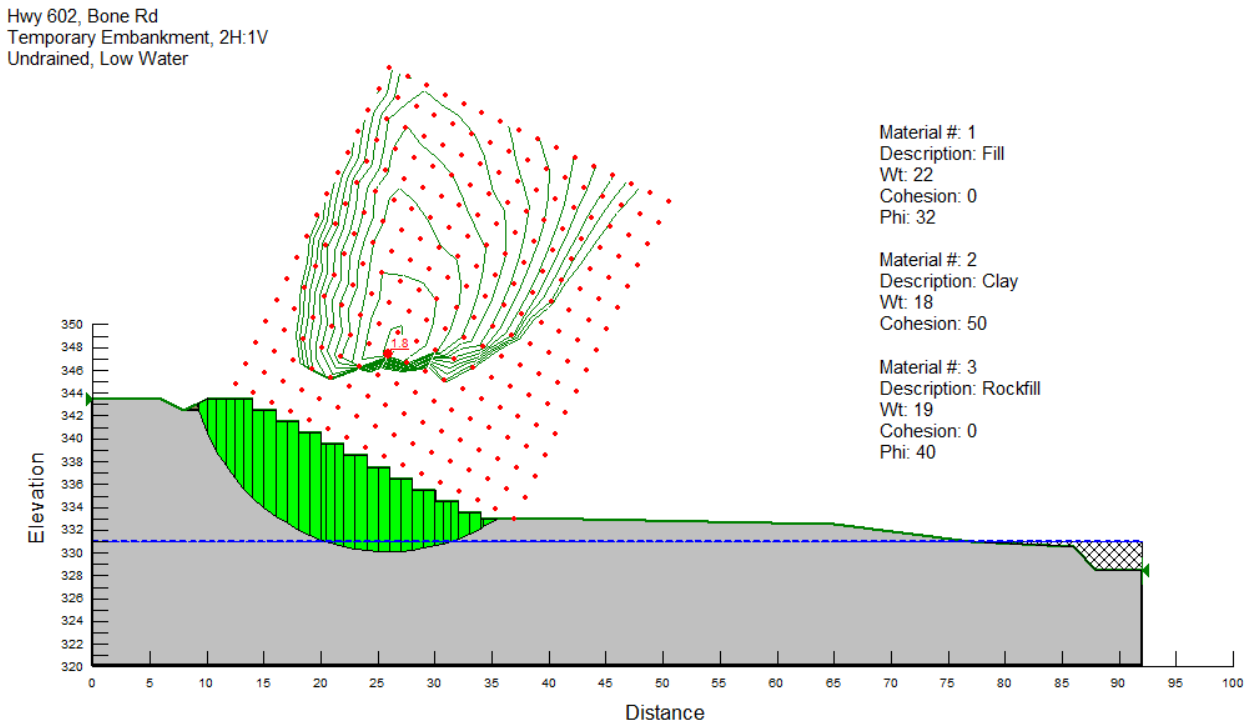


Figure 3 Temporary clay embankment 2H:1V, undrained condition with low water

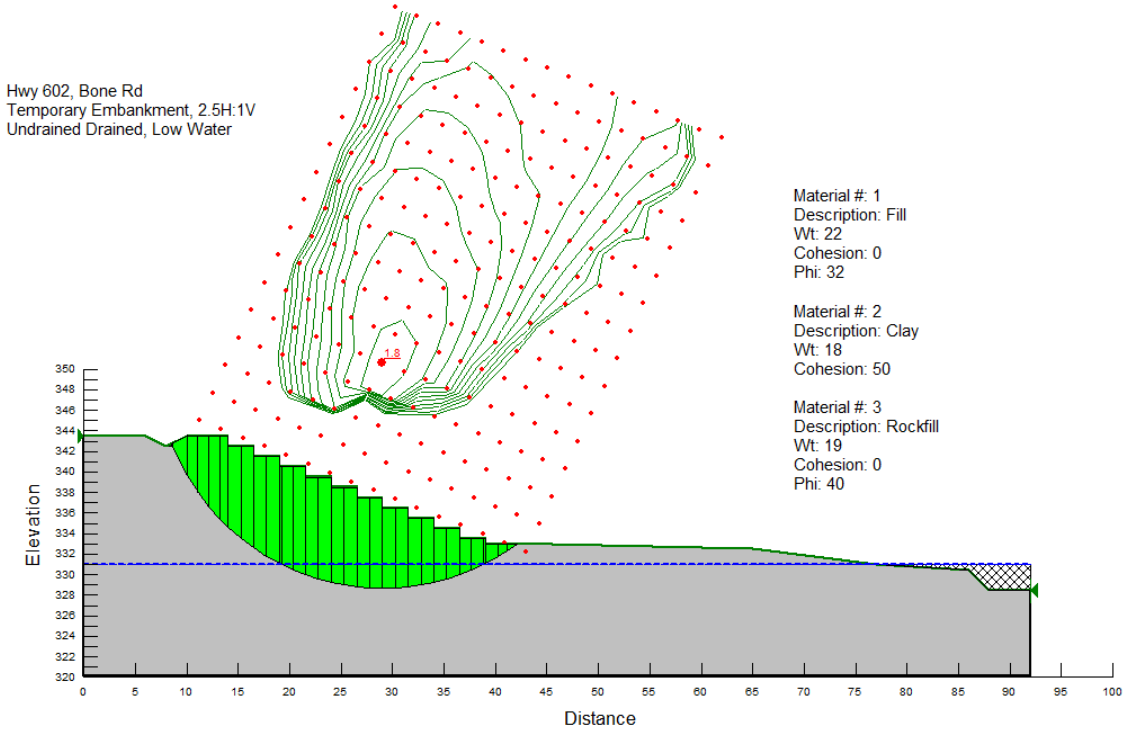


Figure 4 Temporary clay embankment 2.5H:1V, undrained condition with low water

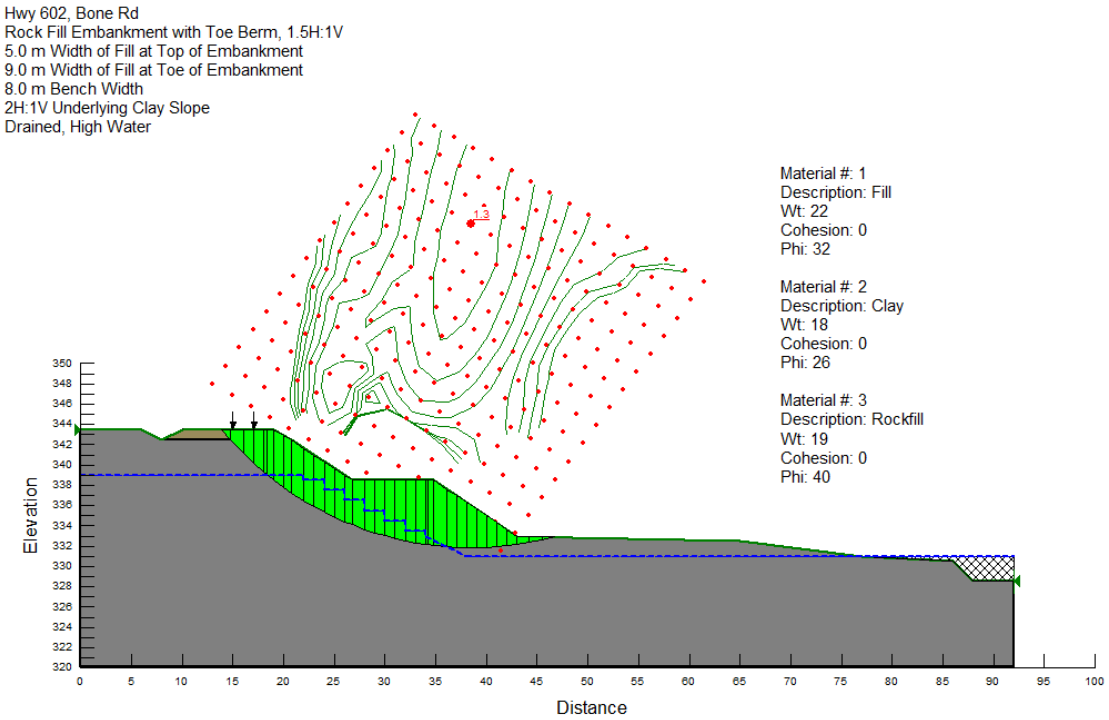


Figure 5 Rock fill embankment with toe berm, 2H:1V underlying clay slope, drained condition with high water

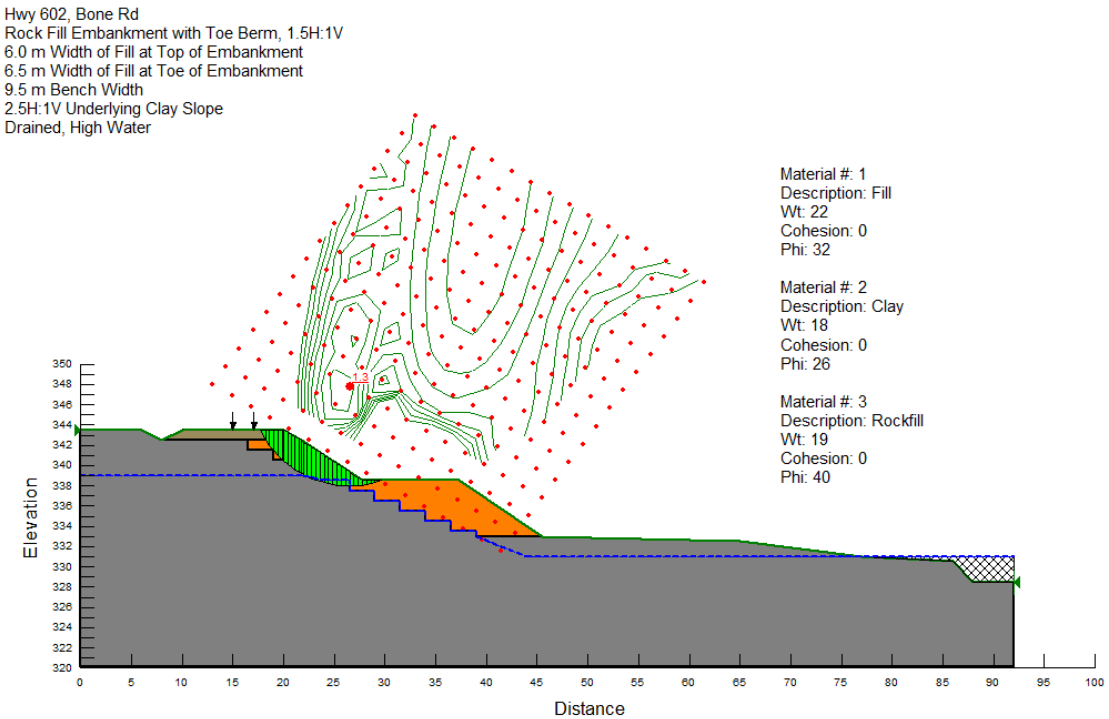


Figure 6 Rock fill embankment with toe berm, 2.5H:1V underlying clay slope, drained condition with low water

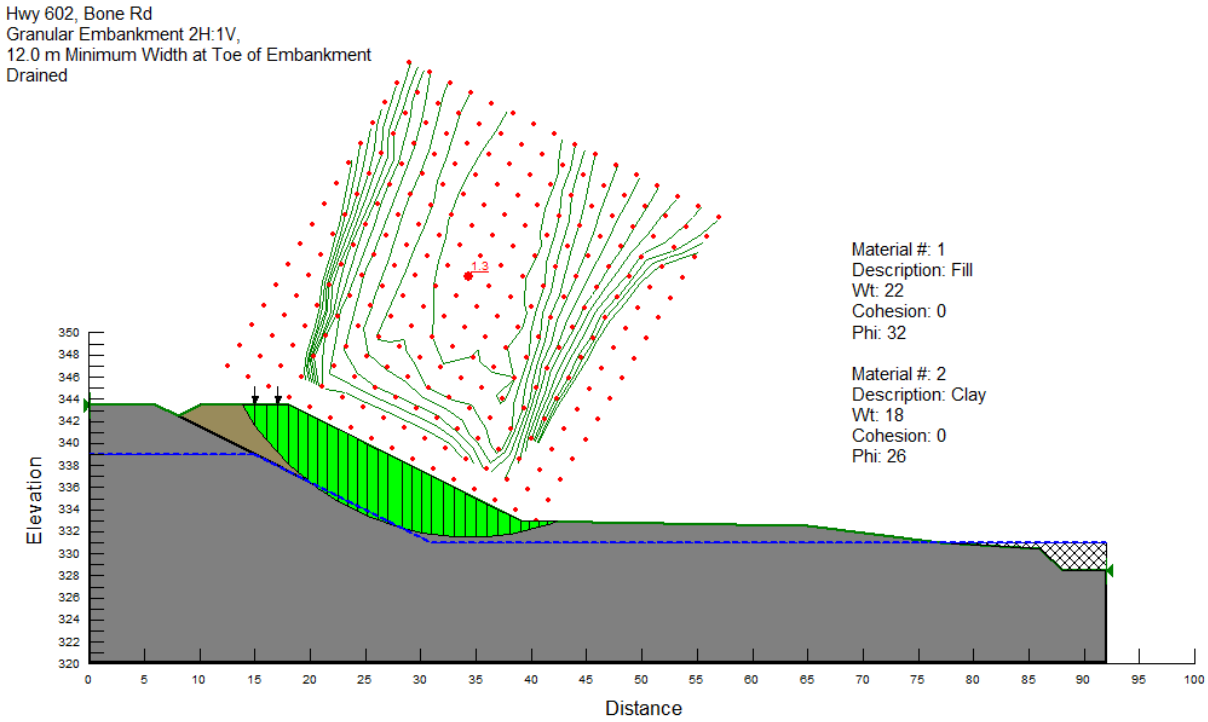


Figure 7 2H:1V Granular embankment, 2H:1V underlying clay slope, drained condition with high water

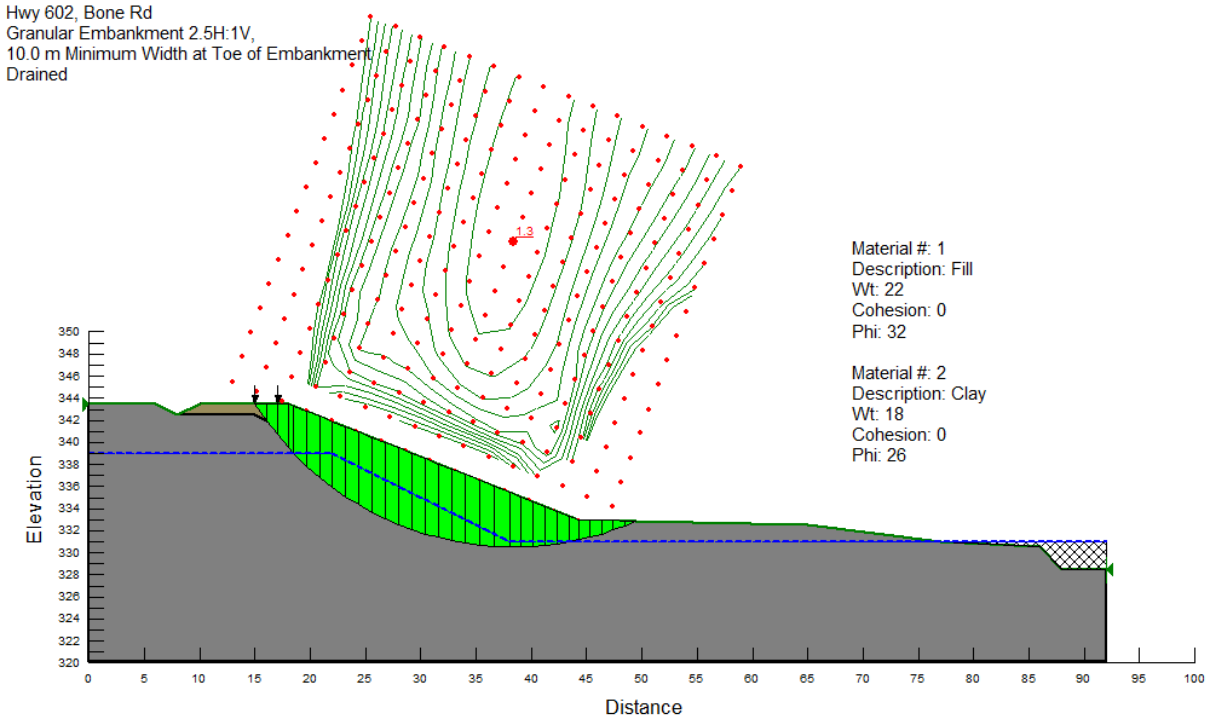


Figure 8 2.5H:1V granular embankment, 2H:1V underlying clay slope, drained condition with high water

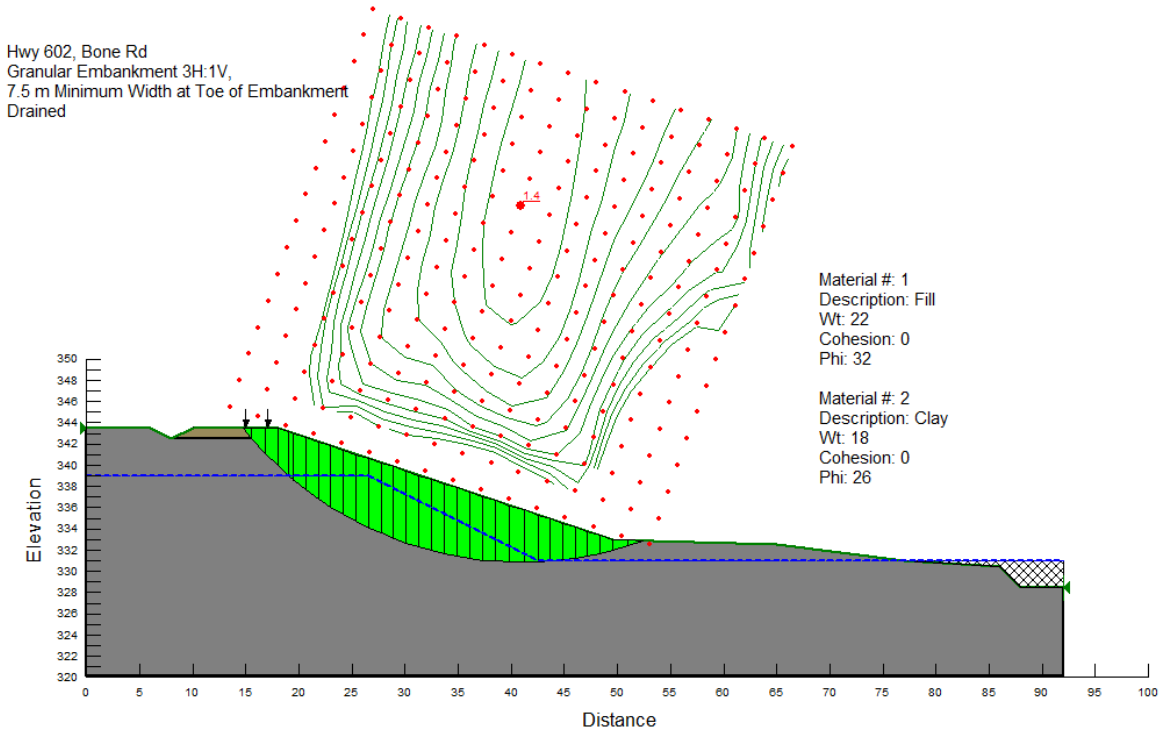


Figure 9 3H:1V granular embankment, 2H:1V underlying clay slope, drained condition with high water

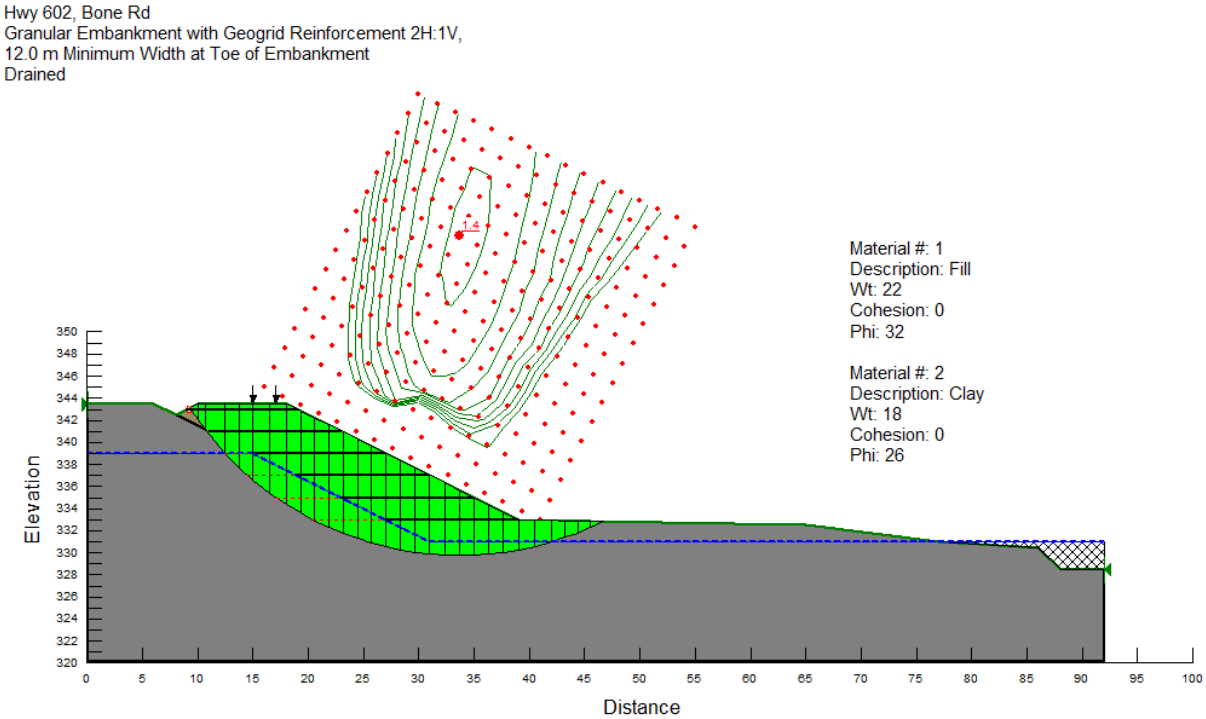


Figure 10 2H:1V granular embankment with geogrid reinforcement, 2H:1V underlying clay slope, drained condition with high water

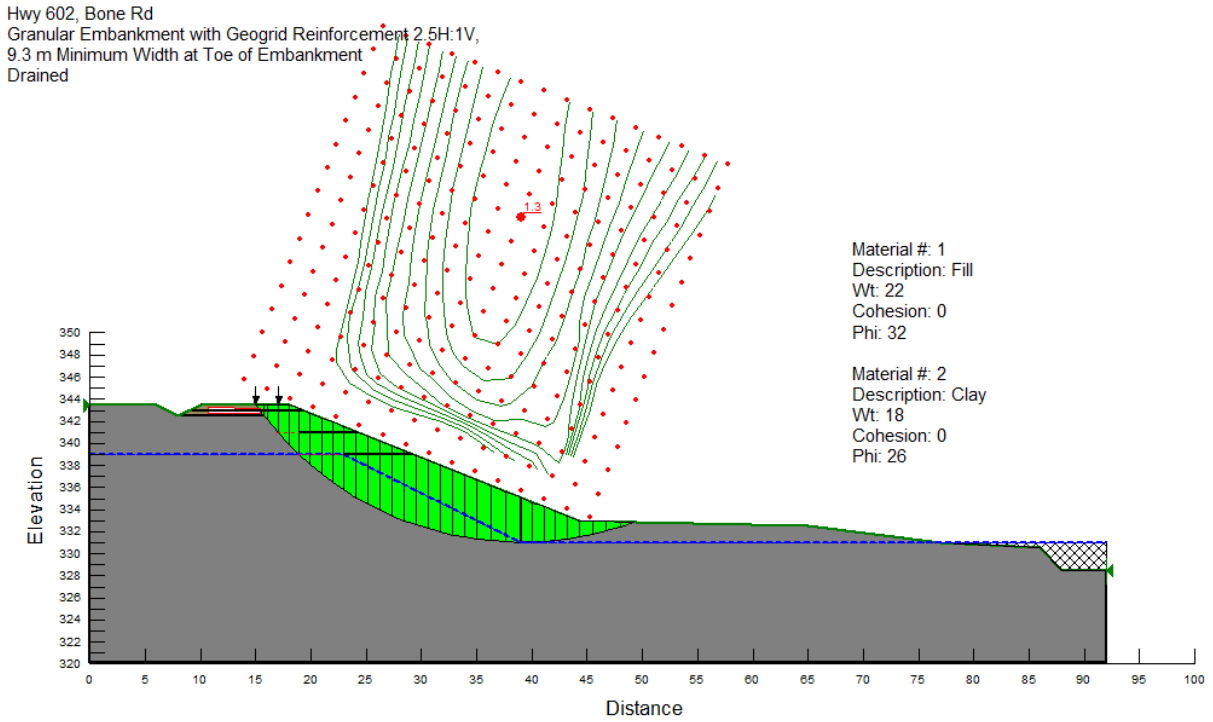


Figure 11 2.5H:1V granular embankment with geogrid reinforcement, 2H:1V underlying clay slope, drained condition with high water

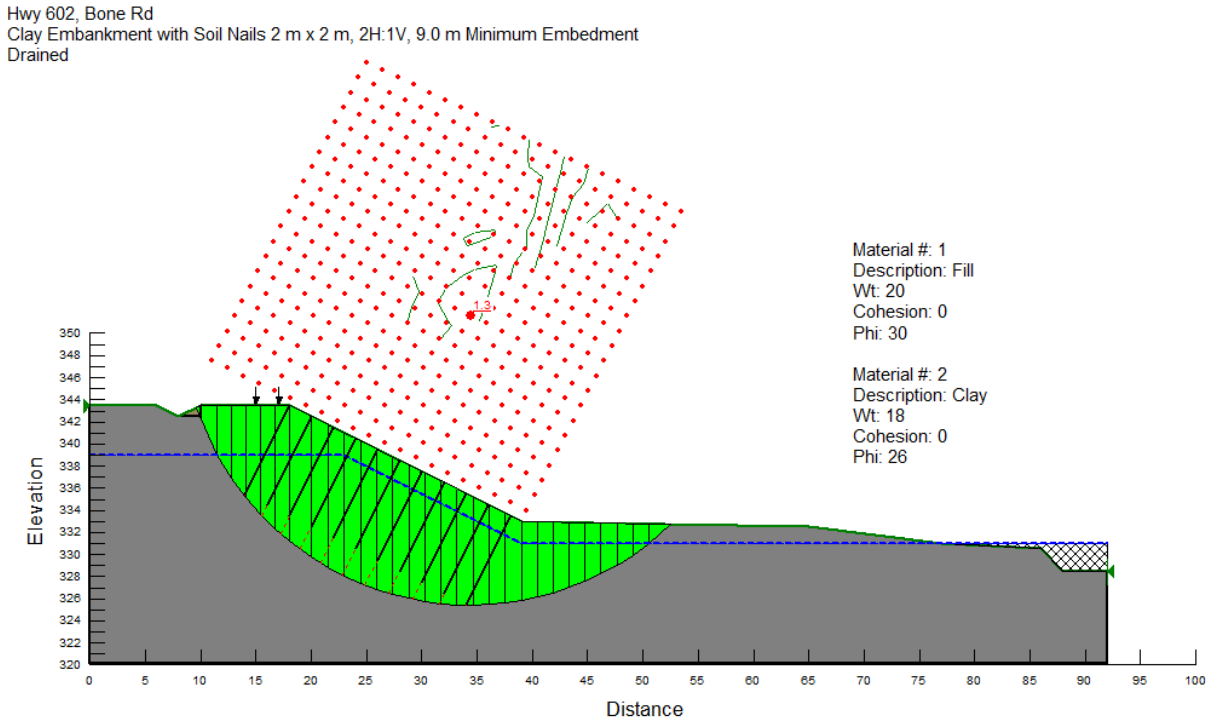


Figure 12 2H:1V clay embankment with soil nails, 9.0 m embedment, drained condition with high water