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A REPORT TO
2491837 ONTARIO LTD.

A GEOTECHNICAL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

BETTY BOULEVARD AND SHORE LANE

TOWN OF WASAGA BEACH

REFERENCE NO. 1704-S066

JUNE 2017

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1.0 **INTRODUCTION**

In accordance with written authorization dated April 12, 2017, from Mr. Ary VanderMeer of 2491837 Ontario Ltd., a geotechnical investigation was carried out at a parcel of land located between Betty Boulevard and Shore Lane, in the Town of Wasaga Beach, for a proposed Residential Development.

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

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

2.0 SITE AND PROJECT DESCRIPTION

The west portion of the Town of Wasaga Beach is situated in the Simcoe Lowlands, bordering the Niagara Escarpment where lacustrine sand, silt and clay deposits, and glacial tills have bedded onto undulated Black River and Trenton Group of bedrock.

The investigated site, situated between Betty Boulevard and Shore Lane, in the Town of Wasaga Beach, is a vacant parcel with dense trees and bushes. The existing ground is relatively level, with undulations.

The proposed project consists of the construction of a new residential subdivision, provided with municipal services and roadways meeting current municipal standards.

3.0 FIELD WORK

The field work, consisting of 9 boreholes to depths of 5.0 to 6.6 m, was performed on May 4 and 8, 2017, at the locations shown on the Borehole Location Plan, Drawing No. 1.

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.

The sampling depths and the depths of the soil strata changes were referred to the prevailing ground surface at each of the borehole locations.

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

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 9, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing No. 2, and the engineering properties of the disclosed soils are discussed herein.

The investigation has revealed that beneath a veneer of topsoil and a layer of earth fill in places, the site is underlain by a stratum of glacial till with embedded layers of silty clay.

4.1 **Topsoil** (All Boreholes, except Boreholes 6 and 8)

Boreholes 6 and 8 were located beside a trail connecting to Betty Boulevard. The ground surface at these locations was bald, without vegetation or topsoil. The revealed topsoil at the other borehole locations was 10 to 36 cm thick. It is dark brown in colour, indicating 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. Due to its humus content, it may produce volatile gases and generate an offensive odour under anaerobic conditions. Therefore, the topsoil must not be buried below any structures or deeper than 1.2 m below the finished grade, so that it will not have an adverse impact on the environmental well-being of the developed areas.

Since the topsoil is considered void of engineering value, it can only be used for general landscaping and landscape contouring purposes. A fertility analysis can be carried out to determine the suitability of the topsoil as a planting material.

4.2 **Earth Fill** (Boreholes 4, 6, 7, 8 and 9)

An earth fill was contacted at the ground surface or below the topsoil. It extended to depths of 0.6 m and 0.7 m below the prevailing ground surface. The fill consists of sand or silty sand, with gravel, cobbles, rock fragments and occasional topsoil inclusions.

The obtained 'N' values range from 2 to 15, with a median of 8 blows per 30 cm of penetration, indicating that the fill was loosely placed. Its relative density is non-uniform and is unsuitable to support any structure sensitive to settlement.

The natural water content values range from 8% to 22%, with a median of 16%, indicating that the fill is in a moist to wet, generally wet condition, which corresponds with our sample examinations.

For structural use, the existing earth fill must be subexcavated, inspected, sorted free of topsoil inclusions and any deleterious material, if detected, and properly compacted.

One must be aware that the samples retrieved from boreholes 10 cm in diameter may not be truly representative of the geotechnical and environmental quality of the fill, and do not indicate whether the topsoil beneath the earth fill was completely stripped. This should be further assessed by laboratory testing and/or test pits.

4.3 **Silty Clay Till** (All Boreholes) **and Silty Clay** (Boreholes 2, 3, 5 and 6)

The silty clay till was generally encountered at the upper zone of the stratigraphy. It consists of a random mixture of soils; the particle sizes range from clay to gravel, with the clay fraction exerting the dominant influence on its soil properties. Occasional sand and silt seams and layers were also detected in the clay till mantle. The till is amorphous and heterogeneous in structure, indicating that it is a glacial deposit and has generally been reworked by the past glaciation.

At Boreholes 2, 3, 5 and 6, a silty clay deposit was contacted below the silty clay till. It is laminated with sand and silt seams and layers, showing that it is a glacio lacustrine deposit.

The obtained 'N' values range from 5 to 29, with a median of 11 blows per 30 cm of penetration, indicating that the consistency of the clay till is firm to very stiff, being generally stiff, confirming that the till has generally been reworked by the past glaciation. The consistency of the silty clay is soft to firm, being generally firm as shown by the 'N' values ranging from 3 to 7, with a median of 7 blows per 30 cm.

The Atterberg Limits of 1 representative sample of the clay till, 1 representative sample of the silty clay, and the natural water content values of all the samples were determined; the results are plotted on the Borehole Logs and summarized below:

	Clay Till	Silty Clay
Liquid Limit	43%	46%
Plastic Limit	22%	23%
Natural Water Content	8% to 25% (median 11%)	22% to 33% (median 24%)

The results show that the clay and clay till are cohesive materials with medium plasticity. The natural water content generally lies below the plastic and liquid limits, confirming the generally firm or stiff consistency of the soils as determined by the ‘N’ values.

Grain size analyses were performed on 1 representative sample each of the clay till and the silty clay. The results are plotted on Figures 10 and 11, respectively.

Based on the above findings, the soil engineering properties pertaining to the project are given below:

- High frost susceptibility and high soil-adfreezing potential.
- Low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-7} cm/sec, an estimated percolation rate of over 80 min/cm, and runoff coefficients of:

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

- Cohesive soils, their shear strength is primarily derived from consistency which is inversely related to its moisture content. They contains sand; therefore, their shear strength is augmented by internal friction.
- The soft clay is susceptible to consolidation under a surcharge load exceeding 50 kPa.
- In steep cuts, the firm clay till and clay will slough readily, and a cut face in the sound clay may collapse as the wet silt slowly sloughs.
- Bottom heaving will likely occur in trenches cut steeply into the soft clay below 4 m.

- Poor pavement-supportive materials, with an estimated CBR value of 3%.
- High to moderately high corrosivity to buried metal, with an estimated electrical resistivity of 2000 to 2500 ohm·cm.

4.4 **Silty Sand Till/Sandy Silt Till** (All Boreholes, except Borehole 6)

The sand till or silt till was encountered at various depths and extends to the maximum investigated depth at the boreholes where it was encountered. The tills consist of a random mixture of soil particle sizes ranging from clay to gravel, with the silt and sand being the dominant fraction. They are heterogeneous in structure, showing a glacial deposit.

Frequent hard resistance to augering was encountered, showing that appreciable amounts of cobbles and boulders are embedded in the till deposits

The natural water content value of the samples was determined, and the results are plotted on the Borehole Logs; the values range from 6% to 20%, with a median of 8%, showing the till is in a moist to wet, generally moist condition.

The obtained ‘N’ values range from 5 blows per 30 cm to 50 blows per 15 cm, with a median of 35 blows per 30 cm of penetration, showing that its relative density is loose to very dense, being generally dense.

Grain size analyses were performed on 2 sand till samples and the results are plotted on Figure 12.

The deduced engineering properties pertaining to the project are given below:

- High frost susceptibility and moderate water erodibility.

- Moderately impervious, depending on the clay content, with an estimated coefficient of permeability of 10^{-5} to 10^{-6} cm/sec, an estimated percolation rate of about 50 min/cm, and runoff coefficients of:

Slope			
0% - 2%	0.11	to	0.15
2% - 6%	0.16	to	0.20
6% +	0.23	to	0.28

- A frictional soils, their shear strength is primarily derived from internal friction and is augmented by cementation. Therefore, their strength is density dependent.
- They will be stable in steep cuts; however, under prolonged exposure, immediate sloughing and sheet collapse will likely occur, particularly where seepage occurs.
- Fair pavement-supportive materials with an estimated CBR value of 8%.
- Moderately 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 +**
Earth Fill	8 to 22 (median 16)	11	7 to 16
Silty Clay/Clay Till	8 to 33 (median 24)	22	17 to 26
Silty Sand Till and Sandy Silt Till	6 to 20 (median 8)	10	6 to 15

Based on the above findings, the on-site material is generally suitable for a 95% or + Standard Proctor compaction, whereas, the wet material will require aeration in dry and warm weather prior to structural compaction. The earth fill must be sorted free of topsoil inclusions and deleterious materials prior to use as structural fill.

The silty clay and tills should be compacted using a heavy-weight, kneading-type roller. The lifts for compaction should be limited to 20 cm, or to a suitable thickness as assessed by test strips performed by the equipment which will be used at the time of construction.

When compacting the cemented till on the dry side of the optimum, the compactive energy will frequently bridge over the chunks in the soil and be transmitted laterally in the soil mantle. Therefore, the lifts of these soils 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 pavement 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 pavement 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 foundation 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 in the tills 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 during augering was recorded on the field logs. The level of groundwater and the occurrence of cave-in were measured upon completion of the boreholes; the data are plotted on the Borehole Logs and listed in Table 2.

Table 2 - Groundwater Levels

BH No.	**Borehole Depth (m)**	**Soil Colour Changes Brown to Grey**	**Seepage Encountered During Augering**		**Measured Groundwater/ Cave-In* Level On Completion**	
		Depth (m)	**Depth (m)**	**Amount**	**Depth (m)**	**El. (m)**
1	6.6	2.3	1.7	Slight	5.9	-
2	5.0	2.1	2.1	Slight	Dry	-
3	6.3	4.0	2.2	Slight	5.9	-
4	5.0	2.3	-	-	Dry	-
5	6.6	2.3	4.0	Slight	Dry	-
6	5.0	4.0	4.6	Slight	Dry	-
7	6.6	2.3	-	-	Dry	-
8	6.3	1.4	-	-	Dry	-
9	5.0	2.3	-	-	4.0	-

Groundwater was detected at depths of 4.0 m and 5.9 m at three of the boreholes; all other boreholes remained dry upon completion of field work. The groundwater represents a perched water in wet sand seams. It will fluctuate with the seasons.

The soil colour changes from brown to grey at depths ranging from 1.4 to 4.0 m below the prevailing ground surface. The brown colour indicates that the soils have oxidized.

In excavations, the groundwater yield is anticipated to be small and limited. It can be drained to a sump pit and removed by conventional pumping.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has disclosed that beneath a veneer of topsoil and a layer of earth fill in places, the site is underlain by strata of firm to very stiff, generally stiff silty clay till and loose to very dense, generally dense sandy silt till and silty sand till, with layers of soft to firm, generally firm silty clay.

Groundwater was detected at depths of 4.0 m and 5.9 m at three of the boreholes; all other boreholes remained dry upon completion of field work. The groundwater represents a perched water in wet sand seams. It will fluctuate with the seasons.

The geotechnical findings which warrant special consideration are presented below:

1. The existing trees must be removed and the topsoil must be stripped for the project construction. The topsoil will generate volatile gases under anaerobic conditions and is unsuitable for engineering applications. Therefore, it should be placed in the landscaped areas only and should not be buried within the building envelope, or deeper than 1.2 m below the exterior finished grade of the project.
2. The earth fill in its present condition is not capable of supporting any structures susceptible to settlement. It must be upgraded to structural status by sorting it free of serious topsoil inclusions and deleterious material and by proper compaction.
3. The sound, natural soils are suitable for normal spread and strip footing construction. Due to the presence of topsoil and earth fill, the footing subgrade must be inspected by either 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. The project site is underlain by strata of soft to firm silty clay or till at various depths and locations, caution must be exercised in the construction of the project where excessive earth fill or over 2 m will be placed for site grading.
5. The soft silty clay will consolidate under surcharge loads. Where the site grade will be raised by more than 2 m, a preloading scheme incorporating the proposed building load and the surcharge load will be required. The amount of fill required for the preloading must be assessed once the site grading plans and the details of houses have been determined. Settlement plates should be installed to monitor the degree of consolidation of the underlying soils prior to the construction of the project. The suitable time of commencing the project construction should be carefully monitored by settlement plates to ensure that the consolidation of the soft clay is completed.
6. For slab-on-grade construction, the slab should be placed on sound soil or properly compacted earth fill. Any loose soil or soft areas in the subgrade must be subexcavated and replaced with inorganic material compacted to 98% or + Standard Proctor dry density.
7. A Class 'B' bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The sewer joints should be leak-proof, or wrapped with an appropriate waterproof membrane to prevent subgrade migration.
8. The revealed soils are frost susceptible, with high soil-adfreezing potential. Where these soils are used to backfill against foundation walls, special measures must be incorporated into the building construction to prevent serious damage due to soil adfreezing.
9. Excavation into the very dense till containing boulders will 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.
10. Bottom heaving will likely occur in trenches cut steeply to depths of more than 5.0 m into the soft clay. Therefore, the spoil from the excavations should be

placed at a distance from the edge of the excavation at least equal to 3 times the depth of the excavation, and the sides should be cut at 1 vertical: 2 or + horizontal.

11. It is advised that the contractor be requested to record the occurrences of soft clay during trenching. This information can be used to forewarn the house builders to exercise caution in footing construction.

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 house footings for the proposed project must be placed below the topsoil, earth fill and onto the sound native soils. The recommended soil pressures and suitable founding levels are presented in Table 3.

Table 3 - Founding Levels

	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Suitable Founding Level	
	75 kPa (SLS) 120 kPa (ULS)	**150 kPa (SLS) 250 kPa (ULS)**
BH No.	**Depth (m)**	**Depth (m)**
1	1.0 to 4.0 *	4.0 or +
2	1.0 to 4.5*	4.5 or +
3	1.0 to 4.5*	4.5 or +
4	1.0 to 4.5	4.5 or +

Table 3 – Founding Levels (Cont'd)

	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Suitable Founding Level	
	75 kPa (SLS) 120 kPa (ULS)	**150 kPa (SLS) 250 kPa (ULS)**
BH No.	**Depth (m)**	**Depth (m)**
5	1.0 to 4.5*	4.5 or +
6	1.0 or +	-
7	1.0 to 4.5	4.5 or +
8	-	1.0 or +
9	-	1.0 or +

* Due to the soft or firm clay and clay till the Designed Bearing Pressures should be reduced to 50 kPa (SLS) and 80 kPa (ULS) below the founding depth of 2 m from the prevailing ground surface

The recommended soil pressures (SLS) incorporate a safety factor of 3. The total and differential settlements of the foundations are estimated to be 40 mm and 25 mm, respectively.

The footing subgrade should be inspected by either a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that the revealed conditions are compatible with the foundation design requirements.

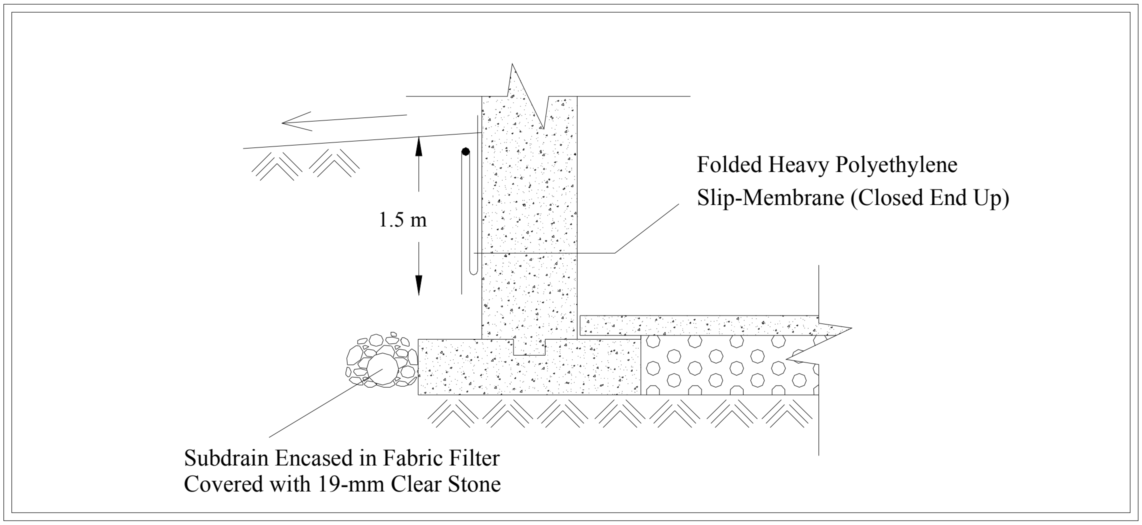
Foundations exposed to weathering or in unheated areas should be protected against frost action by a minimum of 1.5 m of earth cover, or must be properly insulated.

Where a basement is contemplated, perimeter subdrains and dampproofing of the foundation walls will be required. All the subdrains must be encased in a fabric filter to protect them against blockage by silting, and must be connected to a positive outlet.

Where soft clay is present, it will consolidate under a surcharge load exceeding 50 kPa. In case the site will be raised by more than 2 m of earth fill, the site should be pregraded with an engineered fill, and a pre-loading scheme incorporating the proposed building load and finished grade load should be carried out. While settlement will typically occur for about 4 to 6 months after placement of the surcharge fill, the suitable time for commencing the project construction should be carefully monitored by settlement plates to ensure that the consolidation of the soft clay is complete. The surcharge load for the preloading program can be determined when the site grading and the underside of footing for the buildings are available.

The occurring soils are high in frost heave and soil-adfreezing potential. If these soils are to be used for the foundation backfill, the foundation walls should be shielded by a polyethylene slip-membrane for protection against soil adfreezing. The membrane will allow vertical movement of the heaving soil (due to frost) without imposing structural distress on the foundations. The recommended measures are schematically illustrated in Diagram 1.

Diagram 1 - Frost Protection Measures (Foundations)



The necessity to implement the above recommendations should be further assessed by a geotechnical engineer at the time of construction.

The foundations must meet the requirements specified by the latest Ontario Building Code, and the buildings must be designed to resist a minimum earthquake force using Site Classification 'D' (stiff soil).

6.2 **Engineered Fill**

Where earth fill is required to raise the site or where extended footings are necessary, the engineering requirements for a certifiable fill for road construction, municipal services, slab-on-grade, and footings designed with a Maximum Allowable Soil Pressure (SLS) of 75 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 120 kPa, are presented below:

1. The topsoil must be removed. The loose earth fill must be subexcavated. The subgrade must be inspected and surface proof-rolled.
2. Inorganic soils must be used, 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. 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, it should be inorganic soils, free of deleterious material with environmental issue (contamination). Any potential imported earth fill from off-site must be reviewed for geotechnical and environmental quality by the appropriate personnel as authorized by the developer or agency, before hauling to the site.

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 finished elevations must be clearly and accurately defined in the field, and 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 (about 25 mm) between the natural soil 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 fill is to be placed on a bank steeper than 1 vertical:3 horizontal, the face of the bank must be flattened to 3 + so that it is suitable for safe operation of the compactor and the required compaction can be obtained.
8. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement, particularly if it is to be carried out on sloping ground.
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 supervised 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 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 may 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.
13. Due to the presence of soft clay, the engineered fill must be left in place for a period of time prior to the start of any construction. This must be confirmed by the installation of settlement plates to ensure that the consolidation of the very soft to soft clay and clay till is completed prior to the start of the construction.

6.3 Slab-On-Grade

The subgrade should be inspected and assessed by proof-rolling prior to slab-on-grade construction. Where loose or soft soil is detected, it should be subexcavated and replaced with inorganic material uniformly compacted to 98% or + of its maximum Standard Proctor dry density.

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.

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 20 MPa/m can be used for the design of the floor slab. If the subgrade is wet, a vapour barrier must be placed below the granular base of the floor slab to prevent upfiltration of moisture that may wet the slab surface.

The ground around the buildings must be graded to direct water away from the structure to minimize the frost heave phenomenon generally associated with the disclosed soils.

The requirements for the above measures can be further assessed during construction.

6.4 **Underground Services**

The subgrade for the underground services should consist of natural soils or compacted organic-free earth fill. Where topsoil, earth fill and soft subgrade are encountered, these materials must be subexcavated and replaced with properly compacted bedding material.

A Class ‘B bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The pipe joints should be leak-proof or wrapped with an appropriate waterproof membrane to prevent subgrade migration.

Where the subgrade consists of soft soils, it should be subexcavated and replaced by the bedding material.

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

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

Since the silty clay has high to moderately high corrosivity to buried metal, the water main should be protected against corrosion. In determining the mode of protection, an electrical resistivity of 2000 ohm·cm should be used. This, however, should be confirmed by testing the soil along the water main alignment at the time of sewer construction.

6.5 **Trench Backfilling**

The on-site inorganic soils are suitable for trench backfill. 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 moisture content 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered to be adequate; however, the material must be compacted on the wet side of the optimum.

Below the floor slab, the backfill must be compacted to 98% or + of its Standard Proctor dry density.

In normal underground services construction practice, the problem areas of road settlement largely occur adjacent to manholes, catch basins, services crossings, foundation walls and columns, and it is recommended that a sand backfill 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 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 soils have a water content on the dry side of the optimum, it would be impossible to wet the soils 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 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 construction.
- 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, seepage collars should be provided.

6.6 Garages, Driveways and Interlocking Stone Pavement

Due to the high frost susceptibility of the underlying soils, heaving of the pavement is expected to occur during the cold weather.

The driveways at the entrances to the garages should be backfilled with non-frost-susceptible granular material, with a frost taper at a slope of 1 vertical:1 horizontal.

Interlocking stone pavement in areas which are sensitive to frost-induced ground movement, such as entrances, must be constructed on a free-draining, non-frost-susceptible granular material such as Granular 'B'. It must extend to 0.3 to 1.2 m below the slab or pavement surface, depending on the tolerance for ground movement, and be provided with positive drainage such as weeper subdrains connected to manholes or catch basins. Alternatively, the sidewalks and the interlocking stone pavement should be properly insulated with 50-mm Styrofoam, or equivalent, as approved by a geotechnical engineer.

The grading around the structures must be sloped such that surface runoff is directed away from the structures.

6.7 Pavement Design

Based on the borehole findings, the recommended pavement design for local roads is presented in Table 4.

Table 4 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder Local Collector	 50 75	HL-4
Granular Base	150	Granular 'A' or equivalent
Granular Sub-base	300	Granular 'B' or equivalent

In preparation of the subgrade, the fine-graded surface should be proof-rolled; any soft subgrade, organics and deleterious materials within 1.0 m below the underside of the granular sub-base should be subexcavated and replaced by properly compacted organic-free earth fill.

All 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 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered adequate.

The road subgrade will suffer a strength regression if water is allowed to infiltrate prior to paving. 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 the ponding of large amounts of water during the interim construction period.
- Curb subdrains will be required. The subdrains should consist of filter-sleeved weepers to prevent blockage by silting.
- If the roads are to be constructed during the wet seasons and extensively soft subgrade occurs, the granular sub-base may require thickening. This can be assessed during construction.

6.8 Soil Parameters

The recommended soil parameters for the project design are given in Table 5.

Table 5 - Soil Parameters

Unit Weight and Bulk Factor	**Unit Weight (kN/m^3)**	**Estimated Bulk Factor**	
	Bulk	**Loose**	**Compacted**
Earth Fill	20.5	1.25	1.00
Silty Clay	21.5	1.30	1.00
Sound Tills	22.0	1.33	1.05

Lateral Earth Pressure Coefficients	**Active K_a**	**At Rest K_o**	**Passive K_p**
Compacted Earth Fill/Silty Clay	0.45	0.60	2.20
Tills	0.35	0.50	3.00

6.9 Preloading Scheme

The overburden for a grade raise of 2 m or more will consolidate the underlying soft silty clay; therefore, if the site is raised for the construction of the project, it is recommended that the construction of the project should not be carried out until at least 6 months after placement of fill, or for a period as determined by settlement plates. The depth of fill required for preloading can be determined once the site grading plan and details of the house foundations are available.

6.10 Excavation

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

For excavation purposes, the types of soils are classified in Table 6.

Table 6 - Classification of Soils for Excavation

Material	Type
Sound Tills	2
Firm Till, Silty Clay and Earth Fill	3
Soft Clay	4

Excavation into the very dense till containing boulders will require extra effort and the use of a heavy-duty, properly equipped backhoe.

Bottom heaving will likely occur in trenches cut steeply to depths of more than 5.0 m into the soft clay. Therefore, the spoil from the excavations should be placed at a distance from the edge of the excavation at least equal to 3 times the height of the excavation, and the sides should be cut at 1 vertical:2 or + horizontal.

The groundwater yield in excavations will be small and limited and can be controlled by pumping from sumps.

Prospective contractors must be asked to assess the in situ subsurface conditions for soil cuts by digging test pits to at least 0.5 m below the intended bottom of excavation. 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

This report was prepared by Soil Engineers Ltd. for the account of 2491837 Ontario Ltd., and for review by their designated agents, financial institutions, and government agencies. Use of the report is subject to the conditions and limitations of the contractual agreement. The material in the report reflects the judgment of Frank Lee, P.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, and/or any reliance on decisions to be made based on it are 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.

Frank Lee, P.Eng.

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FL/BL:cy

LICENSED PROFESSIONAL ENGINEER
CHUN C. B. SUN
June 13, 2017
PROVINCE OF ONTARIO

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6/13/2017
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26894506
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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
1lb = 0.454 kg
1 inch = 25.4 mm
1ksf = 47.88 kPa

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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

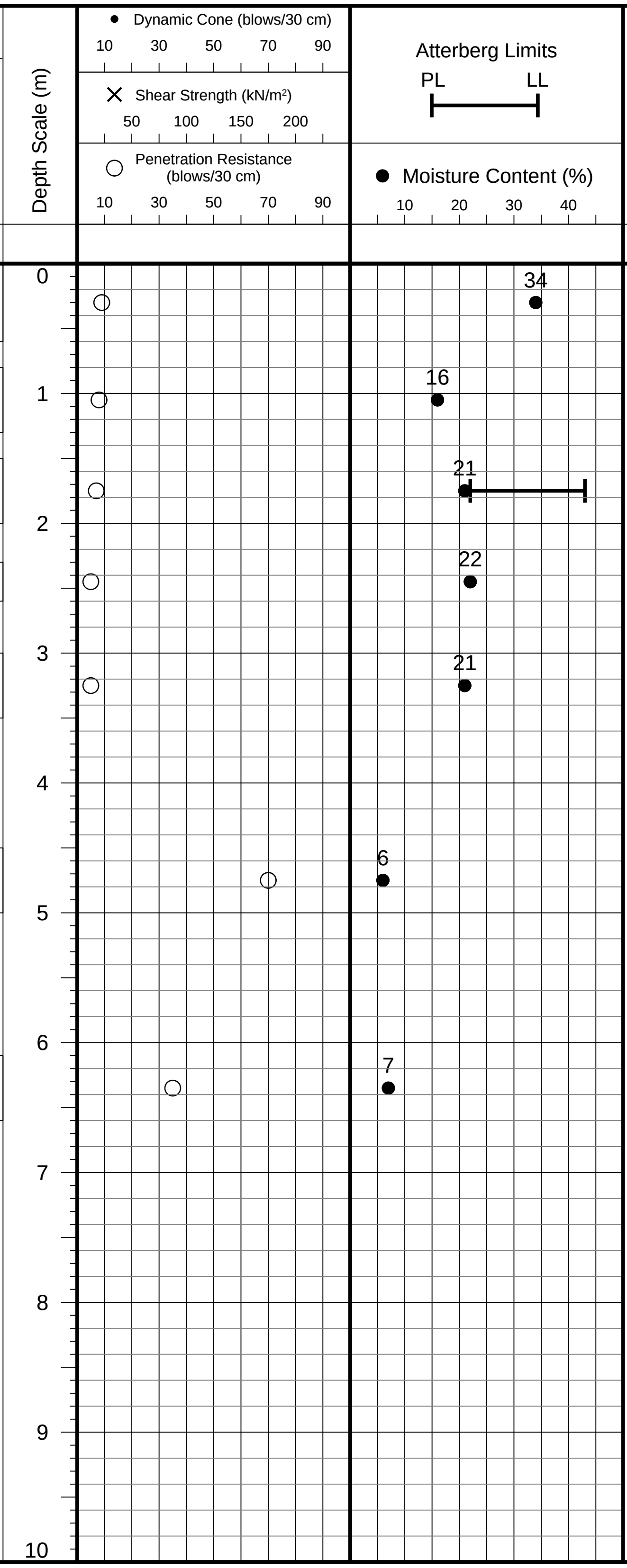
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
0.0	Ground Surface			
0.0	**30 cm TOPSOIL**	1A	DO	9
0.3	Brown, firm to stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	1B		
		2	DO	8
		3	DO	7
	brown grey	4	DO	5
		5	DO	5
4.0	Grey, dense to very dense **SILTY SAND TILL** occ. wet sand and silt seams and layers, cobbles and boulders	6	DO	70
		7	DO	35
6.6	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ a depth of 5.9 m on completion

JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

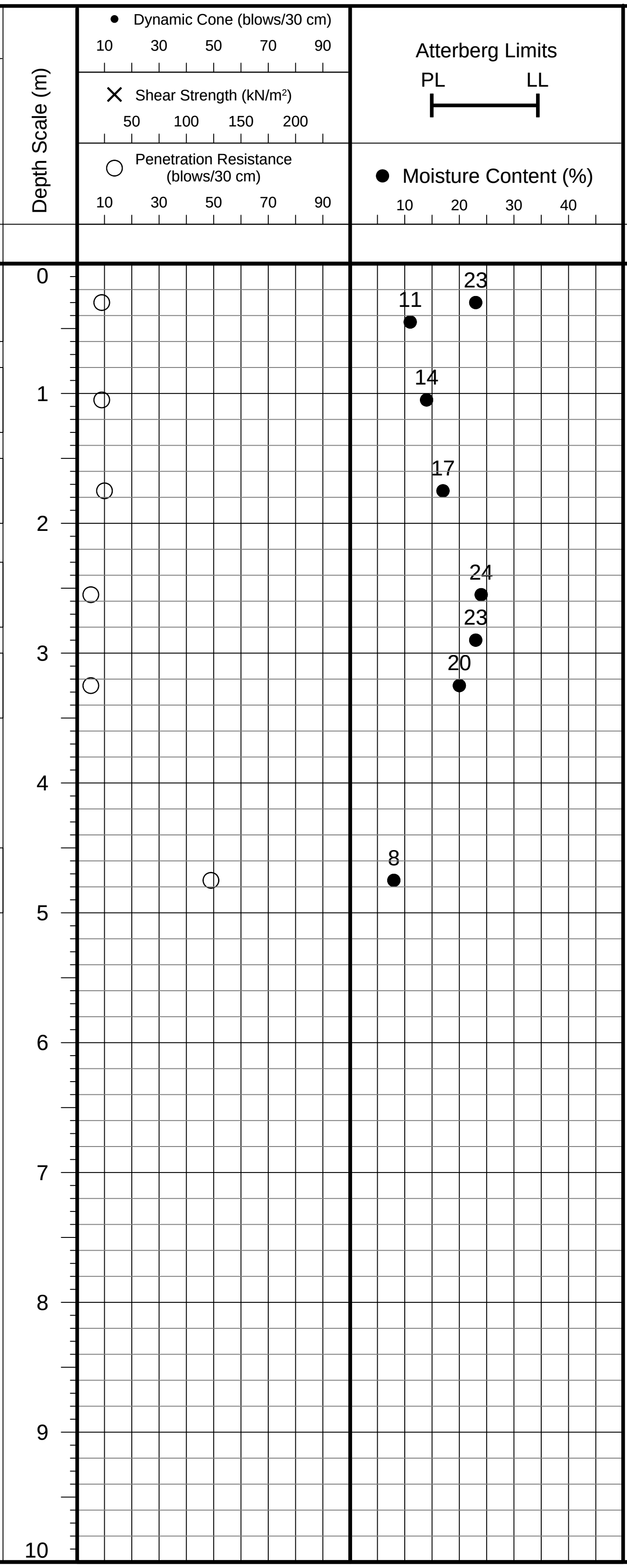
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
0.0	Ground Surface				
0.0	**36 cm TOPSOIL**	1A	DO	9	
0.4	Brown, stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	1B			
		2	DO	9	
		3	DO	10	
2.1	Grey, firm **SILTY CLAY**	4	DO	5	
		5A	AS		
3.0	Grey, loose to dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	5B	DO	5	Dry on completion
		6	DO	49	
5.0	**END OF BOREHOLE**				



JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

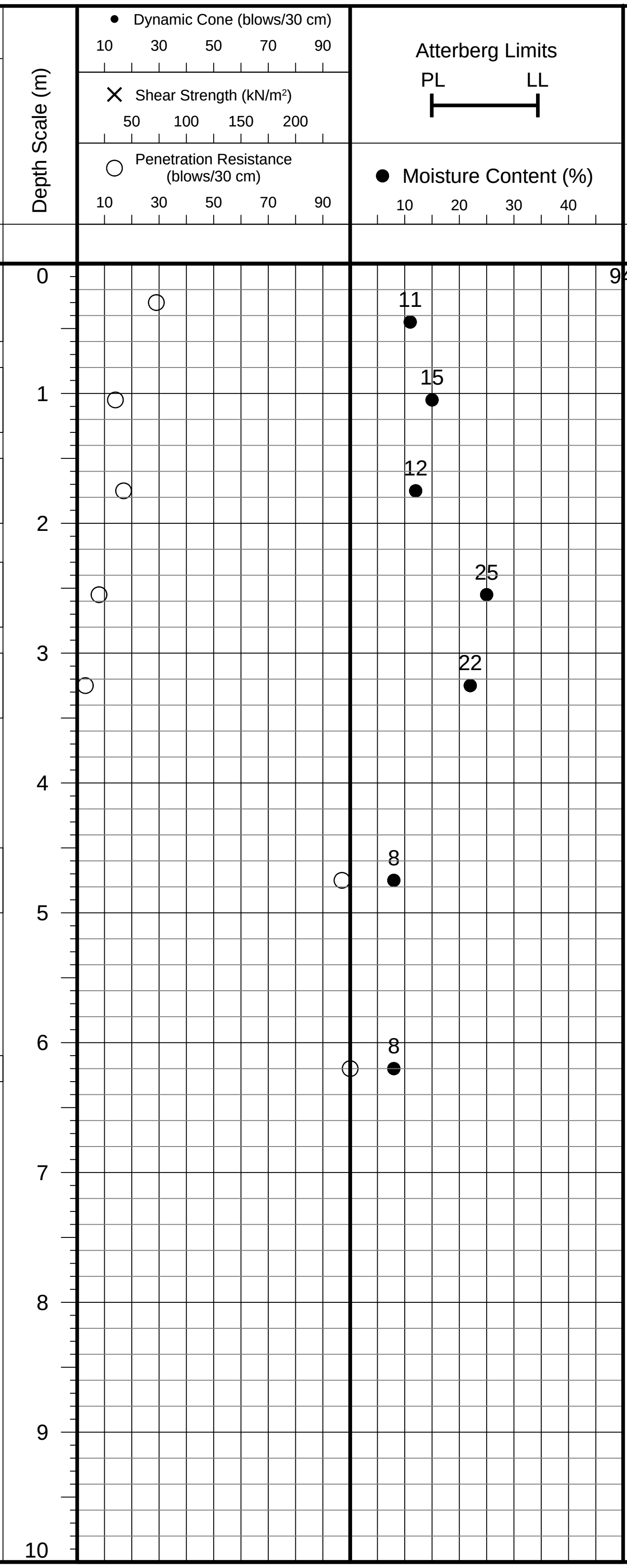
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
0.0	Ground Surface			
0.0	**10 cm TOPSOIL**	1A	DO	29
	Brown, firm to very stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	1B		
		2	DO	14
		3	DO	17
		4	DO	8
2.9	Brown, soft **SILTY CLAY**	5	DO	3
4.0	Grey, very dense **SILTY SAND TILL** occ. wet sand and silt seams and layers, cobbles and boulders	6	DO	97
		7	DO	50/15
6.3	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ a depth of 5.9 m on completion

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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

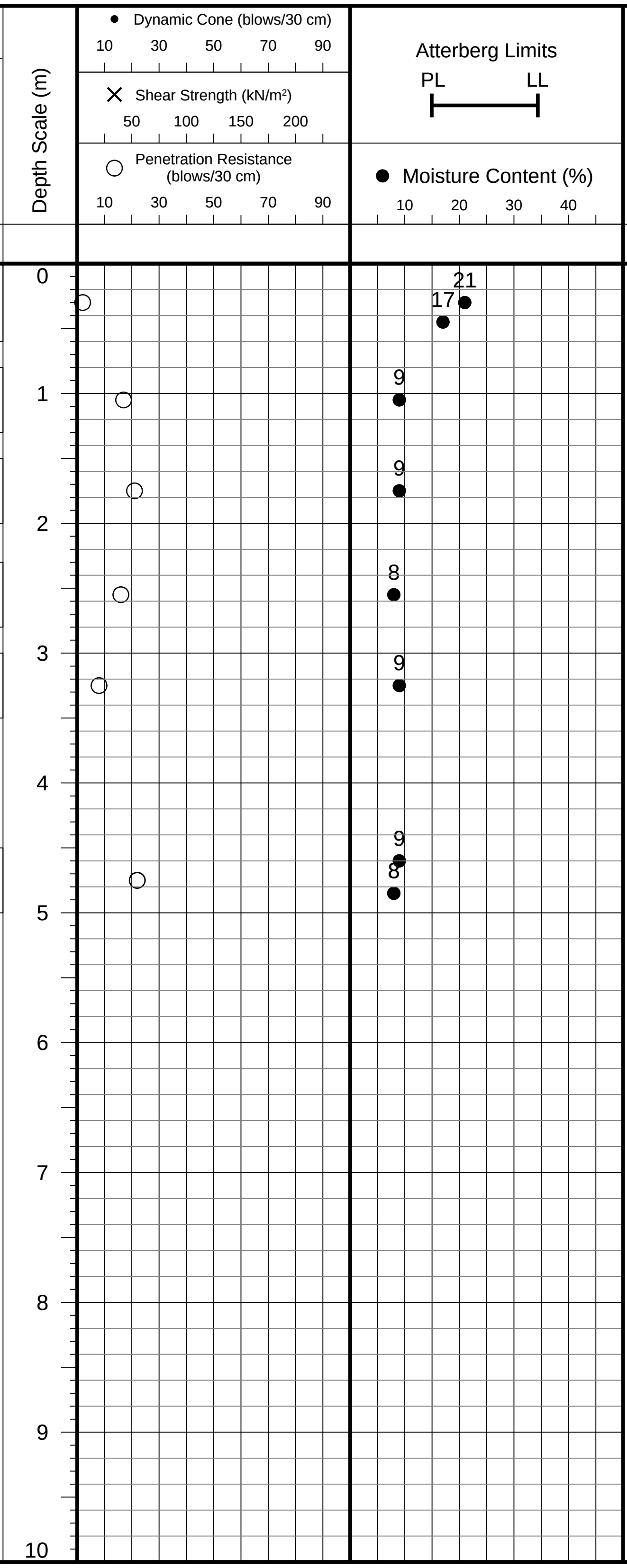
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value	WATER LEVEL
0.0	Ground Surface				
0.0	**36 cm TOPSOIL**	1A	DO	2	Dry on completion
	Brown **EARTH FILL** silty sand	1B			
0.6	Brown, compact **SILTY SAND TILL**	2	DO	17	
1.4	Firm to very stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders — brown / grey	3	DO	21	
		4	DO	16	
		5	DO	8	
4.0	Grey, compact **SILTY SAND TILL**	6A	DO	22	
		6B			
5.0	**END OF BOREHOLE**				



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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

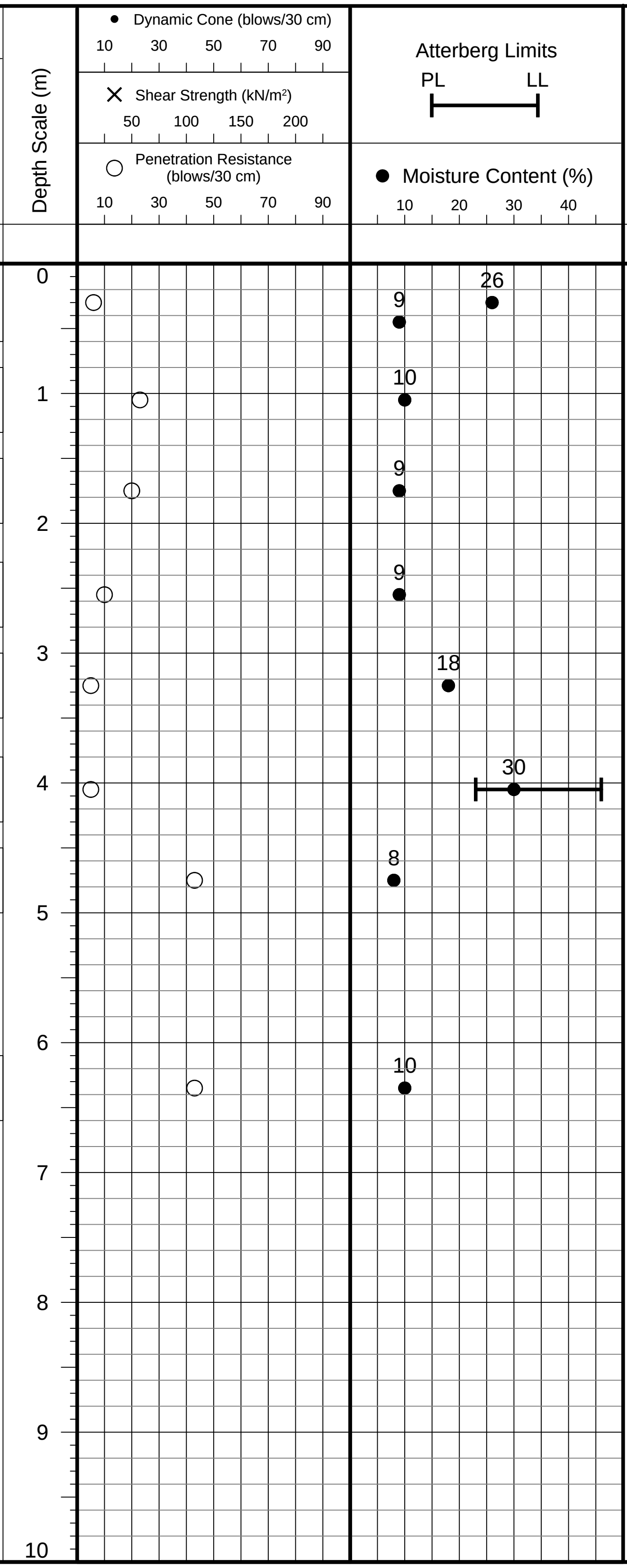
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
0.0	Ground Surface				
0.0	**36 cm TOPSOIL**	1A	DO	6	Dry on completion
0.4	Brown, loose, weathered **SANDY SILT TILL**	1B			
0.7	Firm to very stiff	2	DO	23	
	SILTY CLAY TILL occ. wet sand and silt seams and layers, cobbles and boulders	3	DO	20	
	brown grey	4	DO	10	
		5	DO	5	
3.7	Grey, firm **SILTY CLAY**	6	DO	5	
4.4	Grey, dense	7	DO	43	
	SILTY SAND TILL occ. wet sand and silt seams and layers, cobbles and boulders	8	DO	43	
6.6	**END OF BOREHOLE**				



JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

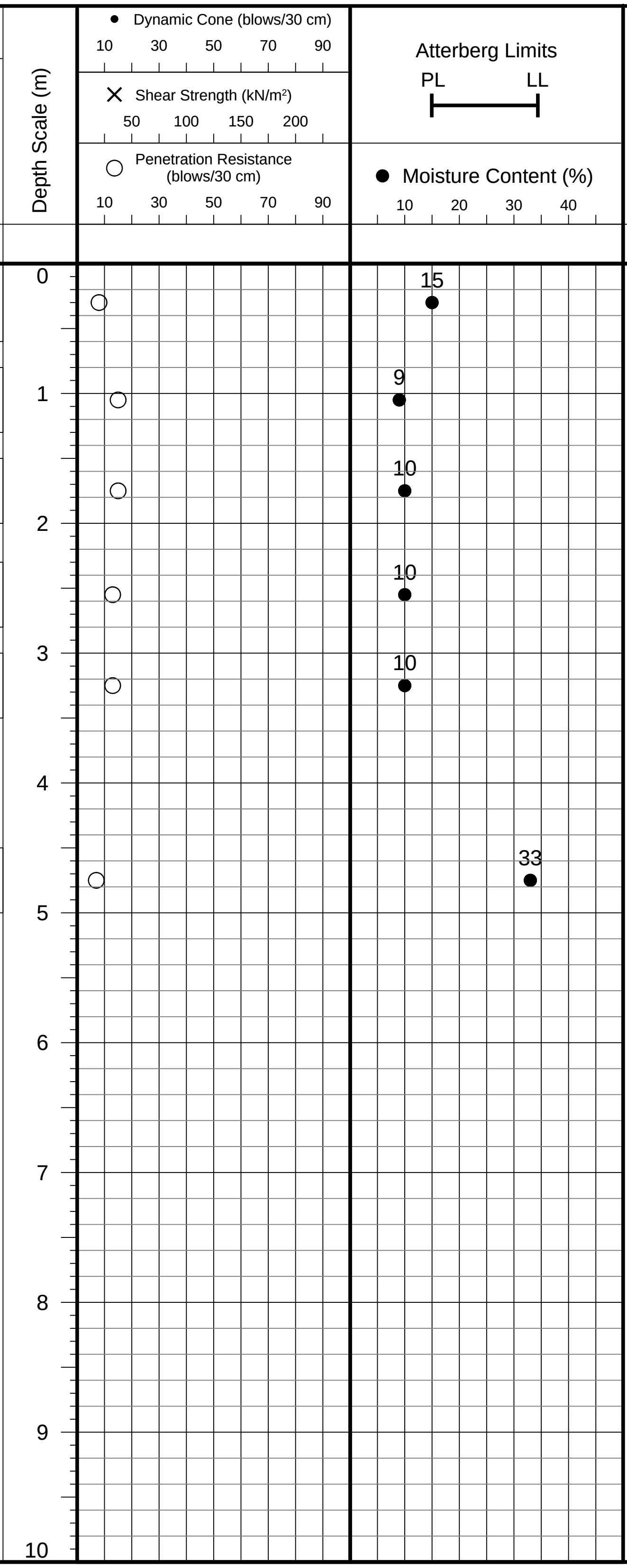
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 4, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0	Ground Surface			
0.0	Brown **EARTH FILL** sand with gravel and cobbles occ. topsoil inclusions	1	DO	8
0.7	Brown, stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	2	DO	15
		3	DO	15
		4	DO	13
		5	DO	13
4.0	Grey, firm **SILTY CLAY**	6	DO	7
5.0	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

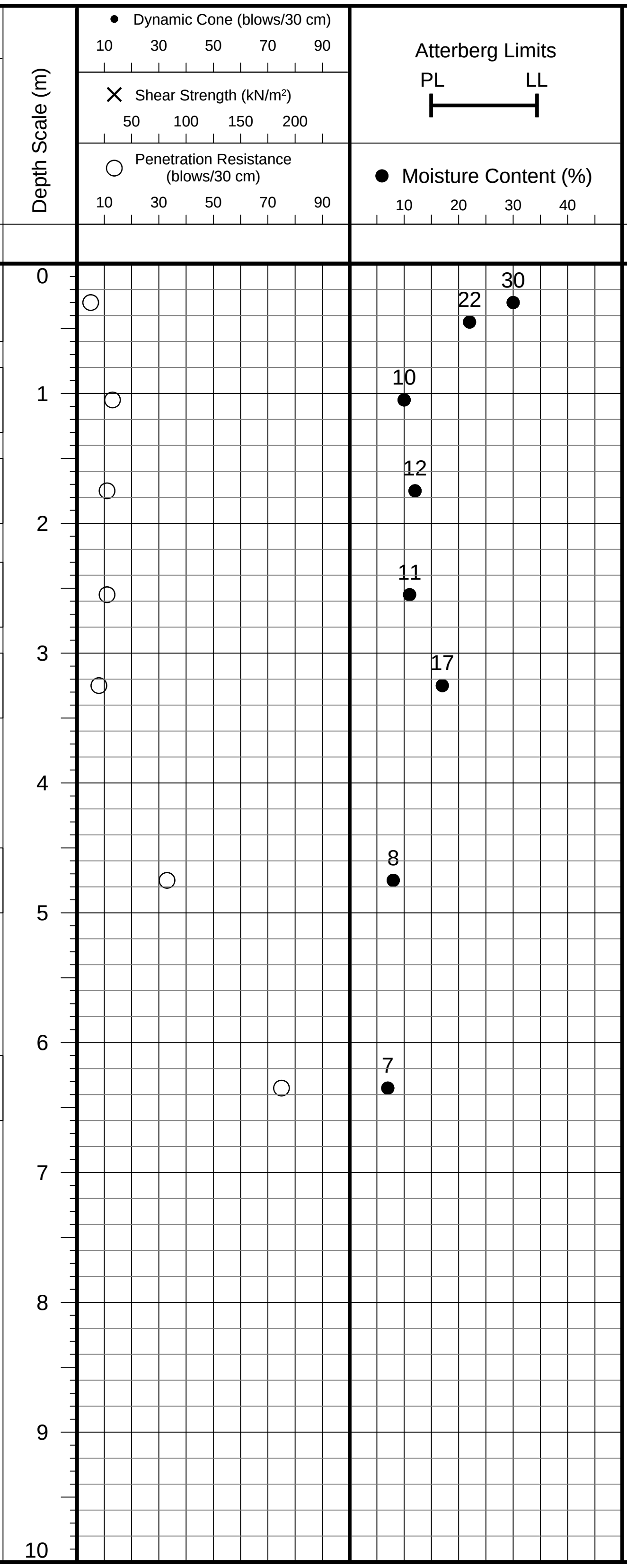
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 8, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
0.0	Ground Surface				
0.0	**30 cm TOPSOIL**	1A	DO	5	Dry on completion
	Brown **EARTH FILL** sand with gravel and cobbles	1B			
0.7	Firm to stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders — brown/grey	2	DO	13	
		3	DO	11	
		4	DO	11	
		5	DO	8	
4.0	Grey, dense to very dense **SILTY SAND TILL** occ. wet sand and silt seams and layers, cobbles and boulders	6	DO	33	
		7	DO	75+	
6.6	**END OF BOREHOLE**				



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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

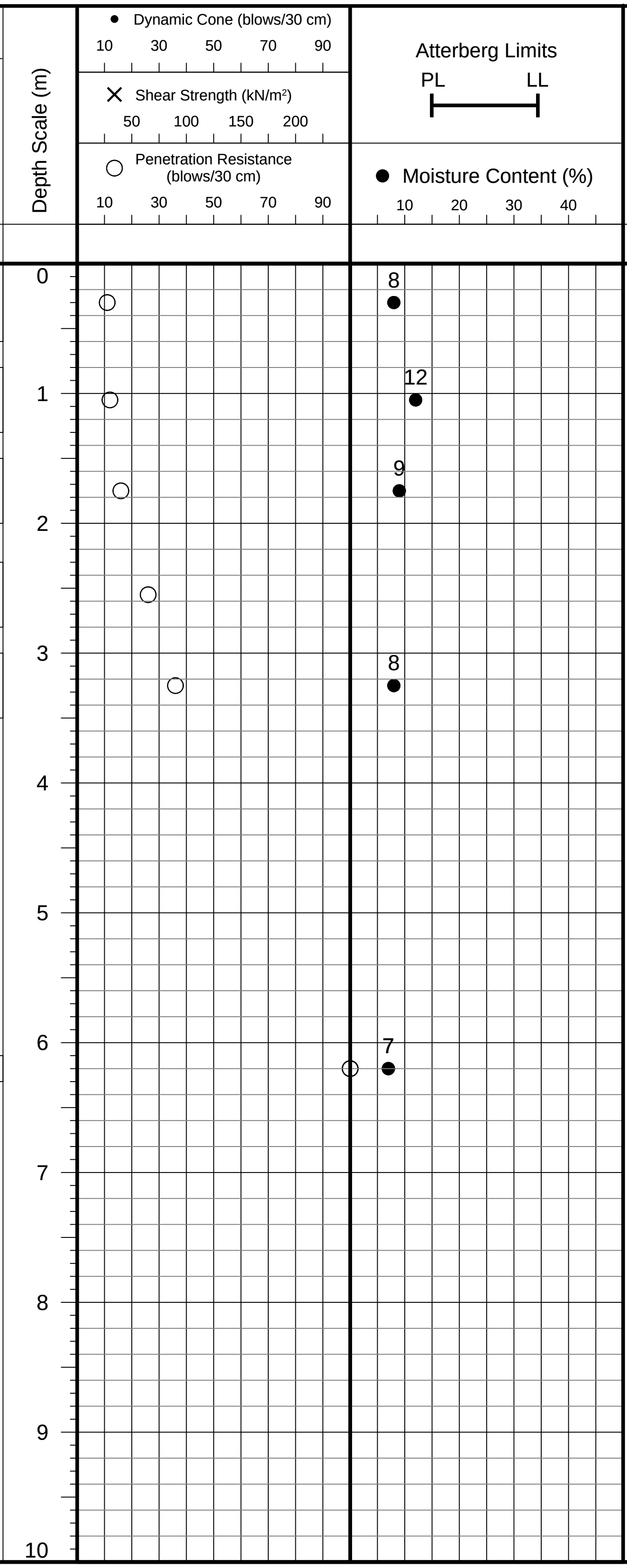
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 4, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES			WATER LEVEL
		Number	Type	N-Value	
0.0	Ground Surface				
0.0	Brown **EARTH FILL** sand with gravel, rock fragments occ. topsoil inclusions	1	DO	11	Dry on completion
0.7	Brown, stiff **SILTY CLAY TILL**	2	DO	12	
1.4	Grey, compact to very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	3	DO	16	
		4	DO	26	
		5	DO	36	
		6			
		7	DO	50/15	
6.3	**END OF BOREHOLE**				



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JOB NO.: 1704-S066

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

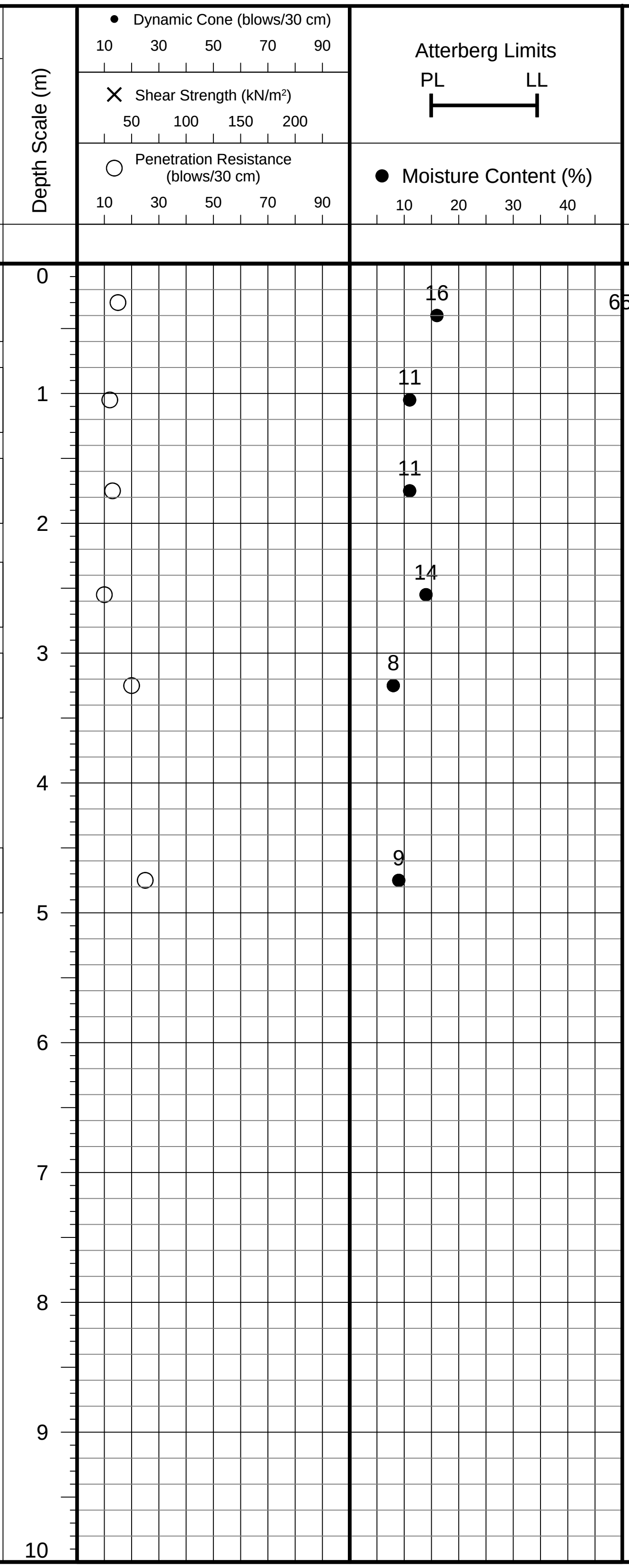
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Hollow Stem

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

DRILLING DATE: May 4, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0	Ground Surface			
0.0	**10 cm TOPSOIL**	1A	DO	15
0.1	Brown **EARTH FILL** sand with gravel and cobbles	1B	AS	
0.7	Stiff **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	2	DO	12
		3	DO	13
	brown grey	4	DO	10
2.9	Grey, compact **SILTY SAND TILL** occ. wet sand and silt seams and layers, cobbles and boulders	5	DO	20
		6	DO	25
5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ a depth of 4.0 m on completion

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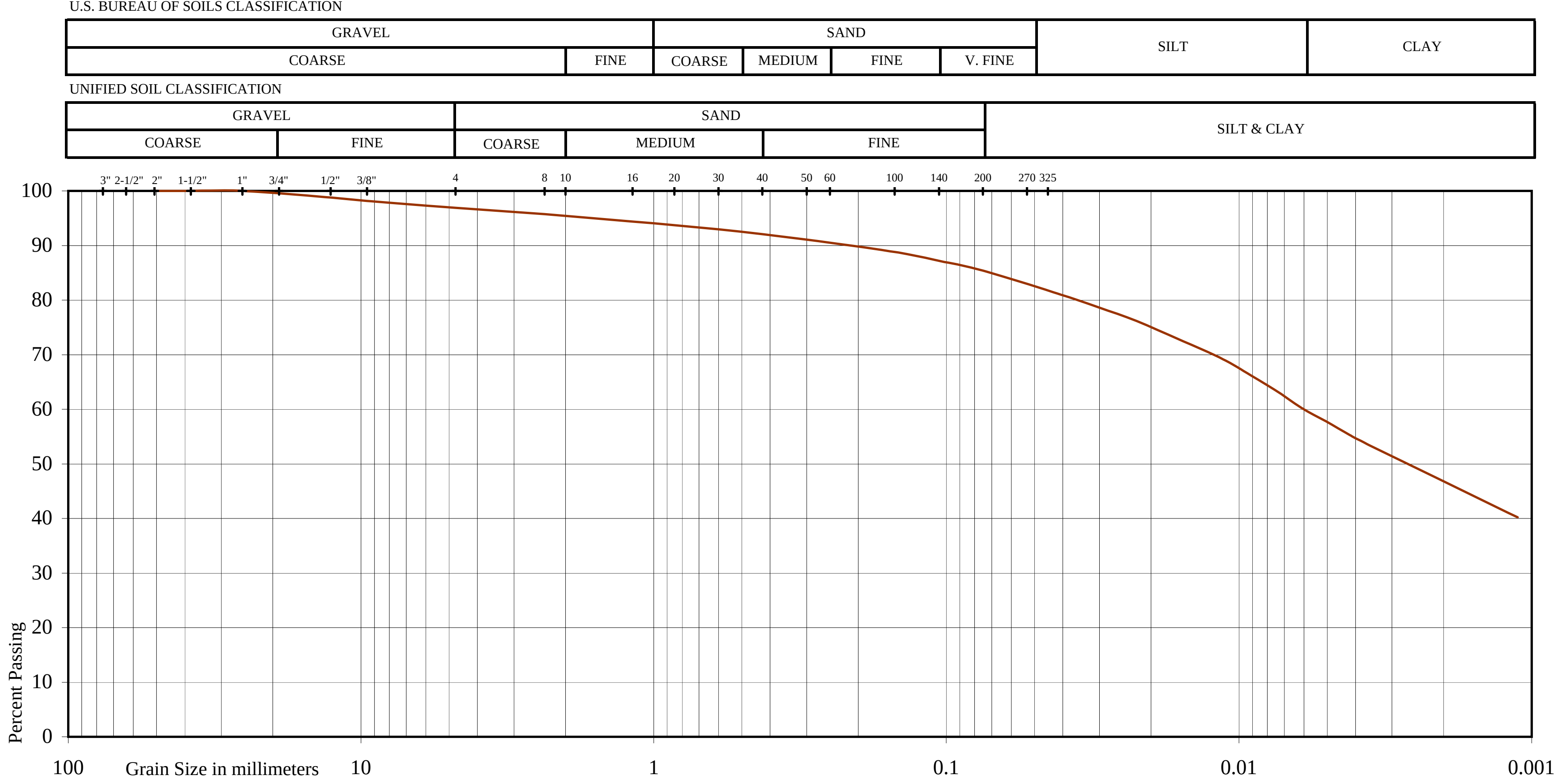
GRAIN SIZE DISTRIBUTION

Reference No: 1704-S066



Project:	Proposed Residential Development
Location:	Betty Boulevard and Shore Lane, Town of Wasaga Beach
Borehole No:	1
Sample No:	3
Depth (m):	1.7
Elevation (m):	-

Liquid Limit (%) = 43

Plastic Limit (%) = 22

Plasticity Index (%) = 21

Moisture Content (%) = 21

Estimated Permeability (cm./sec.) = 10^{-7}

Classification of Sample [& Group Symbol]: SILTY CLAY TILL

some sand, a trace of gravel

Figure: 10

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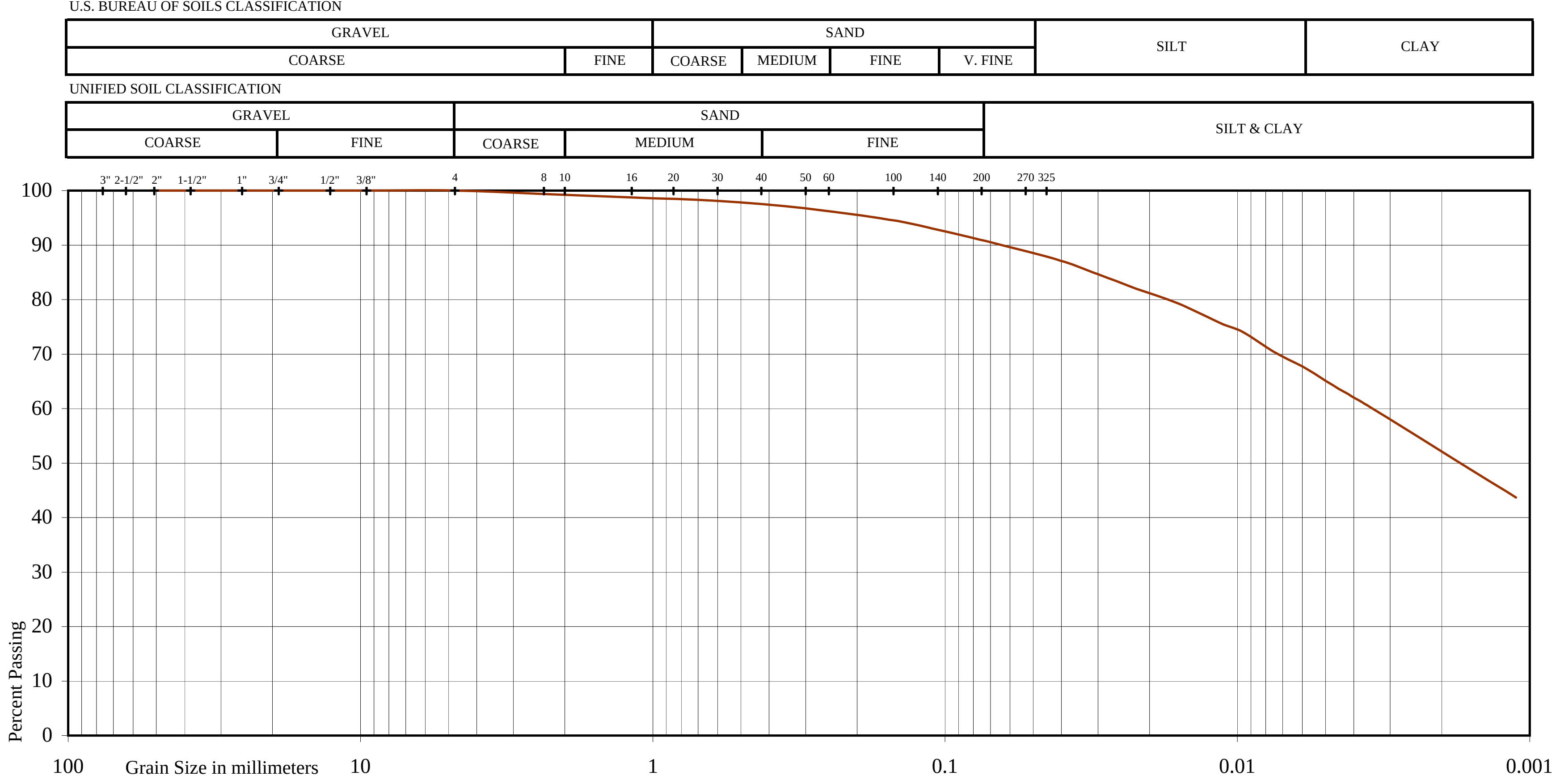
GRAIN SIZE DISTRIBUTION

Reference No: 1704-S066



Project: Proposed Residential Development

Location: Betty Boulevard and Shore Lane, Town of Wasaga Beach

Liquid Limit (%) = 46

Plastic Limit (%) = 23

Borehole No: 5

Plasticity Index (%) = 23

Sample No: 6

Moisture Content (%) = 30

Depth (m): 4.0

Estimated Permeability (cm./sec.) = 10^{-7}

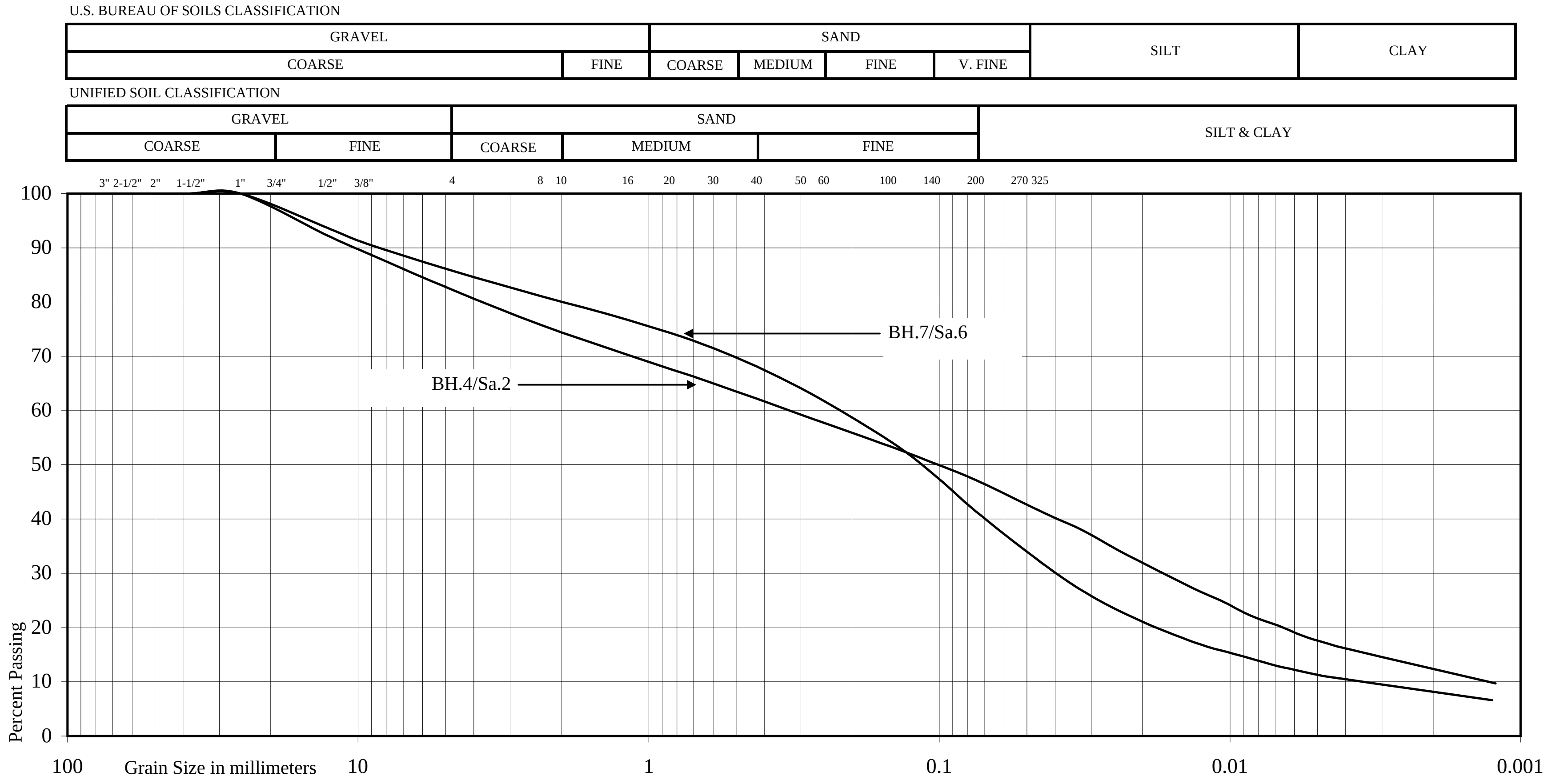
Elevation (m): -

Classification of Sample [& Group Symbol]: SILTY CLAY
a trace of fine sand

Figure: 11

GRAIN SIZE DISTRIBUTION

Reference No: 1704-S066



Project: Proposed Residential Development

Location: Betty Boulevard and Shore Lane, Town of Wasaga Beach

Borehole No:	4	7
Sample No:	2	6
Depth (m):	1.1	4.7
Elevation (m):	-	-

BH./Sa.	4/2	7/6
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	9	8
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-5}

Classification of Sample [& Group Symbol]: SILTY SAND TILL
some gravel, a trace to some clay

Figure: 12

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90 West Beaver Creek Road, Richmond Hill, Ontario L4B 1E 7 Tel:(416) 754-8515 Fax: (905) 881-8335

BOREHOLE LOCATION PLAN

DESIGNED	CHECKED	DWG NO. 1	REV
SCALE NTS	REF. NO. 1704-S066	DATE June 2017	

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SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

JOB NO.: 1704-S066
REPORT DATE: June 2017
PROJECT DESCRIPTION: Proposed Residential Development

PROJECT LOCATION: Between Betty Boulevard and Shore Lane
Town of Wasaga Beach

LEGEND

▨	TOPSOIL	▨	SILTY SAND TILL	▨	SILTY CLAY	▨	SILTY CLAY TILL
▩	FILL	▨	SANDY SILT TILL				

WATER LEVEL (END OF DRILLING) ▽