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Geotechnical Evaluation Proposed Residential Subdivision Mayo, Yukon – 2018



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1.0 INTRODUCTION

Our firm was retained by *Yukon Government – Energy, Mines and Resources – Lands Management Branch* (YG) to conduct a geotechnical evaluation of a proposed residential subdivision which is located approximately 5 kilometers north of Mayo, Yukon as noted in Figure 1.

The purpose of our evaluation was to characterize the subsurface conditions through auger drilling methodologies and provide geotechnical recommendations which would assist in design and construction of residential building foundations and subsurface utility installations. In addition, as there was a need for onsite sewage disposal, we assessed the general suitability of the envisioned accepting soils for use in septic fields. As the subdivision roads had already been constructed, we also assessed the road structure to verify its overall suitability for use relative to geotechnical requirements.

The findings in this report are meant to supplement our September 7th, 2015 Preliminary Site Assessment.

While details regarding the general site conditions and our preliminary findings can be found in our September 7th, 2015 report, we have provided a description of our methodology which was employed during our field and laboratory work programs which were recently conducted. In addition, we have provided corresponding discussions, recommendations and conclusions which should allow for subdivision development as outlined herein and our September 7th, 2015 Preliminary Site Assessment report.

Authorization to proceed with the work was granted on March 19th, 2018 by YG – EMR – *Lands Management Branch - Assistant Project Manager*, Mr. Pierre Marchand. The field work component was conducted between May 25th and May 28th, 2018 in accordance with our February 5th, 2018 Proposal.

A description of our methodology and findings have been provided below.

2.0 METHODOLOGY

The methodology we employed during our field and laboratory work programs have been described below.



2.1 Field Work Program

The field work program was comprised of a site reconnaissance, utility locates and drilling program.

Site Reconnaissance

A site reconnaissance was conducted on May 25th, 2018 by our Sr. Soils Technician, Mr. G. Keitel to note the field conditions and geological features within the study area. This was completed by traversing select regions of the study area on foot and by vehicle where road access was available. During this time, our observations were documented through a combination of field notes, GPS waypoints and photographs. These observations have been summarized in Section 3.0 – Site Conditions and highlight in Figure 1.

Residential Lots

In general, with the exception of Lot #1146, where large amounts of fill had been placed, the terrain observed within the limits of the proposed subdivision appeared suitable for use as residential lots. However, additional consideration would be required at Lot #1126 as the remnants of an abandoned meltwater channel bisected portions of the lot. In addition, while local Mayo residents had indicated to us that there may be potential groundwater seeps located at the base of the slope which terminates along the northern realms of Lots #1139 & #1140, we were unable to verify their presence at the time of our reconnaissance. The remaining portions of these lots (#1126, #1139 & #1140) otherwise appeared suitable for residential lot development. The approximate locations of the fill, potential seeps and abandoned meltwater channel have been noted in Figure 1.



Lot # 1146 Facing South

Roadways

The subdivision roadways had already been established at the time of our evaluation. Based upon our observations, there were no signs of visible disturbance to the road surface or road shoulders. However, it's understood that some of the ditches contained standing water at the time of a YG site visit conducted on April 26th, 2018.



April 26th, 2018 ditch conditions along Silver Trail



Outlet and ditch conditions at CSP 3.

Three 600 mm Ø CSP culverts had been installed along the roadway to allow for drainage. While some amount of protective rip-rap had been placed at the culvert inlets/outlets, additional rip-rap could be placed, particularly at the outlet to CSP 1.

The CSP locations have been shown in Figure 1.

Utility Locates

Utility locates were conducted prior to auger drilling in order to confirm that the proposed borehole locations were clear of potential underground hazards. This involved contacting *Northwestel* and *Yukon Energy Corporation*. In brief, there was no indication of any potential conflicts as each of the service providers utilities were comprised of overhead lines.

Drilling Program

The drilling program was conducted between May 26th and 28th, 2018 by *Donjek Drilling Ltd.* utilizing a CME-750 drill mounted on a GMC 5500 Series 4-wheel drive truck. The drill was employed under the direction of our firm.

The drilling program was comprised of advancing nine (9) boreholes in order to obtain soil samples and characterize the subsurface conditions utilizing both 150 mm Ø solid-stem and 200 mm Ø hollow-stem continuous flight augers. The 200 mm Ø hollow-stem continuous flight augers allowed for standard penetration test (SPT) methodologies to be employed (at boreholes BH 2-18 & BH 5-18).



Drilling of borehole BH 6-18



Standard Penetration Testing (SPT)

The SPT's allowed for an assessment of the relative density of sub-surface soils 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 allowed for correlation of the noted resistance relative to the materials density/consistency where thawed materials were encountered. The approximate correlation has been presented on the 'Notes on Soil Logs' enclosed in Appendix A. In addition to assessment of the materials relative density, the testing allowed for the retention of relatively undisturbed samples to allow for a more accurate characterization of the subsurface soil conditions.



SPT Sample No.32 from Borehole BH 5-18

Five (5) of the nine (9) boreholes were advanced through the road surface to characterize the road structure. The remaining boreholes were advanced beyond the edges of the road surface to better assess the soils from a regional perspective.

The approximate locations of the boreholes have been plotted on Figure 1 relative to prominent site features.

Borehole Survey

The borehole locations were surveyed during the work utilizing a hand-held GPS unit. Although there were minor variations in elevation, the borehole were each given arbitrary elevations of 100.0 meters due to the nature of the study.

Each borehole was subsequently marked in the field utilizing wooden survey lathe. The approximate locations of the boreholes have been illustrated on Figure 1.

Borehole Soil Logs

During drilling, field soil logs were maintained by the undersigned to record the stratigraphy of the soils that were encountered. The logs recorded the following information;

Soil description

(depths, color, relative moisture content and density, gradation/plasticity, inclusions, oxidation, transition zones)

Sample depths and types

Material Classification -

The results of the laboratory analysis formed the basis of the material classification, however, field and laboratory observations were also utilized.

Groundwater observations

Other pertinent geotechnical information

Comments regarding drilling effort

The above noted information was utilized along with visual observations and results of the laboratory analysis in order to compile the Borehole Soil Logs which have been enclosed in Appendix A.

The appendix also includes '*Notes on Soil Classification*' which provides additional information regarding the nature of the soil log descriptions. A copy of the '*Unified Soil Classification System*', has been attached at the beginning of the appendix for reference purposes.

Sampling Program

Soil samples were retained at regular (~0.75 m) intervals during the field work by obtaining grab samples directly from the auger flighting. The exception to this was where SPT's were conducted as the sampling frequency was decreased to approximately 1 sample for every 1.5 meters of auger advancement.

A total of fifty-eight (58) soil samples were retained during the drilling program.

Once the samples were retained, they were described on the field soil logs. Each sample was subsequently sealed in air-tight plastic bags and numbered consecutively. The samples were subsequently transported to our Whitehorse laboratory facilities to undergo more detailed examination and analysis as described in Section 2.2, below.



Borehole 7-18
Sample No.45
Road Structure

Borehole Termination

Excluding the boreholes which were advanced through the road surface, the boreholes were advanced to an average depth of 7.2 meters below the ground surface.

While refusal was not encountered, drilling became difficult at several locations due to possible boulders and extremely dense soil conditions.

The solid-stem boreholes were backfilled with the auger cuttings approximately 15 minutes following completion of drilling. This allowed for time to estimate rates of groundwater seepage or borehole collapse (to assess the relative degree of soil densities). Seepage was not observed in any of the boreholes during this elapsed time frame. However, borehole collapse was noted in all of the solid-stem boreholes upon auger withdrawal as noted on the Borehole Soil Logs.

A 1.0 meter thick zone of bentonite was established near the ground surface in accordance with good drilling practices where boreholes were advanced.

Monitoring Well Installation

A 2" diameter ABS monitoring well was installed in BH 5-18 to a depth of ~6.5 meters below the existing ground surface. The monitoring well will allow for future observations of the local groundwater conditions to be made.

The lower 3.1 meters of the well was slotted. This portion of the well was covered with a silt sock to minimize the influx of fines and extend the life of the well. The annular space was backfilled with imported filter sand. The exception to this was above the slotted portions of the pipe where a 1.0 meter thick bentonite plug was installed to seal the annular space in accordance with good installation practices. A second 1.0 meter thick bentonite seal was established at a depth between ~ 0.5 and 1.5 meters relative to the ground surface.



Auger drilling borehole BH 5-18



Access to the well was restricted through a 4” diameter lockable steel casing which extended approximately 0.8 meters above the existing ground surface. The well casing was painted in a high visibility paint for protective purposes.

Photographs

Photos were taken during the work to document the field work program, laboratory soil samples and site conditions.

2.2 Laboratory Work Program

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

The analysis was comprised of the following analysis;

<i>Description of Analysis</i>	<i>ASTM Analysis</i>	<i>Quantity</i>	<i>Laboratory</i>
Moisture Content	D 2216-92	58	Chilkoot Engineers
Grain Size Distribution	D 422-633	14	Chilkoot Engineers
Hydrometer and Atterberg Limit	D 422-633/D 4318-10	2	Golder Associates

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

The results of the moisture content analysis have been denoted as ‘MC’ (⊙ - Symbol) on the Borehole Soil Logs enclosed in Appendix A.

The results of the hydrometer and limit analysis (BH 1-18 Sample #6 & BH 4-18 Sample #27) has been attached in Appendix B. The results of the hydrometer analysis was utilized to plot the soil types relative to a Soil Texture Classification Triangle as noted in Section 4.0 to determine the materials overall suitability for use as accepting (septic field) soils.

3.0 SITE CONDITIONS

While the site conditions have been described in our September 7th, 2015 Preliminary Site Assessment, we have summarized the sub-surface conditions which were recently encountered as follows;

3.1 Soil Stratigraphy

Granular glaciofluvial deposits were encountered within each of the boreholes which were advanced within the study area. At some locations, these deposits were overlain with a thin veneer of fine grained organic and eolian deposits or else road fill materials.

Organic and Eolian Deposits

These deposits were encountered in approximately half of the boreholes which were advanced. In general, these deposits were comprised of silty and poorly graded sands which were encountered to an average depth of 1.0 meters (but varied between 0.5 and 1.83 meters).

The four boreholes which were advanced beyond the edge of the road surface encountered a layer of organics and organic silts which measured on average 300 mm thick (but varied between 100 and 600 mm).

Road Surface

Five boreholes were advanced through the road surface. Each of these boreholes encountered a granular base material which overlay granular sub-base layer. On average, the thickness of the road surface was noted to be 650 mm (but varied between 400 to 800 mm thick).

The granular base layer measured on average 140 mm thick (but varied between 100 to 200 mm thick). The grain size distribution analysis of two of the five retained samples suggests that the granular base is silty (containing up to 34% fines by weight) and contains crushed gravel particles which are larger than 20 mm in diameter. The moisture content of these materials measured on average 5.6% percent (with a standard deviation of 3.8 %).



Borehole BH7-18 – Sample No.44



The granular sub-base measured on average 510 mm thick (but varied between 270 to 700 mm thick). The sub-base was comprised of what appeared to be a screened granular aggregate with particles which measured up to approximately 100 mm in diameter. The moisture content of these materials measured on average 3.1% percent (with a standard deviation of 0.8 %).

Glaciofluvial Deposits

Glaciofluvial deposits were encountered in all boreholes below the surficial organics/eolian deposits or road fills.

These deposits were granular in nature but varied between silty sands to sandy gravels which contained varying amounts of cobble to possibly boulder sized materials.

In general, a fining downwards sequence was noted as poorly graded sandy gravels overlay sands which contained varying amounts of silt and gravel.

These deposits were encountered at an average depth of 0.86 meters below the ground surface [but varied between 0.3 meters (BH 2-18) and 1.83 meters (BH 9-18)]. The underlying sand deposits were encountered at an average depth of 3.46 meters below the ground surface.

The SPT results suggests that the density of the upper (sandy gravel) realms of this deposit are dense to very dense. The underlying sands were classified as being compact.

3.2 Groundwater

Groundwater was not encountered during our drilling program. However, the presence of oxidation seams in boreholes BH 4-18 and BH 5-18 (at an average depth of 3.8 meters) suggests that groundwater may be seasonally present in some areas.

3.3 Bedrock

There was no indication of bedrock during our field work program.



3.4 Permafrost

While seasonally frozen soils were encountered in boreholes BH 1-18 and BH 2-18 to a depth of 0.9 meters, there was no indication permafrost is present within the study area.



4.0 DISCUSSIONS

4.1 General

Based upon the information retained during our field and laboratory work programs, the sub-surface conditions which were encountered support the findings of our initial assessment as noted in our September 7th, 2015 Preliminary Site Assessment.

In general, with the exception of Lot #1146, where large amounts of fill had been placed, the soil types and conditions encountered within the study area will allow for residential lot development. However, the surficial organics and eolian deposits will need to be removed during foundation preparation and surface works as these soils are weak and compressible.

Additional consideration would be required at;

- Lot #1126 - as the remnants of an abandoned meltwater channel bisected portions of the lot. The channel region is a low-lying area which is susceptible to poor drainage conditions.
- Lots #1139 & #1140 - due to the presence of potential groundwater seeps which may be located at the base of the slope which terminates along the northern realms of these lots.

Buildings and infrastructure on these lots will need to be situated to avoid these potential geotechnical liabilities accordingly.

The approximate locations of the fill, potential seeps and abandoned meltwater channel have been noted in Figure 1.

Standard 30-meter setbacks should be observed for residential building construction relative to any steep slopes.

As with all building sites, some adjustments to the individual building and infrastructure designs may be required to accommodate site-specific conditions. These conditions should be verified through site specific geotechnical evaluations at the locations of any proposed building structures or subsurface utilities.



4.2 Building Foundations

Buildings can be constructed utilizing either monolithic slab or else footings (with slab-on-grade component) types of concrete foundation systems. Once foundation construction has been completed, the building structures should be closed to the weather and heated prior to the onset of winter conditions and for the lifespan of the structure.

Residential buildings which are constructed utilizing monolithic slabs should be founded upon a structural granular pad which extends to the underlying clean granular glaciofluvial deposits. If the glaciofluvial deposits contain >15% fines content by weight, then the structural pad should measure no less than 1.8 meters thick. The overlying surficial organics and eolian deposits and glaciofluvial deposits (which contain >15% fines) will need to be removed during foundation preparation and replaced with an approved clean structural fill to allow for monolithic slab construction.

Residential foundations which are constructed utilizing footings will need to incorporate adequate frost protection through (1.8 m) soil cover above the footings. The footing components will need to be established upon undisturbed granular glaciofluvial deposits. Given the weak compressible nature of the surficial organics and eolian deposits, these materials will need to be removed from below the slab components to the depth of the underlying granular glaciofluvial deposits to allow for placement of structural fills.

4.3 Surface Works

There were no signs of visible disturbance to the road surface or road shoulders at the time of our evaluation. However, the results of the grain size distribution analysis suggest that the granular base materials do not conform to the YG (Department of Highways) specifications for 20 mm minus crushed surfacing aggregate. Specifically, each of the samples contained oversize materials (>20 mm in size) and generally had a sandy composition with a fines content greater than 15%. As such, these materials may undergo undesirable volumetric changes when subject to freezing conditions and potentially shorten the life-span of the roadway particularly if bituminous surface treatment is applied.

On average, the thickness of the road structure measured 650 mm (but varied between 400 to 800 mm). In general, given the presence of the underlying granular glaciofluvial deposits, the thickness of the existing road structure should be suitable to support the



anticipated traffic loads. The exception to this would be in the region of borehole BH 8-18, where it appears the road was not fully stripped (as a thin 50 mm thick veneer of sandy silt was encountered below the road structure) and as the thickness of the road at this location only measured 400 mm.

Additional rip-rap could be incorporated into the culvert inlets/outlets to enhance erosion protection in these areas.

The presence of standing water in some of the ditches during the spring freshet suggests that positive drainage may not have been fully established at the time the ditches were constructed.

4.4 Subsurface Utilities

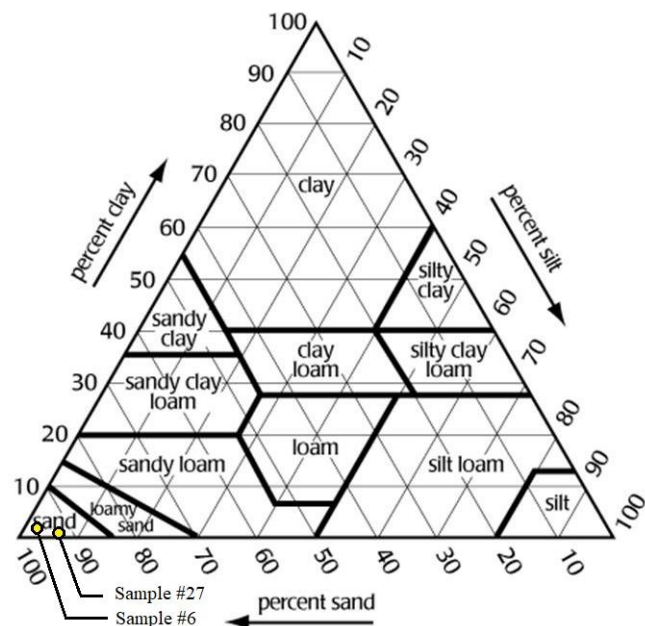
Shallow Utilities

The granular glaciofluvial soils will be suitable to allow for the installation of shallow utilities. However, the surficial organic deposits will not be suitable for use as trench backfill materials and so these materials will need to be wasted. In addition, if large cobbles and/or boulders are encountered, they too will not be suitable for use in trench backfill and so should also be removed from the site (or wasted in designated areas).

Septic Fields

The results of the hydrometer analysis for Sample No.6 (BH 1-18) and Sample No.27 (BH 4-18) were utilized to plot the soil types relative to the *Soil Texture Classification Triangle* to determine the materials overall suitability for use as accepting (septic field) soils.

Each of the samples plotted as a sand. In general, sands are suitable soil types for use as accepting soils as they have percolation rates which are < 10 minutes per 25 mm. However, in regions where coarse grained sands (or gravels) are encountered, the percolation rates may in fact be too high to allow for adequate processing of the sewage effluent. In this case, a filter bedding





sand would need to be placed below the drain field area to slow down the rate of percolation.

Given the variability in the soils, site specific assessments should be conducted at the time of individual lot development through percolation testing to verify the suitability of the envisioned accepting soils relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems*.

There was no indication as to the presence of any underlying confining layer (such as bedrock or a shallow groundwater table located within 1.2 m of the base of the envisioned septic fields) which may preclude construction.



5.0 RECOMMENDATIONS

5.1 General

The following recommendations have been provided to outline the geotechnical requirements for subdivision development.

In general, with the exception of Lot #1146, where large amounts of fill had been placed, the soil types and conditions encountered within the study area will allow for residential lot development. However, the surficial organics and eolian deposits (which were generally encountered within 1 meter of the ground surface) will need to be removed during foundation preparation and surface works as these soils are weak and compressible.

Additional consideration would be required at;

- Lot #1126 - as the remnants of an abandoned meltwater channel bisected portions of the lot. The channel region is a low-lying area which is susceptible to poor drainage conditions.
- Lots #1139 & #1140 - due to the presence of potential groundwater seeps which may be located at the base of the slope which terminates along the northern realms of these lots.

Buildings and infrastructure on these lots will need to be situated to avoid these potential geotechnical liabilities accordingly.

Building structures should be completed immediately following foundation construction. These structures should be closed to the weather and heated prior to the onset of winter conditions and for the lifespan of the structure.

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

Building structures can be supported by a monolithic slab foundation system founded upon an approved granular base constructed in accordance with recommendations provided below.

Founding Strata

The founding soils should be comprised of approved undisturbed granular glaciofluvial deposits.



Allowable Bearing Pressure

The net allowable bearing pressure should not be greater than 135 kilopascals for monolithic slabs constructed on a granular base founded upon approved undisturbed granular glaciofluvial deposits as described herein.

This figure includes the total of all live and dead loads.

Differential Movements

Foundations installed in accordance with the recommendations contained herein can expect to experience differential movements in the order of (+/-) 25 mm.

Structural Fill

The monolithic slab should be founded upon a structural granular pad comprised of an approved, clean (<13% fines), inorganic, well graded sand and gravel mixture.

The structural granular pads should be comprised of the following;

THICKNESS ^A	COMPACTION ^B	COMPOSITION ^C
200 mm ^D	100 %	20 mm minus crushed granular aggregate, Overlying
400 mm	100 %	80 mm minus sub-base course aggregate, Overlying
1200 mm ^E	98 %	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 20 mm minus granular aggregate which can be placed in a single lift so long as adequate compaction is attained. Total pad thickness to be 1.8 meters unless otherwise approved by qualified geotechnical personnel.

^B – Indicates percent compaction relative to the materials Proctor



maximum dry density at (or near, $\pm 2\%$) its optimum moisture content.

^C – The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

^D – This thickness should be maintained below both the central slab and thickened peripheral slab components.

^E – Thickness should be adjusted to attain underlying approved clean (<13% fines) granular glaciofluvial deposits and design elevations or else measure no less than 1200 mm.

5.3 Footings

Proposed residential structures may be supported by continuous or spread footings and slab-on-grade foundation systems constructed in accordance with the recommendations contained herein.

Allowable Bearing Pressure

The net allowable bearing pressure should not be greater than 110 kilopascals for conventional strip footings or 125 kilopascals for spread footing types of foundation systems founded upon undisturbed granular glaciofluvial deposits.

These figures include the total of all live and dead loads.

Differential Movements

Foundations installed in accordance with the recommendations contained herein can expect to experience differential movements in the order of (+/-) 25 mm.

Frost Protection

As a minimum, the underside of the footings should be placed at a depth of no less than 1.8 meters below the top of the prevailing adjacent exterior grade to allow for adequate frost protection.

If isolated spread footings are required, the footings should have a frost protection equivalent to 2.2 meters of earthen cover as measured from the underside of the footing.



The amount of earthen cover can be reduced if protective insulation is incorporated into the design.

Slab Components

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

Structural Fill

The footing components should be founded upon 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 $\pm 2\%$ of) the materials optimum moisture content. These components should be placed upon approved granular alluvial deposits.

Interior backfill (below slab components) should be comprised of the following;

THICKNESS ^A	COMPACTION ^B	COMPOSITION ^C
100 mm	100 %	20 mm minus crushed granular aggregate, Overlying
200 mm	100 %	80 mm minus sub-base course aggregate, Overlying
As required ^D	98 %	200 mm minus pit run, Overlying
NA	NA	^E filter fabric, overlying
NA	95 % (or as directed)	approved granular glaciofluvial deposits

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, $\pm 2\%$) its optimum moisture content.



^C – The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

^D – Thickness should be uniform and adjusted to attain underlying approved granular alluvial deposits.

^E – A geotextile filter fabric may be required at the subgrade elevation to allow for additional structural support in regions where the composition and conditions of the founding soils are considered to be poor as determined by qualified geotechnical personnel.

Exterior backfill around footing columns (and wall components) should be comprised of non-frost susceptible 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 $\pm 2\%$ of) the materials optimum moisture content, unless otherwise over-ridden by recommendations provided herein.

The height of the backfill between the interior and exterior sides of wall components should not measure greater than 150 mm during construction so as not to induce undesirable lateral forces.

All backfill materials should be placed in uniform, level lifts which are 150 mm thick (as measured following compaction).

Backfill around newly placed concrete should not be conducted until a minimum of seven days has elapsed such that the concrete attains adequate strength.

5.4 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.



The potential for sulphate attack from soils placed in direct contact with the concrete should be assessed prior to use.

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

Normal Portland cement (C.S.A. Type 10), should be used in all concrete work.

Residential concrete should have a minimum 28-day compressive strength of 25 MPa and be air entrained (5 to 7 percent). This assumes a maximum aggregate size of 20 mm.

5.5 Structural Breaks & Reinforcing

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

If heavy loads are anticipated, the monolithic slab foundation system(s) should be designed as structural slabs with thickened peripheries. Additional measures should be incorporated into the design if dynamic and/or point loads are expected. This should include thickening the areas of the slab that would be subjected to these additional forces and increasing the compressive strength of the concrete to a minimum of 32 MPa.

5.6 Vapor Barrier

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

5.7 Insulation

The recommendations for foundation construction have been provided assuming that the corresponding buildings are closed to the weather and heated prior to the onset of any freezing temperatures for the remainder of the buildings life-span.

As some of the glaciofluvial deposits may be frost susceptible, frost protection in the form of perimeter insulation or thickness of soil cover is required to reduce the risk of undesirable movements due to frost action as these soils are anticipated at the subgrade



elevation. The thickness of the insulation should be increased in regions where there may be a higher loss of heat such as the corners of the structure.

The minimum frost protection requirements have been outlined in Section 5.2 & 5.3, above.

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 areas). Insulation should be incorporated in these areas to limit soil volume changes to tolerable amounts.

5.8 Deleterious Materials

The organics and eolian deposits that were encountered above the granular glaciofluvial deposits (founding strata) are not suitable to support structural loads. As such, these materials should be removed from within the structural load envelope of building structures and (as may be required in) the roadways. If fine grained glaciofluvial deposits are encountered, then these soils will not be suitable for use in regions where monolithic slabs are to be considered.

If large cobbles and/or boulders are encountered at the founding (subgrade) elevations, then these materials should also be sub-excavated and replaced within clean structural fill as outlined herein and as directed by qualified geotechnical personnel.

If seasonal frost is encountered at the subgrade elevations, the frozen soils should be sub-excavated and wasted until thawed soils are encountered. If permanently frozen soils are encountered, then additional consideration will be required as the use of conventional concrete foundations should not be allowed.

The resulting excavations should be backfilled utilizing non-frost-susceptible materials which are placed and compacted in accordance with Sections 5.2 & 5.3.

In general, the deleterious materials should be suitable for use as general purpose fill so long as they are frost free and are placed and compacted in accordance with the recommendations provided herein. Organic soils should be utilized as soil cover in non-structural areas. Frozen soils will not be suitable for use and so should be wasted in designated areas.



Where excavation common materials are to be utilized for fill in non-structural applications, they should be placed in 300 mm thick lifts which are compacted to 95% of the materials Proctor maximum dry density at (or near, $\pm 2\%$) its optimum moisture content. These regions should be graded so as to maintain positive drainage.

5.9 Excavations

Excavation should be conducted utilizing a heavy tracked excavator equipped with a smooth lip (clean-up) bucket, to minimize disturbance of the native subgrade materials. While excavation difficulties are not expected under thawed conditions, large boulders may be encountered and so this should be considered as additional measures may be required to facilitate their removal.

Loose, disturbed, remolded or slough materials should not be allowed to remain in prepared excavation(s). If a suitable founding surface cannot be prepared through mechanical means, then hand cleaning may be necessary.

The subgrade materials are subject to a loss of strength if they are disturbed and as such, equipment should not be allowed to operate directly on the subgrade surfaces.

The base of building excavation(s) should be prepared in such a manner that the subgrade elevation does not vary. The base of trench excavation(s) should be prepared in such a manner that the subgrade is not undulating.

5.10 Excavation Limits

The excavation limits will be governed by the proposed design elevations 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 perimeter of the structure (plus one meter) until suitable frost protection and founding strata has been attained. A 1:1 back-slope should be incorporated in order to provide for worker safety and maintain slope stability. This angle of repose should be reduced to 2 horizontal to 1 vertical (or less) in regions where fine grained (or saturated) deposits are encountered.

The recommended cut slopes should be verified by qualified personnel at the time of construction and (if required) modified by the construction contractor to accommodate the actual soil conditions which are encountered.



5.11 Driveways and Culverts

The surficial organics and eolian deposits should be removed from below any proposed driveways or culverts.

The driveways should be constructed as follows;

THICKNESS ^A	COMPACTION ^B	COMPOSITION ^C
150 mm	100 %	20 mm minus crushed granular aggregate, overlying
150 mm	98 %	80 mm minus sub-base course aggregate, overlying
300-600 mm ^F	95 %	200 mm minus pit run sub-base, overlying
NA	NA	^D filter fabric, overlying
NA	95 %	^E approved native subgrade materials

Notes;

^A – All materials should be placed in uniform, level lifts that do not exceed 200 mm in thickness, as measured following compaction.

^B – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, $\pm 2\%$) its optimum moisture content.

^C – The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

^D – Geotextile fabric should be utilized if poor soil conditions/types are encountered at the subgrade elevation.

^E - The subgrade surface should be proof-rolled. If excessive deflections are noted, then these regions should be sub-excavated to allow for construction as directed by qualified geotechnical personnel. This surface (and subsequent lifts of backfill) should be shaped with a 2% road crown to promote drainage.

^F – The thickness of the pit run will vary. This granular course can measure 300 mm thick in regions where granular glaciofluvial deposits are encountered. Otherwise the thickness should be increased to 600



mm in regions where fine grained deposits are encountered, where embankments are to be constructed or if heavy traffic loads are anticipated (eg water trucks, etc.).

Standard CSP culverts should be installed between the driveways and the subdivision roadways as may be required to maintain positive drainage within the road ditches. While these culverts should measure no less than 300 mm in diameter, larger diameters may be required depending upon the civil design requirements.

5.12 Subsurface Utility Installations

Any sub-surface (water) pipes or tanks should be embedded in bedding sand which conform to the grain size specifications provided in Appendix C.

Utility pipes and subsurface tanks should be established on a base of bedding sand which measures 300 mm thick. The bedding sand should extend a minimum of 300 mm on all sides of the pipe/tank. The material should be compacted to a minimum of 95% of the materials corresponding Proctor density at (or near) the materials optimum moisture content.

If subgrade conditions are poor, then the use of (clear stone) drain rock encased in geotextile filter fabric can be utilized in lieu of the bedding sand.

The excavation spoils will generally be suitable for use as trench backfill in non-structural areas so long as the materials are inorganic and not frozen. However, cobbles/rocks larger than 150 mm in size should not be placed within 1 meter of the pipe/tanks. The trench backfill should be comprised of an approved granular material in regions where trenches intersect the building load envelope.

Trench (and tank) backfill materials should be placed in lifts which do not exceed 200 mm as measured following compaction. The material 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.

The installed utilities should be placed at depths >1.8 meters or else have equivalent insulation in order to allow for a sufficient degree of frost protection.



If subsurface holding tanks are utilized to store water, then these tanks should be well insulated to prevent freezing through adequate soil (or else protective coating) cover.

5.13 Inclement Weather

The subgrade, excavations and construction materials should be protected from drying, freezing, rain, snow, surface waters and groundwater at all times. The fine grained eolian and glaciofluvial deposits are moisture sensitive and so construction operations may need to cease or be altered at times of precipitation until drier weather conditions prevail. Construction work should be conducted during the summer months.

If construction work is scheduled in the spring or early summer months, additional consideration may be required as seasonally frozen soils may be present. Caution should be exercised to ensure frozen soils are not present within any load envelopes at the time of construction or are utilized during road construction.

5.14 Temporary Stockpiles

Stockpiled materials should be protected from segregation and the ingress of snow, frost, rain and surface waters at all times. Stockpiles should be placed no closer than 1 meter from the edge of any excavation.

5.15 Surface and Groundwater

Construction Operations

The subgrade materials may be subject to a loss of strength if they become wet, saturated or disturbed. As such, the surfaces surrounding excavations should be graded so as to direct water away from the excavation. Surface and groundwater should be removed from excavations at all times during construction.

While groundwater was not encountered during our investigation, seasonal fluctuations may occur and thus the contractor(s) should be prepared to undertake conventional construction dewatering to ensure a dry working area.

Ditches

Ditches should be incorporated into the design and construction phases to control regional, lot and building perimeter drainage.



Site Grading

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

The surrounding areas should be graded to direct surface water away from the building structure 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.

Exterior backfill should be capped with a low permeability soil or surface cover which is placed around the perimeter of building foundations following concrete placement. 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 roof structures. The outlets from the roof drains should extend a minimum of 4.0 meters away from the building structure such that the discharge is directed away from the structure(s).

5.16 Geotechnical Setbacks

Residential building development should not be allowed within ~30 meters of steep scarps/slopes.

5.17 Temporary Excavations & Worker Safety

Worker safety is paramount.

Temporary excavations to conventional depths at this site should comply with current *Occupational Health & Safety Regulations*.

While the excavation sidewall (slope) stability will be dependent upon the material characteristics, configuration of the excavation and length of exposure, in general, one to one cut slopes should provide adequate slope stability during excavation of the anticipated excavation common materials. Slope stability will however be poor where wet/saturated, loose or fine grained materials are encountered and so more gradual cut slopes will be required in these areas to minimize the potential for slope failure.



The contractor should be prepared to adjust their construction methodology and excavation profiles as soil conditions dictate.

5.18 Construction Monitoring & Testing

During construction, qualified geotechnical personnel should inspect all subgrade surfaces prior to backfill to verify that the materials noted at the subgrade elevation are consistent with those identified herein. Side slope parameters should be verified in the field by qualified personnel during the time of construction.

Materials testing services should be provided during foundation construction to assess the suitability of the structural fills and conduct in-situ field density (compaction) and concrete testing.

5.19 Local Infrastructure Upgrades

If bituminous surface treatment (BST) is to be applied to the roadways, then consideration should be given to placing a 150 mm thick lift of 20 mm minus granular base materials prior BST application to increase the longevity of the road surface.

5.20 Additional Assessments

Additional assessments/evaluations should be conducted to verify site specific design parameters as follows;

Geotechnical Evaluations

Site specific geotechnical evaluations should be conducted at the locations of proposed buildings and infrastructure through auger drilling methodologies such that the bearing capacity and soil conditions can be verified.

Site Survey

A detailed site survey (with minimum 1 meter contour intervals) should be conducted to allow for additional evaluation from a geotechnical and civil design perspective.

Environmental Site Assessment(s)

A Phase I Environmental Site Assessment (ESA) should be conducted to identify potential environmental liabilities which may be associated with the study area.



Other Studies and Plans

Development plans should be compiled to identify site grading and surface drainage requirements.



6.0 CONCLUSIONS

In general, with the exception of Lot #1146, where large amounts of fill had been placed, the soil types and conditions encountered within the study area will allow for residential lot development. However, the surficial organics and eolian deposits will need to be removed during foundation preparation and surface works as these soils are weak and compressible.

Additional consideration would be required at;

- Lot #1126 - as the remnants of an abandoned meltwater channel bisected portions of the lot. The channel is a low-lying area which is susceptible to poor drainage conditions.
- Lots #1139 & #1140 - due to the presence of potential groundwater seeps which may be located at the base of the slope which terminates along the northern realms of these lots.

Buildings and infrastructure on these lots will need to be situated to avoid these potential geotechnical liabilities accordingly.

Standard 30-meter setbacks should be observed for residential building construction relative to any steep slopes.

Building Foundations

Buildings can be constructed utilizing either monolithic slab or else footings (with slab-on-grade component) types of concrete foundation systems as described herein. In general, a minimal amount of site preparation will be required to remove deleterious surficial organics and eolian deposits.

Adjustments to the individual foundation designs may be required to accommodate site-specific conditions.

Surface Utilities

Based upon our visual observations, there were no signs of disturbance to the road surface or road shoulders. However, the grain size distribution analysis suggests that the granular base materials do not conform to the YG (Department of Highways) specifications for 20 mm minus crushed surfacing aggregate. Specifically, each of the samples contained oversize materials (>20 mm in size) and generally had a sandy composition with a fines content greater than 15%. As such, these materials may undergo undesirable volumetric changes when subject to freezing conditions and



potentially impact the life-span of the roadway particularly if bituminous surface treatment is applied.

While the thickness of the existing road structure should be suitable to support the anticipated traffic loads some deflection may be noted in the region of borehole BH 8-18 as the road structure only measured 400 mm thick at this location.

The rip-rap at the culvert inlet/outlet locations should be reinforced to reduce their susceptibility to erosion.

Some of the ditches will need to be re-graded to ensure positive drainage is established as determined through the results of the site survey.

If bituminous surface treatment (BST) is to be applied to the roadways, then consideration should be given to placing a 150 mm thick lift of 20 mm minus granular base materials prior BST application to increase the longevity of the road surface. BST should be applied after the driveway accesses have been constructed.

Subsurface Utilities

The glaciofluvial deposits which were encountered should be suitable to allow for the installation of shallow utilities. However, the surficial organics will not be suitable for use as trench backfill materials and so these materials will need to be wasted. In addition, if large cobbles and/or boulders are encountered, they too will not be suitable for use in trench backfill and so should also be removed from the site (or wasted in designated areas).

The envisioned accepting soils appear to be suitable for use during septic field construction, however, site specific percolation tests should be conducted to verify their suitability for use relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems*.

Future Assessments/Evaluations

Geotechnical evaluations should be conducted prior to individual lot development to verify site-specific geotechnical requirements.

A detailed topographical survey should be conducted to characterize the site topography. Specifically, the survey should characterize the width of the road surface, ditch profiles, culverts, side-slopes and other similar types of surface works such that the results can be assessed by qualified civil engineering personnel to verify the



roadways and ditches have been constructed in accordance with required design standards.

A Phase I Environmental Site Assessment (ESA) should be conducted to identify potential environmental liabilities.



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 are based upon the subsurface conditions encountered at the time of our evaluation, current construction techniques and generally accepted engineering practices. The content within this report reflects our best judgment in light of the information available to Chilkoot Geological Engineers Ltd. 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 data presented may not be sufficient to assess all factors that may have an effect upon construction.

It is important to emphasize that a geotechnical evaluation is, in fact, based upon random sampling and that the comments made are based upon the results obtained at the borehole and sample locations. Due to the geomorphological nature of the deposits encountered, interpolations of native subsurface conditions between the borehole locations have not been made or been implied and the conditions noted may change over time.

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



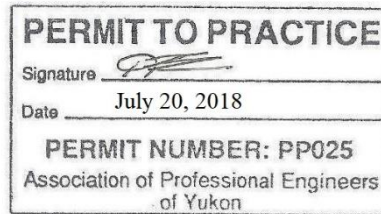
8.0 CLOSURE

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



Tares Dhara, P.Eng.
Senior Geotechnical Engineer

TD/td



Geotechnical Evaluation
Proposed Residential Subdivision – Mayo, Yukon - 2018
Figure 1 – Study Area & Borehole Locations



Based map modified from YG supplied Site Plan – Not to Scale – Locations are approximate.

Compiled July 14th, 2018 by T.Dhara



APPENDIX A

Borehole Soil Logs



NOTES ON SOIL LOGS

Soil Description

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

<u>Percent of Component</u>	<u>Modifier</u>
> 15 %	XXX - ey
10% to 15%	some XXX
5% to 10%	trace XXX

Examples;

<u>SILT</u>	<u>SAND</u>	<u>GRAVEL</u>	<u>Description</u>
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.

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



Relative Density (Qualitative Classification)

Cohesive Soils

- Very Soft - Exudes between fingers when squeezed by hand
- Soft - Moulded by light finger pressure
- Firm - Moulded by strong finger pressure
- Stiff - Cannot be moulded by fingers – Can be indented by thumb
- Very Stiff - Can only be indented by thumbnail
- Hard - Cannot be indented by thumbnail

Granular Soils

- Very Loose - Considerable sidewall sloughage noted
- Loose - Some sidewall sloughage noted – Easy digging
- Compact/
Medium-Dense - Unimpeded excavation – little to no sidewall sloughage
- Dense - Considerable effort required during excavation – Stable vertical sidewalls
- Very Dense - Extreme difficulty in excavation

Soil Log - Sample Type

Symbol

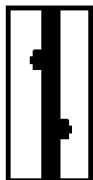


Test Pitting

Grab Sample
Retained from
excavation sidewall
or base

Drilling

Auger Sample
Retained from
Auger flighting



Bucket Sample
Retained from
leading edge of
excavator bucket

Split-Spoon Sample
Retained from
Split-Spoon Sampler
tube



Relative Moisture

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

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

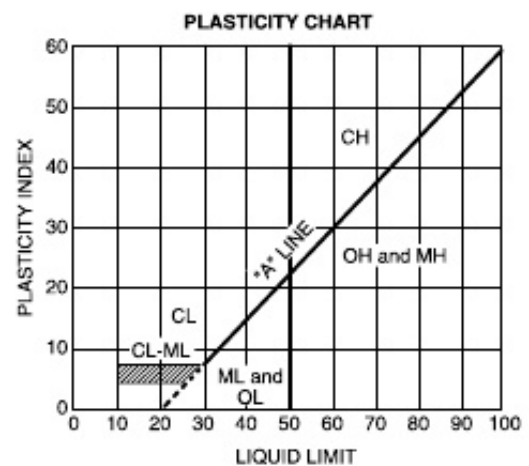
Non-cohesive (Granular) Soil		Cohesive (Clayey) Soils	
Relative Density	Blows per Foot (N-value)	Consistency	Blows per Foot (N-value)
<i>Very Loose</i>	< 5	<i>Very Soft</i>	0 to 2
<i>Loose</i>	5 to 9	<i>Soft</i>	3 to 4
<i>Compact</i>	10 to 29	<i>Firm</i>	5 to 8
<i>Dense</i>	30 to 50	<i>Stiff</i>	9 to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

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

Major Divisions		Group Symbols		Typical Names		Laboratory Classification Criteria			
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines		$c_u = \frac{D_{60}}{D_{10}}$ greater than 4; $c_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3		
			GP		Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW		
		Gravels with fines (Appreciable amount of fines)	GM*	d	Silty gravels, gravel-sand-silt mixtures	Atterberg limits below "A" line or PI less than 4		Above "A" line with PI between 4 and 7 are <i>borderline</i> cases requiring use of dual symbols	
				u					
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$c_u = \frac{D_{60}}{D_{10}}$ greater than 6; $c_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3		
			SP		Poorly graded sand, gravelly sands, little or no fines		Not meeting all gradation requirements for SW		
		Sands with fines (Appreciable amount of fines)	SM*	d	Silty sands, sand-silt mixtures	Atterberg limits below "A" line or PI less than 4		Limits plotting in hatched zone with PI between 4 and 7 are <i>borderline</i> cases requiring use of dual symbols	
				u					
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7			
Fine-grained soils (More than half material is smaller than No. 200 sieve)	Sils and clays (Liquid limit less than 50)	ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity		PLASTICITY CHART			
		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					
	Sils and clays (Liquid limit greater than 50)	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					

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^b



^a Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when LL is 28 or less and the PI is 6 or less; the suffix u used when LL is greater than 28.

^b Borderline classification, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder.

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled: May 26, 2018

Elevation : 100.0 meters
BH Termination Depth: 9.14 meters
Instrumentation: NA
Weather: Partly Cloudy +14 to +17 C

BOREHOLE

1-18

Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Type	Field Sample					Laboratory Results (%)				USCS/NRC	Symbol	Elev. (m)
	ft	m			Number	Temperature (degrees C)	Recovery %	Penetration (kg/cm ²)	SPT 'N'	▲ - FINES	● - SAND	■ - GRAVEL				
99.5	2.0	0.60	soft		1	NA	NA	NA	NA	21.4				ORG		100
99.0	1.0	0.90	compact		2	NA	NA	NA	NA	14.8				SM		99.5
98.5	1.5	1.0	compact		3	NA	NA	NA	NA	5.1				GP		99.1
98.0	2.0	1.5	SILTY SAND - poorly graded, fine-grained, brown		4	NA	NA	NA	NA	2.5				GP		99.0
97.5	2.5	2.44	SANDY GRAVEL - poorly graded, medium to coarse grained, grey-brown		5	NA	NA	NA	NA	1.6				GP		98.5
97.0	3.0	2.5	- odd rounded cobble in size to 150 mm		6	NA	NA	NA	NA	1.8				GP		98.0
96.5	3.5	2.5	GRAVELLY SAND - poorly graded, fine to medium grained, grey-brown		7	NA	NA	NA	NA	1.9				GP		97.56
96.0	4.0	2.5	- Hydrometer Analysis Conducted		8	NA	NA	NA	NA	1.5				GP		97.5
95.5	4.5	2.5	- grindy drilling to 5.18 m - possible cobbles		9	NA	NA	NA	NA	1.1				GP		97.0
95.0	5.0	2.5	- as above		10	NA	NA	NA	NA	1.4				GP		96.5
94.5	5.5	2.5	- as above							4.4				GP		96.0
94.0	6.0	2.5	- as above							4.9				GP		95.5
93.5	6.5	2.5	- as above							4.9				GP		95.0
93.0	7.0	2.5	- as above							4.9				GP		94.6
92.5	7.5	2.5	- as above							4.9				GP		94.5
92.0	8.0	2.5	- as above							4.9				GP		94.0
91.5	8.5	2.5	- as above							4.9				GP		93.8
91.0	9.0	2.5	- as above							4.9				GP		93.5
90.5	9.5	2.5	- as above							4.9				GP		93.0
90.0	10.0	2.5	- as above							4.9				GP		92.6
90.0	10.0	2.5	- as above							4.9				GP		92.5
90.0	10.0	2.5	- as above							4.9				GP		92.0
90.0	10.0	2.5	- as above							4.9				GP		91.5
90.0	10.0	2.5	- as above							4.9				GP		91.1
90.0	10.0	2.5	- as above							4.9				GP		91.0
90.0	10.0	2.5	- as above							4.9				GP		90.88
90.0	10.0	2.5	- as above							4.9				GP		90.5
90.0	10.0	2.5	- as above							4.9				GP		90.0

Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling
At End of Drilling

Logged By : G.Keitel
Date : May 26, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 24, 2018

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BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled: May 26, 2018

Elevation : 100.0 meters
BH Termination Depth: 6.55 meters
Instrumentation: NA
Weather: Partly Cloudy +14 to +17 C

BOREHOLE

2-18

Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description		Field Sample						Laboratory Results (%)				USCS/NRC Depth (m)	Symbol	Elev. (m)
	ft	m			Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT N'	▲ - FINES ● - SAND ■ - GRAVEL						
			PL	MC							LL						

Drilled By : Donjek Drilling Inc.

Auger Type: 200 mm Hollow-Stem

Drill Type : CME 750

Water Level(s)

☐ During Drilling ☐ After Drilling
☐ At End of Drilling

Logged By : G. Keitel
Date : May 26, 2018

Data Entry By : T. Dhara, P. Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 24, 2018

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(867) 335-5804 chilkoote.eng@gmail.com



BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 26, 2018

Elevation : 100.0 meters
BH Termination Depth: 1.52 meters
Instrumentation: NA
Weather: Partly Cloudy +14 to +17 C

BOREHOLE

3-18

Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Type	Field Sample					Laboratory Results (%)					USCS/NRC	Symbol	Elev. (m)
	ft	m			Number	Temperature (degrees C)	Recovery %	Penetration (kg/cm ²)	SPT 'N	▲ - FINES	● - SAND	■ - GRAVEL	PL	MC			
99.5	2.0	0.20	dense		17	NA	NA	NA	NA	3.0						BASE	100
		0.5	dense		18	NA	NA	NA	NA	3.3						SUB-BASE	99.5
99.0		0.75			19	NA	NA	NA	NA	3.3							99.25
	4.0	1.0	compact		20	NA	NA	NA	NA	2.6						SP-SM	99.0
98.5		1.52								6.7							98.48
			(200 mm) SURFACING AGGREGATE - dark brown							18.4							98.3
			(550 mm) GRANULAR SUB-BASE - grey-brown							32.6							
			GRAVELLY SAND trace SILT							49.0							
			- poorly graded, fine to medium grained, grey-brown														
			- odd rounded cobble in size to 150 mm														
			End of BH @ 1.52 m														
			- No groundwater or seepage zones encountered														
98.0																	98.0
97.5																	97.5
97.0																	97.0
96.5																	96.5
96.0																	96.0
95.5																	95.5
95.0																	95.0
94.5																	94.5
94.0																	94.0
93.5																	93.5
93.0																	93.0
92.5																	92.5
92.0																	92.0
91.5																	91.5
91.0																	91.0
90.5																	90.5
90.0																	90.0

Caved To 1.4

Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling

At End of Drilling

Logged By : G.Keitel

Date : May 26, 2018

Data Entry By : T.Dhara, P.Eng.

Date : June 15-20, 2018

Reviewed By:

Date : June 24, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

55 Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com



BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 27, 2018

Elevation : 100.0 meters
BH Termination Depth: 4.57 meters
Instrumentation: NA
Weather: Showers +7 to +11 C

BOREHOLE

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Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Relative Moisture	Field Sample						Laboratory Results (%)				USCS/NRC	Symbol	Elev. (m)
	ft	m			Type	Number	Temperature (degrees C)	Recovery %	Penetration (kg/cm ²)	SPT 'N'	▲ - FINES	● - SAND	■ - GRAVEL	PL MC LL			
99.5	0.15	0.15	soft firm	moist		21	NA	NA	NA	NA	18.8				ORG		100
99.5	0.50	0.50	dense	damp		22	NA	NA	NA	NA	3.5				SM		99.85
99.0	1.0	1.0	(150 mm) ORGANICS & ORGANIC SILT w/ rootlets, black - grass and weed cover								5.9				GP-GM		99.5
98.5	1.30	1.30	SILTY SAND - poorly graded, fine grained, brown	dry-damp		23	NA	NA	NA	NA	1.9						99.0
98.0	2.0	2.0	SANDY GRAVEL trace SILT - poorly graded, fine to medium grained, grey-brown			24	NA	NA	NA	NA	2.3				GP		98.7
97.5	2.5	2.5	- odd rounded cobble in size to 100 mm			25	NA	NA	NA	NA	1.3						98.5
97.0	3.0	3.0	- as above but no SILT			26	NA	NA	NA	NA	3.6						98.0
96.5	3.5	3.5	- as above			27	NA	NA	NA	NA	2.3						97.5
96.0	4.0	4.0	SILTY SAND trace GRAVEL - poorly graded, fine grained, orange brown	damp							7.3				SM		97.0
95.5	4.57	4.57	- some oxidation SAND some GRAVEL trace SILT - poorly graded, fine to medium grained, orange brown	damp							12.1				SP-SM		96.5
95.0			- some oxidation														96.0
94.5			- Hydrometer Analysis Conducted														95.5
94.0			End of BH @ 4.57 m														95.0
93.5			- No groundwater or seepage zones encountered														94.5
93.0																	94.0
92.5																	93.5
92.0																	93.0
91.5																	92.5
91.0																	92.0
90.5																	91.5
90.0																	91.0

Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling

At End of Drilling

Logged By : G.Keitel

Date : May 27, 2018

Data Entry By : T.Dhara, P.Eng.

Date : June 15-20, 2018

Reviewed By:

Date : June 24, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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BOREHOLE SOIL LOG

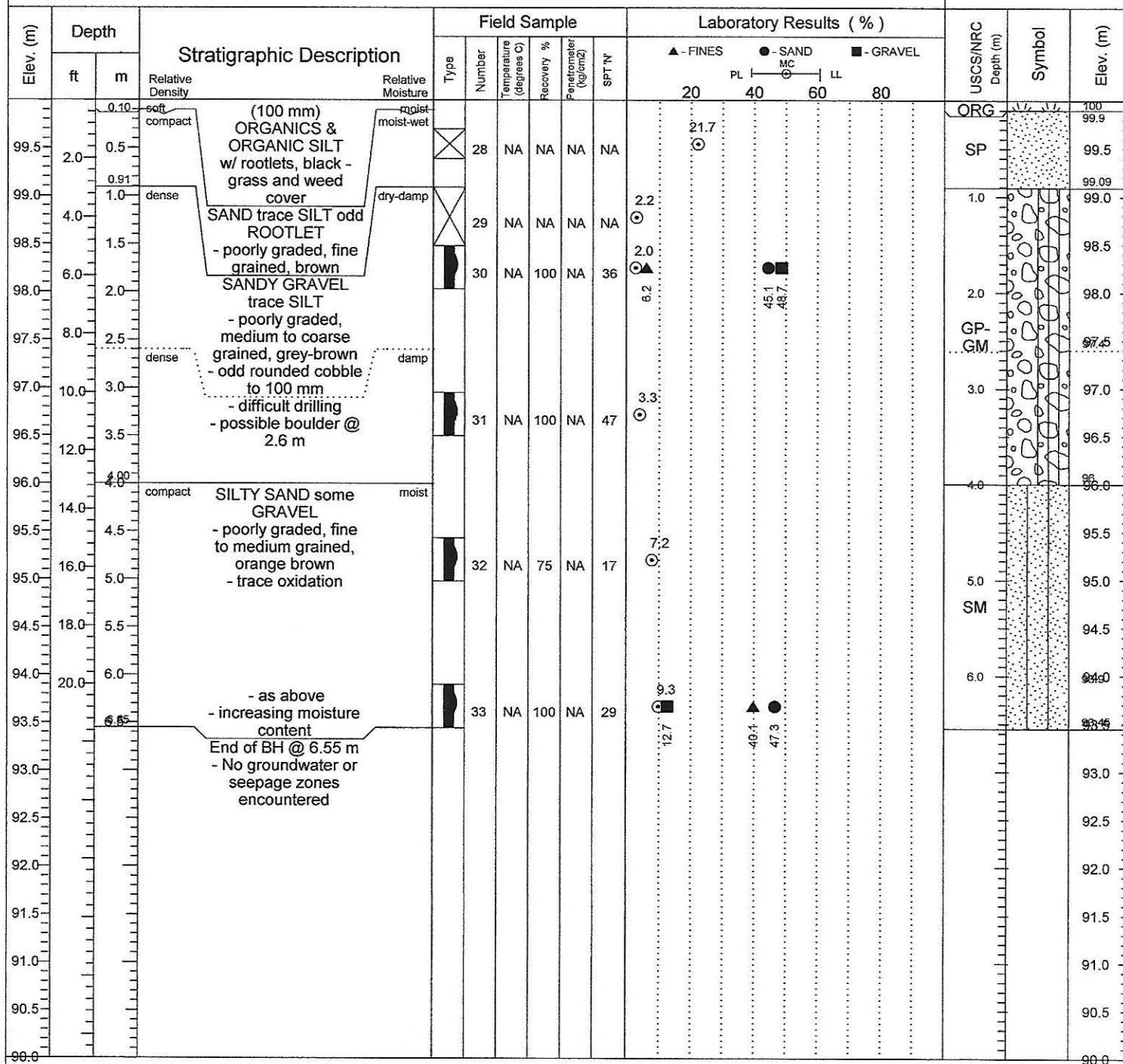
Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 27, 2018

Elevation : 100.0 meters
BH Termination Depth: 6.55 meters
Instrumentation: 2" Monitoring Well
Weather: Showers +7 to +11 C

BOREHOLE

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Sheet 1 of 1



Drilled By : Donjek Drilling Inc.

Auger Type: 200 mm Hollow-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling
At End of Drilling

Logged By : G.Keitel
Date : May 27, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By :
Date : June 24, 2018

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BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 27, 2018

Elevation : 100.0 meters
BH Termination Depth: 9.14 meters
Instrumentation: NA
Weather: Showers +7 to +11 C

BOREHOLE

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Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Type	Field Sample					Laboratory Results (%)				USCS/NRC	Symbol	Elev. (m)
	ft	m			Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	▲ - FINES	● - SAND	■ - GRAVEL	PL MC LL			
99.5	0.15	0.15	dense		34	NA	NA	NA	NA	3.0				BASE		100
99.5	0.5	0.5	dense		35	NA	NA	NA	NA	1.7				SUB-BASE		99.85
99.0	1.0	1.0	dense		36	NA	NA	NA	NA	1.7						99.5
98.5	1.5	1.5	dry-damp							5.7						99.25
98.0	2.0	2.0	dry-damp													99.0
97.5	2.5	2.5	dry-damp													98.5
97.0	3.0	3.0	dry-damp													98.0
96.5	3.5	3.5	dry-damp													97.5
96.0	4.0	4.0	dry-damp													97.0
95.5	4.5	4.5	dry-damp													96.81
95.0	5.0	5.0	dry-damp													96.5
94.5	5.5	5.5	dry-damp													96.0
94.0	6.0	6.0	dry-damp													95.5
93.5	6.5	6.5	dry-damp													95.0
93.0	7.0	7.0	dry-damp													94.8
92.5	7.5	7.5	dry-damp													94.5
92.0	8.0	8.0	dry-damp													94.0
91.5	8.5	8.5	dry-damp													93.5
91.0	9.0	9.0	dry-damp													93.3
90.5	9.14	9.14	dry-damp													93.0
90.0			End of BH @ 9.14 m - No groundwater or seepage zones encountered		43	NA	NA	NA	NA	5.5						92.5

Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling

At End of Drilling

Logged By : G.Keitel

Date : May 27, 2018

Data Entry By : T.Dhara, P.Eng.

Date : June 15-20, 2018

Reviewed By:

Date : June 24, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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BOREHOLE SOIL LOG

Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 28, 2018

Elevation : 100.0 meters
BH Termination Depth: 1.52 meters
Instrumentation: NA
Weather: Showers +8 to +10 C

BOREHOLE

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Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Type	Field Sample					Laboratory Results (%)					USCS/NRC	Symbol	Elev. (m)
	ft	m			Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm ²)	SPT 'N	▲ - FINES	● - SAND	■ - GRAVEL	PL	MC			
99.5	2.0	0.10	dense		44	NA	NA	NA	NA	4.4	20					BASE	100
99.5		0.5	dense		45	NA	NA	NA	NA	3.5						SUB-BASE	99.9
99.0		0.80			46	NA	NA	NA	NA	3.2							99.5
99.0	4.0	1.0	dense													1.0 GP	99.2
98.5		1.52	(700 mm) GRANULAR SUB-BASE - grey-brown		47	NA	NA	NA	NA	2.3							99.0
98.5			SANDY GRAVEL - poorly graded, fine to medium grained, grey-brown - odd rounded cobble in size to 150 mm														98.48
98.0			End of BH @ 1.52 m - No groundwater or seepage zones encountered														98.0
97.5																	97.5
97.0																	97.0
96.5																	96.5
96.0																	96.0
95.5																	95.5
95.0																	95.0
94.5																	94.5
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93.5																	93.5
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92.0																	92.0
91.5																	91.5
91.0																	91.0
90.5																	90.5
90.0																	90.0

Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling

At End of Drilling

Logged By : G.Keitel

Date : May 28, 2018

Data Entry By : T.Dhara, P.Eng.

Date : June 15-20, 2018

Reviewed By:

Date : June 24, 2018

Date : June 24, 2018

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BOREHOLE SOIL LOG

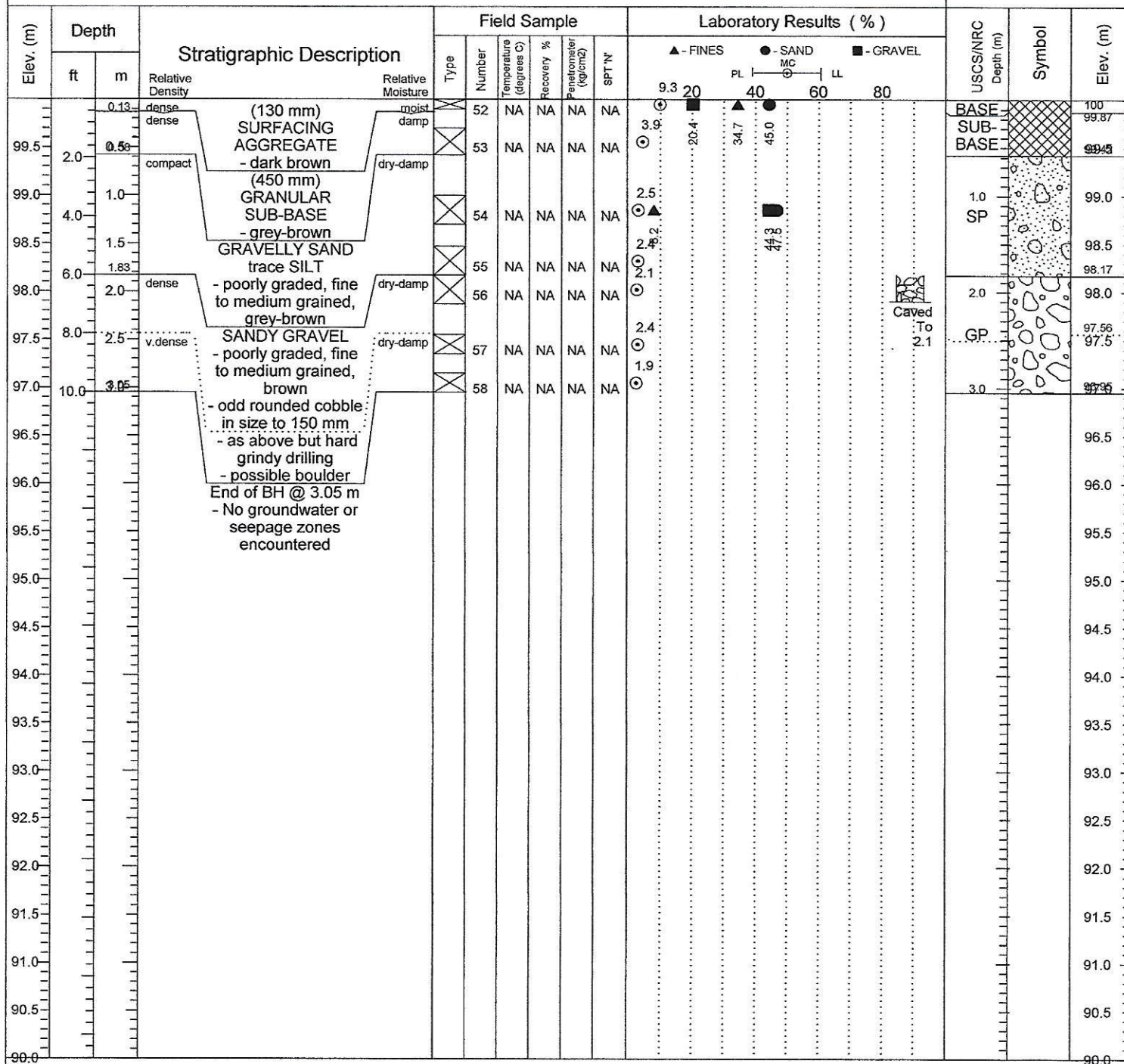
Client : YG - EMR - Lands Branch
Location : Mayo, Yukon
Project : Geotechnical Evaluation - Residential Subdivision
Date Drilled : May 28, 2018

Elevation : 100.0 meters
BH Termination Depth: 3.05 meters
Instrumentation: NA
Weather: Showers +8 to +10 C

BOREHOLE

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Sheet 1 of 1



Drilled By : Donjek Drilling Inc.

Auger Type: 150 mm Solid-Stem

Drill Type : CME 750

Water Level(s)

During Drilling After Drilling

At End of Drilling

Logged By : G.Keitel

Date : May 28, 2018

Data Entry By : T.Dhara, P.Eng.

Date : June 15-20, 2018

Reviewed By :

Date : June 24, 2018



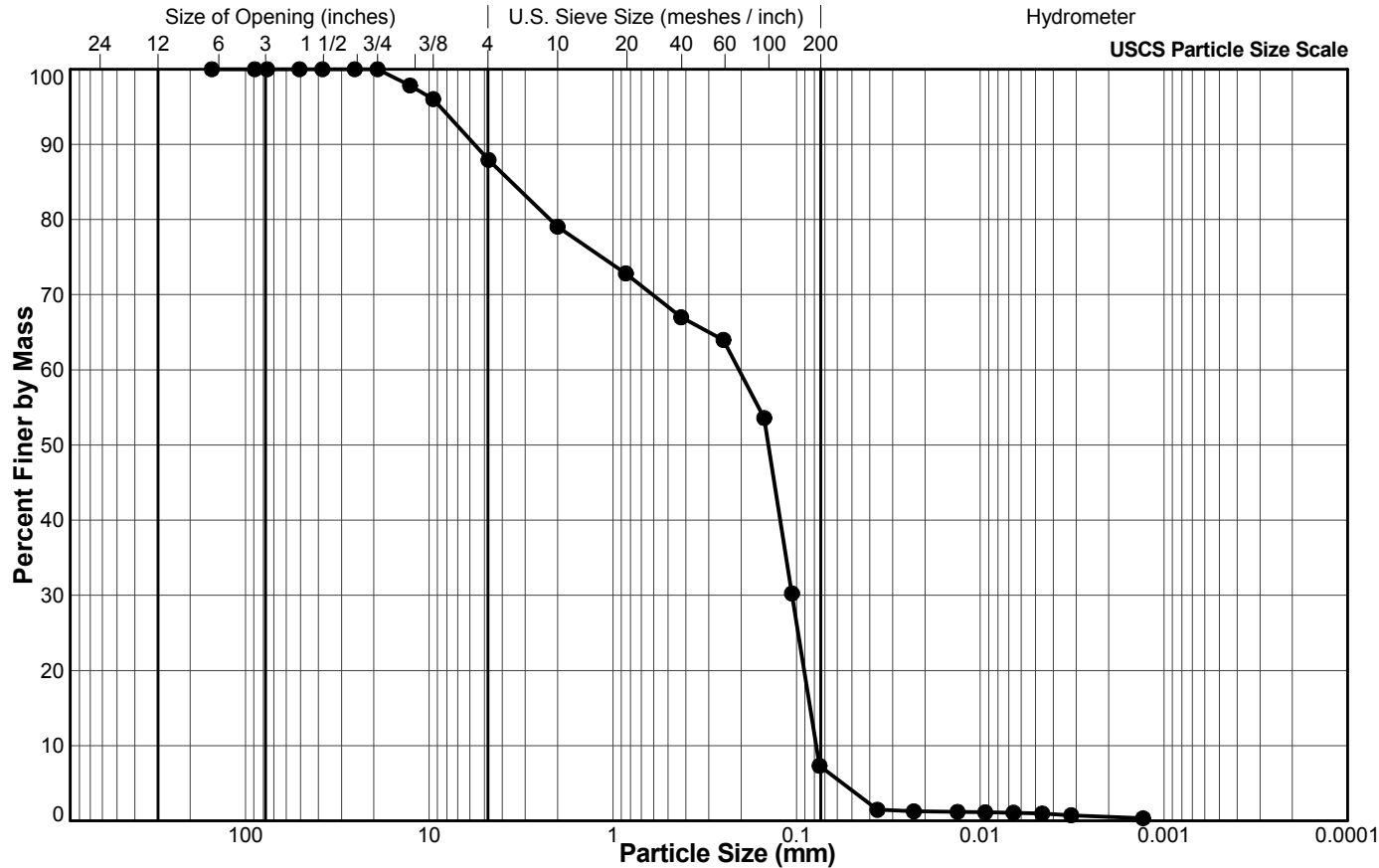
APPENDIX B

Results of Hydrometer and Atterberg Limit Analysis

Golder Associates

Client: Chilkooot Geological Engineers Ltd.
Project: Soil Testing
Location: Vancouver, BC
Project No.: 1780303 Phase: 3000

Sample Location: Mayo Subdivision
Sample No.: BH4-18 SA27
Depth (m): N/A
Lab Schedule No.:





APPENDIX C

Recommended Grain Size Distribution for Imported Fills



Appendix C

Recommended Grain Size Distribution for Imported Fills

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