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A REPORT TO
SOLMAR (NIAGARA 2) INC.

A GEOTECHNICAL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

200 JOHN STREET AND 588 CHARLOTTE STREET

TOWN OF NIAGARA-ON-THE-LAKE

REFERENCE NO. 1807-S136

OCTOBER 2018

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1.0 **INTRODUCTION**

In accordance with written authorization dated July 19, 2018, from Mr. Maurizio Rogato, of Solmar (Niagara 2) Inc., a geotechnical investigation was carried out at a parcel of land at 200 John Street and 588 Charlotte Street, in the Town of Niagara-on-the-Lake, for a proposed Residential Development.

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

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

2.0 **SITE AND PROJECT DESCRIPTION**

The site is located on Iroquois Lake plain where the drifts, in places, have been partly eroded by the water action of the glacial lake and filled with lacustrine sand, silt, clay and water-laid tills (reworked).

The investigated site is irregular in shape and is situated at the southeast of John Street and Charlotte Street, in the Town of Niagara-on-the-Lake. The investigated area is a weed-covered open field with existing sheds and building structures and it is located adjacent to a residential subdivision. The ground surface is relatively level with some undulations.

The proposed project will consist of the construction of a new residential development, with municipal services and roadways meeting the municipal standards.

3.0 FIELD WORK

The field work, consisting of 9 boreholes to depths ranging from 5.4 to 9.3 m, was performed on August 14, 15 and 16, 2018, at the locations shown on the Borehole Location Plan, Drawing No. 1. Refusal to augering was encountered at Borehole 8 at a depth of 5.4 m below the prevailing ground surface. It is inferred that bedrock or boulders occurs at this level. A total of 4 monitoring wells were also installed at Boreholes 1 (nested wells), 2 and 7.

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 from the spot elevations on the site plan provided by the client.

4.0 SUBSURFACE CONDITIONS

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

The investigation has disclosed that beneath a veneer of topsoil and a layer of earth fill at Borehole 8, the site is underlain by strata of silty clay, silty clay till, sandy silt and sandy silt till at various depths and locations and overlying a bedrock in Boreholes 1, 2 and 3.

4.1 Topsoil (All Boreholes)

The revealed topsoil ranges from 8 to 23 cm thick. It is dark brown in colour, indicating that it contains appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil is considered to be void of engineering value. Due to its humus content, it may produce volatile gases and generate an offensive odour under anaerobic conditions. Therefore, the topsoil must not be buried below any structures or deeper than 1.2 m below the finished grade, so that it will not have an adverse impact on the environmental well-being of the developed areas.

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

4.2 **Earth Fill** (Borehole 8)

The earth fill was found extending to a depth of 1.4 m below the prevailing ground surface. The fill consists of sandy silt, with rock fragments and brick debris.

The obtained ‘N’ values of the fill are 18 and 30 blows per 30 cm of penetration, indicating that the earth fill was placed with some compaction.

The natural water content values are 8% and 10%, indicating that the fill is in a moist condition, which was confirmed by the sample examinations.

A grain size analysis was performed on 1 of the earth fill samples; the result is plotted on Figure 10.

Due to its unknown history, and since it contains rock fragments and brick debris, the earth fill is considered unsuitable for supporting structures. For structural use, the fill must be sorted free of any other deleterious material, and properly compacted.

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

4.3 **Silty Clay** (Boreholes 1, 2, 3, 4 and 5)

The silty clay was encountered at various depths and the clay is laminated with sand and silt seams and layers, showing that it is a glaciolacustrine deposit. The clay deposit is weathered to depths of 0.7 m and 1.4 m below the prevailing ground surface.

The obtained ‘N’ values range from 6 blows per 30 cm to 50 blows per 13 cm, with a median of 12 blows per 30 cm of penetration, indicating that the consistency of the clay is firm to hard, being generally stiff. The firm and stiff clay was found in the weathered clay stratum.

The natural water content of the samples was determined, and the results are plotted on the Borehole Logs. The values range from 10% to 17%, with a median of 15%, showing the clay deposit is in a moist to very moist condition.

A grain size analysis was performed on 1 representative sample of the silty clay; the result is plotted on Figure 11.

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

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

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

- A cohesive-frictional soil, its shear strength is derived from consistency and augmented by the internal friction of the silt. Its shear strength is moisture dependent.
- In excavation, the clay will be prone to sloughing if it is exposed for prolonged periods in steep cuts. This would generally be initiated by infiltrating precipitation or groundwater seeping out from the silt and fine sand layers.
- 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 3500 ohm·cm.

4.4 **Silty Clay Till** (Boreholes 2, 3 and 9)

The silty clay till was encountered below a deposit of either silty clay or sandy silt till. It consists of a random mixture of soils; the particle sizes range from clay to gravel, with the clay fraction exerting the dominant influence on its soil properties. Occasional wet sand and silt seams and layers were also detected in the clay till mantle. The till is heterogeneous in structure, indicating that it is a glacial deposit.

The obtained ‘N’ values range from 24 to 73, with a median of 40 blows per 30 cm of penetration, indicating that the consistency of the silty clay till is very stiff to hard, being generally hard.

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

The Atterberg Limits of 3 representative samples and the natural water content values of the samples were determined; the results are plotted on the Borehole Logs and summarized below:

Liquid Limit	24%, 24% and 26%
Plastic Limit	15%, 16% and 16%
Natural Water Content	10% to 13% (median 13%)

The results show that the clay till is a cohesive material with low plasticity. The natural water content values generally lie below its plastic and liquid limits, confirming the generally hard consistency of the till as determined by the 'N' values.

Grain size analyses were performed 3 representative samples of the silty clay till. The results are plotted on Figure 12.

Based on the findings, the engineering properties related to the project are as follows:

- High frost susceptibility, with low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-7} cm/sec, an estimated percolation rate of 80 min/cm, 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 very poor pavement-supportive material, with an estimated CBR value of 3% or less.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4000 ohm·cm.

4.5 **Sandy Silt** (Boreholes 1, 4, 5, 6, 7 and 9)

The sandy silt deposit was encountered at various depths. Occasional wet silty fine sand and silt seams and layers were found laminated in the sandy silt. The laminated structure shows that the sandy silt is a lacustrine deposit. The sandy silt layer is weathered to a depth of 0.7 m at Boreholes 7 and 9.

The obtained 'N' values range from 9 blows per 30 cm to 50 blows per 8 cm, with a median of 32 blows per 30 cm of penetration, showing the relative density of the sandy silt is loose to very dense, being generally dense. The loose and marginally compact silt occurs in the weathered zone.

The natural water content of the samples was determined, and the results are plotted on the Borehole Logs. The values range from 8% to 20%, with a median of 12%, showing the sandy silt deposit is in a moist to wet condition. The wet sandy silt is water-bearing.

A grain size analysis was performed on one of the samples and the result is plotted on Figure 13.

Accordingly, the following engineering properties are deduced:

- Highly frost susceptible with high soil-adfreezing potential.
- Highly water erodible.
- A soil of high capillarity and water retention capability.
- Relatively pervious, with an estimated coefficient of permeability of 10^{-5} cm/sec, an estimated percolation rate of 35 min/cm, and runoff coefficients of:

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

- A frictional soil, its shear strength is derived from internal friction and is density dependent. Due to its dilatancy, the shear strength of the wet sandy silt is susceptible to impact disturbance; i.e., the disturbance will induce a build-up of pore pressure within the soil mantle, resulting in soil dilation and a reduction of shear strength.
- In relatively steep cuts, the sandy silt will be stable in a damp to moist condition, but will slough if it is wet, run with water seepage and boil with a piezometric head of 0.3 m.
- A fair pavement-supportive material, with an estimated CBR value of 10%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

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

The sandy silt till was encountered at various depths and extends to the maximum investigated depth at Boreholes 4, 5, 6, 7, 8 and 9. It consists of a random mixture of soil particle sizes ranging from clay to gravel, with the silt being the predominant fraction. Its structure is heterogeneous, indicating it is a glacial deposit.

Hard resistance to augering was encountered in places, indicating the presence of cobbles and boulders. Occasional wet sand and silt seams and layers were also found in the till mantle.

The obtained ‘N’ values range from 17 blows per 30 cm to 50 blows per 10 cm, with a median of 50 blows per 15 cm, showing that the relative density of the till is compact to very dense, being generally very dense.

The natural water content was determined, and the results are plotted on the Borehole Logs; the values range from 7% to 27%, with a median of 11%, showing the sandy silt till is in a moist to wet condition.

Grain size analyses were performed on 2 representative samples and the results are plotted on Figure 14.

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

- Moderately high frost susceptibility and moderately low water erodibility.
- Relatively low permeability, with an estimated coefficient of permeability of 10^{-6} cm/sec, depending on the clay and silt content, an estimated percolation rate of 50 to 65 min/cm, and runoff coefficients of:

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

- 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 fair pavement-supportive material, with an estimated CBR value of 8% to 10%.
- Moderately low corrosivity to buried metal, an estimated electrical resistivity of 5000 ohm·cm.

4.7 **Shale Bedrock** (Boreholes 1, 2 and 3)

The shale bedrock was encountered at depths from 5.8 to 7.8 m below the prevailing ground surface. It is reddish-brown in colour, showing it is a Queenston formation. It is laminated, sedimentary, moderately soft rock, thin- to thickly bedded and consists predominantly of mudstone with occasional hard, limy shale and sandstone bands.

The upper layer of the shale bedrock can be penetrated through by power-augering, showing that it has been weathered. The weathered shale generally extended 2.0 to 3.0 m below the surface of the bedrock and the sound portion was relatively poor quality.

Infiltrated precipitation and groundwater from the overburden soils will often permeate the fissures in the rock and, in places, will be under subterranean artesian pressure. However, because the shale is a clay rock, it is considered to be a material of low permeability and a poor aquifer, and the groundwater yield from the rock will be limited.

The shale is susceptible to disintegration and swelling upon exposure to air and water, with subsequent reversion to a clay soil, but the laminated limy and sandy layers will remain as rock slabs.

When excavating the sound shale, slight lateral displacement of the excavation walls is often experienced. This is due to the release of residual stress stored in the bedrock mantle and the swelling characteristic of the rock.

The weathered rock can be excavated with considerable effort by a heavy-duty backhoe equipped with a rock-ripper; however, excavation will become progressively more difficult with depth into the sound shale. Efficient removal of the sound shale may require the aid of pneumatic hammering and/or blasting.

Experience has shown that excavations into the sound shale will create a fractured zone, and a wider excavation filled with sand fill and lined with compressible Styrofoam (or equivalent) will diminish the load intensity imposed on buried structures by the rock movement.

The excavated spoil will contain a large amount of hard limy and sandy rock slabs, rendering it virtually impossible to obtain uniform compaction. Therefore, unless the spoil is sorted, it is considered unsuitable for engineering applications.

4.8 Interpretation of Refusal to Augering

Refusal to augering was encountered at Borehole 8 at a depth of 5.4 m below the prevailing ground surface. It is inferred that bedrock or boulders occur at this level.

4.9 Compaction Characteristics of the Revealed Soils

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

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

Table 1 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Earth Fill	8 and 10	12	8 to 16
Silty Clay	10 to 17 (median 15)	18	14 to 23
Silty Clay Till	10 to 13 (median 13)	16	12 to 21
Sandy Silt	8 to 20 (median 12)	12	8 to 16
Sandy Silt Till	7 to 27 (median 11)	12	8 to 16
Shale Bedrock	6, 7 and 10	10	7 to 17

Based on the above findings, the in-situ soils are generally suitable for a 95% or + Standard Proctor compaction. The broken shale must be pulverized to sizes of 15 cm or less and continuously wetted during structural compaction. The earth fill must be sorted free of any deleterious materials prior to use as structural fill.

Some of the soils will require water addition for proper compaction while some of the soils need proper aeration in dry, warm weather conditions prior to using for structured compaction.

The silty clay, silty clay till, sandy silt till and the broken shale (with sizes less than 15 cm) should be compacted using a heavy-weight, kneading-type roller. The sandy and silt can be compacted by a smooth roller with or without vibration, depending on the water content of the soil being compacted. 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 or dense to very dense sandy silt 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). It is difficult to monitor the lifts of backfill placed in deep trenches; therefore, it is preferable that the compaction of backfill at depths over 1.0 m below the pavement subgrade be carried out on the wet side of the optimum. This would allow a wider latitude of lift thickness. Wetting of the tills will be necessary to achieve this requirement.

One should be aware that, with considerable effort, a 90%± Standard Proctor compaction of the wet silt is achievable. Further densification is prevented by the pore pressure induced by the compactive effort; however, large random voids will have been expelled and, with time, the pore pressure will dissipate and the percentage of compaction will increase. There are many cases on record where, after a few months of rest, the density of the compacted mantle has increased to over 95% of its maximum Standard Proctor dry density.

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

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

5.0 GROUNDWATER CONDITIONS

Groundwater seepage encountered during augering was recorded on the field logs. The level of groundwater and the occurrence of cave-in were measured upon completion of the boreholes; the data are plotted on the Borehole Logs and listed in Table 2.

Table 2 - Groundwater Levels

		Soil Colour Changes Brown to Grey	**Seepage Encountered During Augering**		**Measured Groundwater/ Cave-In* Level On Completion**	
BH No.	**Borehole Depth (m)**	**Depth (m)**	**Depth (m)**	**Amount**	**Depth (m)**	**Elevation (m)**
1	9.3	9.3+	1.0	Some	5.8	85.7
2	6.3	6.3+	-	-	4.3/4.6*	86.8/86.5*
3	6.6	6.6+	1.6	Some	Dry	-
4	6.3	2.9	1.7	Some	3.0/5.2*	87.6/85.4*
5	6.6	3.0	1.7	Some	Dry	-
6	6.6	6.6+	1.0	Some	Dry	-
7	6.6	5.8	1.0	Some	Dry	-
8	5.4	5.4+	-	-	Dry	-
9	6.6	2.9	1.0	Some	2.1	88.0

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

Groundwater and cave-in were encountered at depths ranging from 2.1 to 5.8 m below the prevailing ground surface at 4 of the boreholes; all other boreholes remained dry upon completion of field work. The detected groundwater generally represents the groundwater regime of the site at the time of the investigation and will be subject to seasonal fluctuation.

The groundwater yield from the silty clay, silty clay till and sandy silt till, due to their low to relatively low permeability, will be small and limited. The yield of groundwater from the silt, if encountered, will be moderate.

It should be noted that groundwater under subterranean artesian pressure may occur, in places, within the shale bedrock, which is considered to be a poor aquifer. Therefore, the yield of groundwater from the shale, if encountered, will be appreciable initially; however, if allowed to drain freely, it will often dissipate or be depleted with time.

6.0 DISCUSSION AND RECOMMENDATIONS

The findings from the boreholes have revealed that beneath a veneer of topsoil and a layer of earth fill at Borehole 8, the site is underlain by strata of firm to hard, generally stiff silty clay; very stiff to hard, generally hard silty clay till; loose to very dense, generally dense sandy silt; and compact to very dense, generally very dense sandy silt till at various depths and locations; shale bedrock was found in Boreholes 1, 2 and 3. The surficial soil layers are generally weathered to depths of 0.7 m and 1.4 m below the prevailing ground surface. The weathered soils are generally soft to firm and loose to marginally compact.

Groundwater and cave-in were encountered at depths ranging from 2.1 to 5.8 m below the prevailing ground surface at 4 of the boreholes; all other boreholes remained dry upon completion of field work. The detected groundwater generally represents the groundwater regime of the site at the time of the investigation and will be subject to seasonal fluctuation.

The groundwater yield from the silty clay, silty clay till and sandy silt till, due to their low to relatively low permeability, will be small and limited. The yield of groundwater from the silt, if encountered, will be moderate.

It should be noted that groundwater under subterranean artesian pressure may occur, in places, within the shale bedrock, which is considered to be a poor aquifer. Therefore, the yield of groundwater from the shale, if encountered, will be appreciable initially; however, if allowed to drain freely, it will often dissipate or be depleted with time.

The geotechnical findings which warrant special consideration are presented below:

1. The topsoil must be stripped for the project construction. This material will generate volatile gases under anaerobic conditions and is unsuitable for engineering applications. Therefore, this material should be placed in the landscaped areas only and should not be buried within the building envelope, or deeper than 1.2 m below the exterior finished grade of the project. A fertility test must be carried out to assess its suitability as landscaping material.
2. The existing earth fill is unsuitable for supporting structures in its current state. In using the fill for structural backfill, it should be subexcavated, inspected, sorted free of any deleterious materials, proof-rolled and properly compacted.
3. The sound natural soils below the topsoil, earth fill and weathered soil are suitable for normal spread and strip footing construction. Due to the presence of topsoil, 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, to ensure that its condition is compatible with the design of the foundation.
4. For basement construction, perimeter subdrains and dampproofing of the foundation walls will be required. All the subdrains must be encased in a fabric filter to protect them against blockage by silting and must be connected to a positive outlet. This can be assessed at the time of construction.
5. For slab-on-grade construction, the slab should be placed on relatively sound soils or properly compacted earth fill. Prior to the slab construction, the subgrade must be proof-rolled and inspected. Any weathered or soft soils

detected must be subexcavated and replaced with inorganic material compacted to 98% or + Standard Proctor dry density.

6. A Class ‘B’ bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. Where water-bearing silt occurs, the sewer joints should be leak-proof, or wrapped with an appropriate waterproof membrane, to prevent subgrade migration. If subgrade stabilization is required, the stone immersion technique may be applied. In areas where more extensive dewatering is required for sewer construction, a Class ‘A’ bedding should be considered.
7. Some of the soils are highly frost susceptible, with high soil-adfreezing potential. Where these soils are used to backfill against foundation walls, special measures must be incorporated into the building construction to prevent serious damage due to soil adfreezing.
8. The tills contain occasional boulders and cobbles. Boulders over 15 cm in size must not be used for structural backfill. Excavation into the till containing boulders will require extra effort and the use of a heavy-duty backhoe.
9. The weathered shale can be excavated by a heavy-duty backhoe equipped with a rock-ripper; however, extra effort will be required. For excavation into the sound shale, the use of a pneumatic hammer may be required for efficient rock removal.

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

Table 3 - Founding Levels

	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Corresponding Founding Level			
	200 kPa (SLS) 320 kPa (ULS)		**400 kPa (SLS) 660 kPa (ULS)**	
BH No.	**Depth (m)**	**El. (m)**	**Depth (m)**	**El. (m)**
2	1.0 or +	90.1 or -	1.5 or +	89.6 or -
3	1.0 or +	90.0 or -	1.5 or +	89.5 or -
4	2.0 or +	88.6 or -	4.6 or +	86.0 or -
5	1.0 or +	89.4 or -	1.6 or +	88.8 or -
6	1.0 or +	89.4 or -	1.3 or +	89.1 or -
7	1.4 or +	89.1 or -	1.6 or +	88.9 or -
8	-	-	1.6 or +	88.7 or -
9	1.2 or +	88.9 or -	2.0 or +	88.1 or -

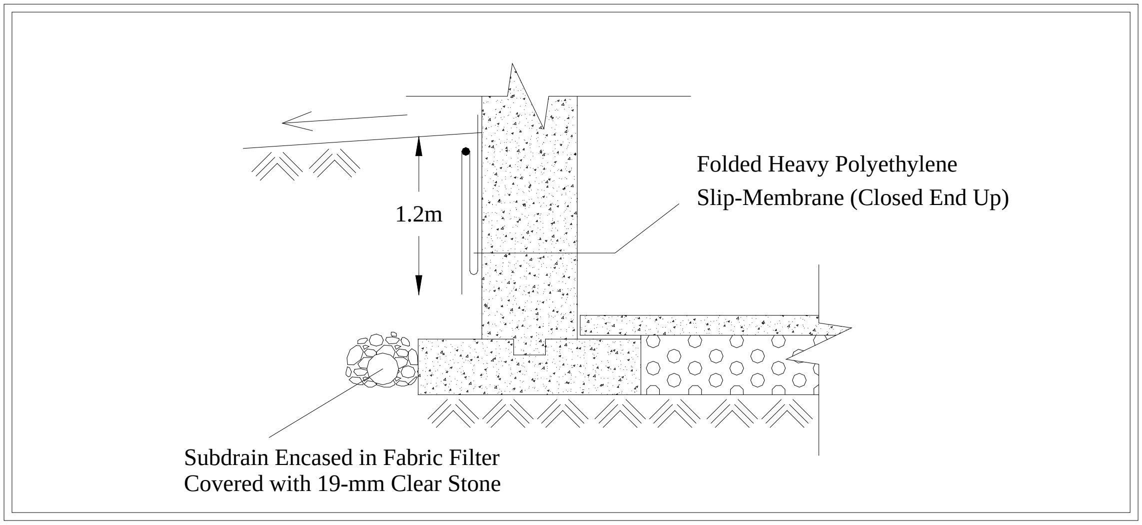
The recommended soil pressures (SLS) for normal foundations incorporate a safety factor of 3. The total and differential settlements of the foundations are estimated to be 25 mm and 15 mm, respectively.

The foundations exposed to weathering and in unheated areas should have at least 1.2 m of earth cover for protection against frost action, or must be properly insulated.

To ensure that the condition of the subgrade is compatible with the foundation design requirements, the footing subgrade of the normal foundations must be inspected by a geotechnical engineer, or a technician under the supervision of a geotechnical engineer.

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

Diagram 1 - Frost Protection Measures (Foundations)



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

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

6.2 **Engineered Fill**

Where earth fill is required to raise the site or where extended footings are necessary for foundation construction, the engineering requirements for a certifiable fill for road construction, municipal services, slab-on-grade, and footings designed with a Maximum Allowable Soil Pressure (SLS) of 150 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 250 kPa for normal footings are presented below:

1. The topsoil and earth fill must be removed.
2. The weathered and loose or firm soils must be subexcavated, and the subgrade must be inspected and proof-rolled prior to any fill placement.
3. Inorganic soils must be used for filling. The fill should be free of topsoil inclusions or other deleterious materials. It must be uniformly compacted in lifts 20 cm thick to 98% or + of their maximum Standard Proctor dry density up to the proposed finished grade. The soil moisture must be properly controlled on the wet side of the optimum.
4. If imported fill is to be used, it should be inorganic soils, free of any deleterious material with environmental issue (contamination). Any potential imported earth fill from off-site must be reviewed for geotechnical and environmental quality by the appropriate personnel as authorized by the developer or agency, before it is hauled to the site.

5. If the house foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum Standard Proctor compaction.
6. 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.
7. The engineered fill must extend over the entire graded area; the engineered fill envelope and finished elevations must be clearly and accurately defined in the field, and they must be precisely documented by qualified surveyors. Foundations partially on engineered fill must be reinforced by two 15-mm steel reinforcing bars in the footings and upper section of the foundation walls, or be designed by a structural engineer, to properly distribute the stress induced by the abrupt differential settlement (about 15 mm) between the natural soil and engineered fill.
8. 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.
9. 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.
10. 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.
11. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
12. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that supervised the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill

envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.

13. Any excavation carried out in certified engineered fill must be reported to the geotechnical consultant who supervised the fill placement in order to document the locations of excavation and/or to supervise reinstatement of the excavated areas to engineered fill status. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the condition of the engineered fill must be assessed for re-certification.
14. Despite stringent control in the placement of the engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the strip footings and the upper section of the foundation walls constructed on the engineered fill may require continuous reinforcement with steel bars, depending on the uniformity of the soils in the engineered fill and the thickness of the engineered fill underlying the foundations. Should the footings and/or walls require reinforcement, the required number and size of reinforcing bars must be assessed by considering the uniformity as well as the thickness of the engineered fill beneath the foundations. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

6.3 **Slab-On-Grade**

For slab-on-grade construction, the subgrade must consist of sound natural soils, or properly compacted inorganic soils, to at least 98% of its maximum Standard Proctor dry density. The slab should be constructed on a granular base, 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density.

The sound natural soils are suitable for slab-on-grade construction. The weathered soils should be aerated and surface compacted for slab-on-grade construction.

A Modulus of Subgrade Reaction of 25 MPa/m is recommended for the design of the floor slab.

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

6.4 Garages, Driveways, Sidewalks and Interlocking Stone Pavement

The driveways at the entrances to the garages should be backfilled with non-frost-susceptible granular material, with a frost taper at a slope of 1 vertical:1 horizontal. Interlocking stone pavement in areas which are sensitive to frost-induced ground movement, such as entrances, must be constructed on a free-draining, non-frost-susceptible granular material such as Granular ‘B’. The material must extend to 1.2 m below the slab or pavement surface and be provided with positive drainage such as weeper subdrains connected to manholes or catch basins. Alternatively, the sidewalks and the interlocking stone pavement should be properly insulated with 50-mm Styrofoam, or equivalent, as approved by a geotechnical engineer.

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

6.5 **Underground Services**

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

A Class ‘B’ bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. Where the services are constructed in water-bearing silt, the pipe joints should be leak-proof or wrapped with an appropriate waterproof membrane to prevent subgrade migration. If subgrade stabilization is required, the stone immersion technique may be applied. In areas where more extensive dewatering is required for sewer construction, a Class ‘A’ bedding should be considered.

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

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

Since the silty clay has moderately high corrosivity to buried metal, the water main should be protected against corrosion. In determining the mode of protection, an electrical resistivity of 3500 ohm·cm should be used. This, however, should be confirmed by testing the soil along the water main alignment at the time of sewer construction.

6.6 **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.

All the backfill below the floor-slabs must be compacted to 98% or + of its Maximum Standard Proctor dry density.

In normal underground services construction practice, the problem areas of road settlement largely occur adjacent to manholes, catch basins, services crossings, foundation walls and columns, and it is recommended that a sand backfill be used.

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

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

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

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

compromise the compaction of the backfill in the upper section. In areas where groundwater movement is expected in the sand fill mantle, anti-seepage collars should be provided.

6.7 Pavement Design

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

Table 4 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder	50	HL-8
Granular Base	150	20-mm Crusher-Run Limestone, or equivalent
Granular Sub-base	300	50-mm Crusher-Run Limestone, or equivalent

In preparation of the subgrade, the final graded subgrade surface should be proof-rolled; any weathered, soft or loose soil and deleterious materials within 1.0 m below the underside of the granular sub-base should be subexcavated and replaced by properly compacted organic-free earth fill. It is necessary to provide a subgrade consisting of uniform material to minimize any differential heaving during the freezing and thawing seasons.

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 into 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 **Stormwater Management Pond** (Borehole 1)

It is understood that the proposed bottom of the Stormwater Management Pond (SWMP) is yet to be determined. The site is underlain by strata of silty clay, sandy silt, sandy silt till and shale bedrock at a depth of 7.8 m. The upper silty clay layer is weathered. The groundwater regime lies at a depth of 5.8 m below the prevailing ground surface. Due to the moderate permeability of the sandy silt and sandy silt till, an impermeable geosynthetic membrane, or a clay liner, 1.0 m thick, compacted to achieve at least 98% of its maximum Standard Proctor dry density, should be placed at the bottom and along the sides of the pond.

The coefficients of permeability and the infiltration rates of the encountered soils are given in Table 5.

Table 5 - Coefficients of Permeability and Infiltration Rates

Soil	**Coefficient of Permeability (cm/sec)**	**Infiltration Rate (min/cm)**
Silty Clay	10^{-7}	80
Sandy Silt and Till	10^{-5} to 10^{-6}	35 to 65

The bank of the pond should be sloped at 1 vertical:4 and 3 horizontal below the wet perimeter and above the water, respectively. The bank above the wet perimeter must be sodded to prevent rainwash erosion. Rip-rap should be placed along the wet perimeter to prevent wave erosion.

Where groundwater is found bleeding from the bank at the time in the construction of the pond, subdrains should be installed to relieve the groundwater seepage or reduce the build-up of seepage pressure behind the clay liner.

The footings for all of the control structures for the SWMP system must be placed onto the natural sound soils. A Maximum Allowable Soil Pressure (SLS) of 200 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 320 kPa are recommended for use in their design. The footings must be placed below the frost depth or scouring depth, whichever is deeper, i.e., to provide at least 1.2 m of earth cover for protection against frost action. The foundation must be properly reinforced.

The footing subgrade must be inspected by a geotechnical engineer prior to concrete pouring to ensure its conformity to the design.

The topsoil must be removed for the construction of the pond and replaced with properly compacted inorganic soils.

Gabion mats, or an approved equivalent, extending a distance of 5.0 m should be placed at the upstream and downstream ends of the control structures to prevent bed scouring.

6.8 Soil Parameters

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

Table 6 - Soil Parameters

Unit Weight and Bulk Factor

	Unit Weight (kN/m^3)	**Estimated Bulk Factor**	
	Bulk	**Loose**	**Compacted**
Weathered Shale Bedrock	24.0	1.50	1.10 to 1.15
Earth Fill and Weathered Soil	21.0	1.20	1.00
Silty Clay	20.5	1.30	1.00
Sound Tills	22.0	1.33	1.05
Silt	20.5	1.20	1.00

Table 6 - Soil parameters (Cont'd)

Lateral Earth Pressure Coefficients

	Active K_a	**At Rest** K_o	**Passive** K_p
Weathered Shale	0.15	0.25	6.70
Compacted Earth Fill, weathered Soil and Silty Clay	0.40	0.50	2.50
Sound Tills and Sandy Silt	0.33	0.45	3.00

6.9 Excavation

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

Excavations in excess of 1.2 m should be sloped at 1 vertical:1 horizontal for stability.

Excavation into the weathered shale and hard or very dense tills containing boulders will require extra effort and the use of a heavy-duty backhoe equipped with a rock-ripper.

For excavation purposes, the types of soils are classified in Table 7.

Table 7 - Classification of Soils for Excavation

Material	**Type**
Sound Shale Bedrock	1
Sound Tills and weathered Shale Bedrock	2
Silty Clay, Earth Fill, weathered Soil and Silt above groundwater	3
Silt below groundwater	4

The yield of groundwater from the silty clay and tills, due to their low to relatively low permeability, is expected to be small and limited. The yield from the silt will be moderate. In some instances, the shale contains occasional pockets of groundwater which are trapped in the rock fissures and may sometimes be under moderate subterranean artesian pressure. Upon release through excavation, this water will likely drain readily with limited yield. The groundwater can generally be controlled by pumping from closely spaced sump-wells.

Prospective contractors must be asked to assess the in situ subsurface conditions for soil cuts by digging test pits to at least 1.0 m below the intended bottom of excavation. These test pits should be allowed to remain open for a period of at least 4 hours to assess the trenching conditions.

7.0 LIMITATIONS OF REPORT

This report was prepared by Soil Engineers Ltd. for the account of Solmar (Niagara 2) Inc., and for review by its designated agents, financial institutions, and government agencies. Use of the report is subject to the conditions and limitations of the contractual agreement. The material in it reflects the judgment of Frank Lee, P.Eng., and Daniel Man, P.Eng., in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, and/or any reliance on decisions to be made based on it are the responsibility of such Third Parties. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

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LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

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

SAMPLE TYPES

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

PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

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

Plotted as '—●—'

Standard Penetration Resistance or 'N' Value:

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

Plotted as '○'

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

SOIL DESCRIPTION

Cohesionless Soils:

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

Cohesive Soils:

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

Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0	Field vane test in borehole; the number denotes the sensitivity to remoulding
△	Laboratory vane test
□	Compression test in laboratory

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

METRIC CONVERSION FACTORS

1 ft = 0.3048 metres

1lb = 0.454 kg

1 inch = 25.4 mm

1ksf = 47.88 kPa

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

JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

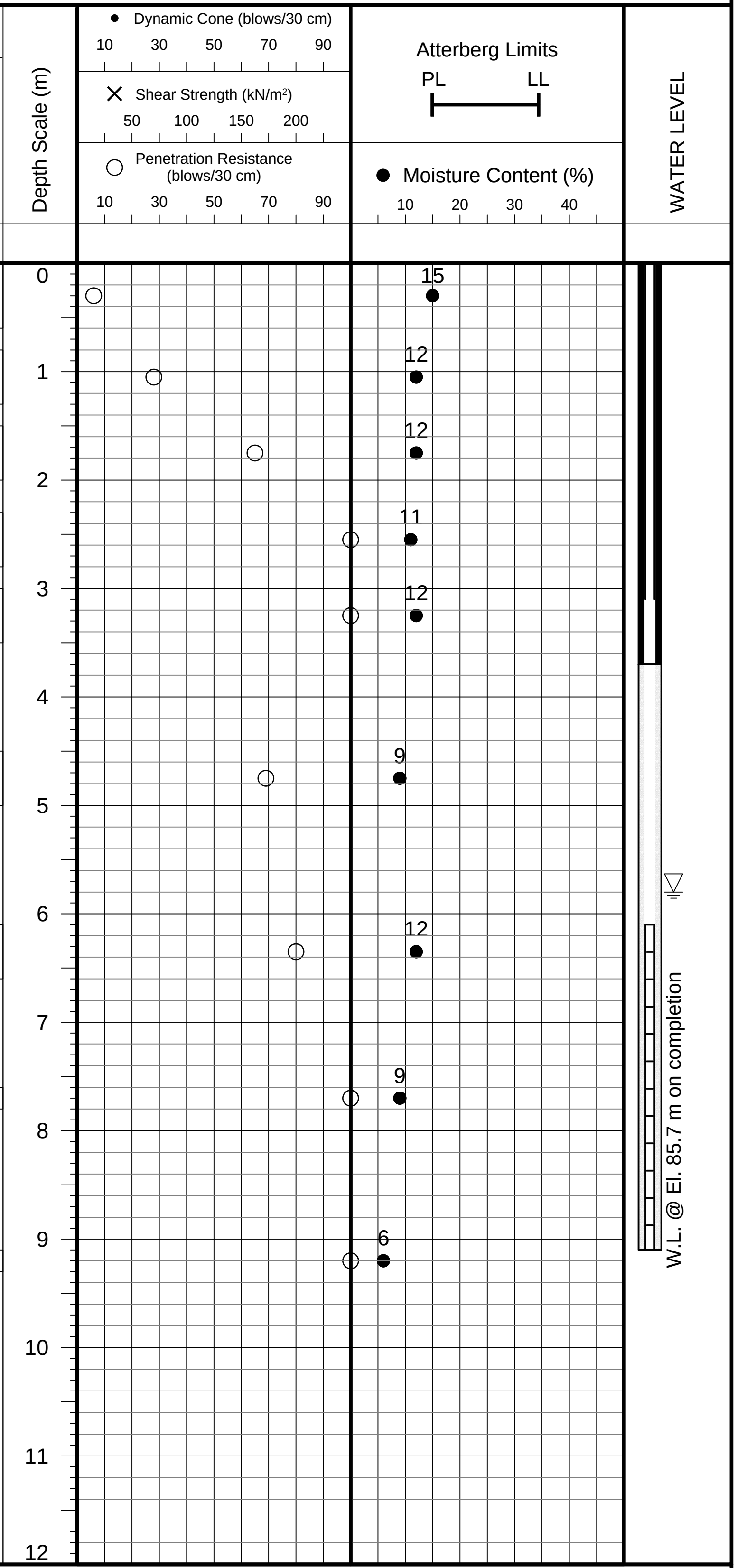
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 14. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
91.5	Ground Surface			
0.0	**18 cm TOPSOIL** Brown, firm, weathered **SILTY CLAY**	1	DO	6
90.8 0.7	Brown, compact to very dense **SANDY SILT**	2	DO	28
		3	DO	65
		4	DO	50/13
		5	DO	50/8
87.5 4.0	Brown to reddish-brown, very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	6	DO	69
		7	DO	80
		8	DO	50/10
83.7 7.8	Reddish-brown **SHALE BEDROCK** (weathered)	9	DO	50/8
82.2 9.3	**END OF BOREHOLE** Installed 50 mm Ø monitoring wells to 6.1 m and 9.1 m (nest wells) provided with a steel protective casing			



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JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

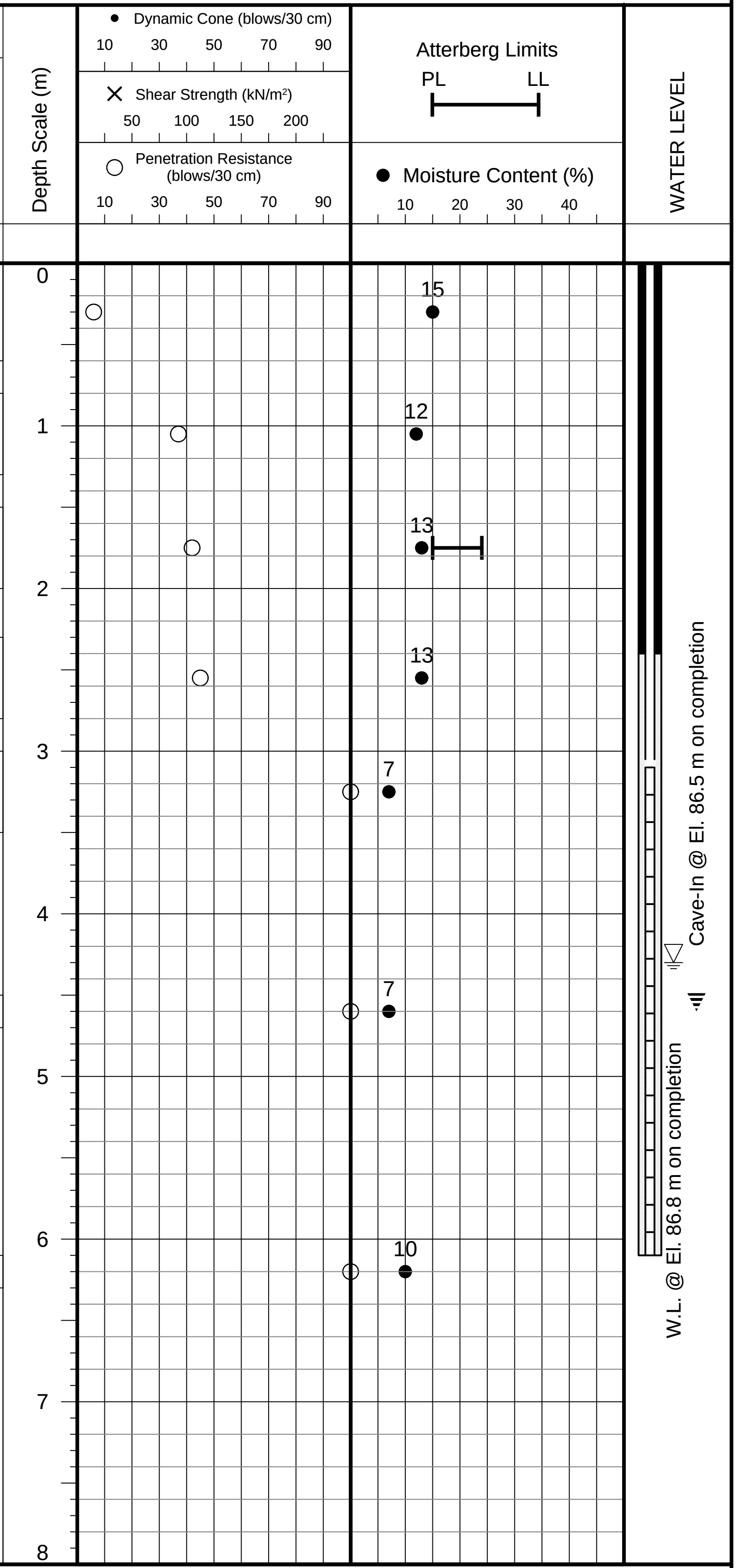
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 14. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
91.1	Ground Surface			
0.0	**20 cm TOPSOIL**			
	Brown, firm, weathered **SILTY CLAY**	1	DO	6
90.4 0.7	Brown, hard **SILTY CLAY TILL** occ. wet sand and silt seams and layers, cobbles and boulders	2	DO	37
		3	DO	42
		4	DO	45
88.2 2.9	Reddish-brown, very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	5	DO	50/13
		6	DO	50/15
85.3 5.8	Reddish-brown **SHALE BEDROCK** (weathered)	7	DO	50/8
84.8 6.3	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 6.1 m provided with a steel protective casing			



JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

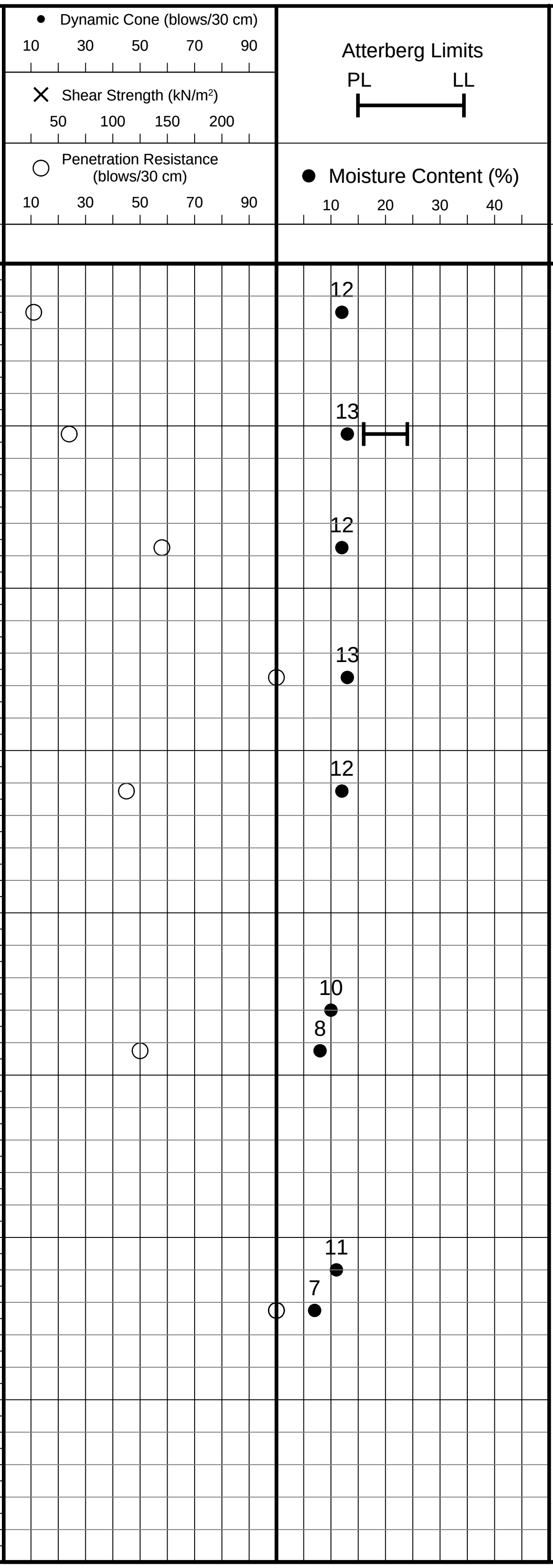
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 14. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Depth Scale (m)	WATER LEVEL
91.0	Ground Surface					
0.0	**23 cm TOPSOIL**				0	Dry on completion
	Brown, stiff, weathered **SILTY CLAY**	1	DO	11		
90.3 0.7	Brown, very stiff **SILTY CLAY TILL**	2	DO	24	1	
89.6 1.4	Brown to reddish-brown, dense to very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	3	DO	58	2	
		4	DO	50/13	3	
		5	DO	45	4	
		6A	DO			
		6B	DO	50	5	
		7A	DO		6	
84.7 6.3	Reddish-brown **SHALE BEDROCK**	7B	DO	50/13		
84.4 6.6	**END OF BOREHOLE**				7 8	



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JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

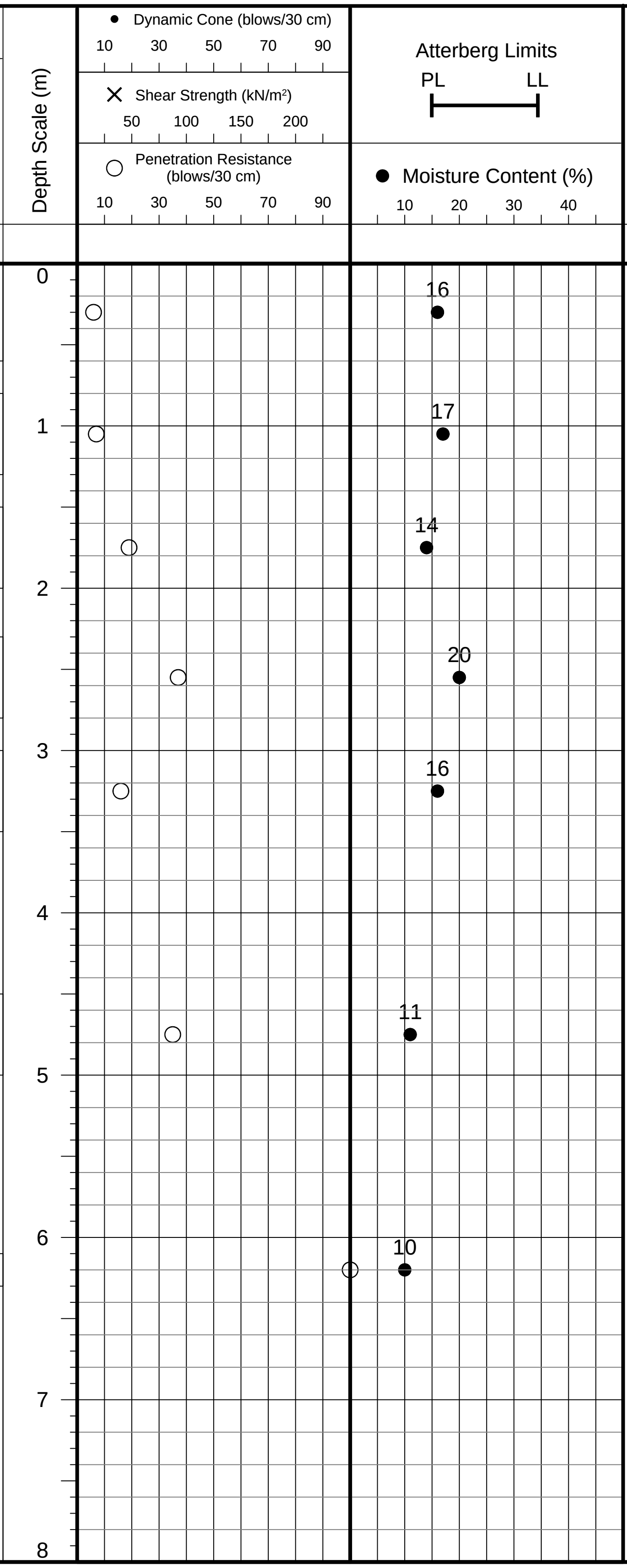
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 16. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
90.6	Ground Surface			
0.0	**15 cm TOPSOIL** Brown, firm, weathered **SILTY CLAY**	1	DO	6
		2	DO	7
89.2 1.4	Brown, compact to dense **SANDY SILT**	3	DO	19
		4	DO	37
87.7 2.9	Grey, stiff **SILTY CLAY**	5	DO	16
86.6 4.0	Reddish-brown, dense to very dense **SANDY SILT TILL**	6	DO	35
		7	DO	50/10
84.3 6.3	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 87.6 m on completion

Cave-In @ El. 85.4 m on completion

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JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

PROJECT DESCRIPTION: Proposed Residential Development

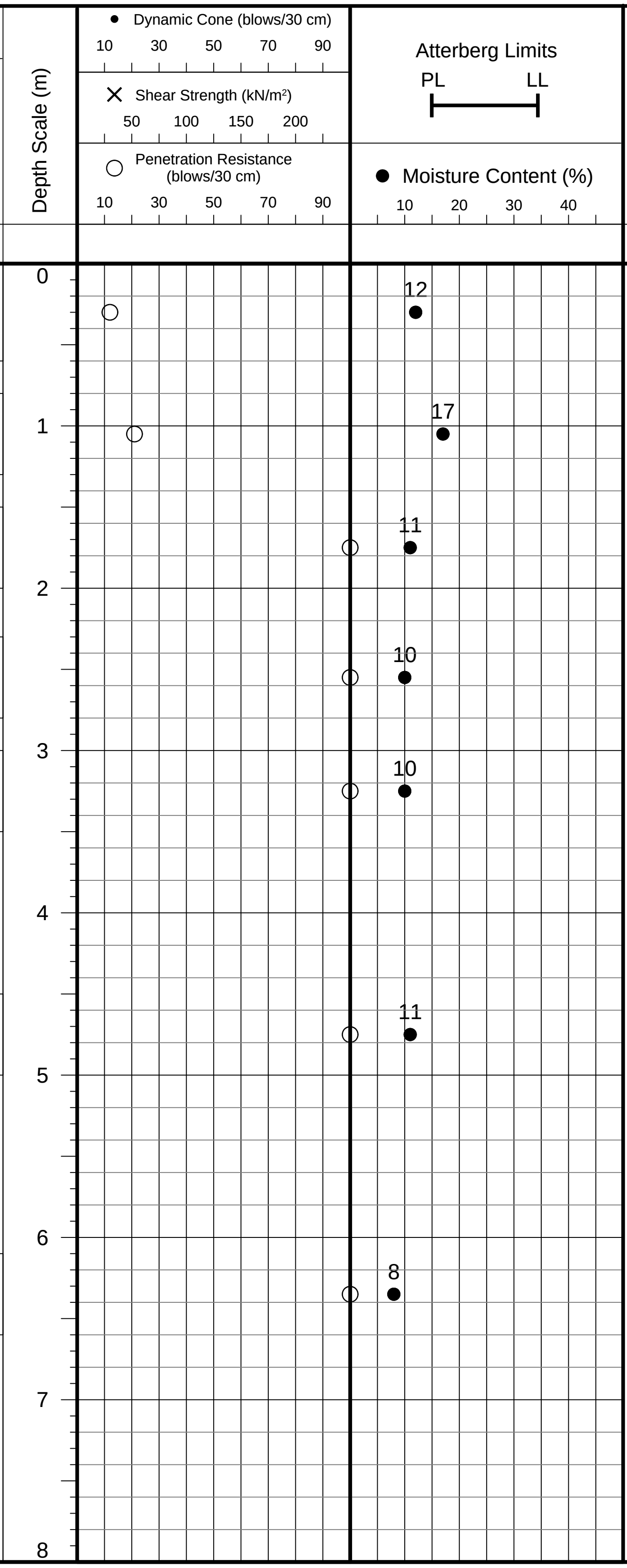
METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 16. 2018

El. (m) Depth (m)	SOIL DESCRIPTION
90.4	Ground Surface
0.0	**10 cm TOPSOIL**
	Brown, stiff to very stiff **SILTY CLAY** weathered
89.0 1.4	Brown, very dense **SANDY SILT**
88.3 2.1	Brown, hard **SILTY CLAY** occ. wet sand and silt seams and layers brown / grey
86.4 4.0	Reddish-brown, very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders
83.8 6.6	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1	DO	12
2	DO	21
3	DO	50/13
4	DO	50/13
5	DO	50/13
6	DO	50/13
7	DO	50/13



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

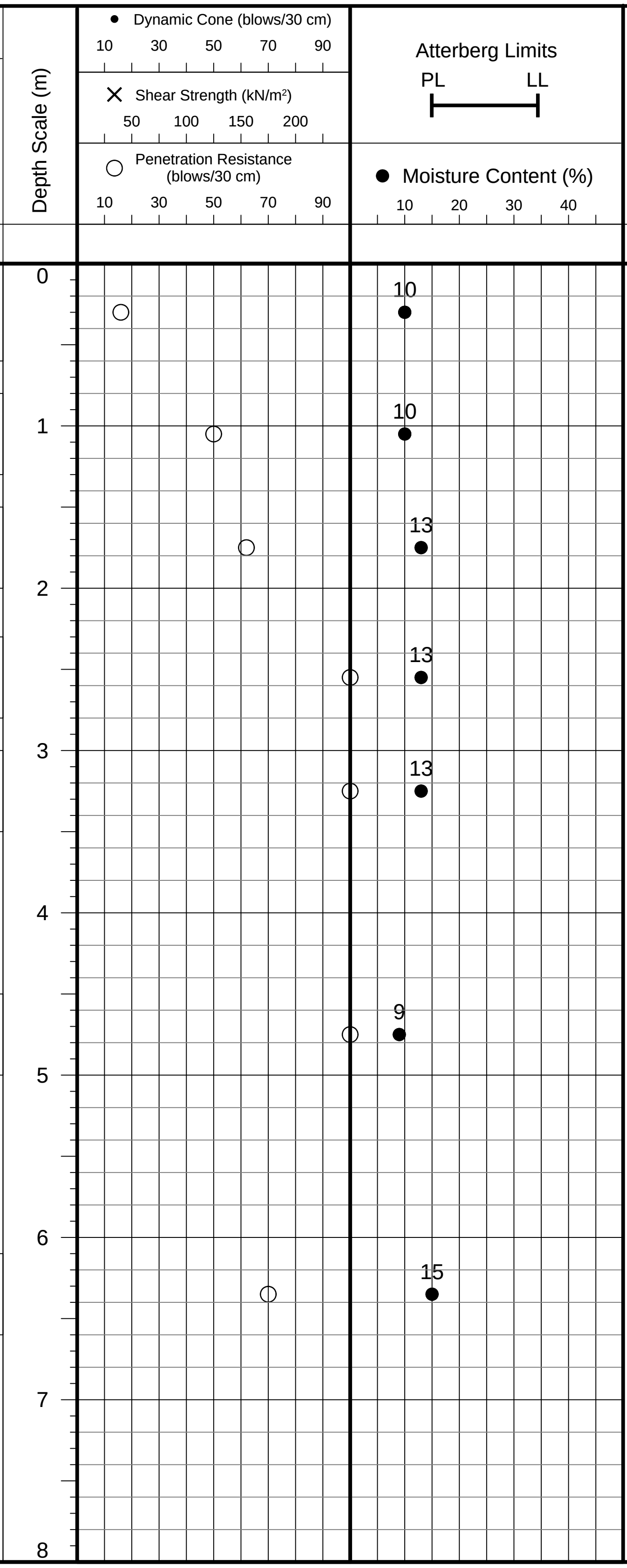
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 15. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
90.4	Ground Surface			
0.0	**8 cm TOPSOIL**			
	Brown, compact to dense **SANDY SILT**	1	DO	16
		2	DO	50
89.0 1.4	Brown, very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	3	DO	62
		4	DO	50/10
		5	DO	50/13
		6	DO	50/10
		7	DO	70
83.8 6.6	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

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Page: 1 of 1

JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

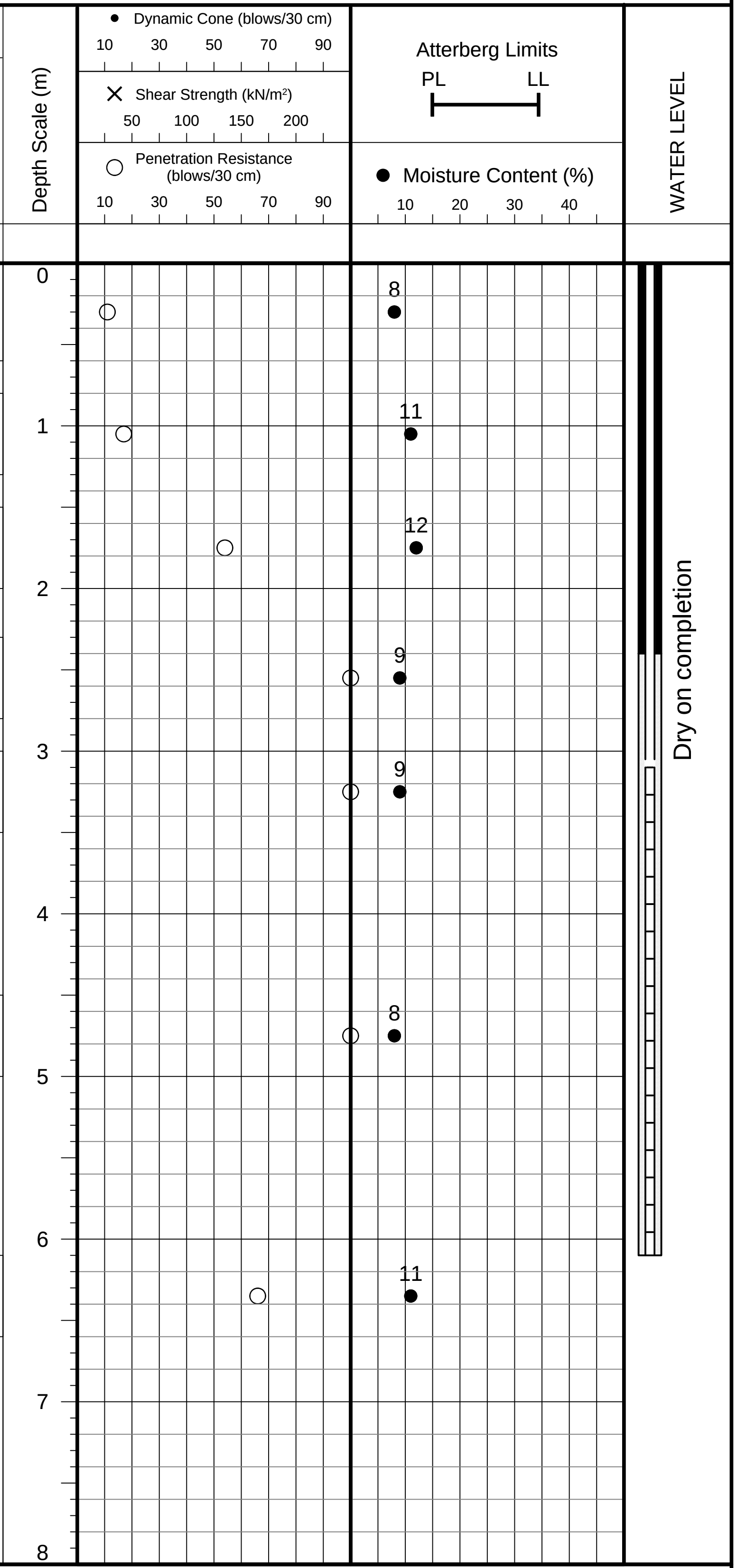
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 14. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
90.5	Ground Surface			
0.0 0.1	**15 cm TOPSOIL** Brown, compact, weathered **SANDY SILT**	1	DO	11
89.8 0.7	Compact to very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	2	DO	17
		3	DO	54
		4	DO	50/15
		5	DO	50/13
		6	DO	50/13
	brown / grey			
		7	DO	66
83.9 6.6	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 6.1 m provided with a steel protective casing			



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JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

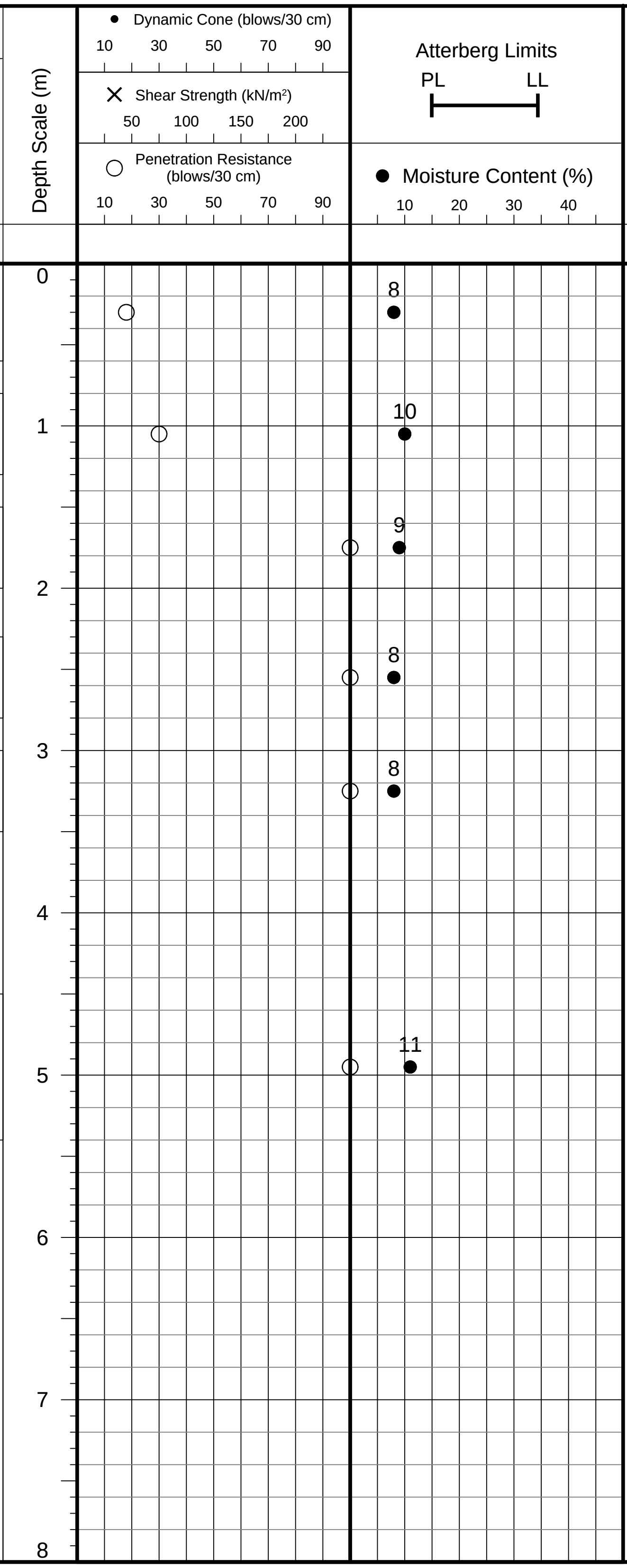
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 15. 2018

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
90.3 0.0	Ground Surface **15 cm TOPSOIL**			
	Brown **EARTH FILL** sandy silt with rock fragments and brick debris	1	DO	18
		2	DO	30
88.9 1.4	Brown to reddish-brown, very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	3	DO	50/15
		4	DO	50/13
		5	DO	50/15
		6	AS	50/15
84.9 5.4	**END OF BOREHOLE** **Refusal to augering** **Inferred bedrock or boulders**			



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO.: 1807-S136

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

PROJECT DESCRIPTION: Proposed Residential Development

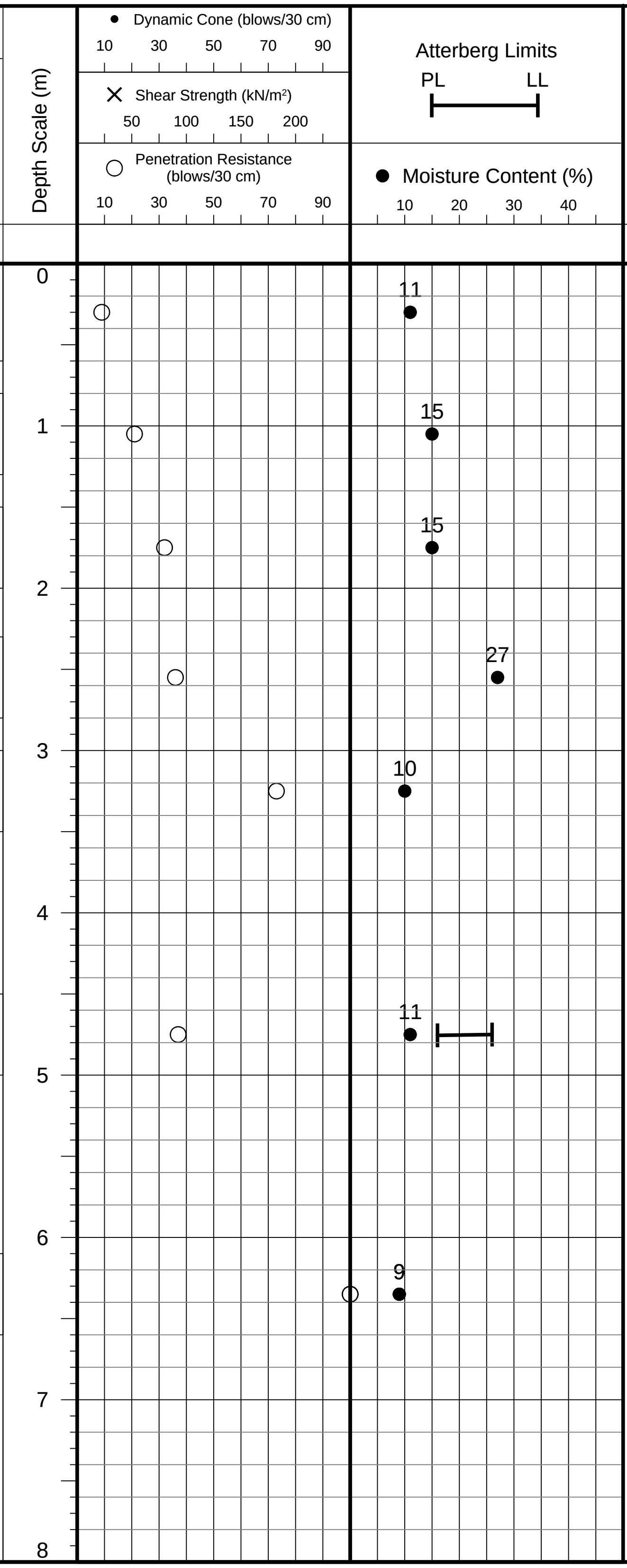
METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

DRILLING DATE: August 16. 2018

El. (m) Depth (m)	SOIL DESCRIPTION
90.1	Ground Surface
0.0	**18 cm TOPSOIL**
	Brown, loose to dense weathered **SANDY SILT**
88.0 2.1	Brown, dense **SANDY SILT TILL**
87.2 2.9	Grey, hard **SILTY CLAY TILL** occ. wet sand and silt seams and layer, cobbles and boulders
84.3 5.8	Reddish-brown, very dense **SANDY SILT TILL**
83.5 6.6	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1	DO	9
2	DO	21
3	DO	32
4	DO	36
5	DO	73
6	DO	37
7	DO	50/13



WATER LEVEL

∇

W.L. @ El. 88.0 m on completion

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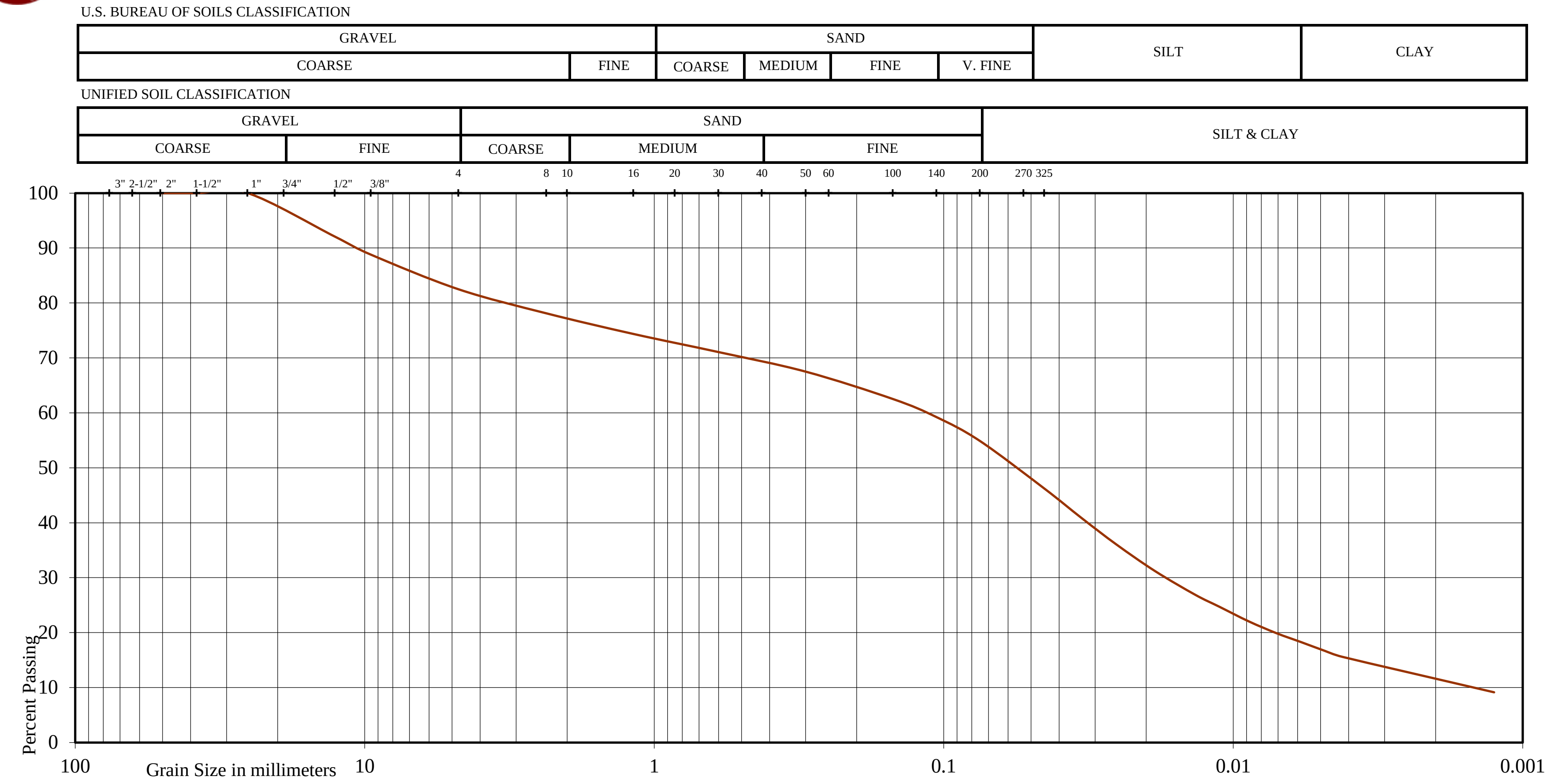
GRAIN SIZE DISTRIBUTION

Reference No: 1807-S136



Project: Proposed Residential Development

Location: 200 John Street and 588 Charlotte Street, Town of Niagara-On-The-Lake

Liquid Limit (%) = -

Plastic Limit (%) = -

Plasticity Index (%) = -

Moisture Content (%) = 10

Estimated Permeability (cm./sec.) = 10^{-6}

Borehole No: 8

Sample No: 2

Depth (m): 1.1

Elevation (m): 89.2

Classification of Sample [& Group Symbol]: SANDY SILT FILL, some clay and gravel

Figure: 10

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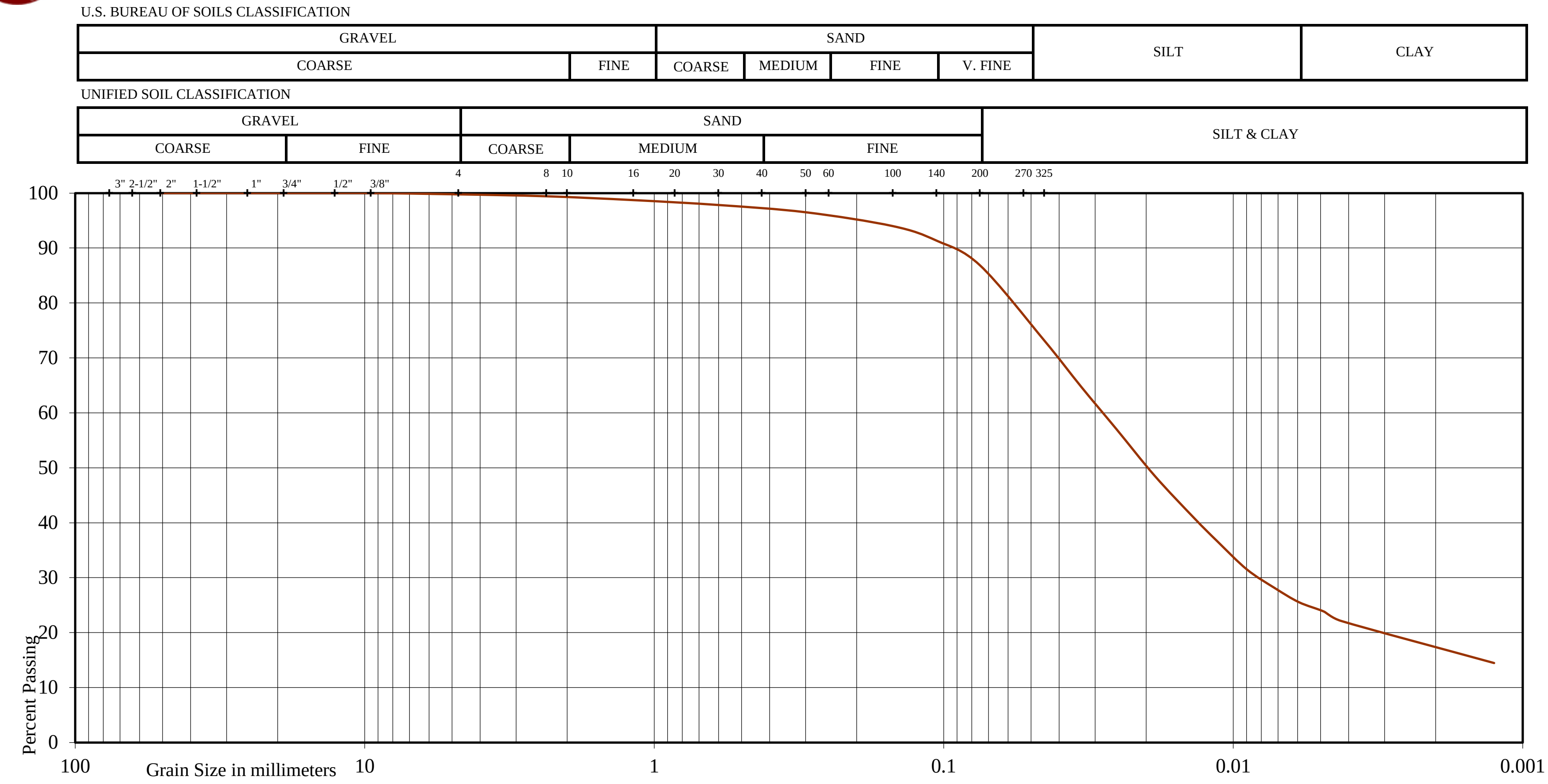
GRAIN SIZE DISTRIBUTION

Reference No: 1807-S136



Project: Proposed Residential Development

Location: 200 John Street and 588 Charlotte Street, Town of Niagara-On-The-Lake

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 5

Plasticity Index (%) = -

Sample No: 5

Moisture Content (%) = 10

Depth (m): 3.3

Estimated Permeability

Elevation (m): 87.1

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

Classification of Sample [& Group Symbol]: SILTY CLAY, some sand

Figure: 11

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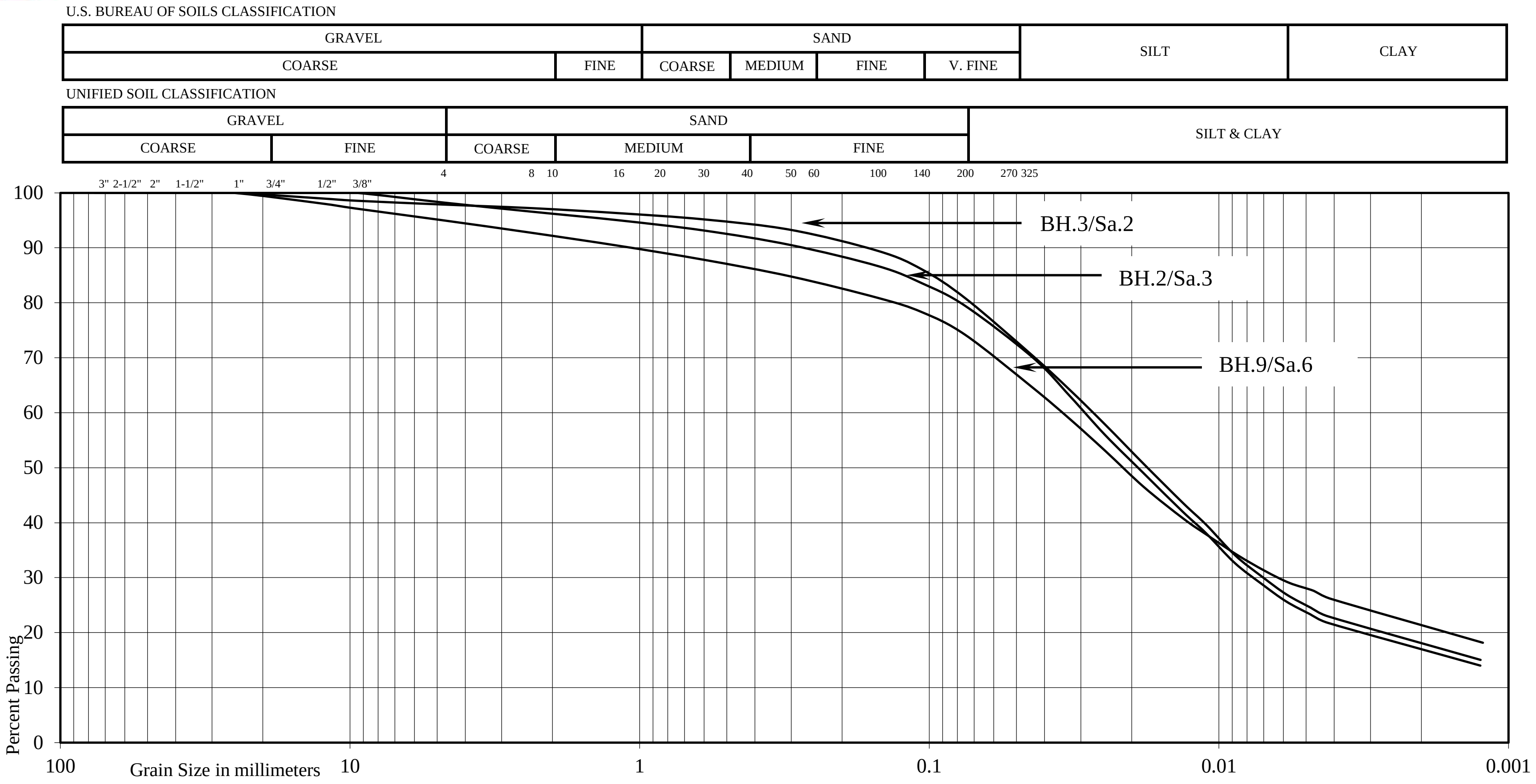
GRAIN SIZE DISTRIBUTION

Reference No: 1807-S136



Project: Proposed Residential Development

Location: 200 John Street and 588 Charlotte Street, Town of Niagara-On-The-Lake

Borehole No:	2	3	9
Sample No:	3	2	6
Depth (m):	1.7	1.1	4.7
Elevation (m):	89.4	89.9	85.4

BH./Sa.	2/3	3/2	9/6
Liquid Limit (%) =	24	24	26
Plastic Limit (%) =	15	16	16
Plasticity Index (%) =	9	8	10
Moisture Content (%) =	13	13	11
Estimated Permeability (cm./sec.) =	10^{-7}	10^{-7}	10^{-7}

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

Figure: 12

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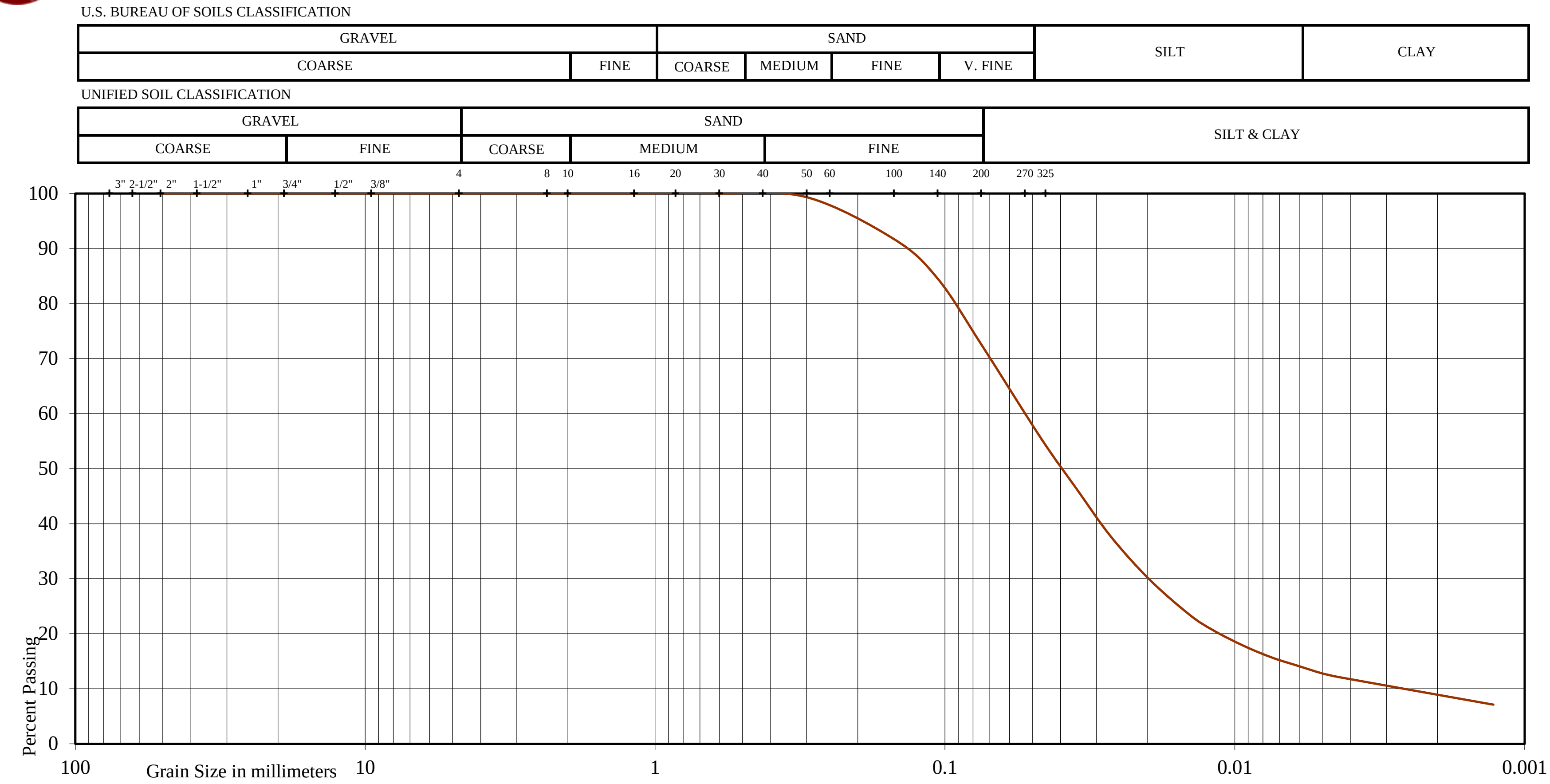
GRAIN SIZE DISTRIBUTION

Reference No: 1807-S136



Project: Proposed Residential Development

Location: 200 John Street and 588 Charlotte Street, Town of Niagara-On-The-Lake

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 1

Plasticity Index (%) = -

Sample No: 4

Moisture Content (%) = 11

Depth (m): 2.5

Estimated Permeability

Elevation (m): 89.0

(cm./sec.) = 10^{-5}

Figure: 13

Classification of Sample [& Group Symbol]: SANDY SILT, a trace of clay

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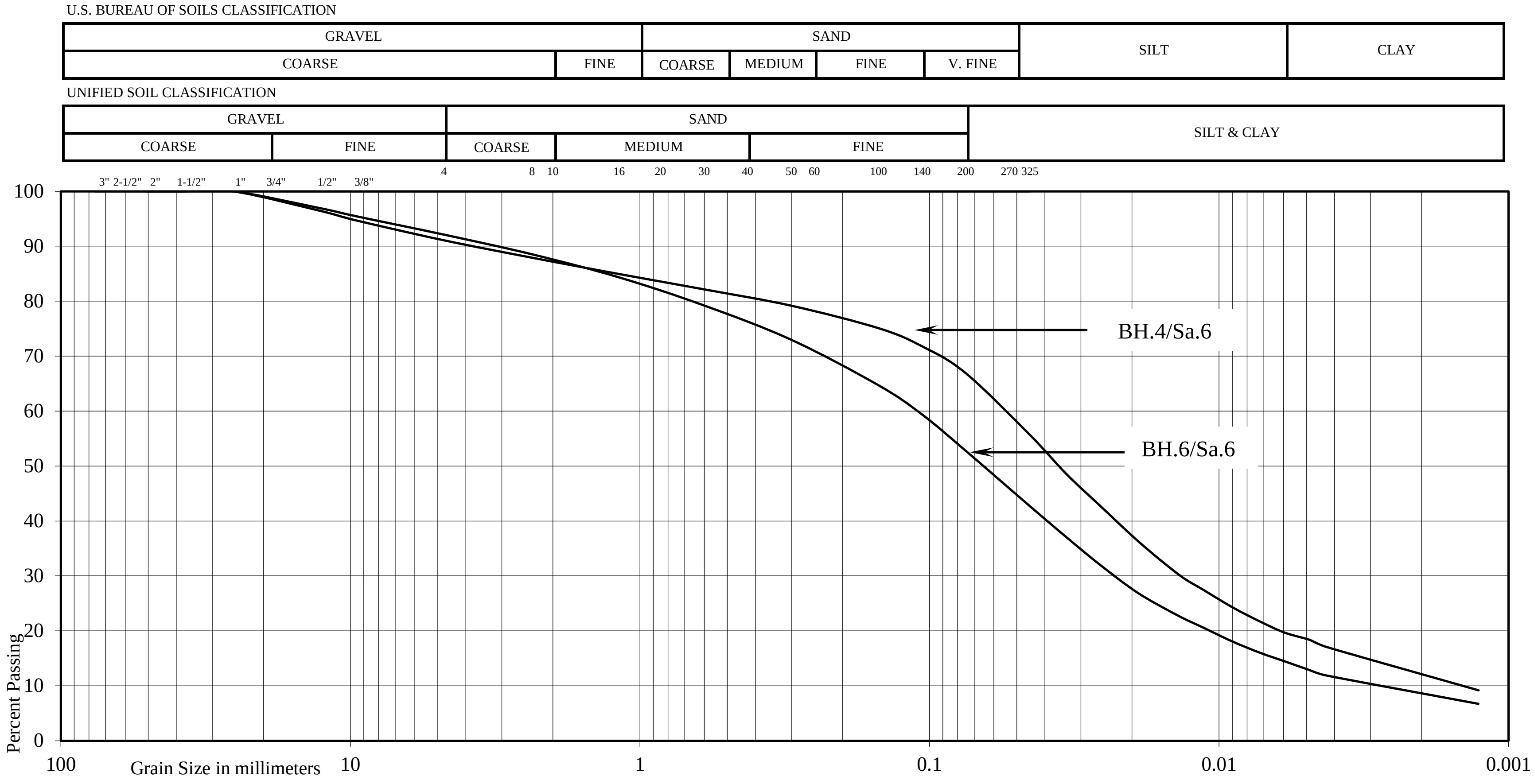
GRAIN SIZE DISTRIBUTION

Reference No: 1807-S136



Project: Proposed Residential Development

Location: 200 John Street and 588 Charlotte Street, Town of Niagara-On-The-Lake

Borehole No:	4	6
Sample No:	6	6
Depth (m):	4.7	4.7
Elevation (m):	85.9	85.7

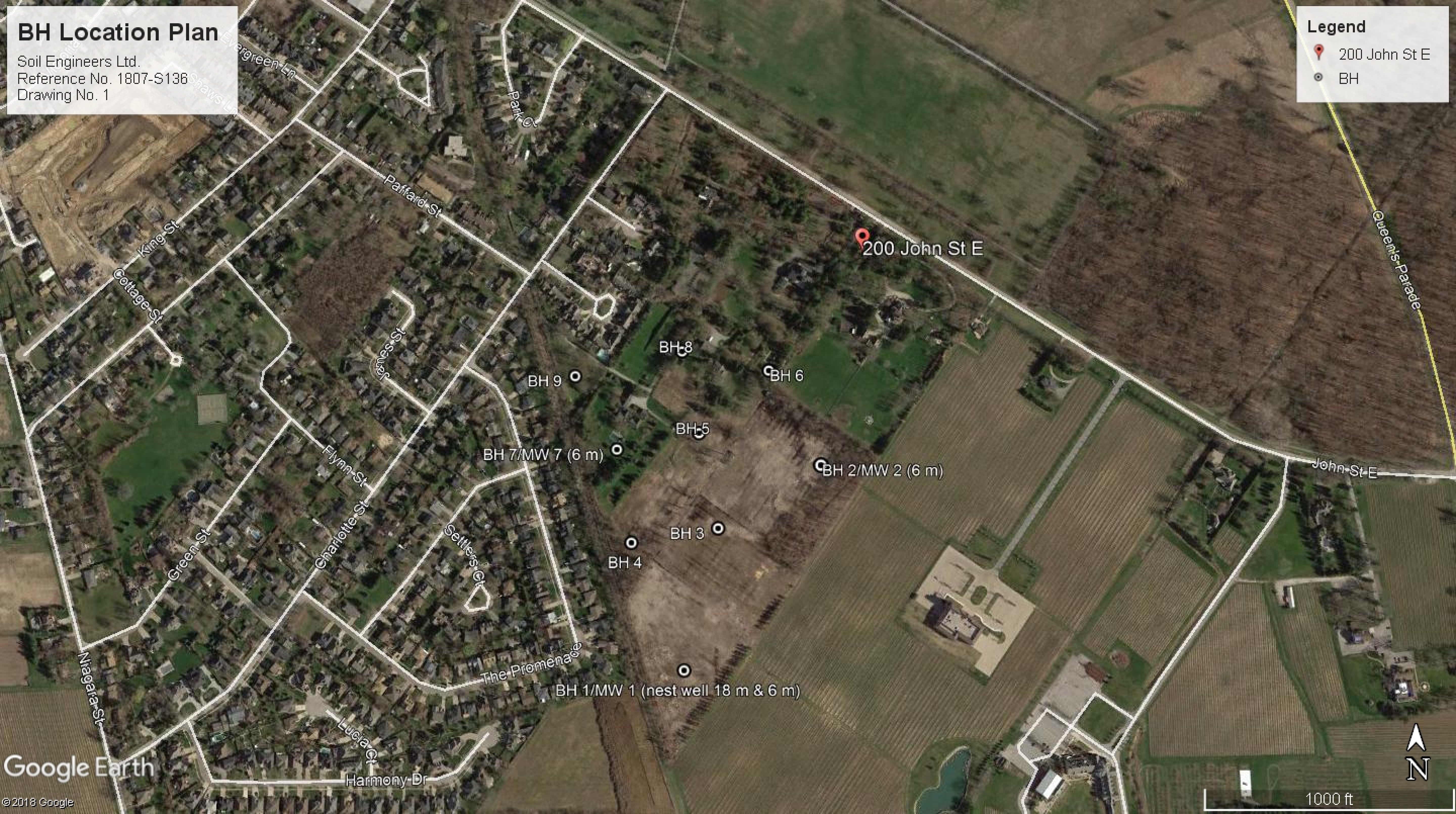
BH./Sa.	4/6	6/6
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	11	9
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-6}

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

Figure: 14

BH Location Plan

Soil Engineers Ltd.
Reference No. 1807-S136
Drawing No. 1



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CONSULTING ENGINEERS
GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE

SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

JOB NO.: 1807-S136

REPORT DATE: October 2018

PROJECT DESCRIPTION: Proposed Residential Development

PROJECT LOCATION: 200 John Street and 588 Charlotte Street
Town of Niagara-on-the-Lake

LEGEND

▤	TOPSOIL	🟥	SANDY SILT	▨	SILTY CLAY	▤	SHALE
▩	FILL	🟩	SANDY SILT TILL	▨	SILTY CLAY TILL		

▽ WATER LEVEL (END OF DRILLING)   ≡ CAVE-IN