

**CHILKOOT GEOLOGICAL ENGINEERS LTD.**

5b Bennett Road, Whitehorse, Yukon Y1A 5Z4  
chilkoot@northwestel.net (867) 335-2085 c



**Geotechnical Evaluation  
Proposed 2<sup>nd</sup> Avenue Upgrades  
Dawson City, Yukon – 2014**



**Prepared For:** Yukon Government – Energy, Mines and Resources

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## 1.0 INTRODUCTION

*Chilkoot Geological Engineers Ltd.* was retained by the *Yukon Government (YG) - Energy Mines and Resources* to conduct a geotechnical evaluation along 2<sup>nd</sup> Avenue from Edward Street to Judge Street in Dawson City, Yukon as noted in Figure 1.

The purpose of the evaluation was to characterize the sub-surface soil conditions along 2<sup>nd</sup> Avenue and assess the regions overall feasibility to allow for;

- an extension of 2<sup>nd</sup> Avenue subsurface utilities from Edward Street to Judge Street,
- road upgrades, and
- future lot development on either side of the avenue assuming engineered cribbing types of foundation systems.

Authorization to proceed was granted on September 1<sup>st</sup>, 2014 by *YG - Energy, Mines and Resources - Lands Management Branch - Lands Availability Manager, Mr.R.Gorczyca.*

The field work was conducted between October 16<sup>th</sup> & 18<sup>th</sup>, 2014 in accordance with our August 15<sup>th</sup>, 2014 Proposal following completion of the sub-surface utility locations. The laboratory work was subsequently conducted at our Whitehorse laboratory on October 19<sup>th</sup> and 20<sup>th</sup>, 2014. Our findings of the collated data have been presented herein. With the exception of the drilling component which was conducted by our sub-contractor *Donjek Services*, all work was conducted by the undersigned.

The methodology our firm utilized to conduct the evaluation has been provided below.



## 2.0 METHODOLOGY

Our work methodology was comprised of a literature review as well as 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 predominately underlain by green schist to lower amphibolite facis metamorphic rocks of the Yukon-Tanana Terrane.

#### *Archives*

A search of YG's – *Department of Tourism and Culture - Yukon Archives* located a hand drawn picture of Dawson entitled 'Birdseye view of Dawson' drawn by Dr.J.Bell in 1903. The picture depicts Dawson as it was viewed



from West Dawson on the north bank of the Yukon River and has been attached as Figure 2.

The historical drawing shows the presence of residential houses and warehouses located along 2<sup>nd</sup> Avenue.

### ***Aerial Photographs***

A selection of aerial photographs which were obtained from the *YG – EMR Library*, were reviewed to assess the potential use of the subject and neighboring properties. The following aerial photos were reviewed;

A22199 #50-51	September 20, 1970
A27857 #75-77	August 28, 1993

Selections of the above noted aerial photographs have been attached in Figure 3. The 1993 aerial photos shows a considerable amount of clearing was conducted in the region west of 2<sup>nd</sup> Avenue and between Edward Street and George Street. This area has since become overgrown.

### ***Sub-surface Utility Plans***

The *City of Dawson – Public Works Department* was contacted to obtain plans which denoted the locations of nearby sub-surface utilities. In brief, the sub-surface utility plans noted the presence of water lines and sanitary sewers located on 2<sup>nd</sup> Avenue, south of Edward Street. The storm drains were noted along Albert Street.

A copy of the water and sanitary plans obtained from the department has been attached as Figure 4.



## 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 conducted to note the field conditions at the subject property on October 10<sup>th</sup>, 2014. Our observations have been presented in Section 3.3 – Site Description, below.

### *Utility Locates*

Utility locates were conducted prior to drilling in order to confirm that the proposed borehole locations were clear of potential underground hazards. This involved contacting *Northwestel*, *Yukon Energy Corporation Ltd (YECL)*, and the *City of Dawson* prior. In brief, while there were local subsurface lines located along 2<sup>nd</sup> Avenue south of Edward Street (as noted in Figure 4), the adjacent roadways, and proposed borehole locations were free of underground utilities.

It was understood that the existing utilities are located in the order of 3 meters below the existing road grades.

### *Drilling Program*

The drilling program was conducted on October 16<sup>th</sup> and 17<sup>th</sup>, 2014 by *Donjek Services* utilizing a CME-750 drill mounted on an FN-60 tracked Nodwell. The drill was employed under the direction of *Chilkoot Geological Engineers Ltd.*

The program was comprised of advancing four (4) boreholes in order to obtain soil samples and characterize the subsurface conditions. The boreholes were advanced utilizing 150 mm Ø solid-stem continuous flight augers to an average depth of 7.1 meters.



The approximate locations of the boreholes have been plotted on Figure 5 relative to prominent site features.

#### *Borehole Locations & Survey*

Following completion of the drilling, the elevation of the boreholes and prominent roadway features were surveyed relative to the intersection of Edward Street and 2<sup>nd</sup> Avenue, utilizing a (*Leica LR Rugby*) laser level. The road surface at this location was given an arbitrary elevation of 100.00 meters. A level survey noted a vertical relief of ~ 10 meters along 2<sup>nd</sup> Avenue between Edward and Judge Streets. The elevations of the boreholes have been noted on the Soil Logs enclosed in Appendix A and have been plotted on Figure 5.

#### *Soil Logs*

During drilling, field soil logs were maintained by the undersigned. The following information was maintained;

##### Soil description

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

##### Sample depths and types

##### Depth of groundwater

##### Other pertinent geotechnical information

##### Comments regarding drilling effort

##### Temperatures -

Intermittent temperature readings were recorded utilizing a digital-thermometer (TPI Model 342, Type K Thermocoupler).

##### Unconfined Compressive Strength -

A *Humboldt Manufacturing Ltd.* pocket penetrometer was intermittently utilized on cohesive (fine-grained) soils to



provide relative estimates (in  $\text{kg/cm}^2$ ) of the materials unconfined compressive strength.

#### Material Classification -

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

This 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*' the '*Unified Soil Classification System*' and the '*Classification for Frozen Soils (adapted by Linnell and Kaplar, 1966)*', for reference purposes.

#### *Sampling Program*

Soil samples were retained at regular intervals (approximately 2 samples per 1.5 meters) during the field work by obtaining grab samples directly from the auger flighting.

A total of thirty-six (36) soil samples were retained.

Once the samples were retained, they were described on the field soil logs. The samples were then 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 described in Section 2.3, below.



### *Borehole Termination*

The boreholes were terminated at an average depth of 7.1 meters below the existing ground surface, but varied between 4.88 (BH 1-14) and 10.36 meters (BH 3-14). Refusal was not encountered in any of the boreholes.

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 boreholes collapse (to assess the relative degree of soil densities). In brief, the borehole sidewalls were noted to collapse approximately 1.05 meters.

Bentonite pellets were placed at the interface between the fills and organic strata in accordance with good drilling practices in order to separate potential hydrological zones.

### *Monitoring Well Installation*

A 2" diameter ABS monitoring well was installed in BH 3-14 to a depth of approximately 9.64 meters below the existing ground surface to allow for future monitoring of the local groundwater conditions.

The lower 6.1 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 bentonite plug was installed to seal the annular space in accordance with good installation practices.

Access to the well was restricted through a 4" diameter lockable steel casing which was concreted into the existing ground surface and extended approximately 1 meter above the existing ground surface.



### *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 C.

## **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 October 19<sup>th</sup> & 20<sup>th</sup>, 2014 at our Whitehorse laboratory facilities.

In brief, the analysis was comprised of natural moisture content determination and visual laboratory classification of all thirty-six (36) 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 twelve (12) 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.



### **3.0 SITE CONDITIONS**

#### **3.1 General**

The 2<sup>nd</sup> Avenue area of Dawson lies in a region which has been historically developed but now lies predominantly dormant. A number of adjacent lots have been developed with residential dwellings. The remainder of the region, on either side of 2<sup>nd</sup> Avenue, are treed and harbor a willow bush understory.

#### **3.2 Site Location**

The subject area is located in the North End Subdivision in Dawson, Yukon, as noted in Figure 1.

#### **3.3 Site Description**

The topography of the region varies. The southern half of the site is predominately level. The elevations rise in the mid-section of 2<sup>nd</sup> Avenue as one traverses to the north, culminating in an elevation gain in the order of 10 meters at Judge Street. The topography and vegetation of northern portions of the study area suggested that it may be bedrock controlled.

In the lower half, there were some regions located on either side of 2<sup>nd</sup> Avenue where the road elevations are in the order of 1-2 meters above the adjacent prevailing grades where swampy and poorly drained conditions were noted.

Locally, the surface drainage is undefined. The prevailing elevations suggest regional site drainage is towards the south-west and west. Standing water can be expected in the local area depressions during the summer months.



Local site development and residential construction is occurring on a number of properties along 2<sup>nd</sup> Avenue, south of Edward Street. The developments appear to be comprised of granular fill placement upon which cribbing and residential houses are being constructed. Several residences are also located along 2<sup>nd</sup> Avenue north of Edward Street.

While a Phase I Environmental Site Assessment of the region has not been conducted, given the historical development of Dawson, it can be expected that the lots adjacent to 2<sup>nd</sup> Avenue harbor buildings remnants and miscellaneous debris.

### **3.4 Geomorphology**

The geomorphology of this region of Dawson is complex as the study area transects several distinct geomorphic regions as outlined in Figure 6. The boundaries in Figure 6 are for illustrative purposes only. The actual boundaries will vary in the field.

In brief, from north to south, these units are comprised of remnants of a slide debris field which overlies potential bedrock (BH 4-14) and alluvial deposits (BH 3-14), a potential slew region which may harbor thicker organic and fine-grained alluvial channel deposits, marsh-like regions which exhibit signs of poor drainage and standard (BH 1-14 & BH 2-14) stratigraphic sequences (Soil Units 1-4 as described in Section 3.7).

#### ***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 are regionally present;



### *Mass Wasting/Creep*

The site is located within the limits of a debris field which originated from a prominent slide area, the head-scarp of which is located ~ 650 meters to the north. The approximate limits of the debris field have been noted on Figure 7.

Central regions of the debris field are known to be undergoing 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 central regions of the debris field are undergoing movements at a rate of up to 5 cm/year.

### *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 have been previously flooded prior to the establishment of the dike given its close proximity to the Yukon River.

## **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 recent development. The historical fills overlie the above noted native deposits and are typically coarse grained but may also contain an appreciable amount of fines and deleterious materials.

Historically, lower elevations in this region of Dawson are known to be poorly drained and swampy. Locally, slide debris was noted in the higher elevations within the study area.

### **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. The northern portions of the site appeared to be underlain with decomposed weathered bedrock which were encountered at shallower depths of ~ 5.5 meters.

### **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 were encountered can be classified fills (or slide debris) which overlay native soil deposits or decomposed bedrock. The soil units can be described as;

#### **Unit # 1 – Fill/Slide Debris;**

which are coarse grained and contain an appreciable amount of fines, overlying;



**Unit # 2 – Peat/Organic Stratum;**

which are wet and rich in organics and organic silt, overlying;

**Unit # 3 – Alluvial Channel Deposits;**

which are predominately silty in nature, but may contain finer clay sized materials and/or coarser 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 these soil units has been provided below.

**Unit # 1 – Fill & Slide Debris (Rubble)**

The surficial soil unit was comprised of either fill or else slide debris (a.k.a. rubble).

Approximately 0.45 meters of fill was encountered along 2<sup>nd</sup> Avenue. These fills are comprised of predominately coarse grained materials which contain varying amounts of fines and organics and have been utilized as the existing road base materials.

These fills are also known to contain miscellaneous deleterious materials such as wood chips, organic inclusions and silt nodules. As with all undocumented fills, the fill may contain rubble, scrap steel, high levels of fines/organics and/or other deleterious materials. Given the sites location in the historical Sawmill District in Dawson City, varying amounts of sawdust, scrap lumber and wood chips may also be encountered.

Approximately 2.6 and 4.9 meters of slide debris (rubble) was encountered in BH 3-14 and BH 4-14, respectively. This material was comprised of predominately sandy



gravel with some silt and contained fractured rock in size to 150 mm. These deposits overlay;

### **Unit # 2 –Peat/Organic Stratum;**

A peat/organic stratum underlay the fill (and rubble) at an average depth of 1.78 meters in BH 1-14 to BH 3-14. The soil unit was absent in BH 4-14 where higher elevations were encountered.

The peat is organic rich, wet to saturated and compressible in nature. The soil unit is comprised of a veneer of organics and rootlets which overlie organic rich silt. The soil unit measured on average 1.88 meters thick but varied between 0.92 (BH 2-14) and 2.9 meters (BH 3-14). These deposits may be thicker in the regions of the marsh and slew areas. This soil unit overlay;

### **Unit # 3 – Alluvial Channel Deposits;**

Alluvial channel deposits were encountered at an average depth of 3.05 meters in BH 1-14 to BH 3-14. These deposits were absent in BH 4-14.

The deposits were comprised of moist to wet, non to low plastic silt which contained varying amounts of clay, sand and gravel. Due to the nature of channel deposition, this deposit was noted to grade coarser with depth although it may also contain regions of predominately organic deposits which would result from channel infilling. Cobbles and possibly boulder sized materials may be encountered near the base of this deposit. This soil unit overlay;

### **Unit # 4 – Alluvial Valley Deposits;**

Granular alluvial deposits were encountered below the channel deposits at an average depth of 4.27 meters in BH 1-14 and BH 2-14. These deposits are likely also present in the region of BH 3-14 although none were encountered despite 10.36 meters of borehole advancement. These deposits were not encountered in BH 4-14 where



higher elevations and potential bedrock conditions were prevalent. These deposits will likely be encountered at depths  $> 4.3$  meters as one traverses west towards the Yukon River.

Based upon the undersigned's past experience, these soils are clean and comprised of coarse grained granular soils. The soil unit is likely frozen, thaw stable, extremely dense and contains cobbles and possibly boulder sized materials. Given the geomorphology they may also include organics, ice lenses and other deleterious materials.

### ***Groundwater***

While groundwater was not encountered during the investigation, the observation wells installed in borehole BH 3-14 should be monitored on a regular basis to characterize the groundwater regime as it may vary over time. The well installed along 2<sup>nd</sup> Avenue at Lot 8, Block 2, installed during the August 19, 2014 geotechnical evaluation should also be monitored.

### ***Permafrost***

The study area lies within a 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 m thick with taliks (thawed subsurface) present beneath large rivers and lakes and beneath south-facing slopes. These thawed areas may also be encountered where the region has been previously cleared.

Permanently frozen soils were encountered in each of the four (4) boreholes at an average depth of 2.28 meters, but varied between 1.52 meters (BH 2-14) and 2.89 meters (BH 3-14). A granulated ice lens up to 630 mm thick was noted in BH 4-14.



The frozen soils were classified in accordance with the *National Research Council Classification System*, as;

V<sub>x</sub> – indicating individual ice crystals or inclusions less than 1 mm. in size and approximately 1 % ice saturation by volume.

N<sub>bn</sub> – indicating segregated ice not visible by eye, well bonded with no excess ice.

N<sub>be</sub> - indicating segregated ice not visible by eye, well bonded with excess ice.

Ice & Silt – indicating the presence of ice greater than 25 mm in thickness along with the primary soil component.

### ***Seasonal Frost***

The soils encountered would generally be exposed to seasonal frost to depths of approximately 1.8 meters. This depth of penetration would vary depending upon the thickness of the organic strata (Soil Unit # 2) which acts as insulation for the underlying soils. At the time of our evaluation, the seasonal frost penetration was noted to be ~ 300 mm.

### ***Cobbles and Boulders***

Cobbles and potential boulders would be present within the base of the alluvial channel deposits (Soil Unit # 3) and throughout the underlying alluvial valley deposits (Soil Unit # 4).

### ***Bedrock***

There was no indication of competent bedrock within the boreholes which were advanced. However, BH 4-14 encountered what appeared to be decomposed regolithic materials at a depth of 5.49 meters.



Given the higher elevations and the proposed utility extensions proximity to the prominent slide area, the potential for encountering bedrock along 2<sup>nd</sup> Avenue would generally increase as one progresses north along 2<sup>nd</sup> Avenue, particularly north of George Street.



## 4.0 DISCUSSIONS

While individual and local developments have been ongoing through recent times, to our knowledge, a truly integrated land-use management plan, which considers long-term thermal impacts of individually isolated projects, residential cut/fill operations and private developments, has not been carried out to date and so this should be considered from a project management perspective.

While not insurmountable, the subsurface conditions which will be encountered in this region of 2<sup>nd</sup> Avenue will pose additional challenges relative to standard construction during sub-surface utility installation, road upgrades and residential construction given the presence of fill, slide rubble, compressible organics, permafrost and potential groundwater and bedrock.

The proposed development area can be separated into the approximate geomorphic areas illustrated in Figure 6. The development potential between these areas will vary dependent upon the soil and permafrost conditions. In general, the regions north of the debris field limits and other well drained areas will have reasonable residential development potential. The regions located within the marsh and poorly drained areas will be less favorable for residential development. The slew region will likely have poor development potential, particularly if thick zones of compressible organics are encountered in these areas. Larger mixed commercial/residential projects which are undertaken by private developers and/or Territorial Agencies, may provide more viable long-term development options in these regions.

As with most construction projects in Dawson, the challenge is to minimize both differential and long-term movements which depend upon the in-situ and constructed conditions and thaw degradation of the permafrost regime. Degradation of the local or regional permafrost is not desirable and as such, efforts should be undertaken to protect the thermal regime.



The use of standard concrete footing and/or slab-on-grade systems will not be feasible (without costly development) in the region due to the presence of underlying permafrost and compressible soils. As such, based upon our findings, light residential building(s) should be supported by standard (PWF) cribbing and ventilated crawlspace foundation system founded on an approved granular pad which extends a minimum of 1.8 meters below the underside of the PWF pad footing. Long-term maintenance will be required throughout the life of the structure(s) to periodically level the residences (on the cribbing) to accommodate fluctuations in underlying soil volumes and overall site conditions.

As with all sub-surface utilities in Dawson City, the long-term structural integrity cannot be assured and so some amount of maintenance will be required intermittently to accommodate the sub-surface conditions.



## 5.0 RECOMMENDATIONS

### 5.1 General Recommendations

#### 5.1.1 Summary

Based upon the information obtained during our investigation, the installation of sub-surface utilities through conventional excavation/backfill construction methodologies will be feasible along 2<sup>nd</sup> Avenue, however, additional consideration will be required where permafrost is encountered at the installation depth. In addition, given the regional location of the proposed installation, the potential for encountering bedrock exists and this should be taken into consideration from a project management perspective.

If the proposed installation depths are in the order of 3.3 meters below the existing ground surface, then the excavation base materials will likely be comprised of materials noted at the interface between Soil Unit # 3 and # 4. These soils would likely be in a thawed state.

The installation of the water and sanitary utilities in separate trenches should be considered to protect the water-line from potential contamination in the event of a break in the sanitary line. As a minimum, if placed in the same trench, the water line should be placed above the sanitary line.

The proposed building may be supported by a cribbing and ventilated crawlspace foundation system founded upon an approved granular base constructed in accordance with recommendations provided herein.

#### 5.1.2 Deleterious Materials

The existing native materials are generally considered unsuitable for use as trench (or structural) backfill. However, if granular materials are encountered, they can be



considered suitable provided that they are placed in 300 mm. thick lifts and compacted as directed by qualified geotechnical personnel.

Exposed sub-grade surfaces should be inspected by qualified geotechnical personnel to assess the suitability of the prepared sub-grade surface on a case-by-case basis. The organic soils are highly compressible and so additional consideration may be required if they are exposed at the sub-grade elevation.

Excavation of the near surface onsite fills will be required allow for subsequent backfill utilizing non-frost-susceptible materials in accordance with Section 5.4.5 – Structural Fill.

Depending upon the composition, select granular fill materials can be utilized as general purpose (non-structural) fill so long as the materials are compacted to approximately 95% of the materials corresponding maximum proctor density at (or near) the materials optimum moisture content.

Excavated materials which are frozen, have high moisture content or are saturated, will not be suitable for re-use and so should be hauled to waste.

### ***5.1.3 Excavations***

Excavation should be conducted utilizing a heavy tracked excavator (equipped with a clean-up bucket) to minimize disturbance to the sub-grade materials. If dense/frozen soils are encountered, then a digging/frost bucket may be required, although caution should be exercised such that loose, disturbed, remolded or slough materials do not remain in the excavation. If a prepared founding surface cannot be prepared through mechanical means, then hand cleaning may be necessary.

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.

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.

#### ***5.1.4 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 and assist in bridging soft compressible areas. 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. Caution should be exercised such that the fabric is not torn or compromised during aggregate placement

#### ***5.1.5 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.

#### ***5.1.6 Inclement Weather***

Excavations, sub-grade and construction materials should be protected from drying, freezing, snow and surface/groundwater at all times. Special attention should be given during construction operations that occur during periods of heavy precipitation and other inclement weather that may have an effect upon construction and subsurface conditions. Any water, snow or ice that accumulates in the excavation(s) should be removed forthwith.

#### ***5.1.7 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. However, as cobbles (and potential boulders) may be present in the fill materials, a 0.5-1.0 meter wide bench should be incorporated into the excavation profile at the transition between loose and dense soils as directed by qualified geotechnical personnel.

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 evaluated at the time of construction.



If large cobbles or boulders are encountered in the trench sidewalls or slopes within the native deposits, they should be removed to allow for safe working conditions.

Slope stability will be poor where soft, wet/saturated materials, fills or recently dewatered materials are encountered and more gradual cut slopes (in the order of 2 to 1, horizontal to vertical) may be required in these areas to minimize the potential for slope failure.

Where frozen materials are encountered, trench sidewalls will be relatively stable although some slumping and surface degradation will occur if the material is allowed to thaw.

#### ***5.1.8 Surface and Groundwater***

Surface and groundwater should be removed from excavations at all times during construction.

As groundwater may be encountered during construction, the Contractor should be prepared to conduct construction dewatering operations throughout the course of foundation preparation and sub-surface utility installations. Surface and groundwater should be removed from excavations at all times during granular pad construction to ensure a dry working area.

The contractor should be aware of potentially undesirable effects that may be caused by dewatering, particularly if groundwater influx is considerable. These effects may include slumping of excavation sidewalls and settlement of surrounding areas (structures) due to a decrease in pore water pressures. 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.



Local areas should be graded to direct drainage away from the excavation and temporary stockpiles.

#### ***5.1.9 Temporary Stockpiles***

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

Frozen materials which are excavated during the work will not be suitable for re-use and should be hauled to waste. These materials should not be stockpiled onsite as these materials will liquefy during thaw degradation.

#### ***5.1.10 Construction Monitoring and Testing***

A Geotechnical Consultant should be retained to review the design and the intended methods of construction prior to construction tender, in order to verify conformance with the geotechnical restrictions and assumptions provided in this report.

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 confirm the suitability of proposed imported fills through laboratory testing, and to verify that adequate compaction has been attained through in-situ field density (compaction) testing.



## 5.2 Sub-surface Utilities

### 5.2.1 *Proposed Construction Materials & Backfill*

The proposed utilities should be comprised of heavy duty HDPE pipe and utilize electro-fusion type connections. The pipes should be well insulated to prevent freezing by means of soil cover, physical coating, heat trace or combinations thereof.

Underground utilities should be placed on a minimum of 450 mm thick layer of bedding sand (or else 10 mm minus clear stone) which conform to the gradation specified in Appendix B – Imported Fill and is placed and compacting in accordance with the recommendations provided herein.

A minimum cover of 300 mm. of bedding material should be provided on all sides of the pipe to protect the utility from oversize materials and potential damage during backfill.

The bedding sand should be compacted to 95 percent of its Standard Proctor Maximum Dry Density at/near its optimum moisture content.

Where possible, underground utilities should be situated outside of building perimeters for ease of maintenance. If utility trenches are located within a 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 soft, compressible materials are encountered at the base of the trench excavation, then an open graded clear stone should be utilized in combination with filter fabric to bridge these areas. These materials may also be required in areas where groundwater or frozen materials are present.



The clear stone fill should be compacted utilizing a heavy duty diesel plate tamper or else double drum roller to the satisfaction of the geotechnical consultant. Caution should be exercised such that the underlying sub-grade materials are not disturbed. If clear stone is utilized as bedding material, it should be fully encased in filter fabric to prevent to the influx of fines from the adjacent soils and subsequent backfill.

All bedding materials should be placed in uniform, level lifts that measure 150 mm. thick (following compaction). The lift thickness can approach 300 mm. if the sub-grade conditions are considered poor by the retained geotechnical consultant and adequate densities are achieved.

Where utility trenches penetrate Unit # 2 – Organics and Unit # 3 – Alluvial Channel Deposits, the base of individual lot service trenches should be sloped away from the building (such that positive subsurface drainage is maintained and the potential for subsurface groundwater inflow from within the utility trench is minimized). The use of a trench plugs should be considered in the individual lot services.

### ***5.2.2 Staged Excavation/Backfill Operations***

Excavation and backfill operations should be staged such that the length of exposed trench at any given time is minimized in case construction difficulties are encountered or the weather deteriorates. Concurrent excavation and backfill operations should be considered.

The length of exposed trench would be dependent upon the proposed construction methodology, work effort employed and sub-surface conditions encountered at the proposed installation depths. These lengths should be determined prior to the time of construction but in general should measure no more than 60 meters in length.

The length of exposed trench should be minimized if permafrost is encountered in order to minimize thaw of the exposed sub-grade and native sidewall materials.



Installation of sub-surface utility pipe should be initiated from regions of lower elevations and progress to regions where higher elevations are present. These pipes should be well insulated to minimize thermal impacts to the adjacent native soils.

### **5.2.3 Design Considerations**

As long-term creep of the soil mass is likely, the sub-surface utility design should incorporate measures to allow for generally southern to south-western movement from the regions north of the debris field limits noted in Figure 6.

### **5.2.4 Proposed Schedule**

Given the presence of permafrost conditions near/at the proposed installation depths, we recommend that utilities be installed in the spring or fall to minimize degradation of the native soils. Additional consideration may however be required as inclement weather may be encountered during these seasons.

## **5.3 Road Structure**

The structure of the roadway surface will be dependent upon the condition and composition of the sub-grade materials and expected traffic loading. As a minimum, the road structure should be comprised of;

<b>Material</b>	<b>Thickness (mm)</b>	<b>SPMDD</b>
Base 20 mm. minus	200	98 %
Granular Sub-Base 80mm. minus	400	98 %
Approved Sub-grade	minimum 300	95 %

SPMDD – Standard Proctor Maximum Dry Density at Optimum Moisture Content

The use of a geotextile fabric may be required at the sub-grade interface depending upon the soil conditions encountered.



The sub-base and base materials should be placed in uniform, level lifts that measure no more than 200 mm. thick (as measured following compaction).

Ditches and drive-way access culverts should be incorporated into the design to maintain positive drainage.

As with all gravel roadways, regular maintenance will be required during the life-span of the roadway which may include placement/compaction of additional surfacing materials along with typical grading operations and winter sanding.

## **5.4 Residential Foundations**

### ***5.4.1 Geotechnical Evaluations***

Given the geomorphology of the native soils, the potential exists that the soils contain deleterious materials which may not allow for long-term use of the site. This would include the presence of massive ice lenses, thick organic deposits, liquefied soils and other similar geotechnical liabilities. As such, we recommend a geotechnical evaluation be conducted to verify the soil conditions within the perimeter of any proposed building load envelope once conceptual designs have been formulated. The sub-surface conditions should be assessed on a case-by-case basis to verify the suitability of the recommendations which have been provided herein.

### ***5.4.2 Allowable Bearing Pressure***

The allowable bearing pressure for light residential building structures 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.



### ***5.4.3 Excavation Parameters***

The excavation parameters will be governed by the underside of PWF cribbing pad elevation.

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 unless otherwise governed by material compositions of the adjacent side-slopes.

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

### ***5.4.4 Differential and Total 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. Additional measures should be considered to allow for long-term thaw-consolidation of regions where residential building construction is to be considered.

### ***5.4.5 Structural Breaks & Reinforcing***

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

#### 5.4.6 Structural Fill

Any residential buildings should be founded upon structural fill, comprised of an approved, clean, inorganic, well graded sand and gravel mixture which conform to the recommended grain size distribution for imported fill attached as Appendix B.

Considering the local elevations, residential granular pads should be constructed such that the pad surface is in the order of 1 meter higher than the prevailing road grade.

The granular pad should measure no less than 1.8 meters thick and should be comprised of the following;

#### *Structural Granular Pad*

UNIT	THICKNESS	COMPACTION <sup>C</sup>	COMPOSITION <sup>D</sup>
Base	150 mm <sup>A</sup>	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 <sup>B</sup>	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;

- <sup>A</sup> – 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.



- <sup>B</sup> – The thickness of this unit should be uniform through-out the building load envelope. The intent is to construct a 1.8 meter thick granular pad while maintaining at minimum 300 mm thick zone of existing fill above the organic soil stratum (Soil Unit # 2).

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 (Soil Unit #4 or decomposed bedrock) provided the site conditions 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.

- <sup>C</sup> – 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.

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.

- <sup>D</sup> - 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 geo-textile fabric.



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

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.

#### ***5.4.7 Crawlspace***

A ventilated crawlspace should be incorporated into the foundation design. Specifically, this would involve skirting the building perimeter with a sub-wall which incorporates a wire mesh or lattice work such that air flow below the structure is unrestricted during the winter months. As a minimum, the south side of the ventilated crawlspace should be well insulated to minimize the undesirable effects of the sun. These openings should be configured in such a manner that they can be opened during the course of the winter to allow for building heat to escape from beneath the structure. Alternately, the zone should be closed in the summer time to prevent exterior (warmer) air from impacting the constructed granular base and underlying permafrost.

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



## 6.0 CONCLUSIONS

The subsurface conditions encountered at the site will be suitable to allow for road upgrades and installation of sub-surface utilities. While feasible, the residential development potential will vary along 2<sup>nd</sup> Avenue.

The overall geomorphic conditions support the construction of standard PWF cribbing and ventilated crawlspace types of residential foundation systems founded upon structural granular pads, however, additional assessment will be required on a case-by-case basis once individual building sites have been identified. Some locations may not support building construction without costly development and so this should be considered.

Regardless of preventative measures which are incorporated into sub-surface utilities and residential foundations, soil movements will occur due to the geomorphology of the region. As such, regular maintenance will be required to repair sub-surface utilities and re-level residential structures to ensure that movements are kept to within tolerable amounts.



## 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 recommendations have been provided without considering the affects of deep and long-term thaw of local and/or regional permafrost which may stem from global warming, building/utility construction, or other causes. A detailed geotechnical evaluation and thermal assessment of any proposed building structure would need to be conducted if suitable founding conditions are to be assured.

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.

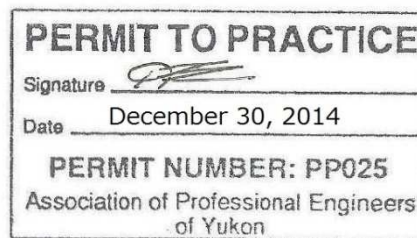
It is important to emphasize our evaluation is in fact, based upon random sampling and the results obtained at the borehole locations. Due to the geomorphological nature of the deposits encountered, interpolations of subsurface conditions between the borehole locations on the site have not been made or been implied. Should unexpected conditions be encountered during construction, our firm should be notified immediately in order to confirm the suitability of our recommendations. If required, our firm may alter or modify our recommendations and conclusions at such time.

## 8.0 CLOSURE

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

Respectfully Submitted,

## CHILKOOT GEOLOGICAL ENGINEERS LTD.



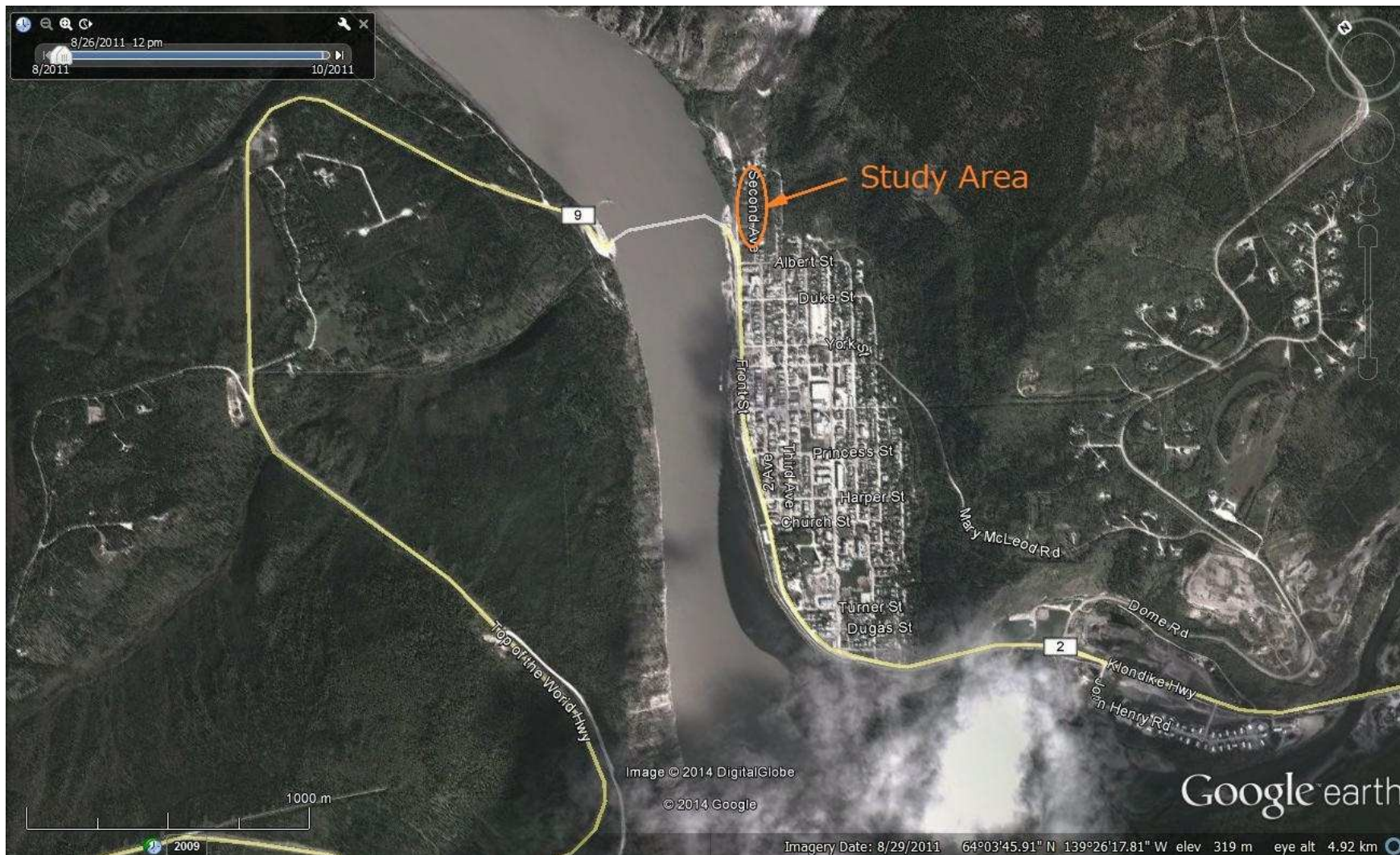
Tares Dhara, P.Eng.  
Senior Geotechnical Engineer

TD/td



Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

FIGURE 1 – Site Location





Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

FIGURE 2 – Historical (1903) Setting





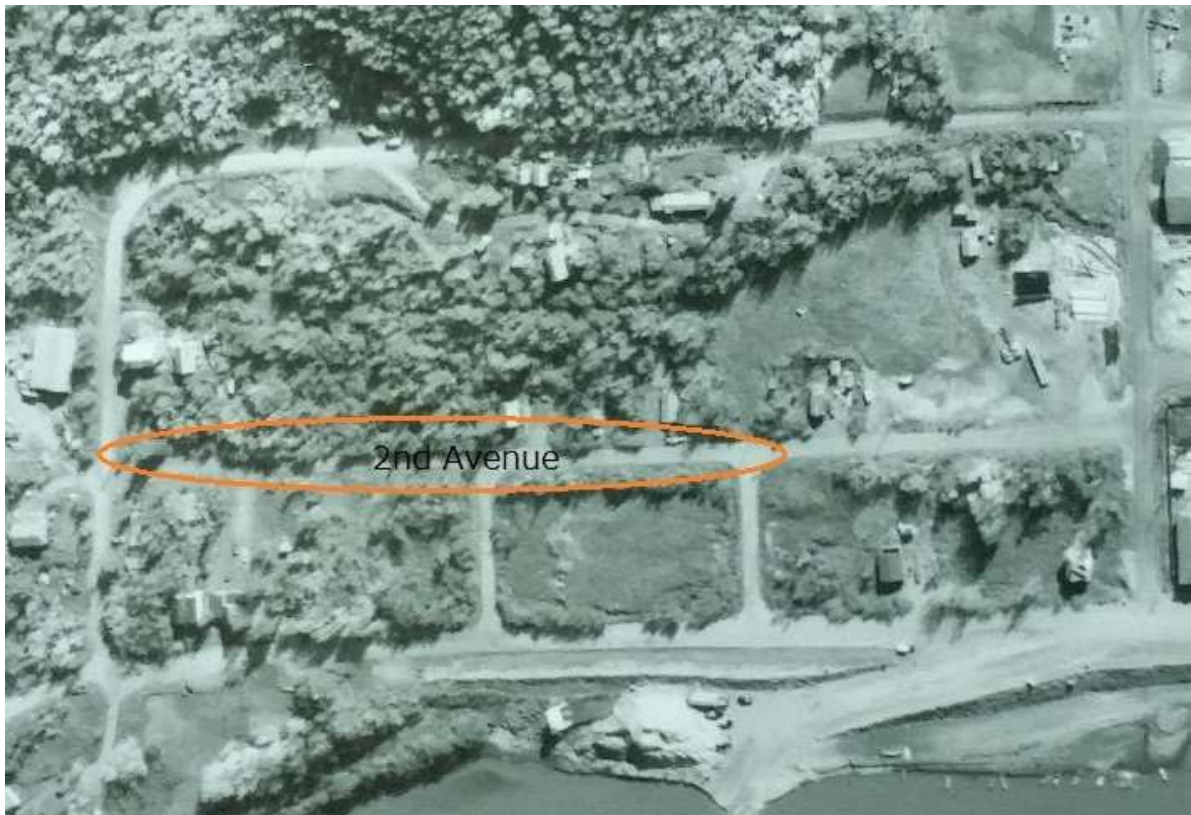
Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

FIGURE 3 - Airphotos



1970 (Above)

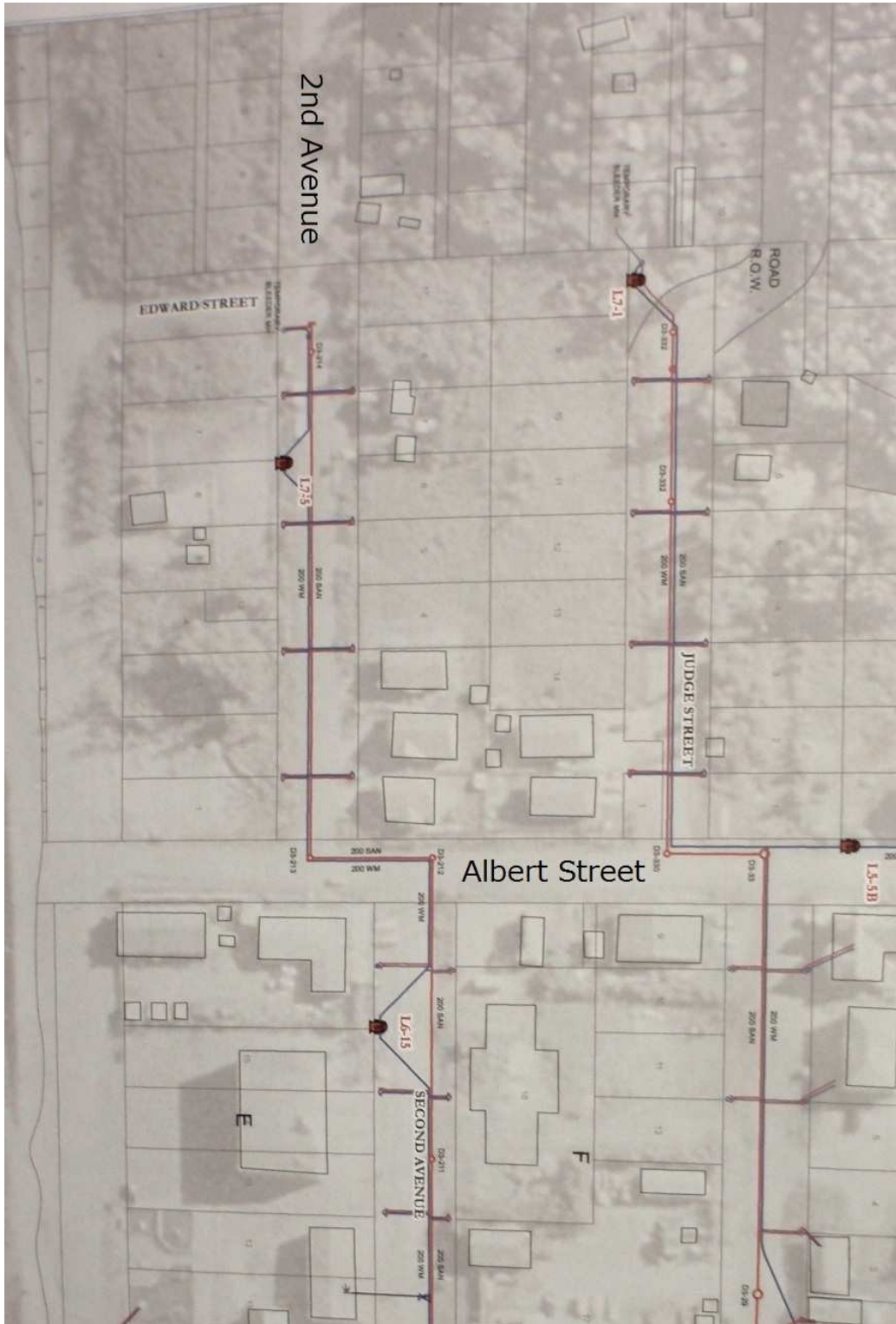
1993 (Below)





Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

FIGURE 4 –Subsurface Utilities





Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

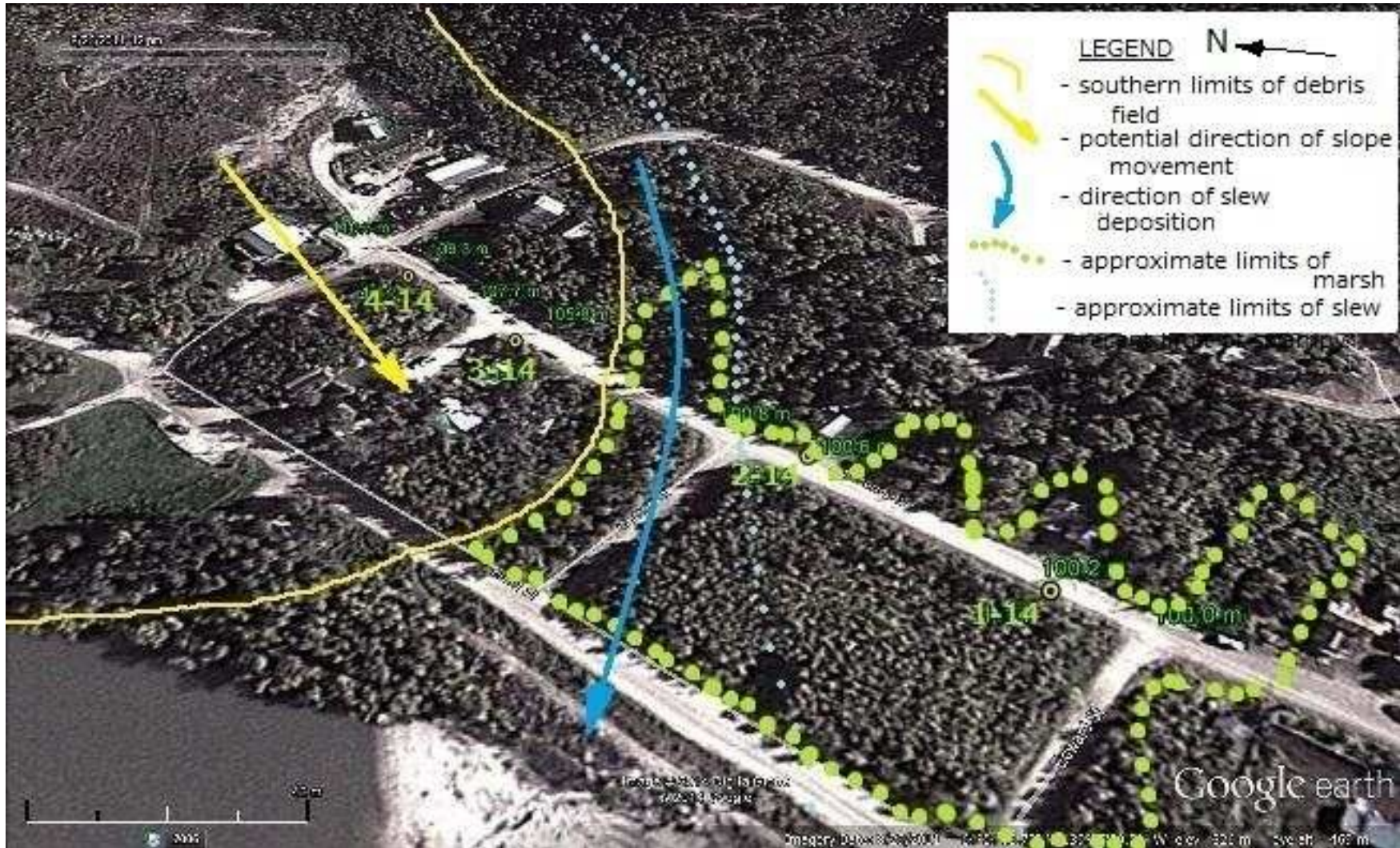
FIGURE 5 –Borehole Locations & Elevations





Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

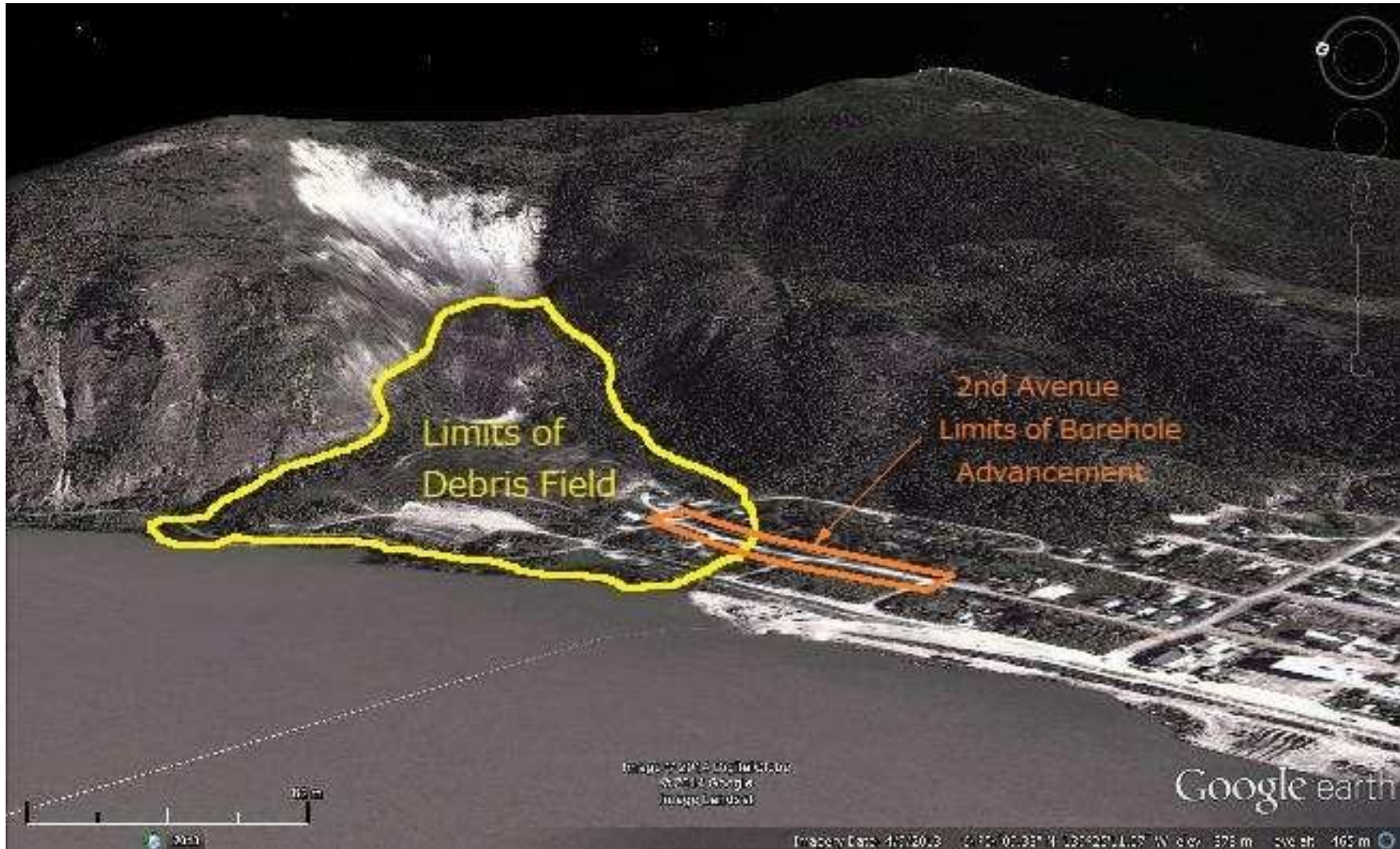
FIGURE 6 – Geomorphic Areas





Geotechnical Evaluation – Proposed 2<sup>nd</sup> Avenue Upgrades – Dawson City, Yukon – 2014

FIGURE 7 –Limits of Slide Debris Field





## **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 <sup>2</sup>
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**



Standard Soil



Test Pit Sampling



Standard Sample  
Maintained from  
excavation adjacent  
to base

Standard Sample  
Maintained from  
Auger Digging



Standard Sample  
Maintained from  
excavation adjacent  
to base

Standard Sample  
Maintained from  
Auger Digging



**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

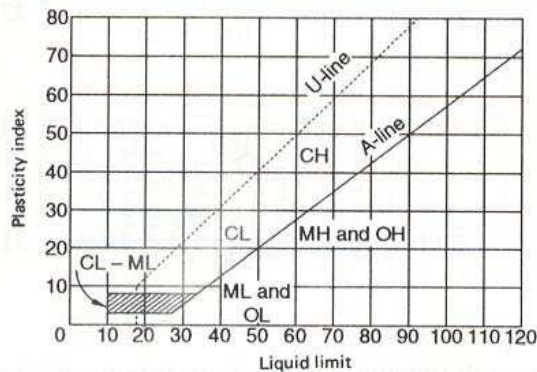
Table 1.2. Description and classification of frozen soils (adapted from Linnell and Kaplan, 1966)

I: Description of soil phase (independent of frozen state)	Classify soil phase by the unified soil classification system				Pertinent properties of frozen materials which can be measured by physical tests to supplement field identification	Thaw characteristics		
	Major group		Subgroup					
	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 <sub>2</sub> 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	Nc				
	Segregated ice visible by eye (ice 25 mm or less thick)	V	Individual ice crystals or inclusions		Vx	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, cundled, 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				
III: Description of substantial ice strata	Ice greater than 25 mm thick	ICE	Pandom or irregularly oriented ice formations	Vr	ICE + soil type	Usually thaw-unstable		
			Stratified or distinctly oriented ice formations	Vs				
			Ice with soil inclusions					
			Ice without soil inclusions	ICE				

(see notes on p. 32)

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
		Sands More than 50% of coarse fraction passes No. 4 sieve	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	Classification on basis of percentage of fines Less than 5% Pass No. 200 sieve More than 12% Pass No. 200 sieve 5% to 12% Pass No. 200 sieve GW, GP, SW, SP GM, GC, SM, SC Borderline classification requiring use of dual symbols Check plasticity chart
	Fine-grained soils 50% or more passes No. 200 sieve	Sands with fines		
		Silts and Clays Liquid limit 50% or less		
	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

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



## BOREHOLE LOG

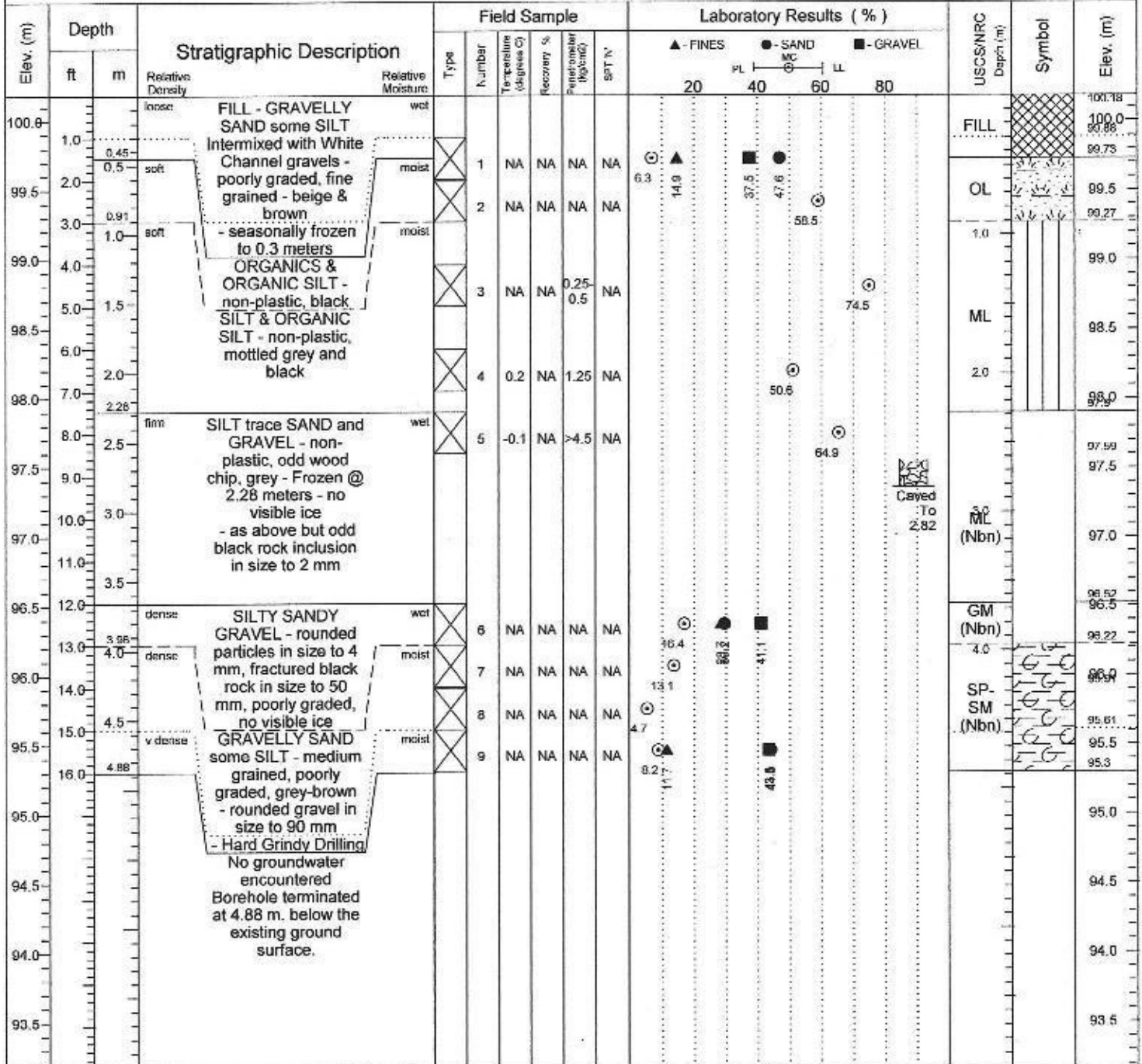
Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoot Project No. : 200-003-14

Date Drilled: Oct.16, 2014  
Elevation : 100.18 meters  
Depth of BH: 4.88 meters  
Instrumentation: NA

BOREHOLE

1-14

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 : Oct.16, 2014

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

Date : Nov.6-7, 2014

Reviewed By: *TD*

Date : Nov.10, 2014

# CHILKOOT GEOLOGICAL ENGINEERS LTD.

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



## BOREHOLE LOG

Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoot Project No. : 200-003-14

Date Drilled: Oct.16, 2014  
Elevation : 100.62 meters  
Depth of BH: 5.49 meters  
Instrumentation: NA

### BOREHOLE

**2-14**

Sheet 1 of 1

Elev. (m)	Depth		Stratigraphic Description	Relative Density	Relative Moisture	Field Sample					Laboratory Results (%)				USCS/NRC Depth (m)	Symbol	Elev. (m)
	ft	m				Type	Number	Temperature (degrees C)	Recovery %	Porosity (Vol/m <sup>3</sup> )	SPT 'N'	PL	NP	LL			
100.5			FILL - SANDY GRAVEL some SILT - poorly graded, grey-brown	dense	wet												100.62
	1.0	0.45															100.5
		0.5															100.32
	2.0	0.76	- seasonally frozen to 0.3 meters		wet												100.17
100.0			ORGANICS & ORGANIC SILT - non-plastic, black		wet	10	NA	NA	NA	NA							100.0
	3.0	1.0	SILT & ORGANIC SILT - non-plastic, mottled grey and black		wet	11	NA	NA	NA	NA							99.96
99.5		1.37			wet	12	NA	NA	NA	NA							99.5
	4.0	1.52	SILT w/ trace fine SAND - non-plastic, grey		wet	13	0.1	NA	0-0.25	NA							99.25
99.0			Frozen @ 1.52 meters - Visible ice inclusions in size to 2 mm, odd organic/wood inclusions in size to 10 mm, trace oxidation, grey-brown		wet	14	-0.3	NA	>4.5	NA							99.1
	6.0	2.0				15	-0.1	NA	>4.5	NA							99.0
98.5		3.5															98.5
	7.0	3.86															98.0
98.0			- as above but with some SAND and odd rounded gravel in size to 7 mm - possible cobbles - odd organic inclusions		wet	16	NA	NA	NA	NA							97.5
	8.0																97.0
97.5		4.69	SILTY SANDY GRAVEL - fine to medium grained, poorly graded, grey-brown		moist	17	NA	NA	NA	NA							96.5
	10.0	5.49				18	NA	NA	NA	NA							96.0
97.0			No groundwater encountered Borehole terminated at 5.49 m. below the existing ground surface.														95.74
	12.0																95.5
96.5																	95.13
96.0																	95.0
95.5																	94.5
95.0																	94.0

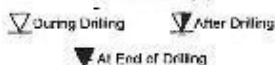
Drilled By : Donjek Services

Drill Type : CME 750 (FN60)

Auger Type : 150 mm Solid Stem

Bit Type : Fish Tail

Water Level(s)



Logged By : T.Dhara, P.Eng.

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

Reviewed By:

Date : Oct.16, 2014

Date : Nov.6-7, 2014

Date : Nov.10, 2014

# CHILKOOT GEOLOGICAL ENGINEERS LTD.

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



## BOREHOLE LOG

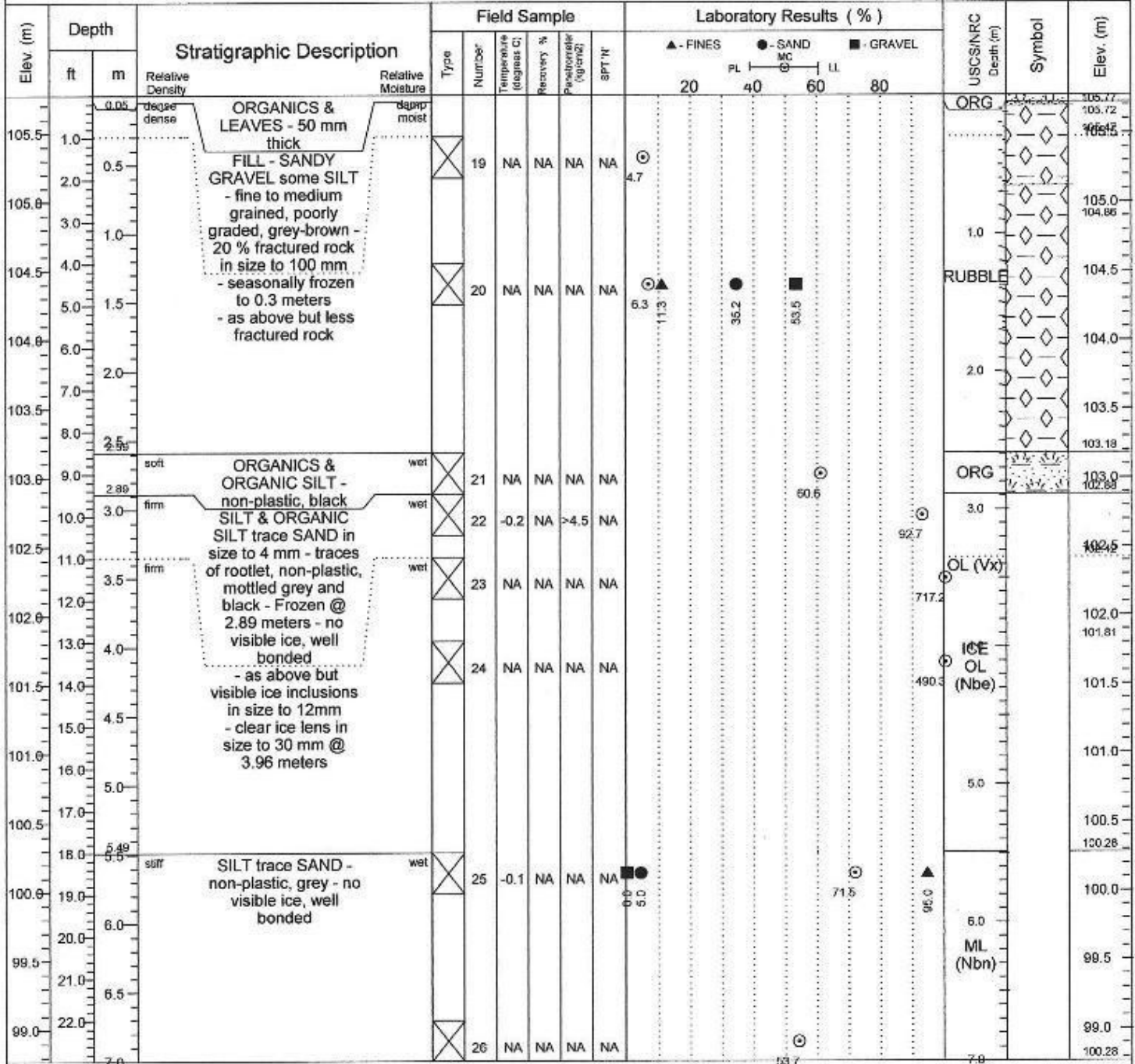
Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoot Project No. : 200-003-14

Date Drilled: Oct.17, 2014  
Elevation : 105.77 meters  
Depth of BH: 10.36 meters  
Instrumentation: 2" Monitoring Well

BOREHOLE

**3-14**

Sheet 1 of 2



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 : Oct.17, 2014

Data Entry By : T.Dhara, P.Eng.  
Date : Nov.6-7, 2014

Reviewed By:   
Date : Nov.10, 2014

# CHILKOOT GEOLOGICAL ENGINEERS LTD.

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



## BOREHOLE LOG

Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoote Project No. : 200-003-14

Date Drilled: Oct. 17, 2014  
Elevation : 105.77 meters  
Depth of BH: 10.36 meters  
Instrumentation: 2" Monitoring Well

**BOREHOLE**

**3-14**  
Sheet 2 of 2

Elev. (m)	Depth		Stratigraphic Description	Field Sample					Laboratory Results (%)				USCS/NRC Depth (m)	Symbol	Elev. (m)	
	ft	m		Type	Number	Temperature (log sec C)	Recovery %	Penetration (kg/cm <sup>2</sup> )	SPT 'N	▲ - FINES	● - SAND MC PL — MC — LL	■ - GRAVEL				
98.5	24.0	7.5	stiff (continued) SILT trace SAND - non-plastic, grey - no visible ice, well bonded wet (continued)													(continued)
98.0	25.0	8.0														
97.5	27.0	8.5														
97.0	28.0	9.0	- as above but no SAND	⊗	27	NA	NA	NA	NA				⊙	72.5	ML (Nbn)	97.0
96.5	29.0	9.5														
96.0	30.0	10.0														
95.5	31.0	10.6														
95.0	32.0	10.36	No groundwater encountered - Monitoring Well installed to 9.64 meters Borehole terminated at 10.36 m. below the existing ground surface.	⊗	28	NA	NA	NA	NA	●			⊙	65.6		95.4
95.5	33.0															
95.0																
94.5																
94.0																
93.5																
93.0																
92.5																
92.0																

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 : Oct. 17, 2014

Data Entry By : T.Dhara, P.Eng.  
Date : Nov. 6-7, 2014

Reviewed By:   
Date : Nov. 10, 2014

# CHILKOOT GEOLOGICAL ENGINEERS LTD.

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



## BOREHOLE LOG

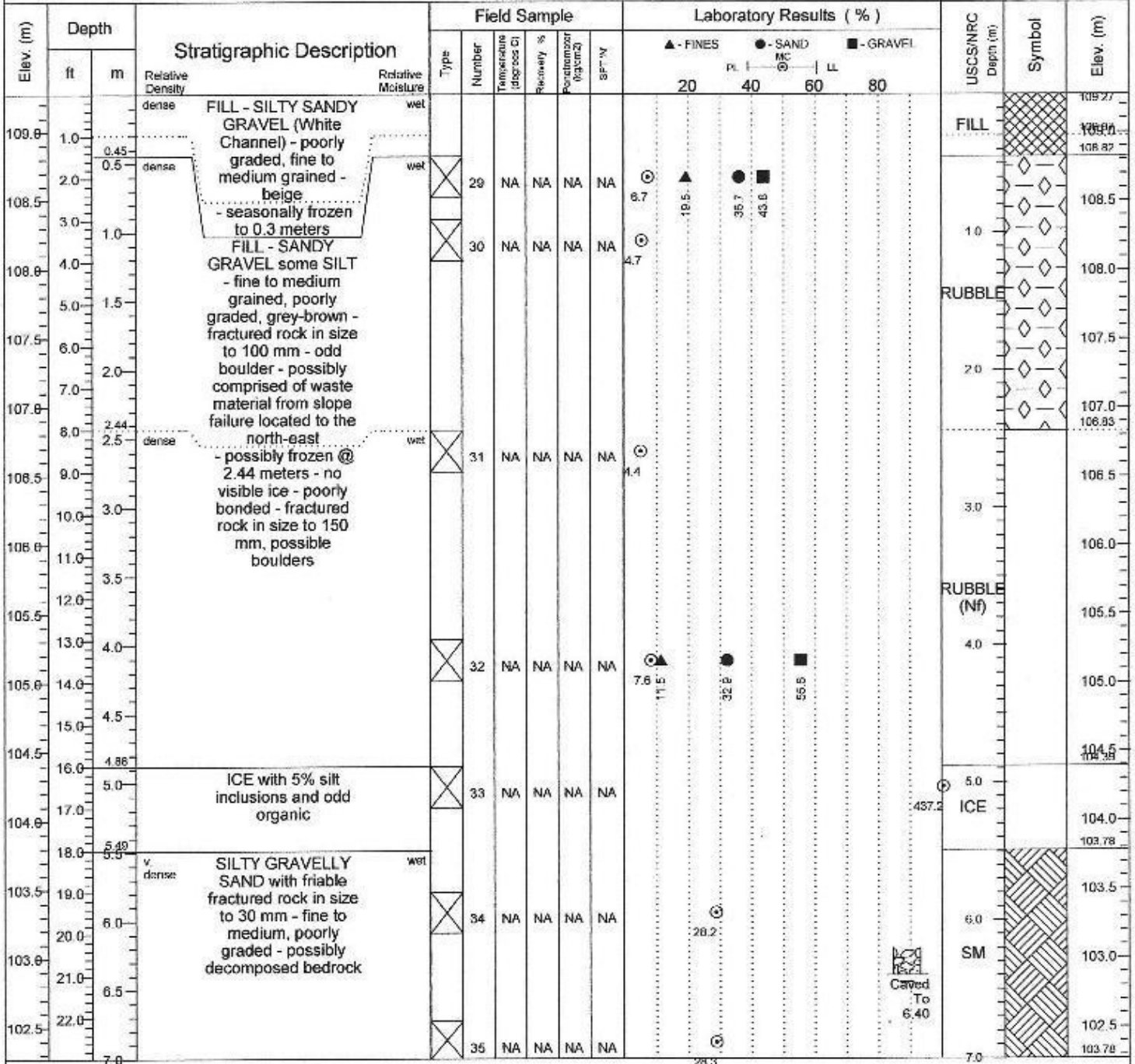
Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoot Project No. : 200-003-14

Date Drilled: Oct.17, 2014  
Elevation : 109.27 meters  
Depth of BH: 7.62 meters  
Instrumentation: NA

**BOREHOLE**

**4-14**

Sheet 1 of 2



Caved To 6.40

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 : Oct.17, 2014

Data Entry By : T.Dhara, P.Eng.  
Date : Nov.6-7, 2014

Reviewed By:   
Date : Nov.10, 2014

# CHILKOOT GEOLOGICAL ENGINEERS LTD.

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



## BOREHOLE LOG

Client : Yukon Government - Energy, Mines & Resources  
Location : Dawson, Yukon  
Project : Geotechnical Evaluation - 2nd Ave Upgrades  
Chilkoot Project No. : 200-003-14

Date Drilled: Oct 17, 2014  
Elevation : 109.27 meters  
Depth of BH: 7.62 meters  
Instrumentation: NA

**BOREHOLE**

**4-14**

Sheet 2 of 2

Elev. (m)	Depth		Stratigraphic Description	Field Sample					Laboratory Results (%)				USCS/NRC Depth (m)	Symbol	Elev. (m)
	ft	m		Type	Number	Temperature (degrees C)	Recovery %	Penetration (kg/cm <sup>2</sup> )	SPT 'N'	FL	MC	LL			
102.0	24.0		v. dense (continued)												(continued)
101.5	25.0	7.62	No groundwater encountered Borehole terminated at 7.62 m. below the existing ground surface.	X	36	NA	NA	NA	NA						102.0
101.5															
101.0															101.5
100.5															101.0
100.0															100.5
99.5															100.0
99.0															99.5
98.5															99.0
98.0															98.5
97.5															98.0
97.0															97.5
96.5															97.0
96.0															96.5
95.5															96.0

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 : Oct.17, 2014

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

Date : Nov.6-7, 2014

Reviewed By:

Date : Nov.10, 2014



APPENDIX B

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 C**

### **Selection of Photos**



Photo # 1 (left) –BH 1-14 site conditions facing north from Edward Street.



Photo # 2 (above) –BH 1-14 - Sample No.7 – Soil Unit # 4



Photo # 3 (above) – BH 4-14  
Ice lens @ 4.9 meters



Photo # 4 (left) – BH 4-14  
Facing south from  
Judge street.