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Geotechnical Evaluation

Lot 7, Block B, Stewart Menzies Subdivision (2007-0058 LTO)

Dawson City, Yukon – 2015



Prepared For: Yukon Government – Energy, Mines & Resources
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1.0 INTRODUCTION

Chilkoot Geological Engineers Ltd. was retained by *Yukon Government (YG) - Energy Mines and Resources* to conduct a Geotechnical Evaluation at Lot 7, Block B located in Stewart Menzies Subdivision in Dawson, Yukon.

The purpose of the evaluation was to determine the subsurface conditions at the proposed subject property and provide geotechnical recommendations regarding residential foundation construction for an envisioned cribbing and ventilated crawlspace foundation system.

Authorization to proceed was granted on July 31st, 2015 by *YG - Energy, Mines and Resources - Lands Management Branch - Lands Availability Manager, Mr.R.Gorczyca.*

The field work was conducted on August 10th, 2015 in accordance with our July 16th, 2015 proposal.

A detailed description of our methodology and geotechnical recommendations which will allow for residential building construction have been provided below



2.0 METHODOLOGY

Our work methodology was comprised of a literature review as well as a field and laboratory work programs.

2.1 Literature Review

A literature review was conducted prior to the field work program to better evaluate the regional conditions. The following sources of information were reviewed;

Surficial Geology Map

A 1:250,000 surficial geology map (YT, File 3288) compiled by A.Duk-Rodkin, 1996, was reviewed to assess the regional soil conditions.

In brief, the map described the area as being comprised of fluvial deposits.

Bedrock Geology Map

The following bedrock geology maps were reviewed through the *Yukon Geological Survey* website;

Geology, Ogilvie, Map 711A, by H.Bostock, 1942 *Scale 1:253,440*

Bedrock Geology, YT, G.S.C. Open File 3754, 2001 *Scale 1:1,000,000*

The maps suggest that Dawson is underlain mainly by green schist to lower amphibolite facis metamorphic rocks of the Yukon-Tanana Terrane.

2.2 Field Work Program

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



Site Reconnaissance

A site reconnaissance was previously conducted during the Phase I ESA to note the field conditions at the subject property on July 3rd, 2015. Our observations have been presented in Section 3.3 – Site Description, below.

Utility Locates

Northwestel, *Yukon Energy Corporation* and the *City of Dawson* were contacted prior to conducting the drilling program in order to verify that the region was clear of potential underground hazards.

While phone and power-lines were located overhead nearby, there were local subsurface sewer and water lines (and stubs) located along the adjacent avenue. Otherwise the proposed borehole locations were free of underground utilities.

Drilling Program

The drilling program was conducted on August 10th, 2015 by *Donjek Services* utilizing a CME-750 drill mounted on an FN-60 Nodwell.

The program was comprised of advancing two boreholes in order to obtain soil samples and characterize the subsurface conditions. The first borehole (BH 1-15) was advanced utilizing 150 mm Ø solid-stem continuous flight augers. The second borehole (BH 2-15) was advanced utilizing 200 mm Ø hollow-stem augers to allow for sampling through Standard Penetration Testing (SPT) and subsequent installation of a 2” Ø monitoring well.

The boreholes were advanced to depths of 1.83 and 4.71 meters, respectively.

Borehole Locations & Survey

Following completion of the drilling, the elevation of the boreholes were surveyed relative to the adjacent concrete slab, utilizing a (*Leica LR Rugby*)



laser level. The ground surface at the location of the monitoring well (at BH 2-15) was given an arbitrary elevation of 100.00 meters. The elevation of the boreholes have been noted on the Soil Log enclosed in Appendix A.

The location of the boreholes were measured relative to prominent reference points and have been plotted on Figure 2.

Soil Log

During drilling, field soil logs were maintained by the undersigned. This information was utilized to compile the Borehole Soil Logs which have been enclosed in Appendix A. The appendix also includes 'Notes on Soil Classification' the 'Unified Soil Classification System' and the 'Classification for Frozen Soils (adapted by Linnell and Kaplar, 1966)', for reference purposes.

In brief, the Borehole Soil Logs were compiled utilizing a combination of field logs, visual observations and results of the laboratory analysis.

Sampling Program

A total of ten (10) soil samples were retained during drilling operations.

The soil samples were retained at regular intervals during the solid-stem drilling by obtaining grab samples directly from the auger flighting or else from the split-spoon sampler tube where the hollow-stem augers were advanced.

Once the soil samples were retained, they were described on the field soil logs. The soil samples were then sealed in air-tight plastic bags and numbered consecutively in order to allow for laboratory analysis.



The samples were subsequently transported to *Chilkoot Geological Engineers Ltd.*'s Whitehorse laboratory facilities to undergo more detailed examination and analysis described in *Section 2.3*, below.

Monitoring Well Installation

A 2" diameter ABS monitoring well was installed to a depth of approximately 4.41 meters below the existing ground surface to allow for future monitoring of the local groundwater conditions.

The lower 1.5 meters of the well was slotted and the annular space was backfilled with imported filter sand. The exception to this were 0.3 meter thick zones (located 0.3 meters above the slotted portions of the pipe and 0.6 meters below the ground surface) where a bentonite plug was installed to seal the annular space in accordance with good installation practices. Access to the well was restricted through the installation of a 4 inch diameter locked steel casing which was concreted into the ground surface.

Borehole Termination

Following drilling the borehole was left undisturbed for approximately 15 minutes to assess the sidewall stability (solid-stem borehole) and better assess groundwater conditions. In brief, the excavation sidewalls in the solid-stem borehole was noted to collapse to a depth of 1.78 meters below the ground surface.

Refusal was not encountered during the drilling.

Backfill

Following our observations, the boreholes were backfilled utilizing the auger cuttings. Bentonite pellets were placed at the zones noted in 'Monitoring Well



Installation' section above, in accordance with good drilling practices to separate potential hydrological zones.

Photographs

Photos were taken during the work to document the field work program, laboratory soils samples and site conditions. A selection of these photos has been provided in Appendix D.

2.3 Laboratory Work Program

A physical laboratory work program was conducted in order to characterize the index properties and conditions of the retained soil samples.

The analysis was conducted between August 12th and 14th, 2015 at our Whitehorse laboratory facilities. In brief, the analysis was comprised of natural moisture content determination and visual laboratory classification of all ten (10) retained soil samples. The moisture content analysis was conducted in accordance with ASTM D 2216-92. The results of the analysis have been denoted as 'MC' (⊙ - Symbol) on the Soil Logs enclosed in Appendix A.

Grain size distribution analysis was also conducted on two (2) of the samples (in accordance with ASTM D 422-633) in order to classify the soil utilizing the *Unified Soils Classification System*. The results of the analysis have been summarized on the Soil Logs enclosed in Appendix A with the percent composition of fines (silt & clay), sand and gravel denoted with the symbols - ▲, ● & ■ respectively. The results of the individual grain size distribution analysis have been presented in Appendix B.



3.0 SITE CONDITIONS

3.1 General

The subject property is comprised of historically developed land which is currently vacant. A residence was once located on the subject property.

3.2 Legal Description and Site Location

The legal description of the subject property is;

Lot 7, Block B, Stewart Menzies Subdivision (2007-0058 LTO-92599 CLSR)

The subject property is located in Dawson, Yukon, as noted in Figure 1.

The subject property (a.k.a. 'site') is approximately $0.070 \pm$ ha in size and is rectangular in shape (75' by 100').

Access to the site is via 7th Avenue which lies to the south and a back alley.

3.3 Site Description

Regionally, the subject property is located on the banks of the Yukon River and so very little relief in elevation is noted within the townsite.

Local site development and residential construction is occurring on a number of nearby properties. The work appears to be comprised of placement of clean granular backfill upon which cribbing and residential houses are being constructed.

Although the subject property is predominately undeveloped, it's currently being utilized by nearby resident(s) for storage of snowmobiles, mini-van, single-axle utility trailer, pick-up truck tailgate and other similar types of household yard equipment



(i.e. lawn mower, pressure washer, etc.). The mini-van and snowmobiles are all being stored on a concrete slab which measures approximately 15' by 24'. It's apparent that the mini-van and two (2) of the snowmobiles have not been used for several years. The license plates for the mini-van expired in May 2007. A small greenhouse which appears to be in use and measures approximately 8' by 12' is also located on the site.

3.4 Geomorphology

Glaciation

Although the full extent of the earliest glaciation is unknown, evidence shows that the Dawson area and Klondike Plateau have probably never been glaciated.

Natural Hazards

The following natural hazards may be regionally present;

Mass Wasting/Creep

Creep is caused by the repeated expansion and contraction of the upper part of the regolith (weathered bedrock surface) through freeze/thaw and wetting/drying cycles. Combined with gravitational forces, this process results in slope movement in generally steep terrain, although even shallow slopes may exhibit this behavior. It is understood that the nearby slide is undergoing such movement at a rate of approximately 5 cm/year.

Generally however, mass wasting/creep would not pose a direct hazard to the site.

Although the majority of Dawson was prone to flood events prior to the (1980's) establishment of the protective dike, given the sites relative elevation, it would not likely have been flooded during recent times.



3.5 Surficial Geology

The deposits noted in the Dawson area are comprised of Klondike River Valley Deposits. These deposits are characterized by organics/peat which overlie fine grained fluvial materials ranging from sands to silts with minor amounts of gravel. These materials overlie predominately coarse grained materials (where the tailings are derived). Based upon the undersigned's past experience in the Dawson area, it is anticipated that these soils are clean and contain high percentages of cobble to boulder sized materials.

Due to the poor founding nature of the soils located in the Dawson area, considerable amounts of fill have been imported to facilitate both historical and more recent development. The historical fills overlie the above noted native deposits and are typically medium to coarse grained but contain an appreciable amount of fines and deleterious (organic) materials.

3.6 Bedrock Geology

In brief, the geology maps suggest that Dawson is underlain mainly by green schist to lower amphibolite facis metamorphic rocks of the Yukon-Tanana Terrane. While the depth to bedrock in the low lying valley regions will vary, it is understood that it is typically encountered at depths of 20 to 30 meters in the region of the townsite.

Given the sites setting at higher elevations relative to downtown areas of Dawson, bedrock may be encountered at shallower depths as the terrain becomes more increasingly bedrock controlled.



3.7 Subsurface Conditions

Soil Stratigraphy

Detailed descriptions of the soil stratigraphy that was encountered have been provided on the Borehole Soil Logs attached in Appendix A.

In general, the subsurface soil units which are typically encountered in Dawson can be classified as;

Unit # 1 – Fill;

which are medium to coarse grained and contain an appreciable amount of fines and potential organics, overlying;

Unit # 2 – Peat/Organic Stratum;

which are wet and rich in organics, overlying;

Unit # 3 – Alluvial Channel Deposits;

which are predominately silty in nature, but may contain finer clay sized materials and/or coarser interbedded granular materials, overlying;

Unit # 4 – Alluvial Valley Deposits;

which are predominately clean, coarse grained and contain cobble and possibly boulder sized materials.

A detailed description of the soil units encountered during our firm's field work program has been provided below.

Unit # 1 – Fill;

The fill is comprised of predominately silty sand to sandy silt materials which contained varying amounts of fines and organics. The depth of the fill varied. BH 1-



15 encountered approximately 1.06 meters of fill while BH 2-15 encountered thicker amounts, approaching 2 meters (as measured from the existing ground surface at the borehole locations). As with all undocumented fills in regions where previous residences were located, the fill may also contain construction/foundation rubble, scrap steel, high levels of fines/organics and/or other deleterious materials and/or abandoned infrastructure.

A groundwater table was encountered within this soil unit in BH 2-15 at a depth of approximately 1.25 meters below the ground surface (at the borehole location).

Native Deposits

The native deposits are comprised of an organic stratum which overlies alluvial channel deposits. Alluvial valley deposits likely underlie these materials.

Unit # 2 –Peat/Organic Stratum;

A veneer of organics, rootlets and organic rich silt was encountered below the fill in both boreholes. The thickness of this unit varied between 0.16 meters in BH 1-15 and greater than 0.45 meters in BH 2-15. In addition, although designated as fill, a 0.3 meter thick layer of organics was also encountered at the ground surface in BH 2-15. The organic/peat layer was moist, organic rich and compressible.

Unit # 3 – Alluvial Channel Deposits;

Alluvial channel deposits were encountered in both of the boreholes immediately below the peat/organic stratum.

The deposits were comprised of predominately sandy silt although the sand and clay content varied. Organic inclusions and rootlets were also intermittently encountered within this soil unit in BH 2-15.



The deposit was noted to grade coarser with depth. Cobbles (and possibly boulder sized materials) were encountered near the base of this soil unit. Conversely, given the nature of channel deposition, it may also contain regions of predominately organic deposits which are a result of channel infilling.

The moisture content of these soils in BH 2-15 were noted to be wet and very soft as they were located below the groundwater table.

Both boreholes were terminated within this soil unit.

Unit # 4 – Alluvial Valley Deposits;

Although these deposits were not encountered, they are known to underlie the alluvial channel deposits and are generally comprised of clean granular materials.

Groundwater

There was no indication of groundwater infiltration in BH 1-15 prior to backfill. However, groundwater was noted in the monitoring well in BH 2-15 (at a depth of 1.26 meters below the existing ground surface) following the well installation.

Groundwater flow would likely be to the north-west, towards the Yukon River.

Seasonally Frozen Soils

While there was no indication of seasonally frozen soils, typically, the upper 1.8 to 2.0 meters of the soil column would be susceptible to seasonal frost. The depth of seasonal frost would depend upon the soil cover and types as well as climatic conditions.

Permafrost

Dawson lies within the zone of widespread discontinuous permafrost. Permanently frozen (alluvial channel) soil deposits were encountered below the organic mat at a



depth of 1.52 meters in BH 1-15. The frozen soils were well bonded and there was no sign of visible ice. Although BH 2-15 was advanced to depths of 4.71 meters, there was no indication of frozen soils.

In general, the permafrost in the region can vary from poorly bonded soils with non-visible ice to massive ice lenses ranging in size to tens of meters. Regionally, where soil conditions allow, the permafrost is probably more than 100 meters thick with taliks (thawed subsurface) present beneath large rivers (and lakes) and beneath south-facing slopes.

Frozen soils may also be encountered in areas where pre-existing structures may have been located as the shade provided by the structures, would promote the creation of permafrost.

Bedrock

There was no indication of bedrock within the boreholes which were advanced.



4.0 DISCUSSIONS

The subsurface conditions encountered at the borehole locations will require the preparation of a granular pad upon which a (PWF) cribbing and ventilated crawlspace type of foundation system can be prepared. The use of standard concrete footing and/or slab-on-grade systems will not be feasible (without costly development) due to the presence of underlying permafrost and weak/compressible soils.



5.0 GEOTECHNICAL RECOMMENDATIONS

5.1 Foundations

Standard residential building structures may be supported by PWF cribbing and ventilated crawlspace foundation system founded upon an approved granular base constructed in accordance with recommendations provided herein.

The PWF cribbing should be configured in such a way that the building structure can be intermittently re-levelled on an as needed basis.

The ventilated crawlspace should incorporate a sub-wall which skirts the buildings perimeter. The sub-wall should be comprised of wire mesh or lattice work such that air flow below the structure is unrestricted during the winter months. These openings should be configured in such a manner that they can be closed in the summer months to prevent (exterior warmer) air from flowing beneath the structure and impacting nearby permafrost. Ultimately, degradation of local or regional permafrost is not desirable and as such, efforts should be undertaken to protect the natural thermal regime.

5.2 Allowable Bearing Pressure

The allowable bearing pressure should not be greater than 105 kilopascals for a cribbing and ventilated crawlspace foundation system constructed on the structural granular pad described herein.

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



5.3 Differential Movements

Differential movements in the order of (+/-) 25 mm may occur with the proposed foundation system. Periodic adjustment to the cribbing system should be anticipated throughout the life of the structure in order to accommodate the movements when these limits are exceeded or if gross settlement/heave occurs.

Given the presence of compressible soils located towards the eastern (Harper Street) side of the lot, the design should anticipate that overall settlement towards the east will prevail.

5.4 Deleterious Materials

Following clearing and grubbing operations, as the near surface organics are highly compressible, they should be removed to expose the underlying fill material. Caution should be exercised as the sub-grade materials are prone to disturbance. Once a level surface is prepared exposed sub-grade surfaces should be inspected by qualified geotechnical personnel to assess the suitability of the prepared surface on a case-by-case basis.

Subsequent preparation of a granular building pad should be conducted in accordance with Section 5.7.

Additional consideration may be required to address the two wooden piles which are located on the west half of the site as they are (frost) jacking due to seasonal frost action. Specifically, they will need to be removed if they lie within the limits of any building load envelope or site development. The annular space should subsequently be filled with a clear stone or low strength concrete grout.



Excavated soils which are frozen, have high moisture and/or organic contents should be hauled to waste as their use in non-structural applications will be limited.

5.5 Excavations

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

While excavation difficulties are not expected, hard digging will be encountered if/where frozen soils are encountered. If permafrost is exposed during excavation, it should be protected from degradation by implementing an accelerated work program, utilizing insulated tarps and/or scheduling the project to such a time that thermal loss would be minimized.

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 surrounding surfaces should be graded so as to direct water away from the excavation.

The sub-grade is sensitive to disturbance and so caution should be exercised during excavation and backfill operations. Wheeled equipment should not be allowed on the sub-grade surface. The sub-grade should be covered once exposed to minimize degradation as the sub-grade is moisture sensitive.

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



5.6 Excavation Parameters

The excavation parameters will be governed by the underside of PWF cribbing pad elevation. The selected elevation should ensure that surface drainage is directed away from the prepared granular base and that positive drainage is attained.

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 (exterior edge of PWF pad) perimeter until the founding strata has been attained (plus 1 meter horizontally).

The base of the excavation should be prepared in such a manner that positive drainage (at 2%) is maintained from a centrally located high spot.

The excavation backslopes should be cut at 1:1 to assist in side slope stability.

The actual configuration of the excavation should be verified by the retained geotechnical consultant at the time of construction.

5.7 Granular Pad

Any residential building constructed on the lot should be founded upon constructed granular pad comprised of an approved, clean, inorganic, well graded sand and gravel mixture which conform to the attached recommended grain size distribution.

The granular pad should measure ~ 1.8 meters thick and should be comprised of the following;

Granular Pad

UNIT ^E	THICKNESS	COMPACTION ^C	COMPOSITION ^D
Base	150 mm ^A	100 %	20 mm minus crushed granular aggregate, overlying
Sub-base	450 mm	98 %	80 mm minus sub-base course aggregate, overlying
Sub-base	1200 mm ^B	95 %	150 mm minus and/or Class I Rip-Rap sub-base course aggregate, overlying
Geotextile Fabric	NA	NA	Non-woven filter fabric
Sub-grade	NA	95 %	approved native sub-grade materials

Notes;

^A – The prepared surface of the granular backfill should be level in the region where PWF pads are to be placed. The granular pad should extend a minimum of 1.0 meters beyond the edge of the pad at these locations.

^B – The thickness of this unit should be uniform through-out the building load envelope.

If long-term movements are to be reduced and/or if an increased allowable bearing capacity is required, then the sub-base should extend to the underlying coarse grained fluvial deposits provided the site conditions on the adjacent lots allow for it. Additional assessment will be required if this option is to be considered as construction dewatering and thermal protection aspects will need to be carefully assessed, on a case-by-case basis.



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

Caution should be exercised during compaction as the underlying sub-grade materials are moisture sensitive and subject to a loss of strength if disturbed. Non-vibratory static rolling will be required.

All materials should be placed in uniform, level lifts that do not exceed 150 mm thick, as measured following compaction. The exception to this would be if Class I Rip-Rap (or equivalent coarse) materials are utilized. Typically these materials are placed in 0.5 meter thick lifts prior to leveling and static rolling.

- ^D - If groundwater infiltration is encountered at the sub-grade elevation, then the backfill should be comprised of Class I Rip-Rap or else some other approved coarse fill. The course Class I Rip Rap (or equivalent) should be fully encased in geotextile fabric.
- ^E - If the underlying organic soil unit is disturbed, then consideration should be given to replacing the soil unit with an equivalent level of thermal protection through the use of SM Styrofoam.

A recommended grain size distribution for the specified imported fills has been attached as Appendix C.

Considering the local site elevations, the granular pad should be constructed such that its surface is in the order of 1 meter higher in elevation than the prevailing grade of the back alleyway.



5.8 Filter Fabric

Due to the potential degradation of the excavation base and other exposed materials over time and potentially poor founding conditions, the use of a filter fabric will be required to facilitate backfill operations. The fabric should extend across the excavation base and excavation sidewalls. If successive pieces are required, they should be either sewn or overlapped by a minimum of 1.5 meters. The overlap should be in the same direction as that of advancing backfill operations.

5.9 Structural Breaks & Reinforcing

Structural breaks, reinforcement and other similar features should be integrated into the building design to allow for differential movements caused by soil volume changes of the underlying soils.

In addition, it should be noted that structures built upon cribbing foundations are inherently more susceptible to seismic action and so this should be considered during design and construction of any residence/structure.

5.10 Site Drainage

The granular pad construction and surrounding areas should be graded to direct surface water away from the building structure. Typically, a 2 percent slope will be suitable for this purpose.

Eaves troughs should be incorporated into the roof structure. The discharge/outflows should extend a minimum of 3 meters away from the building structure.

The crawlspace must be protected from rain, snow and the ingress of surface and groundwater at all times.



5.11 Inclement Weather

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

5.12 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*.

In general, side slopes cut at 1:1 (horizontal/vertical) should allow for adequate stability provided that the depth of the excavation does not exceed 2 meters. If these parameters are to be exceeded, then they should be verified and monitored by qualified geotechnical personnel during the time of construction. The excavation sidewall (slope) stability will be dependent upon the material characteristics, configuration of the excavation, length of exposure, presence of groundwater and other similar factors which should be re-evaluated at the time of construction.

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

5.13 Surface and Groundwater

As the depth to groundwater will vary with seasonal conditions, the Contractor should be prepared to conduct construction dewatering operations on an as needed basis.



Surface and groundwater should be intercepted and removed from excavations (and construction areas) at all times during granular pad construction to ensure a dry working area.

Caution should however be exercised as lowering of the local groundwater regime may affect nearby structures due to settlement of the underlying soils. More detailed analysis would be required to assess the effects of construction dewatering on neighboring structures (i.e., buildings, utility poles, etc.) if the depth of excavation exceeds 1 meter.

5.14 Temporary Stockpiles

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

5.15 Sub-surface Utilities

Sub-utilities should be embedded in a bedding sand conforming to the grain size specifications provided in the imported fill Appendix. The utility pipe should be established on a base of bedding sand which measures 300 mm thick. In addition, the bedding sand should extend a minimum of 300 mm on all sides of the pipe. 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 utility trenches are located within the building load envelope, then the materials should be compacted to 98% of the materials corresponding Proctor density at (or near) the materials optimum moisture content. If poor founding soils are encountered at the sub-grade elevation, then the pipe should be embedded in 28 mm minus clear stone (conforming to the imported fill Appendix) encased in filter fabric.



In general, the excavation spoils should be suitable for use as backfill so long as they are not located within the building load envelope or else parking areas. Otherwise the remaining trench backfill should conform to the recommended grain size distributions for imported fills provided in the Appendix.

Pipes should be well insulated to prevent freezing by means of soil cover, physical coating, heat trace or combination thereof.

Where utility trenches penetrate Unit # 2 – Organics and Unit # 3 – Alluvial Channel Deposits, sloping of the base of the trench away from the building should be conducted (such that positive subsurface drainage is maintained and the potential for subsurface groundwater inflow from within the existing utility trenches is minimized). The use of a trench plug to minimize the potential of groundwater inflow through the trench should be considered.

Where possible, underground utilities be situated outside of the building perimeter to allow for ease of future maintenance.

5.16 Driveways and Parking Areas

The structure for driveways and parking areas should be comprised of;

UNIT	THICKNESS	COMPACTION ^B	COMPOSITION
Base	150 mm	100 %	20 mm minus crushed granular aggregate, overlying
Sub-base	300 mm ^A	98 %	80 mm minus sub-base course aggregate, overlying
Geotextile ^C	NA	NA	approved filter fabric
Sub-grade	NA	95 %	approved native sub-grade materials



Notes; ^A – If additional fill is required to meet the anticipated design elevations, then a clean, well graded ‘pit run’ material with maximum particle size of 150 mm can be utilized below the sub-base materials.

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

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

A recommended grain size distribution for the specified imported fills has been provided in the Appendices.

5.17 Construction Monitoring and Testing

During construction, qualified geotechnical personnel should monitor the excavation and side slopes and inspect all sub-grade surfaces prior to backfill to verify that the prepared sub-grade surface is suitable for use.

Materials testing services should be conducted during granular pad construction to assess the suitability of the imported structural fills through laboratory testing and to verify that adequate compaction has been attained through in-situ field density (compaction) testing.



5.18 Foundation Monitoring

As generally all structures in permafrost regions undergo some amount of movement due to underlying changes in the soil volume, the foundation should be monitored and the structure re-leveled on an as needed basis depending upon the design.



6.0 CONCLUSIONS

The (geotechnical) sub-surface conditions encountered will allow for construction of a structural granular pad upon which a residential structure can be constructed utilizing a (PWF) cribbing and ventilated crawlspace foundation system prepared in accordance with the recommendations provided herein.

Long-term maintenance through periodic re-levelling will be required throughout the life of the structure to accommodate movements caused by fluctuations in the underlying soil volumes as well as thermal and groundwater regimes.



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 investigation, current construction techniques and environmental standards 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 data presented may not be sufficient to assess all factors that may have an effect upon construction. While references to underground utilities have been made, the locations of sub-surface utilities should be verified by prior to construction.

It is important to emphasize our evaluation is based, in fact, on a random sampling of the subject property site. Our comments are based upon the results obtained at the borehole and sample locations. Due to the geomorphological nature of the deposits encountered, interpolations of subsurface conditions between the borehole and other locations on the site have not been made or been implied. The soil and ground conditions at this site are dynamic and thus the subsurface conditions will vary over time.

The recommendations have been provided without consideration to the effects of deep and long-term thaw of local and/or regional permafrost which may stem from global warming, the proposed or nearby construction/structures or other causes. In



addition, geotechnical consideration regarding seismic constraints have not been considered. Structures built upon cribbing foundations are inherently more susceptible to seismic action and so this should be considered during design and construction.

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 at such time.

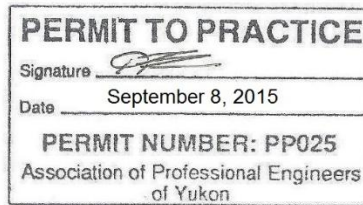


9.0 CLOSURE

Thank you for allowing our firm to provide you with the above noted assessment. While we trust the information will suit your purposes, please feel free to contact the undersigned if you have any questions.

Respectfully Submitted,

CHILKOOT GEOLOGICAL ENGINEERS LTD.



Tares Dhara, P.Eng.
Senior Geotechnical Engineer

TD/td



Geotechnical Evaluation

Lot 7, Block B, Stewart Menzies Subdivision 2007-0058 LTO - Dawson, Yukon – 2015

FIGURE 1 – Site Location





Geotechnical Evaluation
Lot 7, Block B, Stewart Menzies Subdivision 2007-0058 LTO - Dawson, Yukon – 2015
FIGURE 2 – Borehole Locations





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
11% 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

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



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

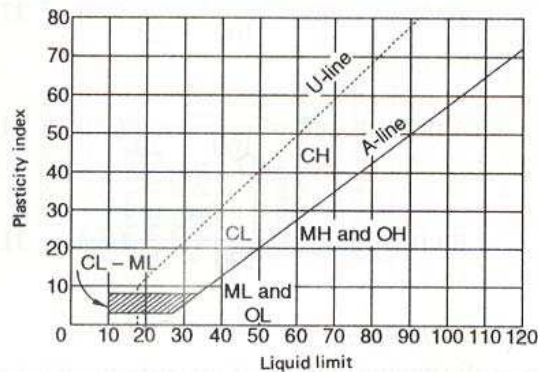
Refers to the total number of blows required to drive the Split Spoon sampler tube the final 12 inches of the 18 inch drive.

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 Designation D-2487)

Major division	Group Symbols	Typical Names	Classification Criteria	
Coarse-grained soils More than 50% retained on No. 200 sieve	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean gravels	GW Well-graded gravels and gravel-sand mixtures, little or no fines GP Poorly graded gravels and gravel-sand mixtures, little or no fines GM Silty gravels, gravel-sand-silt mixtures GC Clayey gravels, gravel-sand-clay mixtures	$C_u = D_{60}/D_{10}$ Greater than 4 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting both criteria for GW Atterberg limits plot below "A" line or plasticity index less than 4 Atterberg limits plot above "A" line and plasticity index greater than 7
		Gravels with fines	SW Well-graded sands and gravelly sands, little or no fines SP Poorly graded sands and gravelly sands, little or no fines SM Silty sands, sand-silt mixtures SC Clayey sands, sand-clay mixtures	$C_u = D_{60}/D_{10}$ Greater than 6 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting both criteria for SW Atterberg limits plot below "A" line or plasticity index less than 4 Atterberg limits plot above "A" line and plasticity index greater than 7
		Clean sands	ML Inorganic silts, very fine sands, rock flour, silty or clayey fine sands 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 MH Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts CH Inorganic clays of high plasticity, fat clays OH Organic clays of medium to high plasticity	Check plasticity chart
	Sands More than 50% of coarse fraction passes No. 4 sieve	Sands with fines	Silty and Clays Liquid limit 50% or less	Silty and Clays Liquid limit greater than 50%
		Sands with fines		
	Fine-grained soils 50% or more passes No. 200 sieve	Silty and Clays Liquid limit 50% or less		
		Silty and Clays Liquid limit greater than 50%		
	Highly organic soils	Pt	Peat, muck and other highly organic soils	Fibrous organic matter; will char, burn, or glow



Note: U-line represents approximate upper limit of LL and PI combinations for natural soils

Plasticity chart for the classification of fine-grained soils.
Tests made on fraction finer than No. 40 sieve.

Unified Soil Classification System

Figure 18. UNIFIED SOIL CLASSIFICATION SYSTEM

Table 1.2 Description and classification of frozen soils (adapted from Linnell and Kaplar, 1966)

I: Description of soil phase (independent of frozen state)	Classify soil phase by the unified soil classification system				Classify soil phase by the unified soil classification system		Thaw characteristics
	Major group		Subgroup		Field identification	Pertinent properties of frozen materials which can be measured by physical tests to supplement field identification	
	Description	Designation	Description	Designation			
II: Description of frozen soil	Segregated ice not visible by eye	N	Poorly bonded or friable	NI	Identify by visual examination; to determine presence of excess ice, use procedure under note (3) and hand magnifying lens as necessary; for soils not fully saturated estimate degree of ice saturation (medium, low); note presence of crystals or of ice coatings around larger particles	In-place temperature Density and void ratio a. In frozen state b. After thawing in place Water content (total H ₂ O, including ice) a. Average b. Distribution Strength a. Compressive b. Tensile c. Shear d. Adfreeze Elastic properties Plastic properties Thermal properties Ice crystal structure (using optical instruments) a. Orientation of axes b. Crystal size c. Crystal shape d. Pattern of arrangement	Usually thaw-stable
			Well bonded	Nb			
			No excess ice				
			Excess ice	e			
III: Description of substantial ice strata	Ice greater than 25 mm thick	ICE	Individual ice crystals or inclusions	Vx	For ice phase, record the following as applicable Location Orientation Thickness Length Spacing Hardness Structure } per part III below Color Estimate volume of visible segregated ice present as percent of total sample volume Designate material as ice and use descriptive terms as follows, usually one item from each group, as applicable: Hardness: hard, soft (of mass, not of individual crystals) Structure: clear, cloudy, porous, candled, granular, stratified Color: colorless, gray, blue Admixtures: contains few thin silt inclusions	Same as part II above, as applicable, with special emphasis on ice crystal structure	
			Ice coatings on particles	Vc			
			Pandom or irregularly oriented ice formations	Vr			
			Stratified or distinctly oriented ice formations	Vs			
			Ice with soil inclusions	ICE + soil type			
			Ice without soil inclusions	ICE			

(see notes on p. 32)

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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BOREHOLE LOG

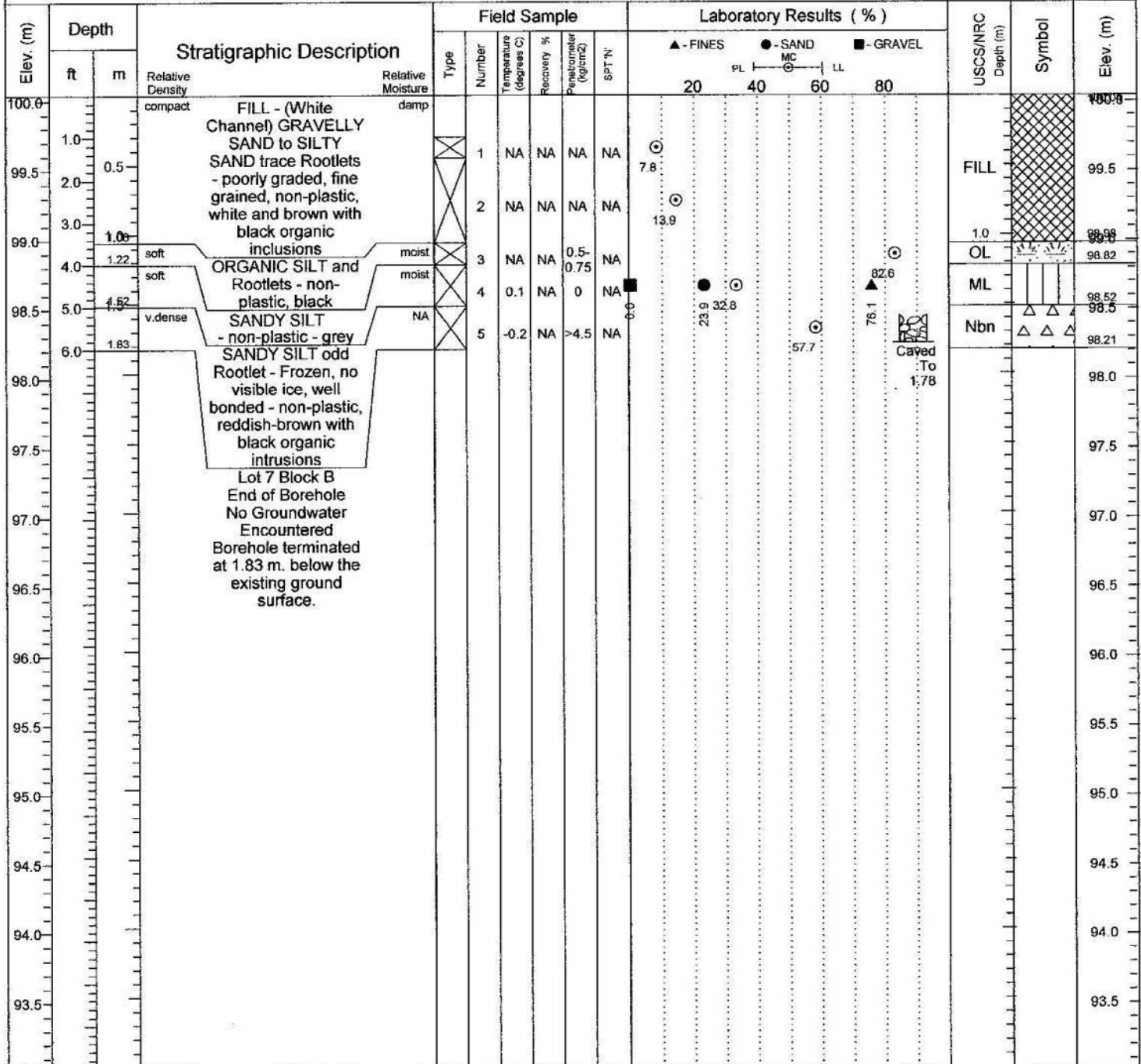
Client : Yukon Government - Energy, Mines & Resources
Location : Dawson, Yukon Lot 7 Block B
Project : Geotechnical Evaluation
Chilkoot Project No. : 200-006-15

Date Drilled: August 10, 2015
Elevation : 100.04 meters
Depth of BH: 1.83 meters
Instrumentation: NA

BOREHOLE

1-15

Sheet 1 of 1



Drilled By : Donjek Services
Drill Type : CME 750 (FN60)

Auger Type : 150 mm Solid Stem
Bit Type : Fish Tail

Water Level(s)
 During Drilling
 After Drilling
 At End of Drilling

Logged By : T.Dhara, P.Eng.
Date : August 10, 2015

Data Entry By : T.Dhara, P.Eng.
Date : Aug 15-21, 2015

Reviewed By:
Date : August 31, 2015



APPENDIX B

Results of Grain Size Distribution Analysis

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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 (867) 335-2085 chilkoot@northwestel.net



GRAIN SIZE ANALYSIS - ASTM D422-633

Client : Yukon Government - Energy, Mines & Resources
 Project : Geotechnical Evaluation
 Location : Dawson, Yukon
 Chilkoot Project No. : 200-006-15

Source : Lot 7 Block B
 Elevation : 98.82
 Depth : 1.22
 Sampling Method : Grab

SAMPLE NUMBER

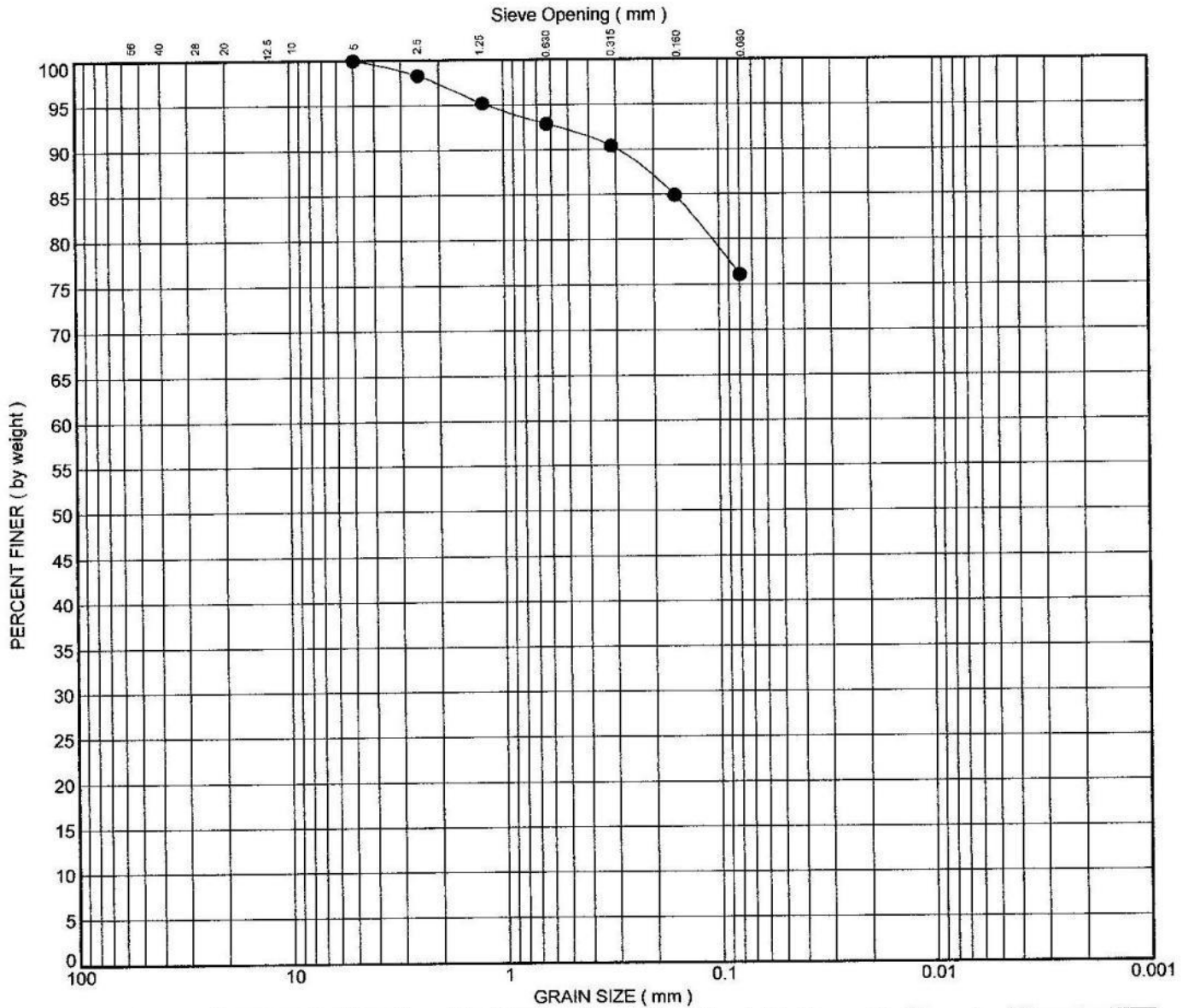
4

Material Description : **Sandy Silt**

USCS Classification : **ML**

Fracture (5 mm) :

Gravel (%)	Sand (%)	Fines - (%) <0.063 mm	Moisture (%)	D100	D60	D30	D10	Cc	Cu
0.0	23.9	76.1	32.8	5					



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sampled By : Chilkoot - T.Dhara
 Date : August 10, 2015

Received By : Chilkoot - T.Dhara
 Date : Aug 11, 2015

Analyzed By : Chilkoot - T.Dhara
 Date : Aug 12-14, 2015

Reviewed By:
 Date : August 31, 2015

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon
(867) 335-2085 chilkoot@northwestel.net



GRAIN SIZE ANALYSIS - ASTM D422-633

Client : Yukon Government - Energy, Mines & Resources
Project : Geotechnical Evaluation
Location : Dawson, Yukon
Chilkoot Project No. : 200-006-15

Source : Lot 7 Block B
Elevation : 95.73
Depth : 4.27
Sampling Method :

SAMPLE NUMBER

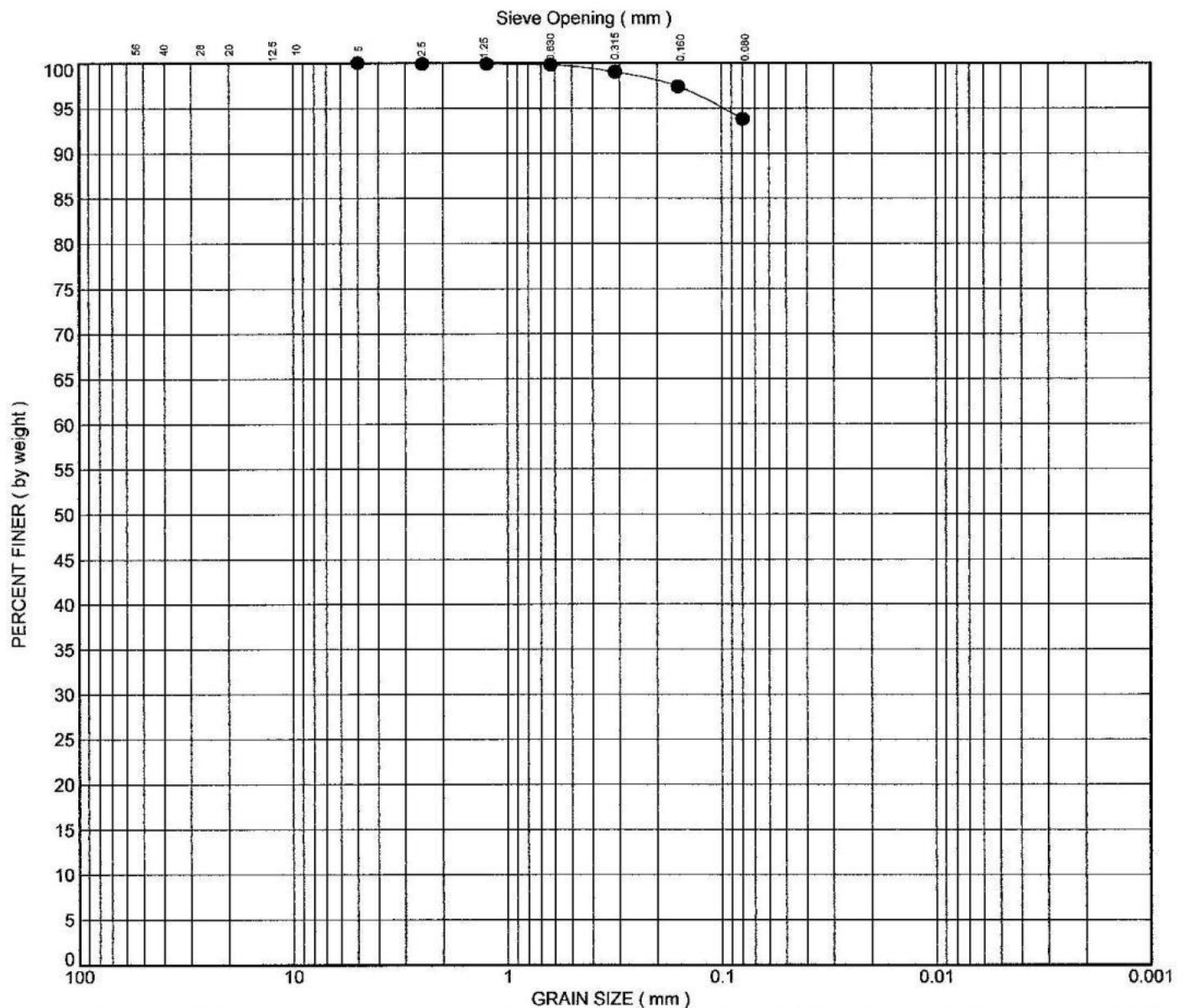
10

Material Description :

USCS Classification :

Fracture (5 mm) :

Gravel (%)	Sand (%)	Fines - (%) <0.063 mm	Moisture (%)	D100	D60	D30	D10	Cc	Cu
0.0	6.2	93.8	25.9	5					



GRAVEL		SAND			SILT	CLAY
		coarse	fine	coarse		

Sampled By : Chilkoot - T.Dhara
Date : August 10, 2015

Received By : Chilkoot - T.Dhara
Date :

Analyzed By : Chilkoot - T.Dhara
Date :

Reviewed By :
Date : August 31, 2015



APPENDIX C

Recommended Grain Size Distribution for Import 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	2-15
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



APPENDIX D – SELECTION OF PHOTOS



Photo # 1 (above) – Drilling BH 1-15 - As viewed from 7th Ave.



Photo # 2 (right) – BH 1-15 – Fill/Native soil interface.



Photo # 3 (left) – BH 1-15 Temperature Reading

Photo # 4 (right)

Site conditions -
Well on right
side of photo.

