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Geotechnical Investigation
Frac Sand Handling Facility, Lacombe County

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EXECUTIVE SUMMARY

Union Street Geotechnical Ltd. performed a geotechnical investigation, on behalf of Taves Management Inc. on the 7th and 8th of January, 2019, within the S.E. ¼ of 29-40-22 W4M in Lacombe County, Alberta for the proposed development of a frac sand handling facility and associated infrastructure. The proposed development includes a scale house, elevator, holding bins, loop track and rail spurs, gravel access roadway and parking lot, and various other infrastructures associated with a development of this type.

Twenty-three boreholes were drilled across the site in order to provide geotechnical recommendations and conclusions regarding site preparation and excavations, foundation design, gravel access roadway and parking lot structures, frost depth, groundwater table elevation, cement type, and other aspects related to the development. Subsurface soils varied, but generally consisted of topsoil overlying sand, clay, and till.

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

LIMITATIONS

Union Street Geotechnical Ltd. prepared this report for the exclusive use of Taves Management Inc., and their agents, for the design and construction of a frac sand handling facility located within the S.E. ¼ of 29-40-22 W4M in Lacombe County, Alberta. The content reflect Union Street's best judgement available to it at the time of preperation. Any use which a third party makes of this report, or any reliance on or decisions 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 made or actions 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 guarentee 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 Taves Management Inc. 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

Taves Management Inc. (Taves) retained Union Street Geotechnical Ltd. (Union Street) to conduct a geotechnical investigation within the S.E. ¼ of 29-40-22 W4M for the proposed development of a frac sand handling facility, and associated infrastructure, in Lacombe County, Alberta. The proposed development includes a scale house, elevator, holding bins, loop track and rail spurs, gravel access roadway and parking lot, and various other infrastructures associated with a development of this type.

1.2 OBJECTIVES

The objectives of the geotechnical investigation are to:

- define the subsurface soil strata, their properties, and existing conditions;
- provide recommendations for structural foundations;
- provide recommendations for site grading and site parking;
- provide recommendations for cut/fill excavations and slopes;
- provide recommendations for frost depth;
- provide cement type recommendations;
- identify potential geotechnical problems related to excavations and foundation construction; 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 situated within the S.E. ¼ of 29-40-22 W4M, located approximately 80 m west of the Hamlet of Mirror, in Lacombe County as shown on Drawing No. 1. At the time of drilling, the site was being utilized for agricultural activities, contained a lease, was undeveloped, and snow covered. A residential acreage and CN rail spur have been subdivided from the quarter. The site was relatively level but, based on a topography map, sloped towards the northeast.

The site is bordered by agricultural land to the north, Range Road 224 and CN rail spur to the east, an acreage and Highway 50 to the south, and an irrigation channel to the west. Photographs depicting the site are appended to this report.

2.2 PROPOSED DEVELOPMENT

The proposed frac sand handling facility consists of a scale house, elevator, holding bins, loop track and rail spurs, gravel access roadway and parking lot, and various other infrastructures associated with a development of this type. Structural loads are unknown at the time of this report writing. The borehole locations relative to the proposed infrastructure are shown on Drawing No. 2.

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 development, or its location, 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 twenty-three boreholes at the locations shown on Drawings No. 2. The borehole locations were established by Union Street personnel based off a client supplied site plan, proposed development footprint, utility clearance, and access. No formal surveying of the borehole locations or site were completed and therefore, all drawings, locations, dimensions, and legal descriptions are approximate and conceptual in nature.

On the 7th and 8th of January, twenty-three boreholes (designated as BH101 to BH123) were advanced using a track-mounted auger drill utilizing 150 mm diameter, continuous flight augers, operated by All Type Drilling Ltd. The boreholes were advanced to depths varying between 3.05 m and 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 were generally obtained at a 1.52 m interval for moisture content determinations. The moisture contents are shown on the borehole logs; and,
- Standard Penetration Tests (SPT's) were conducted in various boreholes at intermittent depth intervals to obtain estimates of consistency, density, and strength of the various soil strata. The STP "N" values (penetration resistances) are shown on the borehole logs.

Seepage was encountered in seventeen boreholes at an average approximate depth of 2.13 m below ground surface during drilling.

Upon completion of drilling, piezometers were installed in four boreholes and all remaining boreholes were backfilled to surface with auger cuttings.

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 and Mechanical Wash Sieves (MWS) were also performed. 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 twenty-three borehole locations for foundation and roadway support purposes. In general, and to the depths drilled, the soil conditions encountered at the borehole locations generally consisted of, in descending order; topsoil, sand, clay, and till. The soil is relatively uniform with little variations; however, there are slight variations and the following soil properties depict the average characteristics. Sand, clay, and till extended to the maximum exploration depth in various boreholes. Detailed soil descriptions are provided in the Borehole Logs, appended to this report.

4.1.1 Topsoil

Topsoil was encountered at surface in all twenty-three boreholes and extended to an average approximate depth of 0.12 m below grade. The topsoil was organic and comprised of clay and was silty and sandy. It was black, oxidized, moist, hard (frozen), and massive.

4.1.2 Sand

Sand was encountered underlying the topsoil in all twenty-three boreholes and extended to an average approximate depth of 2.94 m below grade in fifteen boreholes and to the maximum exploration depth in eight boreholes. The sand varied in consistency from silty to trace silt and some clay to trace clay. It was brown (10YR 4/3) to dark grey (10YR 4/1), oxidized to non-oxidized, dry to wet, loose, and massive.

The moisture content of the sand samples ranged from 2.2% to 30.8% with an average moisture content of 15.9%.

Four Standard Penetration Tests (SPTs) were completed within the sand stratum resulting in an “N” value ranging from 4 to 12 with an average value of 8. This value correlates to a soil with a loose consistency.

Three Mechanical Wash Sieves were performed on sand samples obtained from Boreholes BH101, BH115, and BH118. The test results are summarized in Table 4.1.

TABLE 4.1: SUMMARY OF SAND MECHANICAL WASH SIEVE RESULTS

Sample No. And Depth	Borehole No.	Gravel (%)	Sand (%)	Silt & Clay (%)	Moisture Content (%)
MW1 - 0.76 m	BH101	0.0	94.1	5.9	9.2
MW94 - 0.76 m	BH115	0.6	94.6	4.8	3.2
MW100 - 0.76 m	BH118	0.0	95.5	4.5	6.6
	Average:	0.2	94.7	5.1	6.3

4.1.3 Clay

Clay was encountered underlying sand approximately 2.22 m below grade in ten boreholes which extended to an average approximate depth of 4.79 m below grade in seven boreholes and to the maximum exploration depth in three boreholes. The clay was silty and sandy. It was brown (10YR 4/3) to very dark grey (10YR 3/1), oxidized to non-oxidized, moist, soft to very stiff, massive, and calcareous.

The moisture content of the clay samples ranged from 17.3% to 30.5% with an average moisture content of 25.6%.

Pocket Penetrometer (PP) readings of the clay ranged from 12 kPa to 108 kPa with an average reading of 34 kPa. This correlates to a soil with a firm consistency.

Two Standard Penetration Tests (SPTs) were completed within the clay stratum resulting in an "N" value ranging from 7 to 11 with an average value of 9. This value correlates to a soil with a firm consistency and an undrained shear strength of 56 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 (34 kPa);
K is an empirical constant determined from site specific correlations; and,
N is the SPT "N" value (9).

The corresponding K value was determined to be 3.79.

Based on the PP and SPT test results, the weighted average design undrained shear strength of the clay is 45 kPa. This result indicates a firm consistency.

Two MUSC tests were performed on clay samples obtained from Boreholes BH102 and BH104. The MUSC results are summarized in Table 4.2.

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

Sample No. and Depth	Borehole No.	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Moisture Content (%)	MUSC - Soil Type
MW19 - 2.29 m	BH102	44.3	16.2	28.1	29.6	CI
MW45 - 2.29 m	BH104	49.0	17.8	31.2	30.5	CI
	Average:	46.7	17.0	29.7	30.1	CI

Based on the results in Table 4.2, the clay has an average MUSC of "CI" - Silts or clays of medium plasticity. Results of the MUSC also indicate that the clay contains on average, by mass, 0.0% gravel, 21.1% sand, and 79.0% silt and clay.

4.1.4 Till

Till was encountered at an average depth of 4.91 m below grade in twelve boreholes and extended to the maximum exploration depth in all twelve boreholes. The till consisted of clay, was silty, and contained some sand and trace gravel. The till varied in hue between brown (10YR 4/3) to very dark grey (10YR 3/1), oxidized to non-oxidized, moist, soft to very stiff, massive, contained coal chip inclusions, and was calcareous.

The moisture content of the till samples ranged from 12.6% to 33.3% with an average moisture content of 17.8%.

Pocket Penetrometer (PP) readings ranged from 12 kPa to 72 kPa with an average reading of 29 kPa. This correlates to a soil with a firm consistency.

Thirteen Standard Penetration Tests (SPTs) were completed within the till stratum resulting in an "N" value ranging from 7 to 15 with an average value of 10. This value correlates to a soil with a stiff consistency and an undrained shear strength of 63 kPa.

The corresponding K value was determined to be 2.90.

Based on the PP and SPT test results, the weighted average design undrained shear strength of the till throughout the stratum is 51 kPa. This result indicates a stiff consistency.

Two MUSC tests were performed on till samples obtained from Boreholes BH101 and BH122. The MUSC results are summarized in Table 4.3.

TABLE 4.3: SUMMARY OF TILL MODIFIED UNIFIED SOILS CLASSIFICATION TEST RESULTS

Sample No. and Depth	Borehole No.	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Moisture Content (%)	MUSC - Soil Type
MW7 - 5.33 m	BH101	27.1	12.0	15.1	13.9	CL
MW109 - 2.29 m	BH122	31.9	13.8	18.1	18.3	CI
	Average:	29.5	12.9	16.6	16.1	CL

Based on the results in Table 4.3, the till has an average MUSC of "CL" - Silts or clays of low plasticity. Results of the MUSC also indicate that the till contains on average, by mass, 1.1% gravel, 41.0% sand, and 58.0% silt and clay.

Large rocks were not encountered during drilling; however, 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 seventeen boreholes at an average approximate depth of 2.13 m below ground surface during drilling. Piezometers were installed in four boreholes with the groundwater elevations recorded on the 23rd January, 2019, fifteen days after the final piezometer was installed. The piezometer monitoring results are summarized in Table 4.4.

TABLE 4.4: SUMMARY OF GROUNDWATER MONITORING

Borehole No.	Borehole Depth (m)	Groundwater Level[1] (m), 23rd January, 2019[2]
BH102	12.65	2.44
BH103	12.19	2.00
BH112	9.14	1.94
BH123	6.10	1.74
Average:	**10.02**	**2.03**

Notes:
1 - Below existing grade.

Based on seepage encountered during drilling, piezometer readings, and a knowledge of the area; the average depth to the groundwater table is likely (approx.) 1.5 m to 2.5 m below ground surface. 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 soil 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 manufacturers 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

Driven steel pile and screw pile recommendations have been provided in this report as they are ideal foundational systems for the proposed development at this site. Alternative foundation options can be provided upon request.

Seepage was encountered during drilling and information obtained from piezometers indicates that the average groundwater table across the site is likely between 1.5 m to 2.5 m below grade.

It is recommended that positive drainage be maintained around the development. Positive drainage is particularly important for the improved performance of grade supported foundations, railways, roadways, and parking locations.

Pertinent geotechnical issues for the proposed development are:

1. Topsoil was observed across the site during drilling. If encountered, it is recommended that the site be striped of vegetation and organics prior to construction activities and, if encountered, all organic material below grade supported structures should be removed;

2. The clay and till encountered across the site, according to the MUSC system, is classified as low to medium plastic and will experience minor to moderate volume change with fluctuating moisture conditions. The subgrade is also frost active and will experience volume changes during freezing/thawing cycles. Construction of unheated on-grade structures, where movement would be detrimental, is not recommended on the existing soils unless the bearing surface extends past the frost depth;

3. The subgrade provides a poor bearing capacity for shallow foundations due to the relatively low undrained shear strength and high water table;

4. Due to the nature of the subgrade and the type of structures proposed, a test pile is advised;

5. The sand, clay, and still strata provides poor skin friction and end bearing support for deep foundation systems;

6. The average water table depth is estimated to fluctuate between 1.5 m to 2.0 m below existing grade. It is expected that utility trench excavations extending past these depths will experience seepage, although seepage may be encountered at reduced depths in portions of the site;

7. 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,

8. There is more than one suitable option for the type of foundation system required, however, most foundations systems mobilize their full support and behave differently. Therefore, the use of several different types of foundation systems to support the same structure is not recommended.

5.1 RECOMMENDATIONS FOR SITE GRADING AND EARTHWORKS

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

In areas where the existing grades need to be raised, the exposed native soil subgrade should be proof rolled according to local specifications prior to the 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. All proof roll and compaction testing activities should be monitored/performed by competent geotechnical personnel.

5.1.1 Engineered Fill and Road Construction

Generally, the sand, clay, and till encountered at the site is a moderate fill material and will provide a moderate foundation for road construction, assuming the soil is prepared according to specifications. Care should be taken to ensure the road's subgrade is consistent however, and doesn't alternate between high plastic and low plastic subgrade. The underlying clay and till encountered is low to medium plastic and is a moderate fill material.

Ideally, fill required to raise the grade should be kept consistent to ensure a uniform structure. Fill soils should be free from any frozen soil, organic materials, contamination, and deleterious construction materials. High plastic clay does not provide ideal subgrade support due to the potential for swell and heave of the subgrade with fluctuating moisture conditions. 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.

Although well-graded gravels could also be considered, they are unlikely to be needed other than for the base and sub-base courses of access roads, parking areas, concrete slabs, sidewalks, 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 for fills less than 1.2 m in thickness. A minimum compaction of 100% SPDD at moisture contents ± 2% of optimum for structural fills below slabs, parking lots, roadways, etc. greater than 1.2 m in thickness is recommended. The local soils will likely 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. There may also be some localized areas where the native soils may 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 according to local specifications. 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 (Alberta Transportation) 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. Full time testing is recommended on deep fills exceeding 1.2 m in thickness.

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 footprint. 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 support slabs, etc. The finished grade adjacent to the facilities should be graded at a minimum slope of 1.5% over a distance of 3.0 m.

5.1.3 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.

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.

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.

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 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 foundation 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. Close-ended steel pipe piles are recommended as opposed open-end pipe piles. 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	-	-[1]
2.0 to 3.2	Sand	10	-[1]
3.2 to 4.9	Clay	33	405[2]
Below 4.9	Till	34	459[2]

Notes:
1 - Not recommended.
2 - A minimum preliminary pile length of 8.8 m is recommended.

A preliminary minimum pile length of 8.8 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:

$$\phi R_n$$

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 skin friction and end bearing resistance of the pile. Group reduction factors will be

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

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).

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 fill with groundwater and slough. It is recommended that the driven steel piles be installed immediately following the completion of the pre-boring activities.

If pre-boring is required, pre-bored holes, for 8.8 m long piles, should extend 7.8 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

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

increased to 8.3 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 9.0 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 ϕ = 0.5 for compression and ϕ = 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 another optional 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, typical 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 with the helix embedded in the till and a shaft diameter of 140 mm (5.5 inches) and a helix diameter of 508 mm (20 inches) is calculated using the following:[3]

$$Q_{\mathrm{h}} = (NcSu + \gamma' H)A \qquad \text{Eq. 1}$$

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 51 kPa for the till);
γ' = Effective Unit Weight of the soil (7.85 kN/m^3 for the till);
H = Depth to helical bearing plate; and,
A = Effective helix area (.203 m^2).

Due to the likely long length of the screw piles at this site, skin friction contributions were 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:

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

$$R = Q_h + Q_f$$

Q_f is calculated as:

$$Q_f = c \times h \times F_s$$

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:

$$Q_u = \sum_{i=1}^{n} Q_{ui} R_f \qquad \text{Eq. 2}$$

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:

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

$$\phi R_n$$

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 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 LATERAL EARTH PRESSURES ON SHORING SYSTEMS

Lateral earth pressure values may be required for the design of walls or shoring systems for temporary excavations in specific areas for the development. Table 5.3 provides the coefficients of lateral earth pressures for designing shoring systems.

These values are based on the assumption that the retaining structure utilizes a vertical back, a horizontal backfill behind the shoring system, and normally consolidated cohesionless backfill.

For rigidly tied and unyielding structures, the at-rest earth pressure should be used for design. The unfactored soil parameters provided in Table 5.3 may be used for design of walls with a horizontal soil profile behind the shoring system. The effects of additional loading, equipment, vehicles, stockpiles, frost, seismic, etc. should be accounted for by applying an appropriate surcharge.

The total active (P_A), passive (P_P), and at-rest (P_O) thrusts can be calculated using the following equations:

$$P_A = \tfrac{1}{2}\gamma H^2 K_A$$

$$P_P = \tfrac{1}{2}\gamma H^2 K_P$$

$$P_o = \tfrac{1}{2}\gamma H^2 K_o$$ (assumes zero surcharge and no pore water pressure).

Where H is the height of the wall and γ is the unit weight of the backfill/retained soil. Preliminary values for K_a, K_p, K_o, and γ are provided below. The force generally acts on the wall at a height of H/3 from the base.

TABLE 5.3: LATERAL EARTH PRESSURE PRELIMINARY VALUES

Description	Wash Rock	Sand
Coefficient of Active Earth Pressure (K_A)	0.31	0.33
Coefficient of Passive Earth Pressure (K_P)	3.25	3.00
Coefficient of At-Rest Earth Pressure (K_O)	0.47	0.50
Unit Weight (kN/m^3)	20.6	16.7
Friction Angle (Ø)	32°	30°

5.5 FROST DESIGN RECOMMENDATIONS

5.5.1 General

Winter frost penetration will likely impact foundations, roadway and parking structures, and underground utilities due to the expansion of pore water in the soils.

Based on historical temperature data for the Lacombe County 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 Roadways and Parking Areas

The extent of frost penetration for roadways and parking areas is typically severe due to the gravel structure and lack of snow cover. To reduce the potential for frost heave, it is recommended to set the final road and parking grade well above the water table, provide good structure drainage, and provide a uniform road and parking structure to help prevent distortion of the structure due to different subgrade reactionary effects to cold weather. Movement due to the effects of frost can be expected and would be considered typical for the area.

5.5.3 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 frozen soil. For preliminary purposes, driven piles in unheated structures should have a minimum embedment depth of 8.8. m. The full design dead load must be applied to the piles prior to winter.

5.5.4 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 ground surface. This void space allows for the upward movement of the ground surface by frost heaving, or expansive clays, without those heaving/swelling movements affecting the structure. Structures on grade supported slabs will be

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

subject to movements caused by frost action. Expansive movement can be expected as the subgrade is frost active.

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 subgrade soils at the site generally consist of sand, clay, and till. Pertinent seismic data[6] for the proposed development site is provided in Table 6.1.

- The undrained shear strength is: S_u < 50 kPa; and,
- Site Classification for Seismic Response is Site Class "E".

Seismic Data which has a 2% probability of exceedance in 50 years for the Lacombe area is as follows:

TABLE 6.1: ALBERTA BUILDING CODE INTERPOLATED SEISMIC HAZARD VALUES

S_a (0.2)	S_a (0.5)	S_a (1.0)	S_a (2.0)	PGA (g)
0.095	0.057	0.026	0.010	0.036

7 FLOOR RECOMMENDATIONS

Grade-supported slabs on low to medium plastic clay or till can result in total differential movements exceeding 25 mm. This can result in heaving, warping, and cracking. Positive drainage around the structure and good site drainage will improve the performance of grade supported slabs.

7.1 GRADE SUPPORTED SLABS

Our recommendations for grade supported floor slabs are as follows, and are intended to reduce movement, but likely won't eliminate it:

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

1. Excavate any topsoil, organic soil, soft or wet subgrade below the proposed slab footprint. Construction on organic material and/or non-structural fill material of unknown quality and composition can result in uneven settlement or heave. If encountered, remove all organic material 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.

3. Scarify and uniformly compact the exposed native subgrade to a minimum 98% of its SPDD as determined by test ASTM D698. Adjust the water content of the subgrade to +2% of the optimum moisture content.

4. If required, 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 20 mm crushed granular base course, which complies with the specifications as shown on Table 7.1, 150 mm thick, on the compacted, prepared fill for light loads. If moderate to heavy loads are expected, it is recommended that the slab design be reviewed by a structural engineer. The granular base should be compacted to a minimum 98% of its SPDD using a vibratory compactor. Water may be used as a compaction aid.

6. Install a layer of polyethylene sheeting 150 μm (minimum) thick between the granular base and the concrete slab to prevent the migration of moisture through the floor, if required.

7. 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.

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

9. 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.

10. 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. Second, 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.

11. 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.

12. 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: ALBERTA TRANSPORTATION AGGREGATE SPECIFICATION

Sieve Size (mm)	% Passing For Nominal Maximum Size	
	20 mm (Base)[1]	80 mm (SGSB)[1]
80	---	100
50	---	55-100
25	---	38-100
20	100	---
16	84-94	32-85
10	63-86	---
5.0	40-67	20-65
1.25	20-43	---
0.630	14-34	---
0.315	9-26	6-30
0.160	5-18	---
0.080	2-10	2-10

Note:
1 - Standard Specifications for highway Construction, Section 3, 3.2 Aggregate Production and Stockpiling, Table 3.2.3.1, Specifications for Aggregate.

Grade supported floor slab recommendations containing radon mitigation collection system can be provided upon request.

7.2 STRUCTURALLY SUPPORTED FLOORS

Where heaving or settlement will have unacceptable impacts on floor serviceability, local areas of structurally supported floors should be provided. For example, structural floors are often placed below the door swing areas of external doors. Alternatively, ensure that the top of floor slabs below the exterior door swing is at least 150 mm below the underside of the door. Floor slabs can heave to block the swing of doors that are structurally supported by perimeter grade beams.

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 potential 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 subgrade soils at the site consist mainly of sand, clay, and till. The native subgrade soil stratum offers poor 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 35 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 800,000 ESALs for moderate loads were utilized for pavement designs. These values are similar to those outlined in the City of Red Deer in their *Roadway Design Standards*, *Section No. 13*, *Table 13.3 Pavement Structure*, 2013, for Residential Local (light) and Industrial Local (moderate) roads.

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 those currently referenced by the local municipality'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 light passenger vehicles and Option No. 2 is recommended for areas servicing vehicles with moderate loading. 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

MR	**35,000 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	250	25
Woven Geofabric[1]	1 Layer[2]	-	1 Layer[2]	-
Geogrid[1,3]	-	-	1 Layer	≈10
Totals	425	71	500	96
Design SN		67		95

Notes:
1 - Geotextile should be installed according to the manufactures recommendations.
2 - If the subgrades is cohesive.
3 - Recommend Biaxial Geogrid BX1100™ or equivalent.

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

1. Excavate all topsoil, organic material, and soft or wet soil 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, 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 cohesive soil or a non-frost active granular soil. It is recommended that the asphalt structure be placed on a uniform bearing surface/structure.

3. Scarify and uniformly compact the upper 150 mm of the native subgrade to a minimum 100% 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;

4. Provide cross slope on the subgrade of 2% to a ditch or French Drain system.

5. Place the woven geofabric on the subgrade according to the manufacturer's recommendations. A woven filter fabric with a minimum Grab Tensile Strength of 900 N is recommended. If required, place the geogrid on the geofabric according to the manufacturer's recommendations.

6. Place the 80 mm SGSB, which complies with the specifications as shown in Table 7.1, in maximum 200 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 specifications as shown in Table 7.1, in a 150 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 Lacombe County or local authority.

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 or French Drains. Saturation of the gravel structure will lead to a 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.

8.4 GRAVEL YARD STRUCTURAL DESIGN

A portion of the site will be developed as a gravel yard. Loads are expected to be light (storage areas, passenger vehicle traffic, etc.) to moderate (tractor trailers, construction equipment, service trucks, etc.). As the proposed running surface is to be gravel, it is expected that some maintenance and gravel supplement will be required periodically. Gravel addition, and/or increased maintenance may be required during periods of wet weather, heavy, stop and go or turning traffic, or increased load.

Typical gravel yards have regions of light (around the perimeter, storage areas, etc.) and moderate (entrances/exits, near loading docks or fuelling stations, etc.) areas of loading. Therefore, two gravel structure sections are proposed for this site, for typical light and moderate loads comprising of wheeled vehicles. The gravel structures for the proposed yard area are shown in Table 8.2.

TABLE 8.2: RECOMMENDED GRAVEL YARD STRUCTURE

Design	Light	Moderate
Material	**Thickness (mm)**	**Thickness (mm)**
Base Course	200[2]	200
SGSB	-	200
Woven Geotextile[1]	-	1 Layer[3]
Totals	200	350

Notes:
1 - Geotextile should be installed according to the manufactures recommendations.
2 - Could be switched to SGSB but this would result in a rough running surface.
3 - If the subgrades is cohesive.

The recommendations for subgrade preparation and material placement outlined in Sections 5.1 and 8.3 should be referenced during yard construction.

Good site drainage will improve gravel structure performance.

9 RAILWAY SPUR LINES

Multiple 3.05 m deep boreholes were drilled for railway spur design purposes. The subsurface conditions in these areas were consistent with that encountered throughout the site. No deep organic, fill, or deleterious conditions were encountered.

All topsoil should be removed from the proposed spur line location(s) prior to construction activities. Where the spur line joins with the existing railway berm, it is recommended to step the existing berm to eliminate a potential slip plane in the transitional zone from new to old fill. It is understood that the railway spur berm and ballast specifications will be provided by the railway company design engineers and specifics regarding lift thickness, compaction, berm slope, ballast specification, etc. have not been provided in this report.

10 RETENTION POND

It is understood that the proposed development may include a constructed wetland/storm water retention pond. The depth or elevation of the base of this pond is unknown at this time, but it is expected that it will extend past the groundwater elevation, and contained water, if it is 1.5 m to 2.5 m below existing grade. 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. The liner should be moisture conditioned to 2% to 5% of optimum and compacted to a minimum of 98% Standard Proctor Dry Density.

11 ALBERTA BUILDING CODE CONSIDERATIONS

In accordance with the Alberta Building Code, the construction of all foundations (including shallow foundations) 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-2014* 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 we are 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.

12 CLOSURE

Union Street Geotechnical Ltd. prepared this report for the use of Taves Management Inc., and their agents, for the design and construction of a frac sand handling facility and associated infrastructure located within the S.E. ¼ of 29-40-22 W4M in Lacombe County, 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,

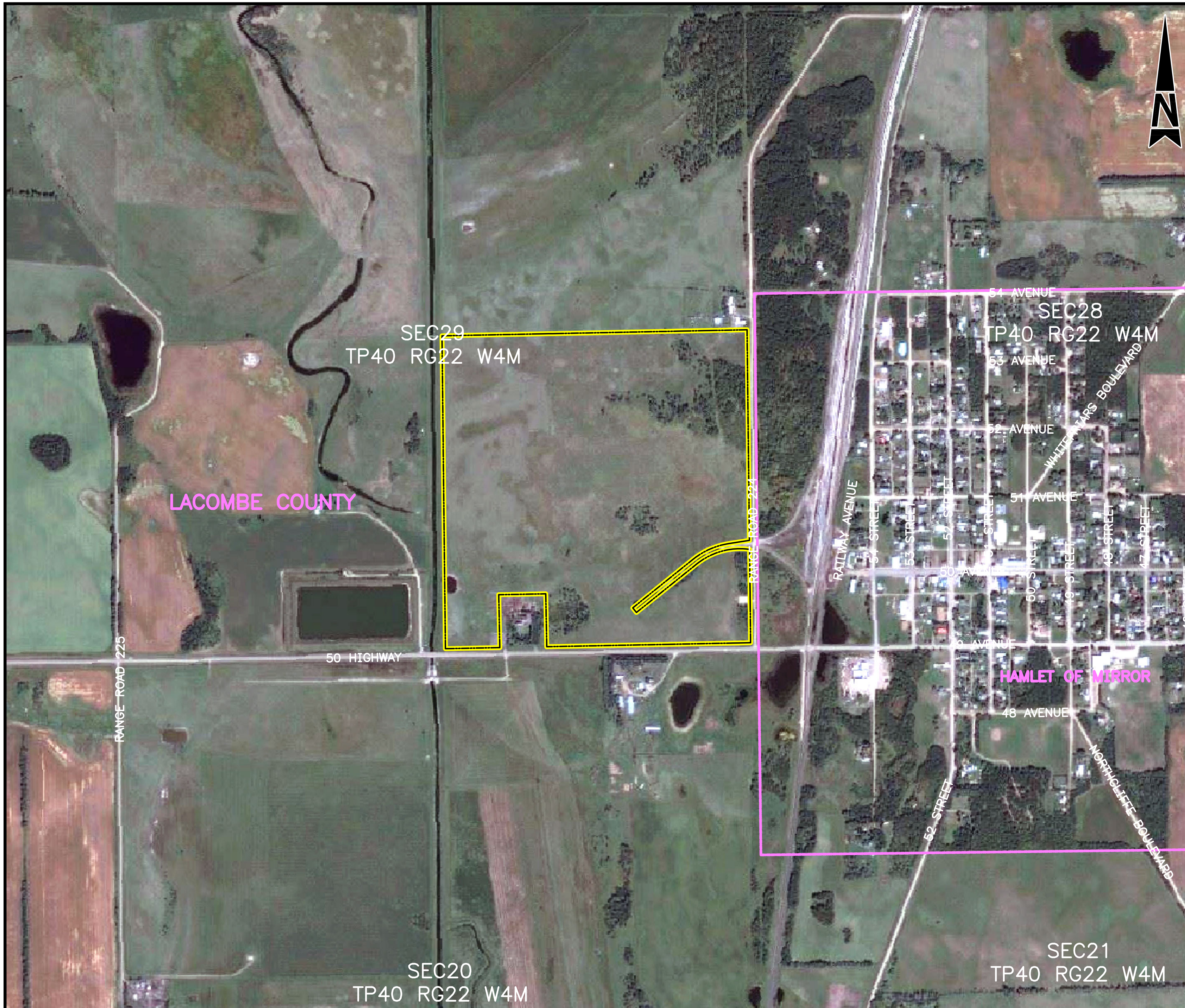
Union Street Geotechnical Ltd.

APEGA Permit to Practice No.: P12644

Prepared By:	Reviewed By:
	29 Jan, 2019
Neil Tomaszewski, E.I.T. Project Engineer	Joshua Wilson, P.Eng. Geotechnical Manager

Union Street Geotechnical

Drawings



LEGEND:

SITE BOUNDARY

MUNICIPAL BOUNDARY

NOTES:

1 DRAWING COMPILED FROM:
MULTIPLE VECTOR AND RASTER GIS FILES AS PUBLISHED BY THE GOVERNMENT OF CANADA; NATURAL RESOURCES CANADA; EARTH SCIENCES SECTOR; CANADA CENTRE FOR MAPPING AND EARTH OBSERVATION,

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& UNION STREET GEOTECHNICAL SITE INVESTIGATION INFORMATION.

2 LEGAL DESCRIPTION:

LINC	SHORT LEGAL	TITLE NUMBER
0028 296 341	4;22;40;29;SE	162 132 105

THE SOUTH EAST QUARTER OF SECTION TWENTY NINE (29)
TOWNSHIP FORTY (40)
RANGE TWENTY TWO (22)
WEST OF THE FOURTH MERIDIAN
CONTAINING 64.7 HECTARES (160 ACRES) MORE OR LESS.

EXCEPTING THEREOUT:	HECTARES	(ACRES) MORE OR LESS	
A) PLAN 2221 CL – RAILWAY	0.539	1.337	
B) PLAN 1290 JY – ROAD	0.405	1.00	
C) PLAN 403 MC – RIGHT OF WAY	0.045	0.11	REGULATING SITE
D) PLAN 8821758 – PUBLIC WORK	1.918	4.74	
E) PLAN 0020272 – DESCRIPTIVE	1.62	4.00	

EXCEPTING THEREOUT ALL MINES AND MINERALS

0 100 200 300 400 500 m

Union Street Geotechnical

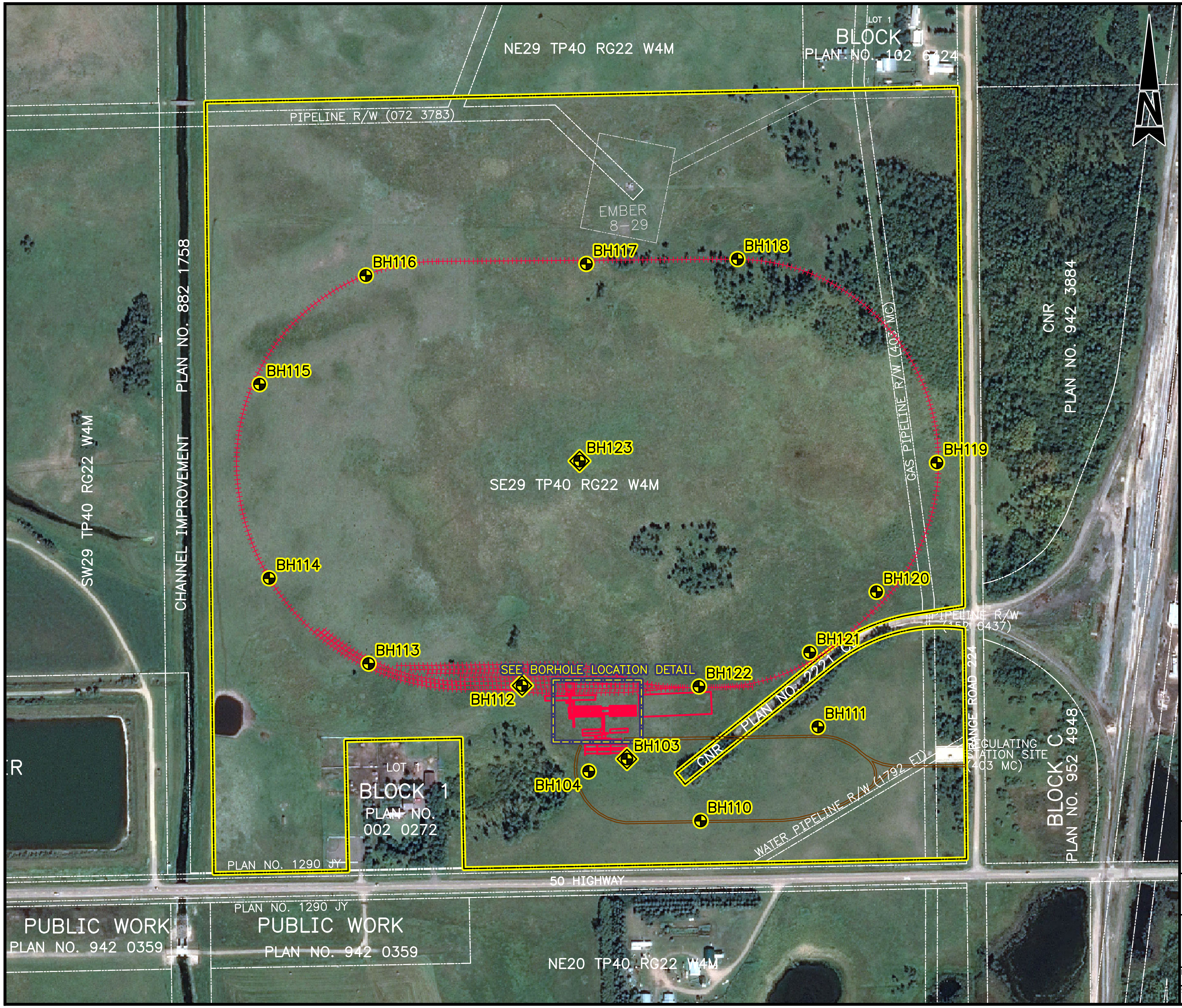
Taves Management Inc.

GEOTECHNICAL INVESTIGATION
SE29 TP40 RG22 W4M
LACOMBE COUNTY, ALBERTA

TITLE

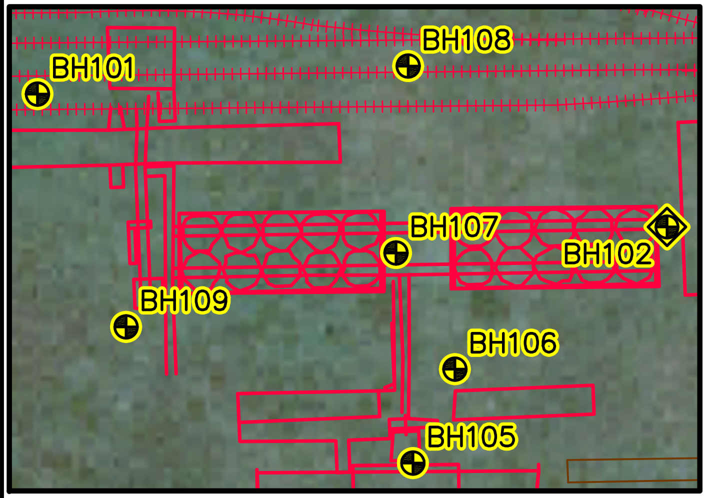
SITE LOCATION PLAN

DATE 2019/01/21	DWN. BY	CHKD. BY	APPD. BY
SCALE 1:10,000	FILE NO. USG0691-A2A	DWG. NO.	001



LEGEND:

BOREHOLE LOCATION	
WATER MONITORING WELL LOCATION	
LEGAL LINE (WHITE)	
SITE BOUNDARY	
MUNICIPAL BOUNDARY	
PROPOSED FEATURE/FACILITIES	
PROPOSED TRUCK ACCESS	
PRPOSED RAILWAY TRACK	



BOREHOLE LOCATION DETAIL

SCALE: 1:1000

0 10 20 30 40 50 m

NOTES:

1 DRAWING COMPILED FROM:
MULTIPLE VECTOR AND RASTER GIS FILES AS PUBLISHED BY THE GOVERNMENT OF CANADA; NATURAL RESOURCES CANADA; EARTH SCIENCES SECTOR; CANADA CENTRE FOR MAPPING AND EARTH OBSERVATION,

AERIAL PHOTOGRAPH ©2019 MICROSOFT CORPORATION ©2019 DIGITALGLOBE ©CNES (2019) DISTRIBUTION AIRBUS DS BING,

COUNTY OF LACOMBE WEB SITE DATA,

CLIENT SUPPLIED DRAWINGS (PDF) AS PRODUCED BY COMPASS GEOMATICS LTD.

& UNION STREET GEOTECHNICAL SITE INVESTIGATION INFORMATION.

2 LEGAL DESCRIPTION:

LINC	SHORT LEGAL	TITLE NUMBER
0028 296 341	4;22;40;29;SE	162 132 105

THE SOUTH EAST QUARTER OF SECTION TWENTY NINE (29)
TOWNSHIP FORTY (40)
RANGE TWENTY TWO (22)
WEST OF THE FOURTH MERIDIAN
CONTAINING 64.7 HECTARES (160 ACRES) MORE OR LESS.

EXCEPTING THEREOUT:	HECTARES	(ACRES)	MORE OR LESS
A) PLAN 2221 CL – RAILWAY	0.539	1.337	
B) PLAN 1290 JY – ROAD	0.405	1.00	
C) PLAN 403 MC – RIGHT OF WAY	0.045	0.11	REGULATING SITE
D) PLAN 8821758 – PUBLIC WORK	1.918	4.74	
E) PLAN 0020272 – DESCRIPTIVE	1.62	4.00	

EXCEPTING THEREOUT ALL MINES AND MINERALS

0 50 100 200 300 m

Union Street Geotechnical

Taves Management Inc.	GEOTECHNICAL INVESTIGATION SE29 TP40 RG22 W4M LACOMBE COUNTY, ALBERTA

TITLE

BOREHOLE LOCATION PLAN

DATE	DWN. BY	CHKD. BY	APPD. BY
2019/01/21			
SCALE 1:4000	FILE NO. USG0691-A2A	DWG. NO. 002	

Union Street Geotechnical

Photographs

PHOTOGRAPHS - Geotechnical Investigation
Frac Sand Facility
Lacombe County, Alberta

Photograph No. 1: Photograph taken from near Borehole BH123, facing north, showing a portion of the proposed rail loop footprint, snow cover, and site conditions at the time of drilling. Photograph taken on 8th January, 2019.

Photograph No. 2: Photograph taken from near Borehole BH123, facing east, showing a portion of the proposed rail loop footprint and site conditions at the time of drilling. Photograph taken on 8th January, 2019.

**PHOTOGRAPHS CONT'D - Geotechnical Investigation
Frac Sand Facility
Lacombe County, Alberta**

Photograph No. 3: Photograph taken from near Borehole BH123, facing south, showing a portion of the proposed rail loop footprint, proposed footprint for main facility, snow cover, and site conditions at the time of drilling. Photograph taken on 8th January, 2019.

Photograph No. 4: Photograph taken from near Borehole BH123, facing west, showing a portion of the proposed rail loop footprint and site conditions at the time of drilling. Photograph taken on 8th January, 2019

Union Street Geotechnical	Borehole Logs

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH101

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **N/A**
TOTAL DEPTH: **12.65 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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Brown (10YR 4/3) to dark grey (10YR 4/1). Oxidized. Moist. Loose to compact. Massive. Coal chip, organic, and clay seam inclusions. Calcareous.										
1.0				MW1		-	9.2					
		@ 0.15 m, black sand, 0.31 m thick.		MW2	12	48	21.4					
2.0		@ 2.29 m, some clay, some silt.		MW3		48	22.3					
3.0		@ 3.35 m, seepage.		MW4	9	12	22.0					
4.0				MW5		24	30.7					
				MW6	8	12	22.5					
5.0		TILL: Clay and sand, silty, trace gravel. Dark grey (10YR 4/1) to very dark grey (10YR 3/1). Oxidized. Moist. Firm to stiff. Massive. Calcareous.		MW7		36	13.9		CL	12.0	27.1	
6.0				MW8	7	12	15.4					Auger cuttings.
7.0				MW9		12	16.0					
8.0				MW10	9	24	17.1					
				MW11		48	16.4					
9.0				MW12	9	24	16.9					
10.0				MW13		24	19.7					

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH101

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **N/A**
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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
11.0				MW14	9	24	18.4					
				MW15		36	18.0					
12.0				MW16	11	60	19.0					
13.0		NOTES: End of borehole at 12.65 m below surface. Seepage and sloughing were encountered during drilling. Borehole backfilled to surface with auger cuttings.										
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												
20.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH102

PROJECT NUMBER: USG691
PROJECT NAME: Geotechnical Investigation
LOCATION: S.E. 1/4 of 29-40-22 W4M
CLIENT: Taves Management Inc.
DRILLING METHOD: 150 mm Solid Stem Auger
LOGGED BY: M.W.
DATE BEGUN: 7 January, 2019
DATE COMPLETED: 7 January, 2019

CASING STICKUP: 1.08 m
TOTAL DEPTH: 12.65 m
GROUND SURFACE ELEVATION: N/A

Union Street Geotechnical

DEPTH (m)	DESCRIPTION
0.0	TOPSOIL
	SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Organic inclusions. Non-calcareous. @ 1.22 m, brown (10YR 4/3) and calcareous.
2.0	CLAY: Silty, sandy. Brown (10YR 4/3). Oxidized. Moist. Soft to firm. Massive. Coal chip inclusions. Calcareous. @ 3.35 m, seepage.
3.6	TILL: Clay, silty, sandy, trace gravel. Dark greyish brown (10YR 4/2) to very dark grey (10YR 3/1). Oxidized to non-oxidized. Moist. Soft to stiff. Massive. Calcareous.

SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)
MW17		-	7.9				
MW18	4	12	19.2				
MW19		12	29.6		CI	16.2	44.3
MW20	11	36	27.4				
MW21		12	32.8				
MW22	13	72	33.3				
MW23		60	14.1				
MW24	11	24	17.8				
MW25		36	17.1				
MW26	10	24	17.6				
MW27		24	17.4				
MW28	8	12	17.9				

WELL INSTALLATION: Casing. Auger cuttings.

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH102

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **1.08 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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
10.0				MW29		12	16.2					
11.0				MW30	8	12	20.1					Hand slotted 25 mm PVC.
				MW31		12	19.3					
12.0				MW32	9	12	20.2					
13.0		NOTES: End of borehole at 12.65 m below surface. Seepage, but no sloughing encountered during drilling. Piezometer installed. Water leverl recorded at 2.44 m below grade on 23 January, 2019.										
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH103

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **1.05 m**
TOTAL DEPTH: **12.19 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	DESCRIPTION
0.0	TOPSOIL
	SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Non-calcareous.
	@ 1.83 m, seepage and brown (10YR 4/3).
	CLAY: Silty, some sand. Brown (10YR 4/3) to dark greyish brown (10YR 4/2). Oxidized. Moist. Firm. Massive. Calcareous.
	@ 4.72 m, sand seam, 0.61 m thick.
	TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Oxidized. Moist. Soft to stiff. Massive. Calcareous.

SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)
MW33		-	8.2				
MW34		-	24.5				
MW35	7	48	22.0				
MW36		36	26.8				
MW37		24	12.6				
MW38	15	72	12.9				
MW39		72	17.7				
MW40		24	17.4				
MW41	10	-	26.2				

WELL INSTALLATION: Casing. Auger cuttings.

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH103

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **1.05 m**
TOTAL DEPTH: **12.19 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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
10.0				MW42		24	21.2					Hand slotted 25 mm PVC.
11.0				MW43		12	18.8					
12.0		NOTES: End of borehole at 12.19 m below surface. Seepage and sloughing encountered during drilling. Piezometer installed. Water level recorded at 2.0 m below grade on 23 January, 2019.										
13.0												
14.0												
15.0												
16.0												
17.0												
18.0												
19.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH104

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
1.0		SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Calcareous.		MW44		36	9.1					
2.0		CLAY: Silty, some sand. Brown (10YR 4/3) to very dark brown (10YR 3/3). Oxidized. Moist. Soft. Massive. Calcareous. @ 0.61 m, frost depth. @ 2.44 m, seepage.		MW45		12	30.5		CI	17.8	48.9	
4.0				MW46		12	25.1					Auger cuttings.
5.0		TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft to stiff. Massive. Calcareous.		MW47		72	16.4					
7.0				MW48		24	15.9					
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.		MW49		24	16.7					
9.0												
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH105

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										Auger cuttings.
0.0–2.0		SAND: Silty, trace clay. Black (10YR 2/1). Non-oxidized. Dry to moist. Loose. Massive. Calcareous. @ 0.61 m, frost depth. @ 1.98 m, seepage.		MW50		-	7.8					
2.0–4.0		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Soft. Massive. Calcareous.		MW51		12	26.6					
				MW52		24	17.3					
4.0–9.14		TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft to firm. Massive. Calcareous.										
				MW53		36	14.9					
				MW54		24	15.6					
		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.		MW55		12	16.9					
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH106

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **N/A**
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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0	TOPSOIL										
	SAND: Silty, some clay. Black (10YR 2/1) to dark grey (10YR 4/1). Oxidized. Moist. Loose. Massive. Organic inclusions. Calcareous.		MW56		12	7.7					
2.0	@ 1.98 m, seepage.		MW57		-	29.1					
4.0			MW58		-	28.7					
	TILL: Clay, silty, some sand, trace gravel. Dark grey (10YR 4/1). Non-oxidized. Moist. Soft to firm. Massive. Calcareous.										Auger cuttings.
5.0			MW59		24	19.0					
7.0			MW60		36	14.8					
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.		MW61		12	18.0					

Depth scale: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH107

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										Auger cuttings.
0.0–7.3		SAND: Some clay, some silt. Brown (10YR 4/3) to very dark grey (10YR 3/1). Oxidized. Moist to wet. Loose. Massive. Calcareous. @ 1.52 m, seepage.										
~0.9				MW62		-	3.6					
~2.4				MW63		-	27.3					
~3.9				MW64		-	21.8					
~5.5				MW65		-	27.4					
7.3–9.14		TILL: Clay, silty, sandy, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft. Massive. Calcareous.										
~7.0				MW66		-	18.7					
~8.5				MW67		24	15.8					

NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH108

PROJECT NUMBER: **USG691**

PROJECT NAME: **Geotechnical Investigation**

LOCATION: **S.E. 1/4 of 29-40-22 W4M**

CLIENT: **Taves Management Inc.**

DRILLING METHOD: **150 mm Solid Stem Auger**

LOGGED BY: **M.W.**

DATE BEGUN: **7 January, 2019**

DATE COMPLETED: **7 January, 2019**

CASING STICKUP: **N/A**

TOTAL DEPTH: **9.14 m**

GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0	TOPSOIL										
	SAND: Silty, some clay. Brown (10YR 4/3). Oxidized. Moist to wet. Loose. Massive. Calcareous. @ 0.61 m, frost depth.		MW68		-	4.1					
1.0											
2.0	@ 2.44 m, seepage.		MW69		-	25.8					
3.0											
4.0			MW70		-	23.2					Auger cuttings.
5.0	CLAY: Silty, some sand. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft. Massive. Calcareous.		MW71		24	24.0					
6.0	SAND: Some clay, some silt. Very dark grey (10YR 3/1). Non-oxidized. Wet. Very loose. Massive. Calcareous.										
7.0			MW72		-	24.0					
	TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft. Massive. Calcareous.										
8.0			MW73		24	15.5					
9.0											
10.0											

NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH109

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
1.0		SAND: Some clay, some silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Calcareous. @ 0.61 m, frost depth. @ 1.52 m, seepage.		MW74		-	5.8					
2.0		CLAY: Silty, some sand. Brown (10YR 4/3) to very dark grey (10YR 3/1). Oxidized to non-oxidized. Moist. Soft. Massive. Calcareous. @ 3.05 m, sandy.		MW75		24	26.4					
4.0				MW76		-	25.2					
5.0		TILL: Clay, silty, sandy, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft. Massive. Calcareous.		MW77		24	16.3					Auger cuttings.
7.0				MW78		24	17.4					
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.		MW79		12	17.5					
10.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH110

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Brown (10YR 4/3). Oxidized. Dry to moist. Loose. Massive. Calcareous.		MW80		-	2.2					
1.0												
		CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Stiff. Massive. Calcareous.										Auger cuttings.
2.0				MW81		72	24.5					
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: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **7 January, 2019**
DATE COMPLETED: **7 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0	Topsoil	TOPSOIL										Auger cuttings.
	Sand	SAND: Some clay, some silt. Dark brown (10YR 3/3). Oxidized. Moist. Loose. Massive. Calcareous.										
1.0				MW82		12	3.9					
2.0	Clay	CLAY: Silty, some sand. Brown (10YR 4/3). Oxidized. Moist. Very stiff. Massive. Calcareous.										
				MW83		108	24.5					
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: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

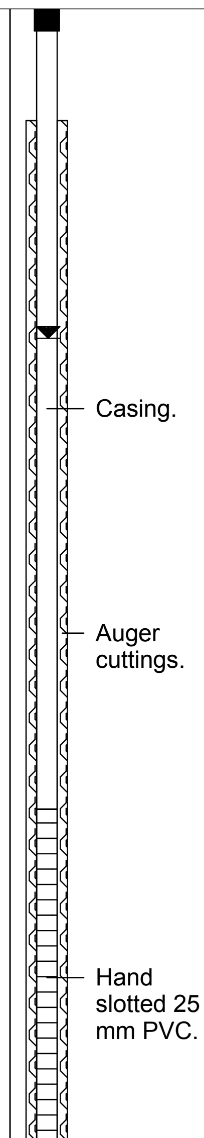
CASING STICKUP: **1.00 m**
TOTAL DEPTH: **9.14 m**
GROUND SURFACE ELEVATION: **N/A**

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)
0.0		TOPSOIL									
		SAND: Some clay, some silt. Dark brown (10YR 3/3) to dark greyish brown (10YR 4/2). Oxidized. Moist. Loose. Massive. Calcareous.		MW84		-	7.7				
		@ 1.07 m, frost depth.									
				MW85		12	24.8				
		@ 3.05 m, seepage.									
		TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Soft to firm. Massive. Calcareous.		MW86		12	15.7				
				MW87		12	15.9				
				MW88		36	17.1				
		NOTES: End of borehole at 9.14 m below surface. Seepage and sloughing encountered during drilling. Piezometer installed. Water level recorded at 1.94 m below grade on 23 January, 2019.		MW89		24	15.5				

Depth scale (m): -1.0, 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

WELL INSTALLATION



FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH113

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										Auger cuttings.
		SAND: Silty, some clay. Black (10YR 2/1) to very dark greyish brown (10YR 3/2). Non-oxidized. Moist to wet. Loose. Massive. Calcareous.										
				MW90		-	11.5					
1.0												
2.0												
				MW91		-	24.0					
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
BH114

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Some clay, some silt, trace gravel. Black (10YR 2/1) to dark greyish brown (10YR 4/2). Oxidized. Moist. Loose. Massive. Calcareous.		MW92		-	4.6					
1.0												
		@ 1.52 m, seepage.										Auger cuttings.
2.0				MW93		-	24.1					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage but no sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH115

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Very dark brown (10YR 2/2) to black (10YR 2/1). Oxidized. Moist. Loose. Massive. Calcareous.		MW94		-	3.2					
1.0												Auger cuttings.
		@ 1.83 m, seepage.										
2.0				MW95		-	30.8					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH116

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										Auger cuttings.
		SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Calcareous.										
				MW96		-	6.1					
1.0		@ 1.07 m, dark brown (10YR 3/3).										
		@ 1.83 m, seepage.										
2.0												
				MW97		-	23.4					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH117

PROJECT NUMBER:	**USG691**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**S.E. 1/4 of 29-40-22 W4M**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Taves Management Inc.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**M.W.**		
DATE BEGUN:	**8 January, 2019**		
DATE COMPLETED:	**8 January, 2019**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Some clay, some silt. Very dark brown (10YR 2/1). Oxidized. Moist to wet. Loose. Massive. Organic inclusions. Calcareous.										
		@ 0.61 m, frost depth.		MW98		-	8.5					
1.0												
		@ 1.68 m, seepage.										Auger cuttings.
2.0												
				MW99		-	23.2					
3.0		NOTES: End of borehole at 3.05 m below surface. No seepage or sloughing was encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER
BH118

PROJECT NUMBER:	**USG691**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**S.E. 1/4 of 29-40-22 W4M**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Taves Management Inc.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**M.W.**		
DATE BEGUN:	**8 January, 2019**		
DATE COMPLETED:	**8 January, 2019**		

Union Street Geotechnical

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SAMPLE SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Very dark brown (10YR 2/1). Oxidized. Moist. Loose. Massive. Organic inclusions. Calcareous.										
				MW100		-	6.6					
1.0		@ 1.07 m, dark brown (10YR 3/3).										
												Auger cuttings.
		@ 1.83 m, seepage.										
2.0												
				MW101		-	19.8					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage and sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH119

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Very dark brown (10YR 2/2). Oxidized. Moist to wet. Loose. Massive. Organic inclusions. Calcareous.		MW102		-	9.5					
1.0												
												Auger cuttings.
2.0		@ 1.83 m, seepage.										
		@ 2.29 m, dark yellowish brown (10YR 4/6).		MW103		-	16.7					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage and sloughing was encountered during drilling. Borehole backfilled with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH120

PROJECT NUMBER: **USG691**
PROJECT NAME: **Geotechnical Investigation**
LOCATION: **S.E. 1/4 of 29-40-22 W4M**
CLIENT: **Taves Management Inc.**
DRILLING METHOD: **150 mm Solid Stem Auger**
LOGGED BY: **M.W.**
DATE BEGUN: **8 January, 2019**
DATE COMPLETED: **8 January, 2019**

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										Auger cuttings.
		SAND: Trace clay, trace silt. Dark brown (10YR 3/3) to dark greyish brown (10YR 4/2). Oxidized. Moist. Loose. Massive. Calcareous.		MW104		-	5.4					
				MW105		-	23.3					
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.										

Depth scale: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH121

PROJECT NUMBER: USG691
PROJECT NAME: Geotechnical Investigation
LOCATION: S.E. 1/4 of 29-40-22 W4M
CLIENT: Taves Management Inc.
DRILLING METHOD: 150 mm Solid Stem Auger
LOGGED BY: M.W.
DATE BEGUN: 8 January, 2019
DATE COMPLETED: 8 January, 2019

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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Organic inclusions. Calcareous.		MW106		-	7.8					
1.0												Auger cuttings.
2.0		CLAY: Silty, trace sand. Brown (10YR 4/3). Oxidized. Moist. Firm. Massive. Calcareous. @ 2.13 m, sandy, seepage.		MW107		24	28.1					
3.0		NOTES: End of borehole at 3.05 m below surface. Seepage, but no sloughing encountered during drilling. Borehole backfilled to surface with auger cuttings.										
4.0												
5.0												

FIELD BOREHOLE LOG

BOREHOLE NUMBER: BH122

Union Street Geotechnical

PROJECT NUMBER:	**USG691**	CASING STICKUP:	**N/A**
PROJECT NAME:	**Geotechnical Investigation**	TOTAL DEPTH:	**3.05 m**
LOCATION:	**S.E. 1/4 of 29-40-22 W4M**	GROUND SURFACE ELEVATION:	**N/A**
CLIENT:	**Taves Management Inc.**		
DRILLING METHOD:	**150 mm Solid Stem Auger**		
LOGGED BY:	**M.W.**		
DATE BEGUN:	**8 January, 2019**		
DATE COMPLETED:	**8 January, 2019**		

DEPTH (m)	LITHOLOGY	DESCRIPTION	SAMPLE TYPE	SAMPLE No.	SPT "N"	POCKET PEN (kPa)	MOISTURE CONT. (%)	SULPHATE (%)	USC	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
0.0		TOPSOIL										
		SAND: Trace clay, trace silt. Dark yellowish brown (10YR 4/6). Oxidized. Moist. Loose. Massive. Organic inclusions. Calcareous. @ 0.76 m, frost depth.		MW108		-	6.0					
1.0		TILL: Clay, silty, sandy, trace gravel. Brown (10YR 4/3). Oxidized. Moist. Firm. Massive. Calcareous.										Auger cuttings.
2.0				MW109		48	18.3		CI	13.8	31.9	
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: BH123

PROJECT NUMBER: USG691
PROJECT NAME: Geotechnical Investigation
LOCATION: S.E. 1/4 of 29-40-22 W4M
CLIENT: Taves Management Inc.
DRILLING METHOD: 150 mm Solid Stem Auger
LOGGED BY: M.W.
DATE BEGUN: 8 January, 2019
DATE COMPLETED: 8 January, 2019

CASING STICKUP: 1.06 m
TOTAL DEPTH: 6.10 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	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	WELL INSTALLATION
-1.0												
0.0		TOPSOIL										
0.0–2.6		SAND: Trace clay, trace silt. Black (10YR 2/1). Oxidized. Moist. Loose. Massive. Calcareous. @ 0.76 m, grey (10YR 5/1). @ 1.83 m, seepage.		MW110		-	10.2					Casing.
				MW111		-	22.7					
2.6–5.35		CLAY: Silty, some sand.Very dark grey (10YR 3/1). Oxidized. Moist. Soft. Massive. Calcareous.		MW112		-	25.5					Auger cuttings.
5.35–6.10		TILL: Clay, silty, some sand, trace gravel. Very dark grey (10YR 3/1). Non-oxidized. Moist. Firm. Massive. Calcareous.		MW113		48	15.9					Hand slotted 25 mm PVC.

Depth scale: -1.0, 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

NOTES: End of borehole at 6.10 m below surface. Seepage, but no sloughing encountered during drilling. Piezometer installed. Water level recorded at 1.74 m below grade on 23 January, 2019.