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Geotechnical Evaluation
Proposed Country Residential Subdivision
km 574.5 RHS Robert Campbell Highway #4
Carmacks, Yukon – 2019

Prepared For: **Yukon Government**

Date : **October 4th, 2019**

TABLE OF CONTENTS

Geotechnical Evaluation
Proposed Country Residential Subdivision
km 574.5 RHS Robert Campbell Highway #4
Carmacks, Yukon – 2019

TABLE OF CONTENTS

Geotechnical Evaluation
Proposed Country Residential Subdivision
km 574.5 RHS Robert Campbell Highway #4
Carmacks, Yukon – 2019

TABLE OF CONTENTS

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Proposed Country Residential Subdivision
km 574.5 RHS Robert Campbell Highway #4
Carmacks, Yukon – 2019

FIGURES & APPENDICES

1.0 INTRODUCTION

Our firm was retained by *Yukon Government - Department of Community Services, Rural Land Development - Land Development Branch* (*YG*) under a Standing Offer Agreement (No.2017/2018-2753) to conduct a geotechnical evaluation of a proposed country residential subdivision which is to be located in Carmacks, Yukon.

The purpose of our evaluation was to assess the development potential of the study area through subsurface investigation and laboratory analysis in order to formulate geotechnical recommendations to assist in site development and preliminary foundation design where development was deemed feasible. A hydrogeological study, which was beyond our scope-of-work, would be required to assess the suitability of the study area relative to water well installations.

The *Village of Carmacks*, located ~ 180 km north of Whitehorse along the North Klondike Highway #2, is one of number of Yukon communities where there is an increasing demand for overall lot development. The study area, which measures ~ 14 ha in size, is located at km 574.5 right-hand side (RHS) of the Robert Campbell Highway #4 as noted in Figure 1.

While our evaluation was meant to supplement our December 27th, 2018 Geotechnical Feasibility Assessment, which identified the overall development potential of the proposed subdivision (based upon a literature review and site reconnaissance), as the eastern realms of the study area were previously identified as harboring shallow bedrock, our evaluation focused upon the western realms of the study area (within the municipal limits of the *Village of Carmacks*) as lot development in this region was deemed to be more feasible. As our recent evaluation was more comprehensive in nature than our Geotechnical Feasibility Assessment, our findings and recommendations contained herein supersede those of our previous report where conflicts may exist.

Authorization to proceed with the evaluation was granted by *YG – Community Services* - Senior Program Manager, Mr.K.Fisher on August 2nd, 2019. Our field work was subsequently conducted between August 10th and 18th in accordance with our July 29th, 2019 proposal.

Our findings have been presented herein along with a description of our methodology.

2.0 METHODOLOGY

Our work methodology was comprised of the following components.

2.1 Literature Review

Our firm reviewed our December 27th, 2018 Geotechnical Feasibility Assessment report to re-familiarize ourselves with the regional conditions and detail the field work programs. During this time, we collated the information relative to newly compiled topographical maps (which were forwarded to us by *Inukshuk Planning & Development Ltd*.) in order to detail the field work program by identifying potential test-pit and borehole locations.

The new topographical survey (which was based upon third party data retained in 2014) has been attached as Figure 2. While the (1.0-meter) contours intervals denoted local fluctuations in the ground surface, considering the age of the survey, it may not necessarily reflect the existing conditions and so this should be considered when viewing the information.

2.2 Field Work Program

The field work program was comprised of the following components;

Utility Locates

Northwestel, *ATCO Electric Yukon* and the *Village of Carmacks* were contacted prior to conducting the test pit and drilling programs to ensure the subsurface investigation would not impact local infrastructure.

In brief, the service providers indicated they did not have any utilities located within the limits of the study area. However, *ATCO Electric Yukon* identified the presence of an overhead power transmission line which is located just beyond the northern edge of the study area.

Site Reconnaissance

A site reconnaissance was conducted by the undersigned on August 10th, 2019 to mark anticipated test pit and borehole locations and delineate equipment access routes such that the potential for disturbance to vegetation and delays during the subsurface investigation was minimized. In addition, during this time we assessed the conditions of the steeper slopes located within and immediately southwest of the study area.

Test Pit Program

A test pit program was conducted on August 13th, 2019 to assess the sub-surface conditions at select locations within the study area utilizing a *Bobcat E60* tracked excavator which was equipped with a digging bucket. The excavator was supplied and operated by *Yellow Truck Excavating Inc.* of Whitehorse, Yukon and was employed under the direction of our firm.

The work consisted of excavating four (4) test pits (TP 1-19 through TP 4-19) which were excavated at the approximate locations noted in Figure 3.

Test Pit Termination

The test pits were typically excavated to a depth of approximately 3.0 meters below the prevailing ground surface. The exception to this was at test pit TP 1-19 where the depth of excavation was limited to 1.7 meters due to the presence of bedrock. Otherwise, with the exception of test pit TP 1-19, each of the test pits were terminated within glaciofluvial terrace deposits which were comprised of interbedded sandy silts to silty sands.

Test Pit TP 3-19

The test pits were backfilled with the excavation spoils approximately fifteen (15) minutes following completion of excavation to allow for a period of time to assess sidewall stability and potential groundwater seepage/recharge rates. The surficial organic cover, which was stockpiled separately from the excavation spoils, was subsequently utilized to cap the backfill to reduce the potential for soil erosion and promote re-vegetation.

Drilling Program

A drilling program was conducted on August 17th & 18th, 2019 utilizing a CME-75 drill mounted on a *5500 Series GMC* truck to obtain soil samples and characterize the subsurface conditions. The drill was owned and operated by *Donjek Drilling* of Whitehorse, Yukon and was employed under the direction of our firm.

The drilling program was comprised of drilling six (6) boreholes (BH 1-19 through BH 6-19) at the approximate locations noted in Figure 3. Five (5) of these boreholes were advanced utilizing 150 mm Ø continuous flight solid-stem augers. The sixth borehole was advanced utilizing 200 mm Ø continuous flight hollow-stem augers.

The use of the hollow-stem augers allowed for a monitoring well to be installed and bearing capacity assessments through standard penetration test (SPT) methodologies which were employed in accordance with *ASTM D1586-11*.

SPT Methodology

In brief, the SPT methodology allows for the relative density of the sub-surface soils to be assessed by measuring the number of blows (N-value) required to drive a 50 mm diameter uncased sampler tube a distance of 300 mm utilizing a 63.5 kg hammer dropped from a height of 760 mm. These 'N' values allow for correlation of the noted resistance relative to the materials density/consistency where thawed materials are encountered. The approximate correlation has been presented on the '*Notes on Soil Logs'* enclosed in Appendix A.

Borehole Termination

The boreholes were advanced to an average depth of 6.22 meters but varied between 3.96 meters (BH 1-19) to 9.14 meters (BH 2-19).

Auger refusal was encountered in boreholes BH 1-19 and BH 4-19 at depths of 3.96 meters and 5.49 meters, respectively. The refusal was attributed to the presence of possible bedrock.

The boreholes were subsequently backfilled utilizing a combination of auger cuttings and bentonite pellets which were established in accordance with good drilling practices.

Central trail conditions facing south - Drilling borehole BH 5-19 – BH 3-19 in foreground.

Central trail conditions facing north – Locations of boreholes BH 1-19 through BH 3-19

<u>*Monitoring Well Installation*</u>

A 2" diameter ABS monitoring well was installed in borehole BH 3-19 to a depth of approximately 6.0 meters below the existing ground surface to allow for monitoring of the local groundwater conditions.

Borehole BH 3-19 – Field Conditions

<u>*Monitoring Well Structure*</u>

The lower 3.05 meters of the well was screened and covered with a silt sock (to minimize the influx of fines and extend the life of the well). The annular space was backfilled with an imported filter sand (conforming to *NSF/ANSI 61* standards). The exception to this was the region ~0.5 meters above the screened portion of the pipe where bentonite was used to seal the annular space to the ground surface in accordance with good well installation practices. Access to the well was restricted through the installation of a high-visibility lockable steel casing which was concreted into the existing ground surface.

Survey Program

The locations of the test pits and boreholes were recorded in the field utilizing a hand-held GPS unit.

Each location was subsequently marked utilizing wooden survey lathe such that if required, they could be more accurately surveyed by a *YG* retained surveyor. Given the regional perspective of our evaluation, the test-pits and boreholes were each given arbitrary elevations of 100.00 meters.

Soil Logs

During the drilling and test pit excavation, field soil logs were maintained by the undersigned to record the stratigraphy of the soils that were encountered. This information was utilized along with visual observations and the results of the laboratory analysis in order to compile the Test Pit and Borehole Soil Logs which have been enclosed in Appendix A. This appendix also includes '*Notes on Soil Classification'* and a description of the *'Unified Soil Classification System'* and '*National Research Council'* permafrost classification systems which were utilized to describe the soils.

Sampling Program

Soil samples were retained at regular intervals during the subsurface investigation to allow for additional observations to be made under field and laboratory settings.

In all, a total of sixty-eight (68) samples were obtained.

Fifteen (15) of these samples were obtained during the test pit program.

> During this time, the near surface samples were retained by hand directly from the excavation sidewalls. The deeper samples were retained from the leading edge of the excavator bucket during the course of test pit excavation.

The remaining fifty-three (53) samples were retained during the drilling program.

> While four (4) of these drilling samples were retained through SPT methodologies, the remainder were retained directly off the auger flighting.

An additional sample was retained from the *Yukon Government* gravel quarry located at km 354.3 RHS of the North Klondike Highway #2 (Disposition No.900101) to characterize potential fill materials which may be utilized during site development.

Once the soil samples were retained, they were described on the field soil logs and subsequently sealed in air-tight plastic bags. The samples were numbered sequentially in order to allow for laboratory analysis as described in Section 2.3, below.

2.3 Laboratory Work Program

The laboratory work program was comprised of both physical and analytical analysis.

Physical Laboratory Analysis

The physical laboratory work program was conducted at our Whitehorse laboratory facilities and those of our sub-consultant, *Golder Associates Ltd.* (located in Burnaby, British Columbia), in order to characterize the index properties and conditions of the retained soil samples.

The analysis was conducted between August 14th and September 6th, 2019 and was comprised of the following;

Description of Analysis	***ASTM Analysis***	***Quantity***	***Laboratory***
Moisture Content	D 2216-92	68	*Chilkoot*
Grain Size Distribution	D 422-633	31	*Chilkoot*
Hydrometer	D 422-633	3	*Golder Associates*

In brief, each sample underwent moisture content analysis to determine the content of water relative to the dry weight of the sample. The results of the analysis have been denoted as 'MC' (⦿ - Symbol) on the Soil Logs enclosed in Appendix A.

The grain size distribution analysis was conducted on a selection of samples in order to assist in soil classification utilizing the *Unified Soil Classification System*. The results of the analysis have been noted on the Soil Logs with the percent composition of fines (silt & clay), sand and gravel denoted with the symbols - ▲, ● & ■, respectively.

The hydrometer analysis was conducted in order to determine the percentage of sand, silt and clay which was contained within each of the test samples. These percentages were subsequently plotted on the *Soil Textural Triangle* to provide a relative assessment of the soils suitability for use as accepting soils relative to septic system design as described in Section 4.4, below. The results of the hydrometer analysis have been attached in Appendix B.

Analytical Laboratory Analysis

The total sulphate ion content of two (2) soil samples was determined by our laboratory sub-consultant *Golder Associates Ltd.* in accordance with *CSA Standard A23.1 – 3C.*

The purpose of the analysis was to assess the aggressiveness of the native and potentially imported soils relative cast-in-place concrete.

The native soil sample (No.12), retained from borehole BH 2-19, was comprised of a silty sand which was similar to other silty sands which were encountered in the study area.

The sample of material which would potentially be imported was retained from the *YG* gravel quarry (Disposition No.900101) located at km 354.3 RHS of North Klondike Highway #2.

The results of the sulphate ion content analysis have been attached in Appendix B.

3.0 SITE CONDITIONS

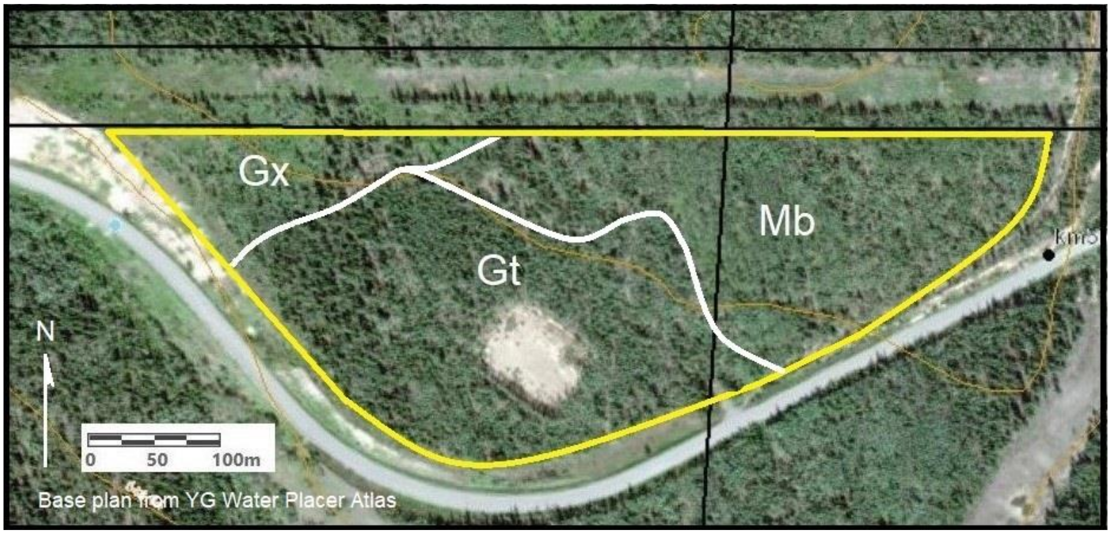
Details regarding the physiographic and geomorphic settings can be found in our December 27th, 2018 Geotechnical Feasibility Assessment report along with a description of the site.

The sub-surface conditions which were encountered during our evaluation have been summarized as follows;

3.1 Soil Stratigraphy

The soils located within the study area were predominately comprised of glaciofluvial terrace deposits. These deposits generally consisted of interbedded sandy silts to silty sands. The deposits located in the steeper northeastern and northwestern realms of the study area varied. A morainal (glacial till) blanket which overlay bedrock dominated the northeastern portions of the site. Glaciofluvial ice stagnation complex deposits which overlay bedrock were present in the northwestern regions of the study area.

The approximate distribution of these soil deposits was delineated as illustrated below;



Base plan from YG Water Placer Atlas

These deposits were characterized as follows;

Glacifluvial Terrace Deposits (Gt)

These deposits were generally comprised of a series of interbedded sandy silts to silty sands which were deposited by glacial meltwaters. At some locations (boreholes BH

4-19 to BH 6-19), these soils overlay dense sandy gravels which contained varying amounts of silt. Some of these gravels were classified as being possibly regolith which suggests the presence of potential bedrock. The fine-grained silts were determined to be non-plastic through Atterberg limit analysis.

The average moisture content of the sandy silts was noted to be 6.8% by weight (but varied between 2.5 and 15.9 %). The average moisture content of the silty sands was noted to be 3.6 % by weight (but varied between 1.7 and 8.3%). These moisture contents generally indicated damp soil conditions.

Based upon the SPT N-values which were obtained during drilling of borehole BH 3-19, the relative density of the silty sands was initially noted to be compact but decreased becoming loose in silty sands which were encountered beyond a depth of ~3.5 meters. Where encountered, the sandy gravels were generally noted to be dense.

Refusal due to possible bedrock was encountered in boreholes BH 1-19 and 4-19 at depths of 3.96 and 5.49 meters, respectively.

Glaciofluvial Ice Stagnation Complex Deposits (Gx)

While these deposits were not encountered during our subsurface investigation, the surficial geology map (*GSC Map 1879A*) classified these deposits as being commonly comprised of a poorly to moderately sorted sand and gravel diamicton which was deposited during equilibrium phases of glacial retreat. They can contain cobble to boulder sized materials and minor amounts of silt and clay.

Morainal (Glacial Till) Blanket Deposits (Mb)

The surficial geology map classified these deposits as being commonly comprised of a stony diamicton which has a sandy/silty matrix. These deposits are massive to crudely stratified and may measure between 1 to 5 meters thick. The surface conforms to the underlying topography which is bedrock controlled in the region of the study area. These deposits, which were encountered in test pit TP 1-19, were predominately comprised of sandy silty gravels which overlay shallow bedrock (@ 1.5 meters).

Site conditions at test pit TP 1-19 location.

Surficial Soil Deposits

The above noted soil deposits were generally overlain with a thin (50-75 mm thick) veneer of surficial organics, (100 to 150 mm of) volcanic ash and up to 0.75 meters of firm to stiff, oxidized silt deposits.

Fills

As most of the boreholes were advanced in regions which had been previously disturbed (as a result of historical trail and highway construction) some fills, which were comprised of the local soil deposits, were encountered. These fills measured up to 0.9 meters thick at borehole BH 4-19.

3.2 Groundwater

While there was no direct indication of groundwater, the presence of oxidation in the soil samples retained beyond a depth of ~3.5 meters in borehole BH 3-19 suggests that the subsurface has harbored groundwater in the past. A monitoring well was installed in borehole BH 3-19 to a depth of ~ 6.0 meters to allow for future groundwater observations as the groundwater may be seasonally present.

3.3 Bedrock

The site is underlain with bedrock. The terrain in steeper regions are bedrock controlled. The depth of bedrock in these regions is expected to be shallow (generally < 2 meters) as was evidenced in test pit TP 1-19 where bedrock was encountered at a depth of 1.5 meters below the prevailing ground surface. Borehole BH 1-19 also encountered refusal due to possible bedrock at a slightly greater depth of 3.96 meters. The greater depth was attributed to advancing the borehole in what was identified as a local gully.

Regionally, bedrock may be present in regions where shallow grades prevail as refusal was encountered at a depth of 5.49 meters in borehole BH 4-19 and as bedrock outcrops were intermittently visible along the exposed slope located immediately south of the study area. While the presence of bedrock could not be verified in boreholes BH 1-19 or BH 4-19, the deeper samples retained from each of these boreholes contained fractured gravels, which, with hard grindy drilling, may be an indication of potential regolith.

3.4 Permafrost

Although Carmacks is located in a zone where extensive discontinuous permafrost may be encountered (as identified in the Permafrost Map of Canada - Heginbottom et al, 1995), there was no evidence permanently frozen soils would be present within the study area.

3.5 Slope Conditions

A prominent slope is located immediately southwest of the study area. While the crest of the slope lies at an elevation of predominately 597 meters, the base of the slope was noted to lie at elevations between 550 to 555 meters. As the face of the slope is bisected by the Robert Campbell Highway #4, which appears to have been cut into the side-slope, the regions of the slope located north of the highway were predominately formed through excavation methodologies. The regions of the slope located south of the highway appear to be comprised of the original terrain.

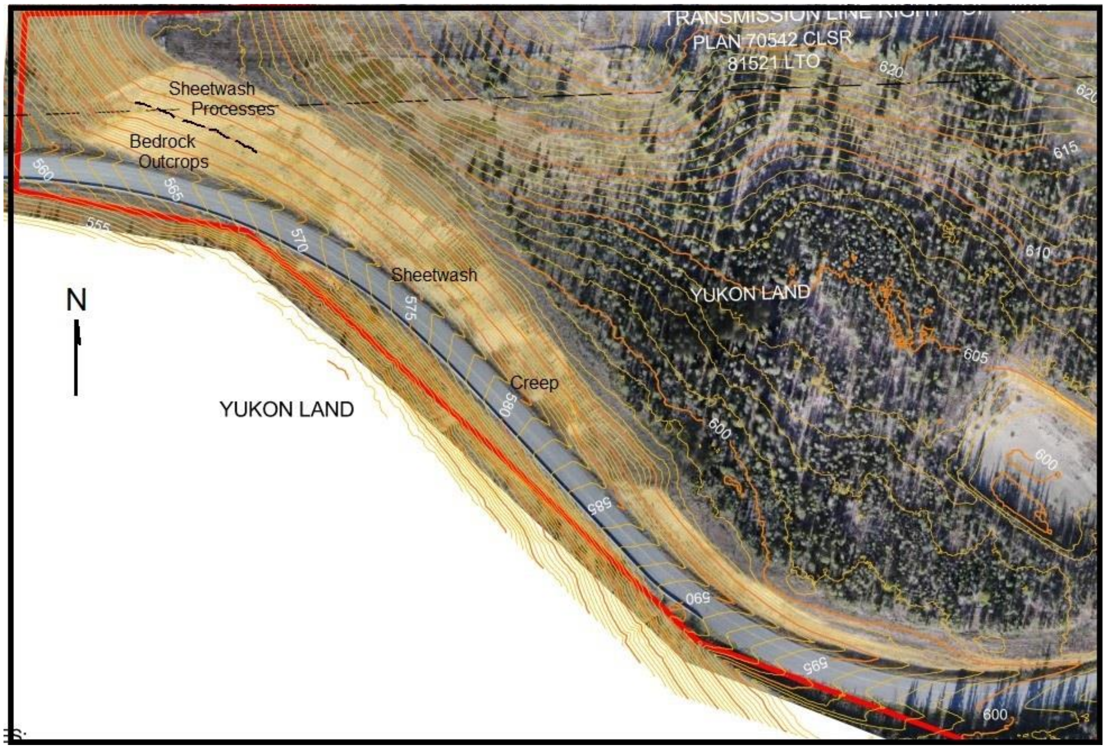
By visual estimate, it appeared that approximately 20-25% of the slope was covered in some form of vegetation. Bedrock outcrops were noted in the western realms of the slope at elevations as high as ~ 480 meters.

Our observations of the slope noted signs of erosion in some areas which were indicative of mass wasting. In general, it appeared the mass wasting was comprised of sheetwash processes which would be active during the spring freshet and at times of precipitation. In addition, as some of the willow stalks in the central regions of the slope were deformed, it’s likely that creep is occurring in this region. There were no signs of any extension cracks in the terrace region located beyond the crest of the slope.

Western slope conditions facing northwest.

Central slope conditions facing southeast

The approximate locations of these slope and erosion features have been illustrated in the figure below.



4.0 DISCUSSIONS

4.1 Development Potential

The site and subsurface conditions which were encountered will allow for country residential subdivision development as noted in Figure 3. In general, it's understood that following clearing and grubbing operations, subdivision development will involve road construction, building construction and septic field installations utilizing conventional construction methodologies.

The subsurface soils encountered within the regions of the site which were deemed to be suitable are generally comprised of glaciofluvial terrace deposits. These deposits were comprised of a series of interbedded sandy silts to silty sands. At some locations (boreholes BH 4-19 to BH 6-19), these soils overlay dense sandy gravels which contained varying amounts of silt. In general, these soil types will be suitable to allow for subdivision development.

The terrain in steeper northern regions are bedrock controlled and so these areas will not generally be suitable for development. The depth of bedrock in these regions is expected to be relatively shallow (generally < 2 meters) as was noted in test pit TP 1-19 where bedrock was encountered at a depth of 1.5 meters.

Regionally, bedrock may also be present in regions where shallow grades prevail as refusal was encountered at a depth of 3.96 and 5.49 meters in boreholes BH 1-19 and BH 4-19 and as bedrock outcrops were intermittently visible along the cut slope located just beyond the southern periphery of the study area.

Additional consideration will be required during individual lot development relative to septic field placement as the percolation rates of some of the sand materials which were encountered may be too high to allow for septic field construction without importing a filter sand. In addition, as bedrock was identified within the study area, it's absence within 1.2 meters of the base of the septic field would need to be verified at the time of site-specific assessment to ensure a confining layer, which would potentially preclude septic field construction, is not present. Furthermore, foundation design and construction would need to accommodate the presence of the glaciofluvial terrace deposits which are predominately frost susceptible. Additional consideration would be required during bearing capacity assessments considering the presence of potentially loose native soils.

4.2 Building Foundations

Buildings can be founded upon conventional footings or monolithic-slab concrete foundation systems which are designed and constructed as described herein. However, additional consideration may be required relative to design and construction given the presence of the loose soil deposits which were encountered below a depth of ~ 3.5 meters in borehole BH 3-19. Specifically, considering these soils are poorly consolidated, the influx of surface water or groundwater may result in undesirable amounts of settlement if these soils are located within the zone of building load influence. As such, site-specific geotechnical evaluations should be conducted to verify the foundation design parameters. In addition, surface waters and roof drainage will need to be carefully managed throughout the life of the building structure.

4.3 Sulphate Ion Analysis

The total sulphate ion content of two (2) soil samples was determined by our laboratory sub-consultant *Golder Associates Ltd.* in accordance with *CSA Standard A23.1 – 3C*. The purpose of the analysis was to assess the aggressiveness of the native and potentially imported soils relative to cast-in-place concrete.

The native soil sample (BH 2-19 - No.12) was comprised of a silty sand which was commonly encountered within the glaciofluvial terrace deposits. The sulphate ion content analysis of this sample revealed the total sulfate ion content was 0.05 %.

The potentially imported material sample was comprised of sandy gravel which was retained from the *YG* gravel quarry (Disposition No.900101) located at km 354.3 RHS of North Klondike Highway #2. The sulphate ion content analysis of this sample revealed the total sulfate ion content was 0.06 %.

As these values are lower than 0.10 % threshold set forth by the *American Concrete Institute – Building Code Requirements for Structural Concrete* (ACI 318-05 – Table 4.3.1), the potential for sulphate exposure is expected to be negligible. As such, its anticipated that standard concrete which is designed as described herein can be utilized during the foundation work. Consideration should be given to testing the imported fills which will be utilized during foundation construction/backfill to verify their suitability once their source has been determined.

The results of the sulphate ion content analysis have been attached in Appendix B.

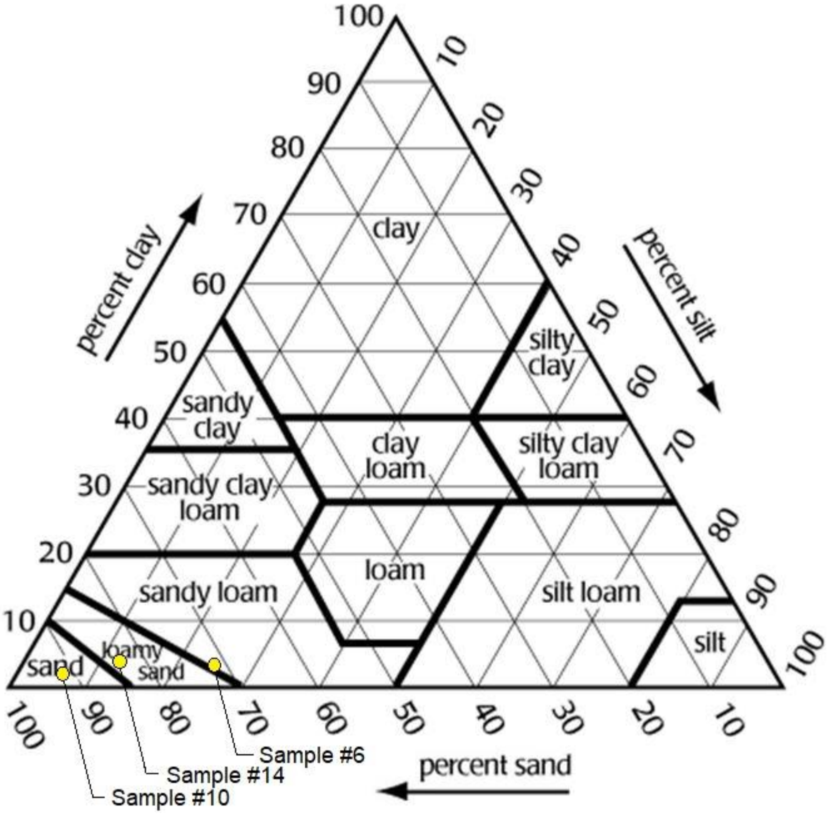
4.4 Septic Field Suitability

The results of the hydrometer analysis were utilized to determine the amount of clay sized particles (<0.002 mm) contained within each of the samples. This allowed for the respective percentages of sand, silt and clay to be plotted on the *Soil Texture Classification Triangle* such that the materials overall suitability for use as accepting (septic field) soils could be determined as is typical in provincial jurisdictions where regional assessments are conducted.

The percentages of sand, silt and clay for the samples analyzed were determined as follows;

Test Pit / Borehole	***Sample No.***	***Sand %***	***Silt %***	***Clay %***	***Textural Soil Classification***
TP 2-19	6	71.5	25.8	2.7	sandy loam
TP 3-19	10	91.5	6.5	2.0	sand
BH 2-19	14	83.8	12.5	3.7	loamy sand

These values subsequently plotted on the *Soil Texture Classification Triangle* as follows;



Relative to the *Province of Manitoba – Onsite Wastewater Management Systems Program*, soil Samples No.6 & No.14 were classified as being suitable for traditional subsurface systems. However, as Sample No.10 was classified as a sand, the percolation rate may in fact be too high to allow for adequate processing of the sewage effluent. In this case, an imported filter bedding sand would need to be placed below the septic field area to slow down the rate of percolation.

Given the variability in the soils which were encountered and as required by *Yukon Health and Social Services*, site-specific assessments should be conducted at the time of individual lot development through percolation testing to verify the suitability of the anticipated accepting soils relative to *YG – Design Specifications for Sewage Disposal Systems*. In addition, during this time, the absence of a confining layer (such as groundwater or bedrock) located within 1.2 meters of the base of the envisioned septic field should be verified, as their presence would potentially preclude septic construction.

If a confining layer prevents septic field construction, then the use of an insulated holding tank or else raised field may be required during lot development.

4.5 Surface Drainage

The surficial soils which were encountered within the study area are generally free draining and so site drainage can be managed through the use of standard ditches/swales and site grading. However, there were several local drainage courses (as illustrated in Figure 3), where additional consideration may be required as these (and steep) areas will harbor an increased potential for excess surface water run-off considering the topography.

While we did not observe any signs of erosion in these regions, the allocation of drainage easements should be considered unless other measures are otherwise undertaken. Building sites should be situated to avoid these potential discharge areas.

4.6 Onsite Hazards

Our observations of the slopes located within and adjacent to the study area did not reveal any signs of slope movement which would be cause for concern. However, as minor indications of slope movement were observed in the prominent slope located immediately southwest of the study area (as discussed in Section 3.5, above), this region and the steep slopes located in the northern realms of the study area may pose a hazard relative to increased surface water runoff and potential for slope movement.

As the central portions of the site harbors the remnants of a granular quarry which does not appear to have been remediated to current standards, additional work will be required during subdivision development to predominately grade the steep slope located on its north-eastern side. In addition, the quarry should be reclaimed by re-establishing an organic cover in order to reduce the influx of surface waters and precipitation as this influx may impact the performance of nearby septic fields.

View of former quarry facing northwest.

4.7 Geotechnical Setbacks

Geotechnical setbacks (which range between 15 to 30 meters in width as noted in Figure 3) should be observed relative to steep slopes which are located within and adjacent to the site as an increased hazard potential related to increased surface run-off and potential slope movements may exist in these areas. While building construction should not be allowed in these regions, the construction of roads and ditches within these setback areas could be considered. While septic field construction in these areas should generally be avoided, if required, they could be considered by qualified personnel on a case-by-case basis.

4.8 Seismic Site Response

The study area was classified for seismic site response in accordance with the *National Building Code of Canada*, based upon the information obtained during the field work program.

In general, the classification is based upon the type of soils that are located below the intended structure(s) as follows:

CLASS	SOIL TYPE
A	hard rock
B	rock
C	dense soil or soft rock
D	stiff soil
E	>3 m of ‘soft soil’
F	Others (liquefiable, peat, etc.)

Based upon the presence of the glaciofluvial terrace deposits and relatively shallow bedrock, the soils within the study area would be classified as a Class D site.

4.9 Geotechnical Evaluations

Geotechnical evaluations should be conducted at any location where buildings and subsurface infrastructure are proposed to verify site-specific geotechnical parameters, particularly considering the presence of loose soils (which were identified in borehole BH 3-19) and bedrock potential.

Additional site-specific evaluation would be required to assess the region of the study area located east of the municipal boundary relative to subdivision development as it may yet harbor isolated areas which may be suitable for lot development.

4.10 Hydrogeological Assessment

A hydrogeological study, which was beyond our scope-of-work, would be required to assess the suitability of the study area relative to water well installations.

5.0 RECOMMENDATIONS

The following recommendations have been provided as a guideline for subdivision development. Considering the variable nature of the soil types and conditions which were encountered, any references to allowable bearing capacities herein are for discussion purposes only. The allowable soil bearing values at any proposed building location would need to be determined by qualified personnel through site-specific geotechnical evaluations which are conducted prior to design and construction.

5.1 Deleterious Materials

Clearing and grubbing operations will be required to remove the existing trees/vegetation from regions where subdivision development is to occur. During this time, trees should be salvaged as outlined by the land use permit(s).

The surficial organics, volcanic ash and near surface (firm to stiff) silts located within ~ 1 meter of the ground surface are deleterious as they contain organics and rootlets. As such, these deleterious materials should be removed through stripping operations. In addition, as the majority of the underlying glaciofluvial terrace deposits were frost susceptible, they too would be considered deleterious unless measures for frost protection are undertaken during building foundation design and construction as described herein.

All deleterious materials should be removed from within the building load envelope(s) such that the structural fills and/or foundation components can be founding upon approved underlying glaciofluvial terrace deposits. In addition, the deleterious surficial organics and volcanic ash materials will need to be removed from below roads and parking areas to allow for sub-base and base construction as described herein.

As the soil deposits are susceptible to a loss of strength if they become disturbed, wet or desiccated, caution will need to be exercised during construction. Temporary roads and laydown areas may need to be prepared in order to facilitate subdivision/lot development and building construction.

Surficial organics which are removed during site preparation should be stockpiled separately and either utilized for landscaping or else removed from the site. The glaciofluvial terrace deposits can be utilized as general purpose (non-structural) fill so long as the materials are compacted to approximately 95% of the materials corresponding maximum proctor density at (or near) the materials optimum moisture content (unless otherwise over-ridden by the recommendations provided herein). If these soils are wet to saturated, they will need to be removed from the site and wasted.

5.2 Footings

Residential buildings may be supported by continuous and spread footings with slab-on-grade concrete foundation systems constructed in accordance with the recommendations contained herein.

Founding Strata
Deleterious materials should be sub-excavated to expose a uniform level sub-grade surface comprised of approved glaciofluvial terrace deposits.

Allowable Bearing Pressure
The net allowable bearing pressure should not be greater than 110 kilopascals for conventional strip footings or 130 kilopascals for spread footing types of foundation systems. These figures include the total of all live and dead loads.

Structural Fill
The footing components should be underlain with a 150 mm thick layer of approved 20 mm minus crushed granular aggregate compacted to a minimum of 100 % of the materials corresponding maximum Proctor dry density at (or within ± 2% of) the materials optimum moisture content.

All deleterious materials below the slab-on-grade components should be sub-excavated to the depth of the approved founding strata and replaced with structural fill as recommended herein. Interior backfill (below the slab components) should be comprised of the following;

THICKNESS ^{A}	**COMPACTION** ^{B}	**COMPOSITION**
100 mm	100 %	20 mm minus crushed granular aggregate, Overlying
200 mm	100 %	80 mm minus sub-base course aggregate, Overlying
As required	100 %	200 mm minus pit run, Overlying
NA	95 % (or as directed)	approved subgrade

Notes;

[A] – The thickness of the granular pad should be uniform throughout its entirety. All materials should be placed in uniform, level lifts that do not exceed 150 mm in thickness, as measured following compaction. The exception to this would be the 200 mm thick layer of 80 mm minus granular aggregate which can be placed in a single lift so long as adequate compaction is attained.

[B] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

Exterior backfill around footing column and wall components should be comprised of non-frost susceptible well graded granular aggregates with particle sizes less than 80 mm. This material should be compacted to a minimum of 95 % of the materials corresponding maximum Proctor dry density at (within ± 2% of) the materials optimum moisture content, unless otherwise over-ridden by recommendations provided herein.

Slab Components

The slab components should be structurally separated from other components of the structure.

Differential Movements

Foundations constructed in accordance with the recommendations contained herein may experience differential movements in the order of (+/-) 25 mm.

Lateral Earth Pressures

The foundation walls (and potentially other retaining walls) should be designed to resist lateral earth pressures.

Walls will be subjected to lateral earth pressures in an 'at-rest' condition and thus should be designed to withstand these pressures. The lateral earth pressure is linear and can be calculated at a given depth 'H' below the ground surface as;

$$P_0 = k_0(\gamma_s H+Q)$$

where: P_0 = Lateral Earth Pressure 'at-rest' condition with no movement at given depth H (in kPa)

k_0 = coefficient of earth pressure 'at-rest' condition (utilize 0.45 for granular backfill)

γ_s = unit weight of soil
(utilize 22.5 kN/m^3 for granular backfill)
H = depth below finished grade (m)
Q = other surcharge pressures at finished grade (in kPa)

The above noted calculation assumes static conditions and that the backfill remains in a drained (unsaturated) condition.

The height of the backfill between the interior and exterior sides of wall components should not measure greater than 300 mm during construction such that undesirable lateral forces are not induced.

Weeping Tile System

In general, a weeping tile system will not be required where free draining soils are encountered at the footing elevations. However, if fine-grained or silty soils are encountered at the footing elevation or if basements are to be considered, a weeping tile system should be incorporated into the foundation design as these types of soils are not generally free draining, or, in the case of basements, as a precautionary measure.

5.3 Monolithic Footing/Slab-On-Grade (Monolithic Slab)

Residential buildings may be supported by monolithic slab foundation systems which are founded on an approved subgrade which is prepared in accordance with the recommendations provided herein.

Founding Strata

Deleterious materials should be sub-excavated to expose a uniform level sub-grade surface comprised of approved glaciofluvial terrace deposits.

Allowable Bearing Pressure

The net allowable bearing pressure should not be greater than 140 kilopascals for a monolithic slab type of foundation system. This figure includes the total of all live and dead loads.

Structural Fill

Monolithic slabs should be founded upon a structural granular pad comprised of the following;

THICKNESS [A]	COMPACTION [B]	COMPOSITION
200 mm [C]	100 %	20 mm minus crushed granular aggregate, Overlying
400 mm	100 %	80 mm minus sub-base course aggregate, Overlying
As required [D]	100 %	200 mm minus pit run, Overlying
NA	95 % (or as directed)	approved subgrade

Notes;

[A] – The thickness of the granular pad should be uniform. All materials should be placed in uniform, level lifts that do not exceed 150 mm in thickness, as measured following compaction. The exception to this would be the 200 mm thick layer of 20 mm minus granular aggregate which can be placed in a single lift so long as adequate compaction is attained.

[B] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

[C] – This thickness should be maintained below both the central slab and peripheral thickened slab components.

[D] – Should extend to the depth of approved sub-grade material such that the thickness of the granular pad and insulation is equivalent to 3 meters.

The above noted structure assumes the presence of a 200 mm thick reinforced concrete slab which incorporates a thickened edge of slab component.

Differential Movements

Foundations constructed in accordance with the recommendations contained herein may experience differential movements in the order of (+/-) 25 mm.

5.4 Excavations

Excavations should be conducted utilizing a heavy tracked excavator equipped with a smooth lipped (clean-up) bucket in order to minimize disturbance of the sub-grade materials.

The sub-grade materials are subject to a loss of strength if they are disturbed (or become wet/saturated). As such, equipment should not be allowed to operate directly on the sub-grade surfaces. The exceptions to this would be tracked equipment and drum compactor as authorized by the onsite geotechnical consultant.

Loose, disturbed, remolded or slough materials should not be allowed to remain in prepared excavation(s). If the sub-grade becomes saturated or loses its strength, these disturbed materials should be sub-excavated to expose a suitable founding surface approved by the retained geotechnical consultant. If a suitable founding surface cannot be prepared through mechanical means, then hand cleaning may be necessary.

Excavation difficulties are not generally anticipated so long as seasonal frost is not encountered. The contractor should be prepared to adjust their construction methodology and excavation profiles as soil and site conditions dictate.

The excavation limits will be governed by the proposed building elevation and that of the founding strata. The excavation limits should be defined by the theoretical loading footprint which can be described as a 1:1 slope which extends outwards from the building perimeter until the founding strata has been attained (plus 1 meter horizontally). This angle of repose should be reduced to 2:1 (horizontal to 1 vertical), or less, in regions where weak, fine-grained (or saturated) soil deposits are encountered.

The base of the excavation(s) should be prepared in such a manner that the sub-grade elevation does not vary. Specifically, the entire excavation should be excavated to the lowest elevation at which approved sub-grade deposits are encountered. This will allow for the establishment of structural backfill which is of uniform thickness.

The locations of sub-surface utilities should be confirmed by the retained contractor prior to excavation.

5.5 Temporary Excavations & Worker Safety

Worker safety is paramount.

Temporary excavations to conventional depths at this site should comply with current regulations under the *Yukon Workers Compensation Board - Occupational Health & Safety Act*.

The excavation sidewall (slope) stability will be dependent upon the material characteristics, configuration of the excavation and length of exposure. In general, side slopes cut at 1:1 should allow for adequate stability provided the depth of excavation does not exceed one (1) meter. Otherwise side slopes should be cut at 2:1 (horizontal/vertical). If these parameters are to be exceeded, then they should be verified and monitored by qualified geotechnical personnel throughout construction.

Slope stability will be poor if wet/saturated materials, fills or clean granular materials are encountered. As such, more gradual cut slopes may be required in these areas to minimize the potential for slope failure(s).

5.6 Backfill Requirements

The structural and imported fills should consist of an approved, clean, inorganic, well graded sand and gravel mixture which conform to the recommended grain size distribution noted in Appendix C.

All materials should be placed in uniform, level lifts that do not exceed 150 mm thick, as measured following compaction.

Exterior backfill should be evenly placed around the sides of the building such that the difference in backfill height between any of the sides is no more than 300 mm such that undesirable lateral forces are not induced. If interior backfill is required, the difference in backfill height on either side of the foundation wall(s) should not measure greater than 300 mm during construction unless authorized by the structural consultant.

Considering backfill will be placed adjacent to foundation walls, the compaction effort should be applied with equipment that will not compromise the foundations integrity. This may require utilizing light hand-operated compaction equipment and reducing the lift thicknesses. Exterior backfill work in these regions should not be conducted until approval is obtained from the structural consultant.

> Typically backfill adjacent to wall components should not be conducted until seven (7) days have elapsed from the time of concrete placement such that adequate concrete strengths are attained.

5.7 Insulation

Care will be required to minimize the degree of potential foundation movement due to frost penetration, which is in the order of 3 meters in the Carmacks region.

Footings

Typically, frost protection is achieved through a combined use of rigid (SM Styrofoam) insulation and depth of soil cover to attain an equivalent of three (3) meters of soil cover. As such, the thickness of rigid insulation will be dependent upon the depth of the footing.

> For design purposes, two (2) inches of rigid (SM Styrofoam) insulation should be provided for every one (1) foot of soil cover which is not provided.

The rigid insulation should extend laterally no less than 1.2 m from the exterior edge of the concrete foundation walls. The thickness of insulation should be increased in regions where additional heat loss is expected, such as the corners of the buildings.

Monolithic Slab

Typically frost protection for monolithic slabs is afforded through the use of the underlying non-frost susceptible structural fills upon which the concrete slab is placed. However, as per good construction practice, some amount of rigid insulation should be placed directly below the concrete and extend laterally no less than 1.2 m from the slab edge.

As the rigid insulation is impervious, it should be placed in such a manner that a positive (2%) gradient (away from the building) is maintained to allow for proper sub-drainage. Seams of successive layers of insulation should be staggered or otherwise taped where weak zones are created.

In addition to frost protective measures, provisions should be included to protect the subsoils from excessive desiccation in regions where there is an intense degree of concentrated heat (such as potential boiler/furnace areas) to limit soil volume changes to tolerable amounts.

Subsurface utilities should be placed at depths >3 meters or else have equivalent insulation in order to protect them from frost. Additional thermal protection (in the form of insulated pipes, heat tape, re-circulation lines, overlying rigid insulation and other similar types of protective measures) should be considered in regions where critical infrastructure is installed.

All building structures should be closed to the weather and heated prior to the onset of freezing temperatures. These buildings should subsequently be heated during the winter months (and when freezing temperatures prevail) for the remainder of the building's lifespan.

5.8 Concrete

All concrete work should conform to *Canadian Standards Association* (*CSA*) standard CAN/CSA – A23.1 and A23.2. According to the standard, the concrete should be designed to satisfy the minimum environmental durability requirements as defined by its exposure class. The exposure class is dependent upon the presence of chlorides and sulphates, freezing/thawing conditions and degree of soil saturation.

Based upon the results of sulphate ion content analysis, the potential for sulphate exposure is expected to be negligible. As such, its anticipated that standard concrete which is designed as described herein can be utilized during foundation work.

> While the sulphate ion content results of the sample retained from the *YG* granular quarry (Disposition No.900101) also indicated that the potential for sulphate exposure is expected to be negligible, consideration should be given to testing the imported fills which will be utilized during foundation construction/backfill to verify their suitability once their source has been determined.

Normal Portland cement (C.S.A. Type 10), should be used in all concrete which is in direct contact with the soil.

Concrete subject to freeze-thaw cycles and potential deicing chemicals should be designed in accordance with C.S.A. A23.1-94, Section 15.

The concrete should have a minimum 28-day compressive strength of 25 megapascals and be air entrained (~ 4 to 6 percent). This assumes a maximum aggregate size of 20 mm.

Higher strength (32 Mpa) concrete should be utilized where concrete may be subject to freeze/thaw cycles.

5.9 Structural Breaks & Reinforcing

Structural breaks and reinforcing (rebar) should be integrated into the foundation to control cracking and allow for differential movements caused by soil volume changes of the underlying soil.

Additional measures should be incorporated into the design if dynamic and/or point loads are expected. This should include thickening and reinforcing the areas of the slab that may be subjected to these additional forces. Monolithic slabs should incorporate a thickened edge of slab component.

The slab component(s) of footing types of foundations should be structurally separated from other foundation components.

5.10 Vapor Barrier

A non-deteriorating vapor barrier should be placed beneath all concrete surfaces to prevent desiccation of the sub-base materials and promote concrete hydration.

5.11 Inclement Weather

The sub-grade, excavations and construction materials should be protected from drying, freezing, rain, snow, surface waters and groundwater at all times.

The sub-grade materials are subject to a loss of strength if they become wet/saturated and so caution will need to be exercised during construction. Once exposed, the sub-grade surface should immediately be covered with a structural granular course to protect it from precipitation, desiccation and/or disturbances.

5.12 Surface and Groundwater

Groundwater is not anticipated during construction. However, as seasonal fluctuations may affect the flow regime, the Contractor should be prepared to undertake construction dewatering measures to ensure a dry working area.

Surface and groundwater should be removed from excavations at all times during foundation construction, subsurface utility installation and access road preparation.

The surrounding surfaces should be graded so as to direct surface waters away from excavations, temporary stockpiles and excavation spoils.

Ditches and Swales

Ditches and swales should be incorporated into the design and construction phases to control perimeter and site drainage.

Site Grading

The drainage in the region of building sites, septic fields and roadways should be carefully controlled.

The surrounding areas should be graded to direct surface water away from the building structures and foundation/excavations. Typically, a 2 percent slope which extends a minimum of 5 meters away from the building perimeter will be sufficient for this purpose.

Surficial Cover

Exterior foundation backfill should be capped with a (200 mm thick layer of) low permeability soil or surface cover which is placed around the perimeter of building foundations following concrete placement in non-structural regions. The low permeability soil/surface cover will assist in directing surface waters away from the foundation and limits of the former excavation. The backfill should be placed to protect the sides of concrete slabs and prevent undermining of the slab during periods of heavy precipitation/run-off.

Eaves troughs

Eaves troughs should be incorporated into the building roof structures. The outlets from the roof drains should extend a minimum of 3.0 meters away from the building structures such that the discharged water is directed away from the structures.

5.13 Culvert Installations

Corrugated steel pipe (CSP) culverts should be incorporated where lot accesses and drainage are required in order to maintain positive drainage.

Culverts should be placed upon a 300 mm thick layer of clean bedding sand. This bedding sand should encompass the culvert such that a protective annulus which is no less than 300 mm thick is established around the culvert. The bedding sand should conform to the grain size specifications provided in Appendix C.

Culvert bedding and backfill should be placed in 150 mm thick lifts compacted to 95% of the materials maximum proctor dry density at (or near ± 2%) of the material’s optimum moisture content.

Culverts should have a minimum soil cover of 500 mm.

The culvert inlet and outlet areas should be covered with protective rip-rap in accordance with good design and construction practices.

5.14 Roads & Parking Areas

Following clearing, grubbing and stripping operations, the structure for roads and parking areas should be comprised of;

UNIT	THICKNESS	COMPACTION [C]	COMPOSITION
Base	200 mm[A]	100 %	20 mm minus crushed granular aggregate, overlying
Sub-base	300 mm	98 %	80 mm minus sub-base course aggregate, overlying
Sub-base	300 mm[B]	95%	150 mm minus pit run, overlying
Sub-grade	NA	95 %	approved native sub-grade materials [D]

Notes;

[A] – Thickness can be reduced to 150 mm in parking areas.

[B] – This sub-base course can be eliminated in parking areas. However, in roadway areas, the thickness of this sub-base layer should be increased if heavy traffic loads are anticipated or if additional material is required to meet the anticipated design elevations.

[C] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content. All materials should be placed in uniform, level lifts that do not exceed 150 mm thick, as measured following compaction.

[D] – The sub-grade should be proof-rolled. If deflections are noted, these weak zones should be sub-excavated and replacement with an approved pit run which is compacted to no less than 95% of the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

The use of geotextile fabric should be considered if poor subgrade materials are encountered or if additional structural support is required.

Roadways and parking areas should be designed to incorporate a minimum of 2% crowns such that positive drainage is provided.

If bituminous surface treatment (BST) of the roadway(s) is to be considered, we recommend that it is applied no earlier than one year following road construction to allow time for consolidation/settlement.

5.15 Temporary Stockpiles

Stockpiled materials that may be utilized during construction should be protected from segregation and the ingress of snow, frost, rain and surface waters.

5.16 Subsurface Utility Installations

New subsurface utility lines should be installed at a depth equivalent to 3 meters of soil cover and protected from frost. Where critical infrastructure is required, these lines should be well protected from frost through the use of insulated pipes, heat tape, re-circulation lines, overlying rigid insulation and other similar types of protective measures as determined by a qualified municipal engineer.

The utility pipes should be placed upon a base of bedding sand which measures 300 mm thick. The bedding sand should extend a minimum of 300 mm around the pipe (to form a protective annulus). If subgrade conditions are poor, then the use of (clear stone) drain rock encased in geotextile filter fabric should be utilized in lieu of the bedding sand. The bedding sand and drain rock should conform to the grain size specifications provided in Appendix C.

The soil deposits which were encountered will generally be suitable for use as trench backfill in non-structural areas so long as these materials are free of organics and are not frozen or wet/saturated.

The trench backfill should be comprised of an approved pit run in regions where trenches intersect building (or road) load envelope(s). Cobbles larger than 150 mm in size should not be placed within 1 meter of the utility pipes.

Trench backfill materials should be placed in lifts which do not exceed 200 mm as measured following compaction. These materials should be compacted to a minimum of 95% of the materials corresponding maximum Proctor dry density at (or near) the materials optimum moisture content. The compaction effort should be increased to a minimum of 98 % of the materials corresponding maximum Proctor dry density in regions where the sub-surface utilities cross roadways/parking areas or other regions where loading envelopes may be affected.

5.17 Other Considerations

As the central portions of the site harbors the remnants of a granular quarry which does not appear to have been remediated to current standards, additional work will be required during subdivision development to predominately grade the steep slope located on its north-eastern side. In addition, the quarry should be reclaimed by re-establishing an organic cover in order to reduce the influx of surface waters and precipitation as this influx may impact the performance of nearby septic fields.

The prominent slope located immediately southwest of the study area should be vegetated to decrease the potential for soil erosion.

5.18 Construction Schedule

Subdivision development (ie road construction, building construction, septic field installations, etc.) should be conducted during the summer months such that the potential of encountering seasonal frost is minimized. These projects should be completed prior to the onset of winter conditions. Building projects which are undertaken should be closed to the weather and heated prior to the onset of freezing temperatures (and whenever freezing temperatures) prevail throughout the remainder of the building’s lifespan.

5.19 Construction Monitoring, Testing and Inspection Services

Qualified geotechnical personnel should provide construction monitoring, testing and inspection services during access road construction and other earthworks which may be required during the course of subdivision development. In addition, the future lot owners should retain geotechnical personnel to monitor, test and inspect building foundations and subsurface infrastructure during individual lot development to identify potential site-specific liabilities and verify good construction practices are undertaken.

5.20 Site Survey

Although topographical survey data of the site is available from 2014, a more recent survey should be undertaken by qualified personnel to assist the design team in establishing site grading profiles relative to the current site conditions.

5.21 Groundwater Monitoring Program

The groundwater elevation in the (BH 3-19) monitoring well should be measured and recorded on a regular (approximately quarterly) basis prior to construction to better characterize the groundwater regime.

5.22 Monitoring Well Decommissioning

The groundwater monitoring well should be properly decommissioned following preparation of the subdivision.

6.0 CONCLUSIONS

6.1 Site Suitability

The site and subsurface conditions which were encountered will allow for country residential subdivision development in regions which were identified as having a suitable development potential as noted in Figure 3. These regions are generally comprised of glaciofluvial terrace deposits which are comprised of interbedded sandy silts to silty sands.

Additional consideration will be required during building design and construction as some of these deposits were noted to be loose and thus may have lower allowable bearing capacities than discussed herein. In addition, as sands which may have too high a percolation rate were encountered, filter sands may need to be imported during septic field construction where these soils are encountered. Additional consideration may be required during subdivision development as bedrock may be encountered in the steeper northern (and potentially other) regions of the study area.

6.2 Deleterious Materials

The presence of deleterious surficial organics, volcanic ash and frost susceptible glaciofluvial terrace deposits were identified throughout the study area. As such, caution will need to be exercised during building foundation and access road preparation by removing these materials from beneath the respective load envelopes and through adequate precautionary measures during design and construction.

Caution will need to be exercised during construction as the soil deposits are susceptible to a loss of strength if they become disturbed, wet or desiccated. As such, temporary roads and laydown areas may need to be prepared in order to facilitate subdivision/lot development and building construction.

6.3 Surface Utilities

The construction of roads and ditches utilizing conventional cut/fill construction methodologies will be feasible in the study area following adequate site preparation. In general, this will require the removal of the surficial organics and volcanic ash following clearing and grubbing operations. While the granular components of the road structure would measure in the order of 0.8 meters thick, the constructed thickness would need to be based upon the subgrade conditions which are encountered at the time of construction, the anticipated traffic loads and the design elevations.

The drainage in the region of building sites, septic fields and roadways should be carefully controlled to direct surface water away from the infrastructure. Additional consideration will be required in regions where local drainage courses were identified (as illustrated in Figure 3) through the establishment of potential drainage easements and by avoiding building construction and septic field placement in these potential discharge areas.

6.4 Building Foundations/Construction

Buildings can be founded upon conventional footing or monolithic-slab types of concrete foundation systems which are founded upon approved glaciofluvial terrace deposits. However, as these deposits are predominately frost susceptible, the foundations will need to be designed and constructed as described herein. Additional consideration may be required relative to the allowable bearing capacities given the presence of loose soils which may be encountered within the deposits. As such, site-specific geotechnical evaluations should be conducted to verify the foundation design parameters.

6.5 Sulphate Attack Potential

The sulphate ion content analysis revealed the potential for sulphate exposure is expected to be negligible. As such, standard concrete which is designed as described herein can be utilized during the foundation work.

6.6 Septic Field Suitability

The glaciofluvial terrace deposits which were encountered should be suitable to allow for the installation of traditional septic fields and subsurface utilities. However, some soils may have too high a percolation rate to allow for adequate processing of the sewage effluent and so an imported filter sand would need to be placed below the septic field in these areas to slow down the rate of percolation.

Site-specific percolation tests will need to be conducted as required by *Yukon Health and Social Services* at the time of individual lot development to verify the suitability of the anticipated accepting soils at the proposed septic field locations relative to *YG – Design Specifications for Sewage Disposal Systems*.

6.7 Subsurface Utilities

New subsurface utility lines should be installed at a depth equivalent to 3 meters of soil cover for frost protection. Critical infrastructure should be well protected from frost through the use of insulated pipes, heat tape, re-circulation lines, overlying rigid insulation and other similar types of protective measures.

6.8 Seismic Site Classification

Based upon the information obtained during the field work program the study area was classified as a Class D site for seismic site response in accordance with the *National Building Code of Canada*.

6.9 Onsite Hazards & Geotechnical Setbacks

As the central portions of the site harbors the remnants of a granular quarry which does not appear to have been remediated to current standards, additional work will be required to re-grade the side-slopes and revegetate the disturbed regions.

Geotechnical setbacks (which range between 15 to 30 meters in width) should be observed relative to steep slopes which are located within and adjacent to the site as an increased hazard potential related to surface run-off and potential slope movements may exist in these areas. In addition, an increased potential for surface water run-off may exist in regions where local drainage courses were identified (as illustrated in Figure 3). As such, building construction and septic field placement in these setback regions and potential discharge areas should not be allowed.

6.10 Geotechnical Evaluations

Geotechnical evaluations should be conducted at any location where buildings and subsurface infrastructure are proposed to verify site-specific geotechnical parameters.

Further evaluation would be required to assess the overall suitability of the region located east of the municipal boundary relative to subdivision development.

6.11 Hydrogeological Assessment

A hydrogeological study would be required to assess the suitability of the study area relative to water well installations.

7.0 LIMITATIONS

This report is intended for the sole use of the *Yukon Government.*

No portion of this report may be used as a separate entity; it is intended to be read in its entirety.

Any use of this report by a third party is the responsibility of such third party.

The recommendations provided herein are based upon the subsurface conditions encountered at the time of our investigation, current construction techniques and generally accepted engineering practices. The content within this report reflects our best judgment in light of the information available to our firm at the time of report preparation.

The anticipated construction conditions have been discussed, but only to the extent that they may influence design decisions. Any references to construction methods contained herein, express our opinion and are not intended to direct contractors on how to carry out construction. Prospective contractors should be aware that the information we have presented and our corresponding discussions may not be sufficient to assess all factors that may have an effect upon construction. The elevations noted herein are for discussion purposes only.

It is important to emphasize that the geotechnical investigation component of any evaluation is, in fact, a random sampling event and that subsequent discussions and assessments are based upon the results retained at the sample locations. Due to the geomorphological nature of the deposits which were encountered, interpolations of the subsurface conditions between the test locations have not been made or been implied.

Should unexpected conditions be encountered during construction, our firm should be notified immediately in order to confirm the suitability of our recommendations. If required, our firm may alter or modify our recommendations and conclusions at such time.

8.0 CLOSURE

Thank you for providing our firm with the opportunity to conduct the above noted geotechnical evaluation.

We trust that the information we have provided will be suitable for your purposes, however, if you should have any questions or concerns, please feel free to contact the undersigned at your convenience.

Respectfully Submitted,

CHILKOOT GEOLOGICAL ENGINEERS LTD.

#1277
TARES DHARA

PERMIT TO PRACTICE
Signature
Date October 4, 2019
PERMIT NUMBER: PP025
Association of Professional Engineers of Yukon

Tares Dhara, P.Eng.
Senior Geotechnical Engineer

TD/td

Geotechnical Evaluation
Proposed Country Residential Subdivision – Carmacks, Yukon – 2019
Figure 1 – Location of Study Area

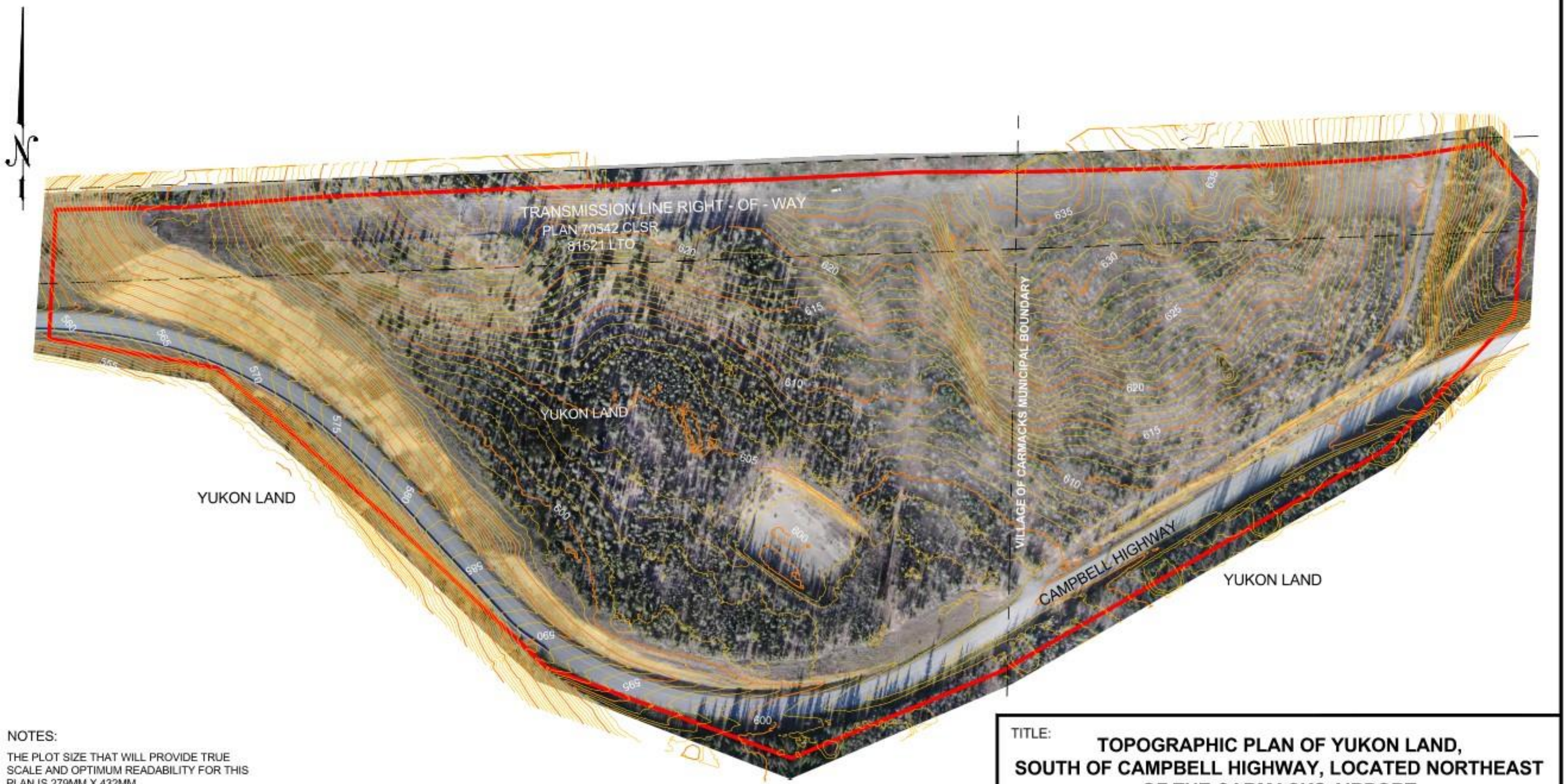
Based map modified from Google Earth – Not to Scale – Locations are approximate

Compiled Sept.10th, 2019 by T.Dhara, P.Eng.

Geotechnical Evaluation

Proposed Country Residential Subdivision – Carmacks, Yukon – 2019

Figure 2 – Site Topography



NOTES:

THE PLOT SIZE THAT WILL PROVIDE TRUE SCALE AND OPTIMUM READABILITY FOR THIS PLAN IS 279MM X 432MM.

ELEVATIONS ARE ORTHOMETRIC BASED ON THE HTV2 GEOID MODEL.

CONTOURS DERIVED FROM 3RD PARTY LIDAR DATA, COLLECTED IN 2014.
CONTOUR INTERVAL = 1.0 METER

SCALE 1 : 2,500

50 0 25 50 100 150 200 250 Metres

LEGEND:

AREA OF INTEREST SHOWN THUS . . . . . . 🟥

MAJOR CONTOUR LINES SHOWN THUS . . . .

MINOR CONTOUR LINES SHOWN THUS . . . .

TITLE: **TOPOGRAPHIC PLAN OF YUKON LAND, SOUTH OF CAMPBELL HIGHWAY, LOCATED NORTHEAST OF THE CARMACKS AIRPORT**

CLIENT: INUKSHUK PLANNING AND DEVELOPMENT

DRAWN BY: T DUNN | CHECKED BY: P BURBIDGE | SCALE: 1 : 2500

CHALLENGER GEOMATICS LTD.
302 Jarvis Street
Whitehorse, Yukon
Y1A 2H2
(PH) 867-668-6940
email:whitehorse@chalgeo.com

DATE: JULY 15, 2019

SHT 1 0F 1

DWG: 19-37573-001

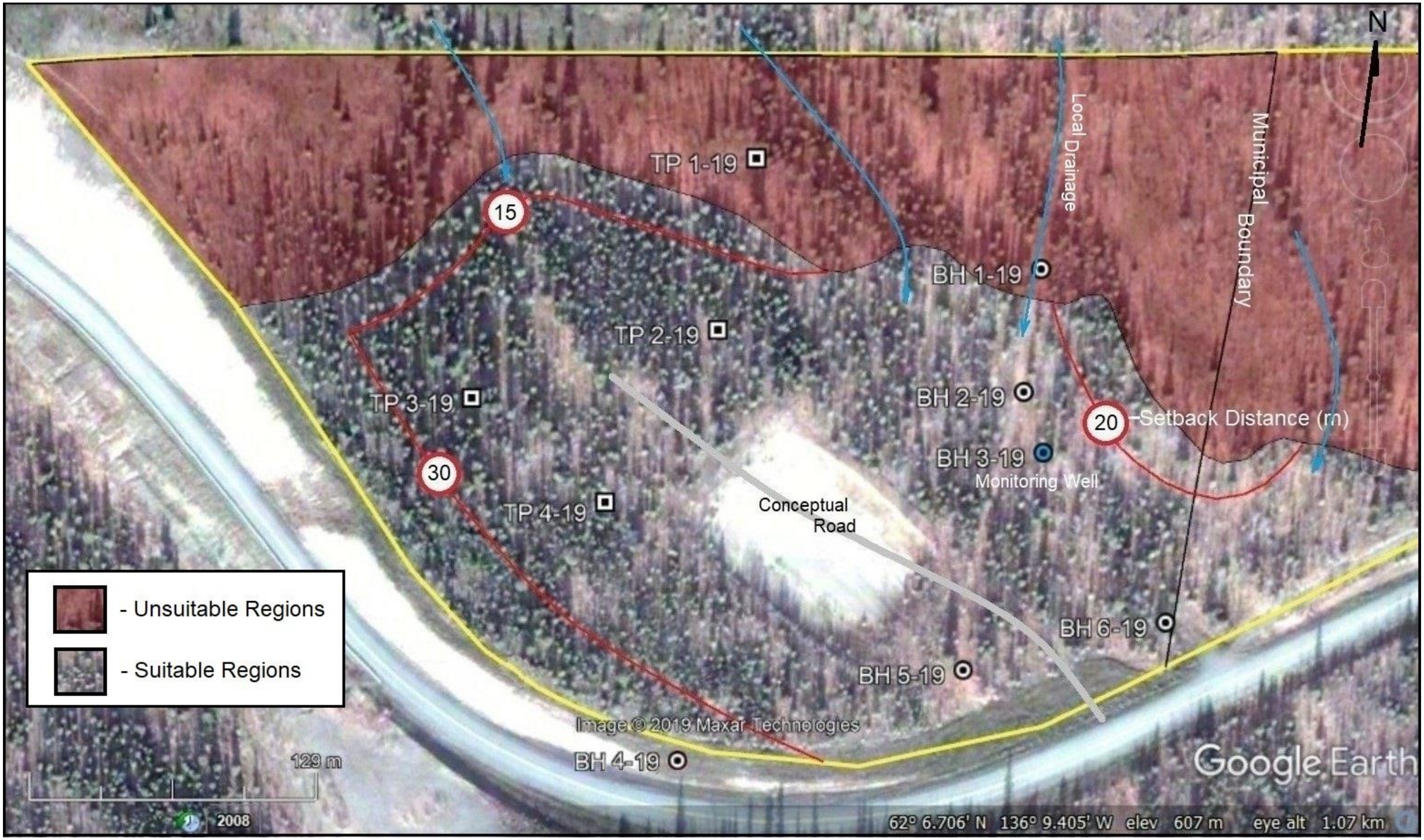
REV. 0

Job:37573

Based map supplied by *Inukshuk Planning & Development Ltd.*

Compiled Sept.10th, 2019 by T.Dhara, P.Eng.

Geotechnical Evaluation
Proposed Country Residential Subdivision
Carmacks, Yukon - 2019
Figure 3 – Development Potential, Test Pit & Borehole Locations



Based map modified from Google Earth – Not to Scale – Locations are approximate.

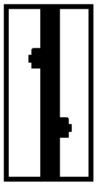
Compiled Sept.10th, 2019 by T.Dhara, P.Eng.

APPENDIX A

Soil Logs

NOTES ON SOIL LOGS

Soil Log - Sample Type

Symbol	Test Pitting	Drilling
	**Grab Samples** Retained from excavation sidewall or base	**Auger Sample** Retained from auger flighting
	**Bucket Sample** Retained from leading edge of excavator bucket	**Split-Spoon Sample** Retained from Split-Spoon sampler tube

Soil Description

The soil is named after its principal component and modified by other components as follows;

Percent of Component	Modifier
> 15 %	XXX - ey
11% to 15%	some XXX
5% to 10%	trace XXX

Examples;

SILT	SAND	GRAVEL	Description
6	32	62	Sandy Gravel trace Silt
55	6	39	Gravelly Silt trace Sand
43	36	21	Silty Gravelly Sand

Note: In the cases where the coarse fraction (sand & gravel) comprise > 50% of the sample, then the larger component of the coarse fraction becomes the principal component.

Relative Density / Consistency (Qualitative Classification)

Granular Soils	(Relative Density)
Very Loose	- Considerable sidewall slough noted
Loose	- Some sidewall slough noted – Easy digging
Compact/ Medium-Dense	- Unimpeded excavation – little to no sidewall slough
Dense	- Considerable effort required during excavation – Stable vertical sidewalls
Very Dense	- Extreme difficulty in excavation

Cohesive (fine-grained) Soils	(Consistency)
Very Soft	- Exudes between fingers when squeezed by hand
Soft	- Molded by light finger pressure
Firm	- Molded by strong finger pressure
Stiff	- Cannot be molded by fingers – Can be indented by thumb
Very Stiff	- Can only be indented by thumbnail
Hard	- Cannot be indented by thumbnail

At times, the consistency of non-plastic fine-grained soils are described utilizing the relative density terms.

Relative Moisture

Described as - *dry, damp, moist* or *wet* - relative to the principal soil matrix.

For example, a moisture content of 10 percent may be classified as '*moist to wet*' for a coarse grained soil (sand or gravel) but '*damp*' for a fine-grained cohesive soil.

The moisture content is recorded as a percentage (%) of the weight of water within the soil sample relative to the dry weight of the sample.

Recovery

Refers to the (linear) amount of sample retained after driving the Split Spoon (SPT) sampler tube 18 inches.

Recorded as a percentage (i.e. 12 inch sample/18 drive = 66 %)

N-Value

Refers to the total number of blows required to drive the Split Spoon sampler tube the final 12 inches of the 18 inch drive.

Relative Density based upon SPT 'N' Value

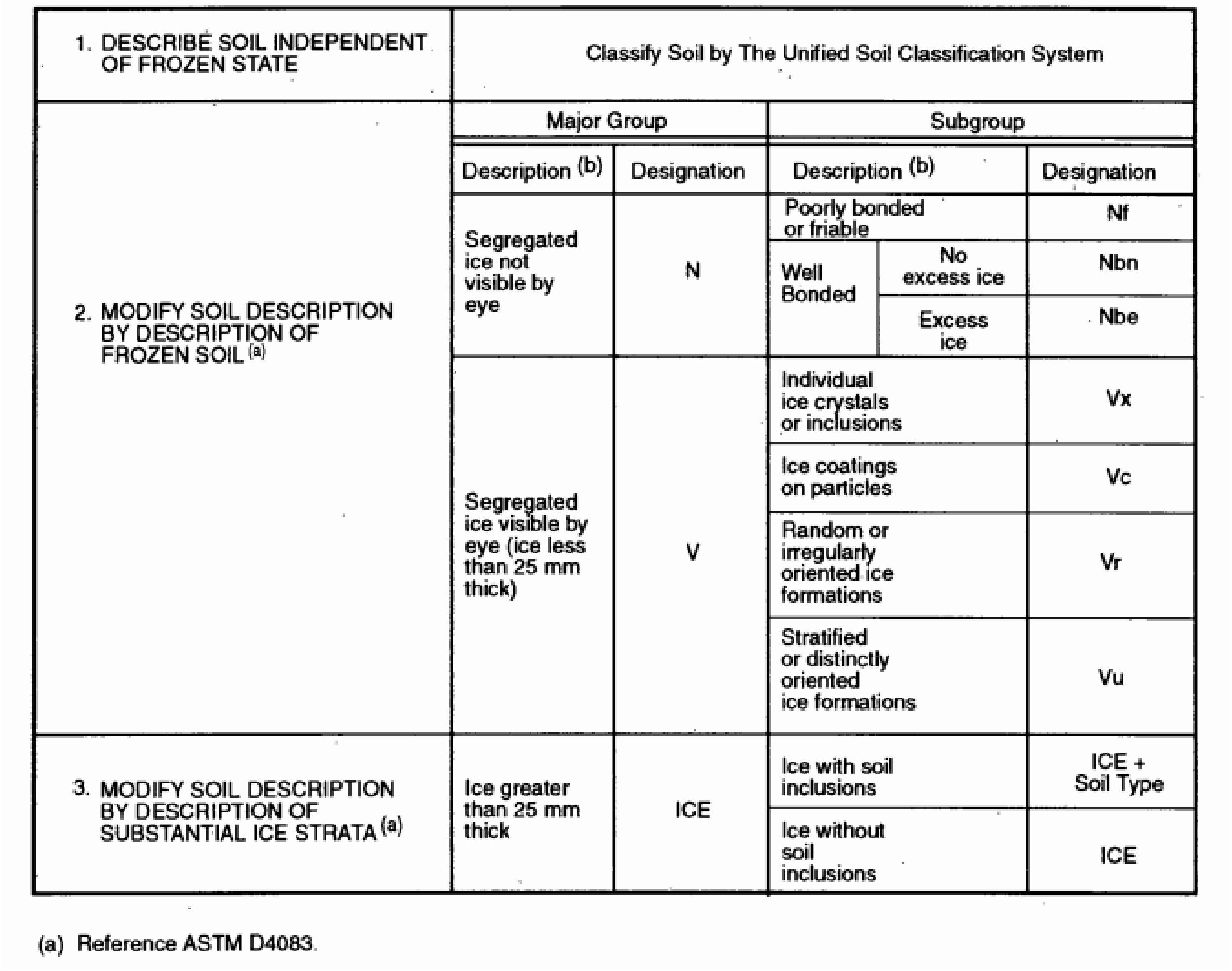
Non-cohesive (Granular) Soil		**Cohesive (Clayey) Soils**	
Relative Density	**Blows per Foot (N-value)**	**Consistency**	**Blows per Foot (N-value)**
Very Loose	< 5	*Very Soft*	0 to 2
Loose	5 to 9	*Soft*	3 to 4
Compact	10 to 29	*Firm*	5 to 8
Dense	30 to 50	*Stiff*	9 to 15
Very Dense	> 50	*Very Stiff*	16 to 30
		Hard	> 30

Undrained Shear Strength of Cohesive Soils

Consistency	Undrained Shear Strength	
	p.s.f	kN/m^2
Very Soft	< 375	<20
Soft	375-750	20-40
Firm	750-1500	40-75
Stiff	1500-3000	75-150
Very Stiff	3000-6000	150-300
Hard	>6000	<300

Description & Classification of Frozen Soils – National Research Council (NRC)

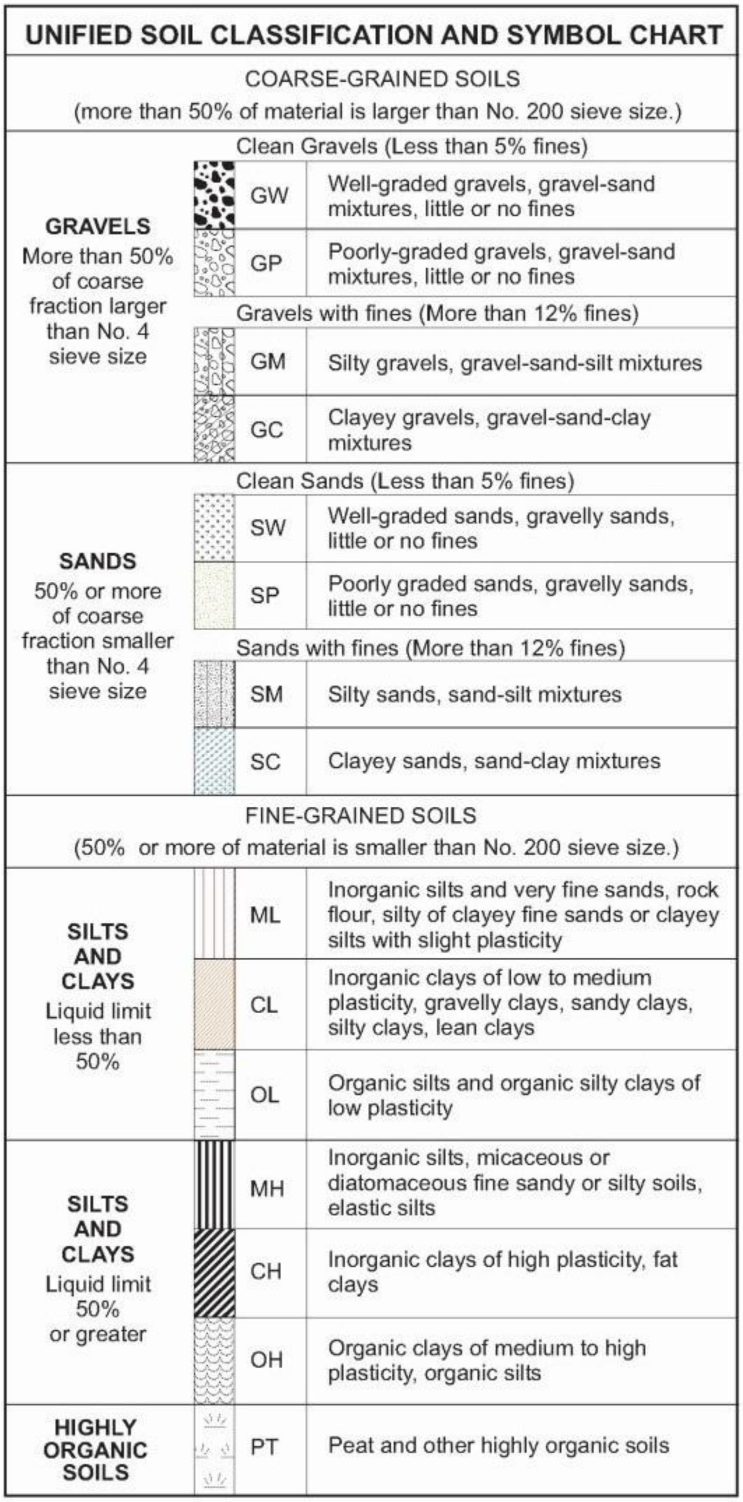
(Adapted from Linnell & Kaplar, 1966)



1. DESCRIBE SOIL INDEPENDENT OF FROZEN STATE	Classify Soil by The Unified Soil Classification System				
2. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF FROZEN SOIL (a)	Major Group		Subgroup		
	Description (b)	Designation	Description (b)		Designation
	Segregated ice not visible by eye	N	Poorly bonded or friable		Nf
			Well Bonded	No excess ice	Nbn
				Excess ice	Nbe
	Segregated ice visible by eye (ice less than 25 mm thick)	V	Individual ice crystals or inclusions		Vx
			Ice coatings on particles		Vc
			Random or irregularly oriented ice formations		Vr
			Stratified or distinctly oriented ice formations		Vu
3. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF SUBSTANTIAL ICE STRATA (a)	Ice greater than 25 mm thick	ICE	Ice with soil inclusions		ICE + Soil Type
			Ice without soil inclusions		ICE

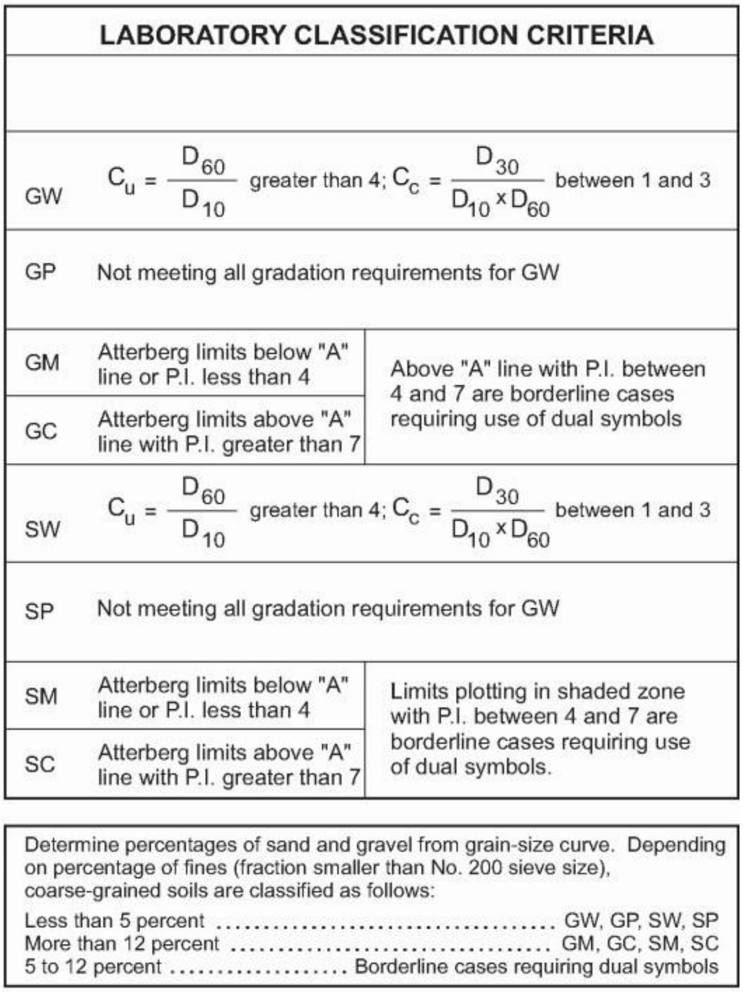
(a) Reference ASTM D4083.

Unified Soil Classification System



UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils



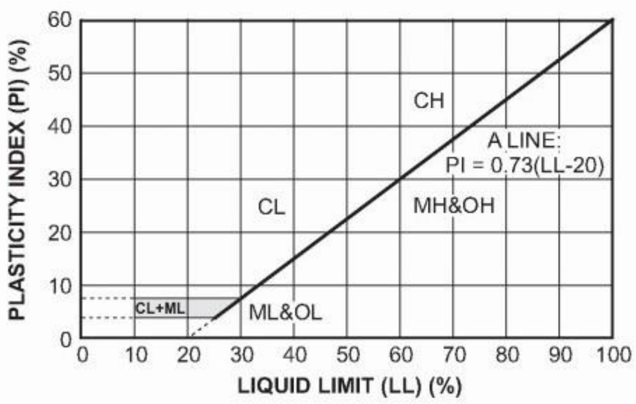
LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent .... GW, GP, SW, SP
More than 12 percent .... GM, GC, SM, SC
5 to 12 percent .... Borderline cases requiring dual symbols

PLASTICITY CHART



CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

TEST PIT LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Excavated: August 13, 2019

Elevation: 100.00 meters
TP Termination Depth: 1.70 meters
Instrumentation: NA
Weather: Scattered Cloud 22°

TEST PIT

1-19

Sheet 1 of 1

Relative Density	Stratigraphic Description	Relative Moisture
soft loose	SURFICIAL ORGANICS (50 mm)	moist damp
firm	VOLCANIC ASH (120 mm)	damp
firm	SANDY SILT -non-plastic, fine grained, rootlets reddish-brown	damp
dense	SANDY SILT -non-plastic, fine grained, beige-brown	damp
dense	SANDY SILTY GRAVEL - fine to medium grained, poorly graded, brown	damp
	FRACTURED BEDROCK - sandstone/shale regolith	

Test Pit terminated at 1.70 m below the ground surface.
Groundwater not encountered.

Field Sample / **Laboratory Results (%)** (▲ - FINES, ● - SAND, ■ - GRAVEL; PL ⊢ MC ⊙ ⊣ LL)

Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	FINES	SAND	GRAVEL
☒	1	NA	NA	NA	NA	2.8			
☒	2	NA	NA	NA	NA	3.9	15.4	34.4	50.1
	3	NA	NA	NA	NA	6.3			

USCS/NRC
ORG
ASH
ML
GM
BEDROCK

Excavated By: Yellow Truck Exc.
Excavator Type: Bobcat E63
Bucket Type: Digging

Groundwater Levels
▽ Inferred ▼ Observed

Logged By: T.Dhara, P.Eng.	Aug.13, 2019
Data Entry By: T.Dhara, P.Eng.	Sept.5-20, 2019
Reviewed By:	Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

TEST PIT LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Excavated: August 13, 2019

Elevation: 100.00 meters
TP Termination Depth: 3.30 meters
Instrumentation: NA
Weather: Scattered Cloud 22°

TEST PIT

2-19

Sheet 1 of 1

Stratigraphic Description	Relative Density	Relative Moisture	USCS/NRC
SURFICIAL ORGANICS (75 mm)	soft loose	moist damp	ORG
VOLCANIC ASH (100 mm)	firm	damp	ASH
SANDY SILT -non-plastic, fine grained, rootlets reddish-brown	firm	damp	ML
SANDY SILT -non-plastic, fine grained, beige-brown	compact	damp	SM
SILTY SAND w/ SILT Inclusions - fine grained, poorly graded beige-brown	compact	damp	SM
- as above but no inclusions			
SANDY SILT - non-plastic, fine grained, beige-brown			ML

Test Pit terminated at 3.30 m below the ground surface.
Groundwater not encountered.

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	■ - GRAVEL	MC	● - SAND	▲ - FINES
4	NA	NA	NA	NA	0.0	3.7	25.4	74.6
5	NA	NA	NA	NA		2.7		
6	NA	NA	NA	NA	0.0	2.7	71.5	28.5
7	NA	NA	NA	NA	0.0	4.0	49.9 50.1	

PL ├─⊙─┤ LL

Excavated By: Yellow Truck Exc.
Excavator Type: Bobcat E63
Bucket Type: Digging

Groundwater Levels
▽ Inferred ▼ Observed

Logged By: T.Dhara, P.Eng. Aug.13, 2019
Data Entry By: T.Dhara, P.Eng. Sept.5-20, 2019
Reviewed By: Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

TEST PIT LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Excavated: August 13, 2019

Elevation: 100.00 meters
TP Termination Depth: 3.00 meters
Instrumentation: NA
Weather: Scattered Cloud 22°

TEST PIT

3-19

Sheet 1 of 1

Laboratory Results (%): ▲ - FINES ● - SAND ■ - GRAVEL; PL ├─ MC ⊙ ─┤ LL; 20 40 60 80

Relative Density	Stratigraphic Description	Relative Moisture	Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC
soft loose	SURFICIAL ORGANICS (50 mm)	moist damp								ORG
firm	VOLCANIC ASH (100 mm)	damp	☒	8	NA	NA	NA	NA	MC 3.4	ASH
firm	SANDY SILT -non-plastic, fine grained, rootlets reddish-brown	damp								ML
compact	SANDY SILT -non-plastic, fine grained, beige-brown	damp	▮	9	NA	NA	NA	NA	■ 0.9 MC 2.5 ▲ 13.8 ● 85.3	SM
	SAND some SILT w/ SILT Inclusions - fine grained, poorly graded grey-brown		▮	10	NA	NA	NA	NA	■ 0.0 MC 2.6 ▲ 8.5 ● 91.5	SP-SM
compact	SAND trace SILT - medium to coarse grained, poorly graded, brown	damp								SP-SM
compact	- as above but fine to medium grained	damp	▮	11	NA	NA	NA	NA	MC 2.8	SP-SM

Test Pit terminated at 3.00 m below the ground surface.
Groundwater not encountered.

Excavated By: Yellow Truck Exc.
Excavator Type: Bobcat E63
Bucket Type: Digging

Groundwater Levels
▽ Inferred ▼ Observed

Logged By: T.Dhara, P.Eng.	Aug.13, 2019
Data Entry By: T.Dhara, P.Eng.	Sept.5-20, 2019
Reviewed By:	Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

TEST PIT LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Excavated: August 13, 2019

Elevation: 100.00 meters
TP Termination Depth: 3.00 meters
Instrumentation: NA
Weather: Scattered Cloud 22°

TEST PIT

4-19

Sheet 1 of 1

Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC
soft loose	SURFICIAL ORGANICS (50 mm)	moist damp	ORG
firm	VOLCANIC ASH (100 mm)	damp	ASH
firm	SANDY SILT -non-plastic, fine grained, rootlets reddish-brown	damp	ML
compact	SANDY SILT -non-plastic, fine grained, rootlets beige-brown	damp	ML
	SANDY SILT - non-plastic, fine grained, grey-brown		
compact	SAND some SILT - fine to medium grained, poorly graded, brown	damp	SM
	- as above		

Test Pit terminated at 3.00 m below the ground surface. Groundwater not encountered.

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	FINES	SAND	GRAVEL
12	NA	NA	NA	NA	2.8			
13	NA	NA	NA	NA	5.8	52.0	48.0	0.0
14	NA	NA	NA	NA	2.9			
15	NA	NA	NA	NA	3.5	12.0	88.0	0.0

Laboratory Results (%): ▲ - FINES ● - SAND ■ - GRAVEL; PL ⊢ MC ⊙ ⊣ LL

Excavated By: Yellow Truck Exc.
Excavator Type: Bobcat E63
Bucket Type: Digging

Groundwater Levels
▽ Inferred ▼ Observed

Logged By: T.Dhara, P.Eng. Aug.13, 2019
Data Entry By: T.Dhara, P.Eng. Sept.5-20, 2019
Reviewed By: Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 17, 2019

Elevation: 100.00 meters
BH Termination Depth: 3.96 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE **1-19**
Sheet 1 of 1

Relative Density	Stratigraphic Description	Relative Moisture	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC
firm	FILL - ORGANIC SILT & SAND 100 mm thick	damp	1	NA	NA	NA	NA	MC 6.8	FILL
firm	SANDY SILT - non-plastic, fine grained, reddish-brown	damp	2	NA	NA	NA	NA	MC 4.7	ML
compact	SILTY SAND - fine grained, poorly graded, beige-brown	dry-damp							SM
	- as above		3	NA	NA	NA	NA	MC 2.4; GRAVEL 0.0; FINES 21.7; SAND 78.3	
	- as above		4	NA	NA	NA	NA	MC 2.2	
dense	SANDY SILTY GRAVEL - fine to medium grained, poorly graded, brown	damp	5	NA	NA	NA	NA	MC 3.6	GM
	- as above but with fractured gravel in size to 45 mm - possible cobbles & regolith Refusal @ 3.96 m due to possible bedrock		6	NA	NA	NA	NA	MC 3.3; FINES 23.0; SAND 36.5; GRAVEL 40.5	
			7	NA	NA	NA	NA	MC 2.3	

▲ - FINES ● - SAND ■ - GRAVEL
PL ⊢ ⊙ MC ⊣ LL

Caved To 2.74 m

Borehole terminated at 3.96 m below the ground surface.
Groundwater not encountered.

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By:	T.Dhara, P.Eng.	Aug.17, 2019
Data Entry By:	T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:		Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

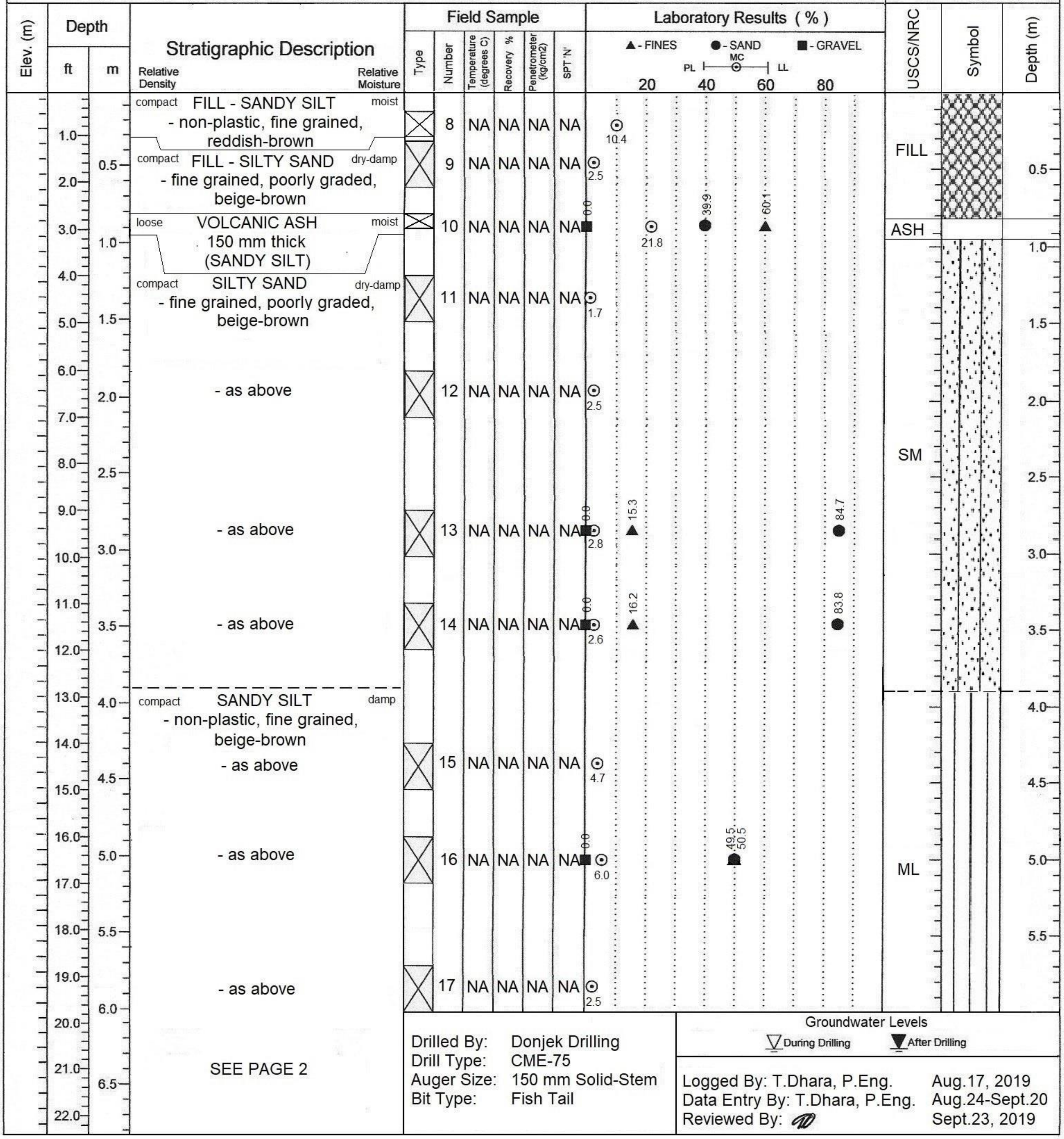
Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 17, 2019

Elevation: 100.00 meters
BH Termination Depth: 9.14 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE

2-19

Sheet 1 of 2



Stratigraphic Description (Relative Density / Relative Moisture)	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC
compact FILL - SANDY SILT moist - non-plastic, fine grained, reddish-brown	8	NA	NA	NA	NA	10.4	FILL
compact FILL - SILTY SAND dry-damp - fine grained, poorly graded, beige-brown	9	NA	NA	NA	NA	2.5	
loose VOLCANIC ASH moist 150 mm thick (SANDY SILT)	10	NA	NA	NA	NA	■ 0.0 21.8 ● 39.9 ▲ 60.1	ASH
compact SILTY SAND dry-damp - fine grained, poorly graded, beige-brown	11	NA	NA	NA	NA	1.7	SM
- as above	12	NA	NA	NA	NA	2.5	
- as above	13	NA	NA	NA	NA	■ 0.0 2.8 ▲ 15.3 ● 84.7	
- as above	14	NA	NA	NA	NA	■ 0.0 2.6 ▲ 16.2 ● 83.8	
compact SANDY SILT damp - non-plastic, fine grained, beige-brown							ML
- as above	15	NA	NA	NA	NA	4.7	
- as above	16	NA	NA	NA	NA	■ 0.0 6.0 49.5 50.5	
- as above	17	NA	NA	NA	NA	2.5	
SEE PAGE 2							

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By:	T.Dhara, P.Eng.	Aug.17, 2019
Data Entry By:	T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:		Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 17, 2019

Elevation: 100.00 meters
BH Termination Depth: 9.14 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE
2-19
Sheet 2 of 2

Laboratory Results (%): ▲ - FINES ● - SAND ■ - GRAVEL PL ⊢⊙⊣ LL (MC); scale 20 40 60 80

Elev. (m)	Depth ft	Depth m	Stratigraphic Description (Relative Density / Relative Moisture)	Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC	Depth (m)
	20.0 21.0 22.0 23.0	6.5 7.0	compact / damp SILTY SAND - fine grained, poorly graded, beige-brown	☒	18	NA	NA	NA	NA	■ 0.0 ⊙ 3.9 ▲ 37.7 ● 62.3	SM	6.5 7.0
	24.0 25.0	7.5	soft / moist SANDY SILT - slight-plasticity, fine grained, beige-brown	☒	19	NA	NA	0.5	NA	■ 0.0 ⊙ 15.9 ● 29.5 ▲ 70.5	ML	7.5
	26.0 27.0	8.0	compact / moist SILTY SAND - fine grained, poorly graded, beige-brown	☒	20	NA	NA	NA	NA	■ 0.3 ⊙ 8.3 ▲ 38.7 ● 61.1	SM	8.0
	28.0 29.0 30.0	8.5 9.0	loose / damp SAND - fine grained, poorly graded, beige-brown	☒	21	NA	NA	NA	NA	Caved To 8.53 m ⊙ 3.2	SP	8.5 9.0

Borehole terminated at 9.14 m below the ground surface.
Groundwater not encountered.

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By: T.Dhara, P.Eng.	Aug.17, 2019
Data Entry By: T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:	Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 17, 2019

Elevation: 100.00 meters
BH Termination Depth: 6.55 meters
Instrumentation: 2" Monitoring Well
Weather: Scattered Cloud 13-16°

BOREHOLE
3-19
Sheet 1of 2

Stratigraphic Description (Relative Density / Relative Moisture)	Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%) ▲ - FINES ● - SAND ■ - GRAVEL PL ⊙ MC LL	USCS/NRC
compact SILTY SAND - fine grained, poorly graded, beige-brown damp		22	NA	100	NA	14	■ 0.0 ⊙ 2.7 ▲ 37.0 ● 63.0	SM
compact SILTY SAND - fine to medium grained, poorly graded, interbedded, grey-brown damp		23	NA	100	NA	18	■ 0.0 ⊙ 2.9 ▲ 15.9 ● 84.1	SM
loose SILTY SAND - fine to medium grained, poorly graded, grey-brown, trace oxidation damp		24	NA	100	NA	6	■ 0.0 ⊙ 4.3 ▲ 29.2 ● 70.8	SM

Laboratory Results scale: 20 40 60 80

Elev. (m)

Depth ft: 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0

Depth m: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Symbol

Depth (m): 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5

SEE PAGE 2

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Hollow-Stem
Bit Type: Carbide Cutter

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By: T.Dhara, P.Eng. Aug.16, 2019
Data Entry By: T.Dhara, P.Eng. Sept.5-20, 2019
Reviewed By: Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 17, 2019

Elevation: 100.00 meters
BH Termination Depth: 6.55 meters
Instrumentation: 2" Monitoring Well
Weather: Scattered Cloud 13-16°

BOREHOLE

3-19

Sheet 2 of 2

Laboratory Results (%): ▲ - FINES ● - SAND ■ - GRAVEL; PL ⊢ ⊙ MC ⊣ LL; scale 20 40 60 80

Elev. (m)	Depth ft	Depth m	Stratigraphic Description (Relative Density / Relative Moisture)	Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC	Symbol	Depth (m)
	20.0 21.0	6.5	loose SILTY SAND damp - fine to medium grained, poorly graded, grey-brown, trace oxidation		25	NA	100	NA	8	■ 0.0 ⊙ 5.0 ▲ 25.9 ● 74.1	SM		6.5
	22.0 23.0	7.0	Borehole terminated at 6.55 m below the ground surface. Groundwater not encountered.										7.0
	24.0 25.0	7.5											7.5
	26.0 27.0	8.0											8.0
	28.0	8.5											8.5
	29.0 30.0	9.0											9.0

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Hollow-Stem
Bit Type: Carbide Cutter

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By: T.Dhara, P.Eng.	Aug.17, 2019
Data Entry By: T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:	Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

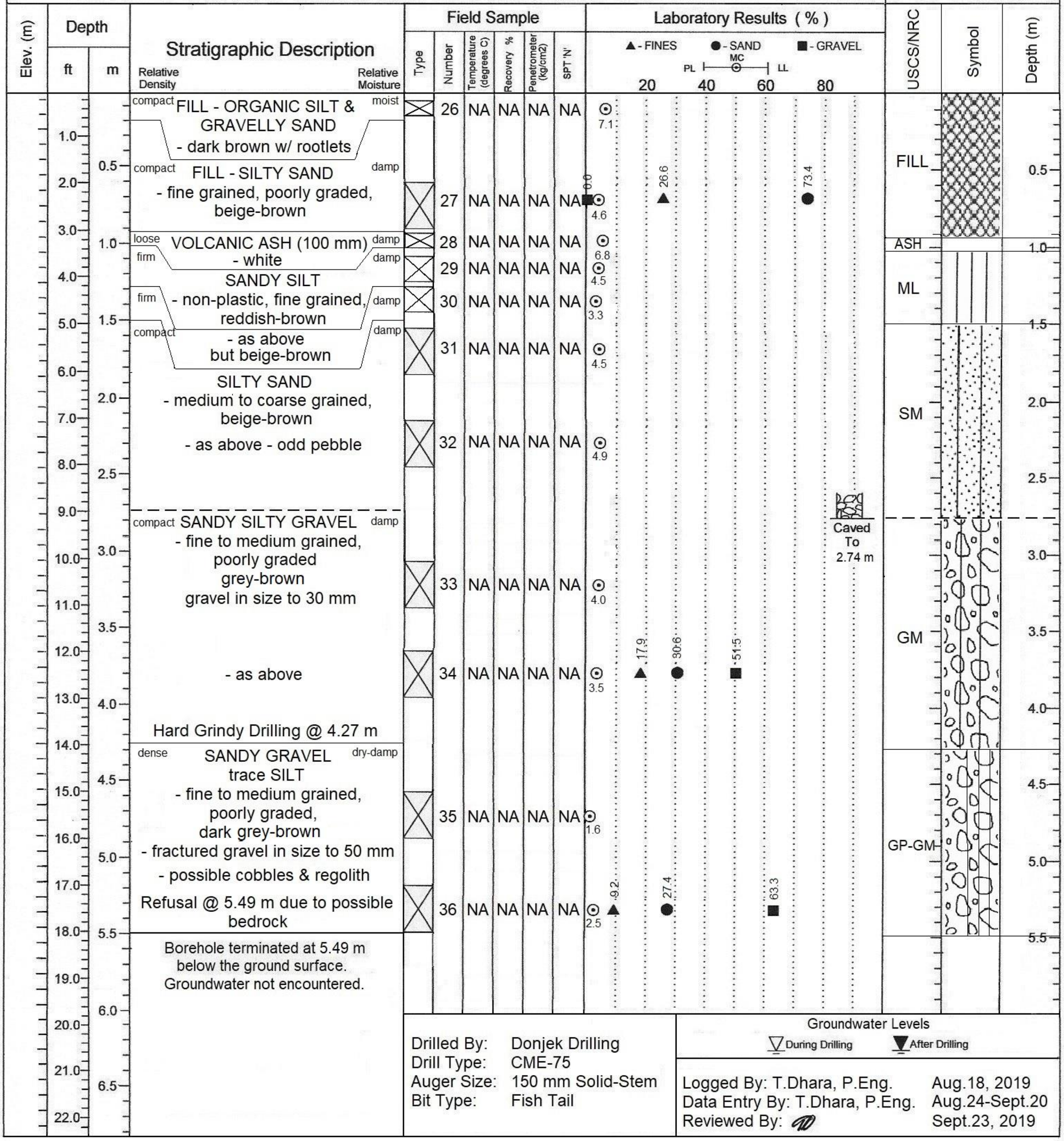
5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 18, 2019

Elevation: 100.00 meters
BH Termination Depth: 5.49 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE
4-19
Sheet 1 of 1



Relative Density	Stratigraphic Description	Relative Moisture
compact	FILL - ORGANIC SILT & GRAVELLY SAND - dark brown w/ rootlets	moist
compact	FILL - SILTY SAND - fine grained, poorly graded, beige-brown	damp
loose	VOLCANIC ASH (100 mm) - white	damp
firm	SANDY SILT - non-plastic, fine grained, reddish-brown	damp
firm	- as above (continued)	damp
compact	- as above but beige-brown	damp
	SILTY SAND - medium to coarse grained, beige-brown - as above - odd pebble	
compact	SANDY SILTY GRAVEL - fine to medium grained, poorly graded grey-brown gravel in size to 30 mm - as above Hard Grindy Drilling @ 4.27 m	damp
dense	SANDY GRAVEL trace SILT - fine to medium grained, poorly graded, dark grey-brown - fractured gravel in size to 50 mm - possible cobbles & regolith Refusal @ 5.49 m due to possible bedrock	dry-damp

Borehole terminated at 5.49 m below the ground surface.
Groundwater not encountered.

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	Fines	Sand	Gravel
26	NA	NA	NA	NA	7.1			
27	NA	NA	NA	NA	4.6	26.6	73.4	0.0
28	NA	NA	NA	NA	6.8			
29	NA	NA	NA	NA	4.5			
30	NA	NA	NA	NA	3.3			
31	NA	NA	NA	NA	4.5			
32	NA	NA	NA	NA	4.9			
33	NA	NA	NA	NA	4.0			
34	NA	NA	NA	NA	3.5	17.9	30.6	51.5
35	NA	NA	NA	NA	1.6			
36	NA	NA	NA	NA	2.5	9.2	27.4	63.3

USCS/NRC: FILL, ASH, ML, SM, GM, GP-GM

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By:	T.Dhara, P.Eng.	Aug.18, 2019
Data Entry By:	T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:		Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 18, 2019

Elevation: 100.00 meters
BH Termination Depth: 6.10 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE 5-19

Sheet 1 of 1

Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC
compact	FILL - SILTY SAND	damp	FILL
firm	SANDY SILT	damp	ML
firm	- non-plastic, fine grained, reddish-brown - as above but beige-brown	damp	
compact	SAND some SILT and GRAVEL - fine to medium grained, poorly graded, grey-brown - as above	damp	SP-SM
compact	GRAVELLY SAND some SILT - fine to medium grained, grey-brown	damp	SP-SM
dense	SANDY GRAVEL some SILT - fine to medium grained, poorly graded, grey-brown - grindy drilling - possible cobbles	damp	GP-GM
dense	- as above but trace SILT - hard grindy drilling - fractured cobble in size to 120 mm - as above but dark grey-brown - as above	dry-damp	GP-GM

Field Sample / Laboratory Results (%)

▲ - FINES ● - SAND ■ - GRAVEL PL ⊢⊙⊣ LL MC

Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	FINES	SAND	GRAVEL
☒	37	NA	NA	NA	NA	5.0			
☒	38	NA	NA	NA	NA	3.0	72.1	27.9	0.0
☒	39	NA	NA	NA	NA	4.9			
☒	40	NA	NA	NA	NA	3.9			
☒	41	NA	NA	NA	NA	3.0	11.7	27.4	60.9
☒	42	NA	NA	NA	NA	2.1			
☒	43	NA	NA	NA	NA	2.0			
☒	44	NA	NA	NA	NA	3.3	8.4	43.4	48.1

Caved To 2.74 m

Borehole terminated at 6.10 m below the ground surface.
Groundwater not encountered.

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By:	T.Dhara, P.Eng.	Aug.18, 2019
Data Entry By:	T.Dhara, P.Eng.	Aug.24-Sept.20
Reviewed By:		Sept.23, 2019

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon

BOREHOLE LOG

Client: Yukon Government - Community Services
Location: Carmacks, Yukon - Country Residential Subdivision #1
Project: Geotechnical Evaluation - Proposed Lot Development
Date Drilled: August 18, 2019

Elevation: 100.00 meters
BH Termination Depth: 6.10 meters
Instrumentation: NA
Weather: Scattered Cloud 13-16°

BOREHOLE
6-19
Sheet 1 of 1

Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC
0 – 0.5	compact	FILL - SANDY SILT - non-plastic, fine grained, beige-brown - some rootlets	damp	FILL (ML)
0.5	loose	VOLCANIC ASH	damp	ASH
	firm	(100 mm thick)	damp	
0.6 – 1.5	firm	SANDY SILT - non-plastic, fine grained, reddish-brown - as above but beige-brown	moist	ML
1.5 – 3.96	compact	GRAVELLY SILTY SAND - fine to medium grained, poorly graded, grey-brown - as above - as above - as above Hard Grindy Drilling @ 3.96 m	damp	SM
3.96 – 6.10	dense	SANDY GRAVEL trace SILT - fine to medium grained, poorly graded, dark grey-brown - possible cobbles and boulder sized materials - as above - as above	damp	GP-GM

Field Sample / Laboratory Results (%)

▲ - FINES ● - SAND ■ - GRAVEL
PL ⊢⊙⊣ LL (MC)

Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	FINES	SAND	GRAVEL
☒	45	NA	NA	NA	NA	5.1			
☒	46	NA	NA	NA	NA	3.2			
☒	47	NA	NA	NA	NA	11.3	74.5	25.5	0.0
☒	48	NA	NA	NA	NA	3.7	25.6	48.8	25.6
☒	49	NA	NA	NA	NA	3.8			
☒	50	NA	NA	NA	NA	4.0	26.1	46.3	27.7
☒	51	NA	NA	NA	NA	2.8			
☒	52	NA	NA	NA	NA	2.4			
☒	53	NA	NA	NA	NA	1.7	8.8	32.9	59.3

Caved To 3.05 m

Borehole terminated at 6.10 m below the ground surface.
Groundwater not encountered.

Drilled By: Donjek Drilling
Drill Type: CME-75
Auger Size: 150 mm Solid-Stem
Bit Type: Fish Tail

Groundwater Levels
▽ During Drilling ▼ After Drilling

Logged By: T.Dhara, P.Eng. Aug.18, 2019
Data Entry By: T.Dhara, P.Eng. Aug.24-Sept.20
Reviewed By: Sept.23, 2019

APPENDIX B

Golder Associates Laboratory Results

Hydrometer Analysis

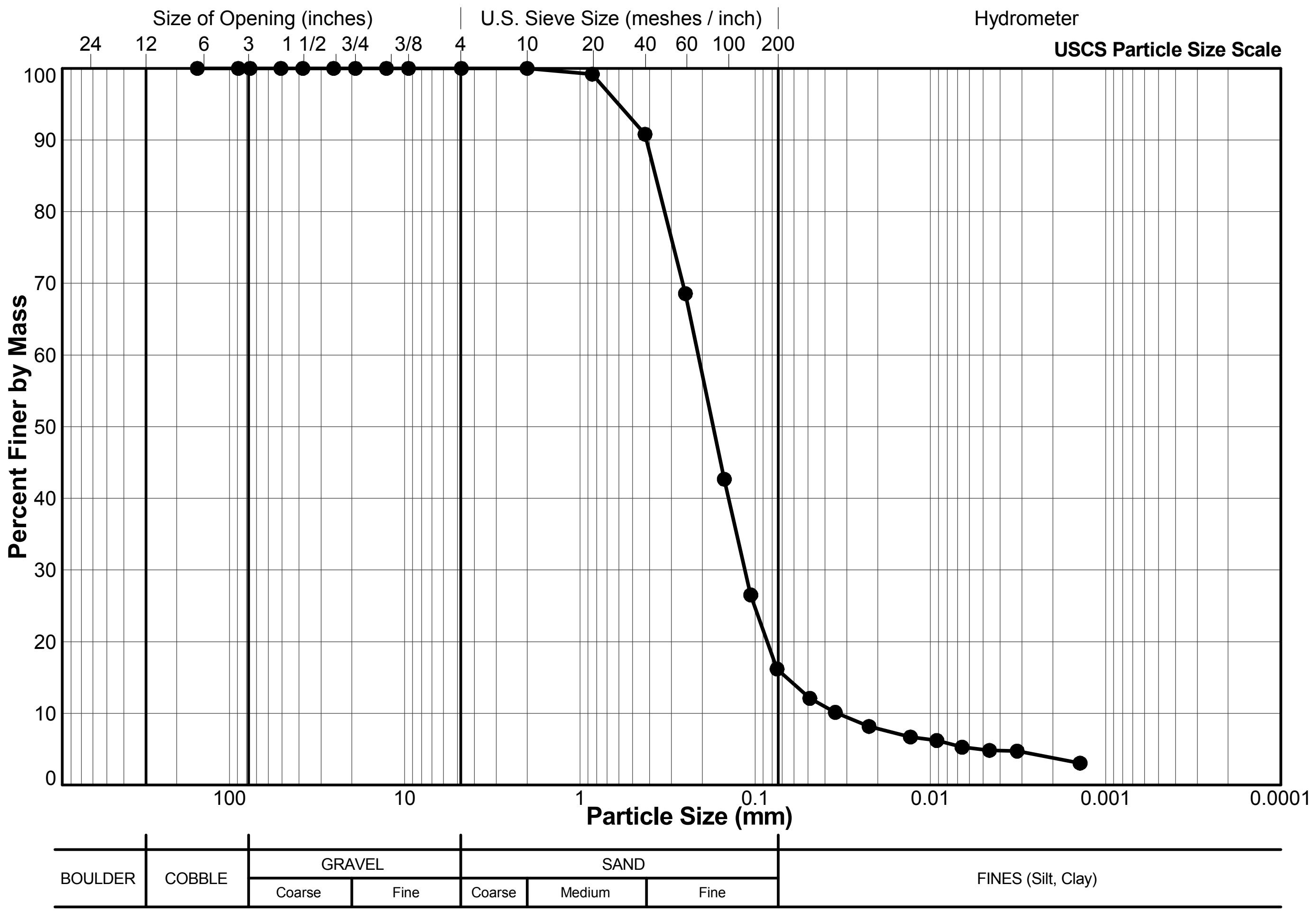
Sulphate Ion Content Analysis

SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client: Chilkoot Geological Engineers Ltd.
Project: Carmacks, Yukon
Location: Whitehorse, YT
Project No.: 1780303 **Phase:** 6000

Sample Location: Country Residential
Sample No.: BH2-19 - SA14
Depth (m): 3.4
Lab Schedule No.: B19-275



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		100.0
#10 US MESH	2		100.0
#20 US MESH	0.85		99.2
#40 US MESH	0.425		90.8
#60 US MESH	0.25		68.6
#100 US MESH	0.15		42.7
#140 US MESH	0.106		26.5
#200 US MESH	0.075		16.2
		0.0488	12.1
		0.0349	10.1
		0.0224	8.2
		0.0130	6.7
		0.0092	6.2
		0.0066	5.3
		0.0046	4.8
		0.0032	4.7
		0.0014	3.0

DC/VN	**8/29/2019**	**SJ**	**9/4/2019**
Tech	Date	Checked	Date

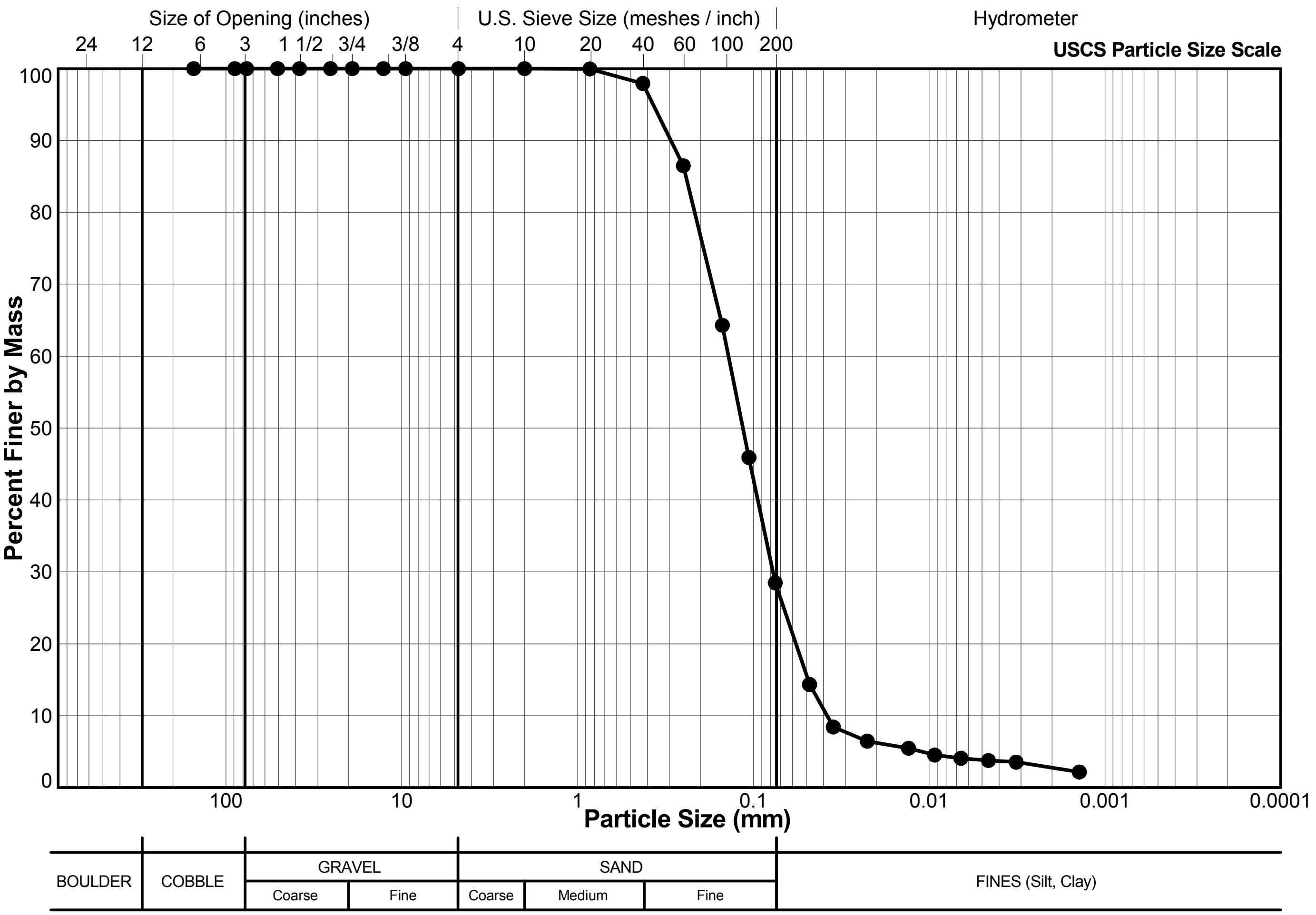
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:2328 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) 2018 SJohn 6/9/19

SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client: Chilkoot Geological Engineers Ltd.
Project: Carmacks, Yukon
Location: Whitehorse, YT
Project No.: 1780303 **Phase:** 6000

Sample Location: Country Residential
Sample No.: TP2-19 - SA6
Depth (m): 1.9
Lab Schedule No.: B19-275



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		100.0
#10 US MESH	2		100.0
#20 US MESH	0.85		100.0
#40 US MESH	0.425		97.9
#60 US MESH	0.25		86.5
#100 US MESH	0.15		64.3
#140 US MESH	0.106		45.9
#200 US MESH	0.075		28.5
		0.0479	14.3
		0.0351	8.4
		0.0225	6.5
		0.0131	5.5
		0.0093	4.5
		0.0066	4.1
		0.0046	3.8
		0.0032	3.5
		0.0014	2.2

DC/VN	**8/29/2019**	**SJ**	**9/4/2019**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:2328 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) 2018 SJohn 6/9/19

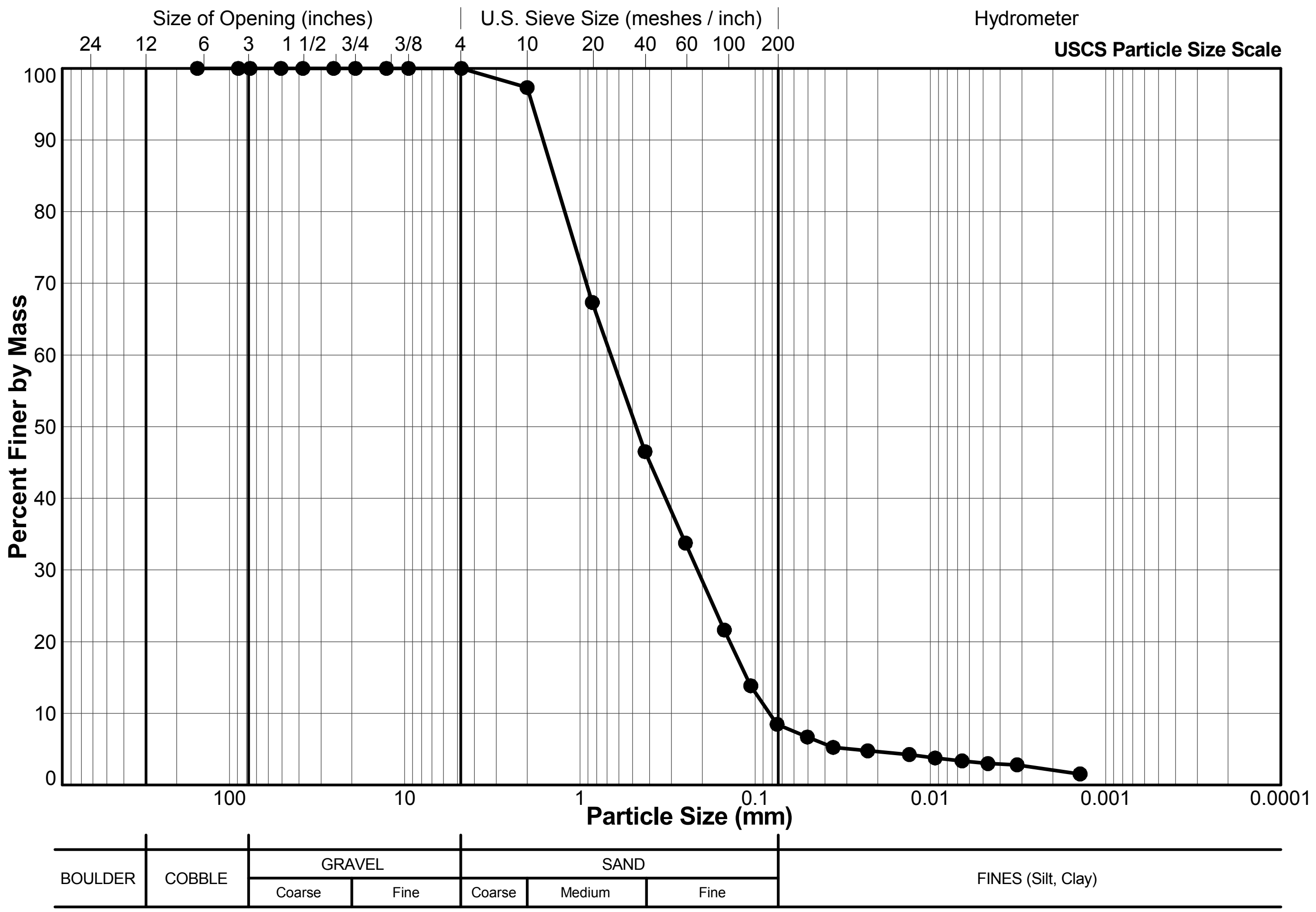
GOLDER

SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client: Chilkoot Geological Engineers Ltd.
Project: Carmacks, Yukon
Location: Whitehorse, YT
Project No.: 1780303 **Phase:** 6000

Sample Location: Country Residential
Sample No.: TP3-19 - SA10
Depth (m): 1.7
Lab Schedule No.: B19-275



Legend

Sieve Size		Particle Size	Percent Passing
(USS)	(mm)	(mm)	
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		100.0
#10 US MESH	2		97.3
#20 US MESH	0.85		67.3
#40 US MESH	0.425		46.5
#60 US MESH	0.25		33.8
#100 US MESH	0.15		21.6
#140 US MESH	0.106		13.8
#200 US MESH	0.075		8.5
		0.0504	6.7
		0.0359	5.2
		0.0228	4.8
		0.0132	4.2
		0.0094	3.8
		0.0066	3.4
		0.0047	3.0
		0.0032	2.8
		0.0014	1.5

DC/VN	**8/28/2019**	**SJ**	**9/4/2019**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:2328 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) 2018 SJohn 6/9/19

DETERMINATION OF TOTAL OR WATER-SOLUBLE SULPHATE ION CONTENT OF SOIL

CSA A23.2-3B

September 6, 2019
Project Number: 1780303-6000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5P7

Attention: Mr. Tares Dhara, P.Eng.

PROJECT: Carmacks, Yukon

Date sampled: August 17, 2019
Date tested: August 30, 2019

Sampled by: Client - TD
Tested by: RZ

Site Location	Sample ID	Total Sulphate Ion Content %	Water-Soluble Sulphate Ion Content %
Country Residential Site	BH2-19, Sample #12	0.05	Not Applicable *
YG Pit - Disposition #900101	Sample #1	0.06	Not Applicable *

Notes:

1. * Per Clause 9.1.4, the water-soluble sulphate ion content need not be tested when the total sulphate ion content is less than 0.20%
2. Detection limit for the test is 0.005%

Reported by: R. Zhu

Reviewed by: ______________________
S. John, AScT

APPENDIX C

Recommended Grain Size Distribution for Imported Fills

Appendix C

Recommended Grain Size Distribution for Imported Fill

Gran E Pit Run	
Sieve Size (mm)	% Passing By Wt
200	100
80	75-100
25	55-100
12.5	42-84
5	26-65
1.25	11-47
0.315	3-30
0.08	2-13
LA Abrasion 35 % Max Loss	

80 mm minus Sub-base	
Sieve Size (mm)	% Passing By Wt
80	100
25	60-100
12.5	40-90
5	20-65
1.25	9-35
0.315	3-15
0.08	0-8
LA Abrasion 35 % Max Loss	

Clear Stone	
Sieve Size (mm)	% Passing By Wt
28	100
20	70-100
12.5	55-100
10	30-80
5	0-40
2	0-10
NA	NA
LA Abrasion 35 % Max Loss	

Bedding Sand	
Sieve Size (mm)	% Passing By Wt
10	100
5	80-100
2	55-100
0.63	25-65
0.25	10-40
0.08	2-10

20 mm minus Base Course	
Sieve Size (mm)	% Passing By Wt
20	100
12.5	64-100
5	36-72
1.25	12-42
0.315	4-22
0.08	3-6

Class I Rip-Rap	
Sieve Size (mm)	% Passing By Wt
450	100
350	80
300	50
200	20

Class II Rip-Rap	
Sieve Size (mm)	% Passing By Wt
800	100
600	80
500	50
300	20

Class III Rip-Rap	
Sieve Size (mm)	% Passing By Wt
1200	100
900	80
800	50
500	20