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
KLM PLANNING PARTNERS INC.

A SOIL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

MOUNT WOLFE ROAD AND HALL'S LAKE SIDEROAD

TOWN OF CALEDON

Reference No. 0511-S088

JANUARY 2015

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1.0 INTRODUCTION

In accordance with written authorization dated November 17, 2005, from Mr. Ted Chlebowski of Ted Chlebowski & Associates, a soil investigation was carried out at the property located at the east side of Mount Wolfe Road and south of Hall's Lake Sideroad in the Town of Caledon, 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 Town of Caledon is situated on Peel-Markham till plain where the drift dominates the soil stratigraphy. In places, lacustrine sand, silt, clay and drift which has been reworked by the water action of Peel Ponding (glacial lake) have modified the drift stratigraphy.

The investigated area is an irregular parcel of land located on the east side of Mount Wolfe Road and south of Hall's Lake Sideroad in the Town of Caledon. The investigated area covers an approximate 63 hectares of open field covered with grass and weeds. The ground surface is rather undulated with hills and ponds located at various areas through out the site. The total relief of the site is about 40± m.

It is understood that the property will be developed into a residential subdivision, which will be provided with municipal water, septic system, landscaped areas, and roadways meeting urban standards.

3.0 FIELD WORK

The field work, consisting of 10 boreholes to depths ranging from 4.7 to 5.0 m, was performed on January 6, 2005, at the locations shown on the Borehole Location Plan and Subsurface Profile, Drawing No. 1. The location of the boreholes was provided by Ted Chlebowski & Associates.

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

The elevation at each of the borehole locations was interpolated from the contours on the Draft Plan of the proposed subdivision provided by Ted Chlebowski & Associates.

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 10, inclusive. The revealed stratigraphy is plotted on the subsurface profile on Drawing No. 1, and the engineering properties of the disclosed soils are discussed herein.

The findings from the investigation reveal that beneath a veneer of topsoil, the site is predominated by a stratum of silty clay till, or in the southern boundary, a stratum of silty sand till. In some locations, the silty clay till is interstratified with or underlain by silty sand till. The tills extend to the maximum investigated depth.

4.1 **Topsoil** (All Boreholes)

The revealed topsoil veneer, 25 to 40 cm thick, is dark brown in colour, indicating that it contains appreciable amounts of roots and humus. The topsoil is unstable and compressible under loads; therefore, it is considered to be void of engineering value, but can be used for general landscaping purposes. A fertility analysis can determine the suitability of the topsoil as planting soil or for sodding. Due to its humus content, it may produce volatile gases and will generate an offensive odour under anaerobic conditions. Therefore, the topsoil must not be buried within the building envelopes or deeper than 1.2 m below the external finished grade. This is to avoid an adverse impact on the environmental well-being of the developed areas.

4.2 **Silty Clay Till** (All Boreholes, except Boreholes 1, 2 and 9)

The clay till was found dominating the soil stratigraphy and consists of a random mixture of soils; the particle sizes range from clay to gravel, with the clay fraction exerting the dominant influence on the soil properties. Occasional sand and silt seams and layers, and cobbles and boulders were also detected in the clay till mantle. It is heterogeneous and amorphous in structure, indicating that it is a glacial deposit.

The obtained 'N' values range from 3 to 100+, with a median of 33 blows per 30 cm of penetration, showing that the consistency of the till is soft to hard, being generally hard. The soft to stiff clay till occurs in the surficial layers of the till within a depth of 1.2± m below the prevailing ground surface, where the soil has been fractured by the weathering process.

The Atterberg Limits of 2 representative samples and the natural water content values of all the samples were determined. The results are plotted on the Borehole Logs and summarized below:

Liquid Limit	22% and 24%
Plastic Limit	14% and 15%
Natural Water Content	12% to 25% (median 14%)

The results indicate that the silty clay till is a cohesive material with low plasticity. The natural water content generally lies at its plastic limit, confirming the consistency of the material determined by the 'N' values. The excessively high water content associated with low 'N' values occurs in the badly weathered zone near the surface.

Grain size analyses were performed on 2 representative samples of the silty clay till, the results are plotted on Figure 11.

According to the above findings, the following engineering properties are deduced:

- Moderately high frost susceptibility and low water erodibility.
- Practically impervious, 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

- Its shear strength is derived from consistency and is augmented by internal friction. The strength is, therefore, inversely dependent on the soil moisture and, to a lesser degree, directly dependent on the soil density.
- It is generally stable in a relatively steep cut; however, prolonged exposure will allow infiltrating precipitation to saturate the soil fissures and the sand and silt layers in the till mantle, and this may lead to localized sloughing.
- A very poor pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 3% or less.
- Moderately high corrosivity to buried metal, with an estimated electrical resistivity of 3,500 ohm/cm.

4.3 **Silty Sand Till** (Boreholes 1, 2, 8, 9 and 10)

The silty sand till was found dominating the soil stratigraphy in the southern boundary of the site. In Boreholes 8 and 10, the sand till deposits were found embedded in or below the silty clay till. The sand till consists of a random mixture of soil particle sizes ranging from clay to gravel with the sand being the predominant fraction. Its structure is generally heterogeneous indicating that the till is a glacial deposit.

Sample examinations show that the till is slightly cemented, and it displays slight cohesion and plasticity when remoulded in a very moist condition, indicating the presence of clay.

The wetted samples became dilatant when shaken by hand, and when placed in water, they slaked and collapsed after a short duration.

Hard resistance was encountered in places during augering showing the presence of cobbles and boulders. Occasional sand and silt seams and layers were found in the till mantle.

The obtained 'N' values of the silty sand till range from 5 to 100+, with a median of 33 showing its relative density is loose to very dense, being generally dense. The loose sand till occurs in the surficial layers of the till within a depth of 1.2± m below the prevailing ground surface, where the soil has been fractured by the weathering process. In Borehole 9, a layer of loose material is also encountered at a depth of 2.5± m below the prevailing ground surface.

The natural water content values of all the samples were determined and the results are plotted on the Borehole Logs. The water content values range from 4% to 24%, with a median of 15%, showing that the till is in a damp to wet, generally moist condition.

Grain size analyses were performed on 4 representative samples of the silty sand till; the gradations are plotted on Figure 12.

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

- Highly frost susceptible with moderate water erodibility.
- Moderate soil-adfreezing potential.
- Moderate to relatively low permeability, with an estimated coefficient of permeability of 10^{-4} to 10^{-5} cm/sec, depending on the clay and silt content, with runoff coefficients of:

Slope	
0% - 2%	0.07 to 0.11
2% - 6%	0.12 to 0.16
6% +	0.18 to 0.23

- A frictional-cohesive soil, its shear strength is density dependent and is augmented by cementation and cohesion.
- It will slough slowly if submerged in an unconfined state, or from an open-face cut under seepage conditions, particularly in the zone where wet sand and silt layers are prevalent.
- A poor pavement-supportive material, with an estimated CBR value of 7%.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4,500 ohm/cm.

4.4 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 +
Silty Clay Till	12 to 25 (median 14)	14 and 15	10 to 20
Silty Sand Till	4 to 24 (median 15)	10	6 to 15

According to the above findings, the overall water content of the tills is generally suitable for 95% or + Standard Proctor compaction provided that the excessively wet material is mixed with the drier material, or is aerated before compaction. Aeration of the in situ soils should be carried out in the dry, warm weather by spreading them thinly on the ground. Some of the occurring silty sand till is too dry for 95% or + Standard Proctor compaction; the addition of water to this material prior to backfilling will be necessary.

The tills should be compacted by a heavy, kneading-type roller compactor. 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.

One must be aware that when compacting the hard clay till and dense to very dense sand till on the dry side of the optimum, the compactive energy will frequently bridge over the chunks in the soil and be transmitted laterally into the soil mantle. Therefore, the lifts of these soils must be limited to 20 cm or less (before compaction). In deep sewer trenches, it is difficult to monitor the lifts during construction. Compaction of backfill at depths over 1.0 m below the road subgrade should, therefore, be carried out on the wet side of the optimum; this allows a wider latitude of lift thickness. Wetting of the dry soils will be necessary to achieve this requirement.

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 an unsuitable condition for road construction since each component of the pavement structure is placed under a dynamic compactive load and the subsequent rolling action will cause structural failure of the new pavement. The foundations or bedding of the sewers, on the other hand, will be placed on a subgrade which will not be subjected to impact loads. Therefore, structural compaction on the wet side or dry side of the optimum will provide an adequate subgrade for the construction.

The presence of boulders in the till mantle 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 construction of engineered fill and/or structural backfill.

5.0 GROUNDWATER CONDITIONS

Groundwater seepage during augering was recorded on the field logs. The boreholes were checked for the presence of groundwater or the occurrence of cave-in upon their completion, and the levels are plotted on the Borehole Logs and listed in Table 2.

Table 2 - Groundwater Levels

	Borehole	Soil Colour Changes Brown to Grey	Seepage Encountered during Augering		Measured Groundwater/ Cave-in* Level On Completion	
BH No.	**Depth (m)**	**Depth (m)**	**Depth (m)**	**Amount**	**Depth (m)**	**El. (m)**
1	4.7	4.7+	-	-	Dry	-
2	4.9	4.9+	2.6	Some	0.6*	303.9
3	4.9	4.9+	-	-	Dry	-
4	4.7	4.7+	-	-	Dry	-
5	5.0	5.0+	-	-	Dry	-
6	5.0	5.0+	-	-	Dry	-
7	5.0	5.0+	-	-	Dry	-
8	5.0	5.0+	1.8	Some	2.4	305.1
9	5.0	5.0+	1.0	Slight	Dry	-
10	5.0	5.0+	-	-	Dry	-

*Cave-in level (In wet sand layers in the till, the level generally represents the groundwater regime at the borehole location.)

Cave-in and groundwater were detected at depths of 0.6 m and 2.4 m at two locations in the brown coloured soils and were mainly derived from infiltrating precipitation trapped in the fissures of the weathered soils, and in the sand and silt layers laminated in the tills. The colour of the soil remained brown to the maximum investigated depth, indicating that the soils have oxidized and the permanent groundwater regime lies in the soils below the maximum investigated depth. However, perched groundwater derived from infiltrated precipitation trapped in the soil fissures and in the sand and silt layers in the tills will occur at shallower depths in the wet seasons. The groundwater level at the site will fluctuate with seasons.

The yield of groundwater from the clay till, due to its low permeability, is expected to be limited. However, the groundwater yield will be some to moderate in the sand till where the permeability is moderately low to moderate.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has disclosed that beneath a veneer of topsoil, the site is predominated by a stratum of soft to hard, generally hard silty clay till, or in the southern boundary, a stratum of loose to very dense, generally dense silty sand till. The soft to stiff clay till and loose sand till are restricted to the weathered zone beneath the topsoil extending to a depth of 1.2± m below the prevailing ground surface. In Borehole 9, a layer of loose sand till was found at a depth of 2.5± m.

The permanent groundwater regime lies below the maximum investigated depth of 5.0 m below the prevailing ground surface with perched groundwater encountered at shallower depths in some places. The groundwater level is expected to fluctuate with seasons and higher perched groundwater will occur in wet seasons. The yield of groundwater from the clay till is expected to be limited due to its low permeability, whereas, the groundwater yield will be some to moderate in the sand till.

The geotechnical findings which warrant special consideration are presented below:

1. As revealed, the topsoil is 25 to 40 cm thick, and it will generate volatile gases under anaerobic conditions and is unsuitable for engineering application. For the environmental as well as the geotechnical well-being of the future development, the topsoil should not be buried over 1.2 m below the proposed finished grade, or below any structure. If using the topsoil for planting and sodding purposes, it must be assessed by fertility analysis.

2. The sound natural soils are suitable for normal spread and strip footing construction, but the weathered soil, which generally extends to a depth of 1.2± m below the prevailing ground surface, is weak in shear strength. Furthermore, a layer of loose sand till was encountered at a depth of 2.5± m in Borehole 9. Thus, caution should be exercised during construction of the foundations to ensure that the subgrade conditions are compatible with the foundation design requirements. It is advisable that the sewer contractor be requested to record the occurrence of the loose sand till during trenching. This information can be used to forewarn the builders to exercise caution in footing construction. The reuse of weathered soil as backfill material for road and general lot grading must be further assessed by a soil consultant.
3. As noted, the ground is rather undulated; cut and fill will be required for development purposes. The cost of constructing footings and services on engineered fill should be compared with extension of the foundations and for the special measures for services construction. In many instances, the cost of the latter may be substantial.
4. The tills contain 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.

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, it is recommended that the normal spread and strip footings for the proposed house foundation must be placed onto the sound natural soil or on engineered fill. As a guide, a Maximum Allowable Soil Pressure of 150 kPa is recommended for the design of normal spread and strip footings for houses founded on the sound natural soil or engineered fill.

The suitable founding levels on sound natural soils lie at depths of 1.0 to 1.5 or + m below the prevailing ground surface, except in the vicinity of Borehole 9 where the suitable founding level lies at a depth of 2.8± m.

As noted, the site is rather undulated, cut and fill will be required for the site grading. It is more practical and economical to place engineered fill suitable for a Maximum Allowable Soil Pressure of 150 kPa for the design of normal house footings. The procedures and requirements for engineered fill are discussed in Section 6.2.

The recommended soil pressures for the normal foundation incorporate a safety factor of 3 against shear failure of the underlying soil. The total and differential settlements of the footings on the soil are estimated to be 25 mm and 15 mm, respectively.

Foundations exposed to weathering, and in unheated areas, should have at least 1.2 m of earth cover for protection against frost action.

The footings should meet the requirements specified by the Ontario Building Code, and the structure should be designed to resist a minimum earthquake force calculated using the following:

F - Foundation Factor	1.0
v - Zonal Velocity Ratio	0.05

Due to the presence of topsoil and weathered soils, the footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that the subgrade conditions are compatible with the foundation design requirements.

Due to the relatively low permeability of the underlying till, perimeter subdrains and dampproofing of the basement walls will be required. All the subdrains must be encased in a fabric filter to protect them against blockage by silting.

6.2 <u>Engineered Fill</u>

Where earth fill is required for the site development, the engineering requirements for a certifiable fill for road construction, municipal services, slab-on-grade and footings designed with a 150 kPa Maximum Allowable Soil Pressure are presented below:

1. All of the topsoil must be removed. The badly weathered soils and loose soil, such as in the vicinity of Borehole 9, must be subexcavated, aerated and properly compacted to at least 98% of their maximum Standard Proctor dry

density. The subgrade surface must be inspected and proof-rolled prior to any fill placement.

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 lot grade and/or road subgrade. The soil moisture must be properly controlled on the wet side of the optimum. If the building 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 it 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, and the fill envelope must be clearly and accurately defined in the field and be precisely documented by qualified surveyors. Foundations partially on engineered fill must be reinforced by two 15-mm or 20-mm steel reinforcing bars, depending on the thickness of the fill, 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 15 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 and snow.

7. 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.
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 the certified engineered fill must be reported to the geotechnical consultant who inspected the fill placement in order to document the locations of the excavation and/or to inspect 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 the 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 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 Exterior Slab-On-Grade, Interlocking Stone Pavement, Driveways and Landscaping

Due to the moderately high to high frost susceptibility of the underlying soil, heaving of the ground 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.

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

Interlocking stone pavement and slab-on-grade to be constructed in areas susceptible to ground movement must be constructed on a free-draining granular base at least 1.0 m thick, with proper drainage, which will prevent water from ponding in the granular base.

6.4 Underground Services

The subgrade for the underground services should consist of properly compacted inorganic earth fill or natural sound soils.

A Class 'B' bedding is recommended for the design of the underground services construction. The bedding material should consist of compacted 20-mm Crusher-Run Limestone, or equivalent. If loose till is encountered, thicker bedding material may be required. This can be assessed by a geotechnical engineer during construction.

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 by a fabric filter to prevent silting.

The silty sand till and silty clay till have moderate to moderately high corrosivity to buried metal. As a guide, an electrical resistivity of 4,500 and 3,500 ohm/cm should be used for the silty sand till and silty clay till, respectively, to determine the mode of protection for water main against soil corrosion.

6.5 Septic Tile Bed

The limitations for normal in-ground septic tile bed construction are that the bottom of the absorption trenches, or the surface of a filter medium be located a minimum of 0.9 m above the highest groundwater level, and above rock or soils with a percolation time exceeding 50 min/cm. The soil in the treatment zone should possess acceptable effluent absorption properties expressed in a percolation time of between 1 min/cm and 50 min/cm.

As shown, the predominant in situ soil in the upper layers consists of silty clay till which is relatively impermeable and unsuitable for in-ground septic tile bed construction; therefore, the bed must be raised to dispose of the septic effluent. Whereas, in the southern boundary of the site, the in situ soil consists of silty sand till which has moderate to relatively low permeability and is considered marginally suitable for in-ground septic tile bed construction. More soil samples should be taken for grain size analysis when the locations of the septic tile beds in the silty sand till are determined.

The recommended percolation time ('T') for the design of the septic tile bed is T=45 min/cm to 75 min/cm for the silty sand till and silty clay till, respectively. A detailed design of the septic tile bed system can be obtained from the 1997 Ontario Building Code, published by the Ontario Ministry of Municipal Affairs and Housing.

To prevent effluent mounding over the silty clay till (which has low permeability) and the groundwater regime, the following criteria must be used for the design of a raised bed:

1. The effluent should be evenly distributed over the entire tile bed area.
2. The filter medium should have a minimum thickness of 1.1 m.

In order to enhance an efficient bed operation, the following requirements should be incorporated in the septic tile bed construction:

1. All topsoil should be stripped from the tile bed area.
2. For the raised septic tile beds, the sand filter should be keyed into the soil mantle to about 15 cm below the surface of the soil.
3. Grading of the surrounding areas should be such that it directs surface runoff away from the tile bed area.
4. The bed should be located in an unshaded area.
5. The fissured pattern of the underlying soil should not be disturbed, as this would reduce its capacity for in-ground effluent absorption.
6. In the low areas, the septic tile bed should be elevated so that surface runoff will not pond.

6.6 **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, as noted in Section 4.4, addition of water to some of the soils will be required.

In normal underground services construction practice, the problem areas of road settlement largely occur adjacent to manholes, catch basins and services crossings.

The lumpy clay is generally difficult to compact in these close quarters, and it is recommended that a sand backfill be used.

The narrow trenches for services crossings should be cut at 1 vertical:2 horizontal so that the backfill in the trenches can be effectively compacted. Otherwise, soil arching in the trenches will prevent achievement of the 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 one 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 the 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.

6.7 Pavement Design

According to the borehole findings, the recommended pavement design for local and minor collector roads which meets the minimum requirements for the Town of Caledon is given in Table 3.

Table 3 - Pavement Design

Course	Thickness (mm)	OPSS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder Local Collector	 65 90	HL-8
Granular Base	150	Granular 'A'
Granular Sub-base Local Collector	 300 450	Granular 'B'

In preparation of the subgrade, the surface should be proof-rolled and any soft subgrade should be subexcavated and replaced by properly compacted, organic-free earth fill or granular materials.

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 4.

Table 4 - Soil Parameters

Unit Weight and Bulk Factor			
	Unit Weight (kN/m^3)	**Estimated Bulk Factor**	
	Bulk	**Loose**	**Compacted**
Weathered Tills	21.5	1.20	1.00
Sound Tills	22.0	1.33	1.05
Lateral Earth Pressure Coefficients			
	Active K_a	**At Rest K_o**	**Passive K_p**
Silty Sand Till	0.30	0.40	3.33
Silty Clay Till	0.35	0.45	2.86

Table 4 - Soil Parameters (Cont'd)

Coefficients of Friction	
Between Concrete and Granular Base	0.60
Between Concrete and Sound Natural Soil	0.40
Maximum Allowable Soil Pressure For Thrust Block Design	
Sound Natural Soil	150 kPa

6.9 Excavation

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

For excavation purposes, the types of soils are classified in Table 5.

Table 5 - Classification of Soils for Excavation

Material	Type
Sound Tills	2
Weathered Tills	3

As previously discussed, the groundwater yield from the clay till will be limited, due to its low permeability. Whereas, the groundwater yield may be moderate in the sand till. Groundwater, if encountered, can be controlled by pumping from sump-wells.

Prospective contractors must assess the in situ subsurface conditions prior to excavation by performing test cuts 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

It should be noted that this report deals only with a study of the geotechnical aspects of the proposed project.

This report was prepared by Soil Engineers Ltd. for the account of Ted Chlebowski & Associates, and for review by their designated consultants and government agencies. The material in it reflects the judgement of Bernard Lee, B.A.Sc., and Ho-Yin Chiu, 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, 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.

Bernard Lee, B.A.Sc.

per

Ho-Yin Chiu, P.Eng.

BL/HYC:jp

LICENSED PROFESSIONAL ENGINEER
H-Y. CHIU
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:

1. SAMPLE TYPES

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

2. PENETRATION RESISTANCE/'N'

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 'O'

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

3. SOIL DESCRIPTION

a) 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

b) 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

c) 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 lb. = 0.453 kg
1 inch = 25.4 mm
1 ksf = 47.88 kN/m^2

Soil Engineers Ltd.
CONSULTING SOIL, FOUNDATION & ENVIRONMENTAL ENGINEERS
100 NUGGET AVENUE, TORONTO, ONTARIO M1S 3A7 • TEL: (416) 754-8515 • FAX: (416) 754-8516

JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

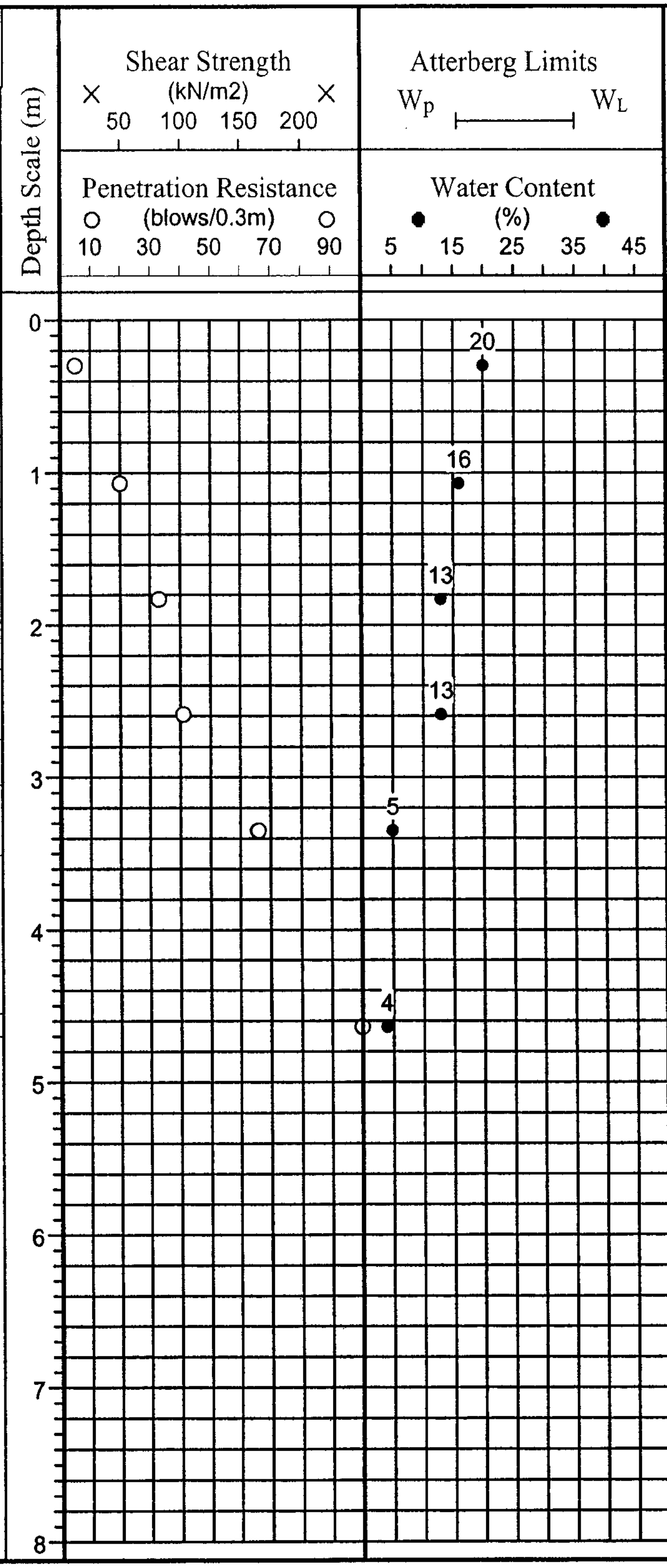
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Water Content (%)	WATER LEVEL
307.4	Ground Surface					
0.0	**28cm TOPSOIL**	1	DO	5	20	Dry on completion
	Brown, loose to very dense; weathered; a tr. of roots	2	DO	20	16	
	SILTY SAND, Till	3	DO	33	13	
		4	DO	41	13	
	a tr. to some clay, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	5	DO	66	5	
302.7 / 4.7	**END OF BOREHOLE**	6	DO	100+	4	



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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

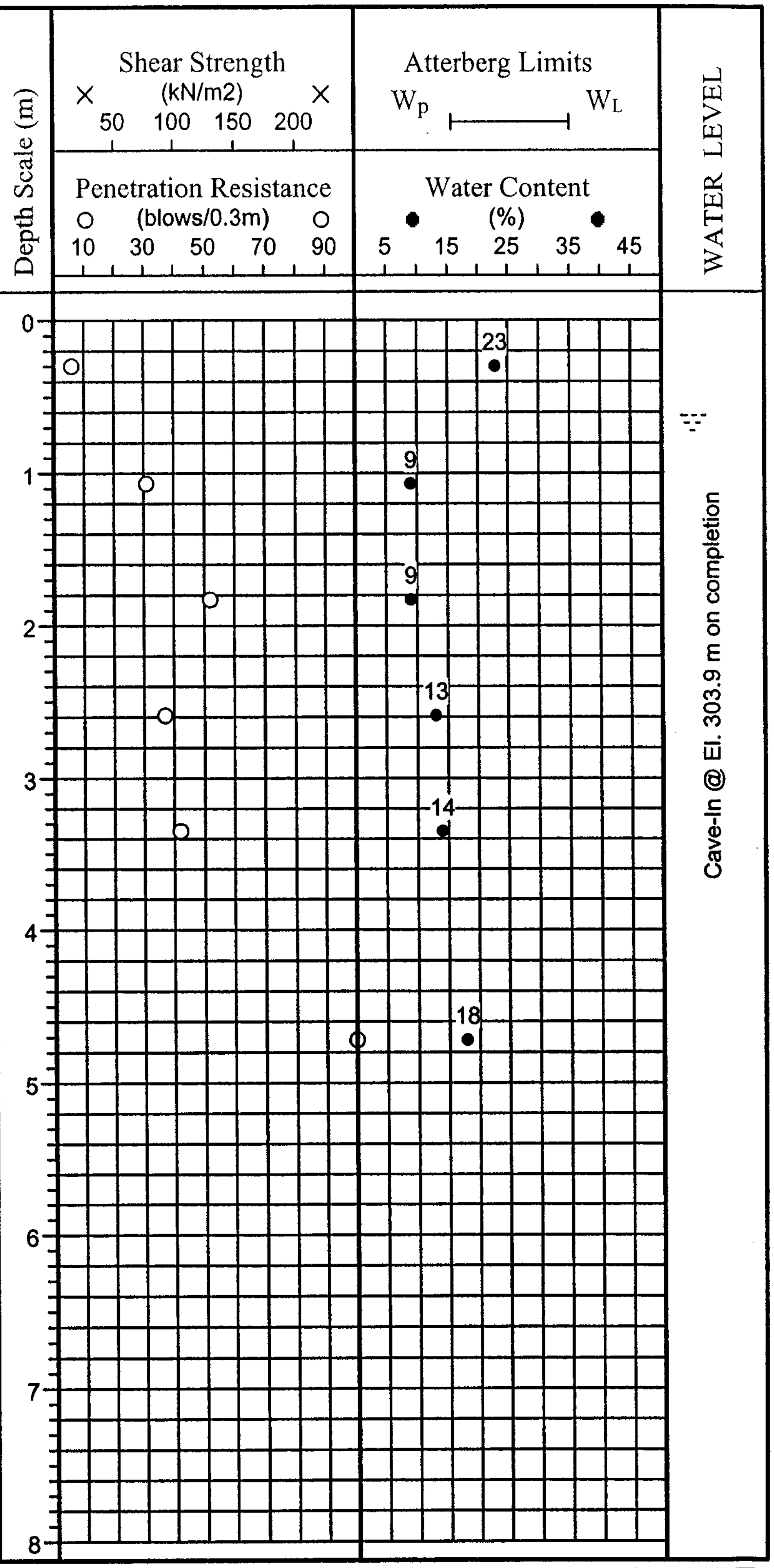
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
304.5	Ground Surface			
0.0	**30cm TOPSOIL**			
	Brown, loose to very dense; weathered	1	DO	6
	some gravel	2	DO	31
	SILTY SAND, Till	3	DO	52
		4	DO	37
	a tr. to some clay a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders	5	DO	42
299.6		6	DO	100+
4.9	**END OF BOREHOLE**			



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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

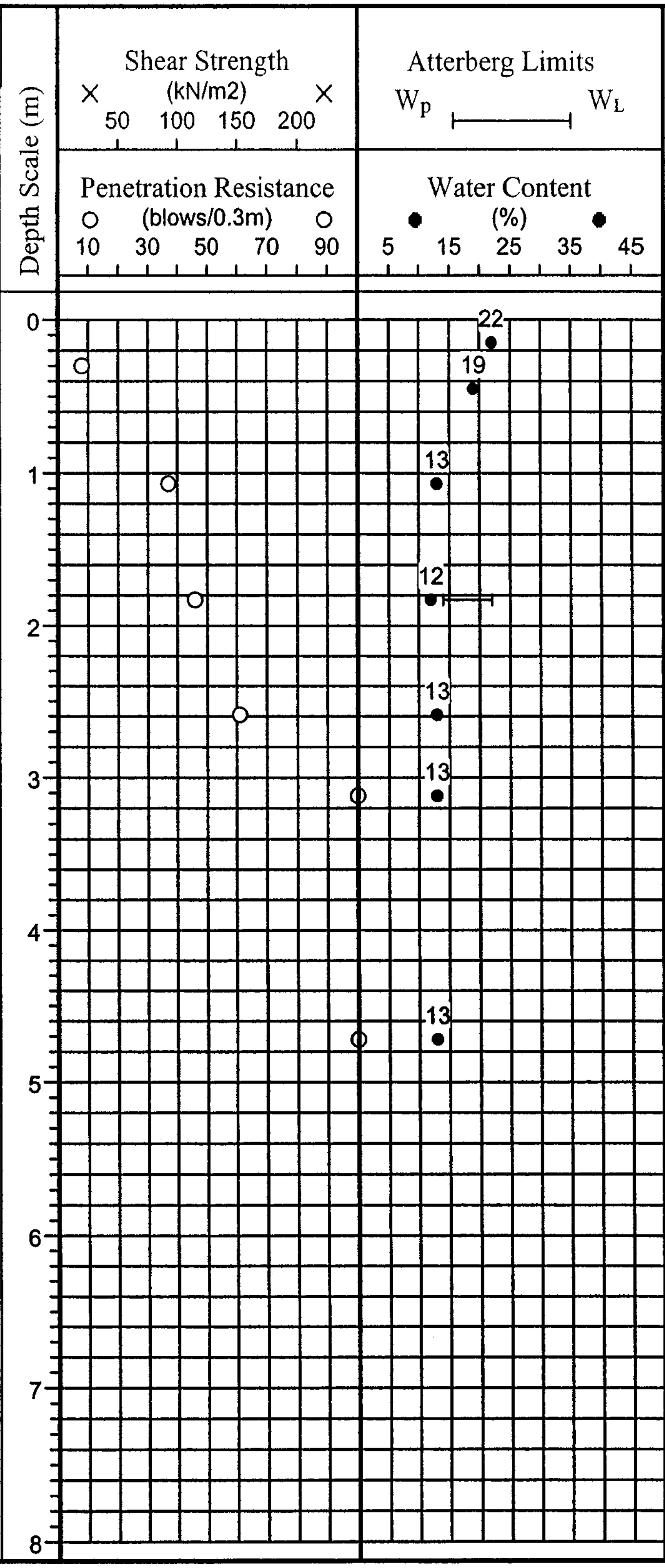
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Water Content (%)
327.2	Ground Surface				
0.0	30cm TOPSOIL				
	Brown, firm to hard SILTY CLAY, Till — weathered, a tr. of roots	1	DO	8	22, 19
		2	DO	37	13
		3	DO	46	12
		4	DO	61	13
	some sand to sandy, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	5	DO	100+	13
		6	DO	100+	13
322.3 / 4.9	END OF BOREHOLE				



WATER LEVEL: Dry on completion

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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Water Content (%)	WATER LEVEL
307.7	Ground Surface					
0.0	**25cm TOPSOIL**					
	SILTY CLAY, Till — Brown, firm to hard; weathered (to approx. 0.7 m)	1	DO	6	19	Dry on completion
		2	DO	31	18	
		3	DO	100+	16	
		4	DO	72	14	
	some sand to sandy, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	5	DO	100+	12	
303.0 / 4.7		6	DO	100+	12	
	END OF BOREHOLE					

Shear Strength (kN/m2) × 50 100 150 200 ×
Penetration Resistance (blows/0.3m) ○ 10 30 50 70 90 ○
Atterberg Limits W_p — W_L
Water Content (%) ● 5 15 25 35 45 ●
Depth Scale (m) 0–8

Soil Engineers Ltd.

JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Depth Scale (m)	Penetration Resistance (blows/0.3m)	Water Content (%)	WATER LEVEL
314.2	Ground Surface							
0.0	**35cm TOPSOIL**				0			Dry on completion
	Brown, soft to hard	1	DO	4		4	21	
	weathered	2	DO	8	1	8	18	
	a tr. of roots							
	SILTY CLAY, Till	3	DO	17	2	17	15	
		4	DO	62		62	14	
	some sand to sandy, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	5	DO	63	3	63	12	
309.2		6	DO	63	4	63	13	
5.0	**END OF BOREHOLE**				5			

Shear Strength (kN/m2): × 50 100 150 200 ×
Atterberg Limits: W_p —— W_L
Penetration Resistance (blows/0.3m): ○ 10 30 50 70 90 ○
Water Content (%): ● 5 15 25 35 45 ●
Depth Scale (m): 0 1 2 3 4 5 6 7 8

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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

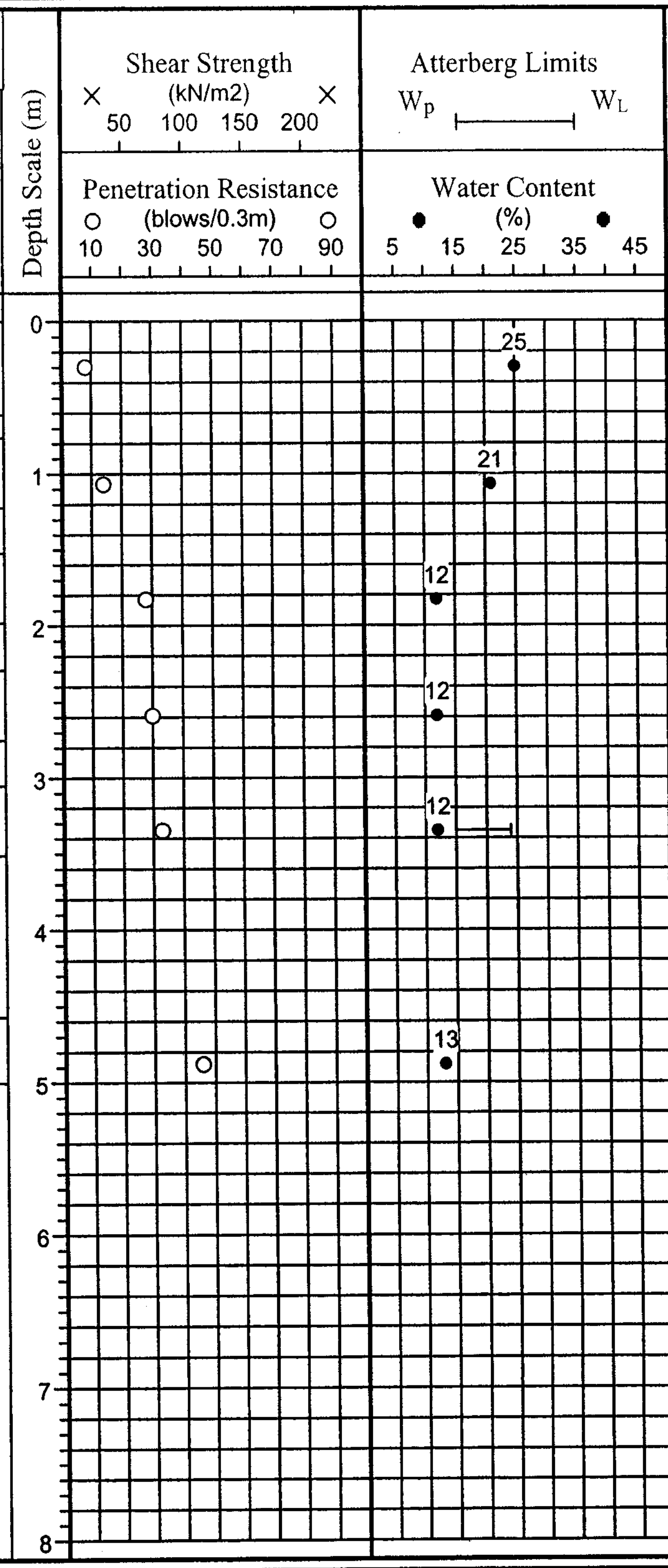
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Water Content (%)	WATER LEVEL
316.3	Ground Surface					
0.0	**28cm TOPSOIL**	1	DO	8	25	Dry on completion
	Brown, firm to hard					
	weathered	2	DO	14	21	
	a tr. of roots					
		3	DO	28	12	
	SILTY CLAY, Till					
		4	DO	30	12	
		5	DO	33	12	
	some sand to sandy a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders					
311.3		6	DO	46	13	
5.0	**END OF BOREHOLE**					



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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

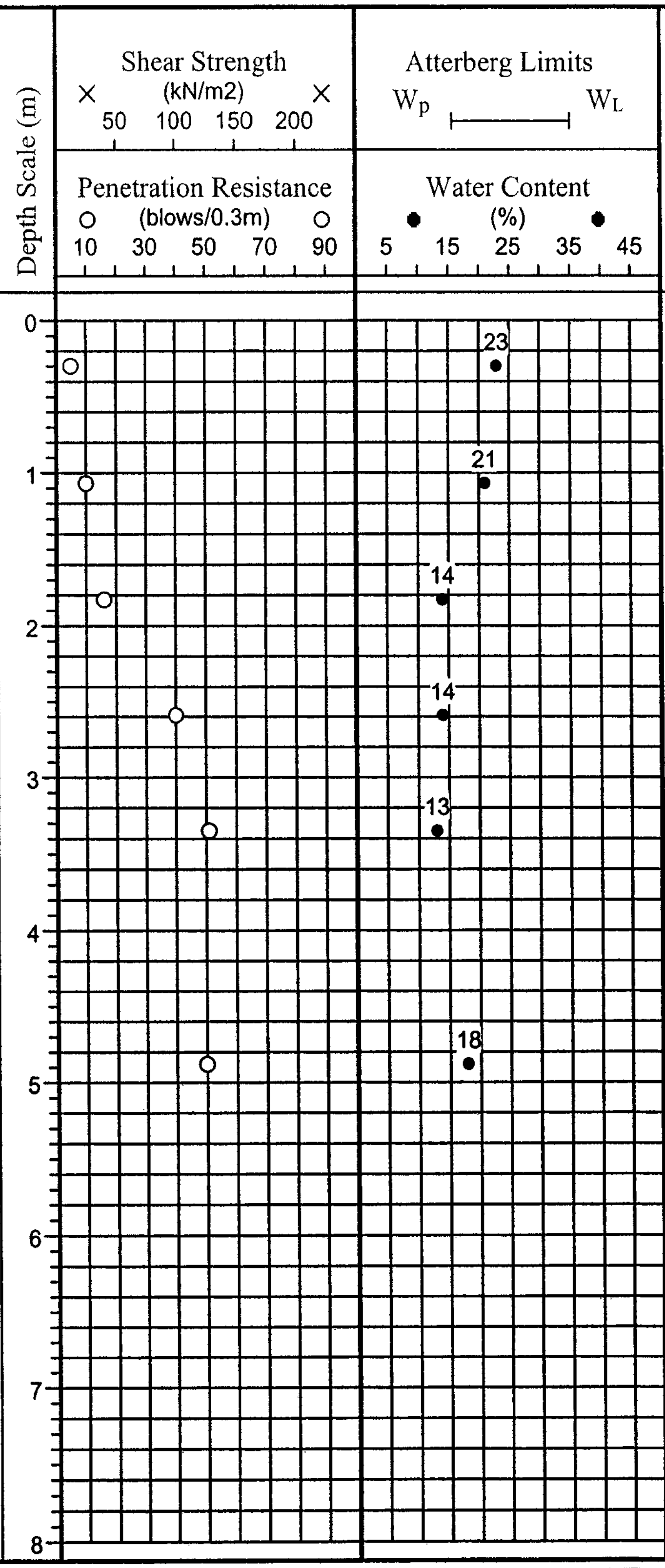
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Water Content (%)	WATER LEVEL
320.0	Ground Surface					
0.0	**35cm TOPSOIL**	1	DO	5	23	Dry on completion
	SILTY CLAY, Till Brown, firm to hard weathered	2	DO	10	21	
	a tr. of roots sand lenses	3	DO	16	14	
		4	DO	40	14	
	sand layers some sand to sandy a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders	5	DO	51	13	
		6	DO	50	18	
315.0 5.0	**END OF BOREHOLE**					



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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

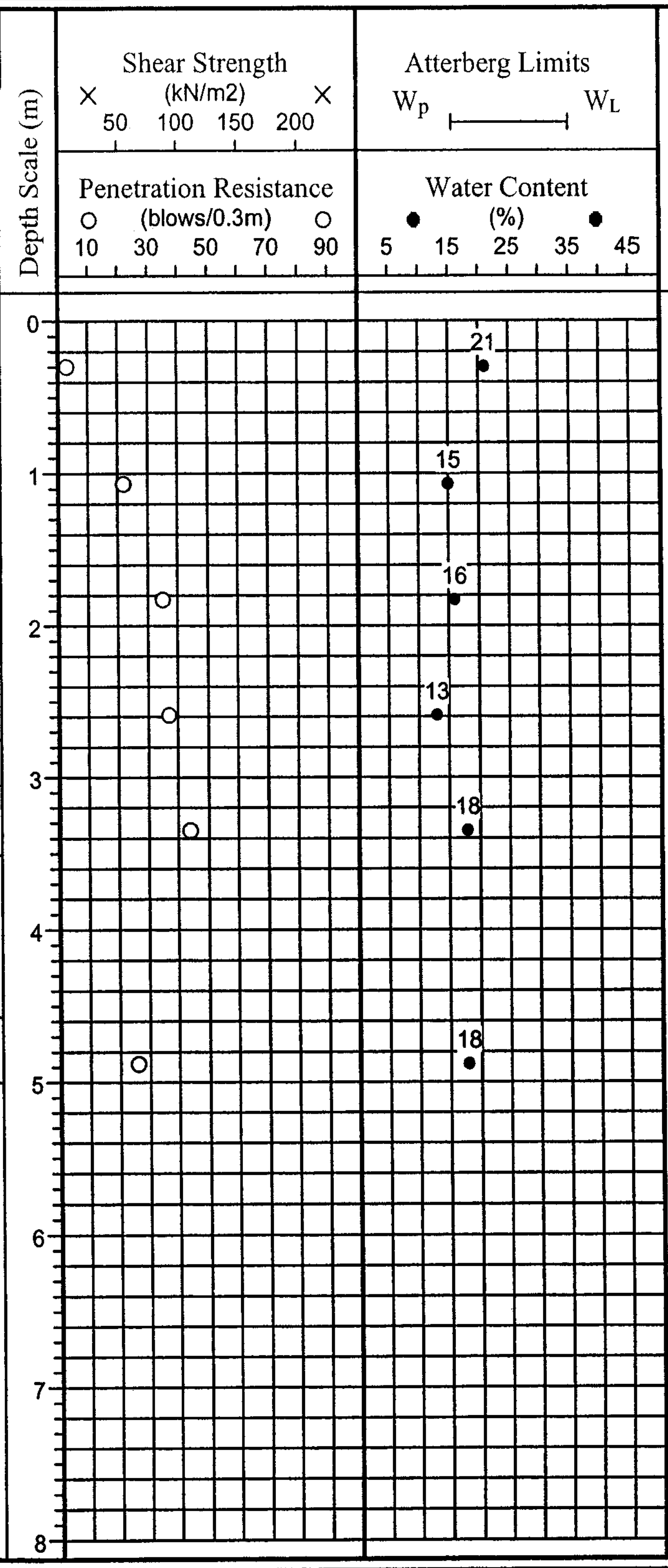
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	Samples: Number	Type	N-Value
307.5	Ground Surface			
0.0	**40cm TOPSOIL** Brown, soft to very stiff **SILTY CLAY, Till** (weathered) some sand to sandy a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders	1	DO	3
		2	DO	22
306.0 1.5	Brown, dense **SILTY SAND, Till** a tr. to some clay, a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders	3	DO	35
305.2 2.3	Brown, very stiff to hard **SILTY CLAY, Till** some sand to sandy a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders	4	DO	37
		5	DO	44
		6	DO	26
302.5 5.0	**END OF BOREHOLE**			



WATER LEVEL: W.L. @ El. 305.1 m on completion

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JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Water Content (%)
321.9	Ground Surface				
0.0	**30cm TOPSOIL**	1	DO	5	26
		1	DO	5	24
	Brown, loose to dense				
	weathered	2	DO	7	21
	a tr. of roots				
		3	DO	15	15
	SILTY SAND, Till	4	DO	6	18
		5	DO	45	15
	a tr. to some clay, a tr. of gravel occ. silt and sand seams and layers, cobbles and boulders				
316.9		6	DO	30	20
5.0	**END OF BOREHOLE**				

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

Penetration Resistance (blows/0.3m): 10, 30, 50, 70, 90

Atterberg Limits: W_p — W_L

Water Content (%): 5, 15, 25, 35, 45

Depth Scale (m): 0–8

WATER LEVEL: Dry on completion

Soil Engineers Ltd.

JOB NO.: 0511-S088

LOG OF BOREHOLE NO.: 10

FIGURE NO.: 10

JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Mount Wolfe Rd./Hall's Lake Sideroad
Town of Caledon

METHOD OF BORING: Flight-Auger

DATE: January 6, 2006

Elev. / Depth (m)	SOIL DESCRIPTION	Sample Number	Sample Type	N-Value
309.0	Ground Surface			
0.0	**28cm TOPSOIL**	1	DO	5
	Brown, firm to hard **SILTY CLAY, Till** weathered - - - a tr. of roots	2	DO	9
		3	DO	23
		4	DO	65
	some sand to sandy, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	5	DO	42
305.0 / 4.0	Brown, very dense **SILTY SAND, Till** a tr. to some clay, a tr. of gravel, occ. silt and sand seams and layers, cobbles and boulders	6	DO	70
304.0 / 5.0	**END OF BOREHOLE**			

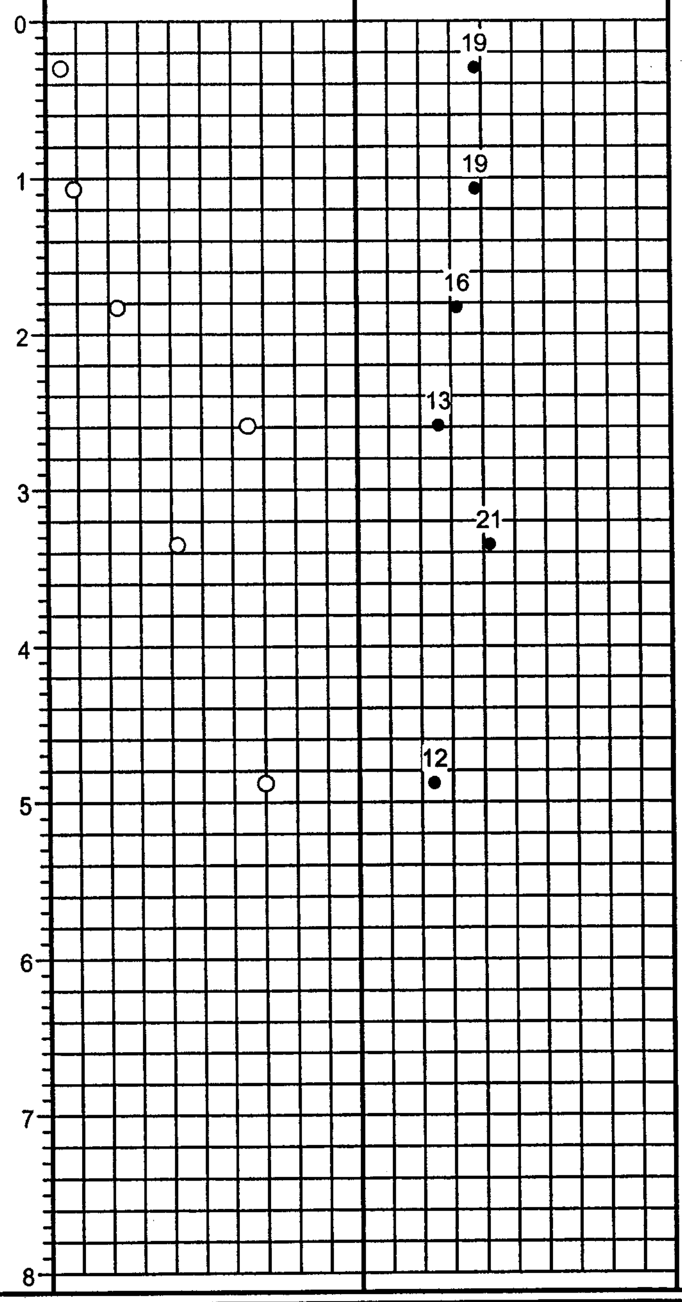
Depth Scale (m): 0–8

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

Penetration Resistance (blows/0.3m) ○ 10 30 50 70 90 ○

Atterberg Limits W_P ⊢—⊣ W_L

Water Content (%) ● 5 15 25 35 45 ●



WATER LEVEL: Dry on completion

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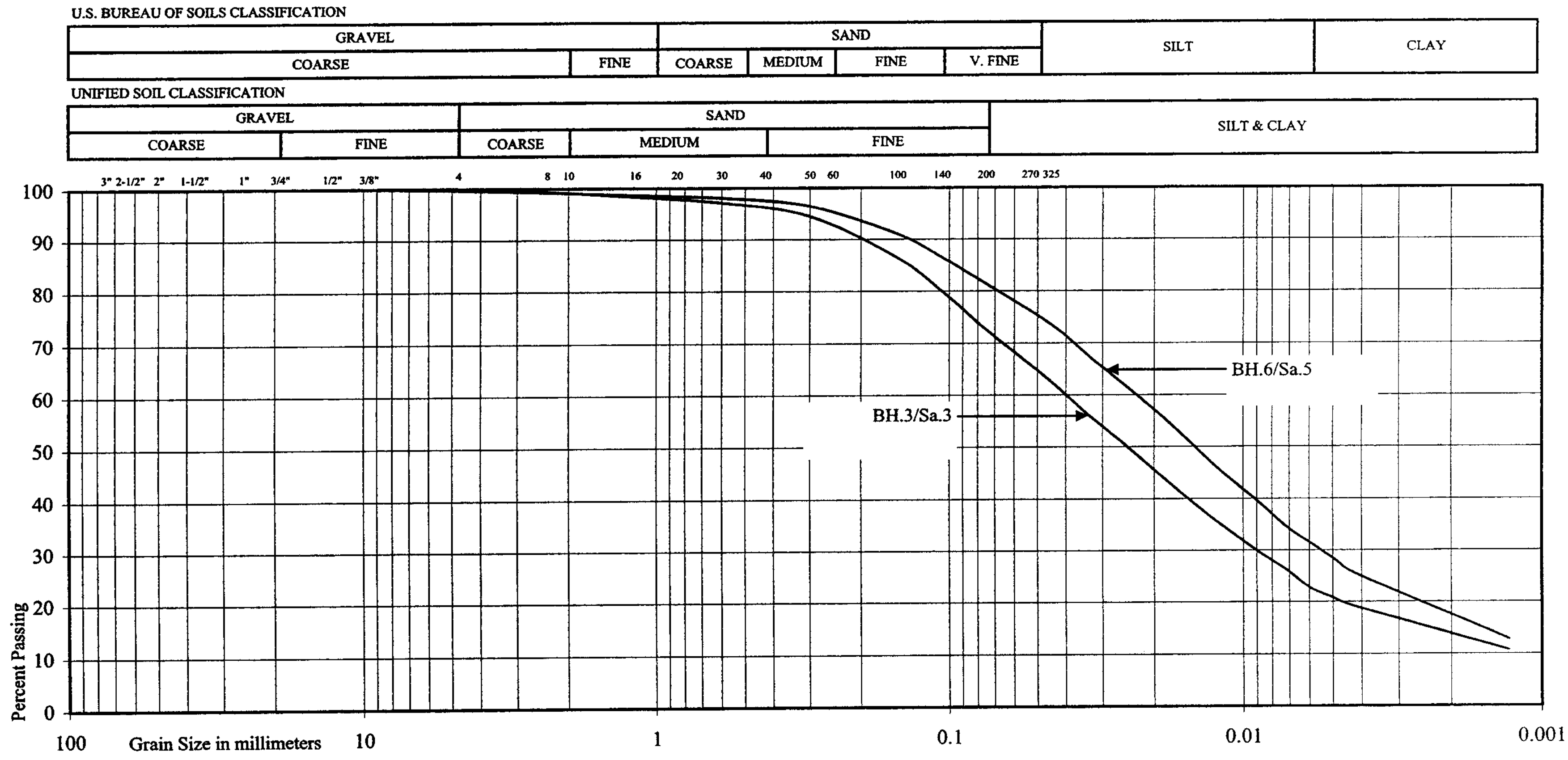
Soil Engineers Ltd. **GRAIN SIZE DISTRIBUTION** Reference No: 0511-S088



BH./Sa.	3/3	6/5
Liquid Limit (%) =	22	24
Plastic Limit (%) =	14	15
Plasticity Index (%) =	9	9
Moisture Content (%) =	12	12
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-6}

Project:	Proposed Residential Development	
Location:	Mount Wolfe Rd./Hall's Lake Sideroad, Town of Caledon	
Borehole No:	3	6
Sample No:	3	5
Depth (m):	1.8	3.4
Elevation (m):	325.4	312.9

Classification of Sample [& Group Symbol]: SILTY CLAY, Till
some sand to sandy, a tr. of gravel

Figure: 11

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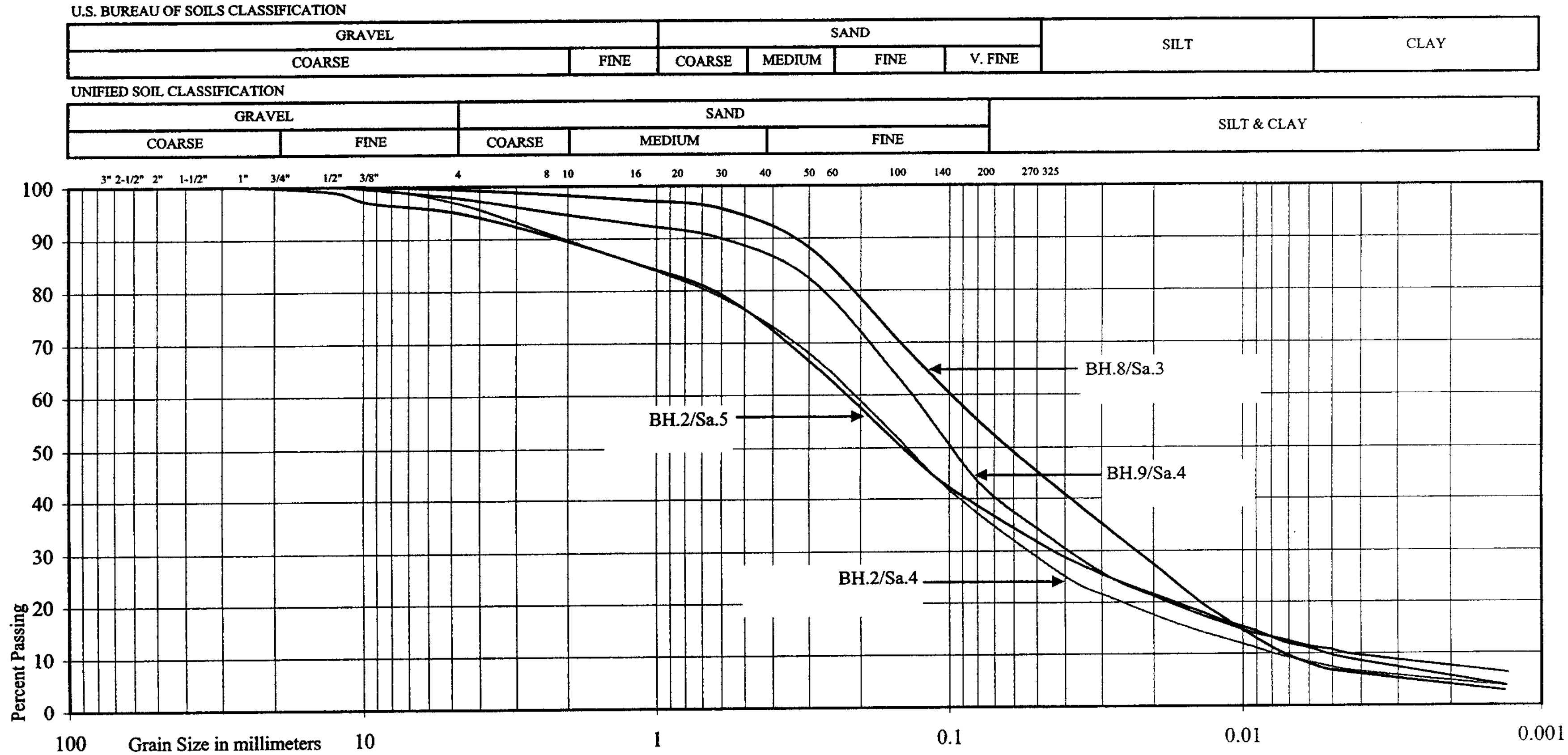
GRAIN SIZE DISTRIBUTION

Reference No: 0511-S088



BH./Sa.	2/4	2/5	8/3	9/4
Liquid Limit (%) =	-	-	-	-
Plastic Limit (%) =	-	-	-	-
Plasticity Index (%) =	-	-	-	-
Moisture Content (%) =	13	14	16	18
Estimated Permeability (cm./sec.) =	10^{-4}	10^{-5}	10^{-4}	10^{-5}

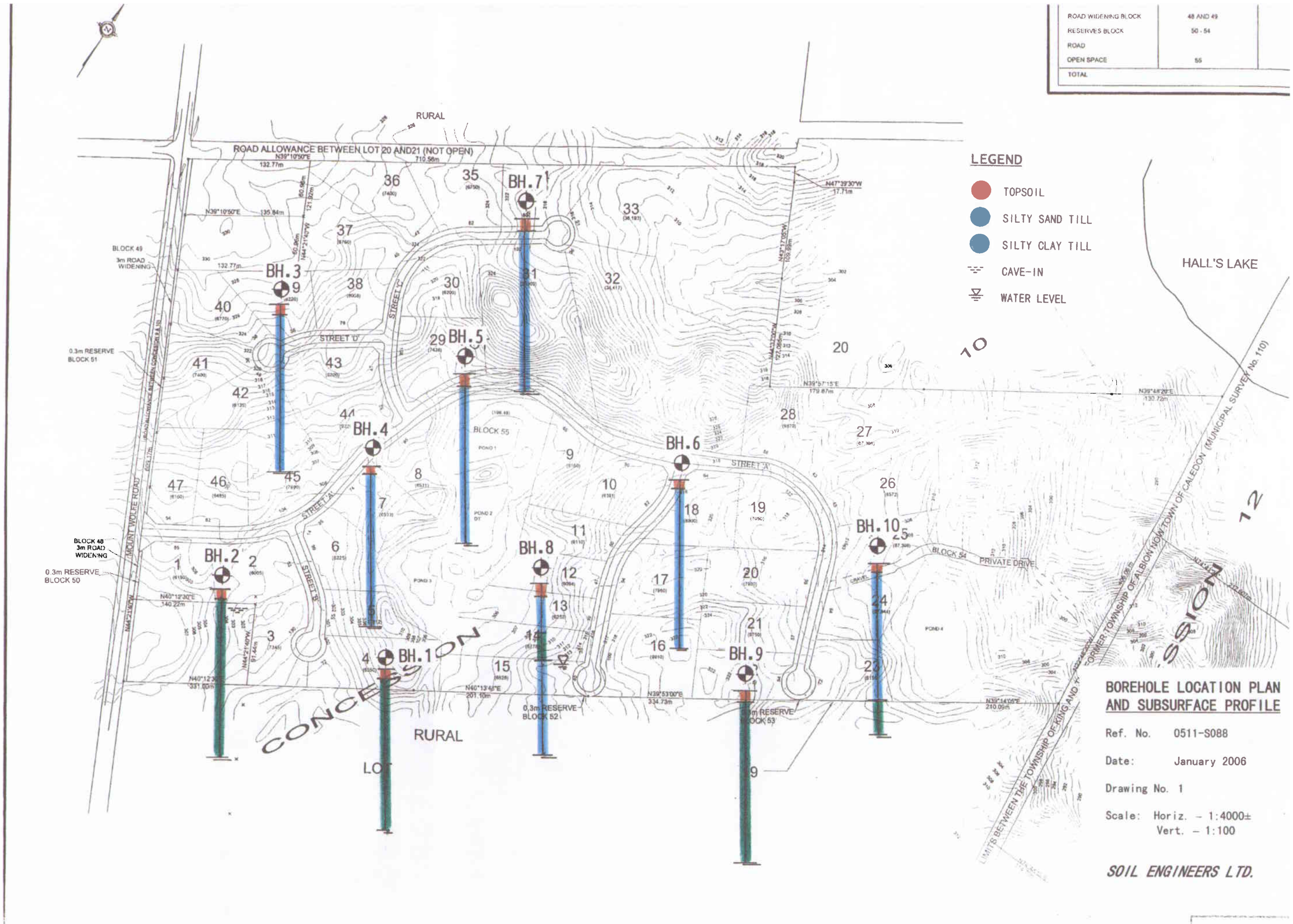
Project: Proposed Residential Development

Location: Mount Wolfe Rd./Hall's Lake Sideroad, Town of Caledon

Borehole No:	2	2	8	9
Sample No:	4	5	3	4
Depth (m):	2.6	3.4	1.8	2.6
Elevation (m):	301.9	301.1	305.7	319.3

Classification of Sample [& Group Symbol]: SILTY SAND, Till
a tr. to some clay, a tr. of gravel

Figure: 12


ROAD WIDENING BLOCK 48 AND 49
RESERVES BLOCK 50 - 54
ROAD
OPEN SPACE 55
TOTAL
LEGEND
TOPSOIL
SILTY SAND TILL
SILTY CLAY TILL
CAVE-IN
WATER LEVEL
HALL'S LAKE
RURAL
ROAD ALLOWANCE BETWEEN LOT 20 AND 21 (NOT OPEN)
MOUNT WOLFE ROAD
BH.1
BH.2
BH.3
BH.4
BH.5
BH.6
BH.7
BH.8
BH.9
BH.10
BLOCK 55
STREET 'A'
STREET 'B'
STREET 'C'
STREET 'D'
BLOCK 54
PRIVATE DRIVE
BLOCK 49
3m ROAD WIDENING
BLOCK 48
3m ROAD WIDENING
0.3m RESERVE BLOCK 50
0.3m RESERVE BLOCK 51
0.3m RESERVE BLOCK 52
0.3m RESERVE BLOCK 53
CONCESSION
LOT
RURAL
10
12
FORMER TOWNSHIP OF ALBION NOW TOWN OF CALEDON (MUNICIPAL SURVEY No. 110)
LIMITS BETWEEN THE TOWNSHIP OF KING AND THE FORMER TOWNSHIP OF ALBION
BOREHOLE LOCATION PLAN AND SUBSURFACE PROFILE
Ref. No. 0511-S088
Date: January 2006
Drawing No. 1
Scale: Horiz. - 1:4000±
Vert. - 1:100
SOIL ENGINEERS LTD.