Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL • ENVIRONMENTAL • HYDROGEOLOGICAL • BUILDING SCIENCE
100 NUGGET AVENUE, TORONTO, ONTARIO M1S 3A7 • TEL: (416) 754-8515 • FAX: (416) 754-8516

BARRIE	MISSISSAUGA	OSHAWA	NEWMARKET	GRAVENHURST	PETERBOROUGH	HAMILTON
TEL: (705) 721-7863	TEL: (905) 542-7605	TEL: (905) 440-2040	TEL: (905) 853-0647	TEL: (705) 684-4242	TEL: (905) 440-2040	TEL: (905) 777-7956
FAX: (705) 721-7864	FAX: (905) 542-2769	FAX: (905) 725-1315	FAX: (416) 754-8516	FAX: (705) 684-8522	FAX: (905) 725-1315	FAX: (905) 542-2769

A REPORT TO
HIGH LEVEL CONSTRUCTION LTD.

A SOIL INVESTIGATION FOR RESIDENTIAL DEVELOPMENT

3879 TOWN LINE

CITY OF ORILLIA

REFERENCE NO. 1606-S168

AUGUST 2016

DISTRIBUTION

3 Copies - High Level Construction Ltd.
1 Copy - Soil Engineers Ltd. (Toronto)

TABLE OF CONTENTS

TABLES

DIAGRAM

ENCLOSURES

1.0 INTRODUCTION

In accordance with a written authorization dated March 22, 2016 from Mr. David Meeks, President of High Level Construction Ltd., a soil investigation was carried out at a property located on the east side of Town Line and south of Millwood Road, in the City of Orillia, for a proposed residential development.

The purpose of the investigation was to reveal the subsurface conditions and determine the engineering properties of the disclosed soils for the proposed development.

The geotechnical findings and resulting recommendations are presented in this Report.

2.0 SITE AND PROJECT DESCRIPTION

City of Orillia is located within the periphery of Lake Simcoe basin where the glacial till has been partly eroded in places, by glacial Lake Algonquin and filled with lacustrine silts and clay.

The subject site is almost rectangular in shape, encompasses an area of 27.4 ac (11.1 ha), having a municipal address of 3879 Town Line, City of Orillia. It is a wooded area with a dense growth of mature trees. The existing ground surface is undulated, generally descends to the east, with a maximum grade difference of nearly 12 m between Boreholes 1 and 4.

It is understood that a residential development is planned for this site, with municipal services, paved access roadways, and a stormwater management pond located at the northeast corner of the site. Details of the development, however, were not available at the time this report was prepared.

3.0 **FIELD WORK**

The field work, consisting of drilling 4 boreholes to depths of 6.3 m and 7.8 m, was performed on July 19, 2016, at the locations shown on the Borehole Location Plan, Drawing No. 1. Due to the heavy growth of trees, a temporary access was created through the centre of the site for the drilling program.

The holes were advanced at intervals to the sampling depths by a track-mounted, continuous-flight power-auger machine equipped for soil sampling. Standard Penetration Tests, using the procedures described on the enclosed “List of Abbreviations and Terms”, were performed at the sampling depths. The test results are recorded as the Standard Penetration Resistance (or ‘N’ values) of the subsoil. The relative density of the granular strata and the consistency of the cohesive strata are inferred from the ‘N’ values. Split-spoon samples were recovered for soil classification and laboratory testing.

Upon completion of drilling, monitoring wells, consisting of 50-mm diameter PVC pipes were installed in the boreholes for future groundwater monitoring and hydrogeological study purpose.

The field work was supervised and the findings were recorded by a Geotechnical Technician.

The elevation at each of the borehole locations was surveyed using hand-held Global Navigation Satellite System surveying equipment (Trimble Geoexplorer 6000 series) with an accuracy of 0.1± m.

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 4, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing No. 2, and the engineering properties of the disclosed soils are discussed herein.

This investigation has disclosed that beneath a veneer of topsoil, the site is generally underlain by strata of silty sand till and sandy silt till, with embedded sand and silt seams and layers at various depths and locations.

4.1 Topsoil (All Boreholes)

The revealed topsoil is 20 to 25 cm in thickness. It is dark brown in colour, showing that it contains appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil is considered to be void of engineering value but can be used for general landscaping purposes.

Due to its humus content, the topsoil will generate an offensive odour under anaerobic conditions and may produce volatile gases; therefore, it must not be buried within the building envelope, or deeper than 1.2 m below the finished grade, as it may have an adverse impact on the environmental well-being of the development.

The topsoil can only be reused in landscaping purpose. A fertility analysis can be carried out to further assess the suitability of topsoil for re-use as a planting soil or sodding medium.

4.2 **Sand** (Boreholes 1, 3 and 4)

A layer of sand was encountered beneath the topsoil, extending to depths of 0.7 m and 1.3 m below ground. Sample examination indicates that it is fine grained in Boreholes 1 and 3, fine to coarse grained in Borehole 4. The sand is a non-cohesive material and its sorted structure indicates that it is a glaciolacustrine deposit.

The natural water content of the samples was found to range from 4% to 12%, with a median of 9%, showing that the sand is in a damp to very moist, generally moist condition.

The obtained 'N' values range from 3 to 6, with a median of 3 blows per 30 cm of penetration, indicating that the relative density of the sand is very loose, probably loosened by the weathering process.

Based on the above findings, the following engineering properties of the sand is deduced:

- Medium frost susceptibility and low soil adfreezing potential.
- High water erodibility under seepage pressure.
- Relatively pervious, with an estimated coefficient of permeability of 10^{-3} cm/sec, an average infiltration rate of 50 mm/hr, and runoff coefficients of:

Slope	
0% - 2%	0.04
2% - 6%	0.09
6% +	0.13

- A frictional soil, its shear strength is derived from its internal friction angle and is soil density dependent.

- In steep cuts, the sand will slough to its angle of repose, run under seepage pressure and boil with a piezometric head of 0.4 m.
- A fair pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 15%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 6000 ohm·cm.

4.3 **Silty Sand Till** (All Boreholes)

The silty sand till was encountered below the topsoil or sand deposit in the upper to mid section of the revealed stratigraphy. It consists of a random mixture of soils; the particle sizes range from clay to gravel, with sand being the dominant fraction. It is heterogeneous in structure, indicating that it is a glacial deposit. The silty sand till contains occasional sand and silt seams and layers, cobbles and boulders.

The obtained 'N' values range from 3 to 100, with a median of 14 blows per 30 cm of penetration, showing the sand till is very loose to very dense, being generally compact. The loose till is restricted to the weathered zone up to a depth of 2.0 m.

The natural water content of the soil samples was determined and the results are plotted on the Borehole Logs; the values range from 8% to 30%, with a median of 11%, indicating that the till is in a damp to wet, generally moist condition.

Grain size analyses were performed on 2 representative samples of the silty sand till; the result is plotted on Figure 5.

Based on the above findings, the following engineering properties are deduced:

- Highly frost susceptible and moderately water erodible.

- The laminated sand and silt layers are water erodible.
- Relatively low permeability, with an estimated coefficient of permeability of 10^{-5} cm/sec, an average infiltration rate of 15 mm/hr, and runoff coefficients of:

Slope	
0% - 2%	0.11
2% - 6%	0.16
6% +	0.23

- Frictional soil, its shear strength is primarily derived from internal friction, and is augmented by cementation. Therefore, its strength is density dependent.
- It will generally be stable in a relatively steep cut; however, prolonged exposure will allow the sand and silt layers to become saturated, which may lead to localized sloughing.
- Fair pavement-supportive material, with an estimated CBR value of 10%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

4.4 **Sandy Silt Till** (All Boreholes)

The sandy silt till was encountered in the lower zone of the revealed stratigraphy, extending to the maximum investigated depth of the boreholes. It consists of a random mixture of particle sizes ranging from clay to gravel, with silt being the dominant fraction. The soil is heterogeneous in structure, showing it is a glacial deposit.

Sample examinations disclosed that the till is slightly cemented and display slight to some cohesion when remoulded, indicating that the clay content varies. The samples slaked readily when placed in water and, when shaken, the samples displayed a low dilatancy. Occasional sand and silt seams and layers were found in the soil samples, and some of them were wet.

Hard resistance to augering was encountered, showing that occasional cobbles and boulders are embedded in the till mantle. The obtained 'N' values range from 27 to 100, with a median of 100 blows per 30 cm of penetration, indicating the relative density of the till deposits is compact to very dense, being generally very dense.

The natural water content of the soil samples was determined and the results are plotted on the Borehole Logs. The values range from 5% to 14%, with a median of 8%, indicating that the tills are in a damp to moist, generally in a damp condition.

Accordingly, the engineering properties relating to the project are given below:

- Moderately high frost susceptible and moderately water erodible.
- Low permeability, with an estimated coefficient of permeability of 10^{-6} cm/sec, and runoff coefficients of:

Slope	
0% - 2%	0.15
2% - 6%	0.20
6% +	0.28

- Frictional soil, the shear strength is primarily derived from internal friction, and is augmented by cementation. Therefore, its strength is density dependent.
- It will be stable in relatively steep cuts; however, under prolonged exposure, localized sheet collapse will likely occur.
- A fair pavement-supportive material, with an estimated CBR value of 8%.
- Moderate low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

4.5 Compaction Characteristics of the Revealed Soils

The obtainable degree of compaction is primarily dependent on the soil moisture and, to a lesser extent, on the type of compactor used and the effort applied.

As a general guide, the typical water content values of the revealed soils for Standard Proctor compaction are presented in Table 1.

Table 1 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Sand	4 to 12 (median 9)	11	5 to 14
Silty Sand Till	8 to 30 (median 11)	12	6 to 15
Sandy Silt Till	5 to 14 (median 8)	13	8 to 17

Based on the above findings, the in situ soils are generally suitable for a 95% or + Standard Proctor compaction. A portion of the silty sand till is too wet and will require aeration prior to structural compaction. The aeration can be effectively carried out by spreading the wet soil thinly on the ground in the dry, warm weather. A portion of the sandy silt till is too dry and will require the addition of water for structural compaction.

The weathered soil must be sorted free of topsoil and rootlets inclusions prior to its use a structural backfill. The native soils should be compacted using a heavy-weight, knead-type roller. The thickness of each lift should be limited to 20 cm before compaction or to a suitable thickness assessed by test strips performed by the equipment which will be used at the time of construction.

When compacting chunks of till, the compactive energy will frequently bridge over the chunks in the soil and be transmitted laterally into the soil mantle. Therefore, the lifts of this soil must be limited to 20 cm or less (before compaction). It is difficult to monitor the lifts of backfill placed in deep trenches; therefore, it is preferable that the compaction of backfill at depths over 1.0 m below the road subgrade be carried out on the wet side of the optimum. This would allow a wider latitude of lift thickness.

If the compaction of the soils is carried out with the water content within the range for 95% Standard Proctor dry density but on the wet side of the optimum, the surface of the compacted soil mantle will roll under the dynamic compactive load. This is unsuitable for road construction since each component of the pavement structure is to be placed under dynamic conditions which will induce the rolling action of the subgrade surface and cause structural failure of the new pavement. The foundations or bedding of the sewer and slab-on-grade will be placed on a subgrade which will not be subjected to impact loads. Therefore, the structurally compacted soil mantle with the water content on the wet side or dry side of the optimum will provide an adequate subgrade for the construction.

The presence of boulders will prevent transmission of the compactive energy into the underlying material to be compacted. If an appreciable amount of boulders over 15 cm in size is mixed with the material, it must either be sorted or must not be used for structural backfill and/or construction of engineered fill.

5.0 GROUNDWATER CONDITIONS

Groundwater seepage encountered in the boreholes during augering was recorded on the borehole logs. The monitoring wells installed in the boreholes were also checked for the presence of groundwater on August 5, 2016. The recorded levels are summarized in Table 2.

Table 2 - Groundwater Levels

BH No.	Borehole Depth (m)	Soil Colour Changes Brown to Grey	Groundwater Level Upon Completion of Drilling		Measured Groundwater Level	
		Depth (m)	Depth (m)	El. (m)	Depth (m)	El. (m)
1	6.3	6.3+	5.9	268.9	1.3	273.5
2	7.8	5.6±	Dry	Dry	3.1	267.5
3	6.3	4.3±	1.7	265.0	2.6	264.1
4	6.3	4.3±	2.0	260.7	2.3	260.4

As shown above, the stabilized groundwater levels in the monitoring wells were recorded at depths ranging from 1.3 to 3.1 m below the ground surface, or at El. 260.4 to 273.5 m. The groundwater level represents wet sand layers within the till deposit and it will fluctuate with the seasons.

The soil colour changes from brown to grey at depths ranging from 4.3 to 5.6± m below the prevailing ground surface in Boreholes 2, 3 and 4. The revealed soil in Borehole 1 remains brown within the investigated depth. The brown colour indicates that the soils have oxidized.

In excavation, the yield of groundwater seepage may be some to moderate and can be removed by conventional pumping from sumps. Further assessment through hydrogeological study can confirm the groundwater condition and the appropriate dewatering method when the excavation depth is determined.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has disclosed that beneath a veneer of topsoil, the site is underlain by strata of very loose to very dense, generally compact silty sand till, and compact to very dense, generally very dense sandy silt till, with embedded very loose sand layers at various depths and locations.

Groundwater was recorded in three of the boreholes upon completion of drilling. On August 5, 2016, the groundwater level in the monitoring wells was recorded at depths ranging from 1.3 to 3.1 m below the ground surface, or at El. 260.4 to 273.5 m. Percolated water from precipitation trapped in the sand and silt layers may also be encountered at shallower depths during excavation. The yield of groundwater during excavation may be some to moderate, which can be removed by conventional pumping from sumps.

The geotechnical findings which warrant special consideration are presented below:

1. The topsoil, 20 to 25 cm in thickness, must be stripped and removed as it is unsuitable for engineering applications. Due to its high humus content, it will generate volatile gases under anaerobic conditions. For the environmental as well as the geotechnical well-being of the future development, the topsoil should not be buried under any structure, or deeper than 1.2 m below the exterior finish grade.
2. The in situ native soils are weathered to depths ranging from 0.7± to 2.0± m below the prevailing ground surface. The weathered soil is generally loose and is not suitable for foundation support. The weathered soils can be subexcavated, assessed and properly recompacted in layers to engineered fill specifications for footing construction.

3. The sound natural soils below the weathered zone are suitable for normal spread and strip footing for house construction. The footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that its condition is compatible with the design of the foundation.
4. Where cut and fill is required for site grading, it is generally more economical to place an engineered fill for normal footing, sewer and road construction. The placement of engineered fill will include the removal of the weathered soils before compacting the fill in layers.
5. For slab-on-grade construction, any weathered or loose soils should be subexcavated, aerated and properly compacted prior to the placement of the slab. The slab should be constructed on a granular base, 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density.
6. Perimeter subdrains and dampproofing of the foundation walls will be required for basement construction. The subdrains should be shielded by a fabric filter to prevent blockage by silting. Depending on the design elevation of the basement structure, underfloor subdrains may also be required below the basement floor; this can be further assessed after the design is finalized or at the time of basement excavation.
7. A Class ‘B’ bedding is recommended for the design of the underground services. The bedding material should consist of compacted 20-mm Crusher-Run Limestone, or equivalent. Where extensive dewatering is required in a saturated soil subgrade a Class ‘A’ bedding should be considered.
8. Excavation into the tills containing cobbles and boulders may require extra effort and the use of a heavy-duty backhoe equipped with a rock ripper. Boulders larger than 15 cm in size are not suitable for structural backfill and/or the construction of engineering fill.

The recommendations appropriate for the project described in Section 2.0 are presented herein. One must be aware that the subsurface conditions may vary between boreholes. Should this become apparent during construction, a geotechnical engineer must be consulted to determine whether the following recommendations require revision.

6.1 Foundations

Based on the borehole findings, the footings for the proposed structures should be placed below the weathered soils and onto the sound natural soils. As a general guide for the design of foundations, the recommended soil bearing pressures and corresponding suitable founding levels are presented in Table 3.

Table 3 - Founding Levels

BH No.	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Suitable Founding Level					
	100 kPa (SLS) 160 kPa (ULS)		200 kPa (SLS) 320 kPa (ULS)		400 kPa (SLS) 600 kPa (ULS)	
	Depth (m)	El. (m)	Depth (m)	El. (m)	Depth (m)	El. (m)
1	1.0 or +	273.8 or -	2.4 or +	272.4 or -	4.6 or +	270.2
2	1.0 or +	269.6 or -	2.4 or +	268.2 or -	3.2 or +	267.4
3	1.0 or +	265.7 or -	-	-	2.4 or +	264.3
4	-	-	2.0 or +	260.7 or -	2.4 or +	260.3

The recommended soil-bearing pressures incorporate a safety factor of three against shear failure of the underlying soils. The total and differential settlements of the footings founded on the sound natural soils are estimated to be 25 mm and 15 mm, respectively.

The footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that its condition is compatible with the design of the foundation.

If groundwater seepage is encountered in the footing excavation, or where the subgrade of the normal foundations is found to be wet, the subgrade should be protected by a concrete mud-slab immediately after exposure. This will prevent construction disturbance and costly rectification.

The foundations exposed to weathering, or in unheated areas, should have at least 1.6 m of earth cover for protection against frost action, or must be properly insulated.

Where earth fill is required for site grading, it is generally more practical and economical to place engineered fill suitable for a Maximum Soil Pressure of 100 kPa for normal footing construction. The requirements and procedures for engineered fill construction are discussed in Section 6.2.

The footings must meet the requirements specified in the latest Ontario Building Code. As a guide, the structure should be designed to resist an earthquake force using Site Classification ‘D’ (stiff soils).

6.2 **Engineered Fill**

Where earth fill is required for site grading, it is generally more economical to place engineered fill for normal footing, underground services and pavement construction. The engineering requirements for a certifiable fill for pavement construction, municipal services, slab-on-grade, and footings designed with a Maximum Allowable Soil Pressure (SLS) of 100 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 160 kPa are presented below:

1. All of the topsoil and organics must be removed, and the subgrade must be inspected and proof-rolled prior to any fill placement. The weathered soil must be subexcavated, sorted free of topsoil inclusions and deleterious materials, if any, aerated and properly compacted in layers.
2. Inorganic soils must be used for backfilling, and they must be uniformly compacted in lifts 20 cm thick to 98% or + of their maximum Standard Proctor dry density up to the proposed finished grade and/or slab-on-grade subgrade. The soil moisture must be properly controlled on the wet side of the optimum. If the house foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum Standard Proctor compaction.
3. If imported fill is to be used, the hauler is responsible for its environmental quality and must provide a document to certify that the material is free of hazardous contaminants.
4. If the engineered fill is to be left over the winter months, adequate earth cover, or equivalent, must be provided for protection against frost action.
5. The engineered fill must extend over the entire graded area; the engineered fill envelope and the finished elevations must be clearly and accurately defined in the field, and they must be precisely documented by qualified surveyors. Foundations partially on engineered fill must be reinforced by two 15-mm steel reinforcing bars in the footings and upper section of the foundation walls, or be designed by a structural engineer, to properly distribute the stress induced by the abrupt differential settlement (estimated to be 15± mm) between the natural soils and engineered fill.
6. The engineered fill must not be placed during the period from late November to early April, when freezing ambient temperatures occur either persistently or intermittently. This is to ensure that the fill is free of frozen soils, ice or snow.

7. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement.
8. Where the fill is to be placed on sloping ground steeper than 1 vertical: 3 horizontal, the face of the sloping ground must be flattened to 3 + so that it is suitable for safe operation of the compactor and the required compaction can be obtained.
9. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
10. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that inspected the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
11. Any excavation carried out in certified engineered fill must be reported to the geotechnical consultant who supervised the fill placement in order to document the locations of the excavation and/or to supervise reinstatement of the excavated areas to engineered fill status. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the condition of the engineered fill must be assessed for re-certification.
12. Despite stringent control in the placement of the engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the strip footings and the upper section of the foundation walls constructed on the engineered fill will require continuous reinforcement with steel bars, depending on the uniformity of the soils in the engineered fill and the thickness of the engineered fill underlying the foundations. Should the footings and/or walls require reinforcement, the required number and size of reinforcing bars must be assessed by considering the uniformity as well as the

thickness of the engineered fill beneath the foundations. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

6.3 **Basement and Slab-On-Grade**

The basement structures should be designed to sustain the lateral earth pressure and applicable surcharge loads which can be calculated using the soil parameters listed in Section 6.9.

The subgrade for the slab-on-grade construction must consist of sound natural soils or properly compacted inorganic earth fill. In preparation of the subgrade, the subgrade must be inspected and assessed by proof-rolling. The badly weathered soils or any soft or loose soils should be subexcavated, sorted free of any deleterious material, aerated and uniformly compacted to 98% or + of its maximum Standard Proctor dry density. If the deleterious materials cannot be sorted, the soils should be replaced by properly compacted, organic-free earth fill.

Any new material for raising the grade should consist of organic-free soil compacted to at least 98% of its maximum Standard Proctor dry density.

If the subgrade has been loosened due to construction traffic, it must be proof-rolled before placement of the granular base.

The slab should be constructed on a granular base, 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density.

A Modulus of Subgrade Reaction of 25 MPa/m can be used for the design of the floor slab.

Where the subgrade is found to be wet, floor subdrains should be provided and connected to a positive outlet. A vapour barrier should be placed at the crown level of the floor subdrains to prevent upfiltration of moisture that may wet the floor. The necessity to implement these measures can be assessed during construction.

The slab-on-grade in open areas should be designed to tolerate frost heave, and the grading around the slab-on-grade and building structure must be such that it directs runoff away from the structures.

6.4 **Underground Services**

The subgrade for the underground services should consist of sound natural soil or properly compacted, organic-free earth fill. Where badly weathered or loose soil is encountered, it should be subexcavated and replaced with bedding material compacted to at least 95% or + of its Standard Proctor compaction.

A Class 'B' bedding is recommended for the underground services construction. The bedding material should consist of compacted 20-mm Crusher-Run Limestone, or equivalent, as approved by a geotechnical engineer. Where extensive dewatering is required in saturated soil subgrade during sewer construction, a Class 'A' bedding should be considered.

In order to prevent pipe floatation when the sewer trench is deluged with water, a soil cover at least equal in thickness to the diameter of the pipe should be in place at all times after completion of the pipe installation.

Where the sand and/or silt subgrade is encountered, the sewer joints should be leak-proof, or wrapped with a waterproof membrane. This is to prevent the infiltration of fines from the subgrade through inadvertent faulty joints. The necessity to implement these measures can best be determined during sewer construction.

Openings to subdrains and catch basins should be shielded with a fabric filter to prevent blockage by silting.

Sewer excavation must be sloped at 1 vertical:1 or + horizontal for stability. Alternatively, a trench box can be used for the construction of the sewer.

For estimation purposes for the anode weight requirements, the electrical resistivity which has been determined for the disclosed soils can be used. This, however, can be confirmed by testing the soil along the water main alignment at the time of sewer construction. Moreover, the anode weight must meet the minimum requirements specified by York Region and City of Orillia.

6.5 **Backfilling in Trenches and Excavated Areas**

The on-site inorganic soils are generally suitable to use for trench backfill. The backfill in the trenches should be compacted to at least 95% of its maximum Standard Proctor dry density. Aeration of the wet in situ soils may be required for proper compaction.

The backfill in service trenches should be compacted to at least 95% of its maximum Standard Proctor dry density. In the zone within 1.0 m below the road subgrade, the materials should be compacted with the water content 2% to 3% drier than the optimum, and the compaction should be increased to at least 98% of the respective maximum Standard Proctor dry density. This is to provide the required stiffness for pavement construction. In the lower zone, the compaction should be carried out on the wet side of the optimum; this allows a wider latitude of lift thickness. Backfill below any slab-on-grade that is sensitive to settlement must be compacted to at least 98% of its maximum Standard Proctor dry density.

In normal construction practice, the problem areas of settlement largely occur adjacent to manholes, catch basins, services crossings, foundation walls and columns. In areas which are inaccessible to a heavy compactor, imported sand backfill should be used. Unless compaction of the backfill is carefully performed, the interface of the native soils and the sand backfill will have to be flooded for a period of several days.

The narrow trenches for services crossings should be cut at 1 vertical:
2 or + horizontal so that the backfill can be effectively compacted. Otherwise, soil arching will prevent the achievement of proper compaction. The lift of each backfill layer should either be limited to a thickness of 20 cm, or the thickness should be determined by test strips.

One must be aware of the possible consequences during trench backfilling and exercise caution as described below:

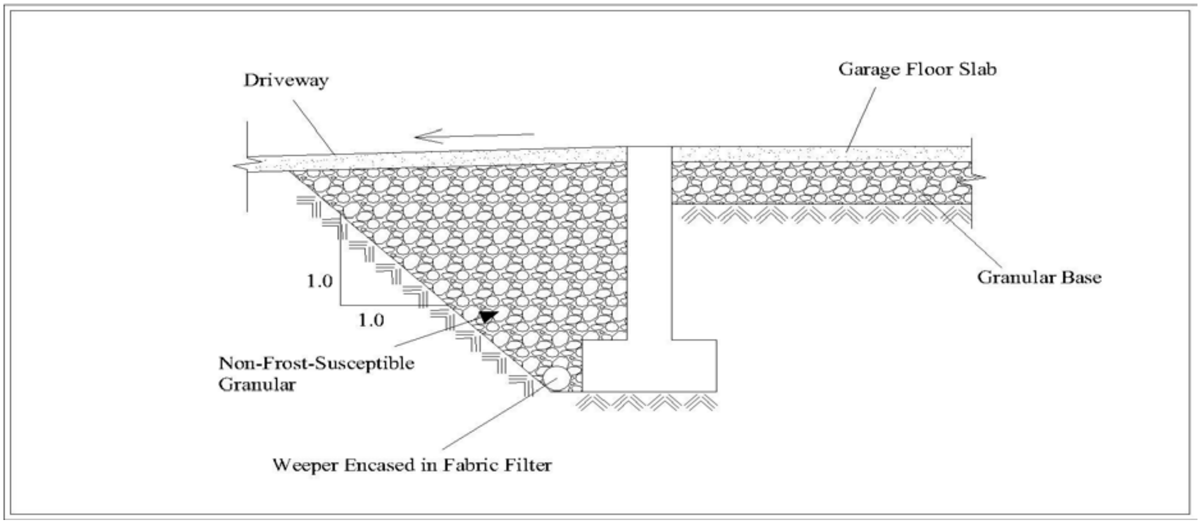
- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soil have a water content on the dry side of the optimum, it would be impossible to wet the soil due to the freezing condition, rendering difficulties in obtaining uniform and proper compaction. Furthermore, the freezing condition will prevent flooding of the backfill when it is required, such as in a narrow vertical trench section, or when the trench box is removed. The above will invariably cause backfill settlement that may become evident within 1 to several years, depending on the depth of the trench which has been backfilled.

- In areas where the underground services construction is carried out during the winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to final surfacing of the new pavement and the slab-on-grade.
- To backfill a deep trench, one must be aware that future settlement is to be expected, unless the side of the cut is flattened to at least 1 vertical:
1.5+ horizontal, and the lifts of the fill and its moisture content are stringently controlled; i.e., lifts should be no more than 20 cm (or less if the backfilling conditions dictate) and uniformly compacted to achieve at least 95% of the maximum Standard Proctor dry density, with the moisture content on the wet side of the optimum.
- It is often difficult to achieve uniform compaction of the backfill in the lower vertical section of a trench which is an open cut or is stabilized by a trench box, particularly in the sector close to the trench walls or the sides of the box. These sectors must be backfilled with sand. In a trench stabilized by a trench box, the void left after the removal of the box will be filled by the backfill. It is necessary to backfill this sector with sand, and the compacted backfill must be flooded for 1 day, prior to the placement of the backfill above this sector, i.e., in the upper sloped trench section. This measure is necessary in order to prevent consolidation of inadvertent voids and loose backfill which will compromise the compaction of the backfill in the upper section. In areas where groundwater movement is expected in the sand fill mantle, anti-seepage collars should be provided.

6.6 Garages, Driveways, Interlocking Stone Pavement and Landscaping

The driveways at the entrances to the garages can be backfilled with non-frost-susceptible granular material, with a frost taper at a slope of 1 vertical:1 horizontal. The recommended scheme is illustrated in Diagram 1.

Diagram 1 - Frost Protection Measures (Garage)



Interlocking stone pavement, slab-on-grade and landscaping structures in areas which are sensitive to frost-induced ground movement, such as in front of building entrances, must be constructed on a free-draining, non-frost-susceptible granular material such as Granular 'B'. This material must extend to at least 0.3 to 1.2 m below the slab or pavement surface, depending on the degree of tolerance of ground movement, and be provided with positive drainage, such as weeper subdrains connected to manholes or catch basins. Alternatively, the landscaping structures, slab-on-grade and interlocking stone pavement should be properly insulated with 50-mm Styrofoam, or equivalent.

The grading around structures must be such that it directs runoff away from the structures.

6.7 **Pavement Design**

The recommended pavement design for the access roads and driveways is presented in Table 4.

Table 4 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder	60	HL-8
Granular Base	150	OPSS Granular 'A' or equivalent
Granular Sub-base Local Collector	 350 450	OPSS Granular 'B' or equivalent

In preparation of the pavement subgrade, topsoil must be removed and final subgrade must be proof-rolled. Any soft spots, as identified, should be subexcavated, sorted free of any concentrated topsoil, if encountered, aerated and properly compacted or replaced with uniformly compacted inorganic earth fill.

The granular bases should be compacted to their maximum Standard Proctor dry density.

In the zone within 1.0 m below the pavement subgrade, the backfill should be compacted to at least 98% of its maximum Standard Proctor dry density, with the water content at 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered adequate.

The subgrade will suffer a strength regression if water is allowed to saturate the mantle. The following measures should, therefore, be incorporated in the construction procedures and road design:

- If the road construction does not immediately follow the trench backfilling, the subgrade should be properly crowned and smooth-rolled to allow interim precipitation to be properly drained.
- Lot areas adjacent to the roads should be properly graded to prevent ponding of large amounts of water. Otherwise, the water will seep into the subgrade mantle and induce a regression of the subgrade strength with costly consequences for the pavement construction.
- Curb subdrains will be required on both sides of the roadway. The subdrains should consist of filter-sleeved weepers to prevent blockage by silting.
- If the pavement is to be constructed during wet seasons and extensively soft subgrade occurs, the granular sub-base should be thickened in order to compensate for the inadequate strength of the subgrade. This can be assessed during construction.

6.8 Stormwater Management Pond

A detailed design of the Stormwater Management Pond (SWM) pond, was not available at the time of report preparation. Based on the Conceptual Development Plan prepared by MHBC Planning Urban Design & Landscape Architecture, it is understood that a SWM pond is proposed at the northeast corner of the property at the vicinity of Borehole 4, where the soil stratigraphy consists of silty sand till and sandy silt till material with a trace to some clay and a trace of gravel. Groundwater was recorded at a depth of 2.3 m below the prevailing ground surface in this borehole, on August 5, 2016.

Depending on the design grades, the pond will likely be constructed by excavating into the till strata. Where the sides or bottom of the pond consist of significant strata of sand and silt, an impermeable geosynthetic membrane or a clay liner should be provided as a water barrier. The thickness of the clay liner or surchange above the geosysthetic membrane should also be capable to overcome the hydrostatic pressure at the bottom of the liner as recorded in the monitoring wells. The clay liner should be compacted to 98% of its maximum Standard Proctor dry density.

The coefficients of permeability and the recommended infiltration rates for the design of the pond are presented in Table 5.

Table 5 - Coefficients of Permeability and Infiltration Rates

Soil	Coefficient of Permeability (cm/sec)	Percolation Time (min/cm)
Silty Sand Till	10^{-5}	15±
Sandy Silt Till	10^{-6}	10±

The estimated infiltration rates are based on the grain size distribution of soil samples and are provided for reference only. In situ infiltration tests can be carried out to verify the above estimation.

The sides of the pond should be sloped at 1 vertical:4 or + horizontal below the wet perimeter and should be 1 vertical:3 or + horizontal in dry areas. All slopes must be vegetated and/or sodded to prevent runoff erosion.

For berm construction, the topsoil must be removed and the subgrade must be proof-rolled. Inorganic soil material consisting of silty clay must be used and compacted to at least 95% of its maximum Standard Proctor dry density. Berm shall be designed with a minimum top width of 2.0 m with a 3:1 maximum side slope on the outside.

The core of the berm shall be constructed with engineered fill on the basis of the recommendation in Section of 6.2 of this report.

The soil bearing capacity given in Section 6.1 can be used for the design of foundations for the control structures. The footings must be placed below the scouring depths and be provided with a minimum earth cover of 1.6 m for protection against frost damage. The inlet and outlet of the pond must be lined with gabion mats for protection against scouring.

6.9 Soil Parameters

The recommended soil parameters for the project design are given in Table 6.

Table 6 - Soil Parameters

Unit Weight and Bulk Factor	**Unit Weight (kN/m^3)**		**Estimated Bulk Factor**	
	Bulk	**Submerged**	**Loose**	**Compacted**
Sand	20.5	10.5	1.20	1.00
Silty Sand Till/ Sandy Silt Till	22.5	12.5	1.33	1.05

Lateral Earth Pressure Coefficients	**Active K_a**	**At Rest K_0**	**Passive K_p**
Compacted Earth Fill/Sand	0.40	0.52	2.00
Silty Sand Till/Sandy Silt Till	0.33	0.48	3.00

6.10 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91.

Excavations in excess of 1.2 m should be sloped at 1 vertical:1 or + horizontal for stability. For excavation purposes, the types of soils are classified in Table 7.

Table 7 - Classification of Soils for Excavation

Material	**Type**
Sound natural Tills	2
Weathered Soils, Earth Fill and drained Sand	3

In excavations, the groundwater yield from the native till deposits will be some to moderate, which can be collected to a sump pump and removed by conventional pumping.

The appropriate method of dewatering should be determined by further assessment of hydrogeological study.

The tills contain occasional cobbles and boulders. Extra effort and a properly equipped backhoe will be required for excavation. Boulders larger than 15 cm in size are not suitable for structural backfill and/or construction of engineered fill.

Prospective contractors must assess the in situ subsurface conditions prior to excavation by digging test pits to at least 0.5 m below the invert elevation. These test pits should be allowed to remain open for a period of at least 4 hours to assess the trenching conditions.

7.0 LIMITATIONS OF REPORT

It should be noted that no testing has been carried out to determine whether environmental contaminants are present in the soils. Therefore, this report deals only with the geotechnical aspects of the proposed project.

This report was prepared by Soil Engineers Ltd. for the account of High Level Construction Ltd. and for review by their designated consultants and government agencies. The material in it reflects the judgement of Preston Hsieh, B.Eng., and Bennett Sun, P.Eng., in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, is the responsibility of such Third Parties. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

SOIL ENGINEERS LTD.

Preston Hsieh, B.Eng.

Bennett Sun, P.Eng.
PH/BS:dd

LICENSED PROFESSIONAL ENGINEER
CHUN C. B. SUN
Aug 30, 2016
PROVINCE OF ONTARIO

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms commonly employed on the borehole logs and figures, and in the text of the report, are as follows:

SAMPLE TYPES

AS	Auger sample
CS	Chunk sample
DO	Drive open (split spoon)
DS	Denison type sample
FS	Foil sample
RC	Rock core (with size and percentage recovery)
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

A continuous profile showing the number of blows for each foot of penetration of a 2-inch diameter, 90° point cone driven by a 140-pound hammer falling 30 inches.

Plotted as '—•—'

Standard Penetration Resistance or 'N' Value:

The number of blows of a 140-pound hammer falling 30 inches required to advance a 2-inch O.D. drive open sampler one foot into undisturbed soil.

Plotted as '○'

WH	Sampler advanced by static weight
PH	Sampler advanced by hydraulic pressure
PM	Sampler advanced by manual pressure
NP	No penetration

SOIL DESCRIPTION

Cohesionless Soils:

'N' (blows/ft)	Relative Density
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

Cohesive Soils:

Undrained Shear Strength (ksf)	'N' (blows/ft)	Consistency
less than 0.25	0 to 2	very soft
0.25 to 0.50	2 to 4	soft
0.50 to 1.0	4 to 8	firm
1.0 to 2.0	8 to 16	stiff
2.0 to 4.0	16 to 32	very stiff
over 4.0	over 32	hard

Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0 Field vane test in borehole; the number denotes the sensitivity to remoulding

△ Laboratory vane test

□ Compression test in laboratory

For a saturated cohesive soil, the undrained shear strength is taken as one half of the undrained compressive strength

METRIC CONVERSION FACTORS

1 ft = 0.3048 metres	1 inch = 25.4 mm
1lb = 0.454 kg	1ksf = 47.88 kPa

Job Number: 1606-S168

LOG OF BOREHOLE NO.: 1

Figure No.: 1

Project Description: Proposed Residential Development

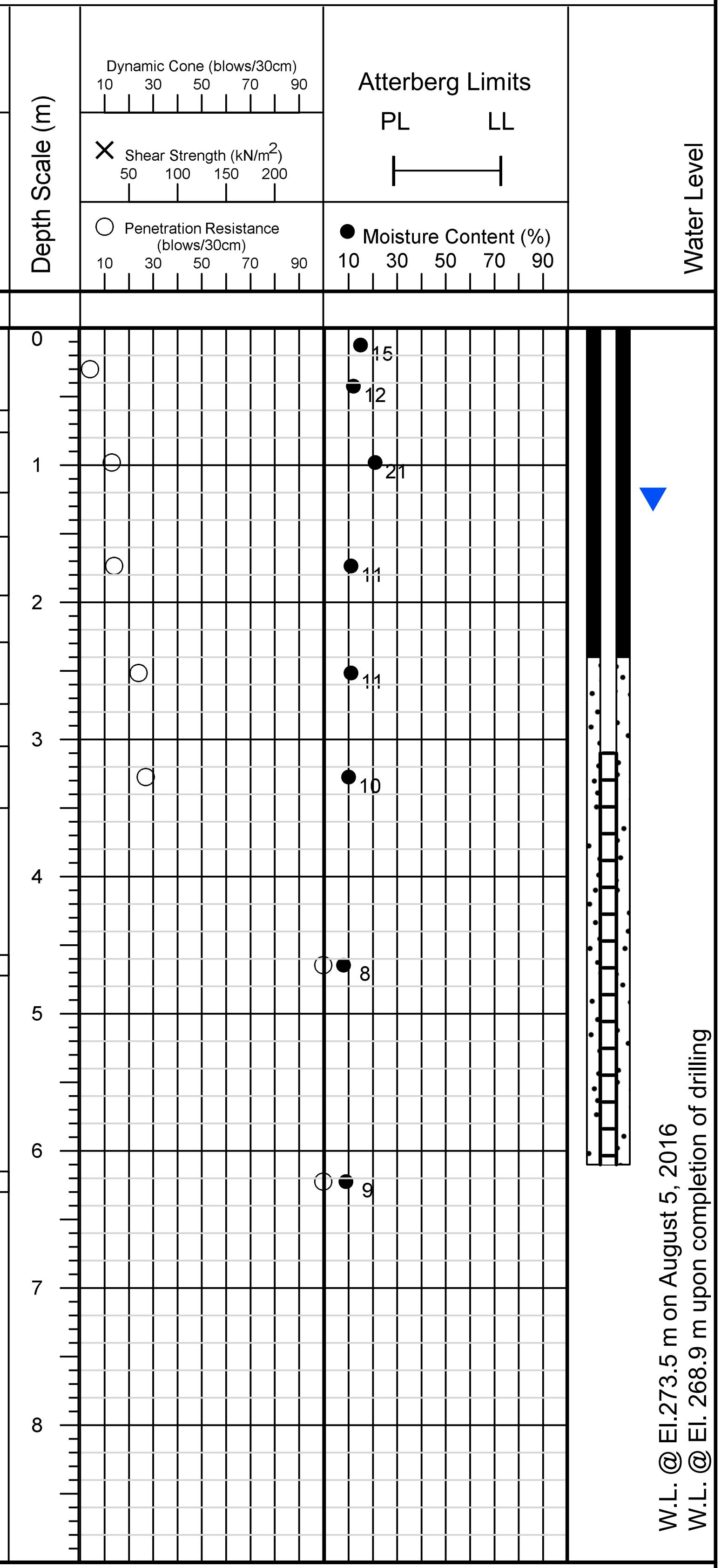
Job Location: 3879 Town Line, City of Orillia

Method of Boring: Flight-Auger

Drilling Date: July 19, 2016

Elev. (m) / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Moisture Content (%)
274.8	Ground Surface				
0.0	25 cm **TOPSOIL**	1A	DO	4	15
	Brown, very loose, weathered **SAND** fine grained	1B			12
274.1 / 0.7	Brown, compact **SILTY SAND, Till** a trace to some clay, some gravel, occ. sand and silt seams and layers, cobbles and boulders, occ. sand pockets	2	DO	13	21
		3	DO	14	11
		4	DO	24	11
271.9 / 2.9	Brown, compact to very dense **SANDY SILT, Till** a trace of clay and gravel, occ. cobbles and boulders	5	DO	27	10
	boulder				
		6	DO	100	8
		7	DO	100	9
268.5 / 6.3	End of Borehole				

Installed 50 mm dia. monitoring well to 6.1 m (3.0 m screen). Sand backfill from 2.4 m to 6.1 m. Bentonite seal from 0 to 2.4 m. Provided with steel monument casing.



W.L. @ El.273.5 m on August 5, 2016
W.L. @ El. 268.9 m upon completion of drilling

Job Number: 1606-S168

LOG OF BOREHOLE NO.: 2

Figure No.: 2

Project Description: Proposed Residential Development

Job Location: 3879 Town Line, City of Orillia

Method of Boring: Flight-Auger

Drilling Date: July 19, 2016

Elev. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Moisture Content (%)
270.6	Ground Surface				
0.0	20 cm **TOPSOIL**	1A	DO	3	28
	Brown, very loose to dense **SILTY SAND, Till** a trace to some clay some gravel occ. sand and silt seams and layers, cobbles and boulders occ. sand pockets occ. topsoil and rootlets inclusions above 0.7 m	1B			17
		2	DO	14	11
		3	DO	14	12
		4	DO	32	10
267.7 / 2.9	Very dense **SANDY SILT, Till** a trace of clay and gravel occ. cobbles and boulders; sand and rock frag.; brown / grey	5	DO	100	7
		6	DO	100	7
		7	DO	100	5
		8	DO	100	7
262.8 / 7.8	End of Borehole. Installed 50 mm dia. monitoring well to 7.4 m (3.0 m screen). Sand backfill from 3.8 m to 6.1 m. Bentonite seal from 0 to 3.8 m. Provided with steel monumount casing.				

Depth Scale (m): 0 – 8

Dynamic Cone (blows/30cm): 10 30 50 70 90

Shear Strength (kN/m²): 50 100 150 200

Penetration Resistance (blows/30cm): 10 30 50 70 90

Atterberg Limits: PL LL

Moisture Content (%): 10 30 50 70 90

Water Level: W.L. @ El. 267.5 m on August 5, 2016. Dry upon completion of drilling

SOIL ENGINEERS LTD.

Job Number: 1606-S168

LOG OF BOREHOLE NO.: 3

Figure No.: 3

Project Description: Proposed Residential Development

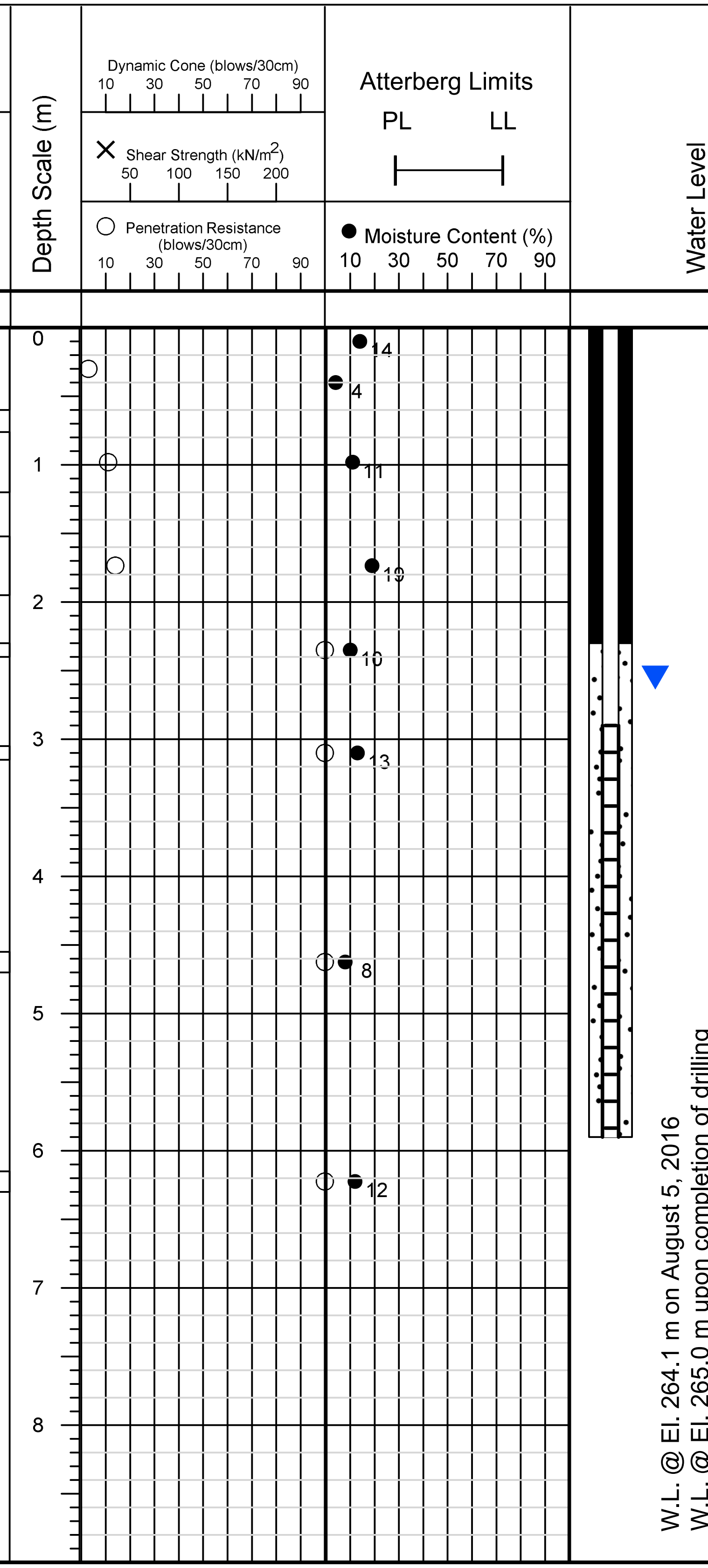
Job Location: 3879 Town Line, City of Orillia

Method of Boring: Flight-Auger

Drilling Date: July 19, 2016

Elev. (m) / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value
266.7	Ground Surface			
0.0	20 cm **TOPSOIL**	1A		
	Brown, very loose, weathered **SAND** fine grained	1B	DO	3
266.0 / 0.7	Brown, compact to very dense **SILTY SAND, Till** a trace to some clay, some gravel, occ. sand and silt seams and layers, cobbles and boulders, occ. sand pockets; sand and rock frag.	2	DO	11
		3	DO	14
		4	DO	100
263.8 / 2.9	Very dense **SANDY SILT, Till** a trace of clay and gravel, occ. cobbles and boulders; brown / grey	5	DO	100
		6	DO	100
		7	DO	100
260.4 / 6.3	End of Borehole			

Installed 50 mm dia. monitoring well to 5.9 m (3.0 m screen). Sand backfill from 2.3 m to 5.9 m. Bentonite seal from 0 to 2.3 m. Provided with steel monument casing.



Job Number: 1606-S168

LOG OF BOREHOLE NO.: 4

Figure No.: 4

Project Description: Proposed Residential Development

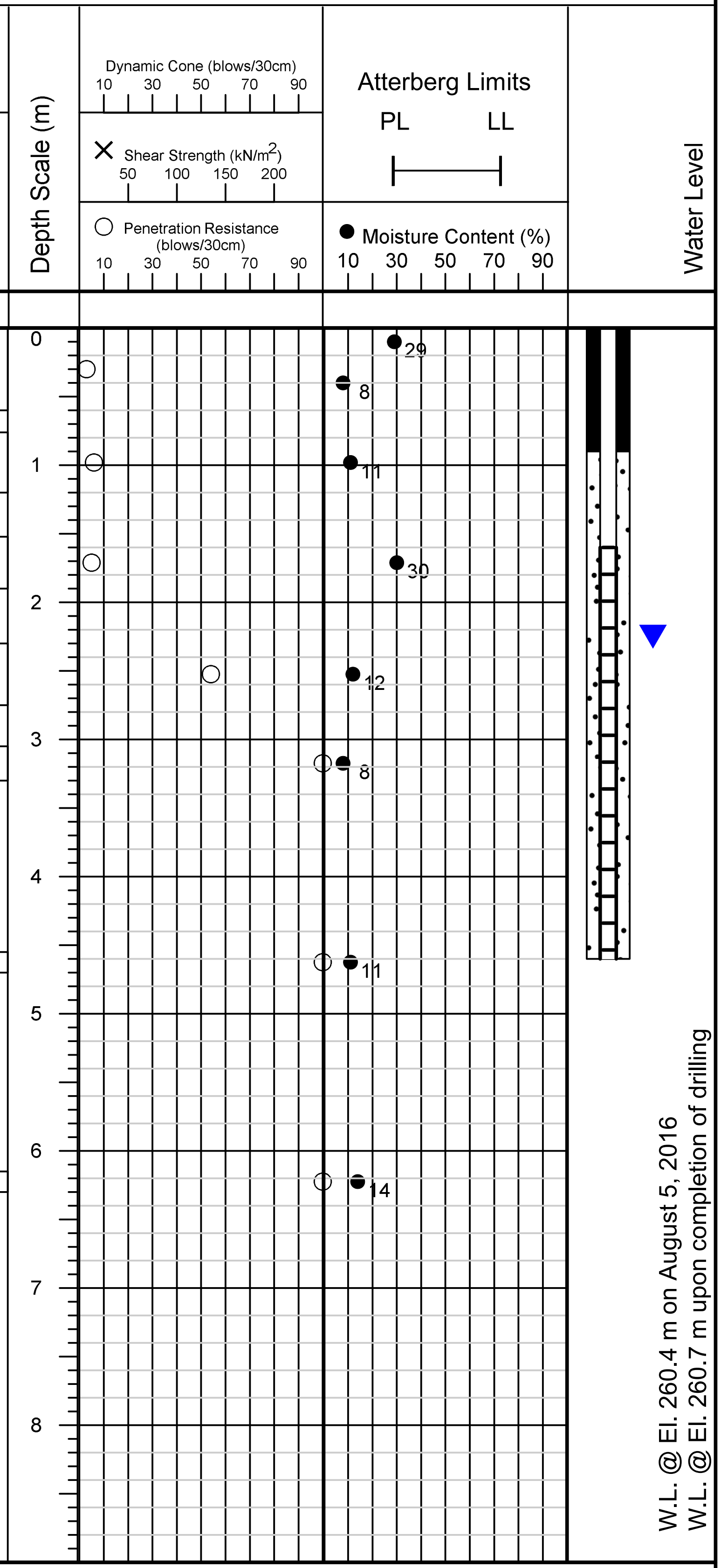
Job Location: 3879 Town Line, City of Orillia

Method of Boring: Flight-Auger

Drilling Date: July 19, 2016

Elev. (m) / Depth (m)	SOIL DESCRIPTION
262.7	Ground Surface
0.0	20 cm **TOPSOIL** Brown, very loose to loose, weathered **SAND** fine grained above 0.7 m, fine to coarse grained below 0.7 m
261.4 / 1.3	Brown, loose to very dense weathered **SILTY SAND, Till** a trace to some clay some gravel occ. sand and silt seams and layers, cobbles and boulders occ. sand pockets
259.0 / 3.7	brown / grey Very dense **SANDY SILT, Till** a trace of clay and gravel occ. cobbles and boulders
256.4 / 6.3	End of Borehole Installed 50 mm dia. monitoring well to 4.6 m (3.0 m screen). Sand backfill from 0.9 m to 4.6 m. Bentonite seal from 0 to 0.9 m. Provided with steel monument casing.

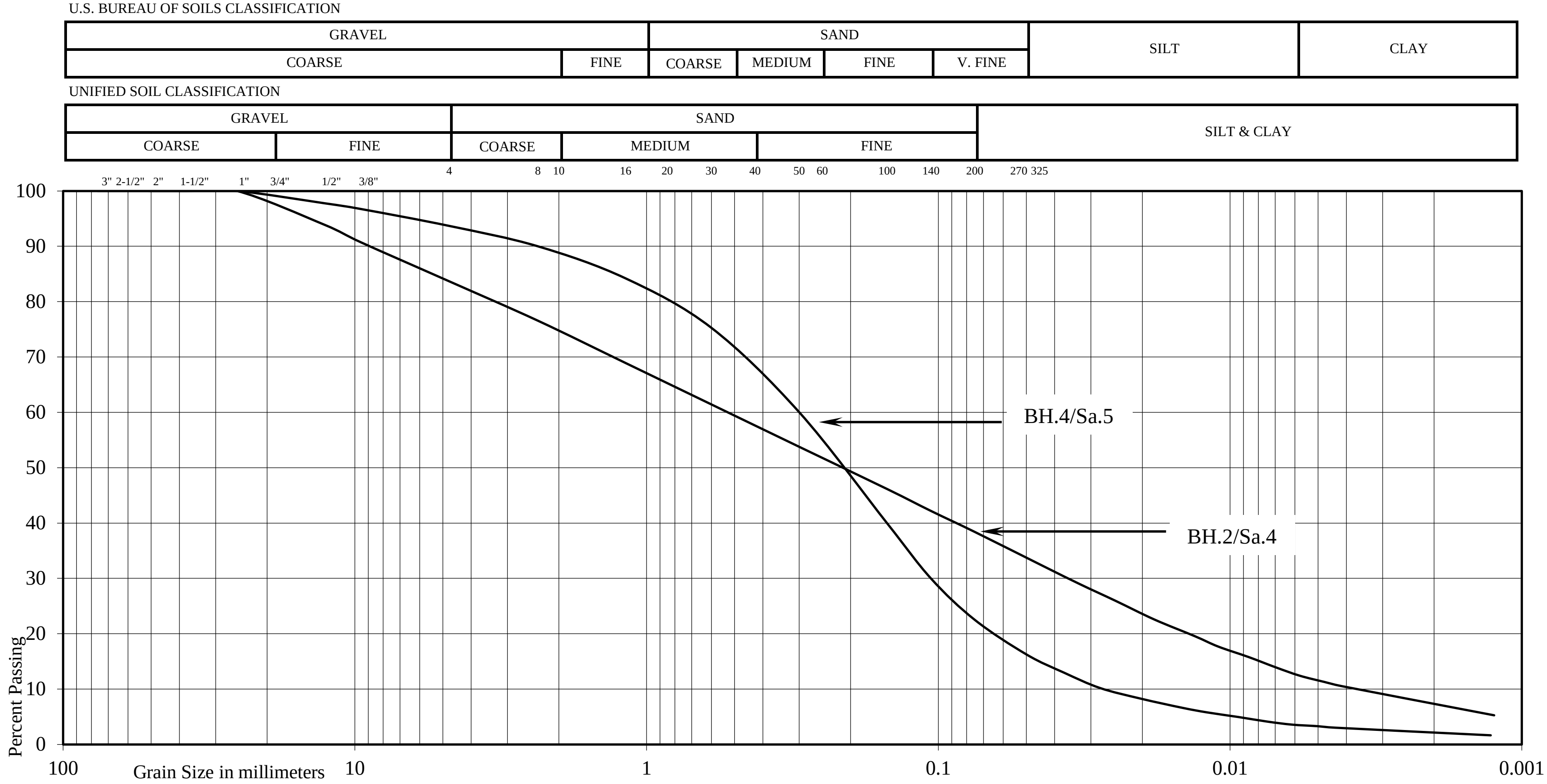
SAMPLES Number	Type	N-Value
1A	DO	3
1B		
2	DO	6
3	DO	5
4	DO	54
5	DO	100
6	DO	100
7	DO	100



Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1606-S168

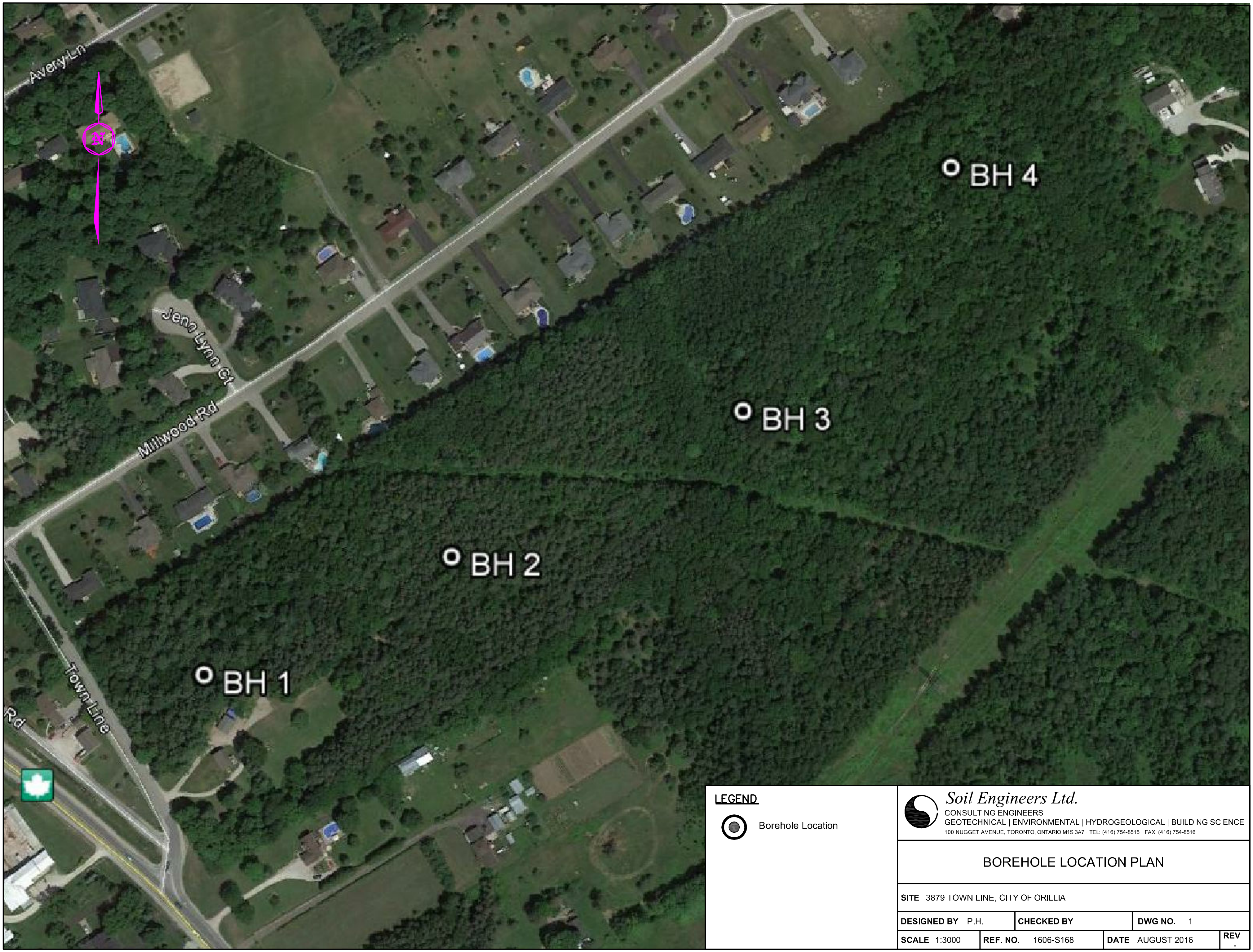


Project:	Residential Development	
Location:	38796 Town Line, City of Orillia	
Borehole No:	2	4
Sample No:	4	5
Depth (m):	2.5	3.2
Elevation (m):	268.1	259.5

BH./Sa.	2/4	4/5
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	10	8
Estimated Permeability (cm./sec.) =	10^{-5}	10^{-5}

Classification of Sample [& Group Symbol]: SAND, Till
trs. of clay and gravel

Figure: 5



LEGEND

Borehole Location

Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE
100 NUGGET AVENUE, TORONTO, ONTARIO M1S 3A7 · TEL: (416) 754-8515 · FAX: (416) 754-8516

BOREHOLE LOCATION PLAN

SITE 3879 TOWN LINE, CITY OF ORILLIA					
DESIGNED BY P.H.		CHECKED BY		DWG NO. 1	
SCALE 1:3000	REF. NO. 1606-S168		DATE AUGUST 2016		REV -

Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE

Subsurface Profile
Drawing No. 2
Scale: As Shown

Job Number: 1606-S168
Report Date: August 2016
Job Location: 3879 Town Line, City of Orillia

Project Description: Proposed Residential Development