AECOM

Appendix B

Greater Cardinal Creek Subwatershed Management Plan

- Geotechnical Investigation and Slope Stability Assessment Cardinal Creek (under separate cover)

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REPORT ON

GEOTECHNICAL INVESTIGATION AND SLOPE STABILITY ASSESSMENT CARDINAL CREEK OTTAWA, ONTARIO

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation and slope stability assessment carried out at six (6) sites along Cardinal Creek in Ottawa, Ontario. The purpose of the investigation was to identify the general subsurface conditions at the sites by means of a limited number of boreholes/hand augerholes and, based on the factual information obtained together with site reconnaissance and slope stability analyses, to develop and assess possible slope stabilization alternatives for each site.

This investigation was carried out in accordance with our proposals dated August 3 and November 22, 2011.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

In order to reduce the risk of property damage and address public safety issues, plans are being prepared to stabilize six (6) sites along Cardinal Creek in Ottawa, Ontario. The sites considered in this Study were previously identified as Priority 1 and 2 Areas in the report titled: "Greater Cardinal Creek Subwatershed Study, Existing Conditions Report", dated August 13, 2009 and prepared by AECOM Canada Ltd. The locations of the sites considered are provided of the Key Plan, Figure 1, and summarized below:

Site	Approximate Chainage from Ottawa River (metres)
Area 8	1565
Area 13	2025
Old Montreal Road	2595 to 2670
Area 18	2820
Area 19	2925
Watters Road	3780

At Areas 8, 13, 18, and 19, the objective of this study was to develop standard slope stabilization alternatives which could be applied to several sites.

2.2 Description of Site and Slope

2.2.1 Old Montreal Road

The study area is located on the south side of Old Montreal Road between about 630 and 700 metres east of Trim Road in Ottawa, Ontario. A site reconnaissance was carried out on September 16, 2011 by members of our engineering staff. At that time, the geometry of the slope was measured at three (3) locations (Sections 'A-A', 'B-B', and 'C-C') using a Trimble R8 GPS survey instrument. The cross sections were positioned at the site by Houle Chevrier Engineering Ltd. personnel at key locations based on slope geometry and height. The locations of the three (3) cross sections considered are provided on Figure 2. Cross sections of the slopes are provided in Appendix A.

The geometries of the cross sections considered are summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	8.9	10 to 36
B-B	7.5	26
C-C	6.8	35

In general, the south side slope is vegetated with grass, small shrubs, and small to large trees. Cardinal Creek is located at the toe of the south embankment side slope. The south side slope in the area of Sections ‘A-A’, ‘B-B’, and ‘C-C’ has been previously treated with rip rap.

The crest of the side slope within the study area is located about 4.2 to 6.9 metres south of the guide rail for Old Montreal Road. It is understood that future plans may include widening Old Montreal Road to a fully urban section with a 44.5 metres right-of-way.

No signs of overall slope instability (i.e., rotational failures, bowing of tree trunks, tension cracks, etc.) were observed at the subject site; however, active erosion along the toe of the slope in the area of Section ‘C-C’ was observed. In this area, erosion has resulted in steep side slopes devoid of vegetation, and ongoing erosion is evident in the form of sloughing of the north bank of the creek channel.

In addition to the geotechnical investigation, a conceptual natural channel design report has been prepared by Geomorphic Solutions for the realignment of Cardinal Creek in order to accommodate a future widening of Old Montreal Road as noted above.

2.2.2 Watters Road

The study area is located on the north side of Watters Road between about 500 and 560 metres east of Trim Road in Ottawa, Ontario. A site reconnaissance was carried out on September 16, 2011 by members of our engineering staff. At that time, the geometry of the slope was measured at two (2) locations (Sections ‘A-A’ and ‘B-B’) using a Trimble R8 GPS survey instrument. The cross sections were positioned at the site by Houle Chevrier Engineering Ltd. personnel at key locations based on slope geometry and height. The locations of the two (2) cross sections considered are provided on Figure 3. Cross sections of the slopes are provided in Appendix B.

The geometries of the cross sections considered are summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	7.5	57
B-B	5.6	31

It should be noted that the slope profile at Section 'A-A' is not representative of the entire slope profile within the study area. Section 'A-A' represents a localized area located at the western extent of the study area; the remaining slope profile is similar to Section 'B-B'.

In general, the north side slope is vegetated with grass, small shrubs, and small to large trees. The crest of the side slope within the study area is located at about 0.5 and 9.0 metres north of the edge of the gravel roadway at Section 'B-B' and 'A-A', respectively.

At about 60 metres south of Watters Road, Cardinal Creek splits into a surface and a subsurface channel. The subsurface channel emerges about 70 metres north of Watters Road. The surface channel crosses Watters Road at the existing bridge (just east of the study area) and crosses the study area at the toe of the north side slope. At the time of our site reconnaissance, the surface channel was dry (i.e., full flow through the subsurface channel). It is understood that the surface channel carries water during some periods of the year, likely during the spring or following periods of heavy precipitation. At Section 'A-A', the surface channel is located at the toe of the slope. At Section 'B-B', the surface channel is located about 5 metres north of the toe.

The bedrock surface is located at the toe of the side slope, within the surface channel, at elevation 77.1 to 77.6 metres, geodetic datum.

No signs of overall slope instability (i.e., rotational failures) were observed at the subject site (e.g., bowing of tree trunks); however, active erosion along the toe of the slope in the area of Section ‘A-A’ was observed. In this area, erosion has resulted in steep side slopes devoid of vegetation.

2.2.3 Area 8

The study area is located about 995 metres north of Old Montreal Road in Ottawa, Ontario. A site reconnaissance was carried out on January 10, 2012, by members of our engineering staff. At that time, the geometry of the slope was measured at three (3) locations (Sections ‘A-A’, ‘B-B’, and ‘C-C’) using a Trimble R8 GPS survey instrument. The cross sections were positioned at the site by Houle Chevrier Engineering Ltd. personnel at key locations based on slope geometry and height. The locations of the three (3) cross sections considered are provided on Figure 4. Cross sections of the slopes are provided in Appendix C.

The geometries of the cross sections considered are summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	4.2	44
B-B	8.4	36
C-C	10.3	8 to 25

In general, the slope is vegetated with grass, small shrubs, and occasional small to large trees. Cardinal Creek is located at the toe of Sections ‘A-A’, ‘B-B’, and ‘C-C’. A previous slope failure observed at Section ‘B-B’ has resulted in a slope face devoid of vegetation. With the exception of Section ‘B-B’, no signs of overall slope instability (i.e., rotational failures, bowing of tree trunks, tension cracks, etc.) were observed at the subject site; active erosion along the toe of the slope in the area of Section ‘C-C’ was observed in the form of sloughing of the creek channel.

The table lands (i.e., beyond the crest of the slope) consist of farmland at Section ‘C-C’ and a forested area at Sections ‘A-A’ and ‘B-B’.

2.2.4 Area 13

The study area is located about 535 metres north of Old Montreal Road in Ottawa, Ontario. A site reconnaissance was carried out on January 10, 2012, by members of our engineering staff. At that time, the geometry of the slope was measured at two (2) locations (Sections ‘A-A’ and ‘B-B’) using a Trimble R8 GPS survey instrument. The cross sections were positioned at the site by Houle Chevrier Engineering Ltd. personnel at key locations based on slope geometry and height. The locations of the two (2) cross sections considered are provided on Figure 5. Cross sections of the slopes are provided in Appendix D.

The geometries of the cross sections considered are summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	11.9	17 to 42
B-B	11.3	30

In general, the slope is vegetated with grass, small shrubs, and occasional small to large trees. Cardinal Creek is located at the toe of Sections ‘A-A’ and ‘B-B’. A historical slope failure was observed at Section ‘B-B’. At this location, the apron/debris at the toe of the slope is being eroded by Cardinal Creek, which has resulted in steep channel banks devoid of vegetation. Active erosion was not observed at Section ‘A-A’.

At Area 13, the table lands are occupied by an existing dairy operation (Ault Foods Limited). The fence line for the dairy operation is located about 15 to 20 metres west of the crest of the slope.

2.2.5 Area 18

The study area is located about 260 metres south of Old Montreal Road in Ottawa, Ontario. A site reconnaissance was carried out on January 10, 2012, by members of our engineering staff. At that time, the geometry of the slope was measured at two (2) locations (Sections ‘A-A’ and ‘B-B’) using a Trimble R8 GPS survey instrument. The cross sections were positioned at the site by Houle Chevrier Engineering Ltd. personnel at key locations based on slope geometry and height. The locations of the two (2) cross sections considered are provided on Figure 6. Cross sections of the slopes are provided in Appendix E.

The geometries of the cross sections considered are summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	8.4	33
B-B	18.3	20 to 46

In general, the slope is vegetated with grass, small shrubs, and occasional small to large trees. Cardinal Creek is located at the toe of Sections 'A-A' and 'B-B'. A previous slope failure observed at Section 'A-A' has resulted in a slope face devoid of vegetation. With the exception of Section 'A-A', No signs of overall slope instability (i.e., rotational failures, bowing of tree trunks, tension cracks, etc.) were observed at the subject site; active erosion along the toe of the slope in the area of Sections 'A-A' and 'B-B' was observed in the form of sloughing of the creek channel.

Bedrock outcropping was observed at the toe of the slope at elevation 54.2 metres, geodetic datum.

At Area 18, the table lands are occupied by a forested area. It appears that a residential property backs onto the slope at Section 'B-B'.

2.2.6 Area 19

The study area is located about 365 metres south of Old Montreal Road in Ottawa, Ontario. A site reconnaissance was carried out on January 10, 2012, by members of our engineering staff. At that time, the geometry of the slope was measured at one (1) location (Section 'A-A') using a Trimble R8 GPS survey instrument. The cross section was positioned at the site by Houle Chevrier Engineering Ltd. personnel at a key location based on slope geometry and height. The location of the cross section considered is provided on Figure 7. A cross section of the slope is provided in Appendix F.

The geometry of the cross section considered is summarized in the following table:

Cross Section	Height (metres)	Overall inclination, from horizontal (degrees)
A-A	10.4	17 to 35

In general, the slope is vegetated with grass, small shrubs, and occasional small to large trees. Cardinal Creek is located at the toe of Section 'A-A'. No signs of overall slope instability (i.e., rotational failures, bowing of tree trunks, etc.) were observed at the subject site. Furthermore, evidence of active erosion was not observed; however, it is pointed out that snow cover in place at the time of our site reconnaissance may have obscured any signs of erosion or tension cracks.

At Area 19, the table lands have been cleared of vegetation and it is understood that a residential development is proposed for this area.

2.3 Review of Geology Maps

Based on available geology maps, the subject sites are underlain by offshore marine sediments composed of silty clay. At Old Montreal Road, Area 8, Area 13, Area 18, and Area 19, the bedrock is mapped as interbedded limestone and dolostone of the Gull River formation at depths of between 15 and 50 metres. At Watters Road, the bedrock is mapped as limestone of the Bobcaygeon formation at depths of between 25 and 50 metres.

3.0 SUBSURFACE INVESTIGATION

3.1 Old Montreal Road

The field work for Old Montreal Road was carried out on September 1 and 22, 2011. During that time, three (3) boreholes, numbered 101, 102, and 103 were advanced across the site using a truck mounted, hollow stem auger drill rig and portable drilling equipment supplied and operated by OGS Inc. of Almonte, Ontario. Details for the boreholes are provided below:

- One (1) borehole, numbered 101, was advanced through the roadway along Old Montreal Road to 14.6 metres below ground surface using a truck mounted drill rig.
- One (1) borehole, numbered 102, was advanced along the south side slope of Old Montreal Road to 7.3 metres below ground surface using portable drilling equipment.
- One (1) borehole, numbered 103, was advanced at the toe of the south side slope of Old Montreal Road to 4.3 metres below ground surface using portable drilling equipment.

Standard penetration tests were carried out in the boreholes and samples of the soils encountered were recovered using a 50 millimetre diameter split barrel sampler. At boreholes 102 and 103, the penetration tests were carried out using a one third weight drive hammer. Standard penetration tests in borehole 101 were carried out using a standard 63.6 kilogram hammer. The penetration values that were obtained using the one third weight drive hammer were corrected by dividing by a factor of 3. In situ vane shear testing was carried out in the boreholes to measure the undrained shear strength of the silty clay. Well screens were sealed in all of the boreholes to measure the groundwater levels.

The field work was supervised throughout by a member of our engineering staff, who located the boreholes, logged the samples and observed the in-situ testing. Following the field work, the soil samples were returned to our laboratory for examination by a geotechnical engineer. Selected samples of the soil were tested for water content and plastic limits.

The borehole locations were selected by Houle Chevrier Engineering Ltd. personnel. The ground surface elevations at the boreholes were determined using a Trimble R8 GPS survey instrument. The elevations are referenced to geodetic datum.

Descriptions of the subsurface conditions logged in the boreholes are provided on the Record of Borehole sheets in Appendix A. The approximate locations of the boreholes are shown on the Site Plan, Figure 2.

3.2 Watters Road

The field work for Watters Road was carried out on September 2 and 22, 2011. During that time, two (2) boreholes, numbered 201 and 202, were advanced across the site using a truck mounted, hollow stem auger drill rig and portable drilling equipment supplied and operated by OGS Inc. of Almonte, Ontario. Details for the boreholes are provided below:

- One (1) borehole, numbered 201, was advanced through the roadway along Watters Road to 5.5 metres below ground surface using a truck mounted drill rig.
- One (1) borehole, numbered 202, was advanced near the toe of the north side slope of Watters Road to 0.9 metres below ground surface using portable drilling equipment.

Standard penetration tests were carried out in the boreholes and samples of the soils encountered were recovered using a 50 millimetre diameter split barrel sampler. At borehole 202, the penetration tests were carried out using a one third weight drive hammer. Standard penetration tests in borehole 201 were carried out using a standard 63.6 kilogram hammer. The penetration values that were obtained using the one third weight drive hammer were corrected by dividing by a factor of 3. A well screen was sealed in borehole 202 to measure the groundwater levels.

The field work was supervised throughout by a member of our engineering staff, who located the boreholes, logged the samples and observed the in-situ testing. Following the field work, the soil samples were returned to our laboratory for examination by a geotechnical engineer. Selected samples of the soil were tested for water content.

The borehole locations were selected by Houle Chevrier Engineering Ltd. personnel. The ground surface elevations at the boreholes were determined using a Trimble R8 GPS survey instrument. The elevations are referenced to geodetic datum.

Descriptions of the subsurface conditions logged in the boreholes are provided on the Record of Borehole sheets in Appendix B. The approximate locations of the boreholes are shown on the Site Plan, Figure 3.

3.3 Areas 8, 13, 18, and 19

As requested, boreholes were not advanced at Areas 8, 13, 18, and 19. In order to confirm the shallow subsurface conditions, one (1) to two (2) hand augerholes were advanced at each site to between 1.0 and 1.5 metres below ground surface, with the exception of Area 8. The subsurface conditions in the augerholes were identified by visual and tactile examination of the materials recovered from the auger flights.

4.0 SUBSURFACE CONDITIONS

4.1 General

As previously indicated, the subsurface conditions identified in the boreholes advanced at Old Montreal Road and Watters are given on the Record of Borehole sheets in Appendix A and B, respectively. The borehole logs indicate the subsurface conditions at the specific test locations only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of drilling, the frequency and recovery of samples, the method of sampling, and the uniformity of the subsurface conditions. Subsurface conditions at other than the test locations may vary from the conditions encountered in the boreholes. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties.

The groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities in the area.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil involves judgement and Houle Chevrier Engineering Ltd. does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The following presents an overview of the subsurface conditions encountered during this investigation.

4.2 Old Montreal Road

4.2.1 Existing Pavement Structure

Borehole 101 was advanced through the asphaltic concrete in the roadway along Old Montreal Road and encountered a pavement structure composed of 150 millimetres of asphaltic concrete followed by 630 millimetres of grey, crushed sand and gravel (base/subbase material). No distinguishable subbase material was encountered in borehole 101.

The water content of a sample of base/subbase material was 4 percent.

4.2.2 Topsoil

A surficial layer of topsoil, having a thickness of about 0.2 metres, was encountered in borehole 103.

4.2.3 Fill Material

A surficial layer of topsoil fill, having a thickness of about 0.2 metres, was encountered in borehole 102.

Fill material was encountered below the topsoil fill at borehole 102. Where encountered, the fill material has a thickness of 0.7 metres and is composed of grey brown silty clay with variable amounts of sand and organic material.

The water content of a sample of fill material was 37 percent.

4.2.4 Silty Clay

Native deposits of silty clay were encountered below the existing pavement structure at borehole 101, below the fill material at borehole 102, and below the topsoil at borehole 103. At boreholes 101 and 103, the silty clay deposits have a thickness of 12.8 and 3.9 metres, respectively. Borehole 102 was terminated within the silty clay deposits at 7.3 metres below ground surface.

The upper part of the silty clay encountered in boreholes 101 and 102 is weathered grey brown. Standard penetration tests carried out in the weathered, grey brown silty clay gave N values ranging from 4 to 13 blows per 0.3 metres of penetration, which reflect a stiff to very stiff consistency. Where encountered, the weathered, grey brown silty clay has a thickness of between about 2.1 to 4.4 metres and extends to depths of about 3.1 to 5.2 metres below ground surface.

In borehole 103, and below the weathered zone in boreholes 101 and 102, the silty clay is grey in colour. Standard penetration tests carried out in the grey silty clay gave N values of 1 to 6 blows per 0.3 metres of penetration. In situ vane shear strength tests carried out in the grey silty clay gave shear strengths of 79 to greater than 100 kilopascals, which indicate a stiff to very stiff consistency. In borehole 101, the silty clay deposit contains sand and gravel below about 12.8 metres from ground surface.

The results of Atterberg limit tests carried out on two samples of the weathered silty clay recovered from boreholes 101 and 102 gave liquid limits of 81 and 85 percent, plastic limits of 26 and 27 percent and corresponding plasticity indices of 55 and 58 (see Figure A18 in Appendix A). This testing indicates that the weathered silty clay has a high plasticity. The water content of the samples tested was 47 and 50 percent, which is between the measured plastic and liquid limit values. The water content of the weathered silty clay ranges from about 31 to 58 percent.

The results of Atterberg limit tests carried out on samples of the grey silty clay recovered from boreholes 101, 102, and 103 gave liquid limits of 65 to 79 percent, plastic limits of 24 to 28 percent and corresponding plasticity indices of 41 to 51 (see Figure A18 in Appendix A). This testing indicates that the grey silty clay has a high plasticity. The water content of the samples tested was 48 to 64 percent, which is between the measured plastic and liquid limit values. The water content of the grey silty clay ranges from about 48 to 70 percent.

4.2.5 Glacial Till

Deposits of glacial till were encountered in boreholes 101 and 103 below the silty clay at 13.6 and 4.1 metres below ground surface, respectively (elevation 47.4 to 48.6 metres, geodetic datum). The glacial till can generally be described as grey silty sand with variable amounts of clay and gravel. Cobbles and boulders should also be expected in the glacial till deposit. One standard penetration test carried out in the glacial till encountered in borehole 101 gave an N value of 31 blows per 0.3 metres of penetration, which reflects a dense relative density. Borehole 103 was terminated within the glacial till deposit at 4.3 metres below ground surface.

The water content of the glacial till ranges from about 7 to 12 percent.

4.2.6 Inferred Bedrock

Practical refusal to further advancement of the hollow stem auger occurred in borehole 101 at 14.6 metres below ground surface (elevation 46.3 metres, geodetic datum). It should be noted that practical auger refusal can sometimes occur within cobbles and boulders and may not necessarily be representative of the upper surface of the bedrock.

4.2.7 Groundwater Levels

The groundwater levels measured to date in the well screens installed in boreholes 101, 102, and 103 are provided in the following table:

Borehole	Groundwater Levels (metres below ground surface)		
	October 4, 2011	October 11, 2011	November 7, 2011
101	-	4.9	4.7
102	2.8	-	2.5
103	0.5	-	0.5

The groundwater levels may be higher during wet periods of the year such as the early spring or following periods of precipitation.

4.3 Watters Road

4.3.1 Existing Roadway Structure

Borehole 201 was advanced through the gravel surfaced roadway along Watters Road and encountered a pavement structure composed of 330 millimetres of grey brown sand and gravel (base/subbase material). No distinguishable subbase material was encountered in borehole 201.

The water content of a sample of base/subbase material was 5 percent.

4.3.2 Topsoil

A surficial layer of topsoil, having a thickness of about 0.2 metres, was encountered in borehole 202.

4.3.3 Silty Clay

Native deposits of weathered, grey brown silty clay were encountered below the existing roadway structure at borehole 201, and below the topsoil at borehole 202. The silty clay deposit encountered in borehole 202 contains trace amounts of sand and gravel. At boreholes 201 and 202, the weathered, grey brown silty clay has a thickness of 4.1 and 0.6 metres, respectively. Standard penetration tests carried out in the weathered, grey brown silty clay gave N values ranging from 7 to 14 blows per 0.3 metres of penetration, which reflect a very stiff consistency.

The water content of the grey silty clay ranges from about 31 to 39 percent.

4.3.4 Glacial Till

Deposits of glacial till were encountered in borehole 201 below the silty clay at 4.5 metres below ground surface (elevation 78.6 metres, geodetic datum). The glacial till can generally be described as grey silty sand with variable amounts of clay and gravel. Cobbles and boulders should also be expected in the glacial till deposit. One standard penetration test carried out in the glacial till encountered in borehole 201 gave an N value of 38 blows per 0.3 metres of penetration, which reflects a dense relative density.

The water content of two (2) samples of the glacial till ranges from 5 to 10 percent.

4.3.5 Inferred Bedrock

Practical refusal to further advancement of the hollow stem auger occurred in borehole 201 at 5.5 metres below ground surface (elevation 77.6 metres, geodetic datum). Practical refusal to further advancement of the split barrel sampler occurred in borehole 202 at 0.9 metres below ground surface (elevation 77.0 metres, geodetic datum).

It should be noted that practical auger and sampler refusal can sometimes occur within cobbles and boulders and may not necessarily be representative of the upper surface of the bedrock.

4.3.6 Groundwater Levels

The well screen installed in borehole 201 was dry on October 4, 2011 and November 7, 2011.

The groundwater levels may be higher during wet periods of the year such as the early spring or following periods of precipitation.

4.4 Areas 8, 13, 18, 19

4.4.1 Silty Clay

The hand augerholes advanced along the slopes at Areas 8, 13, and 18 encountered native deposits of weathered, grey brown silty clay. The augerholes advanced at Areas 13, and 18 were terminated within the weathered, grey brown silty clay at about 1.5 metres below ground surface

4.4.2 Inferred Bedrock

Practical refusal to further advancement of the hand augerhole advanced at the toe of Area 19 occurred at about 1.0 metres below ground surface (elevation 54.1 metres, geodetic datum).

It should be noted that practical refusal can sometimes occur within cobbles and boulders and may not necessarily be representative of the upper surface of the bedrock.

5.0 SLOPE STABILITY ANALYSES

5.1 General

Slope stability analyses were carried out for each site (i.e., Old Montreal Road, Watters Road, Area 8, Area 13, Area 18, and Area 19) at the various cross sections in order to determine the existing factor of safety against overall rotational failure. Additional analyses were carried out for each site in order to develop and evaluate possible slope stabilization alternatives. Seismic conditions were also analysed for specific locations. The slope stability analyses were carried out using SLIDE, a state of the art, two dimensional limit equilibrium slope stability program.

5.2 Input Parameters

5.2.1 Soil Strength Parameters

The soil conditions used in the stability analyses for Old Montreal Road and Watters Road were based on the results of the boreholes advanced at the sites. For Areas 8, 13, 18, and 19, the soil conditions were based on geology maps, our field observations, results of the augerholes, and the results of the boreholes advanced at Old Montreal Road. For the purposes of this study, we have assumed that the slopes at Areas 8, 13, 18, and 19 are composed entirely of silty clay.

The slope stability analyses were carried out using silty clay strength parameters based on site specific studies in the Ottawa area (Klugman and Chung, 1976). The strength parameters provided by Klugman and Chung (1976) were back-calculated from previous slope failures around the Ottawa area by assuming full hydrostatic saturation (i.e., groundwater level at ground surface and groundwater flow horizontally towards the slope). To determine the existing factor of safety against overall rotational failure, the slope stability analyses were carried out using drained soil parameters, which reflect long term conditions. Undrained parameters were used for analyzing seismic conditions.

The following table summarizes the soil parameters used in the analyses:

Soil Type	Undrained Shear Strength, C_u (kilopascals)	Effective Angle of Internal Friction, φ (degrees)	Effective Cohesion, c' (kilopascals)	Unit Weight, γ (kN/m^3)
Pavement structure	-	38	0	22.0
Weathered silty clay	90	33	10	16.5
Grey silty clay	70	33	10	16.0
Glacial till	-	35	2	20.0

5.2.2 Groundwater Conditions

The results of a stability analysis are highly dependent on the assumed groundwater conditions. No information is available on the long term groundwater levels throughout the year; however, to provide a range of possible safety factors we have considered the following groundwater conditions at Old Montreal Road and Watters Road:

- Full hydrostatic saturation with the groundwater level at ground surface and groundwater flow horizontally towards the slope (most conservative).
- Fully saturated with the groundwater level at ground surface and groundwater flow towards the toe of slope (i.e., using the pore pressure parameter, r_u).
- Measured groundwater levels on October 4, October 11, and November 7, 2011. It should be noted that the measured groundwater levels to date are unlikely to be the highest that could occur (least conservative).

Full hydrostatic saturation is the most conservative groundwater condition, and attempts to model the “worst case” scenario. Although assuming full hydrostatic saturation treats the groundwater in a rather idealized manner, the soil strength parameters used in our analyses are consistent with this groundwater condition. That is, the silty clay strength parameters used in our stability analyses were back calculated by Klugman and Chung (1976) for the case of full hydrostatic saturation.

For Section ‘A-A’ at Watters Road, full hydrostatic saturation is somewhat unrealistic (given the inclination of the slope) and full saturation with groundwater flow towards the toe of the slope was used to model the “worst case” scenario.

It should be noted that the measured groundwater levels to date are unlikely to be the highest that could occur and provide the least conservative results.

5.3 Existing Conditions

5.3.1 Existing Factor of Safety

The slope stability analyses were carried out using soil parameters, groundwater conditions and slope profiles that attempt to model the slopes in question but do not exactly represent the actual conditions. For the purposes of this study, a computed factor of safety of less than 1.0 to 1.3 is considered to represent a slope bordering on failure to marginally stable, respectively; a factor of safety of 1.3 to 1.5 is considered to indicate a slope that is less likely to fail in the long term and provides a degree of confidence against failure ranging from marginal (1.3) to adequate (1.4 and greater) should conditions vary from the assumed conditions. A factor of safety of 1.5, or greater, is considered to indicate adequate long term stability.

To provide a range of possible factors of safety, the cross sections at Old Montreal Road and Watters Road were analysed using the three groundwater conditions described above. As previously indicated, full hydrostatic saturation was not considered for Section ‘A-A’ at Watters Road. At Areas 8, 13, 18, and 19, only full hydrostatic saturation was considered. The slope stability analyses indicate that the existing slopes, in their current configurations, have the following factors of safety against overall rotational failure, using drained soil parameters:

Site	Cross-Section	Groundwater Condition			Remarks (based on "worst case" conditions)
		Full hydrostatic saturation	Fully saturated, with groundwater flow towards toe	Measured groundwater levels	
Old Montreal Road	A-A	1.37	1.58	2.47	Adequately Stable
	B-B	1.24	1.43	2.05	Marginally Stable
	C-C	0.94	1.16	1.87	Unstable
Watters Road	A-A	-	1.04	1.33	Unstable
	B-B	1.43	1.62	2.53	Adequately Stable
Area 8	A-A	1.28	-	-	Marginally Stable
	B-B	1.09	-	-	Unstable
	C-C	0.92	-	-	Unstable
Area 13	A-A	0.88	-	-	Unstable
	B-B	0.97	-	-	Unstable
Area 18	A-A	1.09	-	-	Unstable
	B-B	0.97	-	-	Unstable
Area 19	A-A	0.91	-	-	Unstable

As previously indicated, historical slope failures were observed at Areas 8, 13, 18. The results of the slope stability analyses indicate that the existing factors of safety at these sites are generally between about 0.9 and 1.1 under "worst case" conditions (i.e., full hydrostatic saturation). Since a calculated factor of safety of 1.0 or less indicates a slope bordering on failure, our field observations suggest that by assuming full hydrostatic saturation (in conjunction with the appropriate silty clay strength parameters) our stability analyses are in agreement with observed field conditions.

The results of the stability analyses carried out for Old Montreal Road, Watters Road, Area 8, Area 13, Area 18, and Area 19 are provided in Appendices A, B, C, D, E, and F, respectively.

Section 'C-C' at Old Montreal Road and Section 'A-A' at Watters Road were also analysed using pseudo-static (seismic) conditions, with undrained silty clay parameters, resulting in a factor of safety of 2.3 and 4.2, respectively. A seismic coefficient of 0.2 was used in the pseudo-static analyses. The results of the slope stability analyses indicate that long term drained conditions are the most critical (i.e., give the lowest factor of safety against failure).

5.3.2 Erosion Hazard Limit (Area 13)

At Area 13, the tablelands are occupied by existing infrastructure associated with the dairy operation. The fence line for the dairy operation is located about 15 to 20 metres beyond the crest of the slope. To evaluate the potential for future erosion and slope failures of the existing slope to negatively impact the dairy operation, the concept of ‘Hazard Lands’ was adopted. In accordance with the Ministry of Natural Resources (MNR) Technical Guide “Understanding Natural Hazards” dated 2001, the horizontal distance from an unstable slope to the safe setback line is called the ‘Erosion Hazard Limit’. The area between the Erosion Hazard Limit (i.e., safe setback line) and the crest of the slope is called ‘Hazard Lands’. In accordance with MNR policy, Hazard Lands should not be developed with permanent structures, roadway areas, or any other valuable infrastructure.

The Erosion Hazard Limit consists of the following three components:

1) Stable Slope Allowance: Portion of the setback that ensures safety, if slumping or slope failure occurs.

2) Toe Erosion Allowance: Portion of the setback that ensures safety of the top of the slope in the event that a watercourse erodes or weakens the toe of the slope.

3) Erosion Access Allowance: Portion of the setback needed to ensure that there is a large enough safety zone for people and vehicles to enter and exit an area during an emergency, such as a slope failure or flood. Typically, it is also included where construction vehicle access is required to repair a failed slope.

Based on the slope stability analyses, together with the results of our site reconnaissance, the Erosion Hazard Limit extends the following distances from the crest of the slope at Area 13:

Cross-Section	Component			Erosion Hazard Limit
	Stable Slope Allowance[1]	Toe Erosion Allowance[2]	Erosion Access Allowance[3]	
A-A	7 metres (refer to Figure D1)	8 metres	6 metres	21 metres (refer to Figure D1)
B-B	10 metres (refer to Figure D7)	8 metres	6 metres	24 metres (refer to Figure D7)

Notes:

1) The Stable Slope Allowance, as described in the MNR procedures, is the area between the crest of the slope and location where a factor of safety of greater than 1.5 against slope failure is calculated.
2) In accordance with MNR documents, an allowance of 5 to 8 metres is required to allow for erosion at the toe of a slope composed of silty clay. For the purposes of this analysis, we have allowed for an 8 metre wide Toe Erosion Allowance.
3) The MNR procedures include the application of a 6.0 metre wide Erosion Access Allowance.

As indicated above, the Erosion Hazard Limit for the slope at Sections ‘A-A’ and ‘B-B’ is located about 21 and 24 metres from the crest of the slope, respectively (see Site Plan, Figure 5). Therefore, based on the results of this preliminary slope stability assessment, a portion of the dairy operation is located within Hazard Lands. In order to refine the Erosion Hazard Limit, which may reduce the safe setback distance, an intrusive subsurface investigation (i.e., boreholes) could be carried out.

The Erosion Hazard Limit provided above is based on existing site conditions. It is possible to reduce the safe setback requirements by improving the existing factor of safety against slope failure (i.e., slope stabilization) or by reducing/eliminating the potential for erosion.

5.4 Slope Stabilization Alternatives

5.4.1 Old Montreal Road

To develop and evaluate possible slope stabilization alternatives for Old Montreal Road, additional stability analyses were carried at Sections ‘A-A’, ‘B-B’, and ‘C-C’. The slope stabilization measures were analyzed using long term drained parameters with hydrostatic saturation (i.e., “worst case” conditions). A factor of safety of at least 1.5 against overall rotational failure was targeted when developing possible slope stabilization alternatives given that there is potential for a rotational failure to affect the roadway. The desired factor of safety should be confirmed with the City of Ottawa.

The stabilization measures analyzed and corresponding factors of safety against overall rotational failure are provided below (in no particular order):

Alternative	Factor of Safety		
	Section 'A-A'	Section 'B-B'	Section 'C-C'
1) Do nothing, including maintenance	1.37	1.24	0.94
2) Slope regrading while not moving the toe of the slope.	1.61	1.28	1.27
3) Slope regrading while moving the toe of the slope.	n/a	1.54	1.45
4) External toe buttress constructed of earth borrow. The factor of safety is dependent on the geometry of the buttress.	1.78	1.51	1.52
5) External toe buttress constructed of engineered fill. The factor of safety is dependent on the geometry of the buttress.	1.68	1.51	1.48
6) Slope reinforcement involving excavating portions of the slope and rebuilding with compacted engineered fill and plastic or steel grid reinforcement.	1.80	1.53	1.66

We have considered other possible stabilization measures including slope dewatering, roadway lowering, and the use of light weight fill; however, the stabilization measures presented in the above table are the preferred stabilization alternatives from a geotechnical point of view.

Slope regrading while moving the toe of the slope (Alternative 3) is not a practicable alternative at Section 'A-A' given the geometry of the slope.

If Cardinal Creek will not be realigned, the preferred alternative(s) should be combined with the installation of erosion protection to prevent further erosion of the toe of the slope.

The results of the stability analyses, including cross sections of the possible stabilization alternatives, are provided in Appendix A. The possible slope stabilization alternatives are evaluated from a geotechnical point of view in Table 1. The information provided in the table could be used to assist in ranking/selecting the preferred alternative.

Preliminary design details for each of the preferred alternatives are presented in the following sections.

Alternative 1: Do Nothing with Maintenance

Strategy

Consideration could be given to the “do nothing” alternative in conjunction with regular maintenance including directing surface water away from the slope and periodic erosion control measures.

Disadvantages

Although a cost effect alternative, the suitability of the “do nothing” alternative is a risk management issue, since there is potential for a rotational failure to affect the roadway. The risk to the public and infrastructure (such as Old Montreal Road) should be considered. It is pointed out that active erosion along the toe of the slope in the area of Section ‘C-C’ was observed. The “do nothing” alternative should include stabilization of the channel walls to prevent further steepening of the side slope.

Alternative 2: Slope Regrading While Not Moving the Toe

Strategy

Consideration could be given to flattening the existing slope by moving the crest of the slope toward Old Montreal Road (see Figures A2, A7, and A13 in Appendix A). The location of the toe could be maintained, which may be beneficial in the event that Cardinal Creek is not realigned.

Disadvantages

Given the location of the roadway, and in order to maintain the location of the toe, a factor of safety of 1.3 is achieved at Sections ‘B-B’ and ‘C-C’ under “worst case” conditions, which is considered marginally stable. Furthermore, by moving the crest of the slope towards Old Montreal Road, the potential for future widening of the roadway is reduced.

In order to flatten the existing slope, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required.

The existing guiderails will be located about 1 metre from the crest of the regraded slope, which may result in tilting of the guide rail over time. When subjected to cycles of freezing and thawing, frost susceptible soil can creep toward the bottom of a slope under the influence of gravity. Objects, such as guide rails, located within this zone may also migrate and tilt down the slope. This mechanism is not restricted to unstable or marginally stable slopes, but can also occur within stable slopes. The rate of deformation is likely related to slope inclination and the frost susceptibility of the soils along the slope.

Access to the toe of the slope may be required for excavation equipment.

Alternative 3: Slope Regrading While Moving the Toe

Strategy

In order to increase the factor of safety at Sections ‘B-B’ and ‘C-C’ to at least 1.5, consideration could be given to excavating the upper portion of the slope and placing the excavated soil at the toe of the slope (see Figures A8 and A14 in Appendix A). For the particular geometries analysed, the regraded slope is inclined at 2.5 horizontal to 1 vertical. The toe is moved about 4 to 5 metres into Cardinal Creek and the crest is moved about 4 metres toward Old Montreal Road. Guide rail tilting due to creep, as described above, may be an issue at Section ‘B-B’. Off site removal of the excavated soil may be required.

Disadvantages

Removal of the existing vegetation is required in order to regrade the slope. Furthermore, Cardinal Creek realignment is necessary to permit filling at the toe of the existing slope. Furthermore, by moving the crest of the slope towards Old Montreal Road, the potential for future widening of the roadway is reduced.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 4: External Toe Buttress Constructed of Earth Borrow

Strategy

In order to increase the factor of safety at Sections 'A-A', 'B-B' and 'C-C' to at least 1.5, consideration could be given to constructing an external buttress at the toe of the existing slope. The geometry of the upper portion of the slope is maintained, which is beneficial in the event of future roadway widening. The external buttress could be constructed of compacted earth borrow material (see Figures A3, A9, and A15 in Appendix A).

Disadvantages

To achieve a factor of safety of at least 1.5, imported earth borrow is required to construct the particular buttress analysed.

Removal of the existing vegetation along the lower portion of the slope within the footprint of the buttress is required. Furthermore, Cardinal Creek realignment is necessary to permit construction of the external buttress.

Silty clay earth borrow materials are sensitive to changes in moisture content, precipitation and frost heaving. As such, unless the earth material placement is planned during the dry period of the year (June to September), precipitation and freezing conditions may restrict or delay adequate compaction of these materials.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 5: External Toe Buttress Constructed of Engineered Fill

Strategy

In order to increase the factor of safety at Sections 'A-A', 'B-B', and 'C-C' to at least 1.5, consideration could be given to constructing an external buttress at the toe of the existing slope. The external buttress could be constructed of an imported free-draining, granular material (assuming a bulk unit weight of at least 20 kilonewtons per cubic metre) or blast rock fill. The geometry of the upper portion of the slope is maintained, which is beneficial in the event of future roadway widening (see Figures A4, A10, and A16 in Appendix A).

Disadvantages

To achieve a factor of safety of at least 1.5, imported granular material is required to construct the buttress. To allow for landscaping, the buttress could be topped with earth borrow material; however, allowance should be made for a nonwoven geotextile between the earth borrow material and the imported granular material to maintain drainage.

Removal of the existing vegetation along the lower portion of the slope within the footprint of the buttress is required. Furthermore, Cardinal Creek realignment is necessary to permit construction of the external buttress.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 6: Slope Reinforcement

Strategy

Consideration could be given to reinforcing the side slopes using a proprietary retained soil system. A retained soil system generally consists of excavating portions of the slope and rebuilding with compacted granular materials reinforced with plastic or steel grid reinforcement. A permanent erosion control blanket is generally incorporated into the design to prevent erosion and promote vegetative growth.

The existing slope geometry is maintained, which is beneficial in the event of future roadway widening (see Figures A5, A11, and A17 in Appendix A). The retained soil system should be designed by the manufacturer.

The location of the toe could be maintained, which may be beneficial in the event that Cardinal Creek is not realigned.

Disadvantages

Soil excavation and imported granular material is required in order to construct the retained soil system.

In order to construct the retained soil system, removal of the existing vegetation is required.

Access to the toe of the slope is required for excavation/compaction equipment, which may involve construction of working pads in the event that Cardinal Creek is not realigned.

5.4.2 Watters Road

To develop and evaluate possible slope stabilization alternatives for Watters Road, additional stability analyses were carried at Sections 'A-A' and 'B-B'. The slope stabilization measures were analyzed using long term drained parameters with hydrostatic saturation (i.e., "worst case" conditions) since the stabilization alternatives include slope regrading. A factor of safety of at least 1.5 against overall rotational failure was targeted when developing possible slope stabilization alternatives given that there is potential for a rotational failure to affect the roadway. The desired factor of safety should be confirmed with the City of Ottawa.

The stabilization measures analyzed and corresponding factors of safety against overall rotational failure are provided below (in no particular order):

Alternative	Factor of Safety	
	Section 'A-A'	Section 'B-B'
1) Do nothing, including maintenance.	1.04	1.43
2) Slope regrading while not moving the toe of the slope.	1.33	n/a
3) Slope regrading while moving the toe of the slope.	1.48	n/a
4) Slope regrading with an external toe buttress constructed of engineered fill. The factor of safety is dependent on the geometry of the buttress.	1.45	1.57 (buttress only)
5) Slope regrading with toe reinforcement.	2.05	n/a

We have also considered other possible stabilization measures including avoidance, slope dewatering, roadway lowering, and the use of light weight fill; however, the stabilization measures presented in the above table are the preferred stabilization alternatives from a geotechnical point of view. The preferred alternative(s) should be combined with the installation of erosion protection to prevent future erosion of the toe of the slope.

It should be pointed out that the slope profile at Section ‘A-A’ is not representative of the entire slope profile within the study area. Section ‘A-A’ represents a localized area located at the western extent of the study area. The remaining slope profile is similar to Section ‘B-B’ and significantly less effort is required for stabilization in these areas.

The results of the stability analyses, including cross sections of the possible stabilization alternatives, are provided in Appendix B. The possible slope stabilization alternatives are evaluated from a geotechnical point of view in Table 2. The information provided in the table could be used to assist in ranking/selecting the preferred alternative.

Preliminary design details for each of the preferred alternatives are presented in the following sections.

Alternative 1: Do Nothing with Maintenance

Strategy

Consideration could be given to the “do nothing” alternative in conjunction with regular maintenance including directing surface water away from the slope and periodic erosion control measures. At Section ‘A-A’ the slope, having a height of 7.5 metres, is located about 9 metres from Watters Road. Furthermore, at Section ‘B-B’ the slope, in its current configuration, has an adequate factor of safety against overall rotational failure. As such, the potential for a rotational failure to affect the roadway at Sections ‘A-A’ and ‘B-B’ is low.

Disadvantages

Although a cost effect alternative, the suitability of the “do nothing” alternative is a risk management issue. The risk to the public and infrastructure (such as Watters Road) should be considered. It is pointed out that active erosion along the toe of the slope in the area of Section

'A-A' was observed. The "do nothing" alternative should include stabilization of the channel walls to prevent further steepening (under cutting) of the side slope.

Alternative 2: Slope Regrading While Not Moving the Toe

Strategy

Consideration could be given to flattening the existing slope at Section 'A-A' by moving the crest of the slope about 8 metres toward Watters Road, or about 1.5 metres north of the existing roadway (see Figure B2 in Appendix B). The resulting slope is flattened to 2.1 horizontal to 1 vertical. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel.

Disadvantages

Given the location of the roadway, and in order to maintain the location of the toe, a factor of safety of 1.3 is achieved at Section 'A-A' under "worst case" conditions, which is considered marginally stable.

In order to flatten the existing slope, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required.

If guiderails are required following stabilization, tilting of the guiderail over time should be anticipated due to progressive creep.

Access to the toe of the slope may be required for excavation equipment.

Alternative 3: Slope Regrading While Moving the Toe

Strategy

In order to increase the factor of safety at Section 'A-A' to at least 1.5, consideration could be given to excavating the upper portion of the slope and placing a portion of the excavated soil at the toe of the slope (see Figure B3 in Appendix B). For the particular geometry analysed, the regraded slope is inclined at 2.4 horizontal to 1 vertical. The toe is moved about 3 metres into the surface channel and the crest is moved about 6 metres toward Watters Road. Guiderail tilting due to creep is not considered an issue.

Disadvantages

Off site removal of the excavated soil is required. Removal of the existing vegetation is also required. The stabilized slope will encroach about 3 metres into the surface channel.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 4: Slope Regrading with an External Toe Buttress

Strategy

In order to increase the factor of safety at Section ‘A-A’ to at least 1.5, consideration could be given to flattening the existing slope by moving the crest of the slope about 6 metres toward Watters Road and constructing an external buttress at the toe of the slope (see Figure B4 in Appendix B). The resulting slope is flattened to 2.1 horizontal to 1 vertical. The external buttress could be constructed of imported free-draining, granular material (assuming a bulk unit weight of at least 20 kilonewtons per cubic metre) or blast rock fill. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel. Guiderail tilting due to creep is not considered an issue.

At Section ‘B-B’, the factor of safety could be increased to at least 1.5 by constructing a buttress at the toe of the slope. Slope regrading is not required at Section ‘B-B’ (see Figure B7 in Appendix B).

Disadvantages

In order to flatten the existing slope, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required.

To allow for landscaping, the buttress could be topped with earth borrow material; however, allowance should be made for a nonwoven geotextile between the earth borrow material and the imported granular material to maintain drainage.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 5: Slope Reinforcement

Strategy

Consideration could be given to reinforcing the toe of the slope using a proprietary retained soil system. A retained soil system generally consists of excavating a portion of the slope and rebuilding with compacted granular materials reinforced with plastic or steel grid reinforcement. A permanent erosion control blanket is generally incorporated into the design to prevent erosion and promote vegetative growth (see Figure B5 in Appendix B).

The retained soil system could be inclined up to about 60 degrees from the horizontal. The retained soil system should be designed by the manufacturer.

To allow for construction of the retained soil system, the upper portion of the slope could be excavated and flattened to 2.6 horizontal to 1 vertical by moving the crest of the slope 6 metres toward Watters Road. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel. Guiderail tilting due to creep is not considered an issue.

Disadvantages

In order to flatten the existing slope, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required.

Access to the toe of the slope is required for excavation/compaction equipment.

5.4.3 Areas 8, 13, 18, and 19

Additional stability analyses were carried out for Areas 8, 13, 18, and 19 to develop and evaluate possible slope stabilization alternatives. The slope stabilization measures were analyzed using long term drained parameters with hydrostatic saturation (i.e., “worst case” conditions). Given that the slope stability hazard generally relates to limited value property (i.e., farmland), a factor of safety of at least 1.3 against overall rotational failure was targeted at

Areas 8, 18, and 19. At Area 13, slope stabilization alternatives were developed in order to ensure that the dairy operation is not affected by future erosion and slope failures. This could be achieved by implementing measures to increase the factor of safety to at least 1.3 and thereby reducing the Erosion Hazard Limit (such that the dairy operation is not located within Hazard Lands). This could also be achieved by implementing measures to increase the factor of safety at Area 13 to at least 1.5; however, it should be noted that a factor of safety of 1.5 is difficult to achieve without significant earthwork or dewatering.

In order to develop a standard slope stabilization alternative that could be applied to several sites, the following stabilization measures were analysed (in no particular order):

1) Do nothing
2) Slope regrading to 2 horizontal to 1 vertical while not moving the toe of the slope.
3) Slope regrading to 3 horizontal to 1 vertical while not moving the toe of the slope.
4) Slope benching
5) External toe berm constructed of engineered fill
6) Slope dewatering

The corresponding factors of safety against overall rotational failure for each stabilization alternative are provided below:

Site	Cross-Section	Factor of Safety for Stabilization Alternatives					
		Do Nothing	Regrade to 2H to 1V	Regrade to 3H to 1V	Benching	External Toe Berm	Dewatering
Area 8	A-A	1.28	1.67	2.22	1.92	1.51	1.3 to >1.5
	B-B	1.09	1.40	1.79	1.71	1.39	1.3 to >1.5
	C-C	0.92	1.01	1.30	1.26	1.26	1.3 to >1.5
Area 13	A-A	0.88	0.98	1.43	1.34	1.26	1.3 to >1.5
	B-B	0.97	0.99	1.40	1.37	1.26	1.3 to >1.5
Area 18	A-A	1.09	1.21	1.60	1.35	1.33	1.3 to >1.5
	B-B	0.97	n/a	1.20	1.34	n/a	1.3 to >1.5
Area 19	A-A	0.91	1.02	1.46	1.36	n/a	1.3 to >1.5

The results of the stability analyses, including cross sections of the possible stabilization alternatives, are provided in Appendices C, D, E, and F for Areas 8, 13, 18, and 19, respectively. The possible slope stabilization alternatives for Areas 8, 13, 18, and 19 are evaluated from a geotechnical point of view in Tables 3, 4, 5, and 6, respectively. The information provided in the tables could be used to assist in ranking/selecting the preferred alternative.

At Area 13, the location of the Erosion Hazard Limit, relative to the crest of the existing slope, for each of the stabilization alternatives is provided below:

Stabilization Alternative	Erosion Hazard Limit[1]		Encroachment of Hazard Lands onto Dairy Operation
	Section 'A-A'	Section 'B-B'	
Do Nothing (i.e., existing conditions)	21 metres (refer to Figure D1)	24 metres (refer to Figure D7)	Yes
Regrade to 2H to 1V	16 metres	18 metres	Yes
Regrade to 3H to 1V	20 metres	20 metres	Yes
Benching	14 metres (refer to Figure D4)	16 metres (refer to Figure D10)	No
External Toe Berm	11 metres	11 metres	No
Dewatering	0 to 12 metres	0 to 12 metres	No

Notes:

1) The Erosion Hazard Limit assumes that toe erosion protection has been installed (i.e., the Toe Erosion Allowance does not apply).

The preferred alternative(s) should be combined with the installation of erosion protection to prevent future erosion of the toe of the slope. Preliminary design details for each of the preferred alternatives are presented in the following sections.

Alternative 1: Do Nothing with Maintenance

Strategy

Consideration could be given to the “do nothing” alternative in conjunction with regular maintenance including directing surface water away from the slope and periodic erosion control measures.

Disadvantages

Although a cost effect alternative, the suitability of the “do nothing” alternative is a risk management issue. The risk to the public and infrastructure should be considered. For this alternative, loss of tablelands should be anticipated as a result of the natural erosion process. This may be considered acceptable in areas where the tablelands are occupied by limited value property and the risk to the public is low.

In areas where active erosion along the toe of the slope was observed, the “do nothing” alternative could include stabilization of the channel walls to prevent further steepening of the side slope.

Alternative 2: Slope Regrading to 2 Horizontal and 1 Vertical

Strategy

Consideration could be given to regrading the slopes to 2 horizontal to 1 vertical by moving the crest of the slope into the tablelands. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel.

Disadvantages

In most cases, the minimum factor of safety of 1.3 is not achieved if the slopes are regraded to 2 horizontal to 1 vertical when analyzed for “worst case” conditions.

In order to flatten the existing slopes, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required. Furthermore, loss of the tableland area is required in order to construct the remediation alternative.

Access to the slope is required for excavation equipment.

Alternative 3: Slope Regrading to 3 Horizontal and 1 Vertical

Strategy

In order to achieve a factor of safety of at least 1.3, consideration could be given to regrading the slopes to 3 horizontal to 1 vertical by moving the crest of the slope into the tablelands. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel.

Disadvantages

When analyzed for "worst case" conditions, the minimum factor of safety of 1.3 is not achieved at Section 'B-B' in Area 18 if the slope is regraded to 3 horizontal to 1 vertical.

In order to flatten the existing slopes, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required. Furthermore, loss of the tableland area is required in order to construct the remediation alternative. If it is possible to realign the existing creek channel, consideration could be moving toe of the regraded slope into Cardinal Creek. This will limit the amount of excess soil and loss of table land area.

Access to the slope is required for excavation equipment.

Alternative 4: Slope Benching

Strategy

In order to achieve a factor of safety of at least 1.3, consideration could be given to constructing benching along the face of the slope. In general, the benches would be sloped at about 2 horizontal to 1 vertical and separated by a 1.5 to 6.0 metre wide horizontal plateau. The location of the toe could be maintained, which would prevent encroachment of the stabilized slope into the surface channel.

Disadvantages

In order to construct the benches, earth excavation and off site removal of the excavated soil is required. Removal of the existing vegetation is also required. Furthermore, loss of the tableland area is required in order to construct the remediation alternative.

Access to the slope is required for excavation equipment.

Alternative 4: External Toe Berm

Strategy

In order to increase the factor of safety of the slopes to at least 1.3, consideration could be given to constructing an external buttress at the toe of the existing slopes. The external buttress could be constructed of an imported free-draining, granular material (assuming a bulk unit weight of at least 20 kilonewtons per cubic metre) or blast rock fill. The geometry of the upper portion of the slope is maintained.

Disadvantages

Imported granular material is required to construct the buttress. To allow for landscaping, the buttress could be topped with earth borrow material; however, allowance should be made for a nonwoven geotextile between the earth borrow material and the imported granular material to maintain drainage.

Removal of the existing vegetation along the lower portion of the slope within the footprint of the buttress is required. Furthermore, Cardinal Creek realignment is necessary to permit construction of the external buttress.

Access to the toe of the slope is required for excavation/compaction equipment.

Alternative 5: Slope Dewatering

Strategy

In order to increase the factor of safety to at least 1.3, the groundwater level could be lowered to about 1 to 3 metres below the ground surface.

The dewatering system could consist of near horizontal perforated plastic drains installed throughout the slope. The drains could be installed through the slope face using hand held or small track mounted equipment. The drains could be constructed parallel to each other or, alternatively, radially from a common exit location. The drains should be inclined from the horizontal to encourage gravity drainage. In general, the existing grades at the site could be maintained.

Specific design details (i.e., number of drains, diameter, spacing, length, inclination, and elevation) could be provided in the geotechnical report if a slope dewatering system is being considered.

Disadvantages

In order to mobilize equipment on the slopes, working pads are required to provide a level surface. If handheld equipment is used, impacts on existing vegetation would be reduced. Furthermore, impacts on the existing vegetation may be reduced slightly if the dewatering system includes an array of drains from a common exit location.

Since the geometry of the existing slopes will be maintained, there remains the potential for localized surficial sloughing failure of the slope face.

Given the slopes are generally comprised of low permeable soils the drains may result in localized effects only. As such, an increased number of drains may be required to lower groundwater levels within the slope.

Routine cleaning is required to maintain the drains and post construction monitoring of groundwater levels would be required to confirm their effectiveness.

To our knowledge, slope dewatering, as described above, has not been carried out locally. As such, there may be a limited number of contractors willing to bid on the project.

5.5 Potential for Liquefaction

Based on the results of the boreholes, there is no potential for liquefaction of the overburden deposits at Watters Road and Old Montreal Road. The potential for liquefaction of the overburden at Areas 8, 13, 18, and 19 is presently unknown.

5.6 Potential for Earth Flow Slides

The method developed by Mitchell and Markell (1974) was used to assess whether there is potential for future slope failures at Old Montreal Road and Watters Road to develop into earth flow (retrogressive) slides. Using information from previous slope failures, together with air photo studies, field studies, and data from a variety of soils reports, Mitchell and Markell (1974) determined that in order for an earth flow slide to develop the stability number, given by the following equation, should exceed 6.

$$N = (\gamma_s H) / c_u$$

Where,

- N = Stability number
- γ_s = Unit weight of silty clay (17 kilonewtons per cubic metre)
- H = Height of slope (metres)
- c_u = Undrained shear strength of silty clay (average undrained shear strength measured from in-situ vane testing is about 70 kilopascals)

The calculated stability numbers for the cross sections considered along Old Montreal Road and Watters Road are less than 3. Assuming the undrained shear strength of the silty clay at Areas 8, 13, 18, and 19 is similar to the undrained shear strength measured at Old Montreal Road and Watters Road, the calculated stability numbers are generally less than 3. For Section ‘B-B’ at Area 18, the calculated stability number is about 4.4. Based on the research, there does not appear to be potential for an earth flow slide to develop along the sections of Cardinal Creek considered in this Study.

6.0 DETAILED DESIGN AND CONSTRUCTION CONSIDERATIONS

6.1 Detailed Design

As previously indicated, boreholes were not advanced at Areas 8, 13, 18, and 19 and the slope stability analyses were carried out assuming that the slopes were composed entirely of silty clay. During the detailed design stage, it is recommended that boreholes be advanced at Areas 8, 13, 18, and 19 in order to optimize design of the preferred stabilization alternative, provide site specific groundwater conditions, assess the potential for liquefaction of the overburden at the sites, and to assess the potential for an earth flow slide to develop. In our opinion, additional boreholes are not required at Old Montreal Road and Watters Road.

The purpose of this report was to develop possible slope stabilization alternatives for each site and, as such, once the preferred slope stabilization alternative has been selected, the engagement of the services of the geotechnical consultant during the detailed design stage is recommended.

6.2 Construction Considerations

Conventional haulage, excavation and/or compaction equipment is required in order to construct the slope stabilization alternatives presented in Section 5.4, with the exception of the “do nothing” alternative. The majority of the sites are somewhat isolated (e.g., Area 8, 18, and 19) and temporary construction access will be required (e.g., haul roads). Furthermore, equipment access to the toe of the slope is also required (with the exception of the “do nothing” alternative), which may involve the use of smaller construction equipment (e.g., walk-behind compaction equipment, mini-excavator, etc.), construction of working pads adjacent to Cardinal Creek, and implementation of sediment control measures.

It should be noted that a karst terrain feature is located at Watters Road, which provides a subsurface channel for Cardinal Creek. Additional information regarding the karst feature is provided in the report prepared by Golder Associates Ltd. titled “Geotechnical Evaluation, Cardinal Creek, Karst Area, Watters Road, Township of Cumberland, Ontario”, dated June 11, 1991. In order to ensure that the karst feature is not negatively impacted by construction of the preferred stabilization alternative, the location of the karst feature should be considered when selecting the type of construction equipment used to stabilize the slope along Watters Road.

We trust this report provides sufficient information for your present purposes. If you have any questions concerning this report, please do not hesitate to contact our office.

Yours truly,

HOULE CHEVRIER ENGINEERING LTD.

Johnathan A. Cholewa, Ph.D., P.Eng

Andrew Chevrier, M.Eng.P.Eng.
Principal

LICENSED PROFESSIONAL ENGINEER
13 June 2013
A.F. CHEVRIER
7974504
PROVINCE OF ONTARIO

References

Klugman, M.A. and Chung, P. 1976. Slope Stability Study of the Regional Municipality of Ottawa- Carleton Ontario Area. Ontario Geological Survey, MP 68, Ministry of Natural Resources, Ontario. 13pp.

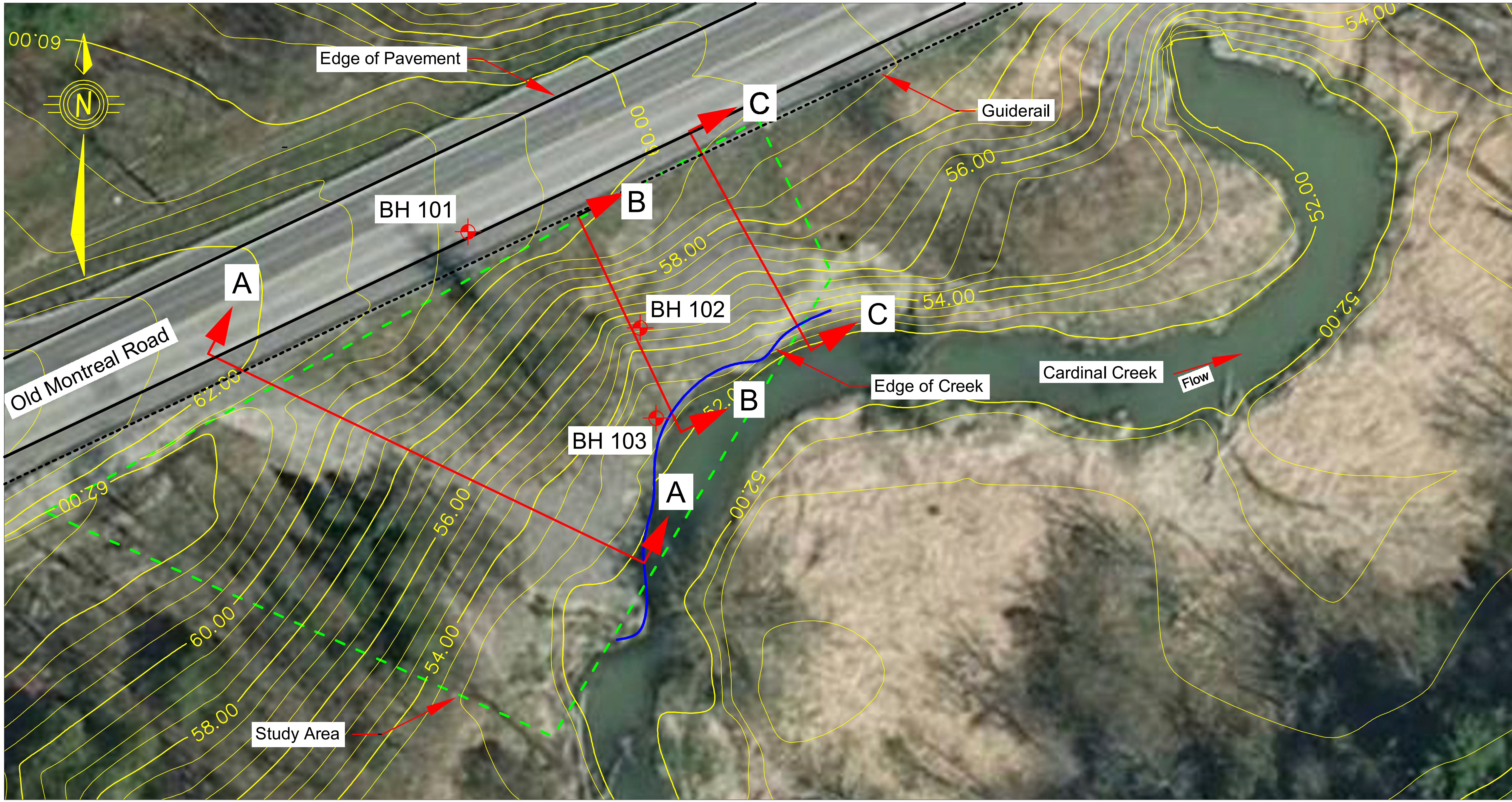
Mitchell. R.J. and Markell, A.R. 1974. Flowsliding in Sensitive Soils, Canadian Geotechnical Journal, 11: 11-31

KEY PLAN	FIGURE 1

Houle Chevrier Engineering

Date: June 2013

Project: 11-378/11-618

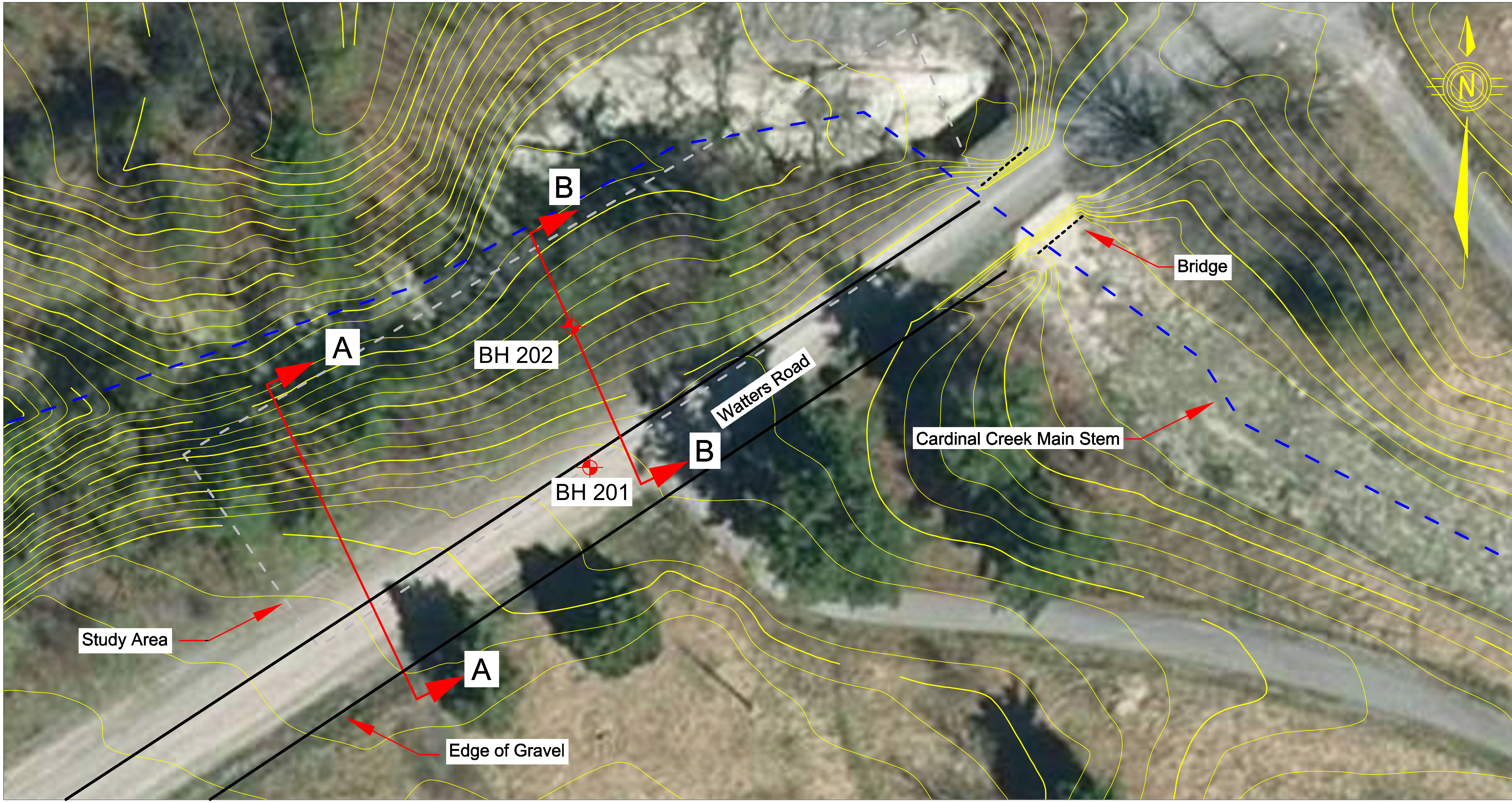


LEGEND

BH 1 — APPROXIMATE BOREHOLE LOCATION IN PLAN, CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

A A — CROSS SECTION

Client: AECOM Canada Ltd.		Location: OLD MONTREAL ROAD OTTAWA, ON	Revision: 0
Drawn by: J.A.C	Approved by: A.F.C	Project No.: 11-378	Scale: 1:300
Houle Chevrier Engineering		Title: OLD MONTREAL ROAD SITE PLAN	
		Date: JUNE 2013	FIGURE 2

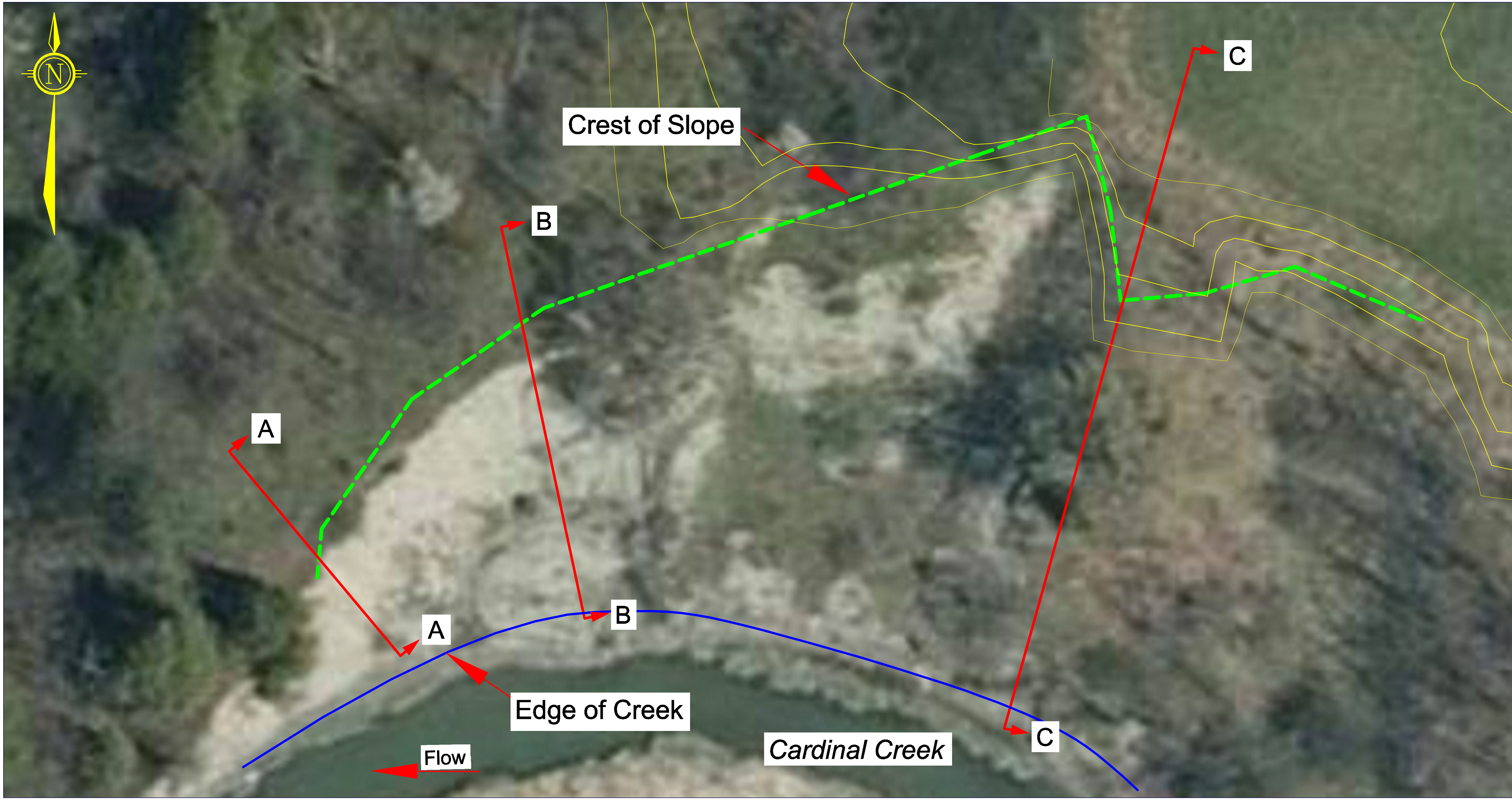


LEGEND

BH 1 — APPROXIMATE BOREHOLE LOCATION IN PLAN, CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

A A — CROSS SECTION

Client: AECOM Canada Ltd.		Location: WATTERS ROAD OTTAWA, ON	Revision: 0
Drawn by: J.A.C	Approved by: A.F.C	Project No.: 11-378	Scale: 1:300
Houle Chevrier Engineering		Title: WATTERS ROAD SITE PLAN	
		Date: JUNE 2013	FIGURE 3

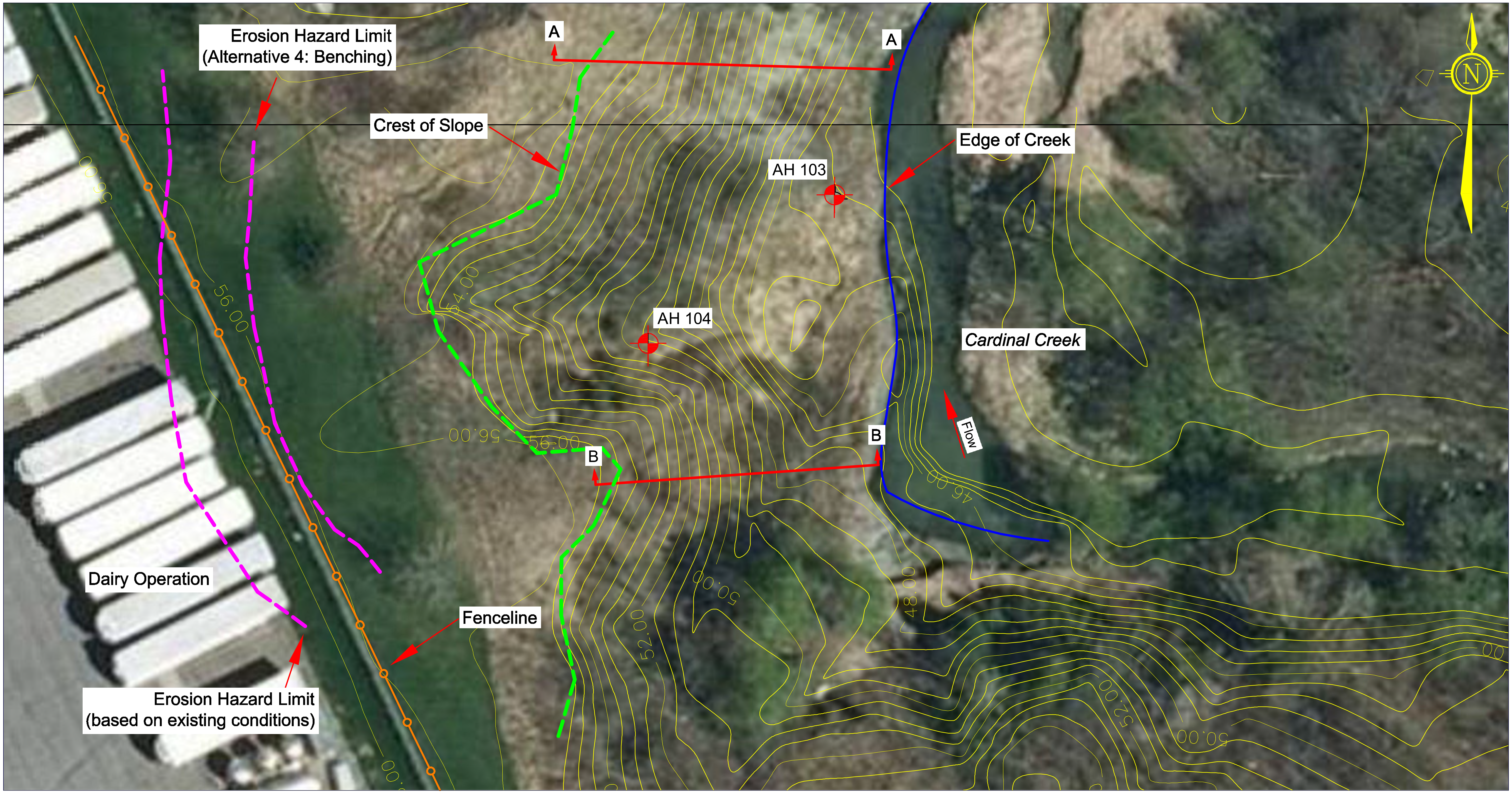


LEGEND

A A

SLOPE CROSS SECTION. CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

Client AECOM Canada Ltd.		Location CARDINAL CREEK OTTAWA, ONTARIO	Revision 0
Drawn by B.T.	Approved by A.F.C	Project No. 11-618	Scale 1 : 200
Houle Chevrier Engineering		Title AREA 8 SITE PLAN	
		Date JUNE 2013	FIGURE 4



LEGEND

A A — SLOPE CROSS SECTION. CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

AH 101 — APPROXIMATE AUGERHOLE LOCATION IN PLAN, CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

Client AECOM Canada Ltd.		Location CARDINAL CREEK OTTAWA, ONTARIO		Revision 0
Drawn by B.T.	Approved by A.F.C	Project No. 11-618		Scale 1 : 300
Houle Chevrier Engineering		Title AREA 13 SITE PLAN		
		Date JUNE 2013	FIGURE 5	

LEGEND

A A SLOPE CROSS SECTION. CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

AH 101 APPROXIMATE AUGERHOLE LOCATION IN PLAN, CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

Client AECOM Canada Ltd.		Location CARDINAL CREEK OTTAWA, ONTARIO	Revision 0
Drawn by B.T.	Approved by A.F.C	Project No. 11-618	Scale 1 : 300
Houle Chevrier Engineering		Title AREA 18 SITE PLAN	
		Date JUNE 2013	FIGURE 6

LEGEND

A A SLOPE CROSS SECTION. CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

AH 101 APPROXIMATE AUGERHOLE LOCATION IN PLAN, CURRENT INVESTIGATION BY HOULE CHEVRIER ENGINEERING LTD.

Client	Location	Revision
AECOM Canada Ltd.	CARDINAL CREEK OTTAWA, ONTARIO	0

Drawn by	Approved by	Project No.	Scale
B.T.	A.F.C	11-618	1 : 200

Houle Chevrier Engineering

Title: AREA 19 SITE PLAN

Date: JUNE 2013

FIGURE 7

TABLE 1
EVALUATION OF STABILIZATION ALTERNATIVES
OLD MONTREAL ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope Not Moving Toe	3) Regrade Slope Moving Toe	4), 5) External Toe Berm	6) Slope Reinforcement
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded by removing (excavating) material from the slope. The location of the toe of the slope would be moved into Cardinal Creek and the crest of the slope would be moved into the table lands. Realignment of Cardinal Creek would be required to accommodate the regrading (not applicable at Section 'A-A'.	An external toe buttress constructed of imported crushed rock (blast rock) or earth fill would be constructed at the toe of the existing slope. Realignment of Cardinal Creek would be required to accommodate the external toe buttress. The location of the crest of the slope would remain unaltered.	The existing slope would be reinforced with engineered fill and plastic/steel grid reinforcement by removing (excavating) material from the slope. The location of the toe and crest of the slope would remain unaltered.
Technical Assessment Group					
Potential for improved safety of slope.	The current factor of safety is between 0.9 and 1.4. The 'Do Nothing' alternative does not improve the factor of safety.	Moderate potential for improving the factor of safety. FOS increases to between 1.3 and 1.6	High potential for improving the FOS, with an increase to 1.5	High potential for improving the FOS, with an increase to 1.5 or greater.	High potential for improving the FOS, with an increase to greater than 1.5.
Potential for future widening of Old Montreal Road to a four lane roadway section	Low potential due to the risk of future slope failures negatively impacting the four lane section.	Low potential due to loss of table lands at the crest of the slope in order to construct stabilization alternative.	Low potential due to loss of table lands at the crest of the slope in order to construct stabilization alternative.	High potential given that the crest of the slope would remain unaltered.	High potential given that the crest of the slope would remain unaltered.

TABLE 1 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
OLD MONTREAL ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope Not Moving Toe	3) Regrade Slope Moving Toe	4), 5) External Toe Berm	6) Slope Reinforcement
Technical Assessment Group - Continued					
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope	Medium potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	Low potential for future maintenance.	Low potential for future maintenance.	Low potential for future maintenance.
Natural Environment Assessment Group					
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in the event a slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Low potential for effects on the terrestrial environment following construction.	Low potential for effects on the terrestrial environment following construction.	Low potential for effects on the terrestrial environment following construction.

TABLE 1 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
OLD MONTREAL ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope Not Moving Toe	3) Regrade Slope Moving Toe	4), 5) External Toe Berm	6) Slope Reinforcement
Natural Environment Assessment Group - Continued					
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the “Do Nothing” alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs along the toe of the slope in order to construct the toe berm.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.
Social Environmental Assessment Group					
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area and disturbance to Old Montreal Road as a result of continual toe erosion/slope failures.	Loss of tableland area in order to construct remediation alternative. High potential for long-term loss of additional tableland and disturbance to Old Montreal Road following construction due to the remaining risk for slope failure.	Loss of tableland area in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Old Montreal Road following construction.	No loss of tableland in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Old Montreal Road following construction	No loss of tableland in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Old Montreal Road following construction.
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from import of materials required to construct toe berm.	Medium potential for temporary traffic disruption resulting from installation of the reinforcement.

TABLE 1 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
OLD MONTREAL ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope Not Moving Toe	3) Regrade Slope Moving Toe	4), 5) External Toe Berm	6) Slope Reinforcement
Financial Assessment Group					
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Medium cost for implementation from a geotechnical perspective	Low cost for implementation from a geotechnical perspective	Low cost for implementation from a geotechnical perspective	Very high cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. High potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.

TABLE 2
EVALUATION OF STABILIZATION ALTERNATIVES
WATTERS ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 2.5H to 1 V	4) External Toe Berm with Slope Regrading	5) Slope Reinforcement with Slope Regrading
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded to 2 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands (not applicable at Section 'B-B').	The existing slope would be regraded to 2.5 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would be moved into Cardinal Creek and the crest of the slope would be moved into the table lands. Realignment of Cardinal Creek (surface channel) would be required to accommodate the regrading (not applicable at Section 'B-B').	An external toe buttress constructed of imported crushed rock (blast rock) would be constructed at the toe of the existing slope. The upper portion of the slope would be regraded to 2.5 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The lower portion of the existing slope would be reinforced with engineered fill and plastic/steel grid reinforcement by removing (excavating) material from the slope. The upper portion of the slope would be regraded at about 2.5 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands (not applicable at Section 'B-B').
Technical Assessment Group					
Potential for improved safety of slope.	The current factor of safety is 1.0. for Section A-A. The 'Do Nothing' alternative does not improve the factor of safety.	Moderate potential for improving the factor of safety at Section A-A. FOS increases from 1.0 to 1.3.	High potential for improving the FOS at Section A-A, with an increase from 1.0 to 1.5.	High potential for improving the FOS, with an increase from 1.0 to 1.5.	High potential for improving the FOS at Section A-A, with an increase from 1.0 to greater than 1.5.

TABLE 2 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
WATTERS ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 2.5H to 1 V	4) External Toe Berm with Slope Regrading	5) Slope Reinforcement with Slope Regrading
Technical Assessment Group - Continued					
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope	High potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	Low potential for future maintenance.	Low potential for future maintenance.	Low potential for future maintenance.
Natural Environment Assessment Group					
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in the event a slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Low potential for effects on the terrestrial environment following construction.	Low potential for effects on the terrestrial environment following construction.	Low potential for effects on the terrestrial environment following construction.
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the "Do Nothing" alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.

TABLE 2 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
WATTERS ROAD

Areas of Consideration/Criteria	Alternative				
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 2.5H to 1 V	4) External Toe Berm with Slope Regrading	5) Slope Reinforcement with Slope Regrading
Social Environmental Assessment Group					
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area as a result of continual toe erosion/slope failures. Medium potential for disturbance to Watters Road as a result of continual toe erosion/slope failure.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland and disturbance to Watters Road following construction due to the remaining risk for slope failure.	Loss of tableland area in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Watters Road following construction due to the remaining risk for slope failure.	Loss of tableland area in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Watters Road following construction due to the remaining risk for slope failure.	Loss of tableland area in order to construct remediation alternative. Low potential for long-term loss of additional tableland and disturbance to Watters Road following construction due to the remaining risk for slope failure.
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading and from import of materials required to construct toe berm.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading and from construction of the reinforcement.
Financial Assessment Group					
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Medium cost for implementation from a geotechnical perspective	Low cost for implementation from a geotechnical perspective	Medium cost for implementation from a geotechnical perspective	High cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.	No annual operating costs. Low potential for maintenance costs.

TABLE 3
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 8

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded to 2 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded to 3 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded with benches by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	An external toe buttress constructed of imported crushed rock (blast rock) would be constructed at the toe of the existing slope. Realignment of Cardinal Creek would be required to accommodate the external toe buttress.	Dewatering would be achieved through a series of near horizontal, perforated plastic drains that are installed through the face of the slope using hand held or small track mounted equipment. A small toe berm would be required where the toe of the slope is undercut.
Technical Assessment Group						
Potential for improved safety of slope.	The current factor of safety is 0.9 to 1.3.. The 'Do Nothing' alternative does not improve the factor of safety.	Low potential for improving the factor of safety. FOS increases to between 1.0 and 1.7.	Moderate potential for improving the FOS, with an increase to between 1.3 and 2.2.	Moderate potential for improving the FOS, with an increase to between 1.3 and 1.9	Moderate potential for improving the FOS, with an increase to between 1.3 and 1.5.	High potential for improving the FOS, with an increase to between 1.3 and 1.5, depending on the amount of groundwater drawdown achieved. There remains a moderate potential for shallow localized sloughing.

TABLE 3 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 8

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Technical Assessment Group - Continued						
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	Moderate potential for constructability. Drainage installation on slopes has not been carried locally. Possible limited number of contractors willing to bid.
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope	High potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	High potential for future maintenance of the drains to ensure they are performing as intended. Furthermore, a groundwater monitoring program should be implemented to check performance of the drains
Natural Environment Assessment Group						
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in the event a slope failure.	High potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for surficial sloughing.

TABLE 3 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 8

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Natural Environment Assessment Group - Continued						
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the "Do Nothing" alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs along the toe of the slope in order to construct the toe berm.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs in order to construct the dewatering system.
Social Environmental Assessment Group						
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area as a result of continual toe erosion/slope failures.	Loss of tableland area in order to construct remediation alternative. High potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Medium potential for long-term disturbance to tableland area. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Low potential for long-term disturbance to tableland area. Will require temporary construction access through private property.

TABLE 3 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 8

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Social Environmental Assessment Group - Continued						
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from import of materials required to construct toe berm.	Low potential for temporary traffic disruption resulting from import of materials to install slope drains and granular fill along toe.
Financial Assessment Group						
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Low cost for implementation from a geotechnical perspective	High cost for implementation from a geotechnical perspective	Medium cost for implementation from a geotechnical perspective	Very low cost for implementation from a geotechnical perspective	Very high cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Medium potential for annual operating costs. High potential for maintenance costs.

TABLE 4
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 13

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded to 2 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe and crest of the slope would remain unaltered.	The existing slope would be regraded to 3 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded with benches by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	An external toe buttress constructed of imported crushed rock (blast rock) would be constructed at the toe of the existing slope. Realignment of Cardinal Creek would be required to accommodate the external toe buttress.	Dewatering would be achieved through a series of near horizontal, perforated plastic drains that are installed through the face of the slope using hand held or small track mounted equipment. A small toe berm would be required where the toe of the slope is undercut.
Technical Assessment Group						
Potential for improved safety of slope.	The current factor of safety is 0.9 to 1.0. The 'Do Nothing' alternative does not improve the factor of safety.	Low potential for improving the factor of safety. FOS increases to 1.0.	Moderate potential for improving the FOS, with a FOS increase to 1.4.	Moderate potential for improving the FOS, with a FOS increase to between 1.3 and 1.4.	Moderate potential for improving the FOS, with a FOS increase to 1.3.	High potential for improving the FOS, with an increase to between 1.3 and 1.5, depending on the amount of groundwater drawdown achieved. There remains a moderate potential for shallow localized sloughing.

TABLE 4 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 13

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Technical Assessment Group - Continued						
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	Moderate potential for constructability. Drainage installation on slopes has not been carried locally. Possible limited number of contractors willing to bid.
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope	High potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	High potential for future maintenance of the drains to ensure they are performing as intended. Furthermore, a groundwater monitoring program should be implemented to check performance of the drains
Natural Environment Assessment Group						
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees in the event a slope failure.	High potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for surficial sloughing.

TABLE 4 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 13

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Natural Environment Assessment Group - Continued						
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the “Do Nothing” alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs along the toe of the slope in order to construct the toe berm.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs in order to construct the dewatering system.
Social Environmental Assessment Group						
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area and disturbance to private property as a result of continual toe erosion/slope failures. Low potential	No loss of tableland in order to construct remediation alternative. High potential for long-term loss of tableland and disturbance to private property following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland and disturbance to private property following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland and disturbance to private property following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Medium potential for long-term disturbance to tableland area and disturbance to private property. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Low potential for long-term disturbance to tableland area and disturbance to private property. Will require temporary construction access through private property.

TABLE 4 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 13

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Social Environmental Assessment Group - Continued						
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Low potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from import of materials required to construct toe berm.	Low potential for temporary traffic disruption resulting from import of materials to install slope drains and granular fill along toe.
Financial Assessment Group						
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Low cost for implementation from a geotechnical perspective	High cost for implementation from a geotechnical perspective	Medium cost for implementation from a geotechnical perspective	Very low cost for implementation from a geotechnical perspective	High cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Medium potential for annual operating costs. High potential for maintenance costs.

TABLE 5
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 18

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded to 2 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands (applicable to Section 'A-A' only).	The existing slope would be regraded to 3 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded with benches by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	An external toe buttress constructed of imported crushed rock (blast rock) would be constructed at the toe of the existing slope. Realignment of Cardinal Creek would be required to accommodate the external toe buttress (applicable to Section 'A-A' only).	Dewatering would be achieved through a series of near horizontal, perforated plastic drains that are installed through the face of the slope using hand held or small track mounted equipment. A small toe berm would be required where the toe of the slope is undercut.
Technical Assessment Group						
Potential for improved safety of slope.	The current factor of safety is 1.1 and 1.0 at Sections 'A-A' and 'B-B', respectively. The 'Do Nothing' alternative does not improve the factor of safety.	Low potential for improving the factor of safety at Section 'A-A'.	Moderate potential for improving the FOS, with an increase from 1.0 to 1.2 at Section 'B-B'.	Moderate potential for improving the FOS, with an increase from 1.0 to 1.3 at Section 'B-B'.	Moderate to high potential for improving the factor of safety at Section 'A-A' only	High potential for improving the FOS, with an increase from 1.0 at Section 'B-B' to between 1.3 and 1.5, depending on the amount of groundwater drawdown achieved. There remains a moderate potential for shallow localized sloughing.

TABLE 5 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 18

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Technical Assessment Group - Continued						
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	Moderate potential for constructability. Drainage installation on slopes has not been carried locally. Possible limited number of contractors willing to bid.
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope	High potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	High potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	Medium potential for future maintenance. Occasional site visit to monitor slope.	High potential for future maintenance of the drains to ensure they are performing as intended. Furthermore, a groundwater monitoring program should be implemented to check performance of the drains

TABLE 5 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 18

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Natural Environment Assessment Group						
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees in the event of a slope failure.	High potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	High potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the “Do Nothing” alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees in order to construct the remediation option.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs along the toe of the slope in order to construct the toe berm.	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs in order to construct the dewatering system.

TABLE 5 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 18

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Social Environmental Assessment Group						
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area as a result of continual toe erosion/slope failures.	Loss of tableland area in order to construct remediation alternative. High potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. High potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Medium potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Medium potential for long-term disturbance to tableland area. Will require temporary construction access through private property.	No loss of tableland in order to construct remediation alternative. Low potential for long-term disturbance to tableland area. Will require temporary construction access through private property.
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Low potential for temporary traffic disruption resulting from import of materials required to construct toe berm.	Low potential for temporary traffic disruption resulting from import of materials to install slope drains and granular fill along toe.
Financial Assessment Group						
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Very low cost for implementation from a geotechnical perspective	Medium cost for implementation from a geotechnical perspective	Low cost for implementation from a geotechnical perspective	Very low cost for implementation from a geotechnical perspective	Very high cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. High potential for maintenance costs.	Low potential for annual operating costs. high potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Low potential for annual operating costs. Medium potential for maintenance costs.	Medium potential for annual operating costs. High potential for maintenance costs.

TABLE 6
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 19

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Description of Alternative	No improvement to the existing slope configuration. Ongoing monitoring will be carried out and remedial measures to correct a slope failure if required.	The existing slope would be regraded to 2 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe and crest of the slope would remain unaltered.	The existing slope would be regraded to 3 horizontal to 1 vertical by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	The existing slope would be regraded with benches by removing (excavating) material from the slope. The location of the toe of the slope would remain unaltered; however, the crest of the slope will be moved into the table lands.	Given the geometry of the existing slope, an external toe buttress is not an applicable stabilization alternative.	Dewatering would be achieved through a series of near horizontal, perforated plastic drains that are installed through the face of the slope using hand held or small track mounted equipment.
Technical Assessment Group						
Potential for improved safety of slope.	The current factor of safety is 0.9 for Section A-A. The 'Do Nothing' alternative does not improve the factor of safety.	Low potential for improving the factor of safety. FOS increases from 0.9 to 1.0.	High potential for improving the FOS, with an increase from 0.9 to 1.5.	Moderate potential for improving the FOS, with an increase from 0.9 to 1.4.	-	High potential for improving the FOS, with an increase from 0.9 to between 1.3 and 1.5, depending on the amount of groundwater drawdown achieved. There remains a moderate potential for shallow localized sloughing.
Constructability of slope remediation.	No infrastructure is required for the 'Do Nothing' approach.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	High potential for implementation involving conventional excavation and haulage equipment.	-	Moderate potential for constructability. Drainage installation on slopes has not been carried locally. Possible limited number of contractors willing to bid.

TABLE 6 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 19

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Technical Assessment Group - Continued						
Potential for future maintenance and monitoring.	High potential for future maintenance should the slope fail. Will require more frequent site visits to monitor slope.	High potential for future maintenance should the slope fail. Occasional site visit to monitor slope.	Low potential for future maintenance. Occasional site visit to monitor slope.	Low to medium potential for future maintenance. Occasional site visit to monitor slope.	-	High potential for future maintenance of the drains to ensure they are performing as intended. Furthermore, a groundwater monitoring program should be implemented to check performance of the drains
Natural Environment Assessment Group						
Potential for effects on the terrestrial environment.	High potential for effects on the terrestrial environment due to loss of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in the event a slope failure.	High potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	Low potential for effects on the terrestrial environment following construction.	Low to medium potential for effects on the terrestrial environment following construction due to the remaining risk for slope failure.	-	Medium potential for effects on the terrestrial environment following construction due to the remaining risk for surficial sloughing.

TABLE 6 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 19

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Natural Environment Assessment Group - Continued						
Potential for temporary construction related effects on the terrestrial environment.	No impacts as the "Do Nothing" alternative does not require construction.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	High potential for effects on the terrestrial environment due to removal of grasses, small to large shrubs, and a limited number of mature trees (i.e., less than 5) in order to construct the remediation option.	-	Medium potential for effects on the terrestrial environment due to localized removal of grasses and small to large shrubs in order to construct the dewatering system.
Social Environmental Assessment Group						
Potential for disturbing existing structures, farmland, etc. through temporary and/or permanent effects (i.e., construction noise, dust, traffic disruption, temporary and/or permanent loss of property, etc.)	High potential for long-term loss of additional tableland area as a result of continual toe erosion/slope failures.	High potential for long-term loss of tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Low potential for long-term loss of additional tableland. Will require temporary construction access through private property.	Loss of tableland area in order to construct remediation alternative. Low to medium potential for long-term loss of additional tableland following construction due to the remaining risk for slope failure. Will require temporary construction access through private property.	-	No loss of tableland in order to construct remediation alternative. Low potential for long-term disturbance to tableland area. Will require temporary construction access through private property.

TABLE 6 - CONTINUED
EVALUATION OF STABILIZATION ALTERNATIVES
AREA 19

Areas of Consideration/Criteria	Alternative					
	1) Do Nothing	2) Regrade Slope to 2H to 1V	3) Regrade Slope to 3H to 1 V	4) Slope Benching	5) External Toe Berm	6) Dewatering
Social Environmental Assessment Group - Continued						
Potential for traffic disruption	No impacts as the “Do Nothing” alternative does not require construction.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	Medium potential for temporary traffic disruption resulting from removal of excess soil during slope grading.	-	Low potential for temporary traffic disruption resulting from import of materials to install slope drains.
Financial Assessment Group						
Costs for implementation (i.e., capital costs)	No cost as “Do Nothing” alternative does not require construction.	Medium cost for implementation from a geotechnical perspective	High cost for implementation from a geotechnical perspective	Very low cost for implementation from a geotechnical perspective	-	Very high cost for implementation from a geotechnical perspective
Annual operating and maintenance costs	Medium annual operating costs. High potential for maintenance costs.	Low annual operating costs. High potential for maintenance costs.	Low annual operating costs. Low potential for maintenance costs.	Low annual operating costs. Low to medium potential for maintenance costs.	-	Medium potential for annual operating costs. High potential for maintenance costs.

APPENDIX A

OLD MONTREAL ROAD
LIST OF ABBREVIATIONS AND TERMINOLOGY
RECORD OF BOREHOLE SHEETS
AND FIGURES A1 to A18

LIST OF ABBREVIATIONS AND TERMINOLOGY

SAMPLE TYPES

AS auger sample
CS chunk sample
DO drive open
MS manual sample
RC rock core
ST slotted tube
TO thin-walled open Shelby tube
TP thin-walled piston Shelby tube
WS wash sample

PENETRATION RESISTANCE

Standard Penetration Resistance, N
The number of blows by a 63.5 kg hammer dropped 760 millimetres required to drive a 50 mm drive open sampler for a distance of 300 mm. For split spoon samples where less than 300 mm of penetration was achieved, the number of blows is reported over the sampler penetration in mm.

Dynamic Penetration Resistance
The number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter, 60^{o} cone attached to 'A' size drill rods for a distance of 300 mm.

WH
Sampler advanced by static weight of hammer and drill rods.

WR
Sampler advanced by static weight of drill rods.

PH
Sampler advanced by hydraulic pressure from drill rig.

PM
Sampler advanced by manual pressure.

SOIL TESTS

C consolidation test
H hydrometer analysis
M sieve analysis
MH sieve and hydrometer analysis
U unconfined compression test
Q undrained triaxial test
V field vane, undisturbed and remoulded shear strength

SOIL DESCRIPTIONS

Relative Density	'N' Value
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	over 50

Consistency	Undrained Shear Strength (kPa)
Very soft	0 to 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very Stiff	over 100

LIST OF COMMON SYMBOLS

c_u undrained shear strength
e void ratio
C_c compression index
c_v coefficient of consolidation
k coefficient of permeability
I_p plasticity index
n porosity
u pore pressure
w moisture content
w_L liquid limit
w_P plastic limit
ϕ^1 effective angle of friction
γ unit weight of soil
γ^1 unit weight of submerged soil
σ normal stress

RECORD OF BOREHOLE 101

PROJECT: 11-378
LOCATION: See Site Plan, Figure 1
BORING DATE: September 1, 2011

SHEET 1 OF 1
DATUM: Geodetic
SPT HAMMER: 63.5 kg; drop 0.76 m

BORING METHOD: Power Auger, 200 mm Diameter Hollow Stem

ROCK PROFILE

DESCRIPTION	ELEV. / DEPTH (m)
Ground Surface	60.91
Asphaltic concrete	0.15
Grey crushed sand and gravel, some silt (BASE/SUBBASE MATERIAL)	60.13 / 0.78
Stiff to very stiff, grey brown SILTY CLAY (Weathered Crust)	55.73 / 5.18
Very stiff, grey SILTY CLAY	48.11 / 12.80
Stiff, grey SILTY CLAY, some sand and gravel	47.35 / 13.56
Dense, grey silty sand, some gravel, trace clay with probable cobbles and boulders (GLACIAL TILL)	46.30 / 14.61
End of Borehole Auger Refusal	

SAMPLES

NUMBER	TYPE	BLOWS/0.3m
1	G.S.	
2	50 D.O.	8
3	50 D.O.	5
4	50 D.O.	6
5	50 D.O.	6
6	50 D.O.	6
7	50 D.O.	4
8	50 D.O.	2
9	50 D.O.	1
10	50 D.O.	2
11	50 D.O.	2
12	50 D.O.	1
13	50 D.O.	2
14	50 D.O.	1
15	50 D.O.	2
16	50 D.O.	6
17	50 D.O.	31
18	50 D.O.	>50 for 50 mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat. V - + Q - ● rem. V - ⊕ U - ○ : 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-7} 10^{-6} 10^{-5} 10^{-4}
WATER CONTENT, PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

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>>

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

PIEZOMETER OR STANDPIPE INSTALLATION

Asphalt coldpatch repair
Bentonite seal
Backfiled with soil cuttings
Bentonite seal
Filter sand
32 mm Diameter, 1.52 metres long well screen
Sand bedding
Bentonite seal
Backfilled with soil cuttings
Groundwater level at 4.86 metres below ground surface (elevation 56.05 metres, geodetic datum) on October 11, 2011

DEPTH SCALE
1 to 85

Houle Chevrier Engineering Ltd.

LOGGED: M.L.
CHECKED: [signature]

RECORD OF BOREHOLE 102

PROJECT: 11-378
LOCATION: See Site Plan, Figure 1
BORING DATE: September 22, 2011

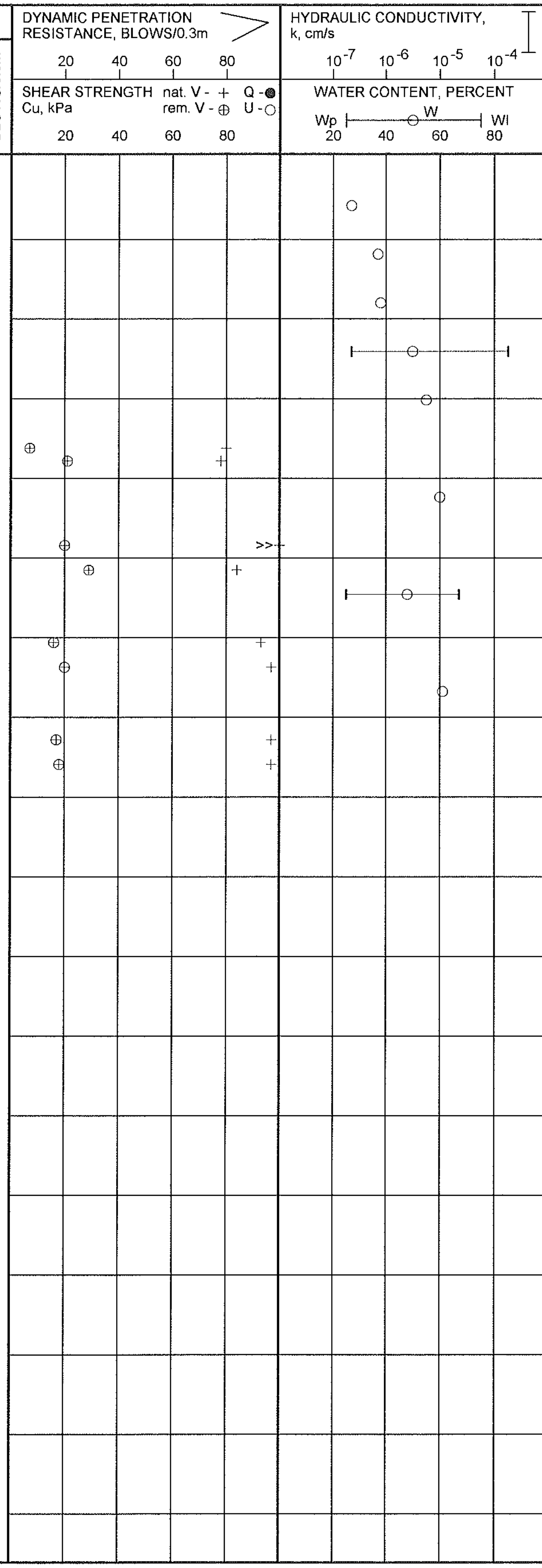
SHEET 1 OF 1
DATUM: Geodetic
SPT HAMMER: 21.2 kg; drop 0.76 m

BORING METHOD: Portable Drilling Equipment, Uncased

ROCK PROFILE – DESCRIPTION	ELEV. / DEPTH (m)
Ground Surface	55.73
Dark brown sandy silt, some clay, some gravel with organic material (Topsoil Fill)	55.53 / 0.20
Very stiff, grey brown silty clay, trace sand with organic material (FILL MATERIAL)	54.82 / 0.91
Very stiff to stiff, grey brown SILTY CLAY (Weathered Crust)	
Stiff to very stiff, grey SILTY CLAY	52.68 / 3.05
End of Borehole	48.41 / 7.32

Note: The penetration values have been corrected by dividing by a factor of 3.

SAMPLES – NUMBER	TYPE	BLOWS/0.3m
1	50 DO	12
2	50 DO	21
3	50 DO	13
4	50 DO	7
5	50 DO	4
6	50 DO	3
7	50 DO	5
8	50 DO	5



PIEZOMETER OR STANDPIPE INSTALLATION

Bentonite

Filter Sand

32mm Diameter, 1.52m length PVC Well Screen

Groundwater level at 2.82 metres below ground surface (elevation 52.91 metres, geodetic datum) on October 4, 2011

DEPTH SCALE 1 to 85

Houle Chevrier Engineering Ltd.

LOGGED: A.N.
CHECKED: JC

ROCK LOGS 2011 OLD MONTREAL.GPJ HCE DATA TEMPLATE.GDT 11/3/11

PROJECT: 11-378

RECORD OF BOREHOLE 103

SHEET 1 OF 1

LOCATION: See Site Plan, Figure 1

DATUM: Geodetic

BORING DATE: September 22, 2011

SPT HAMMER: 21.2 kg; drop 0.76 m

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
0	Portable Drilling Equipment, Uncased	Ground Surface	52.68				
		Grey brown silty clay with organic material (Topsoil)	52.45 / 0.23	1	50 DO	3	Bentonite
1		Stiff, grey SILTY CLAY		2	50 DO	3	Filter Sand
2				3	50 DO	4	
3				4	50 DO	4	32mm Diameter, 1.52m length PVC Well Screen
4		Grey silty sand, some gravel and clay (GLACIAL TILL)	48.59 / 4.09	5	50 DO	19	
		End of Borehole	4.26				
5		Note: The penetration values have been corrected by dividing by a factor of 3.					Groundwater level at 0.51 metres below ground surface (elevation 52.17 metres, geodetic datum) on October 4, 2011

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat. V - + Q - ● rem. V - ⊕ U - ○ (20 40 60 80)

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-7} 10^{-6} 10^{-5} 10^{-4}

WATER CONTENT, PERCENT: Wp W Wl (20 40 60 80)

ADDITIONAL LAB. TESTING

DEPTH SCALE 1 to 85

Houle Chevrier Engineering Ltd.

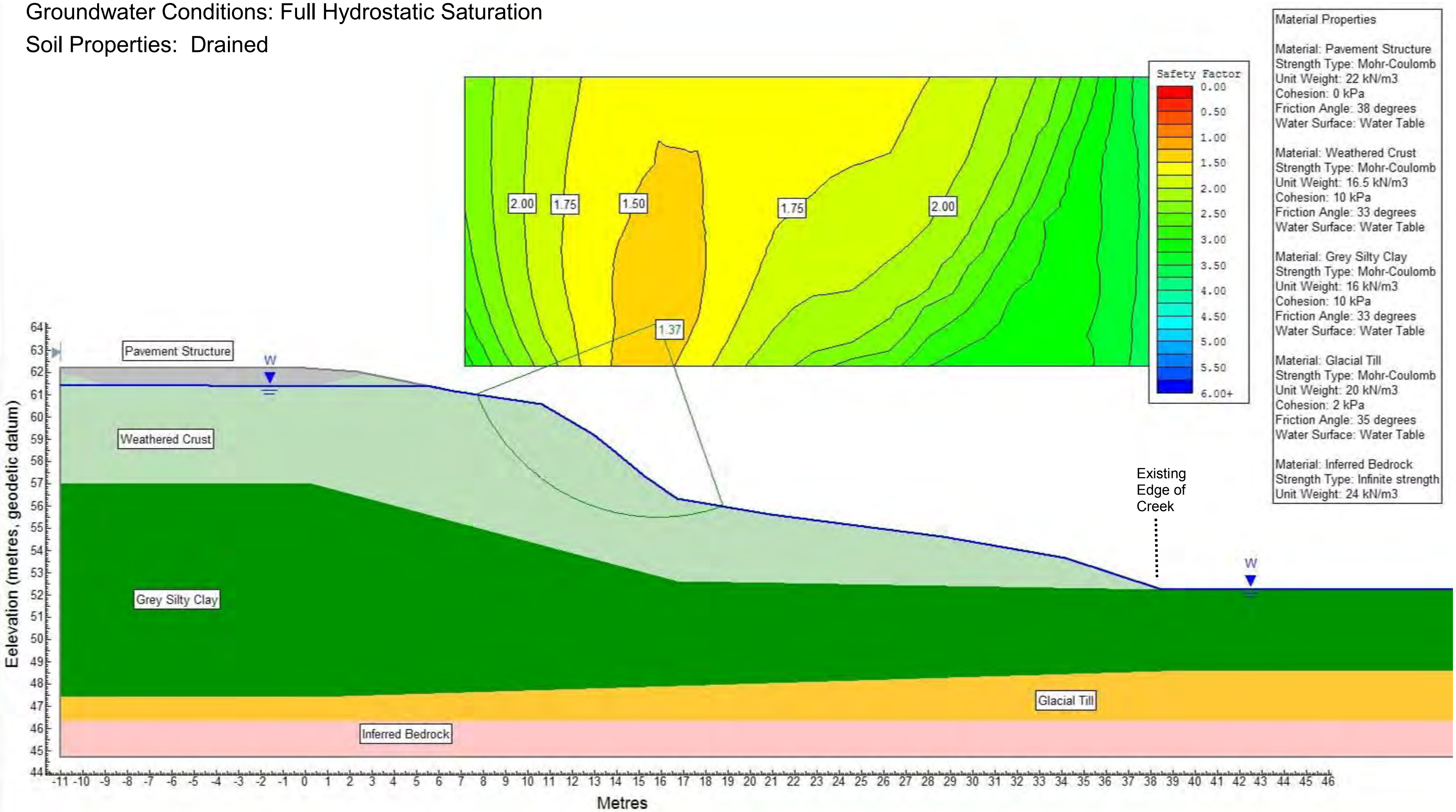
LOGGED: A.N.

CHECKED: [signature]

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION A-A
EXISTING CONDITIONS

FIGURE A1

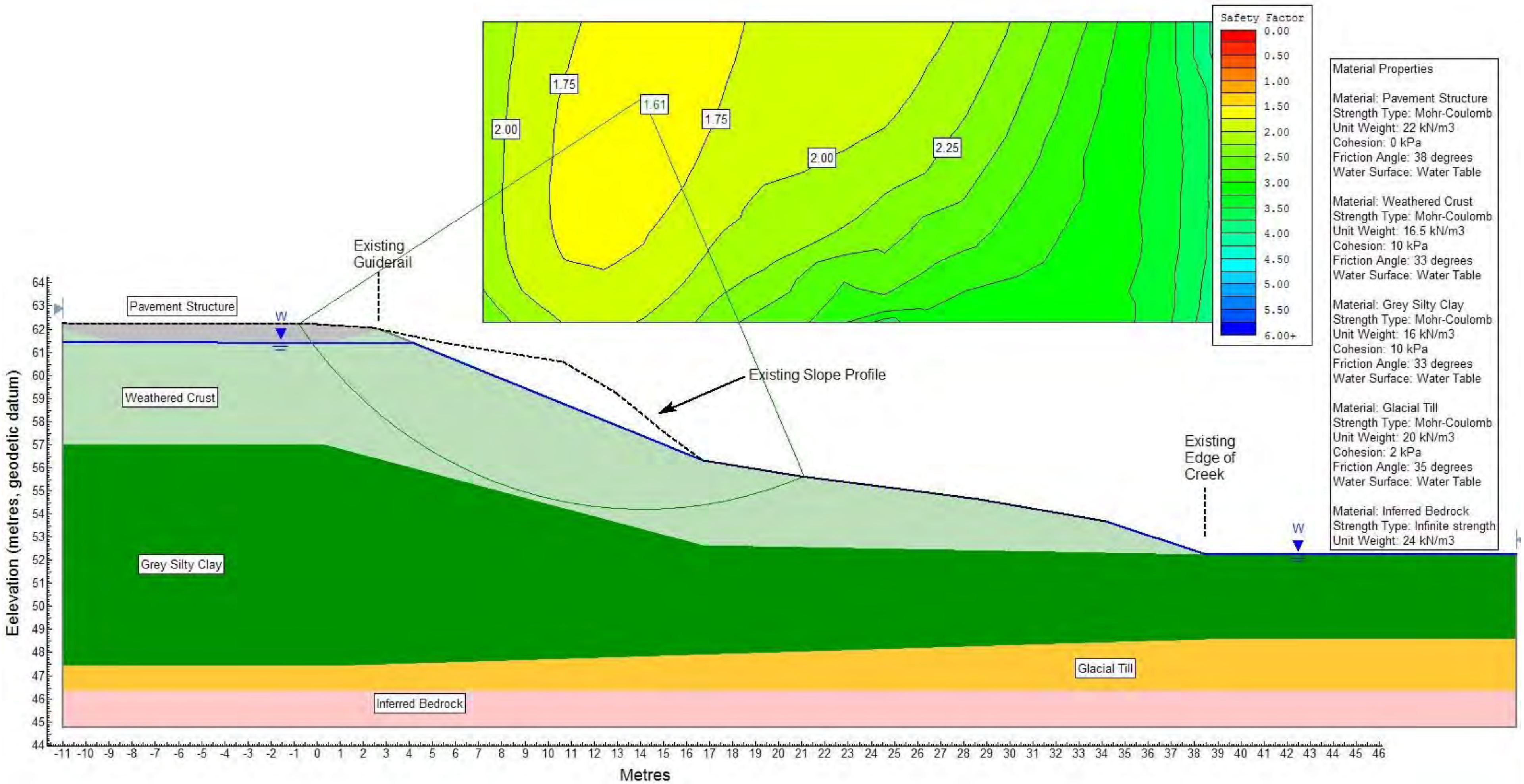
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION A-A
SLOPE REGRADING KEEPING EXISTING TOE LOCATION

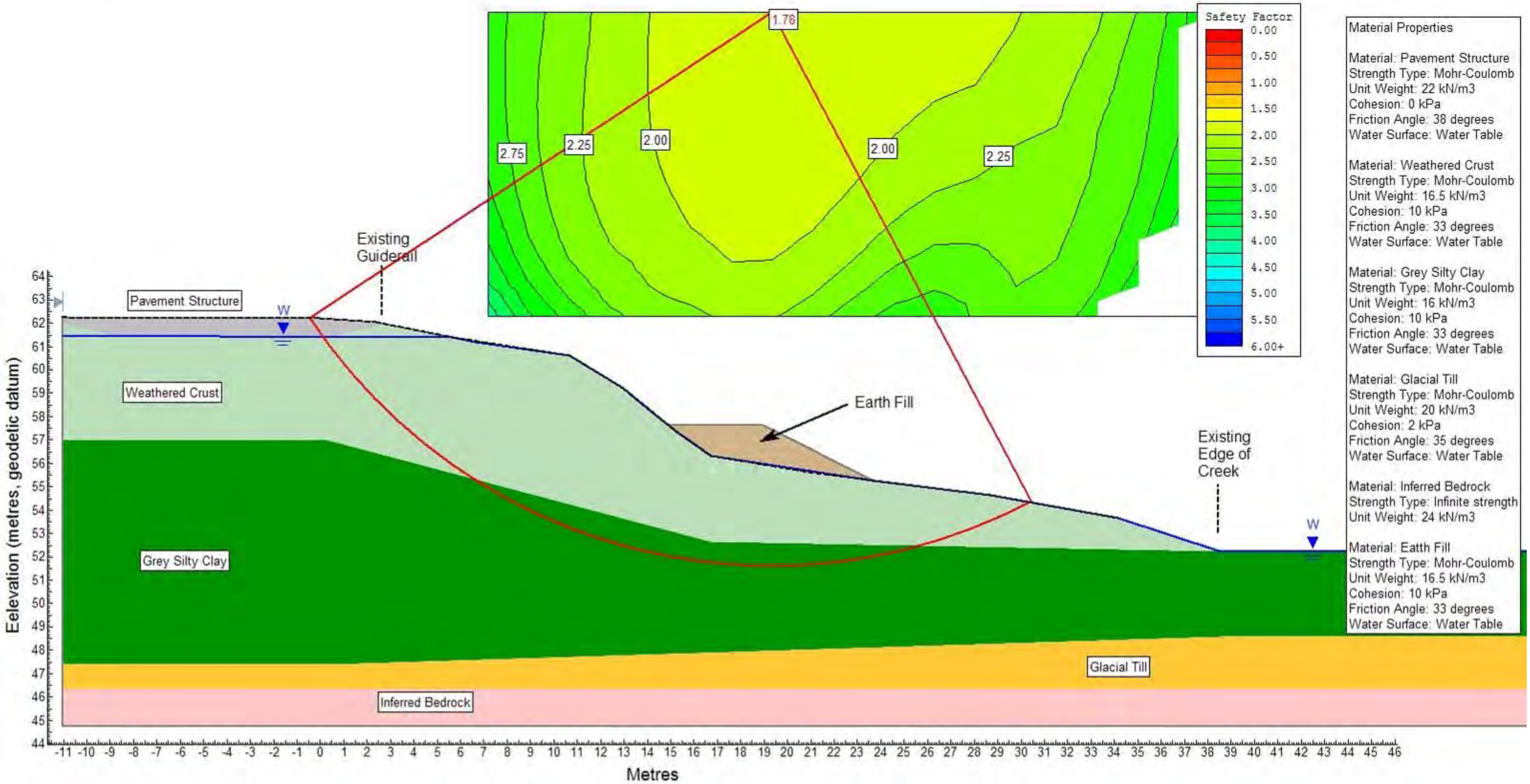
FIGURE A2

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Eatth Fill
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION A-A
EARTH FILL TOE BERM

FIGURE A3

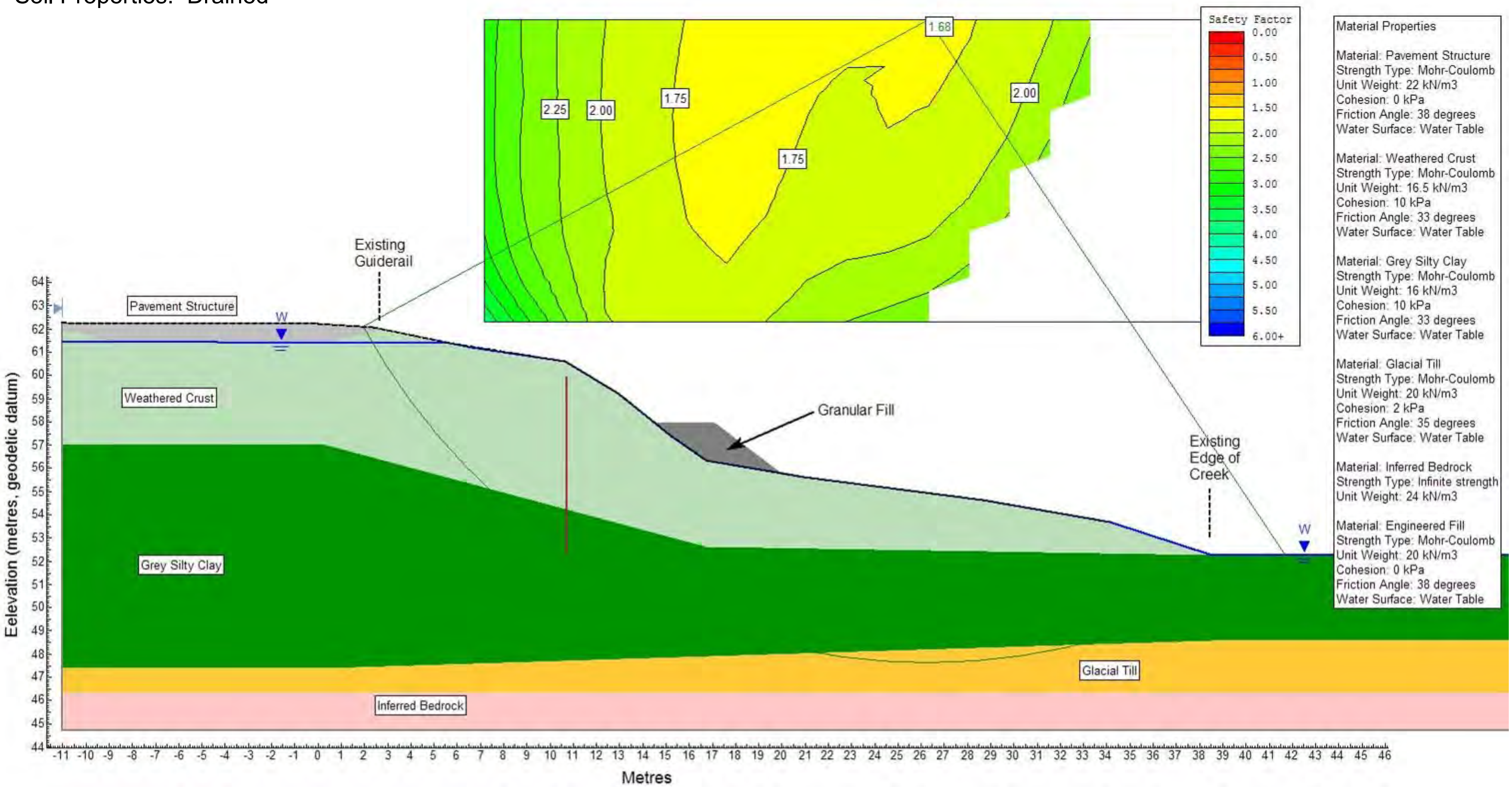
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Engineered Fill
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION A-A
ENGINEERED FILL TOE BERM

FIGURE A4

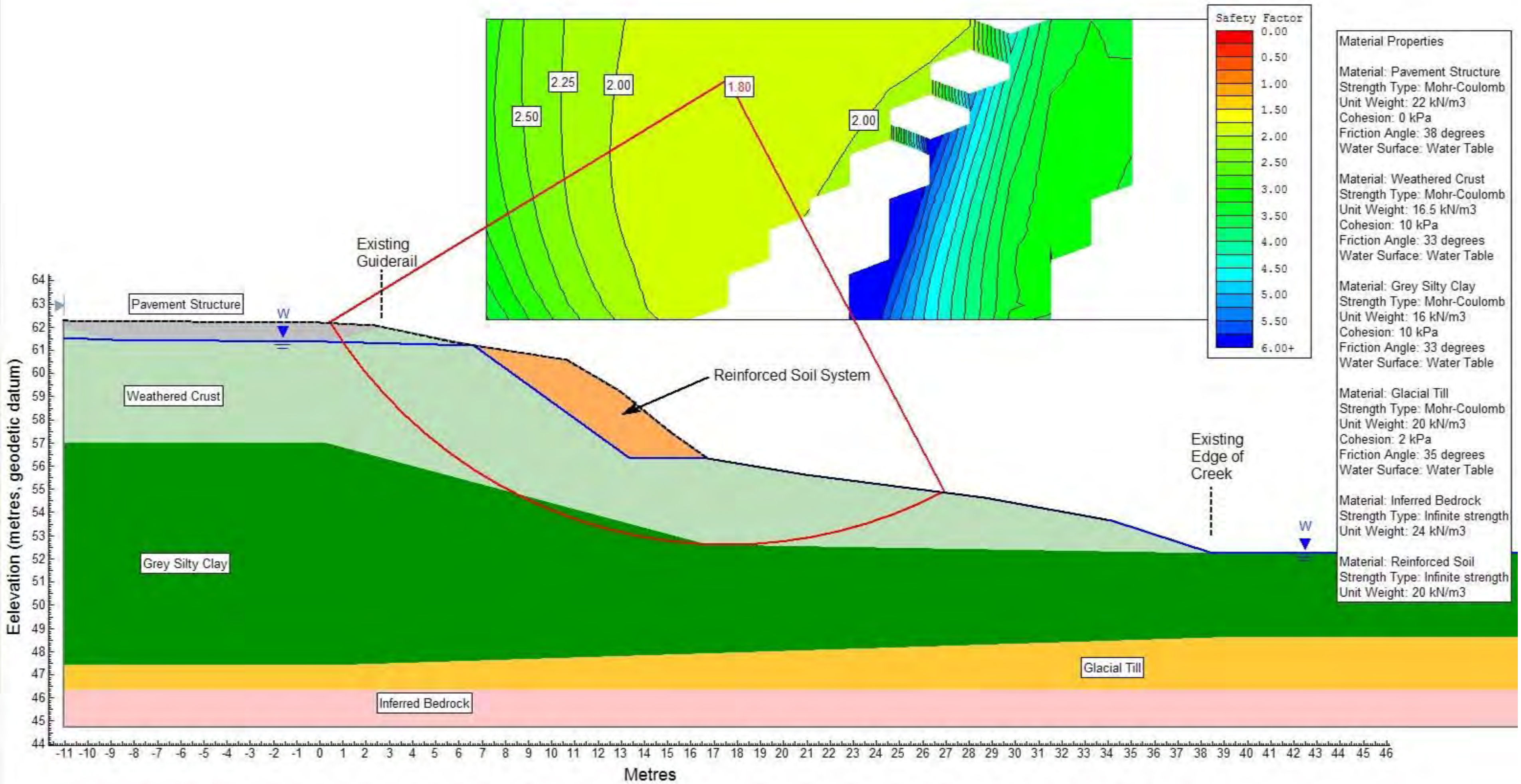
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION A-A
RETAINED SOIL SYSTEM

FIGURE A5

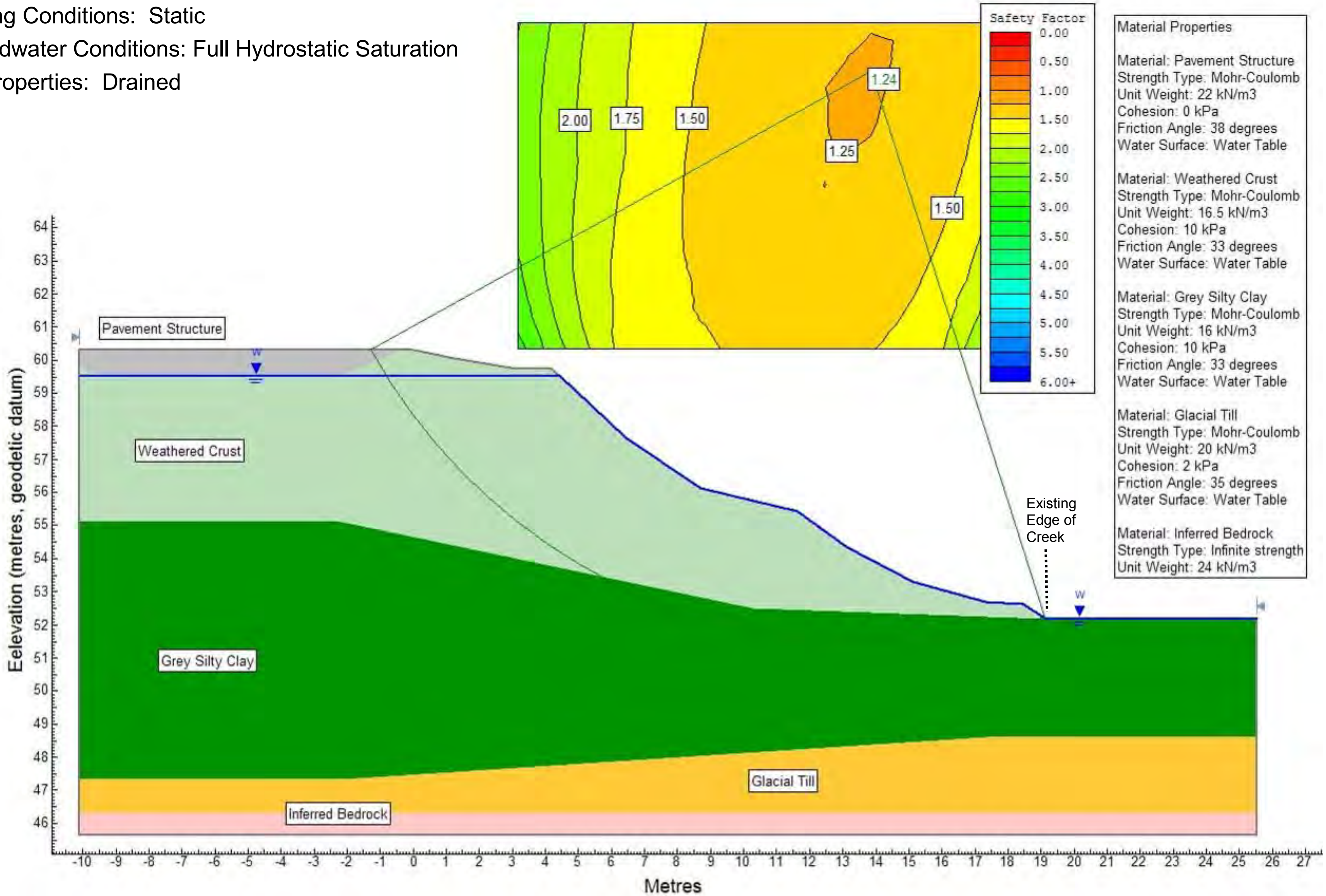
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION B-B
EXISTING CONDITIONS

FIGURE A6

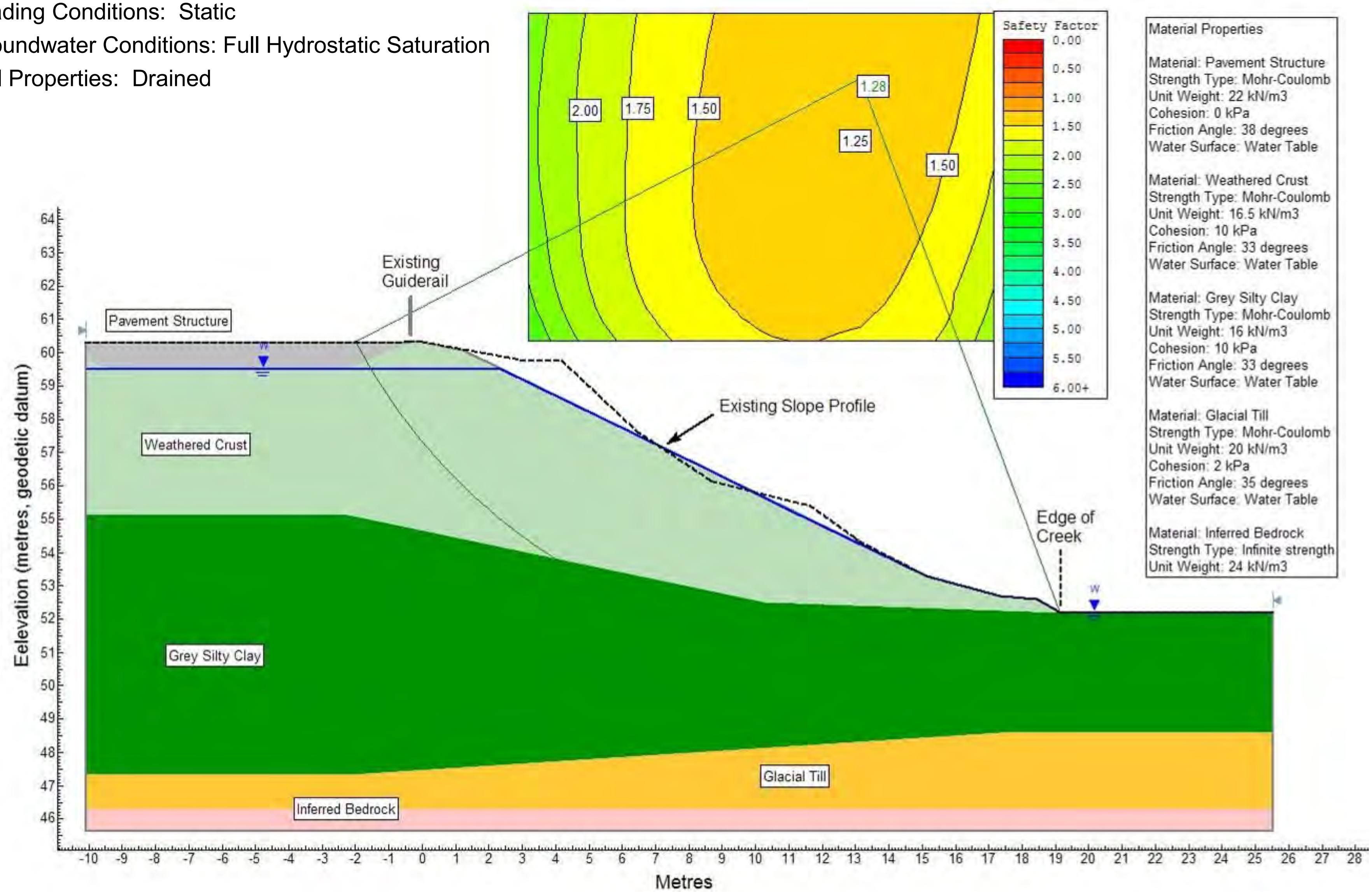
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained

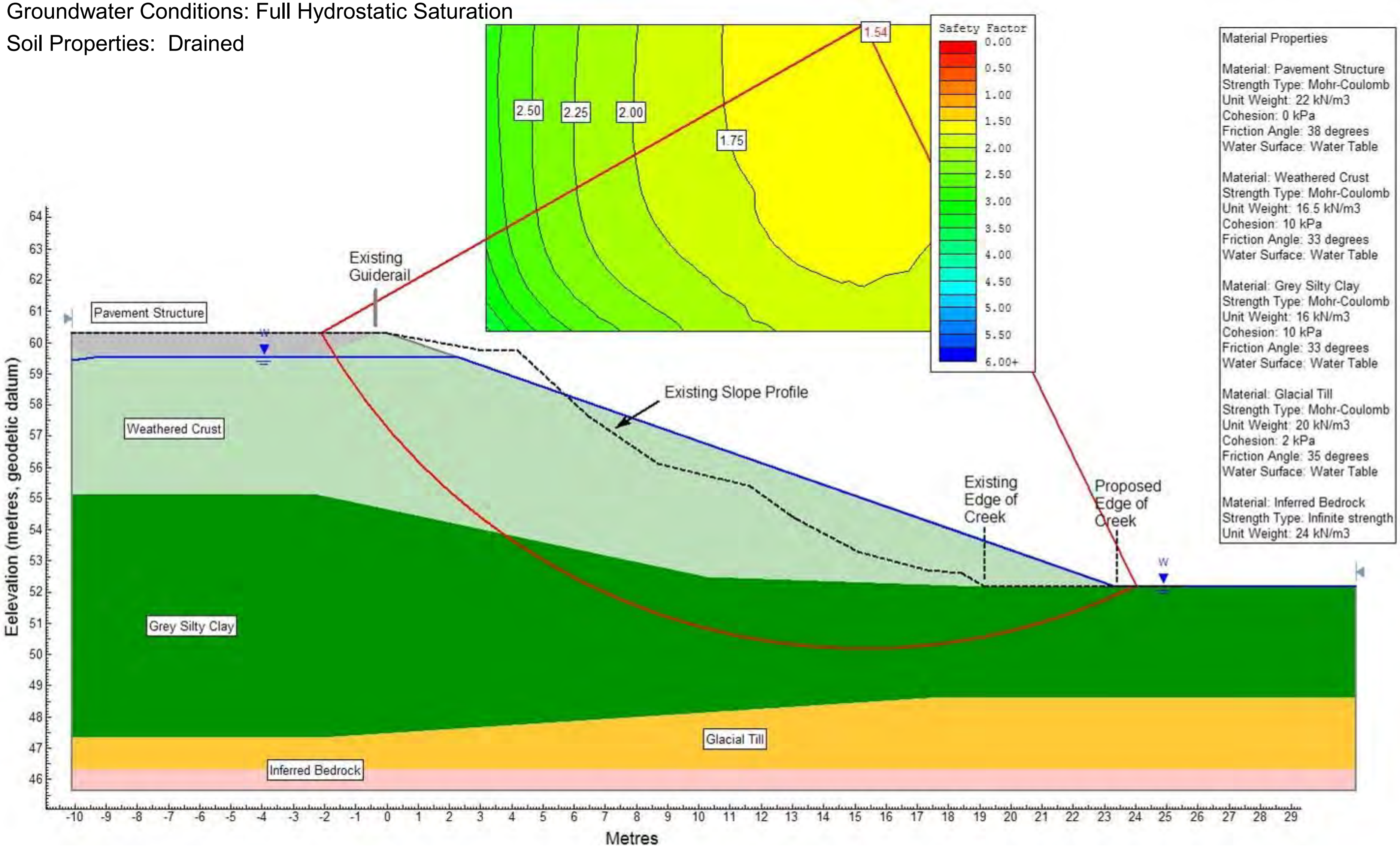


Houle Chevrier Engineering	R.R. 2 180 Wescar Lane Carp, Ontario K0A 1L0 info@hceng.ca (613) 836-1422 Fax: 836 9731	SLOPE STABILITY ANALYSIS OLD MONTREAL ROAD SECTION B-B SLOPE REGRADING MAINTAINING TOE LOCATION	FIGURE A7 PROJECT: 12-618 DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION B-B
SLOPE REGRADING MOVING TOE LOCATION

FIGURE A8

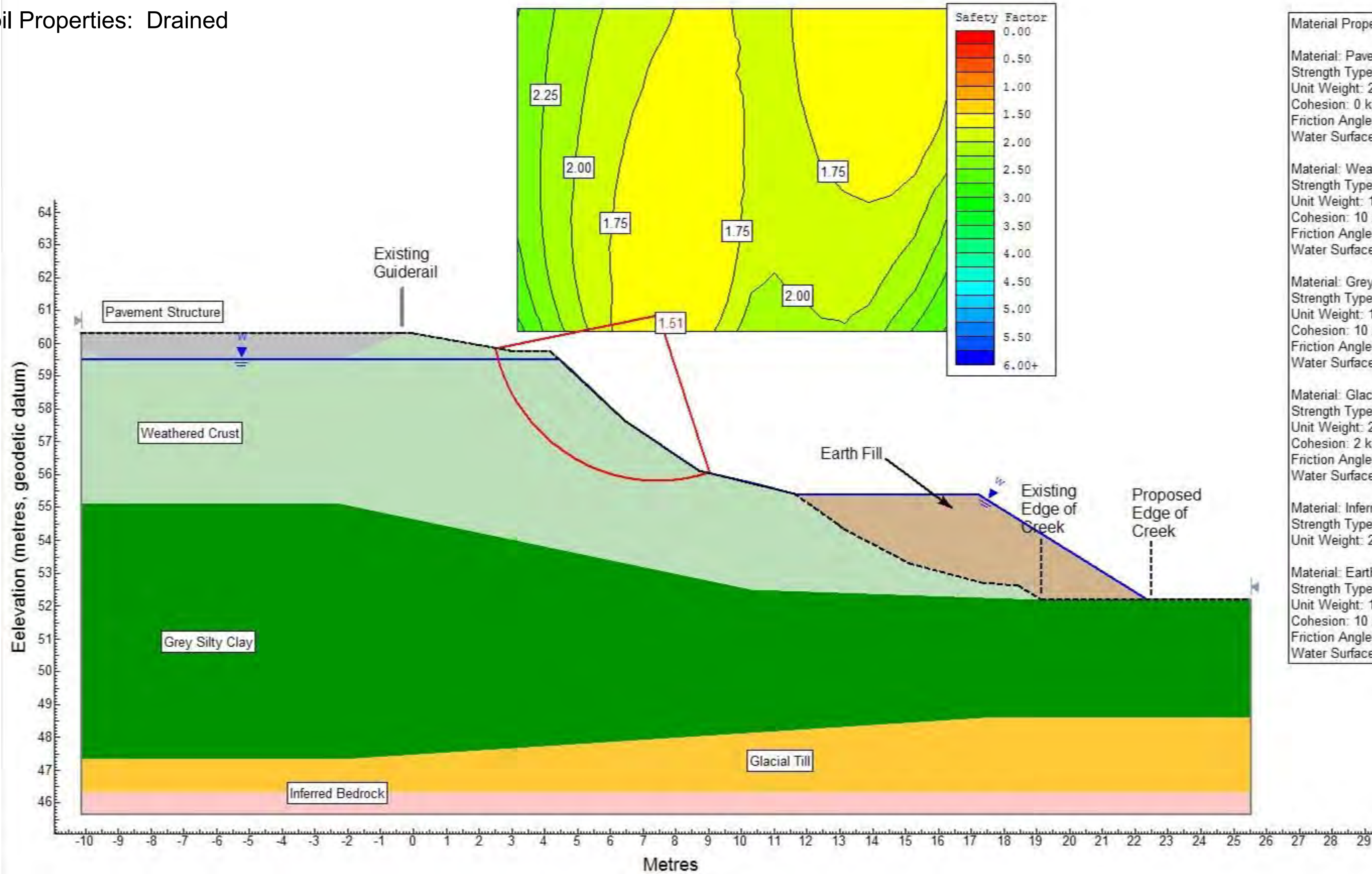
PROJECT: 12-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Earth Fill
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

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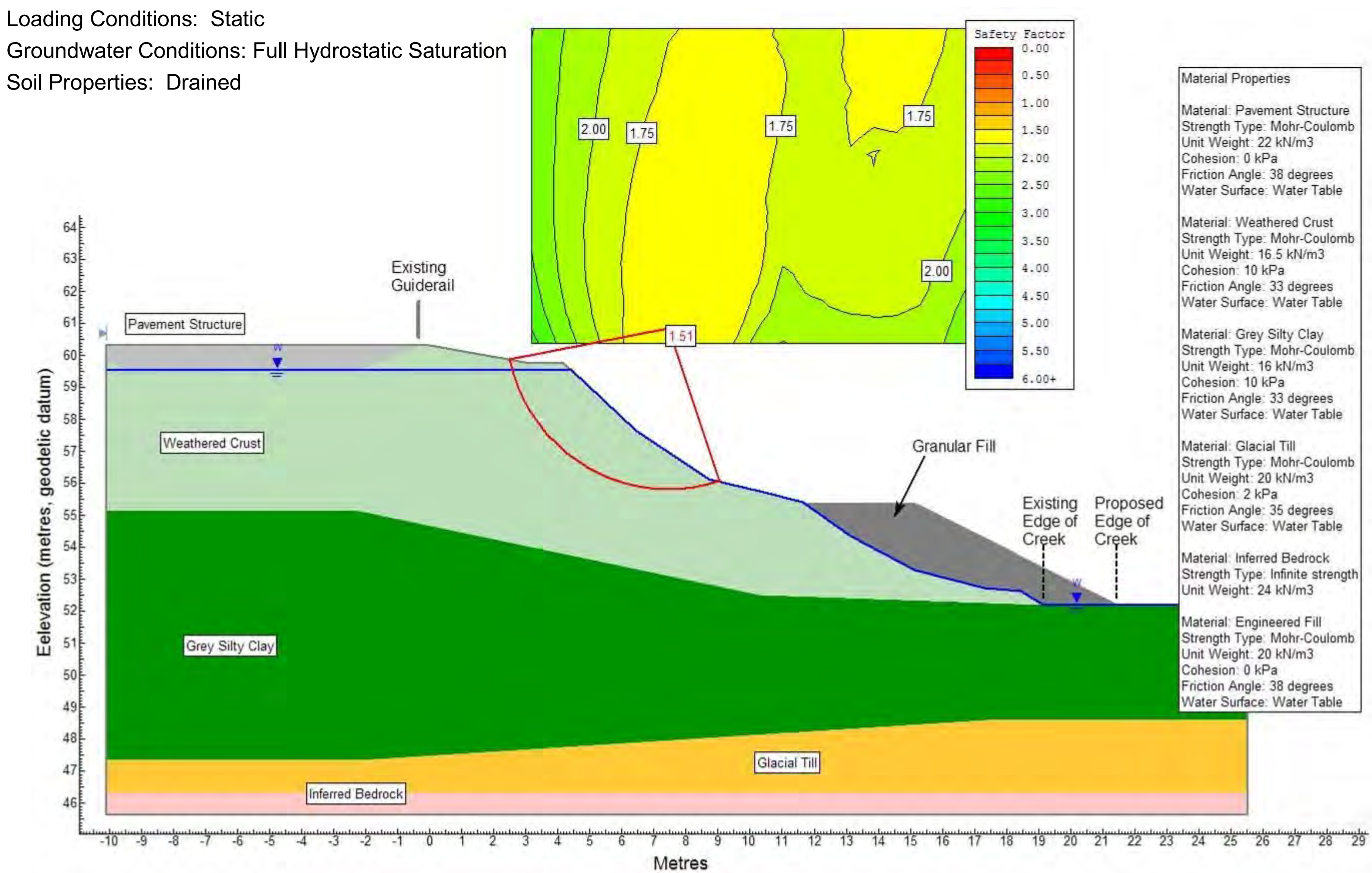
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION B-B
EARTH FILL TOE BERM

FIGURE A9

PROJECT: 12-618

DATE: June 2013



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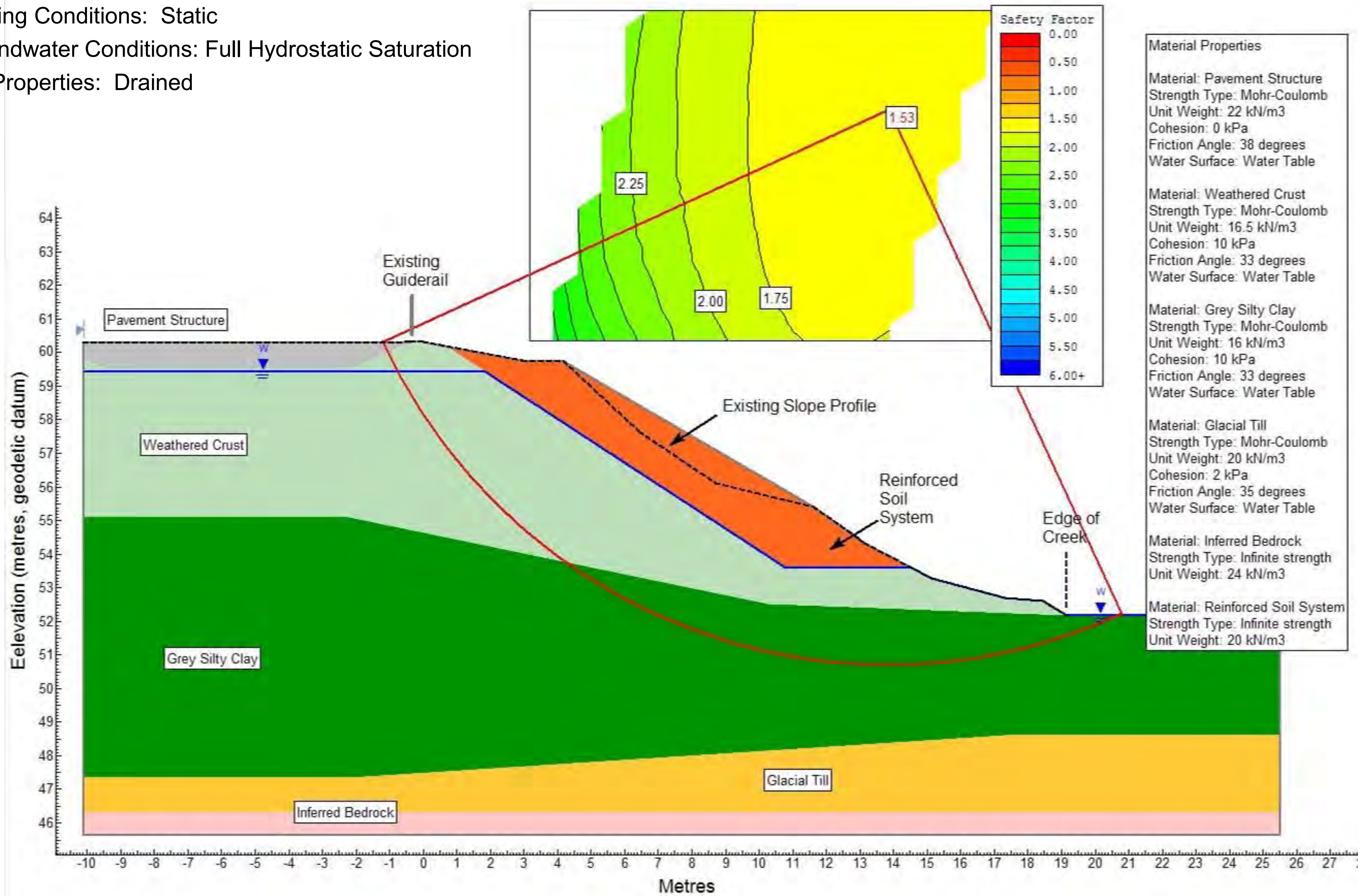
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION B-B
ENGINEERED FILL TOE BERM

FIGURE A10

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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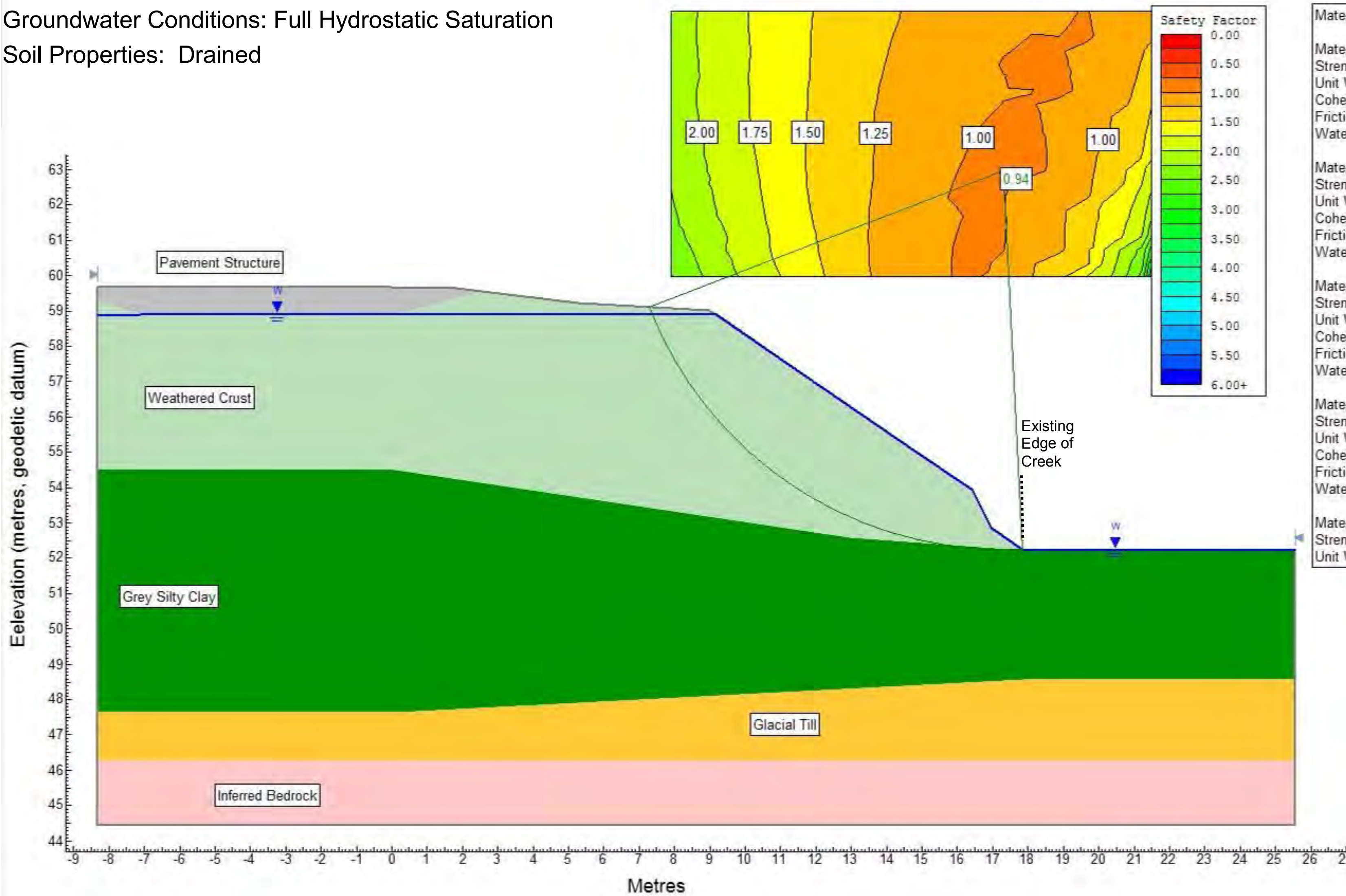
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION B-B
RETAINED SOIL SYSTEM

FIGURE A11

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

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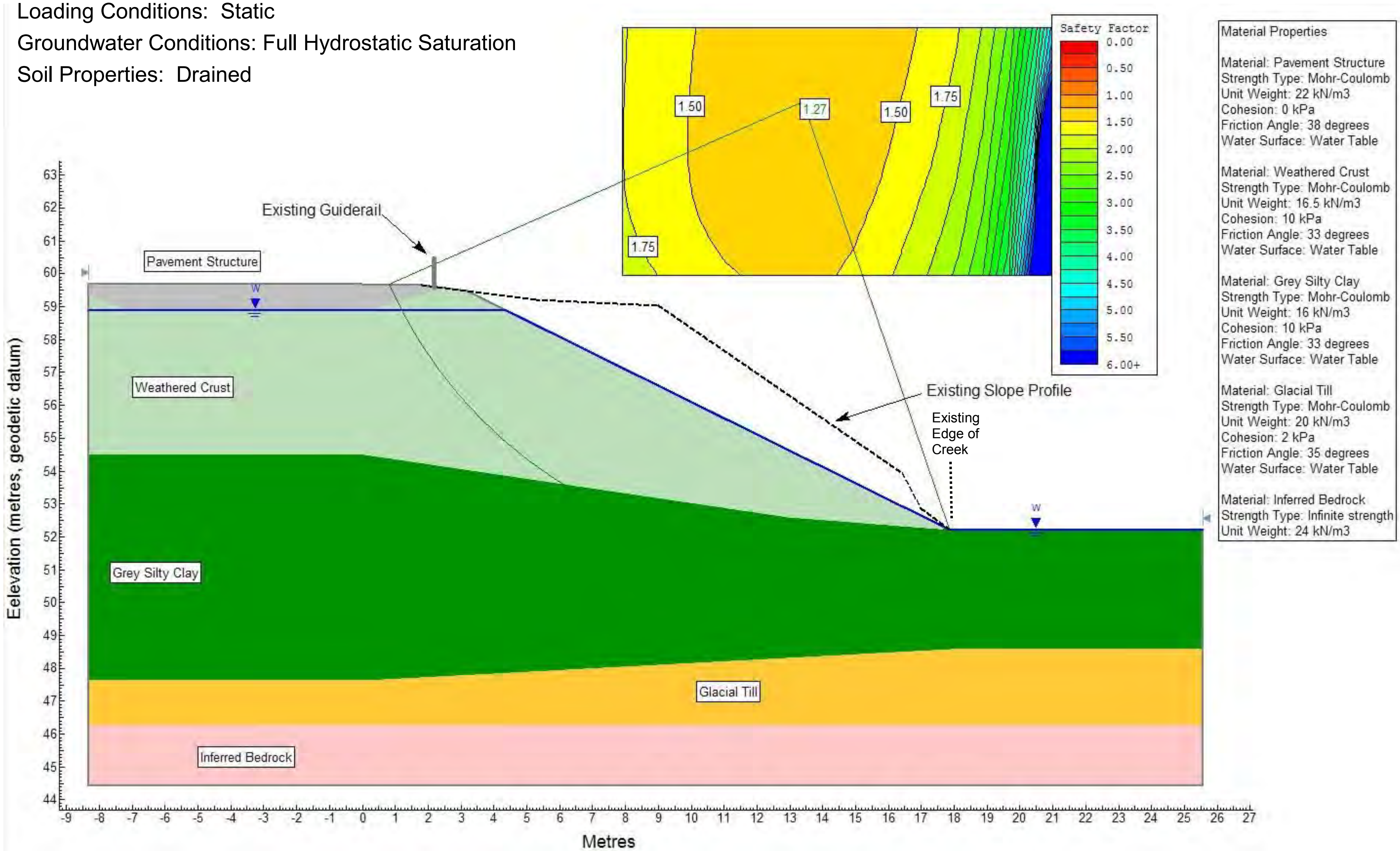
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
EXISTING CONDITIONS

FIGURE A12

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
SLOPE REGRADING MAINTAINING TOE LOCATION

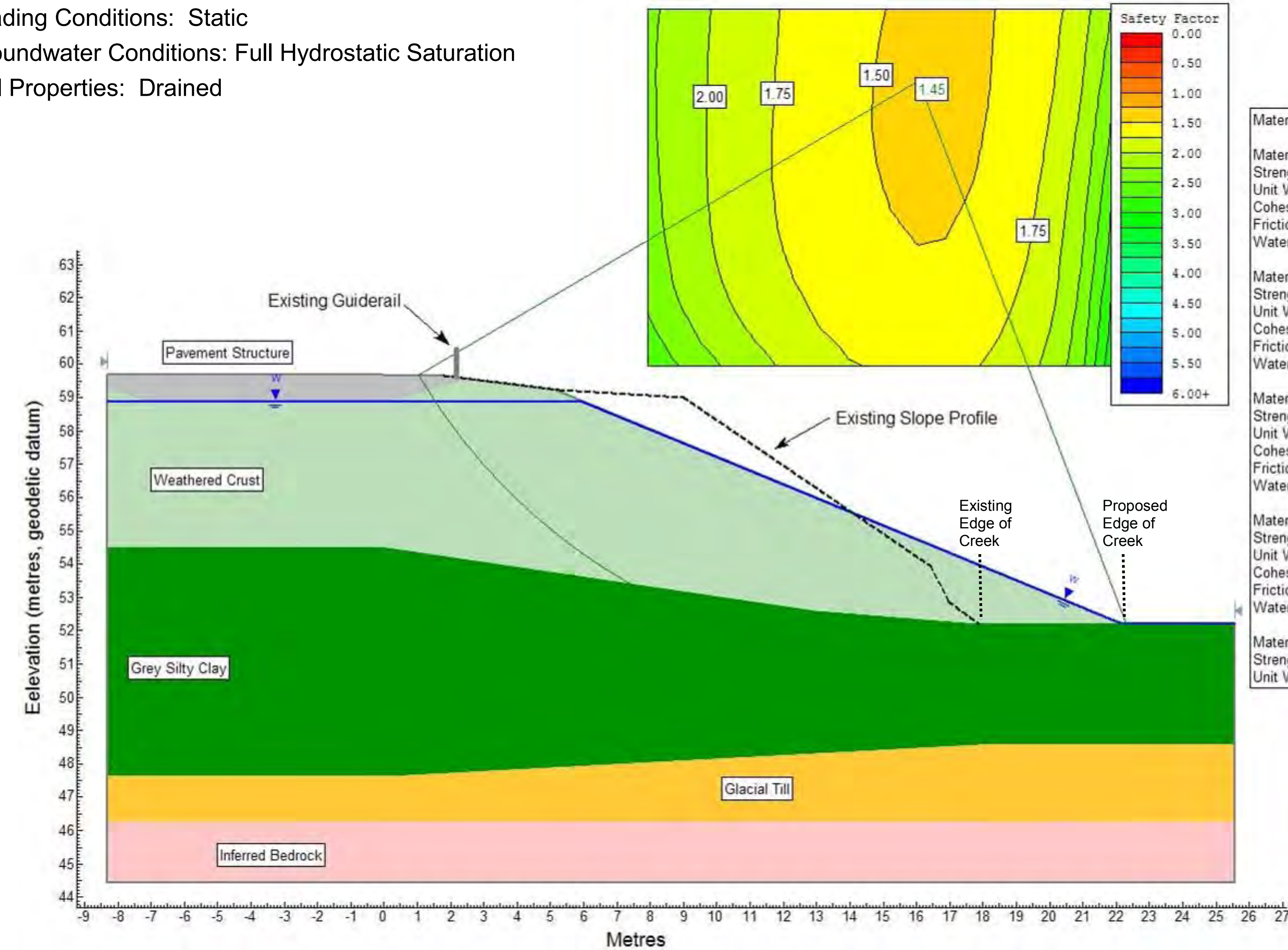
FIGURE A13

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

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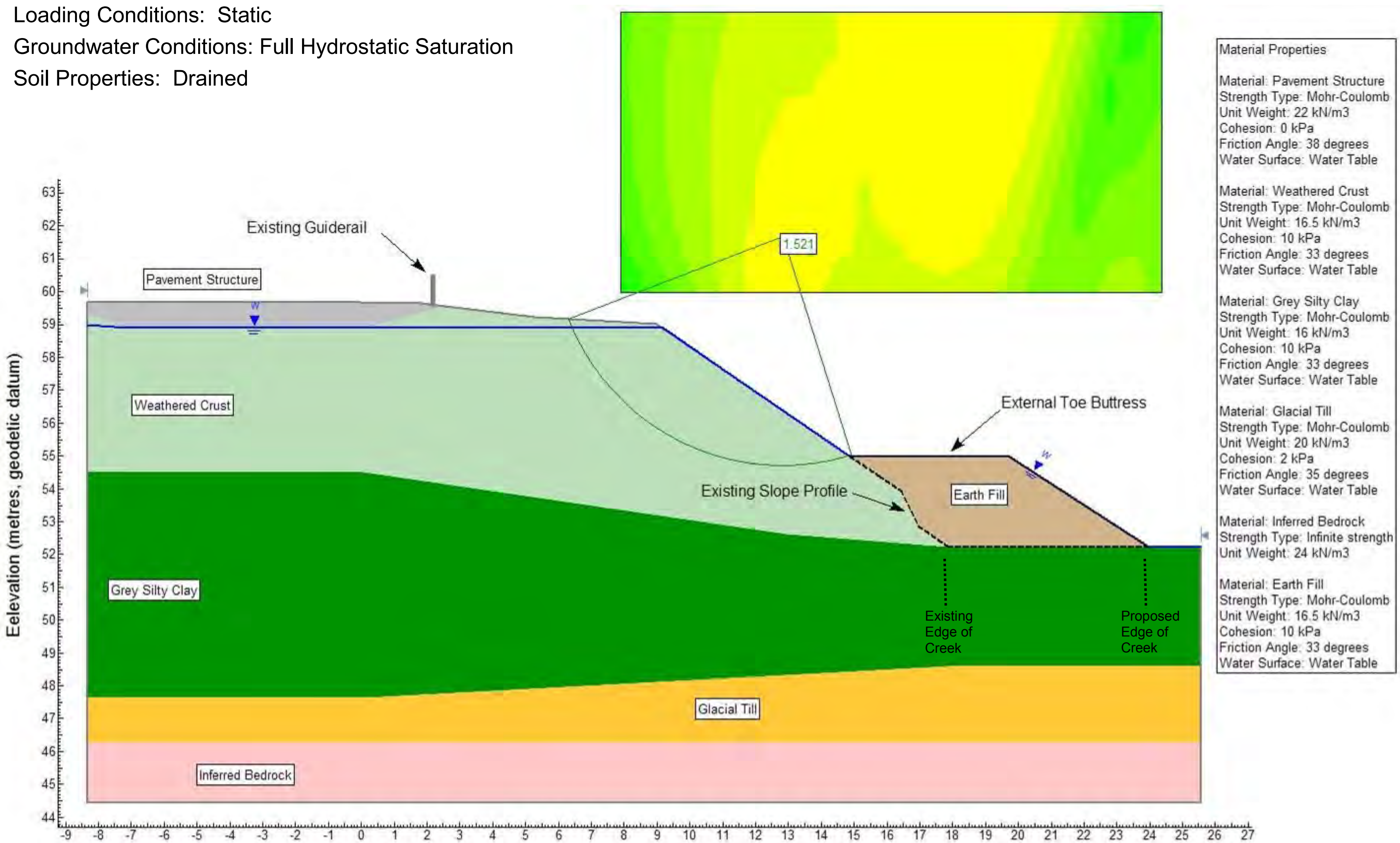
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
SLOPE REGRADING MOVING TOE LOCATION

FIGURE A14

PROJECT: 12-618

DATE: June 2013



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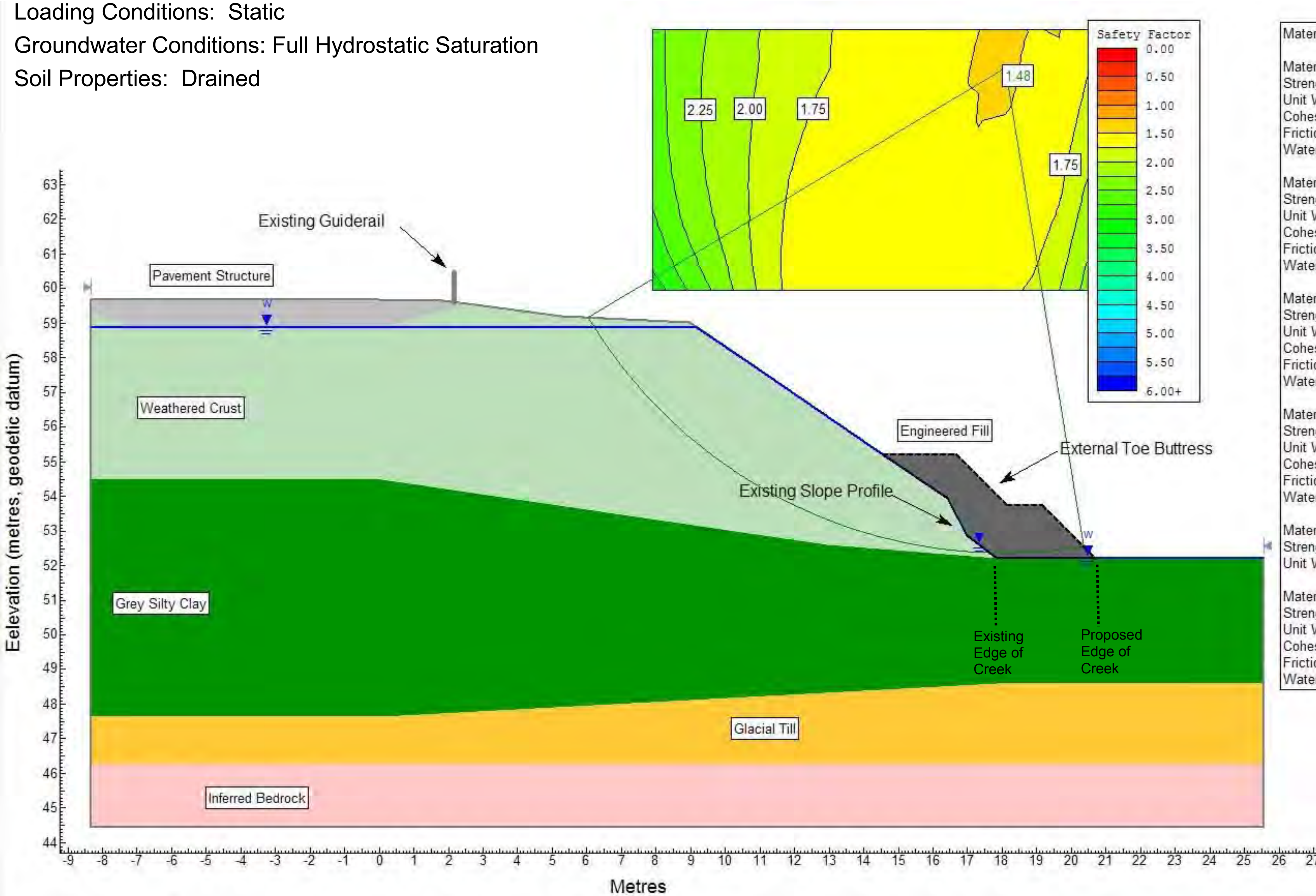
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
EARTH FILL BERM

FIGURE A15

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Engineered Fill
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

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SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
ENGINEERED FILL BERM

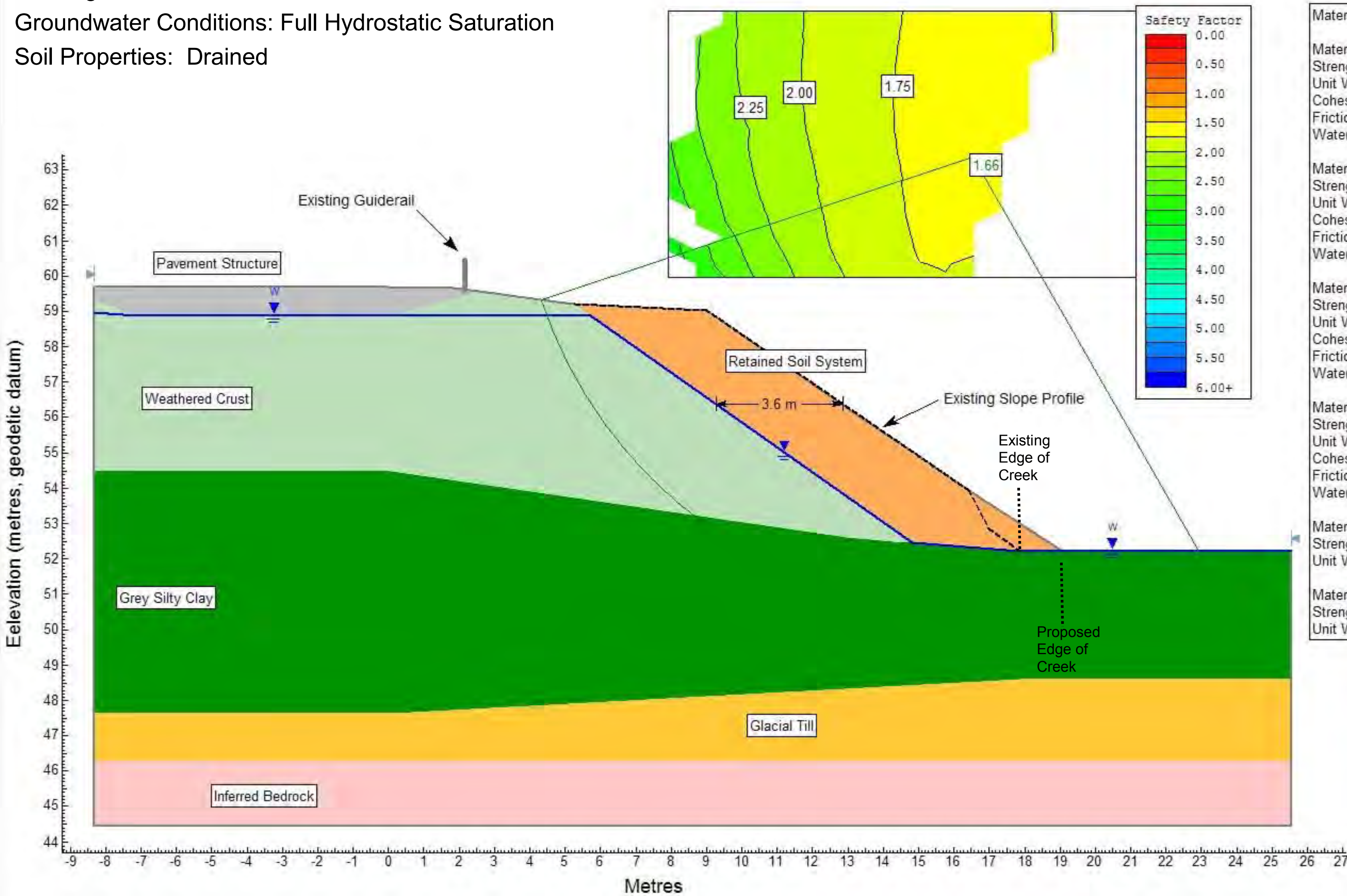
FIGURE A16

PROJECT: 12-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



Material Properties

Material: Pavement Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Grey Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Retained Soil System
Strength Type: Infinite strength
Unit Weight: 20 kN/m3

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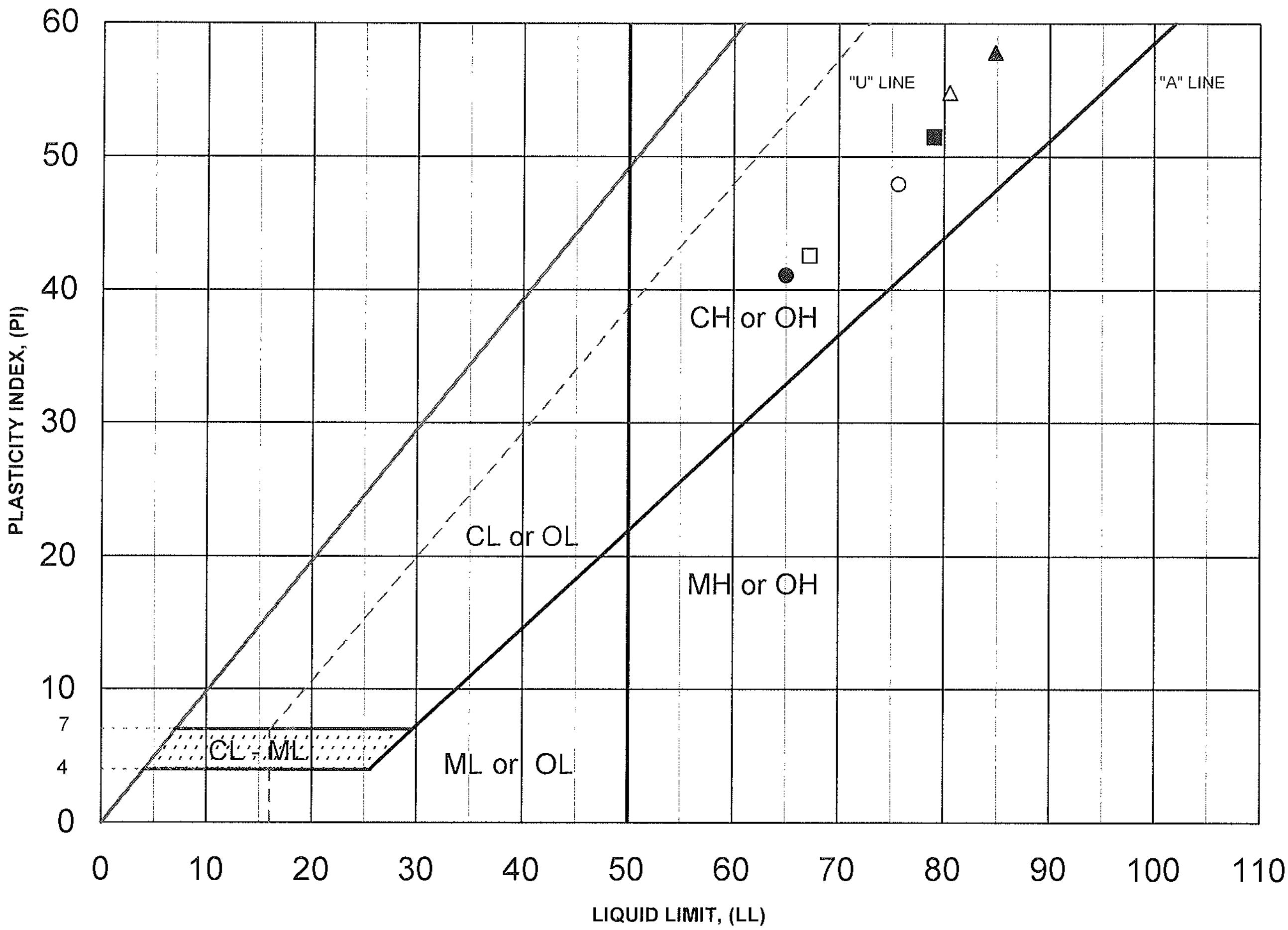
SLOPE STABILITY ANALYSIS
OLD MONTREAL ROAD
SECTION C-C
REINFORCED SOIL SYSTEM

FIGURE A17

PROJECT: 12-618

DATE: June 2013

PLASTICITY CHART	FIGURE A18



Bore Hole	Sample	Depth (m)	Legend	Moisture Content, %
101	5	3.05 - 3.66	△	47.4
101	9	6.10 - 6.71	■	57.0
101	12	9.14 - 9.75	○	64.4
102	4	1.83 - 2.44	▲	49.6
102	7	4.88 - 5.49	□	48.1
103	4	3.05 - 3.66	●	51.9

Houle Chevrier Engineering

Date: July 2012
Project: 11-378

APPENDIX B

WATTERS ROAD
RECORD OF BOREHOLE SHEETS
AND FIGURES B1 to B7

RECORD OF BOREHOLE 201

PROJECT: 11-378
LOCATION: See Site Plan, Figure 1
BORING DATE: September 2, 2011

SHEET 1 OF 1
DATUM: Geodetic
SPT HAMMER: 63.5 kg; drop 0.76 m

BORING METHOD: Power Auger, 200 mm Diameter Hollow Stem

DEPTH (m)	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
0	Ground Surface	83.02				
	Grey brown sand and gravel, some silt (BASE/SUBBASE MATERIAL)		1	G.S.		Coldpatch Asphalt repair
	Stiff, brown SILTY CLAY (Weathered Crust)	82.69 / 0.33				
1			2	50 D.O.	10	Bentonite seal
2			3	50 D.O.	14	Backfilled with soil cuttings
			4	50 D.O.	11	Bentonite seal
3			5	50 D.O.	7	Filter sand
4			6	50 D.O.	7	32 mm diameter, 1.52 metres long well screen
	Dense, grey brown silty sand, some gravel and clay with probable cobbles and boulders (GLACIAL TILL)	78.55 / 4.47	7	50 D.O.	38	Sand bedding
5			8	50 D.O.	>50 for 25 mm	Bentonite seal
	End of Borehole Auger Refusal	77.56 / 5.46				Well screen dry on November 7, 2011

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80)
SHEAR STRENGTH Cu, kPa: nat. V - + Q - ● rem. V - ⊕ U - ○ (20, 40, 60, 80)
HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-7}, 10^{-6}, 10^{-5}, 10^{-4})
WATER CONTENT, PERCENT: Wp ⊢—○ W —⊣ Wl (20, 40, 60, 80)
ADDITIONAL LAB. TESTING

PROJECT: 11-378

RECORD OF BOREHOLE 202

SHEET 1 OF 1

LOCATION: See Site Plan, Figure 1

DATUM: Geodetic

BORING DATE: September 22, 2011

SPT HAMMER: 21.2 kg; drop 0.76 m

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat. V - + Q - ● rem. V - ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-7} 10^{-6} 10^{-5} 10^{-4}); WATER CONTENT, PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Portable Drilling Equipment / Uncased	Ground Surface		77.81							
		Grey brown silty clay, some gravel with organic material (Topsoil)		77.58 0.23							Native Backfill
		Very stiff, grey brown SILTY CLAY, trace sand and gravel (Weathered Crust)			1	50 DO	11		○		
					2	50 DO	>50 for 100 mm		○		
1		End of Borehole Sampler Refusal Note: The penetration values have been corrected by dividing by a factor of 3.		76.95 0.86							Borehole dry upon completion
2											
3											
4											
5											
6											
7											
8											

DEPTH SCALE

1 to 40

Houle Chevrier Engineering Ltd.

LOGGED: A.N.

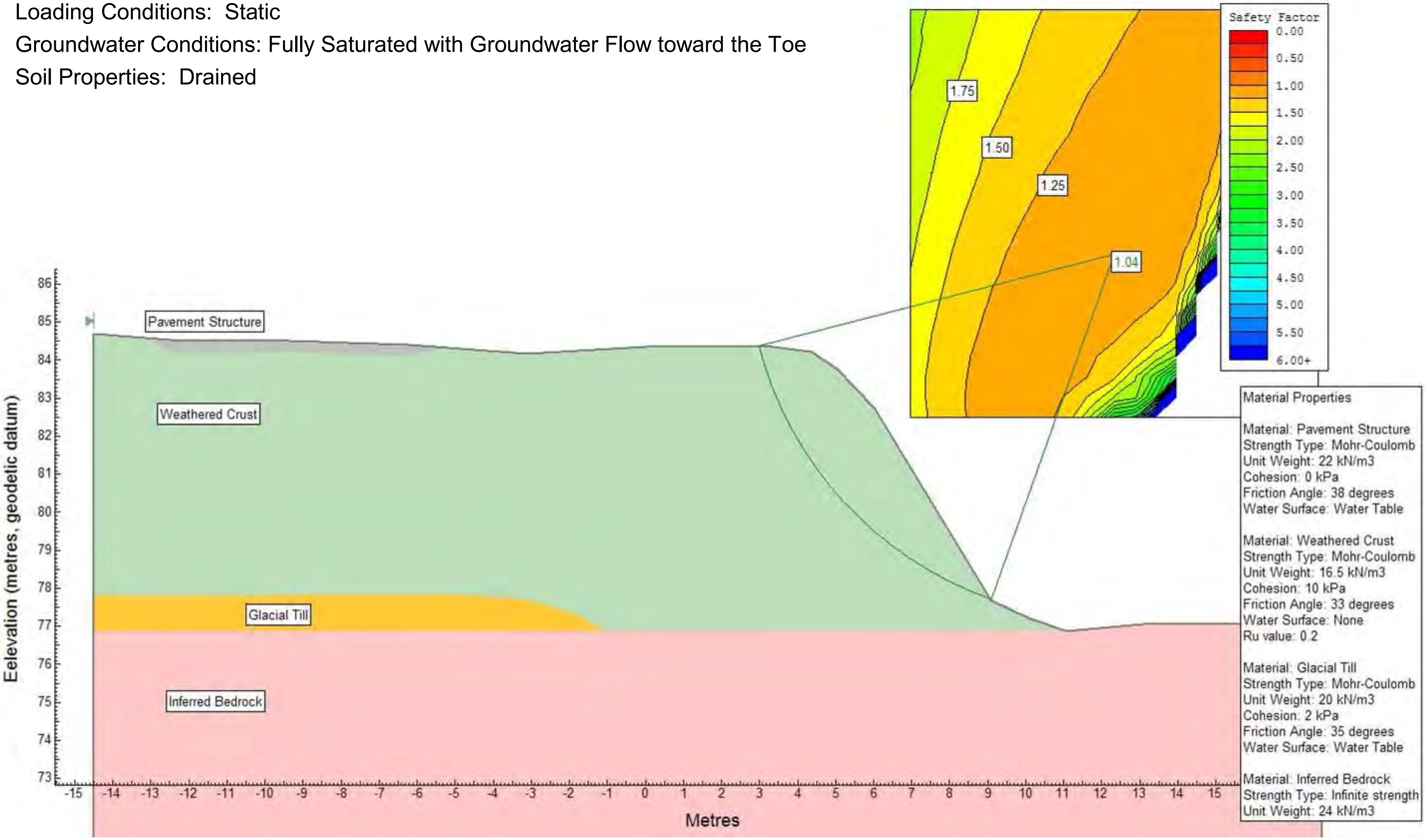
CHECKED: JC

ROCK LOGS 2011 WATTERS.GPJ HCE DATA TEMPLATE.GDT 11/14/11

Loading Conditions: Static

Groundwater Conditions: Fully Saturated with Groundwater Flow toward the Toe

Soil Properties: Drained



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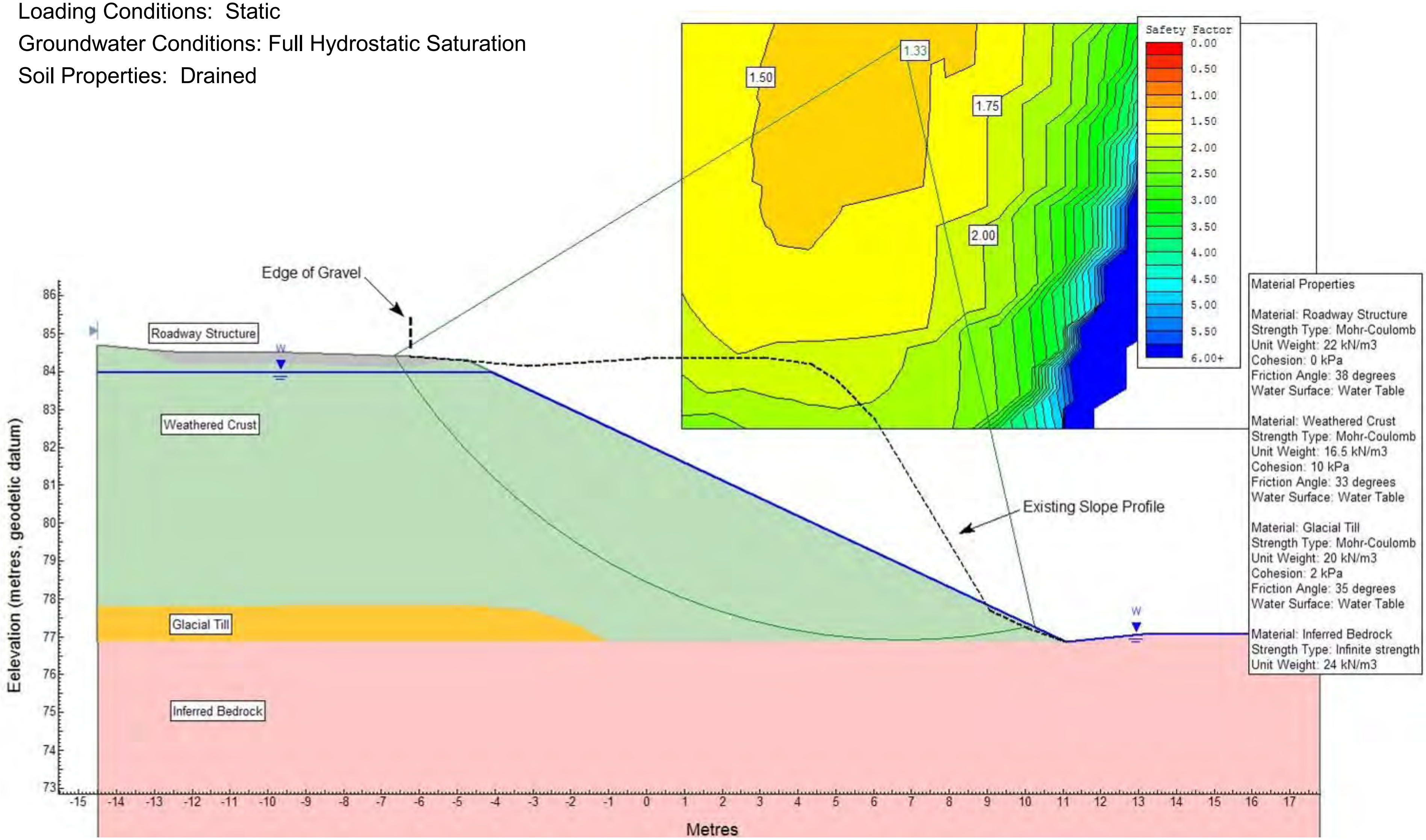
SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION A-A
EXISTING CONDITIONS

FIGURE B1

PROJECT: 11-378

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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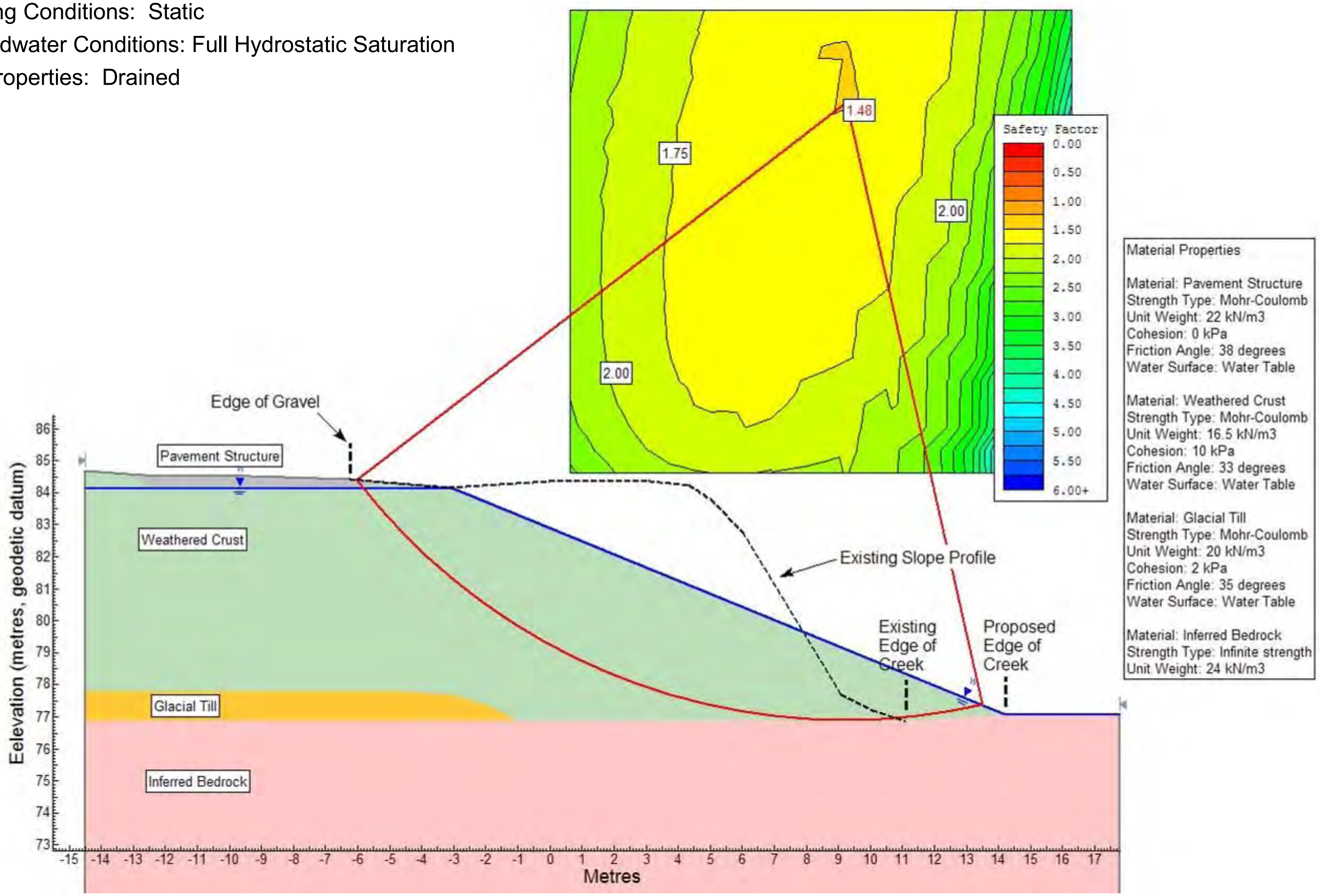
SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION A-A
SLOPE REGRADING KEEPING EXISTING TOE LOCATION

FIGURE B2

PROJECT: 11-378
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION A-A
SLOPE REGRADING MOVING TOE LOCATION

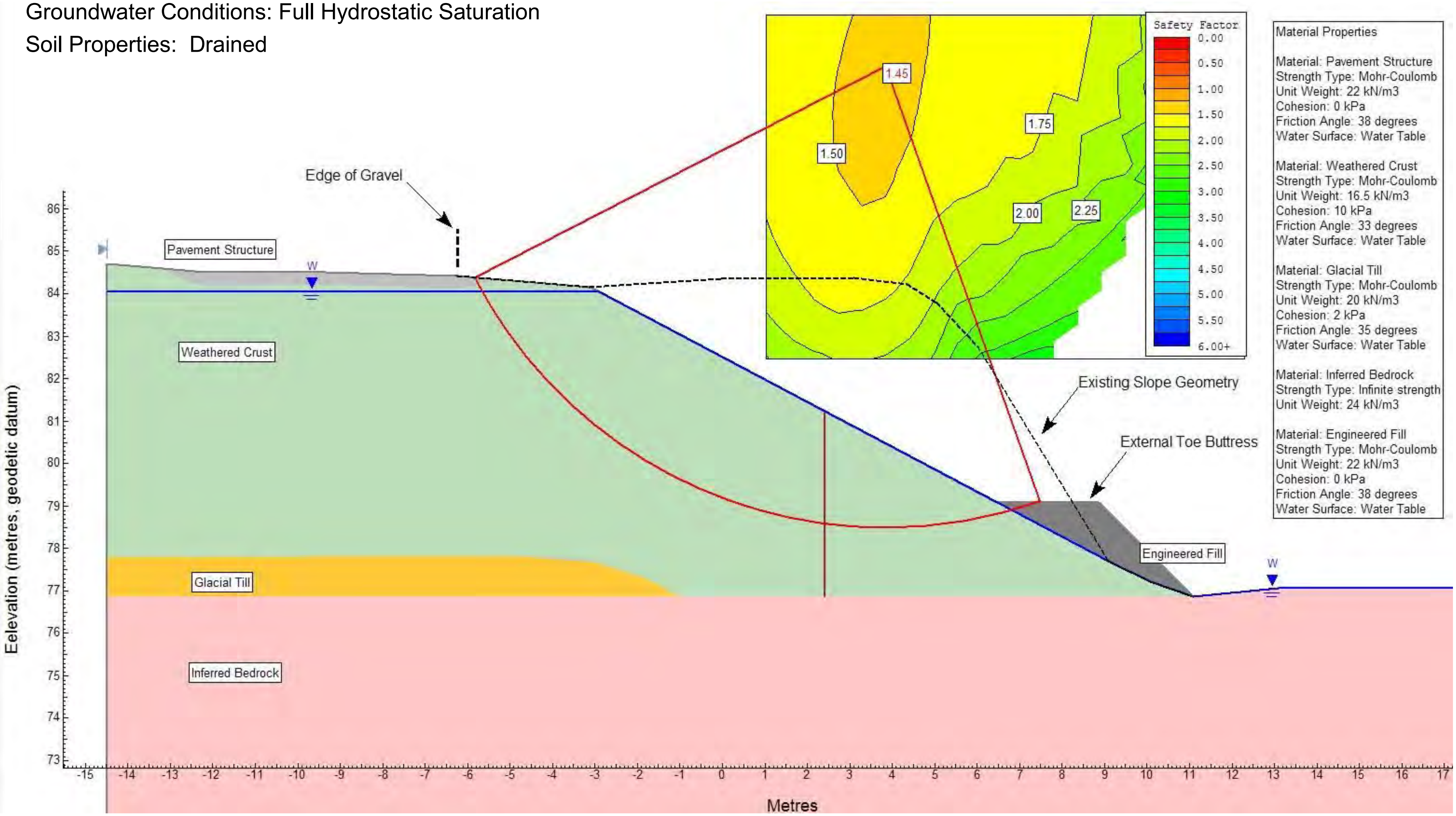
FIGURE B3

PROJECT: 11-378
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION A-A
SLOPE REGRADING WITH TOE BERM

FIGURE B4

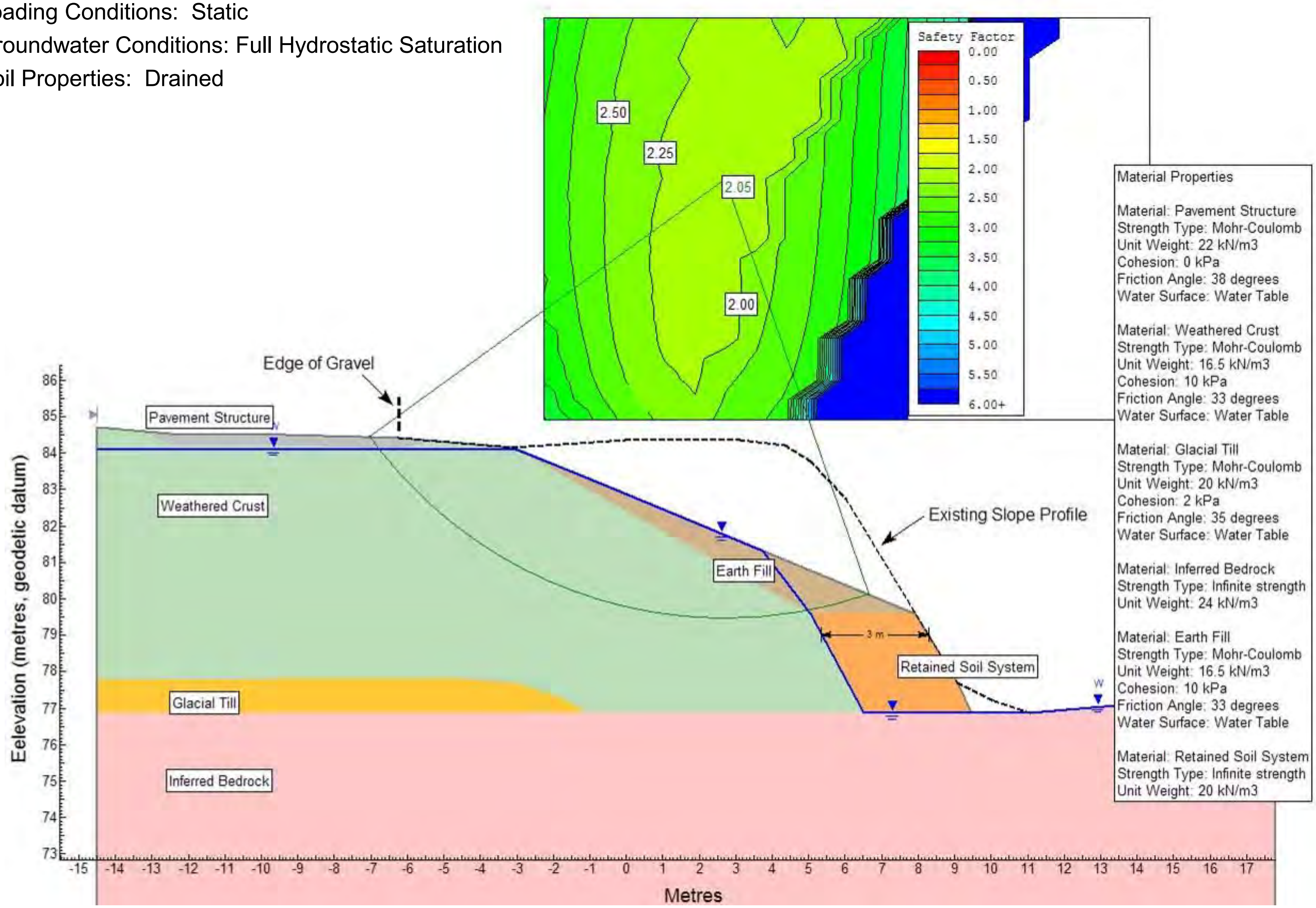
PROJECT: 11-378

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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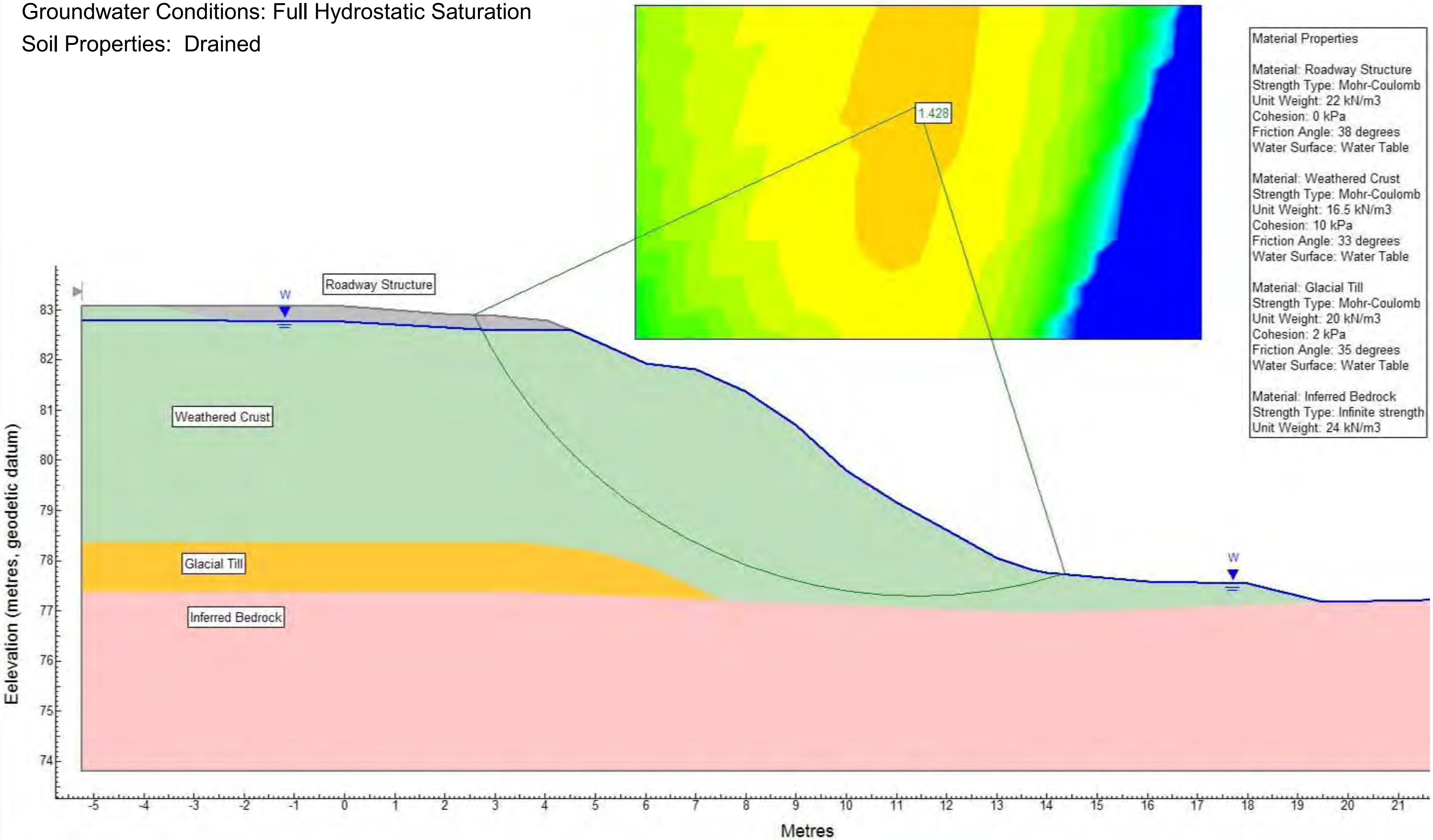
SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION A-A
REINFORCED SOIL SYSTEM WITH REGRADING

FIGURE B5

PROJECT: 11-378

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Material Properties

Material: Roadway Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

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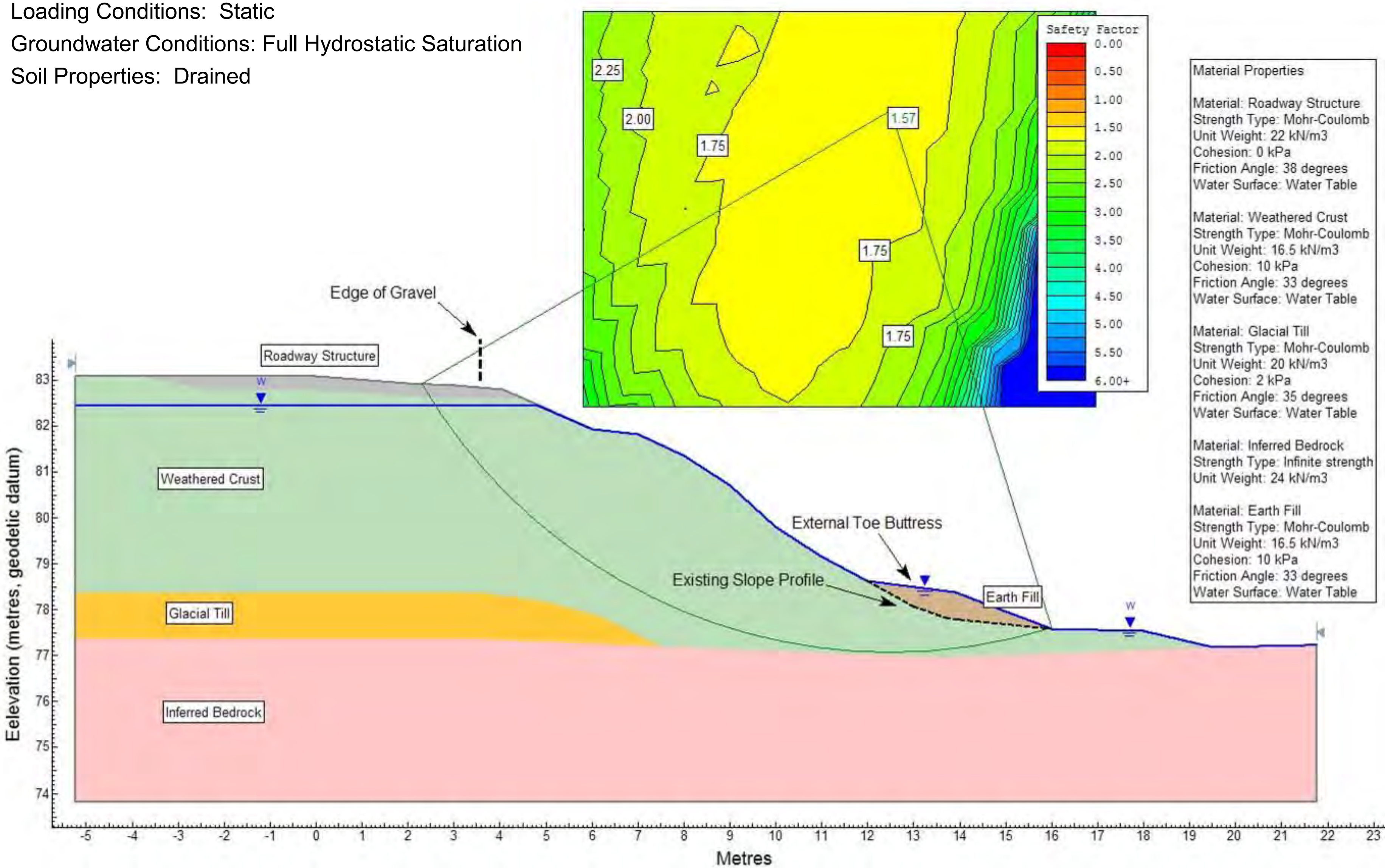
SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION B-B
EXISTING CONDITIONS

FIGURE B6

PROJECT: 11-378
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Material Properties

Material: Roadway Structure
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

Material: Weathered Crust
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Glacial Till
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: Water Table

Material: Inferred Bedrock
Strength Type: Infinite strength
Unit Weight: 24 kN/m3

Material: Earth Fill
Strength Type: Mohr-Coulomb
Unit Weight: 16.5 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

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SLOPE STABILITY ANALYSIS
WATTERS ROAD
SECTION B-B
EARTH BERM

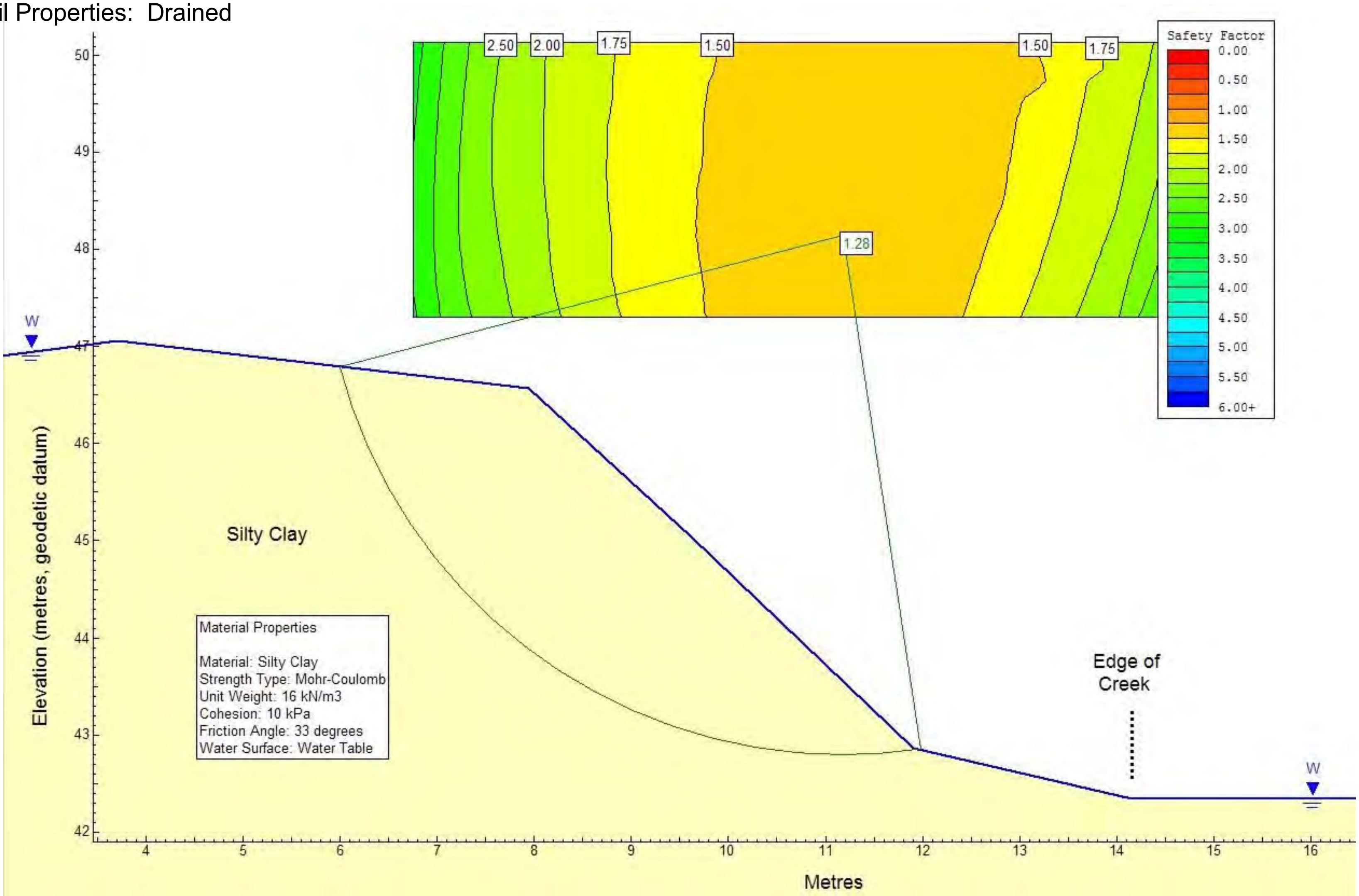
FIGURE B7

PROJECT: 11-378
DATE: June 2013

APPENDIX C

AREA 8
FIGURES C1 to C18

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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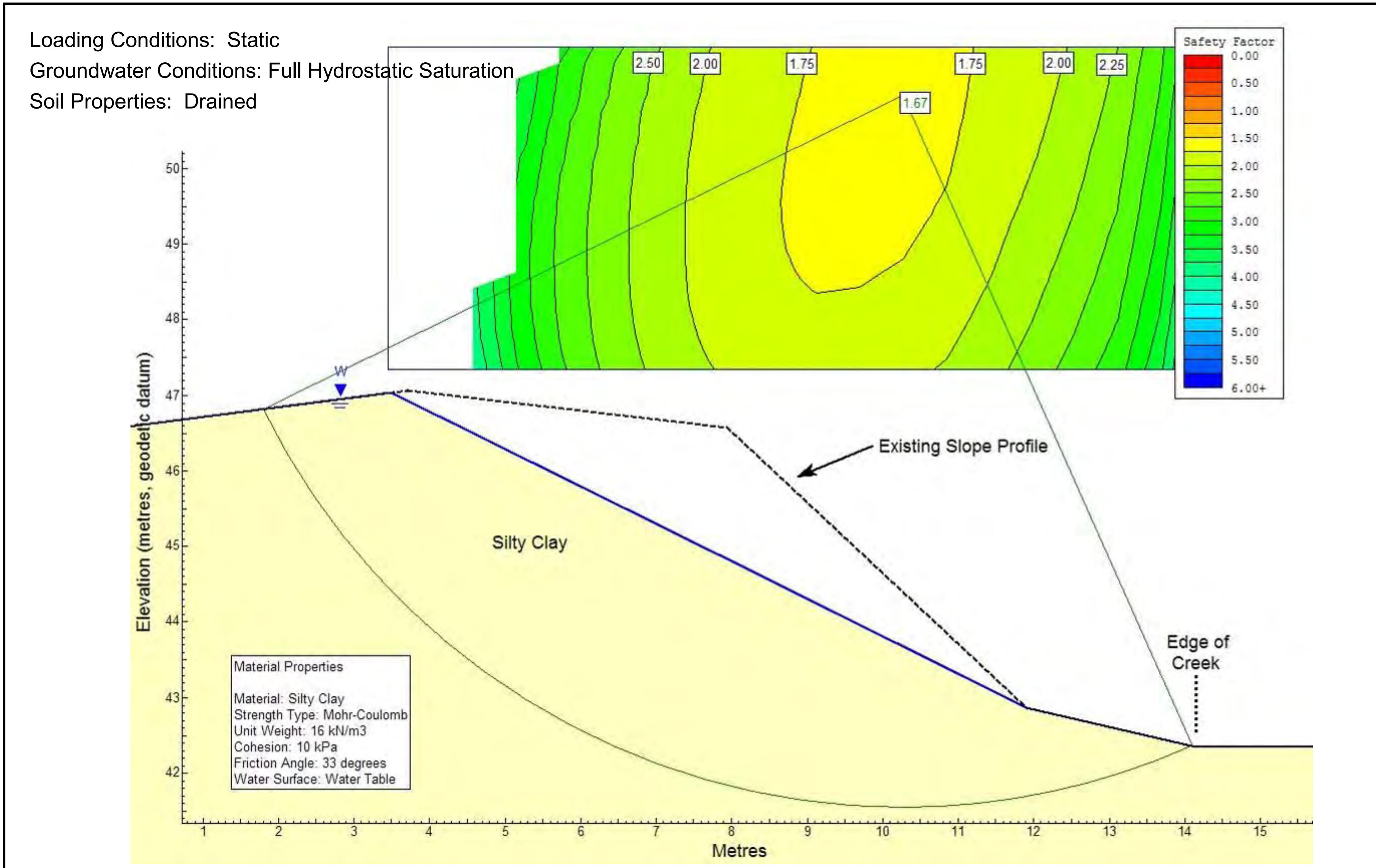
SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
EXISTING CONDITIONS

FIGURE C1

PROJECT: 11-618
DATE: June 2013



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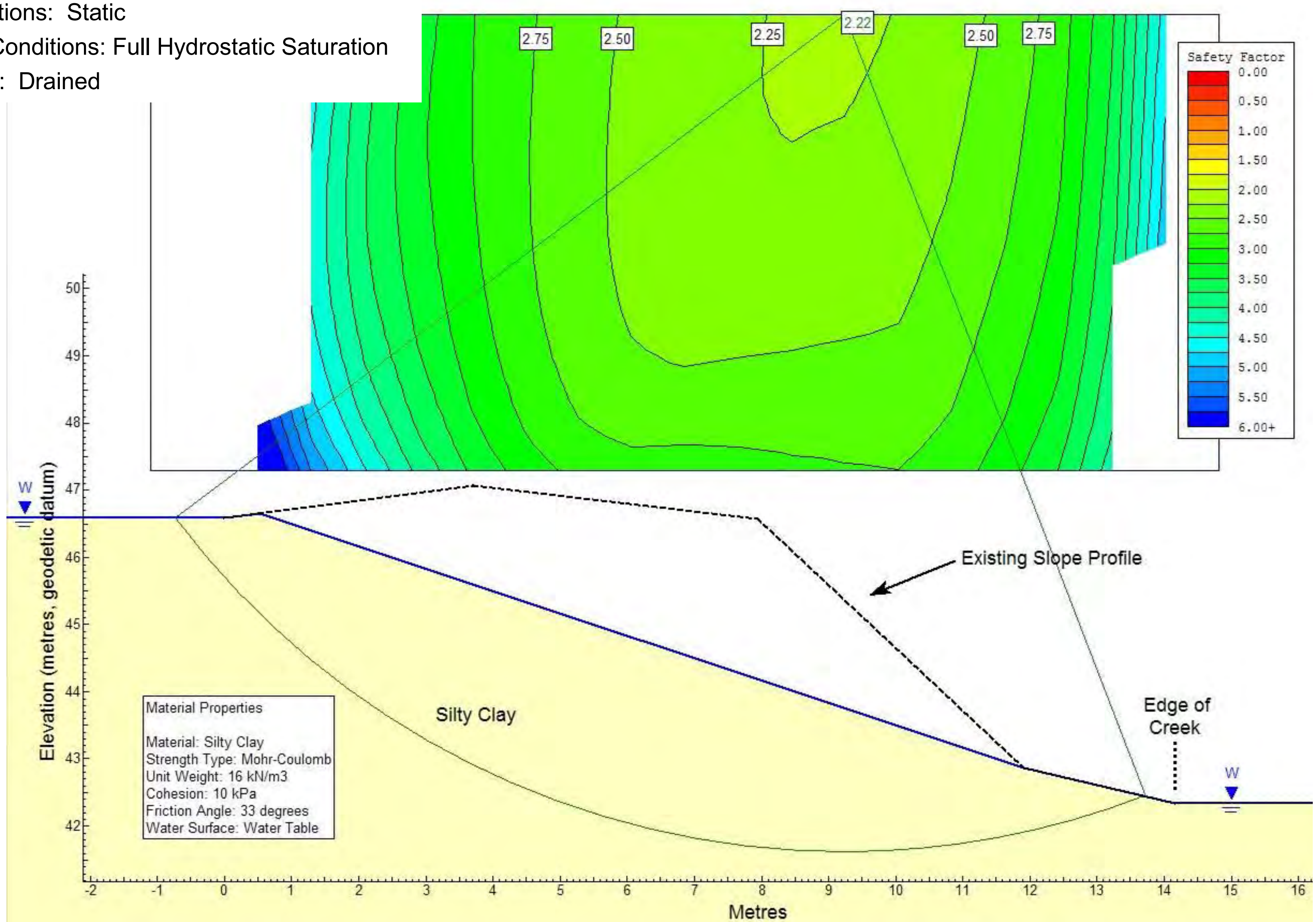
SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE C2

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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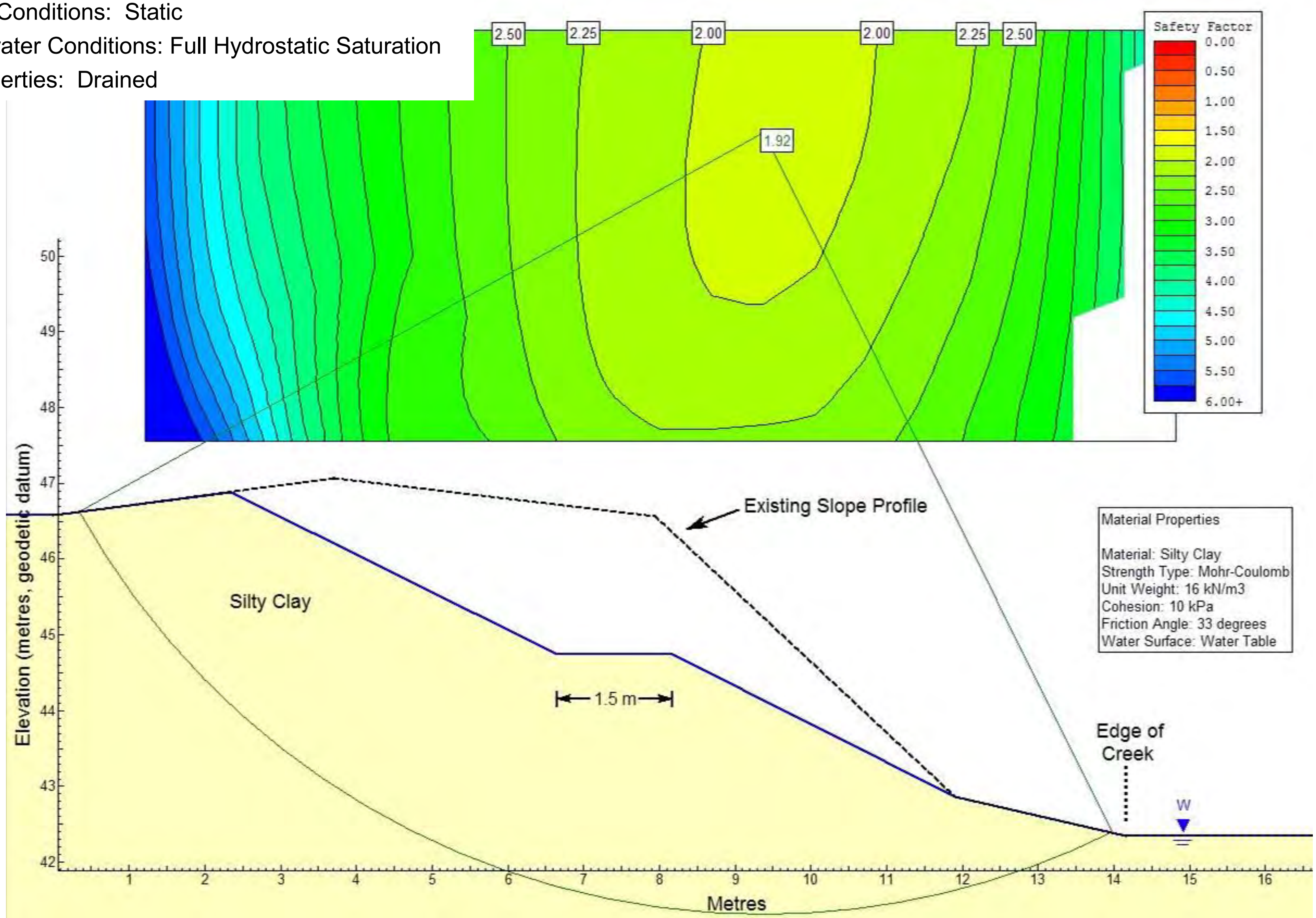
SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE C3

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
BENCHING

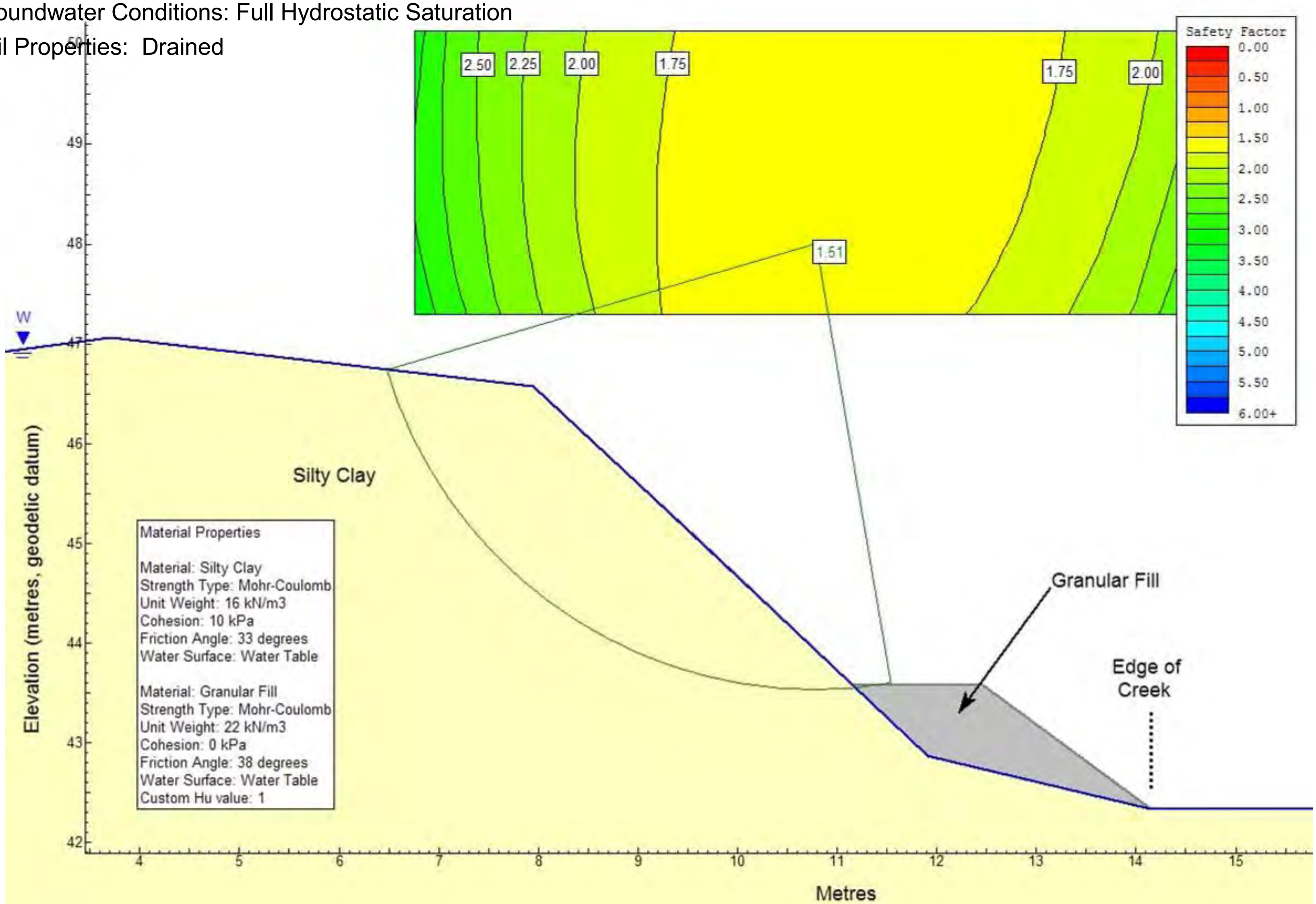
FIGURE C4

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
TOE BERM

FIGURE C5

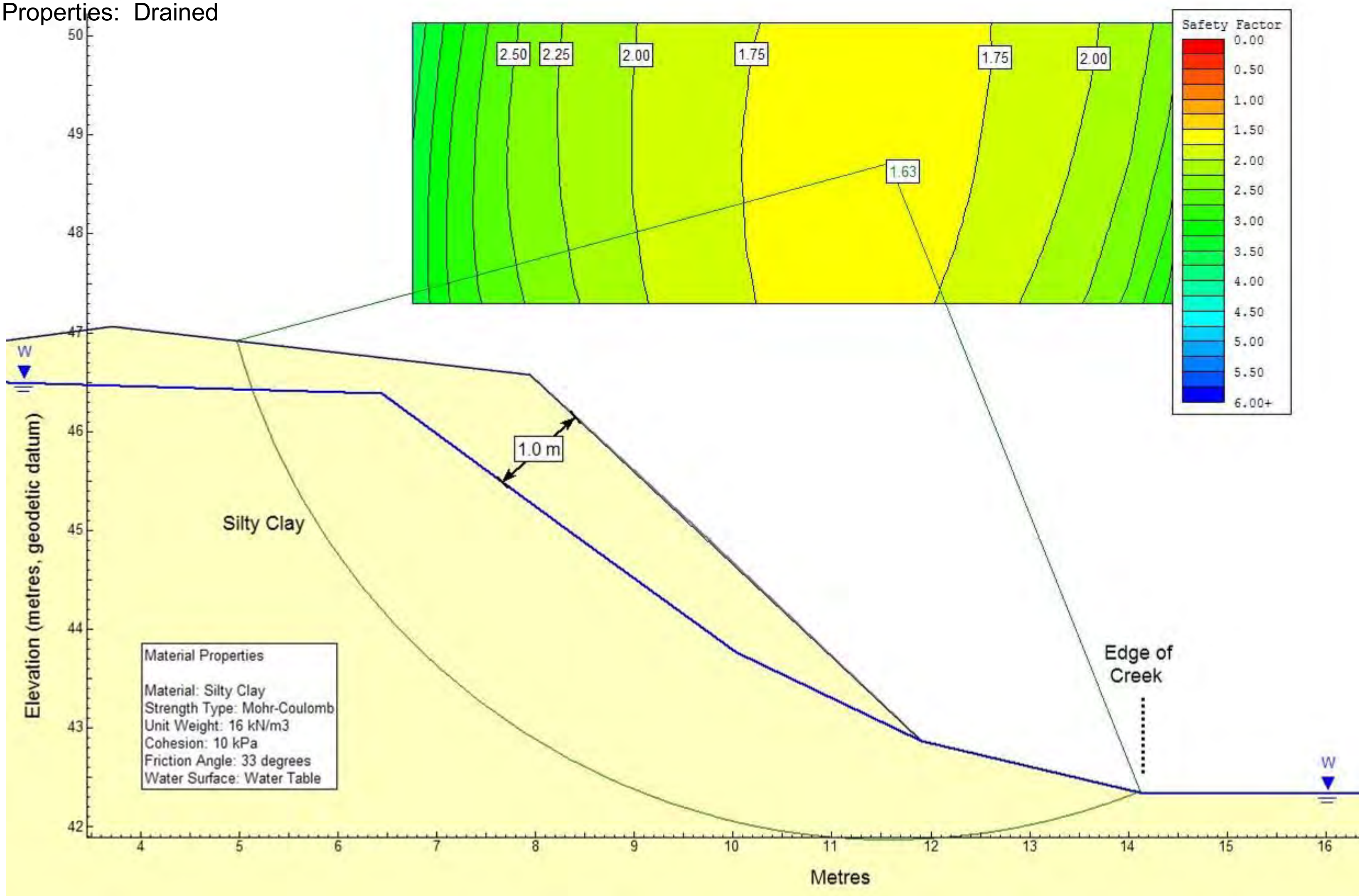
PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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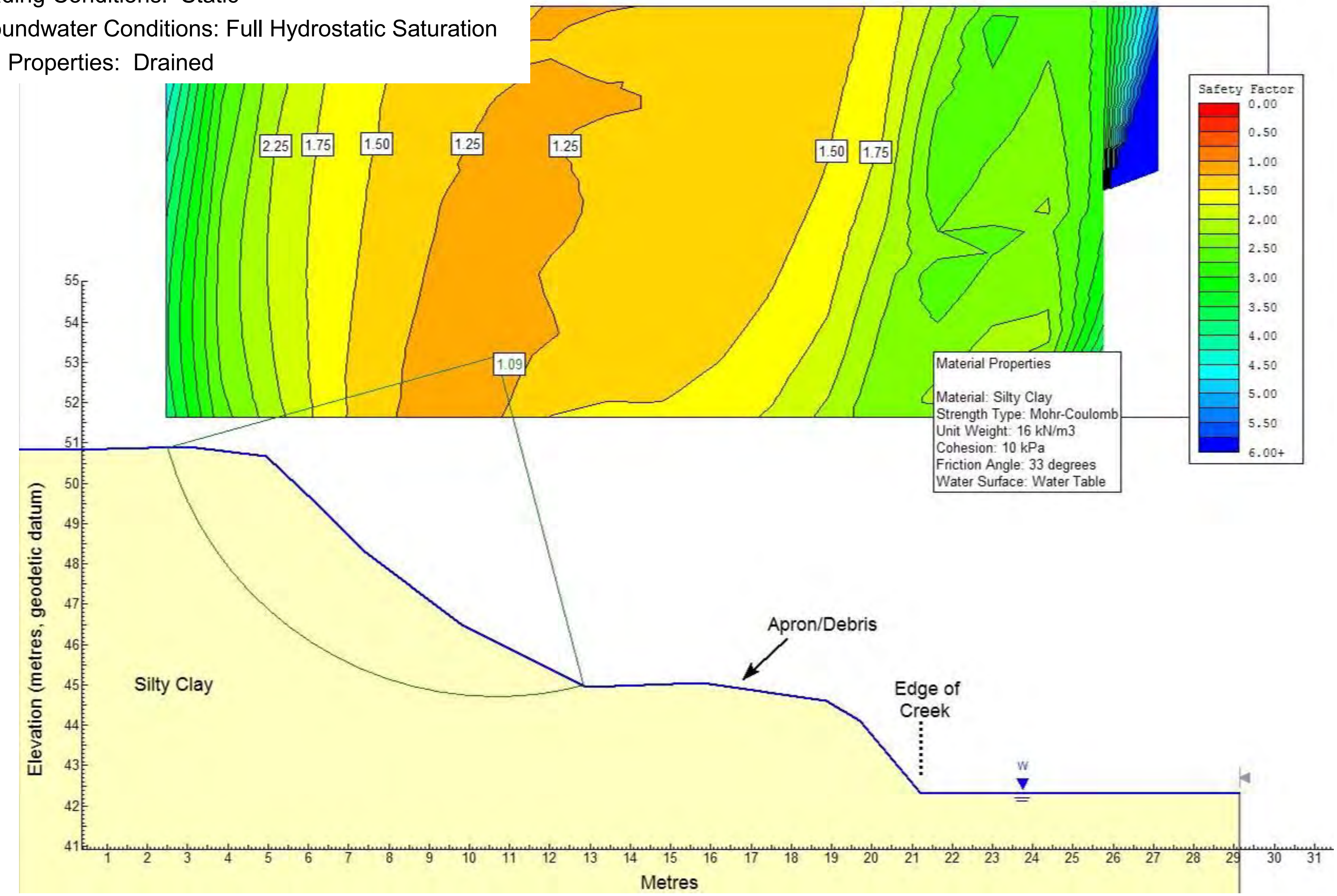
SLOPE STABILITY ANALYSIS
AREA 8
SECTION A-A
DEWATERING

FIGURE C6

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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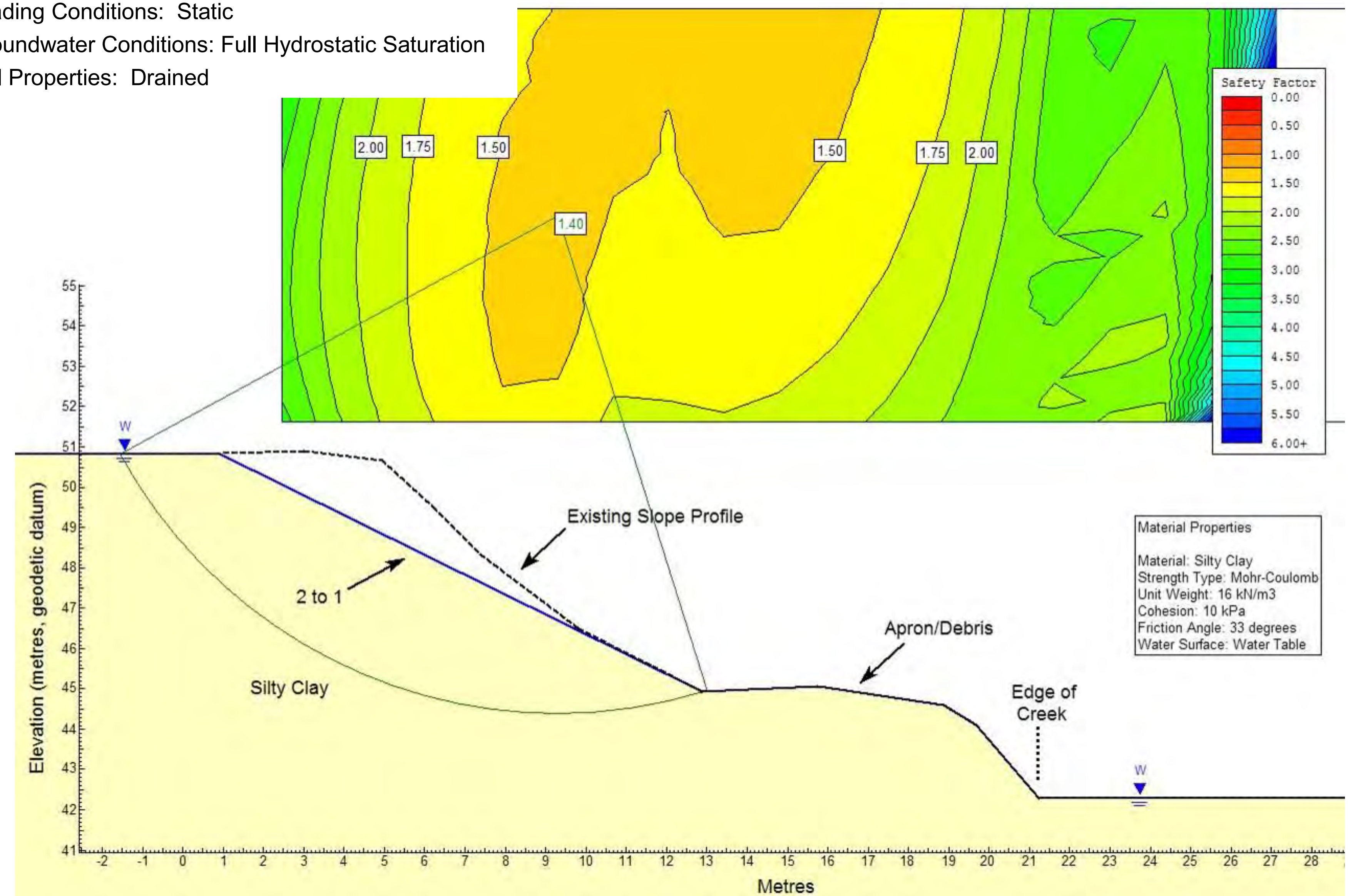
SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
EXISTING CONDITIONS

FIGURE C7

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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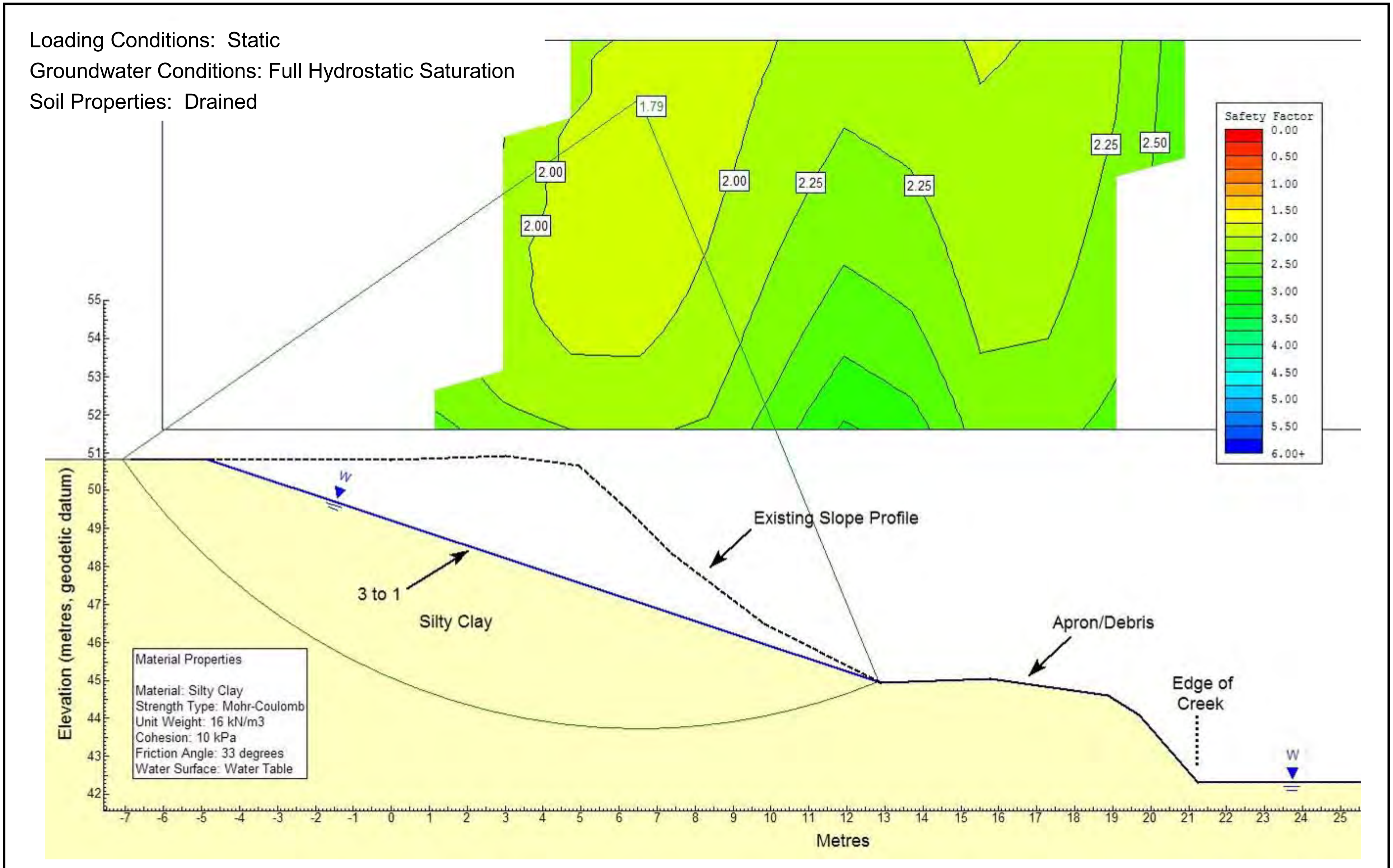
SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE C8

PROJECT: 11-618
DATE: June 2013



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

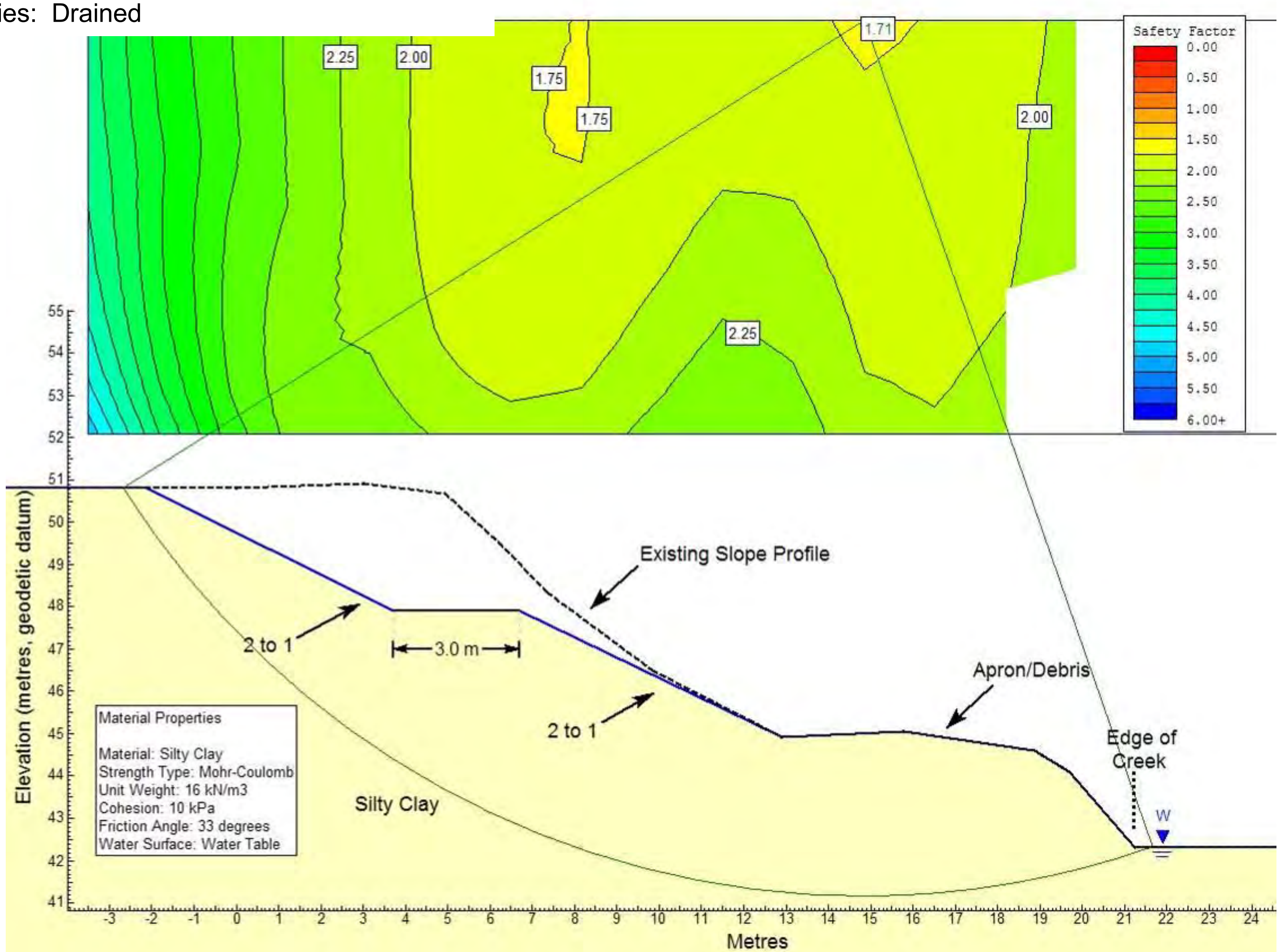
FIGURE C9

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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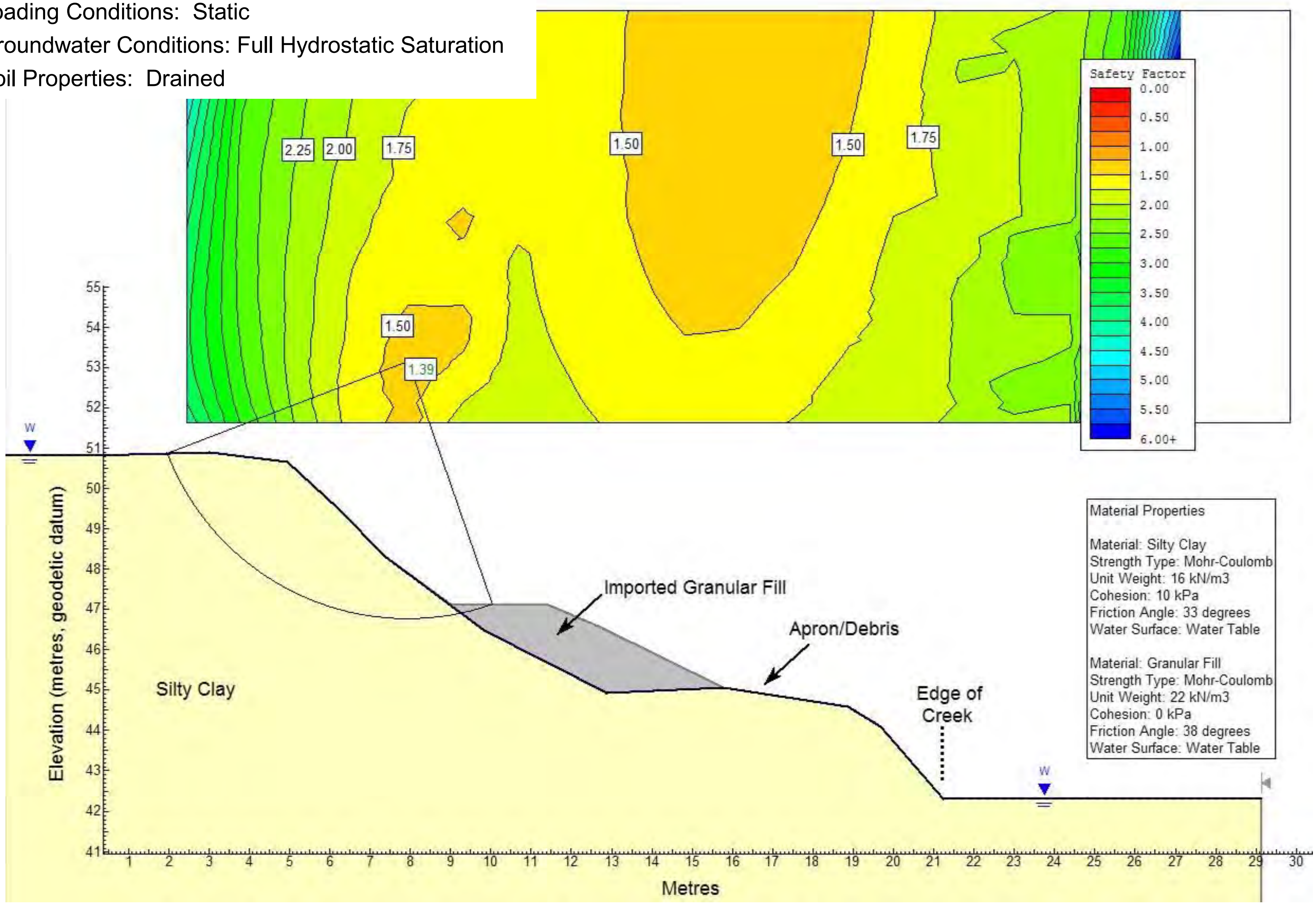
SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
BENCHING

FIGURE C10

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Material Properties

Material: Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 16 kN/m3
Cohesion: 10 kPa
Friction Angle: 33 degrees
Water Surface: Water Table

Material: Granular Fill
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m3
Cohesion: 0 kPa
Friction Angle: 38 degrees
Water Surface: Water Table

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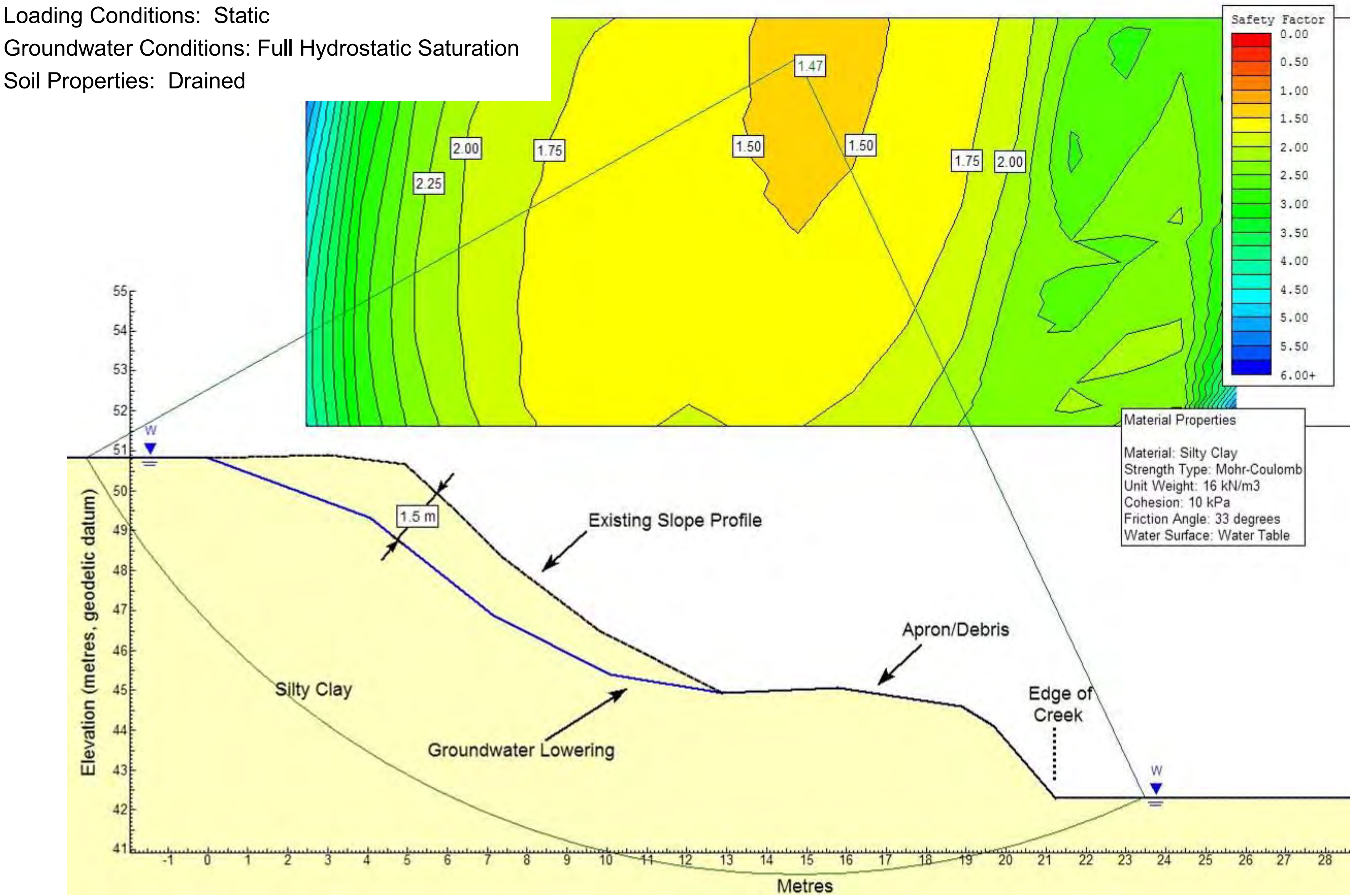
SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
TOE BERM

FIGURE C11

PROJECT: 11-618
DATE: June 2013



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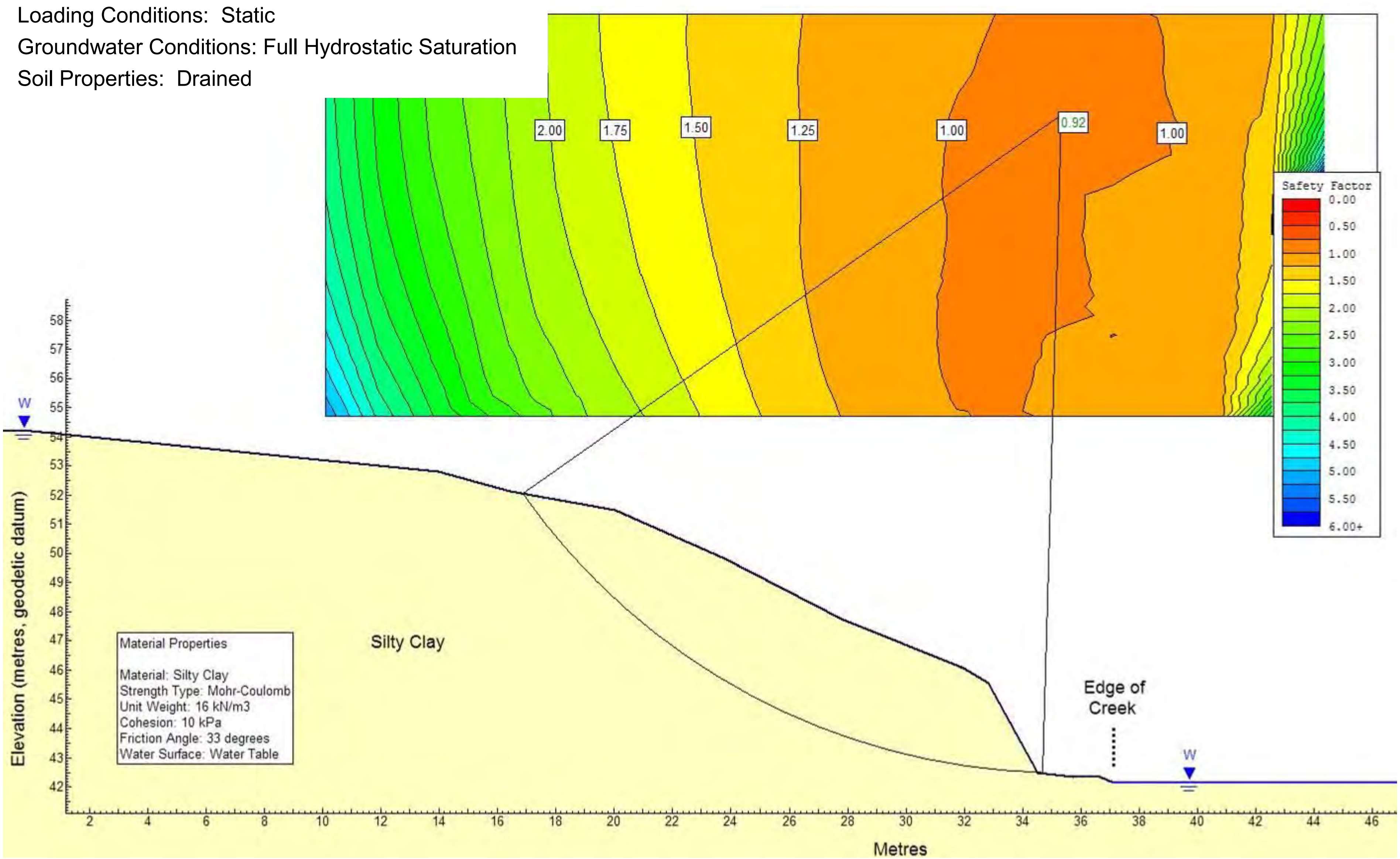
SLOPE STABILITY ANALYSIS
AREA 8
SECTION B-B
DEWATERING

FIGURE C12

PROJECT: 11-618
DATE: June 2013



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
EXISTING CONDITIONS

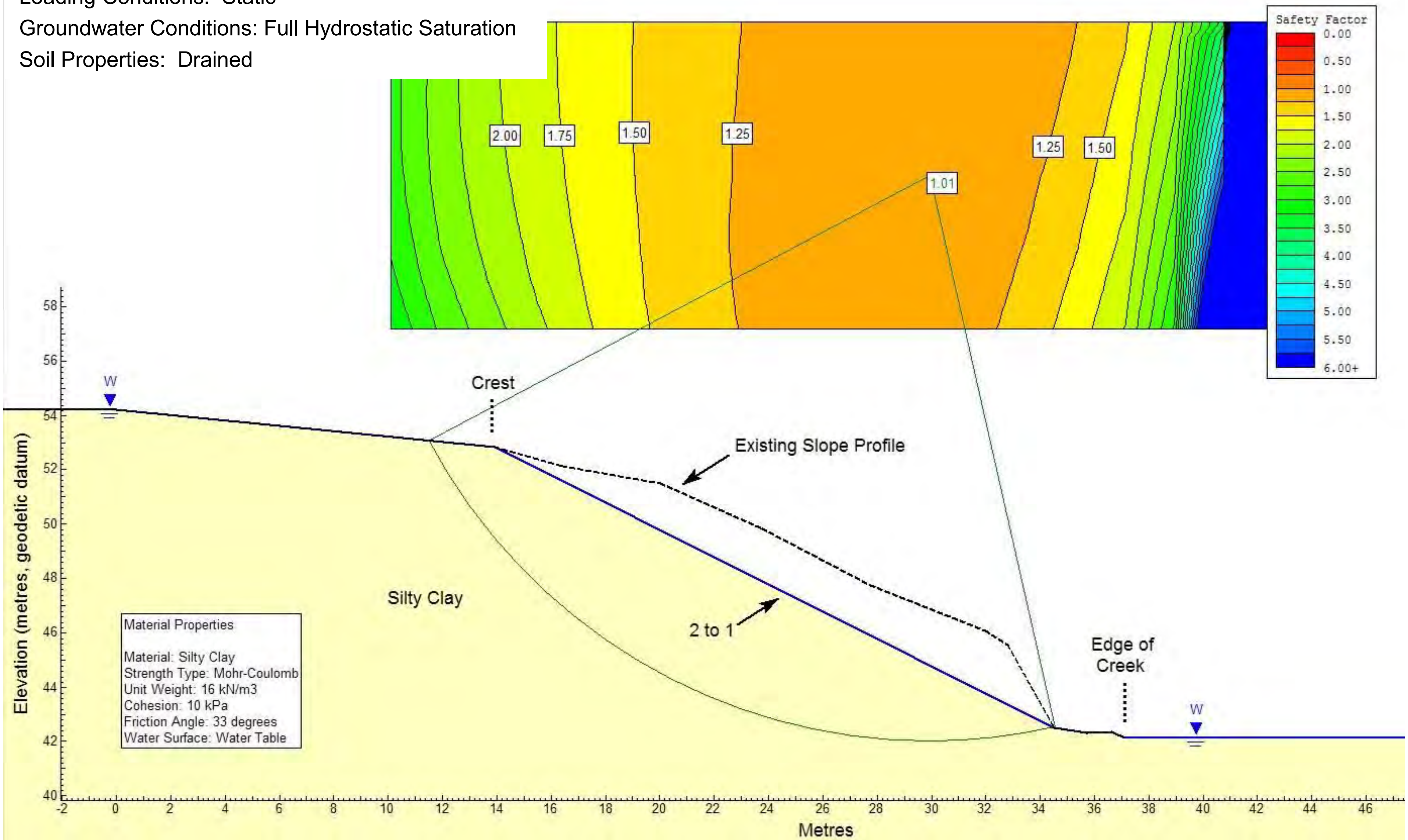
FIGURE C13

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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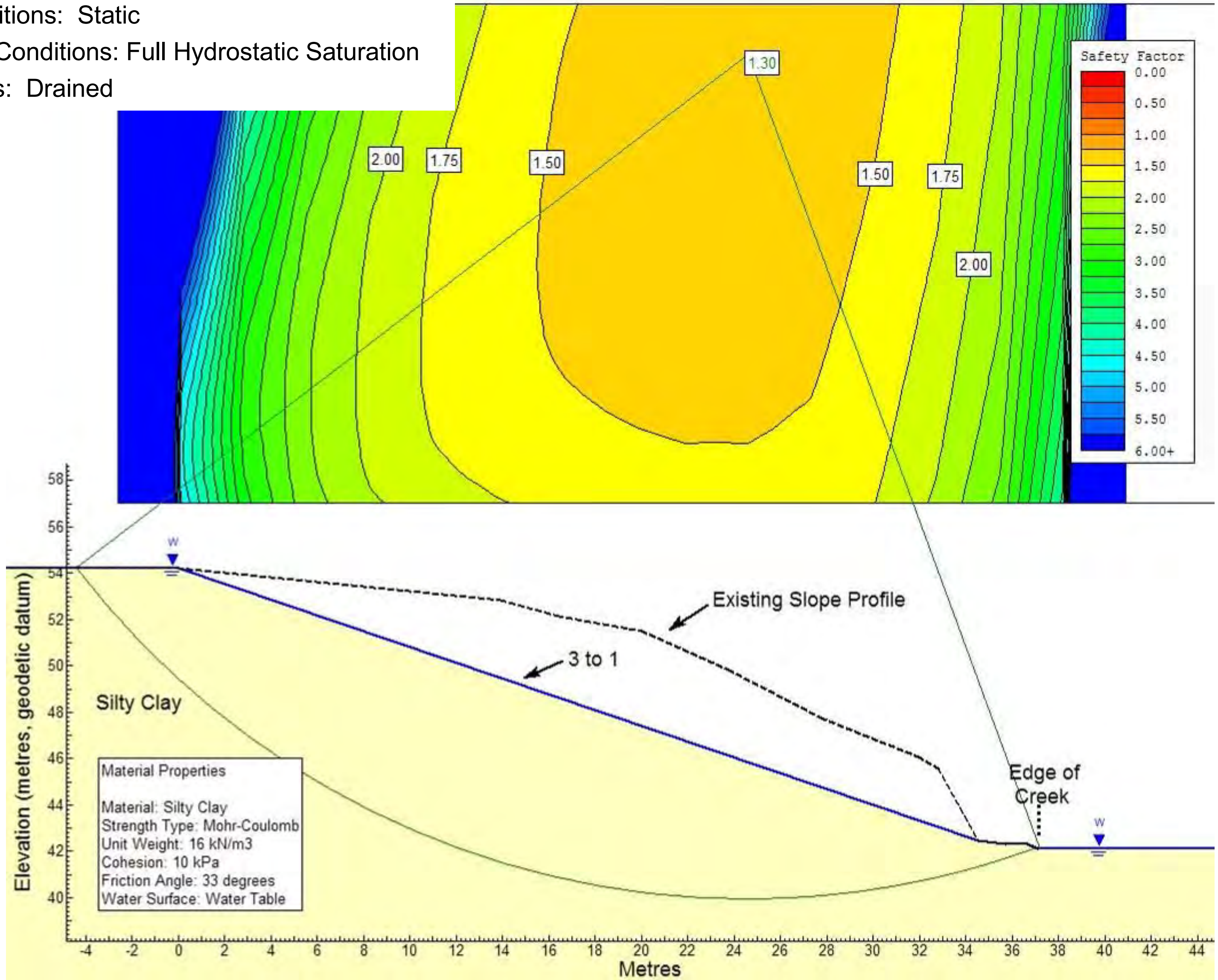
SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE C14

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

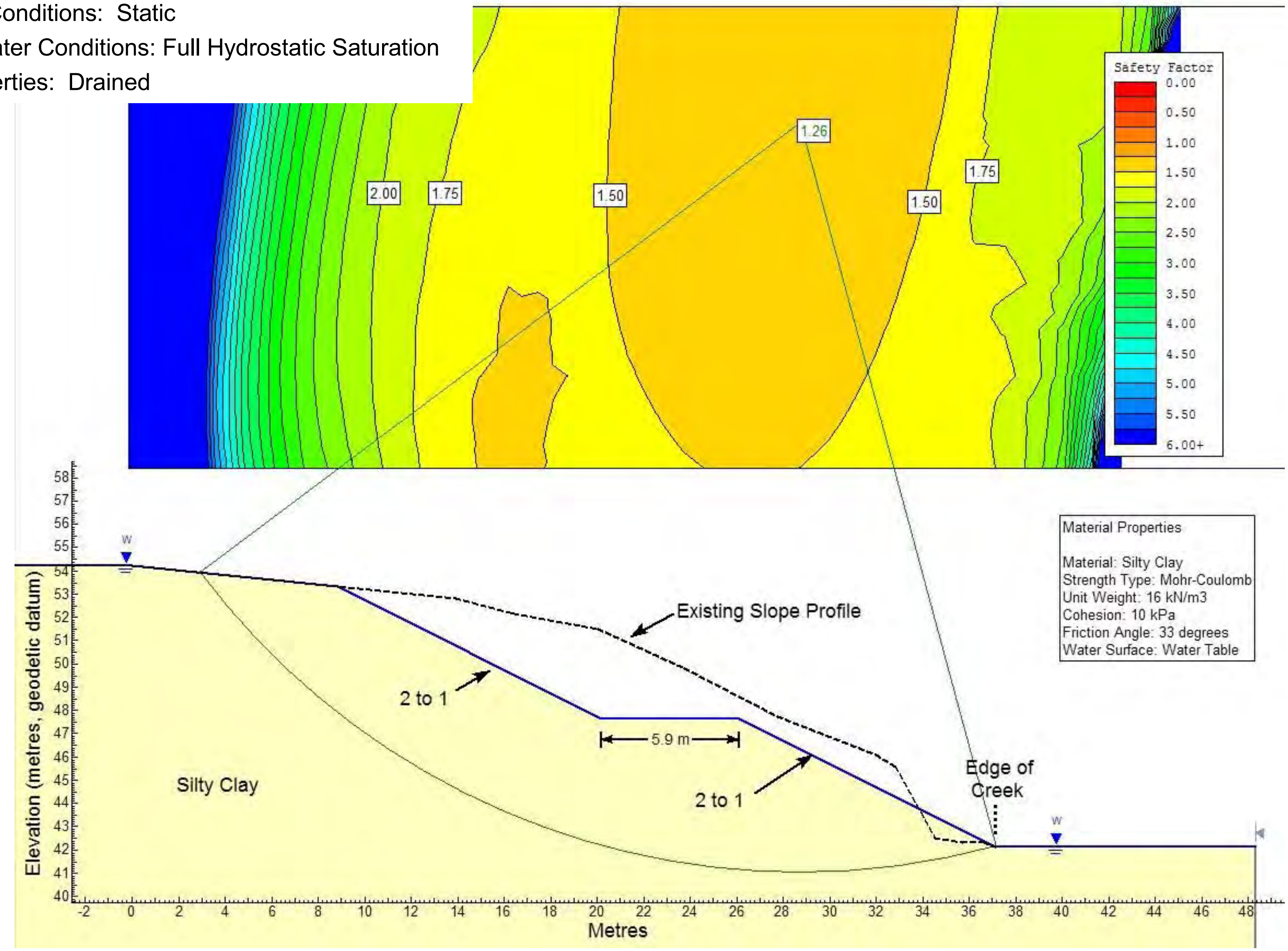
FIGURE C15

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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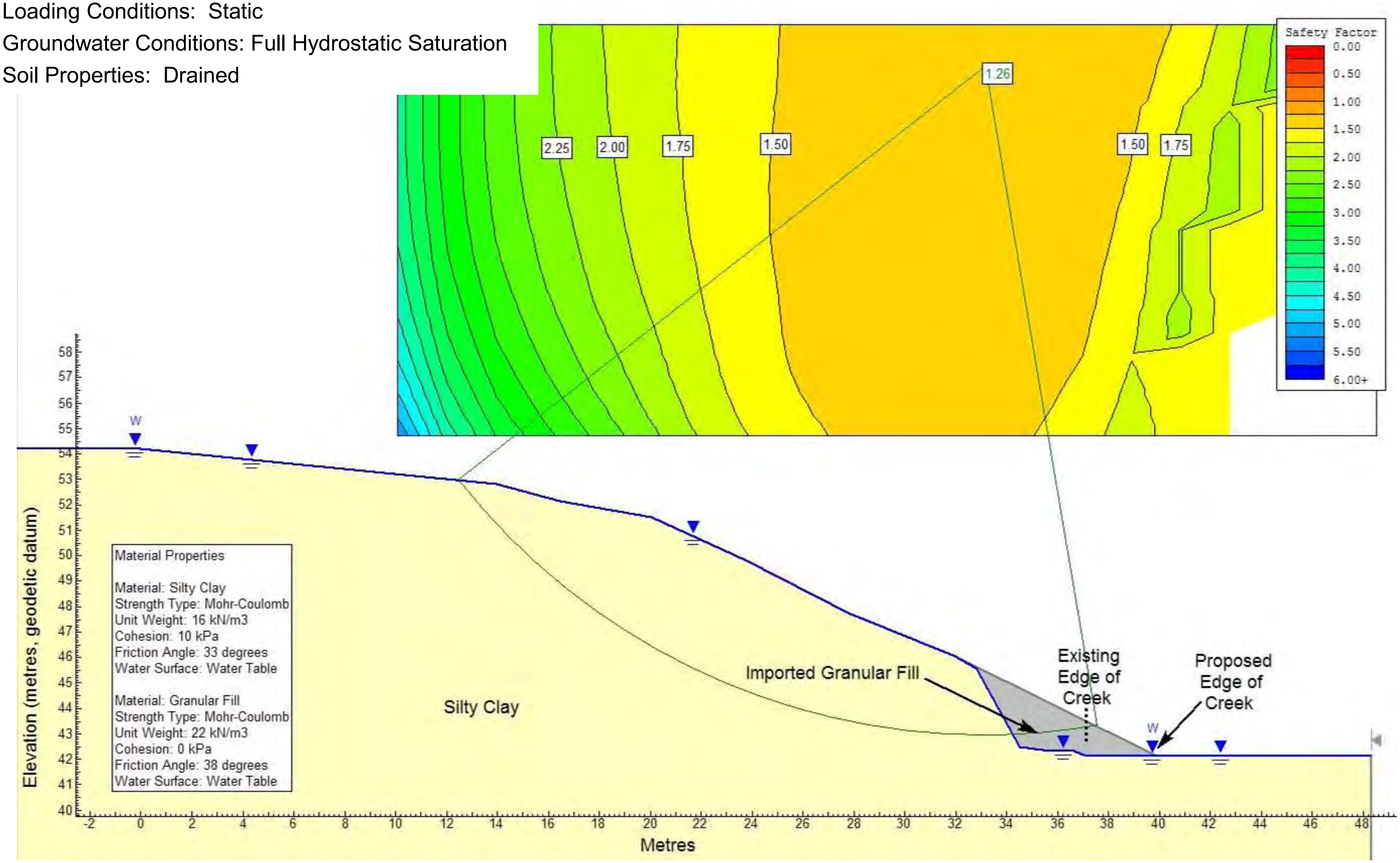
SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
BENCHING

FIGURE C16

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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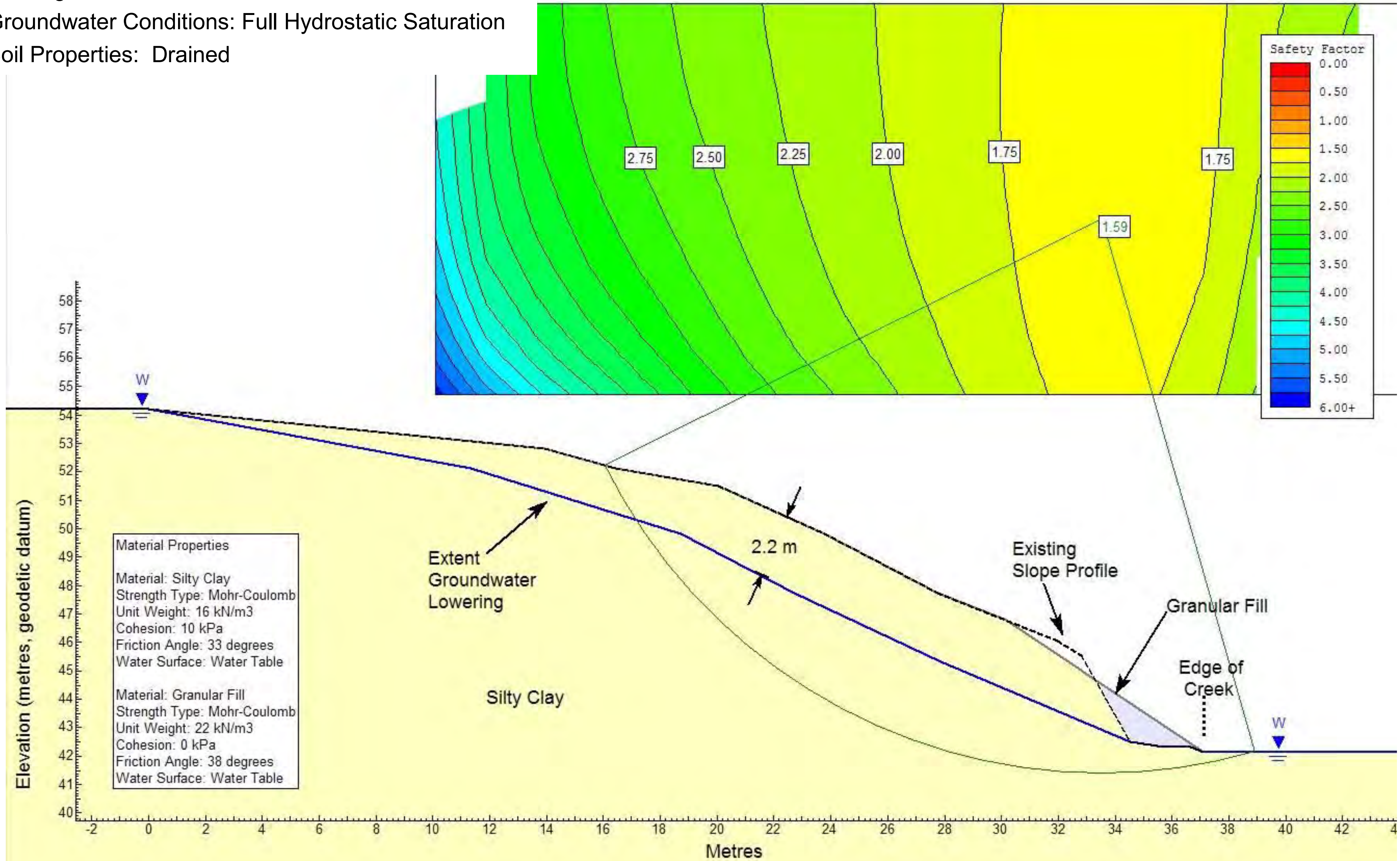
SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
TOE BERM

FIGURE C17

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 8
SECTION C-C
DEWATERING

FIGURE C18

PROJECT: 11-618
DATE: June 2013

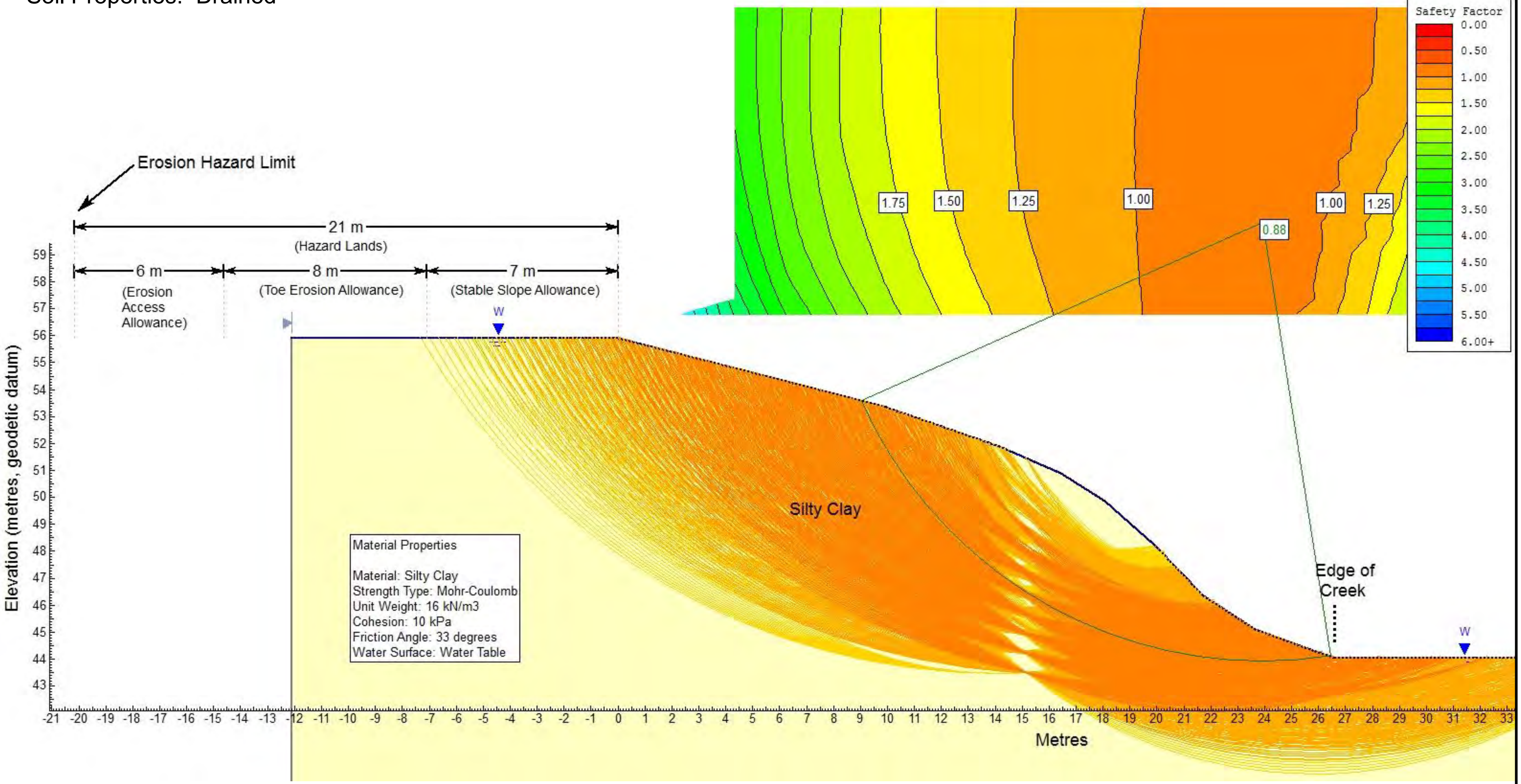
APPENDIX D

AREA 13
FIGURES D1 to D12

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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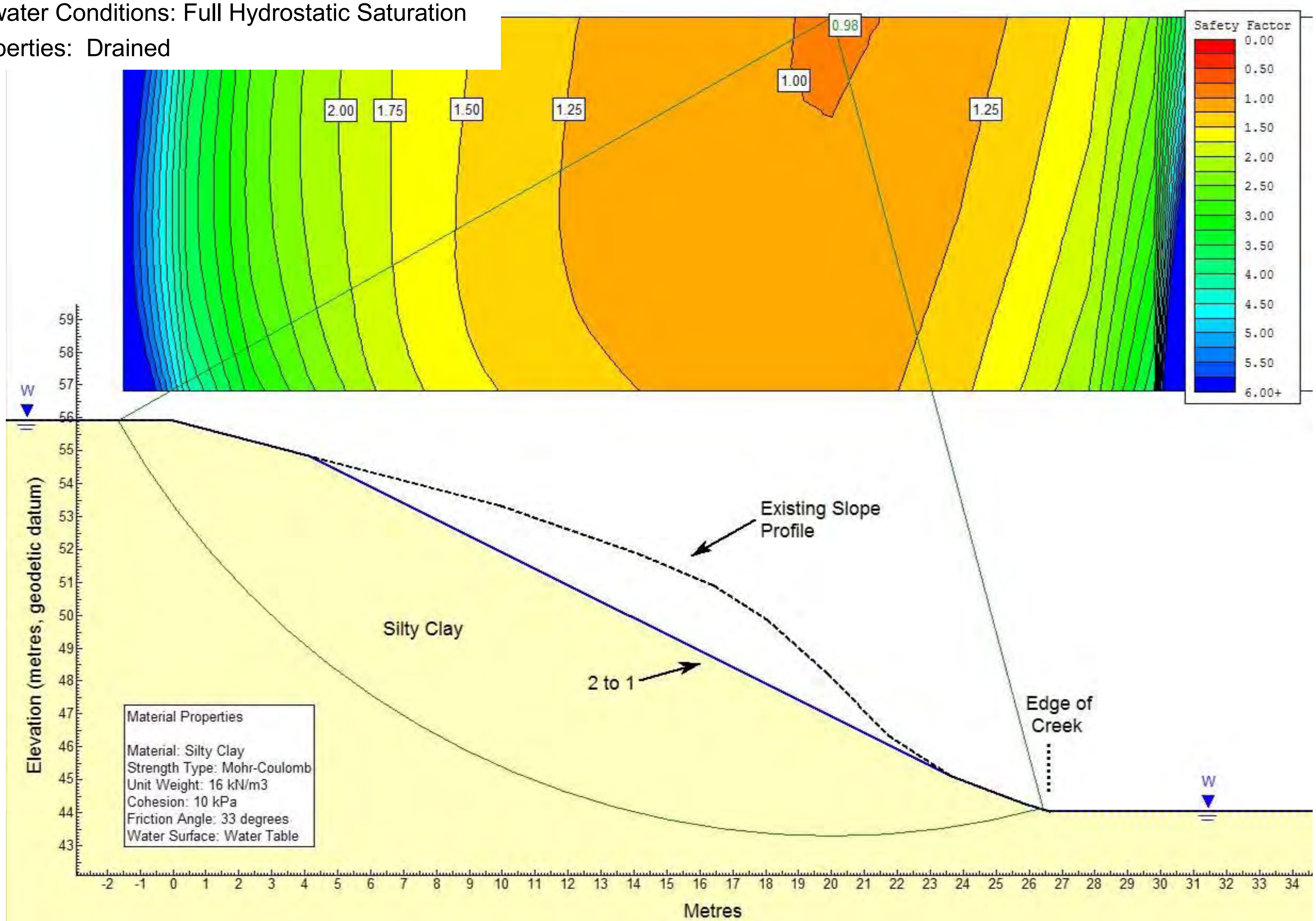
SLOPE STABILITY ANALYSIS
AREA 13
SECTION A-A
EXISTING CONDITIONS

FIGURE D1

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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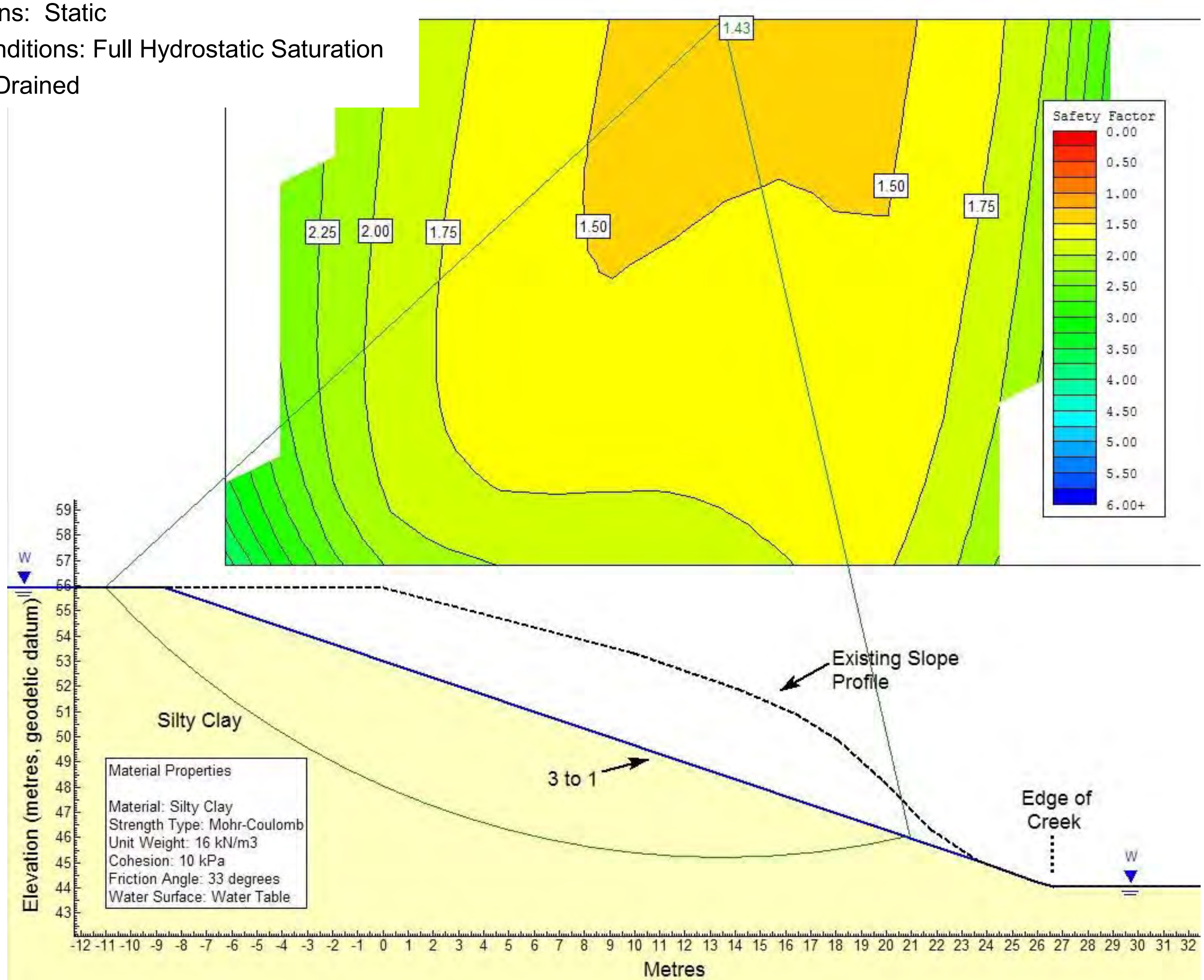
SLOPE STABILITY ANALYSIS
AREA 13
SECTION A-A
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE D2

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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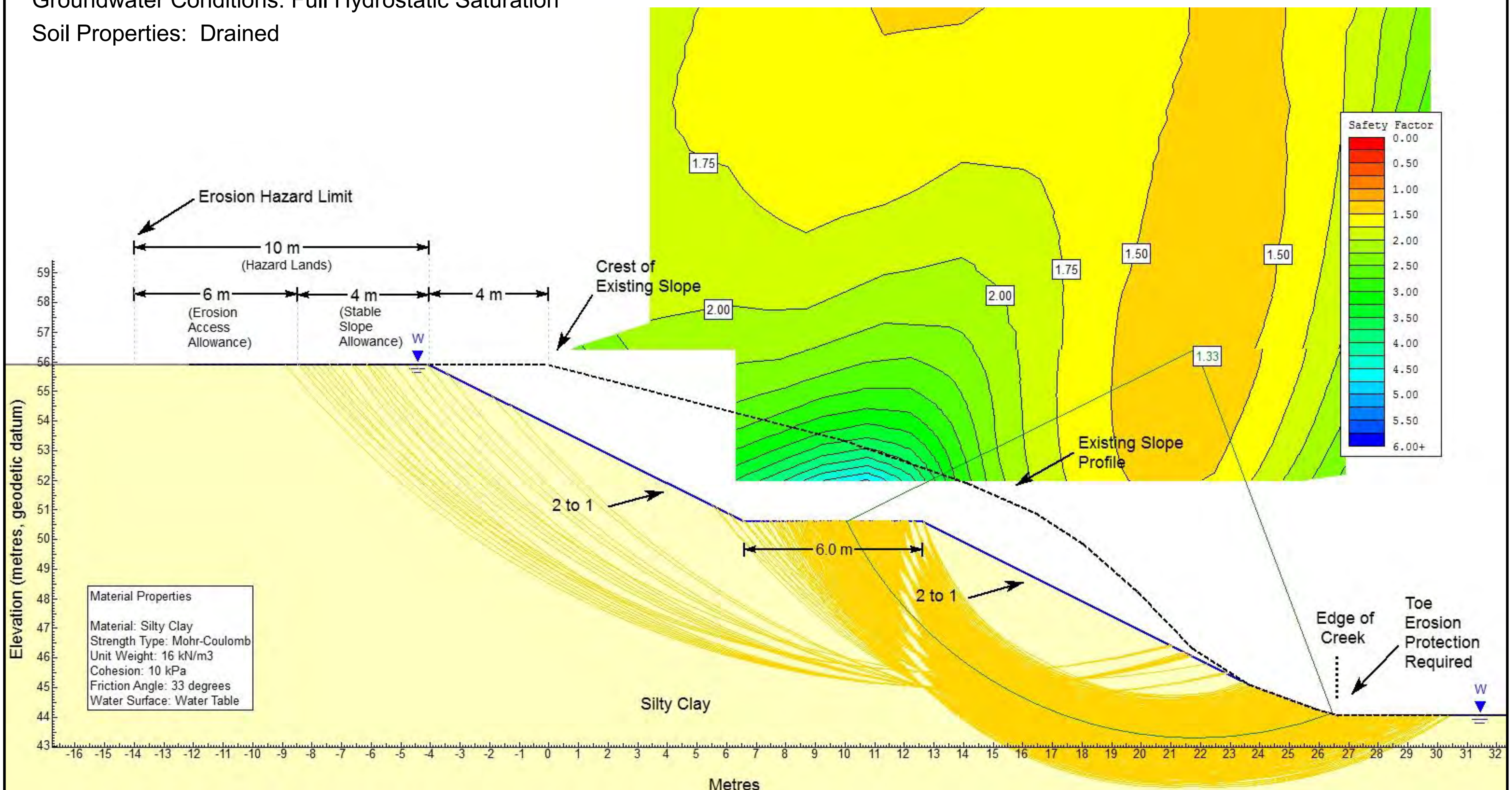
SLOPE STABILITY ANALYSIS
AREA 13
SECTION A-A
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE D3

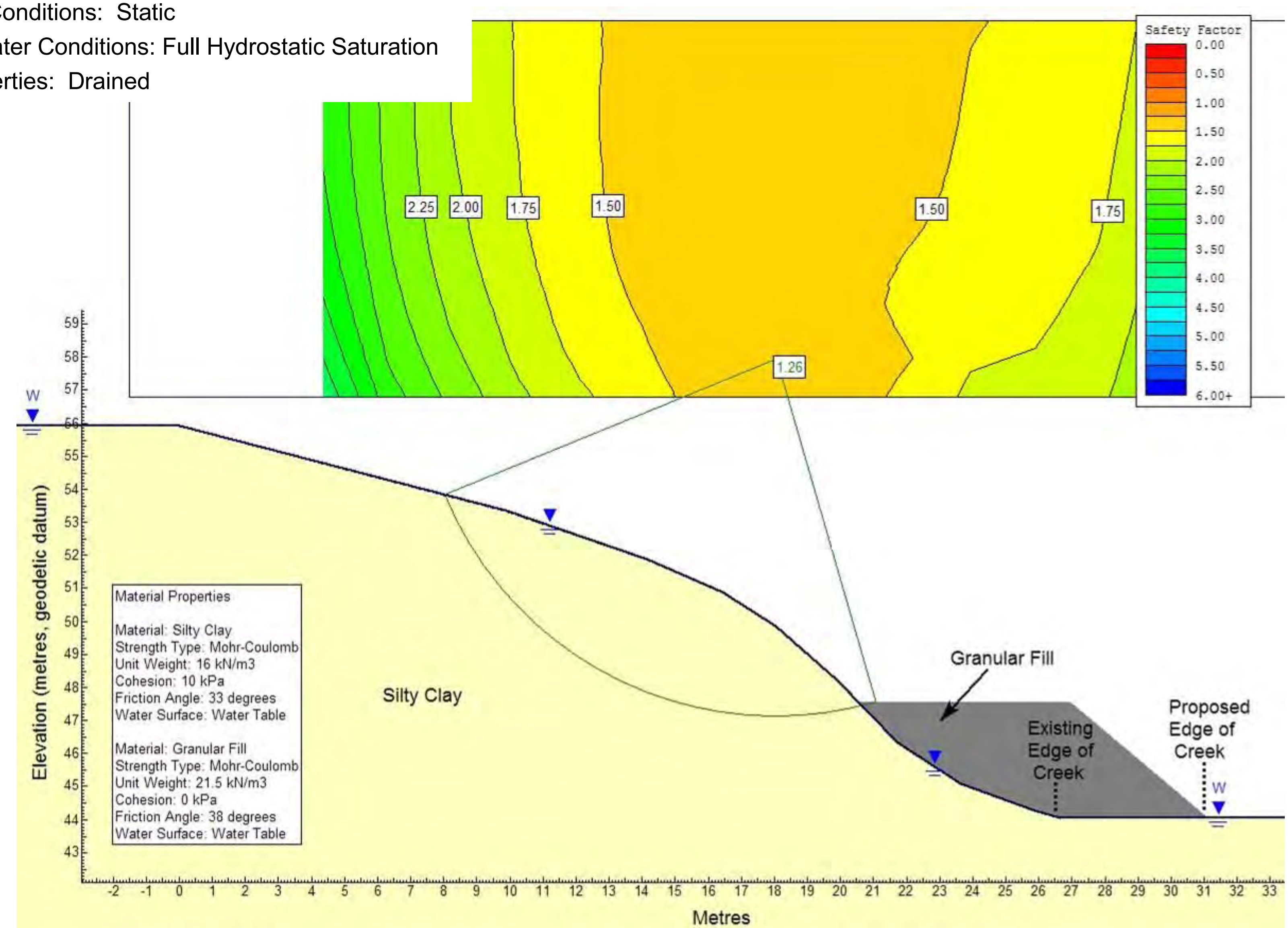
PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



Houle Chevrier Engineering	R.R. 2 180 Wescar Lane Carp, Ontario K0A 1L0 info@hceng.ca (613) 836-1422 Fax: 836 9731	SLOPE STABILITY ANALYSIS AREA 13 SECTION A-A BENCHING	FIGURE D4 PROJECT: 11-618 DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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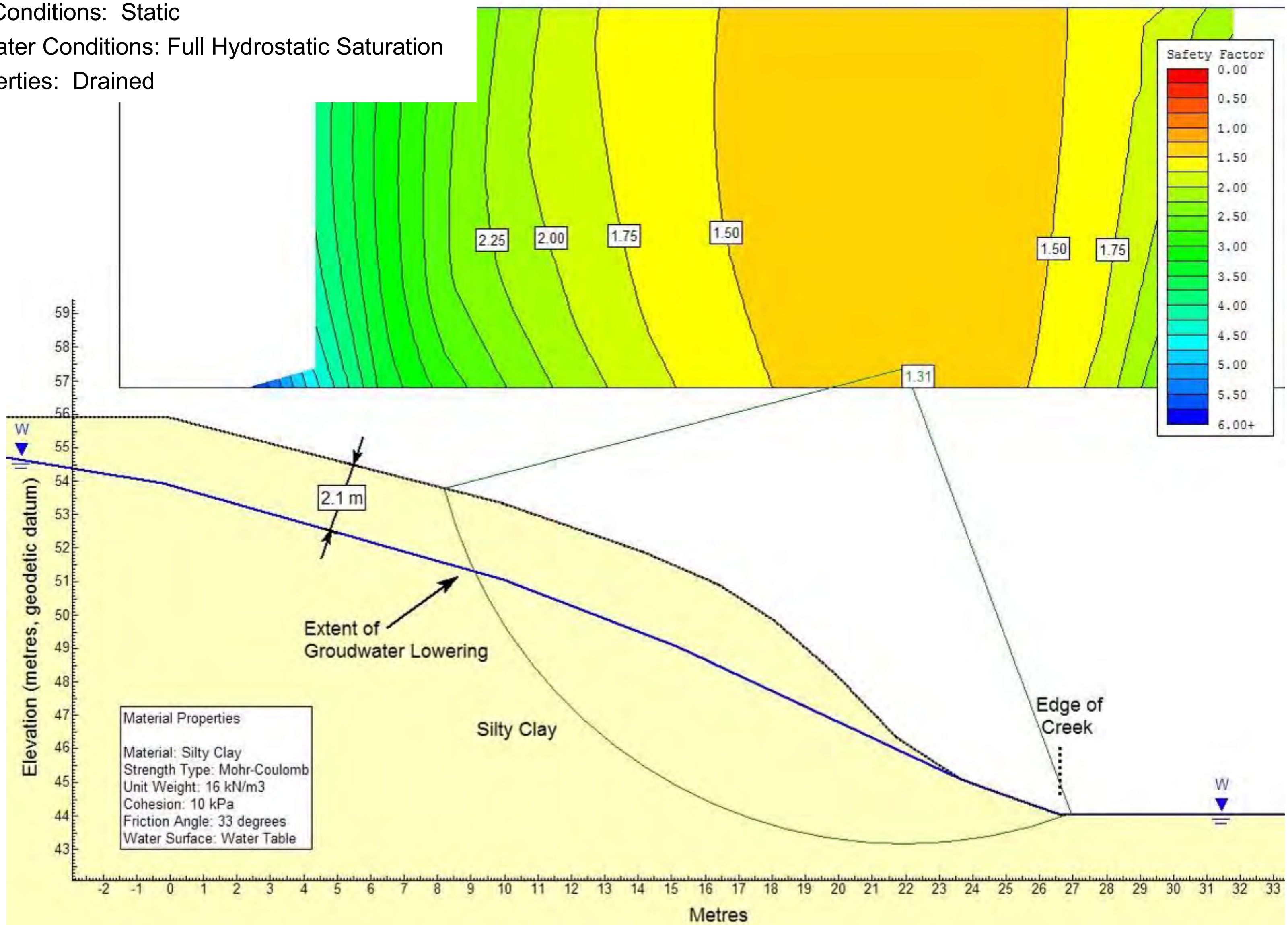
SLOPE STABILITY ANALYSIS
AREA 13
SECTION A-A
EXTERNAL TOE BERM

FIGURE D5

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 13
SECTION A-A
DEWATERING

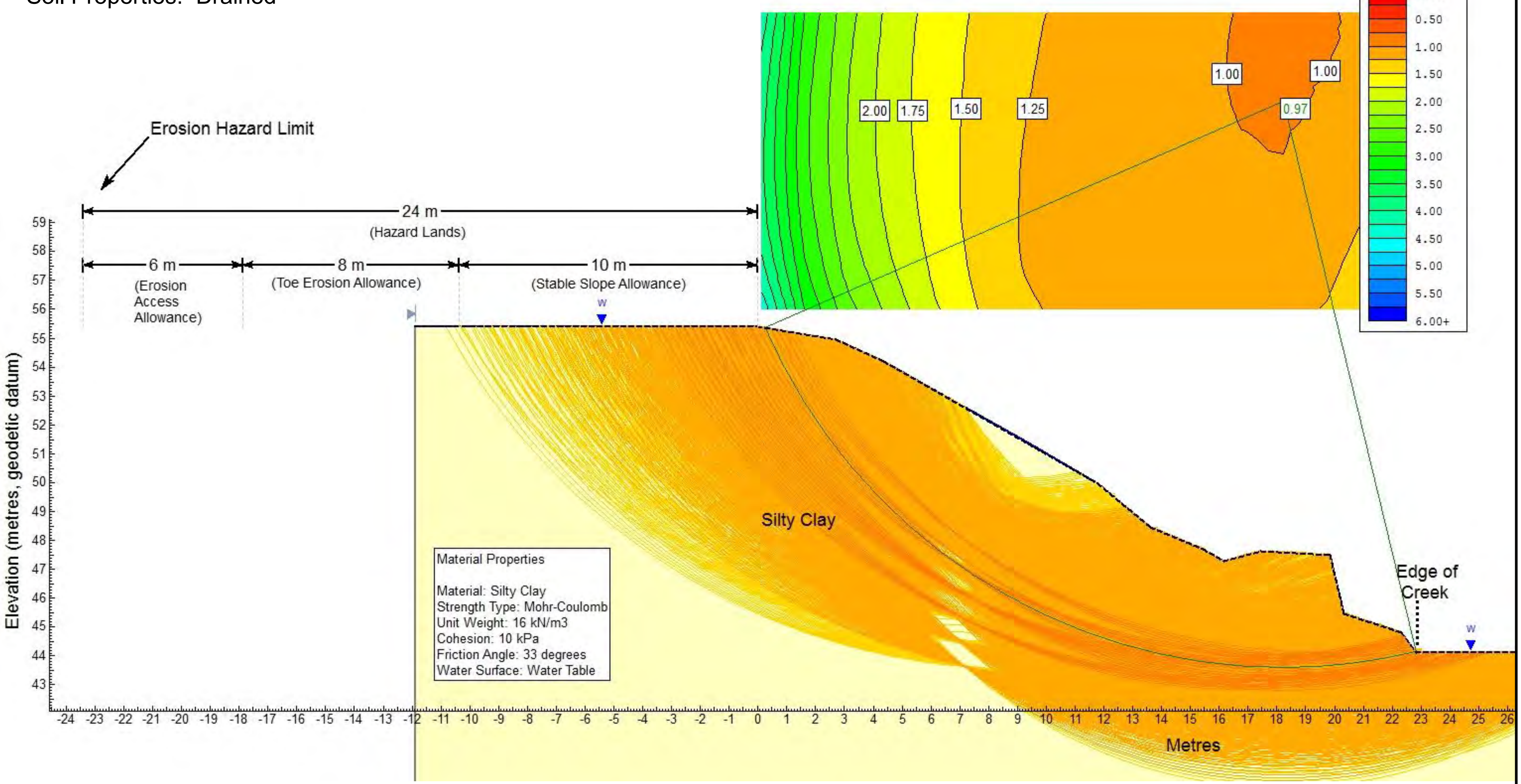
FIGURE D6

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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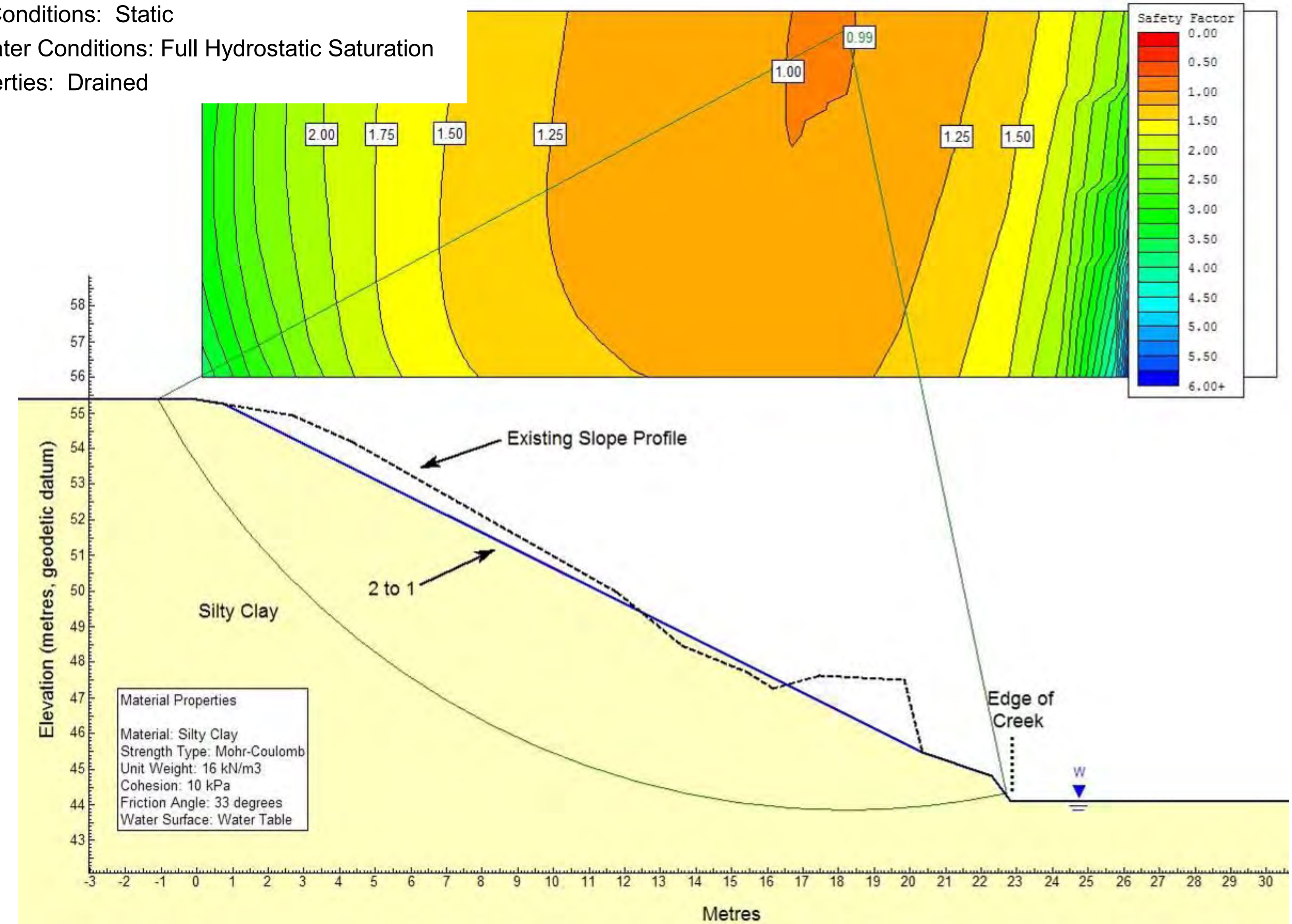
SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
EXISTING CONDITIONS

FIGURE D7

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

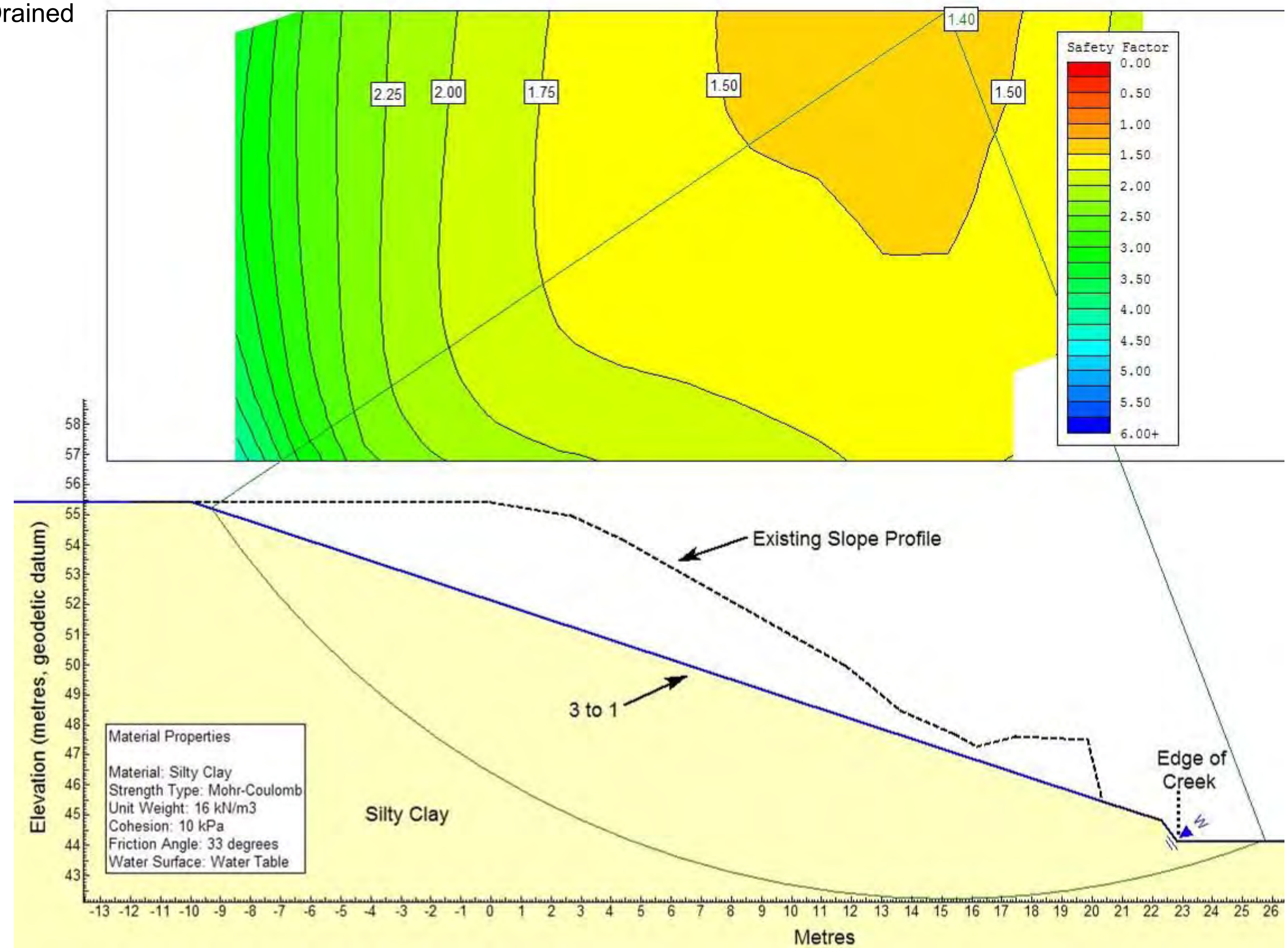
FIGURE D8

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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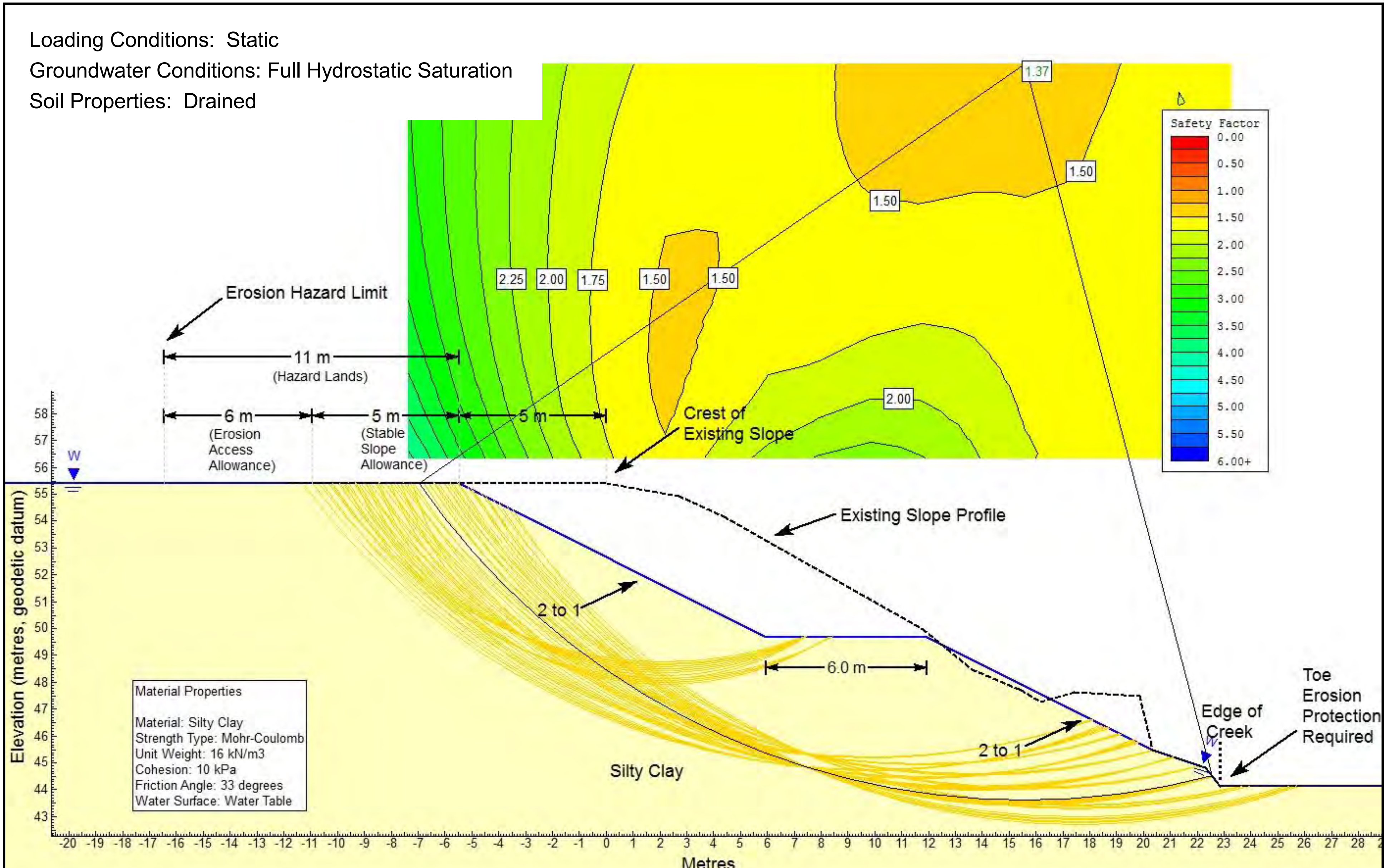
SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE D9

PROJECT: 11-618
DATE: June 2013



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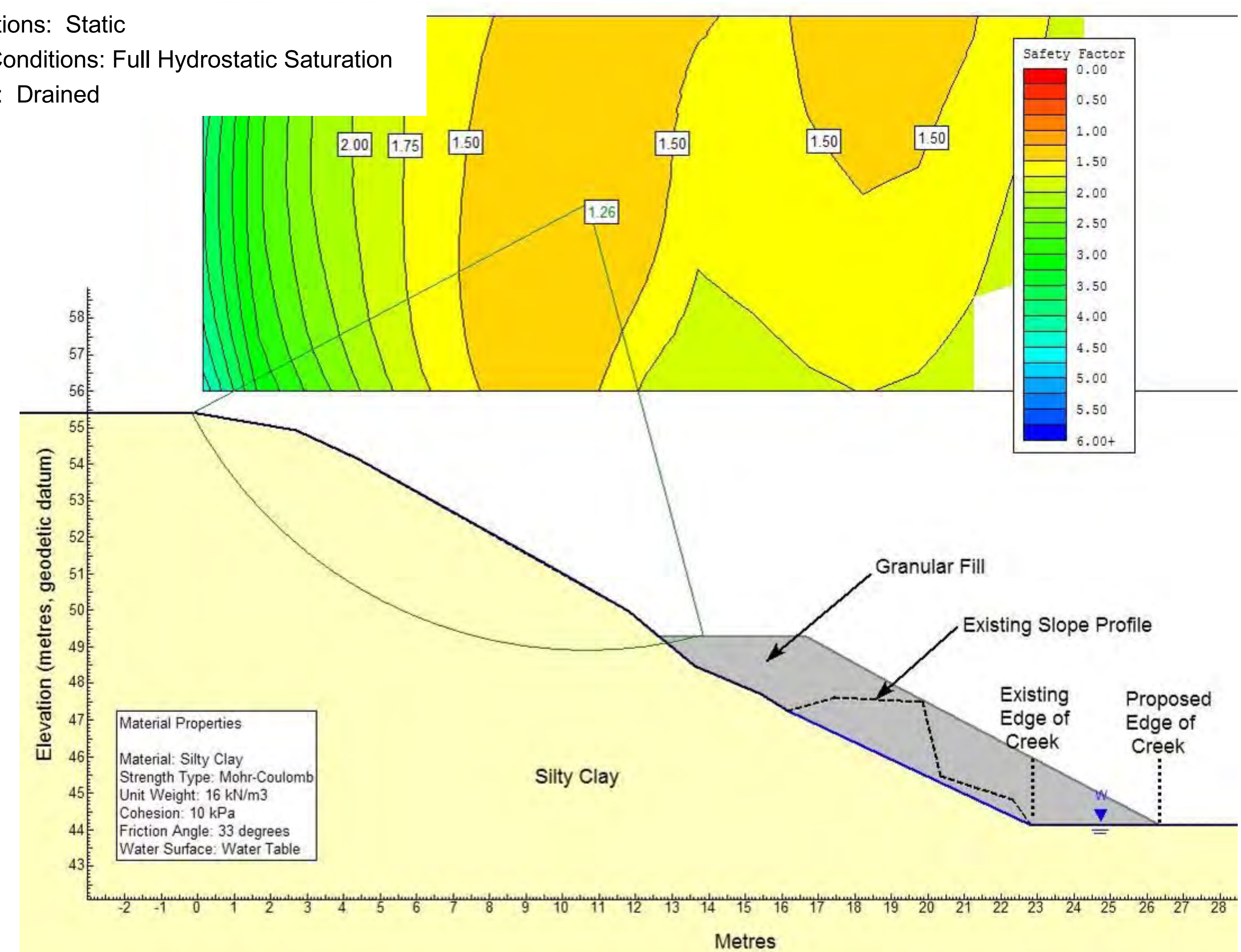
SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
BENCHING

FIGURE D10

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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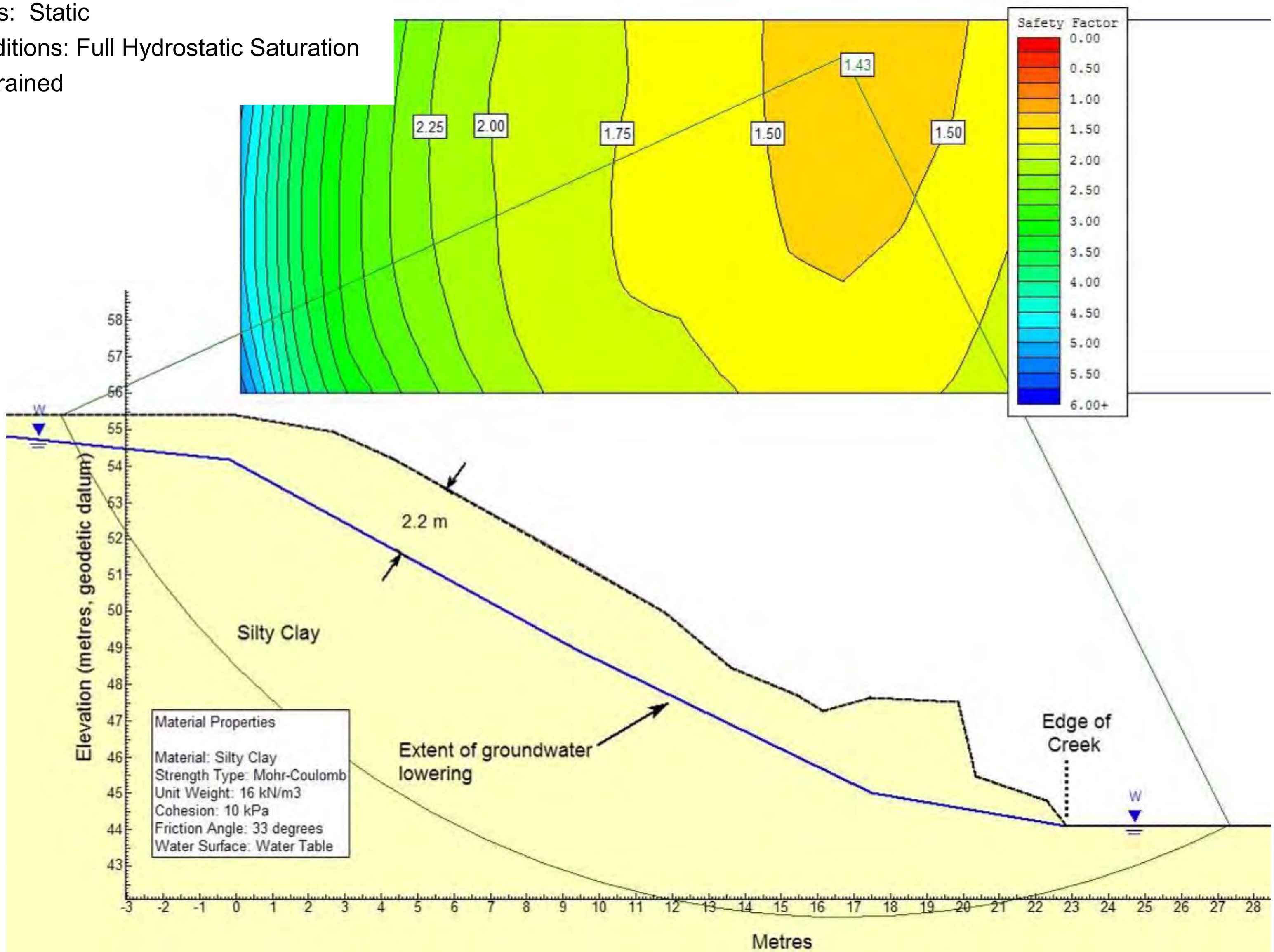
SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
TOE BERM

FIGURE D11

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 13
SECTION B-B
DEWATERING

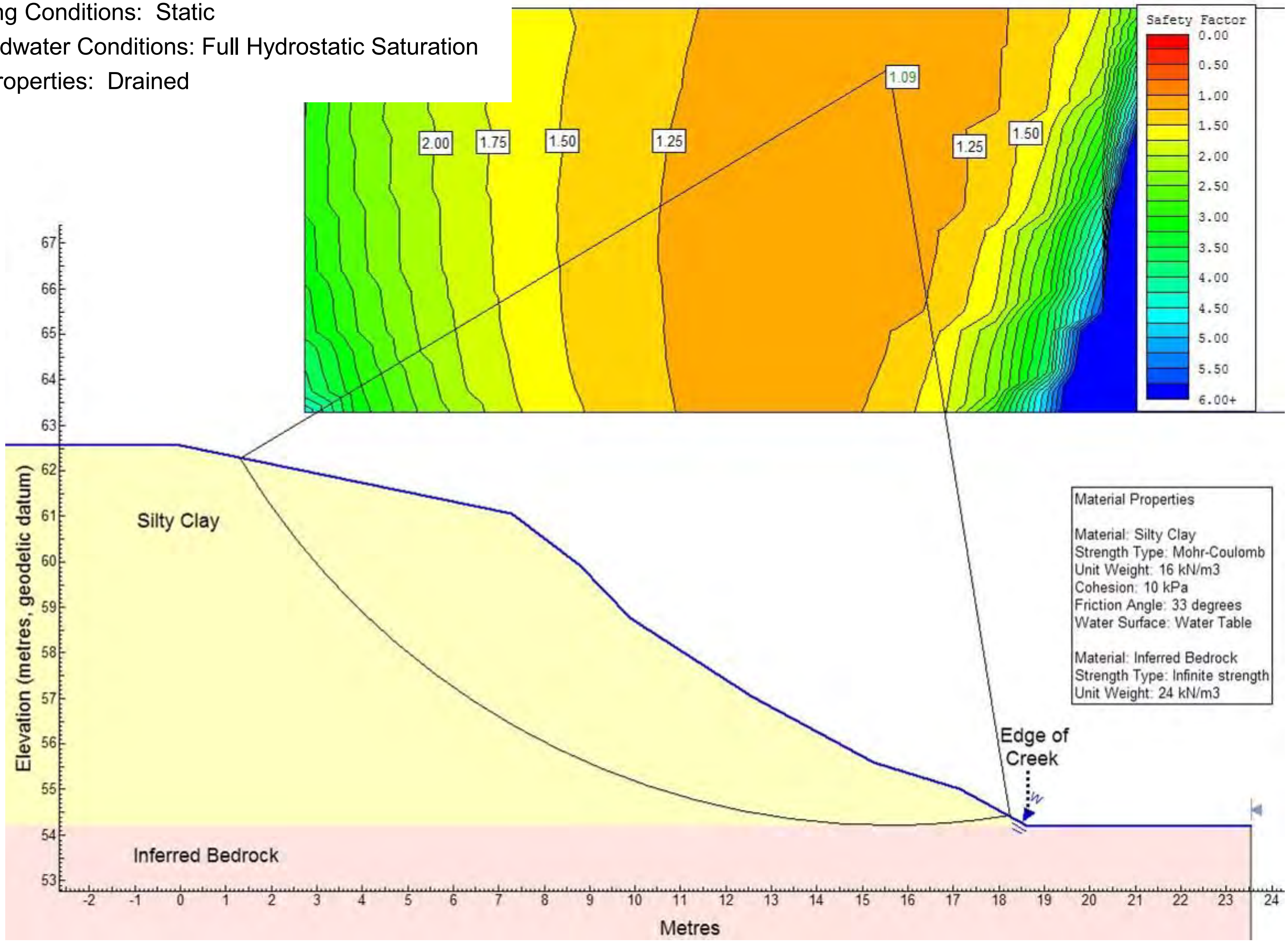
FIGURE D12

PROJECT: 11-618
DATE: June 2013

APPENDIX E

AREA 18
FIGURES E1 to E10

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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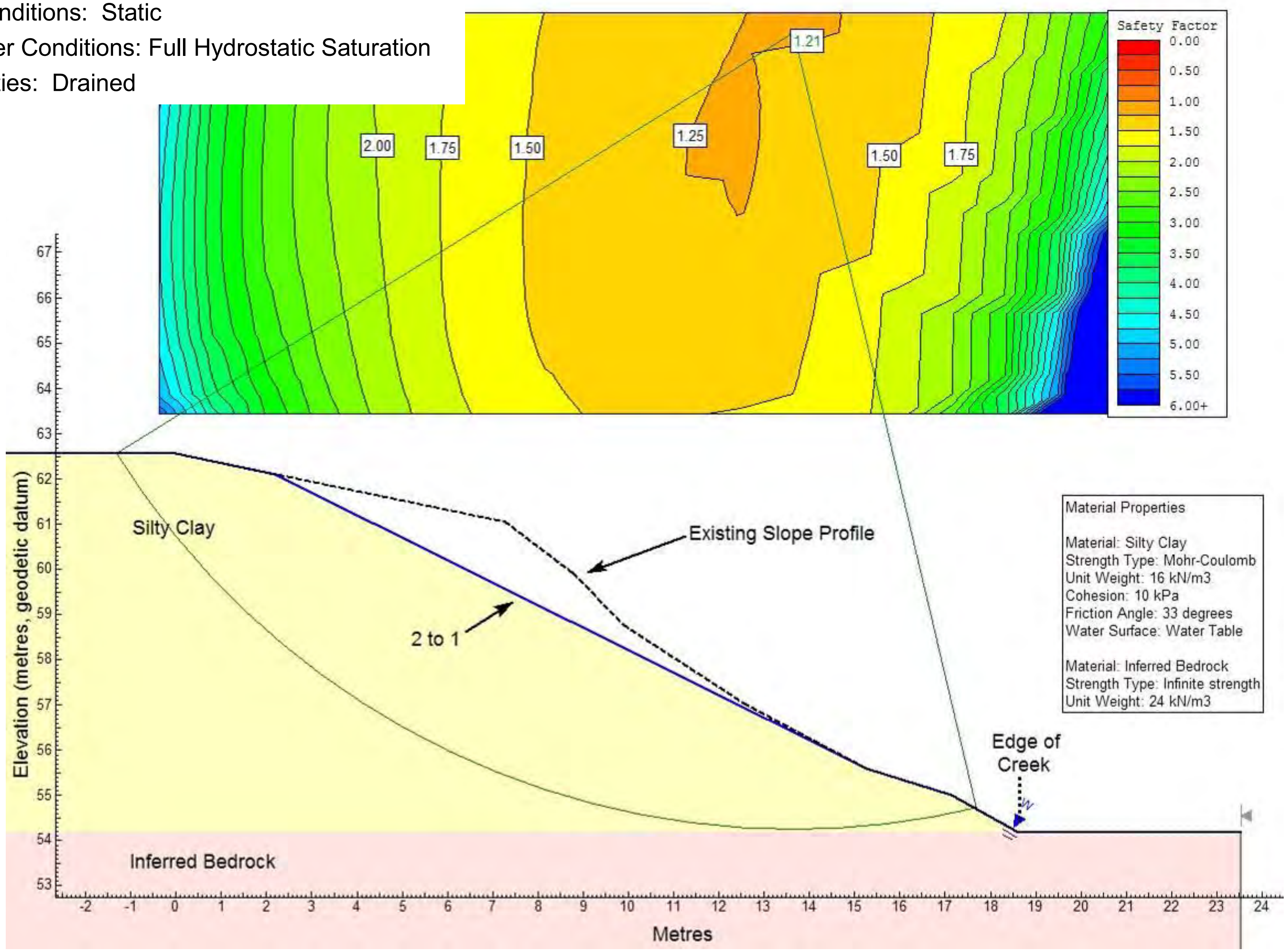
SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
EXISTING CONDITIONS

FIGURE E1

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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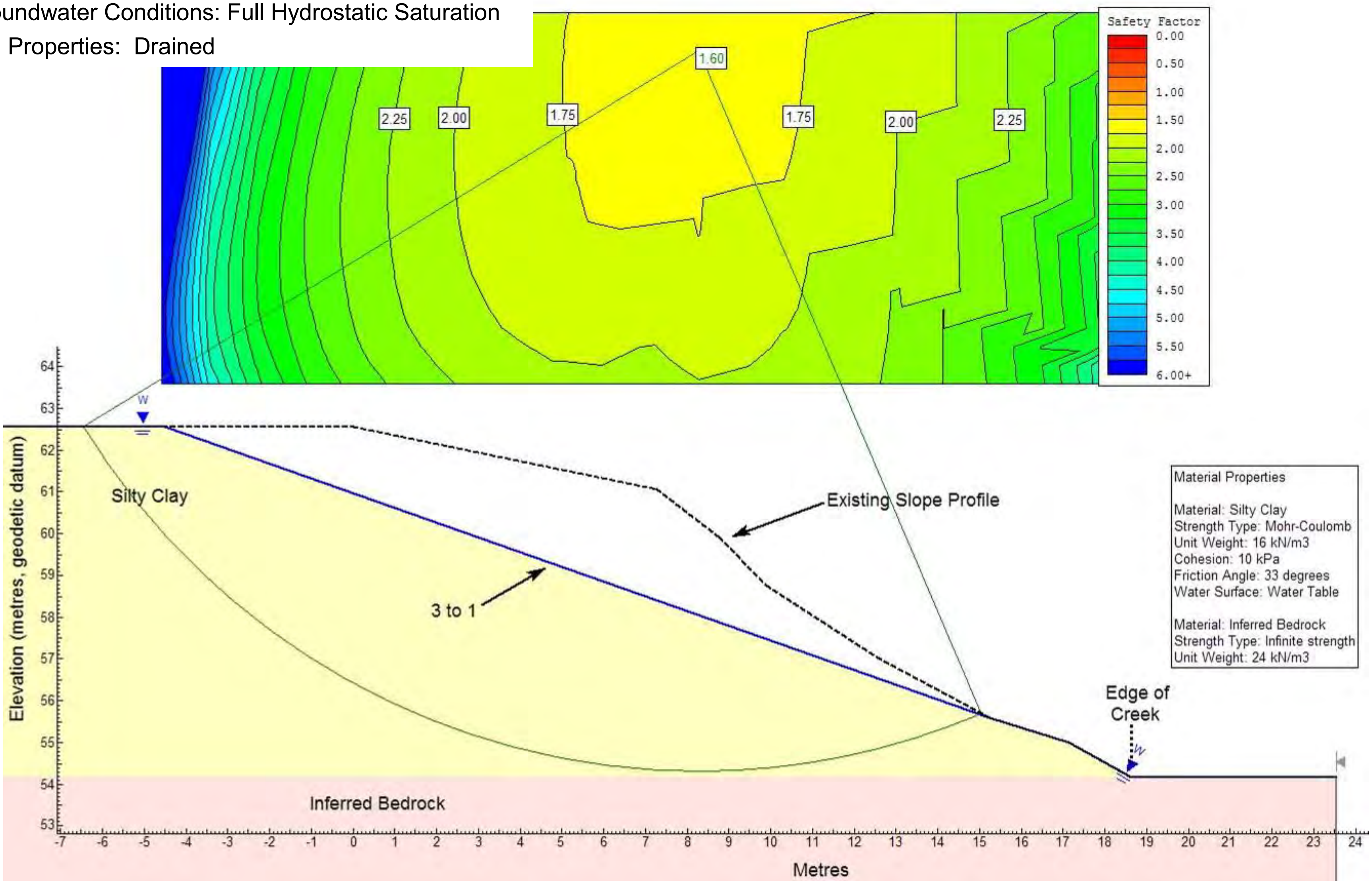
SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE E2

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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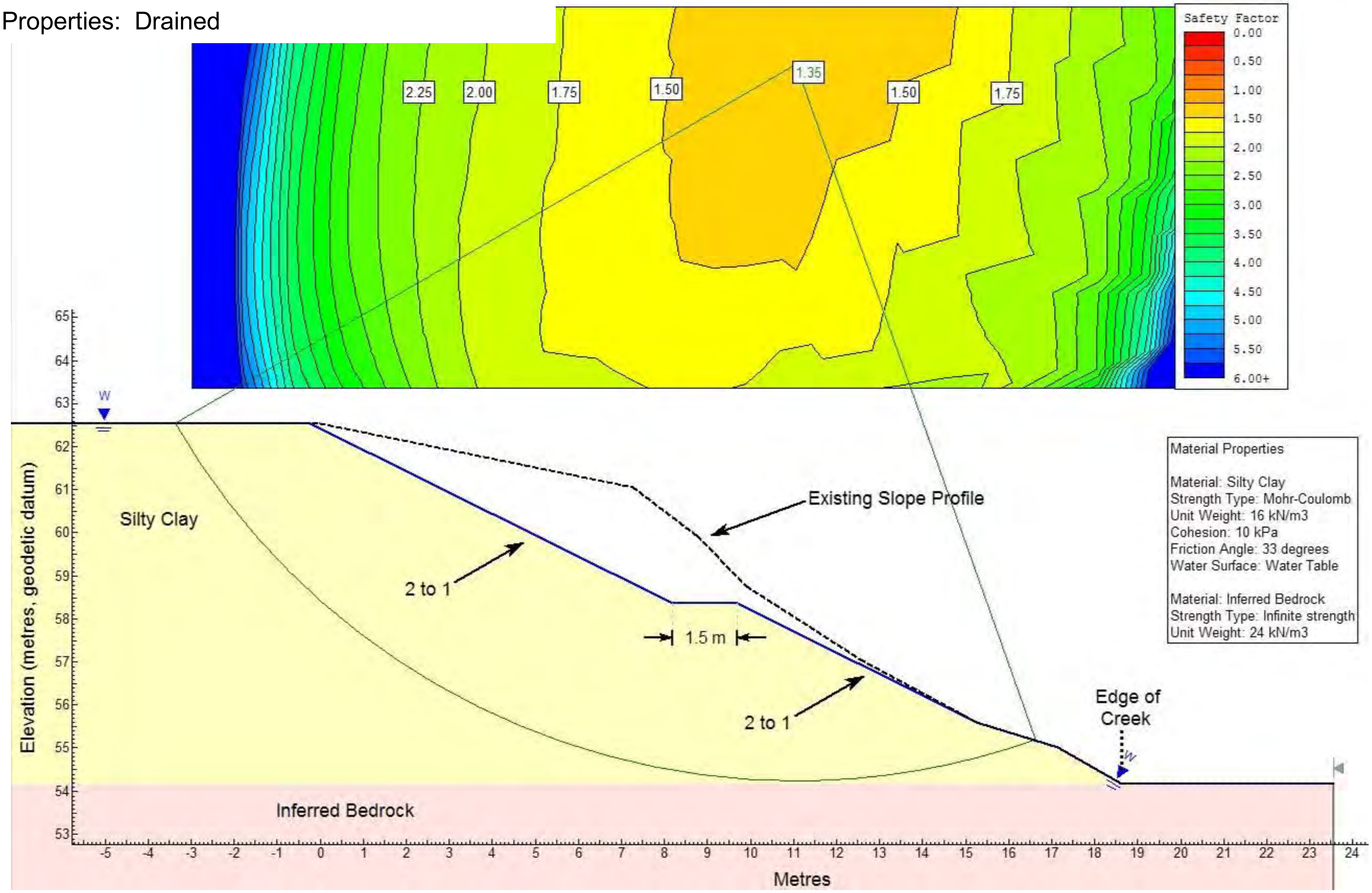
SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE E3

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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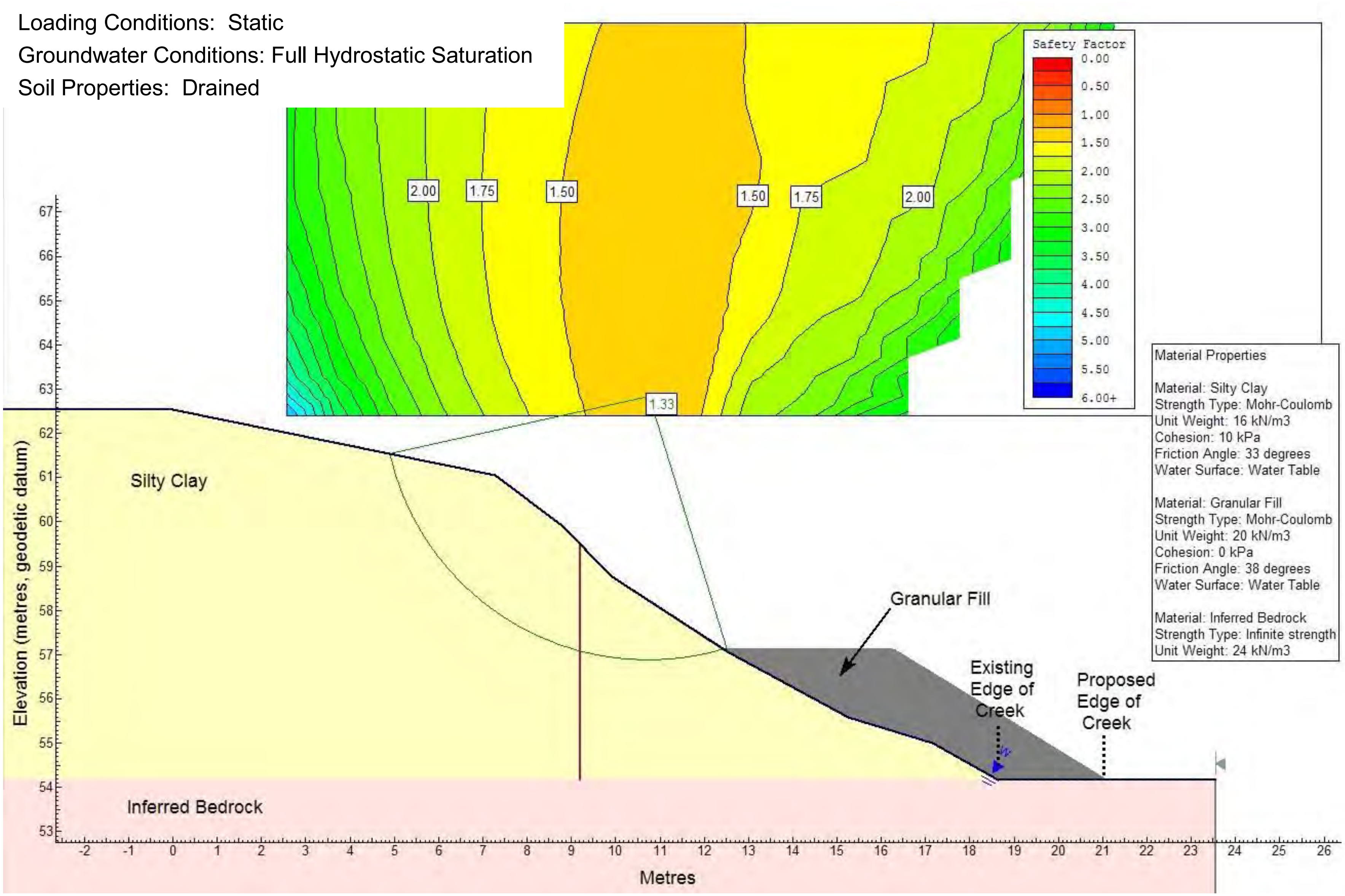
SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
BENCHING

FIGURE E4

PROJECT: 11-618
DATE: June 2013



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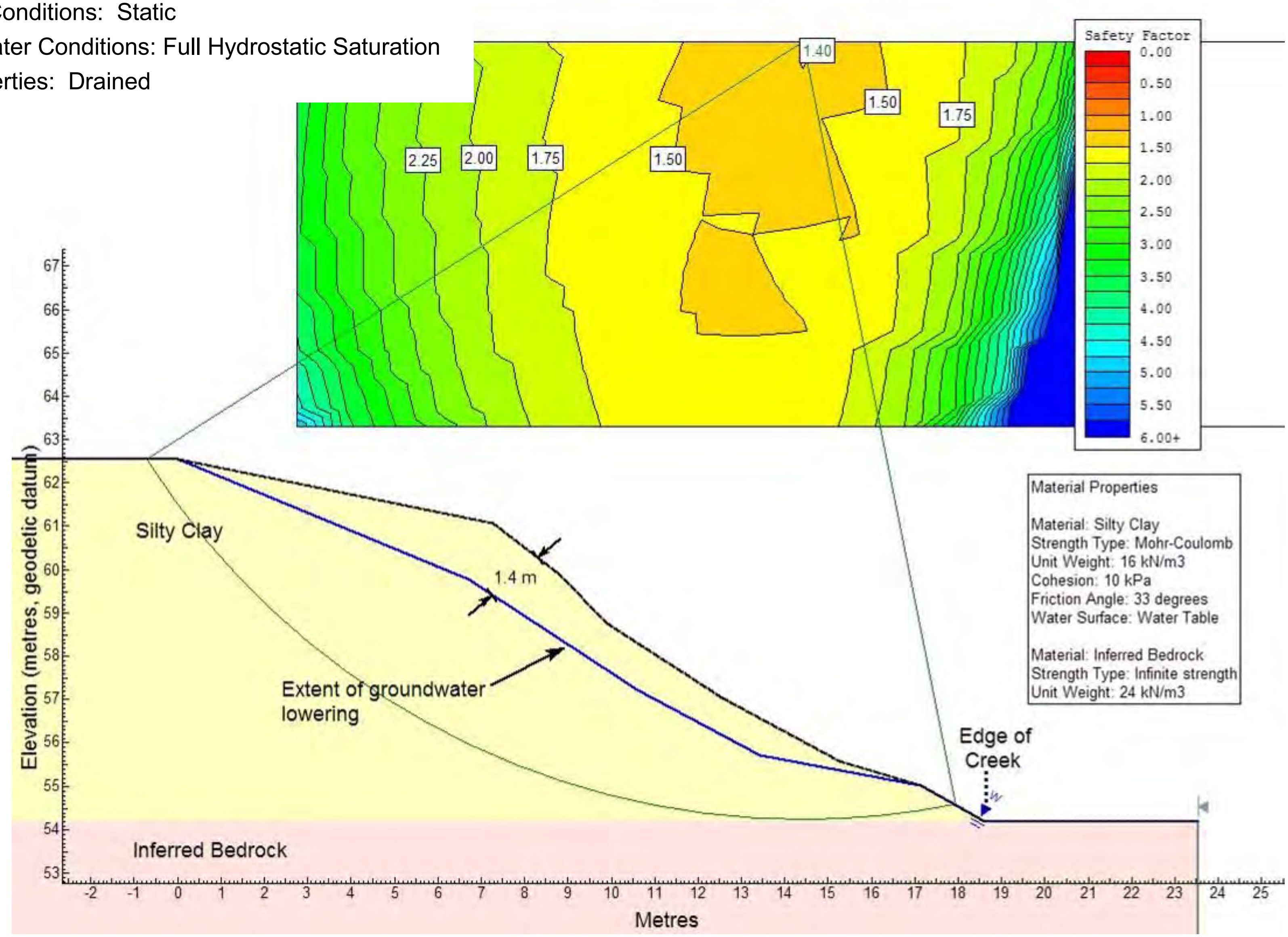
SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
TOE BERM

FIGURE E5

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 18
SECTION A-A
DEWATERING

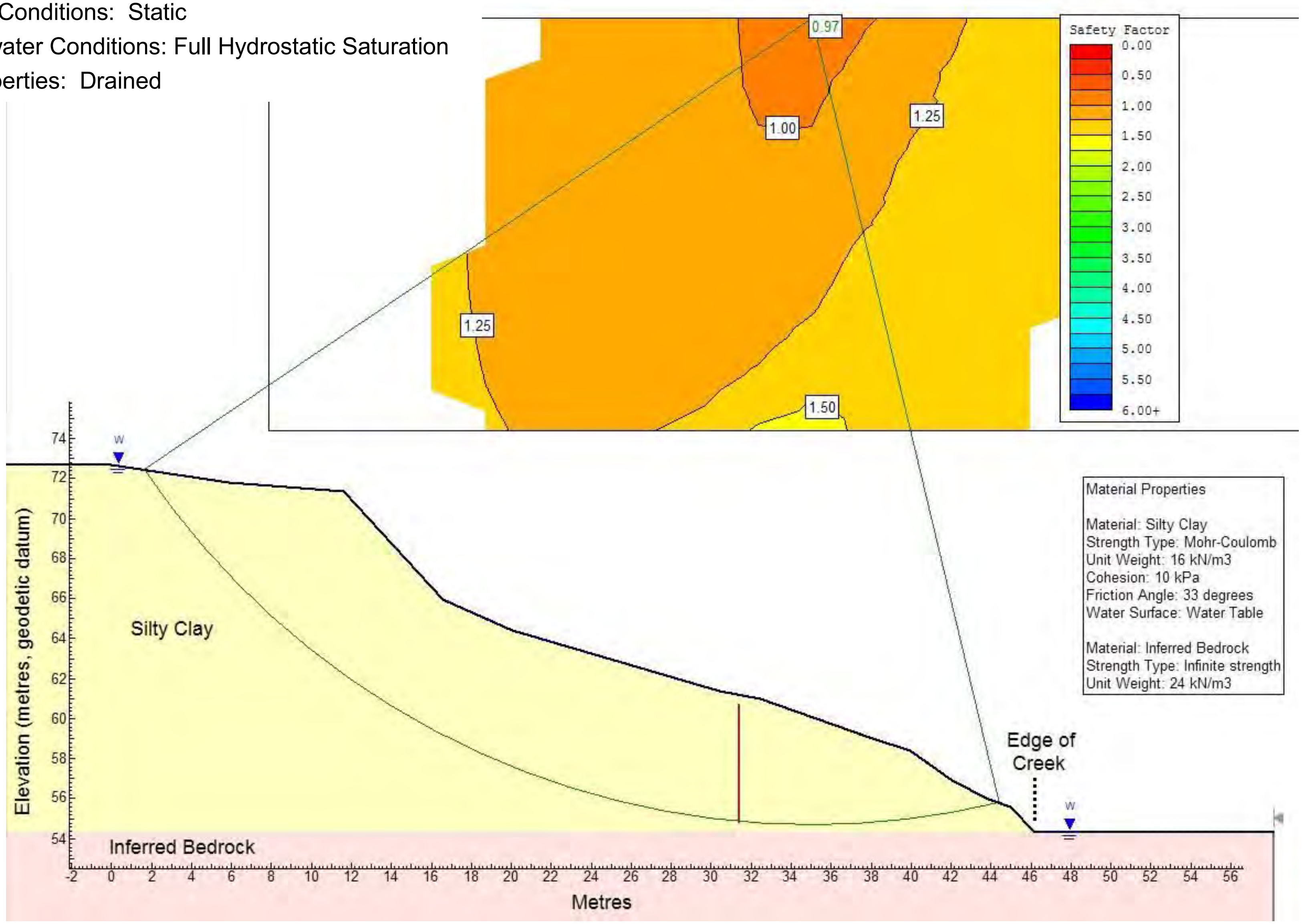
FIGURE E6

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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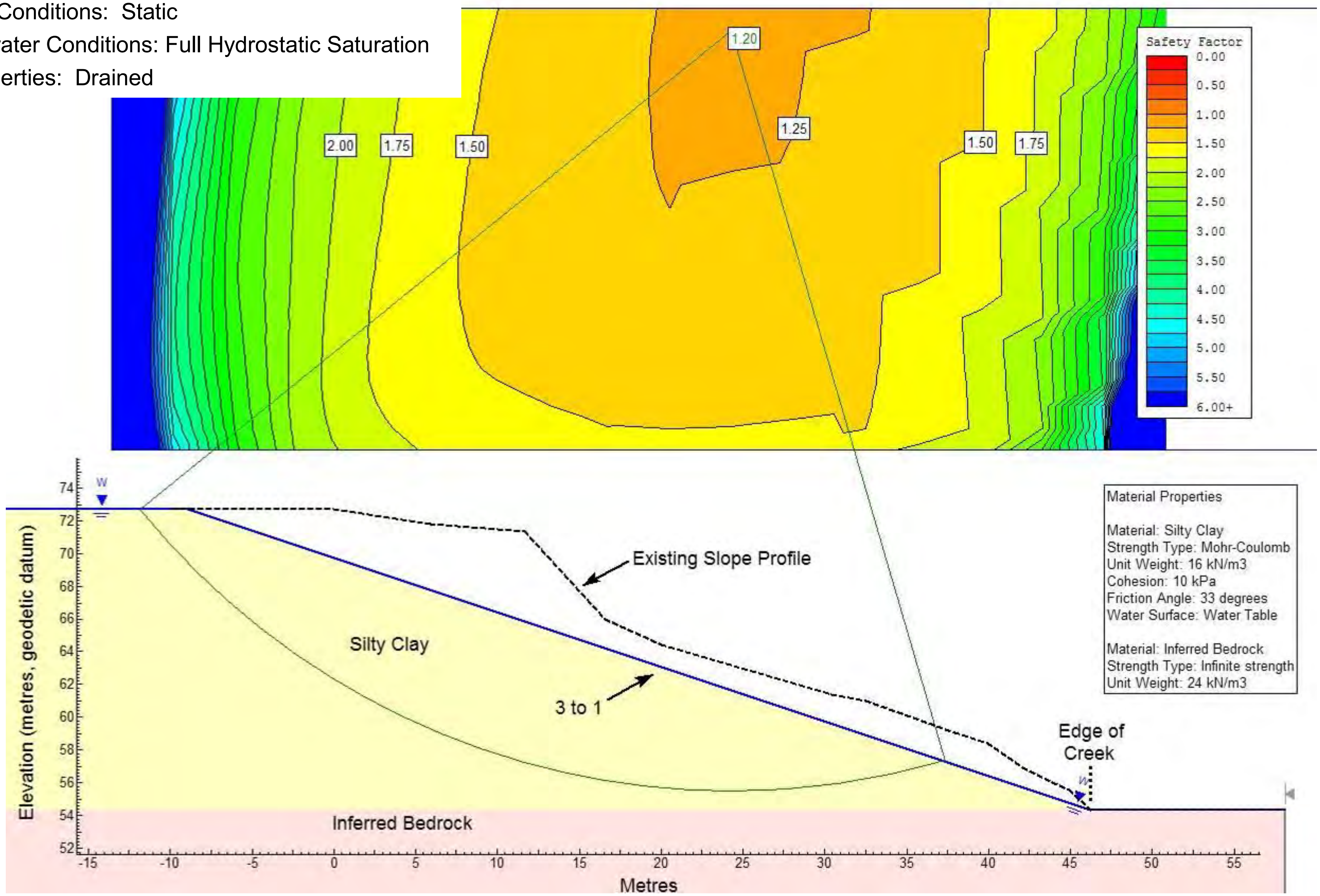
SLOPE STABILITY ANALYSIS
AREA 18
SECTION B-B
EXISTING CONDITIONS

FIGURE E7

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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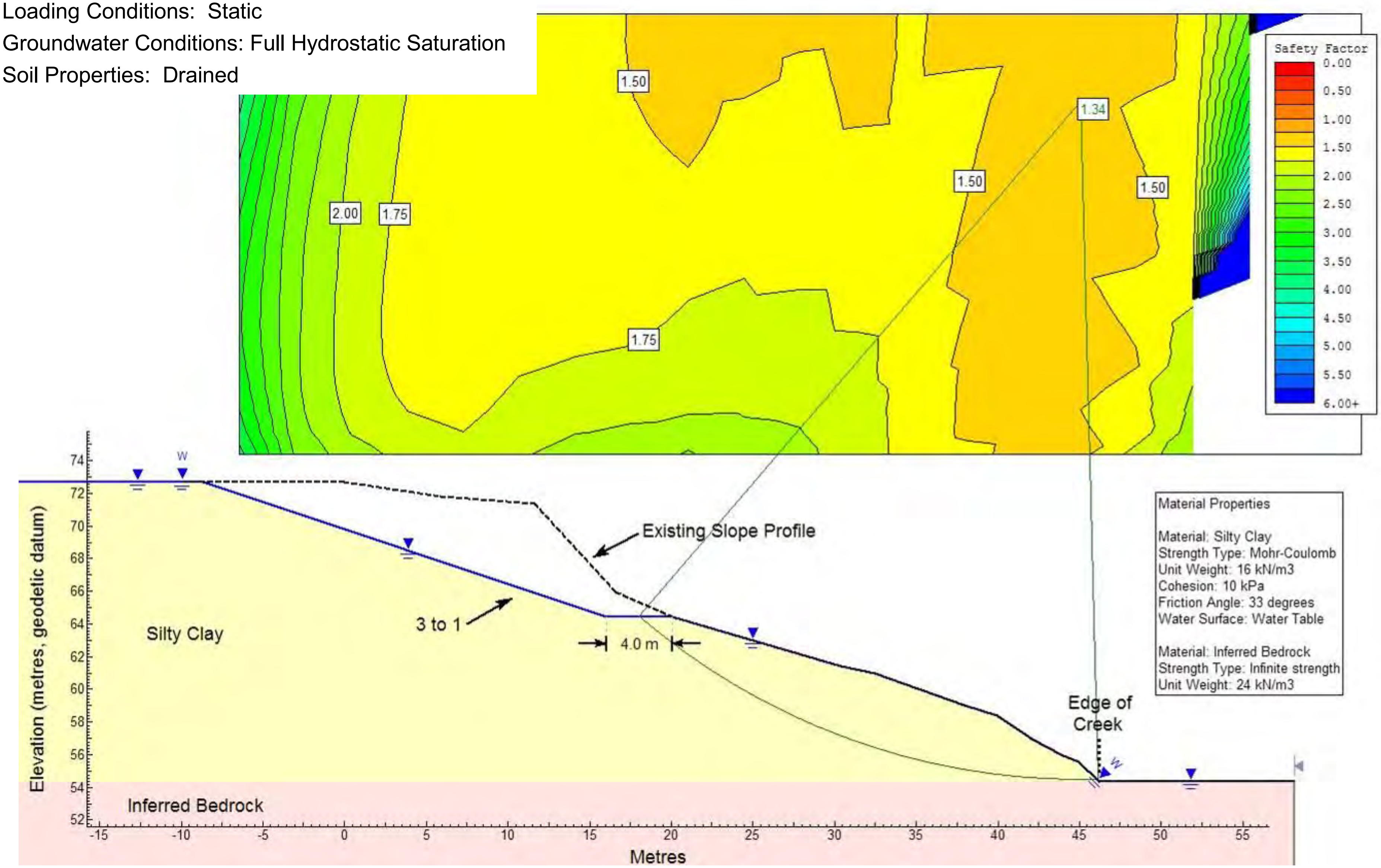
SLOPE STABILITY ANALYSIS
AREA 18
SECTION B-B
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE E8

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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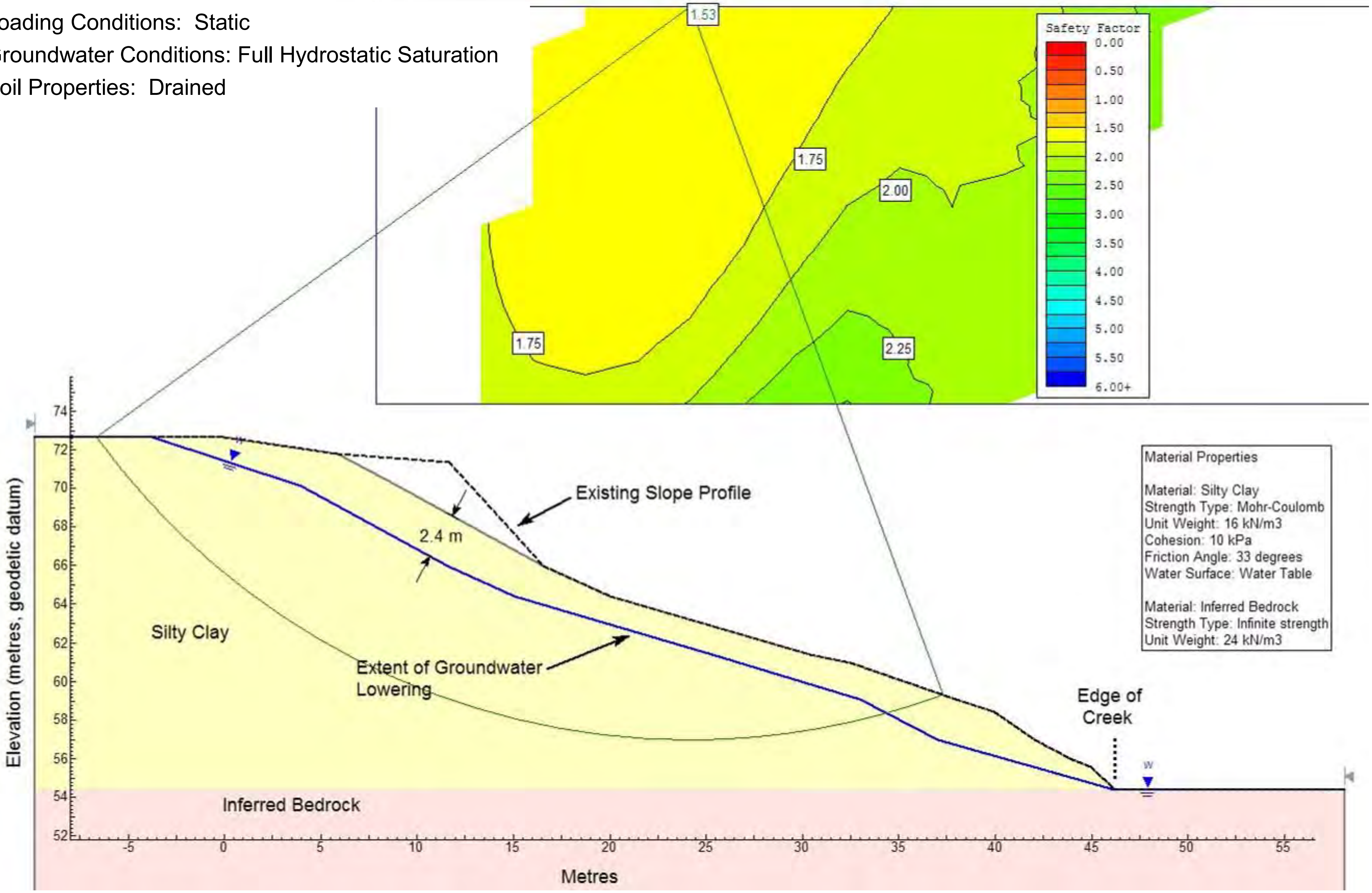
SLOPE STABILITY ANALYSIS
AREA 18
SECTION B-B
BENCHING

FIGURE E9

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 18
SECTION B-B
DEWATERING

FIGURE E10

PROJECT: 11-618
DATE: June 2013

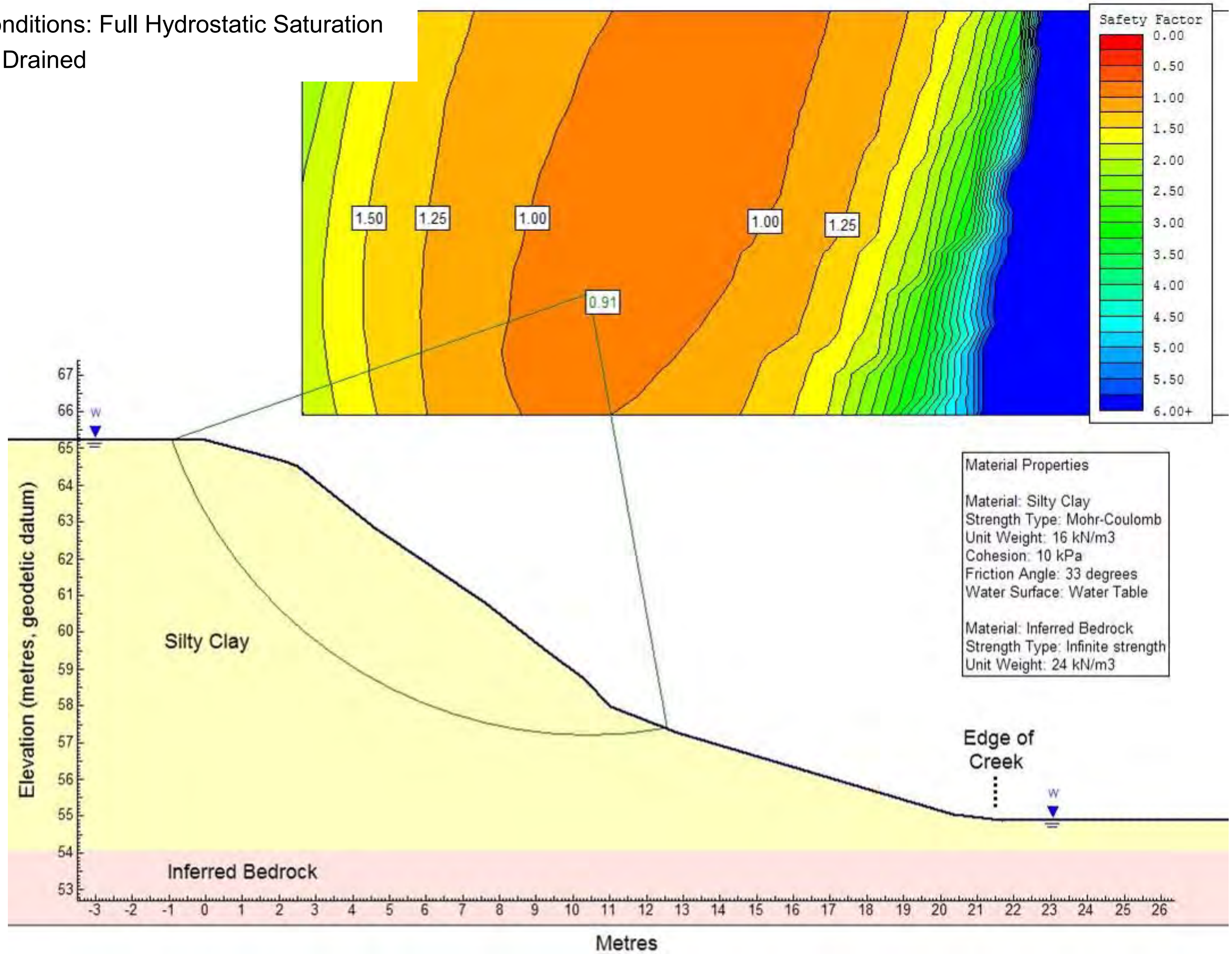
APPENDIX F

AREA 19
FIGURES F1 to F5

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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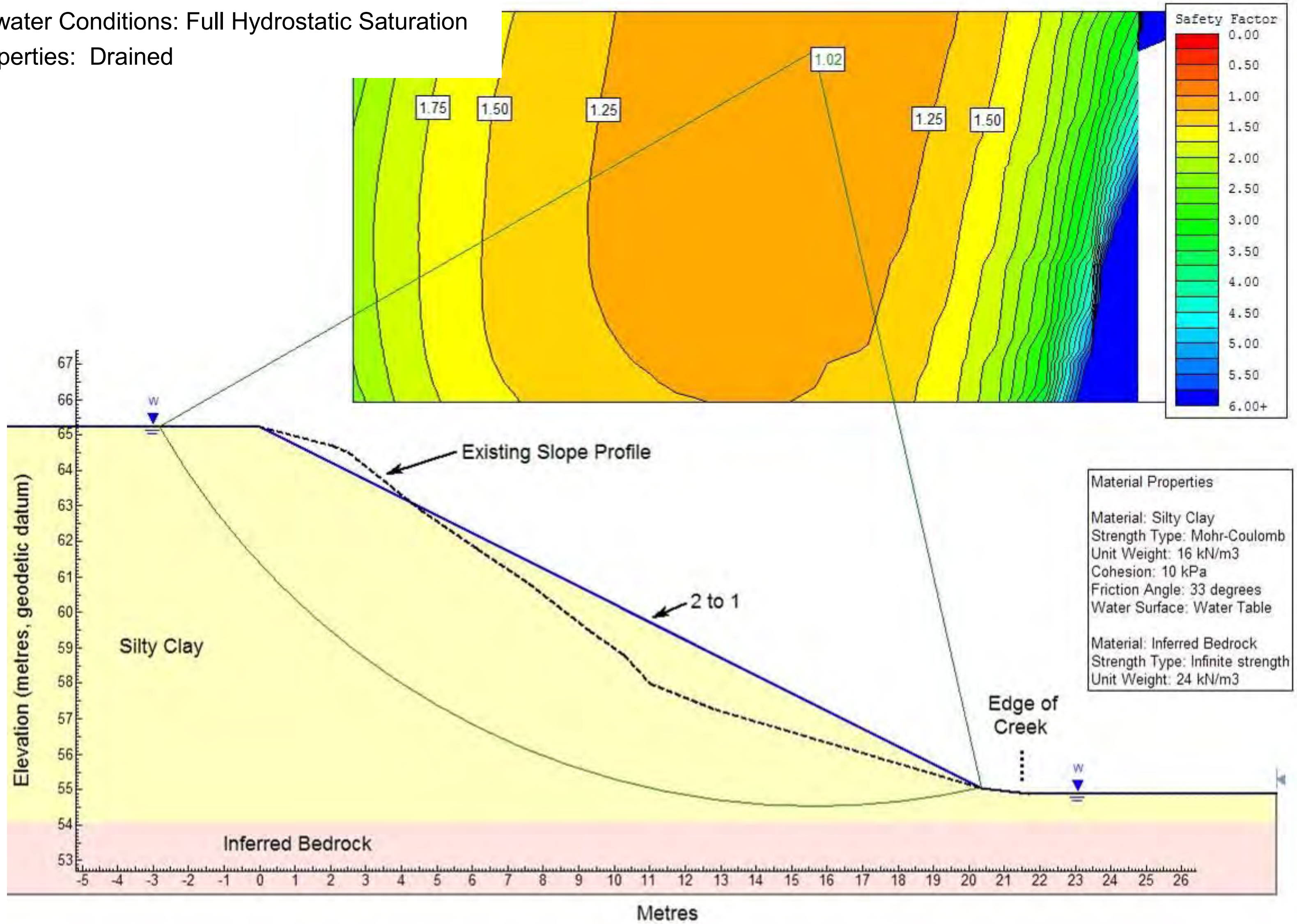
SLOPE STABILITY ANALYSIS
AREA 19
SECTION A-A
EXISTING CONDITIONS

FIGURE F1

PROJECT: 11-618

DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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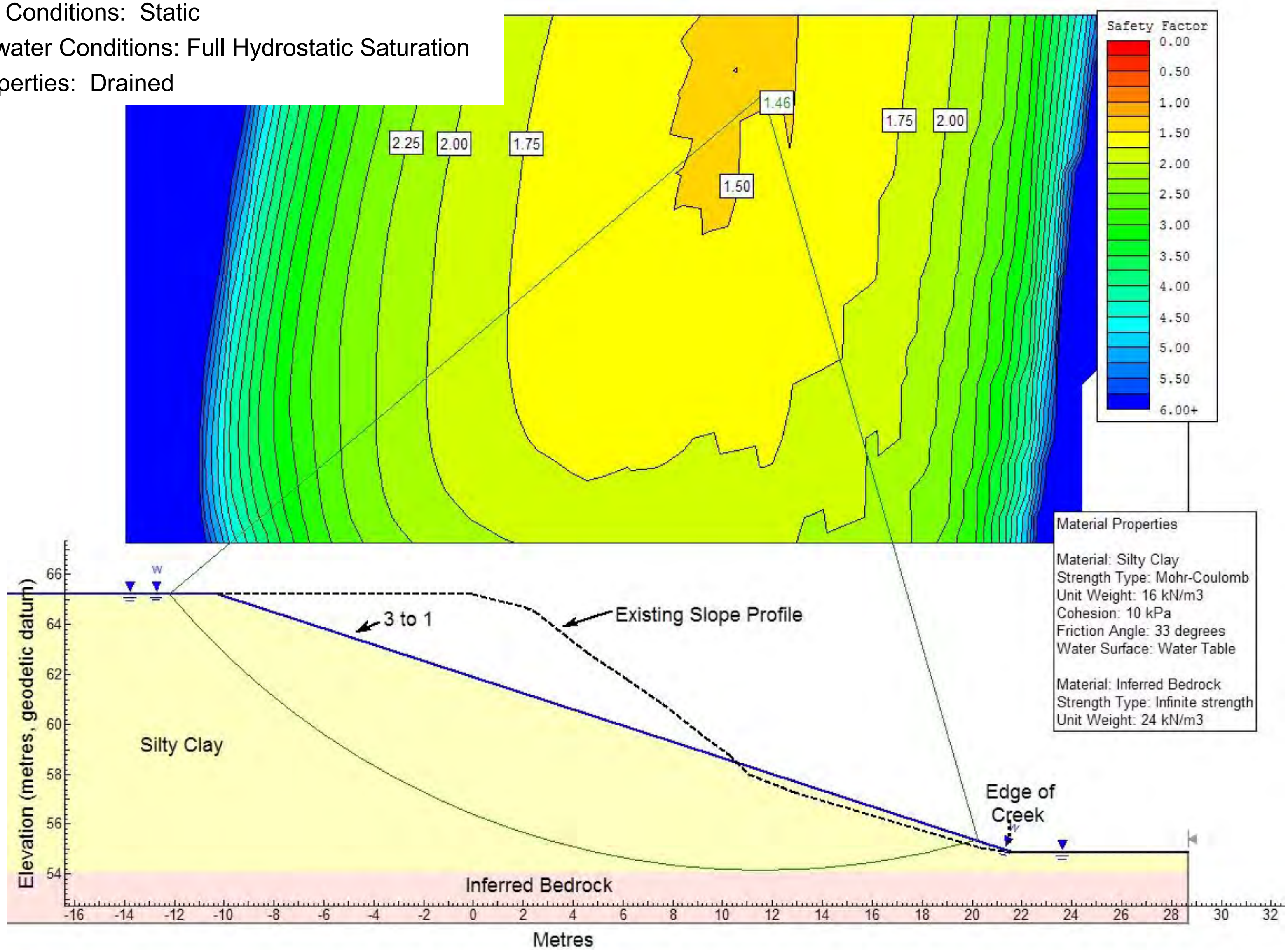
SLOPE STABILITY ANALYSIS
AREA 19
SECTION A-A
REGRADE TO 2 HORIZONTAL TO 1 VERTICAL

FIGURE F2

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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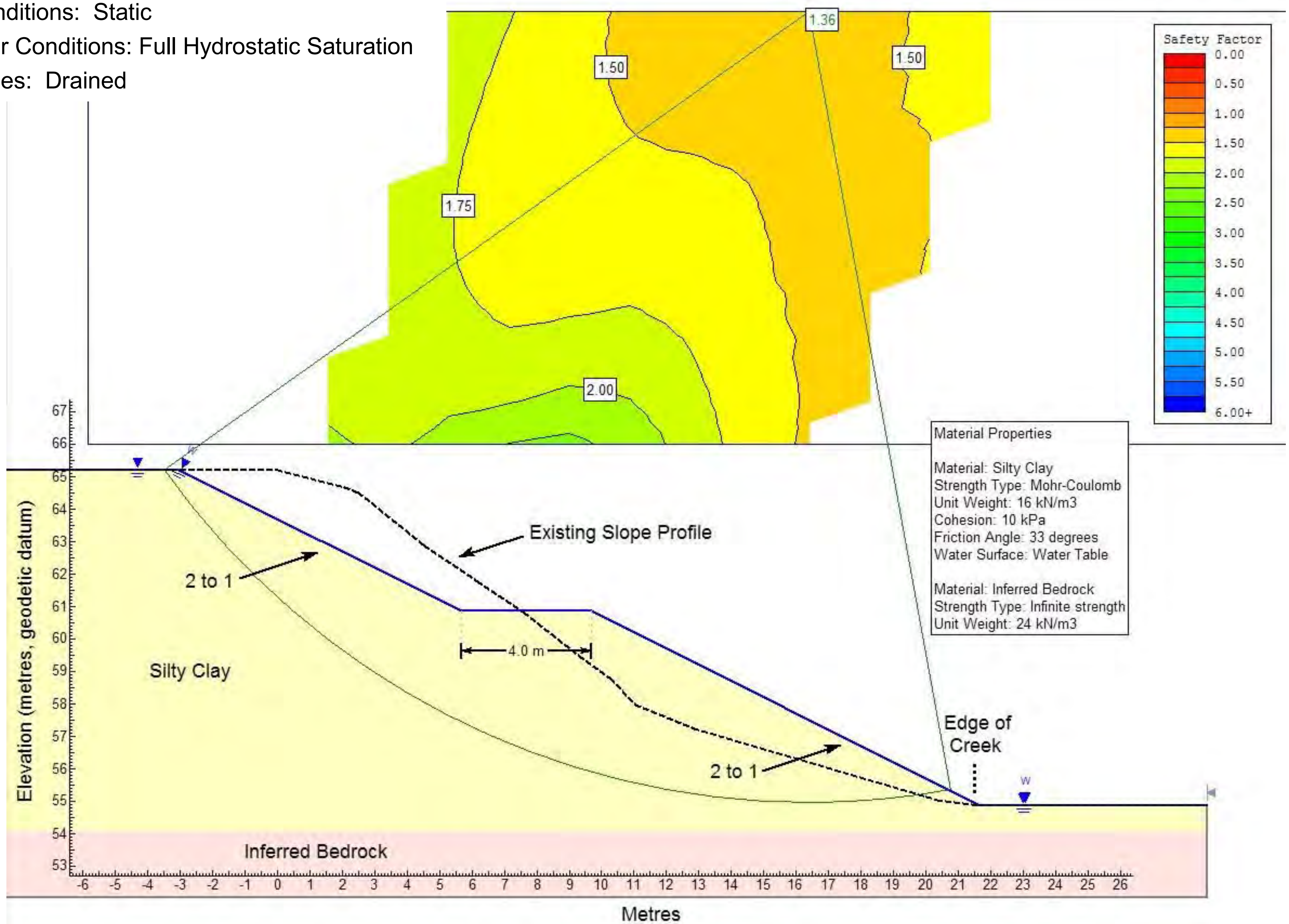
SLOPE STABILITY ANALYSIS
AREA 19
SECTION A-A
REGRADE TO 3 HORIZONTAL TO 1 VERTICAL

FIGURE F3

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static
Groundwater Conditions: Full Hydrostatic Saturation
Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 19
SECTION A-A
BENCHING

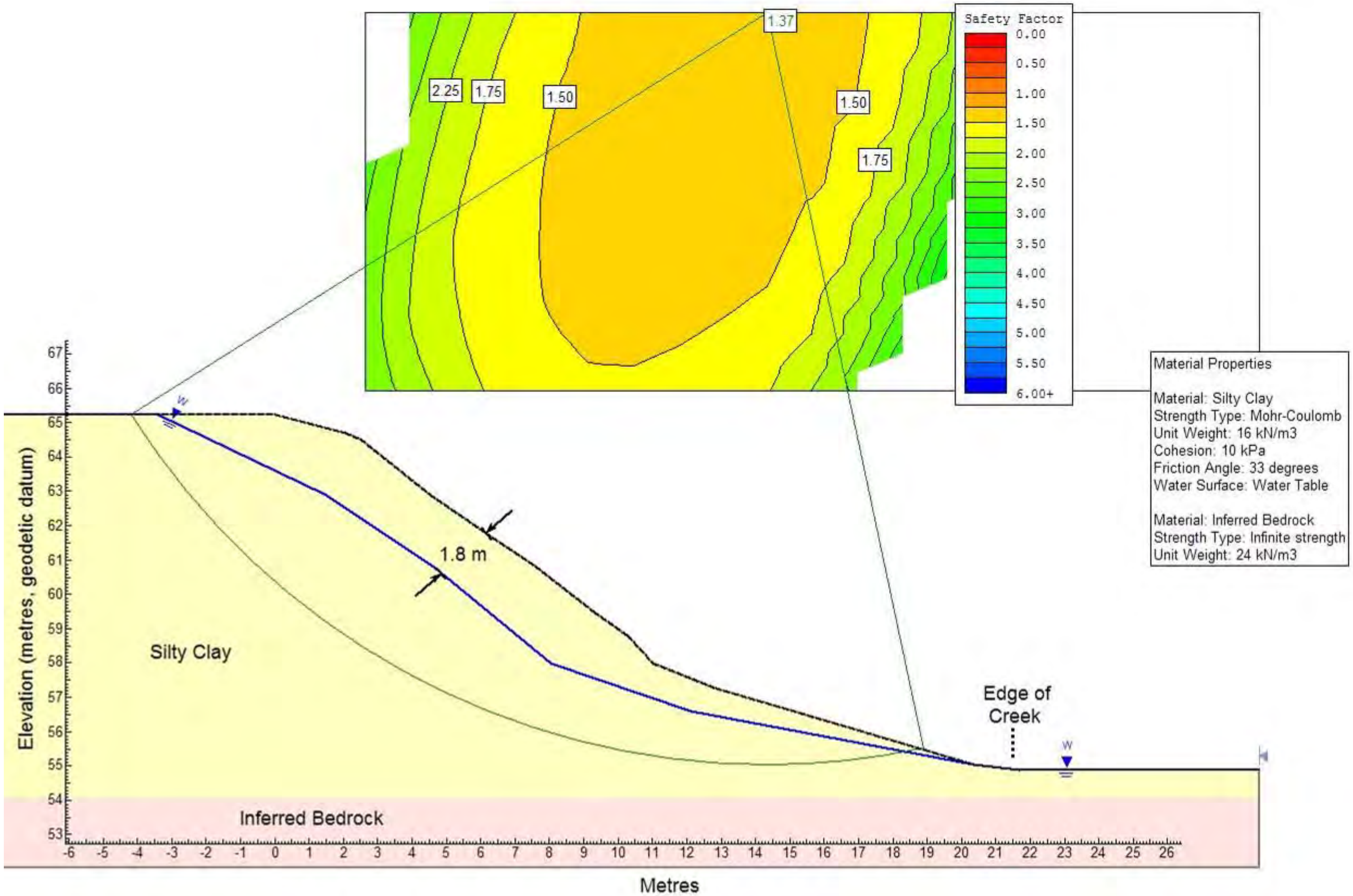
FIGURE F4

PROJECT: 11-618
DATE: June 2013

Loading Conditions: Static

Groundwater Conditions: Full Hydrostatic Saturation

Soil Properties: Drained



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SLOPE STABILITY ANALYSIS
AREA 19
SECTION A-A
DEWATERING

FIGURE F5

PROJECT: 11-618

DATE: June 2013