TETRA TECH EBA

February 19, 2016

ISSUED FOR USE
FILE: W14103698-02
Via Email: brian.crist@gov.yk.ca

Government of Yukon
Highways and Public Works
Transportation Engineering Branch (W-13)
461 Range Road
Box 2703
Whitehorse, YT Y1A 2C6

Attention: Brian Crist, P.Eng.

Subject: Slope Stability Assessment
km 195 Robert Campbell Highway, YT

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by the Government of Yukon, Transportation Engineering Branch (YG-TEB) to complete a slope stability assessment of a landslide impacting the Robert Campbell Highway at about km 195, as measured from km 0 at the southern terminus of the highway in Watson Lake, YT.

Authorization to proceed was provided by Dale Enzenauer of YG, by way of executed YG Contracts C00030555 and C00031202, approving Tetra Tech EBA's budget for field services and for analysis and reporting, respectively.

2.0 BACKGROUND

The site is located at about km 195 of the Robert Campbell Highway, as shown on Figure 1. The highway traverses a slope lying about 15 m in elevation above an outside bend of the Finlayson River.

We understand that slope movements, expressed as cracking and vertical displacement at the road surface, have been occurring at the site over approximately the past 40 years, with the most recent episode occurring in the fall of 2015. We understand that about one metre of progressive vertical displacement occurred in the northbound lane of the highway during this recent episode of slope movement, which necessitated construction of a detour on the uphill side of the road to maintain two-way vehicle traffic on the highway. YG-TEB has advised that the typical strategy to repair the road surface following previous episodes of slope movement has involved placing additional fill to re-level the road surface and maintain the full width of the highway.

YG-TEB has also advised that the recent slope movement, as well as a previous episode that occurred in the fall of 2013, have coincided with periods of heavy precipitation. Aerial photos provided by YG-TEB, taken following the 2013 slope movement, show ponding of water in the ditch on the uphill side of the road, related to poor drainage of the ditches in this area. This suggests that slope movements at the site are likely triggered by high porewater pressures in the slope, caused by water infiltration from the ditches into the slope.

3.0 SITE VISIT

A site visit was completed by Mr. Richard Trimble, P.Eng. of Tetra Tech EBA, and Mr. Brian Crist, P.Eng. of YG-TEB on September 9, 2015 who were met on site by the maintenance supervisor from Tuchitua as well as Stuart Drummond from YG-TEB, who was working in the area. This section of the highway was closed at the time, and barricaded.

An initial review of aerial photos provided by YG-TEB showed that this area appears to have been historically unstable, with indications of previous slope instability created by undercutting the toe of the slope by the Finlayson River.

While on site, traverses upslope and downslope of the slope failure were completed, looking for both historical and recent signs of instability. No indications of recent instability were observed upslope of the highway (although several re-vegetated backscarps and slumps were observed), but recent exposures both downslope of the highway and just above the river indicated recent slope activity. No permafrost or bedrock was observed in the immediate vicinity of the instability. The photo below shows the site on September 9, 2015.

Photo 1: View at km 195 looking north towards Ross River showing slope instability affecting the highway (September 9/15)

Subsequent to this site visit, a meeting was held with representatives of YG-TEB and Tetra Tech EBA, at which time a drilling program was recommended to obtain site-specific subsurface soil information and strength data for further analyses. It was hypothesized at the time that this might be a deep seated slope failure that needed to be confirmed or discounted by drilling and testing.

4.0 SONIC DRILLING PROGRAM

Boart Longyear (BLY) of Calgary, AB was retained by YG-TEB to carry out a geotechnical drilling program at the site using their LS-250 Mini-Sonic rig, for the purpose of exploring the geotechnical conditions and potential failure mechanisms causing the observed slope movements. This drill was already on contract with YG-TEB and was temporarily diverted from other work for the Branch.

Tetra Tech EBA was on site to select borehole locations, log the boreholes, and collect samples.

Drilling was completed on October 1 and 2, 2015. A total of three boreholes (BH15-01 through BH15-03) were advanced to depths between 15.2 and 20.4 m, with a cumulative total of 50.8 lineal metres drilled. The boreholes were logged in the field by a Tetra Tech EBA engineer, and representative disturbed samples were collected and returned to our Whitehorse laboratory for geotechnical index testing. Borehole locations are shown on Figure 1, attached.

Standard Penetration Testing (SPT) was carried out at regular intervals in BH15-01 and BH15-02 to collect disturbed samples provide an indication of the in situ soil density. Additional disturbed samples were collected directly from the sonic core returned to ground surface, particularly at depths where SPT sample recovery was poor and at BH15-03, where SPT was not completed. Where fine-grained soils were encountered, a pocket penetrometer was used to estimate the undrained shear strength of the soil.

All recovered samples (SPT samples and sonic core) were inspected for the presence of shear planes or other evidence of slope movement, to provide an indication of the depth of the slope failure surface(s) below ground surface.

Upon completion of drilling, the boreholes were backfilled with drill cuttings. A 25 mm diameter PVC standpipe was installed in BH15-02 to allow ongoing monitoring of groundwater levels.

5.0 SITE CONDITIONS

5.1 Surface Features

At the time of drilling, the road surface had been repaired and a detour established to maintain two lanes of traffic on the highway; however, cracking was still visible across most of the slope crest.

On the slopes surrounding the site to the north and south, where slope movement has not been observed, vegetation consists of mature evergreen forest. On the slopes adjacent to the site, both above and below the highway, vegetation is comprised of younger willows and other shrubs, and older trees generally have curved “pistol butt” trunks, or are leaning or completely toppled over, all of which are indicative of near surface slope movement. Based on this, the extent of the area of slope distress can be roughly estimated based on observed changes in vegetation.

On the slope face, both above and below the road, numerous small, apparently shallow slumps were observed on the ground surface. In some locations this has resulted in a “stepped” slope face, with the overall slope comprised of nominally flat benches a few metres wide interrupted by nominally 1-2 m high, subvertical scarps, often with exposed soil visible where the surficial vegetation cover has cracked and pulled apart.

At the toe of the slope, erosion of the riverbank was noted, with the water level in the river at the time of drilling about one metre below the crest of the bank. Trees were observed that had fallen into the river, and frozen seepage was observed on the face of the riverbank.

5.2 Subsurface Conditions

The soil conditions encountered at the site are described below and on the borehole logs and results of laboratory testing, attached in Appendix B. Note that the borehole logs and laboratory results provide detailed, borehole-specific geotechnical information, and should be used in preference to the generalized descriptions provided below.

Similar stratigraphy was encountered at each borehole location. In general, about 5 m of loose to compact granular soil was encountered immediately below ground surface, with imported fill encountered below the road surface at BH15-01 and BH15-03 and variable mixtures of sand, silt and gravel encountered at BH15-02, which was drilled a few metres downslope from the road. The thickness of fill is likely a result of frequent fill placement to repair the road through the ongoing slope movement, and the variable surficial soil encountered at BH15-02 is likely a mixture of native soil and fill materials that have migrated down the slope.

Below the surficial granular soil, a stiff mixture of sand, silt and gravel with a till-like composition and texture was encountered. At BH15-02, this layer also included about 4 m of very stiff, silty clay, which was not observed at either BH15-01 or BH15-03, suggesting that the clay layer pinches out in the upslope direction.

Below the layer of till-like soil, a 2-3 m thick layer of gravelly sand was encountered in each of the boreholes, with hard, till-like soil and clay below, extending to the termination depth of each borehole. No shear planes or other evidence of slope movement were observed in the layers of till-like and clay soils, suggesting that slope movements are occurring within the granular materials encountered, probably within the surficial layer of fill and variable native materials.

As noted above, the stratigraphy is generally consistent between each of the boreholes, particularly if the distinctive layer of gravelly sand encountered in each of the boreholes is considered to be a “marker bed”. As such, it was possible to construct cross-sections showing the generalized soil profile between boreholes in directions parallel and perpendicular to the slope, as shown on Figure 2. Based on this, it appears that the soil stratigraphy dips approximately parallel to the slope face, and also slightly from north to south.

5.3 Groundwater

Because sonic drilling uses water in the drilling process, it is often impossible to reliably estimate the depth to groundwater during drilling.

However, the surficial granular soils and gravelly sand layer at depth, which were encountered at each of the boreholes were generally wet. Based on this, it is likely that local groundwater flow at the site is confined within these granular soil layers and perched above the relatively impermeable till-like and clay layers that underlie the granular materials.

If possible, YG personnel passing by the site should measure the groundwater level in the standpipe installed at BH15-02, which is screened within the gravelly, sand at about 12 m depth, and forward results to Tetra Tech EBA for review. Readings during the winter months should continue to be attempted, but the water in the standpipe may be frozen – the depth to the frozen surface should also be recorded.

5.4 Surface Drainage

Drainage at the site consists of a ditch adjacent to the uphill (west) side of the highway, with culverts installed across the road at nominal intervals to allow collected water to flow from the ditch and down the slope towards the river. An old culvert is present in the ditch to the south of the site, and a new culvert has been installed immediately north of the area of recent cracking and slope movement.

However, drainage could still be improved in this area, particularly during the spring thaw when culverts are frozen, resulting in a backup of ponded meltwater in the ditch.

5.5 Permafrost and Bedrock

Neither permafrost nor bedrock was encountered at the site during the preliminary site visit or the sonic drilling program.

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 Slope Stability Modeling

Slope stability modeling was completed using Slope/W software, commercially available from GeoSlope International. Slope/W software was used to assess two-dimensional slope stability of the existing slope and also to assess possible slope remediation options.

Soil stratigraphy used in the Slope/W models was based on that shown on Figure 2, and constitutive soil models and parameters were selected based on the results of the drilling program, including soil gradation, consistency, moisture content and expected behaviour. As such, soil models and parameters for each soil layer are summarized below on Table 1. Note that no detailed laboratory testing has been completed to determine the parameters summarized on Table 1 have been estimated based on typical expected values for each soil type.

Table 1: Summary of Soil Parameters Used in Slope/W Model

Soil Layer	Soil Model	Unit Weight (kN/m^3)	Angle of Internal Friction (°)	Effective Cohesion / Undrained Shear Strength (kPa)
Surficial Granular Material	Mohr-Coulomb	20	30	0
Stiff Till-like	Undrained	20	N/A	80
Gravelly SAND	Mohr-Coulomb	21	35	0
Hard Till-like	Undrained	21	N/A	200
Engineered Fill	Mohr-Coulomb	22	36	0

6.1.1 Existing Slope

The existing slope geometry was modeled using survey data provided by YG-TEB and the generalized soil stratigraphy shown in Figure 2, to assess the potential failure mechanisms impacting the slope.

The slope model was run under both dry conditions and with an elevated groundwater level, reflecting the poor drainage in the ditch along the highway.

No traffic surcharge loading was applied at the road surface in either case.

The Slope/W model used in the analysis is shown in Figure 3, for elevated groundwater conditions.

Results of the Slope/W analysis showing the critical slip surface and contours of the Factor of Safety (FS) against slope failure along various potential slip surfaces for dry and elevated groundwater conditions are shown on Figures 4 and 5, respectively. For reference, the FS is calculated as the ratio of stabilizing to destabilizing forces, such that FS of less than unity implies failure. In general, FS of 1.5 is typically considered to be an acceptable minimum value for most slope stability applications. In some cases where the consequence of failure is relatively low, a reduced FS of 1.3 may be acceptable.

As shown on Figure 4, the slope appears to be stable under dry conditions, with a minimum FS of 1.45 computed by the software. However, as shown on Figure 5, elevated groundwater conditions appear to trigger instability in the slope, with a minimum FS of 0.62. Furthermore, the FS contours shown on Figure 5 suggest that instability is relatively shallow, and is contained entirely within the fill and native granular soils encountered near ground surface; no slip surface penetrating into the stiff till-like material was found to have FS less than 1.5.

6.1.2 Reconstructed Slope

Slope reconstruction, which would consist of excavating disturbed, saturated, organic, or otherwise deleterious material from the slope surface between the road and river elevations, and rebuilding the slope using compacted engineered fill, was also modeled using Slope/W.

For the purposes of this report, the slope reconstruction was assumed to consist of a blanket of compacted engineered fill measuring 5 m in width (horizontal thickness), sloped at 2H:1V and keyed into the base of the slope to El. 868 m, about 2 m below the adjacent riverbank elevation.

The reconstructed slope model was run under dry conditions and elevated groundwater conditions, similar to the model of the existing slope. Intermediate groundwater conditions were also considered, with a shallow groundwater table perched above the stiff till-like soil, which is intended to approximate the effect of improved drainage on groundwater levels in the slope during precipitation or snowmelt events.

A traffic surcharge of 16 kPa was applied to the road surface in all cases.

The Slope/W model used in the analysis is shown in Figure 6, for intermediate groundwater conditions as described above.

Results of the Slope/W analysis for the reconstructed slope are shown in Figures 7, 8 and 9 for dry, intermediate and elevated groundwater conditions, respectively.

Similar to the results for the existing slope, the groundwater levels in the slope are shown to have a significant impact on slope stability; for elevated groundwater conditions, the FS of the reconstructed slope was 0.73, suggesting that groundwater is the main factor driving instability on the slope. For dry conditions and intermediate groundwater conditions, minimum FS of 1.48 and 1.32 were computed, respectively. Similar to the Slope/W results for the existing slope, in each case for the reconstructed slope the slip surfaces with the lowest FS were concentrated within the surficial granular soils.

6.2 Recommendations

6.2.1 Probable Causes of Slope Instability

Based on the results of the drilling program and Slope/W modeling, and on observations of surface conditions collected during site visits, it appears that the slope movements observed at the site are localized within the surficial granular materials, and triggered by high porewater pressure caused by poor drainage in the roadside ditch, then augmented during spring snowmelt and possibly triggered by periods of heavy precipitation in the late summer and fall.

Historical slope movements have been compounded by the typical remedial action of re-filling distressed areas with additional fill at the road surface, which essentially reloads the crest of the slope and contributes to future slope movement.

6.2.2 Drainage

As noted above, slope movement appears to be triggered by high porewater pressures caused by poor drainage in the roadside ditch compounded by periods of high rainfall. As such, improving drainage at the site will likely be the most effective remedial action. In order improve drainage and minimize porewater pressures in the slope, we recommend that the following items be implemented:

- The ditch running parallel to the west side of the Campbell Highway should be re-graded to direct water away from the area of the potentially unstable slope. This would be best accomplished by establishing a crown near the centre of the unstable area (approximately above the apex of the bend in the Finlayson River at the toe of the slope), and directing water away from the slope crest to both the north and south;

- Culverts should also be installed to drain the ditch immediately north and south from the site. Depending on ditch grading, culverts should also be installed at a low point in the ditch to prevent the collection of ponded water above the slope. Culverts should direct water to spill onto stable areas of the slope (generally indicated by mature evergreen tree cover), or ideally into pipes conveying water to the base of the slope;

- Consideration may also be given to deepening the ditch invert, if geometrically practical (i.e., without oversteepening/undercutting the slopes on the uphill side of the road). This action may result in the ditch capturing more water flowing through the ground towards the slope face, although it is uncertain whether groundwater flow plays a significant role in the overall stability of the slope;

To summarize, it is possible that maintenance and monitoring may be adequate to re-open the highway to near its original alignment (pre-detour) and keep it open, and it is understood that this is the approach preferred by YG-TEB at this time.

1. It is critical that regular inspection and maintenance be undertaken on an ongoing basis. The ditches must be monitored and periodically repaired/regraded if necessary, and culverts must be kept clear of obstructions, which may require steaming to clear built up ice so that the culverts function properly during the spring thaw.

2. Regular readings of the water level in the PVC standpipe at Borehole 15-02 should be completed and plotted. If the water level continues to rise at this location, the frequency of inspections should be increased as higher water levels may indicate increased pore water pressure.

3. The specific area with the tension cracks must be monitored regularly, and if more tension cracks develop, they must be repaired (filled in) immediately so that water does not infiltrate the subgrade.

4. Maintenance records must be kept, including photographs (with dates), that summarize all maintenance activities at the site. This will assist in determining if the maintenance program is effective.

If these measures do not significantly improve the stability of this section of the highway, then it may be necessary to reconstruct and permanently stabilize the slope in accordance with the recommendations presented below.

6.2.3 Slope Reconstruction

Notwithstanding any drainage improvements that are completed at the site, it is possible that some residual movement will be observed on the slope, associated with collapse of over-steepened faces lying above “steps” that were observed on the existing slope. Furthermore, ongoing fluvial erosion at the western bank of the Finlayson River will eventually begin to undermine the toe of the slope, which would reduce the overall stability of the slope. Erosion at the riverbank may currently have some impact to the slope, depending on the elevation of seasonal high water levels, although no hydrotechnical information is currently available to estimate timelines or specific impacts to the slope in any detail.

As such, in order to repair the existing disturbed slope face and mitigate against the potential for future erosion, we recommend that the slope face be reconstructed using compacted engineered fill, as shown in concept on Figure 6 and assessed using Slope/W for various groundwater conditions.

Disturbed, saturated, organic, or otherwise unsuitable materials would be removed from the slope face, and replaced with a blanket of compacted, engineered fill. A horizontal fill thickness of 5 m was used in the Slope/W model and can be considered as a reasonable preliminary estimate.

The fill blanket would also need to be keyed into the base of the slope to prevent undermining due to scour and erosion from the river. Further to this, the fill at the base of the slope would likely need to consist of coarse rockfill or riprap to better resist erosion. Input from a hydrotechnical engineer would be required for detailed design of the fill blanket at the toe of the slope.

Similarly, Tetra Tech EBA should be retained to provide detailed geotechnical recommendations for design of the slope reconstruction, and construction supervision, if this option is to be pursued.

Finally, it is possible that deep-seated failure planes are present in the subsurface, which were not detected during the drilling program. If desired, the distribution of slope movement with depth below ground surface can be assessed by installing and monitoring slope indicator casing in one or more locations on the slope. Additional information on this level of slope monitoring can be provided, upon request.

7.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the Government of Yukon and their agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the Government of Yukon, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement and in Tetra Tech EBA's General Conditions that are provided in Appendix A of this report.

8.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

J. RICHARD TRIMBLE
Feb 19/16

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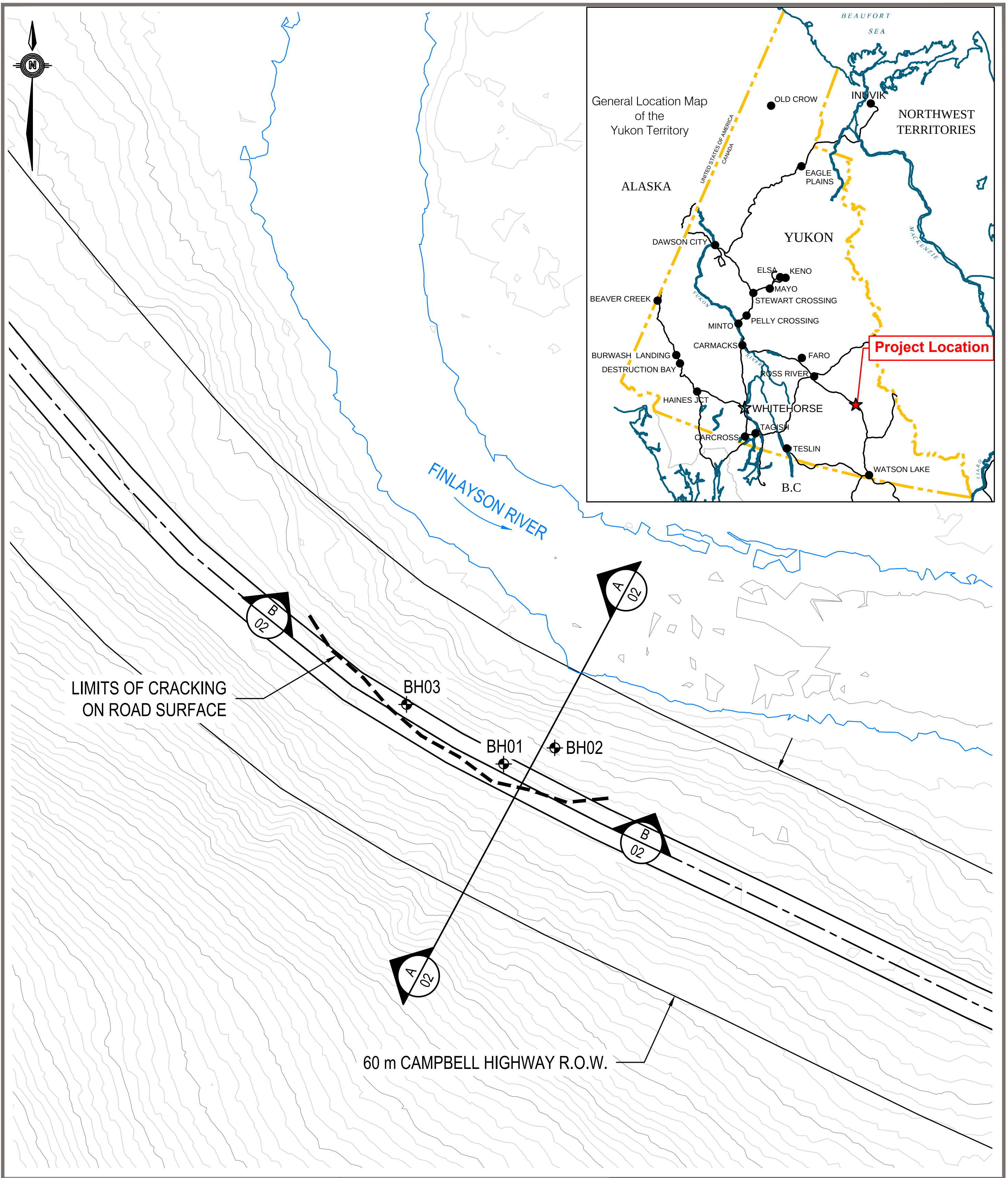
Attachments: Figures (9)
Appendix A: Tetra Tech EBA's General Conditions
Appendix B: Borehole Logs and Laboratory Test Results

PERMIT TO PRACTICE
TETRA TECH EBA INC.
SIGNATURE
Date Feb 19/16
PERMIT NUMBER PP003
Association of Professional
Engineers of Yukon

FIGURES



Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 1] December 10, 2015 - 9:50:55 am (BY: BUCHAN, CAMERON)

LEGEND

⌖ - BOREHOLE LOCATION

0 50m

Scale: 1:1,250 @ 8.5"x11"

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TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

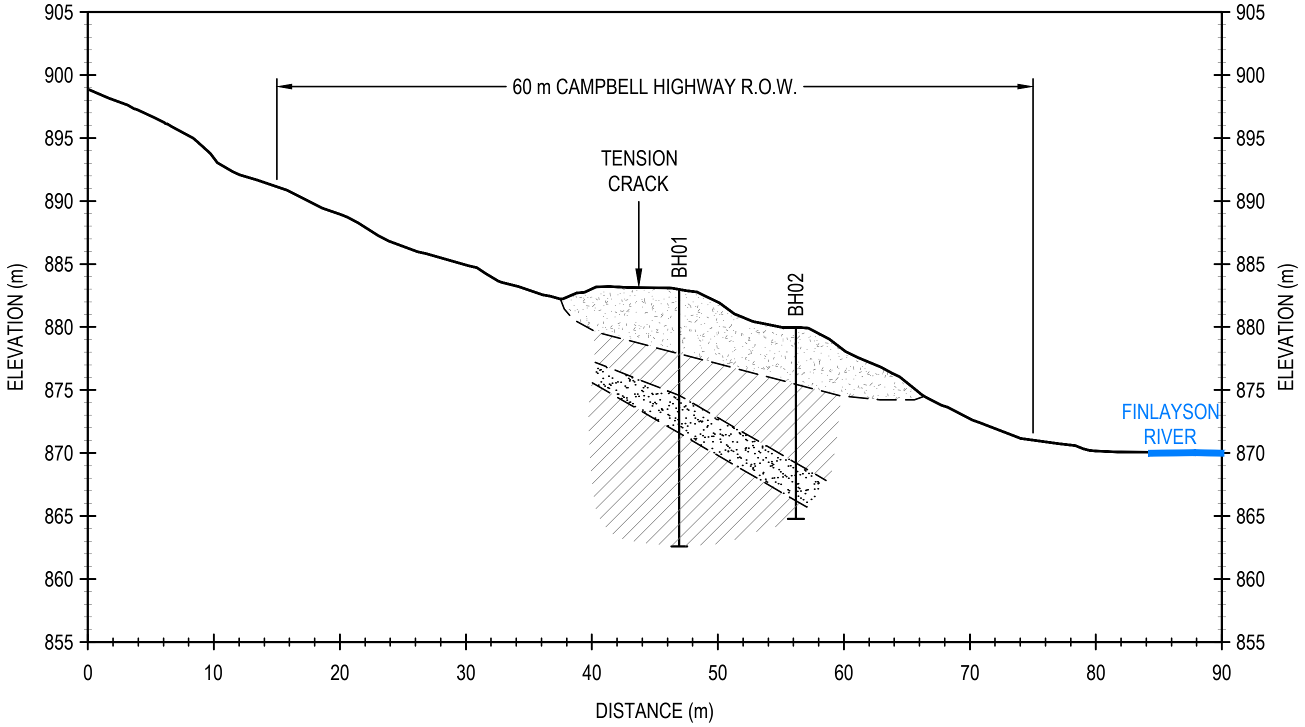
SITE PLAN SHOWING LIMITS OF CRACKING AND BOREHOLE LOCATIONS

PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	JRT	0

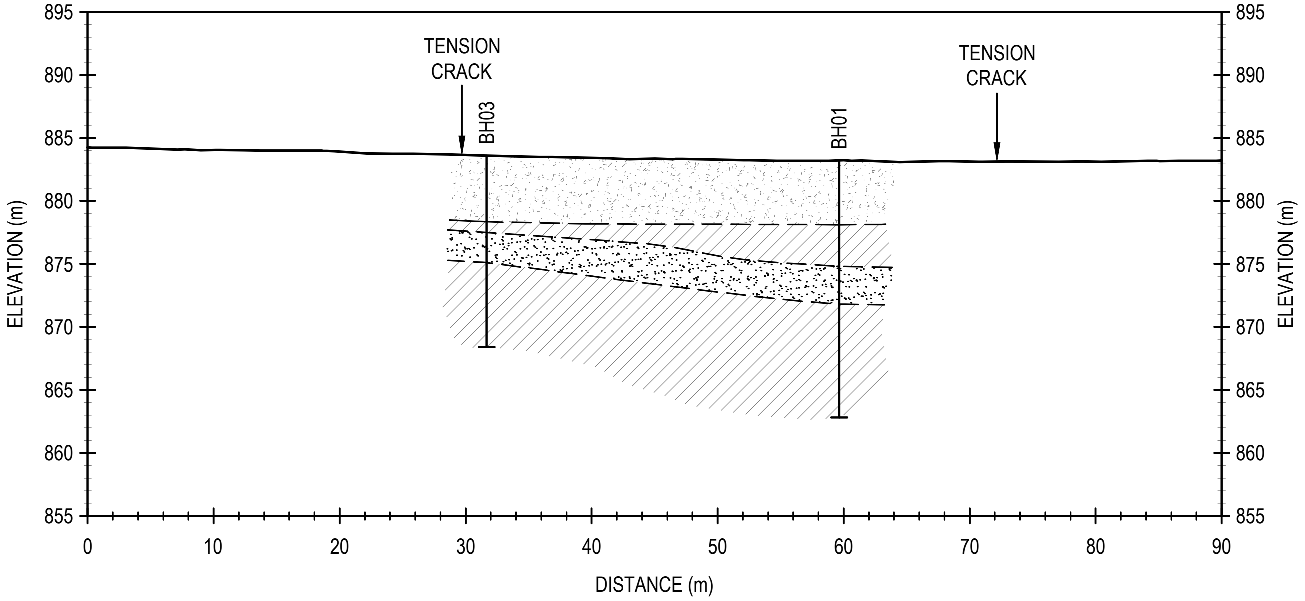
OFFICE	DATE
EBA-WHSE	December 4, 2015

Figure 1

Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 2] December 10, 2015 - 9:51:04 am (BY: BUCHAN, CAMERON)



SECTION A - A'



SECTION B - B'

LEGEND

- ▒ - ROAD FILL AND GRANULAR SURFICIAL SOIL
- ▨ - STIFF NATIVE SOIL
- ▓ - GRAVELLY SAND

0 25m

Scale: 1:750 @ 8.5"x11"

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SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

CROSS-SECTIONS

PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	JRT	0

OFFICE	DATE
EBA-WHSE	December 4, 2015

Figure 2

Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 3] December 10, 2015 - 9:51:14 am (BY: BUCHAN, CAMERON)

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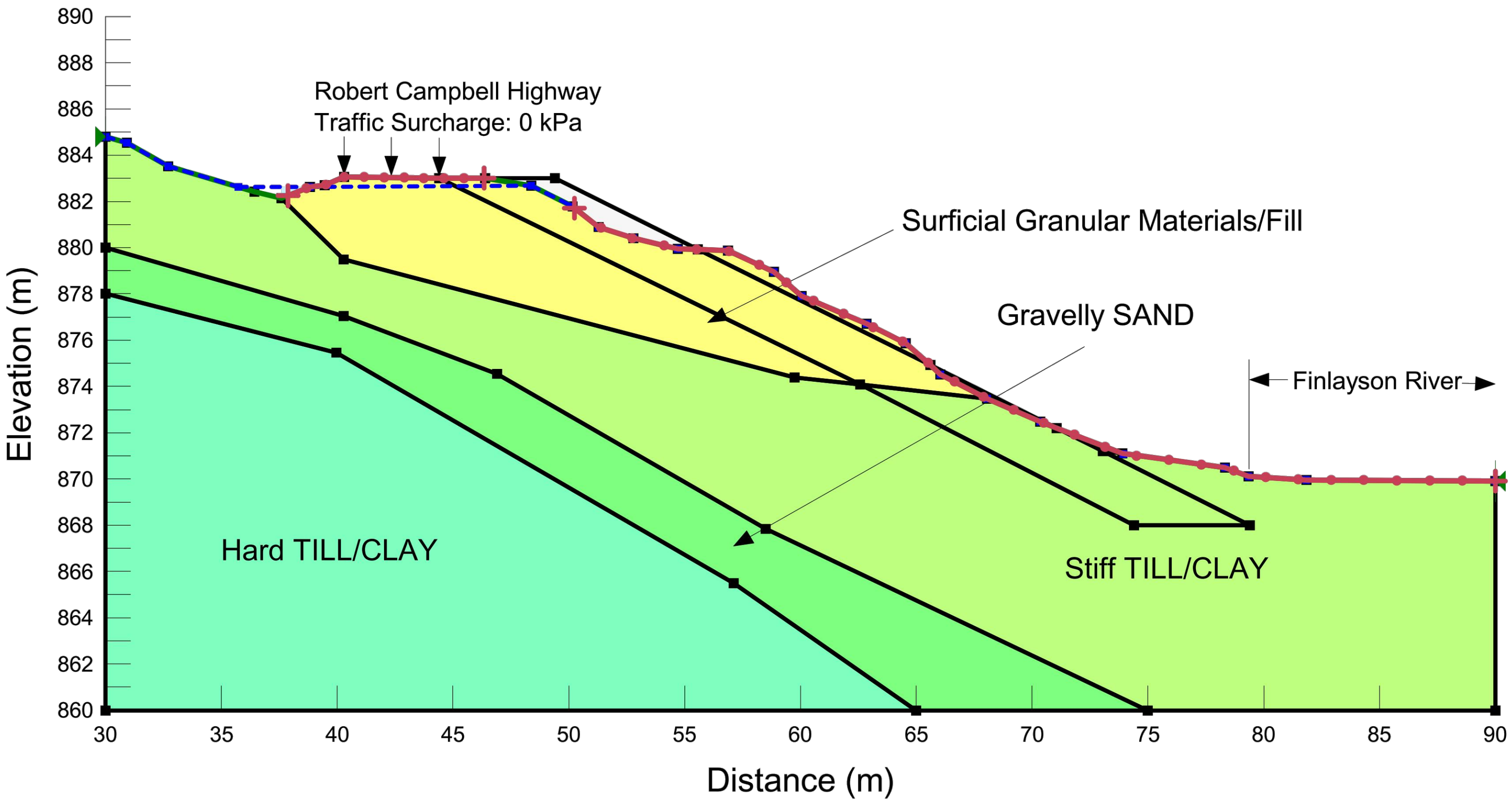
Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 ° Piezometric Line: 1
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa



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Scale: 1:300 @ 8.5"x11"

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TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W MODEL
EXISTING SLOPE

PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

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Figure 3

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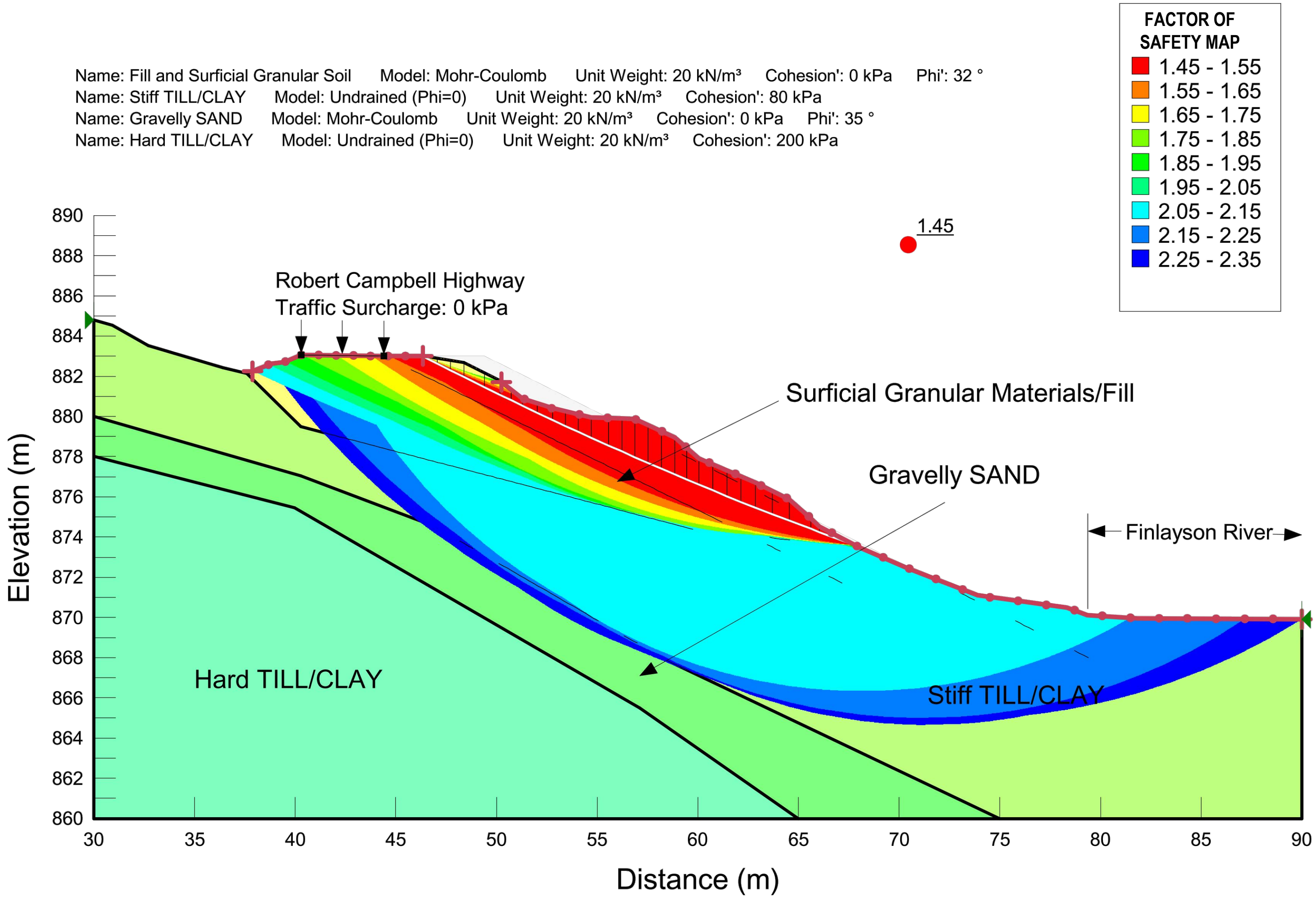
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Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 °
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa

0 15m
Scale: 1:300 @ 8.5"x11"

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TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W RESULTS
EXISTING SLOPE - DRY CONDITIONS

PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

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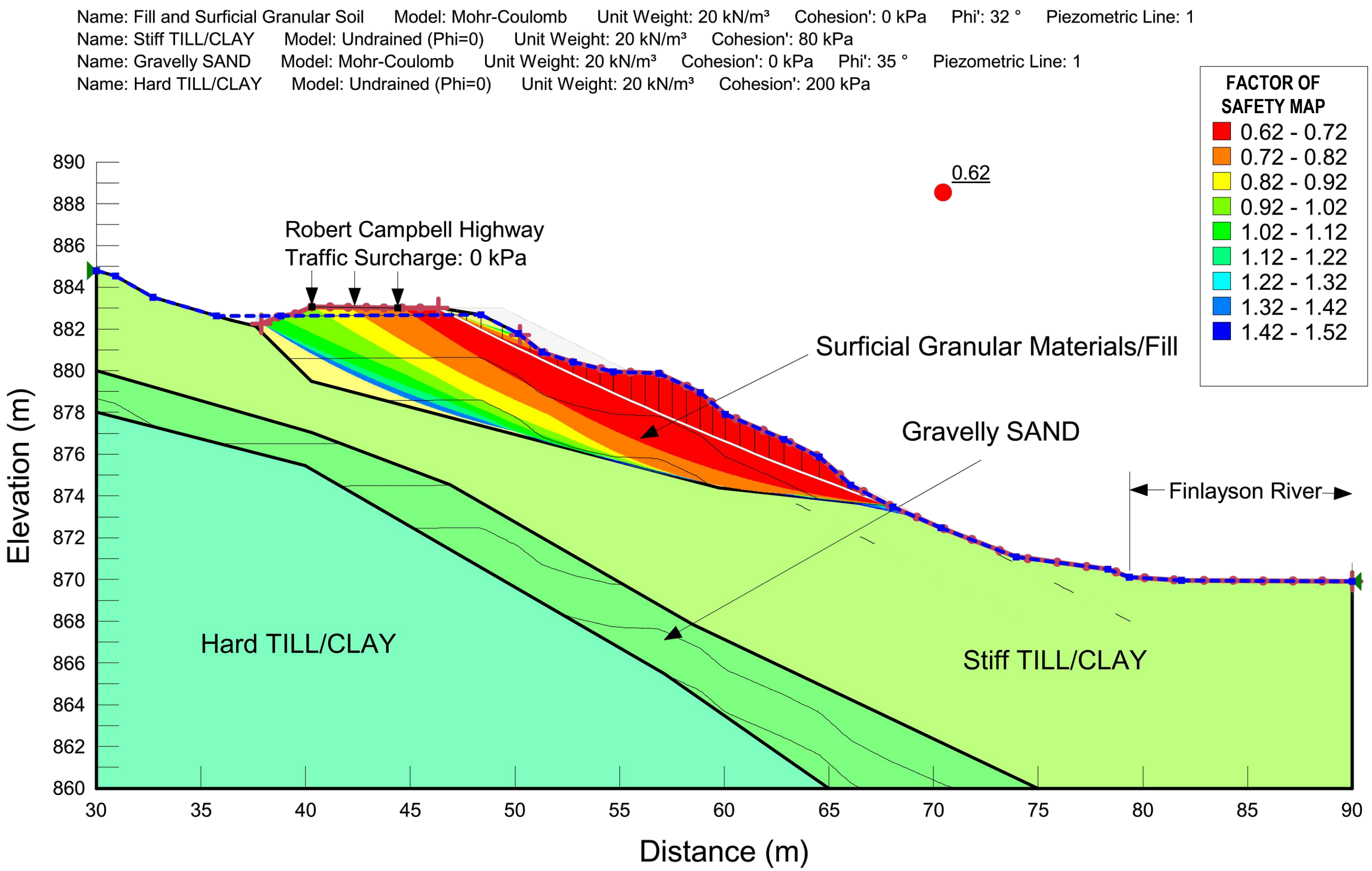
EBA-WHSE	December 4, 2015

Figure 4

Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 5] December 10, 2015 - 9:51:37 am (BY: BUCHAN, CAMERON)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Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 ° Piezometric Line: 1
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa

0 15m
Scale: 1:300 @ 8.5"x11"

CLIENT

Yukon Government

TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W RESULTS
EXISTING SLOPE - ELEVATED GROUNDWATER CONDITIONS

PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

OFFICE
EBA-WHSE

DATE
December 4, 2015

Figure 5

Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 6] December 10, 2015 - 9:51:45 am (BY: BUCHAN, CAMERON)

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Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 ° Piezometric Line: 1
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa
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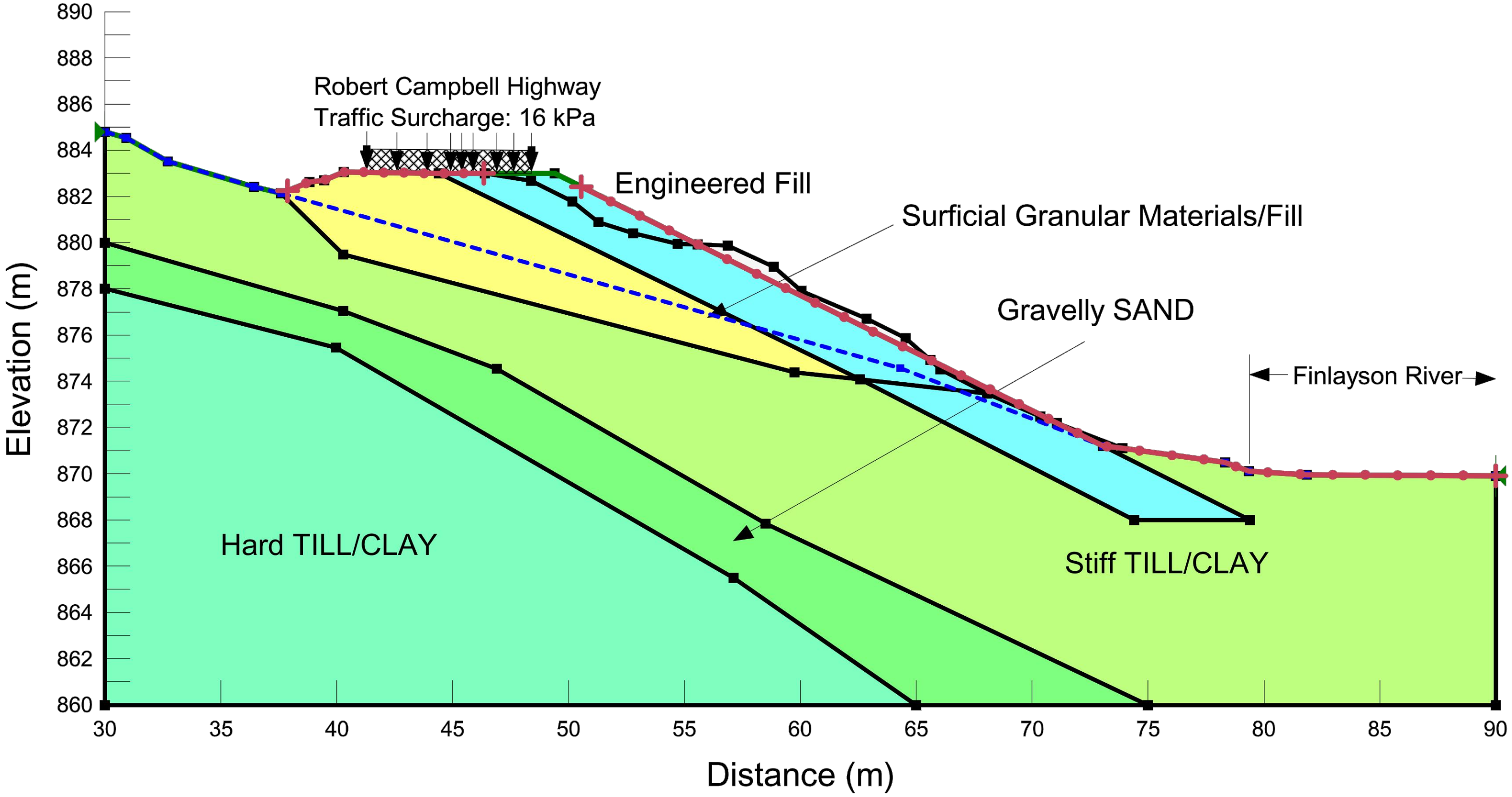


0 15m
Scale: 1:300 @ 8.5"x11"

CLIENT

Yukon Government

TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W MODEL
RECONSTRUCTED SLOPE

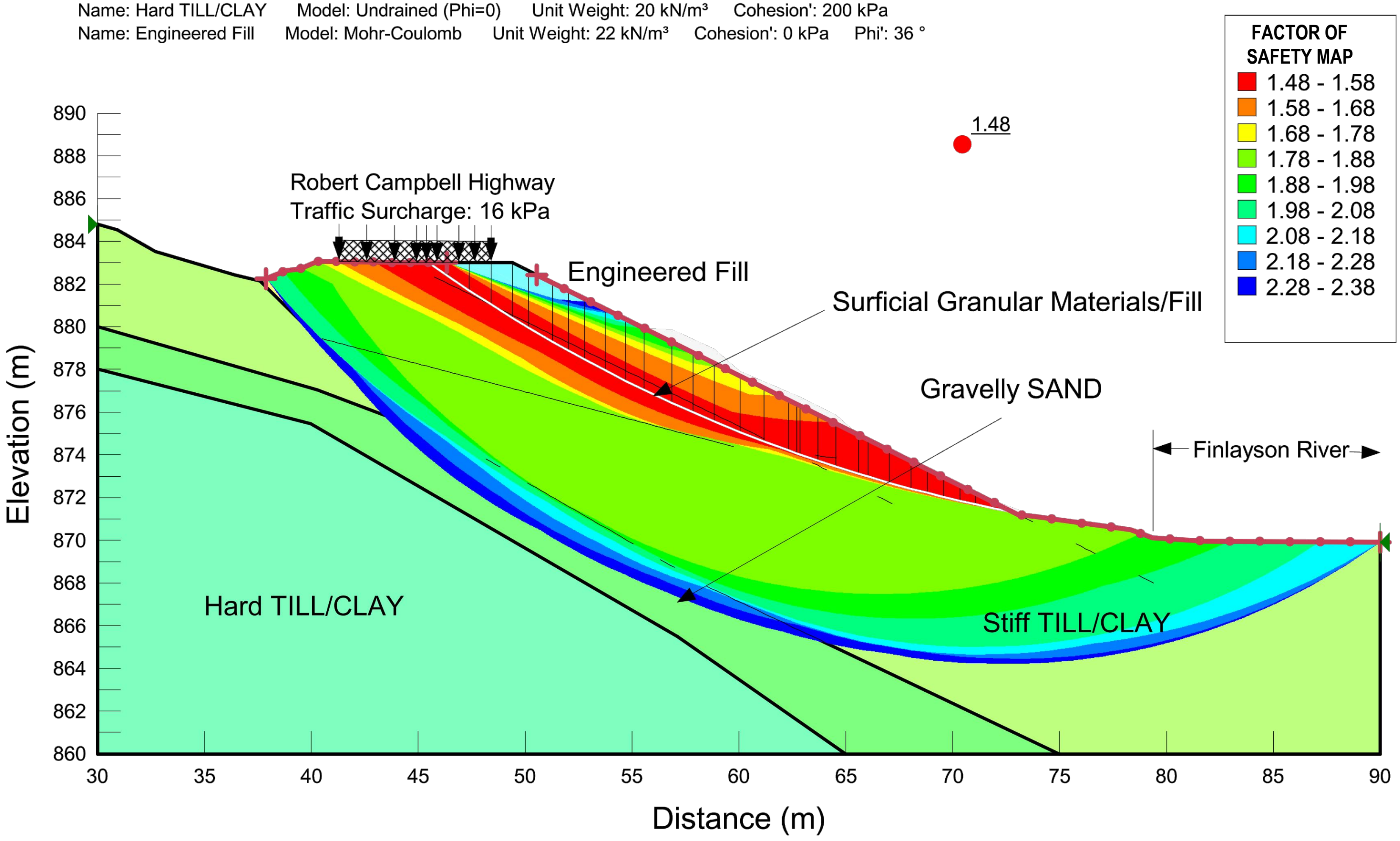
PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

OFFICE
EBA-WHSE

DATE
December 4, 2015

Figure 6

Name: Fill and Surficial Granular Soil Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 32 °
Name: Stiff TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 80 kPa
Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 °
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa
Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion': 0 kPa Phi': 36 °



0 15m
Scale: 1:300 @ 8.5"x11"

CLIENT
Yukon Government

TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W RESULTS
RECONSTRUCTED SLOPE - DRY CONDITIONS

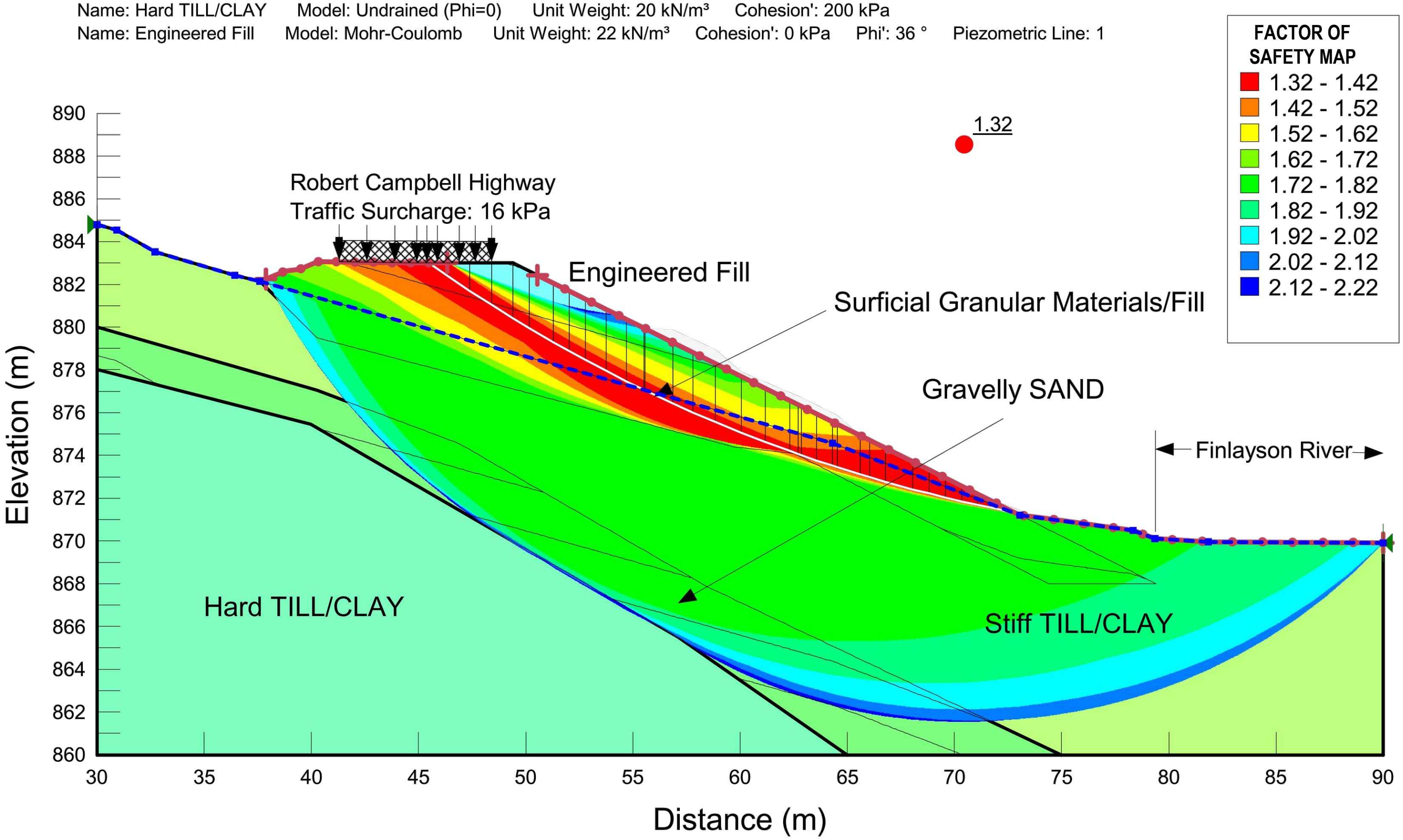
PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

OFFICE
EBA-WHSE

DATE
December 4, 2015

Figure 7

Name: Fill and Surficial Granular Soil Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 32 ° Piezometric Line: 1
Name: Stiff TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 80 kPa
Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 ° Piezometric Line: 1
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa
Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion': 0 kPa Phi': 36 ° Piezometric Line: 1



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Scale: 1:300 @ 8.5"x11"

CLIENT
Yukon Government

TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W RESULTS
RECONSTRUCTED SLOPE - INTERMEDIATE GROUNDWATER CONDITIONS

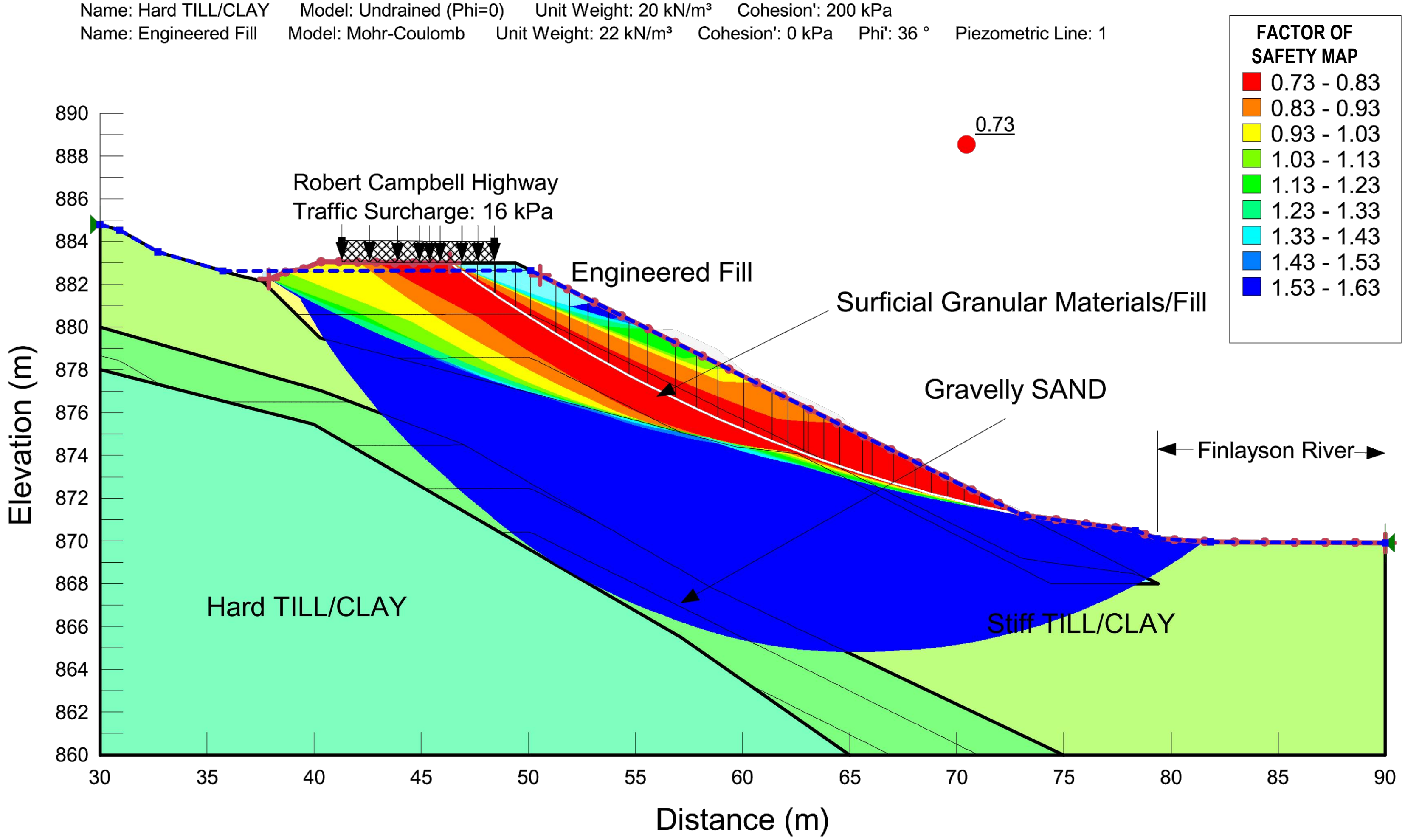
PROJECT NO.	DWN	CKD	REV
W14103698-02	CB	AW	0

OFFICE	DATE
EBA-WHSE	December 4, 2015

Figure 8

Q:\Whitehorse\Data\0201drawings\Campbell Hwy\W14103698-01 km 195 Slope Stability Assessment\02\W14103698-02 Fig.1-R0.dwg [FIGURE 9] December 10, 2015 - 9:52:04 am (BY: BUCHAN, CAMERON)

Name: Fill and Surficial Granular Soil Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 32 ° Piezometric Line: 1
Name: Stiff TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 80 kPa
Name: Gravelly SAND Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion': 0 kPa Phi': 35 ° Piezometric Line: 1
Name: Hard TILL/CLAY Model: Undrained (Phi=0) Unit Weight: 20 kN/m³ Cohesion': 200 kPa
Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion': 0 kPa Phi': 36 ° Piezometric Line: 1



0 15m
Scale: 1:300 @ 8.5"x11"

CLIENT

Yukon Government

TETRA TECH EBA

SLOPE STABILITY ASSESSMENT
KM 195 CAMPBELL HIGHWAY, YUKON

SLOPE/W RESULTS
RECONSTRUCTED SLOPE - ELEVATED
GROUNDWATER CONDITIONS

PROJECT NO. W14103698-02	DWN CB	CKD AW	REV 0
OFFICE EBA-WHSE	DATE December 4, 2015		

Figure 9

APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client’s expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

BOREHOLE LOGS AND LABORATORY TEST RESULTS

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075mm sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

DESCRIPTIVE TERM	RELATIVE DENSITY	N (blows per 0.3m)
Very Loose	0 TO 20%	0 to 4
Loose	20 TO 40%	4 to 10
Compact	40 TO 75%	10 to 30
Dense	75 TO 90%	30 to 50
Very Dense	90 TO 100%	greater than 50

The number of blows, N, on a 51mm O.D. split spoon sampler of a 63.5kg weight falling 0.76m, required to drive the sampler a distance of 0.3m from 0.15m to 0.45m.

FINE GRAINED SOILS (major portion passing 0.075mm sieve): Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

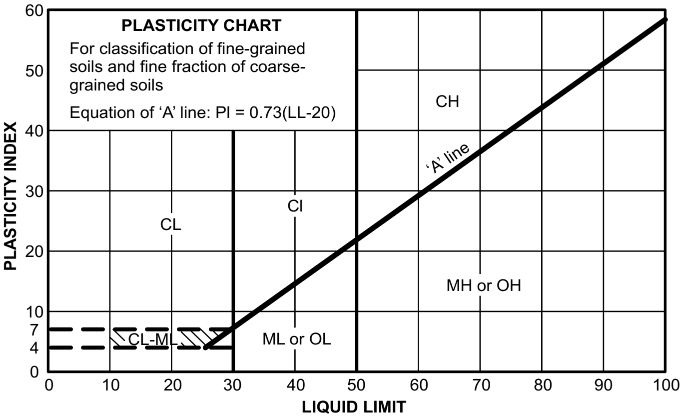
DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH (KPA)
Very Soft	Less than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater than 400

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided - having inclined planes of weakness that are slick and glossy in appearance.
Fissured - containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated - composed of thin layers of varying colour and texture.
Interbedded - composed of alternate layers of different soil types.
Calcareous - containing appreciable quantities of calcium carbonate.;
Well graded - having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded - predominantly of one grain size, or having a range of sizes with some intermediate size missing.

MODIFIED UNIFIED SOIL CLASSIFICATION

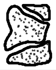
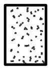
MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA		
COARSE - GRAINED SOILS More than 50% retained on No. 75 µm sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% pass 75 µm sieve GW, GP, SW, SP More than 12% pass 75 µm sieve GM, GC, SM, SC 5% to 12% pass 75 µm sieve Borderline classification requiring use of dual symbols	$C_U = D_{60} / D_{10}$ Greater than 4 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_U = D_{60} / D_{10}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly-graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot above 'A' line and plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
FINE-GRAINED SOILS (by behavior) 50% or more passes 75 µm sieve*	SILTS	Liquid limit <50	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands of slight plasticity			
		Liquid limit >50	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
	CLAYS Above "A" line on plasticity chart negligible organic content	Liquid limit <30	CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays, lean clays			
		Liquid limit 30-50	CI	Inorganic clay of medium plasticity, silty clays			
		Liquid limit >50	CH	Inorganic clay of high plasticity, fat clays			
	ORGANIC SILTS AND CLAYS	Liquid limit <50	OL	Organic silts and organic silty clays of low plasticity			
		Liquid limit >50	OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils			

* Based on the material passing the 75 mm sieve

† ASTM Designation D 2487, for identification procedure see D 2488 USC as modified by PFRA

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

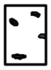
GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

NOTES:

1. Dual symbols are used to indicate borderline or mixed ice classifications.
2. Visual estimates of ice contents indicated on borehole logs ± 5%
3. This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes.

LEGEND: Soil ☐ Ice ■

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
V	Vx	Individual ice crystals or inclusions	
	Vc	Ice coatings on particles	
	Vr	Random or irregularly oriented ice formations	
	Vs	Stratified or distinctly oriented ice formations	

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm thick	

Government of Yukon

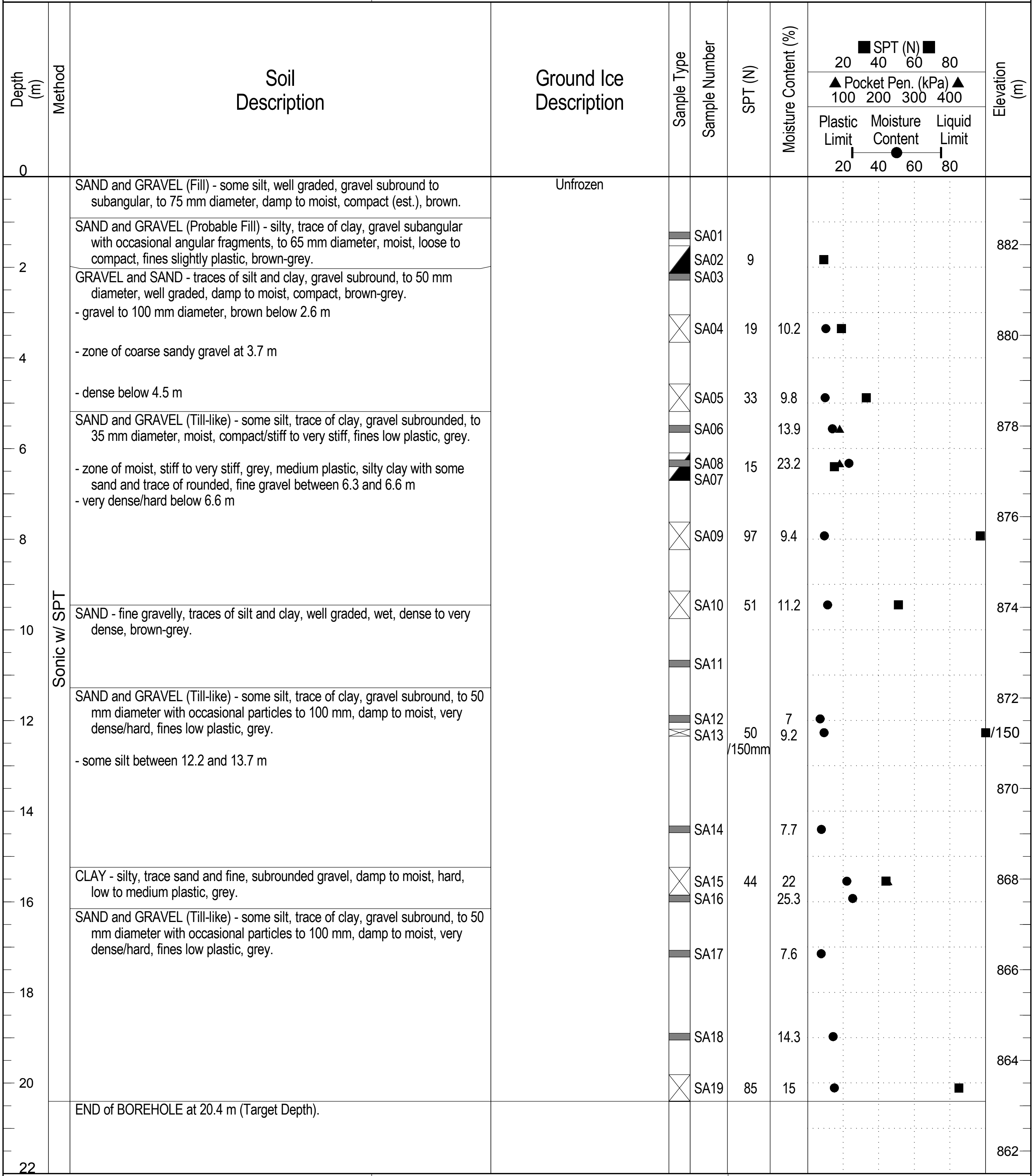
Borehole No: **BH15-01**

Project: Slope Assessment - Campbell Highway km 195	Project No: W14103698-01
Location: km 195 Robert Campbell Highway	Ground Elev: 883.5 m
Tuchitua, YT	UTM: 450430 E; 6822290 N; Z 9 WGS84

Soil Description	Ground Ice Description
SAND and GRAVEL (Fill) - some silt, well graded, gravel subround to subangular, to 75 mm diameter, damp to moist, compact (est.), brown.	Unfrozen
SAND and GRAVEL (Probable Fill) - silty, trace of clay, gravel subangular with occasional angular fragments, to 65 mm diameter, moist, loose to compact, fines slightly plastic, brown-grey.	
GRAVEL and SAND - traces of silt and clay, gravel subround, to 50 mm diameter, well graded, damp to moist, compact, brown-grey. - gravel to 100 mm diameter, brown below 2.6 m - zone of coarse sandy gravel at 3.7 m - dense below 4.5 m	
SAND and GRAVEL (Till-like) - some silt, trace of clay, gravel subrounded, to 35 mm diameter, moist, compact/stiff to very stiff, fines low plastic, grey. - zone of moist, stiff to very stiff, grey, medium plastic, silty clay with some sand and trace of rounded, fine gravel between 6.3 and 6.6 m - very dense/hard below 6.6 m	
SAND - fine gravelly, traces of silt and clay, well graded, wet, dense to very dense, brown-grey.	
SAND and GRAVEL (Till-like) - some silt, trace of clay, gravel subround, to 50 mm diameter with occasional particles to 100 mm, damp to moist, very dense/hard, fines low plastic, grey. - some silt between 12.2 and 13.7 m	
CLAY - silty, trace sand and fine, subrounded gravel, damp to moist, hard, low to medium plastic, grey.	
SAND and GRAVEL (Till-like) - some silt, trace of clay, gravel subround, to 50 mm diameter with occasional particles to 100 mm, damp to moist, very dense/hard, fines low plastic, grey.	
END of BOREHOLE at 20.4 m (Target Depth).	

Method: Sonic w/ SPT

Sample Number	SPT (N)	Moisture Content (%)
SA01		
SA02	9	
SA03		
SA04	19	10.2
SA05	33	9.8
SA06		13.9
SA08	15	23.2
SA07		
SA09	97	9.4
SA10	51	11.2
SA11		
SA12		7
SA13	50 /150mm	9.2
SA14		7.7
SA15	44	22
SA16		25.3
SA17		7.6
SA18		14.3
SA19	85	15



Contractor: Boart Longyear	Completion Depth: 20.4 m
Drilling Rig Type: LS250 Mini-Sonic	Start Date: October 1, 2015
Logged By: AWW	Completion Date: October 2, 2015
Reviewed By: JRT	Page 1 of 1

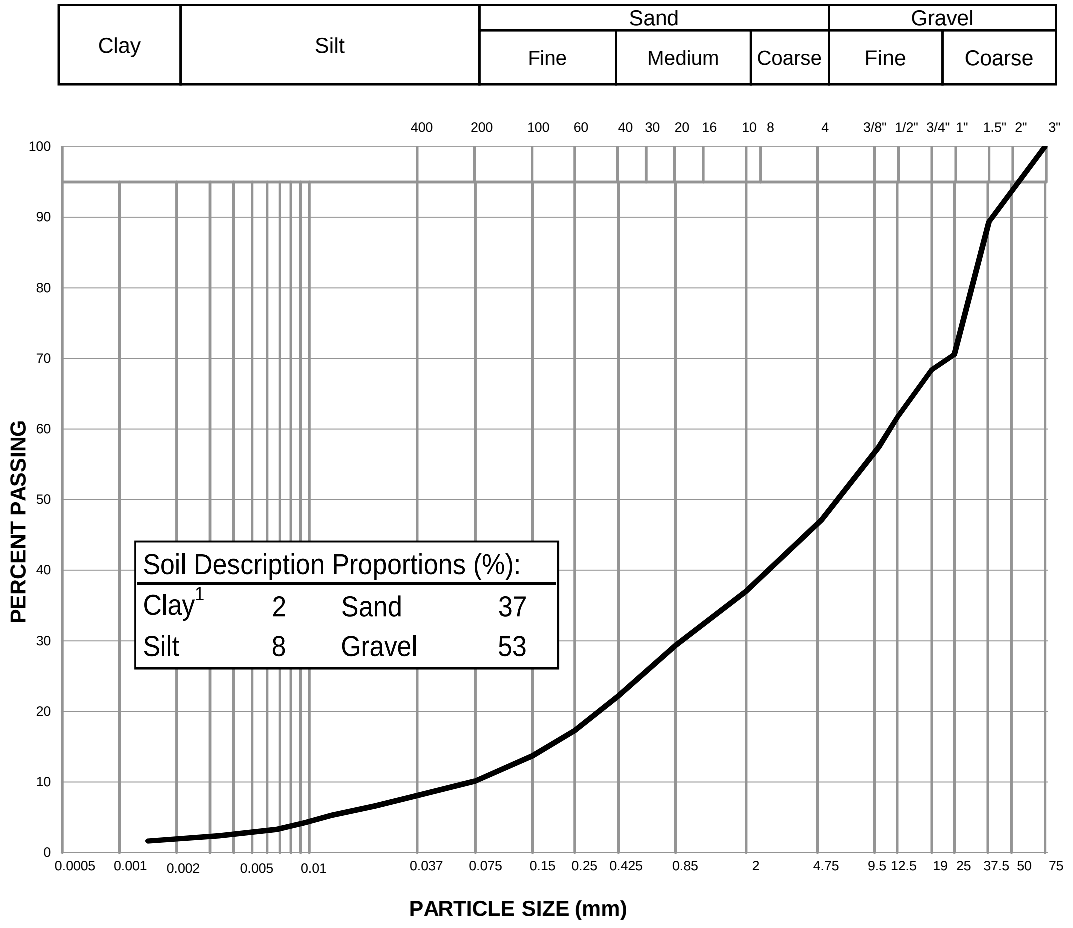
TETRA TECH EBA

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA03
Project No.:	W14103698-01	Material Type:	
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH01
Client:	YG - Highways and Public Works	Sample Depth:	2.1 m
Client Rep.:	Brian Crist	Sampling Method:	Grab
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015
Soil Description[2]:	GRAVEL and SAND - trace silt, trace clay	Sampled By:	AW
		USC Classification:	GW-GM Cu: 158.9
Moisture Content:	3.5%		Cc: 1.1

Particle Size (mm)	Percent Passing
75	100
50	
38	89
25	71
19	68
12.5	62
10	57
5	47
2	37
0.85	29
0.425	22
0.25	17
0.15	14
0.075	10.1
0.0344	7.9
0.0222	6.6
0.0131	5.3
0.0094	4.2
0.0068	3.3
0.0034	2.4
0.0014	1.6



Soil Description Proportions (%):			
Clay[1]	2	Sand	37
Silt	8	Gravel	53

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ______________________________

Remarks: ______________________________

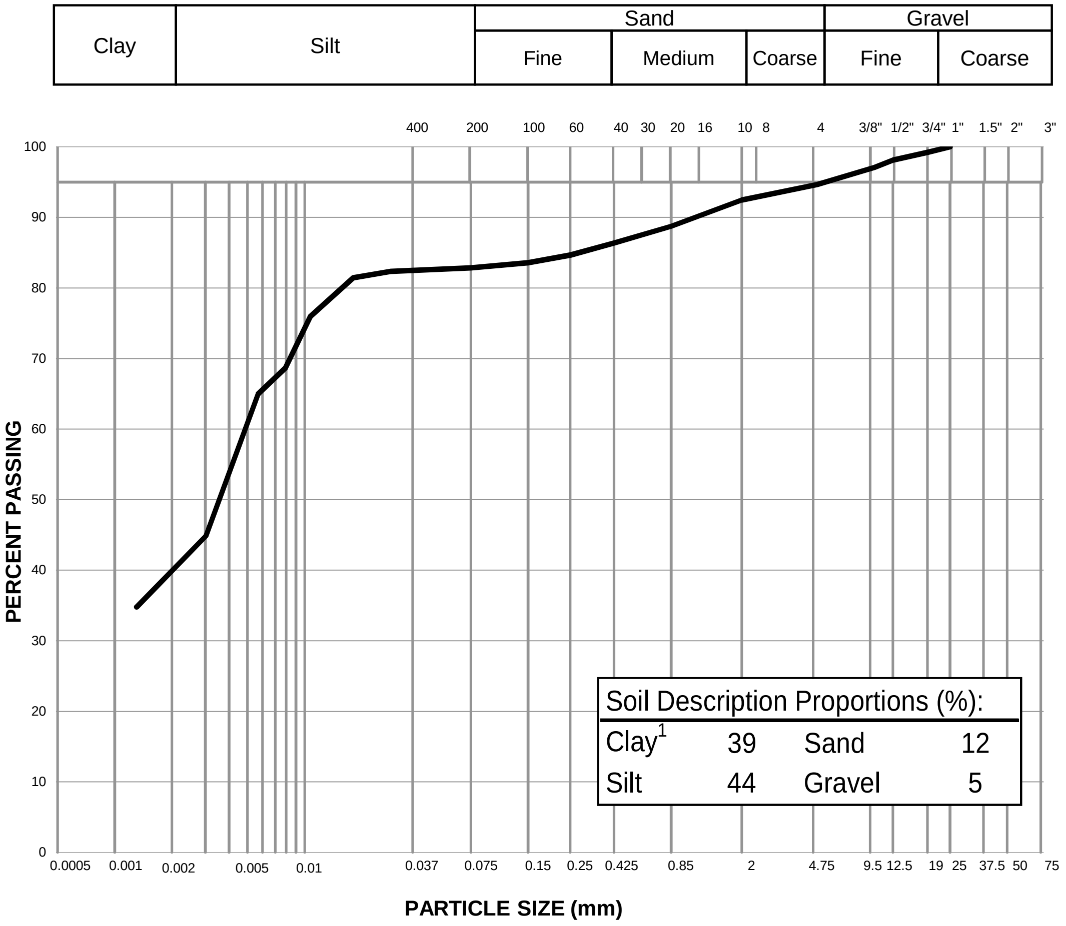
Reviewed By: ______________________________ P.Eng.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA08
Project No.:	W14103698-01	Material Type:	
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH01
Client:	YG - Highways and Public Works	Sample Depth:	6.2 m
Client Rep.:	Brian Crist	Sampling Method:	Grab
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015
Soil Description[2]:	CLAY - silty, some sand, trace gravel	Sampled By:	AW
		USC Classification:	CI Cu: #N/A
Moisture Content:	23.2%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	100
19	99
12.5	98
10	97
5	95
2	92
0.85	89
0.425	86
0.25	85
0.15	84
0.075	82.8
0.0284	82.4
0.0180	81.5
0.0107	76.0
0.0079	68.6
0.0057	65.0
0.0030	44.8
0.0013	34.8



Soil Description Proportions (%):

Clay[1]	39	Sand	12
Silt	44	Gravel	5

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ______________________

Remarks: ______________________

Reviewed By: ______________________ P.Eng.

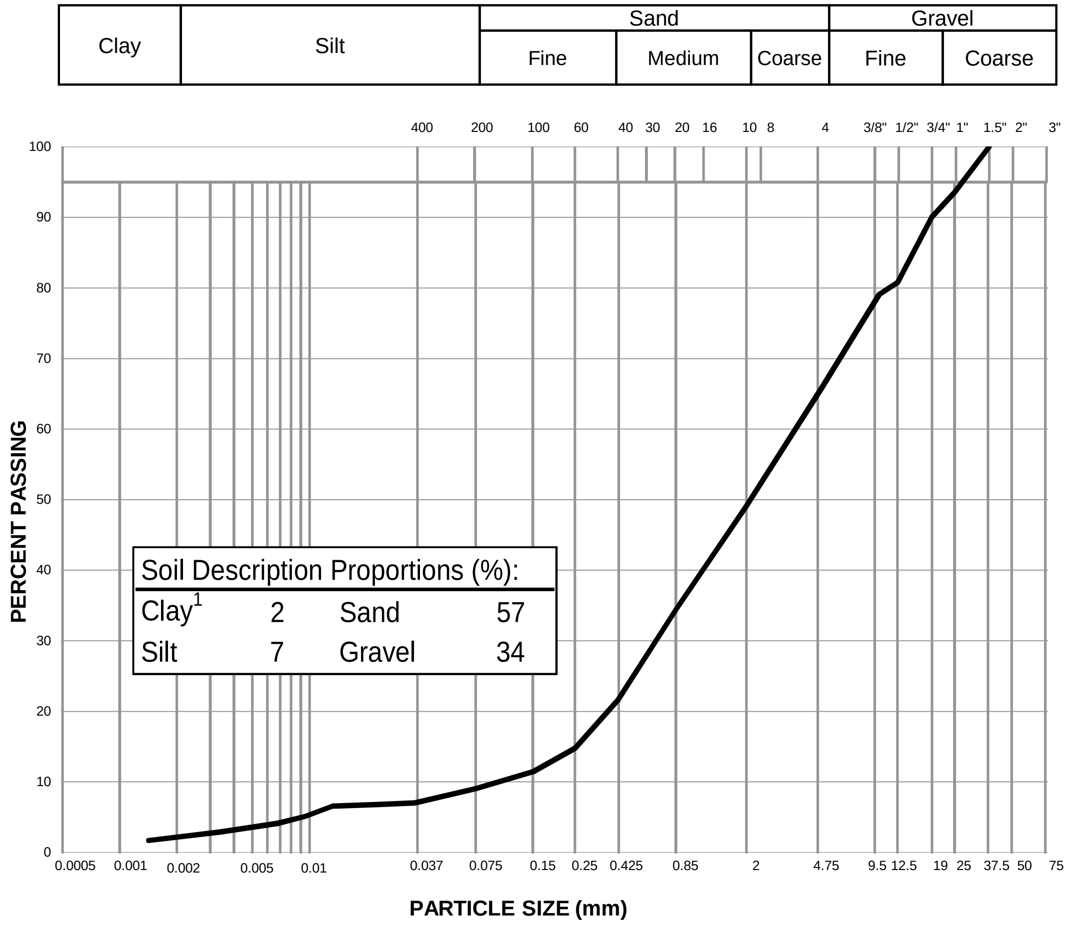
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA11
Project No.:	W14103698-01	Material Type:	
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH01
Client:	YG - Highways and Public Works	Sample Depth:	10.7 m
Client Rep.:	Brian Crist	Sampling Method:	Grab
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015
Soil Description[2]:	SAND - gravelly, trace silt, trace clay	Sampled By:	AW
		USC Classification:	SW-SM Cu: 37.4
Moisture Content:	9.9%		Cc: 1.2

Particle Size (mm)	Percent Passing
75	
50	
38	100
25	94
19	90
12.5	81
10	79
5	66
2	49
0.85	34
0.425	22
0.25	15
0.15	11
0.075	9.0
0.0359	7.0
0.0228	6.8
0.0132	6.6
0.0095	5.1
0.0068	4.1
0.0034	2.9
0.0014	1.7



Soil Description Proportions (%):

Clay[1]	2	Sand	57
Silt	7	Gravel	34

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ____________________

Remarks: ____________________

Reviewed By: ____________________ P.Eng.

TETRA TECH

Government of Yukon

Borehole No: **BH15-02**

Project: Slope Assessment - Campbell Highway km 195	Project No: W14103698-01
Location: km 195 Robert Campbell Highway	Ground Elev: 879 m
Tuchitua, YT	UTM: 450441 E; 6822296 N; Z 9 WGS84

Method: Sonic w/ SPT

Ground Ice Description: Unfrozen

Soil Description

SAND and SILT - gravelly, some organics (roots and wood fragments), trace of clay, gravel subround, to 50 mm diameter, well graded, moist to wet, loose to compact, fine slightly plastic, grey-brown.

- sand and silt and gravel, trace to no organics, brown below 1.5 m

SILT - trace to some clay, trace of sand and fine gravel, moist, very stiff, low plastic, grey-brown.

SAND - silty, gravelly, some clay, trace of organics, gravel subround, to 50 mm diameter, well graded, wet, loose to compact, grey-brown, occasional firm to stiff zones with some clay and occasional seams of dark brown organic silt.

CLAY - silty, trace of gravel and sand, gravel subround, to 35 mm diameter, damp, very stiff, low to medium plastic, grey, occasional brown zones with trace of organics.

- 100 mm layer of wet, brown, fine gravelly, coarse sand at 8.7 m

SAND and GRAVEL (Till-like) - some silt, trace of clay, gravel subround, to 75 mm diameter, wet, compact/stiff, fines slightly plastic, grey.

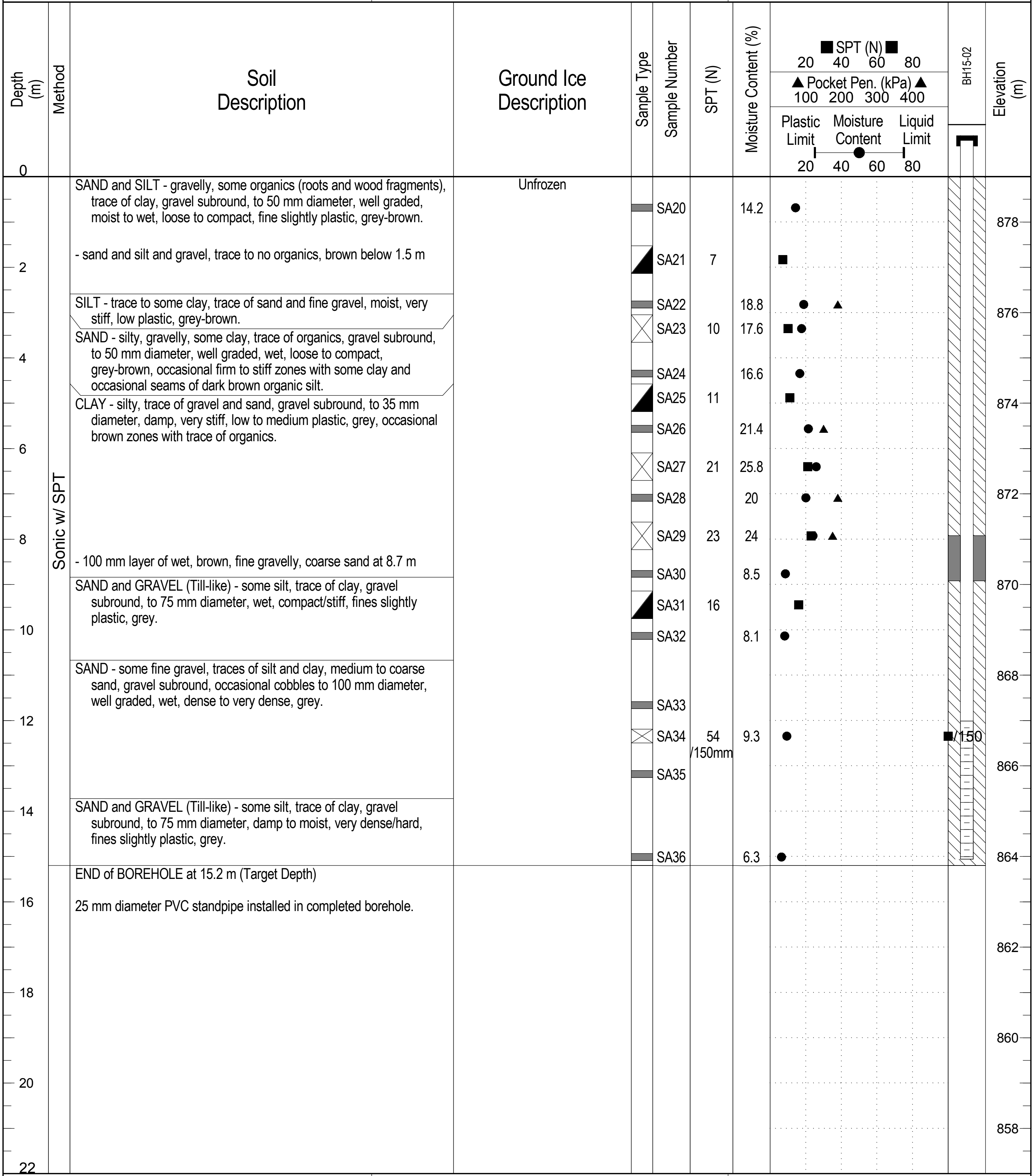
SAND - some fine gravel, traces of silt and clay, medium to coarse sand, gravel subround, occasional cobbles to 100 mm diameter, well graded, wet, dense to very dense, grey.

SAND and GRAVEL (Till-like) - some silt, trace of clay, gravel subround, to 75 mm diameter, damp to moist, very dense/hard, fines slightly plastic, grey.

END of BOREHOLE at 15.2 m (Target Depth)

25 mm diameter PVC standpipe installed in completed borehole.

Sample Type	Sample Number	SPT (N)	Moisture Content (%)
▬	SA20		14.2
◩	SA21	7	
▬	SA22		18.8
☒	SA23	10	17.6
▬	SA24		16.6
◩	SA25	11	
▬	SA26		21.4
☒	SA27	21	25.8
▬	SA28		20
☒	SA29	23	24
▬	SA30		8.5
◩	SA31	16	
▬	SA32		8.1
▬	SA33		
☒	SA34	54 /150mm	9.3
▬	SA35		
▬	SA36		6.3



TETRA TECH EBA

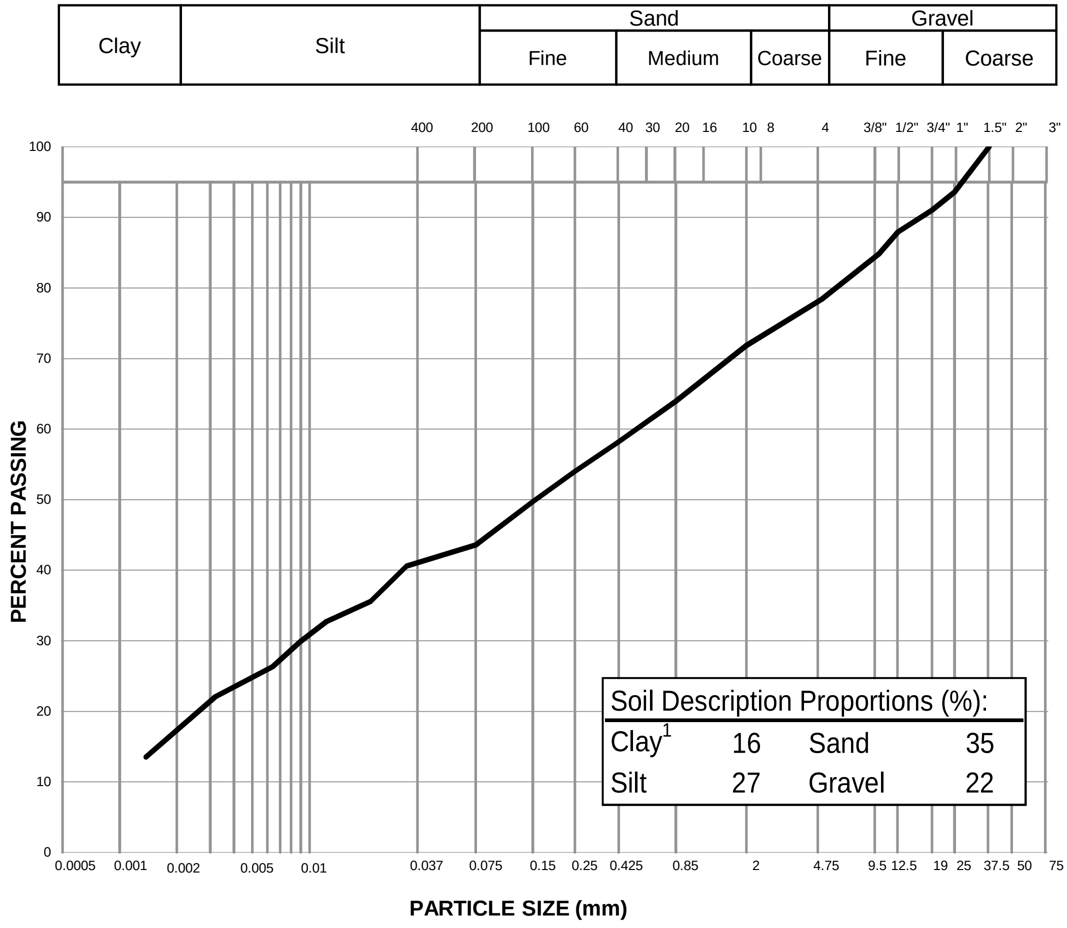
Contractor: Boart Longyear	Completion Depth: 15.2 m
Drilling Rig Type: LS250 Mini-Sonic	Start Date: October 2, 2015
Logged By: AWW	Completion Date: October 2, 2015
Reviewed By: JRT	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA24
Project No.:	W14103698-01	Material Type:	
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH02
Client:	YG - Highways and Public Works	Sample Depth:	4.3 m
Client Rep.:	Brian Crist	Sampling Method:	Grab
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015
Soil Description[2]:	SAND - silty, gravelly, some clay	Sampled By:	AW
		USC Classification:	SM Cu: #N/A
Moisture Content:	16.6%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	100
25	94
19	91
12.5	88
10	85
5	78
2	72
0.85	64
0.425	58
0.25	54
0.15	50
0.075	43.5
0.0324	40.5
0.0210	35.6
0.0123	32.7
0.0089	29.9
0.0064	26.3
0.0032	22.1
0.0014	13.5



Soil Description Proportions (%):

Clay[1]	16	Sand	35
Silt	27	Gravel	22

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ____________________

Remarks: ____________________

Reviewed By: ____________________ P.Eng.

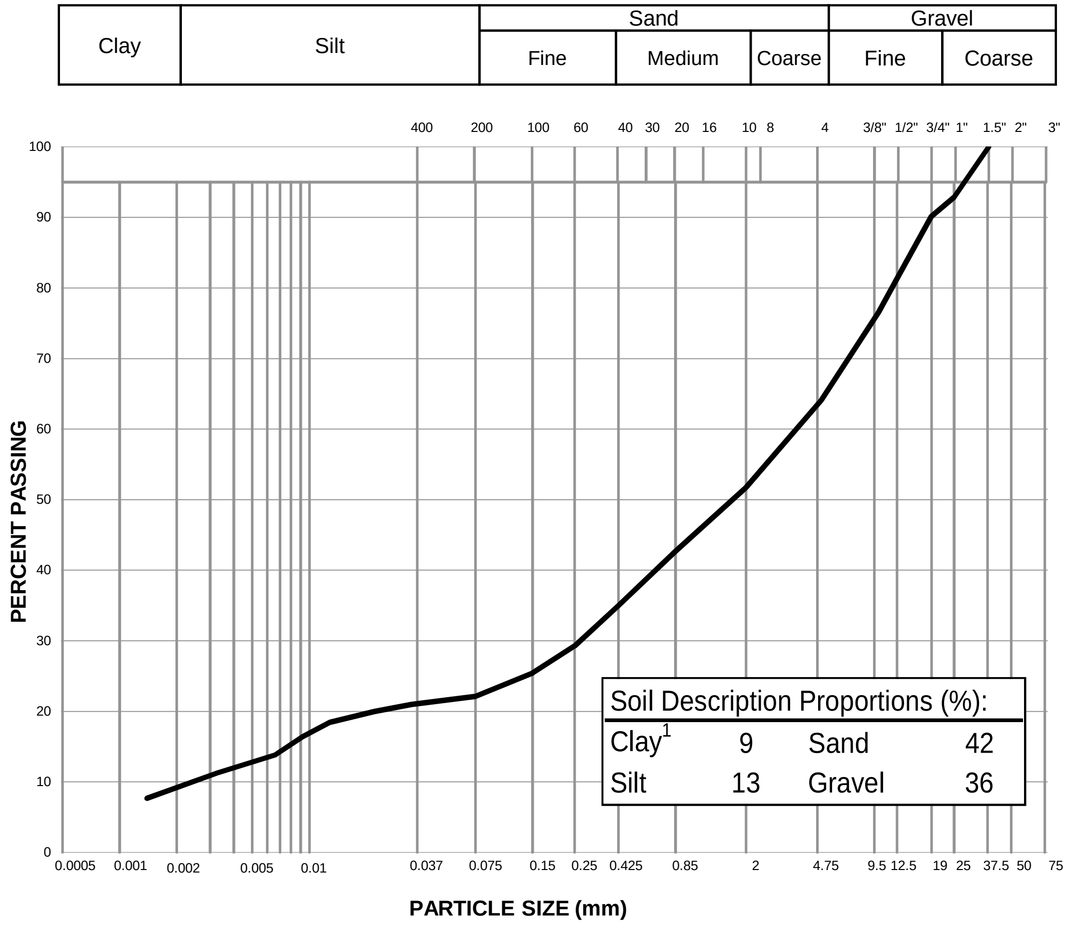
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA32		
Project No.:	W14103698-01	Material Type:			
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH02		
Client:	YG - Highways and Public Works	Sample Depth:	10.1 m		
Client Rep.:	Brian Crist	Sampling Method:	Grab		
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015		
Soil Description[2]:	SAND and GRAVEL - some silt, trace clay	Sampled By:	AW		
		USC Classification:	SM	Cu:	1533.0
Moisture Content:	8.1%			Cc:	7.1

Particle Size (mm)	Percent Passing
75	
50	
38	100
25	93
19	90
12.5	81
10	77
5	64
2	52
0.85	43
0.425	35
0.25	29
0.15	25
0.075	22.1
0.0346	21.0
0.0220	20.0
0.0128	18.4
0.0092	16.4
0.0066	13.8
0.0033	11.3
0.0014	7.7



Soil Description Proportions (%):

Clay[1]	9	Sand	42
Silt	13	Gravel	36

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ______

Remarks: ______

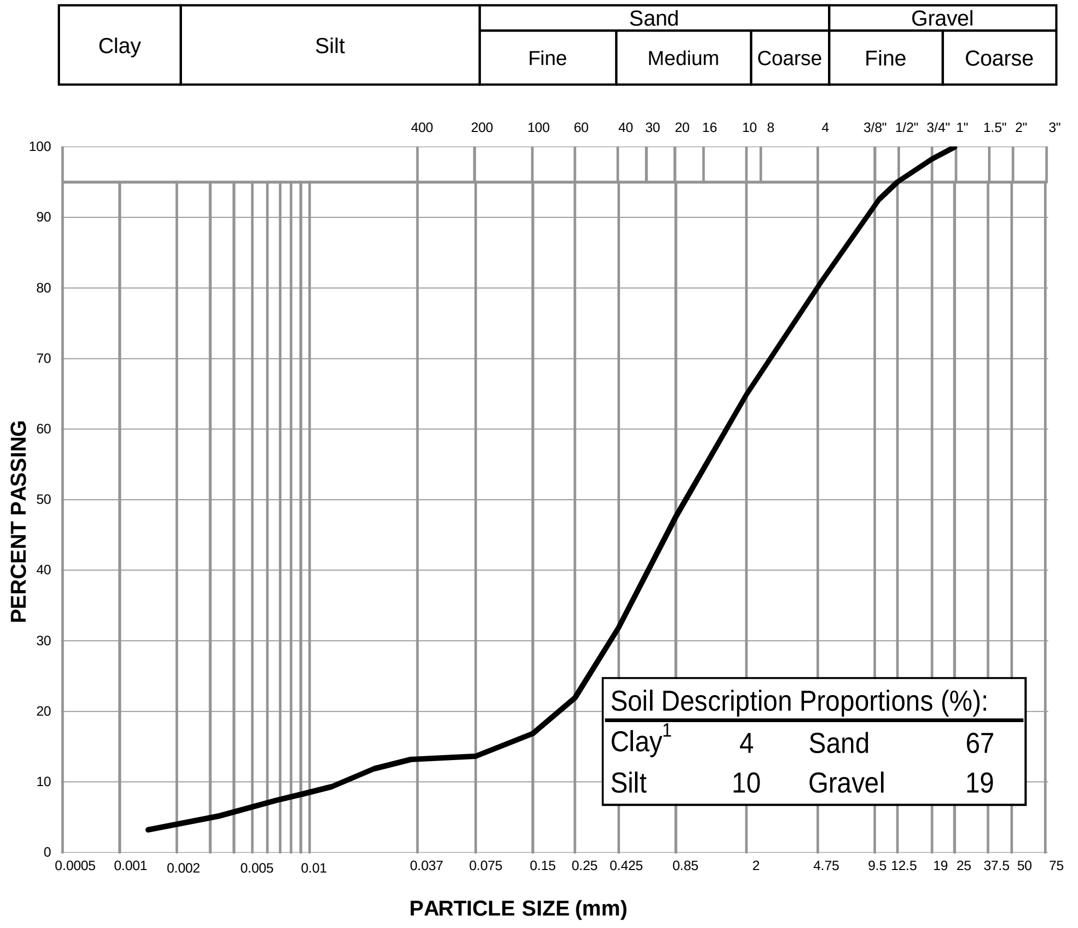
Reviewed By: ______ P.Eng.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Slope Stability Assessment	Sample No.:	SA33
Project No.:	W14103698-01	Material Type:	
Site:	km 195 Robert Campbell Highway	Sample Loc.:	BH02
Client:	YG - Highways and Public Works	Sample Depth:	11.6 m
Client Rep.:	Brian Crist	Sampling Method:	Grab
Date Tested:	October 29, 2015 By: AMT	Date sampled:	October 5, 2015
Soil Description[2]:	SAND - some gravel, trace silt, trace clay	Sampled By:	AW
		USC Classification:	SM Cu: 108.4
Moisture Content:	9.4%		Cc: 5.9

Particle Size (mm)	Percent Passing
75	
50	
38	
25	100
19	98
12.5	95
10	93
5	81
2	65
0.85	48
0.425	32
0.25	22
0.15	17
0.075	13.6
0.0342	13.2
0.0219	11.9
0.0131	9.3
0.0094	8.3
0.0067	7.4
0.0033	5.1
0.0014	3.2



Soil Description Proportions (%):

Clay[1]	4	Sand	67
Silt	10	Gravel	19

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: __________

Remarks: __________

Reviewed By: __________ P.Eng.

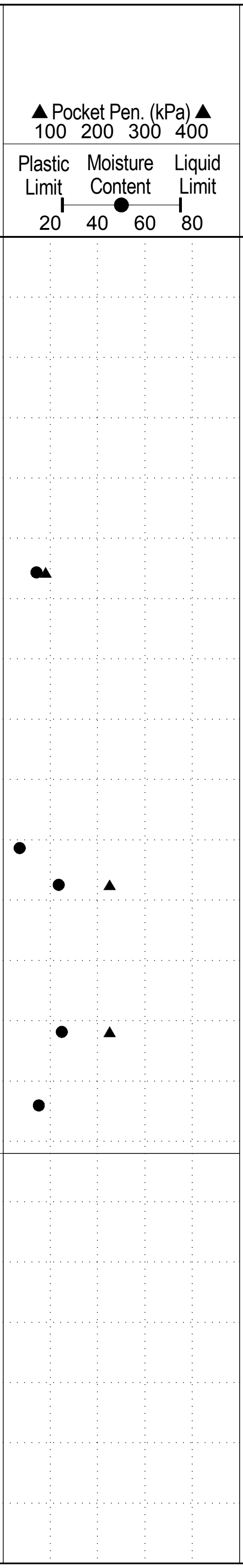
TETRA TECH

Government of Yukon

Borehole No: **BH15-03**

Project: Slope Assessment - Campbell Highway km 195	Project No: W14103698-01
Location: km 195 Robert Campbell Highway	Ground Elev: 883.5 m
Tuchitua, YT	UTM: 450411 E; 6822300 N; Z 9 WGS84

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Number	Moisture Content (%)	Elevation (m)
0 2 4	Sonic	SAND and GRAVEL (Fill) - some silt, gravel subround, to 65 mm diameter, well graded, damp to moist, brown, occasional silty lumps.	Unfrozen	SA37 SA38 SA39		882 880
6		SILT (Till-like) - some gravel, trace to some clay, trace of sand, gravel subangular, to 25 mm diameter, moist, stiff to very stiff, slightly plastic, grey.		SA40	14.1	878
8		SAND - fine gravelly, traces of silt and clay, gravel subround, well graded, wet, grey brown.		SA41 SA42		876
10 12		SAND and GRAVEL (Till-like) - silty, trace of clay, gravel subround, to 40 mm diameter, moist, very dense/hard, grey. - zone of hard, grey, medium plastic, silty clay with traces of sand and fine gravel between 10.4 and 11.0 m - drilled through boulder between 11.3 and 11.9 m		SA43 SA44	7 23.5	874 872
		CLAY - silty, trace of sand and gravel, visible laminations between 1 and 3 mm thick, moist, hard, medium plastic, grey, occasional thin (<1 mm) laminations of fine sand.		SA45	24.8	870
14		SAND and GRAVEL (Till-like) - silty, trace of clay, gravel subround, to 40 mm diameter, well graded, moist, very dense/hard, grey.		SA46	15.1	
16 18 20 22		END of BOREHOLE at 15.2 m (Target Depth).				868 866 864 862



TETRA TECH EBA

Contractor: Boart Longyear	Completion Depth: 15.2 m
Drilling Rig Type: LS250 Mini-Sonic	Start Date: October 2, 2015
Logged By: AWW	Completion Date: October 2, 2015
Reviewed By: JRT	Page 1 of 1