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Geotechnical Feasibility Assessment
Proposed Tagish Avenue Residential Subdivision
Carcross, Yukon – 2018-2019

Prepared For: **Yukon Government**

Date : **January 30th, 2019**

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FIGURES & APPENDICES

1.0 INTRODUCTION

Our firm was retained by *Yukon Government* (*YG*), *Department of Community Services – Land Development Branch* under a Standing Offer Agreement (No.2017/2018-2753) to conduct a geotechnical feasibility assessment of an area located in Carcross, Yukon.

The study area, which measures 6.2 ha in size, is comprised of

- Block 13, 7556 LTO, 42228 CLSR
- Block 14, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 15, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 25, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 26, 7556 LTO, 42228 CLSR
- Block 27, 7556 LTO, 42228 CLSR, and
- a road right-of-way network within this area

Carcross, Yukon is located approximately 73 km south of Whitehorse along the South Klondike Highway #2. The location of the site and limits of the study area have been noted in Figure 1.

Authorization to proceed with the geotechnical assessment was granted by *YG – Community Services* - Project Manager, Mr.K.Fisher on November 8th, 2018. The work was subsequently conducted in accordance with our November 4th, 2018 proposal.

Our findings, which were based upon information retained during a literature review and site reconnaissance have been presented herein along with a description of our methodology.

2.0 SCOPE-OF-WORK

The purpose of our feasibility assessment was to delineate regions within the 6.2 ha study area which may be suitable for residential subdivision development through a literature review and site reconnaissance and provide general geotechnical recommendations regarding infrastructure development where development is deemed feasible.

As our assessment was preliminary in nature, a more comprehensive evaluation(s) will be required through drilling/test pit methodologies to verify site-specific geotechnical parameters and verify development feasibility.

3.0 METHODOLOGY

Our methodology was comprised of a literature review and field work program as described below.

3.1 Literature Review

A literature review was conducted to evaluate satellite imagery, a selection of aerial photos, topographical data and other technical resources which were readily available. This information was utilized to evaluate the regional conditions and detail the field work program by establishing GPS waypoints such that geotechnical points of interest could be better assessed during the site reconnaissance.

The following sources of information were reviewed;

Topographical Information

The regional topography was assessed by viewing a 1:50,000 scale topographical map (NTS – 115I01 Carmacks) and information available on the *YG- Water Placer Atlas* and *Yukon Geology* websites.

A selection of the *Yukon Geology* website showing the local contours (in 100 foot intervals) has been presented in Section 4.1, below.

Surficial Geology Map

A 1:50,000 surficial geology map (#2005-02) entitled Surficial Geology, Carcross (105D/02), Yukon compiled by J.D.Bond, S.Morison and K.McKenna – *Yukon Geological Survey* provided a description of the anticipated distribution of surficial soil deposits.

A portion of this map and the corresponding limits of the study area has been provided in Section 4.5, below.

Bedrock Geology Map

A bedrock geology map, available through the *Yukon Geological Survey*, identified the regional bedrock types and characteristics within the study area. The map was entitled *Yukon Bedrock Geology Map* – *Yukon Geological Survey* – Open File 2016-1 - 1:1,000,000 scale compiled by M.Colpron, S.Israel, D.Murphy, L.Pigage, and D.Moynihan.

A more detailed delineation of these contacts was found on the *Yukon Geological Survey* website as noted in Section 4.6, below.

Aerial Photographs

A selection of aerial photographs was obtained from *YG – Energy, Mines and Resources* to allow for a more detailed assessment through airphoto terrain analysis. The following airphotos were available;

Flight Line	***Photo No.***	***Date***	***Comments***
WP8722	19-21	August 29th, 1987	6,400 altitude – 1:8,000 scale
A27666	62-64 & 151-153	July 21st, 1990	12,500' altitude – 1:20,000 scale

Photo #20 of flight line WP8722 has been attached in Appendix A for reference purposes.

Satellite Imagery

A review of satellite imagery from *Google Earth* allowed for an assessment of the site conditions relative to the more recent imagery. The imagery which was available on the website which was detailed enough to assist in the site assessment was dated June 20th, 2010, March 26th, 2012 and May 12th, 2016.

Carcross – Local Area Plan (LAP) – October, 2013

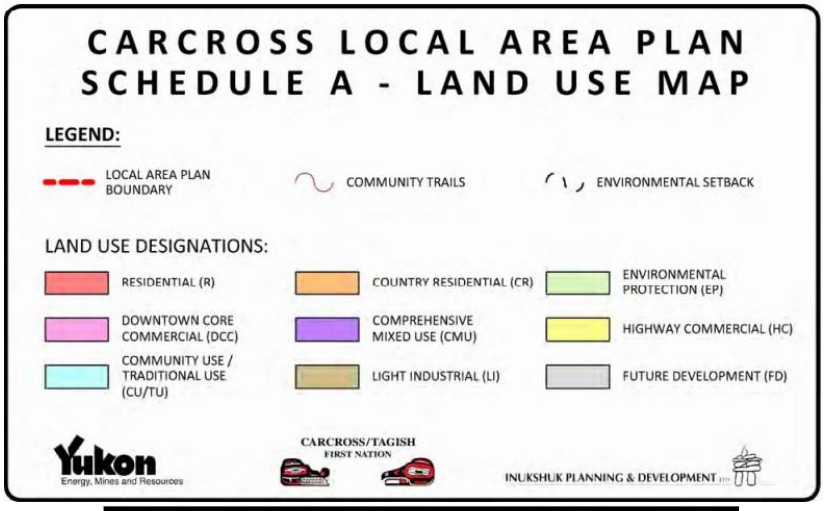
The Local Area Plan (LAP) was compiled by *Inukshuk Planning & Development Ltd.* as a guide to land use within the planning area. As Carcross is unincorporated, the limits of the planning area were agreed upon by the *Yukon Government* and *Carcross Tagish First Nations* governments in order to encompass regions which would be necessary to operate the community such as the waste transfer station, water intake region, sewage lagoon and other similar types of related infrastructure.

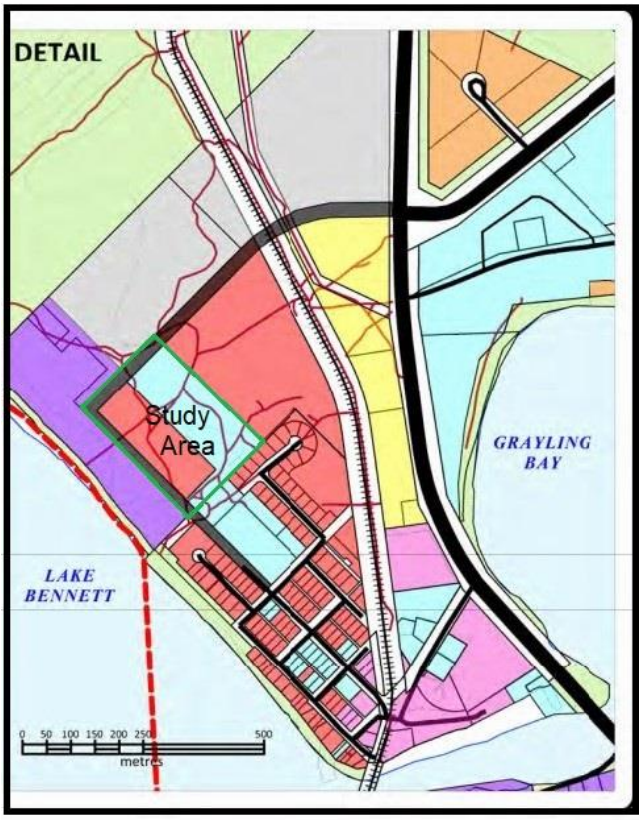
The plan was a collaborative process which was undertaken between local residents, community organizations and government agencies. Ultimately, a series of land-use maps, figures and schedules were generated. A selection of these LAP considerations have been summarized as follows;

<u>*Zoning and Potential Land Use*</u>

The region of the Tagish Avenue study area is currently zoned as 'hinterland'.

Map 9 of the LAP presented a map which denotes regions within the planning area where 'issues, opportunities and concerns' were identified. This map denoted the Tagish Avenue study area and surrounding regions as having residential development potential. A portion of the proposed land use map which proposed zoning through the planning area has been attached below. The limits of the proposed Tagish Avenue study area have been illustrated on this map for reference purposes;





Alternate Access Route

The local area plan identified the lack of an alternate road access to the townsite as being a health and safety concern. Specifically, access to the townsite is seasonally obstructed during the summer when the *White Pass and Yukon Route* (*WP & YR*) trains stop at the downtown station. As such, the LAP presented an option for a conceptual alternate access route to the townsite which was identified by *Quest Engineering Group* during studies entitled '2005 Carcross Alternative Access Routes' and '2007 Carcross Alternate Access Options Review'. Portions of the alternate access route lie within the north-western and south-western limits of the Tagish Avenue study area as noted in Figure 2 of the LAP as shown below;

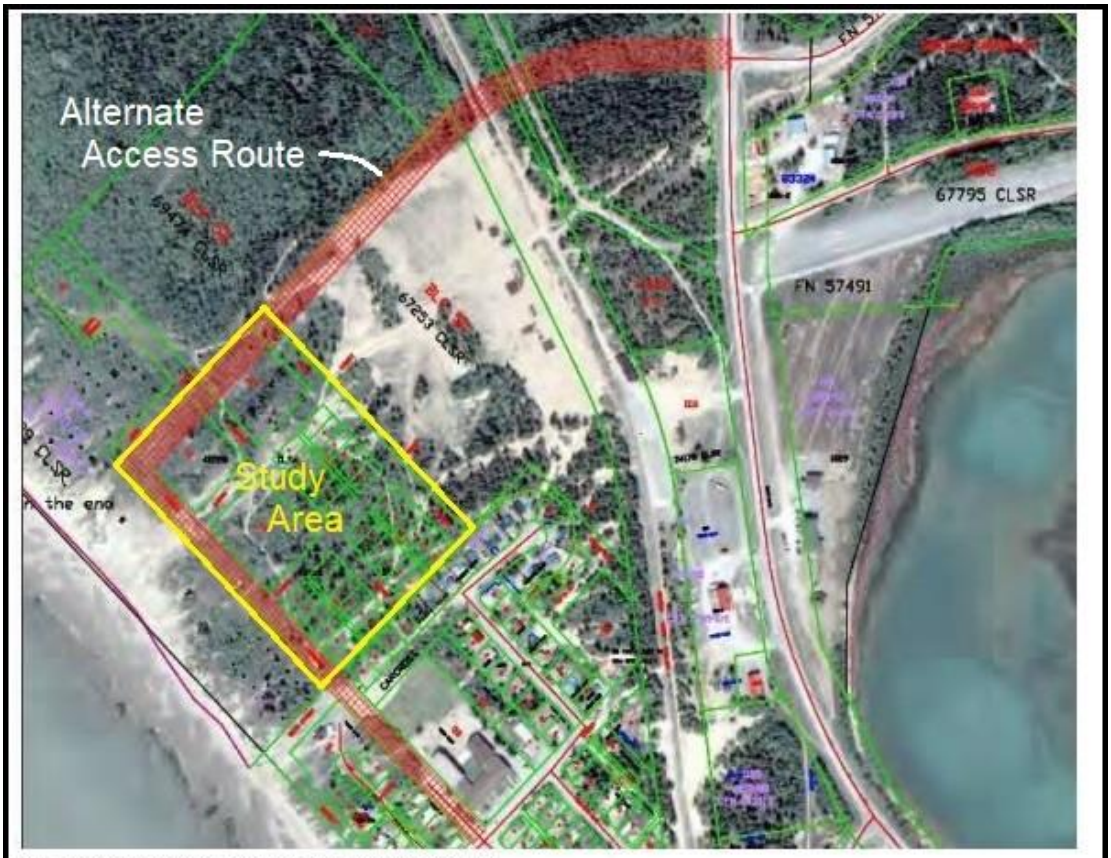


Figure 2: Conceptual Alternate Access Route

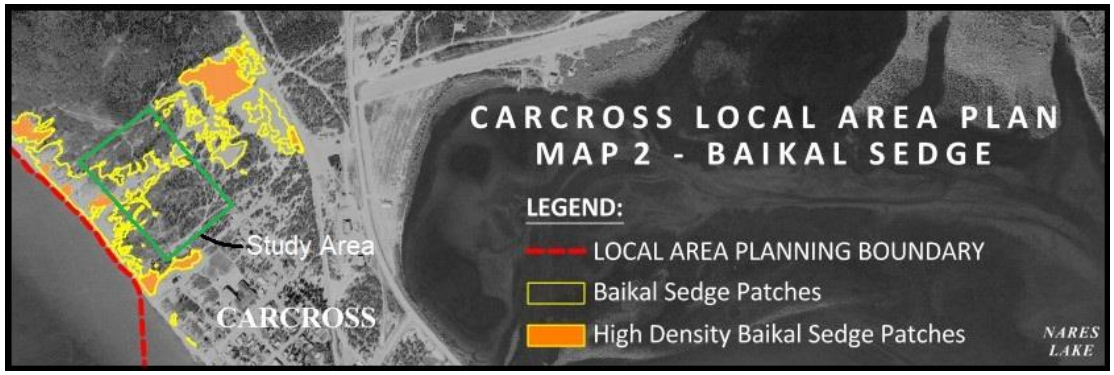
Carcross Area 2007 Flood

A map was generated by information supplied by *Yukon Energy Corporation* and *AECOM* following the 2007 flood which impacted the townsite to an elevation of 657.41 meters. While the limits of the flood were superimposed on a map of the Carcross Area, the Tagish Avenue study area and northwestern

regions of the Carcross townsite were not included. In brief, the study suggested that the 200-year flood elevation would be in the order of the 657.753 meters.

Environmental (Ecosystem) Values

The LAP identified regions within the planning area where sensitive flora and fauna were present. A map denoting the presence of rare Baikal Sedge was presented as Map 2 in the LAP. It's understood that the sedge requires the presence of active, shifting dunes with 0.5 to 4 meters of loose sand. The approximate limits of the Baikal Sedge patches relative to the Tagish Avenue study area have been illustrated as noted below;



Ski Trails

Map 1 of the LAP denoted the presence of '3, 5 & 10 km cross-country ski trails' traversing through the Tagish Avenue study area as illustrated (in red) below;

Contaminated and Unregistered Potentially Contaminated Sites

The LAP listed eight (8) sites which are known to be contaminated and generated Map 3, which denotes the locations of five (5) additional unregistered

potentially contaminated sites. One of these potentially contaminated sites, (potentially) identified as Block 50 - CLSR #67253, is located immediately adjacent to the north-eastern edge of the Tagish Avenue study area as noted below.

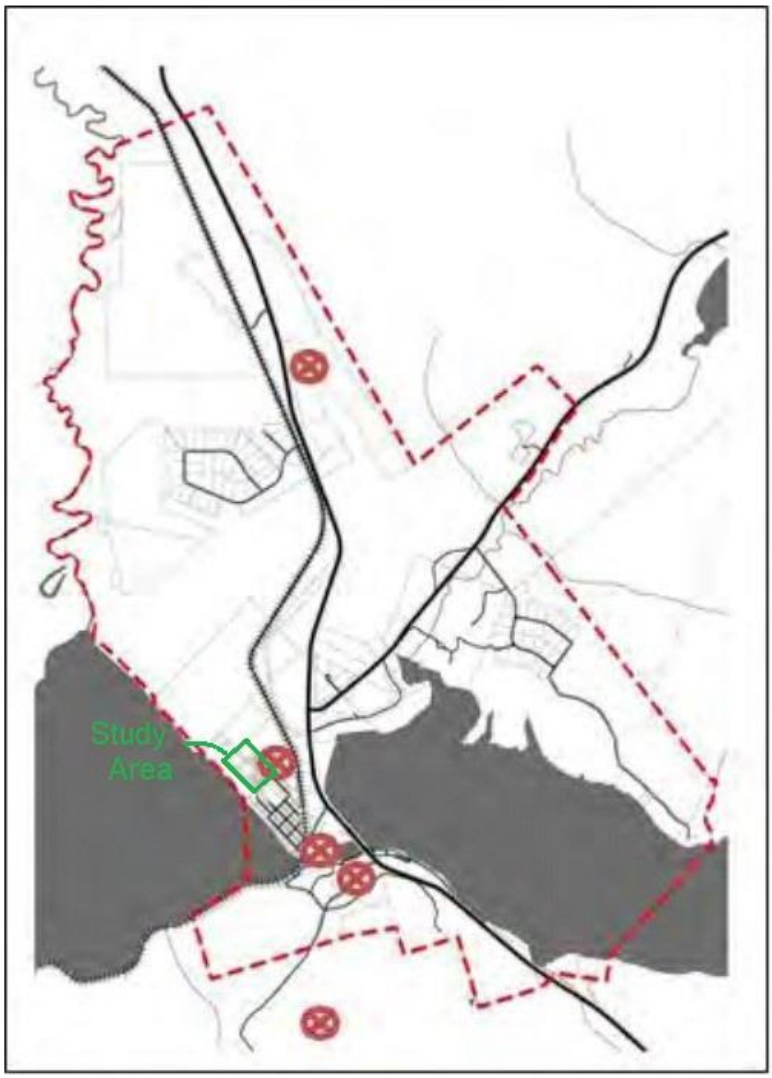


Figure 3: Unregistered Potentially Contaminated Sites

Proximity to Carcross Aerodrome

Map 7 of the LAP denoted the limits of the 'Approach and Transitional Surfaces to the Carcross Aerodrome'. Relative to the map, the Tagish Avenue study area lies just beyond the final transitional limits which were shown which denote maximum building height of 20 meters.

Other Resources

The *Yukon Government – Water Placer Atlas* website was reviewed as it denoted the boundaries of various land dispositions, drainage regimes and other similar types of information. The corresponding boundaries of the study area have been illustrated on the *Water Placer Atlas* map attached in Section 4.1, below.

3.2 Field Work Program

The field work program was comprised of a site reconnaissance which was conducted by our Sr.Soils Technician, Mr.G.Keitel on December 6th, 2018. This work involved traversing the site on foot to note the field conditions and geological features within the study area. Our observations during this time were documented through a combination of field notes, GPS waypoints and photographs. These observations have been summarized in Section 4.0 – Site Conditions.

Fair weather was encountered at the time of our reconnaissance. The daytime highs were in the order of minus 5° C. Given the time of season, the ground surface was frozen and predominately covered in snow.

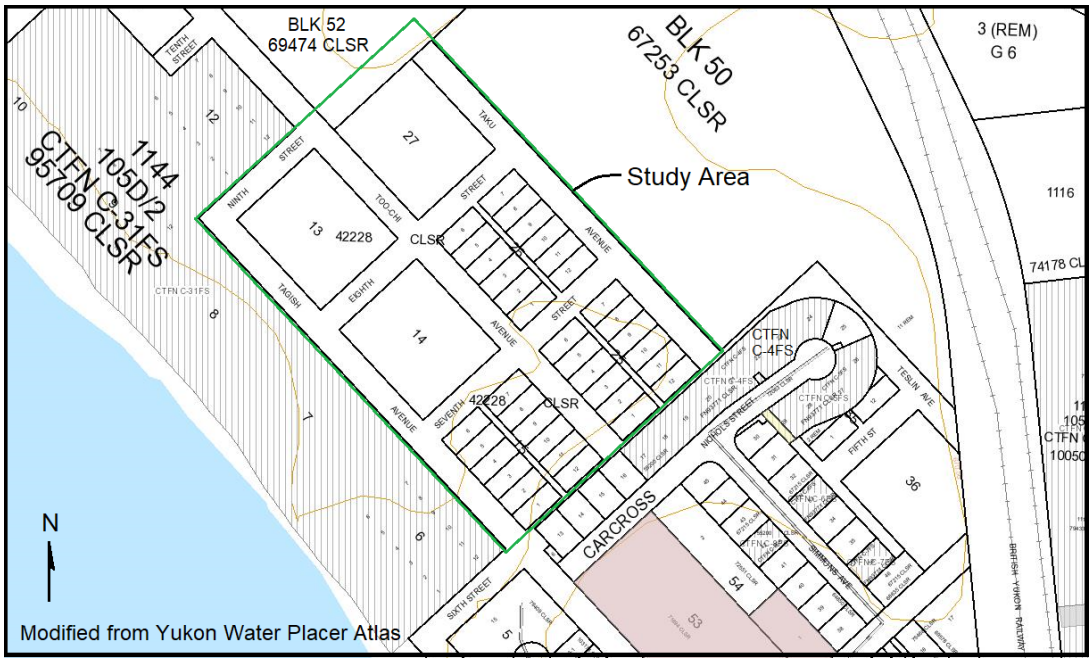
4.0 SITE CONDITIONS

4.1 Study Area

The study area is located in the Village of Carcross as noted in Figure 1. The study area measures 6.2 ha in size and is comprised of

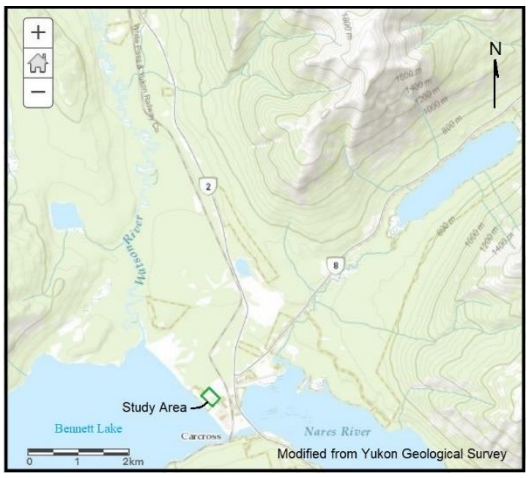
- Block 13, 7556 LTO, 42228 CLSR
- Block 14, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 15, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 25, 7556 LTO, 42228 CLSR
- Lots 1-12, Block 26, 7556 LTO, 42228 CLSR
- Block 27, 7556 LTO, 42228 CLSR, and
- a road right-of-way network within this area

The map retained from the *YG - Water Placer Atlas* website noted that the north-eastern periphery of the study area is bound by Block 50 #67253 CLSR. This block is thought to be owned by *White Pass and Yukon Route* (*WP & YR*). The north-western edge of the study area is bound by two undeveloped areas. Block 52 CLSR #69474, which is also thought to be owned by *WP & YR*, lies along the northern half. The southern half of this boundary and the south-western side of the study area is bound by *Carcross Tagish First Nation* (CTFN) land selection C-31FS. A number of single detached residences are located along the south-eastern side of the study area within CTFN land selection C-4FS.



In viewing the airphoto and satellite imagery, the site appears to have remained generally unchanged between 1987 and 2016. The exception to this is the presence of Tagish Avenue, which appears to have been constructed along the south-western edge of the site sometime between 2012 and 2016 (based upon the satellite imagery). Beyond the limits of the site, an above ground storage tank (AGST), which was noted in each of the airphotos (approximately 80 meters beyond the northern corner of the site on *WP & YR* - Block 50), has been removed by the time of the 2010 satellite imagery. The trail system which traverses through the study area appeared to be relatively unchanged between the 1987 and 2016.

4.2 Physiographic Region

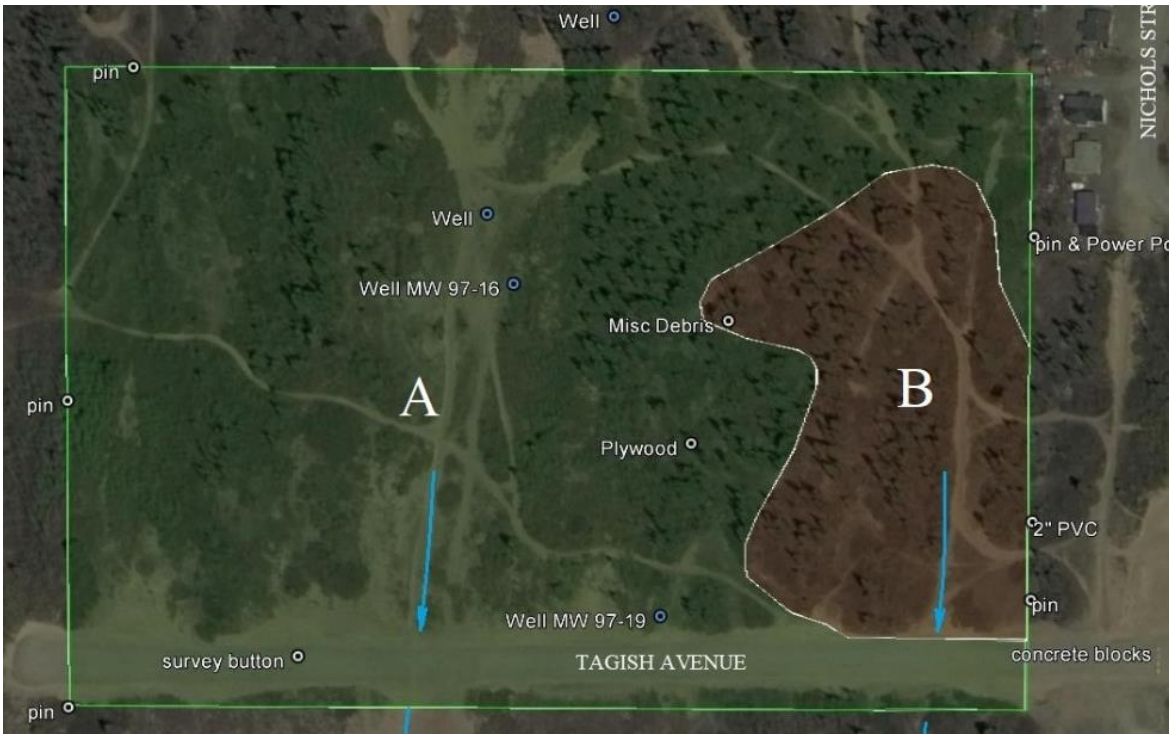


Carcross is located at the confluence of the Yukon Stikine Highlands, the Yukon Southern Lakes and Boreal Mountains and Plateau. The terrain in the region is comprised of broad valleys, large lakes and mountainous terrain.

The prevailing elevations in the region of the study area lie above 670 meters (above sea level). The exception to this is a region of lower terrain which is located in the gully which is situated in the southern third of the site. By comparison, it's understood that Bennett Lake lies near an elevation of approximately 655 meters. Regionally, the surrounding mountain peaks rise to elevations in the order of 2000 meters.

4.3 Site Description

The study area is comprised of a sparsely vegetated slope which can be separated into two (2) distinct regions as noted (below, and) in Figure 2. The primary difference between the two regions is that lower elevations are present within the region denoted as Area B. This region is best described as a gully or draw.



The topography of the study area is best described as gentle to moderately sloping and undulating terrain which increases in elevation as one traverses towards the north-east (away from Bennett Lake). The elevation gain across the site was estimated to be in the order of ~ 20 meters. Two drainage courses bisect the study area as noted in the site plan.

View of central site conditions facing south-west.

The vegetation within the study area is sparse and is predominately comprised of low-lying shrubs with interspersed deciduous and evergreen trees. The presence of the

surficial eolian deposits which, were comprised of fine to coarse grained sands, were noted throughout the study area.

While a series of four (4) concrete blocks restricted vehicle access to Tagish Avenue (which traversed the south-western portion of the study area) the road surface appeared to be sufficiently consolidated to support anticipated traffic loads. Visually, the portions of Tagish Avenue which were constructed within the limits of the site, appeared to have been constructed to recent standards. However, there did not appear to be any defined ditches or culverts which would promote upslope drainage. While the composition of the road structure could not be determined given the snow cover, it appeared that an engineered granular sub-base material was utilized during construction. There did not appear to be a significant amount of road base (which would typically be comprised of a 20 mm minus crushed surfacing aggregate). The width of the road measured in the order of 9 meters wide.


View of Tagish Avenue facing south-east.


View of Tagish Avenue facing north-west.

During the site reconnaissance, three (3) groundwater monitoring wells were encountered within the limits of the study area as noted in Figure 2. Two of these wells were labeled ‘MW 97-16’ and ‘MW 97-19’, which suggests the wells were installed in


View of MW 97-19 facing south-west.


View of MW located north of MW 97-16 facing south-west.

1997. A series of additional wells were noted on the *WP & YR* site (Block 50) located north-east of the study area.

A 2" diameter PVC pipe (which could have at one time been utilized as a groundwater monitoring well) was encountered along the sites south-eastern border. In addition to the monitoring wells, the odd piece of miscellaneous debris (such as plywood, steel pipe, cables, beer cans, etc) was noted within the study area.

4.4 Geomorphology

Glaciation

The terrain in this region of the Yukon was last glaciated during the McConnell Glaciation which is understood to have occurred in the order of 20,000 years ago. The eolian deposits which dominate the Carcross Region are remnants of glacial lake sediments that settled on the bottom of the lake prior to glacial recession.

Soil Stratigraphy

The eolian deposits which underlie the study area are comprised of fine to coarse grained sands which are thought to be massive. These sands are known to be loosely consolidated and are actively shifting in the form of sand dunes. The prevailing direction of movement is generally towards the north-east.

Permafrost

Carcross lies in a region described as sporadic discontinuous permafrost. The general lack of vegetation in the region and nature of soil deposition suggests that permafrost is not present within (or near) the study area.

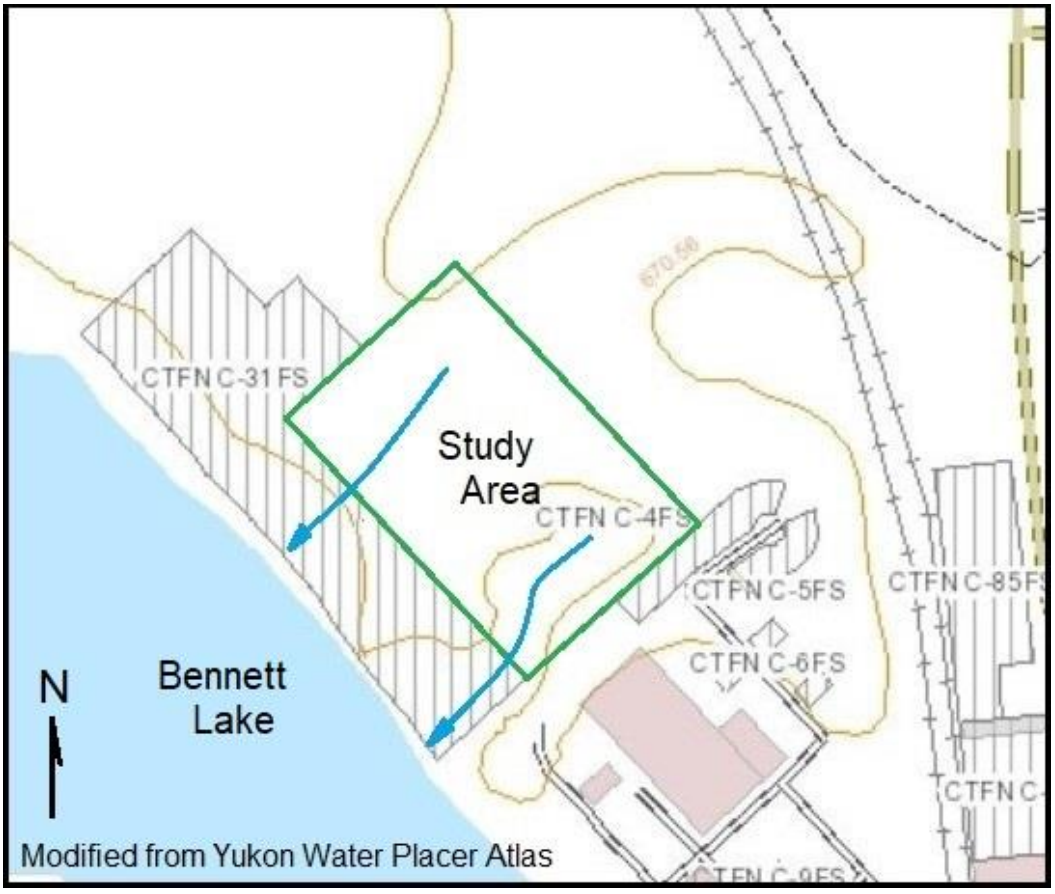
Watercourses

The shoreline of Bennett Lake roughly parallels the south-west side of the study area approximately 85 meters from the site. It's understood that Bennett Lake lies near an elevation of approximately 655 meters. The 2007 floods reached an elevation of 657.41 meters. Information retained from the LAP suggests that the 200-year flood elevation would be in the order of the 657.753 meters.

The Watson River discharges into Bennett Lake approximately 1.5 km north-west of the study area.

Surface Drainage

The surface drainage generally flows from the north-east to the south-west. Two prominent drainage courses bisect the site as noted below;



Although Tagish Avenue has been constructed across each of the two drainage courses without the installation of culverts (essentially blocking surficial drainage), it appears the impacts to the surface drainage in these areas was negligible. This is likely due to the highly permeable nature of the eolian deposits which are prevalent throughout the site. Some degree of subterranean flow (in the form of seeps) would be expected, as evidenced by a number of discharge regions which are present along the shoreline of Bennett Lake.


View of northern drainage discharge area facing south-west.

Groundwater

Given the study areas proximity to Bennett Lake, groundwater likely underlies the site at elevations which parallel those of the lake (elevation ~655 m).

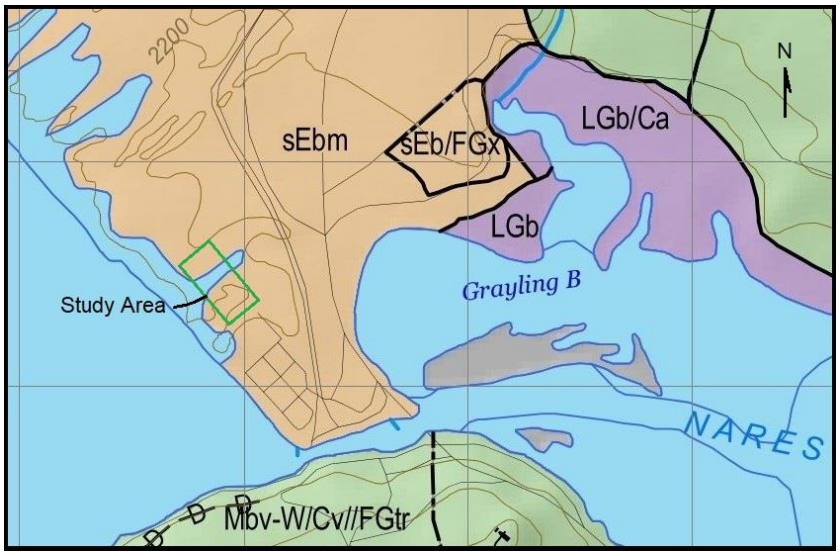
Bedrock

There was no indication of bedrock outcrops during our literature review or site reconnaissance.

4.5 Surficial Geology

The distribution of surficial deposits within the study area has been illustrated in the (1:50,000 scale) surficial geology map Carcross - Yukon Territory - Map 2005-02 compiled by J.D.Bond, S.Morison and K.McKenna.

The approximate limits of the study area have been illustrated on a portion of the surficial geology map (right).



In brief, the map shows that the surficial deposits which are located within the study area are comprised of eolian deposits. The eolian deposits in Carcross are the remnants of glacial lake sediment that settled to the bottom of the lake and were subsequently exposed following glacial recession. These deposits have since been modified by wind processes. The presence of the blue colored lobe which is shown within the study area is likely due to a printing error as the true shoreline of Bennett Lake (which roughly parallels the south-west side of the site) lies in the order of 85 meters south-west of the site.

The surficial geology map described the eolian deposits as follows;

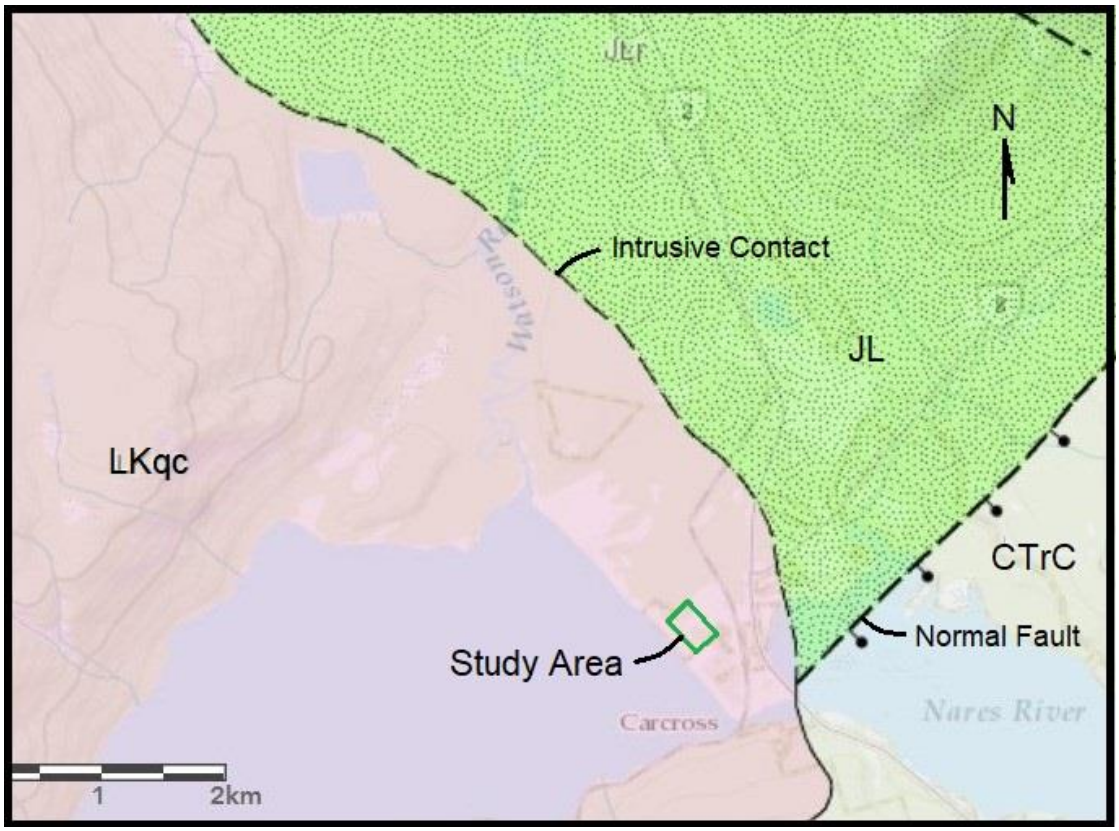
> *Eolian Deposits (E)*
>
> Eolian deposits are comprised of sediment which has been transported and deposited by wind action. The deposits are generally comprised of fine to

medium grained sands and coarse silts which are well sorted and non-compacted. They may contain internal structures such as cross bedding and/or ripple laminae or else may be massively bedded. These deposits may be active in the form of dunes or inactive where vegetation prevails.

4.6 Bedrock Geology

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

The geology map noted on the *Yukon Geology* website indicates that the site is underlain by plutonic rock (LKqc) which may be comprised of quartz monzonite, granite, alaskite and/or granodiorite. An intrusive contact and normal fault were identified ~750 m east of the study area.



5.0 DISCUSSIONS

As the geotechnical development potential of the site will vary, we have for discussion purposes classified regions which exhibit similar potentials for development based upon the local types of terrain and anticipated subsurface conditions as illustrated in Figure 2. In general, the figure illustrates the relative development potential within each of the areas as being either 'Unfavorable, Suitable or Favorable'. A description of each of these levels of classification is as follows;

Unfavorable
Development within these regions is not recommended due to the presence of either poor soil conditions, shallow groundwater/bedrock, steep slopes or combination thereof. If development within these regions is required, it should be limited to supporting infrastructure as building construction if these regions would not be recommended.

Suitable
These regions should support building/infrastructure development however, additional site preparation will generally be required relative to regions which have been deemed to be favorable.

Favorable
Development within these regions should allow for unfettered lot development utilizing conventional construction methodologies.

Some variations between these boundaries can be expected in the field given the scale of mapping and local geomorphology. Where development is to be conducted, additional consideration will need to be given through a subsurface geotechnical evaluation such that local geotechnical design parameters can be determined relative to the soil and terrain conditions.

Development will require careful planning and design relative to building construction, (septic and water) holding tank placement, road alignments, lot access/development and surface drainage management.

5.1 Development Potential

Based upon the information retained during our assessment, the development potential of the site will vary. In ignoring the potential impacts of natural and environmental hazards, the anticipated soil conditions will be favorable to allow for unrestricted site development throughout the study area. However, the sloping and undulating nature of the terrain will require some degree of pre-grading operations in order to allow for road/lot access and site development. Residential building development may need to be restricted in Area B (as noted in Figure 2) as the terrain within this region lies at generally lower elevations relative to Area A.

While residential buildings should be able to incorporate full basements, the use of (septic and water) holding tanks will likely be required considering the permeable nature of the sands which are anticipated in the region.

Surface drainage and erosion control will need to be carefully considered throughout the study area.

While it appears the primary road grade for Tagish Avenue has been constructed, it will require upgrading in order install culverts, establish drainage ditches and construct/complete road base/surfacing. In addition, considering the nature of the sloping terrain, access to the adjacent lots which border the existing and future roadways is not readily available without undertaking cut/fill operations.

5.2 Subsurface Considerations

The eolian soils which are located within the study area should allow for unfettered residential subdivision development of the study area. However, the anticipated bearing capacity of the soils which are anticipated at building sub-grade elevations are expected to be low as eolian sands are typically poorly consolidated given their wind-blown nature of deposition. The sands which are anticipated at the road sub-grade elevations should however be suitable to support the anticipated traffic loads following granular sub-base and base course construction.

The thickness of fills which may result from pre-grading operations will need to be carefully considered to ensure that building foundations are able to extend through the fill to the underlying undisturbed sands/soils. Buildings should not be allowed in regions of fill if their foundations are unable to extend to the underlying undisturbed

sands/soils unless they are founded upon engineer approved structural fills. Some adjustments to individual building foundation design(s) may be required to accommodate site-specific conditions as the soil types and subsurface conditions may vary across the study area.

As the permeability of the eolian sand deposits are expected to be high and considering the proximity to Bennett Lake and the groundwater table, the use of (septic and water) holding tanks is generally the preferred method to allow for site servicing in Carcross.

The surficial organics/silts will need to be removed from beneath proposed road (and building) load envelopes during construction as these soils are generally weak, compressible and susceptible to frost. The amount of stripping across the study area is anticipated to be minimal as the thickness of surficial organics appeared to be relatively thin.

5.3 Terrain Considerations

From a lot development perspective, given the existing slopes and undulating nature of the terrain, some amount of pre-grading will be required to construct roadways and prepare building sites within the study area. Unless heavy pre-grading operations are conducted, lot access (and building site) construction will need to be considered on a case-by-case basis. The proposed road right-of-way's and lot limits may need to be re-configured if pre-grading operations are to be minimized.

Careful consideration will be required relative to road construction (for 7th, 8th and 9th Streets in particular) as the proposed road alignments will require the construction of steep grades. As such, large right-of-way widths should be anticipated along these streets (and avenues) to allow for adequate backslopes (which may be in the order of 3 to 1 (horizontal to vertical), or shallower) considering the sandy and hence erosion prone nature of the eolian deposits.

The nature of the sand dunes which are located within and around the study area may require additional consideration relative to long-term maintenance of the subdivision.

5.4 Geotechnical Evaluation

While the eolian deposits are thought to be massive, the depths to which they extend is currently unknown and so additional consideration should be given relative to pre-grading operations as these operations will be somewhat dependent upon the nature of the underlying soil stratigraphy.

A subsurface geotechnical evaluation should be conducted through test pit/drilling methodologies to verify the local subsurface conditions and outline geotechnical design parameters regarding site development.

A site-specific geotechnical evaluation should be conducted utilizing standard penetration test (SPT) methodologies at any proposed building location such that the maximum net allowable bearing capacity and founding soil conditions can be determined prior to building design and construction.

5.5 Environmental Considerations

From an environmental perspective, the monitoring wells which are located on the site and neighboring properties is cause for concern as their presence suggests the site may have been impacted by potential environmental liabilities. Additional study would be required through an environmental site assessment (ESA) to determine whether or not potential environmental liabilities may exist. If possible, groundwater samples should be obtained during this time from the monitoring wells to allow for chemical laboratory analysis relative to *Yukon - Department of Environment – Contaminated Site Regulations* (*YG-CSR*).

6.0 RECOMMENDATIONS

6.1 General

The following recommendations have been provided to outline the envisioned geotechnical requirements for residential subdivision development. As our recommendations are preliminary in nature, additional consideration may be required once the geotechnical parameters have been determined following a subsurface geotechnical evaluation and additional assessments.

6.2 Building Foundations

Residential (single and multi-family) buildings should be constructed utilizing footing and monolithic slab (slab-on-grade) types of concrete foundation systems. Some adjustments to the individual designs may be required to accommodate site-specific conditions as the soil types, local terrain and subsurface conditions will vary across the study area.

Although permafrost is not anticipated, additional consideration should be given if it is encountered as the use of conventional building foundations would no longer be suitable.

6.3 Surface Works

The construction of roads and surface utilities should be feasible throughout the study area. While the road structure would need to be determined based upon the subgrade conditions and expected traffic loads, we anticipate the thickness of the imported granular components of the road structure would measure in the order of 0.7-1.0 meters thick.

The near surface organic mat and other fine-grained deleterious materials will need to be removed from beneath the respective load envelopes prior to construction.

6.4 Subsurface Utilities

The anticipated soils should allow for subsurface utility installation relative to anticipated (septic and water) holding tanks.

6.5 Additional Assessments & Evaluations

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

Site Survey

A detailed site survey (minimum 2-meter contour intervals) should be conducted to allow for additional geotechnical evaluation as the scale of mapping available at the time of our assessment was not sufficient to note site-specific variations in the topography. This component of work should be conducted prior to the subsurface geotechnical evaluation such that the retained information can be considering accordingly.

Geotechnical Evaluations

A subsurface geotechnical evaluation should be conducted through test pit and/or drilling methodologies to verify the local subsurface conditions and outline geotechnical design parameters regarding site development and road access.

Site-specific geotechnical evaluations should be conducted utilizing standard penetration test (SPT) auger drilling methodologies at all proposed building locations such that the maximum net allowable bearing capacity and founding soil conditions can be determined prior to building design and construction.

Roadway/Lot Configuration

The proposed road right-of-way's and lot limits may need to be re-configured if pre-grading operations are to be minimized. Large right-of-way widths should be anticipated (particularly along steep roadways) to allow for adequate backslopes considering the sandy and hence erosion prone nature of the eolian deposits.

Site Grading, Surface Drainage and Erosion Control Plans

Site grading, surface drainage and erosion control plans should be formulated once conceptual designs have been established to ensure surface waters (and potential seepage zones) are adequately controlled. Additional consideration will be required relative to the potentially active and shifting nature of the eolian sand deposits.

CSP culverts should be utilized to ensure drainage is unimpeded where roadways and lot accesses are constructed.

As the sands within the study area are prone to erosion, drainage in steep areas should be controlled utilizing silt fencing, straw bales, turf mats and/or other similar types of erosion control measures as deemed necessary. Similar types of erosion control measures may be required in other regions which may be impacted by active/shifting eolian sand deposits.

Environmental Site Assessment(s)

A Phase I Environmental Site Assessment (ESA) should be conducted to determine whether or not there may be any potential environmental liabilities associated with the study area. Considering the presence of the monitoring wells, if possible, groundwater samples should be retained to allow for screening relative to *Yukon - Department of Environment – Contaminated Site Regulations* (*YG-CSR*).

Natural Hazard Assessments

Considering the unconsolidated nature of the eolian deposits, further assessment should be conducted relative to the potential impacts of seismic events and/or a rise in the groundwater table relative to consolidation/settlement and the potential for liquefaction.

The potential impacts of the active and shifting sands should be considered relative to long-term subdivision maintenance.

A natural hazard assessment should be conducted by qualified personnel to assess the forest fire potential if development is to be considered in greater detail.

7.0 CONCLUSIONS

Development Potential

Based upon the information retained during our assessment, the development potential of the site will vary. In ignoring the potential impacts of natural and environmental hazards, the anticipated soil conditions will be favorable to allow for unrestricted site development relative to single and multi-family housing units throughout the study area. However, the sloping and undulating nature of the terrain will require pre-grading operations in order to allow for lot access and site development. Residential building development may need to be restricted in Area B (Figure 2) as the terrain within this region lies at generally lower elevations relative to Area A.

Surface drainage and erosion control will need to be carefully considered throughout the study area.

While it appears the primary road grade for Tagish Avenue has been constructed, it will require upgrading in order install culverts, establish drainage ditches and construct/complete road base/surfacing. In addition, considering the nature of the sloping terrain, access to the adjacent lots which border the existing and future roadways is not readily available without undertaking cut/fill operations.

Building Foundations

The anticipated eolian deposits should allow for residential building construction utilizing conventional (footing and monolithic-slab types of) foundation systems. These buildings should be able to incorporate full basements.

Surface Utilities

The construction of roads and ditches utilizing conventional cut/fill construction methodologies will be feasible following adequate site preparation.

Subsurface Utilities

The use of (septic and water) holding tanks will likely be required considering the permeable nature of the sands which are anticipated in the region.

Geotechnical Evaluation(s)

Additional consideration will be required through a subsurface geotechnical evaluation(s) such that the geotechnical design parameters associated with the study area, roadways and lot access/development can be characterized in greater detail.

Roadway/Lot Configuration

The proposed road right-of-way's and lot limits may need to be re-configured if pre-grading operations are to be minimized. Large right-of-way widths should be anticipated (particularly along steep roadways) to allow for adequate backslopes considering the sandy and hence erosion prone nature of the surficial deposits.

Site Grading, Surface Drainage and Erosion Control Plan

Site grading, surface drainage and erosion control plans should be formulated once conceptual designs have been established to ensure surface waters (and potential seepage zones) are adequately controlled.

Potential Environmental Hazards

Considering the presence of the monitoring wells which are located within and adjacent to the study area, a Phase I Environmental Site Assessment (ESA) should be conducted to determine whether or not there may be any potential environmental liabilities which may impact the study area.

Potential Natural Hazards

Considering the unconsolidated nature of the eolian deposits, further assessment should be conducted relative to the potential impacts of seismic events and/or a rise in the groundwater table relative to consolidation/settlement and the potential for liquefaction.

The (potentially) active and shifting nature of the sand dunes which are located within and around the study area may require additional consideration relative to long-term maintenance of the subdivision.

A natural hazard assessment should be conducted by qualified personnel to assess the forest fire potential if development is to be considered in greater detail.

8.0 LIMITATIONS

This report is intended for the sole use of *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 comments contained herein reflect our best judgment in light of the information available to our firm at the time of our assessment. They are based upon our collation of available literature, observations made during our site reconnaissance, recognition of geomorphic features and generally accepted engineering practices.

Given the nature of our assessment and scale of mapping, the information contained herein will not be sufficient to assess all factors that may have an effect upon design and construction and so this should be considered from a project management perspective. As such, our findings should be supplemented through subsurface geotechnical evaluations and other technical studies as may be required to verify site specific design parameters and verify development feasibility.

Due to the geomorphological nature of the deposits encountered, interpolations of subsurface conditions have not been made or implied other than for discussion purposes. The anticipated conditions have also been discussed, but only to the extent that they may influence design decisions. Suggestions of construction methods contained herein express our opinion and are not intended to direct contractors on how to carry out construction. Any reference to structures, roads or overall use of the study area have been made for discussion purposes only. The actual use will need to be determined during subsequent evaluation, planning and design processes.

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

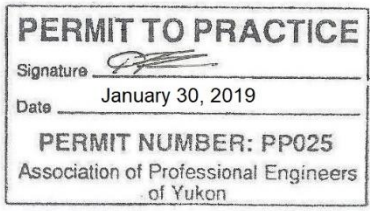
9.0 CLOSURE

Thank you for providing our firm with the opportunity to conduct this geotechnical feasibility assessment.

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

Respectfully Submitted,

CHILKOOT GEOLOGICAL ENGINEERS LTD.



Tares Dhara, P.Eng.
Senior Geotechnical Engineer

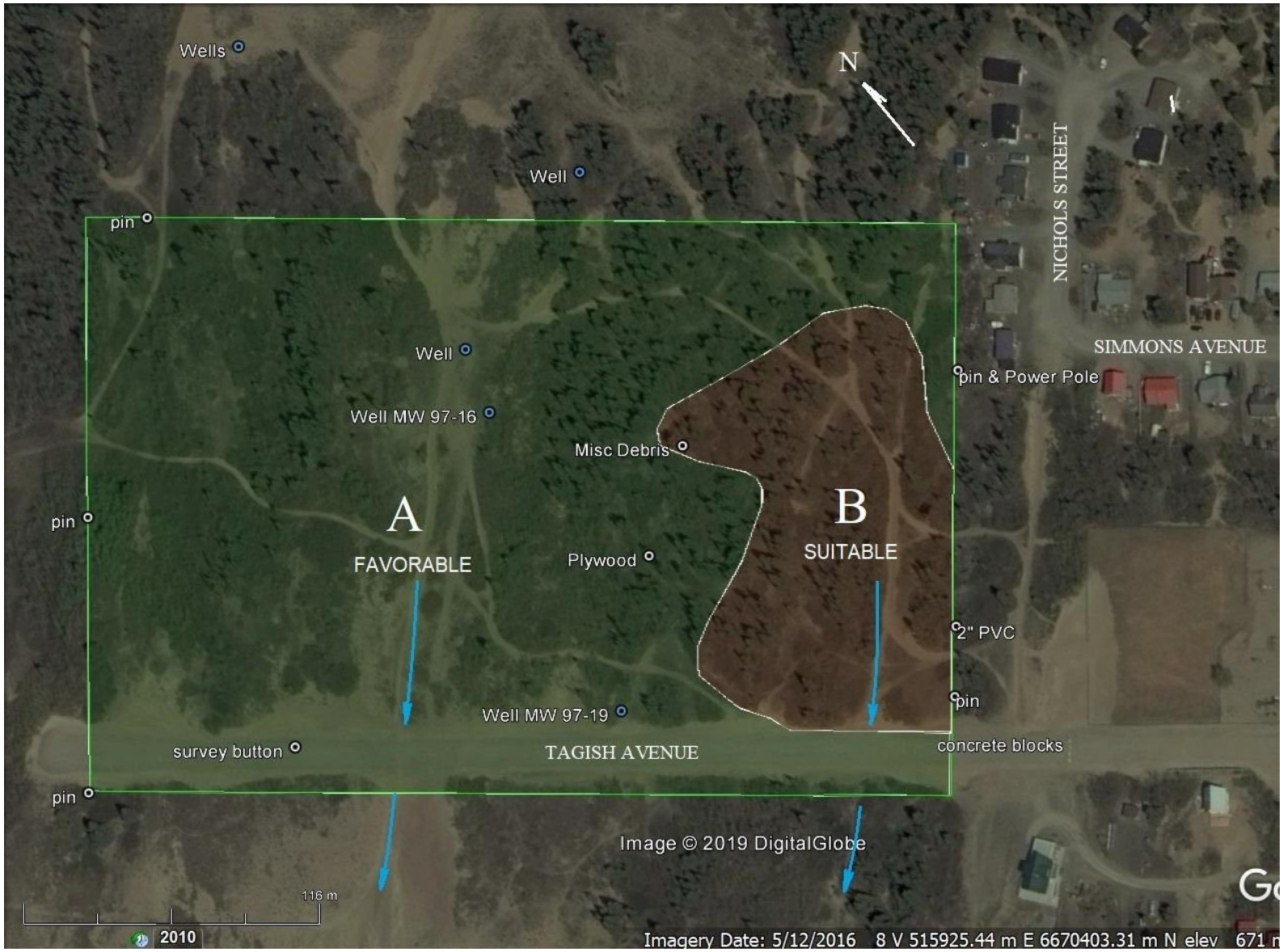
TD/td

Geotechnical Feasibility Assessment
Proposed Tagish Avenue Residential Subdivision – Carcross, Yukon – 2018-2019
Figure 1 – Location of Study Area

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

Compiled Jan.20th, 2019 by T.Dhara, P.Eng.

Geotechnical Feasibility Assessment
Proposed Tagish Avenue Residential Subdivision
Carcross, Yukon – 2018-2019
Figure 2 – Development Potential



Based map from Google Earth – Limits and locations are approximate - Not to Scale

Compiled Jan.20th, 2019 by T.Dhara, P.Eng.

Geotechnical Feasibility Assessment
Proposed Tagish Avenue Residential Subdivision – Carcross, Yukon – 2018-2019
Appendix A – 1987 Airphoto WP8722 #20

Limits are approximate.

Compiled January 20th, 2019 by T.Dhara