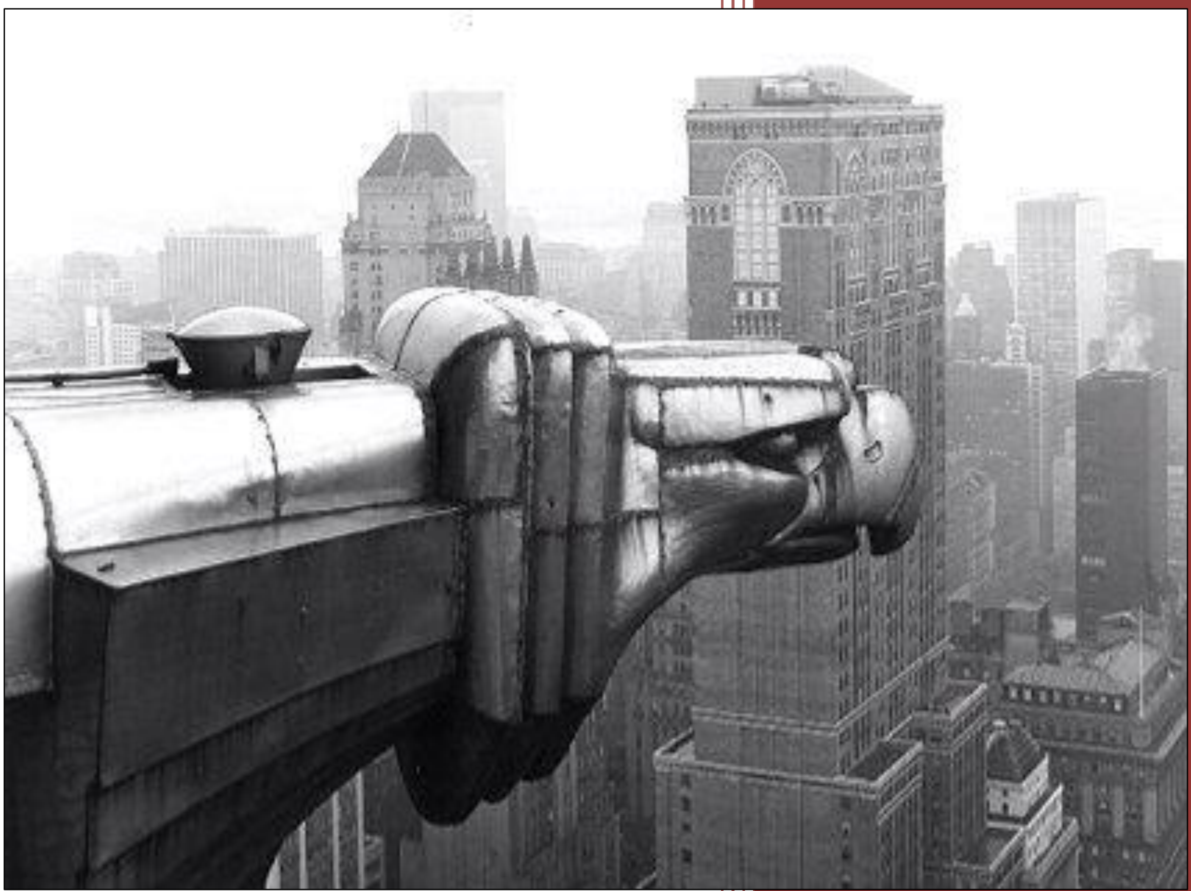
12th February, 2021

File No.: USG1123

Geotechnical Investigation
Public Works Operations Center
Penhold, Alberta



Union Street Geotechnical Ltd.
4726 - 78A Street Close
Red Deer, Alberta
T4P 2J2

Ph.: 403-350-9688
www.unionstreetgeo.ca

TABLE OF CONTENTS

LIST OF TABLES

Attachments

Drawings

Drawing No. A1 - Site Location Plan

Drawing No. A2 - Borehole Location Plan

Photographs

Photographs No. 1 to 4, inclusive

Borehole Logs

Boreholes No. BH101 to BH118, inclusive

EXECUTIVE SUMMARY

Union Street Geotechnical Ltd. performed a geotechnical investigation, on behalf of Tagish Engineering Ltd., on the 27th and 28th January, 2021, in Penhold, Alberta, for a proposed Public Works Operations Centre development. As proposed, the development consists of a single storey, 1,875 m^2 shop and office building, a single storey, 900 m^2 fire hall, asphalt parking lot, gravel yard, storm pond, and infrastructure typically associated with a development of this nature. Additionally, the project includes the development of a future collector roadway, located north of the site, and upgrades to Waskasoo Avenue, located west of the site. The site is located in the southwest portion of the N.W. ¼ of 06-37-27 W4.

Eighteen boreholes were drilled across the site for foundation and roadway design purposes. The soil stratigraphy generally consisted of, in descending order, topsoil, sand, clay, and till, however, gravel, fill, and organics were encountered in Boreholes BH117 and BH118 drilled within Waskasoo Avenue's Right-of-Way.

Considering the type of facility proposed, the site location, and the subsurface soil conditions; shallow foundations, driven steel pipe pile, and screw pile design recommendations have been included.

The Scope of Work for this geotechnical investigation was outlined in Union Street Geotechnical Ltd.'s proposal, PN1143, Rev. 1, issued to Tagish Engineering Ltd. on the 13th January, 2020.

LIMITATIONS

Union Street Geotechnical Ltd. prepared this report for the exclusive use of Tagish Engineering Ltd., and their agents, for a proposed Public Works Operations Centre, and associated development, located within the southwest portion of the N.W. ¼ of 06-37-27 W4M in Penhold, Alberta. The content reflect Union Street's best judgement available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third party and Union Street accepts no responsibility for damages, if any, suffered by any third party as a result of decisions or actions made based on this report.

Our recommendations and conclusions are based upon the information obtained from the subsurface exploration. The borings and associated laboratory testing indicate subsurface conditions only at the time and to the depth, of the specific boring location investigated and only for the soil properties tested. The subsurface conditions may vary between the boreholes and over time. The interpretation of subsurface conditions provided is a professional opinion of encountered conditions and is not a certification or guarantee of site conditions. If variations, or other latent conditions become evident, Union Street should be notified immediately so that our conclusions and recommendations can be re-evaluated. Although subsurface conditions have been explored, we have not conducted investigations, sampling, field or laboratory testing, evaluations, or modelling of the site or subsurface conditions with respect to the presence of contaminated soil or groundwater or slope stability conditions.

This report contains the results of our geotechnical investigation as well as certain recommendations arising from our investigation. The recommendations herein do not constitute a design, in whole or in part, of any of the structural elements of the proposed work. Incorporation of any or all of our recommendations into the design of any such element does not constitute us as designers or co-designers of such elements, nor does it mean that such design is appropriate in geotechnical terms. The designers of such elements must consider the appropriateness of our recommendations in light of all design criteria known to them, many of which are not known by us. Our mandate has been to perform a geotechnical investigation and recommend, which we have completed by means of this report. We have had no mandate to design, or review the design of any elements of the proposed work and accept no responsibility for such design or design review.

This report has been prepared in accordance with generally accepted geotechnical engineering practice common to the local area. No other warranty, expressed or implied, is made.

This document, and the information contained within, are the confidential property of Tagish Engineer Ltd. and any disclosure of same is governed by the provisions of each of the applicable provincial or territorial Freedom of Information legislation, the Privacy Act (Canada) 1980-81-82-83, c.111, Sch. II “2”, and the Access to Information Act (Canada) 1980-81-82-83, c.111, Sch. I “1”, as such legislation may be amended or replaced from time to time.

1 INTRODUCTION

1.1 BACKGROUND

Tagish Engineering Ltd. (Tagish) retained Union Street Geotechnical Ltd. (Union Street) to conduct a geotechnical investigation for a proposed Public Works Operations Centre in Penhold, Alberta. The development consists of a single storey, 1,875 m^2 shop and office building, a single storey, 900 m^2 fire hall, asphalt parking lot, gravel yard, storm water retention pond, and other infrastructure typically associated with a development of this type. Additionally, the development will include a proposed 172 m collector road to the north and roadway upgrade to Waskasoo Avenue to the west. The "site" is located within the southwest corner of the N.W. ¼ of 06-37-27 W4 as shown on Drawing No. A1.

1.2 OBJECTIVES

The objectives of the geotechnical investigation were to:

- define the subsurface soil strata, their properties, and existing conditions;
- provide recommendations for site grading;
- provide recommendations for cut/fill excavations and slopes;
- provide recommendations for frost depth;
- provide cement type recommendations;
- provide asphalt structure recommendations;
- identify potential geotechnical problems related to excavations and foundation construction;
- provide recommendations for structural foundations; and,
- provide recommendations on pertinent geotechnical issues identified during the subsurface investigation.

2 DESCRIPTION OF THE PROJECT AND SITE

2.1 SITE DESCRIPTION

The site is located within the N.W. ¼ of 06-37-27 W4M in Penhold, Alberta, as shown on Drawing No. A1. The civic address of the site is unknown at the time of reporting. The site consists of approximately 9.97 ha, was vacant, undeveloped, and being utilized for agricultural purposes at the time of drilling, and was generally flat with various minor grades sloping east towards Waskasoo Creek.

The site was bordered by a farm and agricultural land, containing Waskasoo Creek, to the north, agricultural land to the east and south, and Waskasoo Avenue to the west. Photographs depicting the site at the time of drilling are attached to this report.

2.2 PROPOSED STRUCTURES

The proposed development, the Town of Penhold's Public Works Operations Centre, consists of a single storey, 1,875 m^2 shop and office building, single storey 900 m^2 fire hall, asphalt parking lot, gravel yard, storm water retention pond, and associated infrastructure. Additionally, a future collector roadway, approximately 172 m in length, to the north and upgrades to Waskasoo Avenue are proposed. The recommendations herein are tailored for the proposed development. The structural loads at the time of this report writing are unknown, but are expected to be light to moderate. The proposed development and borehole locations are shown on Drawing No. A2.

Recommendations contained in this report have been given for the above-described development and those typical of a development of this nature. If there are any changes to the proposed developments, or their locations, these changes should be reviewed by Union Street personnel to confirm the applicability of this report to the revised development plans.

3 FIELD INVESTIGATION AND LABORATORY ANALYSIS

The field investigation program included drilling eighteen boreholes at the locations shown on Drawing No. A2. The borehole locations were established by Union Street personnel based on utility clearance, access, and the proposed development footprint shown on a client supplied site plan. No formal surveying of the borehole locations, or site, were completed and all drawings, locations, measurements, and legal descriptions are approximate and conceptual in nature.

On 27^{th} and 28^{th} January, 2021, eighteen boreholes (designated as BH101 to BH118) were advanced using a track-mounted auger drill utilizing 150 mm diameter, continuous flight augers, operated by J.E.D. Anchors & Environmental Drilling Ltd. The boreholes were advanced to depths varying between 3.05 m to 12.65 m below ground surface.

Supervision of the drilling, soil sampling, and logging of the various soil strata were performed by Union Street personnel. All soil samples and auger cuttings were visually examined and classified in the field in accordance with the Modified Unified Soil Classification System. The Borehole Logs are also appended.

The soil sampling and testing sequences which are shown on the borehole logs consisted of:

- Disturbed (‘grab’) samples obtained at a depth interval of 1.52 m for moisture content determinations. The moisture contents are shown on the logs; and,
- Standard Penetration Tests (SPT’s) were conducted in specific boreholes at various depths to obtain estimates of consistency, density, and strength of the various soil strata. The SPT “N” values (penetration resistances) are shown on the borehole logs.

Following drilling activities, piezometers were installed in Boreholes BH101, BH104, BH106, and BH108 and all remaining boreholes were backfilled to surface with auger cuttings. Seepage was observed in eight boreholes at an average depth of 5.22 m below grade. Sloughing was observed in seven of the eight deeper boreholes.

Subsequent to the drilling operations, laboratory analyses were performed to determine visual soil classification and in-situ water contents of all collected samples. Modified Unified Soils Classification (MUSC) analyses were performed on select soil samples. Observations made during the field investigation, visual descriptions of the soils, and the results of laboratory tests are presented in the attached Borehole Logs.

4 ANALYSIS AND DISCUSSION

4.1 GENERAL STRATIGRAPHY

The subsurface conditions were relatively uniform in all eighteen borehole locations for foundation and roadway support purposes. In general, and to the depths drilled, the stratigraphy encountered at the borehole locations generally consisted of, in descending order; topsoil, sand, clay, and till. Gravel, fill, and organics were encountered overlying the above mentioned general soil stratigraphy in the Waskasoo Avenue ROW. The soil is relatively uniform with little variations; however, there are slight variations and the following soil properties depict the average characteristics observed within the strata. Till extended to the maximum exploration depth in Boreholes BH101 to BH108 and clay extended to the maximum exploration depth in the remaining boreholes. Detailed soil descriptions are provided in the Borehole Logs, appended to this report.

4.1.1 Gravel

Gravel, with an approximate average thickness of 0.14 m, was encountered at surface in Boreholes BH117 and BH118.

4.1.2 Fill

Fill, averaging approximately 0.24 m thick, was encountered underlying the surficial gravel in Boreholes BH117 and BH118. The fill consisted of clay, was silty and sandy. It was brown to dark brown, oxidized, moist, hard (frozen), and massive.

4.1.3 Topsoil/Organics

Topsoil was encountered at surface in Boreholes BH101 to BH116. The topsoil varied in thickness across the site but had an average approximate thickness of 72 mm. Organics, averaging approximately 0.13 m thick, were encountered underlying the fill in Boreholes BH117 and BH118.

4.1.4 Sand

Sand was encountered underlying the topsoil/organics in all eighteen boreholes and extended to an approximate depth of 1.35 m below grade. The sand consisted of varying quantities of clay and silt but was generally clayey and silty. It was pale brown (10YR 6/3) to dark brown (10YR 3/3), oxidized, dry to moist, loose to compact, massive, and was calcareous.

The moisture content of the sand samples ranged from 8.3% to 15.7% with an overall average moisture content of 11.2%.

Five MUSC tests were performed on sand samples obtained from Boreholes BH101, BH104, BH107, BH116, and BH118. The MUSC results are summarized in Table 4.1.

TABLE 4.1: SUMMARY OF SAND MODIFIED UNIFIED SOILS CLASSIFICATION TEST RESULTS

Sample No. and Depth	Borehole No.	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Moisture Content (%)	MUSC - Soil Type
NT1 - 0.76 m	BH101	32.0	9.0	23.0	9.0	SC
NT27 - 0.76 m	BH104	44.7	11.2	33.5	10.1	SC
NT50 - 0.76 m	BH107	48.2	12.2	36.0	11.9	CI
NT80 - 0.76 m	BH116	43.7	10.6	33.1	14.3	SC
NT84 - 0.76 m	BH118	37.3	11.8	25.5	15.7	SC
Average:		41.2	11.0	30.2	12.2	SC

Based on the results in Table 4.1 the sand has an average MUSC of "SC" - Clayey Sand and is medium plastic. Results of the MUSCs also indicate that the sand contains an average, by mass, 0.0% gravel, 54.3% sand, and 45.7% silt and clay.

4.1.5 Clay

Clay was encountered underlying the sand at an average 1.35 m below grade in all eighteen boreholes which extended to an average approximate depth of 3.17 m in Boreholes BH101 to BH108 and the maximum exploration depth in the remaining boreholes. The clay was silty and sandy to contained some sand. It was dark yellowish brown (10YR 4/4), oxidized, moist, stiff to very stiff, laminated, and was calcareous.

The moisture content of the clay samples ranged from 9.3% to 50.2% with an overall average moisture content of 28.7%.

Pocket Penetrometer (PP) readings of the clay ranged from 60 kPa to 192 kPa with an average undrained shear strength reading of 124 kPa. This correlates to a soil with a very stiff consistency.

Seven Standard Penetration Tests (SPTs) were completed within the clay stratum resulting in an "N" value ranging from 6 to 15 with an average "N" value of 10. This value correlates to a soil with a stiff consistency and an undrained shear strength of 63 kPa.

For conversion of SPT "N" blow count values to an undrained shear strength, an empirical constant is determined by the following relationship:

$$S_u = K \bullet N$$

Where:

S_u is the undrained shear strength (124 kPa);
K is an empirical constant determined from site specific correlations; and,
N is the SPT "N" value (10).

The corresponding K value was determined to be 12.40.

Based on the PP and SPT test results the weighted average design undrained shear strength of the clay throughout the encountered stratum is 90 kPa.

One MUSC test was performed on a clay sample obtained from Boreholes BH101. The MUSC result is summarized in Table 4.2.

TABLE 4.2: SUMMARY OF CLAY MODIFIED UNIFIED SOILS CLASSIFICATION TEST RESULT

Sample No. and Depth	Borehole No.	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Moisture Content (%)	MUSC - Soil Type
NT3 - 2.29 m	BH101	87.8	21.7	66.1	39.6	CH

Based on the result in Table 4.2, the clay has a MUSC of “CH” - Silts or Clays of high plasticity. The MUSCs also indicate that the clay contains, by mass, 0.0% gravel, 20.9% sand, and 79.1% silt and clay.

4.1.6 Till

Till was encountered at an average approximate depth of 3.17 m below grade, and extended to the maximum exploration depth, in Boreholes BH101 to BH108. The till consisted of varying quantities of clay, silt, sand, and gravel but was generally composed of clay and sand and was silty. It was brown (10YR 4/3) to very dark grey (10YR 3/1), oxidized to non-oxidized, moist, firm to hard, massive, contained sand seam, gravel, and coal chip inclusions, and was calcareous.

The moisture content of the till samples ranged from 11.0% to 23.3% with an overall average moisture content of 15.3%.

Pocket Penetrometer (PP) readings of the till ranged from 36 kPa to 215 kPa with an average undrained shear strength reading of 154 kPa. This correlates to a soil with a very stiff consistency.

Eight Standard Penetration Tests (SPTs) were completed within the till stratum resulting in an “N” value ranging from 18 to 61 with an average “N” value of 32. This value correlates to a soil with a very stiff consistency and an undrained shear strength of 213 kPa.

The corresponding K value was determined to be 4.81.

Based on the PP and SPT test results the weighted average design undrained shear strength of the till throughout the encountered stratum is 184 kPa.

The till is a heterogeneous mixture of all grain sizes and cobbles and boulders may be encountered during construction.

4.2 GROUNDWATER

Seepage was encountered in eight boreholes during drilling at an average depth of 5.22 m below grade. Piezometers were installed in Boreholes BH101, BH104, BH106, and BH108 following drilling. The groundwater elevations were recorded on the 3rd February, 2021, 6 days following installation, and the results are summarized in Table 4.3.

TABLE 4.3: SUMMARY OF GROUNDWATER MEASUREMENTS

Borehole No.	Borehole Depth (m)	Water Level[1] (m), 2nd February, 2021
BH101	12.65	3.88
BH104	9.60	3.44
BH106	9.14	3.26
BH108	9.14	5.98
Average:		**4.14**

Notes:
1 - Below existing grade.

Based on seepage encountered during drilling, piezometer readings, and experience in the area; the groundwater table is likely (approx.) 3.0 m to 4.0 m below ground surface throughout the majority of the site. It is likely that the depth to groundwater changes as Waaskasoo Creek is approached. Groundwater levels are subject to meteorological events, seasonal variations, site gradient, and other salient factors resulting in the water table varying with time.

4.3 SULPHATE ATTACK

Laboratory testing was not performed for water soluble content in the soils due to the client's schedule. Design concrete in contact with native or cohesive fill for severe sulphate levels (Class S-2) with sulphate resistant Portland Cement (Type HS) having a minimum specified 56-day compressive strength of 32 MPa and a maximum water-cement ratio of 0.45 (see Table 3 in CAN/CSA A23.1-2014). Calcium chloride or any other admixture containing chlorides should not be used since the sulphate resisting property of the cement would be reduced. Calcium salts used as an accelerating admixture should also be avoided as they may increase the severity of sulphate attack.

If Portland Cement (Type HS) is unavailable or cannot be used due to adverse construction considerations, then Type 10 cement in combination with approximately 25% (depending upon the manufacturer's stamped mix design) by mass of cement of a Type F or CI fly ash, is expected to produce sulphate resistance equivalent, or superior, to concrete made with a Type HS.

To enhance durability, an appropriate amount of air entrainment as per CSA Specification CAN/CSA A23.1-2014, Clause 4.3.3 and Table 4, is also recommended for all concrete exposed to freezing and thawing at this site.

There may be other design criteria or exposure conditions as outlined in Tables 11 and 14 of CSA A23.1-2014 that could necessitate additional requirements for subsurface concrete.

If concrete construction proceeds during the winter, Union Street recommends that the concrete be manufactured and placed in a manner that complies with the cold weather provisions of CSA Concrete Specifications CAN/CSA-A23.1.

5 GEOTECHNICAL RECOMMENDATIONS

The sand offers moderate bearing support for shallow foundations, however, it is not recommended to use the clay as bearing stratum for shallow foundations due to its plasticity. The till offers moderate to good skin friction and end bearing support for deep foundations. The foundation recommendations in this report are limited to shallow foundations, driven steel pipe piles, and screw piles. Cast-in-place concrete piles could be utilized, but due to seepage and sloughing observed in multiple boreholes, would likely require casing/pumping. Alternative foundation recommendations can be provided if required.

Seepage encountered during drilling and piezometer measurements indicate that the average groundwater table is approximately 3.0 m to 4.0 m below grade. Therefore, estimated groundwater elevations indicate that trench and pit excavations extending beyond these depths will likely encounter seepage if left open for periods of time.

It is recommended that positive drainage be maintained around the structures. Positive drainage is particularly important for the improved performance of grade supported foundations, roadways, and parking locations. It is also recommended to avoid landscaped areas up against the building and downspouts should discharge the water well away from the building.

Pertinent geotechnical issues for the proposed development are:

1. It is recommended that vegetation, organics, and non-structural fill are stripped prior to construction activities;

2. Based on the MUSC analyses, the sand encountered was generally SC" - Clayey Sand, is medium plastic, and will experience minor to moderate volume changes with fluctuating moisture conditions. A MUSC analysis indicated that the clay was "CH" - Silts or Clays of high plasticity and will generally experience significant volume changes with fluctuating moisture conditions. Additionally, the subgrade is frost active and will experience volume changes during freezing/thawing cycles. Construction of unheated, on-grade structures and/or shallow foundations, where movement would be detrimental, is not recommended at this site;

3. The sand encountered offers poor to moderate bearing support for shallow foundations, however, it is not recommended to utilize the clay as a bearing stratum for shallow foundations. The clay is considered high plastic and is a poor bearing soil for shallow foundations.

4. The till provides moderate to good skin friction resistance and end bearing support for deep foundations;

5. There is more than one suitable option for the type of foundation system used, however, most foundations systems mobilize their full support and behave differently. Therefore, the use of several different types of foundations systems to support the same structure is not recommended. For proper building performance, choose one type of foundations system for supporting the same structure;

6. Although the till matrix is typically a uniform gradation, it may contain random cobbles, boulders, or pockets of other soil types, such as granular soils; and,

7. The water table depth is estimated to be, on average, 3.0 m to 4.0 m below ground surface throughout the site. Excavations beyond these depths will

likely start seeping and filling with water if they are left open for periods of time.

Concrete slabs should be supported by gravel pad foundations constructed on a prepared subgrade.

5.1 RECOMMENDATIONS FOR SITE GRADING AND EARTHWORKS

All unprepared fill, topsoil, organic material, and non-structural fill should be removed from the areas where subgrade support will be required, which typically would include parking, roadways, grade-supported slabs, sidewalks, aprons, etc. Moderate conditions are expected for the mobility of wheeled construction equipment during minor precipitation events. Moderate conditions are expected for the mobility of wheeled construction equipment on the exposed sand subgrade during minor precipitation events.

In areas where the existing grades need to be raised, the exposed subgrade should be proof rolled according to the local specifications prior to placement of any fill. In areas of cut, or those currently at grade, the exposed subgrade following excavation should be compacted and a similar proof roll performed. Alternatively in place of proof rolling activities, compaction testing can be performed. In areas of cut, the exposed subgrade following excavation should also be compacted in a similar manner. All proof roll activities should be monitored by competent geotechnical personnel.

5.1.1 Engineered Fill and Road Construction

Ideally, fill required to raise the grade should consist of low to medium plastic soils with moisture contents near the Optimum Moisture Content. Fill soils should be free from any frozen soil, organic materials, contamination, and deleterious construction materials. High plastic clay is not recommended as backfill where subgrade support is required due to the potential for swell and heave of the subgrade. Uniform graded sand, or silt, should also be avoided, since such soils require strict moisture content control to achieve required degrees of compaction and would be difficult to compact in unconfined areas. MUSC analyses classified the existing sand as medium plastic and clay as high plastic. Low to medium plastic soils are recommended as fill but it is recommended to maintain a uniform bearing surface to avoid non-uniform reactions due to loading conditions and changing moisture contents.

Depending on the grading required, well-graded gravels could also be considered, in conjunction with the existing gravel. Gravel fill will likely be required for the base and sub-base for access roads, parking areas, concrete slabs, storage areas, etc.

Cohesive fill should be placed in lifts not exceeding 200 mm and compacted to a minimum 98% SPDD at moisture contents ±2% of optimum. A minimum compaction of 100% SPDD at moisture contents ±2% of optimum for structural fills below slabs, parking lots, aprons, etc. greater than 1.2 m in thickness is recommended. The local soils may require moisture conditioning to achieve the required degrees of compaction. The degree to which moisture conditioning of the fill would be required may vary with the local soils and construction season. The native soils will likely require drying, or blending with drier soils, in order to achieve the required degrees of compaction.

Upon achieving the design top-of-subgrade elevation, the completed subgrade should be proof-rolled by two passes of a single axle, dual wheel truck with an 80 kN axle load. Areas displaying appreciable deflections should be sub-excavated to competent strata, and the weak soils should be replaced with a more competent soil. All proof-rolls should be observed by competent geotechnical personnel.

Where imported granular fill is to be used to raise the grades, it should consist of 80 mm minus pit run gravel. A structurally acceptable gravel gradation (City of Red Deer) is provided in Table 7.1. Gradations outside of these limits may be used; however, a qualified geotechnical engineer should approve any imported fill prior to use.

Qualified geotechnical personnel should monitor the quality and placement of fill soils. The compaction of the fill should be monitored by field density testing at regular frequencies. The minimum test frequency should be one test per lift every 500 m^2.

5.1.2 Drainage

In general, site drainage measures should be implemented during early stages of the site grading earthworks. Surface runoff should be directed into ditches and discharged outside the development area. To promote surface runoff, and to minimize potential saturation and degradation of the subgrade, the subgrade surface should be graded at a minimum slope of 2%, directed towards drainage ditches. Water should not be allowed to pond within, or adjacent to, any buildings, roadways, grade supported slabs, etc. The finished grade adjacent to the facilities should be graded at a minimum slope of 3% over a distance of 3.0 m.

5.1.3 General Excavation Cut Slopes

Cut slopes in fine grained soils should be constructed at angles of 3H:1V or less for slopes over 3.0 m high but less than 6.0 m high. For cut slopes in fine grained soils less than 3.0 m in height, and in soils with low moisture levels, angles of 2.5H:1V may be used. Cover slopes that are over 3.0 m with polyethylene sheeting to protect them from rainfall and to reduce drying. If sand is encountered during cut excavations, the cuts will need to be constructed at a minimum 3H:1V and covered to ensure water does not impact the cut surface.

Cut slopes in saturated (wet) soils or soils with significant seepage should not exceed 4.0 m in height without additional geotechnical input. Higher cut slopes may have a tendency to be unstable in view of the saturated ground conditions and seepage, and thus may require additional geotechnical input on mitigative measures. Union Street can provide additional input as and when required.

If bedrock is encountered, a cut slope angle of 0.75H:1V may be used provided the bedrock is competent and relatively unfractured. Bedrock bedding and dipping planes may supersede the recommended slope angle. Cut slopes over 6.0 m in height should be reviewed by a qualified Geotechnical Engineer.

All cuts should have adequate ditching of at least 0.5 m from the base of the cut and absolutely no water should be allowed to pond at the base of any cut. Additionally, surface water should be directed away at the top of all cut surfaces to eliminate sand erosion and loss of soil strength along the slope. Equipment access, and any activity that would load the cut, should also be restricted from a horizontal distance equal to the vertical depth of the cut, from the crest of the slope for all slopes.

5.1.4 General Fill Embankment Slopes

Fill slopes in fine grained soils should be constructed at angles of 3H:1V or less for slopes over 3.0 m high but less than 6.0 m high. Where native soils are well-drained and/or unsaturated and the fill slopes do not exceed 3.0 m in height, a slope angle of 2.5H:1V may be used. Additional review of fill slopes over 6.0 m in height will be required by a qualified Geotechnical Engineer.

Fill slopes should be constructed in lifts not exceeding 150 mm and compacted to 98% SPDD. Add water or dry the fill as necessary to achieve the specified density.

Again, fill slopes should have adequate ditching of at least 0.5 m from the base of the cut and absolutely no water should be allowed to pond at the base of any cut. Additionally, surface water should be directed away at the top of all cut surfaces to eliminate sand erosion and loss of soil strength along the slope. Equipment access, and any activity that would load the cut, should also be restricted from a horizontal distance equal to the vertical depth of the cut, from the crest of the slope for all slopes.

5.1.5 Temporary Construction Excavations

Temporary construction excavations will likely be required for underground utility installation, ditches, etc. Alberta's Occupational Health and Safety Code, 2009, Part 32 - Excavating and Tunnelling, must be followed.

Proper cut back and/or shoring will be required for all excavations exceeding 1.5 m in depth where worker access is required. Excavations greater than 1.5 m should be inspected by a geotechnical engineer for signs of seepage and instability, and at three month intervals, unless the slopes are frozen. Cover slopes that are higher than 3.0 m with polyethylene sheeting to protect them from rainfall and to reduce drying. Under no circumstances should water be allowed to pond on a side slope or at the base of the excavation.

5.2 DRIVEN STEEL PIPE PILE DESIGN

Driven steel pipe piles are an optional foundational system to support the proposed development at this site. Open-end steel pipe piles are recommended as opposed to closed-end pipe piles for piles terminating in the till. Open-end steel pipe piles are recommended as opposed to close-end pipe piles for piles terminating in the till. For compressive loads, both skin and end bearing resistances can be included in the design. The ultimate skin friction values to be used in the ULS Design for driven steel pipe piles under compressive loads for the site are given in Table 5.1.

Skin friction should be neglected along the portion of the pile that extends through the upper 2.0 m of soil below finished grade. "Negative" skin friction will be required in areas utilizing fill. For pipe piles, only the exterior surface area of the pile in contact with the soil should be used in the calculation of the frictional resistance. The end-bearing resistance should be applied to the gross area at the pile tip which may be taken as the area enclosed by the outer diameter of the pipe section if the pile is less than 0.5 m in diameter. The area should be reduced by 2/3 if the pile diameter is greater than 0.5 m.

TABLE 5.1: ULTIMATE SKIN FRICTION AND END BEARING RESISTANCE FOR DRIVEN STEEL PIPE PILES

Depth Below Existing Grade (m)	Soil Type	Ultimate	
		Skin Friction Resistance (kPa)	End Bearing Resistance (kPa)
0.0 to 2.0	Sand/Clay	-	-[1]
2.0 to 3.2	Clay	43	-[1]
Below 3.2	Till	72	1,656[2]

Notes:
1 - Not recommended.
2 - A minimum preliminary pile length of 5.3 m is recommended.

A preliminary minimum driven pile length, for a structure, of 5.3 m is recommended to resist uplift due to frost jacking, see Section 5.5 for further information.

The factored[1] geotechnical driven pipe pile resistance is given as follows:

[1] Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual, 4th Edition*, P. 136.

$$\phi R_n$$

where:

ϕ is the geotechnical resistance factor as follows:

ϕ = 0.4, for axial compression piles; and,

ϕ = 0.3, for axial tension (uplift) piles.

R_n is the ultimate geotechnical resistance and is determined by combining the relative skin friction and end bearing resistance of the pile. Group reduction factors will be required if any piles are placed within a center-to-center spacing of less than three times the diameter of a pile.

The vertical load capacity of steel piles should be limited to no more than the allowable internal stress, which should be determined by multiplying the cross-sectional area of steel at the pile tip by 0.35 f_y, where f_y is the yield strength of the steel. This is equivalent to limiting the unfactored resistance of the piles to less than about 0.87 f_y. This recommendation is provided mainly to improve drivability and to control driving stresses, as past experience indicates that if the compressive load capacities are reduced to this degree, the likelihood of structural damage caused by pile driving is also reduced.

For the steel pipe piles, the preliminary wall thickness of the piles can be determined according to the minimum values recommended by the American Petroleum Institute[2] based on expected driving conditions. The minimum wall thickness is given as:

$$t = 6.35 + \left(\frac{D}{100}\right)$$

Where:

t = wall thickness (mm); and,
D = outside pile diameter (mm).

[2] American Petroleum Institute (API), 1993. *API Recommended Practice for Planning, Designing, and Construction of Fixed Offshore Platforms*. Report RP-2A.

5.2.1 Pre-Bore

Although likely not required at this site, the following applies for piles requiring pre-boring. Pre-bore holes will likely remain open for a limited time and there is the potential that some pre-bored pile holes may fill with groundwater and slough. It is recommended that the driven steel piles be installed immediately following the completion of the pre-bored holes.

If pre-boring is required, pre-bored holes, for 5.3 m long piles, should extend 4.3 m and have a diameter of approximately 90% of the outside diameter of the pipe piles. Should difficult driving conditions be encountered, the pre-bored depth may be increased to 4.8 m with a 90% diameter pre-bored hole. If difficulties are still encountered during pile driving, the depth of the pre-bored hole can be extended to the maximum depth of 5.3 m or a larger pre-bored hole should be drilled but not exceeding 95% of the outside diameter of the pipe piles to be used in the design.

5.2.2 Installation and Monitoring

Pile lengths may vary greatly, particularly in pile groups; therefore, the need for qualified inspection, testing of piles, and suitable specifications is paramount.

As a guide, for steel piles 200 mm in diameter or less, typical hammer energies in the range between 25 kJ and 35 kJ per blow should be used. For pile sections 250 mm to 300 mm in diameter, typical hammer energies in the range between 45 kJ and 65 kJ per blow are recommended. Refusal criteria should be based on the delivered energy of the hammer used. Union Street recommends a preliminary driving refusal criterion over the last 250 mm of penetration to be 10 blows per 25.4 mm (1 inch) of penetration, unless mushrooming and deformation of the pile top occurs first.

Prior to the pile installation, the piles should be inspected to confirm that the material specifications are satisfied. The piles should be free from protrusions, including protruding welds which could create voids in the soil around the pile during driving. If a driving shoe is used, it must not protrude beyond the outside diameter of the pipe pile.

5.2.3 Pile Driving Analysis Testing

In accordance with the Canadian Foundation Engineering Manual, 4th Edition - 2006, the design engineer should apply an appropriate resistance factor to all ultimate design loads for uplift and compression:

Resistance Factors for Factored pile loads:

- Static Analyses Compression: $\phi = 0.4$ Axial load; and,
- Static Analyses Tension: $\phi = 0.3$ Axial load (up-lift).

However, depending upon the structural loads, and number of piles, Union Street recommends performing Pile Driving Analysis (PDA) on driven pipe piles which can increase the resistance factors for factored piles loads to $\phi = 0.5$ for compression and $\phi = 0.4$ for tension piles. If performed, PDA testing may significantly increase the allowable design load, reducing steel costs.

5.3 SCREW PILES

Screw piles are an ideal foundation system for the proposed development at this site. Screw piles have an advantage over other pile types with respect to depth of embedment to resist frost jacking and that, at some point in the future, they can be easily removed. The frost jacking forces that develop on the screw shaft in frozen soils is relatively small compared to the pull strength of the helix embedded in soil below the frozen zone. Consequently, screw anchors do not require the additional depth needed for other pile types to resist frost jacking. The screw pile's helical plate/plates must be completely below the depth of frost penetration, estimated to be 2.0 m at this site, however, to be effective against frost resistance.

The ultimate end bearing resistances for screw pile design having a steel shaft diameter of 140 mm (5.5 inches) and a helix diameter of 508 mm (20 inches) is calculated using the following:[3]

[3] Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual* 4th Edition, p. 267.

$$Q_h = (NcSu + \gamma' H)A$$

Where:

Q_h = Individual helix bearing capacity;

N_c = 9 if H/D >4 (D = helix plate diameter);

S_u = Undrained shear strength of the soil at helix (184 kPa for the till);

γ' = Effective Unit Weight of the soil (8.3 kN/m^3 for the till);

H = Depth to helical bearing plate; and,

A = Effective helix area (0.203 m^2).

Due to the likely moderate to long length of the screw piles at this site, skin friction contributions may be considered. The ultimate total resistance of the helical pile or anchor equals the bearing capacity of the soil applied to the individual helical plate(s) and the skin friction of the shaft. Therefore the ultimate capacity of the screw pile is:

$$R = Q_h + Q_f$$

Q_f is calculated as:

$$Q_f = c \ x \ h \ x \ F_s$$

Where:

c = Circumference of pile shaft (0.44 m);

h = Height from helix plate to top of soil skin friction area; and,

F_s = Skin friction of soil in h area (see Table 5.1).

The capacities of multiple helix screw piles are calculated as follows:

$$Q_u = \sum_{i=1}^{n} Q_{ui} R_f$$

Where:

Q_u = ultimate pile capacity (kN);

i = helical plate number, from 1 to n, increasing with depth;

Q_{ui} = ultimate capacity of the helical plate, number i, (kN); and,

R_f = helical plate interaction factor as shown in Table 5.2.

TABLE 5.2: INTERACTION FACTOR

Ratio of Average Spacing to Average Plate Diameter (S/D)	Interaction Factor (R_f)
1.0	0.30
2.0	0.50
2.5	0.65
3.0	0.75
3.4	0.85
4.0	0.95
5.0	1.00

The factored[4] geotechnical screw pile resistance is given as follows:

$$\phi R_n$$

where:

ϕ is the geotechnical resistance factor as follows:

$\phi = 0.4$, for axial compression piles; and,

$\phi = 0.3$, for axial tension (uplift) piles.

R_n is the ultimate geotechnical resistance and is determined by combining the relative resistance of each helix on the pile. Group reduction factors will be required if any piles are placed within a center-to-center spacing of less than three times the diameter of the helix.

Screw anchors may be installed in frozen soil. Screw anchors are a favourable foundation system for structures with light to moderate loads. These anchors are provided on a design-build basis. We recommend the anchor designs be prepared or reviewed by a qualified geotechnical engineer. During screw pile installation, care must be taken to match the pitch of the helix with the rate of advancement and rotation to minimize disturbance of the supporting soil. Additionally, double helix

[4] Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual, 4th Edition*, P. 136.

screw piles must be designed so the upper helix follows in the path of the lower helix during installation. The vertical load capacity of steel piles should be limited to no more than the allowable internal stress, which should be determined by multiplying the cross-sectional area of steel at the pile tip by 0.35 f_y, where f_y is the yield strength of the steel. This is equivalent to limiting the unfactored resistance of the piles to less than about 0.87 f_y.

It is outside Union Street's scope of work to provide pile wall thicknesses, helical thickness, welding specifications/codes, or metal characteristics and these should be provided by the owner or the owners' agent.

5.4 SHALLOW FOUNDATIONS

Footings founded at depths below 2.0 m founded on native clay will likely not be subject to movements by frost. Footings founded above this depth will be subject to movement by frost, and therefore, will require insulation and heating to prevent frost penetration below the footing. Due to the plasticity of the clay, it is recommended that all shallow foundations bear on the medium plastic sand or till and if bearing on the sand, utilize a minimum 0.50 m buffer between the bottom of footing and clay stratum. Shallow foundations should not be placed on organic, non-structural fill, soft, wet, frozen, or high plastic soil.

The following recommendations are made for shallow foundations at this site:

1. The shallow foundations must be founded on undisturbed native sand or till subgrade. No footings should be constructed on non-structural fill, organic, or high plastic material. Ideally, the bearing stratum will be similar for the entire structure to maintain equal reactionary effects of changing load conditions.

2. Expose undisturbed native sand or till as the founding stratum for shallow foundations. A minimum footing depth of 2.0 m is recommended if the structure is not insulated and/or heated.

3. Prepare the founding surface by removing any pockets of soft, saturated, or organic soil to a uniform bearing surface. The founding surface must be maintained in an undisturbed state. The surface should not be left exposed to the environment which could result in wetting, softening, or drying.

4. In areas beneath the shallow foundation, excavate to expose the founding stratum below the footing level. Backfill over-excavated areas below the footing with concrete.

5. The footings/pads must be adequately reinforced to distribute the applied loads and also have sufficient stiffness to distribute local overstresses.

6. Design strip footings deeper than 0.61 m, founded on native sand, for ULS Design with an ultimate bearing capacity of 300 kPa. The factored ULS capacity can be calculated by multiplying the ultimate capacity by a resistance factor of 0.5. For SLS Design, an allowable bearing capacity of 100 kPa can be used for strip footings on the native sand. The SLS bearing capacity is based on limiting settlement to less than 25 mm. The bearing capacity values recommended above are only applicable to a strip footing with a maximum width of 1.2 m or a pad footing with maximum dimensions of 1.5 m x 1.5 m. For square pad footings, the bearing capacity values can be increased by 20%. If larger size footings are required, the footing size and settlement potential should be reviewed.

7. If the sand stratum is utilized as a bearing soil, compaction of the exposed surface is recommended prior to placing any forms to eliminate disturbances associated with excavating a non-cohesive soil;

8. Design strip footings deeper than 2.0 m, founded on native till, for ULS Design with an ultimate bearing capacity of 360 kPa. The factored ULS capacity can be calculated by multiplying the ultimate capacity by a resistance factor of 0.5. For SLS Design, an allowable bearing capacity of 120 kPa can be used for strip footings on the native till. The SLS bearing capacity is based on limiting settlement to less than 25 mm. The bearing capacity values recommended above are only applicable to a strip footing with a maximum width of 1.2 m or a pad footing with maximum dimensions of 1.5 m x 1.5 m. For square pad footings, the bearing capacity values can be increased by 20%. If larger size footings are required, the footing size and settlement potential should be reviewed.

9. The minimum width for a footing as required by the applicable building code must be used in design regardless of bearing capacity considerations.

10. A qualified geotechnical engineer must inspect all shallow foundation bearing surfaces prior to casting footings.

11. If wet, soft, or firm subgrade is encountered as the bearing surface, these areas must be further excavated and backfilled with concrete.

12. In cases where footings support a wall, granular backfill is ideal because it provides subsurface drainage on the exterior of the wall (lowers the hydrostatic pressure) and tends to settle less than uncompacted clayey soil backfill. Where granular backfill of walls is used, a clay cap is recommended for porous surface areas to prevent the influx of surface water

Basement and retaining walls must be designed to support the horizontal loads imposed by the earth behind the wall. If the backfill behind the walls cannot be fully drained, the hydrostatic forces from impounded water must be added to the wall loads. Any surcharge loading at the top of these walls, such as parked vehicles, must also be included in the wall loading. The structural design of these walls must provide mechanisms to prevent leakage, such as water stops and planned shrinkage joints to minimize random cracking. The exterior of the walls require heavy water proofing materials.

Place a minimum 450 mm of impermeable clay soil at the exterior surface to reduce surface infiltration into the granular backfill. Provide factory installed geotextile wrapped plastic perforated subdrain pipes around the base of basement or retaining walls. Provide for gravity discharge of the subdrain pipe to a frost-free sump, which is drained by gravity or level activated pumping.

The soil properties to use in the design of basement and retaining walls are given in Table 5.3. These values are estimated based on soil index properties.

TABLE 5.3: SOIL PROPERTIES FOR BASEMENT AND RETAINING WALL DESIGN

Soil Type	K_o	Unit Weight (kN/m^3)	Friction Angle
Granular Fill	0.36	23.0	40°
Sand	0.44	17.7	34°
Till	0.50	18.1	30°

5.5 FROST DESIGN RECOMMENDATIONS

5.5.1 General

Winter frost penetration will likely impact roadway structures, sidewalks, aprons, and/or underground utilities due to the expansion of pore water in the soils. Based on historical temperature data for the Penhold region, the estimated frost penetration depth is 2.0 m. The depth of frost penetration is applicable for areas of the site where organic materials have been removed and where snow cover is non-existent. The effect of snow cover, a higher ground water surface, soil type, and higher moisture contents affect the depth of frost penetration.

5.5.2 Adfreezing Stresses on Piles

For piles, the required minimum pile embedment depth to resist adfreezing (frost jacking) must be rationally determined whereby the resistance to adfreezing stresses will be provided by the dead load, the weight of the pile, and by the shaft friction below the depth of frost penetration. The frost jacking adfreeze stresses may be assumed to be 100 kPa[5] above a depth of 2.0 m for fine grained soil frozen to steel. For preliminary purposes, driven piles in unheated structures should have a minimum embedment depth of 5.3 m. For a typical screw pile, the upper helix must be installed below the frost depth. The full design dead load must be applied to the piles prior to winter.

5.5.3 Frost Heave and Swelling Clays

To reduce the potential of frost heave and swelling clay pressures, provide a minimum 100 mm void between the underside of pile supported structures and the sand subgrade (150 mm void if the subgrade is clay). This void space allows for the upward movement of the ground surface by frost heaving, or expansive soil, without those heaving/swelling movements affecting the structure. Structures on grade supported slabs will be subject to movements caused by frost action. Expansive movement may occur as the subgrade is medium to high plastic and is frost active

---

[5] Penner, E., (1974). *Uplift Forces on Foundations in Frost Heaving Soils,* Canadian Geotechnical Journal, Vol. 11, No. 3, August, pp. 323-328.

The finished grade adjacent to each skid, pile cap, grade beam, etc. should be capped with a well-compacted clay, and sloped away so that the surface runoff is not allowed to infiltrate and collect in the void space.

6 Earthquake Design Parameters

The soil stratigraphy encountered generally consisted of, in descending order, topsoil, sand, clay, and till. Pertinent seismic data[6] for the proposed development site is provided in Table 6.1.

- The average soil Undrained Shear Strength is: $S_u > 100$ kPa; and,
- Site Classification for Seismic Response is Site Class "C" with a corresponding Average Shear Wave Velocity of $360 < Vs < 760$ m/s.

7 Floor Recommendations

7.1 Grade Supported Slabs

Our recommendations for a grade supported floor slab are as follows, including radon mitigation system, and assume the elevation of the slab will be similar to existing grades (within the proposed building footprint) at the time of drilling:

1. Strip the site of topsoil, organics, and/or non-structural fill below the proposed slab, exposing the native sand subgrade. Construction on material of unknown quality and composition can result in uneven settlement or heave. If encountered, remove all organics from the floor area during subgrade preparation. Remove all loose soil and debris. Soft, wet areas, which do not have sufficient trafficability for construction purposes, should be further excavated and replaced with a more competent material.

2. A uniform bearing subgrade and structure is desired to maintain equal reactionary effects to changing loading conditions and fluctuating subgrade moisture contents.

[6] Data was obtained from the *Geological Survey of Canada* and the *Alberta Building Code 2006, Volume 2*.

3. Scarify and uniformly compact the exposed subgrade to a minimum 98% (100% for fills exceeding 1.2 m) of its SPDD as determined by test ASTM D698. Adjust the water content of the subgrade to within +2% of the optimum moisture content.

4. Any material required to raise the grade before construction of the grade supported floor should be a non-expansive soil such as low to medium plastic soil which would be placed on the subgrade. Place the structural fill in lifts not exceeding 200 mm compacted thickness and compact to a minimum 98% of its SPDD as determined by test ASTM D698 for shallow fills. Adjust the water content of the structural fill to within ±2% of the optimum moisture content.

5. Place a roughed in radon sump, near the centre of the footprint, connected to a minimum 100 mm diameter collection system whose top end is sealed and permits connection to depressurization equipment (depending on the building's footprint, it may be more economical to install multiple collection systems). Sleeves may be required through any barrier (footing, footing wall, etc.) that would prevent depressurization of the entire building footprint.

6. For light loads, place not less than 150 mm of 20 mm screened or washed rock of which not more than 10% of material will pass a 4 mm sieve (Radon Rock), on the compacted, prepared subgrade. The radon rock should be compacted using a vibratory compactor. The slab specifications should be provided by the structural engineer.

7. Install polyethylene sheeting, conforming to CAN/CGSB-51.34-M, between the granular base and the concrete slab, and seal it, to prevent the migration of moisture and radon through the floor.

8. The design must not allow load transfer from stable building elements supported by the foundation to potentially vertically moving building elements supported by the soil or grade supported slab.

9. Provide site drainage away from the slab. Minimum slopes of at least 2% are recommended.

10. Provide separation boards between the floor slab and any structurally supported structures if adjacent to one another. This separation prevents load transfer from the moving floor to the stable, foundation supported structure.

11. It is not recommended to place reinforcing steel to connect the grade supported floor slab to the edge of the grade beam. Such reinforcement has two consequences. First, there will be a major crack and fault in the floor along a line parallel to the grade beam face at exactly the end of the connecting steel. Secondly, a strongly reinforced connection can rotate the top of the grade beam outward if the floor adjacent heaves. Structural damage, such as the displacement and pop out of plate glass windows, has been observed. If the client wishes to tie the slab to the grade beam, strategically placed saw joints within the slab are strongly recommended.

12. Use sleeves through the grade-supported floor slab and telescoping or collapsing connections for all pipes passing through or supported by the grade-supported slab.

13. Review the building design to identify and revise any construction details which allow load transfer from moving grade-supported building elements to stable structurally supported building elements.

TABLE 7.1: CITY OF RED DEER AGGREGATE SPECIFICATION

Sieve Size (mm)	% Passing For Nominal Maximum Size	
	20 mm (Base)[1]	80 mm (SGSB)[1]
80	---	100
50	---	55-100
25	---	50-75
20	100	---
16	84-94	---
10	63-86	---
5.0	40-67	25-55
1.25	20-43	---
0.630	14-34	---
0.315	9-26	---
0.160	5-18	---
0.080	2-10	2-10

Note:
1 - City of Red Deer Engineering Services Contract Specifications, 2017 Edition, Section 31 05 17 Aggregate Materials, Table A.2 Aggregate Gradation Specifications.

If radon is going to be accounted for mechanically, recommendations for a traditional floor slab structure utilizing 20 mm base gravel can be provided upon request.

7.2 STRUCTURALLY SUPPORTED FLOORS

Where heaving or settlement will have unacceptable impacts on floor serviceability, structurally supported floors should be provided.

Our recommendations for structurally supported floors are as follows:

1. The floor should be designed to derive its support structurally from the structural foundation system.

2. The void or crawl space must be a minimum 150 mm below the underside of the floor slab.

3. If a crawl space is used, provision must be made for accumulated waters to drain to a frost-free sump by sloping the crawl space floor. Additionally, the soil below the crawl space should be covered with 150 μm polyethylene sheeting

held in place by at least 50 mm of sand. Alternately, a thin concrete mud floor may be used on the bottom of the crawl space. Ventilation must be provided to the crawl space during the non-freezing season to remove moisture and possible gas accumulations. It is desirable to design the ventilation system with vents that may be closed with insulated covers during freezing weather.

Void form systems that rely on the decomposition of an organic void forming material should be avoided.

8 ROADWAY DESIGN

8.1 SUBGRADE CONDITIONS FOR PAVEMENT DESIGN

The stratigraphy at the site consists mainly of topsoil, sand, clay, and till. The sand subgrade offers moderate support for asphalt pavement.

Pavement structural thickness will be designed using the AASHTO 1993 Pavement Design Method. In this method, the higher summer or drained subgrade strength condition is reduced by a factor to give the seasonally adjusted or design strength, expressed as a resilient modulus in MPa. The seasonal adjustment factor (0.36) was developed as suitable for local climate conditions in western Canada. A design Resilient Modulus (M_R) of 45 MPa was utilized for roadway and parking design.

8.2 TRAFFIC CONDITIONS FOR PAVEMENT DESIGN

There is no measured traffic data with details of Average Annual Daily Traffic (AADT), annual traffic growth, or vehicle classification available to Union Street personnel.

Equivalent Single Axle Load (ESAL) is an expression for an axle load that causes the same pavement response as a single axle with dual tires carrying a legal load of 80 kN. Pavement design methods use ESALs to quantify the traffic loading on pavements. Some trucks are loaded; some trucks are empty. Typically on Western Canadian highways there are about 2.0 ESAL per Tractor Trailer Combination (TTC).

An estimated 100,000 ESALs for light and $8x10^5$ ESALs for moderate loads were utilized for pavement designs relative to the proposed Public Works Operations Centre. An estimated $2x10^6$ ESALs for the future collector roadway and $4x10^6$ ESALs for the proposed upgrades to Waskasoo Avenue were utilized. These values are similar to those outlined in the City of Red Deer's *Design Guidelines 2020 Edition*, Section 13, Part 7 Roadway Construction, Table 13.3 - Pavement Structure, for Residential Local (light), Industrial Local (Moderate), Industrial Collector (Future Collector), and Undivided Arterial (Waskasoo Avenue) roadways. Roadway classifications were provided by the client.

Pavement thickness is relatively insensitive to changes in truck volume and weights for higher strength granular subgrades. For example, a change in design ESALs from 2.0×10^6 to 5.0×10^6 on a design subgrade of 70 MPa will increase the asphalt concrete thickness by 12.5 mm. This design insensitivity makes designs, such as this, based on basic estimates of truck traffic reasonably reliable.

8.3 STRUCTURAL DESIGN

The structural pavement thickness recommendations herein were designed using the AASHTO 1993 Pavement Design Guide. The design used an overall standard deviation of 0.45, a loss of serviceability of 1.7 (initial serviceability of 4.2 and a terminal serviceability of 2.5), a drainage coefficient of 1.0 and a reliability of 85%. The recommended pavement structures are shown in Table 8.1.

The Structural Number (SN) is a value that indicates relative structural capacity of pavement layers and total pavement structures. Higher capacity pavement structures have higher SN values.

The recommended pavement structures assume the construction materials and methods used meet or exceed local specifications or those currently referenced by the City of Red Deer's construction specifications.

A minimum cross slope on driving lanes, parking areas, and shoulders should be greater than 2% to ensure adequate draining to reduce frost susceptibility.

Two pavement structures have been provided in Table 8.1. Option No. 1 is recommended for asphalt parking areas servicing low volume traffic areas with light loading and Option No. 2 is recommended for asphalt parking areas servicing moderate traffic areas with light to moderate loading on the existing subgrade. Concrete surfacing should be considered for areas that will experience heavy, stop and go or turning traffic, as asphalt will be susceptible to rutting in these areas. A concrete roadway design can be issued upon request.

TABLE 8.1: RECOMMENDED PAVEMENT THICKNESSES

M_R	45,000 kPa			
Design ESAL	**100,000**		**800,000**	
Material	**Thickness (mm)**	**SN (SI)**	**Thickness (mm)**	**SN (SI)**
HMAC	75	30	100	40
Base Course	150	21	150	21
SGSB	200	20	200	20
Geofabric[1]	1 Layer	-	1 Layer	-
Geogrid[1,2,3]	-	-	1 Layer	≈8
Totals	425	71	450	89
Design SN		62		87

Notes:
1 - Geofabric should be installed according to the manufactures recommendations.
2 - Recommend TenCate Mirafi RS380i™ or equivalent.
3 - Recommend woven geotextile and geogrid if a combigrid isn't utilized.

An additional two pavement structures have been provided in Table 8.2. Option No. 3, $2\text{x}10^6$ ESALS, is recommended for the proposed Industrial Collector and Option No. 4, $4\text{x}10^6$ ESALS, is recommended for Waskasoo Avenue, a proposed Undivided Arterial.

TABLE 8.2: RECOMMENDED PAVEMENT THICKNESSES

MR	45,000 kPa			
Design ESAL	$2x10^6$		$4x10^6$	
Material	Thickness (mm)	SN (SI)	Thickness (mm)	SN (SI)
HMAC	100	40	125	50
Base Course	200	28	200	28
SGSB	250	25	250	25
Geofabric[1]	1 Layer	-	1 Layer	-
Geogrid[1,2,3]	1 Layer	≈8	1 Layer	≈10
Totals	550	101	575	113
Design SN		100		112

Notes:
1 - Geofabric should be installed according to the manufactures recommendations.
2 - Recommend TenCate Mirafi RS380i™ or equivalent.
3 - Recommend woven geotextile and geogrid if a combigrid isn't utilized.

Options No. 1 to 4 shown above are less than the recommended minimum pavement structure as outlined by the City of Red Deer, in part, due to the use of geotextiles.

Our recommendations for construction of new pavement structures are as follows:

1. If encountered, excavate all asphalt, topsoil, non-structural fill, organic material, and soft or wet soil, exposing native sand, in the proposed pavement areas. Construction on fill material of unknown quality and composition can result in uneven settlement or heave. Soft, wet areas, which do not have sufficient trafficability for construction purposes, or frozen soil, should be further excavated.

2. Any fill material required to raise the grade during construction should be a non-expansive soil such as low to medium plastic soil or a non-frost active granular soil. Avoid "sandwiching" cohesive and non-cohesive material.

3. Scarify and uniformly compact the upper 200 mm of the subgrade to a minimum 98% of its maximum SPDD as determined by test ASTM D698. Adjust the moisture content of the subgrade to within ±2% of the optimum moisture content. Prior to placing the SGSB, the surface of the subgrade should be

finished to a tight, smooth surface that is free from ruts, waves, and roller marks. Cobbles and boulders should be removed from the upper subgrade;

4. Provide cross slope on driving surfaces and shoulders of 2% to a ditch or French Drain system.

5. Place the geotextile on the subgrade according to the manufacturer's recommendations. If a combgrid isn't utilized, a woven geofabric, with a minimum Grab Tensile Strength of 900 N, is recommended in conjunction with a geogrid. If required, place the geogrid on the geofabric according to the manufacturer's recommendations.

6. Place the 80 mm SGSB, which complies with the gradation as shown in Table 7.1, in maximum 300 mm thick lifts, on the compacted subgrade. The granular sub-base should be compacted to a minimum 100% of its SPDD as determined by test ASTM D698 using a vibratory compactor. Water may be used as a compaction aid.

7. Place the 20 mm Base, which complies with the gradation as shown in Table 7.1, in a maximum 200 mm thick lift, on the compacted sub-base. The granular base should be compacted to a minimum 100% of its SPDD as determined by test ASTM D698 using a vibratory compactor. Water may be used as a compaction aid.

8. Place a spreader-laid hot mix asphalt concrete having specifications equivalent to those given by the local authority for the road classification.

9. The hot mix asphalt concrete should be compacted to a minimum 97% of a 75 blow Marshall Density and should be finished to a tight, smooth surface that is free from ruts, waves, roller marks, cracks or segregation.

It is recommended that the subgrade be sloped to a ditch system, French Drains (factory installed geotextile wrapped plastic perforated subdrain pipe bedded in drain rock placed in a shallow trench, typically draining to the storm sewer, located along the outer edges of the roadway), or other suitable system that prevents saturation of the road structure and supporting subgrade. Saturation of the gravel structure will lead to weakened subgrade conditions which will degrade pavement performance.

Typical gradation specifications for the base and sub-base gravels are shown in Table 7.1 but gravel and asphalt specification, testing standards, etc., should meet all local specifications. The selective use of geo-grid reinforcement may be prudent for critical traffic areas at this site.

9 RETENTION POND

As proposed, the development is to include a constructed storm water retention pond. The location, dimensions, depth, and elevation of the pond are unknown at this time. It is expected that if the base extends beyond the groundwater table, estimated to be an average 3.0 m to 4.0 m below grade throughout the site, it will permanently contain water. Typical design considerations for wet ponds of this nature include shoreline slope stability, shoreline erosion potential, and the effect of retained water on the local groundwater elevation and the possible changing groundwater elevation due to the development.

All material from the pond excavation that is determined to be suitable for reuse should be stockpiled.

For preliminary design purposes, the banks of the pond should be cut at 5H:1V above the water level to allow for wave erosion and increased slope stability and a 3H:1V below the water level. Alternatively, wave erosion can be eliminated by proper armouring and bank protection measures. It is the responsibility of the contractor to remove water from trenches and excavations, regardless of origin. If while constructing the slopes of the pond subsurface, groundwater begins eroding the slopes and entering the pond, construction will need to be halted immediately and dewatering techniques will need to be implemented before construction continues. It is anticipated that potential groundwater problems can be resolved with well graded ditching and the installation of subgrade sumps around the perimeter of the excavation. If extreme groundwater seepage becomes present, more advanced dewatering techniques can be implemented.

Pumps and other materials necessary to keep the excavation free of water while work is in progress should be provided. Provisions should be made in case of accidental stoppage of dewatering equipment to prevent damage to the work area. The excavations must be protected against flooding and damage from surface run-off.

Water removed from the site is to be disposed of in a manner that will not damage the work area or other property or persons.

Materials will be excavated and removed to the depths necessary for the construction of the structure and drainage system. Care must be taken to minimize the disturbance to the supporting soil. After the excavation has been shaped, any over-excavated areas will be backfilled and compacted to a density equal to or greater than the undisturbed soil. All slopes in the subgrade are to be uniform and in a condition suitable for a pond.

If utilized, a clay liner should be constructed utilizing till material, free of rocks greater than 50 mm in size and of deleterious material. The material will be placed in thin lifts such that complete mixing of materials is achieved and uniform compaction is achieved for the full depth of the lift. Lifts should not exceed 150 mm thickness. All lifts should be compacted using a pad foot packer weighing a minimum of 3,500 kg, except for the final lift in which a smooth drummed packer should be used. Side slopes should be placed in horizontal lifts keyed into the slope, with the minimum thickness of liner being maintained perpendicular to the slope. For preliminary design purposes, the clay should be moisture conditioned to 2% to 5% of optimum and compacted to a minimum of 98% Standard Proctor Dry Density.

10 ALBERTA BUILDING CODE CONSIDERATIONS

In accordance with the Alberta Building Code, the construction of all foundations (including all piles) should be monitored by a qualified geotechnical engineer, or a suitable representative under the direction of a qualified geotechnical engineer, to verify the subsurface conditions and to confirm construction procedures are implemented as recommended in this report.

Union Street Geotechnical Ltd. provides services required for Schedules A, B, and C of the *Alberta Building Code-2019* for:

- Inspection of excavations, embankments, earthworks, and compaction;
- Inspections of foundations, basement walls, grade beams, and earth retaining structures; and,

- Materials quality control testing for soil, aggregates, concrete, and pavements.

These services are provided on an as-called basis. We must provide the inspection and testing services at the appropriate times during construction in order to approve and complete these schedules.

It should be noted that the Alberta Building Code Letters of Assurance Schedule B, and subsequently Schedule C, can only be signed and submitted by Union Street Geotechnical Ltd. if Union Street Geotechnical Ltd. is retained to undertake field reviews and field testing (density testing, concrete testing, etc.) as are warranted for this project, and if satisfactory completion of all geotechnical aspects of construction is appreciated by Union Street Geotechnical Ltd.

11 CLOSURE

Union Street Geotechnical Ltd. prepared this report for the use of Tagish Engineering Ltd., and their agents, for the design and construction of a proposed Town of Penhold Public Works Operations Centre located with the N.W. ¼ of 06-37-27 W4M in Penhold, Alberta.

Samples obtained from this geotechnical investigation will be retained in our laboratory for 30 days following the date of the final report. Should no instructions be received to the contrary, these samples will then be discarded.

Yours truly,

Union Street Geotechnical Ltd.

Prepared By:

Neil Tomaszewski, E.I.T.
Project Engineer

Reviewed By:

PROFESSIONAL ENGINEER
JOSHUA WILSON
ALBERTA

12th Feb., 2021

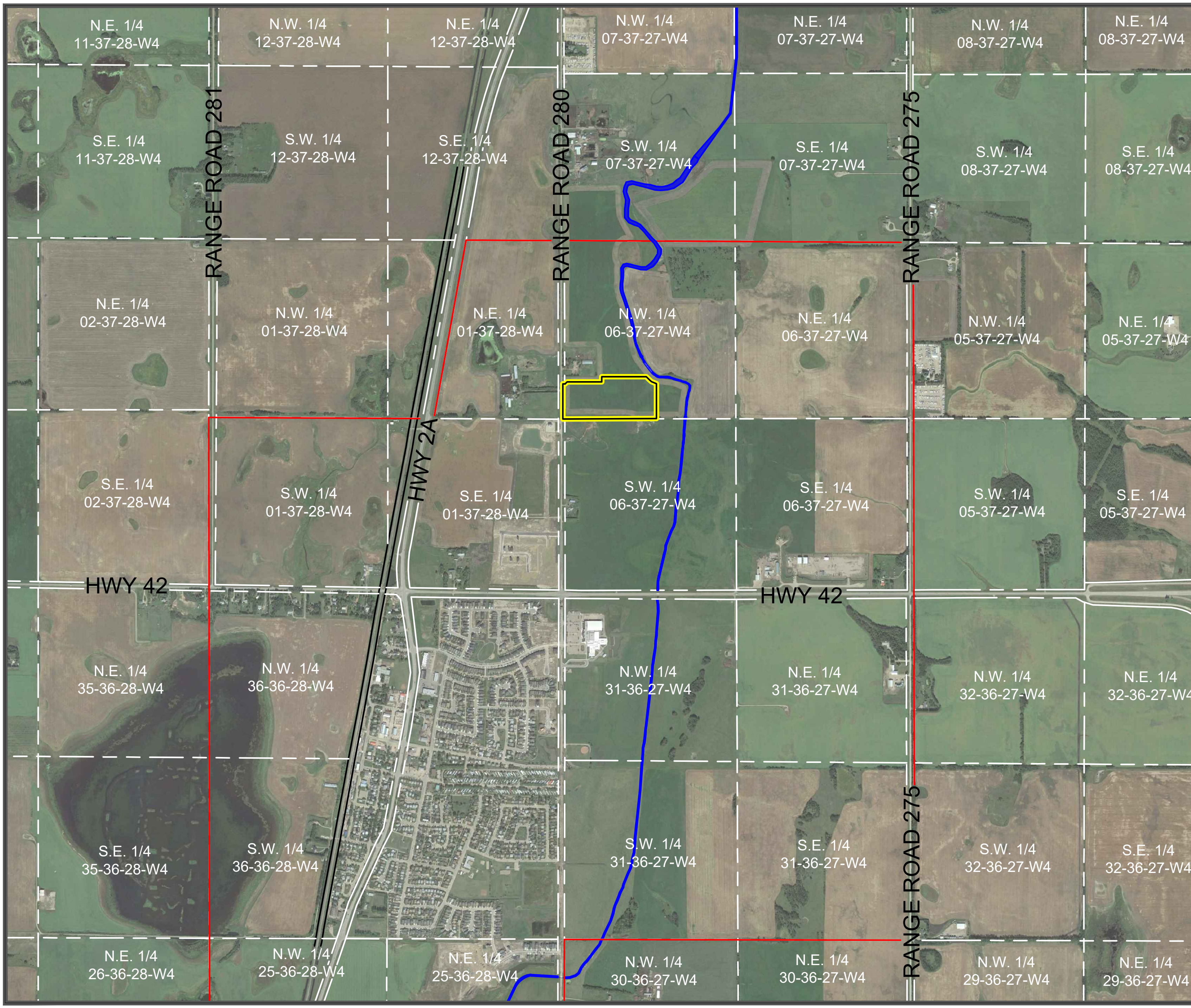
Joshua Wilson, P.Eng.
Project Engineer

Union Street Geotechnical Ltd.
APEGA Permit No. P12644

, P.Eng

12th Feb., 2021

Union Street Geotechnical	**Drawings**



LEGEND:

- SITE BOUNDARY
- PROPERTY LINE (WHITE)
- RAILWAY LINE
- TOWN OF PENHOLD LIMITS
- WASKASOO CREEK

GENERAL NOTES

1 DRAWINGS COMPLIED FROM:

MULTIPLE VECTOR AND RASTER GIS FIELDS AS PUBLISHED BY THE GOVERNMENT OF CANADA; THE GOVERMENT OF ALBERTA; NATURAL RESOURCES CANADA; EARTH SCIENCES SECTOR; CANADA CENTRE FOR MAPPING AND EARTH OBSERVATION, RED DEER COUNTY,

AREIAL PHOTOGRAPH (C) 2020 MAXAR TECHNOLOGIES (C) GOOGLE EARTH PRO,

PDF SKETCH PROVIDED BY THE CLIENT,

& UNION STREET GEOTECHNICAL SITE INVESTIGATION

2 LEGAL ADDRESS PORTION OF N.W. 1/4; 06-37-27-W4M

0 100 200 300 400 500
SCALE 1:25,000

N

No.	REVISION/ISSUE	DATE

UNION STREET GEOTECHNICAL LTD.

Union Street Geotechnical

PROJECT NAME AND ADDRESS
GEOTECHNICAL INVESTIGATION
PENHOLD PUBLIC WORKS OPERATIONS CENTRE
RANGE ROAD 280,
PENHOLD,
ALBERTA

PROJECT: GEOTECHNICAL INVESTIGATION	SHEET: A1
PROJECT NUMBER: USG1123	
DATE: 05.02.2021	
DRAWING NAME: SITE LOCATION MAP	

USG1123 - Drawing.dwg

30.09.2020

LEGEND:

- WASKASOO CREEK
- PROPOSED BUILDING
- PROPERTY LINE (WHITE)
- SITE BOUNDARY
- EXISTING BUILDINGS
- PIEZOMETER LOCATION
- BOREHOLE LOCATION

GENERAL NOTES

1 DRAWINGS COMPLIED FROM:

MULTIPLE VECTOR AND RASTER GIS FIELDS AS PUBLISHED BY THE GOVERNMENT OF CANADA; THE GOVERMENT OF ALBERTA; NATURAL RESOURCES CANADA; EARTH SCIENCES SECTOR; CANADA CENTRE FOR MAPPING AND EARTH OBSERVATION, RED DEER COUNTY,

AREIAL PHOTOGRAPH (C) 2020 MAXAR TECHNOLOGIES (C) GOOGLE EARTH PRO,

PDF SKETCH PROVIDED BY THE CLIENT,

& UNION STREET GEOTECHNICAL SITE INVESTIGATION

2 LEGAL ADDRESS PORTION OF N.W. 1/4; 06-37-27-W4M

0 10 20 30 40 50

SCALE 1:2,500

N

No.	REVISION/ISSUE	DATE

UNION STREET GEOTECHNICAL LTD.

Union Street Geotechnical

PROJECT NAME AND ADDRESS

GEOTECHNICAL INVESTIGATION
PENHOLD PUBLIC WORKS
OPERATIONS CENTRE
RANGE ROAD 280,
PENHOLD,
ALBERTA

PROJECT: GEOTECHNICAL INVESTIGATION

PROJECT NUMBER: USG1123

DATE: 05.02.2021

SHEET: A2

DRAWING NAME: BOREHOLE LOCATION PLAN

USG1123 - Drawing.dwg

30.09.2020

Union Street Geotechnical	**Photographs**

Photographs - Geotechnical Investigation
Portion of N.W. ¼ of 06-37-27 W4M
Penhold, Alberta

Photograph No. 1: Photograph taken from near Borehole BH114, facing west, showing the proposed operations center building footprint, site grading, snow cover, straw bales stored on-site, and site conditions at the time of drilling. Photograph taken on 28th January, 2021.

Photograph No. 2: Photograph taken from near the site's southwest corner, facing northeast, showing the proposed operations centre and fire hall building footprints, site grading, farm to the north, snow cover, and site conditions at the time of drilling. Photograph taken on 28th January, 2021.

Photographs Cont'd - Geotechnical Investigation
Portion of N.W. ¼ of 06-37-27 W4M
Penhold, Alberta

Photograph No. 3: Photograph taken from near the northwest property corner, facing east, showing a majority of the proposed future collector road Right-of-Way, bordering farm, site grading, straw bales, snow cover, and site conditions at the time of drilling. Photograph taken on 28th January, 2021.

Photograph No. 4: Photograph taken from near the site's northwest corner on Waskasso Avenue (Range Road 280), facing south, showing a section of Waskasoo Avenue, drainage ditches, bordering farm to the west, and site conditions at the time of drilling. Photograph taken on 28th January, 2021.

Union Street Geotechnical	**Borehole Logs**

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH101

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**0.94 m**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**12.65 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**27 January, 2021**		
DATE COMPLETED:	**27 January, 2021**		

Union Street Geotechnical

DEPTH (m)	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
-1.0											Cap.
0.0	TOPSOIL: 76 mm.										Bentonite cap.
0.0 – 1.5	SAND: Clayey, silty. Pale brown (10YR 6/3). Oxidized. Dry to moist. Loose. Massive. Calcareous.		NT1		-	9.0		SC	32.0	9.0	
1.5 – 3.5	CLAY: Silty, sandy. Dark yellowish brown (10YR 4/4) to brown (10YR 4/3). Oxidized. Moist. Stiff to very stiff. Laminated. Calcareous.		NT2	15	96	32.4					
			NT3		108	39.6		CH	87.8	21.7	
			NT4	7	72	50.2					
3.5 – 9.0	TILL: Clay, silty, sandy. Brown (10YR 4/3). Oxidized. Moist. Firm to very stiff. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT5		60	20.3					
	@ 4.57 m, seepage.		NT6	22	168	15.1					Solid 25 mm PVC casing.
	@ 5.18 m, sand seam, 0.61 m thick.		NT7		36	18.1					
	@ 6.10 m, non-oxidized, very dark grey (10YR 3/1).		NT8	32	168	12.4					Auger cuttings.
			NT9		168	14.6					
			NT10		215	16.6					
9.0											

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH101

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **0.94 m**
TOTAL DEPTH: **12.65 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
9.0				NT11	29	215	13.7					
10.0				NT12		144	14.7					
11.0												Hand slotted 25 mm PVC.
				NT13		168	17.1					
12.0				NT14	18	168	13.5					
13.0		NOTES: End of borehole at 12.65 m below surface. Seepage and sloughing encountered during drilling. Piezometer installed, annulus backfilled to surface with auger cuttings and capped with bentonite. Water level at 3.88 m below grade on 3 February, 2021.										
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH102

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 38 mm.										
1.0		SAND: Clayey, silty. Dark brown (10YR 3/3). Oxidized. Dry to moist. Compact. Massive. Calcareous. @ 0.61 m, frost depth.		NT15		72	12.1					
2.0		CLAY: Silty, sandy. Dark yellowish brown (10YR 4/4). Oxidized. Moist. Stiff. Laminated. Calcareous.		NT16		72	19.3					
3.0–4.0		TILL: Clay and sand, silty. Brown (10YR 4/3) to very dark greyish brown (10YR 3/2). Oxidized to non-oxidized. Moist. Very stiff to hard. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT17		120	15.2					Auger cuttings.
5.0		@ 5.18 m, seepage.		NT18		144	14.3					
7.0				NT19		168	17.6					
8.0–9.0		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.		NT20		215	13.6					
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH103

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 51 mm.										
		SAND: Silty, some clay. Dark yellowish brown (10YR 5/4). Oxidized. Dry to moist. Compact. Massive. Calcareous.										
1.0				NT21		-	10.1					
2.0		CLAY: Silty, some sand. Dark yellowish brown (10YR 4/4). Oxidized. Moist. Very stiff. Laminated. Calcareous.		NT22		120	21.7					
3.0		TILL: Clay, silty, sandy. Brown (10YR 4/3). Oxidized. Moist. Very stiff to hard. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.										
4.0				NT23		120	23.3					
		@ 4.27 m, sand seam, 0.31 m thick.										Auger cuttings.
5.0		@ 4.57 m, clay and sand till.										
				NT24		120	16.0					
6.0		@ 6.10 m, seepage.										
7.0				NT25		168	13.7					
8.0		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.		NT26		203	16.1					
9.0												
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH104

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**0.97 m**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**9.60 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**27 January, 2021**		
DATE COMPLETED:	**27 January, 2021**		

Union Street Geotechnical

DEPTH (m)	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)
-1.0										
0.0	TOPSOIL: 102 mm.									
	SAND: Clayey, silty. Dark yellowish brown (10YR 4/4). Oxidized. Moist. Compact. Massive. Calcareous. @ 0.91 m, frost depth.		NT27		96	10.1		SC	44.7	11.2
	CLAY: Silty, some sand. Dark yellowish brown (10YR 4/4) to brown (10YR 4/3). Oxidized. Moist. Stiff to very stiff. Laminated. Calcareous.		NT28	10	168	10.6				
2.0			NT29		168	21.3				
3.0	@ 3.35 m, seepage and sloughing.		NT30	6	72	40.7				
4.0	TILL: Clay and sand, silty. Brown (10YR 4/3) to dark brown (10YR 3/3). Oxidized. Moist. Firm to hard. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT31		48	16.6				
5.0			NT32		144	12.9				
6.0	@ 6.10 m, clay, silty, sandy.		NT33	23	168	13.5				
7.0			NT34		192	15.8				
8.0			NT35		192	12.4				
9.0										

WELL INSTALLATION

- Cap.
- Bentonite cap.
- Solid 25 mm PVC casing.
- Auger cuttings.
- Hand slotted 25 mm PVC.

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH104

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **0.97 m**
TOTAL DEPTH: **9.60 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
9.0				NT36	23	215	13.2					
10.0		NOTES: End of borehole at 9.60 m below surface. Seepage and sloughing encountered during drilling. Piezometer installed, annulus backfilled to surface with auger cuttings and capped with bentonite. Water level at 3.44 m below grade on 3 February, 2021.										
11.0												
12.0												
13.0												
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH105

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**9.14 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**27 January, 2021**		
DATE COMPLETED:	**27 January, 2021**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 25 mm.										
1.0		SAND: Clayey, silty. Pale brown (10YR 6/3). Oxidized. Moist. Compact. Massive. Calcareous. @ 0.46 m, frost depth.		NT37		-	10.8					
2.0		CLAY: Silty, some sand. Pale brown (10YR 6/3) to brown (10YR 4/3). Oxidized. Moist. Stiff to very stiff. Laminated. Calcareous.		NT38	12	168	16.4					
				NT39		144	38.5					
3.0		TILL: Clay and sand, silty. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.										
4.0		@ 3.35 m, seepage.		NT40		168	15.4					
5.0		@ 4.27 m, non-oxdized, very dark greyish brown (10YR 3/2).										Auger cuttings.
		@ 4.57 m, sand, clayey, silty.		NT41		120	18.5					
6.0												
7.0				NT42		120	15.2					
8.0		@ 7.62 m, clay, silty, sandy.										
		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.		NT43		168	14.8					
9.0												
10.0												

FIELD BOREHOLE LOG

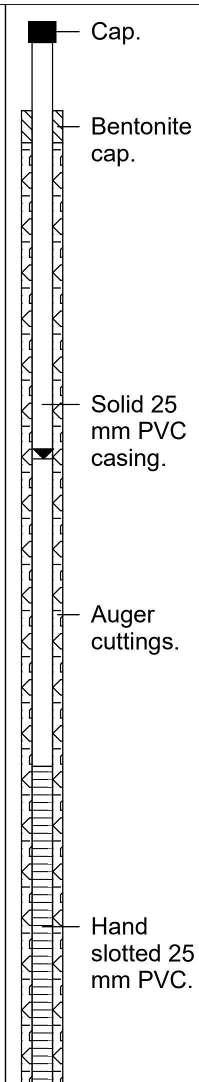
BOREHOLE NUMBER
BH106

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **0.84 m**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
-1.0												
0.0		TOPSOIL: 76 mm.										
1.0		SAND: Clayey, silty. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous. @ 0.91 m, frost depth.		NT44		96	12.5					
2.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.		NT45		144	31.4					
3.0–4.0		TILL: Clay and sand, silty. Brown (10YR 4/3) to dark brown (10YR 3/3). Oxidized. Moist. Stiff to very stiff. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT46		144	16.2					
5.0		@ 4.57 m, sand, clayey, silty. @ 4.88 m, sand seam, 0.31 m thick, seepage.		NT47		96	12.3					
6.0		@ 6.10 m, clay, silty, sandy.										
7.0				NT48		192	14.8					
8.0–9.0		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Piezometer installed, annulus backfilled to surface with auger cuttings and capped with bentonite. Water level at 3.26 m below grade on 3 February, 2021.		NT49		192	16.5					



FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH107

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **9.60 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 64 mm.										
1.0		SAND: Clayey, silty. Dark yellowish brown (10YR 4/4). Oxidized. Dry to moist. Loose. Massive. Calcareous.		NT50		-	11.9		CI	48.2	12.2	
2.0		CLAY: Silty, some sand. Dark yellowish brown (10YR 4/4) to brown (10YR 4/3). Oxidized. Moist. Stiff. Laminated. Calcareous.		NT51	13	96	9.3					
				NT52		96	37.2					
3.0				NT53	7	60	34.7					
4.0		TILL: Clay and sand, silty. Brown (10YR 4/3) to very dark grey (10YR 3/1). Oxidized to non-oxidized. Moist. Stiff to hard. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT54		192	12.7					
5.0												Auger cuttings.
				NT55		84	18.0					
6.0		@ 6.10 m, sand seam, 0.91 m thick, seepage.		NT56	50	215	14.2					
7.0				NT57		-	19.5					
8.0												
9.0		NOTES: End of borehole at 9.60 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.		NT58		203	11.0					
				NT59	61	192	11.2					
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH108

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **0.93 m**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
-1.0											Cap.
0.0	TOPSOIL: 50 mm.										Bentonite cap.
	SAND: Silty, some clay. Pale brown (10YR 6/3). Oxidized. Dry to moist. Loose. Massive. Calcareous.		NT60		-	10.6					
2.0	CLAY: Silty, some sand. Dark yellowish brown (10YR 4/4). Oxidized. Moist. Stiff to very stiff. Laminated. Calcareous.		NT61		120	27.8					Solid 25 mm PVC casing.
3.0	TILL: Clay, silty, sandy. Dark brown (10YR 3/3). Oxidized. Moist. Stiff to very stiff. Massive. Coal chip, sand seam, and gravel inclusions. Calcareous.		NT62		144	15.4					
	@ 4.57 m, sand, clayey, silty.										Auger cuttings.
			NT63		96	11.2					
			NT64		120	15.6					
	@ 7.32 m, sand seam, 1.52 m thick.										Hand slotted 25 mm PVC.
	@ 8.23 m, seepage.		NT65		-	20.8					
9.0	@ 8.84 m, clay, silty, sandy.										

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH108

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **27 January, 2021**
DATE COMPLETED: **27 January, 2021**

CASING STICKUP: **0.93 m**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
9.0												
		NOTES: End of borehole at 9.14 m below surface. Seepage, but no sloughing encountered during drilling. Piezometer installed, annulus backfilled to surface with auger cuttings and capped with bentonite. Water level at 5.98 m below grade on 3 February, 2021.										
10.0												
11.0												
12.0												
13.0												
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH109

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 76 mm.										
		SAND: Clayey, silty. Pale brown (10YR 6/3). Oxidized. Dry to moist. Loose to compact. Massive. Calcareous. @ 0.76 m, frost depth.		NT66		72	11.4					
1.0												
		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT67		96	30.0					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH110

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**28 January, 2021**		
DATE COMPLETED:	**28 January, 2021**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 76 mm.										
		SAND: Clayey, silty. Brown (10YR 4/3). Oxidized. Dry to moist. Compact. Massive. Calcareous.		NT68		72	11.8					
1.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT69		120	39.0					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH111

PROJECT NUMBER:	USG1123	CASING STICKUP:	N/A
PROJECT NAME:	Geotechnical Investigation	TOTAL DEPTH:	3.05 m
LOCATION:	N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta	GROUND SURFACE ELEVATION:	N/A
CLIENT:	Tagish Engineering Ltd.		
DRILLING METHOD:	150 mm Solid Stem Auger		
LOGGED BY:	N.T.		
DATE BEGUN:	28 January, 2021		
DATE COMPLETED:	28 January, 2021		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 76 mm.										
		SAND: Silty, some clay. Brown (10YR 4/3). Oxidized. Dry. Loose. Massive. Calcareous.		NT70		-	9.2					
1.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT71		120	35.8					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH112

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**28 January, 2021**		
DATE COMPLETED:	**28 January, 2021**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 64 mm.										
		SAND: Silty, some clay. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.		NT72		96	10.8					
1.0												
		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0												
				NT73		168	25.4					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH113

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 102 mm.										
		SAND: Some clay, some silt. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.		NT74		72	8.3					
1.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT75		192	25.8					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH114

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 102 mm.										
		SAND: Clayey, silty. Brown (10YR 4/3). Oxidized. Dry. Loose. Massive. Calcareous.		NT76		-	8.5					
1.0												Auger cuttings.
		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										
2.0				NT77		192	18.8					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH115

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 76 mm.										
		SAND: Clayey, silty. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.		NT78		120	9.2					
1.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT79		120	24.8					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH116

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL: 102 mm.										
		SAND: Clayey, some silt. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.		NT80		144	14.3		SC	43.7	10.6	
1.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.										Auger cuttings.
2.0				NT81		108	36.6					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH117

PROJECT NUMBER: **USG1123**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**
CLIENT: **Tagish Engineering Ltd.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **N.T.**
DATE BEGUN: **28 January, 2021**
DATE COMPLETED: **28 January, 2021**

CASING STICKUP: **N/A**
TOTAL DEPTH: **3.05 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		GRAVEL: 152 mm.										
		FILL: Clay, silty, sandy. Brown. Oxidized. Moist. Hard (frozen). Massive.										
		ORGANICS: 102 mm.		NT82		144	14.7					
1.0		SAND: Clayey, silty. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.										Auger cuttings.
2.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.		NT83		144	19.7					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH118

PROJECT NUMBER:	**USG1123**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**N.W. 1/4 of 06-37-27 W4M, Penhold, Alberta**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Tagish Engineering Ltd.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**N.T.**		
DATE BEGUN:	**28 January, 2021**		
DATE COMPLETED:	**28 January, 2021**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	WELL INSTALLATION
0.0		GRAVEL: 127 mm.										
		FILL: Clay, silty, sandy. Dark brown. Oxidized. Moist. Hard (frozen). Massive. @ 1.22 m, frost depth.										
		ORGANICS: 152 mm.		NT84		192	15.7		SC	37.3	11.8	
1.0		SAND: Some clay, some silt. Brown (10YR 4/3). Oxidized. Moist. Compact. Massive. Calcareous.										Auger cuttings.
2.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Laminated. Calcareous.		NT85		144	29.8					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												