May 3, 2016

GEOTECHNICAL REPORT

Slope Stability Analysis York Downs Golf Club Redevelopment Markham, Ontario

Submitted to:
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Report Number: 1413472 (8000)

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Golder Associates

REPORT

Table of Contents

FIGURES

APPENDICES

1.0 INTRODUCTION

This report presents the results of slope stability analyses conducted for two slope sections located along the west bank of Bruce Creek within the York Downs Golf Club located at 4134 16th Avenue in Markham, Ontario (i.e., the Site).

The slope sections of concern were identified in a visual inspection of Bruce Creek during a preliminary geotechnical investigation conducted at the site by Golder Associates Ltd. (Golder) in June 2015, entitled "*Acquisition Due Diligence, York Downs Golf and Country Club, 4134 16th Ave. Markham, Ontario*". The visual inspection identified significant erosion on the west bank of the Bruce Creek generally in the North third of the property, which is resulting in over-steepening of the slopes. The preliminary investigation recommended completing setback analysis and a slope stability investigation to better define the development setbacks for this portion of the Bruce Creek within the property.

Golder completed a geotechnical investigation of the slope areas of concern (as identified in the preliminary geotechnical report) in conjunction with the installation of monitoring wells for a hydrogeological study. Based on the results of the geotechnical investigation for the west bank of Bruce Creek, slope stability analyses have been performed using the commercial software Geo-Studio provided by Geo-Slope International Ltd to provide input into the development setback, as recommended in the preliminary geotechnical report. This report provides a summary of the geotechnical investigation for the west bank of Bruce Creek, the results of the slope stability analysis and the geotechnical setback that should be used for development, based on the investigation and the Toronto and Region Conservation Authority Geotechnical Design and Engineering Requirements, 2007 ("TRCA Guidelines") and the Natural Hazards Technical Guide – River and Stream Systems: Erosion Hazard Limit, prepared by the Ministry of Natural Resources Ontario, 2002 ("MNR Guidelines").

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen months of the date of the report, Golder should be given an opportunity to confirm that the preliminary recommendations are still valid. In addition, this report should be read in conjunction with the attached "Important Information and Limitations of This Report", included in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 INVESTIGATION PROCEDURE

The field work for the geotechnical investigation for slope stability was carried out on February 29 and March 1, 2016. Boreholes 16-1 and 16-2 were advanced at the top of the bank in critical locations within the area of concern as identified in the preliminary geotechnical investigation, as outlined in the topographic drawing attached to this report as Figure 1.

The boreholes were drilled using a low ground pressure drill-rig supplied and operated by a specialist drilling contractor, subcontracted to Golder. Standard penetration testing and sampling were carried out at regular intervals of depth in the boreholes using conventional 35 mm internal diameter split spoon sampling equipment advanced using an automatic hammer. All of the soil samples obtained during this investigation were brought to our Markham laboratory for further examination, natural water content testing and soil classification testing.

The field work for this investigation was directed by a member of our engineering staff, who also logged the boreholes and cared for the recovered soil samples. The boreholes were staked out in the field and ground surface elevations were obtained by J.D. Barnes Limited. It is understood that the elevations are referenced to geodetic datum. The table below outlines the elevations and depth drilled of both boreholes.

Borehole	Surface Elevation (m)	Termination Depth (m)
16-1	187.4	12.8
16-2	185.4	12.4

3.0 SUBSURFACE CONDITIONS

The subsurface soil and shallow groundwater conditions encountered in the boreholes, as well as the results of the field and laboratory testing are shown in detail on the Record of Borehole sheets, attached in Appendix B.

In general, the sub-surface conditions at the slope areas of concerns consisted topsoil underlain by a surficial sandy silty clay deposit with trace to some of organics. Underlying the topsoil and sandy silty clay glacial till deposits were encountered ranging in gradation from silty sand till to silty clay till. The presence of cobbles and/or boulders is suspected within the till deposit at Borehole 16-2 due to observations of drilling progress. Groundwater was measured upon completion of drilling in Boreholes 16-1 and 16-2 at 11.2 m below ground surface (bgs) and 2.0 m bgs, respectively. A more detailed description of each soil strata encountered is below.

3.1 Topsoil

Topsoil was encountered in Boreholes 16-1 and 16-2 to depths of 0.4 m and 0.3 m, respectively; the natural water content of the topsoil material was 16 per cent and 22 per cent.

3.2 Silty Clay to Clayey Silt

A cohesive silty clay to clayey silt stratum was encountered directly underlying the topsoil in both boreholes. The stratum was characterized as sandy with traces of gravel and traces of fibrous organics. The stratum ranged from grey to dark brown in colour. The natural water content of the silty clay to clayey silt ranged from 17 per cent to 25 per cent. Four standard penetration tests (SPTs) were completed within this strata which resulted in SPT “N-values” ranging from 3 to 17 blows for 0.3 m of penetration, suggesting a soft to very stiff consistency. The silty clay to clayey silt strata extended to a depth of about 1.5 m bgs and about 1.4 m bgs in Boreholes 16-1 and 16-2, respectively.

3.3 Silty Sand to Sandy Silt Till

A non-cohesive silty sand to sandy silt glacial till stratum was encountered directly underlying the upper clayey silt stratum in Borehole 16-1 and underlying a cohesive clayey silt to silty clay glacial till stratum (which will be described further below) in Borehole 16-2. The silty sand to sandy silt till stratum contained some cohesive fines and traces of gravel. The natural water content of the silty sand to sandy silt ranged from 9 per cent to 12 per cent. Nine SPTs were completed within this stratum which resulted in SPT “N-values” ranging from 46 blows to greater than 100 blows for 0.3 m of penetration, indicating a dense to very dense compactness. In Borehole 16-1 the silty sand till stratum extended to a depth of 4.5 m bgs. Borehole 16-2 was terminated in the sandy silt till and a depth of 12.4 m bgs.

3.4 Silty Clay to Clayey Silt Till

A cohesive silty clay to clayey silt glacial till stratum was encountered underlying the silty sand till stratum in Borehole 16-1. Borehole 16-1 was terminated in the silty clay to clayey silt till at a depth of 12.8 m bgs. The silty clay to clayey silt stratum was encountered underlying the near surface sandy clayey silt stratum and overlying the sandy silt till stratum in Borehole 16-2. The silty clay to clayey silt till stratum extends to a depth of 5.6 m bgs in Borehole 16-2. The silty clay to clayey silt till stratum is characterized as sandy and contains trace to some gravel. The natural water content of the silty clay to clayey silt ranged from 9 per cent to 20 per cent.

Two grain size distributions were completed on samples obtained from this stratum and the results are presented in Appendix C, as Figure C1. Two Atterberg Limit Tests were completed on samples within this stratum which resulted in Liquid Limits (LL) of 19 per cent, Plastic Limits (PL) of 12 percent and Plasticity Indices (PI) of 7 per cent. The results of the Atterberg Limits are show on the Record of Borehole Sheets and Figure C2, in Appendix C. Eleven SPTs were completed within this stratum which resulted in SPT "N-values" ranging from 11 to 57 blows for 0.3 m of penetration, indicating a very stiff to hard consistency.

3.5 Shallow Groundwater Conditions

Observations of groundwater were made at the completion of drilling in the open borehole. The table below outlines the shallow groundwater conditions observed during the investigation.

Borehole	Groundwater Level Measured on March 1, 2016 at Completion of Drilling (m bgs)	Elevation of Groundwater Level Measured (m)
16-1	11.2	176.2
16-2	2.0	183.4

The observed groundwater conditions may not represent stabilized levels and groundwater levels should be expected to fluctuate seasonally.

4.0 DISCUSSION

This section of the report provides the results of a slope stability assessment completed for the subject slopes and recommends geotechnical setback requirements based on our interpretation of the borehole data and on our understanding of the project requirements. The information in this portion of the report is provided for the guidance of the design engineers and professionals. Our professional services for this assignment address only the geotechnical (physical) aspects of the subsurface conditions at this site. The geo-environmental (chemical) aspects, including the consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, are outside the terms of reference for this report.

The assessment of the stability of the subject slopes consisted of two parts: a site reconnaissance to observe and document the current slope conditions; and a series of static global stability analyses based on the subsurface conditions encountered during the geotechnical investigation.

4.1 Visual Slope Field Review

A site reconnaissance was carried out on February 9, 2016. This site reconnaissance was limited to the area of concern identified in the preliminary geotechnical report, near Boreholes 16-1 and 16-2, on the west side of Bruce Creek (study area). The following section provides a summary of observations related to the slopes adjacent to the abovementioned boreholes:

- Based on our site reconnaissance and the slope profiles provided by the surveyor, the portion of slope near Borehole 16-1 is approximately 6 m high, with an average slope inclination of about 1.5H:1V. The portion of the slope near Borehole 16-2 is approximately 4 m high, with an average slope inclination of approximately 1.7H:1V.
- The study area is currently covered by grass, brush and mature trees.
- The Bruce Creek channel is generally at the toe of the slope within the study area (i.e there is no flood plain between the creek bank and the top of the slope). Bank erosion due to undercutting was noted at the toe of the slope throughout the study area. At the toe of the slope near Borehole 16-2 the undercutting appears to have led to local failure of the near surface slope material. The observed bank erosion appears to have been caused by water flow within the creek channel.
- Localized areas of shallow sloughing of the near-surface slope materials were noted along the slope face adjacent to Borehole 16-1. The shallow sloughing appears to have been the result of bank erosion at the toe of the slope due to undercutting of the bank by the creek.
- Indications of surficial creep (e.g. curved tree trunks) were noted in an isolated area south of Borehole 16-2. Surficial creep may be due to the steady erosion of the toe of the slope due to undercutting and erosion of the creek bank.
- A few small drainage gullies are present within the slope area of concern near Boreholes 16-1 and 16-2. The drainage gullies are likely the result of runoff water flowing down the slope.
- Tension cracks and/or other indicators of deep seated movement of the slopes were not observed at or beyond the crest of the slopes.

In summary, toe erosion in the form of undercutting was observed on the west side of Bruce Creek where the creek channel is present at the toe of the slope. It is likely that the erosion of the toe of the slope has led to local slope failures at the toe and on the face of the slope. Curved tree trunks were noted south of Borehole 16-2, which may indicate long-term surficial movement of the slope, which could be caused by the on-going erosion of the toe of the slope. In addition, a few small gullies have formed at the crest and down the face of the slope. However, no signs of deep-seated slope instability, such as tension cracks, were noted during the visual reconnaissance on the western bank of Bruce Creek within the study area. A selection of site photos taken during the visual slope field review are attached to this report as Appendix D.

4.2 Slope Stability Assessment and Recommendations

The geotechnical setback criteria as discussed below are based on the subsurface conditions obtained from the geotechnical investigation (Boreholes 16-1 and 16-2), the topographic drawing and slope geometry information provided by J.D. Barnes and takes into account slope stability and erosion considerations. The geotechnical setback distance is comprised of an allowance for a potential zone of slope failure / instability, an allowance for potential erosion at the toe of the slope, and an allowance for erosion access at the top of the slope.

The criteria for the estimation of required set-backs along the slopes is governed by the Toronto and Region Conservation Authority Geotechnical Design and Engineering Requirements, 2007 (“TRCA Guidelines”) and the Natural Hazards Technical Guide – River and Stream Systems: Erosion Hazard Limit, prepared by the Ministry of Natural Resources Ontario, 2002 (“MNR Guidelines”). The setback allowances provided in this report are based on the approximate edge of creek. The geotechnical setback allowances provided also include a development/access setback component as required by TRCA. Any setback required for safety against flood conditions or preservation of vegetation or wildlife is independent of the geotechnical setback criteria and is not considered in this assessment.

The proposed final grading at the site is currently unknown. In this regard, the information in this report should be reviewed by the geotechnical engineer and additional analysis be carried out once the proposed grading plans are available.

4.3 General Setback Guidelines

The setback distance behind the crest of the slope is comprised of three components as follows:

- Toe Erosion Allowance: an allowance for erosion at the toe of the slope if the creek is located within 15 metres of the slope’s toe;
- Stable Slope Allowance: an allowance for potential slope failure or instability; and
- TRCA Access Allowance: an allowance to determine the landward limit of erosion hazards.

4.3.1 Toe Erosion Allowance

The erosion component of the geotechnical setback distance is governed by the proximity of the slope toe to a watercourse, the susceptibility of the slope or bank materials to erosion and whether active erosion is noted. The magnitude of the erosion component is typically the estimated recession of the slope toe due to erosion over the design life assumed in the MNR Guidelines, and is measured as a horizontal distance from the top of the channel bank.

Bruce Creek is within 15 m of the toe of the slope throughout the entire study area and as noted in Section 4.1 active erosion was noted along the bank of Bruce Creek throughout the study area. The material at the bank of Bruce Creek has been determined based on the soil strata observed in Boreholes 16-1 and 16-2 at the elevation of the creek, which consists of stiff to hard sandy silty clay till and sandy clayey silt till. Based on the MNR Guidelines the required toe erosion allowance should be assumed to be 8 m from the edge of the watercourse.

4.3.2 Stable Slope Allowance

In general, the stable slope allowance is a function of the existing surface and subsurface conditions of the slope such as slope geometry, soil strength, groundwater conditions and vegetation, as well as surcharge loading at the crest of the slope.

The stable top-of-slope line is derived from general stability guidelines (e.g. a line drawn upward at 3H:1V from the toe of the slope to intersect the tableland above the slope crest) or based on stability analyses (for potential failure/slip surfaces for a required Factor of Safety) using site-specific subsoil conditions and groundwater conditions obtained from geotechnical investigations.

If site-specific subsurface information is obtained to define the soil stratigraphy and design parameters, as is the case for this site, the stable slope allowance may be derived from a detailed stability analysis using appropriate analytical methods. The intersection of the stable slope alignment and the ground surface is considered as the stable top of the slope.

For the proposed development at this site, the geotechnical stability component of the setback has been assessed for slope sections adjacent to Boreholes 16-1 and Borehole 16-2 by carrying out a limited equilibrium slope stability analyses using the commercially-available program GeoStudio 2007, produced by Geo-Slope Internation Ltd., using the Morgenstern-Price (M-P) method of analysis. The static slope stability analyses were carried out utilizing the topographic survey drawing and cross-sectional survey carried out by J.D. Barnes, and from the soil stratigraphy and shallow groundwater conditions as encountered in Boreholes 16-1 and 16-2.

The following geotechnical parameters were used in the analysis, based on the SPT "N" values measured in the boreholes, accepted correlations in literature, and Golder's experience with the soil in this area.

Soil Conditions	Bulk Unit Weight (kN/m^3)	Effective Friction Angle
Slope Section Adjacent to Borehole 16-1		
Sandy Clayey Silt	19	29°
Silty Sand (Till)	21	35°
Sandy Silty Clay (Till) to Sandy Clayey Silt (Till)	21	35°
Slope Section Adjacent to Borehole 16-2		
Sandy Clayey Silt	19	29°
Sandy Silty Clay (Till) to Sandy Clayey Silt (Till)	21	35°
Sandy Silt (Till)	20	35°

The stability component of the geotechnical setback is based on the family of "slip surfaces", or potential failure surfaces. A minimum safety factor of 1.5 is recommended for the stable slope allowances.

The results of the slope stability analysis conducted for the slope section near the location of Borehole 16-1, as shown on Figure E1, in Appendix E, indicate that the family of slip surfaces required to achieve a Factor of Safety of about 1.5 against global (i.e. deep-seated) slope instability requires a slope angle of approximately 2.5H:1V extending up from the toe of the slope. This corresponds to a stable slope allowance of approximately 15.0 m (based on a 6 m high slope).

The results of the slope stability analysis for the slope section in the vicinity of Borehole 16-2, as shown on Figure E2, in Appendix E, indicate that the family of slip surfaces required to achieve a Factor of Safety of about 1.5 against global slope instability define a slope angle of approximately 2.3H:1V extending up from the toe of the slope. This corresponds to a stable slope allowance of approximately 9.2 m (based on a 4 m high slope).

4.3.3 TRCA Access Allowance

The Access Allowance is typically applied to the geotechnical setback to provide for emergency access to erosion prone areas, construction access for maintenance or for an erosion event or failure, and to provide protection against external conditions which could have an adverse effect on the existing natural condition of the slope. As per the TRCA policy, the minimum erosion access allowance should be 10 m from the crest of the geotechnical stable slope.

4.3.4 Total Recommended Setbacks

Based on the data derived from the detailed analysis carried out at the slopes adjacent to the borehole locations, Golder has also assessed additional slope sections at the 3 other sections shown on Figure 1. The detailed sections and setbacks are shown on Figure 2. The following table summarizes the individual setback requirements, and the total setback from the edge of the creek (creek bank) at all five of the sections.

Section ID	Toe Erosion Allowance (m)	Stable Slope Allowance (m)	TRCA Access Allowance (m)	Total Setback from Creek Bank (m)
Section A-A’	8.0	15.0	10.0	33.0
Section B-B’	8.0	9.2	10.0	27.2
Section C-C’	8.0	11.3	10.0	29.3
Section D-D’	8.0	10.0	10.0	28.0
Section E-E’	8.0	14.4	10.0	32.4

Refer to Figure 2 for the setback limit within the study area. As noted above the setback provided in the above table and on Figure 2 is based on the Toe erosion allowance, stable slope configuration, and TRCA access allowance. Based on our analysis, on four of the five sections (B-B’ to E-E’) the Top of Stable Slope was determined to be inside (closer to the creek) of the Staked Top of Slope Line. Within the study area, the Natural Hazard Setback line shown on Figure 2 reflects the Top of Stable Slope Line plus the 10m TRCA Access Allowance.

4.4 Additional Recommendations

The following conditions should be considered for development at this site in order to minimize adverse effects on the stability of the slope:

- All surface water run-off should be directed away from the slope surface;
- No fill placement (i.e. grade raise) should be carried out on the slope or on the tableland within the geotechnical setback distance;
- All existing vegetation on the slope face and at the slope crest should be preserved; and

The surficial erosions and local failures on the slope surface should be re-vegetated.

5.0 CLOSURE

We trust that this report meets your current requirements. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Report Signature Page

GOLDER ASSOCIATES LTD.

DRAFT	**DRAFT**
David Marmor, E.I.T. Geotechnical Engineer-in-Training	Nick LaPosta Geotechnical Engineer

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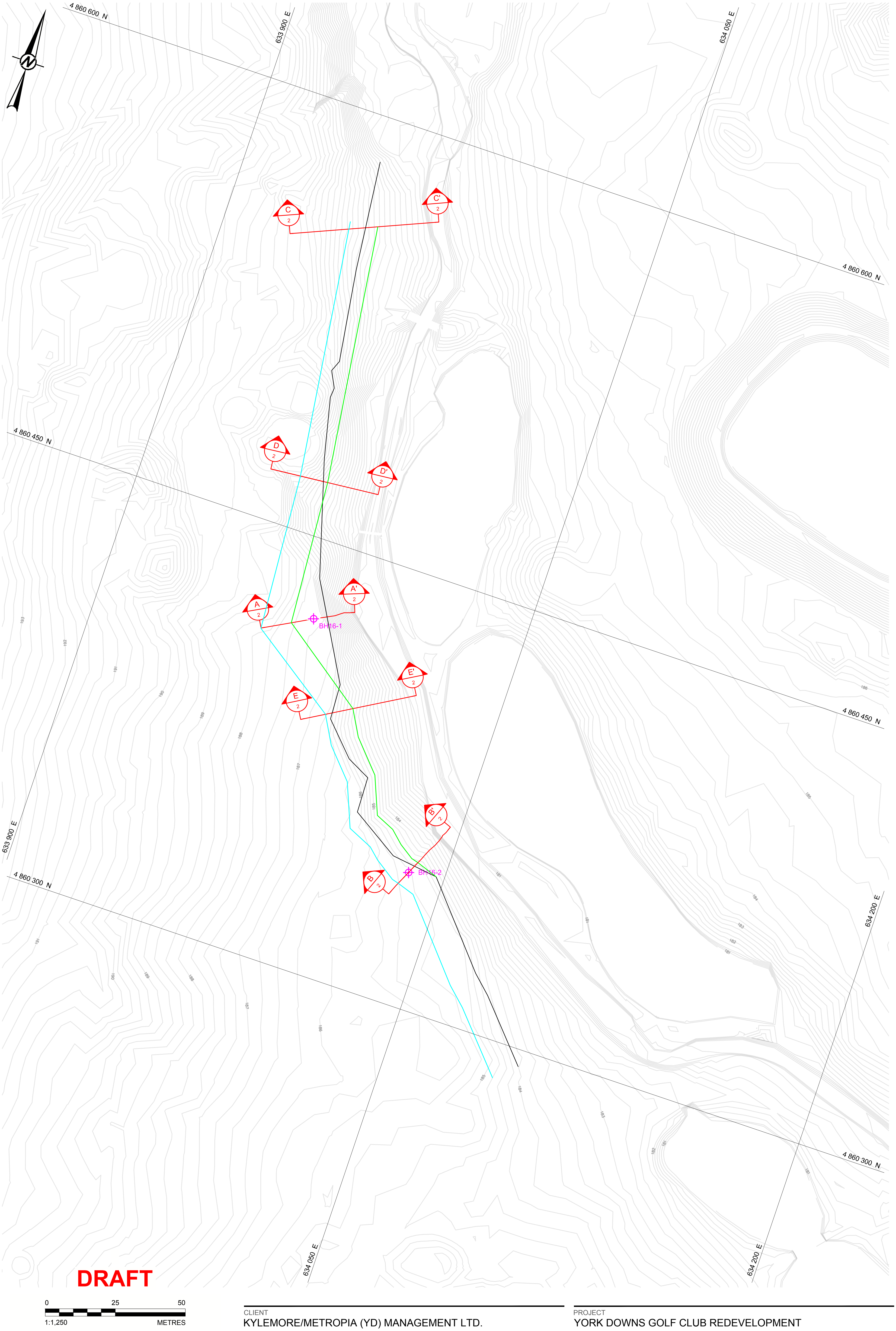

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LEGEND

⌖	BOREHOLE LOCATION
—	TOP OF SLOPE MARCH 29, 2016/ SEPTEMBER 10, 2010
—	TOP OF STABLE SLOPE
—	NATURAL HAZARD SETBACK BASED OFF OF TOP OF STABLE SLOPE

CLIENT
KYLEMORE/METROPIA (YD) MANAGEMENT LTD.

CONSULTANT

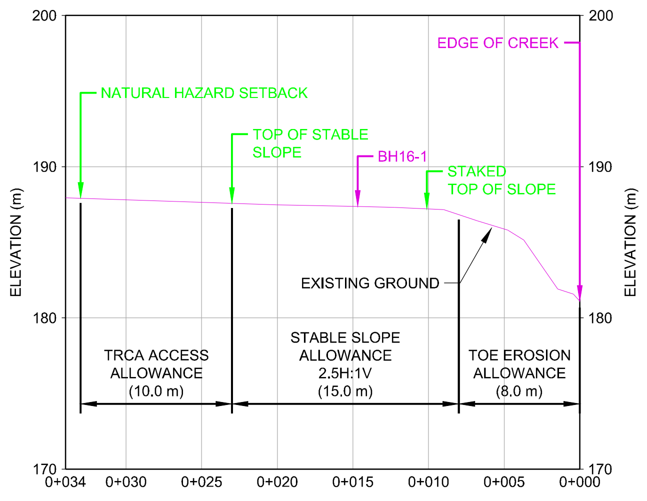
Golder Associates

YYYY-MM-DD	2016-04-06
DESIGNED	
PREPARED	JS
REVIEWED	
APPROVED	

PROJECT
YORK DOWNS GOLF CLUB REDEVELOPMENT
4134 16TH AVENUE, MARKHAM, ONTARIO

TITLE
SLOPE SETBACK ANALYSIS

PROJECT NO.	PHASE NO.	REV.	FIGURE
1413472	8000	A	1



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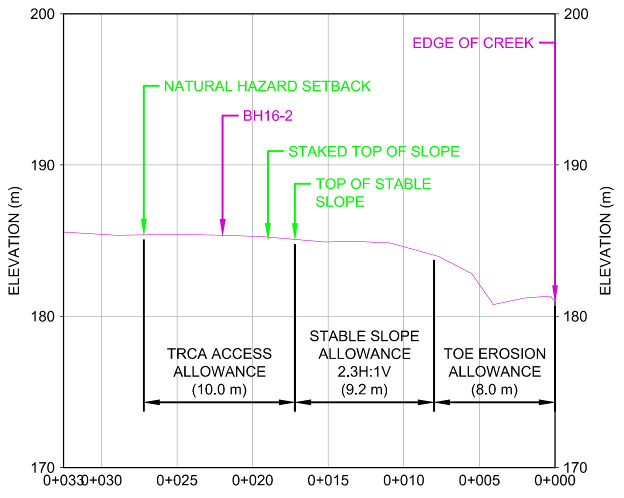

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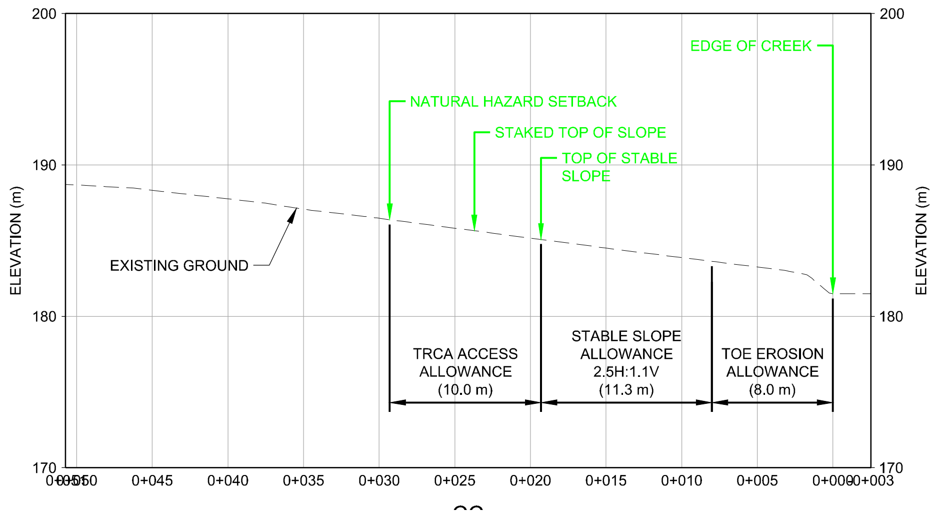

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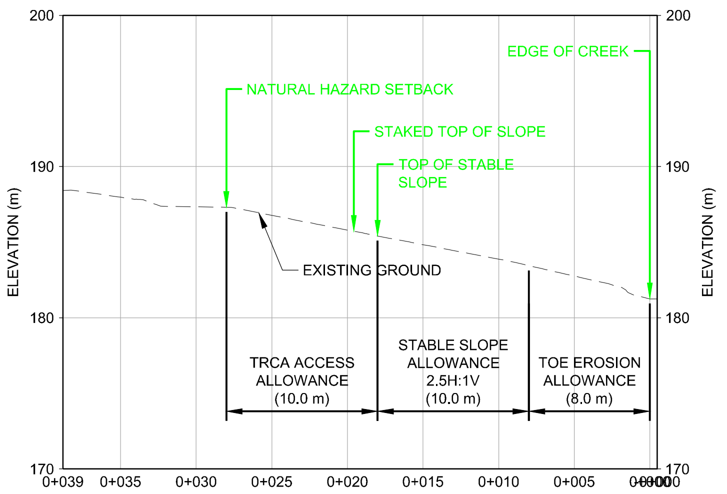

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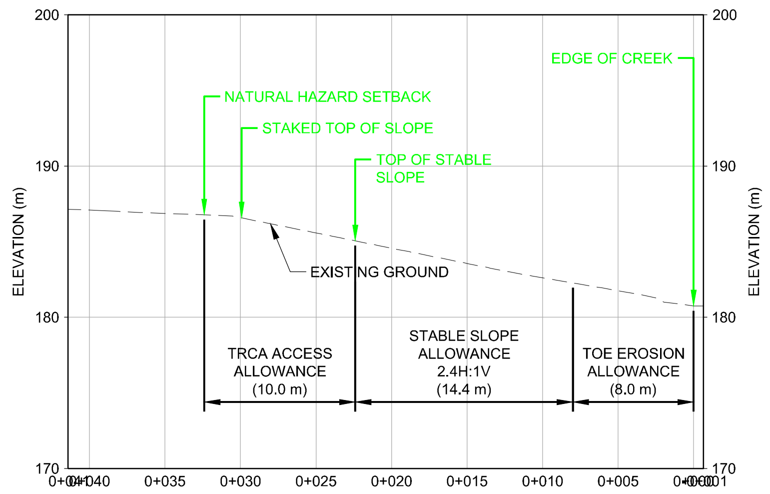

SCALE 1:500 m E-E' 1 CROSS-SECTION

LEGEND

- - - - EXISTING GROUND INTERPOLATED FROM CONTOURS WITHIN FEBRUARY 4, 2016 SURVEY CAD FILE

——— EXISTING GROUND OBTAINED FROM CROSS-SECTIONS LOCATED WITHIN MARCH 15, 2016 SURVEY CAD FILE

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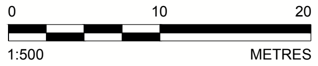

CLIENT
KYLEMORE/METROPIA (YD) MANAGEMENT LTD.

PROJECT
YORK DOWNS GOLF CLUB REDEVELOPMENT
4134 16TH AVENUE, MARKHAM, ONTARIO

CONSULTANT
Golder Associates

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PREPARED	JS
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APPROVED	

TITLE
SLOPE CROSS-SECTIONS

PROJECT NO.	PHASE NO.	REV.	FIGURE
1413472	8000	A	2

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APPENDIX A

Important Information and Limitations of This Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. 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 professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

APPENDIX B

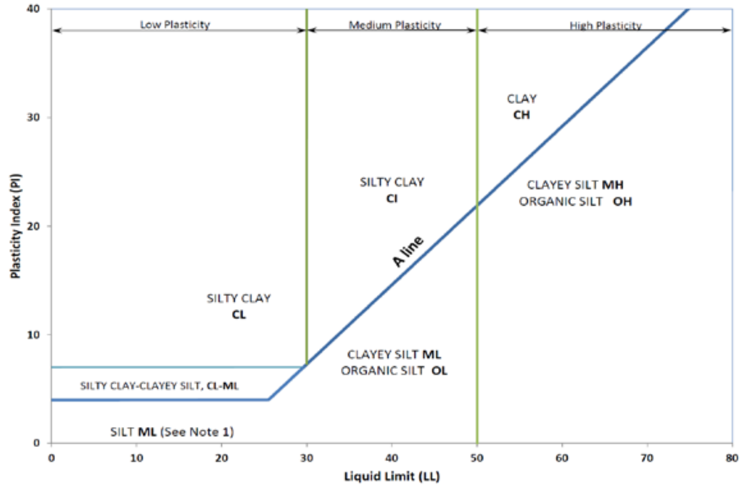
Method of Soil Classification
Abbreviations and Terms Used on Records of Boreholes and Test Pits
List of Symbols
Record of Boreholes (16-1 and 16-2)

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:

1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

PROJECT: 1413472

LOCATION: N 4860422.01; E 633976.14

RECORD OF BOREHOLE: 16-1

BORING DATE: February 29 to March 1, 2016

SHEET 1 OF 2

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: CME-85 TRUCK MOUNTED - POWER AUGER; 100 mm O.D. Solid Stem Augers

SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	187.38
TOPSOIL	0.00
(CL-ML) Sandy CLAYEY SILT, trace gravel; brown to dark brown to grey; cohesive, w>PL, stiff to very stiff	187.00 0.38
(SM) SILTY SAND, trace gravel, some cohesive fines; brown to grey, oxidation staining to a depth of 3.8 m (TILL); moist, non-cohesive, very dense - Fibrous organics noted to a depth of 2.1 m -Becoming grey below a depth of 3.8 m	185.86 1.52
(CL-ML) Sandy SILTY CLAY to Sandy CLAYEY SILT, trace to some gravel; grey (TILL); cohesive, w<PL to w~PL, very stiff to hard	182.88 4.50

CONTINUED NEXT PAGE

NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	SS	8	
2	SS	17	
3	SS	49	
4	SS	62	
5	SS	69	
6	SS	53	
7	SS	24	
8	SS	25	
9	SS	23	MH/AL
10	SS	57	

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

LOGGED: DM

CHECKED: OS

PROJECT: 1413472

RECORD OF BOREHOLE: 16-1

SHEET 2 OF 2

LOCATION: N 4860422.01; E 633976.14

BORING DATE: February 29 to March 1, 2016

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES 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^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME-85 TRUCK MOUNTED - POWER AUGER 100 mm O.D. Solid Stem Augers	(CL-ML) Sandy SILTY CLAY to Sandy CLAYEY SILT, trace to some gravel; grey (TILL); cohesive, w<PL to w~PL, very stiff to hard	▨								
11					11	SS	48		○		▽ March 1, 2016
12					12	SS	37		○		
				174.58 12.80							
13		END OF BOREHOLE NOTES: 1. Water level measured in open borehole at a depth of 11.2 m upon completion of drilling.									
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: OS

PROJECT: 1413472

LOCATION: N 4860347.14; E 634037.23

RECORD OF BOREHOLE: 16-2

BORING DATE: March 1, 2016

SHEET 1 OF 2

DATUM: Geodetic

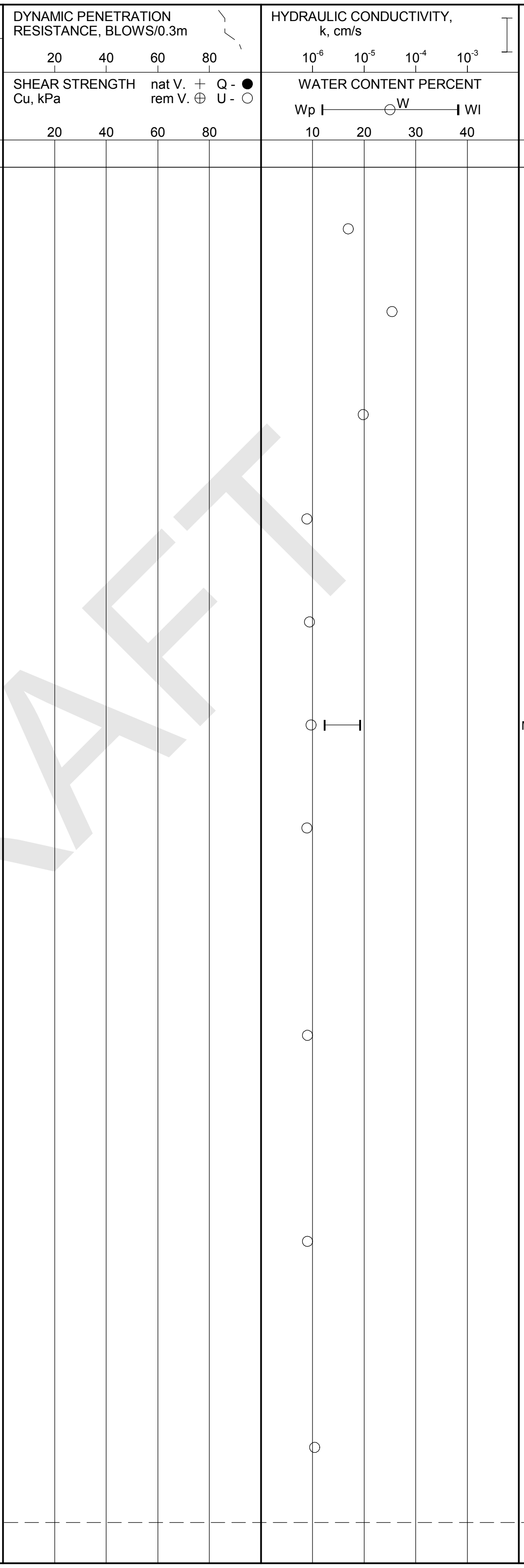
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: CME-85 TRUCK MOUNTED - POWER AUGER, 100 mm O.D. Solid Stem Augers

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	185.36
TOPSOIL	0.00
(CL) Sandy SILTY CLAY, trace gravel; brown to dark brown, trace fibrous organics; cohesive, w>PL, soft to firm	185.06 0.30
(CL-ML) Sandy CLAYEY SILT to Sandy SILTY CLAY, trace to some gravel; brown to grey (TILL); cohesive, w<PL, stiff to very stiff - Becoming grey below a depth of 2.6 m	183.91 1.45
- Auger grinding on probable cobbles/boulders at a depth of 5.6 m (ML) Sandy SILT, some cohesive fines, trace gravel; grey (TILL); non-cohesive, moist, dense to very dense	179.72 5.64

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1A	SS	3	
1B			
2	SS	7	
3	SS	15	
4	SS	24	
5	SS	21	
6	SS	28	MH/AL
7	SS	24	
8	SS	59	
9	SS	46	
10	SS	60	



PIEZOMETER OR STANDPIPE INSTALLATION: ∇ March 1, 2016

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: OS

PROJECT: 1413472

LOCATION: N 4860347.14; E 634037.23

RECORD OF BOREHOLE: 16-2

BORING DATE: March 1, 2016

SHEET 2 OF 2

DATUM: Geodetic

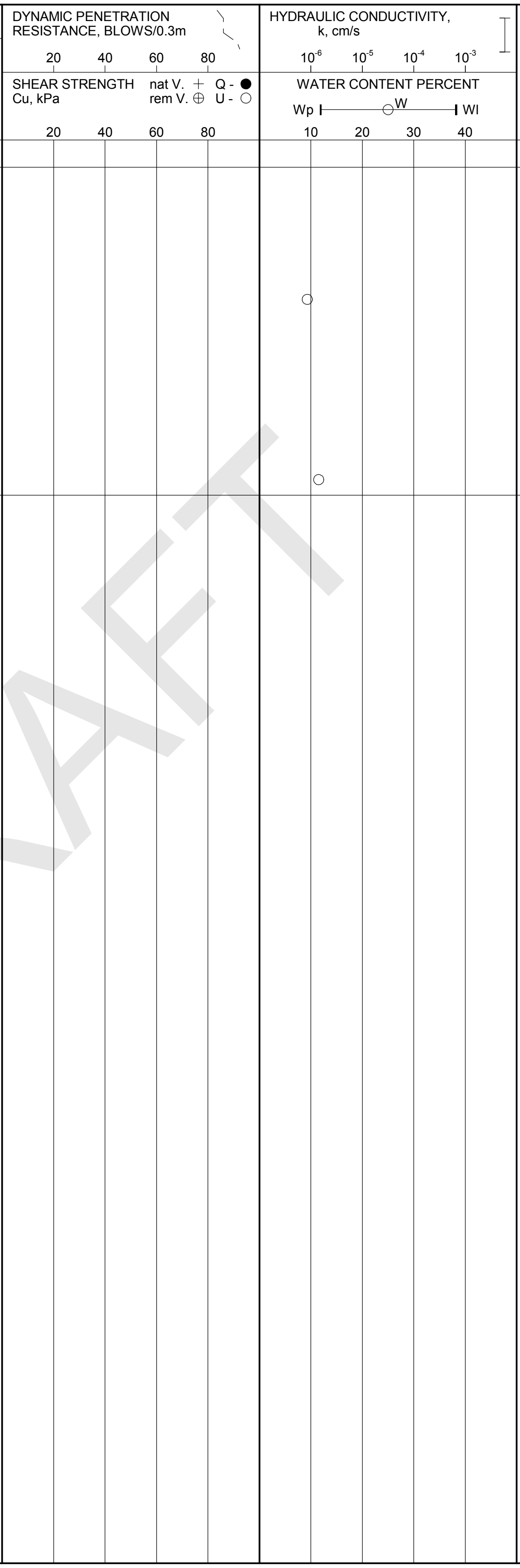
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
10	CME-85 TRUCK MOUNTED - POWER AUGER 100 mm O.D. Solid Stem Augers	(ML) Sandy SILT, some cohesive fines, trace gravel; grey (TILL); non-cohesive, moist, dense to very dense		172.94 12.42					
11					11	SS	54		
12					12	SS	50/ 0.08		
		END OF BOREHOLE							

NOTES:

1. Water level measured in open borehole at a depth of 2.0 m upon completion of drilling, March 1, 2016



DEPTH SCALE

1 : 50

LOGGED: DM

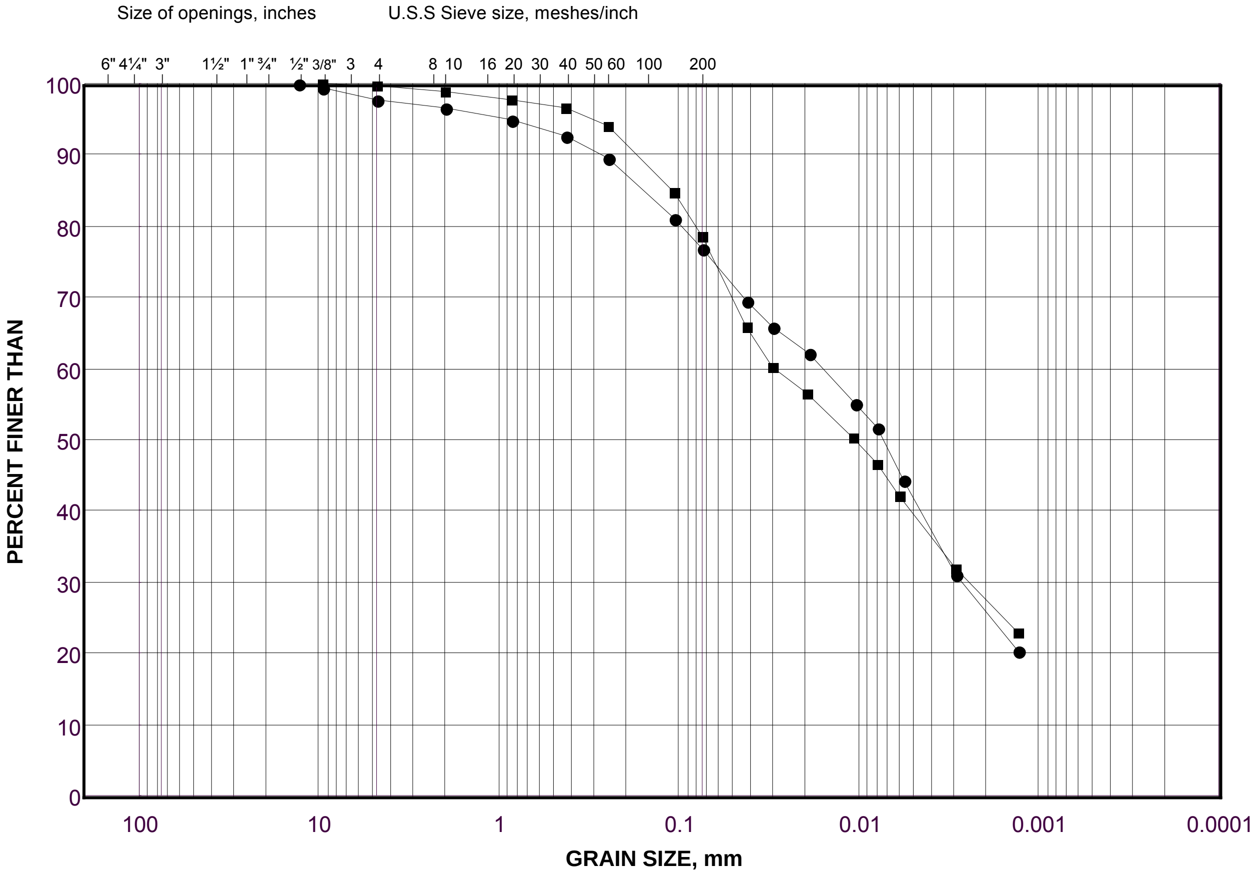
CHECKED: OS

APPENDIX C

Figure C1: Grain Size Distribution
Figure C2: Plasticity Chart

GRAIN SIZE DISTRIBUTION
(CL-ML) sandy SILTY CLAY to sandy CLAYEY SILT (TILL)

FIGURE C1



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	**GRAVEL SIZE**		**SAND SIZE**			**FINE GRAINED**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	16-2	6	181.24
■	16-1	9	179.45

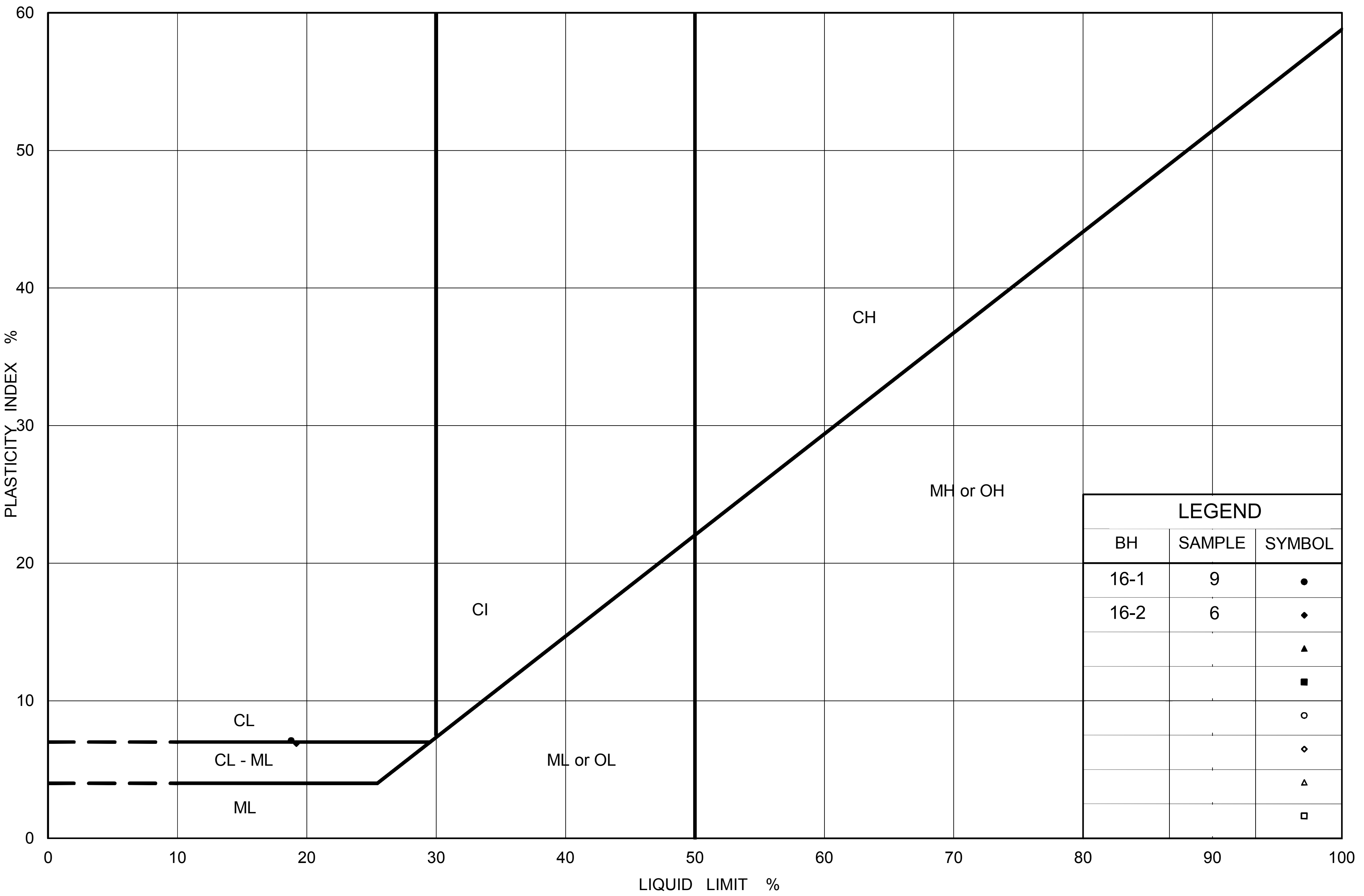
DRAFT

Project Number: 1413472 (8000)

Checked By: OS

Golder Associates

Date: 01-Apr-16



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PLASTICITY CHART

(CL-ML) SILTY CLAY TO CLAYEY SILT (TILL)

DRAFT

Figure No. C2

Project No. 1413472 (8000)

Checked By: OS

APPENDIX D

Figures D1 and to D2: Site Photographs

Site Photographs - Figure D1

Local sloughing of slope adjacent to Borehole 16-1 looking to the south

Local sloughing of slope adjacent to Borehole 16-1 looking to the north

Project No.	1413472 (8000)	**Golder Associates Ltd.**	Inputted by:	DPM
Date:	May, 2016	**DRAFT**	Checked by:	

Site Photographs - Figure D2


Undercutting at toe of slope adjacent to Borehole 16-2


Undercutting at toe of slope leads to bank erosion adjacent to Borehole 16-2

Project No.	1413472 (8000)	**Golder Associates Ltd.**	Inputted by:	DPM
Date:	May, 2016	**DRAFT**	Checked by:	

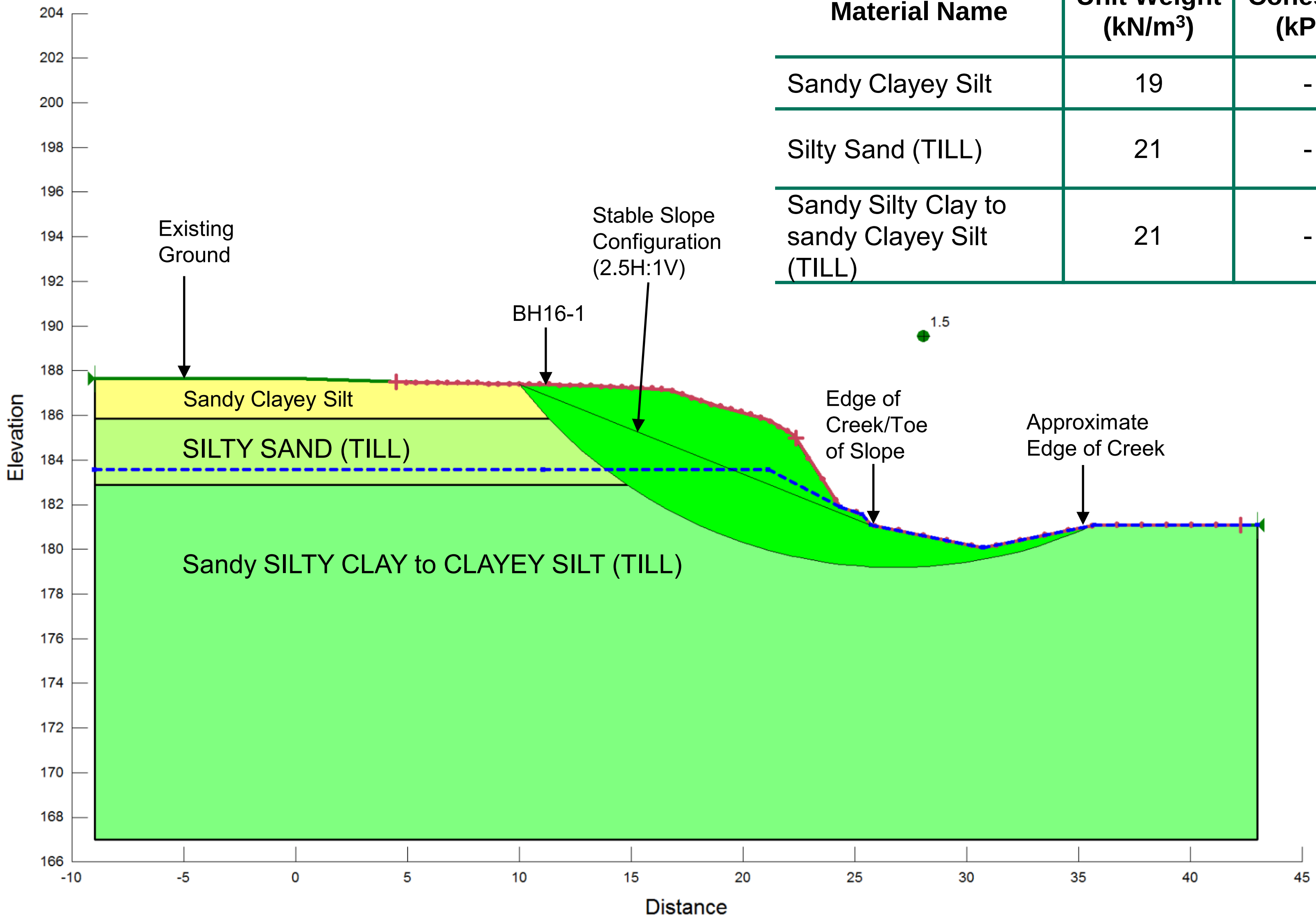
APPENDIX E

Figures E1 and E2: Slope Stability Analysis

Slope Stability Analysis
Section A-A (Borehole 16-1)

Figure E1

Material Name	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (°)
Sandy Clayey Silt	19	-	29
Silty Sand (TILL)	21	-	35
Sandy Silty Clay to sandy Clayey Silt (TILL)	21	-	35



Date: April 2016
Project No: 1413472 (8000)

DRAFT

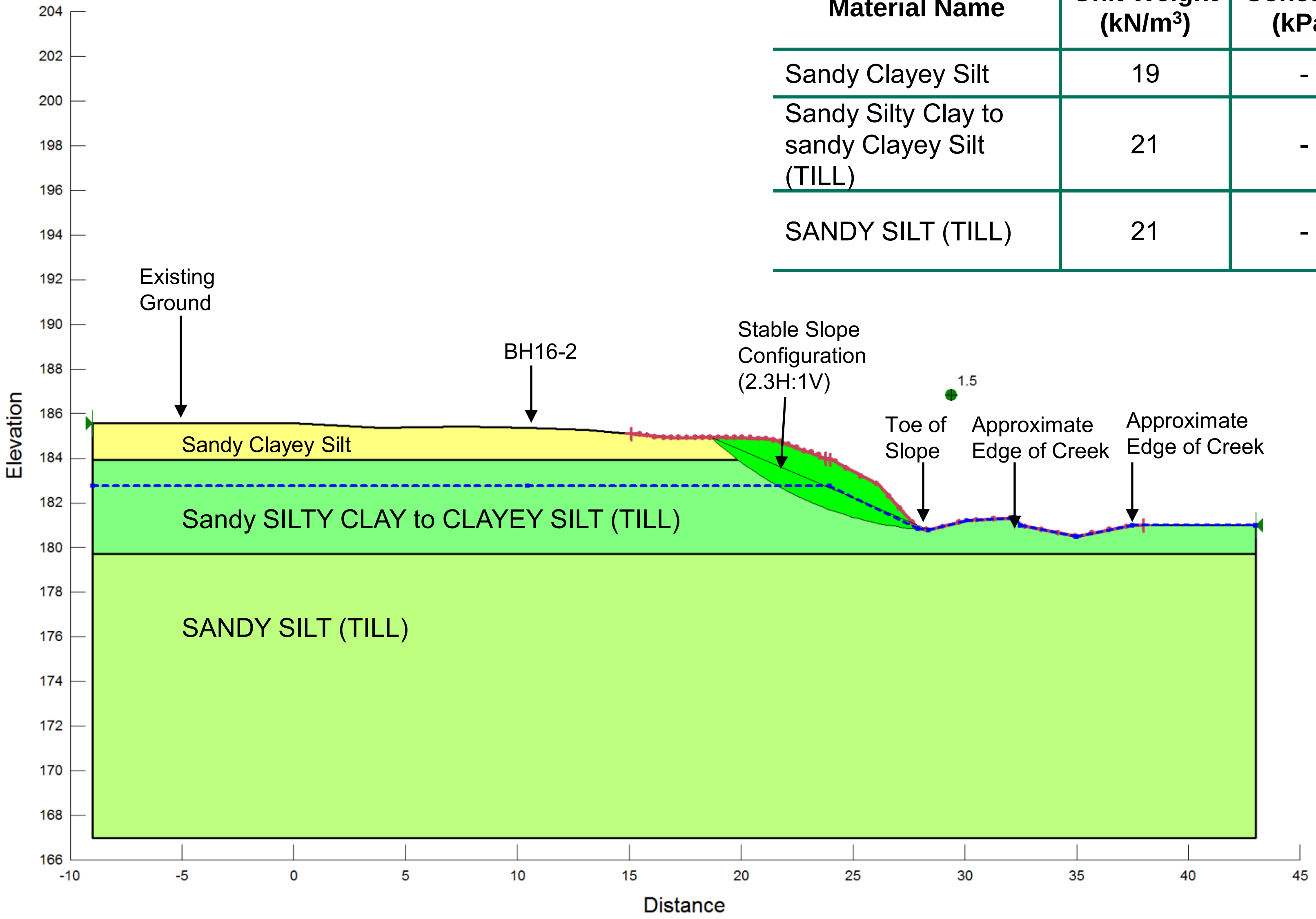
Analysis By: DPM **Reviewed By:** SEMP

Golder Associates

Slope Stability Analysis
Section B-B (Borehole 16-2)

Figure E2

Material Name	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (^{o})
Sandy Clayey Silt	19	-	29
Sandy Silty Clay to sandy Clayey Silt (TILL)	21	-	35
SANDY SILT (TILL)	21	-	35



Date: April 2016

DRAFT

Project No: 1413472 (8000)

Analysis By: DPM **Reviewed By:** SEMP

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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