Foundation Investigation and Design Report
Slope Stability of Proposed Embankment Fill and Excavation Cut Areas
Highway 7 & 6th Line, Township of Guelph Eramasa, Ontario (MTO GEOCRES No. 40P9-66)

Type of Document:
Part B – Geotechnical Design Report

Submitted to:
James Dick Construction Limited

Project Number:

HAM-00802002-B0

Submitted By:

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Date Submitted:

August 5, 2022

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6. Global Slope Stability Analysis

The proposed road widening will include embankment fill and excavation cut areas. The slope stability analyses are carried out on the basis of the provided cross sections, as shown in Appendix B.

6.1 Cross Section Selection

Based on the provided cross sections, anticipated loading conditions and subsurface conditions, four slope cross sections were selected with specific consideration of the slope height and inclination to represent critical slope conditions. The general slope configurations of the selected cross sections are presented as following.

Table 11: Slope Configuration of the Selected Cross Sections

Road / Station		Fill / Cut	Overall Slope (xH:1V)	Slope Height (m)
Highway 7	10+330	Fill	3.0	3.2
Highway 7	10+600	Cut	3.0	6.5
Highway 7	10+720	Fill	3.0	4.8
6th Line	20+090	Cut	3.0	3.7

These cross sections were identified as the critical sections for the embankment fill and excavation cut areas shown Section 1 of this report.

6.2 Soil and Groundwater Parameters

Based on the borehole data from the investigation, the strata and soil parameters adopted in the analyses are summarized in the following table. These parameters were estimated from the index properties of the soil strata, and are considered to be appropriate for this site.

Table 12: Soil Parameters

Material / Stratum	Unit Weight (kN/m^3)	Undrained / Drained Cohesion (kPa)	Friction Angle (°)
Fill	20.0	0 / 0	30
Silty sand	20.5	0 / 0	31
Silty sand till	22.0	0 / 0	33

On the basis of groundwater monitoring data in May 2022 during the current geotechnical investigation, the groundwater level is considered to be below the explored depths of the boreholes.

6.3 Earthquake Loading

The recommendations for the geotechnical aspects to determine the earthquake loading for design are provided with reference to Canadian Highway Bridge Design Code (CSA S6:19). The subsoil and groundwater information at this site have been examined in relation to Section 4.4.3 of the Canadian Highway Bridge Design Code (CHBDC). The subsoils generally consist of granular materials, fill, silty sand and silty sand till. Table 4.1 Site Classification for Seismic Site Response of the CHBDC indicated that to determine the site classification, the average properties in the top 30 m are to be used. The explored soil information at this site was up to 6.7 m in depth from the existing grade. Therefore, the site classification recommendation would be based on the available information as well as our interpretation of conditions below the boreholes based on our knowledge of the soil conditions in the area.

Based on the above assumptions, interpretations and the general understanding of soil conditions of the area, the seismic site response for this site may be Class D, as per the Table 4.1 of the CHBDC.

The selected sections were analyzed under static and pseudo-static conditions. For pseudo-static analyses, design ground acceleration for the subject site was determined by site classification and peak ground acceleration. Design ground acceleration for the project site was determined from the Earthquake Hazards Program Website by interpolating 2015 National Building Code of Canada Seismic Hazard values, see Appendix C. The earthquake design ground motion was determined with an earthquake having 2 percent probability of exceedance in a 50-year period (0.000404 per annum probability or 2,475 return year). The map indicates a peak ground acceleration (PGA) value of approximately 0.087 g at the subject site.

Considering the structure importance and site classification for seismic site response, the factored PGA is about 0.090 g. For sustained earthquake loading, horizontal seismic coefficient of 0.060 g (2/3 of the factored PGA) was applied for the analyses. It is assumed that horizontal and vertical acceleration will not occur simultaneously. Therefore, the applied vertical seismic coefficient is equal to 0.

6.4 Slope Stability Results

Global stability analyses were undertaken for the selected cross sections, using the commercial two-dimensional slope stability computer program Slope/W (GeoStudio 2018). The factor of safety (FS) against slope failure was evaluated based on the limit equilibrium analysis method proposed by Morgenstern and Price for circular sliding surfaces. The method was applied for the static analyses. The sections were also analyzed under pseudo-static conditions to consider the earthquake loading.

The results of the analyses for the proposed road widening are shown in Figures 1 to 8 in Appendix D and are summarized in the following table.

Table 13: Results of Slope Stability Analysis

Cross Section	Soil Drain Conditions	Water Level	Static / Pseudo-static	Min. FS	Figure No.
Highway 7, 10+330	Drained	Assumed	Static	1.76	1
	Undrained	Assumed	Pseudo-static	1.49	2
Highway 7, 10+600	Drained	Assumed	Static	1.94	3
	Undrained	Assumed	Pseudo-static	1.61	4
Highway 7, 10+720	Drained	Assumed	Static	1.75	5
	Undrained	Assumed	Pseudo-static	1.47	6
6th Line, 20+090	Drained	Assumed	Static	1.84	7
	Undrained	Assumed	Pseudo-static	1.53	8

The results indicated calculated FS values ranging from 1.8 to 1.9 against global instability for the static conditions, and 1.5 to 1.6 for pseudo-static conditions. Typically, the minimum acceptable FS values are 1.5 for static global slope stability and 1.2 for pseudo-static slope stability analysis. For the analyzed slopes of the proposed road widening, the calculated FS values are above the minimum required FS. The slip surfaces are generally extending to the fills

and the upper portion of silty sand till. Thus, there will be no slope instability for the proposed 3H:1V side slopes for the embankment fill and excavation cut areas.

7. Dewatering Requirements at Deep Excavation Cut Areas

On Highway 7, the proposed maximum depth of the deep excavation in the cut area is about 6.5 m from 6th Line to Station 10+660. The lowest elevation of the excavation is anticipated to be 351.0 m. Based on the data from the monitoring wells in Boreholes 2, 4 and 5, the groundwater level is considered to be below Elevation 350.5 m. The monitored groundwater level is restricted by the explored borehole depth. In this case, the groundwater will be at least 0.5 m below the excavation, and no positive dewatering is envisaged for this excavation depth.

On 6th line, the proposed maximum depth of the deep excavation cut area is about 3.7 m from Highway 7 to Station 20+256. The lowest elevation of the excavation is anticipated to be 356.0 m. Based on the data from the monitoring wells in Boreholes 2 and 6, the groundwater level is considered to be below Elevation 354.5 m. Therefore, the groundwater will be at least 1.5 m below the excavation. No positive dewatering is envisaged for this excavation depth.

8. Material Requirements at Embankment Fill Areas

The proposed maximum heights of the embankment fills along Highway 7 are about 3.2 m between Station 10+240 and 6th Line, and 4.8 m between Stations 10+660 and 10+746.

The materials used for the construction of the embankment fills should consist of approved, acceptable fill (e.g. Granular A or B for base and sub-base and Select Subgrade Materials SSM as per *OPSS 1010 – Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material*). Fill used for construction of the embankments should be in accordance with *OPSS 212 – Construction Specification for Earth Borrow* and fill placement should meet or exceed the requirements of *OPSS 501 – Construction Specification for Compacting* and *OPSS 206 - Construction Specification for Grading*.

The excavated materials from the cut areas for this project consist of fill materials (granular, sand and gravel, silty sand to sandy silt, and clayey silt), native silty sand and silty sand till. These materials may be considered to be used as embankment fills, as long as the materials meet the requirements of OPSS 1010 and OPSS 212. In general, the gradations of the native silty sand and silty sand till are acceptable for SSM. If as much as possible, the use of cohesive fills (i.e. clayey silt) should be discouraged, as in some instances such fills exhibit slope creep, as well as it could undergo more time dependent settlements.

9. General Comments

The information presented in this report is based on a limited investigation designed to provide information to support an overall assessment of the current geotechnical conditions of the subject property. The conclusions presented in this report reflect site conditions existing at the time of the investigation.

EXP Services Inc. should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, EXP Services Inc. will assume no responsibility for interpretation of the recommendations in the report.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

EXP Services Inc.

Hongliu Wang, Ph.D., P.Eng.
Senior Geotechnical Engineer
Earth & Environmental

Stephen S. M. Cheng

Digitally signed by Stephen S. M. Cheng
Date: 2022.08.05 14:40:22 -04'00'

Stephen S. M. Cheng, P.Eng.
Discipline Manager
Geotechnical Division

APPENDICES

APPENDIX B

Cross Sections of the Embankment Fill and Excavation Cut Areas

METRIC

PLATE No ----

CONT ----

WP ----

X-SECTIONS – HIGHWAY 7

STA 10+120 TO STA 10+760

Survey ________ Revised ________

SHEET 10

exp.

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

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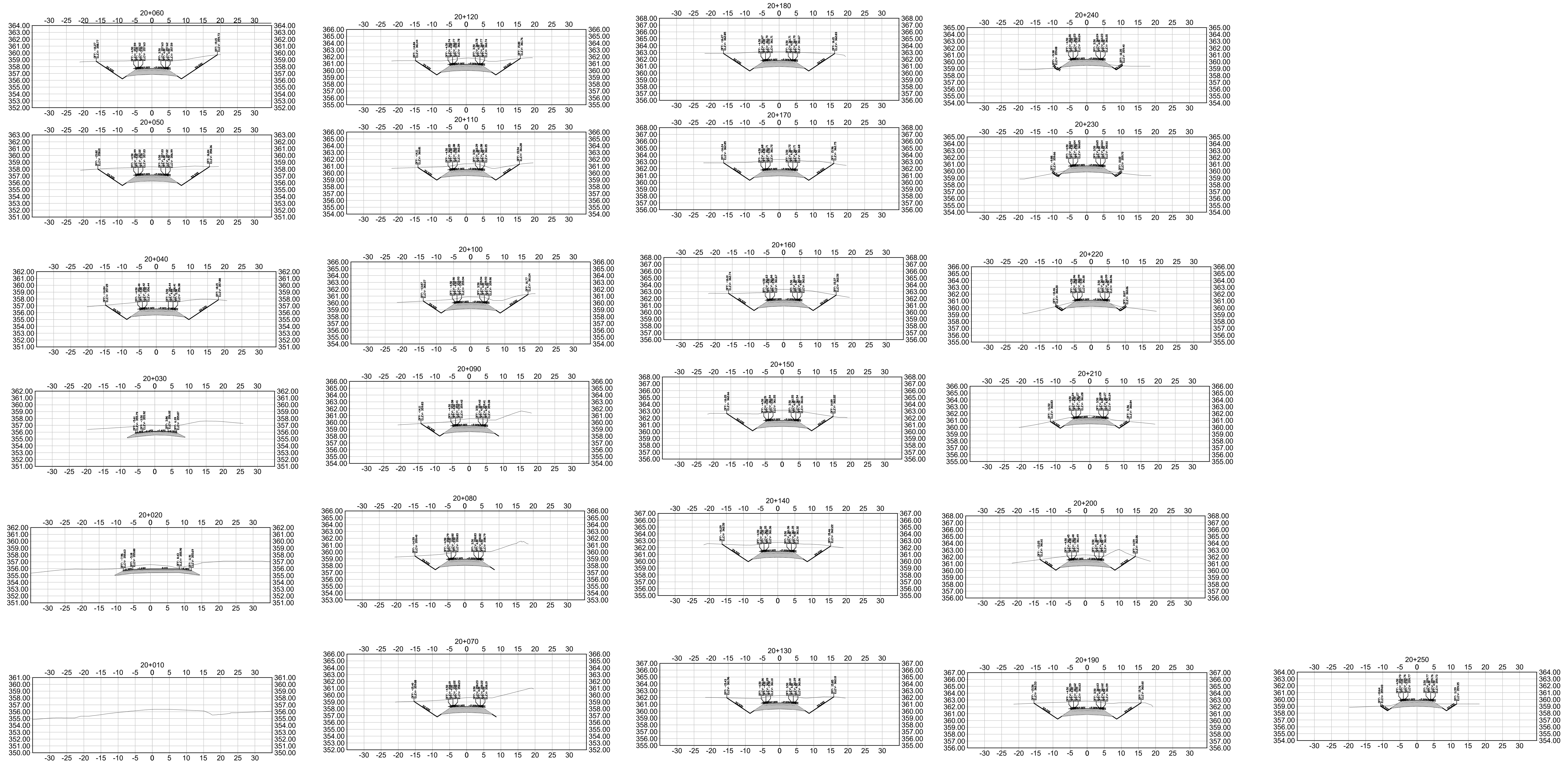

METRIC

PLATE No ----

CONT ----
WP ----

X-SECTIONS – SIXTH LINE
STA 20+010 TO STA 20+250
Survey ______ Revised ______

SHEET
11

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APPENDIX C

2015 National Building Code Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 43.610N 80.107W **User File Reference:** Hwy 7 & 6th Line, Guelph Eramasa 2022-05-26 18:55 UT

Requested by: EXP Services Inc.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.123	0.069	0.040	0.010
Sa (0.1)	0.158	0.093	0.057	0.016
Sa (0.2)	0.141	0.085	0.054	0.018
Sa (0.3)	0.112	0.069	0.045	0.016
Sa (0.5)	0.085	0.054	0.036	0.012
Sa (1.0)	0.048	0.031	0.020	0.006
Sa (2.0)	0.024	0.015	0.010	0.003
Sa (5.0)	0.006	0.004	0.002	0.001
Sa (10.0)	0.003	0.002	0.001	0.000
PGA (g)	0.087	0.051	0.031	0.009
PGV (m/s)	0.068	0.041	0.026	0.007

Notes: Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

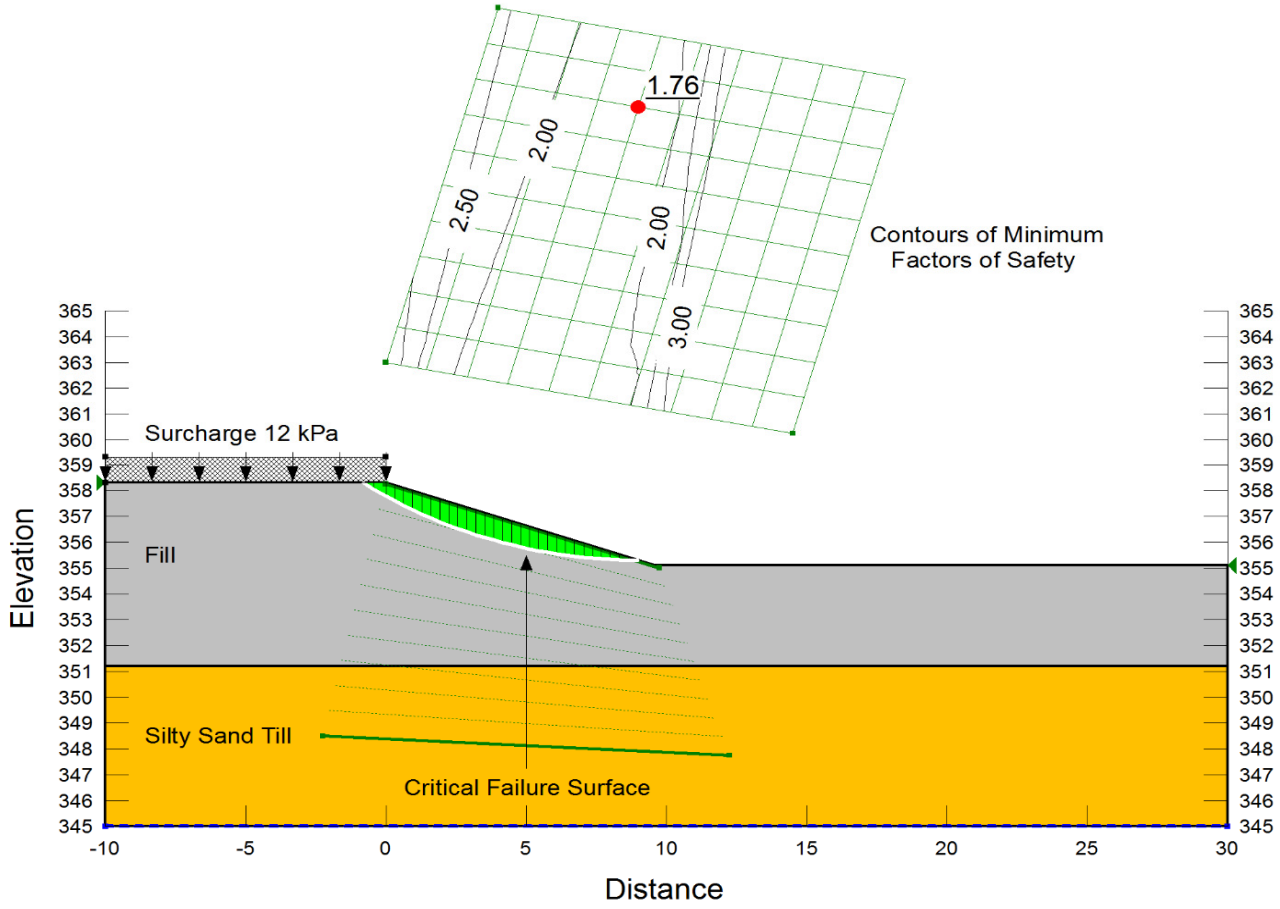
APPENDIX D

Results of Global Stability Analyses

STATIC SLOPE STABILITY ANALYSIS
Highway 7
Highway 7 & 6th Line, Guelph Eramasa

BRM-00229573-G0

Figure No. 1



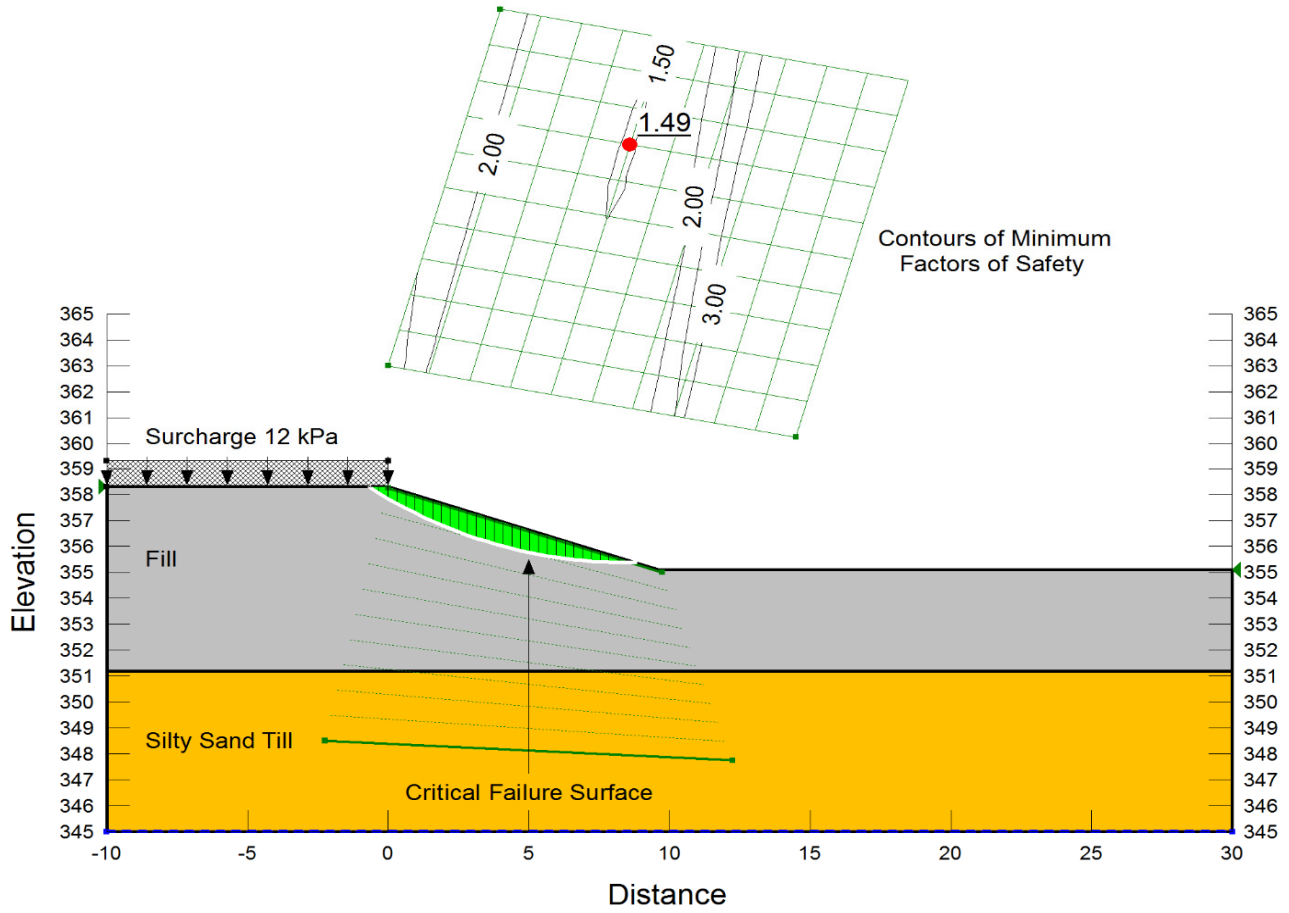
Section / Location	:	10+330
Slope	:	3H:1V
Height	:	3.2 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Drained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33

PSEUDO-STATIC SLOPE STABILITY ANALYSIS **BRM-00229573-G0**

Highway 7

Highway 7 & 6th Line, Guelph Eramasa **Figure No. 2**



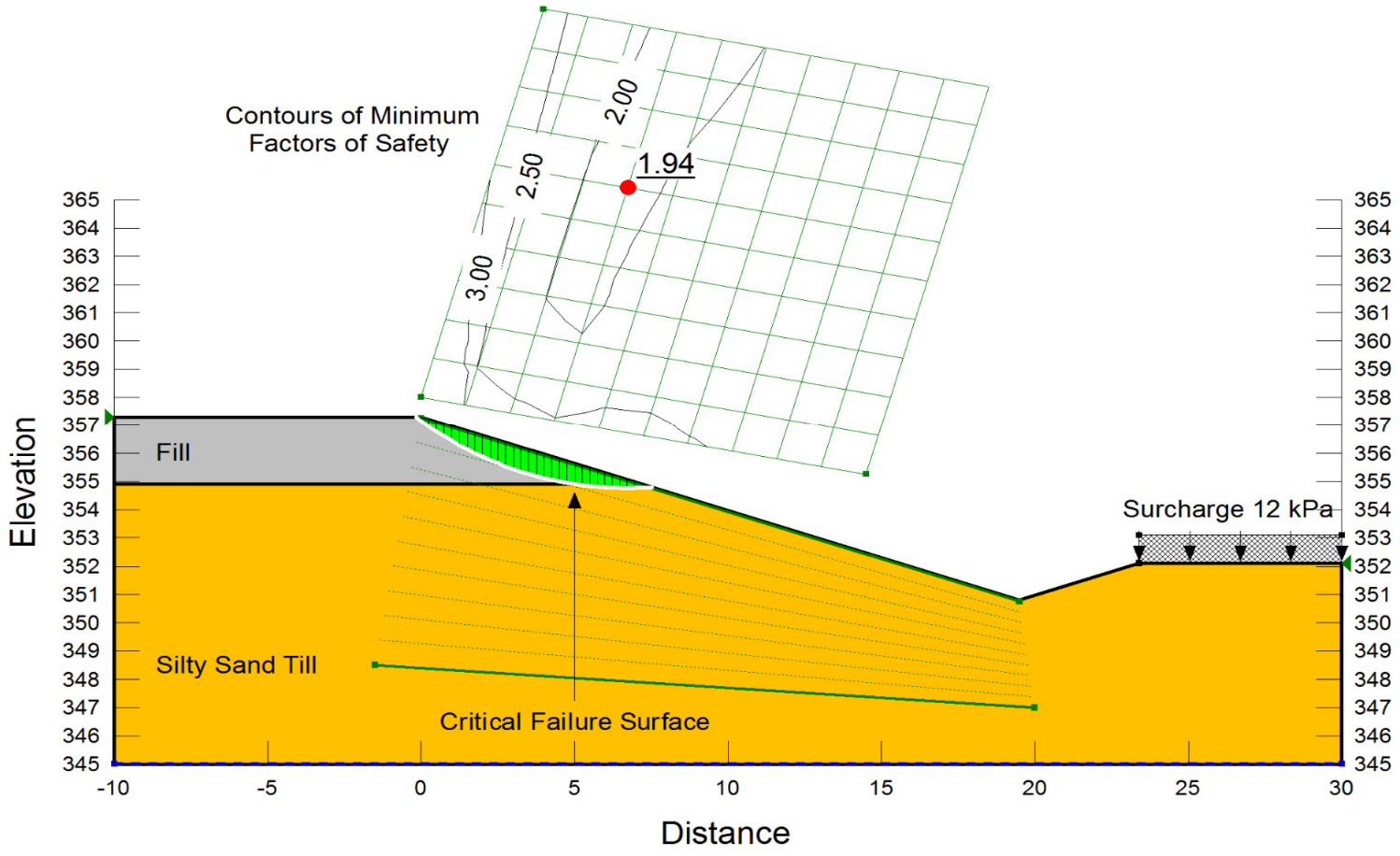
Section / Location	:	10+330
Slope	:	3H:1V
Height	:	3.2 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Undrained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33

STATIC SLOPE STABILITY ANALYSIS
Highway 7
Highway 7 & 6th Line, Guelph Eramasa

BRM-00229573-G0

Figure No. 3



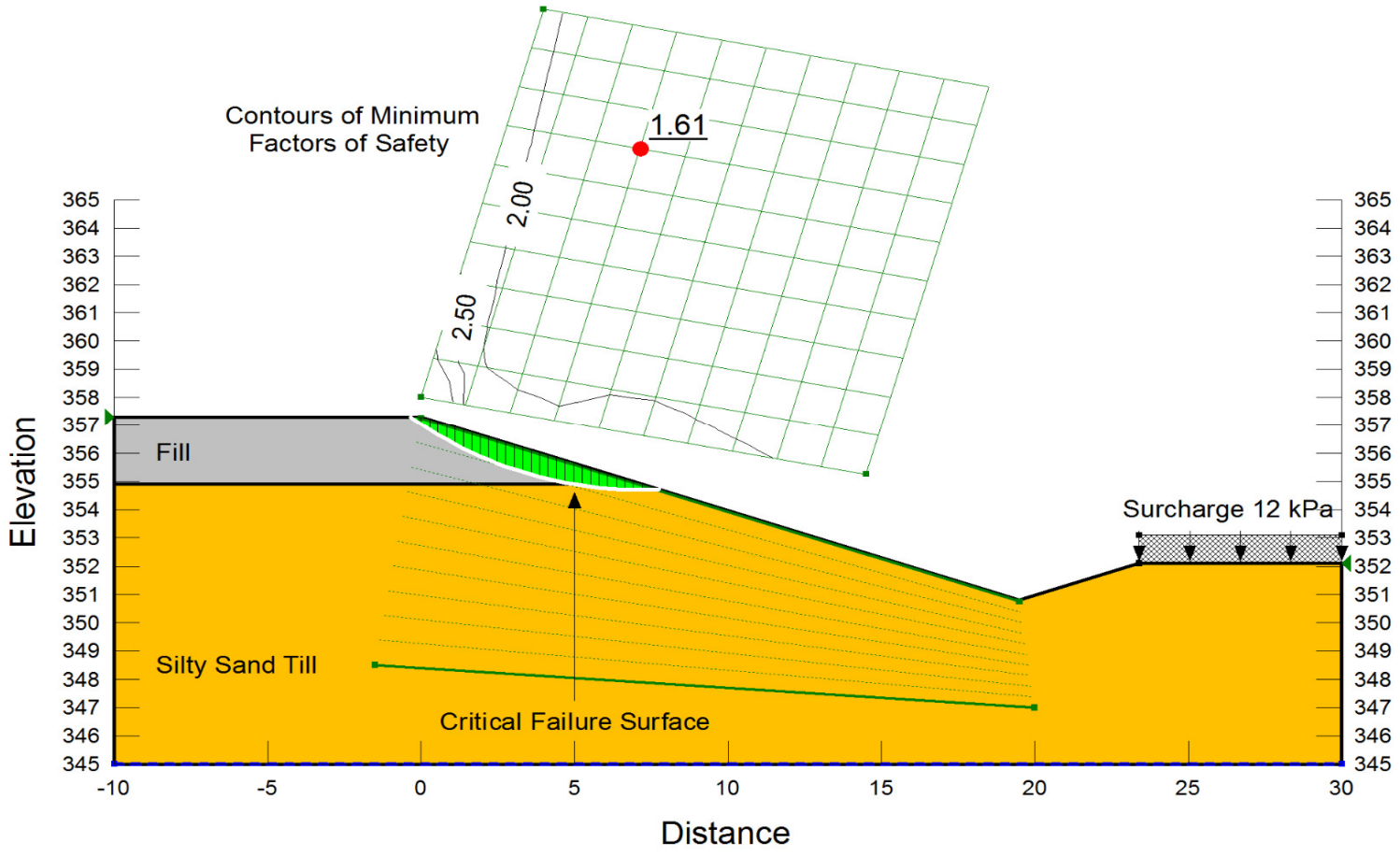
Section / Location	:	10+600
Slope	:	3H:1V
Height	:	6.5 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Drained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33

PSEUDO-STATIC SLOPE STABILITY ANALYSIS **BRM-00229573-G0**

Highway 7

Highway 7 & 6th Line, Guelph Eramasa **Figure No. 4**



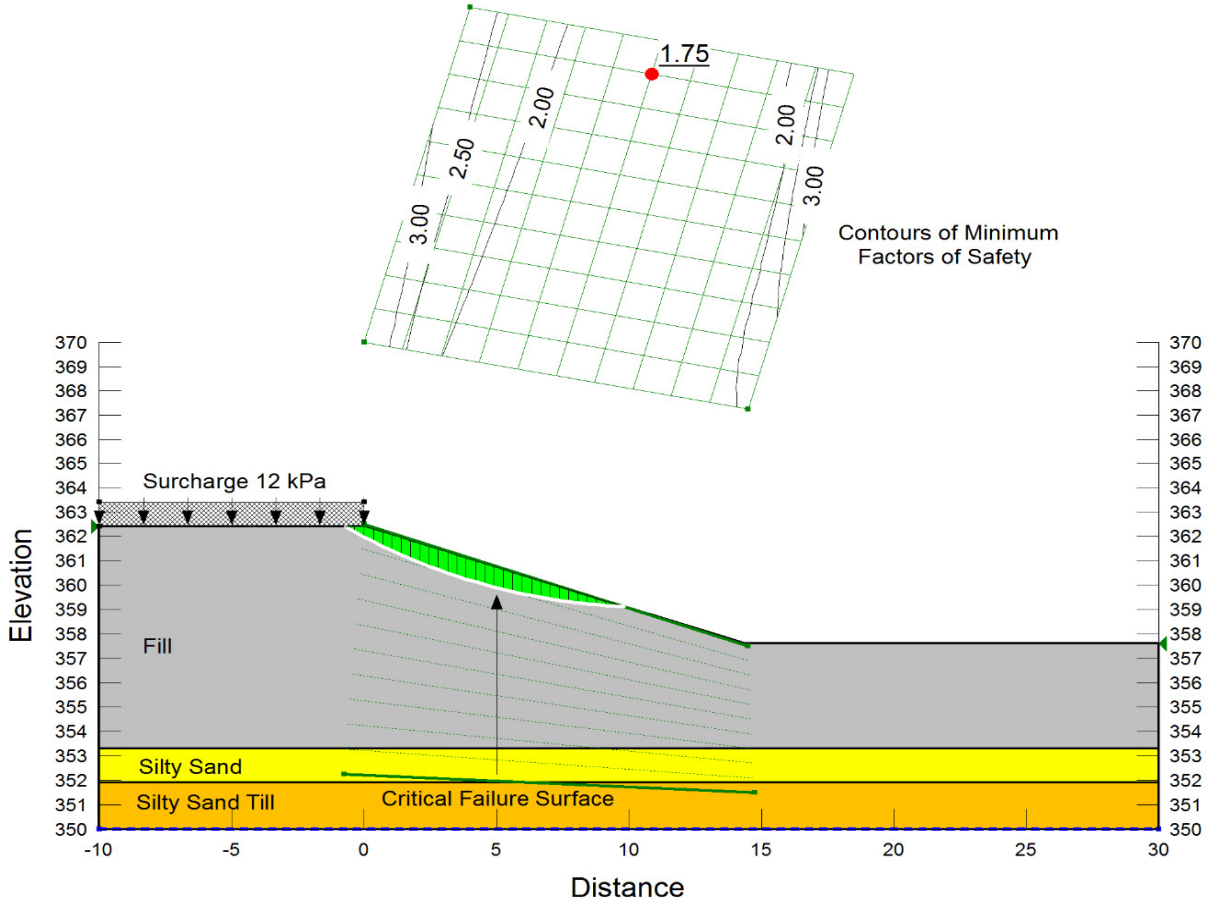
Section / Location	:	10+600
Slope	:	3H:1V
Height	:	6.5 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Undrained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33

STATIC SLOPE STABILITY ANALYSIS
Highway 7
Highway 7 & 6th Line, Guelph Eramasa

BRM-00229573-G0

Figure No. 5



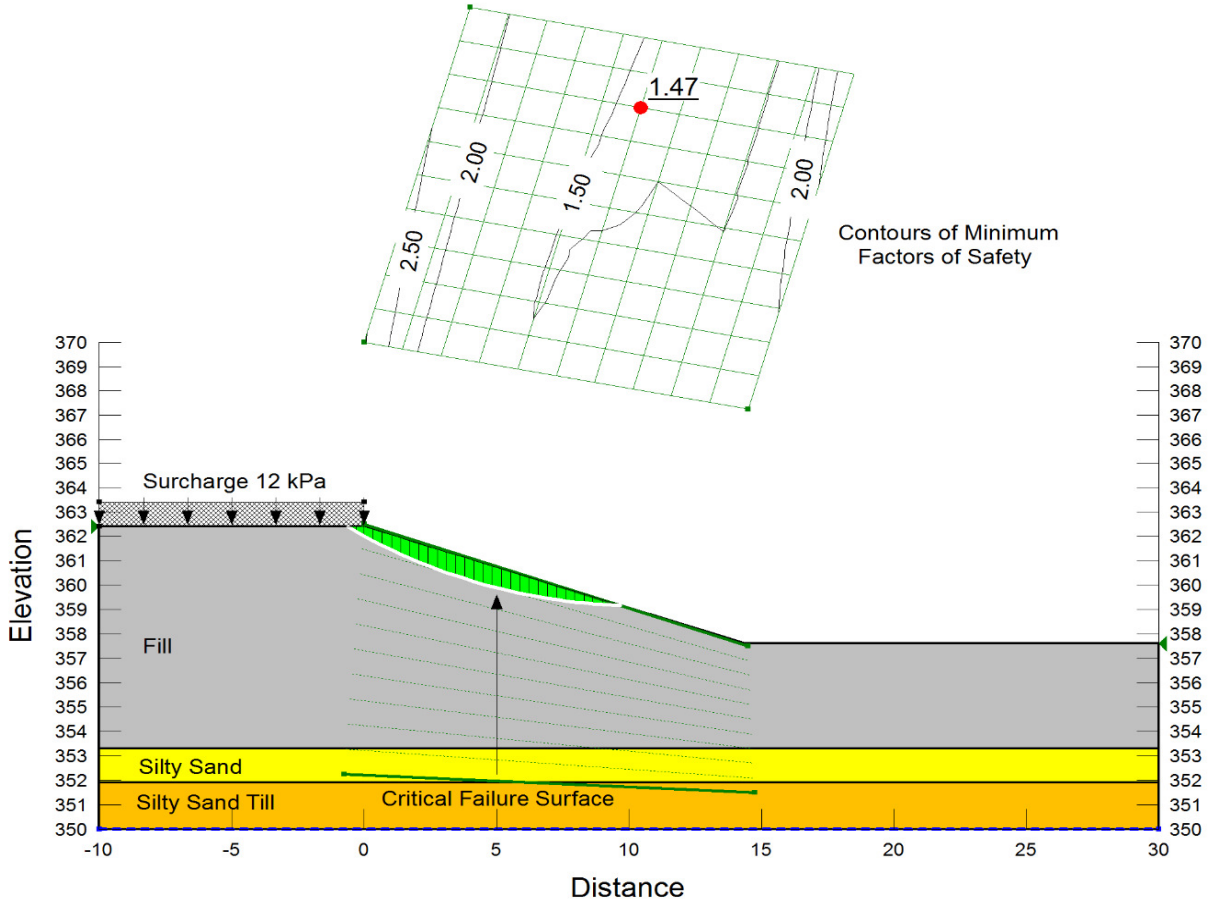
Section / Location	:	10+720
Slope	:	3H:1V
Height	:	4.8 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Drained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand	20.5	0	31
Silty Sand Till	22.0	0	33

PSEUDO-STATIC SLOPE STABILITY ANALYSIS **BRM-00229573-G0**

Highway 7

Highway 7 & 6th Line, Guelph Eramasa **Figure No. 6**



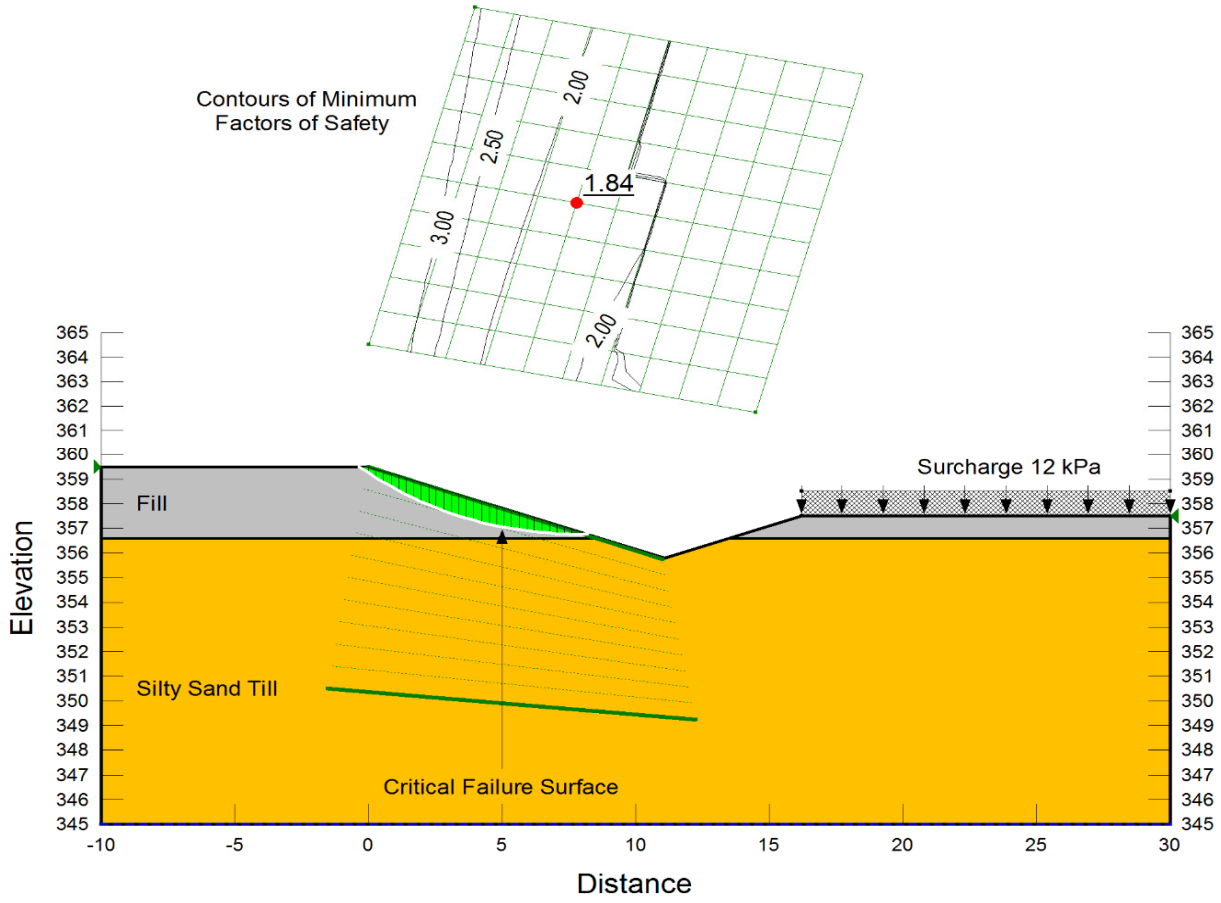
Section / Location	:	10+720
Slope	:	3H:1V
Height	:	4.8 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Undrained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand	20.5	0	31
Silty Sand Till	22.0	0	33

STATIC SLOPE STABILITY ANALYSIS
6th Line
Highway 7 & 6th Line, Guelph Eramasa

BRM-00229573-G0

Figure No. 7



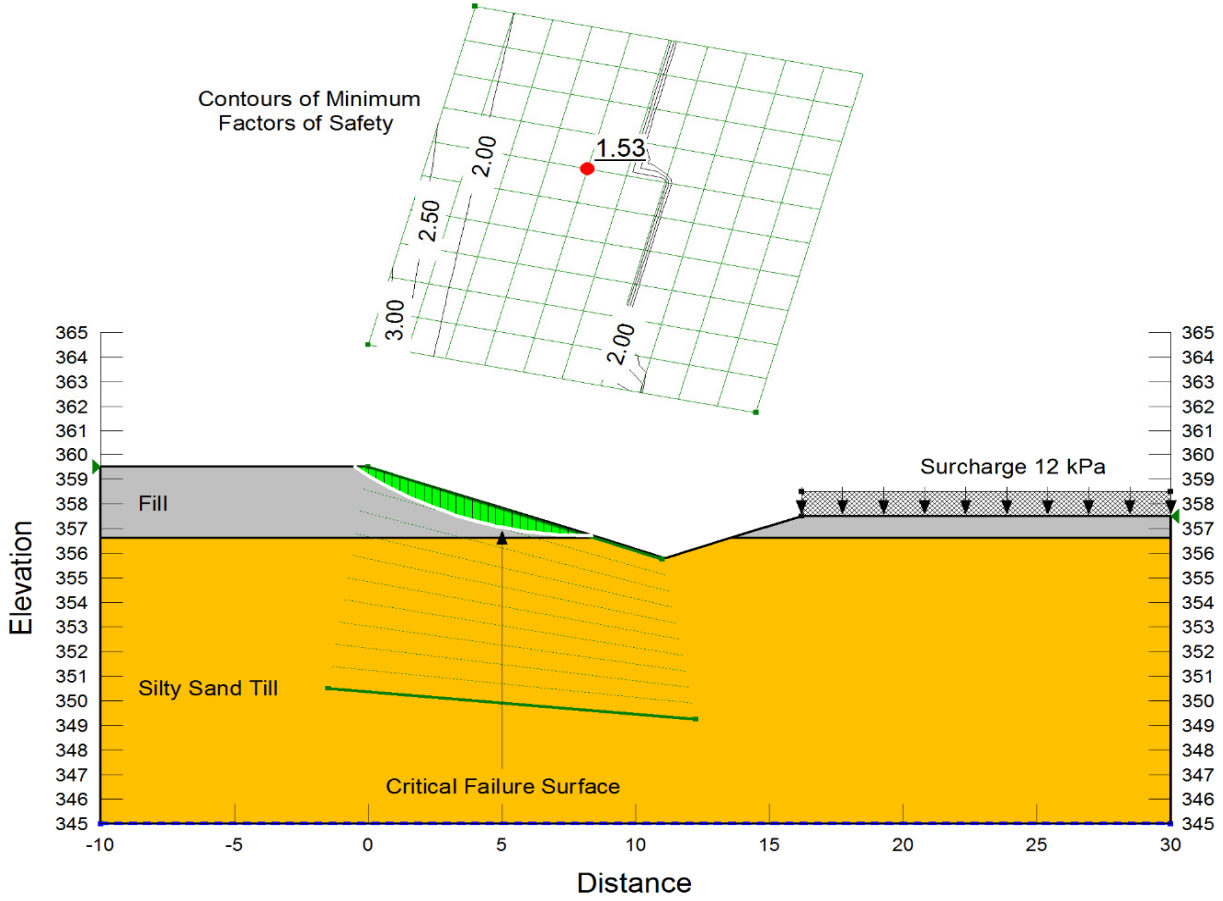
Section / Location	: 20+090
Slope	: 3H:1V
Height	: 3.7 m
Water Table	: Assumed
Seepage Analysis	: Steady
Drained Condition	: Drained
Analysis Method	: Morgenstern - Price
Surcharge	: 12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33

PSEUDO-STATIC SLOPE STABILITY ANALYSIS **BRM-00229573-G0**

6th Line

Highway 7 & 6th Line, Guelph Eramasa **Figure No. 8**



Section / Location	:	20+090
Slope	:	3H:1V
Height	:	3.7 m
Water Table	:	Assumed
Seepage Analysis	:	Steady
Drained Condition	:	Undrained
Analysis Method	:	Morgenstern - Price
Surcharge	:	12 kPa

Stratum	γ (kN/m^3)	c (kPa)	ϕ (^{o})
Fill	20.0	0	30
Silty Sand Till	22.0	0	33