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A REPORT TO
1361605 ONTARIO LTD.

A SOIL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

13576 AND 13584 COLERAINE DRIVE

TOWN OF BOLTON

Reference No. 1006-S045

MAY 2013

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1.0 **INTRODUCTION**

In accordance with instructions from Mr. Ted Minor, P.Eng., Project Manager, of Calder Engineering Ltd., and written authorization dated June 5, 2010, from Mr. Peter Halmos of 1361605 Ontario Ltd., a soil investigation was carried out at a parcel of land which is the east half of Lot 8, Concession 5 and Part of Block 307, Registered Plan 43M-1324 in the Town of Bolton, 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 site is situated on Halton-Peel till plain where drift dominates the soil stratigraphy. In places, the drift has been modified by the water action of the glacial lake known as Peel Ponding and filled with lacustrine clay, silt, sand and/or reworked till.

The subject site is located east of Jack Kenny Court, west of Coleraine Drive and north of Grapevine Road in the Town of Bolton. The investigated area is located in the backyard of the existing residences. The site is generally grass-covered with part of the site being wooded.

The site is bounded on the east side by the properties at 13576 and 13584 Coleraine Drive and on the north, south and west by a residential subdivision.

It is understood that the proposed project will consist of a residential development, and will be provided with municipal services and roadways meeting urban standards.

3.0 FIELD WORK

The field work, consisting of 4 boreholes to a depth of 6.6 m, was performed on June 22 and 23, 2010, at the locations shown on the Borehole Location Plan and Subsurface Profile, 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 field work was supervised and the findings recorded by a Geotechnical Technician.

The elevation at each of the borehole locations was determined with reference to the site bench mark shown on Drawing No. 1, which is the top of the back door sill of the property at 13576 Coleraine Drive. It has been given an assumed elevation of 100.00 m.

4.0 SUBSURFACE CONDITIONS

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

The investigation has disclosed that beneath a topsoil veneer or, in 3 locations, a layer of topsoil fill and earth fill, the site is underlain by a stratum of silty clay till.

4.1 **Topsoil** (Borehole 4) and **Topsoil Fill** (Boreholes 1, 2 and 3)

The topsoil and topsoil fill are 4 cm and 15 cm thick. They are dark brown in colour, indicating they contain appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil and topsoil fill are considered to be void of engineering value. Due to their humus content, they may produce volatile gases and may generate an offensive odour under anaerobic conditions. Therefore, they must not be buried within the building envelope or deeper than 1.2 m below the finished grade so they will not adversely impact the environmental well-being of the developed areas.

Since the topsoil and topsoil fill are considered void of engineering value, they can only be used for general landscaping and landscape contouring purposes. Fertility analyses can determine their suitability as planting material.

4.2 **Earth Fill** (Boreholes 1, 2 and 3)

A layer of earth fill was encountered in 3 of the 4 boreholes and was found extending to depths ranging from 1.5 to 3.0 m below the prevailing ground surface. It is amorphous in structure and consists predominantly of silty clay with variable amounts of gravel and occasional topsoil inclusions.

The original topsoil was detected beneath the earth fill in Borehole 3 at a depth of 2.0+ m below the prevailing ground surface, and may have been obscured by the augering in the remaining boreholes.

The water content of the samples was determined, and the results are plotted on the Borehole Logs; the values range from 15% to 36%, with a median of 22%, indicating that the fill is in a moist to wet, generally wet condition. The high water content values are likely due to the concentrated topsoil inclusions in the fill.

The obtained 'N' values range from 6 to 44, with a median of 10 blows per 30 cm of penetration. This shows that the fill has generally self-consolidated. The high 'N' value of 44 is probably due to the presence of gravel and wood, plant and other debris found in the fill.

The earth fill likely originates from vicinal construction, contains topsoil inclusions and other deleterious material, and its density is non-uniform; therefore, it is unsuitable for supporting structures. In using the fill for structural backfill, or in pavement and slab construction, it should be subexcavated, inspected, sorted free of topsoil inclusions and any deleterious material, and properly recompacted.

A grain size analysis was performed on 1 representative sample of the earth fill; the result is plotted on Figure 5.

As noted, the fill is amorphous in structure; it will ravel and is susceptible to sudden collapse in steep cuts, particularly if it is in a wet condition. Where the earth fill is free of deleterious materials, its engineering properties are generally similar to those of the silty clay till, described in the following section.

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)

The clay till is the predominant soil on the property and it extends to at least the maximum investigated depth in all boreholes. 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 were detected in the clay till mantle. The till is heterogeneous in structure, indicating it is a glacial deposit.

Sample examinations show that fissures permeate the upper layer of the till within a depth of 0.8± m from the prevailing ground surface in the vicinity of Borehole 4, becoming less prevalent with depth. This shows that the upper layer has been fractured by the weathering process.

Hard resistance was encountered during augering, showing that the clay till is embedded with occasional cobbles and boulders.

The obtained 'N' values range from 12 to 64, with a median of 32, indicating that the consistency of the clay till is stiff to hard, being generally very stiff. In places, the obtained 'N' values decrease with depth where the soil colour changes from brown to grey. This indicates that in these areas, the till has been reworked by the water action of the glacial lake; above the reworked till, a harder soil layer has been formed by soil desiccation.

The Atterberg Limits of 4 representative samples and the natural water content of all the samples were determined; the results are plotted on the Borehole Logs and summarized below:

Liquid Limit	29%, 31%, 32% and 33%
Plastic Limit	17%, 18% and 19%
Natural Water Content	12% to 21% (median 15%)

The results show that the clay till is a cohesive material with low to medium plasticity. The natural water content generally lies below its plastic limit, confirming the consistency as determined from the 'N' values.

Grain size analyses were performed on 4 representative samples of the clay till. The results are plotted on Figure 6.

The deduced engineering properties related to the project are as follows:

- Moderate frost susceptibility and soil-adfreezing potential.
- Low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-7} cm/sec, and runoff coefficients of:

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

- A cohesive soil, its shear strength is primarily derived from consistency which is inversely related to its moisture content. It contains sand; therefore, its shear strength is augmented by internal friction.
- It will generally be stable in a relatively steep cut; however, prolonged exposure will allow the fissures in the weathered zone and the wet sand and silt seams and layers to become saturated, which may lead to localized sloughing.
- A poor pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 3%.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4000 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 +**
Earth Fill	15 to 36 (median 22)	17	13 to 22
Silty Clay Till	12 to 21 (median 15)	17 and 18	14 to 23

Based on the above findings, the silty clay till is generally suitable for a 95% or + Standard Proctor compaction. The majority of the earth fill is either too wet or on the wet side of the optimum and will require aeration or mixing with drier soils prior to structural compaction. The aeration can be effectively carried out by spreading the fill thinly on the ground in dry, warm weather.

The earth fill must be sorted free of concentrated topsoil inclusions and other deleterious materials prior to structural use.

The earth fill and silty clay till 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 very stiff to hard silty clay 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 this soil must be limited to 20 cm or less (before compaction). It is difficult to monitor the lifts of backfill placed in deep trenches; therefore, it is preferable that the compaction of backfill at depths over 1.0 m below the road subgrade be carried out on the wet side of the optimum. This would allow a wider latitude of lift thickness. Wetting of the sound till 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 unsuitable for road construction since each component of the pavement structure is to be placed under dynamic conditions which will induce the rolling action of the subgrade surface and cause structural failure of the new pavement. The foundations or bedding of the sewer and slab-on-grade, on the other hand, will be placed on a subgrade which will not be subjected to impact loads. Therefore, the structurally compacted soil mantle with the water content on the wet side or dry side of the optimum will provide an adequate subgrade for the construction.

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

5.0 GROUNDWATER CONDITIONS

Groundwater seepage encountered during augering was recorded on the field logs. The boreholes were checked for the presence of groundwater and/or the occurrence of cave-in upon their completion and the levels are plotted on the Borehole Logs. The data are plotted on the Borehole Logs and summarized 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	6.6	4.5	-	-	Dry	-
2	6.6	4.5	5.0	Slight	4.9	91.5
3	6.6	4.5	3.0	Moderate	3.0	93.1
4	6.6	4.5	-	-	Dry	-

Groundwater and groundwater seepage were measured at depths of 3.0 m and 4.9± m below the prevailing ground surface (El. 93.1 m and El. 91.5± m) in 2 out of the 4 boreholes. The relatively shallow groundwater level in Borehole 3 is likely due to infiltrated precipitation trapped in the voids of the earth fill, rendering perched groundwater at shallower depths, particularly in wet seasons.

The colour of the soil changes from brown to grey at a depth of 4.5 m below the prevailing ground surface. This indicates that the upper soil has oxidized; the groundwater regime of the site is inferred to occur in the saturated grey soils and will fluctuate with the seasons.

The yield of groundwater from the silty clay till, due to its low permeability, will be small and limited, and can be controlled by normal pumping from sumps.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has disclosed that beneath a topsoil veneer or, in 3 locations, a layer of topsoil fill and earth fill, the site is underlain predominantly by a stratum of stiff to hard, generally very stiff silty clay till. The stiff silty clay till is restricted to the weathered zone which extends to a depth of 0.8± m below the prevailing ground surface in the vicinity of Borehole 4.

Groundwater was detected in 2 out of the 4 boreholes at depths of 3.0 m and 4.9 m below the prevailing ground surface (El. 93.1 m and El. 91.5 m). The groundwater regime of the site is inferred to lie in the saturated grey soils which occur at a depth of 4.5 m below the prevailing ground surface, and will fluctuate with the seasons.

The groundwater yield from the encountered soil, due to its low permeability, will be small and limited, and can be controlled by normal pumping from sumps.

The geotechnical findings within the investigated depth of 6.6± m which warrant special consideration are presented below:

1. The topsoil and topsoil fill are highly compressible and must be stripped as they are unsuitable for engineering applications. Due to their high humus content, they will generate volatile gases under anaerobic conditions. For the environmental as well as the geotechnical well-being of the future development, the topsoil and topsoil fill should not be buried within the building envelope, or deeper than 1.2 m below the exterior finished grade.
2. The earth fill found at the site extends to depths of 1.5 m, 2.3 m and 3.0 m below the prevailing ground surface, and appears to be spoil from vicinal construction. The density of the fill is non-uniform and consists of topsoil

inclusions and other deleterious material, rendering the fill unsuitable for supporting foundations. For other structural use, the fill must be subexcavated, inspected, assessed, sorted free of topsoil inclusions and deleterious materials, aerated and properly compacted. If it is impractical to sort the topsoil and other deleterious material from the fill, then the fill must be wasted and replaced with properly compacted inorganic earth fill.

3. Due to the presence of topsoil, topsoil fill, earth fill and weathered soil, the footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, or by a building inspector who has geotechnical experience, to assess its suitability for bearing the designed foundations.
4. The sound natural soils are suitable for normal spread and strip footing construction.
5. Earth fill will be required for the site grading. It is generally more economical to place engineered fill for normal footing, sewer and road construction.
6. Depending on the design grade of the basement, perimeter and floor subdrains and dampproofing of the foundation walls will be required for the basement construction. The subdrains should be shielded by a fabric filter to prevent blockage by silting. This can be further assessed at the time of basement excavation.
7. Excavation into the very stiff to hard silty clay till containing boulders may require extra effort and the use of a heavy-duty backhoe. 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, the footings should be placed below the topsoil, topsoil fill, earth fill and weathered soil onto the sound natural soil. As a general guide, the recommended soil pressures for the design of the spread and strip footings, and the corresponding suitable founding level, are presented in Table 3.

Table 3 - Founding Levels

	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Corresponding Founding Level			
	250 kPa (SLS) 420 kPa (ULS)		**350 kPa (SLS) 580 kPa (ULS)**	
Borehole No.	**Depth (m)**	**El. (m)**	**Depth (m)**	**El. (m)**
1	2.4 or +*	99.1 or -*	-	-
2	1.7 or +*	94.7 or -*	-	-
3	3.2 or +**	92.9 or -**	-	-
4	1.0 or +	99.1 or -	1.6 or +	98.5 or -

* Due to the decrease of ‘N’ values with depth, the 250 kPa (SLS) and 420 kPa (ULS) pressures must be linearly reduced to 150 kPa (SLS) and 250 kPa (ULS), respectively, from a depth of 5.0 to 6.0 m below the prevailing ground surface, and the footing size for spread and strip footings should not be greater than 1.6 m and 1.1 m, respectively.

** Due to the decrease of ‘N’ values with depth, the 250 kPa (SLS) and 420 kPa (ULS) pressure must be linearly reduced to 150 kPa (SLS) and 250 kPa (ULS), respectively, from a depth of 3.6 to 4.6 m below the prevailing ground surface, and the footing size for spread and strip footings should not be greater than 1.6 m and 1.1 m, respectively.

The recommended soil pressures (SLS) for the foundations incorporate a safety factor of 3 against shear failure of the underlying soils. The total and differential settlements of the foundations are estimated to be 25 mm and 15 mm, respectively.

Due to the presence of topsoil, topsoil fill, earth fill and weathered soil, the footing subgrade and the subgrade of the foundation must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, or by a building inspector who has geotechnical experience, to ensure that the revealed conditions are compatible with the foundation design requirements.

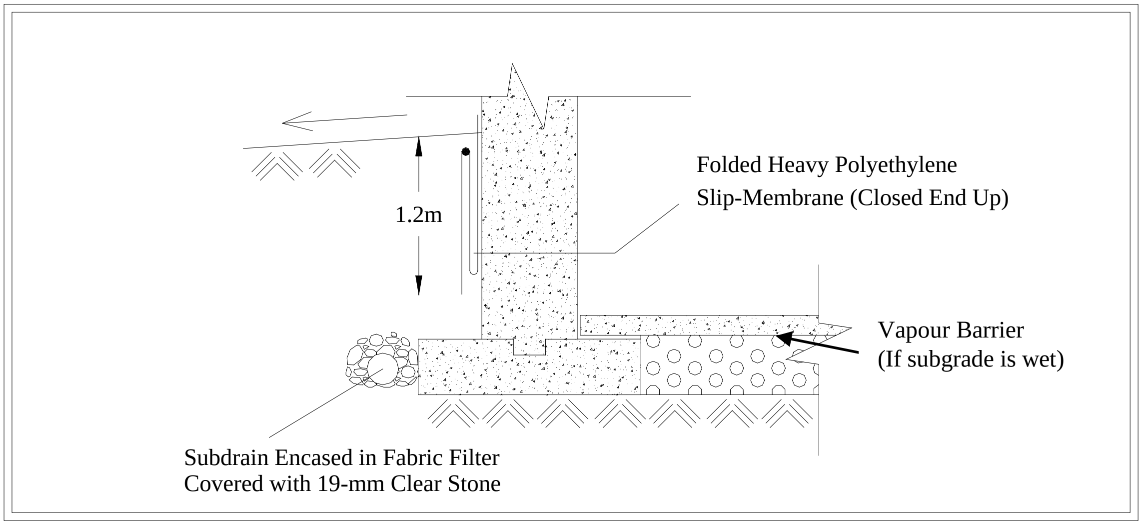
The footings should meet the requirements specified in the Ontario Building Code 2006, and the buildings must be designed to resist a minimum earthquake force using Site Classification 'D' (stiff soil).

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

The earth fill and weathered soil can be upgraded to engineered status suitable for normal footing construction. Where earth fill is required to raise the site or where cut and fill is required for site grading, it is generally more practical and economical to place engineered fill for normal footing construction designed with a Maximum Allowable Soil Pressure (SLS) of 150 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 250 kPa. The requirements and procedures for engineered fill construction are discussed in Section 6.2.

As noted, the silty clay till has moderate frost heave and soil-adfreezing potential. If excavated till is to be used for the foundation backfill, the foundation walls should be shielded by a polyethylene slip-membrane for protection against soil adfreezing. The recommended measures are schematically illustrated in Diagram 1.

Diagram 1 - Frost Protection Measures (Foundations)



The membrane will allow vertical movement of the heaving soil (due to frost) without imposing structural distress on the foundations. The external grading should be such that runoff is directed away from the foundation.

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

6.2 Engineered Fill

Where earth fill is required to raise the site, it is generally more economical to place engineered fill for normal footing, slab-on-grade, underground services and pavement construction.

The engineering requirements for a certifiable fill for pavement construction, municipal services, and footings designed with a 150 kPa Maximum Allowable Soil Pressure (SLS) and a 250 kPa Factored Ultimate Soil Bearing Pressure (ULS) are presented below:

1. All of the topsoils, organics and earth fill must be removed, and the subgrade must be inspected and proof-rolled prior to any fill placement. Badly weathered soil must be subexcavated, sorted free of topsoil inclusions and deleterious materials, if any, aerated and properly compacted.
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 lot grade and/or road subgrade. The soil moisture must be properly controlled on the wet side of the optimum. If the foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum Standard Proctor compaction.
3. If imported fill is to be used, the hauler is responsible for its environmental quality and must provide a document to certify that the material is free of hazardous contaminants.
4. If the engineered fill is to be left over the winter months, adequate earth cover or equivalent must be provided for protection against frost action.
5. The engineered fill must extend over the entire graded area, 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 and designed by a structural engineer to properly distribute the stress induced by the abrupt differential settlement (estimated to be 15± mm) between the natural soils and engineered fill.
6. The engineered fill must not be placed during the period from late November to early April, when freezing ambient temperatures occur either persistently or intermittently. This is to ensure that the fill is free of frozen soils, ice 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.

8. 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.
9. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
10. The footings and underground services subgrade must be inspected by the geotechnical consulting firm that inspected the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
11. Any excavation carried out in certified engineered fill must be reported to the geotechnical consultant who inspected the fill placement in order to document the locations of 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 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. If engineered fill exceeds 5.0 m in depth, construction of the foundations must not begin until 1 year after completion of the engineered fill placement.

6.3 **Underground Services**

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

A Class ‘B’ bedding is recommended for construction of the underground services. The bedding material should consist of compacted 20-mm Crusher-Run Limestone, or equivalent.

In order to prevent pipe floatation when the 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 till has moderate corrosivity to buried metal, the ductile iron pipes and metal fittings should be protected against corrosion. In determining the mode of protection, an electrical resistivity of 4000 ohm·cm should be used. This, however, should be confirmed by testing the soil along the water main alignment at the time of underground services construction.

6.4 **Backfilling in Trenches and Excavated Areas**

The on-site organic-free native soils are suitable for use as structural 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. This allows a wider latitude of lift thickness. Wetting of dry soil will be necessary to achieve this requirement.

In normal sewer construction practice, the problem areas of road settlement largely occur adjacent to manholes, catch basins and services crossings. In areas which are inaccessible to a heavy compactor, sand backfill should be used. Unless compaction of the backfill is carefully performed, the interface of the native soils and the sand backfill will have to be flooded for a period of at least 1 day.

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

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

- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soil have a water content on the dry side of the optimum, it would be impossible to wet the soil due to the freezing condition, rendering difficulties in obtaining uniform and proper compaction. Furthermore, the freezing condition will prevent flooding of the backfill when it is required, such as 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.
- 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

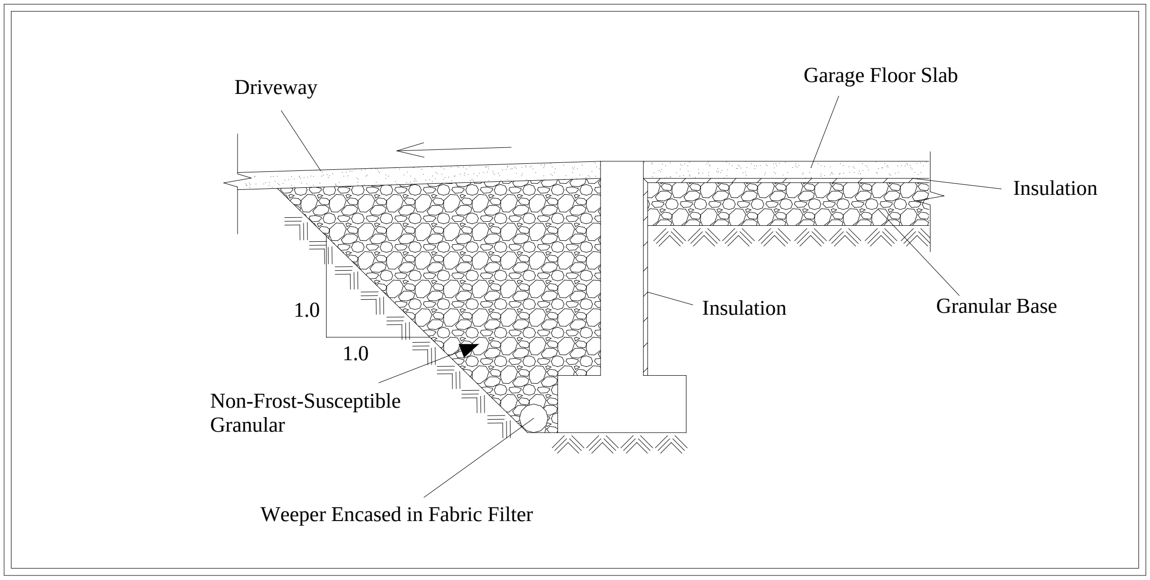
necessary in order to prevent consolidation of inadvertent voids and loose backfill which will compromise the compaction of the backfill in the upper section. In areas where groundwater movement is expected in the sand fill mantle, seepage collars should be provided.

6.5 Garages, Driveways and Landscaping

As noted, the encountered soils are moderately frost susceptible, with moderate soil-adfreezing potential; therefore, the ground is expected to heave during cold weather.

The driveway at entrances to the garages must be backfilled with non-frost-susceptible granular material, with a frost taper at a slope of 1 vertical:1 horizontal. The garage floor slab and interior garage foundation walls must be insulated with 50-mm Styrofoam, or equivalent. The recommended scheme is illustrated in Diagram 2.

Diagram 2 - Frost Protection Measures (Garage)



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 structure.

In areas where ground movement due to frost heave cannot be tolerated, the slab-on-grade, sidewalks and interlocking stone pavement must be constructed on a free-draining granular base, 0.3 to 1.2 m thick, depending on the degree of tolerance for settlement. Alternatively, the slab-on-grade, sidewalks and interlocking stone pavement should be insulated with 50-mm Styrofoam, or equivalent.

6.6 Pavement Design

Based on the borehole findings, the pavement subgrade will consist mainly of silty clay till. Accordingly, the recommended pavement design for local and collector roads is presented in Table 4.

Table 4 - Pavement Design

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

Prior to placement of the granular bases, the subgrade surface should be proof-rolled, and any soft subgrade should be subexcavated and replaced by properly compacted inorganic earth fill or granular material. All the granular bases should be compacted to their maximum Standard Proctor dry density.

The earth fill in the zone within 1.0 m below the pavement must be compacted to 98% or + 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 adequate.

The pavement 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 pavement design:

- If the roads 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.
- The 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 sitting.
- If the pavement is 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.

6.7 **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	1.20	0.98
Silty Clay Till	22.0	1.30	1.05
Lateral Earth Pressure Coefficients			
	Active K_a	**At Rest K_o**	**Passive K_p**
Earth Fill	0.50	0.60	2.22
Silty Clay Till	0.35	0.45	2.85
Maximum Allowable Soil Pressures (SLS) For Thrust Block Design (kPa)			
Engineered Fill		100	
Sound Natural Soil		150	

6.8 Excavation

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

The sides of the excavation should be cut at 1 vertical:1 or + horizontal and may need to be flattened to 1 vertical:1.5 or + horizontal in the earth fill. The spoil from the excavation and/or trenches must be placed at a distance from the edge of the excavation equal to twice the depth of the excavation.

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

Table 6 - Classification of Soils for Excavation

Material	**Type**
Sound Natural Soil	2
Earth Fill and weathered Till	3

The groundwater yield from the encountered soil, due to its relatively low permeability, will be small and can be controlled by pumping from sumps.

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

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

It should be noted that no tests have been carried out to determine whether environmental contaminants are present in the soils. Therefore, 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 1361605 Ontario Ltd., and for review by their designated consultants and government agencies. The material in it reflects the judgement of Basim Al-Ali, P.Eng., and Victor S. Chan, 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.

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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:

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

JOB NO: 1006-S045

LOG OF BOREHOLE NO: 1

FIGURE NO: 1

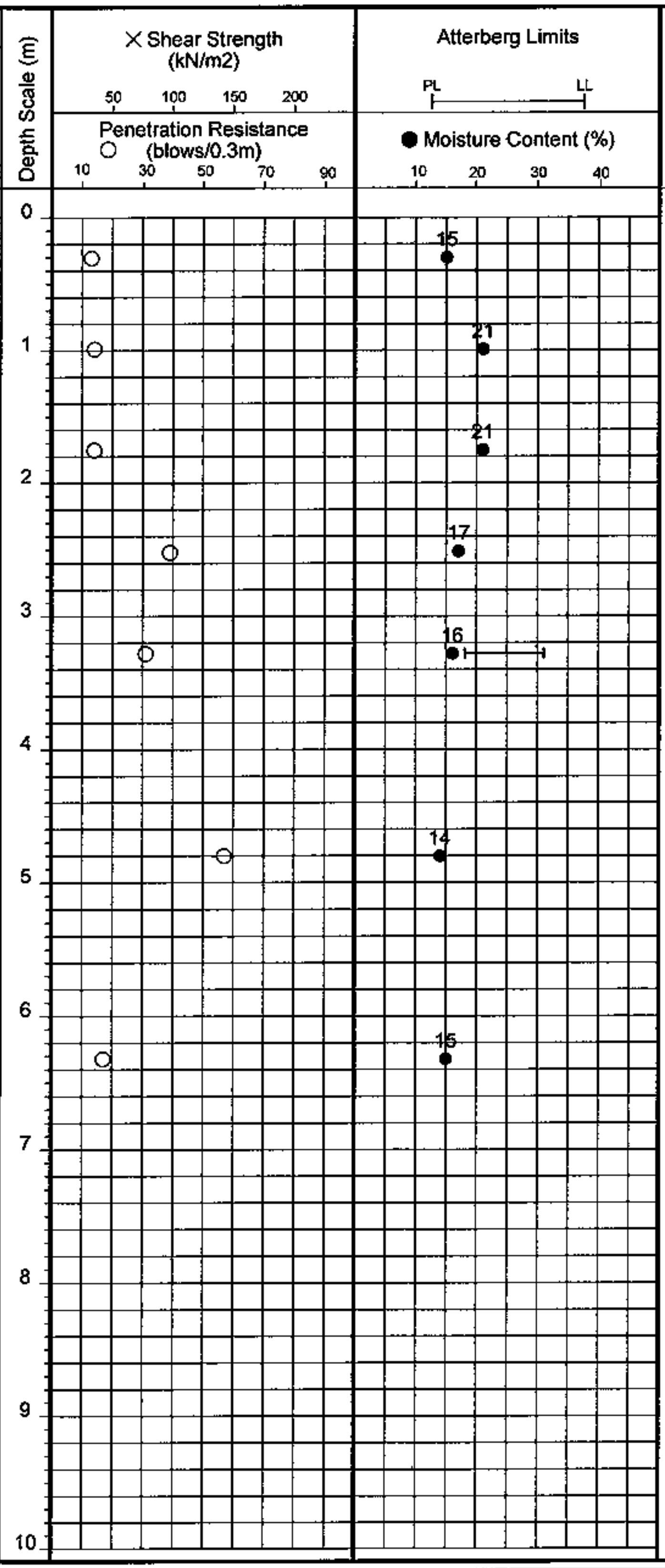
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: 13576 and 13584 Coleraine Drive
Town of Bolton

METHOD OF BORING: Flight-Auger

DATE: June 22, 2010

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0	Ground Surface			
101.5	**4 cm TOPSOIL, Fill** Brown	1	DO	13
	EARTH, Fill silty clay, some sand a tr. of gravel and occ. topsoil inclusions	2	DO	14
		3	DO	14
2.3 99.2	Very stiff to hard	4	DO	39
	SILTY CLAY, Till	5	DO	31
	some sand, a tr. of gravel occ. sand and silt seams and layers, cobbles and boulders brown grey	6	DO	57
		7	DO	17
6.6 94.9	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO: 1006-S045

LOG OF BOREHOLE NO: 2

FIGURE NO: 2

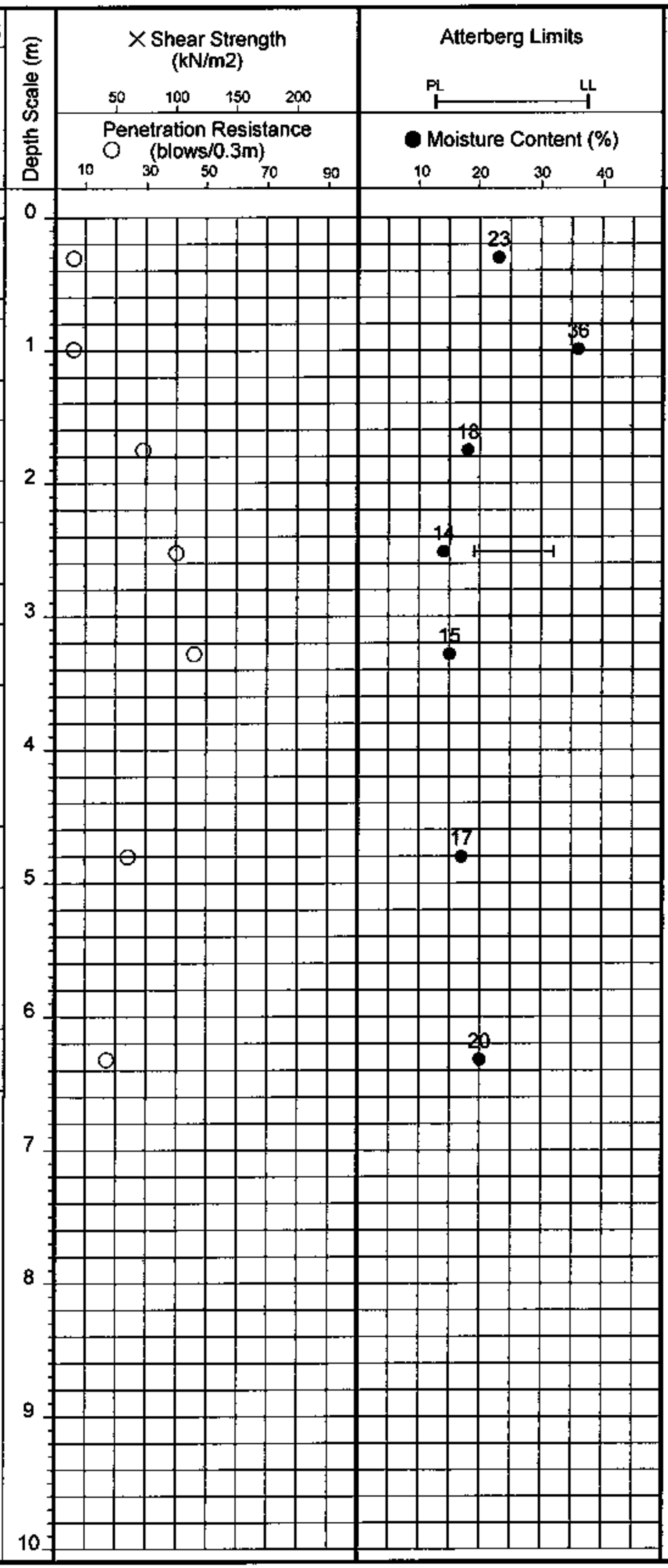
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: 13576 and 13584 Coleraine Drive
Town of Bolton

METHOD OF BORING: Flight-Auger

DATE: June 23, 2010

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0	Ground Surface			
96.4	**15 cm TOPSOIL, Fill**			
	Brown/grey	1	DO	6
	EARTH, Fill silty clay, some sand a tr. of gravel and occ. topsoil inclusions	2	DO	6
1.5 94.9	Very stiff to hard	3	DO	29
	SILTY CLAY, Till	4	DO	40
	some sand, a tr. of gravel occ. sand and silt seams and layers, cobbles and boulders	5	DO	46
	brown grey	6	DO	24
		7	DO	17
6.6 89.8	**END OF BOREHOLE**			



WATER LEVEL

∇ W.L. @ El. 91.5 m on completion

Soil Engineers Ltd.

JOB NO: 1006-S045

LOG OF BOREHOLE NO: 3

FIGURE NO: 3

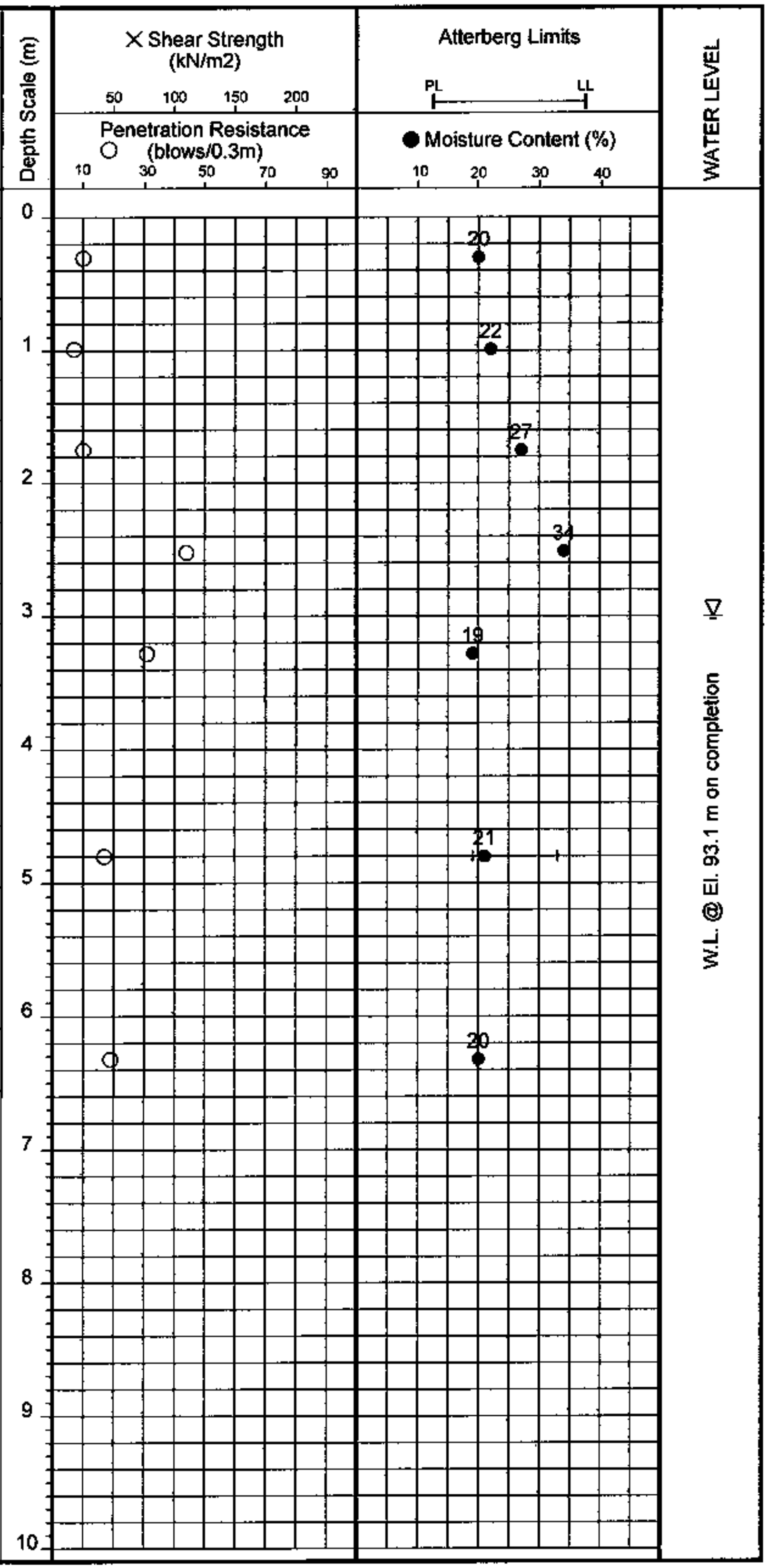
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: 13576 and 13584 Coleraine Drive
Town of Bolton

METHOD OF BORING: Flight-Auger

DATE: June 23, 2010

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0	Ground Surface			
96.1	**15 cm TOPSOIL, Fill** Brown/grey **EARTH, Fill** silty clay, some sand a tr. of gravel and occ. topsoil inclusions	1	DO	10
		2	DO	7
		3	DO	10
	original topsoil	4	DO	44
3.0 93.1	Very stiff **SILTY CLAY, Till** some sand, a tr. of gravel occ. sand and silt seams and layers, cobbles and boulders	5	DO	31
	brown grey	6	DO	17
		7	DO	19
6.6 89.5	**END OF BOREHOLE**			



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JOB NO: 1006-S045

LOG OF BOREHOLE NO: 4

FIGURE NO: 4

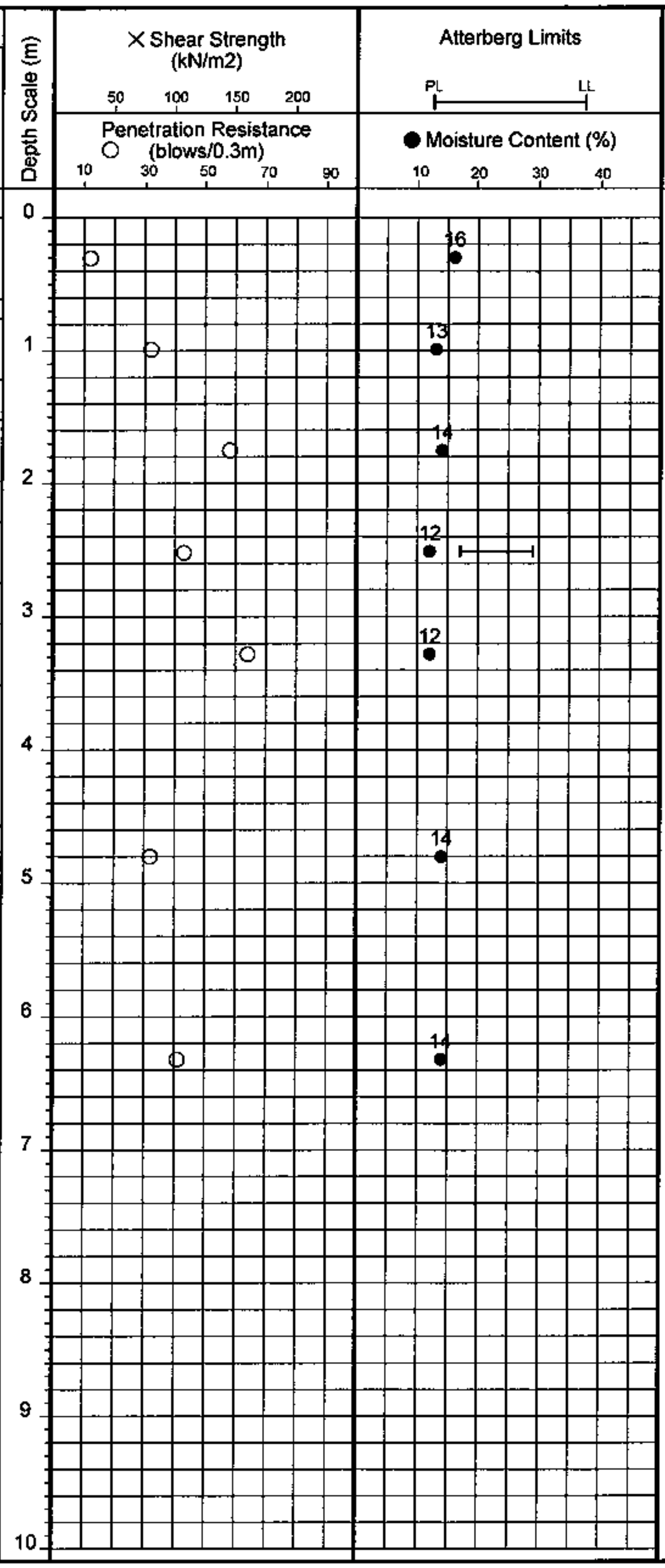
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: 13576 and 13584 Coleraine Drive
Town of Bolton

METHOD OF BORING: Flight-Auger

DATE: June 22, 2010

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
0.0 100.1	Ground Surface **15 cm TOPSOIL**			
	Stiff to hard	1	DO	12
	weathered			
	SILTY CLAY, TIll	2	DO	32
	some sand, a tr. of gravel occ. sand and silt seams and layers, cobbles and boulders	3	DO	58
		4	DO	43
		5	DO	64
	brown grey			
		6	DO	32
		7	DO	41
6.6 93.5	**END OF BOREHOLE**			



WATER LEVEL

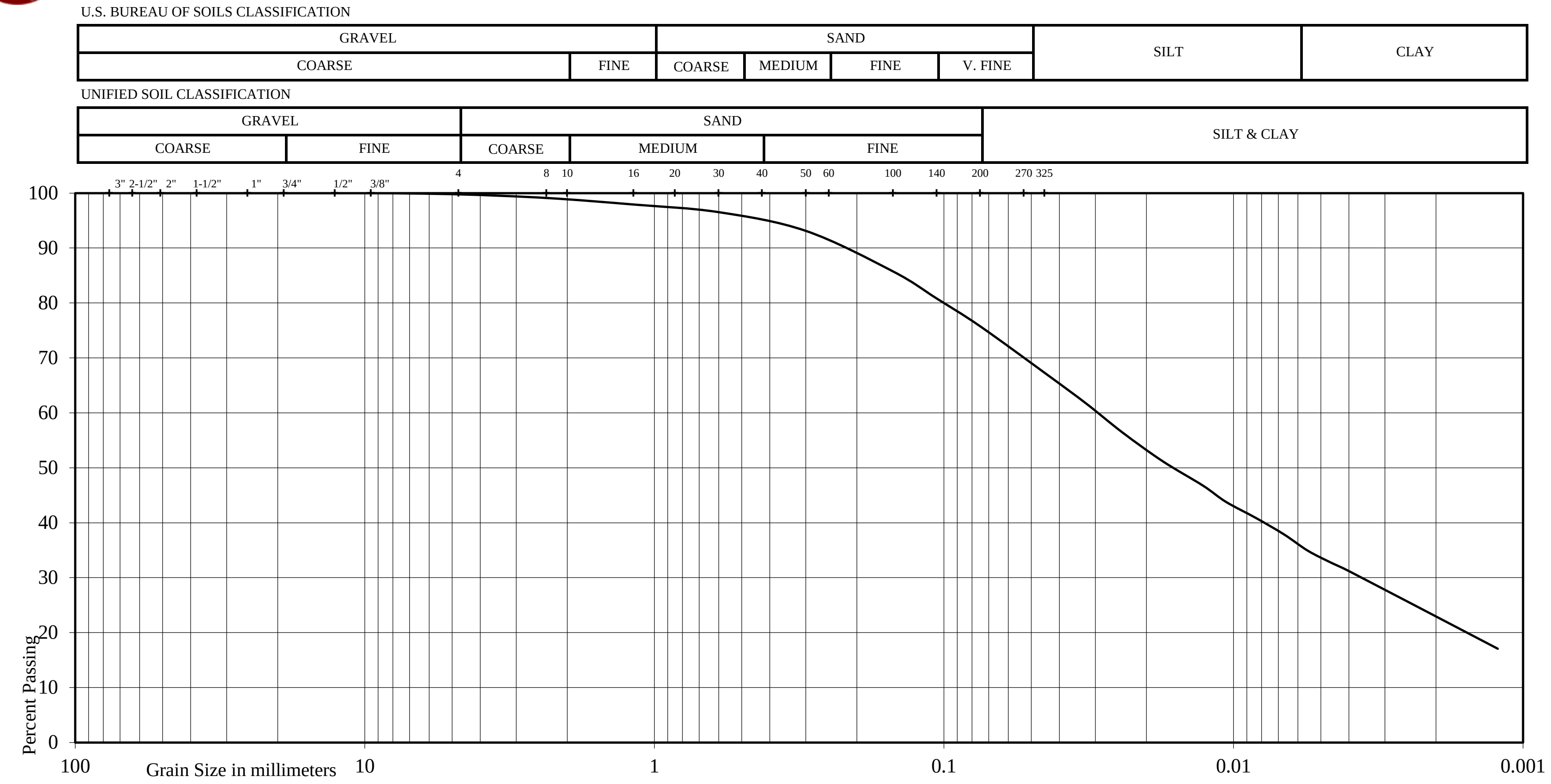
Dry on completion

Soil Engineers Ltd.

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1006-S045



Project:	Proposed Residential Development		
Location:	13576 and 13584 Coleraine Drive, Town of Bolton	Liquid Limit (%) =	-
		Plastic Limit (%) =	-
Borehole No:	1	Plasticity Index (%) =	-
Sample No:	3	Moisture Content (%) =	21
Depth (m):	1.8	Estimated Permeability	
Elevation (m):	99.7	(cm./sec.) =	10^{-7}

Classification of Sample [& Group Symbol]: EARTH, Fill

silty clay, some sand and a trace of gravel

Figure: 5

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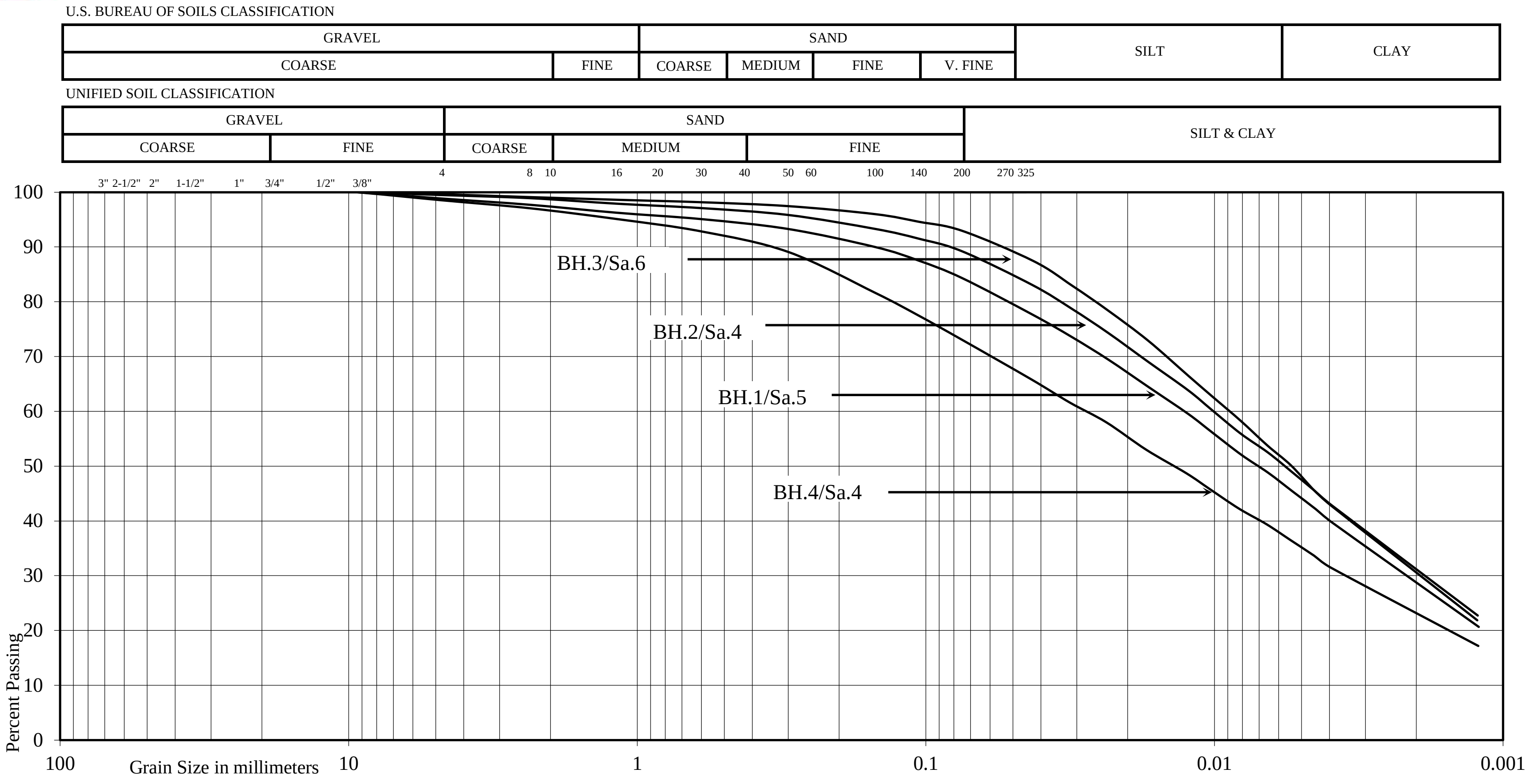
GRAIN SIZE DISTRIBUTION

Reference No: 1006-S045



Project: Proposed Residential Development

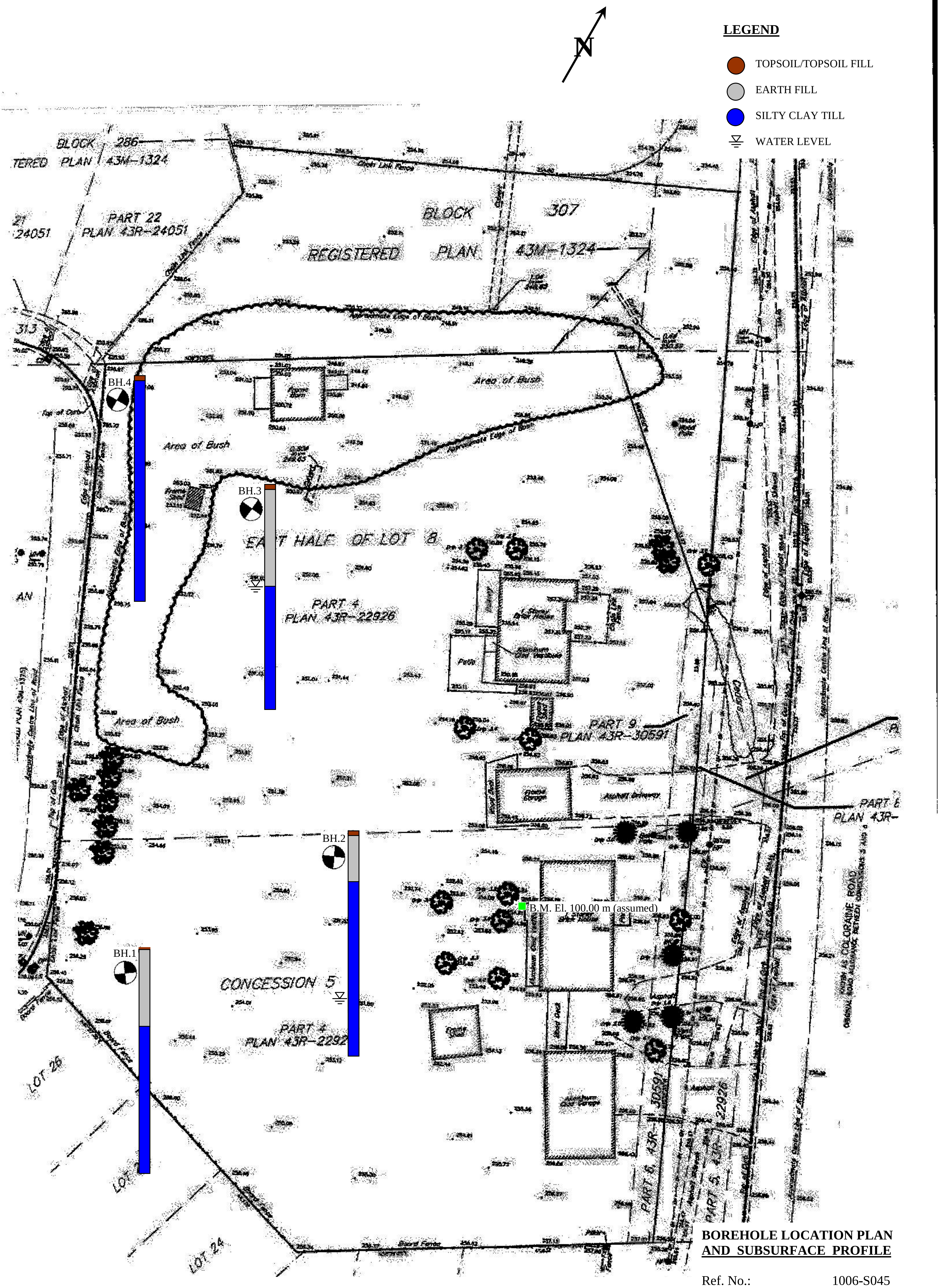
Location: 13576 and 13584 Coleraine Drive, Town of Bolton

Borehole No:	1	2	3	4
Sample No:	5	4	6	4
Depth (m):	3.3	2.5	4.8	2.5
Elevation (m):	98.2	93.9	91.3	97.6

BH./Sa.	1/5	2/4	3/6	4/4
Liquid Limit (%) =	31	32	33	29
Plastic Limit (%) =	18	19	19	17
Plasticity Index (%) =	13	13	14	12
Moisture Content (%) =	16	14	21	12
Estimated Permeability (cm./sec.) =	10^{-7}	10^{-7}	10^{-7}	10^{-7}

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

Figure: 6



LEGEND

🟤 TOPSOIL/TOPSOIL FILL

⚪ EARTH FILL

🔵 SILTY CLAY TILL

▽ WATER LEVEL

BOREHOLE LOCATION PLAN AND SUBSURFACE PROFILE

Ref. No.:	1006-S045
Date:	May 2013
Drawing No.:	1
Scale: Vert.: 1:100	Horiz.: 1:400

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