APPENDIX H

Preliminary Geotechnical Investigation

PRELIMINARY GEOTECHNICAL INVESTIGATION THE HAVILLAND FIELD DEVELOPMENT REVISION 01

Wheatland County, Alberta

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engineering ltd.

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1.0 INTRODUCTION

As requested, E2K Engineering Ltd. (E2K) has completed a preliminary geotechnical investigation in support of a proposed industrial development to be located within the West Highway 1 Area Structure Plan. The subject property consists of three zones with approximately rectangular shapes, located approximately forty (40) kilometres east of the City of Calgary, along the south and the north sides of TransCanada Highway 1 in Wheatland County, Alberta.

Details of the development plans, including layout and final grades, were not available at the time of this study. Accordingly, the comments and recommendations provided in the report are general in nature and suitable only for preliminary design and planning purposes. When design details are available, supplementary investigation and analysis will be required to finalize the geotechnical recommendations.

Based on the information provided by B&A Planning Group, it is understood that this property has been identified by the authorities of Wheatland County, Alberta, as a corridor for industrial development.

The preliminary geotechnical investigation completed on the property consisted of drilling twenty (20) boreholes, installing PVC standpipes, and conducting soil sampling and laboratory testing. The objective of the preliminary geotechnical investigation was to obtain subsurface soil and groundwater information to provide recommendations about the geotechnical aspects of the proposed development. This report provides recommendations regarding site preparation, shallow and deep foundation options, frost protection, groundwater considerations, temporary excavation stability, concrete type, and other factors that may be relevant.

2.0 SITE DESCRIPTION

The Project Site is adjacent to an existing industrial development. The site contains numerous wetlands and existing oil and gas infrastructure, including oil wells and pipelines.

According to available geodetical information, the approximate project area is approximately 1,500 Acres (610 Ha), divided into three separate zones (see Figure 1):

- **Zone 1:**

Located approximately 800 m south of TransCanada Highway 1, is delimited by Range Road 264 to the east, Range Road 265 to the west, a vacant land adjacent to Highway 1 to the north and Township Road 240 to the south.

The zone has an approximately rectangular shape with an approximate area of 940 Acres (380 Ha) and a very flat surface sloping from east to west with an approximate average slope of 0.12%. The zone has a depression running from the northeast to the southwest corner.

This zone includes six parcels with the following legal description:

- 4-26-24-8 SW 0012 901 294
- 4-26-24-8 SE 0028 909 794
- 4-26-24-5 NW 0021 883 971
- 4-26-24-5 NE 0013 787 866
- 4-26-24-5 SW 0021 777 891
- 4-26-24-5 SE 0021 777 909

- **Zone 2:**

Located next to TransCanada Highway 1, Zone 2 is delimited by Range Road 264 to the east, Range Road 265 to the west, a vacant land to the north and Highway 1 to the south. The zone has an approximately rectangular shape and a very flat surface sloping to a depression located on the north border of the area with an approximate average slope of 0.7%. The approximate area of the zone is 320 Acres (130 Ha).

This zone includes two parcels with the following legal description:

- 4-26-24-17 SW 0021 843 693
- 4-26-24-17 SE 0021 843 701

- **Zone 3:**

Located approximately 220 meters south of the TransCanada Highway 1, Zone 3 is delimited by Range Road 263 to the east, Range Road 264 to the west and a vacant land to the north and south. The zone has an irregular shape with an approximate area of 240 Acres (100 Ha) and grades sloping from the east border to a depression found at the west border with an average slope of 1.7%.

This zone includes two parcels with the following legal description:

- 4-26-24-9 NW 0021 809 728
- 4-26-24-9 SE 0021 809 736

At the time of this investigation, the Project Site was mostly covered by grassland vegetation, which is a sign of an arid to semi-arid climate.

3.0 METHOD OF INVESTIGATION

3.1 INVESTIGATION SUMMARY

The geotechnical investigation was conducted between October 15, 2019, and October 17, 2019, utilizing a track-mounted auger drill rig using solid stem augers. The rig was owned and operated by All Service Drilling Ltd. in Airdrie, AB. Twelve (12) boreholes were drilled within the footprint of the Zone 1, four (4) boreholes were drilled within the footprint of Zone 2, and four (4) boreholes were drilled within the footprint of Zone 3.

The boreholes were drilled to a maximum depth of 9.1 meters below the ground surface or auger refusal. Standard Penetration Tests (SPT's) were performed, and split spoon samples were collected at selected intervals during the investigation. Approximate borehole locations are presented in Figure 2 and approximate coordinates and elevations of these boreholes are provided in Table 1.

Table 1 : Boreholes Coordinates and Elevations

Borehole Number	Easting (m)	Northing (m)	Elevation (masl)
BH-01	317,076.83	5,656,196.87	1,006.41
BH-02	317,094.99	5,655,603.67	1,106.39
BH-03	317,104.80	5,654,990.40	1,007.52
BH-04	317,117.74	5,654,300.43	1,005.54
BH-05	317,902.95	5,656,366.38	1,007.37
BH-06	317,864.37	5,655,810.03	1,005.67
BH-07	317,816.19	5,655,293.77	1,005.56
BH-08	317,777.52	5,654,491.97	1,005.39
BH-09	318,548.25	5,656,128.38	1,006.00
BH-10	318,578.19	5,656,127.32	1,003.98
BH-11	318,292.45	5,654,867.34	1,002.71
BH-12	318,439.58	5,654,296.34	1,002.76
BH-13	317,228.74	5,657,913.83	1,107.27
BH-14	317,229.89	5,657,478.64	1,011.86
BH-15	318,409.76	5,657,876.71	1,105.57
BH-16	318,328.16	5,657,444.55	1,105.27
BH-17	318,970.18	5,656,940.32	1,002.03
BH-18	318,959.31	5,656,560.22	1,002.25
BH-19	319,683.74	5,656,870.94	992.86
BH-20	320,248.11	5,656,463.66	991.17

Coordinate System: UTM Zone 12

The subsurface soil conditions were continuously logged using the Modified Unified Soil Classification System which includes soil types along with descriptions. Depths at which different soil types were encountered along with their color and moisture content were also logged. Disturbed soil samples were acquired at regular intervals from the auger and split spoon sampler.

Following drilling, 25 mm PVC standpipes were installed in all boreholes to the completion depths. The standpipes were slotted from the bottom up to a three meters length of the standpipe to allow for groundwater to infiltrate the pipes and allow for measurements. The boreholes were then backfilled with sand, drill cuttings, and sealed near the surface with bentonite. Detailed logs of the boreholes can be found in the Attachments of this report.

3.2 LABORATORY TESTING

Laboratory testing included determination of the natural moisture contents of all soil samples recovered during the investigation. Also, grain size distribution analyses, Atterberg limits, and sulphate tests were performed on select samples recovered during the investigation.

The results of the laboratory testing program are summarized on the borehole logs in the Attachments of this report and are discussed when relevant throughout the report.

4.0 SUBSURFACE SOIL CONDITIONS

The details of the soil and groundwater conditions encountered at the boreholes are presented in borehole logs in the Attachments. The following is a summary of the soil conditions encountered in these boreholes.

It should be noted that geological conditions are innately variable. The subsurface stratigraphy is available only at the borehole locations. In order to develop recommendations from this information, it is necessary to make some assumptions concerning conditions other than at borehole locations. Adequate field reviews should be undertaken during further development of this project to confirm that these assumptions are reasonable.

4.1 SOIL STRATIGRAPHY OVERVIEW

The soil stratigraphy at the borehole locations generally consisted of topsoil overlying interbedded layers of native non-plastic silt, silty clay, and sand, overlying bedrock.

4.2 TOPSOIL

Topsoil was encountered at the surface with thicknesses ranging from 150 to 300 mm. The topsoil generally was generally low plastic and consisted of silt, trace of clay, containing some organics.

4.3 SILT

Deposits of silt were encountered underneath topsoil in all the boreholes except Borehole BH-01, BH-05, BH-12, BH-16, BH-19, and BH-20, and extended to depths ranging between 0.9 m and 3.0 m below the existing ground surface(mbgs). The silt was generally described as non-plastic, trace to some sand, and a trace of clay.

Deposits of silt and sand were encountered below the clay layer in Boreholes BH-13, BH-14, BH-15, and BH-16 and extended to depths ranging from 5.8 m to 7.6 mbgs. The silt was loose to compact and brown. Moisture contents of the silt ranged from 8% to 15%.

4.4 SILTY CLAY (TILL)

Deposits of silty clay were encountered below the topsoil and below the silt in all the boreholes except Borehole BH-20, where the clay till was encountered below a sand layer, and BH-01, BH-05, BH-12, BH-16, BH-19, and BH-20 where this silty clay layer was found underneath the topsoil. This clay till extended to depths ranging from 1.8 m to 9.2 mbgs. The clay was described as silty, some sand, trace of gravel and brown in colour.

SPT testing, together with pocket penetrometer measurements on auger samples, were conducted within the silty clay deposit. The standard penetration test performed within this silty clay resulted in N values ranging between 7 and 38 for 300 mm of penetration. This is indicative of a firm to hard consistency. The undrained shear strength, as determined by the pocket penetrometer varies from 25 kPa to 225 kPa.

The results of the Atterberg Limit tests conducted on the clay indicated a Liquid Limit ranging from 33 to 63 percent, confirming medium to high plasticity. Corresponding Plastic Limits and Plastic Indexes ranged between 12 to 24 percent and 20 to 39 percent, respectively.

Moisture content within the samples from the clay resulted in values ranging from 11.0 percent to 28.5 percent.

4.5 SAND

Deposits of sand were encountered below the topsoil in Borehole BH-20 and below the silty clay in Boreholes BH-14, BH-15, and BH-19. The sand extended to depths ranging from 2.3 m to 7.6 mbgs. The sand layer was described as silty, trace of clay, trace of gravel, and brown. Moisture contents from within the sand layer varied between 8.2% and 20.4%. SPT blow counts within the sand layer varied between 9 and more than 100 blows for 300 mm, indicating a compact to very dense relative density.

4.6 BEDROCK

Bedrock was encountered below the silty clay in all the boreholes except Boreholes BH-05 and BH-13, where the bedrock was encountered below the silt layer, and BH-14 and BH-15 where the bedrock was encountered below the sand layer. All the boreholes were terminated on auger refusal or bedrock encountered. The bedrock was generally described as siltstone, sandstone, or mudstone, extremely weak to very weak, highly weathered, and brown to grey.

4.7 FROST DEPTH PREDICTION

Protection against the effects of frost action will likely be a concern at this site due to the inherent frost susceptibility of the near-surface soil. The design frost penetration depth can be estimated based on the thermal conductivity method outlined in Section 13 of the Canadian Foundation Engineering Manual (CFEM).

For preliminary analysis purposes, an average of the values for the upper portion of the soils encountered in the site investigation was assumed. Based on the encountered subsoils along with using an average moisture content of 13.1% in the upper silt and silty clay deposits, and a long term (30 year) mean air freezing index of 995^{o}C-days obtained from Figure 13.6 of the Canadian Foundation Engineering Manual (2006), the frost depth for this site is anticipated to be 2.2 mbgs.

4.8 GROUNDWATER

Standpipes were installed in all the boreholes. Upon drilling completion, groundwater was only encountered in Borehole BH-01 at 2.7 mbgs and Borehole BH-10 at 6.0 mbgs. Groundwater levels were also monitored on-site on November 18, 2019, with the results shown in Table 2.

The relative high groundwater elevations found in the area during the final monitoring could be the result of the accumulation of rainwater perched on relatively impermeable strata of clay and bedrock. It should be noted that the groundwater table varies with seasonal conditions including precipitation, site drainage conditions, and local hydrogeology. Fluctuations in the groundwater levels should be anticipated.

Table 2: Groundwater Elevations Monitored on-site on November 18, 2019.

Borehole Number	Ground Water Depth (mbgs.)	Borehole Number	Ground Water Depth (mbgs.)
BH-01	1.85	BH-11	1.85
BH-02	4.75	BH-12	2.75
BH-03	4.30	BH-13	3.45
BH-04	2.60	BH-14	5.60
BH-05	3.80	BH-15	3.70
BH-06	5.30	BH-16	0.75
BH-07	4.60	BH-17	7.70
BH-08	1.05	BH-18	5.45
BH-09	5.05	BH-19	1.50
BH-10	3.60	BH-20	2.80

Groundwater levels in Alberta typically fluctuate up to 1.0 m seasonally (approximately), with a maximum water level occurring during spring and summer and a minimum in winter.

5.0 RECOMMENDATIONS AND CONSIDERATIONS

Preliminary design and construction recommendations for geotechnical aspects of the project are presented in the subsection below. The recommendations below offer varying options intended to aid in the development of the project concepts and specifications.

The recommendations are provided on the understanding and condition that E2K will be retained to review the relevant aspects of the final foundation design (drawings and specification) and will be retained to conduct such field reviews as are necessary to ensure compliance with geotechnical aspects of the Alberta Building Code, this report and the final plans and specifications.

5.1 GENERAL DISCUSSION

The soils are relatively competent and will provide an adequate bearing for industrial and other infrastructure. A shallow foundation system consisting of spread and strip footings founded on native undisturbed silty clay or silt may be considered suitable for the proposed development. Deep foundation systems bearing on bedrock may be considered suitable if a higher bearing capacity is required, given the presence of shallow bedrock in the project site.

Floor slabs-on-grade are considered feasible provided that certain precautions are undertaken as discussed below in the relevant subsection.

5.2 SITE PREPARATION

All topsoil and weeds including any debris should be removed within the proposed development areas to prevent post-construction settlement and production of methane. Topsoil may be stockpiled and reused for non-structural areas only, such as landscaping. Reusing this material as backfill soil for subgrade support is not recommended.

Sub-excavation should extend beyond the perimeter of the proposed structures a minimum distance at least equal to the depth from the bearing grades to the surface of the suitable subgrade.

It is recommended that the exposed subgrade in areas requiring structural subgrade support be proof rolled to identify any soft or loose areas. Where soft or loose areas are identified, specific remediation measures for the encountered conditions should be recommended by the geotechnical engineer. The exposed subgrade should be reviewed and approved by the geotechnical engineer before proceeding with construction activities.

5.3 SITE GRADING AND DRAINAGE

It is anticipated that grading will be required at this site. The finished grade in the vicinity of the proposed buildings, including paved areas and sidewalks, should be sloped away from the proposed structures. The upper 0.3 m of backfill around the structures should consist of compacted clay, concrete, or asphalt to function as an impermeable barrier against the ingress of surface runoff. Finished grades should be sloped away from the structures at a minimum slope of 2%.

Site grading should be provided in paved areas both during and following constructions, such that water is rapidly shed from the surface of the pavement to a positive drainage system.

Downspouts should be positively directed away from buildings or if the local regulation permit, directed into the storm drainage system. The downspout should not be directed into foundation perimeter drains.

5.4 TEMPORARY EXCAVATIONS

Excavation safety is the responsibility of the contractor. It is anticipated that excavation will be required for the foundation footings and deep utilities.

Temporary excavations are to be sloped from the bottom of the excavation at an angle not steeper than 45 degrees, or 1H:1V. Where site constraints make it not possible to comply with the above requirements, and where the excavation is near to adjacent buildings or other settlement sensitive structures, the underpinning of the adjacent buildings and shoring would be required.

The degree of stability of excavation walls typically decreases with time. Therefore, it is recommended that excavation work is planned such that the length of time the excavation remains open is minimized. If signs of instability such as sloughing, seepage or tension cracks are observed, the excavation would need to be cut back to flatter slopes or a shoring system implemented. Where minor seepage is encountered, it may be sufficient to grade the excavation to a low point and pump the water out of the area.

Stockpiles of materials and excavated soils should be placed away from the slope crest by a distance equal to the depth of the excavation. Similarly, wheel loads should be kept back at least 1 m from the crest of the excavation. The applicable sections of the Occupational Health and Safety Act must be followed.

5.5 FILL AND COMPACTION

Acceptable fill materials would include imported well-graded crushed gravels with a maximum particle size of 25 mm to 80 mm containing less than 10% fines. Alternatively, onsite low plastic clay would be suitable although the settlement would be larger and frost susceptibility higher.

Fill materials must not contain organics, frozen soils, construction debris, concrete, boulders larger than two-thirds of the lift thickness, or any other deleterious materials. Fill must not be placed on the frozen ground, or any subgrade surface not approved by the geotechnical engineer. Where clay fill is used, clods or lumps should be broken up as much as possible before placement. Where clay backfill is used, sheepsfoot rollers are recommended. Where gravel backfill is used, smooth drum rollers are recommended.

It is recommended to place and compact any fill to a minimum of 98% of the Standard Proctor Maximum Dry Density (SPMDD), in uniform lifts not exceeding 200 mm loose thickness. Compaction requirements must be achieved for the full thickness and extents of each lift. Moisture conditioning to within 2% of the optimum moisture content is required. Uniformity of compaction and uniformity of backfill materials will be critical to minimizing differential settlements.

For gravel fills placed and compacted to 98% SPMDD, settlement of up to 0.5% of the lift thickness is anticipated. For clays compacted to 98% SPMDD, settlement of up to 1.0% of the lift thickness is anticipated. The estimation of this settlement is based only on the self-weight of the fill. It is anticipated that the majority of the settlement would occur during the first freeze-thaw cycle.

5.6 UNDERGROUND SERVICES

The burial depths for water lines and sewer lines should be established based on Wheatland County Design and Construction Standarads (2016), as shown in Table 3.

Table 3: Minimum Cover for Underground Services

Service	Clay and Silt Backfill (m)	Gravel Backfill (m)
Water Mains	3.0	3.3
Sanitary Sewer Mains	2.5	2.8

Insulation may be required for any main that is installed with less than the minimum cover described above. This insulation should be designed by a qualified professional to prevent the pipes from freezing.

The use of trench boxes may be required during utility installation. All these services shall be installed as per Wheatland County minimum requirements.

Pipe support using conventional bedding methods is anticipated to be suitable for this site. The grain size distribution of the proposed bedding materials should be reviewed by the geotechnical engineer and checked for filter compatibility with the native soils. A non-woven geotextile fabric may be required to separate bedding materials from native soils.

5.7 FOUNDATION SYSTEMS

Details of the development plans, including layout and final grades, were not available at the time of this study. Based on our evaluation of the encountered soils, shallow and deep foundations are considered suitable at the project site. Recommendations for shallow and deep foundations are provided below.

5.7.1 Foundation Geotechnical Resistance Factors

The geotechnical resistance factors required to calculate the factored foundation resistance to axial and horizontal loads in accordance with the 2019 National Building Code of Canada (NBCC – Alberta Edition) are provided in Table 4.

Table 4: Geotechnical Resistance Factors for Foundations

Case	Analysis Method	Resistance Factor, φ
Deep Foundations Axial Compression	Semi-empirical analysis using laboratory and in-situ test data	0.4
Deep Foundations Axial Compression	Dynamic load test results	0.5
Deep Foundations Axial Compression	Static load test results	0.6
Deep Foundations Axial Tension	Semi-empirical analysis using laboratory and in-situ test data	0.3
Deep Foundations Axial Tension	Static load test results	0.4
Horizontal Load Resistance	All	0.5
Shallow footings	Semi-empirical analysis using laboratory and in-situ test data	0.5

5.7.2 Strip and Spread Footings

Based on the investigation completed by E2K, strip and spread footings founded at a depth of 1.5 m below grade at the project site would be suitable for the proposed structures.

For protection against frost action, perimeter footings in the heated area should be extended to provide at least 1.5 m of soil cover. Isolated footings or footings in the unheated portion of the building should have at least 2.2 m of soil cover unless provided with equivalent insulation. It should be noted that where under slab-on-grade insulation is utilized to support an in-floor heating system, the structure should be treated as unheated and have the footings founded below the frost line.

The minimum factored geotechnical bearing resistance at the Ultimate Limit State (ULS) for footings based at a depth of 1.5 m below the existing ground surface on native silty clay (Till), silt or sand is generally considered to be 100 kPa and the minimum factored geotechnical bearing resistance at the Ultimate Limit State (ULS) for footings based at a depth of 3.0 m below the existing ground surface on native silty clay (Till), silt or sand is generally considered to be 150 kPa.

Higher bearing capacities can be expected at increasing depths below the existing ground surface. It should be noted that the Serviceability Limit States (SLS) values shall be estimated based on a maximum total settlement of 25 mm and 10 mm differential settlement for the footings ranging from 0.6 to 1.5 m.

It is recommended that provision should be made for drainage (weeping tile) around the foundation perimeter to the depth of maximum frost penetration. The weeping tile is to be connected to a storm sewer system if permitted by the County. It should be installed with a positive slope away from foundation elements or pumped to a stormwater drain in accordance with the current Alberta Building Code requirements.

Where it is necessary to place footings at different levels, the foundation elevations between footings should be stepped in a maximum of 600 mm steps at a maximum inclination of 10 horizontal to 7 vertical (10H:7V). The lower footing must be installed first to help minimize the risk of undermining the upper footing.

A consistent bearing surface is important as different soils have different capacities to resist loads and may consolidate and settle at different rates, which can cause significant structural deformation. Once foundation grade has been excavated, a qualified geotechnical engineer should be present to inspect the subgrade soils to confirm the soil conditions and that a consistent bearing surface has been prepared.

Additionally, the excavation for foundations should not be exposed to rain, snow, freezing temperatures and ponded water before footing construction. Insulated tarps should be utilized on the bearing surface if freezing temperatures are anticipated before concrete placement. Heating and hoarding of the bearing surface may be required should sustained temperatures below zero be encountered. Groundwater was not expected to adversely affect the bearing surfaces.

Although not anticipated, foundation footings can also be placed on engineered fill provided a geotechnical engineer inspects the soil conditions. The fill material should consist of approved granular material and should be compacted to 98% SPMDD with optimum moisture content within 2% of optimum value.

5.7.3 Cast-in-Placed Concrete Piles

Piles should be designed to support the statically structural loading by the unfactored geotechnical shaft resistance at Ultimate Limit State (ULS) multiplied by a corresponding Geotechnical Resistance Factor (Φ) in accordance with the current Alberta Building Code requirements.

Cast-in-place concrete piles founded in very stiff to hard silty clay or bedrock may be pre-designed to resist axial compressive loads and lateral loads by a combination of the unfactored typical shaft and base resistances provided in Table 5.

Table 5: Typical Ultimate Limit State Design Parameters for Pile Foundation

Type of Material	Ultimate Shaft Resistance (kPa)	Ultimate Base Resistance (kPa)
Silt or Clay Till (0 m-2.2m)	-	-
Clay Till or Silt (below 2.2 m to bedrock)	60	600 @ 6.0 mbgs and below
Bedrock	180	2500

Note: Ultimate Limit State Design Parameters in this Table are unfactored

It should be noted that a Geotechnical Resistance Factor (Φ) of 0.4 is to be applied to the ultimate values of compressive strength as recommended by CFEM (2006). Where uplifting is applied, a Geotechnical Resistance Factor (Φ) of 0.3 should be applied to the pile shaft ultimate value.

Bored piles should have an overall length below the maximum expected frost depth for this property (2.2 mbgs) of not less than 6.0 m and a minimum shaft diameter of 450 mm (18 inches). It is recommended that longitudinal reinforcement in the piles should extend to the full length of the piles to provide adequate lateral and uplift resistance. Base resistance should only be considered in the design where base cleaning can be verified. E2K should review the design, layout, and installation procedure prior to finalization of the foundation plan.

Bored cast-in-place piles should be spaced no closer than 2.5 times the pile diameter (measured center-to-center). Pile group effects should be considered for piles spaced closer than 2.5 times the base diameter.

Groundwater is anticipated to be encountered during pile installation. Considering the potential of encountering groundwater seepage, casing will likely be required during pile installation. Casing should be at hand before drilling starts and used, if necessary, to seal off the water and prevent sloughing of the pile bore.

5.7.4 Laterally Loaded Piles (Modulus of Horizontal Subgrade Reaction)

The resistance of vertical piles to horizontal load should be considered in the foundation design. The resistance of vertical piles to horizontal loads involves soil-structure interaction and is commonly analyzed using computer structural analysis or with lateral pile analysis. Lateral pile performance in compact sandy or silty soil or stiff silty clay till may also be analyzed using a modulus of horizontal subgrade reaction (ks).

The modulus of horizontal subgrade reaction has been estimated based on the soil properties at the site. It is recommended that the design ks value increase linearly with depths. The SLS modulus of horizontal subgrade reaction for a pile of diameter 'D' has been estimated as shown in Table 6:

Table 6: SLS Modulus of Subgrade

Type of Material	Ks (MPa/m)
Native Silty Clay, Sand or and Silt Soil below excavation depths (depth >2.2 mbgs)	25/D
Bedrock Surface	40/D
Bedrock at 2 m below bedrock surface. (Increasing linearly from bedrock surface)	80/D

The spring constant (K) for use in modeling lateral pile capacity may be obtained as follows:

K = ks x D x L (MN/m)

Where:

L = Length of the pile segment (m).

5.8 FLOOR SLAB-ON-GRADE

The slab-on-grade construction is considered suitable for the proposed structures. With this type of floor system, construction is to be completed during non-freezing temperatures. Should any topsoil be encountered during the excavations, it should be removed from the slab on grade subgrade soils.

Small vertical movements are inevitable for a grade-supported floor slab due to the consolidation of soft or native soils. Slabs should be allowed to float on the subgrade and be tied into the foundation walls or grade beams only at doorways.

To further reduce the potential effects of vertical slab movement, the following design provisions should be implemented to allow the slab to move independently of the structural components of the building:

- Partitions and non-bearing walls should not be rigidly connected to bearing walls or columns.
- Slabs should be allowed to float on the subgrade and be tied into the foundation walls or grade beams only at doorways.
- Concrete slabs should be reinforced and articulated at regular intervals to provide for controlled cracking.
- The installation of buried water supply lines beneath the floor slab should be avoided wherever possible. Wastewater lines beneath the floor slabs should consist of PVC pressure pipe with welded joints.
- Positive site drainage should be provided away from the proposed building footprint.
- Frost should not be allowed to penetrate beneath the floor slab just prior to, during or after construction.

5.9 CONCRETE TYPE

Sulphate content testing was performed on five (5) samples recovered during the investigation to determine the potential for sulphate attack on any concrete that would come in contact with soils. The location and results of this testing are shown in the following table:

Table 7: Sulphate Content Testing Results

Borehole No.	Depth	Degree of Exposure
BH-01	2.3 m	Severe
BH-05	1.5 m	Very Severe
BH-09	3.1 m	Severe
BH-13	3.1 m	Negligible
BH-17	4.6 m	Negligible

These results show a negligible to very severe potential for sulphate attack for the soils at this property. Therefore, as per CSA guidelines, all concrete placed in contact with the native soil at this site should be made from CSA Type HS (Type 50), HSb, HSL or HSe cement having a minimum compressive strength of 35 MPa at 56 days. The maximum water-cement ratio should be 0.40 and an air entrainment agent is recommended for improved workability and durability.

5.10 RESISTIVITY

In order to estimate the conductivity of the native soils for potential corrosion and to design a cathodic protection system, laboratory resistivity testing was conducted on five (5) soil samples recovered from depths between 1.5 to 3.1 mbgs. The results of the resistivity test are shown in Table 8.

Table 8: Soil Resistivity Results

Borehole No.	Depth	Moisture	Dial Reading	Multiplication Factor	Resistivity (Ohms-cm)
BH-01	3.1	15.3	1.45	1000	1450
BH-05	3.1	12.2	3.9	1000	3900
BH-09	3.1	15.4	1.4	1000	1400
BH-13	2.3	14.8	1.4	1000	1400
BH-17	1.5	16.3	1.8	1000	1800

The results indicated a ‘Severe” degree of corrosion potential for the steel elements in all the boreholes, except for BH-05, which corresponds to a “Moderate” degree of corrosion potential on the steel elements, as shown in Table 9 below.

Table 9: Typical Soil Resistivity Range for Different Degrees of Corrosion

Soil Resistivity (ohm-cm)	Degree of Corrosion
6,000 – 10,000	Very Low
4,500 – 6,000	Low
2,000 – 4,500	Moderate
< 2,000	Severe

Detailed investigation and testing for specific areas of the property could provide different degree of corrosion potential on the steel elements for the different areas of this project site.

6.0 LATERAL EARTH PRESSURE ON WALL

Lateral earth pressures for foundation walls can be calculated using the following equation and the parameters provided below.

$P_0 = K_0 (\gamma_b \, . \, H + q)$

Where:

P_0 = Lateral earth pressure at rest condition where no movements of walls occur at a given depth (kPa).

K_0 = Coefficient of earth pressure at rest condition; use 0.5 for backfill material assumed to consist of the silty clay and silt native soils found on site.

γ_b = Bulk unit weight of soil for backfill; for compact fine sand and silts, use 19.5 kN/m3.

H = Depth below final grade (m).

q = Any surcharge pressure at ground level.

If drainage is not provided, allowance should be made for hydrostatic pressures. In addition, the hydrostatic pressure due to water should be applied.

$$P_w = \gamma_w \; . \; H_w$$

Where:

P_w = Hydrostatic pressure (kPa).
γ_w = Unit weight of water (9.8 kN/m3).
H_w = Depth below the top of the water table (m).

The above-noted expression assumes native material compacted to approximately 95% of Standard Proctor maximum dry density and the horizontal ground behind the basement wall. If the ground surface slopes upwards away from the wall, design wall pressures should be re-evaluated.

7.0 SEISMIC CLASSIFICATION OF THE SITE

Seismic design for various structures is based on the 2019 National Building Code - Alberta Edition (ABC). The primary objective of the ABC earthquake resistant design requirements is to protect the life and safety of the public in response to strong ground shaking. Structures designed in conformance to the code may undergo structural damage but should not collapse as a result of the ground shaking.

The 2014 ABC seismic design procedures are based on ground motion parameters (e.g., peak ground acceleration, (PGA) and spectral acceleration, Sa values) having a 2% probability of exceedance in 50 years; i.e., the 2,475-year return period earthquake event.

Based on the results of the E2K field investigation, it is appropriate to classify the ground conditions at the subject site as a Class D site, in a conservative way and in accordance with the 2014 ABC This classification must be confirmed for the different developments to be built in this area.

Liquefaction of the clay till and silt material at this site is not of substantial concern in the event of significant seismic activity.

8.0 PAVEMENT DESIGN AND CONSTRUCTION

The locations of the roadways or pavement structures have yet to be finalized and grading is still to be determined. Based on the preliminary information obtained during this Geotechnical Investigation, it is anticipated that the pavement subgrade will comprise near-surface soils (moderately to highly frost susceptible native silt and silty clay, typically very moist).

The minimum depth requirements for asphalt concrete pavement in Wheatland County are included in the Wheatland County Design and Construction Standards Manual (2016).

Based on the information above, the following preliminary pavement structures in Table 10 are recommended

Table 10: Preliminary Pavement Structures

Road Classification	Minimum Granular Base Course Thickness (mm)	Minimum Granular Sub-Base Course Thickness (mm)	Minimum Asphalt Pavement Thickness (mm)
UL (Urban Lane)	50	200	50 Mix B
UIC (Urban Industrial Commercial)	150	250	60 Mix B 70 Mix A
UR (Urban Residential)	100	200	40 Mix B 50 Mix A
URC (Urban residential Collector)	100	200	60 Mix B 70 Mix A
UPC (Urban Primary Collector)	150	250	60 Mix B 70 Mix A

The minimum asphalt concrete pavement thicknesses for major roads, as specified in the Wheatland County Design and Construction Standards Manual (2016), area shown in Table 11.

Table 11: Preliminary Pavement Structures

Road Classification	Minimum Granular Base Course Thickness (mm)	Minimum Granular Sub-Base Course Thickness (mm)	Minimum Asphalt Pavement Thickness (mm)
Local Road Collector – Service Road	100	50	50 (Min.)
Collector - Industrial / Commercial Road	130	75 (Max.)	70 (Max.)
Major Collector – Road Allowance (Paved Standard)	110	60	50 (Min.)

These recommended pavement designs and should be reviewed when grading/subgrade conditions have been finalized and traffic conditions determined. The pavement structures should be constructed in agreement with applicable Wheatland County and Alberta Transportation Specifications.

9.0 GEOTECHNICAL REVIEW

It is recommended that the final drawings be submitted to E2K for general geotechnical review for compatibility with the site conditions and the recommendations provided in this report.

The comments and recommendations provided in this report are based on the site conditions as revealed in a limited number of boreholes at the time of the investigation. Further, details of the development plans, including layout and final grades were not available at the time of this study.

Accordingly, the comments and recommendations provided in this report are general in nature and suitable only for preliminary design and planning purposes. When design details are available, they should be submitted for review by E2K to verify the applicability of the recommendations presented in this report and may require additional investigation and/or analysis.

10.0 LIMITATIONS

Recommendations made within this report are based on the interpreted findings encountered in twenty (20) boreholes. It should be noted that natural conditions are innately variable. Should conditions other than those reported herein, be identified at any stage of development, E2K should be notified and given the opportunity to re-evaluate current information, if required.

The recommendations presented herein, are subject to an adequate level of inspection during construction. Levels of inspection are generally set out by the 2019 National Building Code - Alberta Edition (ABC) and therefore should be followed to not contravene relevant code requirements.

The ABC Schedules are an integral part of the development process and stipulate that a “Geotechnical Engineer of Record” shall be assigned to each project falling under code jurisdiction. This title shall not infer any overall responsibility for geotechnical aspects of this construction project, without the prior consent of E2K and written clarification of project responsibility.

This report has been prepared with accepted soil and foundation engineering practices for the project specified above in this report. No third party may rely on the information contained in this report without the express written permission of E2K. No other warranty is expressed or implied.

11.0 CLOSURE

We trust the information contained herein meets your present requirements. Should you require further information, please do not hesitate to contact our office.

Yours Truly;
E2K Engineering Ltd.

Prepared by:	Reviewed by:
Miguel Ardin, P.Eng.	Brad Ellingwood, P.Eng.
Project Geotechnical Engineer	Senior Geotechnical Engineer

Attachments:
Figure 1: Location Drawing
Figure 2: Borehole Locations
Borehole Logs
Explanation of Terms and Symbols

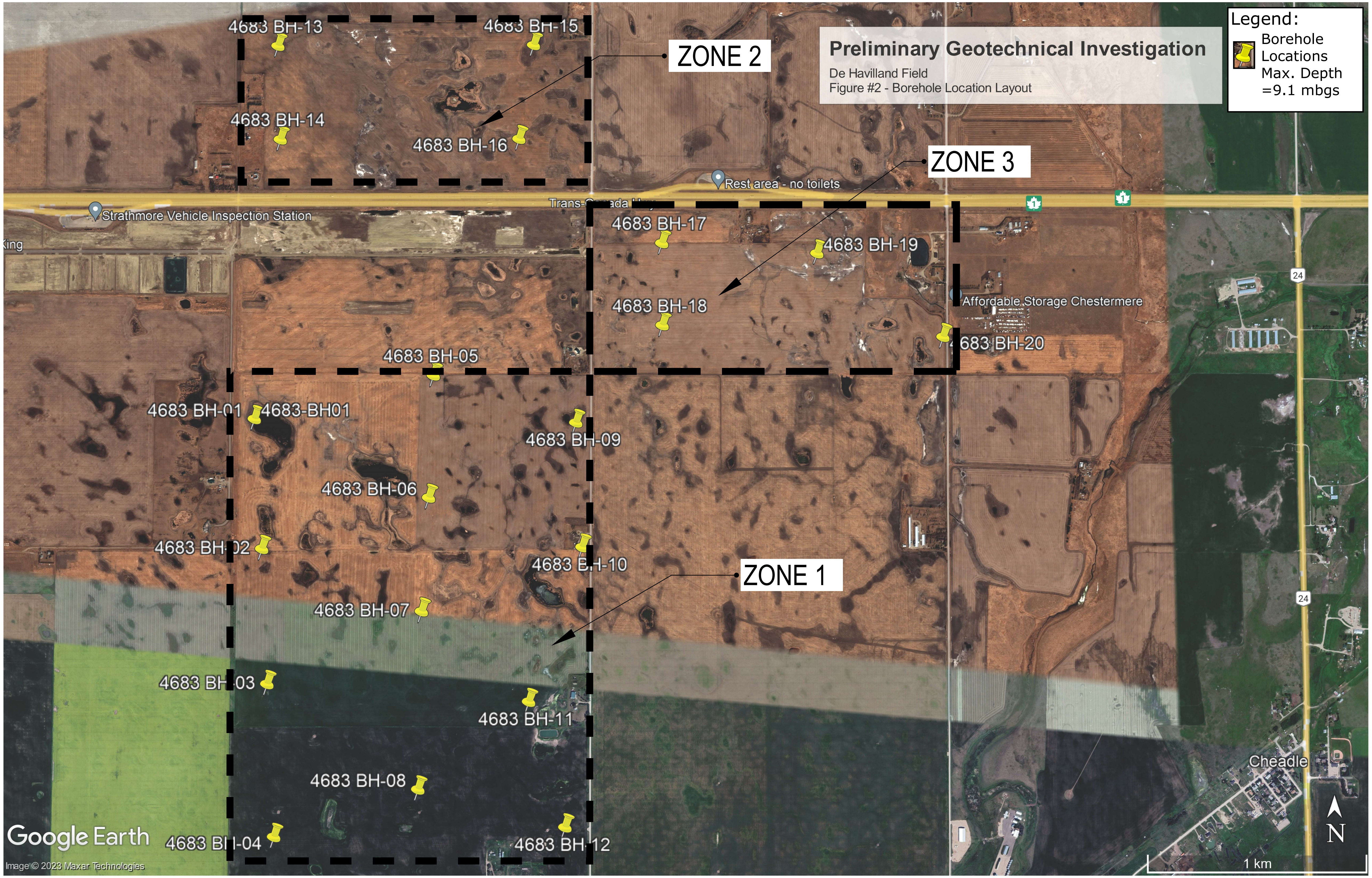
Borehole Location Plan

PRELIMINARY GEOTECHNICAL INVESTIGATION
THE HAVILLAND FIELD
WHEATLAND COUNTY, ALBERTA

E2K PROJECT#: 2019-4683
FEBRUARY 2023
FIGURE 1 - LOCATION DRAWING

PRELIMINARY GEOTECHNICAL INVESTIGATION
THE HAVILLAND FIELD
WHEATLAND COUNTY, ALBERTA

E2K PROJECT#: 2019-4683
FEBRUARY 2023
FIGURE 2 - BOREHOLE LOCATIONS



Notes:
- See Table 1 for Borehole Coordinates and Elev.
- 25 mm Standpipes installed in all Boreholes

APPENDIX A
Borehole Logs

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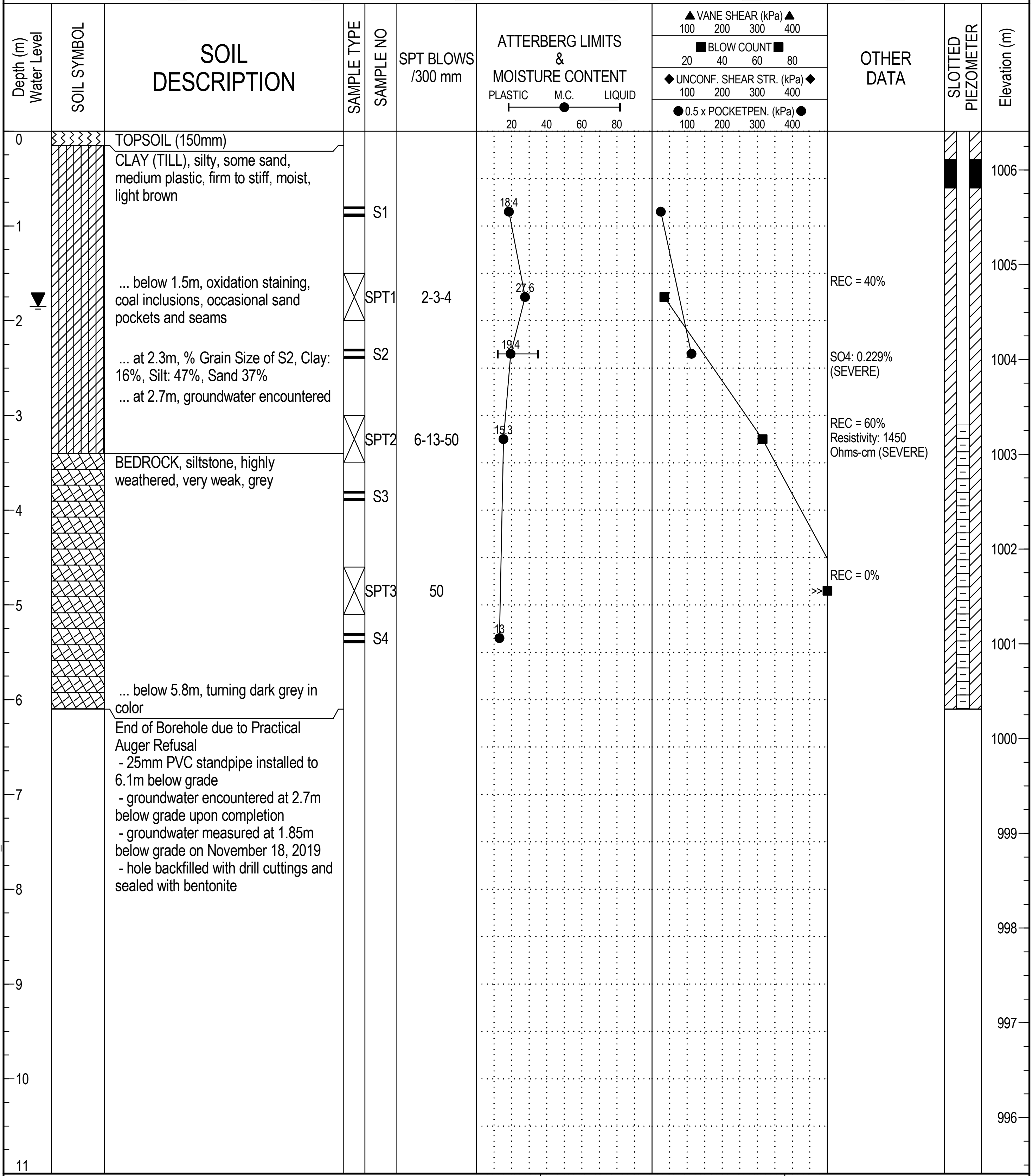
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-01**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656196.87	EASTING: 317076.83	ELEVATION: 1006.41 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁛ PEA GRAVEL ▥ SLOUGH ⁛ GROUT ▨ DRILL CUTTINGS ⁛ SAND



SOIL DESCRIPTION

TOPSOIL (150mm)

CLAY (TILL), silty, some sand, medium plastic, firm to stiff, moist, light brown

... below 1.5m, oxidation staining, coal inclusions, occasional sand pockets and seams

... at 2.3m, % Grain Size of S2, Clay: 16%, Silt: 47%, Sand 37%

... at 2.7m, groundwater encountered

BEDROCK, siltstone, highly weathered, very weak, grey

... below 5.8m, turning dark grey in color

End of Borehole due to Practical Auger Refusal
- 25mm PVC standpipe installed to 6.1m below grade
- groundwater encountered at 2.7m below grade upon completion
- groundwater measured at 1.85m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

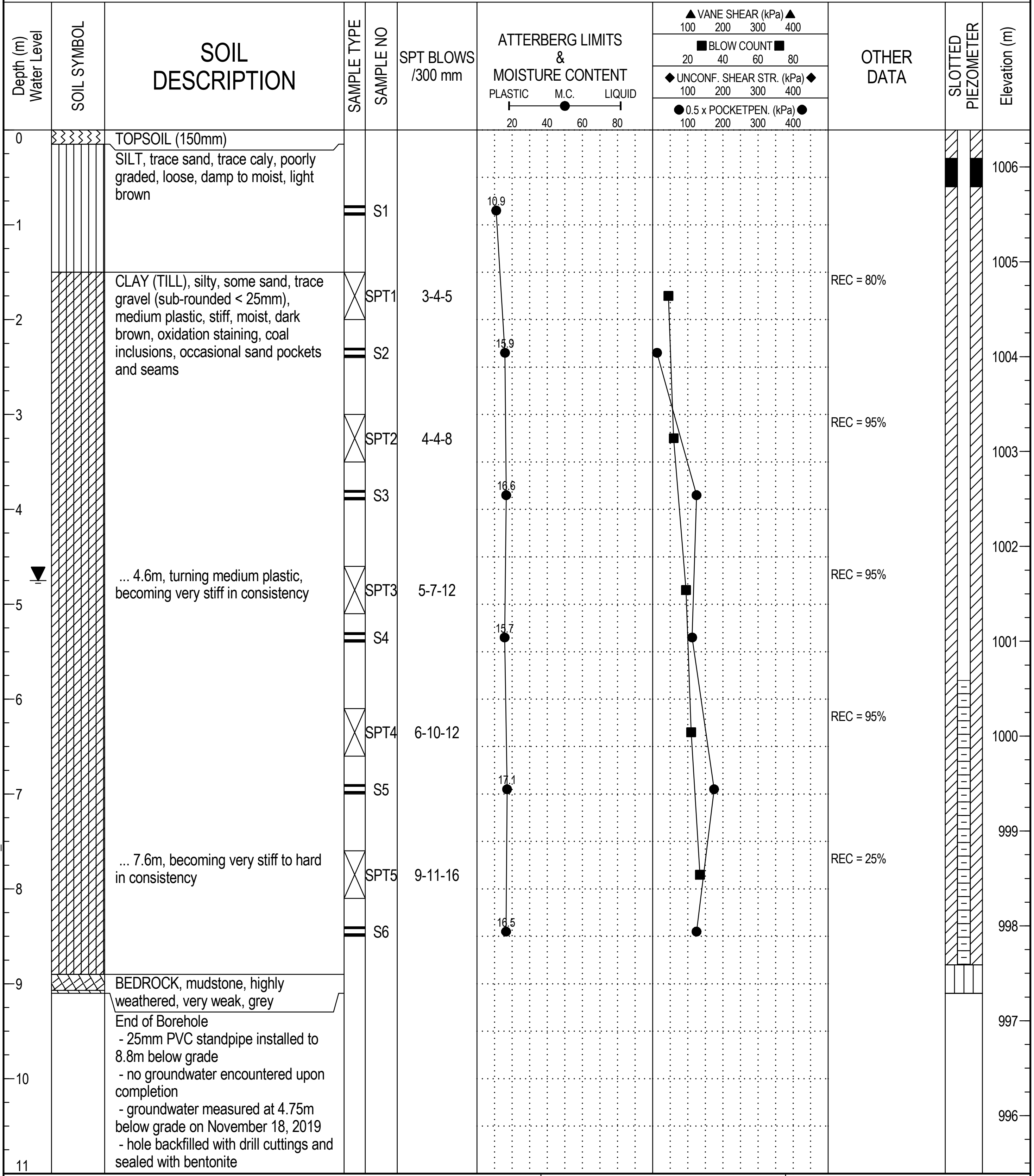
SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
S1		
SPT1	2-3-4	REC = 40%
S2		SO4: 0.229% (SEVERE)
SPT2	6-13-50	REC = 60% Resistivity: 1450 Ohms-cm (SEVERE)
S3		
SPT3	50	REC = 0%
S4		

LOGGED BY: HL	COMPLETION DEPTH: 6.10 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-02**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5655603.67	EASTING: 317094.99	ELEVATION: 1006.39 m

SAMPLE TYPE: ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND



SOIL DESCRIPTION
TOPSOIL (150mm)
SILT, trace sand, trace caly, poorly graded, loose, damp to moist, light brown
CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 25mm), medium plastic, stiff, moist, dark brown, oxidation staining, coal inclusions, occasional sand pockets and seams
... 4.6m, turning medium plastic, becoming very stiff in consistency
... 7.6m, becoming very stiff to hard in consistency
BEDROCK, mudstone, highly weathered, very weak, grey

End of Borehole
- 25mm PVC standpipe installed to 8.8m below grade
- no groundwater encountered upon completion
- groundwater measured at 4.75m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

SAMPLE NO	SPT BLOWS /300 mm	MOISTURE CONTENT	OTHER DATA
S1		10.9	
SPT1	3-4-5		REC = 80%
S2		15.9	
SPT2	4-4-8		REC = 95%
S3		16.6	
SPT3	5-7-12		REC = 95%
S4		15.7	
SPT4	6-10-12		REC = 95%
S5		17.1	
SPT5	9-11-16		REC = 25%
S6		16.5	

LOGGED BY: HL	COMPLETION DEPTH: 9.10 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

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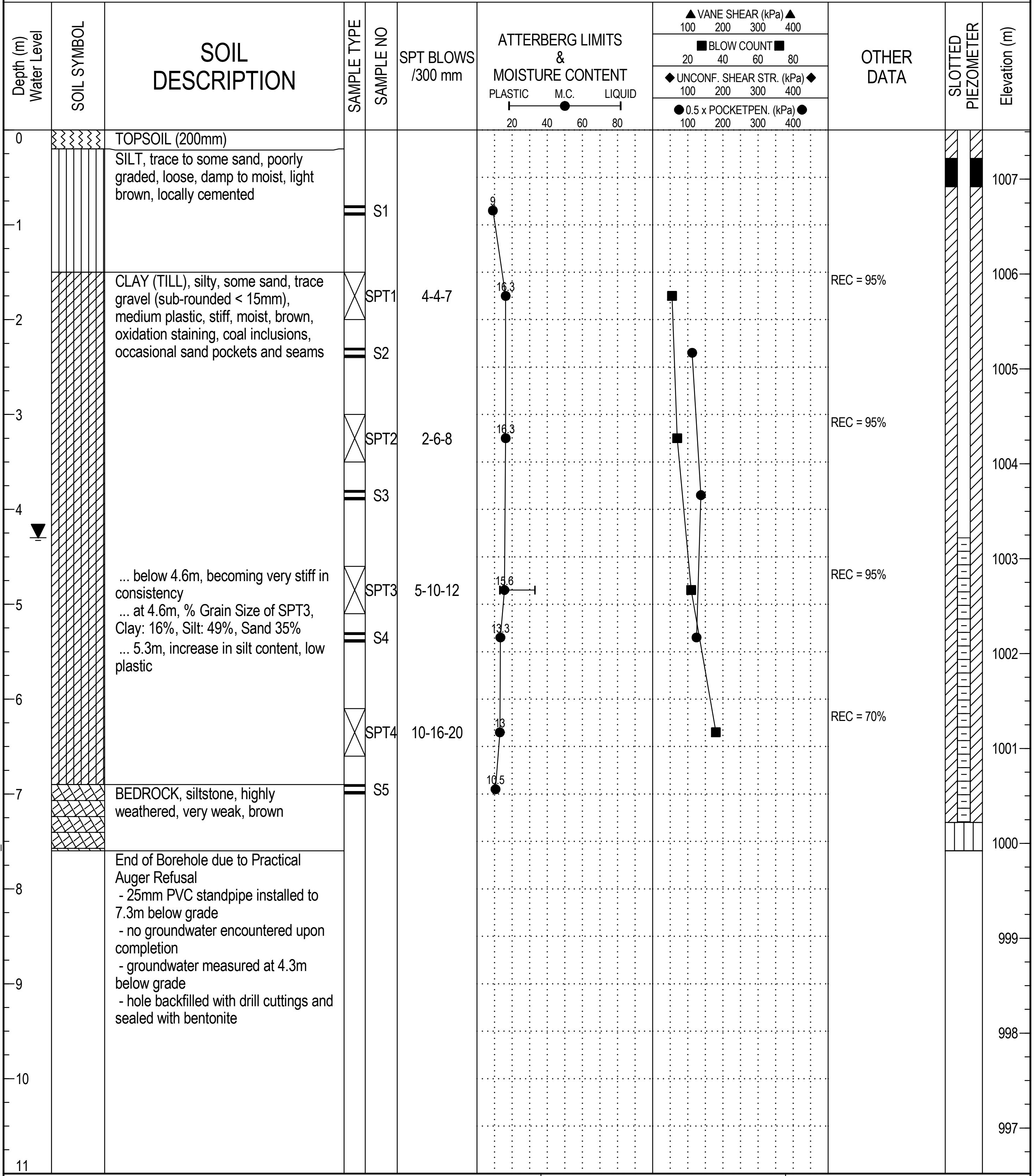
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-03**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5654990.4	EASTING: 317104.8	ELEVATION: 1007.52 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ▩ GROUT ▨ DRILL CUTTINGS ⁘ SAND



TOPSOIL (200mm)

SILT, trace to some sand, poorly graded, loose, damp to moist, light brown, locally cemented

CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 15mm), medium plastic, stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams

... below 4.6m, becoming very stiff in consistency
... at 4.6m, % Grain Size of SPT3, Clay: 16%, Silt: 49%, Sand 35%
... 5.3m, increase in silt content, low plastic

BEDROCK, siltstone, highly weathered, very weak, brown

End of Borehole due to Practical Auger Refusal
- 25mm PVC standpipe installed to 7.3m below grade
- no groundwater encountered upon completion
- groundwater measured at 4.3m below grade
- hole backfilled with drill cuttings and sealed with bentonite

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

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GEOTECHNICAL BOREHOLE LOG BH LOGS 4683 RECOVERED.GPJ AB_TRANS1.GDT 12/13/19

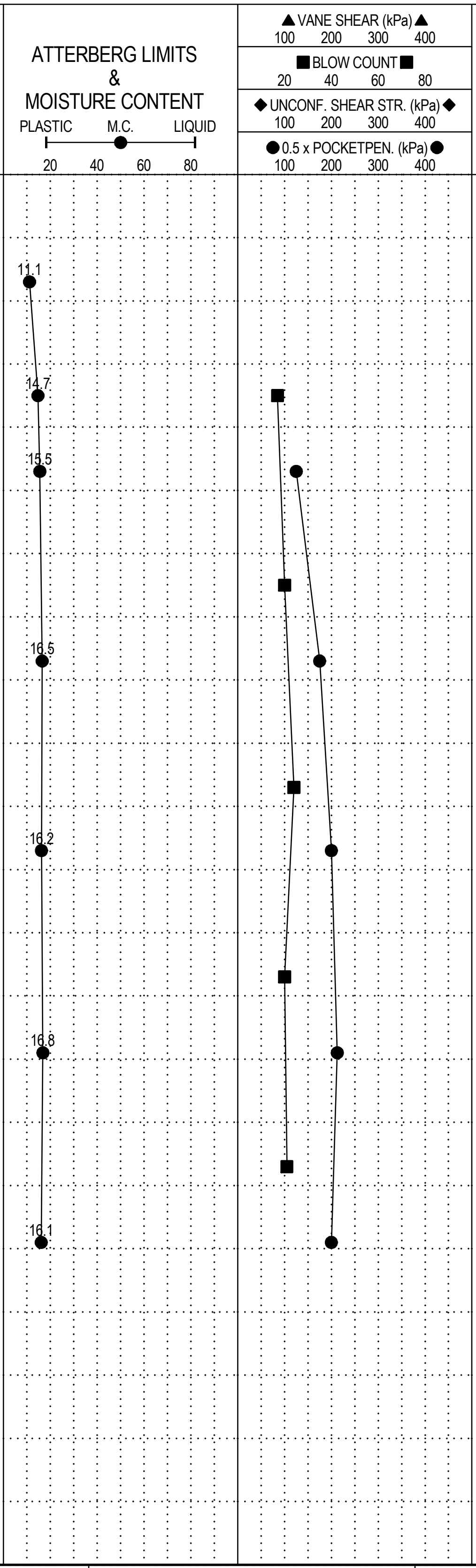
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-04**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5654300.43	EASTING: 317117.74	ELEVATION: 1005.54 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m) Water Level	SOIL SYMBOL	SOIL DESCRIPTION
0		TOPSOIL (250mm)
		SILT, some sand, trace clay, poorly graded, loose to compact, damp to moist, light brown
		CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 10mm), medium plastic, very stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams
▼		
		... below 5.3m, turning grey in color, becoming medium to high plastic, maximum recovered grain size (mrgs) < 30mm
		End of Borehole - 25mm PVC standpipe installed to 9.1m below grade - no groundwater encountered upon completion - groundwater measured at 2.6m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite

SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
☰	S1		
☒	SPT1	5-7-10	REC = 50%
☰	S2		
☒	SPT2	5-8-12	REC = 95%
☰	S3		
☒	SPT3	6-10-14	REC = 90%
☰	S4		
☒	SPT4	5-8-12	REC = 95%
☰	S5		
☒	SPT5	6-9-12	REC = 0%
☰	S6		



SLOTTED PIEZOMETER

Elevation (m)

1005 1004 1003 1002 1001 1000 999 998 997 996 995

Depth (m): 0 1 2 3 4 5 6 7 8 9 10 11

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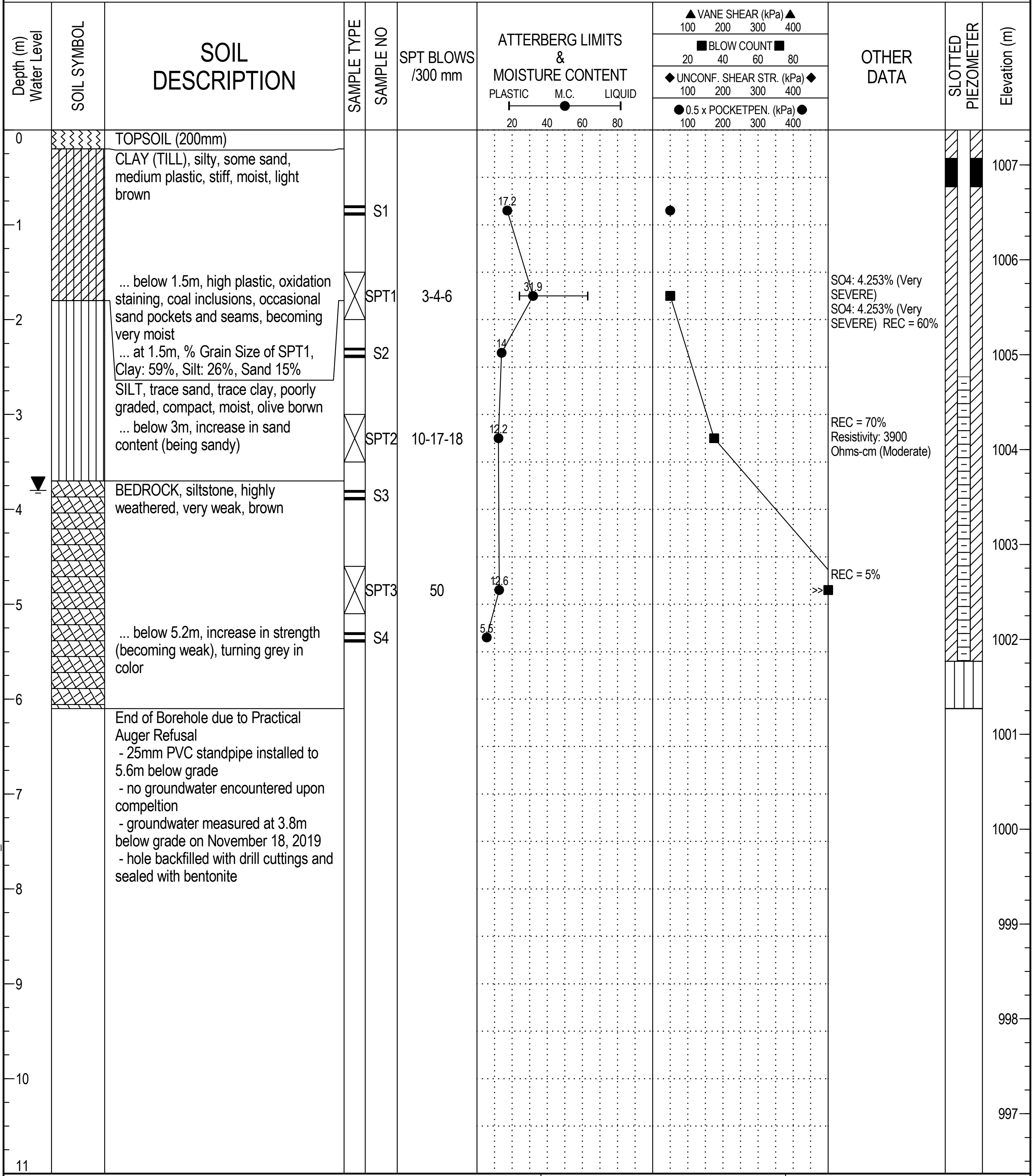
LOGGED BY: HL	COMPLETION DEPTH: 9.10 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-05**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656366.38	EASTING: 317902.95	ELEVATION: 1007.37 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND



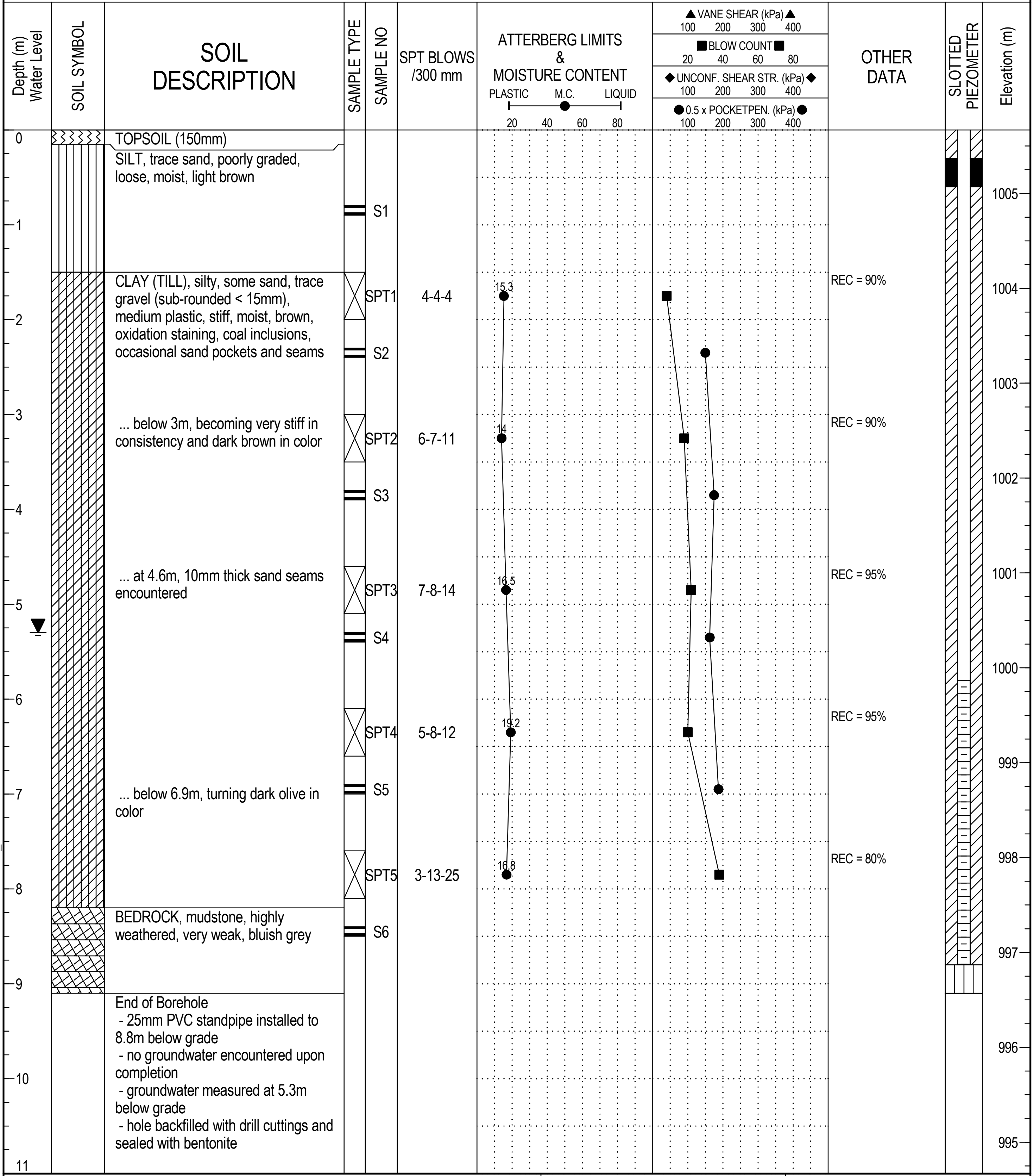
SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
TOPSOIL (200mm)				
CLAY (TILL), silty, some sand, medium plastic, stiff, moist, light brown	☰	S1		
... below 1.5m, high plastic, oxidation staining, coal inclusions, occasional sand pockets and seams, becoming very moist ... at 1.5m, % Grain Size of SPT1, Clay: 59%, Silt: 26%, Sand 15%	☒	SPT1	3-4-6	SO4: 4.253% (Very SEVERE) SO4: 4.253% (Very SEVERE) REC = 60%
	☰	S2		
SILT, trace sand, trace clay, poorly graded, compact, moist, olive borwn ... below 3m, increase in sand content (being sandy)	☒	SPT2	10-17-18	REC = 70% Resistivity: 3900 Ohms-cm (Moderate)
▼ BEDROCK, siltstone, highly weathered, very weak, brown	☰	S3		
	☒	SPT3	50	REC = 5%
... below 5.2m, increase in strength (becoming weak), turning grey in color	☰	S4		
End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 5.6m below grade - no groundwater encountered upon compeltion - groundwater measured at 3.8m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite				

LOGGED BY: HL	COMPLETION DEPTH: 6.10 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-06**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5655810.03	EASTING: 317864.37	ELEVATION: 1005.67 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⬚ GROUT ▨ DRILL CUTTINGS ⬚ SAND



SOIL DESCRIPTION

TOPSOIL (150mm)

SILT, trace sand, poorly graded, loose, moist, light brown

CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 15mm), medium plastic, stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams

... below 3m, becoming very stiff in consistency and dark brown in color

... at 4.6m, 10mm thick sand seams encountered

... below 6.9m, turning dark olive in color

BEDROCK, mudstone, highly weathered, very weak, bluish grey

End of Borehole
- 25mm PVC standpipe installed to 8.8m below grade
- no groundwater encountered upon completion
- groundwater measured at 5.3m below grade
- hole backfilled with drill cuttings and sealed with bentonite

SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
S1		
SPT1	4-4-4	REC = 90%
S2		
SPT2	6-7-11	REC = 90%
S3		
SPT3	7-8-14	REC = 95%
S4		
SPT4	5-8-12	REC = 95%
S5		
SPT5	3-13-25	REC = 80%
S6		

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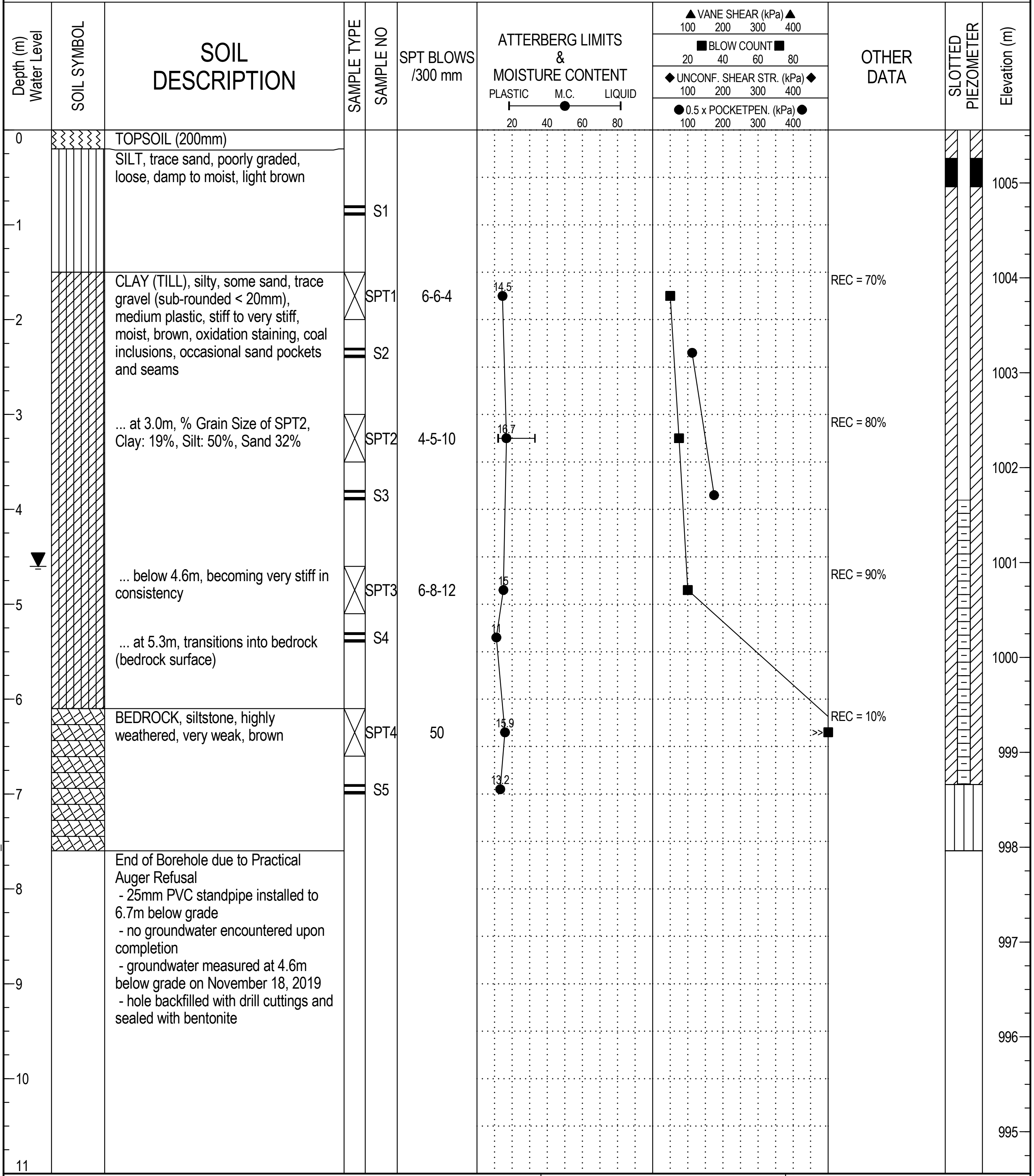
LOGGED BY: HL	COMPLETION DEPTH: 10.00 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-07**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5655293.77	EASTING: 317816.19	ELEVATION: 1005.56 m

SAMPLE TYPE: ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁙ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND



SOIL DESCRIPTION	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
TOPSOIL (200mm)			
SILT, trace sand, poorly graded, loose, damp to moist, light brown	S1		
CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 20mm), medium plastic, stiff to very stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams	SPT1	6-6-4	REC = 70%
	S2		
... at 3.0m, % Grain Size of SPT2, Clay: 19%, Silt: 50%, Sand 32%	SPT2	4-5-10	REC = 80%
	S3		
... below 4.6m, becoming very stiff in consistency	SPT3	6-8-12	REC = 90%
... at 5.3m, transitions into bedrock (bedrock surface)	S4		
BEDROCK, siltstone, highly weathered, very weak, brown	SPT4	50	REC = 10%
	S5		

End of Borehole due to Practical Auger Refusal
- 25mm PVC standpipe installed to 6.7m below grade
- no groundwater encountered upon completion
- groundwater measured at 4.6m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

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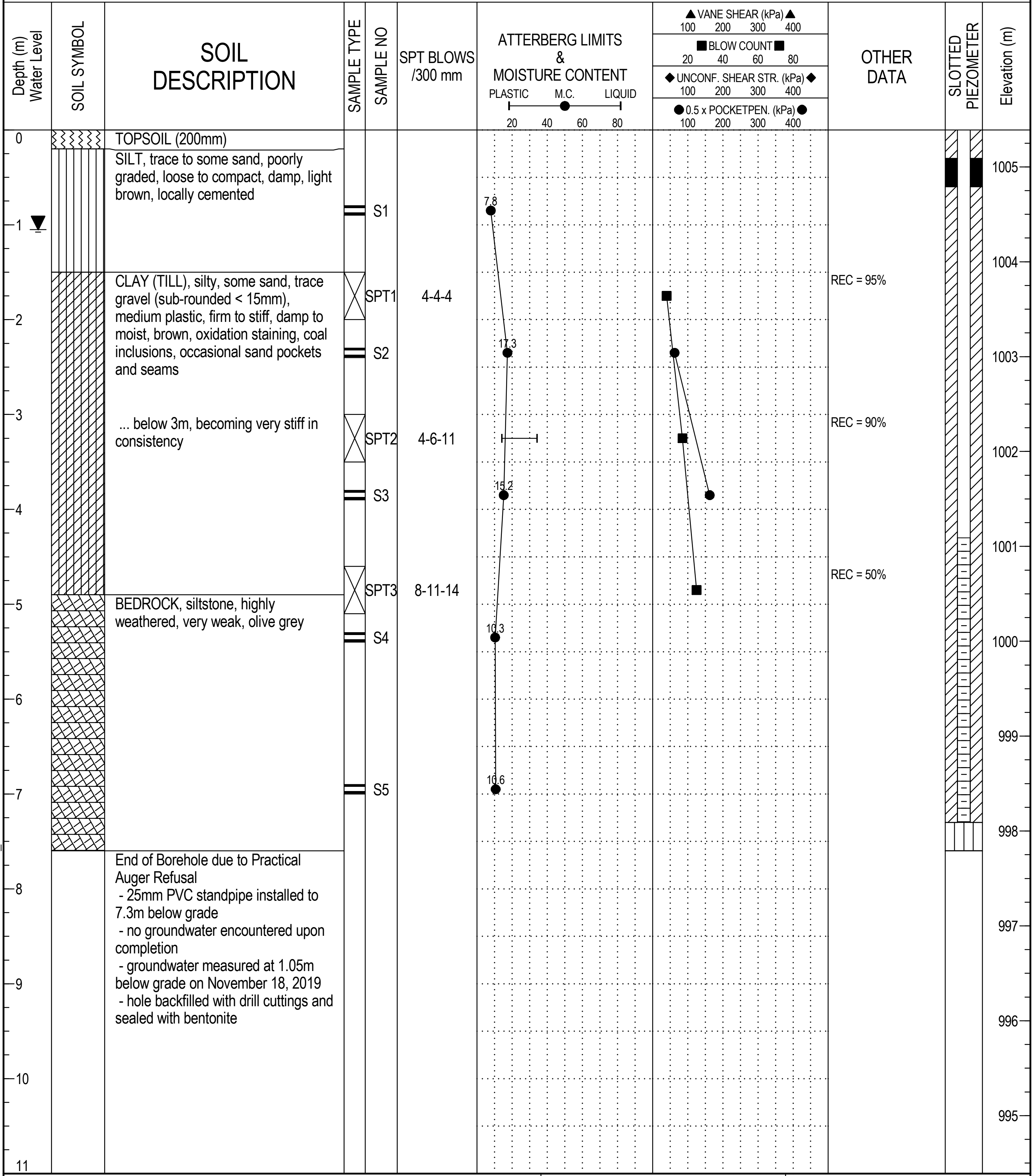
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-08**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5654491.97	EASTING: 317777.52	ELEVATION: 1005.39 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⬚ GROUT ▨ DRILL CUTTINGS ⬚ SAND



Depth (m)	SOIL DESCRIPTION	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
0	TOPSOIL (200mm)			
	SILT, trace to some sand, poorly graded, loose to compact, damp, light brown, locally cemented	S1		
	CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 15mm), medium plastic, firm to stiff, damp to moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams	SPT1	4-4-4	REC = 95%
		S2		
	... below 3m, becoming very stiff in consistency	SPT2	4-6-11	REC = 90%
		S3		
		SPT3	8-11-14	REC = 50%
	BEDROCK, siltstone, highly weathered, very weak, olive grey	S4		
		S5		
	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.3m below grade - no groundwater encountered upon completion - groundwater measured at 1.05m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite			

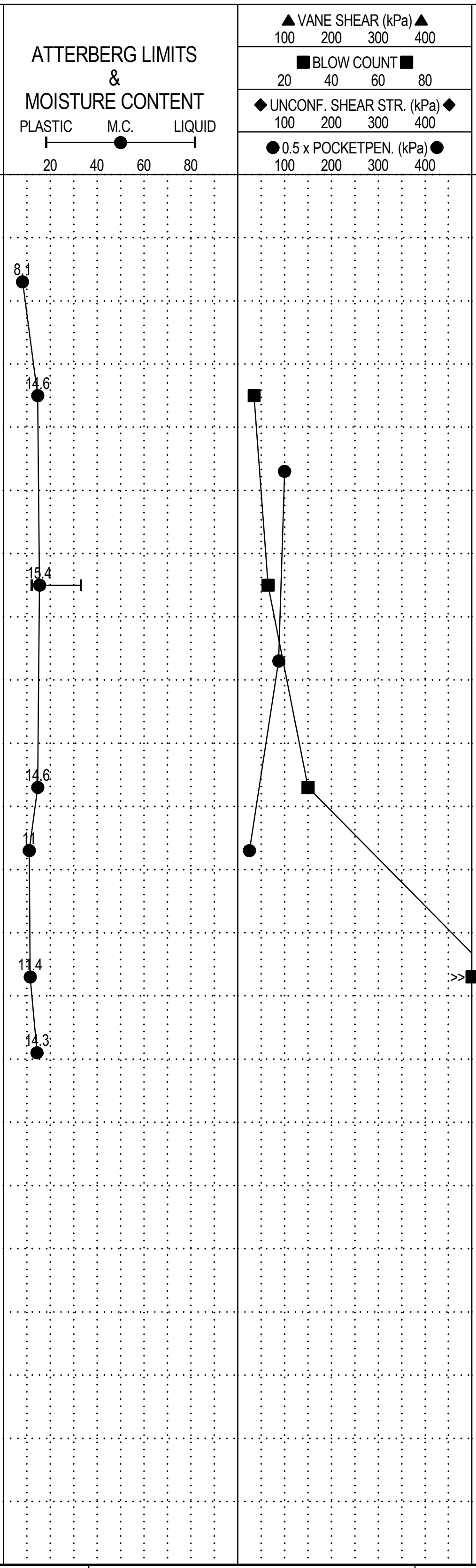
LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-09**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656128.38	EASTING: 318548.25	ELEVATION: 1006 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⬚ GROUT ▨ DRILL CUTTINGS ⬚ SAND

Depth (m) Water Level	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA	Elevation (m)
0	TOPSOIL (150mm)					1006
	SILT, some sand, fine grained, poorly-graded, loose, damp to moist, light brown	☰	S1			
1						1005
	CLAY (TILL), silty, some sand, trace gravel (sub-angular < 30mm), medium plastic, stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams	☒	SPT1	3-3-4	REC = 70%	
2						1004
		☰	S2			
3	... at 3.0m, % Grain Size of SPT2, Clay: 16%, Silt: 49%, Sand 35%	☒	SPT2	4-5-8	SO4: 1.639% (SEVERE) Resistivity: 1400 Ohms-cm (SEVERE) SO4: 1.639% (SEVERE) Resistivity: 1400 Ohms-cm (SEVERE) REC = 95%	1003
		☰	S3			
4						1002
	BEDROCK, siltstone, highly weathered, very weak, brown	☒	SPT3	4-8-22	REC = 95%	
5 ▼						1001
		☰	S4			
6						1000
		☒	SPT4	50	REC = 20%	
7		☰	S5			999
	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.3m below grade - no groundwater encountered upon completion - groundwater measured at 5.05m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite					
8						998
9						997
10						996
11						



LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

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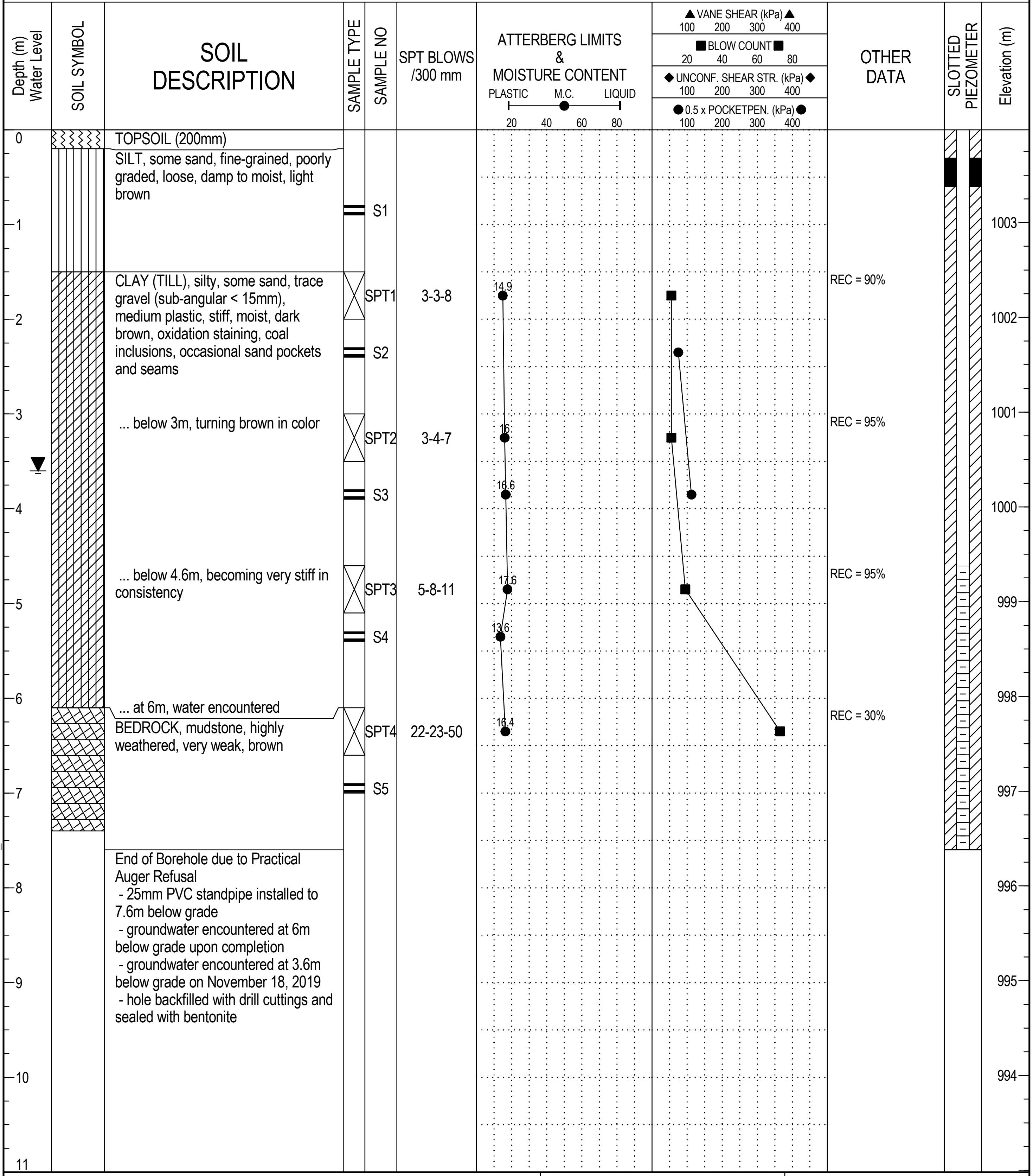
PROJECT NAME: Wheatland County 2151836 AB Inc
LOCATION: See Figure 1
BOREHOLE NO: **BH-10**
CLIENT: B&A Planning Group
DRILL TYPE: Solid Stem Auger
PROJECT NO: 2019-4683
NORTHING: 5656127.32
EASTING: 318578.19
ELEVATION: 1003.98 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▯ NO RECOVERY
BACKFILL TYPE: ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
TOPSOIL (200mm)				
SILT, some sand, fine-grained, poorly graded, loose, damp to moist, light brown	☰	S1		
CLAY (TILL), silty, some sand, trace gravel (sub-angular < 15mm), medium plastic, stiff, moist, dark brown, oxidation staining, coal inclusions, occasional sand pockets and seams	☒	SPT1	3-3-8	REC = 90%
	☰	S2		
... below 3m, turning brown in color	☒	SPT2	3-4-7	REC = 95%
	☰	S3		
... below 4.6m, becoming very stiff in consistency	☒	SPT3	5-8-11	REC = 95%
	☰	S4		
... at 6m, water encountered				
BEDROCK, mudstone, highly weathered, very weak, brown	☒	SPT4	22-23-50	REC = 30%
	☰	S5		
End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.6m below grade - groundwater encountered at 6m below grade upon completion - groundwater encountered at 3.6m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite				



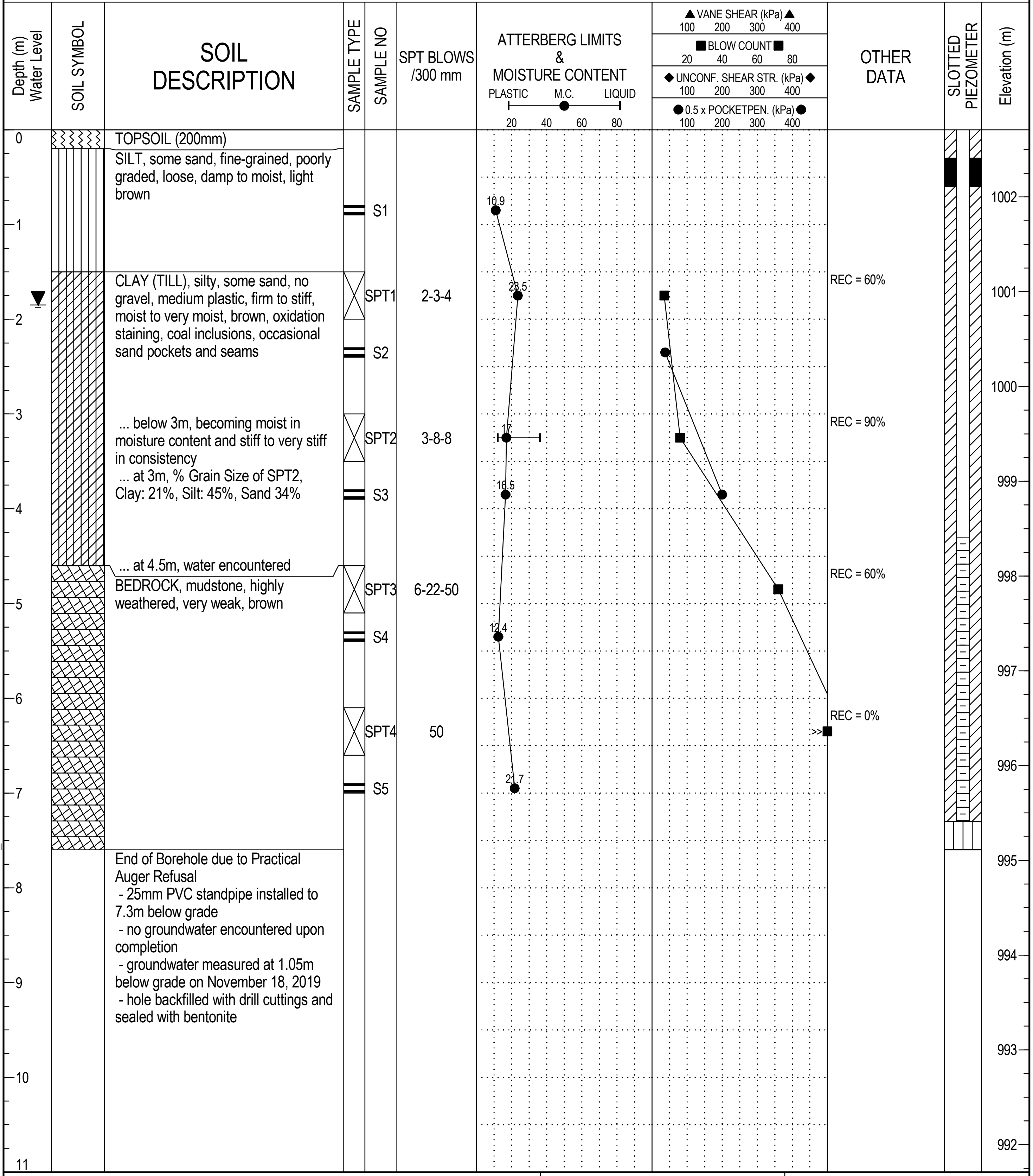
LOGGED BY: HL
REVIEWED BY: MA
COMPLETION DEPTH: 7.60 m
COMPLETION DATE: 10/16/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-11**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5654867.34	EASTING: 318292.45	ELEVATION: 1002.71 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	MOISTURE CONTENT	OTHER DATA
0	TOPSOIL (200mm)					
0.2	SILT, some sand, fine-grained, poorly graded, loose, damp to moist, light brown	☰	S1		10.9	
1.5	CLAY (TILL), silty, some sand, no gravel, medium plastic, firm to stiff, moist to very moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams	☒	SPT1	2-3-4	23.5	REC = 60%
		☰	S2			
3	... below 3m, becoming moist in moisture content and stiff to very stiff in consistency ... at 3m, % Grain Size of SPT2, Clay: 21%, Silt: 45%, Sand 34%	☒	SPT2	3-8-8	17	REC = 90%
		☰	S3		16.5	
4.5	... at 4.5m, water encountered					
4.6	BEDROCK, mudstone, highly weathered, very weak, brown	☒	SPT3	6-22-50		REC = 60%
		☰	S4		12.4	
		☒	SPT4	50		REC = 0%
		☰	S5		21.7	
7.6	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.3m below grade - no groundwater encountered upon completion - groundwater measured at 1.05m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite					



LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

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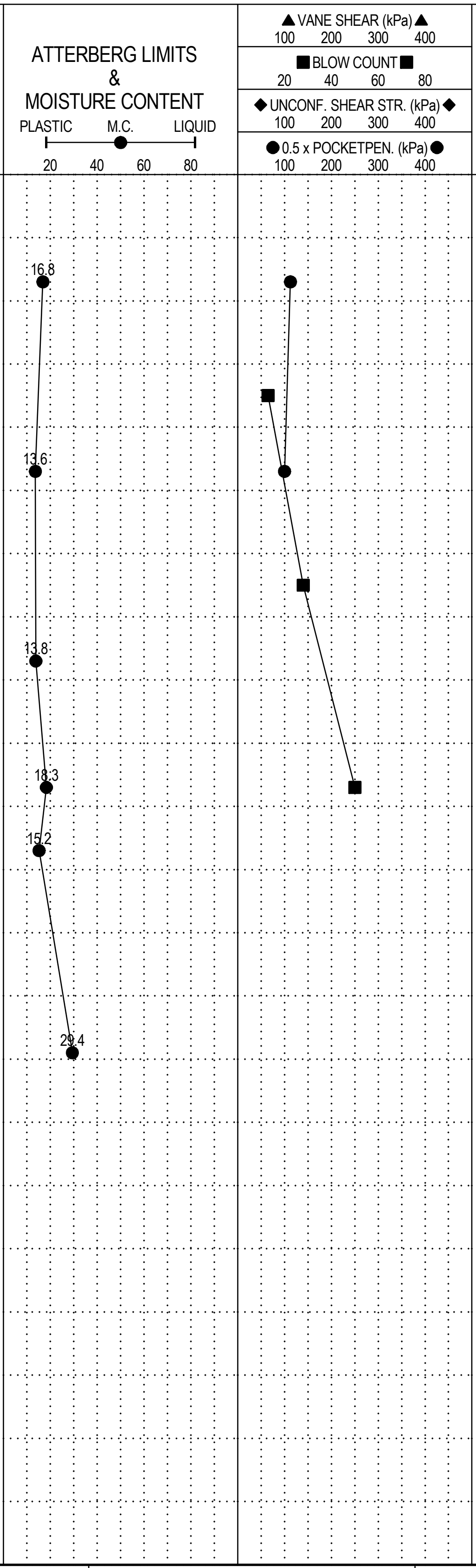
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-12**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5654296.34	EASTING: 318439.58	ELEVATION: 1002.76 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▯ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m) Water Level	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA	SLOTTED PIEZOMETER	Elevation (m)
0		TOPSOIL (300mm)						
		CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 15mm), medium plastic, stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams	☰	S1				1002
1								
			☒	SPT1	4-5-8	REC = 50%		1001
2								
		... at 2.3m, sand lense (0.6m thickness)	☰	S2				
▼								1000
3		... below 3m, becoming very stiff in consistency	☒	SPT2	7-11-17	REC = 90%		
		... below 3.8m, transition into bedrock (bedrock surface)	☰	S3				999
4								
		BEDROCK, mudstone, highly weathered, very weak, dark brown	☒	SPT3	22-25-25	REC = 95%		998
5			☰	S4				
								997
6		... below 6.1m, turtning brown in color						
								996
7		... below 6.9m, turning bluish grey in color	☰	S5				
		End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.6m below grade - no groundwater encountered upon completion - groundwater measured at 2.75m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite						995
8								
								994
9								
								993
10								
								992
11								



LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/17/19

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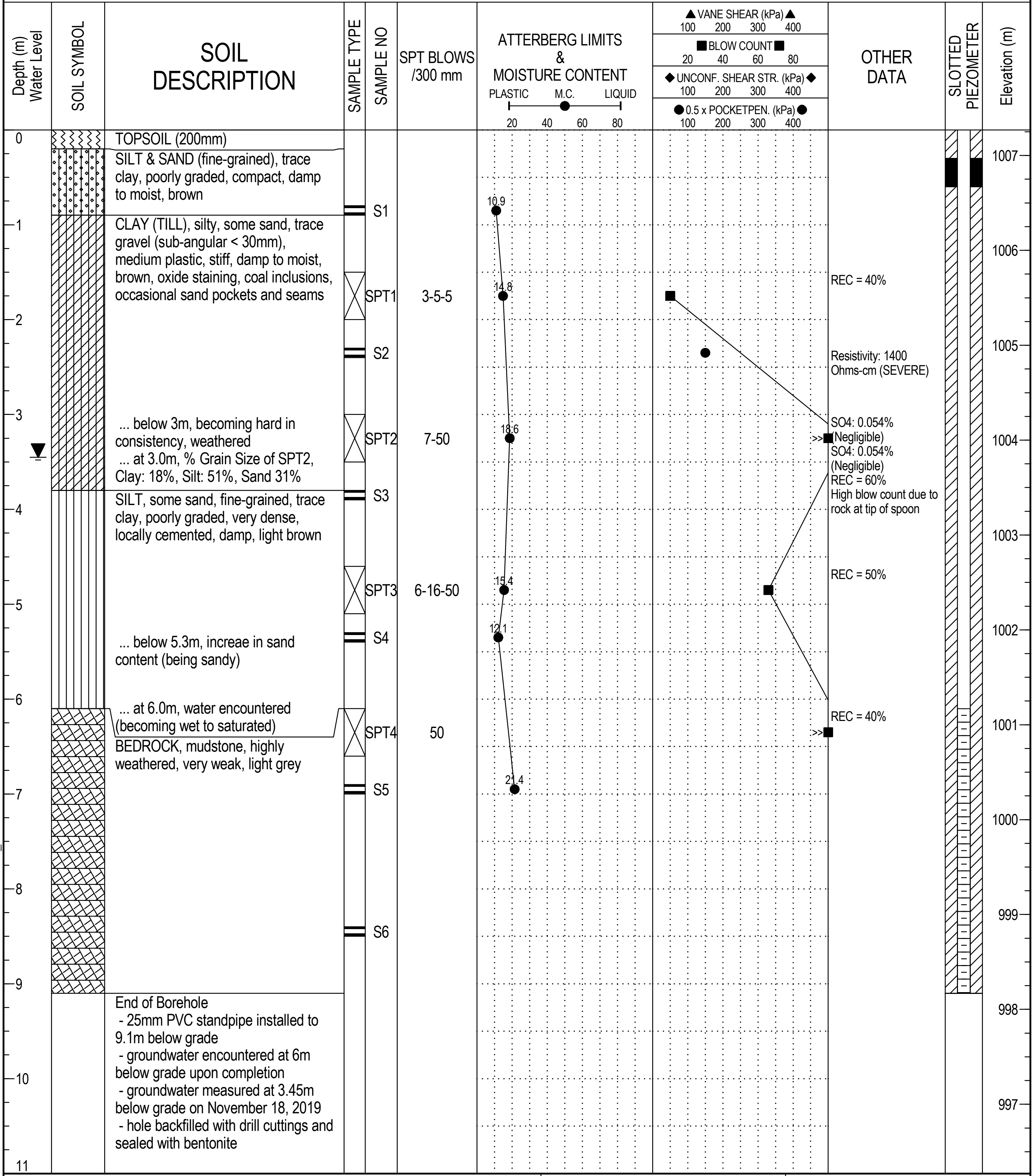
GEOTECHNICAL BOREHOLE LOG BH LOGS 4683 RECOVERED.GPJ AB_TRANS1.GDT 12/13/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-13**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5657913.83	EASTING: 317228.74	ELEVATION: 1007.27 m

SAMPLE TYPE	■ SHELBY TUBE	◩ CORE SAMPLE	☒ SPT SAMPLE	☰ GRAB SAMPLE	▥ NO RECOVERY	
BACKFILL TYPE	■ BENTONITE	⁙ PEA GRAVEL	▥ SLOUGH	⁙ GROUT	▨ DRILL CUTTINGS	⁙ SAND



SOIL DESCRIPTION

TOPSOIL (200mm)

SILT & SAND (fine-grained), trace clay, poorly graded, compact, damp to moist, brown

CLAY (TILL), silty, some sand, trace gravel (sub-angular < 30mm), medium plastic, stiff, damp to moist, brown, oxide staining, coal inclusions, occasional sand pockets and seams

... below 3m, becoming hard in consistency, weathered

... at 3.0m, % Grain Size of SPT2, Clay: 18%, Silt: 51%, Sand 31%

SILT, some sand, fine-grained, trace clay, poorly graded, very dense, locally cemented, damp, light brown

... below 5.3m, increae in sand content (being sandy)

... at 6.0m, water encountered (becoming wet to saturated)

BEDROCK, mudstone, highly weathered, very weak, light grey

End of Borehole

- 25mm PVC standpipe installed to 9.1m below grade
- groundwater encountered at 6m below grade upon completion
- groundwater measured at 3.45m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

SAMPLE NO	SPT BLOWS /300 mm
S1	
SPT1	3-5-5
S2	
SPT2	7-50
S3	
SPT3	6-16-50
S4	
SPT4	50
S5	
S6	

OTHER DATA

REC = 40%

Resistivity: 1400 Ohms-cm (SEVERE)

SO4: 0.054% (Negligible)

SO4: 0.054% (Negligible)

REC = 60%

High blow count due to rock at tip of spoon

REC = 50%

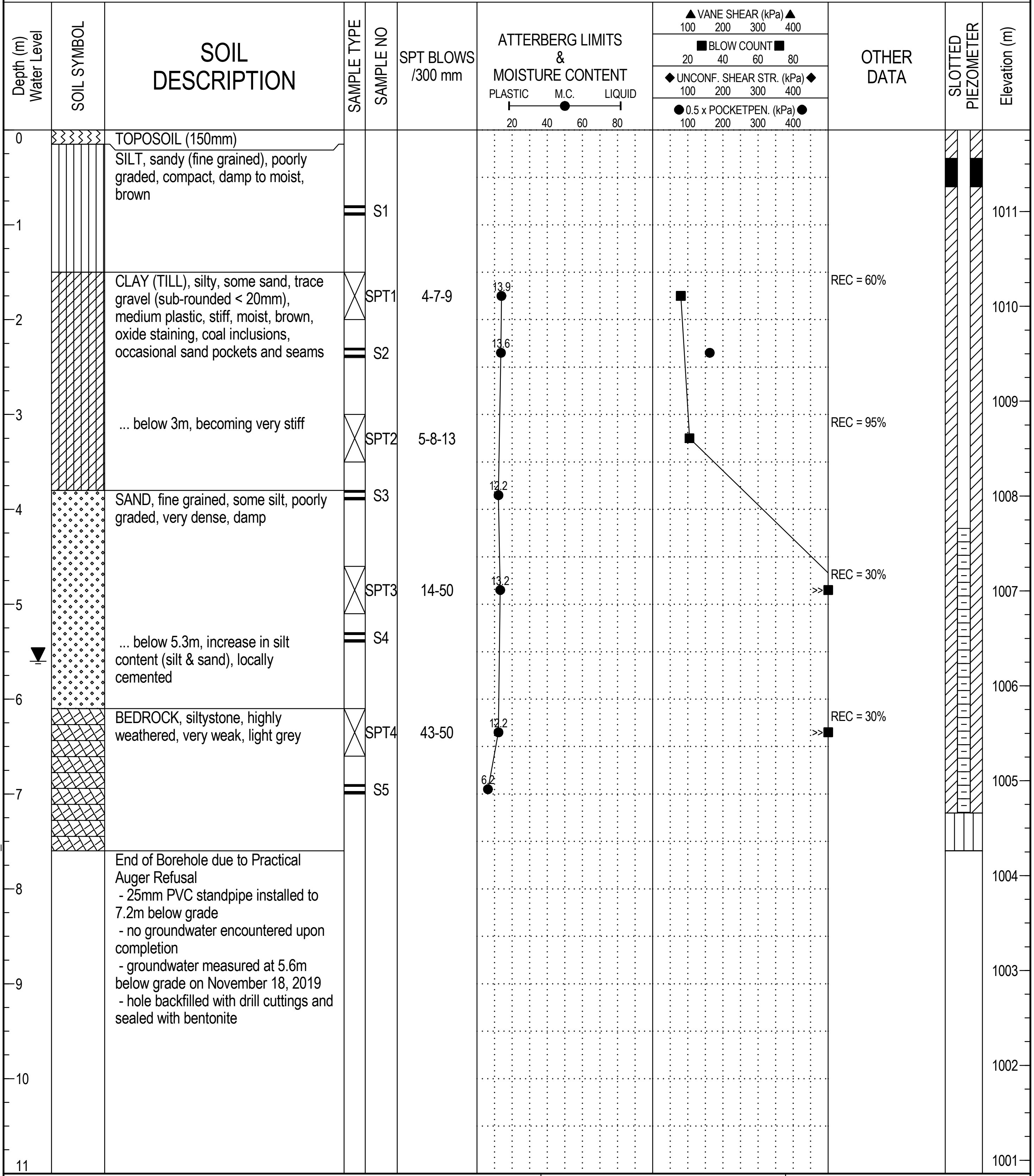
REC = 40%

engineering ltd.	LOGGED BY: HL	COMPLETION DEPTH: 9.10 m
	REVIEWED BY: MA	COMPLETION DATE: 10/15/19
		Page 1 of 1

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-14**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5657478.64	EASTING: 317229.89	ELEVATION: 1011.86 m

SAMPLE TYPE: ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND



TOPOSOIL (150mm)

SILT, sandy (fine grained), poorly graded, compact, damp to moist, brown

CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 20mm), medium plastic, stiff, moist, brown, oxide staining, coal inclusions, occasional sand pockets and seams

... below 3m, becoming very stiff

SAND, fine grained, some silt, poorly graded, very dense, damp

... below 5.3m, increase in silt content (silt & sand), locally cemented

BEDROCK, siltystone, highly weathered, very weak, light grey

End of Borehole due to Practical Auger Refusal
- 25mm PVC standpipe installed to 7.2m below grade
- no groundwater encountered upon completion
- groundwater measured at 5.6m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	MOISTURE CONTENT	OTHER DATA
☰	S1			
☒	SPT1	4-7-9	13.9	REC = 60%
☰	S2		13.6	
☒	SPT2	5-8-13		REC = 95%
☰	S3		12.2	
☒	SPT3	14-50	13.2	REC = 30%
☰	S4			
☒	SPT4	43-50	12.2	REC = 30%
☰	S5		6.2	

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/15/19

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PROJECT NAME: Wheatland County 2151836 AB Inc | LOCATION: See Figure 1 | BOREHOLE NO: **BH-15**

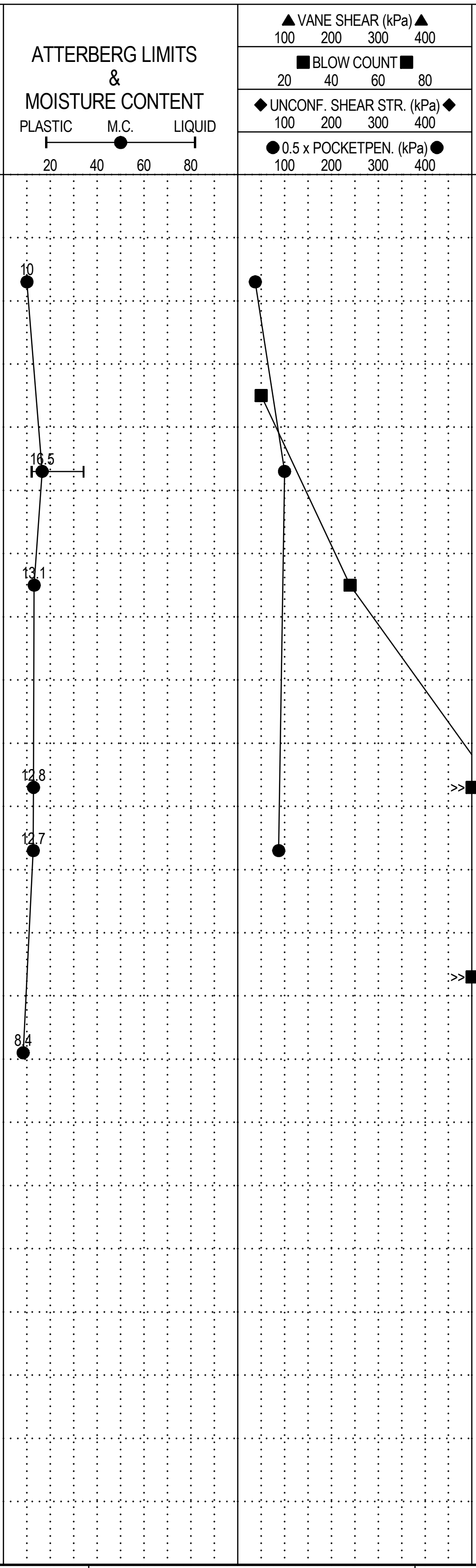
CLIENT: B&A Planning Group | DRILL TYPE: Solid Stem Auger | PROJECT NO: 2019-4683

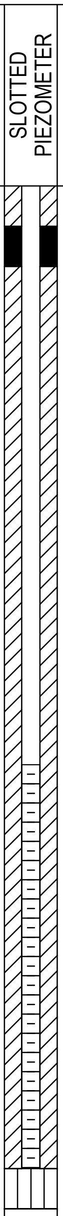
NORTHING: 5657876.71 | EASTING: 318409.76 | ELEVATION: 1005.57 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁖ GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA	Elevation (m)
0	TOPSOIL (200mm)					
	SILT & SAND (fine-grained), trace clay, poorly graded, compact, damp to moist, brown	☰	S1			1005
1	CLAY (TILL), silty, some sand, trace gravel (sub-rounded < 15mm), medium plastic, stiff, moist, brown, oxide staining, coal inclusions, occasional sand pockets and seams	☒	SPT1	3-5-5	REC = 50%	1004
2	... at 2.3m, % Grain Size of S2, Clay: 19%, Silt: 51%, Sand 30%	☰	S2			1003
3	... below 3m, becoming hard in consistency	☒	SPT2	6-16-32	REC = 80%	1002
▼	SAND (fine-grained), silty, trace clay, poorly graded, very dense, moist, brown, possible uncemented bedrock	☰	S3			
4	... below 4.6m, increase in clay content (trace to some clay)	☒	SPT3	14-50	REC = 30%	1001
5		☰	S4			1000
6	BEDROCK, siltstone, highly weathered, very weak, light grey	☒	SPT4	50	REC = 5%	999
7		☰	S5			998
8	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.3m below grade - no groundwater encountered upon completion - groundwater measured at 3.7m below grade - hole backfilled with drill cuttings and sealed with bentonite					997
9						996
10						995
11						





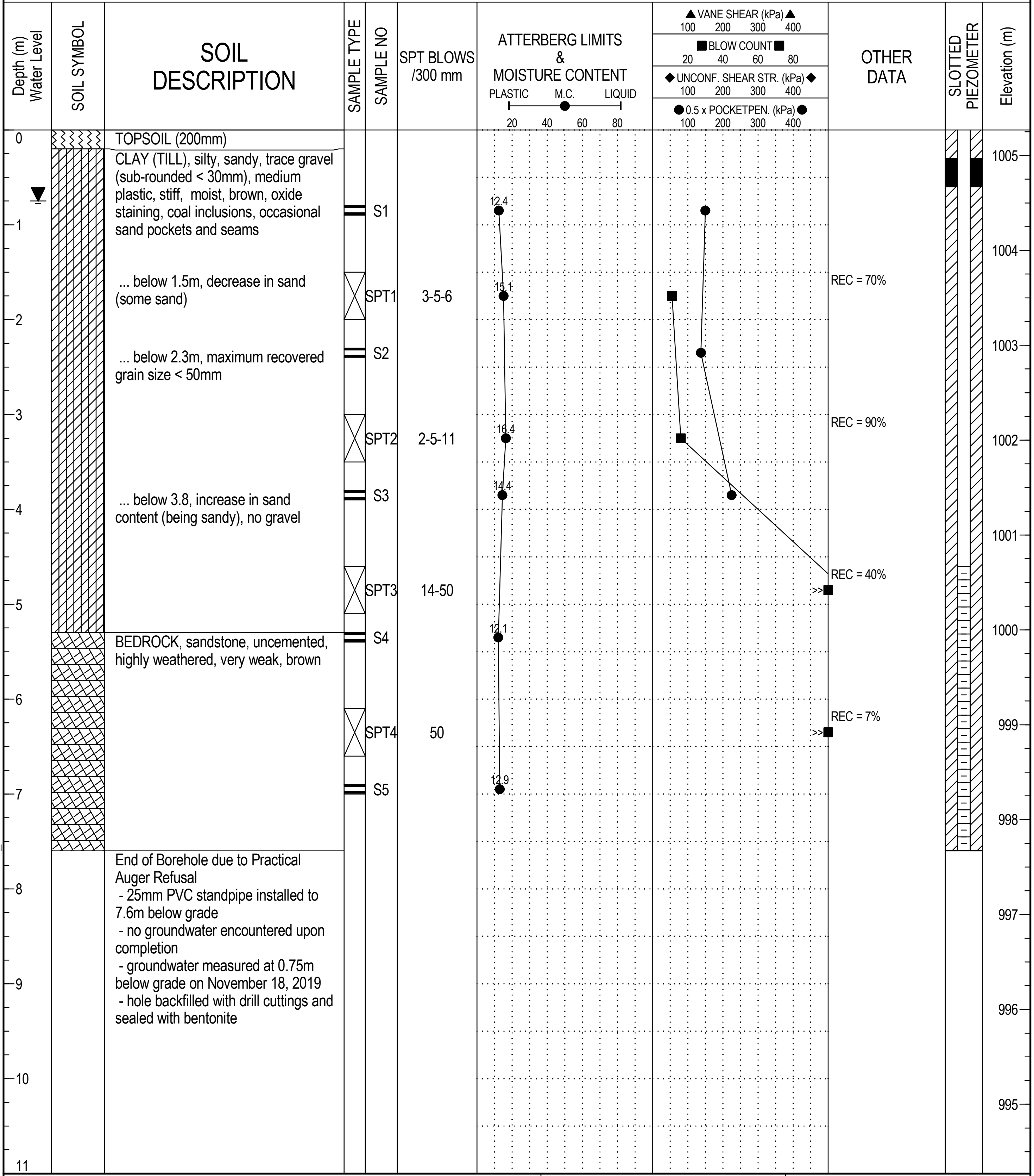
LOGGED BY: HL | COMPLETION DEPTH: 7.60 m

REVIEWED BY: MA | COMPLETION DATE: 10/15/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-16**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5657444.55	EASTING: 318328.16	ELEVATION: 1005.27 m

SAMPLE TYPE: ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND



TOPSOIL (200mm)

CLAY (TILL), silty, sandy, trace gravel (sub-rounded < 30mm), medium plastic, stiff, moist, brown, oxide staining, coal inclusions, occasional sand pockets and seams

... below 1.5m, decrease in sand (some sand)

... below 2.3m, maximum recovered grain size < 50mm

... below 3.8, increase in sand content (being sandy), no gravel

BEDROCK, sandstone, uncemented, highly weathered, very weak, brown

End of Borehole due to Practical Auger Refusal
- 25mm PVC standpipe installed to 7.6m below grade
- no groundwater encountered upon completion
- groundwater measured at 0.75m below grade on November 18, 2019
- hole backfilled with drill cuttings and sealed with bentonite

S1		12.4	
SPT1	3-5-6	15.1	REC = 70%
S2			
SPT2	2-5-11	16.4	REC = 90%
S3		14.4	
SPT3	14-50		REC = 40%
S4		12.1	
SPT4	50		REC = 7%
S5		12.9	

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/15/19

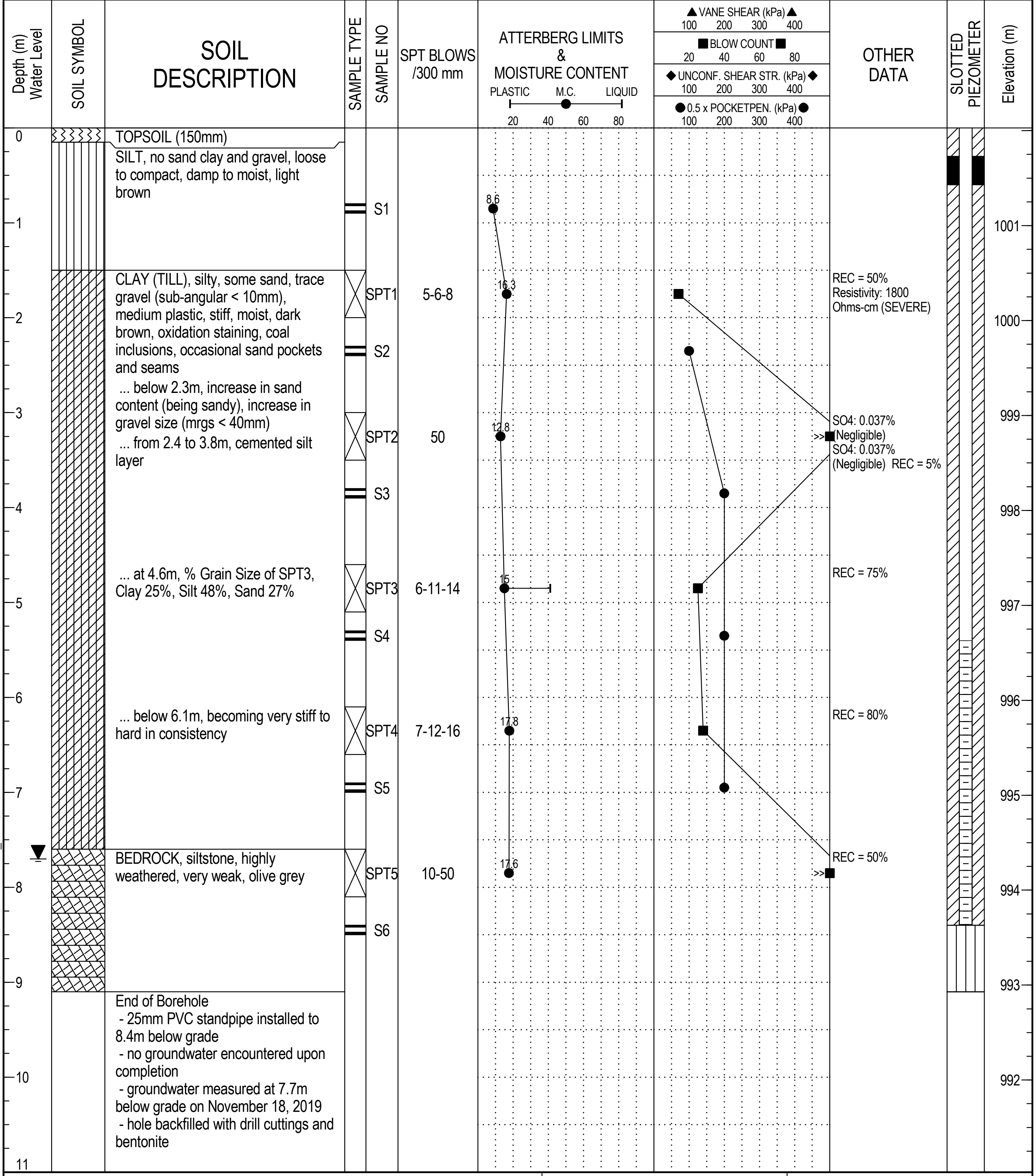
PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-17**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656940.32	EASTING: 318970.18	ELEVATION: 1002.03 m

SAMPLE TYPE: ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE: ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

SOIL DESCRIPTION	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
TOPSOIL (150mm) SILT, no sand clay and gravel, loose to compact, damp to moist, light brown	S1		
CLAY (TILL), silty, some sand, trace gravel (sub-angular < 10mm), medium plastic, stiff, moist, dark brown, oxidation staining, coal inclusions, occasional sand pockets and seams	SPT1	5-6-8	REC = 50% Resistivity: 1800 Ohms-cm (SEVERE)
	S2		
... below 2.3m, increase in sand content (being sandy), increase in gravel size (mrgs < 40mm) ... from 2.4 to 3.8m, cemented silt layer	SPT2	50	SO4: 0.037% (Negligible) SO4: 0.037% (Negligible) REC = 5%
	S3		
... at 4.6m, % Grain Size of SPT3, Clay 25%, Silt 48%, Sand 27%	SPT3	6-11-14	REC = 75%
	S4		
... below 6.1m, becoming very stiff to hard in consistency	SPT4	7-12-16	REC = 80%
	S5		
BEDROCK, siltstone, highly weathered, very weak, olive grey	SPT5	10-50	REC = 50%
	S6		

End of Borehole
- 25mm PVC standpipe installed to 8.4m below grade
- no groundwater encountered upon completion
- groundwater measured at 7.7m below grade on November 18, 2019
- hole backfilled with drill cuttings and bentonite

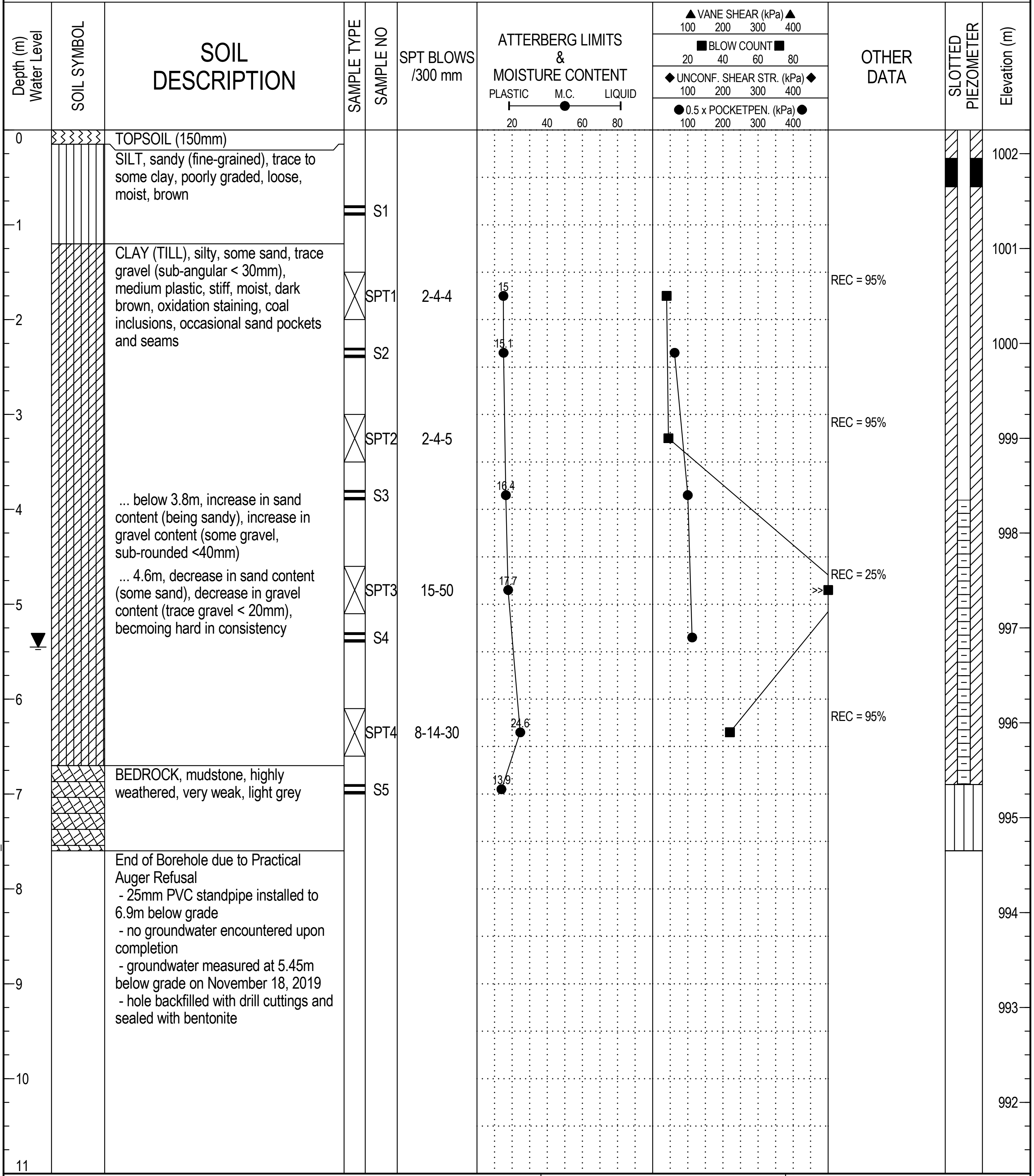


LOGGED BY: HL	COMPLETION DEPTH: 10.00 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-18**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656560.22	EASTING: 318959.31	ELEVATION: 1002.25 m

SAMPLE TYPE ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND



Depth (m)	SOIL DESCRIPTION
0	TOPSOIL (150mm)
	SILT, sandy (fine-grained), trace to some clay, poorly graded, loose, moist, brown
	CLAY (TILL), silty, some sand, trace gravel (sub-angular < 30mm), medium plastic, stiff, moist, dark brown, oxidation staining, coal inclusions, occasional sand pockets and seams
	... below 3.8m, increase in sand content (being sandy), increase in gravel content (some gravel, sub-rounded <40mm)
	... 4.6m, decrease in sand content (some sand), decrease in gravel content (trace gravel < 20mm), becmoing hard in consistency
	BEDROCK, mudstone, highly weathered, very weak, light grey
	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 6.9m below grade - no groundwater encountered upon completion - groundwater measured at 5.45m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite

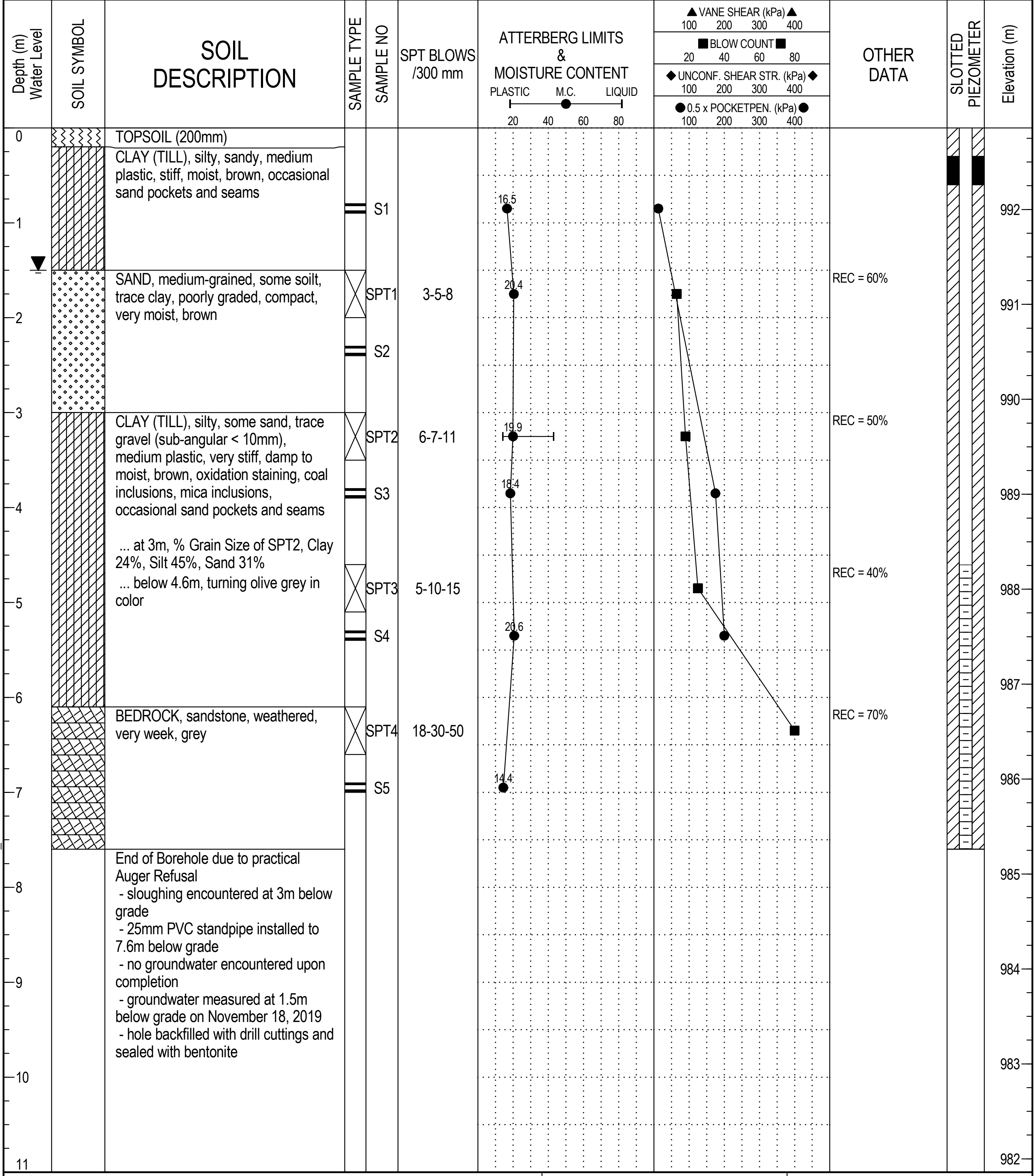
SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	MOISTURE CONTENT	OTHER DATA
☰	S1			
☒	SPT1	2-4-4	15	REC = 95%
☰	S2		15.1	
☒	SPT2	2-4-5		REC = 95%
☰	S3		16.4	
☒	SPT3	15-50	17.7	REC = 25%
☰	S4			
☒	SPT4	8-14-30	24.6	REC = 95%
☰	S5		13.9	

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/15/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-19**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656870.94	EASTING: 319683.74	ELEVATION: 992.86 m

SAMPLE TYPE ■ SHELBY TUBE ◩ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⬚ PEA GRAVEL ▥ SLOUGH ⬚ GROUT ▨ DRILL CUTTINGS ⬚ SAND



SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA
TOPSOIL (200mm)				
CLAY (TILL), silty, sandy, medium plastic, stiff, moist, brown, occasional sand pockets and seams	☰	S1		
SAND, medium-grained, some soilt, trace clay, poorly graded, compact, very moist, brown	☒	SPT1	3-5-8	REC = 60%
	☰	S2		
CLAY (TILL), silty, some sand, trace gravel (sub-angular < 10mm), medium plastic, very stiff, damp to moist, brown, oxidation staining, coal inclusions, mica inclusions, occasional sand pockets and seams ... at 3m, % Grain Size of SPT2, Clay 24%, Silt 45%, Sand 31% ... below 4.6m, turning olive grey in color	☒	SPT2	6-7-11	REC = 50%
	☰	S3		
	☒	SPT3	5-10-15	REC = 40%
	☰	S4		
BEDROCK, sandstone, weathered, very week, grey	☒	SPT4	18-30-50	REC = 70%
	☰	S5		
End of Borehole due to practical Auger Refusal - sloughing encountered at 3m below grade - 25mm PVC standpipe installed to 7.6m below grade - no groundwater encountered upon completion - groundwater measured at 1.5m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite				

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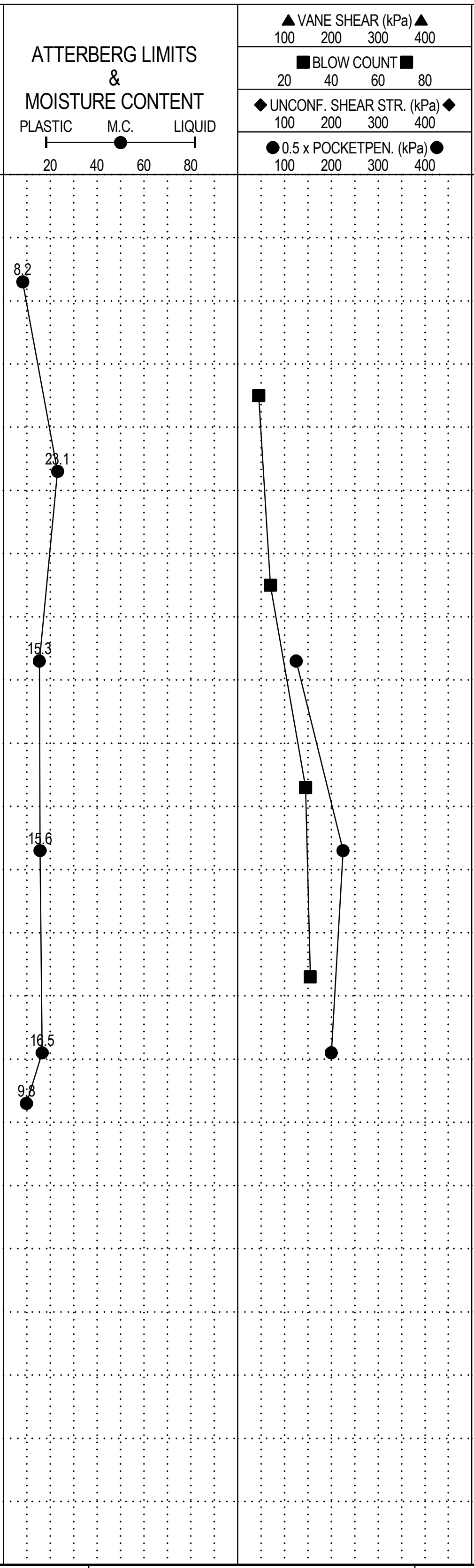
LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/16/19

PROJECT NAME: Wheatland County 2151836 AB Inc	LOCATION: See Figure 1	BOREHOLE NO: **BH-20**
CLIENT: B&A Planning Group	DRILL TYPE: Solid Stem Auger	PROJECT NO: 2019-4683
NORTHING: 5656463.66	EASTING: 320248.11	ELEVATION: 991.7 m

SAMPLE TYPE ■ SHELBY TUBE ◪ CORE SAMPLE ☒ SPT SAMPLE ☰ GRAB SAMPLE ▥ NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m) Water Level	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT BLOWS /300 mm	OTHER DATA	Elevation (m)
0	TOPSOIL (150mm)					
	SAND, fine-grained, trace silt, poorly graded, loose to compact, damp to moist, brown	☰	S1			991
1						
	... below 1.5m, increase in silt and clay contents (becoming some silt, trace clay), becoming moist	☒	SPT1	4-4-5	REC = 40%	990
2	... below 2.3m, increase in silt and clay contents (becoming silty, trace to some clay)	☰	S2			
▼						989
3	CLAY (TILL), silty, some sand, medium plastic, stiff to very stiff, moist, brown, oxidation staining, coal inclusions, occasional sand pockets and seams, weathered	☒	SPT2	5-7-7	REC = 80%	
		☰	S3			988
4	... at 3m, minor seepage encountered ... below 3.8m, increase in water content (very moist)					
	... at 4.5m, increaes in sand content (being sandy), moderate seepage encountered	☒	SPT3	4-12-17	REC = 30%	987
5	... below 4.6m, becoming very stiff to hard in consistency, occasional slough-in encountered	☰	S4			
						986
6	... below 6.1m, becoming hard in consistency, decrease in sand content (some sand), becoming grey in color	☒	SPT4	7-13-18	REC = 10%	
		☰	S5			985
7	BEDROCK, sandstone, weathred, weak, grey		S6			
	End of Borehole due to Practical Auger Refusal - 25mm PVC standpipe installed to 7.6m below grade - no goundwater encountered upon completion - groundwater measured at 2.8m below grade on November 18, 2019 - hole backfilled with drill cuttings and sealed with bentonite					984
8						983
9						982
10						981
11						



SLOTTED PIEZOMETER

LOGGED BY: HL	COMPLETION DEPTH: 7.60 m
REVIEWED BY: MA	COMPLETION DATE: 10/15/19

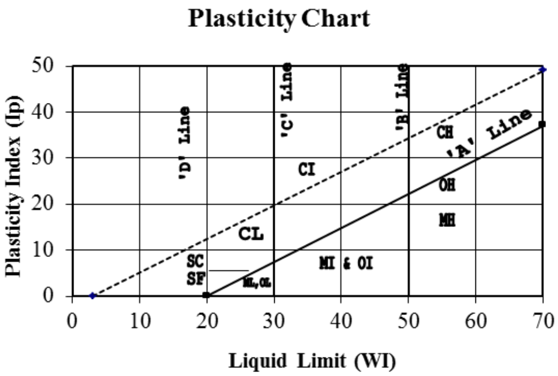
EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of the field investigation and subsequent laboratory testing are described below. It should be noted that materials, boundaries, and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

SOIL DESCRIPTIONS

The soils in the borehole logs have been described using the Modified Unified Soil Classification System in conjunction with description guidelines from the Canadian Foundation Engineering Manual, 4th Edition.

Secondary Constituents	
Descriptor	Percentage by Weight
And	> 35%
y/ey	20 – 35%
Some	10 – 20%
Trace	< 10%



Consistency of Cohesive Soils		
Classification	Undrained	“N” Blow
Very Soft	< 12	< 2
Soft	12 – 25	2 – 4
Firm	25 – 50	4 – 8
Stiff	50 – 100	8 – 15
Very Stiff	100 – 200	15 – 30
Hard	> 200	> 30

Relative Density of Non-Cohesive Soils	
Classification	SPT – N
Very Loose	0 – 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	> 50

SYMBOLS

■	▨	▨	▨	▩	▨	▨	▥	▥
Asphalt	High-plasticity Clay	Intermediate-plasticity Clay	Low-plasticity Clay	Fill	Poorly-graded Gravel	Well-graded Gravel	High-plasticity Silt	Intermediate-plasticity Silt
▥	▥	▨	▨	▨	▨	▤	░	▼
Low-plasticity Silt	Low-plasticity Organics	Clayey Sand	Silty Sand	Poorly-graded Sand	Well-graded Sand	Shale	Sandstone	Measured Water Level

MODIFIED UNIFIED
SOIL CLASSIFICATION SYSTEM

Major Division			Symbol	Description	Criteria	
Coarse Grained Soils	Gravel (More than half coarse grains larger than 4.75 mm)	Clean Gravel (little or no fines)	GW	Well graded gravels, little or no fines	$C_u = \frac{D_{60}}{D_{10}} > 4 \ C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \ to \ 3$	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting above criteria	
		Gravel with fines	GM	Silty gravels, gravel-sand-silt mixtures	Fines content > 12%	Atterberg Limit below “A” Line, $w_p < 4$
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg Limit above “A” Line, $w_p > 7$
	Sand (More than half of coarse grains smaller than 4.75 mm)	Clean Sand (little or no fines)	SW	Well graded sands, gravelly sands, little or no fines	$C_u = \frac{D_{60}}{D_{10}} > 6 \ C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \ to \ 3$	
			SP	Poorly graded sands, little or no fines	Not meeting above criteria	
		Sand with fines	SM	Silty sand, sand-silt mixtures	Fines content > 12%	Atterberg Limit below “A” Line, $w_p < 4$
			SC	Clayey sand, sand-clay mixtures		Atterberg Limit above “A” Line, $w_p > 7$
Fine Grained Soils	Silts (Below “A” line, negligible organic content)	$W_L < 50$	ML	Inorganic silts and very fine sands, rock flour, silty sands with low plasticity	See plasticity chart	
		$W_L > 50$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils		
	Clays (Above “A” line, negligible organic content)	$W_L < 30$	CL	Inorganic clays of low plasticity, gravelly, sandy, or silty clays, lean clays		
		$30 < W_L < 50$	CI	Inorganic clays of medium plasticity, silty clays		
		$W_L > 50$	CH	Inorganic clays of high plasticity, fat clays		
	Organic silts and clays (Below “A” line	$W_L < 50$	OL	Organic silts and organic silty clays of low plasticity		
		$W_L > 50$	OH	Organic clays of high plasticity		
Highly Organic Soils			Pt	Peat and other highly organic soils	Strong colour or odour, often fibrous texture	

- The soil of each stratum is described using the Unified Soil Classification System modified slightly so that an inorganic clay of “medium plasticity” is recognized
- “REC” denotes percentage sample recovery
- SPT “N” values represent the number of blows by a 63.6 kg hammer dropped 760 mm to drive a 50 mm diameter open sampler a distance of 300 mm after an initial penetration of 150 mm