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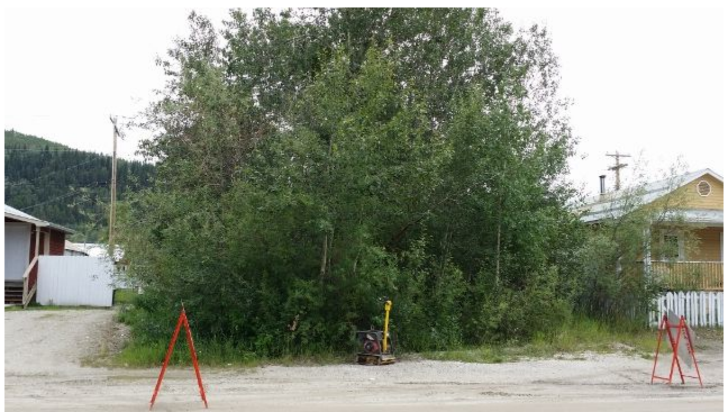
Geotechnical Evaluation and Limited Phase II Environmental Site Assessment Lot 2, Block HB, Haper Estate (8338A CLSR) Dawson City, Yukon – 2015



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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 2, Block HB located in the Haper Estate Stewart Menzies Subdivision in Dawson, Yukon. In addition, as our firm identified a potential environmental concern during the Phase I Environmental Site Assessment for the property, a sampling program was conducted to characterize the site in greater detail.

Specifically, the environmental concern was associated with the sites proximity to a former *White Pass* site. The *White Pass* company was commonly associated with poor environmental practices and fuel distribution.

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. The purpose of the limited Phase II ESA was to obtain a soil and water sample to allow for analytical analysis relative to potential hydrocarbon contaminants.

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 8th, 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 1st, 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 8th, 2015 *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 4.27 and 4.41 respectively.

Borehole Locations & Survey

Following completion of the drilling, the elevation of the boreholes were surveyed relative to the adjacent alleyway, 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 spot elevations taken on the adjacent roadways was noted to be in the order of 0.3 to 0.5 meters higher in elevation than those of the prevailing grades.

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.

In addition to the drilling samples, a single soil sample was obtained from a local low spot (noted in Figure 2) through hand sampling techniques. The sample was retained from soils located directly below a 0.1 meter thick organic mat which was encountered at this location.

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 2.44 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 E.

2.3 Laboratory Work Program

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

2.3.1 Physical Laboratory Analysis

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.

2.3.2 Analytical Laboratory Analysis

An analytical laboratory work program was conducted in order to characterize the levels of hydrocarbon contaminants in a soil and water sample retained during the field work program. In addition, the water sample was analyzed to determine its metals content.

The analysis was conducted between August 13th and 19th, 2015 at our laboratory sub-consultants *EXOVA*'s laboratory facilities. The results of the analytical analysis have been enclosed in Appendix C.

In brief, the result of the soil analysis indicated heavy extractable petroleum hydrocarbon (HEPH) levels of 1140 ppm. These readings exceed the allowable corresponding *YG - Contaminated Site Regulation* residential standards of 1000 ppm.

3.0 SITE CONDITIONS

3.1 General

The subject property is comprised of historically disturbed land which is currently vacant. The lot was however vegetated with trees and willow bush.

3.2 Legal Description and Site Location

The legal description of the subject property is;

Lot 2, Block HB, Haper Estate (8338A CLSR)

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

The subject property (a.k.a. 'site') is approximately 0.046 ± ha in size and is rectangular in shape (50' by 100'.

Access to the site is via 2nd Avenue which lies to the north 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.

The subject property is currently comprised of undeveloped land which is moderately vegetated. It's apparent that people have traversed the site as evidenced by miscellaneous incidental debris such as the odd pop can, plastic bag, etc.

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;

> *Floods*
>
> As with the majority of Dawson, the site would be prone to flood events if it were not for the protective dike which was established in the 1980's. The site would likely have been previously flooded prior to the establishment of the dike.

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.

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;
This unit was notably absent at the locations where the boreholes were advanced and may have been removed during previous site development.

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 fill extended to a depth of approximately 1.2 meters below the existing ground surface. As with all undocumented fills, the fill may contain rubble, scrap steel, high levels of fines/organics and/or other deleterious materials.

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 and valley deposits.

Unit # 2 –Peat/Organic Stratum;

The peat/organic stratum which typically underlies the fill in Dawson was notably absent at the borehole locations. However, as black organic inclusions were encountered in the upper realm of the Unit #3 materials, the stratum was likely present but may have been stripped (from this area) during historical lot development.

Unit # 3 – Alluvial Channel Deposits;

Alluvial channel deposits were encountered at a depth of 1.06 and 0.75 meters in BH 1-15 and BH 2-15, respectively.

The deposits were comprised of moist, non-plastic silt which contained varying amounts of clay, sand and gravel as well as organic inclusions and rootlets. The deposit was noted to grade coarser with depth to a silty and gravelly sand. Cobbles (and possibly boulder sized materials) may be 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.

Unit # 4 – Alluvial Valley Deposits;

Alluvial valley deposits comprised of sandy gravel were encountered below the fine grained channel deposits at a depth of approximately 2.45 meters and 2.30 meters, in BH 1-15 and BH 2-15, respectively.

These soils were noted to be well washed, suggesting the presence of a fluctuating groundwater table. The groundwater table was encountered in each of these boreholes within this soil unit at a depth of approximately 3.4 to 3.5 meters

The boreholes were terminated within the soil unit at a depth of 4.27 and 4.41 meters, respectively.

Groundwater

The depth to groundwater was noted at 3.42 and 3.47 meters below the existing ground surface in BH 1-15 and BH 2-15, respectively.

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

Although there was no evidence of permafrost, Dawson lies within the zone of widespread discontinuous permafrost. The permafrost can vary from poorly bonded soils with non-visible ice to massive ice lenses ranging in size to tens of meters. Regionally the permafrost is probably more than 100 meters thick with taliks (thawed subsurface) present beneath large rivers (and lakes) and beneath south-facing slopes.

Bedrock

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

4.0 DISCUSSIONS

The analytical results of the soil sample retained from the site noted hydrocarbon (HEPH) contaminants which exceeded the recommended soil criteria relative to residential standards.

The groundwater sample retained from the monitoring well however, did not show any signs of hydrocarbon contamination.

With the exception of the iron content, the metals analysis of the water sample retained from the monitoring well did not exceed any of the limits set forth by the *YG – Contaminated Site Regulations* (*CSR)*. The levels of iron exceeded the CSR criteria to protect against taste and odor concerns.

Following adequate site remediation, the existing subsurface conditions would allow for the construction of a granular pad upon which a residence could be supported on a PWF cribbing and ventilated crawlspace type of foundation system. Although thawed ground conditions were encountered, the construction of conventional footing or slab-on-grade foundation systems would not be recommended as regional fluctuations in the thermal and groundwater regime may affect the long-term performance of the structure.

5.0 ENVIRONMENTAL RECOMMENDATIONS

As the retained soil sample exceeded the limits for hydrocarbon contamination, additional sampling should be conducted to better characterize its extent and other site locations. Given the existing tree cover, the characterization should be conducted by implementing a hand sampling program. The program should involve utilizing a hand auger to retain soil samples from the ground surface to depths of~ 1 meter, in anticipation that the contamination is limited to the near surface soils. If following the hand sampling program contamination is encountered to depths of 1 meter, clearing operations may be required to allow for drill rig access to obtain samples from greater depths.

Additional water samples should be retained to reconfirm the groundwater conditions.

Caution should be exercised during site remediation to ensure that backfill materials are comprised of clean, well-graded granular materials that are compacted to the required (80 mm minus) sub-base specifications contained within the recommendations provided herein within the limits of the building load envelope. Otherwise, poorly compacted backfill will become a liability during future site development.

6.0 GEOTECHNICAL RECOMMENDATIONS

6.1 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.

6.2 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.

6.3 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.

6.4 Deleterious Materials

Following clearing and grubbing operations, the near surface organics should be removed and a level sub-grade surface should be prepared. The exposed sub-grade surface should be 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 6.7.

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.

6.5 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.

6.6 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.

6.7 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	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, ± 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 may 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.

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

Considering the local site elevations, the granular pad should be constructed such that the prepared surface is in the order of 1 meter higher in elevation than the prevailing road grades.

6.8 Filter Fabric

Due to the potential degradation of the excavation base and other exposed materials over time, 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.

6.9 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.

6.10 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.

6.11 Inclement Weather

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

6.12 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.

6.13 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.

6.14 Temporary Stockpiles

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

6.15 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.

6.16 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, ± 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.

6.17 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.

6.18 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.

7.0 CONCLUSIONS

As the results of the chemical analysis noted hydrocarbon limits within the soil that exceed the recommended *CSR* criteria, the site would be considered contaminated in accordance with the regulations. As such, additional characterization as per the above noted environmental recommendations should be conducted to better assess potential site remediation options.

Following site remediation, the (geotechnical) sub-surface conditions encountered will allow for construction of a 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.

8.0 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.

PROFESSIONAL #1277 YUKON TARES DHARA TERRITORY ENGINEER

PERMIT TO PRACTICE
Signature
Date September 8, 2015
PERMIT NUMBER: PP025
Association of Professional Engineers of Yukon

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TD/td